Changes:
Fall Cok

Documents Supporting Changing to Information Presented on the 1998 303(d) List

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Cache Creek	UTX, Hg	Fact Sheet	3 ; Change: Mines
Cache Creek	UTX, Hg	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. Inventory and Assessment of Water Quality Problems Related to Abandoned and Inactive Mines in the Central Valley Region of California. California Regional Water Quality Control Board, Central Valley Region Draft Report, 1979.	3; Change: Mines
Cache Creek	UTX, Hg	Foe, C. and W. Croyle. 1998. Mercury Concentrations and Loads from the Sacramento River and from Cache Creek to the Sacramento-San Joaquin Delta Estuary, California Regional Water Quality Control Board, Central Valley Region. June 1998.	1; Bear Crk
Cache Creek	UTX, Hg	Montoya, B. and X. Pan. 1992. Inactive Mine Drainage in the Sacramento Valley, California. California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU: 516 & 517
Camanche Reservoir	Copper	Fact Sheet	1 ; Camanche Res
Camanche Reservoir	Copper	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. *Inventory and Assessment of Water Quality Problems related to Abandoned and Inactive Mines in the Central Valley Region of California.* CRWQCB-CVR (California Regional Water Quality Control Board, Central Valley Region), Report.	1; Camanche Res
Camanche Reservoir	Copper	CDFG (California Department of Fish and Game). 1991. *Lower Mokelumne River Fisheries Plan.* The Resources Agency, Department of Fish and Game, Stream flow Requirements Program. November 1991.	1; Camanche Res
Camanche Reservoir	Copper	CH2MHILL. 2000a. *Closure Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. December 2000.	1; Camanche Res
Camanche Reservoir	Copper	CH2MHILL. 2000b. *(Draft) Post-Restoration Final Effectiveness Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. September 2000.	1; Camanche Res
Camanche Reservoir	Copper	EBMUD (East Bay Municipal Utility District). 2001. Unpublished dissolved copper concentration data for the lower Mokelumne River downstream of Camanche Dam, generated as part of EBMUD's NPDES requirements. Provided electronically by Alexander R. Coate (Manger of Regulatory Compliance, EBMUD) to Michelle L. Wood (Environmental Specialist, Central Valley Regional Water Quality Control Board) on August 2, 2001.	1; Camanche Res
Camanche Reservoir	Copper	EDAW, Inc. 1992. *Draft EIS/EIR for the Updated Water Supply Management Program, Volume III, Technical Appendices B1 and B2.* Prepared for: East Bay Municipal Utility District. Oakland, California. December 1992.	1; Camanche Res
Camanche Reservoir	Copper	Montoya, B., and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU: 516 & 517
Camanche Reservoir	Copper	SCH EIR. 1996. *Draft EIR for The Penn Mine Site, Long-Term Solution Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. SCH EIR No. 95103036.	1; Camanche Res

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Camanche Reservoir	Zinc	Fact Sheet	1; Camanche Res
Camanche Reservoir	Zinc	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. *Inventory and Assessment of Water Quality Problems related to Abandoned and Inactive Mines in the Central Valley Region of California.* CRWQCB-CVR (California Regional Water Quality Control Board, Central Valley Region), Report.	1; Camanche Res
Camanche Reservoir	Zinc	CDFG (California Department of Fish and Game). 1991. *Lower Mokelumne River Fisheries Plan.* The Resources Agency, Department of Fish and Game, Stream flow Requirements Program. November 1991.	1; Camanche Res
Camanche Reservoir	Zinc	CH2MHILL. 2000a. *Closure Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. December 2000.	1; Camanche Res
Camanche Reservoir	Zinc	CH2MHILL. 2000b. *(Draft) Post-Restoration Final Effectiveness Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. September 2000.	1; Camanche Res
Camanche Reservoir	Zinc	EBMUD (East Bay Municipal Utility District). 2001. Unpublished dissolved copper concentration data for the lower Mokelumne River downstream of Camanche Dam, generated as part of EBMUD's NPDES requirements. Provided electronically by Alexander R. Coate (Manger of Regulatory Compliance, EBMUD) to Michelle L. Wood (Environmental Specialist, Central Valley Regional Water Quality Control Board) on August 2, 2001.	1; Camanche Res
Camanche Reservoir	Zinc	EDAW, Inc. 1992. *Draft EIS/EIR for the Updated Water Supply Management Program, Volume III, Technical Appendices B1 and B2.* Prepared for: East Bay Municipal Utility District. Oakland, California. December 1992.	1; Camanche Res
Camanche Reservoir	Zinc	Montoya, B., and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	1; Camanche Res
Camanche Reservoir	Zinc	SCH EIR. 1996. *Draft EIR for The Penn Mine Site, Long-Term Solution Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. SCH EIR No. 95103036.	1; Camanche Res
Delta	2; Low DO	Fact Sheet	3; Change: General
Delta	All (except 2; Low DO)	Fact Sheet	3; Change: General
Delta	All	NA (extent of impairment corrected)	NA
Dunn Creek	Hg, Metals	Fact Sheet	3; Change: Mt Diablo
Dunn Creek	Hg, Metals	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. Inventory and Assessment of Water Quality Problems Related to Abandoned and Inactive Mines in the Central Valley Region of California. CRWQCB-CVR.	3; Change: Mines
Dunn Creek	Hg, Metals	Iovenitti, J.L., Weiss Associates, and J. Wessman. 1989. Mount Diablo Mine: Surface Impoundment Technical Report. Pleasant Hill, Ca.	3; Change:Mt Diablo
Dunn Creek	Hg, Metals	Slotton DG, SM Ayers, and JE Reuter. 1996. Marsh Creek Watershed: 1995 Mercury Assessment Project. March 1996.	3; Change:Mt Diablo
Fall Creek	Sedimentation/Siltation	Fact Sheet	3; Change: Fall Crk

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Fall Creek	Sedimentation/Siltation	CRWQCB-CVR (California Regional Water Quality Control Board, Central Valley Region). 1982. Fall River Water Quality Monitoring Survey. July 1982.	3; Change: Fall Crk
Fall Creek	Sedimentation/Siltation	CDWR (Department of Water Resources). 1998. Aquatic Monitoring and Assessment for the Upper Fall River, Memorandum Report. May 1998.	3; Change: Fall Crk
Fall Creek	Sedimentation/Siltation	North State Resources and T Holmes (prepared for the Fall River Resource Conservation District). A study of the Habitat Characteristics of the Aquatic Vegetation of the Upper Fall River: Final Report. Redding, Ca. December 8, 1997.	3; Change: Fall Crk
Fall Creek	Sedimentation/Siltation	Tetra Tech, Inc (for the Fall River Resource Conservation District). 1998. Analysis of Sedimentation and Action Plan Development for the Upper Fall River, Shasta County, California. San Francisco, Ca. May 20, 1998.	3; Change: Fall Crk
Fall Creek	Sedimentation/Siltation	USDA (United States Department of Agriculture), River Basin Planning Staff, in cooperation with Fall River Resource Conservation District. 1983. Fall River Watershed Area Study, Summary Report. Davis, Ca. June 1983.	3; Change: Fall Crk
French Ravine	Bacteria	Fact Sheet	3; Change: General
French Ravine	Bacteria	Horizons Technology, Inc., 1997. Sure! MAPS® RASTER Map Sets (U.S. Geological Survey 7.5' Topographic Quadrangles), Version 2.1.2.	NA
Horse Creek	Metals	Fact Sheet	3; Change: Mines
Horse Creek	Metals	Montoya, B., and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU: 516 & 517
Humbug Creek	Sedimentation/Siltation, Metals, Hg	Fact Sheet	3; Change: Mines
Humbug Creek	Sedimentation/Siltation, Metals, Hg	Montoya, B., and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU: 516 & 517
James Creek	Hg, Ni	Fact Sheet	3; Change: Mines
James Creek	Hg, Ni	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. *Inventory and Assessment of Water Quality Problems Related to Abandoned and Inactive Mines in the Central Valley Region of California.* California Regional Water Quality Control Board, Central Valley Region Draft Report. 1979.	3; Change: Mines
James Creek	Hg, Ni	Montoya, B. and Pan, X., 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU: 516 & 517- Hg
Marsh Creek	Metals	Fact Sheet	3; Change: Mt Diablo
Marsh Creek	Hg	Fact Sheet	3; Change: Mt Diablo

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Marsh Creek	Metals, Hg	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. Inventory and Assessment of Water Quality Problems Related to Abandoned and Inactive Mines in the Central Valley Region of California. CRWQCB-CVR.	3; Change : Mines
Marsh Creek	Metals, Hg	CRWQCB-CVR. 1978. *Waste Discharge Requirements for Mount Diablo Quicksilver Mine, Contra Costa County.* Sacramento, Ca: CRWQCB.	3; Change: Mt Diablo
Marsh Creek	Metals, Hg	Iovenitti, J.L., Weiss Associates, and J. Wessman. 1989. Mount Diablo Mine: Surface Impoundment Technical Report. Pleasant Hill, Ca.	3; Change: Mt Diablo
Marsh Creek	Metals, Hg	Slotton DG, SM Ayers, and JE Reuter. 1996. Marsh Creek Watershed: 1995 Mercury Assessment Project. March 1996.	3; Change: Mt Diablo
Mokulmne River, Lower	Copper	Fact Sheet	1 ; Camanche Res
Mokulmne River, Lower	Copper	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. *Inventory and Assessment of Water Quality Problems related to Abandoned and Inactive Mines in the Central Valley Region of California.* CRWQCB-CVR (California Regional Water Quality Control Board, Central Valley Region), Report.	1; Camanche Res
Mokulmne River	Copper	CDFG (California Department of Fish and Game). 1991. *Lower Mokelumne River Fisheries Plan.* The Resources Agency, Department of Fish and Game, Stream flow Requirements Program. November 1991.	1; Camanche Res
Mokulmne River	Copper	CH2MHILL. 2000a. *Closure Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. December 2000.	1; Camanche Res
Mokulmne River	Copper	CH2MHILL. 2000b. *(Draft) Post-Restoration Final Effectiveness Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. September 2000.	1; Camanche Res
Mokulmne River	Copper	EBMUD (East Bay Municipal Utility District). 2001. Unpublished dissolved copper concentration data for the lower Mokelumne River downstream of Camanche Dam, generated as part of EBMUD's NPDES requirements. Provided electronically by Alexander R. Coate (Manger of Regulatory Compliance, EBMUD) to Michelle L. Wood (Environmental Specialist, Central Valley Regional Water Quality Control Board) on August 2, 2001.	1; Camanche Res
Mokulmne River	Copper	EDAW, Inc. 1992. *Draft EIS/EIR for the Updated Water Supply Management Program, Volume III, Technical Appendices B1 and B2.* Prepared for: East Bay Municipal Utility District. Oakland, California. December 1992.	1; Camanche Res
Mokulmne River	Copper	Montoya, B., and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU: 516 & 517
Mokulmne River	Copper	SCH EIR. 1996. *Draft EIR for The Penn Mine Site, Long-Term Solution Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. SCH EIR No. 95103036.	1; Camanche Res
Mokulmne River	Zinc	Fact Sheet	1; Camanche Res
Mokulmne River	Zinc	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. *Inventory and Assessment of Water Quality Problems related to Abandoned and Inactive Mines in the Central Valley Region of California.* CRWQCB-CVR (California Regional Water Quality Control Board, Central Valley Region), Report.	1; Camanche Res

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Mokulmne River	Zinc	CDFG (California Department of Fish and Game). 1991. *Lower Mokelumne River Fisheries Plan.* The Resources Agency, Department of Fish and Game, Stream flow Requirements Program. November 1991.	1; Camanche Res
Mokulmne River	Zinc	CH2MHILL. 2000a. *Closure Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. December 2000.	1; Camanche Res
Mokulmne River	Zinc	CH2MHILL. 2000b. *(Draft) Post-Restoration Final Effectiveness Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. September 2000.	1; Camanche Res
Mokulmne River	Zinc	EBMUD (East Bay Municipal Utility District). 2001. Unpublished dissolved copper concentration data for the lower Mokelumne River downstream of Camanche Dam, generated as part of EBMUD's NPDES requirements. Provided electronically by Alexander R. Coate (Manger of Regulatory Compliance, EBMUD) to Michelle L. Wood (Environmental Specialist, Central Valley Regional Water Quality Control Board) on August 2, 2001.	1; Camanche Res
Mokulmne River	Zinc	EDAW, Inc. 1992. *Draft EIS/EIR for the Updated Water Supply Management Program, Volume III, Technical Appendices B1 and B2.* Prepared for: East Bay Municipal Utility District. Oakland, California. December 1992.	1; Camanche Res
Mokulmne River	Zinc	Montoya, B., and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	1; Camanche Res
Mokulmne River	Zinc	SCH EIR. 1996. *Draft EIR for The Penn Mine Site, Long-Term Solution Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. SCH EIR No. 95103036.	1; Camanche Res
Mosher Slough	Chlorpyrifos, Diazinon	Fact Sheet	3; Change: General
Mosher Slough	Chlorpyrifos, Diazinon	DeLorme 1998. Northern California Atlas and Gazetteer- Detailed Topographic Maps. 1:150,000 Scale. Fourth Edition. (http://www.delorme.com.)	NA
Mosher Slough	Chlorpyrifos, Diazinon	Horizons Technology, Inc., 1997. Sure! MAPS® RASTER Map Sets (U.S. Geological Survey 7.5' Topographic Quadrangles), Version 2.1.2.	NA
San Carlos Creek	Hg	Fact Sheet	3; Change: New Idrea
San Carlos Creek	Hg	USGS (United States Geological Survey). 1969-1981. Ciervo Mountain (1969), Idria (1969), San Benito Mountain (1981), and Tumey Hills (1971). California 7.5' Topographic Quadrangle, as presented by TopoZone.com (© 2000 Maps a la carte, Inc.). Accessed on March 13, 2001 (http://www.topozone.com/default.asp).	NA
San Carlos Creek	Hg	CRWQCB-CVR. 1971-1995. *Futures Foundation, New Idria Mine File.* Electronic database of all water sampling results for San Carlos Creek and New Idria Mine drainage. Mercury data for water samples collected June 1971 to December 1995.	1; Disk 2
San Carlos Creek	Hg	CRMP (Panoche/Silver Creek Coordinated Resource Management Plan) TRC (Technical Review Committee). 1996. *Draft Water Quality Report.* February 29, 1996.	3; Change: New Idrea
Stanislaus River	Diazinon, GAP, UTX	Fact Sheet	3; Change: General

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Stanislaus River	Diazinon, GAP, UTX	USBR (U.S. Bureau of Reclamation). 2001. *U.S. Bureau of Reclamation DataWeb: Power Plants, Dams & Reservoirs.* Accessed on August 22, 2001 (http://dataweb.usbr.gov/).	NA
Stanislaus River	Diazinon, GAP, UTX	USGS (United States Geological Survey). 1987, 1991. *Knights Ferry* (1987) and *Ripon* (1991). California 7.5' Topographic Quadrangles, as presented by TopoZone.com (© 2000 Maps a la carte, Inc.). Accessed on August 22, 2001 (http://www.topozone.com/default.asp).	NA
Tuolumne River	Diazinon	Fact Sheet	3; Change: General
Tuolumne River	GAP, UTX	Fact Sheet	3; Change: General
Tuolumne River	Diazinon, GAP, UTX	USGS (United States Geological Survey). 1987, 1991, 1969. La Grange (1987), Westley (1991), and Brush Lake (1969). California 7.5' Topographic Quadrangles, as presented by TopoZone.com (© 2000 Maps a la carte, Inc.). Accessed on August 23, 2001 (http://www.topozone.com/default.asp).	NA

Documents Supporting Delisting a Waterbody-Pollutant from the 2002 303(d) List

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
American River, Lower	Group A 2; Pesticides	Fact Sheet	3; Removals
American River, Lower	Group A 2; Pesticides	Davis, J.A., M.D. May, G. Ichikawa, and D. Crane. 2000. Contaminant Concentrations in Fish from the Sacramento-San Joaquin Delta and Lower San Joaquin River, 1998. San Francisco Estuary Institute, Richmond, CA. September 1998	2; Pesticides
American River, Lower	Group A 2; Pesticides	Larry Walker Associates. 2001b. *Sacramento River Watershed Program Annual Monitoring Report: 1999-2000.* Prepared for the Sacramento River Watershed Program by Larry Walker Associates, Davis, California.	3; Removals
American River, Lower	Group A 2; Pesticides	SWRCB-DWQ (State Water Resources Control Board, Division of Water Quality). 1995. *Toxic Substances Monitoring Program: Freshwater Bioaccumulation Monitoring Program: Data Base (Org_Wet).*	1; Disk 1
Grasslands Marshes	Selenium	Grober, L.F. 1999. *Selenium Total Maximum Daily Load for the Grassland Marshes.* California Regional Water Quality Control Board, Central Valley Region.	NA
Salt Slough	Selenium	Grober, L. 2000. *Selenium Total Maximum Daily Load for Salt Slough.* California Regional Water Quality Control Board, Central Valley Region.	NA

Documents Supporting Listing a Waterbody-Pollutant on the 2002 303(d) List

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Arcade Creek	Cu	Fact Sheet	1; Arcade Creek
Arcade Creek	Cu	Larry Walker Associates. 2001a. SRWP 99-00 Database. Unpublished Data.	1; Disk 1
Arcade Creek	Cu	Larry Walker Associates. 2001b. *Sacramento River Watershed Program Annual Monitoring Report: 1999-2000.* Prepared for the Sacramento River Watershed Program by Larry Walker Associates, Davis, California.	1; Arcade Creek
Arcade Creek	Cu	Russick, K. 2001. *Characterization of OP 2; Pesticides in Sacramento Urban Runoff and Receiving Waters.* Unpublished Draft CALFED Repot. Russik Environmental Consultant, Elk Grove, California.	1; Arcade Creek
Arcade Creek	Cu	USGS (U.S. Geological Survey). 2001. *National Water Information System.* http://water.usgs.gov/nwis/ (August 28, 2001). Query: 1; Arcade Creek.	1; Disk 2
Arcade Creek	Cu	Woodward-Clyde. 1992. *Source Identification and Control Report, December 1, 1992.* Report prepared for the Santa Clara Valley Nonpoint Source Pollution Control Program by Woodward-Clyde Consultants, Oakland, California.	NA
Arcade Creek	Ammonia	Fact Sheet	1; Avena Drain
Avena Drain	Ammonia	CRWQCB-CVR. 2001a. *1; Avena Drain File.* File Containing Regional Board Staff Field notes and lab results from 1; Avena Drain and surrounding dairies.	1; Avena Drain
Avena Drain	Pathogens	Fact Sheet	1; Bacteria
Avena Drain	Pathogens	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper com	1; Bacteria
Bear Creek	Mercury	Fact Sheet	1; Bear Crk
Bear Creek	Mercury	Foe, C. and W. Croyle. 1998. *Mercury Concentrations and Loads from the Sacramento River and from Cache Creek to the Sacramento-San Joaquin Delta Estuary.* California Regional Water Quality Control Board, Central Valley Region Report. June 1998.	1; Bear Crk
Bear River, Lower	Diazinon	Fact Sheet	1; Bear and Butte Crks
Bear River, Lower	Diazinon	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Bear River and diazinon	1; Disk 1
Bear River, Lower	Diazinon	Dileanis, P.D., J.L. Domagalski, and K.P. Bennett. 2000. Occurrence and Transport of Diazinon in the Sacramento River and its Tributaries During Three Winter Storms, January-February 2000. Water-Resources Investigations Draft Report. U.S. Geological Survey. Sacramento, CA.	1; Bear and Butte Crks
Bear River, Lower	Diazinon	Holmes, R., C. Foe, and V. de Vlaming. 2000. *Sources and Concentrations of Diazinon in the Sacramento Watershed During the 1994 Orchard Dormant Spray Season.* California Regional Water Quality Control Board – Central Valley Region. Sacramento, CA. (CDPR and hard copy)	1; Bear and Butte Crks
Bear River, Upper	Mercury	Fact Sheet	2; HU:516 & 517
Bear River, Upper	Mercury	Alpers and Hunerlach. 2000. *Mercury Contamination from Historic Gold Mining in California.* USGS Report FS-061-00. Ca.water.usgs.gov/mercury/fs06100.html	2; HU:516 & 517

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Bear River, Upper	Mercury	May, J.T., R.L. Hothem, C.N. Alpers, M.A. Law. 2000. *Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999.* U.S. Geological Survey. Sacramento, CA. 2000.	2; HU:516 & 517
Bear River, Upper	Mercury	Montoya, B. and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU:516 & 517
Bear River, Upper	Mercury	Nevada County, Department of Environmental Health. 2000. *Press Release, Three County Environmental Health Agencies Issue Interim Public Health Notification on Mercury in Fish.* (http://www.co.nevada.ca.us/ehealth/hg/press_release_10-03-00.htm)	2; HU:516 & 517
Black Butte Res	Mercury	Fact Sheet	1; Black Butte
Black Butte Reservoir	Mercury	Brodberg, R. K. and G. A. Pollock. 1999. *Prevalence of Selected Target Chemical Contaminants in Sport Fish from Two California Lakes: Public Health Designed Screening Study.* California Environmental Protection Agency, Office of Environmental Health Hazard Assessment Final Report. June 1999. Sacramento, California.	1; Black Butte
Black Butte Reservoir	Mercury	OEHHA (Office of Environmental Health Hazard Assessment). 2000. Draft Evaluation of Potential Health Effects of Eating Fish From 1; Black Butte Reservoir (Glenn and Tehama Counties): Guidelines for Sport Fish Consumption, Pesticide and Environmental Toxicology Section, California Environmental Protection Agency, Office of Environmental Health Hazard Assessment.	1; Black Butte
Butte Slough	Diazinon	Fact Sheet	1; Bear and Butte Crks
Butte Slough	Diazinon	Chilcott, J. 1992. *Agenda Item #11 for Meeting of California Regional Water Quality Control Board, Central Valley Region. September 25, 1992. Fresno, CA.* Staff Report on Consideration of Water Body Designations to Comply with Provisions of the Water Quality Control Plan for Inland Surface Waters of California. Including Appendix B.	1; Bear and Butte Crks
Butte Slough	Diazinon	Dileanis, P.D., J.L. Domagalski, and K.P. Bennett. 2000. *Occurrence and Transport of Diazinon in the Sacramento River and its Tributaries During Three Winter Storms, January-February 2000.* U.S. Geological Survey Water Resources Investigations Report, Draft. Sacramento, CA.	1; Bear and Butte Crks
Butte Slough	Diazinon	Holmes, R., C. Foe, and V. de Vlaming. 2000. *Sources and Concentrations of Diazinon in the Sacramento Watershed During the 1994 Orchard Dormant Spray Season.* California Regional Water Quality Control Board – Central Valley Region. Sacramento, CA. (CDPR and hard copy)	1; Bear and Butte Crks
Butte Slough	Diazinon	NCWA (Northern California Water Association). *The Lower Butte Creek Project.* (http://norcalwater.org/lower_butte_creek_project.htm). Last updated Sept 4, 2001.	1; Bear and Butte Crks
Butte Slough	Molinate	Fact Sheet	1; Bear and Butte Crks
Butte Slough	Molinate	California Rice Commission. 2001. *CA Rice.* Chapter 3: Water Quality in Relation to Rice Farming http://www.calrice.org/frame.tpl?_page=environment/balance-sheet/	1; Bear and Butte Crks
Butte Slough	Molinate	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Butte Slough and molinate	1; Disk 1
Butte Slough	Molinate	Gorder, N.K.N., J.M. Lee, and K. Newhart. 1995. *Information on Rice 2; Pesticides Submitted to the California Regional Water Quality Control Board Central Valley Region.* Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation, Sacramento, CA. December 28, 1995.	1; Bear and Butte Crks

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Butte Slough	Molinate	Gorder, N.K.N., J.M. Lee, and K. Newhart. 1996. *Information on Rice 2; Pesticides Submitted to the California Regional Water Quality Control Board Central Valley Region.* Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation, Sacramento, CA. December 31, 1996.	1; Bear and Butte Crks
Butte Slough	Molinate	NCWA (Northern California Water Association). *The Lower Butte Creek Project.* (http://norcalwater.org/lower_butte_creek_project.htm). Last updated Sept 4, 2001.	1; Bear and Butte Crks
Butte Slough	Molinate	Newhart, K., D. Jones, and S. Ceesay. 2000. *Information on Rice 2; Pesticides-Submitted to the California Regional Water Quality Control Board.* California Environmental Protection Agency, Department of Pesticide Regulation. Environmental Monitoring and Pest Management Branch. Environmental Hazards Assessment Program. December 31, 2000.	1; Bear and Butte Crks
Butte Slough	Molinate	Newhart, K. and K. Bennett. 1999. *Information on Rice 2; Pesticides-Submitted to the California Regional Water Quality Control Board.* California Environmental Protection Agency, Department of Pesticide Regulation. Environmental Monitoring and Pest Management Branch. Environmental Hazards Assessment Program. December 31, 1999.	1; Bear and Butte Crks
Calaveras River, Lower	Dissolved Oxygen	Fact Sheet	2; Low DO
Calaveras River, Lower	Dissolved Oxygen	*CALFED Bay-Delta Program. 2000. Water Quality Program Plan, Final Programmatic EIS/EIR Technical Appendix. July 2000.	2; Low DO
Calaveras River, Lower	Dissolved Oxygen	Lee G.F. Dissolved Oxygen Depletion in the Stockton Sloughs. August 2000. (Prepared for DeltaKeeper)	2; Low DO
Calaveras River, Lower	Dissolved Oxygen	Lee, G.F. and A. Jones-Lee. 2001b. *Review of the City of Stockton Urban Stormwater Runoff Aquatic Life Toxicity Studies Conducted by the Central Valley Regional Water Quality Control Board, DeltaKeeper, and the University of California, Davis, Aquatic Toxicology Laboratory between 1994 and 1999.* Final Report. November 2001. G. Fred Lee & Associates. El Macero, CA. (Prepared for DeltaKeeper).	2; Putah Creek
Calaveras River, Lower	Pathogens	Fact Sheet	1; Bacteria
Calaveras River, Lower	Pathogens	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper comments on section 303(d) list update.	1; Bacteria
Camanche Reservoir	Aluminum	Fact Sheet	1; Camanche Res
Camanche Reservoir	Aluminum	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. *Inventory and Assessment of Water Quality Problems related to Abandoned and Inactive Mines in the Central Valley Region of California.* CRWQCB-CVR (California Regional Water Quality Control Board, Central Valley Region), Report.	1; Camanche Res
Camanche Reservoir	Aluminum	CDFG (California Department of Fish and Game). 1991. *Lower Mokelumne River Fisheries Plan.* The Resources Agency, Department of Fish and Game, Stream flow Requirements Program. November 1991.	1; Camanche Res
Camanche Reservoir	Aluminum	CH2MHILL. 2000a. *Closure Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. December 2000.	1; Camanche Res
Camanche Reservoir	Aluminum	CH2MHILL. 2000b. *(Draft) Post-Restoration Final Effectiveness Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. September 2000.	1; Camanche Res

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Camanche Reservoir	Aluminum	EBMUD (East Bay Municipal Utility District). 2000. All About EBMUD. EBMUD Public Affairs Office publication. Available: http://www.ebmud.com/pubs/annual/allaboutebmud_2000.pdf. Accessed: August 2, 2001.	1; Camanche Res
Camanche Reservoir	Aluminum	EDAW, Inc. 1992. *Draft EIS/EIR for the Updated Water Supply Management Program, Volume III, Technical Appendices B1 and B2.* Prepared for: East Bay Municipal Utility District. Oakland, California. December 1992.	1; Camanche Res
Camanche Reservoir	Aluminum	SCH EIR. 1996. *Draft EIR for The Penn Mine Site, Long-Term Solution Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. SCH EIR No. 95103036. May 1996.	1; Camanche Res
Camanche Reservoir	Aluminum	SWRCB (State Water Resources Control Board). 1990. *Water Quality Problems Associated with Operation of Pardee and Camanche Reservoir.* State Water Resources Control Board, Division of Water Quality staff report.	1; Camanche Res
Camp Far West Reservoir	Mercury	Fact Sheet	2; 516 & 517-Mercury
Camp Far West Reservoir	Mercury	Alpers, C.N., M.P. Hunerlach. 2000. *Mercury Contamination from Historic Gold Mining in California.* U.S. Geological Survey. Fact Sheet FS-061-00. May 2000.	2; 516 & 517-Mercury
Camp Far West Reservoir	Mercury	May, J.T., R.L. Hothem, C.N. Alpers, M.A. Law. 2000. *Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999.* U.S. Geological Survey. Sacramento, CA. 2000.	2; 516 & 517-Mercury
Camp Far West Reservoir	Mercury	Montoya, B. and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; 516 & 517
Camp Far West Reservoir	Mercury	Nevada County, Department of Environmental Health. 2000. Press Release, Three County Environmental Health Agencies Issue Interim Public Health Notification on Mercury in Fish. (http://www.co.nevada.ca.us/ehealth/hg/press_release_10-03-00.htm)	2; 516 & 517-Mercury
Camp Far West Reservoir	Mercury	Slotton, D.G., S.M. Ayers, J.E. Reuter, C.R. Goldman. 1996. Gold Mining Impacts on Food Chain Mercury in Northwestern Sierra Nevada Streams (1996 Revision). Division of Environmental Studies, University of California, Davis. December 1996.	2; 516 & 517-Mercury
Clover Creek	Fecal Coliform	Fact Sheet	1; cow creek
Clover Creek	Fecal Coliform	Hannaford MJ and North State Institute for Sustainable Communities. 2000. Preliminary Water Quality Assessment of 1; cow creek Tributaries. Department of Fish and Game. May 15, 2000. (http://www.delta.dfg.ca.gov/afrp/documents/cowcrk.rpt.pdf).	1; cow creek
Colusa Drain	Azinphos Methyl	Fact Sheet	1; CBD
Colusa Drain	Azinphos Methyl	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Colusa Drain and Azinphos Methyl.	1; Disk 1
Colusa Drain	Azinphos Methyl	Domagalski, J.L. 2000. *Pesticide Monitoring in the Sacramento River Basin for the USGS National Water Quality Assessment Program.* Report in prep. USGS. As presented in CDPR, 2000a.	1; Disk 1
Colusa Drain	Diazinon	Fact Sheet	1; CBD

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Colusa Drain	Diazinon	Holmes, R., C. Foe, and V. de Vlaming. 2000. *Sources and Concentrations of Diazinon in the Sacramento Watershed During the 1994 Orchard Dormant Spray Season.* California Regional Water Quality Control Board – Central Valley Region. Sacramento, CA. (CDPR and hard copy)	1; Bear and Butte Crks
Colusa Drain	Molinate	Fact Sheet	1; CBD
Colusa Drain	Molinate	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Colusa Drain and molinate.	1; CBD
Colusa Drain	Molinate	Domagalski, J.L. 2000. *Pesticide Monitoring in the Sacramento River Basin for the USGS National Water Quality Assessment Program.* Report in prep. USGS. As presented in CDPR, 2000a.	1; Disk 1
Colusa Drain	Molinate	Gorder, N.K.N., J.M. Lee, and K. Newhart. 1995. Information on Rice 2; Pesticides Submitted to the California Regional Water Quality Control Board Central Valley Region. Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation, Sacramento, CA. December 28, 1995.	1; CBD
Colusa Drain	Molinate	Gorder, N.K.N., J.M. Lee, and K. Newhart. 1996. *Information on Rice 2; Pesticides Submitted to the California Regional Water Quality Control Board Central Valley Region.* Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation, Sacramento, CA. December 31, 1996.	1; CBD
Colusa Drain	Molinate	Gorder, N.K.N., J.M. Lee, and K. Newhart. 1997. *Information on Rice 2; Pesticides Submitted to the California Regional Water Quality Control Board Central Valley Region.* Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation, Sacramento, CA. December 31, 1997.	1; CBD
Colusa Drain	Molinate	Gorder, N.K.N., J.M. Lee, and K. Newhart. 1998. *Information on Rice 2; Pesticides Submitted to the California Regional Water Quality Control Board Central Valley Region.* Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation, Sacramento, CA. December 31, 1998.	1; CBD
Colusa Drain	Molinate	Holmes, R., C. Foe and V. de Vlaming. 1998. *Sources and Concentrations of Diazinon in the Sacramento Watershed During the 1994 Orchard Dormant Spray Season.* Central Valley Regional Water Quality Control Board. Draft, June 1998.	1; Bear and Butte Crks
Colusa Drain	Molinate	Newhart, K. and K. Bennett. 1999. *Information on Rice 2; Pesticides-Submitted to the California Regional Water Quality Control Board.* California Environmental Protection Agency, Department of Pesticide Regulation. Environmental Monitoring and Pest Management Branch. Environmental Hazards Assessment Program. December 31, 1999.	1; Bear and Butte Crks
Colusa Drain	Molinate	Newhart, K., D. Jones, and S. Ceesay. 2000. *Information on Rice 2; Pesticides-Submitted to the California Regional Water Quality Control Board.* California Environmental Protection Agency, Department of Pesticide Regulation. Environmental Monitoring and Pest Management Branch. Environmental Hazards Assessment Program. December 31, 2000.	1; Bear and Butte Crks
Del Puerto Crk	Chlorpyrifos	Fact Sheet	2; Pesticides
Del Puerto Crk	Chlorpyrifos	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Del Puerto Crk and chlorpyrifos	1; Disk 1

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Colusa Drain	Diazinon	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Colusa Drain and diazinon.	1; Disk 1
Colusa Drain	Diazinon	Dileanis, P., J. Domagalski, and K.P. Bennett. 2001. *Occurrence and Transport of Diazinon in the Sacramento River and its Tributaries During Three Winter Storms, January-February 2000.* U.S. Geological Survey Water Resources Investigations Report, Draft. Sacramento, CA	1; Bear and Butte Crks
Colusa Drain	Diazinon	Domagalski, J.L. 2000. *Pesticide Monitoring in the Sacramento River Basin for the USGS National Water Quality Assessment Program.* Report in prep. USGS. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Foe, C. 1995. *Insecticide Concentrations and Invertebrate Bioassay Mortality in Agricultural Return Water from the San Joaquin Basin.* Central Valley Regional Water Quality Control Board. Sacramento, CA December 1995.	2; Pesticides
Del Puerto Crk	Chlorpyrifos	Fujimura, R. 1991a. *Chemical and Toxicity Test Results from the San Joaquin River at Three Sites from July 2 to September 13, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Fujimura, R. 1991b. *Chemical and Toxicity Test Results from the San Joaquin River and Tributaries During March 4 to April 26, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Fujimura, R. 1993a. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 29 to February 25,, 1993.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 26, 1993. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Fujimura, R. 1993b. *Chemical Analyses and Bioassay Test Results for Samples Collected from July 9 to September 9, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Fujimura, R. 1993c. *Chemical Analyses and Bioassay Test Results for Samples Collected from March 16 to April 30, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Fujimura, R. 1993d. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 23, 1991 to February 27, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. February 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Ross, L. 1992. Preliminary Results of the San Joaquin River Study; Summer, 1991. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. May 21, 1992. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Ross, L. 1993. Preliminary Results of the San Joaquin River Study; Summer, 1992. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. September 22, 1993. As presented in CDPR, 2000a.	1; Disk 1

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Del Puerto Crk	Chlorpyrifos	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1996. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Winter 1991-92 and 1992-93. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 96-02. November, 1996. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Chlorpyrifos	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1999. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Spring 1991 and 1992. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 99-01. April, 1999. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Diazinon	Fact Sheet	2; Pesticides
Del Puerto Crk	Diazinon	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Del Puertro Creek and diazinon.	1; Disk 1
Del Puerto Crk	Diazinon	Foe, C. 1995. *Insecticide Concentrations and Invertebrate Bioassay Mortality in Agricultural Return Water from the San Joaquin Basin.* Central Valley Regional Water Quality Control Board. Sacramento, CA December 1995.	2; Pesticides
Del Puerto Crk	Diazinon	Fujimura, R. 1991a. *Chemical and Toxicity Test Results from the San Joaquin River at Three Sites from July 2 to September 13, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Diazinon	Fujimura, R. 1991b. *Chemical and Toxicity Test Results from the San Joaquin River and Tributaries During March 4 to April 26, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Diazinon	Fujimura, R. 1993a. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 29 to February 25,, 1993.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 26, 1993. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Diazinon	Fujimura, R. 1993b. *Chemical Analyses and Bioassay Test Results for Samples Collected from July 9 to September 9, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Diazinon	Fujimura, R. 1993c. *Chemical Analyses and Bioassay Test Results for Samples Collected from March 16 to April 30, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Del Puerto Crk	Diazinon	Fujimura, R. 1993d. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 23, 1991 to February 27, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. February 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
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Del Puerto Crk	Diazinon	Ross, L. 1993. Preliminary Results of the San Joaquin River Study; Summer, 1992. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. September 22, 1993.	1; Disk 1
Del Puerto Crk	Diazinon	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1996. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Winter 1991-92 and 1992-93. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 96-02. November, 1996.	1; Disk 1
Del Puerto Crk	Diazinon	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1999. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Spring 1991 and 1992. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 99-01. April, 1999.	1; Disk 1
Don Pedro Lake	Mercury	Fact Sheet	1; Don Pedro Lake
Don Pedro Lake	Mercury	DWR (California Department of Water Resources). 1993. Dams within Jurisdiction of the State of California. DWR Bulletin 17, as presented by the Berkeley Digital Library Project. Accessed on August 23, 2001 (http://elib.cs.berkeley.edu/dams/about.html).	1; Don Pedro Lake
Don Pedro Lake	Mercury	OMR. 2000. California's Abandoned Mines – A Report on the Magnitude and Scope of the Issue in the State. California Department of Conservation, Office of Mine Reclamation, Abandoned Mine Lands Unit (OMR). http://www.consrv.ca.gov/omr/AMLU/amlurpt/Sacramento, CA. June 2000.	1; Don Pedro Lake
Don Pedro Lake	Mercury	SWRCB (State Water Resources Control Board, Division of Water Quality). 1995. Toxic Substances Monitoring Program: Freshwater Bioaccumulation Monitoring Program: Data Base (Metals_Wet).	1; Disk 1
Five Mile Slough	Dissolved Oxygen	Fact Sheet	2; Low DO
Five Mile Slough	Dissolved Oxygen	Lee G.F. *Dissolved Oxygen Depletion in the Stockton Sloughs*. August 2000. (Prepared for DeltaKeeper)	2; Low DO
Five Mile Slough	Dissolved Oxygen	Lee, G.F. and A. Jones-Lee. 2001b. *Review of the City of Stockton Urban Stormwater Runoff Aquatic Life Toxicity Studies Conducted by the Central Valley Regional Water Quality Control Board, DeltaKeeper, and the University of California, Davis, Aquatic Toxicology Laboratory between 1994 and 1999.* Final Report. November 2001. G. Fred Lee & Associates. El Macero, CA. (Prepared for DeltaKeeper).	2; Smith Canal
Five Mile Slough	Pathogens	Fact Sheet	1; Bacteria
Five Mile Slough	Pathogens	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper comments on section 303(d) list update.	1; Bacteria
Ingram/ Hospital Crk	Chlorpyrifos	Fact Sheet	2; Pesticides
Ingram/ Hospital Crk	Chlorpyrifos	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Ingram/Hospital Creek and chlorpyrifos.	1; Disk 1

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Ingram/ Hospital Crk	Chlorpyrifos	Foe, C. 1995. *Insecticide Concentrations and Invertebrate Bioassay Mortality in Agricultural Return Water from the San Joaquin Basin.* Central Valley Regional Water Quality Control Board. Sacramento, CA December 1995.	2; Pesticides
Ingram/ Hospital Crk	Chlorpyrifos	Fujimura, R. 1991a. *Chemical and Toxicity Test Results from the San Joaquin River at Three Sites from July 2 to September 13, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Fujimura, R. 1991b. *Chemical and Toxicity Test Results from the San Joaquin River and Tributaries During March 4 to April 26, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Fujimura, R. 1993a. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 29 to February 25,, 1993.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 26, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Fujimura, R. 1993b. *Chemical Analyses and Bioassay Test Results for Samples Collected from July 9 to September 9, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Fujimura, R. 1993c. *Chemical Analyses and Bioassay Test Results for Samples Collected from March 16 to April 30, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Fujimura, R. 1993d. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 23, 1991 to February 27, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. February 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Ross, L. 1992. Preliminary Results of the San Joaquin River Study; Summer, 1991. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. May 21, 1992.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Ross, L. 1993. Preliminary Results of the San Joaquin River Study; Summer, 1992. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. September 22, 1993.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1996. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Winter 1991-92 and 1992-93. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 96-02. November, 1996.	1; Disk 1
Ingram/ Hospital Crk	Chlorpyrifos	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1999. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Spring 1991 and 1992. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 99-01. April, 1999. As presented in CDPR, 2000a.	1; Disk 1

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Ingram/ Hospital Crk	Diazinon	Fact Sheet	2; Pesticides
Ingram/ Hospital Crk	Diazinon	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Ingram/Hospital Creek and diazinon	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Foe, C. 1995. *Insecticide Concentrations and Invertebrate Bioassay Mortality in Agricultural Return Water from the San Joaquin Basin.* Central Valley Regional Water Quality Control Board. Sacramento, CA December 1995.	2; Pesticides
Ingram/ Hospital Crk	Diazinon	Fujimura, R. 1991a. *Chemical and Toxicity Test Results from the San Joaquin River at Three Sites from July 2 to September 13, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Fujimura, R. 1991b. *Chemical and Toxicity Test Results from the San Joaquin River and Tributaries During March 4 to April 26, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Fujimura, R. 1993a. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 29 to February 25,, 1993.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 26, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Fujimura, R. 1993b. *Chemical Analyses and Bioassay Test Results for Samples Collected from July 9 to September 9, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Fujimura, R. 1993c. *Chemical Analyses and Bioassay Test Results for Samples Collected from March 16 to April 30, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Fujimura, R. 1993d. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 23, 1991 to February 27, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. February 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Ross, L. 1992. Preliminary Results of the San Joaquin River Study; Summer, 1991. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. May 21, 1992. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Ross, L. 1993. Preliminary Results of the San Joaquin River Study; Summer, 1992. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. September 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Ingram/ Hospital Crk	Diazinon	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1996. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Winter 1991-92 and 1992-93. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 96-02. November, 1996. As presented in CDPR, 2000a.	1; Disk 1

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Jack Slough	Diazinon	Fact Sheet	1; Bear and Butte Crks
Jack Slough	Diazinon	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Jack Slough and diazinon	1; Disk 1
Jack Slough	Diazinon	Dileanis, P.D., J.L. Domagalski, and K.P. Bennett. 2000. Occurrence and Transport of Diazinon in the Sacramento River and its Tributaries During Three Winter Storms, January-February 2000. Water-Resources Investigations Draft Report. U.S. Geological Survey. Sacramento, CA.	1; Bear and Butte Crks
Jack Slough	Diazinon	Holmes, R. 2001. Personal Communication with C. Spector. CVRWQCB. August 28, 2001.	1; Bear and Butte Crks
Jack Slough	Diazinon	Holmes, R., C. Foe, and V. de Vlaming. 2000. *Sources and Concentrations of Diazinon in the Sacramento Watershed During the 1994 Orchard Dormant Spray Season.* California Regional Water Quality Control Board – Central Valley Region. Sacramento, CA. (CDPR and hard copy)	1; Bear and Butte Crks
Lake Combie	Mercury	Fact Sheet	2; HU:516 & 517
Lake Combie	Mercury	Alpers, C.N., M.P. Hunerlach. 2000. *Mercury Contamination from Historic Gold Mining in California.* U.S. Geological Survey. Fact Sheet FS-061-00. May 2000.	2; HU:516 & 517
Lake Combie	Mercury	May, J.T., R.L. Hothem, C.N. Alpers, M.A. Law. 2000. *Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999.* U.S. Geological Survey. Sacramento, CA. 2000.	2; HU:516 & 517
Lake Combie	Mercury	Montoya, B. and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU:516 & 517
Lake Combie	Mercury	Nevada County, Department of Environmental Health. 2000. *Press Release, Three County Environmental Health Agencies Issue Interim Public Health Notification on Mercury in Fish.* (http://www.co.nevada.ca.us/ehealth/hg/press_release_10-03-00.htm)	2; HU:516 & 517
Lake Englebright	Mercury	Fact Sheet	2; HU:516 & 517
Lake Englebright	Mercury	Alpers, C.N., M.P. Hunerlach. 2000. *Mercury Contamination from Historic Gold Mining in California.* U.S. Geological Survey. Fact Sheet FS-061-00. May 2000.	2; HU:516 & 517
Lake Englebright	Mercury	May, J.T., R.L. Hothem, C.N. Alpers, M.A. Law. 2000. *Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999.* U.S. Geological Survey. Sacramento, CA. 2000.	2; HU:516 & 517
Lake Englebright	Mercury	Montoya, B. and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU:516 & 517
Lake Englebright	Mercury	Nevada County, Department of Environmental Health. 2000. *Press Release, Three County Environmental Health Agencies Issue Interim Public Health Notification on Mercury in Fish.* (http://www.co.nevada.ca.us/ehealth/hg/press_release_10-03-00.htm)	2; HU:516 & 517

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Lake Englebright	Mercury	Slotton, D.G., S.M. Ayers, J.E. Reuter, C.R. Goldman. 1996. *Gold Mining Impacts on Food Chain Mercury in Northwestern Sierra Nevada Streams (1996 Revision).* Division of Environmental Studies, University of California, Davis. December 1996.	2; HU:516 & 517
Little Deer Creek	Mercury	Fact Sheet	2; HU:516 & 517
Little Deer Creek	Mercury	Alpers, C.N., M.P. Hunerlach. 2000. *Mercury Contamination from Historic Gold Mining in California.* U.S. Geological Survey. Fact Sheet FS-061-00. May 2000.	2; HU:516 & 517
Little Deer Creek	Mercury	May, J.T., R.L. Hothem, C.N. Alpers, M.A. Law. 2000. *Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999.* U.S. Geological Survey. Sacramento, CA. 2000.	2; HU:516 & 517
Little Deer Creek	Mercury	Montoya, B. and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU:516 & 517
Little Deer Creek	Mercury	Nevada County, Department of Environmental Health. 2000. *Press Release, Three County Environmental Health Agencies Issue Interim Public Health Notification on Mercury in Fish.* (http://www.co.nevada.ca.us/ehealth/hg/press_release_10-03-00.htm)	2; HU:516 & 517
Little Deer Creek	Mercury	Slotton, D.G., S.M. Ayers, J.E. Reuter, C.R. Goldman. 1996. *Gold Mining Impacts on Food Chain Mercury in Northwestern Sierra Nevada Streams (1996 Revision).* Division of Environmental Studies, University of California, Davis. December 1996.	2; HU:516 & 517
Mokelumne River, Lower	Aluminum	Fact Sheet	1; Camanche Res
Mokelumne River, Lower	Aluminum	Buer, S.M., S.R. Phillippe, and T.R. Pinkos. 1979. *Inventory and Assessment of Water Quality Problems related to Abandoned and Inactive Mines in the Central Valley Region of California.* CRWQCB-CVR (California Regional Water Quality Control Board, Central Valley Region), Report.	1; Camanche Res
Mokelumne River, Lower	Aluminum	CDFG (California Department of Fish and Game). 1991. *Lower Mokelumne River Fisheries Plan.* The Resources Agency, Department of Fish and Game, Stream flow Requirements Program. November 1991.	1; Camanche Res
Mokelumne River, Lower	Aluminum	CH2MHILL. 2000a. *Closure Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. December 2000.	1; Camanche Res
Mokelumne River, Lower	Aluminum	CH2MHILL. 2000b. *(Draft) Post-Restoration Final Effectiveness Report: Penn Mine Environmental Restoration Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. Oakland, California. September 2000.	1; Camanche Res
Mokelumne River, Lower	Aluminum	EBMUD (East Bay Municipal Utility District). 2000. All About EBMUD. EBMUD Public Affairs Office publication. Available: http://www.ebmud.com/pubs/annual/allaboutebmud_2000.pdf. Accessed: August 2, 2001.	1; Camanche Res
Mokelumne River, Lower	Aluminum	EDAW, Inc. 1992. *Draft EIS/EIR for the Updated Water Supply Management Program, Volume III, Technical Appendices B1 and B2.* Prepared for: East Bay Municipal Utility District. Oakland, California. December 1992.	1; Camanche Res
Mokelumne River, Lower	Aluminum	SCH EIR. 1996. *Draft EIR for The Penn Mine Site, Long-Term Solution Project.* Prepared for: East Bay Municipal Utility District and Regional Water Quality Control Board-Central Valley Region. SCH EIR No. 95103036. May 1996.	1; Camanche Res

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Mokelumne River, Lower	Aluminum	SWRCB (State Water Resources Control Board). 1990. *Water Quality Problems Associated with Operation of Pardee and Camanche Reservoir.* State Water Resources Control Board, Division of Water Quality staff report.	1; Camanche Res
Mokelumne River, Lower	Aluminum	USFWS (U.S. Fish & Wildlife Service). 1992. *Before the State Water Resources Control: In the Matter of the Water Rights Hearing for the Lower Mokelumne River – Closing Statement, Enclosure 2 (EBMUD Data – Aluminum, Cadmium, Zinc, Iron and Zinc).* Prepared by J.W. Burke, III (Regional Solicitor, USFWS Pacific Southwest Region) and Lynn Cox (Assistant Regional Solicitor, USFWS Pacific Southwest Region).	1; Camanche Res
Mokelumne River, Lower	Aluminum	USGS (U.S. Geological Survey). 1976. Lodi North, California. 7.5' Topographic Quadrangles, as presented by TopoZone.com (© 2000 Maps a la carte, Inc.). Accessed on August 6, 2001 (http://www.topozone.com/default.asp).	1; Camanche Res
Mormon Slough	Dissolved Oxygen	Fact Sheet	2; Low DO
Mormon Slough	Dissolved Oxygen	Lee G.F. Dissolved Oxygen Depletion in the Stockton Sloughs. August 2000. (Prepared for DeltaKeeper)	2; Low DO
Mormon Slough	Dissolved Oxygen	Lee, G.F. and A. Jones-Lee. 2001b. *Review of the City of Stockton Urban Stormwater Runoff Aquatic Life Toxicity Studies Conducted by the Central Valley Regional Water Quality Control Board, DeltaKeeper, and the University of California, Davis, Aquatic Toxicology Laboratory between 1994 and 1999.* Final Report. November 2001. G. Fred Lee & Associates. El Macero, CA. (Prepared for DeltaKeeper).	2; Smith Canal
Mormon Slough	Pathogens	Fact Sheet	1; Bacteria
Mormon Slough	Pathogens	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper comments on section 303(d) list update.	1; Bacteria
Mosher Slough	Dissolved Oxygen	Fact Sheet	2; Low DO
Mosher Slough	Dissolved Oxygen	Lee G.F. Dissolved Oxygen Depletion in the Stockton Sloughs. August 2000. (Prepared for DeltaKeeper)	2; Low DO
Mosher Slough	Dissolved Oxygen	Lee, G.F. and A. Jones-Lee. 2001b. *Review of the City of Stockton Urban Stormwater Runoff Aquatic Life Toxicity Studies Conducted by the Central Valley Regional Water Quality Control Board, DeltaKeeper, and the University of California, Davis, Aquatic Toxicology Laboratory between 1994 and 1999.* Final Report. November 2001. G. Fred Lee & Associates. El Macero, CA. (Prepared for DeltaKeeper).	2; Smith Canal
Mosher Slough	Pathogens	Fact Sheet	1; Bacteria
Mosher Slough	Pathogens	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper comments on section 303(d) list update.	1; Bacteria
Newman Wasteway	Chlorpyrifos	Fact Sheet	2; Pesticides
Newman Wasteway	Chlorpyrifos	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Newman Wasteway and chlorpyrifos	1; Disk 1

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Newman Wasteway	Chlorpyrifos	Foe, C. 1995. *Insecticide Concentrations and Invertebrate Bioassay Mortality in Agricultural Return Water from the San Joaquin Basin.* Central Valley Regional Water Quality Control Board. Sacramento, CA December 1995.	2; Pesticides
Newman Wasteway	Chlorpyrifos	Fujimura, R. 1991a. *Chemical and Toxicity Test Results from the San Joaquin River at Three Sites from July 2 to September 13, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Chlorpyrifos	Fujimura, R. 1991b. *Chemical and Toxicity Test Results from the San Joaquin River and Tributaries During March 4 to April 26, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Chlorpyrifos	Fujimura, R. 1993a. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 29 to February 25,, 1993.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 26, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Chlorpyrifos	Fujimura, R. 1993b. *Chemical Analyses and Bioassay Test Results for Samples Collected from July 9 to September 9, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Chlorpyrifos	Fujimura, R. 1993c. *Chemical Analyses and Bioassay Test Results for Samples Collected from March 16 to April 30, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Chlorpyrifos	Fujimura, R. 1993d. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 23, 1991 to February 27, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. February 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Chlorpyrifos	Ross, L. 1992. Preliminary Results of the San Joaquin River Study; Summer, 1991. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. May 21, 1992. As presented in CDPR, 2000a.	1; Disk 1

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Newman Wasteway	Chlorpyrifos	Ross, L. 1993. Preliminary Results of the San Joaquin River Study; Summer, 1992. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. September 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Chlorpyrifos	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1996. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Winter 1991-92 and 1992-93. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 96-02. November, 1996. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Chlorpyrifos	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1999. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Spring 1991 and 1992. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 99-01. April, 1999. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Fact Sheet	2; Pesticides
Newman Wasteway	Diazinon	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Newman Wasteway and diazinon.	1; Disk 1
Newman Wasteway	Diazinon	Foe, C. 1995. *Insecticide Concentrations and Invertebrate Bioassay Mortality in Agricultural Return Water from the San Joaquin Basin.* Central Valley Regional Water Quality Control Board. Sacramento, CA December 1995.	2; Pesticides
Newman Wasteway	Diazinon	Fujimura, R. 1991a. *Chemical and Toxicity Test Results from the San Joaquin River at Three Sites from July 2 to September 13, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Fujimura, R. 1991b. *Chemical and Toxicity Test Results from the San Joaquin River and Tributaries During March 4 to April 26, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Fujimura, R. 1993a. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 29 to February 25,, 1993.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 26, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Fujimura, R. 1993b. *Chemical Analyses and Bioassay Test Results for Samples Collected from July 9 to September 9, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Fujimura, R. 1993c. *Chemical Analyses and Bioassay Test Results for Samples Collected from March 16 to April 30, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Fujimura, R. 1993d. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 23, 1991 to February 27, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. February 23, 1993. As presented in CDPR, 2000a.	1; Disk 1

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Newman Wasteway	Diazinon	Ross, L. 1992. Preliminary Results of the San Joaquin River Study; Summer, 1991. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. May 21, 1992. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Ross, L. 1993. Preliminary Results of the San Joaquin River Study; Summer, 1992. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. September 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1996. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Winter 1991-92 and 1992-93. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 96-02. November, 1996. As presented in CDPR, 2000a.	1; Disk 1
Newman Wasteway	Diazinon	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1999. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Spring 1991 and 1992. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 99-01. April, 1999. As presented in CDPR, 2000a.	1; Disk 1
Oak Run Creek	Fecal Coliform	Fact Sheet	1; cow creek
Oak Run Creek	Fecal Coliform	Hannaford MJ and North State Institute for Sustainable Communities. 2000. Preliminary Water Quality Assessment of 1; cow creek Tributaries. Department of Fish and Game. May 15, 2000. (http://www.delta.dfg.ca.gov/afrp/documents/cowcrk.rpt.pdf).	1; cow creek
Orestimba Creek	Azinphos Methyl	Fact Sheet	2; Pesticides
Orestimba Creek	Azinphos Methyl	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Orestimba and azinphos methyl	1; Disk 1
Orestimba Creek	Azinphos Methyl	Fujimura, R. 1991a. *Chemical and Toxicity Test Results from the San Joaquin River at Three Sites from July 2 to September 13, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Fujimura, R. 1991b. *Chemical and Toxicity Test Results from the San Joaquin River and Tributaries During March 4 to April 26, 1991.* Memorandum to Lisa Ross, Department of Pesticide Regulation. Sacramento, CA. November 6, 1991. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Fujimura, R. 1993a. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 29 to February 25,, 1993.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 26, 1993. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Fujimura, R. 1993b. *Chemical Analyses and Bioassay Test Results for Samples Collected from July 9 to September 9, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 23, 1993. As presented in CDPR, 2000a.	1; Disk 1

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Orestimba Creek	Azinphos Methyl	Fujimura, R. 1993c. *Chemical Analyses and Bioassay Test Results for Samples Collected from March 16 to April 30, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. March 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Fujimura, R. 1993d. *Chemical Analyses and Bioassay Test Results for Samples Collected from December 23, 1991 to February 27, 1992.* Memorandum to Brian Finlayson, Pesticide Investigations Unit, California Department of Fish and Game. Rancho Cordova, CA. February 23, 1993. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Panshin, S.Y., N.M. Dubrovsky, J.M. Gronberg, and J.L. Domagalski. 1998. Occurrence and Distribution of Dissolved 2; Pesticides in the San Joaquin River Basin, California. USGS National Water Quality Assessment Program, Water Resources Investigations report No. 98-4032.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Ross, L. 1992. Preliminary Results of the San Joaquin River Study; Summer, 1991. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. May 21, 1992. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Ross, L. 1993. Preliminary Results of the San Joaquin River Study; Summer, 1992. Memorandum to Kean Goh. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. September 22, 1993. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1996. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Winter 1991-92 and 1992-93. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 96-02. November, 1996. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	Azinphos Methyl	Ross, L., J. Stein, J. Hsu, J. White, and K. Hefner. 1999. Distribution and Mass Loading of Insecticides in the San Joaquin River, California: Spring 1991 and 1992. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. California Department of Pesticide Regulation. Sacramento, CA. Report EH 99-01. April, 1999. As presented in CDPR, 2000a.	1; Disk 1
Orestimba Creek	DDE	Fact Sheet	2; Pesticides
Orestimba Creek	DDE	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Orestimba and DDE	1; Disk 1
Orestimba Creek	DDE	Panshin, S.Y., N.M. Dubrovsky, J.M. Gronberg, and J.L. Domagalski. 1998. Occurrence and Distribution of Dissolved 2; Pesticides in the San Joaquin River Basin, California. USGS National Water Quality Assessment Program, Water Resources Investigations report No. 98-4032.	1; Disk 1
Putah Creek, Lower	Mercury	Fact Sheet	2; Putah Creek
Putah Creek, Lower	Mercury	Slotton, D.G., S.M. Ayers, J.E. Reuter, C.R. Goldman. 1999. *Lower 2; Putah Creek 1997-1998 Mercury Biological Distribution Study. February 1999.* Dept. of Environmental Science and Policy, University of California, Davis. February 1999.	2; Putah Creek
Putah Creek, Lower	Mercury	USDHHS- ATSDR, 1998. *Fish Sampling in 2; Putah Creek (Phase II), Laboratory for Energy Related Health Research, Davis, Yolo County California, Cerclis No. CA2890190000.* Agency for Toxic Substance and Disease Registry. September 1998.	2; Putah Creek

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Putah Creek, Lower	Mercury	USDHHS-ATSDR, 1997. *Fish Sampling in 2; Putah Creek, 1996, Laboratory for Energy Related Health Research, Davis, Yolo County California, Cerclis No. CA2890190000.* Agency for Toxic Substance and Disease Registry (ATSDR). April 1997.	2; Putah Creek
Putah Creek, Lower	Unknown Toxicity	Fact Sheet	2; Putah Creek
Putah Creek, Lower	Unknown Toxicity	Larsen K, M McGraw, V Connor, L Deanovic, T Kimball, and D Hinton. 2000. *Cache Creek and 2; Putah Creek Watersheds Toxicity Monitoring Results: 1998-1999* Final Report. November 2000.	2; Putah Creek
Putah Creek, Upper	Unknown Toxicity	Fact Sheet	2; Putah Creek
Putah Creek, Upper	Unknown Toxicity	Larsen K, M McGraw, V Connor, L Deanovic, T Kimball, and D Hinton. 2000. *Cache Creek and 2; Putah Creek Watersheds Toxicity Monitoring Results: 1998-1999* Final Report. November 2000.	2; Putah Creek
Rollins Reservoir	Mercury	Fact Sheet	2; HU:516 & 517
Rollins Reservoir	Mercury	Alpers, C.N., M.P. Hunerlach. 2000. *Mercury Contamination from Historic Gold Mining in California.* U.S. Geological Survey. Fact Sheet FS-061-00. May 2000.	2; HU:516 & 517
Rollins Reservoir	Mercury	May, J.T., R.L. Hothem, C.N. Alpers, M.A. Law. 2000. *Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999.* U.S. Geological Survey. Sacramento, CA. 2000.	2; HU:516 & 517
Rollins Reservoir	Mercury	Montoya, B. and X. Pan. 1992. *Inactive Mine Drainage in the Sacramento Valley, California.* California Regional Water Quality Control Board, Central Valley Region Report. July 1992.	2; HU:516 & 517
Rollins Reservoir	Mercury	Nevada County, Department of Environmental Health. 2000. *Press Release, Three County Environmental Health Agencies Issue Interim Public Health Notification on Mercury in Fish.* (http://www.co.nevada.ca.us/ehealth/hg/press_release_10-03-00.htm)	2; HU:516 & 517
Rollins Reservoir	Mercury	SWRCB-DWQ (State Water Resources Control Board, Division of Water Quality). 1995. *Toxic Substances Monitoring Program: Freshwater Bioaccumulation Monitoring Program: Data Base (Met_Wet).*	1; Disk 1
San Joaquin River	Mercury	Fact Sheet	2; SJR
San Joaquin River	Mercury	Davis, J. A. and M. D. May. 2000. *Contaminant Concentrations in Fish from the Sacramento-San Joaquin Delta and Lower San Joaquin River – 1998.* San Francisco Estuary Institute report. Richmond, California. September 2000.	2; Pesticides
San Joaquin River	Mercury	Slotton, D. G., T.H. Suchanek, and S.M. Ayers. 2000. Delta Wetlands Restoration and the Mercury Question: Year 2 Findings of the CALFED UC Davis Mercury Study. IEP Newsletter. 13(4): 34-44.	2; SJR
San Joaquin River	Mercury	SWRCB (State Water Resources Control Board, Division of Water Quality). 1995. Toxic Substances Monitoring Program: Freshwater Bioaccumulation Monitoring Program: Data Base (Metals_Wet).	1; Disk 1
Scott's Flat Reservoir	Mercury	Fact Sheet	2; HU:516 & 517
Scott's Flat Reservoir	Mercury	Alpers, C.N., M.P. Hunerlach. 2000. *Mercury Contamination from Historic Gold Mining in California.* U.S. Geological Survey. Fact Sheet FS-061-00. May 2000.	2; HU:516 & 517

Scott's Flat Reservoir	Mercury	May, J.T., R.L. Hothem, C.N. Alpers, M.A. Law. 2000. *Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999.* U.S. Geological Survey. Sacramento, CA. 2000.	2; HU:516 & 517
Scott's Flat Reservoir	Mercury	Nevada County, Department of Environmental Health. 2000. *Press Release, Three County Environmental Health Agencies Issue Interim Public Health Notification on Mercury in Fish.* (http://www.co.nevada.ca.us/ehealth/hg/press_release_10-03-00.htm)	2; HU:516 & 517
Scott's Flat Reservoir	Mercury	Slotton, D.G., S.M. Ayers, J.E. Reuter, C.R. Goldman. 1996. *Gold Mining Impacts on Food Chain Mercury in Northwestern Sierra Nevada Streams (1996 Revision).* Division of Environmental Studies, University of California, Davis. December 1996.	2; HU:516 & 517
Smith Canal	Dissolved Oxygen	Fact Sheet	2; Low DO
Smith Canal	Dissolved Oxygen	CDM (Camp Dresser & McKee Inc). 1999. Assessment of Water Quality Data from 2; Smith Canal Canal. July 27, 1999. (Appendix B-2 to City of Stockton & San Joaquin County Storm Water Management Program).	2; Low DO
Smith Canal	Dissolved Oxygen	Chen C., and Tsai W. *Application of Stockton's Water Quality Model to Evaluate Stormwater Impact on 2; Smith Canal Canal*. February 23, 1999. (Attachment to March 17, 1999 letter from City of Stockton, G. Birdzell)	2; Low DO
Smith Canal	Dissolved Oxygen	Lee, G.F. and A. Jones-Lee. 2001b. *Review of the City of Stockton Urban Stormwater Runoff Aquatic Life Toxicity Studies Conducted by the Central Valley Regional Water Quality Control Board, DeltaKeeper, and the University of California, Davis, Aquatic Toxicology Laboratory between 1994 and 1999.* Final Report. November 2001. G. Fred Lee & Associates. El Macero, CA. (Prepared for DeltaKeeper).	2; Smith Canal

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Smith Canal	Dissolved Oxygen	Larsen, K., K.A. Cortright., P.Young, V. Connor, L.A.Deanovic, D.E. Hinton. 1998. *Stockton Fish Kills Associated With Urban Storm Runoff: The Role of Low Dissolved Oxygen.* CRWQCB-CVR. June 1998.	2; Low DO
Smith Canal	Dissolved Oxygen	Lee G.F. *2000. Dissolved Oxygen Depletion in the Stockton Sloughs.* August 2000. (Prepared for DeltaKeeper)	2; Low DO
Smith Canal	Organo-phosphorus Pesticides	Fact Sheet	2; Smith Canal
Smith Canal	Organo-phosphorus Pesticides	Larsen K, M McGraw, V Connor, L Deanovic, T Kimball, and D Hinton. 2000. *Cache Creek and 2; Putah Creek Watersheds Toxicity Monitoring Results: 1998-1999* Final Report. November 2000.	2; Putah Creek
Smith Canal	Organo-phosphorus Pesticides	Lee G.F., and A. Jones – Lee. 2001. Review of the City of Stockton Urban Stormwater Runoff Aquatic Life Toxicity Studies Conducted by the CVRWQCB, DeltaKeeper and the University of California, Davis, Aquatic Toxicology Laboratory between 1994 and 1999. April 1, 2001.	2; Smith Canal
Smith Canal	Pathogens	Fact Sheet	1; Bacteria
Smith Canal	Pathogens	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper comments on section 303(d) list update.	1; Bacteria
South cow creek	Fecal Coliform	Fact Sheet	1; cow creek
South cow creek	Fecal Coliform	Hannaford MJ and North State Institute for Sustainable Communities. 2000. Preliminary Water Quality Assessment of 1; cow creek Tributaries. Department of Fish and Game. May 15, 2000. (http://www.delta.dfg.ca.gov/afrp/documents/cowcrk.rpt.pdf).	1; cow creek
Stanislaus River, Lower	Mercury	Fact Sheet	2; SJR
Stanislaus River, Lower	Mercury	USBR (U.S. Bureau of Reclamation). 2001. *U.S. Bureau of Reclamation DataWeb: Power Plants, Dams & Reservoirs.* Accessed on August 22, 2001 (http://dataweb.usbr.gov/).	NA
Stanislaus River, Lower	Mercury	SWRCB (State Water Resources Control Board). 1995. *Toxic Substances Monitoring Program: Freshwater Bioaccumulation Monitoring Program: Data Base.* As presented in TSMP database (Metals_Wet).	1; Disk 1
Stanislaus River, Lower	Mercury	Davis, J.A., M.D. May, G. Ichikawa, and D. Crane. 2000. *Contaminant Concentrations in Fish from the Sacramento-San Joaquin Delta and Lower San Joaquin River – 1998.* San Francisco Estuary Institute report. Richmond, California. September 2000.	2; Pesticides
Stanislaus River, Lower	Mercury	OMR (Office of Mine Reclamation). 2000. *California's Abandoned Mines – A Report on the Magnitude and Scope of the Issue in the State.* California Department of Conservation, Office of Mine Reclamation, Abandoned Mine Lands Unit (OMR). Sacramento, CA. June 2000.	1; Don Pedro Lake
Stockton Deep Water Channel	Pathogens	Fact Sheet	1; Bacteria
Stockton Deep Water Channel	Pathogens	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper comments on section 303(d) list update.	1; Bacteria

Waterbody	Pollutant	Sources	Location: Folder #; Tab Title
Sutter Bypass	Diazinon	Fact Sheet	2; Pesticides
Sutter Bypass	Diazinon	CDPR. 2001. Surface Water Database. Access formatted database, using the parameters of Sutter Bypass and Diazinon	1; Disk 1
Sutter Bypass	Diazinon	Nordmark, C. In prep. *Preliminary Results of Acute and Chronic Toxicity Testing of Surface Water Monitored in the Sacramento River Watershed, Winter 1999-00.* Memorandum to Don Weaver, Environmental Monitoring and Pest Management, Department of Pesticide Regulation. Sacramento, CA. As presented in CDPR, 2000a.	1; Disk 1
Sutter Bypass	Diazinon	Nordmark, C. 1998. *Preliminary Results of Acute and Chronic Toxicity Testing of Surface Water Monitored in the Sacramento River Watershed, Winter 1998-99.* Memorandum to Don Weaver, Environmental Monitoring and Pest Management, Department of Pesticide Regulation. Sacramento, CA. July 31, 1998 As presented in CDPR, 2000a.	1; Disk 1
Sutter Bypass	Diazinon	Nordmark, C. 1999. *Preliminary Results of Acute and Chronic Toxicity Testing of Surface Water Monitored in the Sacramento River Watershed, Winter 1998-99.* Memorandum to Don Weaver, Environmental Monitoring and Pest Management, Department of Pesticide Regulation, Sacramento, CA. May 26, 1999. As presented in CDPR, 2000a.	1; Disk 1
Sutter Bypass	Diazinon	Nordmark, C.E., K.P. Bennett, H. Feng, J. Hernandez, and P. Lee. 1998. Occurrence of aquatic toxicity and dormant spray pesticide detections in the Sacramento River watershed. Winter 1996-97. Environmental Hazards Assessment Program, Environmental Monitoring and Pest Management Branch. Department of Pesticide Regulation. Sacramento, CA. Report EH98-01. February, 1998. As presented in CDPR, 2000a.	1; Disk 1
Walker Slough	Pathogens	Fact Sheet	1; Bacteria
Walker Slough	Pathogens	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper comments on section 303(d) list update.	1; Bacteria
Wolf Creek	Fecal Coliform	Fact Sheet	1; Bacteria
Wolf Creek	Fecal Coliform	City of Grass Valley. 2000. *Discharger self-monitoring reports (DSMRs) for Grass Valley Waste Water Treatment Plant.*	NA
Wolf Creek	Fecal Coliform	City of Grass Valley. 2001. *Discharger self-monitoring reports (DSMRs) for Grass Valley Waste Water Treatment Plant.*	NA
Wolf Creek	Fecal Coliform	Jennings, B. 2001. Letter from Bill Jennings (DeltaKeeper A Project of San Francisco BayKeeper) to Mr. Jerry Bruns and Mr. Joe Karkoski (California Regional Water Quality Control Board, Central Valley Region) dated May 14, 2001, regarding DeltaKeeper comments on section 303(d) list update.	1; Bacteria

Tracking List of Public Comments to Region 5's 303(d) List Draft Staff Report

Date Comment Received	Comment Source/Agency	Contact Name for Comment/ Acknowledgement (Name of Author(s)*)	Comment Contact Address	Comment Contact Phone No.	Other Contact Method
10/1/01	Minasian, Spruance, Baber, Meith, Soares & Sexton, LLP	Michael Sexton	1681 Bird Street P.O. Box 1679 Oroville, Ca 95965	(530) 533-2885	msexton@minasianlaw.com
10/4/01	U.S. Fish and Wildlife Service	Bill Beckon (Steve Schwarzbach)	2800 Cottage Way, Suite W-2605, Sacramento, CA 95825-1846	(916) 414-6597	Ph.D. Chief, Environmental Contaminants Division Sacramento Fish and Wildlife Office 2800 Cottage Way room W-2605 Sacramento, California 95825-1846 phone: (916) 414-6591 fax :(916)
10/4/01	Westlands Water District	Mark Rhodes, Associate Resources Analyst			mrhodes@westlandswater.org
10/8/01	Westlands Water District	Mark Rhodes, Associate Resources Analyst			mrhodes@westlandswater.org
10/24/01	Minasian, Spruance, Baber, Meith, Soares & Sexton, LLP	Michael Sexton	1681 Bird Street P.O. Box 1679 Oroville, Ca 95965	(530) 533-2885	msexton@minasianlaw.com
11/1/01	Nevada Irrigation District	James P Chatigny, General Manager	P.O. Box 1019 Grass Valley CA 95945	530/273-6185	chatigny@nid.dst.ca.us
11/1/01	Herum Crabtree Brown	Jeanne M. Zolezzi, Attorney at Law	2291 West March Lane Suite B100 Stockton, CA 95207	(209) 472-7700	jzolezzi@herumcrabtree.com
11/1/01	Brown and Caldwell	Cynthia Paulson, Ph.D., P.E., Vice President; Ronda Sandquist, Esq., Baker & Hostetler LLP	201 North Civic Drive Walnut Creek, CA 94596	(925) 210-2477 [Paulson]; (303) 674-4031 [Sandquist]	
11/1/01	Sierra Nevada Alliance	Laurel W. Ames, Executive Director	PO Box 7989 S. Lake Tahoe, CA 96158	(530) 542-4546	www.sierranevadaalliance.org
11/2/01	City of Stockton	Bob Murdoch			Bob.Murdoch@ci.stockton.ca.us
11/2/01	Sacramento Regional County Sanitation District	Robert F. Shanks, District Engineer	10545 Armstrong Avenue, Mather, CA 95655	(916) 876-6000	www.srcsd.com
11/9/01	San Joaquin Farm Bureau Federation	Joe Petersen, Proram Director	P.O. Box 8444 3290 North Ad Art Road, Stockton, CA 95208	(209) 931-4931	

B.3.7 Fall River, Sediment/Siltation – Change in Size Affected

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, recommends changes to California's Clean Water Act Section 303(d) list for the impairment of Fall River due to impairment by sediment and silt. The Regional Board recommends that the identified impaired length change from 25 to 9.5 miles. The basis for the recommended change is described below.

Watershed Characteristics

Fall River flows for approximately 25 miles, from Thousand Springs (in the southeast portion of Siskiyou County) to its confluence with the Pit River (in Shasta County). The Upper Fall River (8.3 miles) meanders through a broad, flat floodplain, and receives inflow, plus sediment and silt, from numerous creeks and springs (including Bear, Spring, and Dry Creeks in wet years). Overall, the water quality and volume (for all areas) is influenced by agricultural uses (including irrigation returns to the river, water collected for irrigation uses, and grazing), tributary inflows, silviculture, and highway, road, and bridge construction. These sources have resulted in sediment and silt entering the river, covering the natural riverbed (composed primarily of clay, hardpan, and exposed volcanic cobbles) with sand, and impairing the water quality of Fall River.

Extent of Impairment

Fall River is impaired from its headwaters to just downstream of Spring Creek Bridge, a total distance of approximately 9.5 miles. This is demonstrated by 3 types of studies—identification of erosion sites, sediment studies, and studies of organisms within Fall Creek (including aquatic vegetation, aquatic macroinvertebrates, and fish). Because the studies generally compared upper and lower Fall River, most of the evidence suggests that upper Fall Creek is impaired relative to lower Fall River (CRWQCB-CVR, 1982; CDWR, 1998; North State Resources and T. Holmes, 1997; Tetra Tech, Inc., 1998; USDA, 1983).

FALL RIVER WATER QUALITY MONITORING SURVEY

JULY 1982

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD

CENTRAL VALLEY REGION

I. INTRODUCTION

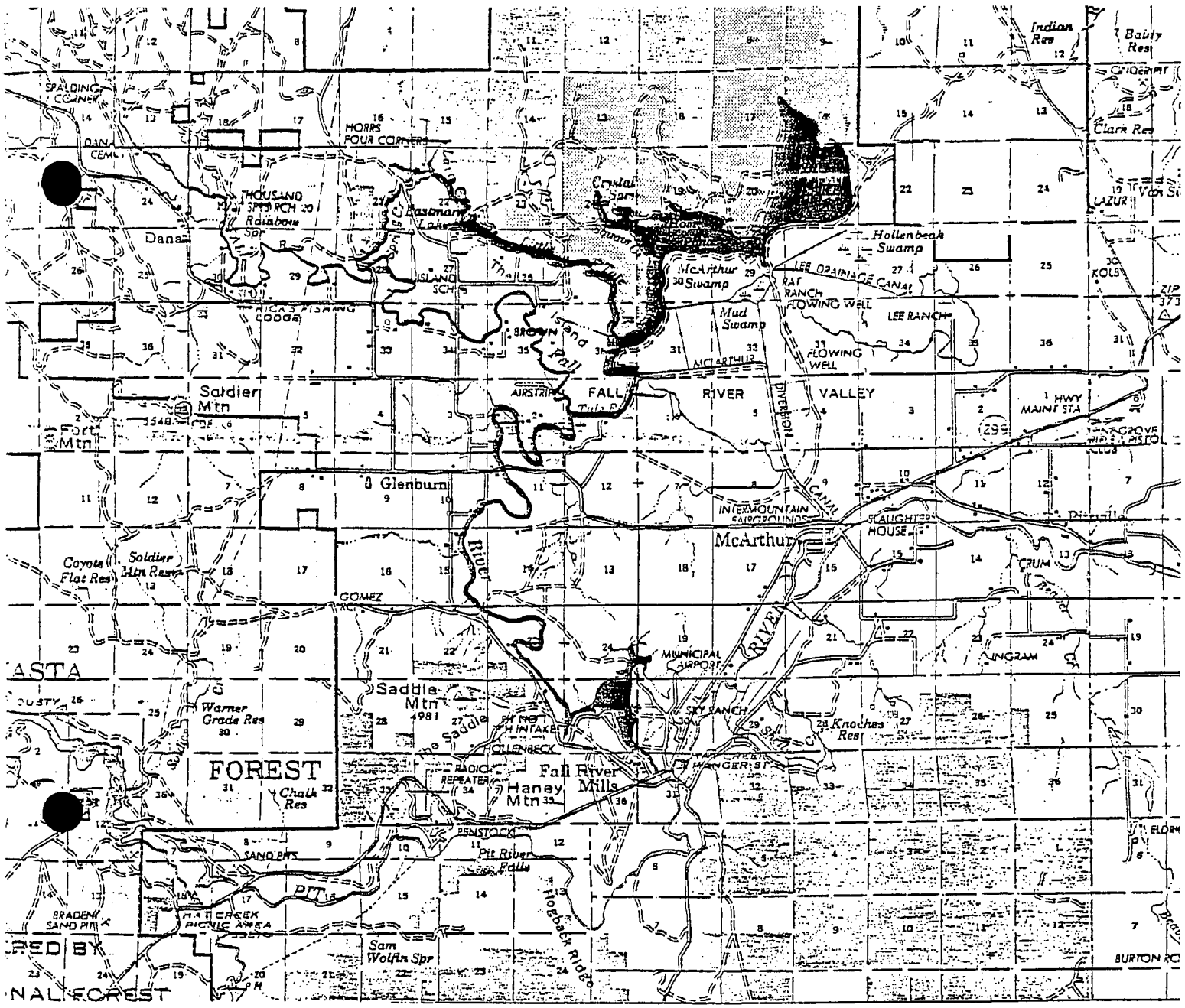
Over the past several years, there has developed an increased concern for possible water quality problems in the Fall River Valley. In 1979, the Regional Board received a petition from approximately 60 residents from the Glenburn area of the valley requesting a survey of potential problems from individual septic tank/leachfield systems. The Board was notified by the Shasta County Environmental Health Department of several contaminated domestic wells in the area. In addition, the Board received complaints from several local residents of nuisance conditions resulting from livestock operations adjacent to Fall River. It became apparent that there was a need for a comprehensive investigation of water quality conditions in the river.

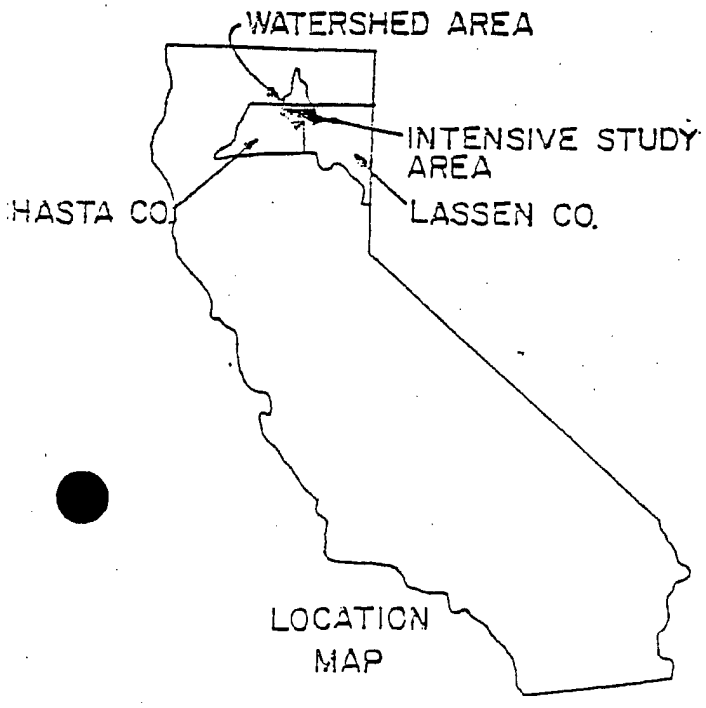
As a result, the Regional Board, in cooperation with the U.S. Soil Conservation Service, conducted a one-year monitoring study of the Fall River as part of the state's 208 Water Quality Management Program.

Description of Study Area

Fall River is in Shasta and Lassen Counties approximately 70 miles northeast of Redding. The river is formed at its headwaters by a number of large springs that enter the river system through several short tributaries: Spring Creek, Lava Creek, and Tule River. The approximate location of the major springs is shown in Figure 1. Two intermittent streams, Bear Creek and Frazier Creek, also contribute some inflow. The river winds for approximately 25 miles through the valley, then is diverted through a Pacific Gas and Electric powerhouse and into the Pit River.

The Fall River is a large meandering meadow stream. The bottom is composed largely of sand and silt which supports extensive weed beds. The maintenance of these weed beds is vital to the continued productivity of the stream. The river is one of the premier flyfishing streams in California and is known throughout the United States for its blue-ribbon trout fishery. In 1972, the Fish and Game Commission designated Fall River for special management and habitat protection as one of the original streams in the state's Wild Trout Program. The river and its surrounding marshes also provide some of the state's most important waterfowl habitat.





LOCATION MAP

FALL RIVER WATER QUALITY STUDY

Fall River Valley, which includes an area of approximately 97 square miles (estimated population 2,400) has a combination of agricultural and residential land uses. Primary agricultural uses include livestock operations, alfalfa, grain, and specialty crop productions. The area has also been used increasingly for rural subdivisions with lot sizes ranging from one-half to five acres. Numerous individual homes are being built adjacent to the river.

Urban centers include the communities of McArthur and Fall River Mills. The town of Fall River Mills is served by a sewage collection and treatment facility, and domestic water taken from the Fall River is filtered and chlorinated prior to being supplied by the Fall River Community Services District. Approximately 400 rural residents living adjacent to the river above Fall River Mills use untreated water from the Fall River as their domestic water source.

II. DESCRIPTION OF THE MONITORING PROGRAM

Due to limited funds, the monitoring program was restricted primarily to a one-year bacteriological survey of the Fall River. Since suspected problem sources were from septic systems and confined animal facilities, it was believed that bacteriological contamination was the principal threat to beneficial uses in the river. The overall monitoring is described below (and summarized in Table 1):

Fall River

Fifteen stations were established over the entire length of the river and sampled monthly for total and fecal coliform bacteria (Figure 2). Eight of the stations were on the main stem of the river. Others were located at the confluence of major tributaries. Samples were tested periodically for temperature, turbidity, nutrients, MBAS and pesticides. Analyses were performed according to Standard Methods by the state certified CH_2M Hill laboratory in Redding.

Drains

In an attempt to help define sources of contamination, eleven surface drains which discharge to the river were sampled twice during high runoff (Figure 3). Several drains, which were still flowing, were also sampled in July. Drain samples were tested for total and fecal coliform bacteria and MBAS.

Ground Water

Shallow observation wells (5 to 15 feet) were installed to monitor the ground water above and below the hardpan. Observation wells were installed at 24 sites that were selected to reflect different topography and soil types in the valley (Figure 4). Wells were sampled twice for total and fecal coliform bacteria and once for chlorides. In addition, the Shasta County Health Department randomly sampled 25 domestic wells in the area and tested for total and fecal coliforms.

III. MONITORING RESULTS

The one-year monitoring program for total and fecal coliform bacteria and other water quality parameters in the Fall River, tributary drains, and ground water produced the following results:

A. FALL RIVER

1. Total and Fecal Coliform Bacteria

Results of the bacteriological survey at 15 stations in the Fall River are presented in Figure 5 and Table 2.

In reviewing the coliform data, one apparent trend is that bacteriological concentrations in the river were relatively low during the winter period, increased rapidly during the spring, and reached peak concentrations during the late summer-fall months (Figure 6). This trend probably

is not the result of an actual increase in bacteriological loading to the river during summer and fall, but rather is the result of increasing water temperature and decreasing river flow during this period. Annual water temperatures ranged from a 15-station mean of 7.5°C in January to 16.7°C in July.

Annual average total and fecal coliform concentrations at the eight stations on the main stem of the Fall River was compared starting at the headwaters and moving progressively downstream. In general, bacteriological concentrations are low from river stations one through three (Thousand Springs to Ricks Lodge), then increase and remain relatively constant throughout the remaining length of the river (Figure 7).

Overall, the Fall River showed relatively high concentrations of total and fecal coliform bacteria when compared with other Northern California streams and rivers. This is a reflection of the intensive agricultural and residential land uses in the valley. Bacteriological quality is not satisfactory for untreated domestic use. The water quality objective for water contact recreation, as contained in the Regional Board's Basin Plan, specifies that fecal coliform concentrations shall not exceed a geometric mean of 200 MPN/100 ml or a maximum of 400 MPN/100 ml. Although sampling frequency in this study was not sufficient to statistically compare with the Basin Plan objective, it is apparent that river concentrations approach and exceed the objective during certain periods of the year.

2. Nutrients

Limited data for NO_3, total N, and total P indicate that nutrient levels are not excessively high and compare closely with other streams and rivers in the area (Table 3).

3. Pesticides

Pesticides were tested for chlorinated hydrocarbon and organophosphorus insecticides and chlorophenoxy herbicides during the period coinciding with heaviest use. No detectable concentrations were found.

4. Suspended Sediment and Turbidity

The Soil Conservation Service investigated sources of erosion/sedimentation throughout the watershed and on lands adjacent to the river. No significant erosion is occurring on the valley lands. The overall rate of stream bank erosion along Fall River is low, but some localized problem areas exist.

Low to moderate rates of erosion are occurring in the Bear Creek watershed from unsurfaced roads, cattle overgrazing, and stream bank erosion. Bear Creek was very turbid during high runoff in March and April 1982. Sediment loading from the stream has created a large silt delta near the Bear Creek/Fall River confluence. The primary source of sediment appears to be bank cutting.

Turbidity samples taken in Fall River during low flow and runoff events were relatively low (1 to 5 JTU's).

B. DRAINS

Results of bacteriological sampling in drains is summarized in Table 4. Fecal coliform conentrations varied from <3 to 46,000 MPN 100 ml. There were no discernible land use patterns associated with high fecal coliform concentrations, i.e., high concentrations occurred in areas which were primarily residential and in areas primarily agricultural.

C. GROUND WATER QUALITY

Shallow observations wells were sampled for total and fecal coliform bacteria in July 1981 and March 1982. The results are summarized in Table 5. Concen-

trations varied but, in general, it is apparent there is bacteriological contamination of the shallow ground water. It appears this contamination is confined to the perched aquifers above and below the hardpan layer and is not affecting usable ground water (deep aquifer). Of the 25 domestic wells sampled by the Shasta County Health Department, 21 showed no bacteriological contamination. The four wells that showed contamination were found to have improper sanitary seals.

D. SUMMARY

Results of the one-year sampling program in the Fall River, tributary drains, and ground water are summarized in following findings:

1. Coliform bacteria concentrations in the Fall River consistently exceed recommended limits for undisinfected raw surface supplies.

2. Coliform bacteria concentrations in the Fall River at times approach and exceed contact recreation limits as contained in the Regional Board's Water Quality Control Plan.

3. There was seasonal variation in the Fall River bacteriological quality. Coliform bacteria concentrations were higher in summer and fall as compared to the winter-spring period.

4. With the exception of headwater stations where concentrations were low, bacteria concentrations remained relatively constant from Spring Creek to the river outlet.

5. High coliform bacteria concentrations were found in surface drains leading to the river.

6. Bacteriological quality of shallow ground water was generally poor.

7. All other measured parameters (i.e., nutrients, pesticides, turbidity, and temperature) were within acceptable limits for all beneficial uses.

8. Soil erosion and sedimentation rates were generally low.

IV. SOURCES OF CONTAMINATION

The most probable sources of bacteriological contamination to Fall River are septic tank/leachfield systems and livestock operations. Initially, it was hoped that the monitoring study would define and compare the amount of contamination originating from these two sources. It was found that there is no reliable test for segregating bacteria from human and livestock origin. The testing, which was done along with general observations of the area, indicates that contamination is from both sources. For pollution control purposes, it is recommended that initial efforts focus on eliminating the most obvious and easily correctable sources associated with both septic tank systems and livestock operations.

Septic Tank/Leachfield Systems

The following natural features of the Fall River Valley make it generally unsuitable for septic tank/leachfield systems:

- shallow hardpan
- high water table
- inadequate surface drainage
- poor soil permeability

There are 359 septic systems in the study area. Seventy-three systems are installed over hardpan, 171 systems are installed over a high water table and 153 systems are in areas subject to flooding or ponding (Figures 8, 9, and 10). Under the current Shasta County ordinance for on-site sewage disposal, none of these systems could be approved.

Review of septic tank pumping records indicate that an average of 71 tanks were pumped becuase of high ground water during the months of February, March and April.

Because of possible problems with septic tank/leachfield systems, the Regional Board has initiated a survey of individual homes adjacent to the river. To date, dye tests have not been successful in pinpointing septic tank/leachfield failures.

Livestock Operations

Approximately 3,000 head of livestock are grazed in the Fall River Valley during the summer months. There are approximately five large "confined animal" areas adjacent to the river. These operations are seasonal with large numbers of cattle held in the corrals for a few days during spring and fall. There are also a number of small corrals adjacent to the river which periodically hold a few cattle or horses.

Regional Board "Guidelines for Protection of Water Quality from Animal Wastes", in part, specify that animals in confinement shall be prevented from entering surface waters and that corral areas shall have capacity to retain surface drainage during a 10-year 24-hour storm. Most of the livestock operations adjacent to the river are in violation of the Board's guidelines.

Other problems result where animals on open range concentrate along stream banks to feed and water. This causes damage to stream banks and riparian vegetation, and increases downstream turbidity. The Board's policy does not restrict access to surface waters for cattle on open range.

V. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are based on the one-year bacteriological survey of ground and surface waters in the Fall River Valley.

1. Fall River is unsuitable as an undisinfected domestic supply because of high concentrations of total and fecal coliform bacteria.

   Recommended Action - State/local health departments should inform local users of the problems and encourage disinfection and treatment before use.

2. Much of the land area of the Fall River Valley consists of soils with slow permeability and high water table. These areas are unsuitable for use of individual septic tank/leachfield systems.

   Recommended Action - a. Regional Board staff should continue review of all proposals for new land divisions.
   b. Shasta County Health Department should strictly enforce the current ordinance for on-site sewage disposal.
   c. Regional Board staff should complete a survey to identify possible contamination from failing septic tank/leachfield systems immediately adjacent to the Fall River.

3. Confined livestock facilities are contributing to the bacteriological contamination of Fall River, however, it was not possible to determine the precise contribution from this source as compared to other potential sources in the valley.

   Recommended Action - a. The Regional Board or other appropriate agency should implement a program for modifying those

major confined animal facilities which are in violation of Regional Board animal waste guidelines.

b. The Regional Board or other appropriate agency should work with landowners to mitigate problems associated with large numbers of cattle concentrating on the river banks.

4. Due to the unique environmental qualities of the Fall River and the changing land uses within the valley, it is appropriate that specific water quality objectives be established so as to maintain existing high quality of the river.

Recommended Action - The Regional Board should collect the necessary baseline water quality data and establish specific water quality objectives for the Fall River.

State of California

The Resources Agency

Department of Water Resources

Northern District

AQUATIC MONITORING AND ASSESSMENT FOR THE UPPER FALL RIVER

MEMORANDUM REPORT

May 1998

State of California The Resources Agency

Memorandum

Date : May 22, 1998

To : Naser Bateni, Chief
Northern District

Koll Buer
Jerry Boles

From : Department of Water Resources

Subject: Aquatic Monitoring and Assessment for the Upper Fall River

This report presents data and results for the Aquatic Monitoring and Assessment for the Upper Fall River. This study was conducted under a grant from the Cantara Loop Council (CTC 96004).

This study was developed as a multi-year effort to serve as a starting point for the analysis of sediment problems in the Fall River. However, it was funded only for one year. This report documents the results of this single year study. Data were collected primarily during the fall and winter of 1996, with some field work extending into 1997. Cross-sections and sediment corings were completed for 12 sections of the river. Transport rates for bedload, suspended sediment and suspended sand were measured at four sections, generally over a range of four streamflow events. Gradations of the bedload samples are provided. Limited water quality and macroinvertebrate data were also collected. This information will provide a baseline and a protocol for future studies.

This study was also designed to determine the status of aquatic resources within the upper 10 to 12 miles of Fall River. This study was designed to complement and integrate with other watershed wide resource assessment and rehabilitation studies currently underway. The monitoring provides information for the upper Fall River and will be beneficial in future watershed activities. Further studies are needed to estimate accurately the transport rates, sedimentation volume, and impacts of sediment on biological resources of the upper Fall River. The development of specific recommendations was not a study task.

The following people assisted in report preparation and field activities: John Clements, Senior Engineer; Curtis Anderson, Associate Engineer WR; Jon Anderson, Associate Engineering Geologist; Fraser Sime, Environmental Specialist III; Gail Kuenster, Environmental Specialist II; Earl Hanson, Engineer WR; Bill Lane, Kelly Staton, Perry LeBeouf, Douglas John, and Arin Connor, Fish & Wildlife Scientific Aids; Tonya Watson, Jeff VanGilder, Jason Jurrens, Mark Souverville, and Denise Jennings, Student Assistants.

Enclosure

SURNAME | K. Buer 5/22/98 | Boles 5/22/98 | Pearson 5/26/98

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Introduction

The Fall River, in northeastern Shasta County, originates from an area called Thousand Springs near the community of Dana (Figure 1). The Bear Creek and headwater springs produce a near constant flow of clear, cold water. The Fall River a gently meandering stream channel with a locally scoured clay substrate, supports a variety of beneficial uses, including an internationally renowned wild trout fishery. A variety of migratory waterfowl, shorebirds, and other wildlife use the extensive riparian and wetland habitats associated with the river. The Shasta crayfish (*Pacifastacus fortis*), a State and federally "endangered" species, occurs within the Fall River.

Most of the lands along the Fall River are privately owned. Land use activities include livestock grazing, hay and wild rice production, recreation, and residential development.

Bear Creek provides the only significant surface water flow to the Fall River system. This tributary has a drainage area of less than 100 square miles and enters the Fall River just downstream from the headwater springs. Land use activities within the Bear Creek watershed include silviculture and grazing.

This study was developed as a multi-year effort to serve as a starting point for the analysis of sediment deposition and movement and its possible impacts on the aquatic vegetation in the Fall River. At the end of the first year only a few figures were planned to be produced. However, this study was not funded after the first year and this report was developed to document our efforts. Data were collected primarily during the fall and winter of 1996, with some portions of the field work extending into 1997. Cross-sections and sediment corings were completed for 12 sections of the river. Transport rates for bedload, suspended sediment, and suspended sand were measured at four sections, generally over a range of four streamflow events. Gradations of the bedload samples are provided. Limited water quality and macroinvertebrate data were also collected. This information will provide a baseline and a protocol for future studies. The development of specific recommendations was not a study task and is limited by incomplete data.

This study was also designed to determine the status of aquatic resources within the upper 10 to 12 miles of Fall River. This study was designed to complement and integrate with other watershed wide resource assessment and rehabilitation studies currently underway. The monitoring provides information for the upper Fall River and will benefit future watershed investigations.

Aquatic vegetation within the Fall River is one of the bases of the food chain. Without systematic evaluation of the aquatic vegetation, there is no way to determine the impacts, if any, from sediment movement and deposition or the effects from watershed activities. This study establishes a foundation for evaluating future changes in aquatic vegetation.

As mentioned in the study proposal, a single year of monitoring is inadequate to assess trends; a multi-year monitoring effort would allow development of adaptive management strategies. The multi-year study was designed to determine the effects of increased streamflow (during years of significant surface water inflow) on sediment movement, depths, and locations.

Only limited data were available prior to this study. Baseline (pre -1986) surveys are available only for trout populations and angler success rates. Measurable data on sediment characteristics, benthic macroinvertebrate community composition, channel dimensions, or vegetation composition and density are not available.

This report documents what was accomplished during this one-year investigation from September 1996 to June 1997. The report is divided based on each of the major data acquisition activities. The first two sections, physical cross section monitoring and sediment deposits, describe the morphology of the river and the sediment it contains. The next two sections, streamflow gaging and sediment transport, describes the river flows and the sediment it carries. The final two sections, macroinvertebrate and aquatic vegetation monitoring, describes the biological regime of the river.

The physical cross section monitoring showed that there was very little change between measurements, considering the magnitude of the flows that occurred during the intervening January 1997 flood event. There was a 80 square foot increase in sediment in the cross sections above the Spring Creek confluence and a 17 square foot loss downstream of the confluence. Long-term measurements are needed to confirm this trend. There was also a change in river stage that did not always correspond with the change in flow. This could be attributed to operation of the Pacific Gas and Electric Company's forebay, which caused a back water affect, or the seasonal change in aquatic plant mass.

In general, only minor distinctions between sediment deposits are discernable. These are typically limited to only slight variations in grain size and sorting. Sediment depths were separated into two categories. Loose sediment included the top layer of sediment in which penetration of the coring tool could easily be done by hand. The more consolidated sediment included all sediment in which more than five drop hammer blows were needed to drive the coring tool one foot into the sediment. Sediment coring should not need to be repeated as morphological surveys should suffice to indicate any changes. If supplemental, intermediate sections are added, the depth of loose, unconsolidated sediments can probably be adequately defined by hand probing.

Steamflow gaging showed, in general, that the data from the Fall River near Dana gage are rated fair while those from the Fall River at Spring Creek gage are rated poor. Based on our experience a good gaging station site does not exist downstream from Spring Creek. The Fall River near Dana gage, on Fletcher's Bridge, experienced a shifting control, but not nearly as extreme as the Spring Creek gage. If stream gaging is to be continued, the Spring Creek site should not be used. The Fletcher's Bridge site may be acceptable if numerous discharge measurements are performed to compensate for the shifting control.

Very fine sand constitutes a major portion of the granular material transported by the Fall River. Additionally, at any given time, this fraction probably comprises a significant portion of the bed material. Baseline data collected to date are too sparse to develop any general conclusions as to the overall processes of transport. The limited data do indicate that suspended sand transport may be more significant than bedload transport at higher flows. Future efforts might be directed toward collecting more data at fewer sections over a range of moderate to high flows. Bedform translation processes have not been studied for this river. Considering that the streambed is typically composed of a relatively mobile sand, this could be an active sediment-transport mechanism.

A wide variety of organisms was collected at each site. Freshwater snails (Gastropoda), chironomids (Chironomidae), and segmented worms (Oligochaeta) were the dominant taxa present, though mayflies (Ephemerella) were co-dominant at cross section 19 upstream from Spring Creek. Generally, the monitoring sites downstream from Spring Creek contained a far greater number of organisms than the sites upstream from Spring Creek in both the fall of 1996 and spring of 1997. The diversity, as indicated by the diversity index, was generally quite high, and again indicated little difference between the downstream and upstream stations. The monitoring sites downstream from Spring Creek have substantially more aquatic vegetation than those upstream. Aquatic macrophytes provide food and cover for a wide variety of aquatic macroinvertebrates, and may be the cause of the substantially greater number of macroinvertebrates found downstream from Spring Creek.

Submersed aquatic vegetation in the Fall River system is dominated by five vascular plant species and one species of algae. The riparian zone along the Fall River is not well developed. Agricultural fields or grazing is common up to the immediate bank. Upstream from Spring Creek, some woody riparian vegetation occurs, consisting mainly of willows, ash, and alders. Downstream from Spring Creek and upstream from Island Road Bridge, very little woody riparian vegetation is present. Results of the vegetation transects indicate a significantly higher percentage of aquatic plant cover in the transects downstream from Spring Creek bridge (87 percent average cover) than in those upstream from the bridge (23 percent average cover) during this study. The submersed aquatic plant community of the Fall River is significantly different between that portion of the river between Bear Creek and Spring Creek and that downstream from the Spring Creek bridge. Although there is little variation in species composition

between the two reaches, distribution, density, and coverage of each species varies significantly. There is not enough information with a one-year baseline study to determine if the vegetation is in a state of recovery or decline. Before any revegetation efforts occur or could be successful, more information is needed on the movement of the sediment and its nutritional ability to support plant growth.

Physical Cross Section Monitoring

The rate of change of a river's channel pattern and cross section is an important indication of physical changes occurring over long periods. While it is easy to document large scale changes to a river's channel pattern through aerial photography, changes to the cross section of a river are best determined through a ground survey.

There has been much discussion that the Fall River has changed its cross sectional shape in many locations over the last 20 years. Most comments indicate that there has been a general filling in of the deeper holes with sediment from upstream sources. Because no cross sectional data were available one of this study's goals was to develop cross sectional data in the study area.

The U. S. Geological Survey stream gage (#A17220) on the Fall River near Dana was installed on November 19, 1957 and discontinued on October 1, 1967. The station was at the private wooden bridge owned by Robert Read that was washed out during the January 1997 flood. No historical cross sectional information could be found related to this gage, however photographs indicate the area looked very much the same as it does now. The following pictures were taken of the gaging station on March 19, 1958.



Stream Gage Flow Measurement



Stream Gage Cross Section

This study of the physical characteristics of the Fall River was intended to establish a baseline set of measurements for 1996. The rate of change of these physical characteristics of the River could then be determined by re-surveying the cross sections.

Methods

Twelve permanent cross sections were established along the Fall River downstream from the mouth of Bear Creek (Figure 1). Eight of the cross sections are upstream from the Spring Creek Bridge, and four of the cross sections are downstream from Spring Creek. The eight cross upstream sections were used to determine how much the river is changing where there is sparse aquatic vegetation, compared to the four cross downstream sections where there is relatively abundant aquatic vegetation growing on the streambed.

The locations of the cross sections were determined by consultation with Department of Fish and Game (DFG) and Resource Conservation District (RCD) staff. There was an ongoing study of cross sections along the Fall River being performed by staff and students of California State University, Sacramento (CSUS). This study is still in preliminary form and has not been released for public review. The goal of the DWR survey was to match these CSUS cross sections as closely as possible so that if their data were released to the RCD, a continuous record of cross section measurements could be maintained. The cross sections chosen for this study were spaced as evenly as possible throughout the study area and were positioned to represent fluvial characteristics for sediment transport calculations.

Monuments were established using 18"X ¾" steel pipes with brass caps placed in concrete at the two endpoints of each cross section. These monuments were surveyed with Global Positioning System (GPS) receivers so any destroyed monuments could be re-established and the study continued. Each monument was surveyed twice using a fast-static GPS survey for at least 30 minutes. This double occupation of each monument ensured that a redundant position was obtained.

Six-foot long steel posts were driven near the water's edge so a steel cable could be stretched tightly across the river. This cable was used for horizontal distance across the cross section and was specifically made for measuring across a river. The control cable has copper beads placed at intervals of five feet for its entire length. If it was necessary to determine the stationing of an object between the beads, a tape measure was used. Zero of the steel cable was placed as close as possible to the left bank monument looking downstream.

Each cross section was surveyed using an automatic level for elevation control and the beaded cable for horizontal distance. The GPS derived

elevation for the left bank monument was used as the starting elevation for the cross section. Monuments and water surface elevations were surveyed to the nearest 0.01 foot, while the bed elevation was surveyed to the nearest 0.1 foot. An elevation point was taken along the cross section where every major break in slope occurred or at ten feet of horizontal distance, whichever was less.

Surveying of the cross sections was first completed between September 1996 and November 1996. While doing the spring aquatic vegetation survey, the cross sections were surveyed again during May of 1997 to quantify the changes that occurred after the January 1997 flood event.

The survey data for each cross section were entered into a computer spreadsheet and graphed. Then the two sets of survey data were compared.

Results

Most of the coordinates determined for each cross section end point monument are accurate to 0.60 feet at the 95 percent confidence level. Four of the monuments have an accuracy of 0.90 feet at the 95 percent confidence level. This indicates that the monuments could be placed within one foot of their original location if they were destroyed. All of the monuments were found after the high water in January of 1997; however, a few of the steel posts were damaged. Appendix 1 shows the coordinates for all of the monuments.

Due to the thick aquatic vegetation on a few of the cross sections, and the soft bottom of the river, the repeatable accuracy of the cross section was about 0.10 feet. On most of the cross sections, the bottom of the river consisted of sand that was fairly easy to penetrate with the survey rod. Care had to be used when shooting the cross sections so that the survey rod was not inadvertently pushed into the bottom sediments. Appendix 2 shows the plots of each cross section for the fall 1996 and spring 1997 surveys.

A comparison was made between the fall 1996 and spring 1997 cross section surveys to quantify any change. The highest surveyed end-point monument from each cross section was used to determine the differences. The distance from this assumed datum and each point on the cross section was calculated and then summed to determine the area. Figure 2 shows this procedure graphically. The fall 1996 and spring 1997 areas were compared to determine the difference between the two surveys. For example, cross section #3 had 2,781 ft^2 of area during the fall of 1996, and 2,712 ft^2 of area during the spring measurement. This indicates that cross section #3 had 68 ft^2 of sediment come into the cross section between the two measurements. Table 1 summarizes the changes for each cross section between the two surveys.

Figure 2. Cross Section Area Calculation

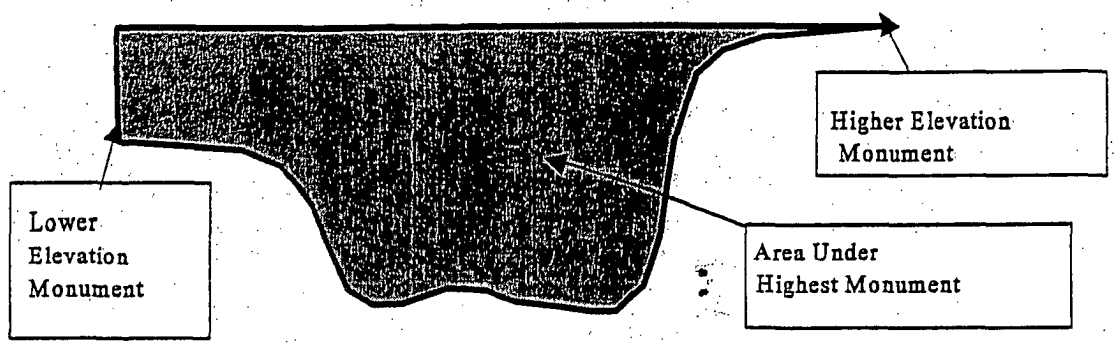


Table 1. Change in cross sectional area (in square feet below the elevation of the highest monument).

Location	Fall 1996 (ft^2)	Spring 1997 (ft^2)	Difference (ft^2)
X-Sect #3	2781	2770	11
X-Sect #5	1348	1343	6
X-Sect #7	1684	1676	8
X-Sect #9	1119	1085	34
X-Sect #11	1042	1040	2
X-Sect #15	1419	1387	31
X-Sect #18	1166	1186	-20
X-Sect #19	2131	2123	8
X-Sect #21	946	933	13
X-Sect #22	1434	1432	2
X-Sect #23	1408	1420	-12
X-Sect #24	1321	1341	-20

Discussion

The cross sections changed very little between measurement, considering the magnitude of the flows that occurred during the January 1997 flood event. During the May 1997 surveys, it appeared that sediment had been deposited at many of the cross sections, including #22 near the Wipple Ranch. A survey of cross section # 22, however, indicated that the water surface elevation was almost one foot lower than during the fall survey. This lowering of water surface gave the appearance that the bottom had filled with sediment.

This change of water surface makes it very difficult to analyze parameters that are changing the cross sections of the Fall River. This changing of water surface becomes apparent when evaluating cross section #22. Cross section #22 is at stream gage A17300 downstream from Spring Creek Bridge on the Wipple Ranch. Cross section #22 was surveyed on November 13, 1996 and the water surface elevation was 3309.12 feet with a mean daily flow of 561 cubic feet per second (cfs). The cross section was again surveyed on May 15, 1997 with a water surface elevation of 3308.40 feet and a mean daily flow of 585 cfs. These data show that even though there was 24 cfs more flowing in the river during the spring survey and the cross section had not significantly changed, the stage was 0.72 feet lower. There were no major water diversions between the stream gage at the Spring Creek Bridge and cross section #22 that could explain this reduction in water surface.

We also noticed this drop in water surface elevation during the fall measurements. The first cross sections were surveyed at the end of September 1996 and the last cross sections were completed during the second week of November 1996. The water surface of the river appeared to have dropped at least a half-foot at all of the cross sections during that two month period. The records for the gage at Fletcher's Bridge shows that the flow was 376 cfs on October 1,1996 and 353 cfs on November 13, 1996. This 23 cfs reduction would not be expected to cause a 0.5 foot drop in water surface elevation.

One possible explanation for a drop in water surface elevation for the same flow is that Pacific Gas & Electric changed the pool elevation of the forebay downstream from the project. The slight slope of the Fall River makes it possible to have a backwater effect that extends through the project area.

Another possible explanation is the seasonal changes in aquatic vegetation. Some species of aquatic vegetation turn dormant during the winter months and dislodge from their root system. This loss of aquatic vegetation would reduce the stream's resistance to flow. With less resistance to flow, the river could transport the same amount of water through a smaller cross sectional area, thereby reducing the water surface elevation. Further study with numerous flow measurements throughout the study area at different times of year would indicate if the aquatic vegetation controls the flow elevation as much as the preliminary data suggests.

Cross section #9 had the largest change between the fall of 1996 and the spring of 1997, gaining 34 ft^2 of material. The center of the cross section increased in elevation by approximately one foot for a horizontal distance of about 40 feet. A case could be made that a mid-channel bar is starting to form at this cross section, but that conclusion would be premature due to the lack of long term data. These cross sections should be resurveyed for a number of years, both in the spring and fall, so that long term trends can be determined.

After carefully examining the pictures shown at the beginning of this section at Read's Bridge in 1958, it does not appear that the river has changed significantly in that location. It is unfortunate that this gage was not maintained continuously so long term cross sectional information would be available.

When the cross sectional changes for all of the cross sections above the confluence with Spring Creek (#3-#19) are summed, there is a net increase of 80 square feet of sediment. The sum of cross sectional changes for all of the cross sections downstream from Spring Creek (#21-#24) yields a net loss of 17 square feet of sediment. Without more years of data it is impossible to determine if the Fall River's gaining of sediment upstream from Spring Creek and reduction of sediment downstream of the confluence indicates a long-term trend.

During the spring 1997 survey it became apparent that the bed material had increased in size since the fall 1996 survey. A Ponar bottom sampling dredge was used to collect macroinvertebrates contained in river bed sediments. These samples were washed through a #30 Tyler sieve, which has openings of 0.0234 inches. Significantly more bed material was retained on the sieve during the spring 1997 survey than during the fall 1996 survey. This change in bed material size indicates that the bed of the Fall River had become mobile during the high flows in January and then had filled in with slightly coarser material. It would be impossible to prove this phenomenon quantitatively because no complete sieve analysis samples of the bed material were taken as part of this study, only samples of bedload and suspended load.

Recommendations

To better trace long-term trends of the movement of sediment through the Fall River, the cross sections in this study should be re-surveyed during the spring and fall of every year. This would will help determine long-term trends of sediment movement and storage.

A way must be found to determine how deep the bed becomes mobile during periods of high flows. Placing bed chains at the cross sections and then digging them up after high flows could quantify the depth of bed mobilization. This would be a difficult and expensive process, but would provide some valuable information.

PG&E stage records should be examined to determine if their operations have caused a backwater effect throughout the study area. Additional flow determinations should be made to determine the cause for the water surface fluctuations throughout the study area.

Sediment Deposits

Knowing the grain size distribution of the sediment in the river bed is an important factor in trying to determine sediment transport rates. Sediment coring was completed at 12 cross sections to determine the nature and thickness of the bed material.

Methods

Streambed sediment deposits were sampled in accordance with Appendix 3, *Field Procedure for Collecting Sediment Core Samples.* The sediment core samples were texturally classified. The resulting textural descriptions were correlated to the relative in-place material densities as generalized from drop-hammer data. These data were compiled to develop the core logs found in Appendix 4.

Results

Lithologic cross sections were developed for each of the twelve river sections. These are shown in Appendix 5. Sediment depths were separated into two categories: loose and consolidated. Loose sediment included the top layer of sediment in which penetration of the coring tool could easily be done by hand or by using fewer than five blows per foot of the drop hammer. The more consolidated sediment included all sediment in which more than five blows were needed to penetrate a foot of sediment.

Discussion

In general, only minor distinctions between sediment deposits are discernable. These are typically limited to only slight variations in grain size and sorting. No evidence of a true bedrock was noted. The sediment layers were less consistent upstream from Spring Creek with more variation both in the channel profile and the sediment depth. Downstream from Spring Creek, the sediment depth was more consistent across the entire length of the channel.

This task should not need to be repeated; as morphological surveys should suffice to indicate any changes. If supplemental, intermediate sections are added in the future, the depth of loose, unconsolidated sediments can probably be adequately defined by hand probing.

Accurate estimates of the total volume of loose, unconsolidated sediments in channel storage that might be mobile cannot be developed with current information. Two factors severely limit such a calculation: first, the distances between channel cross sections are too great; and second, the channel sections were all selected on runs, to

the exclusion of pools. Hence, the sections are not fully representative and were chosen for their fluvial properties to determine sediment transport rates rather than sections for the determination of sediment volume.

Streamflow Gaging

DWR installed and maintained two continuous recording stream gaging stations on upper Fall River. One station, Fall River near Dana, is upstream from the confluence of Spring Creek and another, Fall River at Spring Creek, is downstream from the confluence (Figure 1).

Methods

Standard USGS streamflow methodologies were used to insure that streamflow measurements were within five percent of actual streamflow. Monthly current meter measurements were taken to develop a rating curve for each site.

Results

Appendix 6 contains the results of the stream gaging activities. These include:

- Average daily discharge data for these two gages,
- List of current meter discharge measurements,
- Rating curve computations,
- Rating curves,
- Hydrograph showing difference between average daily discharges.

Discussion

In general, the data from the Fall River near Dana gage are rated fair while those from the Spring Creek gage are rated poor. Both gages experienced severe rating curve shifts during the water year. This was probably the result of a combination of channel morphology changes after the large flood event of January 1997, shifting control due to aquatic plant growth, releases to a downstream wildlife area, or changes in level in the downstream PG&E forebay.

Based on our experience there is no good gaging station site downstream from Spring Creek. The Fall River near Dana gage, located on Fletcher's Bridge, experienced a shifting control, but not nearly as extreme as the Spring Creek gage. If stream gaging is to be continued, using the Spring Creek site is not recommended. The Fletcher's Bridge site may be acceptable if numerous discharge measurements are performed to compensate for the shifting control.

Sediment Transport

Samples of bedload, suspended sediment, and suspended sand were collected at four pre-selected locations during the fall and winter of 1996-97. These samples reflected conditions for a wide range of streamflow events. The rates of bedload transport, concentrations, and transport rates of suspended sediment and suspended sand were determined following laboratory analysis.

Methods

Bedload samples were collected pursuant to Appendix 7, *Field Procedure for Collecting Bedload Samples.*

Bedload samples were analyzed and quantified in accordance with the methodology outlined in Appendix 8, *Laboratory Procedure for Analyzing Bedload Samples.* Gradation of the bedload samples was performed according to Appendix 9, *Laboratory Procedure for Determining Bedload Grain-size Distribution.*

Suspended sediment and suspended sand samples were collected with a depth-integrating DH-48 sampler in general conformance with the protocol for equal transit rate (ETR) samples described in Guy and Norman, 1970 (*Field Methods for Measurement of Fluvial Sediment).*

Suspended sediment concentrations were determined in accordance with the methodology outlined in Appendix 10, *Laboratory Procedure for Determining Suspended Sediment Concentration.* Suspended sand concentrations were determined in accordance with the methodology outlined in Appendix 11, *Laboratory Procedure for Determining Suspended Sand Concentration.*

Results

The rates of bedload transport and the application of appropriate unit conversions were calculated as shown in Appendix 8.

The rates of transport for the suspended load were determined via calculation by multiplying the laboratory concentrations by the index streamflow and performing appropriate unit conversions pursuant to Porterfield, 1972 *(Computation of Fluvial Sediment Discharge).*

Sediment transport results are summarized for River Sections 3, 7,15, and 21 in Tables 2 through 5, respectively. Specific conductance and temperature are also included. Tables 2 through 5 also contain calculations for total granular load to help

understand the nature of the sediment size in transport. Granular load, as defined for this study, represents the total transport rate of very fine sand and coarser fractions, in tons per day, and should, theoretically, be representative of the transport rate of all coarse-grained sediments. It was calculated as the summation of the bedload and suspended-sand transport rates.

In addition to Tables 2 through 5, these data are also summarized by sampling date, along with a tabulation of bedload gradations, in Appendix 12.

Discussion

This investigation had the fortune of monitoring a substantial range of flow events. Originally, very little information on the high flow regimen was available for this reach of the River. These flow events were encountered in a sequence of successively higher flows that ranged from low flow during the fall, to the highest flows during the winter. Cross section 15 proved to be the most stable and consistent section for sampling, as exactly the same location could be used for all flows. The other cross sections were useable, but were more problematic for field operations.

Very fine sand constitutes a major portion of the granular material transported by the Fall River. Additionally, at any given time, this fraction probably comprises a significant portion of the bed material. The standard Helley-Smith bedload sampler mesh will pass much of this size fraction and the standard DH-48 suspended sediment sampler samples to within 0.3 feet above the bottom of the river. Hence, for 0.3-feet from the bottom, sands finer than 125 microns (approximately No. 120 sieve) are not being sampled. This size fraction of the bedload was not sampled or accounted for in this investigation.

The island bar immediately upstream from Fletcher's Bridge (Section 7) is of interest as it could be either a contemporary sediment sink or source. The vegetation on this bar appears to be less than 10-years of age, suggesting that it may be a transient feature. Hence, an assessment of its temporal morphology may be warranted. Uncertainty about whether this bar is in a depositional or erosional regimen may be affecting some of the downstream sediment-transport characteristics and data, particularly at Section 7.

Within the stated limitations, the sediment data are good. This baseline data that have been collected to date are too sparse to develop any general conclusions as to the overall processes of transport, but they do indicate that suspended sand transport may be more significant than bedload transport at higher flows. Future efforts might be directed toward collecting more data at fewer sections over a range of moderate to high

flows. The development of good all-weather access and launching facilities would greatly expedite such efforts.

Observations

Several general observations for the Fall River system follow. These are offered to further the efforts of future investigations.

The downstream PG&E forebay (Pit 1 Dam) sustains a persistent backwater regime at most river stages. This is most pronounced in the lower reaches, but due to the extremely mild energy and hydraulic grade lines of the Fall River, the effect of the backwater profile often extends well upstream. This could affect evaluations of stream sediment transport capacity.

A clear-water scour regime is generally in effect for the river, primarily due to the substantial base flow provided by the spring sources.

Bedform translation processes have not been studied for this river. Considering that the streambed is typically composed of a relatively mobile sand, this could be an active sediment-transport mechanism (see Dinehart, 1992).

PG&E reportedly releases water to flood a downstream wildlife area during some high water periods. Due to the very flat river profile, this practice could cause unaccounted shifts (drawdowns) to occur at upstream gaging stations as well as modify the natural sediment-transport regimen of the stream.

Sediment capture basins are used on the Trinity River and gravel (bedload) extractors are used on Spanish Fork in Plumas County. Similar installations on the Fall River might be worthwhile as a means to better quantify transport rates and remove a portion of the bedload transport.

Table 2. Sediment Transport Summary for Section 3 (Read's Bridge)

Date & time of sample	Index Stream Discharge in cfs (1)	Water Temp. in °C	Specific Conduct. in μsiemens/cm	Suspended Sediment, in tons/day (2)	Suspended Sand in tons/day (3)	Bedload in tons/day (4)	Total Granular Load, in tons/day (5)	Total Load, in tons/day (6)
9/25/96	371	11.6	133	–	–	0.69	–	–
(1202-1229 PST)								
11/21/96	500	9.2	58	–	–	1.1	–	–
(1115-1205 PST)								
12/12/96	880	6.6	80	13.5	0.57	10.3	10.9	23.8
(1510-1610 PST)				(5.7 ppm)	(4.2%)			
1/3/97	2,300	6.3	55	308*	12.3*	0.76**	13.1	309
(1505-1555 PST)				*(50 ppm)	(4.0%)			

*Due to excessive depths and velocities, five depth-integrated transits at middle stations of Equal-Transport Rate section did not completely reach the streambed. Individual transits were estimated to be within 1 or 2 feet of the streambed. Values cited are probably too low.

**Probably low due to excessive depths and velocities.

(1) Streamflow value for 9/25/96 (1230 PST) is from actual discharge measurement at Section 3. The remaining (index) flows are from DWR streamflow records for Fall River nr. Dana, DWR Station #A17200, located approximately 0.8 mile d/s. Actual streamflows at this Section are probably lower than the index flows.

(2) Suspended sediment concentration x streamflow x 0.00269. Parentheses indicate the composite concentration of depth-integrated samples.

(3) Parentheses indicate percentage of suspended sediment (transport or concentration) that is very fine sand.

(4) As obtained with Helley-Smith sampler, as adjusted for period of sampling, wetted perimeters and width of active stream transport.

(5) Sum of bedload and suspended-sand transport.

(6) Sum of bedload and suspended-sediment transport.

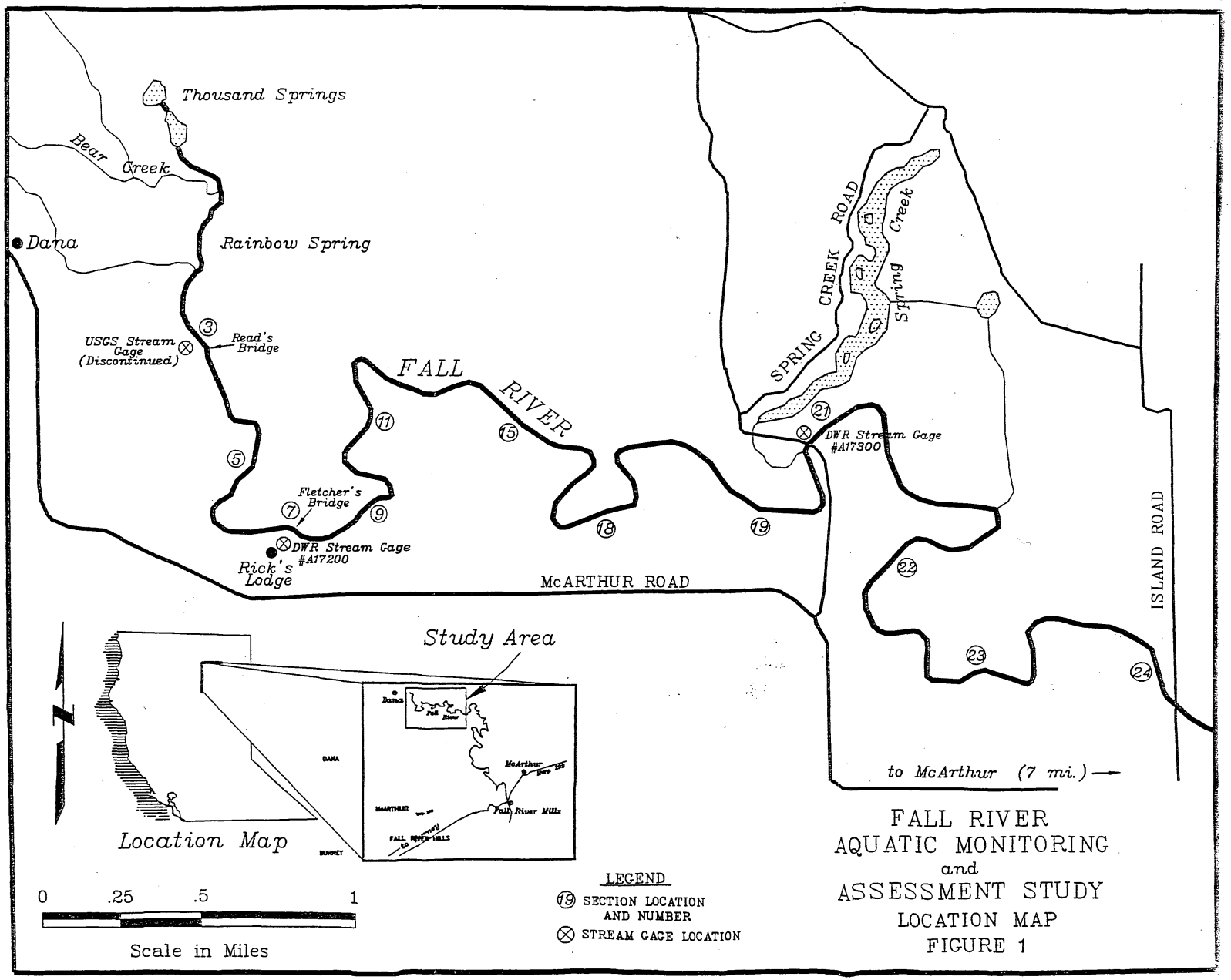

Thousand Springs
Bear Creek
Dana
Rainbow Spring
USGS Stream Gage (Discontinued)
Read's Bridge
FALL RIVER
SPRING CREEK ROAD
Spring Creek
DWR Stream Gage #A17300
Fletcher's Bridge
DWR Stream Gage #A17200
Rick's Lodge
McARTHUR ROAD
ISLAND ROAD
to McArthur (7 mi.)
Study Area
Location Map
0 .25 .5 1
Scale in Miles
LEGEND
SECTION LOCATION AND NUMBER
STREAM GAGE LOCATION
FALL RIVER AQUATIC MONITORING and ASSESSMENT STUDY
LOCATION MAP
FIGURE 1

Table 3. Sediment Transport Summary for Section 7 (Fletcher's Bridge)

Date & time of sample	Index Stream Discharge in cfs (1)	Water Temp. in °C	Specific Conduct. in μSiemens/cm	Suspended Sediment, in tons/day (2)	Suspended Sand in tons/day (3)	Bedload in tons/day (4)	Total Granular Load, in tons/day (5)	Total Load, in tons/day (6)
9/24/96	380	12.0	139	–	–	1.5	–	–
(1210-1240 PST)								
11/20/96	660	9.5	99	–	–	8.7	–	–
(1410-1510 PST)								
12/12/96	990	6.5	80	42.9	1.3	7.9	9.2	50.8
(0935-1050 PST)				(16 ppm)	(3.1%)			
12/31/96	3450	5.6	31	1650	65.4	10.5	75.9	1660
(1020-1137 PST)				(178 ppm)	(4.0%)			

(1) From DWR streamflow records for Fall River nr. Dana, DWR Station #A17200, located on Fletcher's Bridge approximately 200 feet u/s.

(2) Suspended sediment concentration x Streamflow x 0.00269. Parentheses indicate the composite concentration of depth-integrated samples..

(3) Parentheses indicate percentage of suspended sediment (transport or concentration) that is very fine sand.

(4) As obtained with Helley-Smith sampler, as adjusted for period of sampling, wetted perimeters and width of active stream transport.

(5) Sum of bedload and suspended-sand transport.

(6) Sum of bedload and suspended-sediment transport.

Table 4. Sediment Transport Summary for Section 15 (D/S of New Bridge)

Date & time of sample	Index Stream Discharge in cfs (1)	Water Temp. in °C	Specific Conduct. in µSiemens/cm	Suspended Sediment, in tons/day (2)	Suspended Sand in tons/day (3)	Bedload in tons/day (4)	Total Granular Load, in tons/day (5)	Total Load, in tons/day (6)
9/26/96	415	11.1	134	–	–	4.05	–	–
(1230-1350 PST)								
11/21/96	490	9.7	125	–	–	3.0	–	–
(1415-1500 PST)								
12/12/96	910	6.8	81	15.2	3.1	6.0	9.1	21.2
(1215-1330 PST)				(6.2 ppm)	(20.4%)			
1/4/97	1570	5.8	71	764	517	56.6	574	821
(1415-1505 PST)				(181 ppm)	(67.7%)			
6/27/97	385	12.0	150	3.5	0.88a	4.1	5.0	7.6
(1130-1240 PST)				(3.4 ppm)	(25.0%a)			

a Possibly due to cattle upstream.

(1) Streamflow value for 9/26/96 (1345 PST) is from actual discharge measurement at Section 15. The remaining (index) flows are from DWR streamflow records for Fall River nr. Dana, DWR Station #A17200, located approximately 1.6 miles u/s. Actual streamflows at this Section are probably higher than index flows.

(2) Suspended sediment concentration x Streamflow x 0.00269. Parentheses indicate the composite concentration of depth-integrated samples.

(3) Parentheses indicate percentage of suspended sediment (transport or concentration) that is very fine sand.

(4) As obtained with Helley-Smith sampler, as adjusted for period of sampling, wetted perimeters and width of active stream transport.

(5) Sum of bedload and suspended-sand transport.

(6) Sum of bedload and suspended-sediment transport.

Table 5. Sediment Transport Summary for Section 21 (D/S of Spring Creek Bridge)

Date & time of sample	Index Stream Discharge in cfs (1)	Water Temp. in °C	Specific Conduct. in μsiemens/cm	Suspended Sediment, in tons/day (2)	Suspended Sand in tons/day (3)	Bedload in tons/day (4)	Total Granular Load, in tons/day (5)	Total Load, in tons/day (6)
10/8/96	600 est.	12.0	139	—	—	0.01a	—	—
(1145-1235 PST)								
12/13/96	1,030	7.6	100	130	43.3	6.9	50.3	137
(0945-1045 PST)				(47 ppm)	(33.3%)			
12/30/96	2,200	6.6	28	719	394b	21.6	416b	741
(1515-1605 PST)				(122 ppm)	(54.8%b)			

a Extremely dense vegetation compromised verity of data. Use as a low range estimate only.

b Value may be too low due to laboratory error.

(1) From DWR streamflow records for Fall River at Spring Creek, DWR Station #A17300, located approximately 1.6 miles u/s. Actual streamflows at this Section are probably higher than index flows.

(2) Suspended sediment concentration x Streamflow x 0.00269. Parentheses indicate the composite concentration of depth-integrated samples.

(3) Parentheses indicate percentage of suspended sediment (transport or concentration) that is very fine sand.

(4) As obtained with Helley-Smith sampler, as adjusted for period of sampling, wetted perimeters and width of active stream transport.

(5) Sum of bedload and suspended-sand transport.

(6) Sum of bedload and suspended-sediment transport.

Macroinvertebrate Monitoring

Aquatic macroinvertebrates live in bottom rubble, sediments, and vegetation in the aquatic environment. These organisms feed on organic debris, periphyton, and other aquatic macroinvertebrates. Many aquatic macroinvertebrate species contribute significantly to the diet of fish and other organisms.

Aquatic macroinvertebrates have specific habitat requirements. Some require clean, rocky, well aerated substrates and are intolerant of siltation or other pollution, while others tolerate or are adapted to conditions of silt and stagnation. In the Fall River, much of the bottom substrate habitat for aquatic macroinvertebrates is fine grained materials including sand and fine sediments. Few riffles are present. However, dense stands of aquatic vegetation do provide important habitat for aquatic macroinvertebrates. Large numbers of certain aquatic macroinvertebrate species, especially the mayfly *Hexagenia limbata* (commonly referred to as a "spinner"), have been reported along the Fall River. This species is tolerant of silty but stable substrates. Sedimentation and high sediment transport in the Fall River, which have been reported, could adversely impact this and other aquatic macroinvertebrate species.

Methods

Aquatic macroinvertebrates were sampled at seven sites during September through November of 1996 and in May of 1997 (Table 6). A Ponar bottom sampling dredge was used to collect sediments containing aquatic macroinvertebrates inhabiting the substrate. This unit samples an area of nine inches square.

Table 6. Aquatic macroinvertebrate monitoring schedule

Cross Section Number	Station Description	Date sampled 1996	Date sampled 1997
1	riffle at fence line across Fall River near headwaters	11/14/96	not sampled
3	upstream from Read's Bridge	09/25/96	05/13/97
7	below Fletcher's Bridge	09/24/96	05/13/97
15	at New Bridge	09/26/96	05/14/97
19	upstream from Spring Creek	10/11/96	05/14/97
21	downstream from Spring Creek Bridge	10/08/96	05/12/97
23	Lackey property near pump	11/13/96	05/12/97

Transects across the river were established at the desired locations. Five equally spaced sampling sites along each transect were sampled by lowering the dredge approximately one foot downstream from the transect line. The dredge was retrieved into the boat and the contents, which often included sediments as well as macrophytic vegetation, were washed with river water through a standard #30 Tyler sieve. The organisms, vegetation, and debris remaining in the sieve were transferred to one liter sample bottles containing 95 percent ethyl alcohol preservative. The sample contents from all five sites along the transect were composited to form one sample per transect. Several sample bottles were required to contain the dredge contents from each station.

At the Department's laboratory in Red Bluff, samples were checked for proper preservative levels and logged into a computerized inventory file. The samples were archived in a locked room until processed. Samples were tracked throughout the sorting and identification process using a Chain of Custody Form.

Prior to sorting aquatic macroinvertebrates from debris, samples were rinsed through a #30 Tyler sieve with cold running water under a vent hood until all traces of the preservative were gone. The contents were then transferred to a sorting tray and covered with approximately one inch of water. The sample was stirred for even distribution and inspected for any large and unusual specimens. These were removed and placed in a separate plastic tray labeled "Large-Rare Portion." A plastic insert with 45 numbered and equal sized grids was placed carefully in the pan and worked into the sample until it seated on the bottom of the pan. Grids were chosen for sorting using a random number table. As many grids as necessary were sorted to obtain a minimum total of 300 organisms. All organisms from the last grid in which the 300 number was achieved were removed, which resulted in a total somewhat greater than 300. All organisms removed from the grids were placed in a clean labeled tray containing 75 percent ethanol. The numbers of macroinvertebrates from each grid were recorded separately. Debris from processed grids was placed into a jar marked "Remnant," while the unsorted portion of the sample from the tray was discarded. A solution of 95 percent ethanol was added to all the containers for preservation and archiving purposes.

Macroinvertebrates were identified to the lowest practical taxonomic level using current keys, supporting literature, and a binocular dissecting scope at 10 to 70 power. Professional judgement was used when determining the level to which to identify an organism based on life stage, size, and physical condition. Specimens that were badly damaged, very small, or otherwise unrecognizable were left at a higher taxonomic level. Following identification, individuals in each taxonomic category were counted. This information was entered into the computer database for future use.

Results

A wide variety of organisms was collected at each site (Appendix 13). Freshwater snails (Gastropoda), chironomids (Chironomidae), and segmented worms (Oligochaeta) were the dominant taxa present, though mayflies (Ephemerella) were co-dominant at cross section 19 upstream from Spring Creek (Table 7).

Table 7. Dominant species at each station

Cross Section Number	Dominant Taxa 1996	Functional Feeding Group	Dominant Taxa 1997	Functional Feeding Group
1	Gastropoda	scrapers	not sampled	-
3	Chironomidae Oligochaeta	collector-gatherer	Chironomidae	collector-gatherer
7	Chironomidae	collector-gatherer	Chironomidae Oligochaeta	collector-gatherer
15	Chironomidae Oligochaeta	collector-gatherer	Chironomidae Oligochaeta	collector-gatherer
19	Ephemerella Chironomidae	collector-gatherer	Chironomidae Oligochaeta	collector-gatherer
21	Gastropoda Oligochaeta	scrapers collector-gatherer	Chironomidae Oligochaeta	collector-gatherer
23	Gastropoda Oligochaeta	scrapers collector-gatherer	Gastropoda Oligochaeta	scrapers collector-gatherer

The numbers of organisms and species, diversity, and equitability were quite varied between stations (Tables 8 and 9). The monitoring sites downstream from Spring Creek contained a far greater number of organisms than the sites upstream from Spring Creek, other than Cross Section 1 (riffle at fence line), in both the fall of 1996 and spring of 1997. Little difference in the number of species is evident between the downstream and upstream stations. The diversity, as indicated by the diversity index, was generally quite high, and again indicated little difference between the downstream and upstream stations. The equitability indices showed a similar relationship.

Table 8. Numerical summary of aquatic macroinvertebrate composition in 1996

Cross section number	1	3	7	15	19	21	23
Station description	Fence line near headwater	Upstream from Read's Bridge	Downstream from Fletcher's Bridge	At New Bridge	Upstream from Spring Creek	Downstream from Spring Creek	Lackey property
Number of organisms (#/ft^2)	2444	1118	478	1152	706	2400	2237
Number of species	34	38	32	27	30	37	32
Diversity index	3.2	4.1	3.7	3.5	3.5	4.1	3.7
Equitability	0.38	0.65	0.60	0.59	0.55	0.67	0.60

Table 9. Numerical summary of aquatic macroinvertebrate composition in 1997

Cross section number	1	3	7	15	19	21	23
Station description	Fence line near headwater	Upstream from Read's Bridge	Downstream from Fletcher's Bridge	At New Bridge	Upstream from Spring Creek	Downstream from Spring Creek	Lackey property
Number of organisms	-	237	208	252	267	1148	1544
Number of species	-	23	31	18	34	24	33
Diversity index	-	3.5	3.3	2.3	3.2	2.9	3.7
Equitability	-	0.72	0.47	0.38	0.39	0.44	0.55

Discussion

The gastropods, classified as scrapers, feed mainly on periphyton or attached algae and associated materials. The riffle environment at Cross Section 1 (riffle at fence line) provides suitable substrate for growth of periphyton for these organisms to feed upon. The rich abundance of aquatic plants downstream from Spring Creek also provides suitable substrate for the growth of periphyton, and hence food supply for gastropods. Gastropods were not dominant in the river reach between the riffle and Spring Creek, possibly the result of less dense stands of aquatic macrophytes or silt inhibition of periphyton growth on the existing macrophytes. There were generally far more gastropods at the downstream stations in both 1996 and 1997.

The dominant food supply for the Chironominae and Oligochaeta, classified as collectors-gatherers, is the fine particled, decomposing organic matter found in the substrate. While chironomids are found in a variety of aquatic habitats, they most often are found in large numbers in habitats containing high levels of organic materials and sediment. The segmented worms (Oligochaeta) also prefer a sediment rich environment. Chironomids, particularly the Orthocladiinae, were far more abundant at the monitoring sites upstream from Spring Creek than at the sites downstream from the confluence of the creek in the fall of 1996. In the spring of 1997, chironomids still dominated, though both upstream and downstream sites contained similar numbers of the subfamily Orthocladiinae. The chironomid subfamily Chironominae contained far more members in 1997 than 1996, particularly at the upstream sites. Though segmented worms were prevalent at the upstream stations, far more were found at the downstream stations in both years.

The Ephemerella mayfly is also classified as a collector-gatherer and feeds on bits of fine organic matter strained from flowing water. This genus was very abundant at the monitoring station upstream from Spring Creek (Cross section 19). Members of this genus generally prefer firm substrates, such as cobbles or organic materials. The substrate at Cross section 19, though dominated by finer materials, did contain

scattered cobbles and woody debris which provided suitable habitat for ephemerellid mayflies. The downstream sites generally contained more mayflies, particularly the genera Baetis and Ephemerella, in 1996, but in 1997 mayfly species compositions were similar though larger numbers of Ephemerella were found at the upstream sites. The adult mayfly *Hexagenia limbata* (or "spinner") has been reported by local residents and fishermen as being extremely abundant during the emergence period for this species. However, not a single specimen was found from the aquatic macroinvertebrate samples. This species in streams normally inhabits quiet backwaters with an accumulation of silt (Edmunds et al. 1976). In lakes, they are found from very shallow areas to depths of up to 60 feet, indicating that depths in the Fall River should not adversely affect the distribution of this species. The nymphs burrow to a depth of about five inches in the bottom substrate. Tolerant of low dissolved oxygen conditions, the nymphs still require an oxygen concentration above one part-per-million. The nymphs are usually found in large numbers only in areas where the bottom substrate is composed of soft mud or clay which is soft enough for burrowing but firm enough to maintain the burrow. They do not normally inhabit sand, gravel, rubble, or peat bottoms that are flocculent.

Also present at most stations, but especially downstream from Spring Creek, were a variety of freshwater leech species (Hirudinea). These organisms are often found in warmer, slow moving streams and ponds and in a variety of other habitats. Most leeches are usually found between the shoreline and a depth of six feet. They prefer some form of rough substrate on which to adhere and, therefore, are uncommon on silt, clay, or mud bottoms. Leeches are primarily predatory in nature, with various species showing preference for feeding upon fish, crustaceans, and aquatic insects. Some species are parasitic. Many of these organisms are excellent swimmers while others move along the bottom substrate. These organisms provide a food source for aquatic beetles (Dytiscidae), caddisfly larvae (Trichoptera), and fish.

Freshwater clams (Pelecypoda) and stoneflies (Plecoptera) were also more prevalent at the downstream sites than the upstream sites in both 1996 and 1997.

Both upstream and downstream sites contained similar numbers of species, but downstream sites contained far more individuals than the monitoring stations between Cross section 3 (upstream from Read's Bridge) to Cross section 19 (upstream from Spring Creek). Though the species composition was similar between upstream and downstream sites, the upstream sites generally contained fewer individuals per species than the downstream sites. Few of these sites, either upstream or downstream, were disproportionately dominated by any one species. Cross section 1 (riffle at fence line), however, was dominated by a gastropod species, which contributed 40 percent of the total number of individuals at this site in 1996. Forty-seven percent of the individuals at cross section 15 (at New Bridge) were the Orthocladiinae, while 25 percent of the individuals at Cross section 19 (upstream from Spring Creek) were ephemerellid mayflies in 1996 and 31 percent were of one oligochaete species in 1997.

Cross section 1 (at fence line) is a riffle environment. The water depth is relatively shallow and composed of clean gravels. Riffles are generally the most productive stream environments in terms of both numbers of individuals and species. The riffle characteristics undoubtedly were responsible for the large number of

organisms collected at this site. Bear Creek, which enters the Fall River just upstream from this site, has been implicated as the source of adverse sedimentation. The swifter flow at the riffle environment apparently flushes sufficient sediments from the substrate to maintain a productive environment.

Cross sections downstream from the riffle are deeper sites with slow moving water, which allows sediment deposition. The monitoring sites downstream from Spring Creek have substantially more aquatic vegetation than those upstream. Aquatic macrophytes provide food and cover for a wide variety of aquatic macroinvertebrates, and may be the cause of the substantially greater number of macroinvertebrates found downstream from Spring Creek.

Recommendations

Differences in community compositions between 1996 and 1997 may be due to emergence patterns. Some species may not have been collected due to their particular life stage (e.g., egg, terrestrial adult) during the different collection periods. However, winter flooding and subsequent wash out of community members may also have contributed to differences in community compositions. Continued monitoring will provide information to help determine causes for the community differences.

Substantial differences are apparent between the aquatic macroinvertebrate communities upstream from the confluence of Spring Creek and those present downstream from the confluence. Detailed habitat evaluation is necessary to determine factors that may be contributing to these differences. In addition, continued monitoring should be conducted to determine any effects on downstream macroinvertebrate communities from transport of sediments from the upper reaches. The upper reaches should also be monitored as sediments move out of the area to determine effects to the community from any decline in sediments and changes in the vegetative community.

Additional sampling should be conducted to determine the habitat supporting the large numbers of the mayfly *Hexagenia limbata* that have been reported. Monitoring in this study failed to collect any of this species, indicating that an important habitat may have been overlooked.

Aquatic plants play a key role in maintaining fish productivity in freshwater aquatic ecosystems by providing both essential habitat and refuges and by stimulating invertebrate productivity. The biomass and diversity of invertebrates associated with aquatic plants may exceed that of the fauna in the sediment at the same location. A variety of interacting environmental factors affect both aquatic and terrestrial plant species diversity, abundance, and distribution. These include light, temperature, nutrients, inorganic carbon, and sediment composition (Barko et al. 1986, Barko et al. 1991). Submersed aquatic vegetation, like all plants, requires light for photosynthesis and its availability is important in determining the morphology, abundance, and distribution of the plant species. Temperature also plays an important role in species composition. Rooted aquatic plants obtain their nutrients from sediments as well as from those in solution. Nutrients such as nitrogen and phosphorus and many micronutrients are less available in the surface waters and are obtained principally from the sediments. Sediment composition also affects growth rates and distribution of aquatic plants. Texture of the sediments is important in relation to differing abilities of plant species to physically penetrate the surface. Shifting sediments may affect the plant's ability to maintain its position or to reestablish itself in an area. Some sediments such as very coarse textured or sandy soils may be nutritionally poor. Sediment depth affects the plant's ability for reestablishment by seeds or propagules when new sediments are deposited and rearranged.

Historically, the Fall River is reported to have supported extensive stands of submersed aquatic vegetation both upstream and downstream from Spring Creek. *Zannichellia palustris* (horned pondweed, locally known as Z grass) occurs in vast flowing stands downstream from the confluence of Fall River and Spring Creek. However, a reported decline in aquatic vegetation, mainly *Z. palustris*, upstream from Spring Creek bridge and a subsequent decline in the trophy trout fishery are believed by some groups to be a direct result of sediment accumulation in that portion of the Fall River between Bear Creek and Spring Creek bridge.

No data or documentation has been available on change in the submersed aquatic vegetation diversity or abundance. Although the sediment accumulations are believed by some groups to be responsible for the reported degradation of the aquatic invertebrate and plant communities, no data prior to this study was available on sediment depths, their movement, or their relation to aquatic plant distribution. This study of the aquatic plant community proposed to develop a baseline for what is present in relation to the depth of sediment. A multi-year monitoring effort would document the rate of natural recovery or decline of the plant species and aid in developing a management strategy for reestablishing or maintaining plant populations capable of providing essential habitat for invertebrate populations and ultimately increasing fish productivity.

The twelve transects used for the cross sections, sediment coring, sediment transport flow, and macroinvertebrate collection were used for the aquatic vegetation monitoring. Aquatic vegetation was surveyed along each cross section to determine species present and their relative abundance within the system. A line-intercept method was used to identify all plants lying on a straight line across the channel at each transect. A wire tag line was stretched horizontally between each monument with zero at the left bank monument. A tape measure was stretched along the tag line to determine exact location and abundance of each species. All plants lying below the line were identified with location and distance recorded on data sheets. Plants that were not identifiable in the field were collected and identified in the California State University at Chico Biology Department Herbarium.

Species composition and distribution at each sampling site were graphed in relation to the channel cross section and sediment depth data. Sediment depths were separated into two categories for use in identifying relationships between plant species and sediment depths. Loose sediment included the top layer of sediment in which penetration of the coring tool could easily be done by hand or using less than five blows per foot. The more consolidated sediment included all sediment in which more than five blows per foot was needed to penetrate the soil.

A literature review was conducted for each of the five dominant aquatic plant species within this reach of the Fall River. Aspects of their biology and life history were reviewed as well as seed germination and vegetative reproduction requirements.

Results

Submersed aquatic vegetation in the Fall River system is dominated by five vascular plant species and one species of algae. The most common plant species include *Zannichellia palustris* (horned pondweed, Z grass), *Elodea nuttallii* (Nuttall's elodea), *Elodea canadensis* (common elodea or waterweed), *Ranunculus aquatilis* (aquatic buttercup), and *Myriophyllum sibiricum* (water milfoil). Common emergent vegetation include *Sparganium emersum* (bur-reed), *Juncus effusus* (common rush), and *Scirpus acutus* (tule). *Lemna minor* (duckweed), a free-floating aquatic species, is also common along this portion of the river. The species of algae present was not determined but is most likely a species of *Chara*, a common alga in slow-moving rivers and lake systems.

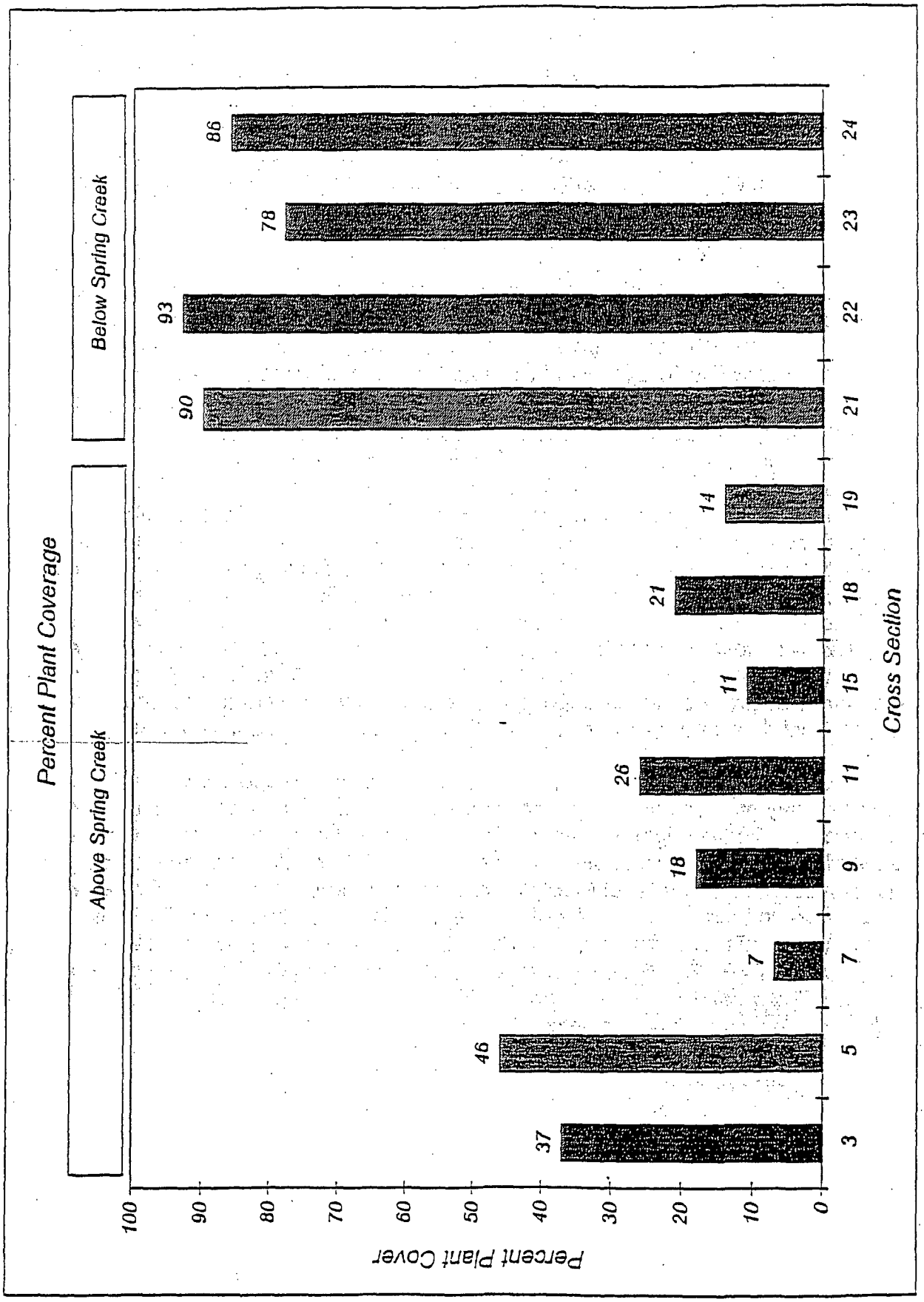
The riparian zone along the Fall River is not well developed. Agricultural fields or grazing is common up to the immediate bank. Some woody riparian vegetation occurs upstream from Spring Creek, consisting mainly of willows, ash, and alders. Downstream from Spring Creek and upstream from Island Road Bridge, very little woody riparian vegetation is present. Occasional willows and cottonwoods occur in this stretch. Much of the Fall River has been fenced to restrict grazing along the banks, with open access areas for cattle to reach the water. The banks are heavily degraded and eroded at these access locations, but this area is only a small percentage of the total bank area. Downstream from Spring Creek, less area is fenced to restrict cattle. The banks are gently sloped and erosion due to muskrat or cattle usage is evident.

Results of the vegetation transects indicate a significantly higher percentage of aquatic plant cover in the transects downstream from Spring Creek bridge than in those upstream from the bridge during this study (Figure 3). Downstream, 78 to 93 percent of each channel cross section was covered with submersed aquatic plants with an average of 87 percent. Upstream the cross sections averaged only 23 percent vegetative cover with submersed aquatic plants covering as little as 7 percent of Cross Section #7 downstream from Fletcher's Bridge and up to 46 percent of Cross Section #5 downstream from Read's Bridge. Figure 4 shows percent plant species distribution at each cross section.

Appendix 14 shows species occurrence and location for each cross section. Upstream from Spring Creek, *Z. palustris* occurs in only two of the transects and occurs in less than five percent of the length of each. These plants upstream from Spring Creek tend to be small and widely scattered, but downstream from Spring Creek *Z. palustris* covers 68 to 93 percent of the length of each of the cross sections. These plants occur in large flowing stands with long stems and are much more robust than the plants in the upper reach. *Z. palustris* is dominant in the first three transects downstream from Spring Creek bridge but is codominant with the two elodeas in the last cross section (#24). *E. nuttallii*, *E. canadensis*, and *R. aquatilis* are the dominant plant species in the upper reach between Read's Bridge and Spring Creek Bridge. Although both elodea species occur downstream from Spring Creek Bridge in as high or higher percentages than upstream from Spring Creek, the large stands of *Z. palustris* at these locations clearly dominate most of the cross sections. *R. aquatilis* and *M.sibiricum* were both limited in distribution and abundance in the cross sections. *R. aquatilis* was most abundant in the upper two cross sections near Read's Bridge and was not encountered in any of the transects downstream from Cross Section #15. *M. sibiricum* was not seen in the upper cross sections and was not abundant in any except for the most downstream cross section #24 upstream from Island Road Bridge.

Literature on the life history and biology of these five species is somewhat limited. They are common in slow-moving streams, ditches, and lakes and tend to be nuisance species in irrigation canals. Thus, much of the literature focuses on factors facilitating their removal instead of their reestablishment. Many submersed aquatic plants reproduce almost exclusively by vegetative reproduction. Seed formation is usually rare in these species. Vegetative reproduction can be accomplished by underground buds on structures such as rhizomes or by the ability to root from nodes on fragmented plants. Rhizomes are underground stems that can invade areas near the parent plant and each node can give rise to a new flowering shoot. This not only aids in reproduction, but also helps to anchor the plant in the substrate.

Figure 3


Percent Plant Coverage
Above Spring Creek
Below Spring Creek
Percent Plant Cover
100
90
80
70
60
50
40
30
20
10
0
37
46
7
18
26
11
21
11
14
90
93
78
86
3
5
7
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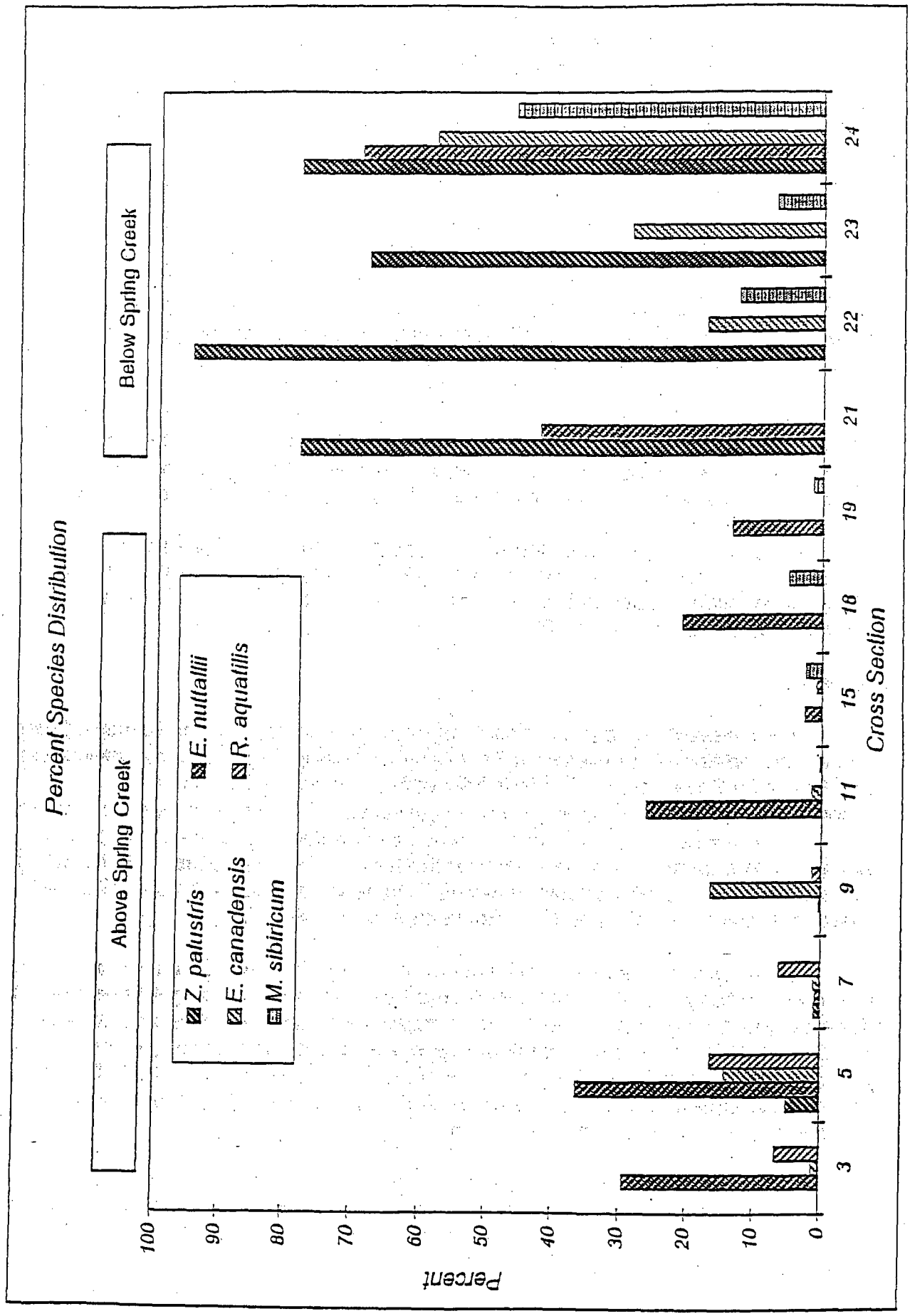
24
Cross Section

Figure 4


Percent Species Distribution
Above Spring Creek
Below Spring Creek
Z. palustris
E. nuttallii
E. canadensis
R. aquatilis
M. sibiricum
Percent
100
90
80
70
60
50
40
30
20
10
0
3
5
7
9
11
15
18
19
21
22
23
24
Cross Section

Z. palustris is a perennial herbaceous species that grows totally submerged in fresh or brackish water. It is distributed worldwide and in California occurs in slow-moving streams, ditches, ponds, and lakes below the 6,600 foot elevation. It has a slender branching habit with creeping rhizomes. Reproduction in *Z. palustris* is by both seed formation and vegetative growth from the rhizomes. Although fruit set in underwater species is thought to be highly inefficient, studies show a high fruit-set efficiency from self pollination in *Z. palustris* (Guo et al. 1990, Hickman 1993).

E. nuttallii and *E. canadensis* are perennial herbaceous species native to North America. Both occur in California in shallow waters of ditches, streams, lakes, and ponds between the 1,000 and 9,000 foot elevation. This species has slender unbranched roots from nodes along the stem. The stems easily fragment and these fragments can develop into new plants from axillary or terminal buds. Seed formation is very rare and is not a primary means of reproduction (Mason 1957, Spicer et al. 1988).

R. aquatilis is a perennial herb that has both submersed and floating leaves. This species is native to California and occurs in ponds, lake margins, marshes, and rivers below the 10,000 foot elevation. Like the elodeas, rooting at lower nodes and vegetative reproduction by fragmentation is common (Hickman 1993, Mason 1957).

M. sibiricum is a perennial herbaceous species with both submersed and emergent leaves. It occurs in California in ponds, ditches, lakes, and streams below 9,000 foot elevation. Vegetative reproduction occurs by underground rhizomes (Hickman 1993, Lillie and Budd 1992).

Discussion

The submersed aquatic plant community of the Fall River is significantly different between that portion of the river from Bear Creek to Spring Creek and that downstream from the Spring Creek bridge. There is little variation in species composition, but distribution, density, and coverage of each species varies significantly between the two reaches. Reports by residents about a change and decline in submersed vegetative coverage upstream from Spring Creek over the last couple of decades could be due to a variety of interacting environmental factors. These include water temperature, light, nutrient availability, and the depth and movement of the sediment.

Temperature and light are both important factors affecting plant abundance and distribution. However, in the Fall River changes in temperature and light have probably not been significant over time. Although no measurements were taken and no prior data are available, the relatively shallow waters and low turbidity should not present photosynthetic problems. The temperature of the spring-fed waters of the Fall River remains fairly constant year round and also should not present growth problems or restrictions to the vegetation in this system.

There are several factors determining the impact of sediment on the aquatic plant distribution and coverage. The composition of the sediment and its supply of available nutrients directly affects plant growth. The dominant species, *Z. palustris, E. canadensis*, and *E. nuttallii,* and the other submersed aquatic species, are all rooted species that obtain their nutrient requirements primarily from the sediment. The

sediments in the study area are composed primarily of sands with coarser textured gravels and some silt. Upstream from Spring Creek the sampled sediments typically contained very little silt or organic matter with slightly more buildup of silt and organic matter in the sediments downstream from the Spring Creek bridge. No data are available on the nutrient composition of the Fall River sediments nor their ability to support aquatic plant growth. However, extremely sandy or otherwise coarse-textured sediments generally are lacking in important nutrients and thus can inhibit plant growth. The relatively sandy sediments with few fines in the upper reach of the Fall River may have inadequate nutrients available and may play a part in limiting plant growth in this part of the river. Further studies on the nutrient composition of these sediments both upstream and downstream from Spring Creek are necessary to determine the relative sterility of these sandy sediments and their ability to support large stands of submersed aquatic vegetation.

Although nutrient availability is important to the submersed aquatic vegetation, the distribution and abundance of the submersed community is linked with the physical characteristics and changes of the substrate and with the general stability of the habitat. A plant's ability to recolonize an area varies with the type of deposit and its depth. Seeds of some aquatic species have shown decreased germination when buried under more than 0.8 inches of sediment (Hartleb et al. 1993). Also, the interval between movement of the sediment layers directly affects the aquatic plant species survival and ability for reestablishment. In general there were no striking differences between sediment depth in the cross sections upstream or downstream from Spring Creek. The sediment layers were less consistent upstream from Spring Creek with more variation both in the channel profile and the sediment depth. Downstream from Spring Creek, the sediment depth was more consistent across the entire length of the channel. Overall, results of the cross-sectional data do not correlate increased plant biomass with any pattern of sediment depth or substrate type. Areas of scoured river bottom with no sediment accumulation were more common upstream from Spring Creek than downstream and were lacking any vegetation.

The submersed vegetation upstream from Spring Creek was most often clustered near the banks and did not generally inhabit the center of the channel with the exception of the two uppermost cross sections, whereas downstream from Spring Creek vegetation covered the entire cross section. If the sediments are limiting nutrient availability in the upper reach, this would in part account for the lack of vegetation throughout the channel. Nutrients leaching from the adjacent banks could be supplying the submersed aquatic plants clustered in these areas. Future nutrient studies should include sampling throughout the channel cross section.

Recommendations

Further studies are needed to identify correlations between sediment accumulation, movement, and impact on the submersed aquatic vegetation of the Fall River. There is not enough information with a one-year baseline study to determine if the vegetation is in a state of recovery or decline. Before any revegetation efforts occur or could be successful, more information is needed on the movement of the sediment and its nutritional ability to support plant growth. A multi-year monitoring effort identifying sediment movement and its ability to support large stands of vegetation

would help in developing a long-term management strategy for reestablishing plant populations. Future studies should include the importance of the submersed plant community in providing essential habitat for invertebrate populations and ultimately fish populations.

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APPENDIX 1

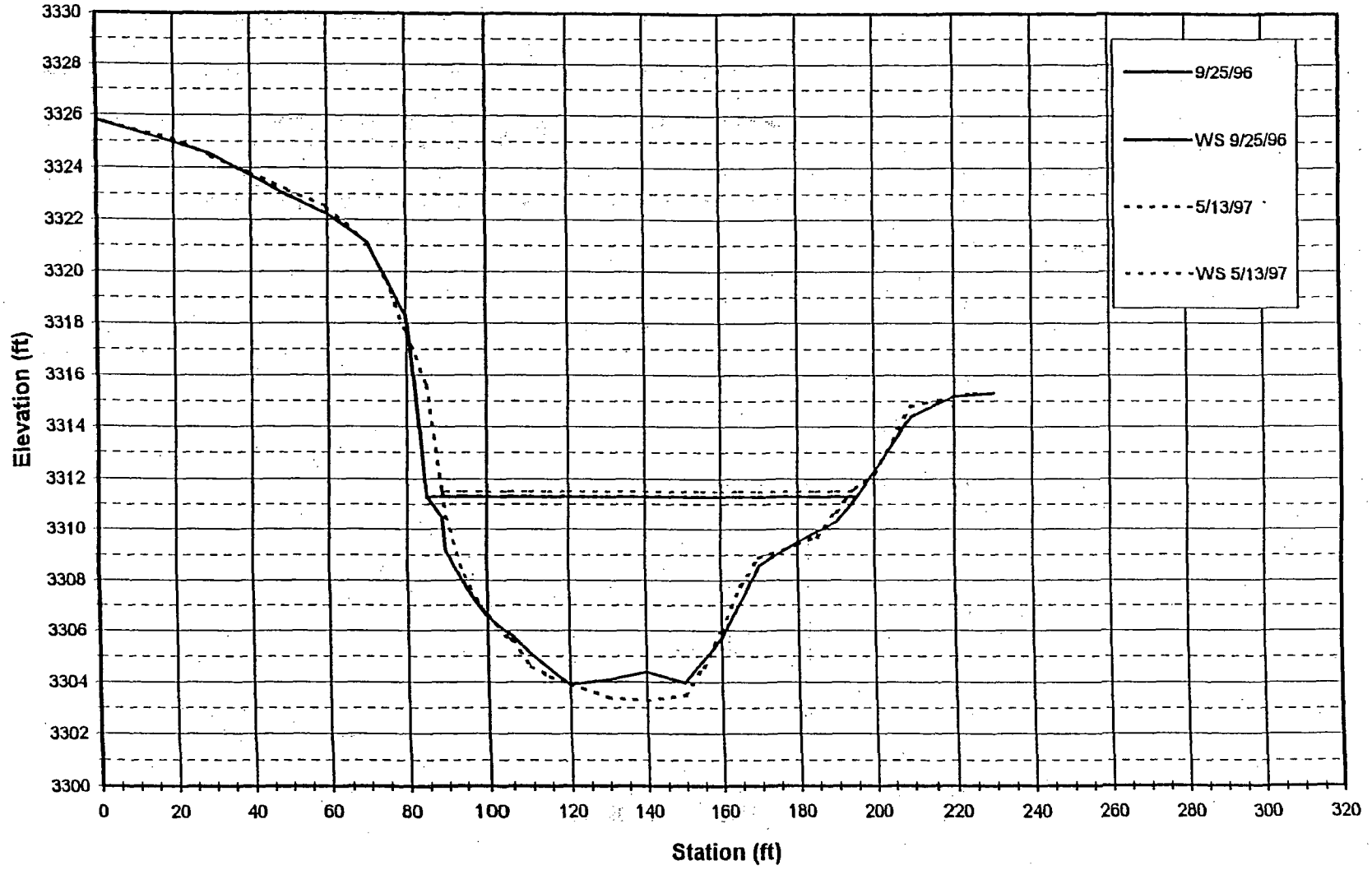
Fall River Cross Section Endpoint Coordinates

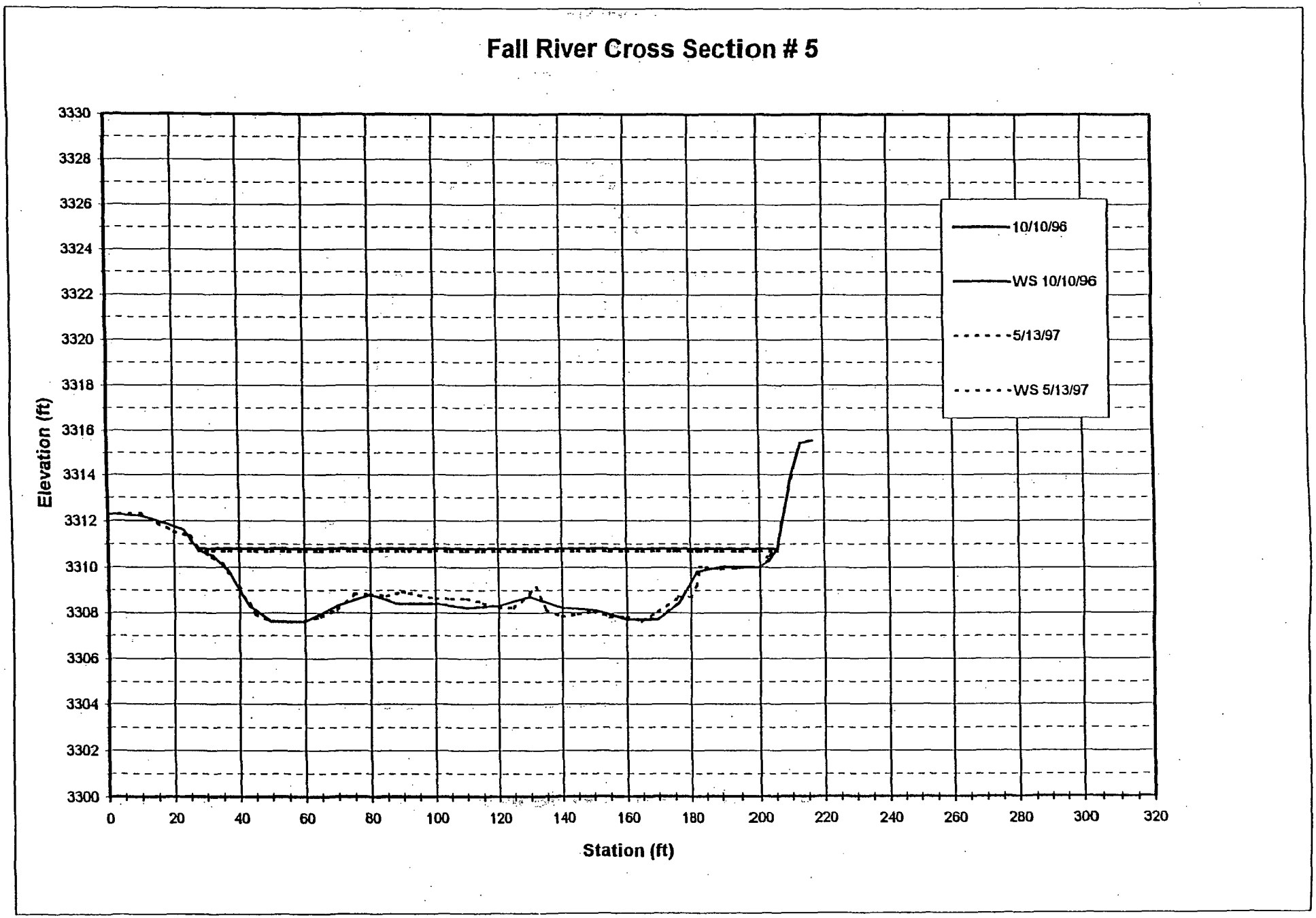
Horizontal Datum: NAD83 State Plane Zone 1 Feet
Vertical Datum: NAVD 88

Station	Northing	Easting	Elevation
BC3LB	2286261.2	6685384.3	3325.9
BC3RB	2286171.6	6685180.2	3315.3
BC7LB	2283630.2	6686498.6	3316.6
BC7RB	2283329.9	6686406.3	3314.1
BCLB11	2285273.8	6687643.4	3313.7
BCLB15	2285176.0	6690655.5	3312.9
BCLB18	2285021.9	6692849.6	3311.7
BCLB19	2283766.8	6694692.6	3311.7
BCLB22	2282917.0	6696864.6	3309.7
BCLB23	2281013.4	6697916.6	3311.4
BCLB24	2280854.4	6701226.4	3310.4
BCLB5	2284233.9	6685741.2	3312.3
BCLB9	2283992.8	6687816.5	3314.5
BCRB11	2285145.0	6687877.6	3311.1
BCRB15	2285004.2	6690508.3	3314.4
BCRB18	2284834.9	6692862.9	3313.0
BCRB19	2283584.6	6694665.1	3319.8
BCRB22	2283060.2	6696708.8	3312.9
BCRB23	2280780.8	6698046.1	3310.2
BCRB24	2280780.7	6700999.9	3309.2
BCRB5	2284411.1	6685616.9	3315.5
BCRB9	2283831.2	6687899.0	3312.8
BCSPBRLB(21)	2285308.3	6695608.4	3311.0
BCSPBRRB(21)	2285148.9	6695734.6	3310.3
QUIN (Base)	1875796.47	6857507.76	3710.74

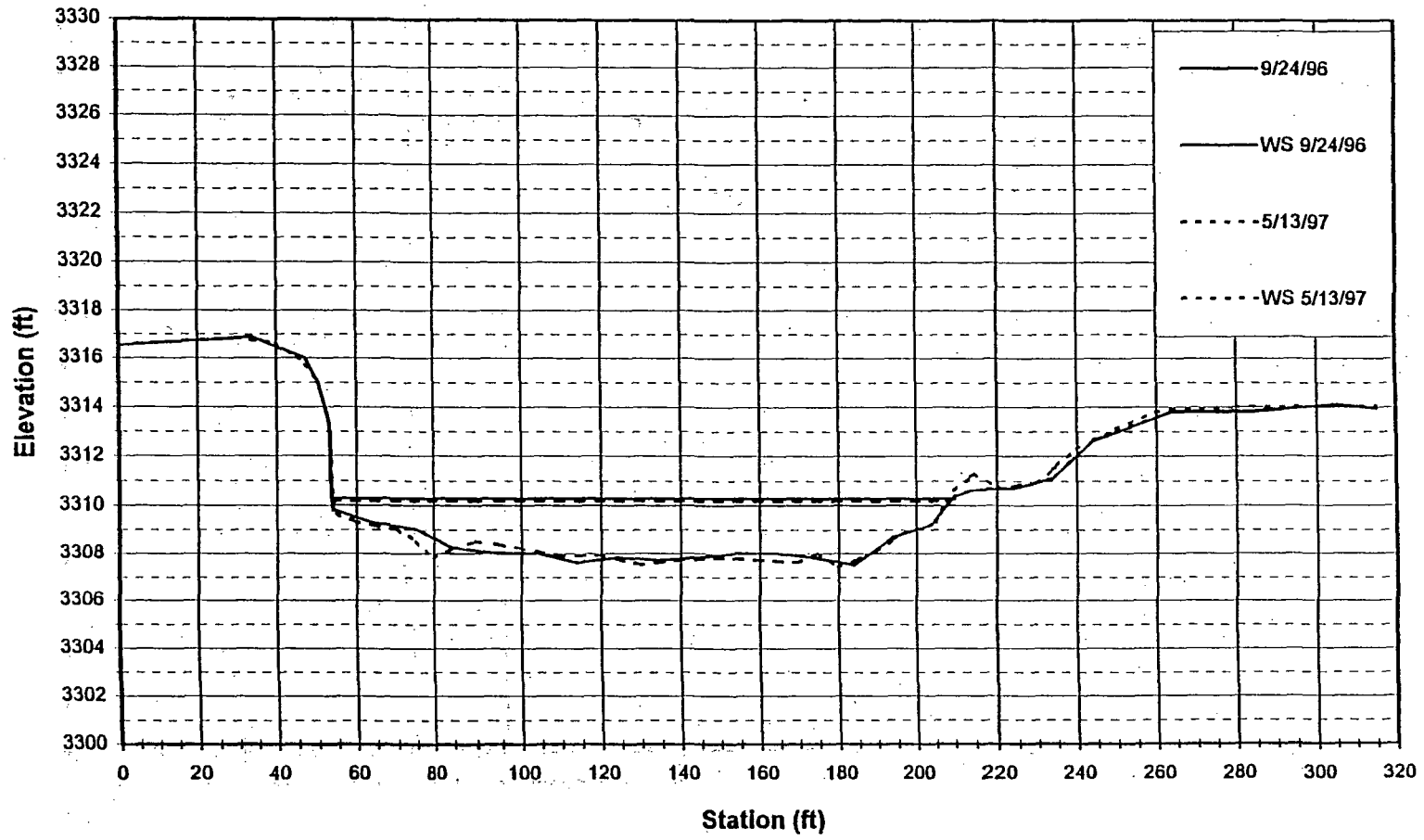
APPENDIX 2

Fall River Cross Section # 3

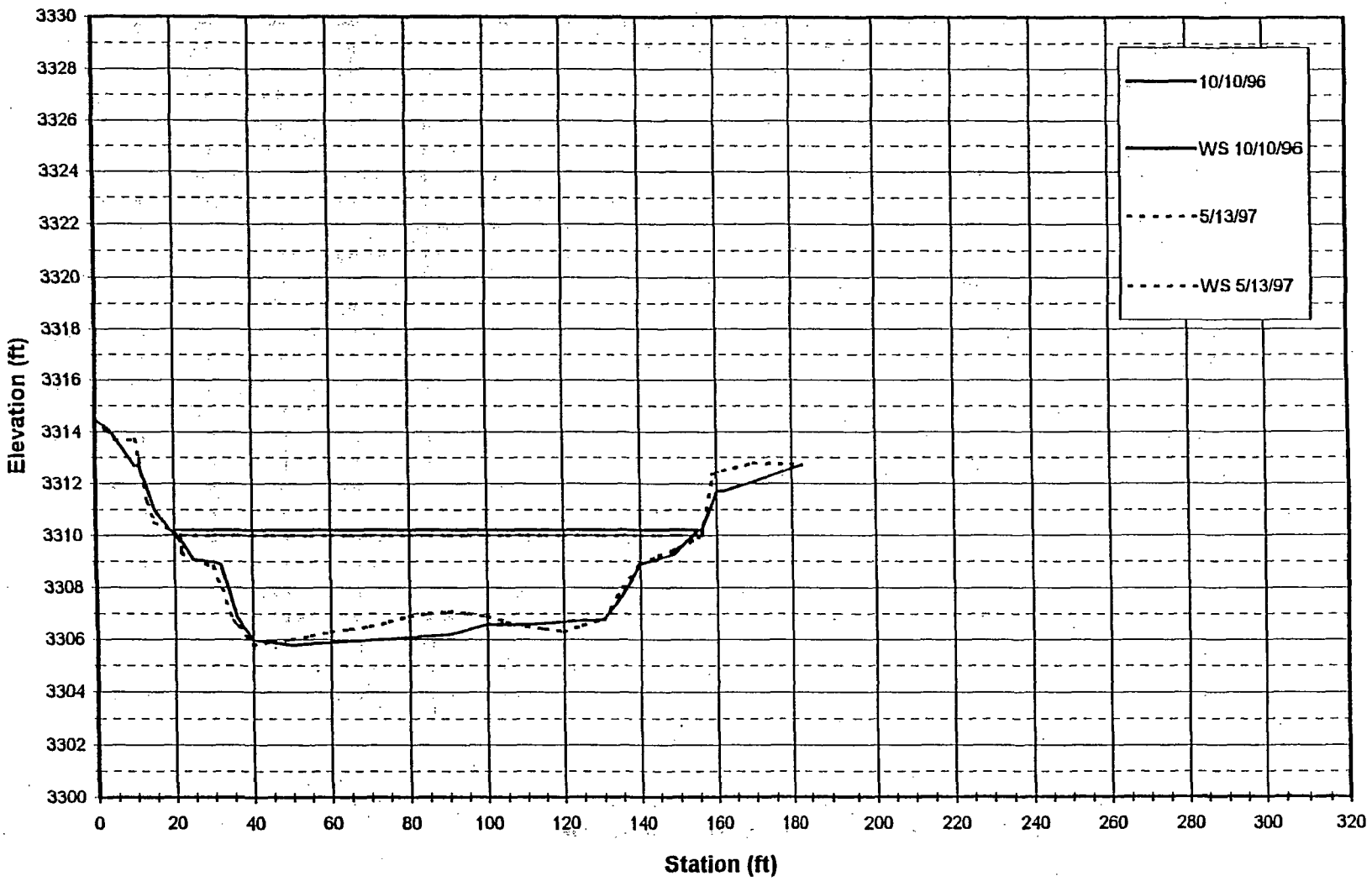



Fall River Cross Section # 5
Elevation (ft)
3330
3328
3326
3324
3322
3320
3318
3316
3314
3312
3310
3308
3306
3304
3302
3300
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
Station (ft)
10/10/96
WS 10/10/96
5/13/97
WS 5/13/97

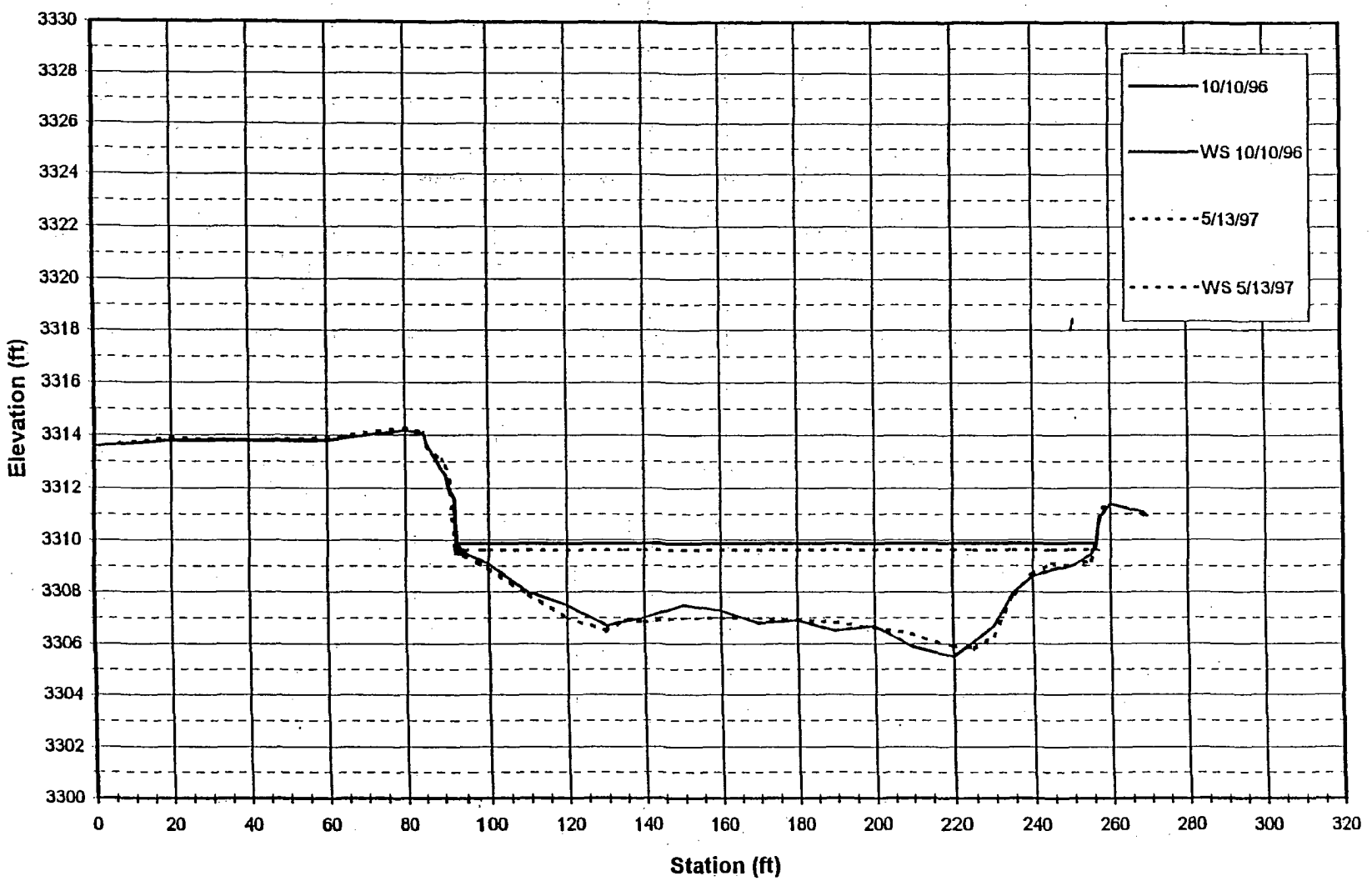
Fall River Cross Section # 7



Fall River Cross Section # 9



Fall River Cross Section # 11



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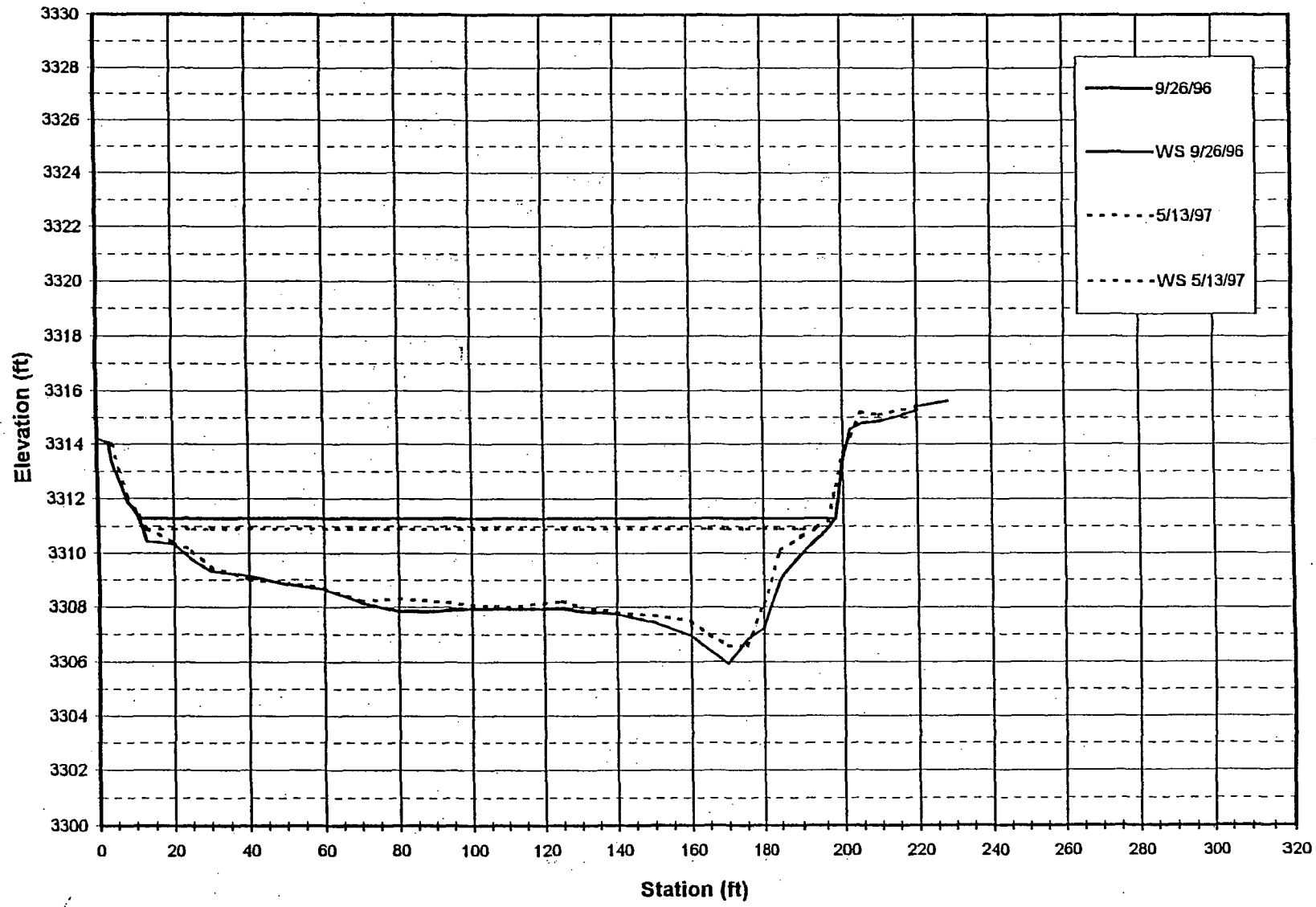

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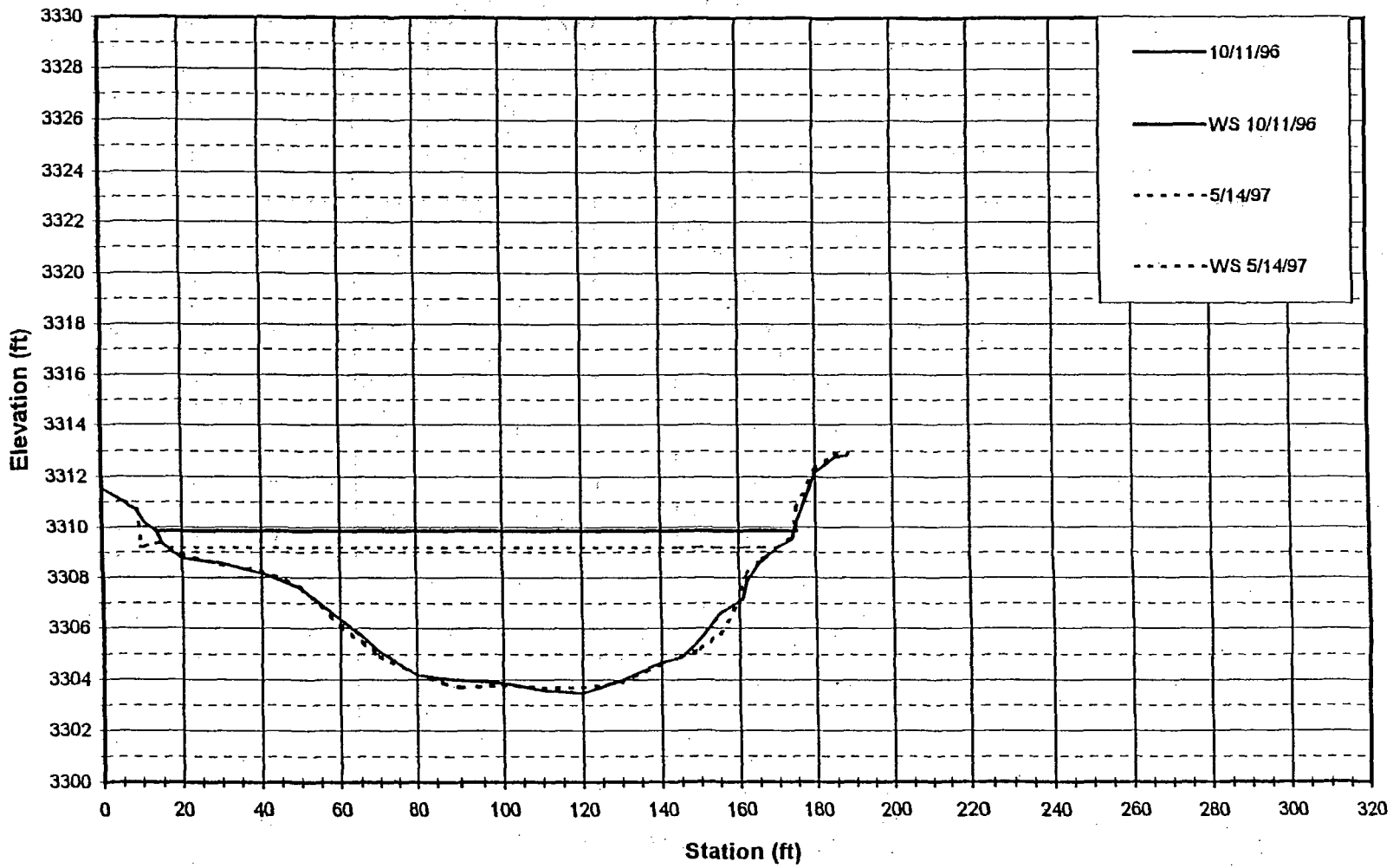
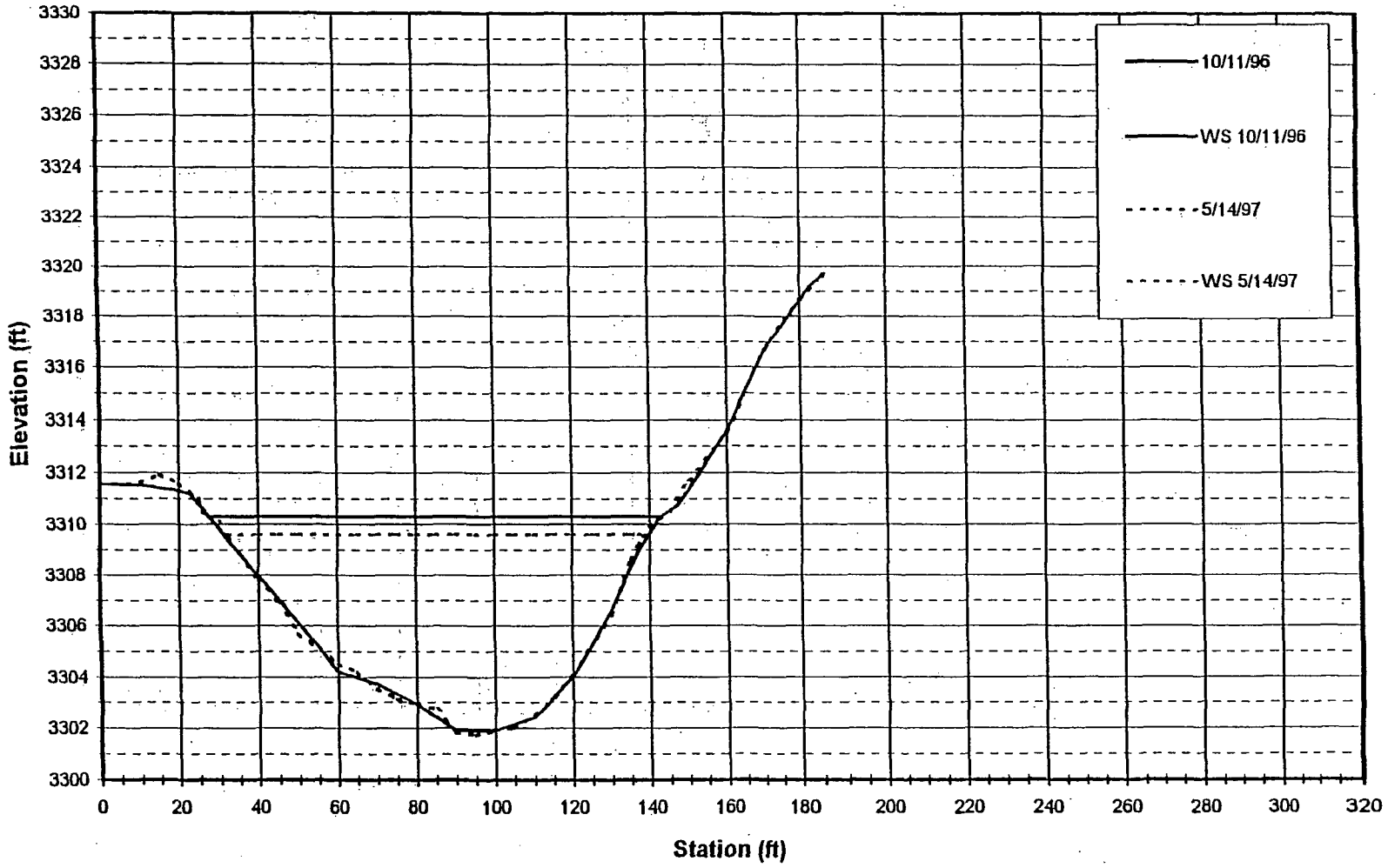
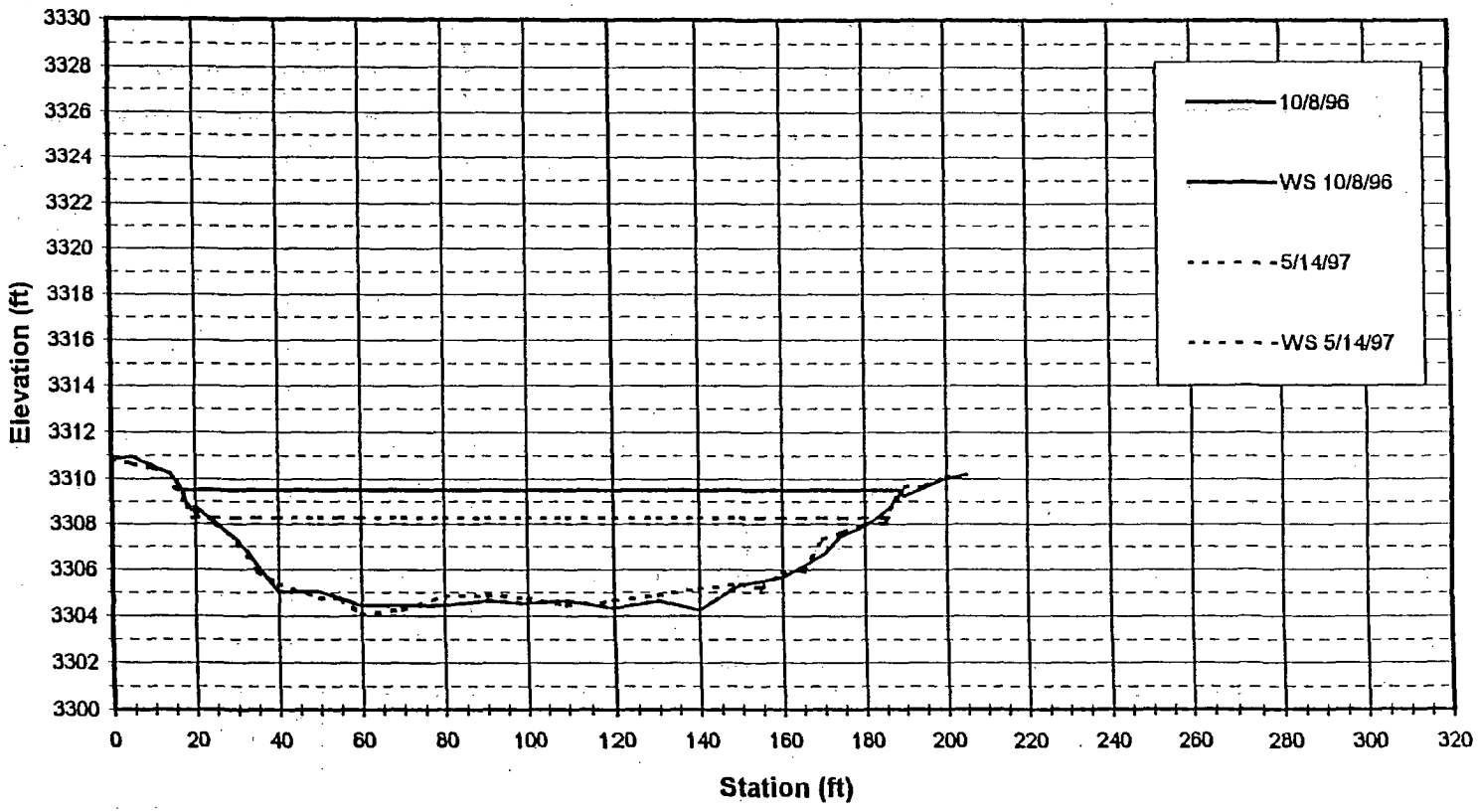


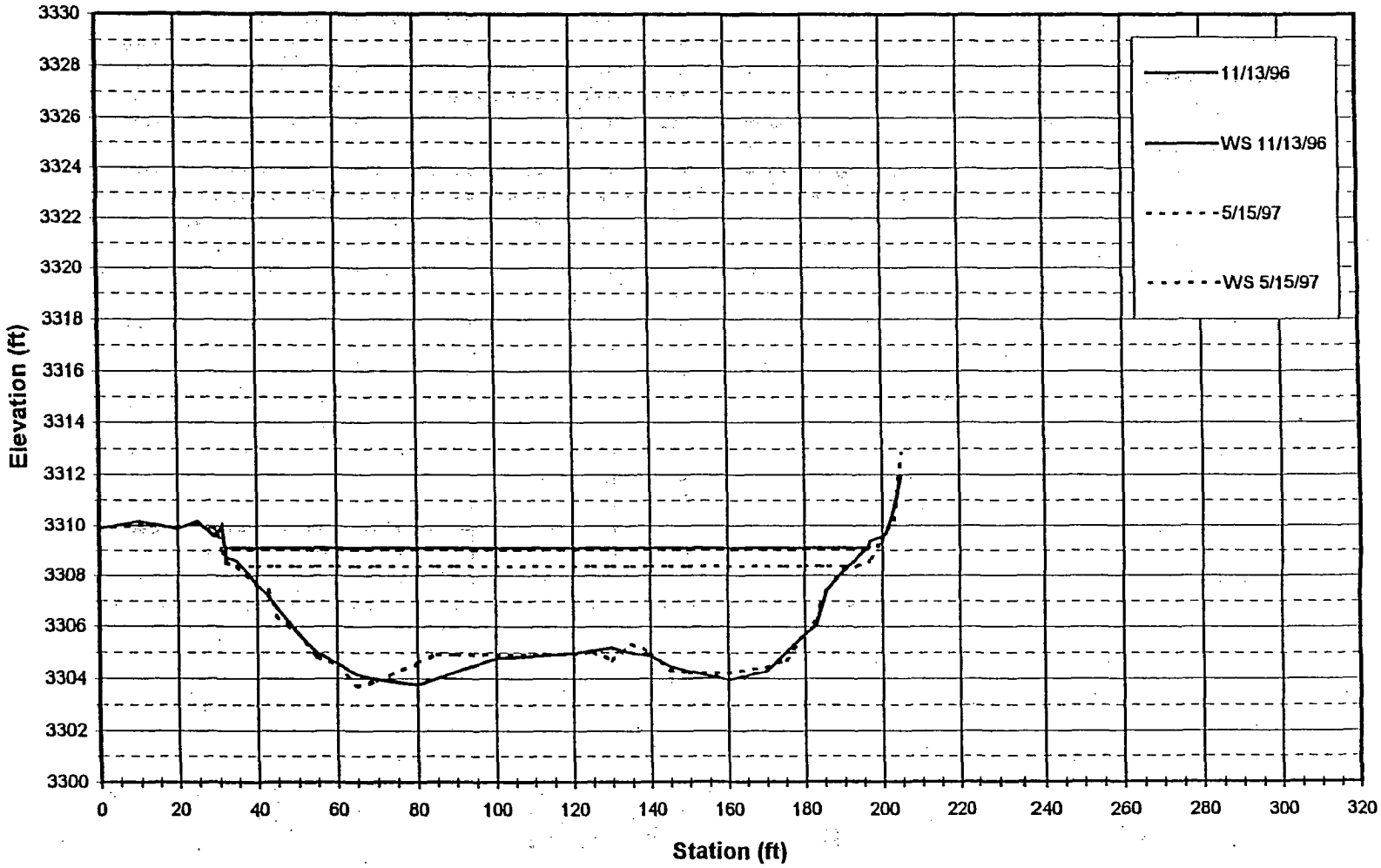
Fall River Cross Section # 19



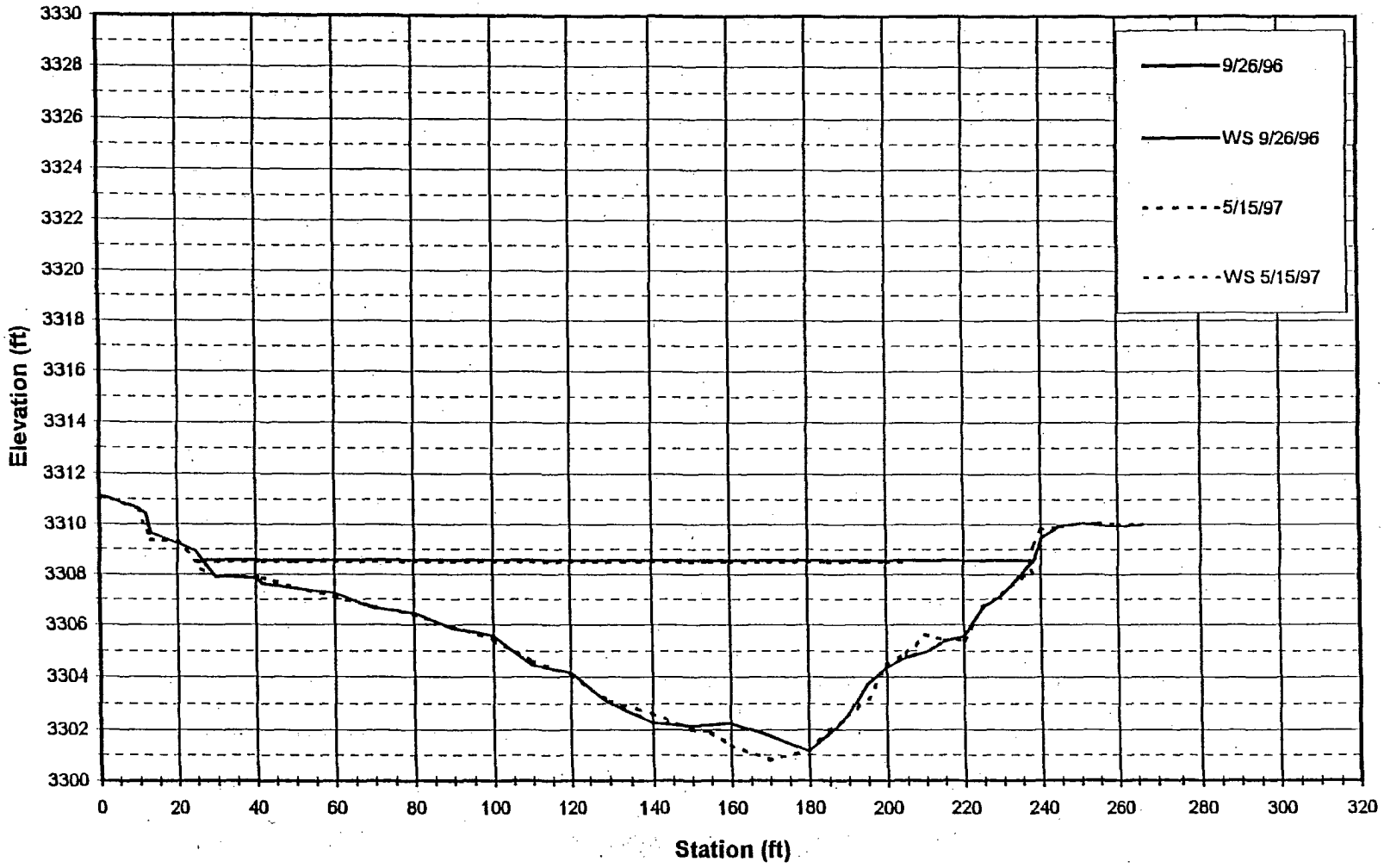
Fall River Cross Section # 21



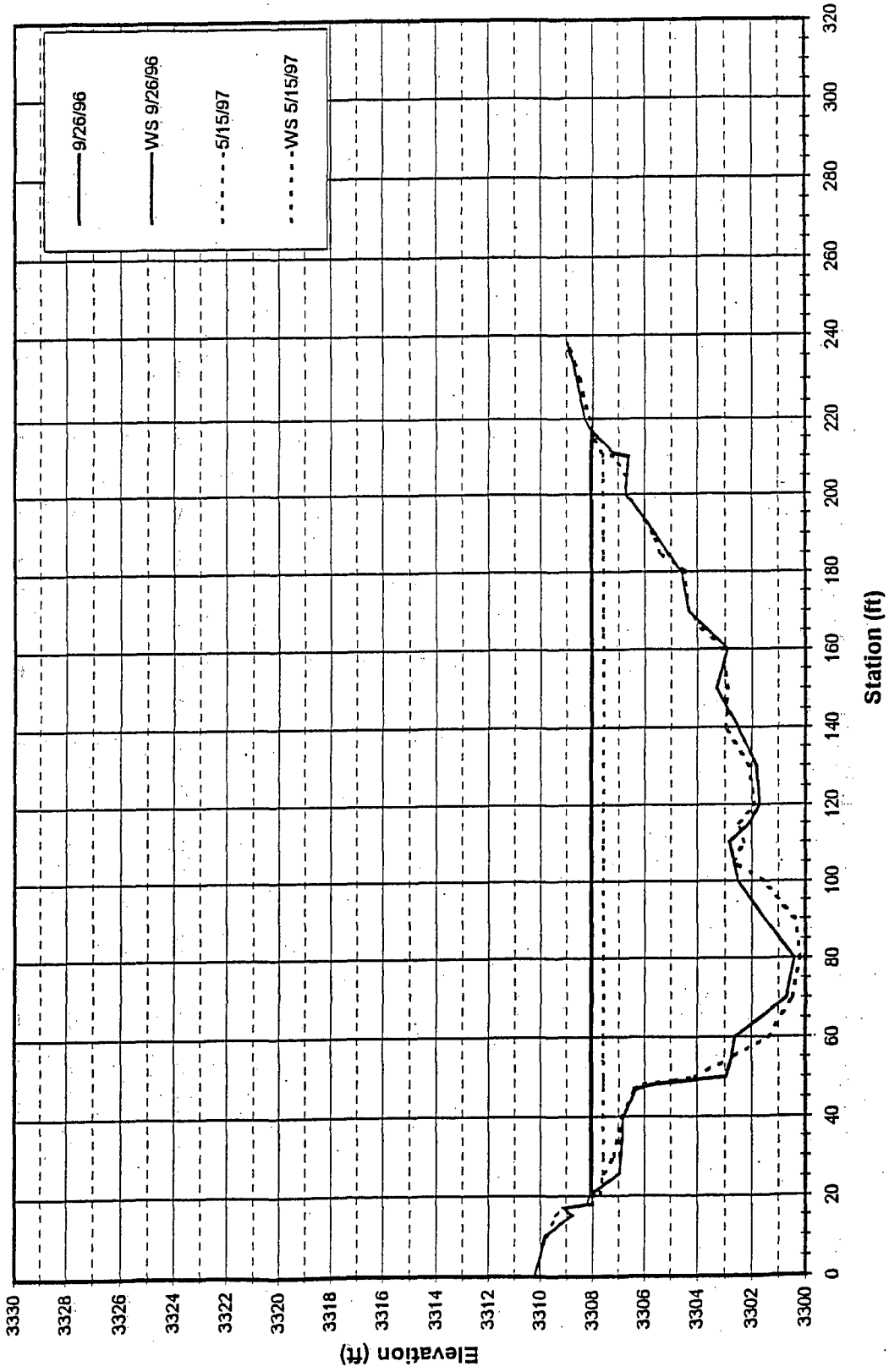
Fall River Cross Section # 22



Fall River Cross Section # 23



Fall River Cross Section # 24



APPENDIX 3

Field Procedure for Collecting Sediment Core Samples

Equipment Required:

1" Nominal Diameter Coring Tube (18 l.f., in 2 and 3-ft. sections)
Coring Bit (0.9-in. ID, 1.25-in. OD) plus spare
Drive Shoe for Coring Tube
25.8-pound Coring Drop Hammer with guide rod
Doweling, 4-ft. (for core removal)
Strap wrench & Pipe wrench
Hand Sledge
Steel Pocket Leveling Rod
Plastic Bags (1-gal. Ziploc)
Sample Bags (5-gal. canvas)
Sample Tags
Field Book
Boat with Cable Guide
Tag line & Leather Gloves
Cable Grabs
Waterproof Pens
Dumpy Level & Philadelphia Rod
Magnetic Monument Locator
Chest Waders & Boots (optional)

Procedure:

Determine the water surface elevation with the LB or RB monuments (known elevations). The water surface will be used as a datum for coring.

Using the LB and RB monuments as section endpoints, stretch a Tag line across the section. The LB monument is Station 0+00.

Determine the approximate width of the river and with consideration to channel morphology, roughly plan the station locations for coring. Concentrate on locations that are fluvially active and minimize areas that have bank-slough deposits.

At a selected coring station, position boat with the cable guide Tag line clamp.

Sample Collection:

Position coring tube to the surface of the bed and determine the depth of water.

Push the coring tube into the bed by hand, to refusal, and determine depth of penetration. Record these values.

Using the 25.8# hammer and 1-foot free drops, advance the coring tube. Count the

number of hammer blows to advance the coring tube one foot, or until there is a noticeable change in the rate of advancement. Record depth interval and number of hammer blows between each perceivable facies change. Continue to depth until refusal or until the rate of advancement has substantially diminished.

Remove coring tube and core sample.

With the doweling and hand sledge eject the coring onto a clean, smooth surface. Be sure to eject the compressed core sample in stratigraphic order, so as not to mix layers.

By color and texture separate the compressed core sample at obvious lithologic changes. Place representative samples into labeled plastic bags. Also collect a sample that is representative of the shallow, bed-surface material if possible. Label the sample bags, surface, top ¼, upper middle ¼, lower middle ¼, and bottom ¼. Sample distortion from the coring process generally makes finer refinement impracticable.

Repeat this process for the remaining sample stations at the section.

APPENDIX 4

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 25, 1996

Cross-Section No.	Station No.
Section #3	**0 + 90.2**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	0.9	0.9			Water	
0.9	2.4	1.5	By Hand		Fine to Med sand. Poorly sorted. Very Dirty.	Occ. Gravel
2.4	3.0	0.6	10	17	Fine sandy silt loam. Well Sorted.	

Total Sediment Cored	2.1

NOTE: All depths measured from water surface (elevation 3311.29 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sect. by S. Sunding

NOTE: Read's Bridge was essentially washed out by the January '97 flooding. The remaining piers were removed by June '97.

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 25, 1996

Cross-Section No.	Station No.
Section #3	**1 + 06.4**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	5.0	5.0			Water	
5.0	5.3	0.3	By Hand		Very Fine Sand Silt Loam. Well sorted.	
5.3	6.0	0.7	20	29	Fine Sandy Silt Loam. Well-sorted.	

Total Sediment Cored	1.0

NOTE: All depths measured from water surface (elevation 3311.29 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sect. by S. Sunding

NOTE: Read's Bridge was essentially washed out by the January '97 flooding. The remaining piers were removed by June '97.

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 25, 1996

Cross-Section No.	Station No.
Section #3	**1 + 25**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	6.5	6.5			Water	
6.5	7.7	1.2	By Hand		Fine - Coarse sand. Poorly-sorted. Slightly Dirty.	
7.7	8.3	0.6	20	33	Fine - Med sandy silt. Mod-sorted.	Organics

Total sediment cored	1.8

NOTE: All depths measured from water surface (elevation 3311.29 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sect. by S. Sunding

NOTE: Read's Bridge was essentially washed out by the January '97 flooding. The remaining piers were removed by June '97.

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 25, 1996

Cross-Section No.	Station No.
Section #3	**1 + 42**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	6.5	6.5			Water	
6.5	7.5	1.0	By Hand		Fine - Med sand. Mod-sorted. Very Dirty.	
7.5	8.2	0.7	30	43	Very Fine - Med sand. Mod- sorted. Dirty.	

Total sediment cored	1.7

NOTE: All depths measured from water surface (elevation 3311.29 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sect. by S. Sunding

NOTE: Read's Bridge was essentially washed out by the January '97 flooding. The remaining piers were removed by June '97.

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 25, 1996

Cross-Section No.	Station No.
Section #3	**1 + 65**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.5	3.5			Water	
3.5	7.1	3.6	By Hand		Fine Sandy Silt.	
7.1	8.1	1.0	14	14	Silt Loam.	Organics.
8.1	8.5	0.4	7	18	Fine - Med Sand. Poorly-Sorted. Very Dirty.	

Total sediment cored 5.0

NOTE: All depths measured from water surface (elevation 3311.29 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sect. by S. Sunding

NOTE: Read's Bridge was essentially washed out by the January '97 flooding. The remaining piers were removed by June '97.

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 25, 1996

Cross-Section No.	Station No.
Section #3	**1 + 78**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	1.5	1.5			Water	
1.5	5.1	3.6	By Hand		Very Silty Fine Sand. Mod-Sorted.	
5.1	6.1	1.0	13	13	Fine - Med Sand. Poorly-Sorted. Very Dirty.	Organics.
6.1	7.1	1.0	13	13	Very Fine - Med Sand. Poorly-Sorted. Dirty	
7.1	7.3	0.2	5	25	Fine - Med Sand. Well-Sorted. Dirty.	

Total sediment cored	5.8

NOTE: All depths measured from water surface (elevation 3311.29 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sect. by S. Sunding

NOTE: Read's Bridge was essentially washed out by the January '97 flooding. The remaining piers were removed by June '97.

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 25, 1996

Cross-Section No.	Station No.
Section #3	**1 + 89**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	1.0	1.0			Water	
1.0	2.1	1.1	By Hand		Very Silty Very Fine-Fine Sand, Mod-Sorted, Very Dirty.	Consolidated
2.1	3.1	1.0	7	7	Loamy Sand.	Small Gravel
3.1	4.1	1.0	13	13	Very Silty Fine Sand Loam, Well-Sorted.	
4.1	4.5	5.0	10	2	Very Fine Sandy Loam.	

Total sediment cored	8.1

NOTE: All depths measured from water surface (elevation 3311.29 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sect. by S. Sunding

NOTE: Read's Bridge was essentially washed out by the January '97 flooding. The remaining piers were removed by June '97.

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28, 1996

Cross-Section No.	Station No.
Section #5	**0 + 60**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.2	3.2			Water	
3.2	4.5	1.3	28	22	Silty Fine to Med. Sand, Mod-Sorted, Slightly Dirty.	Gravelly

Total sediment cored	1.3

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by K. Staton, G. Pearson, K. Buer
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28, 1996

Cross-Section No.	Station No.
Section #5	**0 + 80**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	2.2	2.2			Water	
2.2	2.8	0.6	By Hand		Very Fine to Med Sand. Poorly-Sorted. Dirty.	
2.8	3.2	0.4	4	10	Very Fine to Med Sand. Poorly-Sorted. Dirty.	
3.2	4.2	1.0	24	24	Fine to Coarse Sand. Poorly-Sorted.	Very gravelly

Total sediment cored 2.0

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by K. Staton, G. Pearson, K. Buer
Lab work by J. VanGilder
X-Sec. by S. Sunding

NOTE: Appears to be a wedge of recent, sandy sediment that begins at Sta. 0+71 and ends at Sta. 1+11 (from field observations)

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28, 1996

Cross-Section No.	Station No.
Section #5	**1 + 00**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	2.3	2.3			Water	
2.3	3.0	0.7	By Hand		Very Fine to Coarse Sand. Poorly-Sorted. Dirty.	Occ. Gravel.
3.0	4.2	1.2	11	9	Fine to Med. Sand. Mod-Sorted. Slightly Dirty.	Gravelly.

Total sediment cored	1.9

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by K. Staton, G. Pearson, K. Buer
Lab work by J. VanGilder
X-Sec. by S. Sunding

NOTE: Appears to be a wedge of recent, sandy sediment that begins at Sta. 0+71 and ends at Sta. 1+11 (from field observations)

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28, 1996

Cross-Section No.	Station No.
Section #5	**1 + 20**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	2.6	2.6			Water	
2.6	2.7	0.1	By Hand		Fine to Med. Sand. Mod-Sorted. Slightly Dirty.	Occ. Gravel
2.7	3.9	1.2	16	12	Fine to Coarse Sand. Mod-Sorted. Dirty.	Very Gravelly

Total sediment cored	1.3

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by K. Staton, G. Pearson, K. Buer
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28,1997

Cross-Section No.	Station No.
Section #5	**1 + 40**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
					No Sample Collected	

Total sediment cored

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by K. Staton, G. Pearson, K. Buer
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28,1997

Cross-Section No.	Station No.
Section #5	**1 + 60**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
					No Sample Collected	

Total sediment cored

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by K. Staton, G. Pearson, K. Buer
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28, 1996

Cross-Section No.	Station No.
Section #5	**1 + 80**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	1.4	1.4			Water	
1.4	3.2	1.8	By Hand		Very Fine Sandy Silt.	
3.2	3.9	0.7	15	21	Fine to Coarse Sand, Mod-Sorted, Dirty.	Gravelly

Total sediment cored	2.5

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by K. Staton, G. Pearson, K. Buer
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28,1997

Cross-Section No.	Station No.
Section #5	**1 + 89**

Depth		Thickness	Blow	Blows	Soil Description	Remarks
From	To	in Feet	Count	per foot		
					No Sample Collected	

Total sediment cored

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by K. Staton, G. Pearson, K. Buer
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 24, 1996

Cross-Section No.	Station No.
Section #7	**0 + 55**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	0.6	0.6			Water	
0.6	2.6	2.0	By Hand		Fine sand. Well-sorted. Dirty.	
2.6	3.6	1.0	11	11	Fine sand. Well-sorted. Dirty.	
3.6	4.5	0.9	5	6	Fine sand. Well-sorted. Dirty.	
4.5	4.8	0.3	12	40	Fine sand. Well-sorted. Dirty.	

Total sediment cored 4.2

NOTE: *All depths measured from water surface (elevation = 3310.31 ft.)*

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 24, 1996

Cross-Section No.	Station No.
Section #7	**0 + 75**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	1.4	1.4			Water	
1.4	2.4	1.0	By Hand		Very fine to med sand. Poorly-sorted. Slightly dirty.	
2.4	3.2	0.8	8	10	Fine sand. Well-sorted. Dirty.	
3.2	3.9	0.7	11	16	Fine to coarse sand. Poorly-sorted. Dirty.	

Total sediment cored	2.5

NOTE: All depths measured from water surface (elevation = 3310.31 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 24, 1996

Cross-Section No.	Station No.
Section #7	**0 + 95**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	2.4	2.4			Water	
2.4	2.8	0.4	By Hand		Fine to very coarse sand. Mod-sorted. Dirty	
2.8	6.0	3.2	3	1	Very fine to med sand. Mod-sorted. Slightly dirty.	
6.0	6.2	0.2	11	55	Very fine to med sand. Mod-sorted. Slightly dirty.	

Total sediment cored	3.8

NOTE: All depths measured from water surface (elevation = 3310.31 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 24, 1996

Cross-Section No.	Station No.
Section #7	**1 + 15**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	2.6	2.6			Water	
2.6	2.7	0.1	By Hand		Slightly Silty Very Fine to Coarse Sand. Poorly Sorted.	Gravelly.
2.7	3.7	1.0	7	7	Fine to Med sand. Well-Sorted. Slightly Dirty.	
3.7	4.2	0.5	9	18	Fine to Med sand. Poorly-Sorted. Dirty.	Occ. Gravel.

Total sediment cored	1.6

NOTE: *All depths measured from water surface (elevation = 3310.31 ft.)*

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 24, 1996

Cross-Section No.	Station No.
Section #7	**1 + 35**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	2.4	2.4			Water	
2.4	2.6	0.2	By Hand		Med to Coarse Sand. Poorly-Sorted. Slightly Dirty.	Gravelly
2.6	3.6	1.0	15	15	Med to Coarse Sand. Poorly-Sorted. Slightly Dirty.	Gravelly
3.6	3.7	0.1	9	90	Med to Coarse Sand. Poorly-Sorted. Slightly Dirty.	Gravelly

Total sediment cored	1.3

NOTE: All depths measured from water surface (elevation = 3310.31 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 24, 1996

Cross-Section No.	Station No.
Section #7	**1 + 55**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	2.2	2.2			Water	
2.2	2.4	0.2	By Hand		Fine to Very Coarse Sand. Poorly-Sorted. Slightly Dirty.	Gravelly
2.4	3.4	1.0	10	10	Med to Very Coarse Sand. Poorly-Sorted. Slightly Dirty.	Very Gravelly
3.4	3.5	0.1	5	50	Slightly Silty Fine to Coarse Sand. Poorly-Sorted.	Gravelly

Total sediment cored	1.3

NOTE: All depths measured from water surface (elevation = 3310.31 Ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 24, 1996

Cross-Section No.	Station No.
Section #7	**1 + 75**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	2.7	2.7			Water	
2.7	3.1	0.4	By Hand		Fine to Coarse Sand. Mod-Sorted. *Slightly Dirty.*	Gravelly
3.1	4.1	1.0	15	15	Silty Fine Sand. Well-sorted.	
4.1	4.6	0.5	9	18	Very Silty Fine Sand. Well-sorted.	

Total sediment cored	1.9

NOTE: *All depths measured from water surface (elevation = 3310.31 ft.)*

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 24, 1996

Cross-Section No.	Station No.
Section #7	**1 + 95**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	0.9	0.9			Water	
0.9	1.6	0.7	By hand		Very Silty Very Fine to Med. Sand. Mod-Sorted.	Occ. Gravelly
1.6	2.6	1.0	11	11	Fine to Very Coarse Sand. Poorly-Sorted. Slightly Dirty.	Gravelly
2.6	3.6	1.0	33	33	Fine to Med. Sand. Mod-Sorted. Slightly Dirty.	Gravelly
3.6	3.7	0.1	10	100	Fine to Med. Sand. Mod-Sorted. Slightly Dirty.	Very Gravelly

Total sediment cored	2.8

NOTE: All depths measured from water surface (elevation = 3310.31 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28, 1996

Cross-Section No.	Station No.
Section #9	**0 + 40**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	4.1	4.1			Water	
4.1	4.9	0.8	By hand		No Sample	
4.9	5.8	0.9	6	7	Very Fine Sandy Silt.	
5.8	7.1	1.3	25	19	Very Fine Sandy Silt.	

Total sediment cored	3.0

NOTE: All depths measured from water surface (elevation = 3310.2 ft.)

Field work by K. Staton, G. Pearson, K. Buer.
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28, 1996

Cross-Section No.	Station No.
Section #9	**0 + 60**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	4.2	4.2			Water	
4.2	5.2	1.0	By hand		No Sample	
5.2	5.7	0.5	3	6	No Sample	
5.7	6.3	0.6	13	22	Very Fine to Med. Sand. Mod-Sorted.. Very Dirty.	

Total sediment cored	2.1

NOTE: All depths measured from water surface (elevation = 3310.2 ft.)

Field work by K. Staton, G. Pearson, K. Buer.
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28, 1996

Cross-Section No.	Station No.
Section #9	**0 + 80**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	4.2	4.2			Water	
4.2	5.2	1.0	By Hand		Very Fine Sand. Mod-Sorted. Dirty.	Occ. Gravelly
5.2	6.2	1.0	10	10	Fine to Coarse Sand. Poorly-Sorted. Slightly Dirty.	

Total sediment cored	2.0

NOTE: All depths measured from water surface (elevation = 3310.2 ft.)

Field work by K. Staton, G. Pearson, K. Buer.
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28, 1996

Cross-Section No.	Station No.
Section #9	**1 + 00**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	4.1	4.1			Water	
4.1	4.6	0.5	By Hand		No Sample.	
4.6	5.2	0.6	7	12	Very Fine to Coarse Sand. Poorly-Sorted. Very Dirty.	Occ. Gravelly
5.2	6.2	1.0	13	13	Slightly Dirty Fine to Very Coarse sand. Poorly-Sorted.	Gravelly

Total sediment cored	2.1

NOTE: All depths measured from water surface (elevation = 3310.2 ft.)

Field work by K. Staton, G. Pearson, K. Buer.
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28, 1996

Cross-Section No.	Station No.
Section #9	**1 + 20**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.8	3.8			Water	
3.8	4.8	1.0	By hand		Very Silty Fine to Med. Sand. Mod-Sorted.	
4.8	5.6	0.8	6	8	Very Silty Fine to Med. Sand. Mod-Sorted.	
5.6	6.2	0.6	11	18	Very Silty Very Fine to Med. Sand. Mod-Sorted.	

Total sediment cored	2.4

NOTE: All depths measured from water surface (elevation = 3310.2 ft.)

Field work by K. Staton, G. Pearson, K. Buer.
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28, 1996

Cross-Section No.	Station No.
Section #9	1 + 36

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	2.2	2.2			Water	
2.2	5.1	2.9	By Hand		Slightly Clayey Silt.	
5.1	6.2	1.1	19	17	Very Silty Fine to Med. Sand. Mod-Sorted.	

Total sediment cored	4.0

NOTE: All depths measured from water surface (elevation = 3310.2 ft.)

Field work by K. Staton, G. Pearson, K. Buer.
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28-29, 1996

Cross-Section No.	Station No.
Section #11	**0 + 20**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0	1.6	1.6			Water	
1.6	3.8	2.2	By Hand		Slightly Clayey Silt.	
3.8	4.6	0.8	11	14	Silt Loam.	

Total sediment cored	3.0

NOTE: All depths measured from water surface (elevation = 3309.86 ft.)

Field work by K. Buer, G. Pearson, K. Staton
Lab work by J VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28-29, 1996

Cross-Section No.	Station No.
Section #11	**0 + 40**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.0	3.0			Water	
3.0	4.3	1.3	By Hand		No sample taken	

Total sediment cored	1.3

NOTE: All depths measured from water surface (elevation = 3309.86 ft.)

Field work by K. Buer, G. Pearson, K. Staton
Lab work by J. Van Gilder
X-Sect by S. Sunding

Department of Water Resources
Fail River Sediment Investigation

Samples taken on: Oct. 28-29, 1996

Cross-Section No.	Station No.
Section #11	**0 + 60**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	2.3	2.3			Water	
2.3	3.3	1.0	By Hand		Very Fine to Coarse Sand. Poorly-Sorted. Slightly dirty.	
3.3	5.2	1.9	18	9	No Sample	

Total sediment cored 2.9

NOTE: All depths measured from water surface (elevation 3309.86 ft.)

Field work by K. Buer, G. Pearson, K. Staton
Lab work by J. Van Gilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28-29, 1996

Cross-Section No.	Station No.
Section #11	**0 + 80**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0	2.8	2.8			Water	
2.8	4.2	1.4	By Hand		No sample taken	

Total sediment cored	1.4

NOTE: All depths measured from water surface (elevation 3309.86 ft.)

Field work by K. Buer, G. Pearson, K. Staton
Lab work by J. Van Gilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28-29, 1996

Cross-Section No.	Station No.
Section #11	**1 + 00**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.0	3.0			Water	
3.0	4.8	1.8	By Hand		No Sample Taken.	
4.8	5.3	0.5	5	10	Slightly Silty Fine - Med Sand. Mod Sorted.	

Total sediment cored	2.3

NOTE: All depths measured from water surface (elevation 3309.86 ft.)

Field work by K. Buer, G. Pearson, K. Staton
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28-29, 1996

Cross-Section No.	Station No.
Section #11	**1 + 20**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0	3.8	3.8			Water	
3.8	4.9	1.1	By Hand		No Sample Taken	
4.9	6.2	1.3	21	16	Slightly Silty Very Fine - Med Sand. Mod-Sorted.	

Total sediment cored 2.4

NOTE: All depths measured from water surface (elevation 3309.86 ft.)

Field work by K. Buer, G. Pearson, K. Staton
Lab work by J. Van Gilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28-29, 1996

Cross-Section No.	Station No.
Section #11	**1 + 40**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	2.3	2.3			Water	
2.3	5.0	2.7	By Hand		Loamy Fine Sand.	
5.0	6.2	1.2	22	18	Very Silty Very Fine Sand. Well-sorted.	

Total sediment cored	3.9

NOTE: *All depths measured from water surface (elevation 3309.86 ft.)*

Field work by K. Buer, G. Pearson, K. Staton
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 28-29, 1996

Cross-Section No.	Station No.
Section #11	**1 + 60**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0	1.3	1.3			Water	
1.3	3.4	2.1	By Hand		No Sample Taken.	

Total sediment cored	2.1

NOTE: All depths measured from water surface (elevation 3309.86 ft.)

Field work by K. Buer, G. Pearson, K. Staton
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 26, 1996

Cross-Section No.	Station No.
Section #15	**0 + 20**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	0.7	0.7			Water	
0.7	2.5	1.8	By Hand		Very Fine Sand.	Organics
2.5	3.5	1.0	25	25	Fine to Very Coarse Sand. Mod.-Sorted.	

Total sediment cored	2.8

NOTE: All depths measured from water surface (elevation = 3309.93 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 26, 1996

Cross-Section No.	Station No.
Section #15	**0 + 60**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	2.5	2.5			Water	
2.5	4.0	1.5	By Hand		Fine to Coarse Sand. Poorly-Sorted.	
4.0	5.0	1.0	17	17	Fine to Med. Sand. Mod-Sorted Sand.	
5.0	5.4	0.4	10	25	Fine to Med. Sand. Mod-Sorted Sand.	

Total sediment cored	2.9

NOTE: All depths measured from water surface (elevation = 3309.93 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 26, 1996

Cross-Section No.	Station No.
Section #15	**0 + 80**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.3	3.3			Water	
3.3	4.3	1.0	By Hand		Fine to Med. Mod.-Sorted Sand.	
4.3	5.3	1.0	12	12	Fine to Very Coarse, Poorly-Sorted Sand.	
5.3	5.7	0.4	10	25	Very Fine to Coarse, Poorly-Sorted Sand.	

Total sediment cored	2.4

NOTE: All depths measured from water surface (elevation = 3309.93 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 26, 1996

Cross-Section No.	Station No.
Section #15	**1 + 00**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.2	3.2			Water	
3.2	4.8	1.6	By Hand		Very Fine Sand.	Minor Organics.
4.8	6.8	2.0	33	17	Clay Loam.	
6.8	9.0	2.2	38	19	Silty Clay.	

Total sediment cored	5.8

NOTE: All depths measured from water surface (elevation = 3309.93 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 26, 1996

Cross-Section No.	Station No.
Section #15	**1 + 20**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.1	3.1			Water	
3.1	3.9	0.8	By Hand		Very Fine to Med. Sand. Mod.- Sorted.	
3.9	4.9	1.0	6	6	Fine to Med. Sand. Well-Sorted.	
4.9	5.8	0.9	20	22	Fine to Med. Sand. Well-Sorted.	

Total sediment cored 2.7

NOTE: All depths measured from water surface (elevation = 3309.93 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 26, 1996

Cross-Section No.	Station No.
Section #15	**1 + 20**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.1	3.1			Water	
3.1	3.9	0.8	By Hand		Very Fine to Med. Sand. Mod.- Sorted.	
3.9	4.9	1.0	6	6	Fine to Med. Sand. Well-Sorted.	
4.9	5.8	0.9	20	22	Fine to Med. Sand. Well-Sorted.	

Total sediment cored 2.7

NOTE: All depths measured from water surface (elevation = 3309.93 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 26, 1996

Cross-Section No.	Station No.
Section #15	**1 + 40**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.3	3.3			Water	
3.3	4.8	1.5	By Hand		Very Fine to Fine Sand. Well- Sorted.	
4.8	5.8	1.0	19	19	Fine to Coarse Sand. Poorly-Sorted.	Minor Organics
5.8	6.3	0.5	10	20	Fine to Coarse Sand. Poorly-Sorted.	

Total sediment cored	3.0

NOTE: All depths measured from water surface (elevation = 3309.93 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 26, 1996

Cross-Section No.	Station No.
Section #15	**1 + 60**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	4.2	4.2			Water	
4.2	5.2	1.0	By hand		Fine to Med. Sand. Mod.- Sorted.	
5.2	6.2	1.0	16	16	Fine to Med. Sand. Mod.- Sorted.	
6.2	6.3	0.1	10	100	Very Fine to Fine Sand. Well-Sorted.	

Total sediment cored	2.1

NOTE: All depths measured from water surface (elevation = 3309.93 ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Sept. 26, 1996

Cross-Section No.	Station No.
Section #15	**1 + 80**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.8	3.8			Water	
3.8	5.0	1.2	By Hand		Slightly Clayey Silt.	Minor Organics.
5.0	5.8	0.8	25	31	Fine to Med. Slightly Silty Sand. Mod.-Sorted.	

Total sediment cored	2.0

NOTE: All depths measured from water surface (elevation = 3309.93 Ft.)

Field work by J. Anderson, C. Anderson, W. Lane & G. Kuenster
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 2, 1996

Cross-Section No.	Station No.
Section #18	**0 + 25**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	0.8	0.8			Water	
0.8	4.3	3.5	By Hand		Very Fine to Med. Sand. Mod-Sorted. Clean.	
4.3	5.6	1.3	12	9	Light Brown Silt	

Total sediment cored	4.8

NOTE: All depths measured from water surface (elevation = 3309.85 ft.)

Field work by K. Buer, J. Anderson, E. Hanson
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 2, 1996

Cross-Section No.	Station No.
Section #18	**0 + 40**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	1.3	1.3			Water	
1.3	4.8	3.5	By Hand		Fine to Med Sand. Mod-Sorted. Clean.	
4.8	5.5	0.7	12	15	Very Fine to Fine Sand. Well-sorted. Clean.	Occ. Gravel

Total sediment cored 4.2

NOTE: All depths measured from water surface (elevation = 3309.85 ft.)

Field work by K. Buer, J. Anderson, E. Hanson
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 2, 1996

Cross-Section No.	Station No.
Section #18	**0 + 60**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.3	3.3			Water	
3.3	5.2	1.9	By Hand		Very Fine to Fine Sand. Well-sorted. Clean.	
5.2	6.2	1.0	12	12	Fine to Med. Sand. Well-sorted. Clean.	

Total sediment cored	2.9

NOTE: All depths measured from water surface (elevation = 3309.85 ft.)

Field work by K. Buer, J. Anderson, E. Hanson
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 2, 1996

Cross-Section No.	Station No.
Section #18	**0 + 80**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	5.6	5.6			Water	
5.6	6.3	0.7	By Hand		No Sample	Sample Lost
6.3	7.6	1.3	12	9	No Sample	Sample Lost

Total sediment cored	2.0

NOTE: All depths measured from water surface (elevation = 3309.85 ft.)

Field work by K. Buer, J. Anderson, E. Hanson
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 2, 1996

Cross-Section No.	Station No.
Section #18	**1 + 00**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	5.6	5.6			Water	
5.6	7.1	1.5	By Hand		Coarse to Fine Sand. Mod-Sorted. Dirty.	Occ. Gravel
7.1	8.3	1.2	12	10	Fine to Med. Sand. Well-sorted. Clean.	

Total sediment cored	2.7

NOTE: All depths measured from water surface (elevation = 3309.85 ft.)

Field work by K. Buer, J. Anderson, E. Hanson
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 2, 1996

Cross-Section No.	Station No.
Section #18	**1 + 00**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	5.6	5.6			Water	
5.6	7.1	1.5	By Hand		Coarse to Fine Sand. Mod-Sorted. Dirty.	Occ. Gravel
7.1	8.3	1.2	12	10	Fine to Med. Sand. Well-sorted. Clean.	

Total sediment cored	2.7

NOTE: *All depths measured from water surface (elevation = 3309.85 ft.)*

Field work by K. Buer, J. Anderson, E. Hanson
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 2, 1996

Cross-Section No.	Station No.
Section #18	**1 + 20**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	6.2	6.2			Water	
6.2	8.5	2.3	By Hand		No Sample.	
8.5	8.8	0.3	5	17	No Sample.	

Total sediment cored	2.6

NOTE: All depths measured from water surface (elevation = 3309.85 ft.)

Field work by K. Buer, J. Anderson, E. Hanson
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 2, 1996

Cross-Section No.	Station No.
Section #18	**1 + 40**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	5.1	5.1			Water	
5.1	5.8	0.7	By Hand		Very Fine to Fine Sand. Well-sorted. Clean.	
5.8	6.4	0.6	10	17	Very Fine to Fine Sand. Well-sorted. Clean.	

Total sediment cored	1.3

NOTE: All depths measured from water surface (elevation = 3309.85 ft.)

Field work by K. Buer, J. Anderson, E. Hanson
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 2, 1996

Cross-Section No.	Station No.
Section #18	**1 + 60**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	1.8	1.8			Water	
1.8	1.9	0.1	By Hand		Lt. Brown Silt.	

Total sediment cored	0.1

NOTE: All depths measured from water surface (elevation = 3309.85 ft.)

Field work by K. Buer, J. Anderson, E. Hanson
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 2, 1996

Cross-Section No.	Station No.
Section #19	**0 + 40**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	2.2	2.2			Water	
2.2	4.8	2.6	By Hand		No Sample.	
4.8	5.2	0.4	5	13	No Sample.	
5.2	5.8	0.6	6	10	No Sample.	

Total sediment cored	3.6

NOTE: All depths measured from water surface (elevation = 3310.31 ft.)

Field work by K. Buer, J. Anderson, E. Hanson
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 2, 1996

Cross-Section No.	Station No.
Section #19	**0 + 60**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	5.8	5.8			Water	
5.8	7.8	2.0	By Hand		Slightly Silty Sand. Mod-Sorted.	Occ. Gravel
7.8	8.4	0.6	12	17	No Sample.	

Total sediment cored	2.6

NOTE: All depths measured from water surface (elevation = 3310.31 ft.)

Field work by K. Buer, J. Anderson, E. Hanson
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 2, 1996

Cross-Section No.	Station No.
Section #19	**0 + 80**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	7.5	7.5			Water	
7.5	8.3	0.8	By Hand		Sand. Poorly-Sorted. Dirty.	Occ. Gravel
8.3	8.7	0.4	8	20	Sand. Poorly-Sorted. Dirty.	Occ. Gravel and Wood Fragments

Total sediment cored 1.2

NOTE: All depths measured from water surface (elevation = 3310.31 ft.)

Field work by K. Buer, J. Anderson, E. Hanson
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 2, 1996

Cross-Section No.	Station No.
Section #19	**1 + 00**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	8.2	8.2			Water	
8.2	8.3	0.1	By Hand		Silty Sand. Poorly-Sorted.	Gravelly
8.3	10.2	1.9	12	6	Clayey Silt.	

Total sediment cored	2.0

NOTE: All depths measured from water surface (elevation = 3310.31 ft.)

Field work by K. Buer, J. Anderson, E. Hanson
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 2, 1996

Cross-Section No.	Station No.
Section #19	**1 + 20**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	6.0	6.0			Water	
6.0	6.7	0.7	By Hand		Clayey Silt.	
6.7	7.9	1.2	12	10.0	Clayey Silt.	

Total sediment cored	1.9

NOTE: All depths measured from water surface (elevation = 3310.31 ft.)

Field work by K. Buer, J. Anderson, E. Hanson
Lab work by J. VanGilder
X-Sect by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 9, 1996

Cross-Section No.	Station No.
Section #21	**0 + 20**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	1.0	1.0			Water	Heavy Vegetation
1.0	3.0	2.0	By Hand		Dark brown to black silt.	Highly Organic.
3.0	4.0	1.0	15	15	Dark brown to black clayey-silt.	Organics.
4.0	5.0	1.0	25	25	Very fine silty-sand.	

Total sediment cored	4.0

Note: All depths measured from water surface (elevation = 3309.5 ft.)

Field work by J. Anderson, C. Anderson, G. Kuenster
Lab work by J VanGilder
X-Sec by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 9, 1996

Cross-Section No.	Station No.
Section #21	**0+40**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	4.1	4.1			Water	Heavy Vegetation
4.1	5.7	1.6	By Hand		Silty fine sand; Well sorted.	
5.7	6.7	1.0	15	15	Slightly silty fine sand; Well-sorted.	
6.7	7.5	0.8	25	31	Slightly silty fine to med sand; Mod-sorted.	

Total sediment cored	3.4

Note: All depths measured from water surface (elevation = 3309.5 ft.)

Field work by J. Anderson, C. Anderson, G. Kuenster
Lab work by J. VanGilder
X-Sec by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 9, 1996

Cross-Section No.	Station No.
Section #21	**0+60**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	4.9	4.9			Water	Heavy Vegetation
4.9	5.5	0.6	By Hand		Silty fine to coarse sand; Poorly-sorted.	Occasional Gravel.
5.5	6.5	1.0	8	8	Silty-fine to coarse sand; Poorly-sorted.	
6.5	7.5	1.0	15	15	Fine to coarse sand; Poorly-sorted; Clean.	
7.5	8.0	0.5	15	30	Very fine to coarse sand; Poorly-sorted; Clean	

Total thickness of sediment	3.1

Note: All depths measured from water surface (elevation = 3309.5 ft.)

Field work by J Anderson, C Anderson, G Kuenster
Lab work by J VanGilder
X-Sec by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 9, 1996

Cross-Section No.	Station No.
Section #21	**0+80**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	4.5	4.5			Water	Heavy Vegetation
4.5	6.4	1.9	By Hand		Fine to coarse sand; Poorly sorted; Slightly dirty.	Occasional Gravel.
6.4	7.5	1.1	25	23	Fine to med sand; Mod-sorted; Clean.	
7.5	7.8	0.3	10	33	Fine to coarse sand; Poorly-sorted; Clean.	Occasional Gravel.

Total sediment cored	3.3

Note: All depths measured from water surface (elevation = 3309.5 ft.)

Field work by J. Anderson, C. Anderson, G. Kuenster
Lab work by J VanGilder
X-Sec by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 9, 1996

Cross-Section No.	Station No.
Section #21	**1+00**

Depth		Thickness	Blow	Blows	Soil Description	Remarks
From	To	in Feet	Count	per foot		
0.0	4.9	4.9			Water	Heavy Vegetation
4.9	6.3	1.4	By Hand		Fine to med sand; Mod- to well-sorted; Clean.	Occasional gravel.
6.3	7.3	1.0	26	26	Fine to coarse sand; Mod-sorted; Clean.	Gravelly.

Total sediment cored	2.4

Note: All depths measured from water surface (elevation = 3309.5 ft.)

Field work by J. Anderson, C. Anderson, G Kuenster
Lab work by J VanGilder
X-Sec by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 9, 1996

Cross-Section No.	Station No.
Section #21	**1+20**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	5.1	5.1			Water	Heavy Vegetation
5.1	5.8	0.7	By Hand		Very fine to med sand; Mod-sorted; Clean.	
5.8	6.8	1.0	10	10	Fine sand; Well-sorted; Clean.	
6.8	7.0	0.2	6	30	Fine to med. sand; Well-sorted; Clean.	
7.0	7.3	0.3	12	40	Fine to coarse sand; Poorly-sorted; Slightly dirty	Occasional gravel.

Total sediment cored	2.2

Note: All depths measured from water surface (elevation = 3309.5 ft.)

Field work by J Anderson, C Anderson, G Kuenster
Lab work by J VanGilder
X-Sec by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 9, 1996

Cross-Section No.	Station No.
Section #21	**1+40**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	6.0	6.0			Water	Heavy Vegetation
6.0	6.4	0.4	By Hand		Fine to med sand; Mod-sorted; Slightly dirty.	
6.4	7.4	1.0	9	. 9	Silty-fine sand	
7.4	8.4	1.0	17	17	Fine to med sand; Mod-sorted; Slightly dirty.	
8.4	8.7	0.3	10	33.33	Fine to med sand; Mod-sorted; Slightly dirty.	

Total sediment cored	2.7

Note: All depths measured from water surface (elevation = 3309.5 ft.)

Field work by J Anderson, C Anderson, G Kuenster
Lab work by J VanGilder
X-Sec by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 9, 1996

Cross-Section No.	Station No.
Section #21	**1+60**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	4.8	4.8			Water	Heavy Vegetation
4.8	5.9	1.1	By Hand		Very fine sand; Well-sorted; Slightly dirty.	
5.9	6.9	1.0	16	16	Very fine sand; Well-sorted; Slightly dirty.	
6.9	7.3	0.4	10	25	Very fine sand; Well-sorted; Slightly dirty.	

Total sediment cored	2.5

Note: All depths measured from water surface (elevation = 3309.5 ft.)

Field work by J Anderson, C Anderson, G Kuenster
Lab work by J VanGilder
X-Sect by S Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Oct. 9, 1996

Cross-Section No.	Station No.
Section #21	**1+80**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	1.4	1.4			Water	Heavy Vegetation
1.4	3.5	2.1	By Hand		Very fine to fine sand; Well-sorted; Clean.	
3.5	4.0	0.5	5	10	Fine to coarse sand; Mod. Sorted; Slightly dirty.	
4.0	5.0	1.0	19	19	Fine to coarse sand; Mod. Sorted; Slightly dirty.	
5.0	5.7	0.7	25	36	Very fine to fine sand; Well-sorted; Clean.	

Total sediment cored	4.3

Note: All depths measured from water surface (elevation = 3309.5 ft.)

Field work by J Anderson, C Anderson, G Kuenster
Lab work by J VanGilder
X-Sec by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 27, 1997

Cross-Section No.	Station No.
Section #22	**0 + 50**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	2.4	2.4			Water	
2.4	4.7	2.3	By Hand		No Sample Collected	

Total sediment cored	2.3

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by J.Anderson, D.Jennings, B.Webster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 27, 1997

Cross-Section No.	Station No.
Section #22	**0 + 60**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.7	3.7			Water	
3.7	5.9	2.2	By Hand		Silty Loam.	
5.9	6.6	0.7	12	17	Silty Sand.	

Total sediment cored	2.9

NOTE: All depths measured from water surface (elevation 3309.11 ft.)

Field work by J.Anderson, D.Jennings, B.Webster
Lab work by J. VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 27, 1997

Cross-Section No.	Station No.
Section #22	**0 + 75**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	4.3	4.3			Water	
4.3	6.0	1.7	By Hand		Silty Sand.	
6.0	7.4	1.4	12	9	Silty Sand.	
7.4	8.3	0.9	12	13	Very Silty Sand.	

Total sediment cored	4.0

NOTE: All depths measured from water surface (elevation 3309.11 ft.)

Field work by J.Anderson, D.Jennings, B.Webster
Lab work by J. VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 27, 1997

Cross-Section No.	Station No.
Section #22	**0 + 90**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.6	3.6			Water	
3.6	5.6	2.0	By Hand		No Sample Collected	

Total sediment cored	2.0

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by J.Anderson, D.Jennings, B.Webster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 27, 1997

Cross-Section No.	Station No.
Section #22	**1+05**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.7	3.7			Water	
3.7	5.0	1.3	By Hand		Slightly Silty, Med-Coarse Sand.	
5.0	5.9	0.9	10	11	Slightly Silty, Fine to Med. Well-Sorted Sand.	
5.9	6.1	0.2	5	25	Slightly Silty, Med-Very Fine, Mod-Sorted Sand.	

Total sediment cored	2.4

NOTE: All depths measured from water surface (elevation 3309.11 ft.)

Field work by J.Anderson, D.Jennings, B.Webster
Lab work by J. VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 27, 1997

Cross-Section No.	Station No.
Section #22	**1+20**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.6	3.6			Water	
3.6	4.6	1.0	By Hand		Slightly Silty, Fine-Coarse, Poorly-Sorted Sand.	
4.6	5.4	0.8	10	13	Very Silty Fine to Med, Mod-Sorted Sand.	
5.4	7.2	1.8	10	6	Slightly Silty, Fine to Coarse, Poorly-Sorted Sand.	

Total sediment cored	3.6

NOTE: All depths measured from water surface (elevation 3309.11 ft.)

Field work by J.Anderson, D.Jennings, B.Webster
Lab work by J. VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 27, 1997

Cross-Section No.	Station No.
Section #22	**1+35**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.0	3.0			Water	
3.0	4.8	1.8	By Hand		Fine to Very Coarse, Poorly-Sorted Sand.	
4.8	5.5	0.7	10	14	Fine to Coarse, Mod-Sorted Sand.	
5.5	5.9	0.4	5	13	Slightly Silty, Fine to Coarse, Poorly-Sorted Sand.	

Total sediment cored	2.9

NOTE: All depths measured from water surface (elevation 3309.11 ft.)

Field work by J.Anderson, D.Jennings, B.Webster
Lab work by J. VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 27, 1997

Cross-Section No.	Station No.
Section #22	1+50

Depth		Thickness	Blow	Blows	Soil Description	Remarks
From	To	in Feet	Count	per foot		
0.0	4.6	4.6			Water	
4.6	6.4	1.8	By Hand		Fine to Very Coarse, Poorly-Sorted Sand.	
6.4	7.4	1.0	20	20	Fine to Medium, Mod-Sorted Sand.	
7.4	8.4	1.0	15	15	Very Fine Sandy Silt	

Total sediment cored	3.8

NOTE: All depths measured from water surface (elevation 3309.11 ft.)

Field work by J.Anderson, D.Jennings, B.Webster
Lab work by J. VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 27, 1997

Cross-Section No.	Station No.
Section #22	**1+65**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	4.1	4.1			Water	
4.1	5.8	1.7	By Hand		Slightly Silty, Very Fine to Fine Sand.	
5.8	6.7	0.9	10	11	Slightly Silty, Very Fine to Fine Sand.	
6.7	7.5	0.8	10	13	Slightly Clayey Silt.	

Total sediment cored	3.4

NOTE: All depths measured from water surface (elevation 3309.11 ft.)

Field work by J.Anderson, D.Jennings, B.Webster
Lab work by J. VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 27, 1997

Cross-Section No.	Station No.
Section #22	**1 + 80**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	3.7	3.7			Water	
3.7	3.9	0.2	By Hand		No Sample Collected	

Total sediment cored	0.2

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by J.Anderson, D.Jennings, B.Webster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 26, 1997

Cross-Section No.	Station No.
Section # 23	**0 + 55**

Depth		Thickness	Blow	Blows	Soil Description	Remarks
From	To	in Feet	Count	per foot		
0.0	0.6	0.6	By Hand		Water	
0.6	5.4	4.8			No Sample Collected	

Total sediment cored	0.0

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by J.Anderson, D. Jennings, B. Webster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 26, 1997

Cross-Section No.	Station No.
Section #23	**0 + 75**

Depth		Thickness	Blow	Blows	Soil Description	Remarks
From	To	in Feet	Count	per foot		
0.0	0.8	0.8	By Hand		Water	
0.8	4.2	3.4			No Sample Collected	

Total sediment cored	0.0

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by J.Anderson, D. Jennings, B. Webster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 26, 1997

Cross-Section No.	Station No.
Section #23	**0 + 90**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	1.8	1.8	By Hand		Water	
1.8	4.6	2.8			No Sample Collected	

Total sediment cored	0.0

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by J.Anderson, D. Jennings, B. Webster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 26, 1997

Cross-Section No.	Station No.
Section #23	**1 + 05**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	2.8	2.8	By Hand		Water	
2.8	4.8	2.0			No Sample Collected	

Total sediment cored	0.0

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by J.Anderson, D. Jennings, B. Webster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 26, 1997

Cross-Section No.	Station No.
Section #23	**1+10**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0	3.3	3.3			Water	
3.3	4.9	1.6	By Hand		Very Fine to Fine, Well -Sorted Sand.	
4.9	5.8	0.9	6	7	Very Fine to Fine, Well -Sorted Sand.	
5.8	6.5	0.7	6	9	Silty Fine Sand.	
6.5	6.7	0.2	5	25	Slightly Silty Fine Sand.	

Total sediment cored	3.4

NOTE: All depths measured from water surface (elevation 3308.56 ft.)

Field work by J.Anderson, D.Jennings, B.Webster
Lab work by J. VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 26, 1997

Cross-Section No.	Station No.
Section #23	**1+20**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0	3.8	3.8			Water	
3.8	5.4	1.6	By Hand		Fine to Med, Well-Sorted Sand.	
5.4	6.3	0.9	8	9	Fine to Coarse, Mod-Sorted Sand.	
6.3	6.5	0.2	7	35	Fine to Med, Mod-Sorted Sand.	

Total sediment cored	2.7

NOTE: All depths measured from water surface (elevation 3308.56 ft.)

Field work by J.Anderson, D.Jennings, B.Webster
Lab work by J. VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 26, 1997

Cross-Section No.	Station No.
Section #23	**1 + 35**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	5.9	5.9	By Hand		Water	
5.9	6.1	0.2			No Sample Collected	

Total sediment cored	0.0

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by J.Anderson, D. Jennings, B. Webster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 26, 1997

Cross-Section No.	Station No.
Section #23	**1+50**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0	6.5	6.5			Water	
6.5	6.8	0.3	By Hand		Very Fine to Medium, Mod-Sorted Sand.	
6.8	7.8	1	12	12	Silt.	
7.8	8.3	0.5	10	20	Slightly Clayey Silt.	

Total sediment cored	1.8

NOTE: All depths measured from water surface (elevation 3308.56 ft.)

Field work by J.Anderson, D.Jennings, B.Webster
Lab work by J. VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 26, 1997

Cross-Section No.	Station No.
Section #23	**1 + 65**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	6.5	6.5	By Hand		Water	
6.5	7.4	0.9			No Sample Collected	

Total sediment cored	0.0

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by J.Anderson, D. Jennings, B. Webster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 26, 1997

Cross-Section No.	Station No.
Section #23	**1+80**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0	6.7	6.7			Water	
6.7	6.8	0.1	By Hand		Silty Fine To Coarse, Poorly-Sorted Sand.	
6.8	8.1	1.3	10	8	Slightly Silty, Fine to Very Coarse, Poorly-Sorted Sand.	Gravelly.

Total sediment cored 1.4

NOTE: All depths measured from water surface (elevation 3308.56 ft.)

Field work by J.Anderson, D.Jennings, B.Webster
Lab work by J. VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 26, 1997

Cross-Section No.	Station No.
Section #23	**1+95**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	5.0	5.0			Water	
5.0	5.3	0.3	By Hand		Fine to Coarse, Mod-Sorted Sand.	
5.3	5.8	0.5	10	20	Slightly Silty, Fine to Coarse, Poorly-Sorted Sand.	

Total sediment cored	0.8

NOTE: All depths measured from water surface (elevation 3308.56 ft.)

Field work by J.Anderson, D.Jennings, B.Webster
Lab work by J. VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 26, 1997

Cross-Section No.	Station No.
Section #23	**2 + 10**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	2.6	2.6	By Hand		Water	
2.6	3.5	0.9			No Sample Collected	

Total sediment cored	0.0

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by J.Anderson, D. Jennings, B. Webster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: June 26, 1997

Cross-Section No.	Station No.
Section #23	**2 + 25**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	1.7	1.7	By Hand		Water	
1.7	3.0	1.3			No Sample Collected	

Total sediment cored	0.0

NOTE: All depths measured from water surface (elevation = 3310.71 ft.)

Field work by J.Anderson, D. Jennings, B. Webster
Lab work by J. VanGilder
X-Sec. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 18, 1996

Cross-Section No.	Station No.
Section #24	**0+40**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	1.3	1.3			Water	
1.3	1.5	0.2	By Hand		No Sample Collected.	

Total sediment cored	0.2

NOTE: All depths measured from water surface (elevation 3308.08 ft.)

Field work by J.Anderson, E Hanson, M Souverville
Lab work by J.VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fail River Sediment Investigation

Samples taken on: Dec. 18, 1996

Cross-Section No.	Station No.
Section #24	**0+60**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0.0	6.5	6.5			Water	
6.5	7.5	1.0	By Hand		Fine Sandy Silt.	
7.5	8.6	1.1	No Record		Fine Sandy Silt.	

Total sediment cored	2.1

NOTE: All depths measured from water surface (elevation 3308.08 ft.)

Field work by J.Anderson, E Hanson, M Souverville
Lab work by J.VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 18, 1996

Cross-Section No.	Station No.
Section #24	0 + 80

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0	7.8	7.8			Water	
7.8	8.5	0.7	By Hand		Very Fine Sandy Silt.	
8.5	9.0	0.5	15	30	Very Fine to Med, Well Sorted Sand.	

Total sediment cored	1.2

NOTE: All depths measured from water surface (elevation 3308.08 ft.)

Field work by J.Anderson, E. Hanson, M. Souverville
Lab work by J.VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 18, 1996

Cross-Section No.	Station No.
Section #24	**1+00**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0	5.9	5.9			Water	
5.9	6.8	0.9	By Hand		Fine to Med, Well-Sorted Sand.	
6.8	7.8	1	15	15	Fine to Coarse, Mod-Sorted Sand.	

Total sediment cored	1.9

NOTE: All depths measured from water surface (elevation 3308.08 ft.)

Field work by J.Anderson, E. Hanson, M. Souverville
Lab work by J.VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 18, 1996

Cross-Section No.	Station No.
Section #24	**1+20**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0	6.7	6.7			Water	
6.7	7.6	0.9	By Hand		Fine to Very Coarse, Poorly Sorted Sand.	
7.6	8.5	0.9	10	11	Fine to Very Coarse, Mod-Sorted Sand.	

Total sediment cored	1.8

NOTE: All depths measured from water surface (elevation 3308.08 ft.)

Field work by J.Anderson, E. Hanson, M. Souverville
Lab work by J.VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 18, 1996

Cross-Section No.	Station No.
Section #24	**1+40**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0	5.8	5.8			Water	
5.8	6.6	0.8	By Hand		Fine to Coarse, Mod-Sorted Sand.	
6.6	7.6	1	15	15	Fine to Med, Well-Sorted Sand.	

Total sediment cored	1.8

NOTE: All depths measured from water surface (elevation 3308.08 ft.)

Field work by J.Anderson, E. Hanson, M. Souverville
Lab work by J.VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 18, 1996

Cross-Section No.	Station No.
Section #24	**1+60**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0	5.2	5.2			Water	
5.2	6.6	1.4	By Hand		Very Fine to Fine, Well-Sorted Sand.	
6.6	7.3	0.7	16	23	Very Fine to Coarse, Mod-Sorted Sand.	

Total sediment cored	2.1

NOTE: All depths measured from water surface (elevation 3308.08 ft.)

Field work by J.Anderson, E. Hanson, M. Souverville
Lab work by J.VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 18, 1996

Cross-Section No.	Station No.
Section #24	**1+80**

Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0	3.9	3.9			Water	
3.9	5.5	1.6	By Hand		Fine to Coarse, Mod-Sorted Sand	Minor Organics.
5.5	6.5	1.0	11	11	Very Fine to Med, Well-Sorted Sand.	

Total sediment cored	2.6

NOTE: All depths measured from water surface (elevation 3308.08 ft.)

Field work by J.Anderson, E. Hanson, M. Souverville
Lab work by J.VanGilder
X-Sect. by S. Sunding

Department of Water Resources
Fall River Sediment Investigation

Samples taken on: Dec. 18, 1996

Cross-Section No.	Station No.
Section #24	**2 + 00**

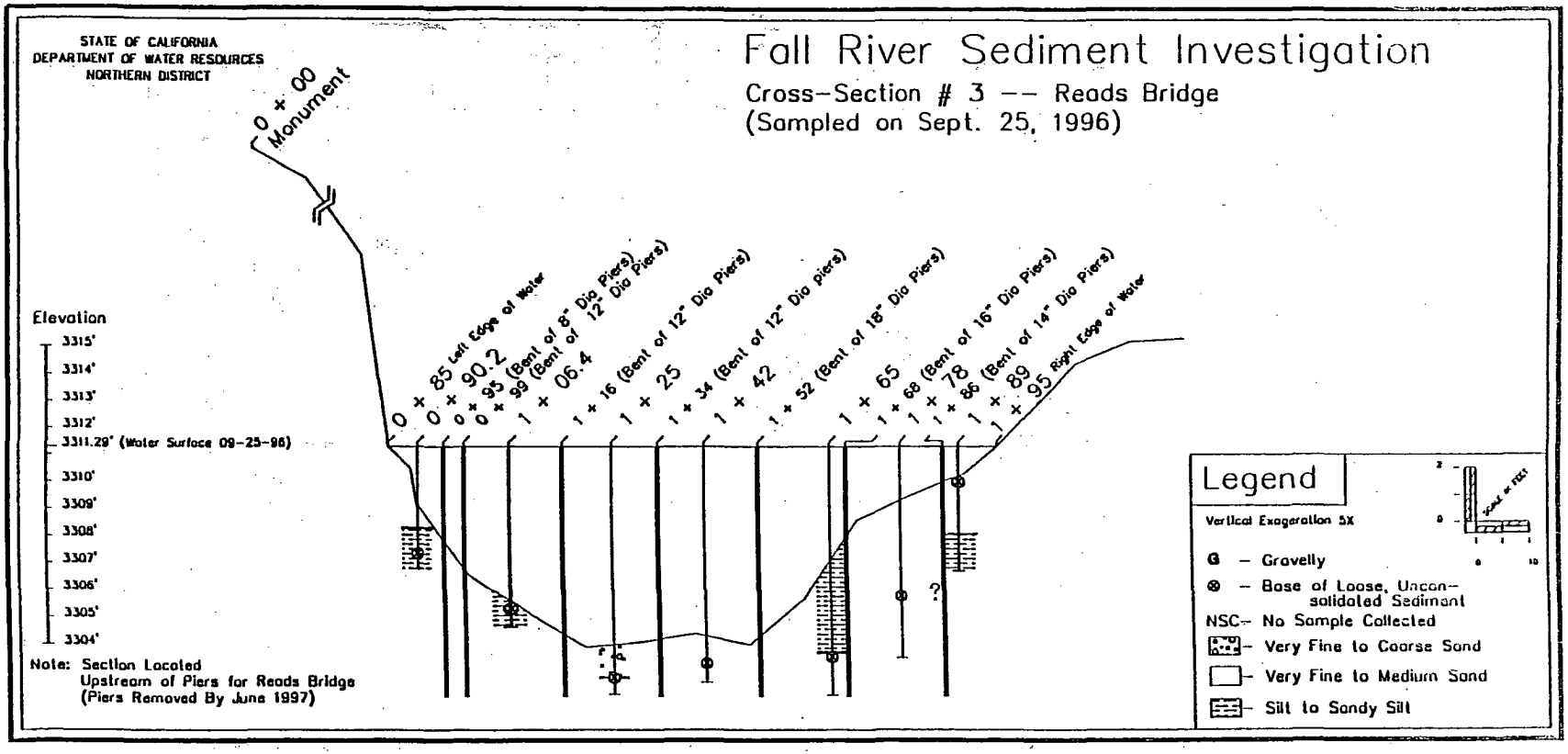
Depth From	Depth To	Thickness in Feet	Blow Count	Blows per foot	Soil Description	Remarks
0	1.1	1.1			Water	
1.1	4.3	3.2	By Hand		No Sample Collected	

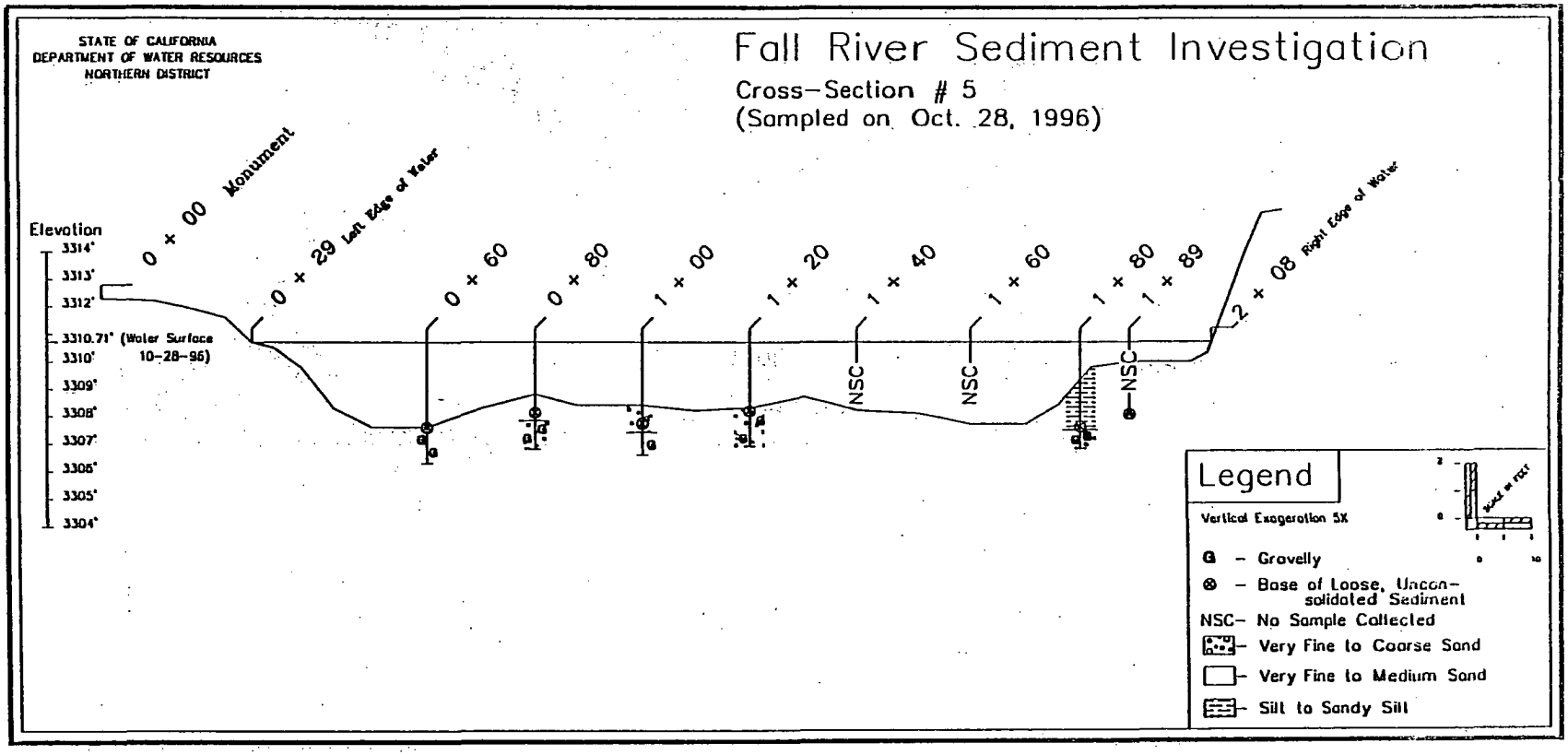
Total sediment cored	3.2

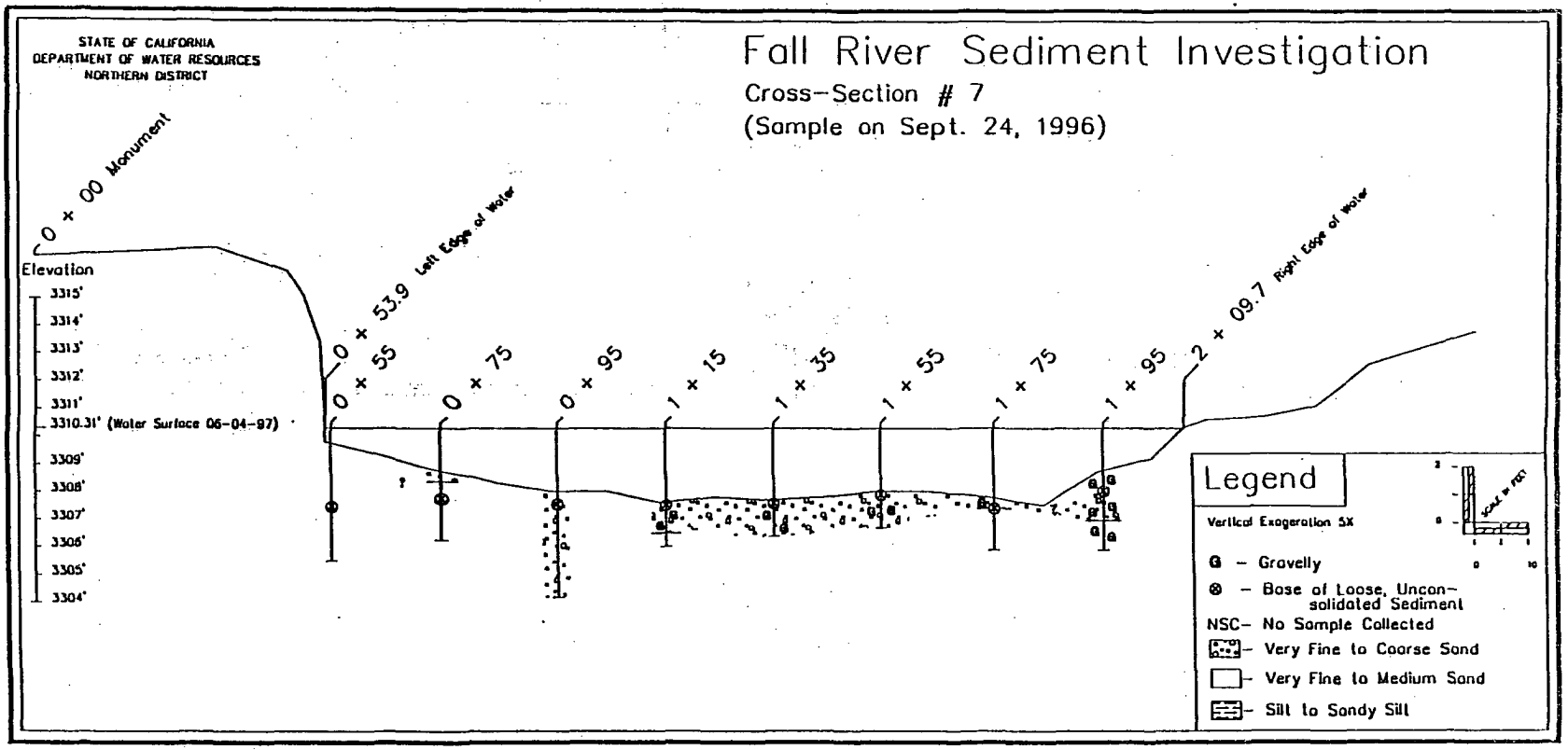
NOTE: All depths measured from water surface (elevation 3308.08 ft.)

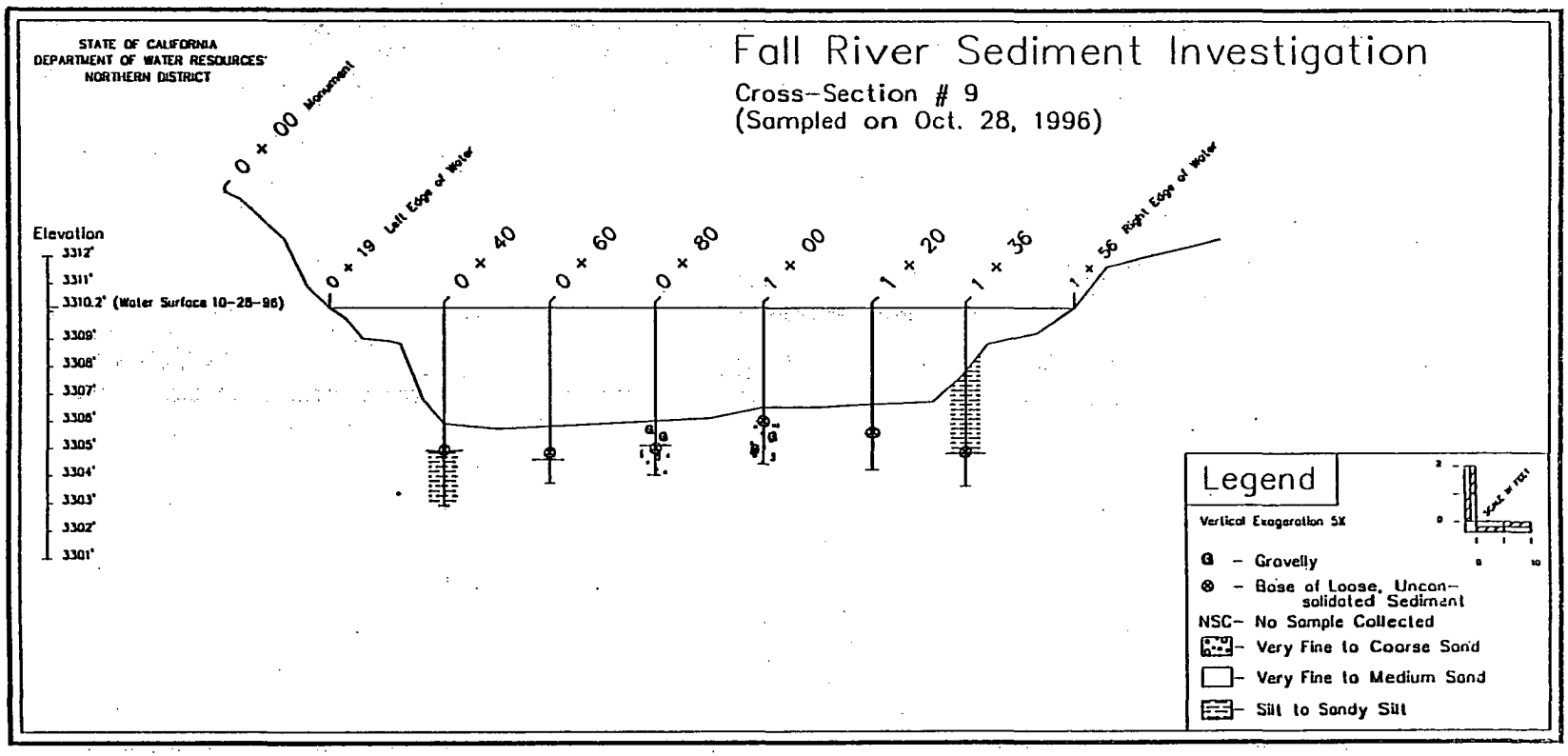
Field work by J.Anderson, E. Hanson, M. Souverville
Lab work by J.VanGilder
X-Sect. by S. Sunding

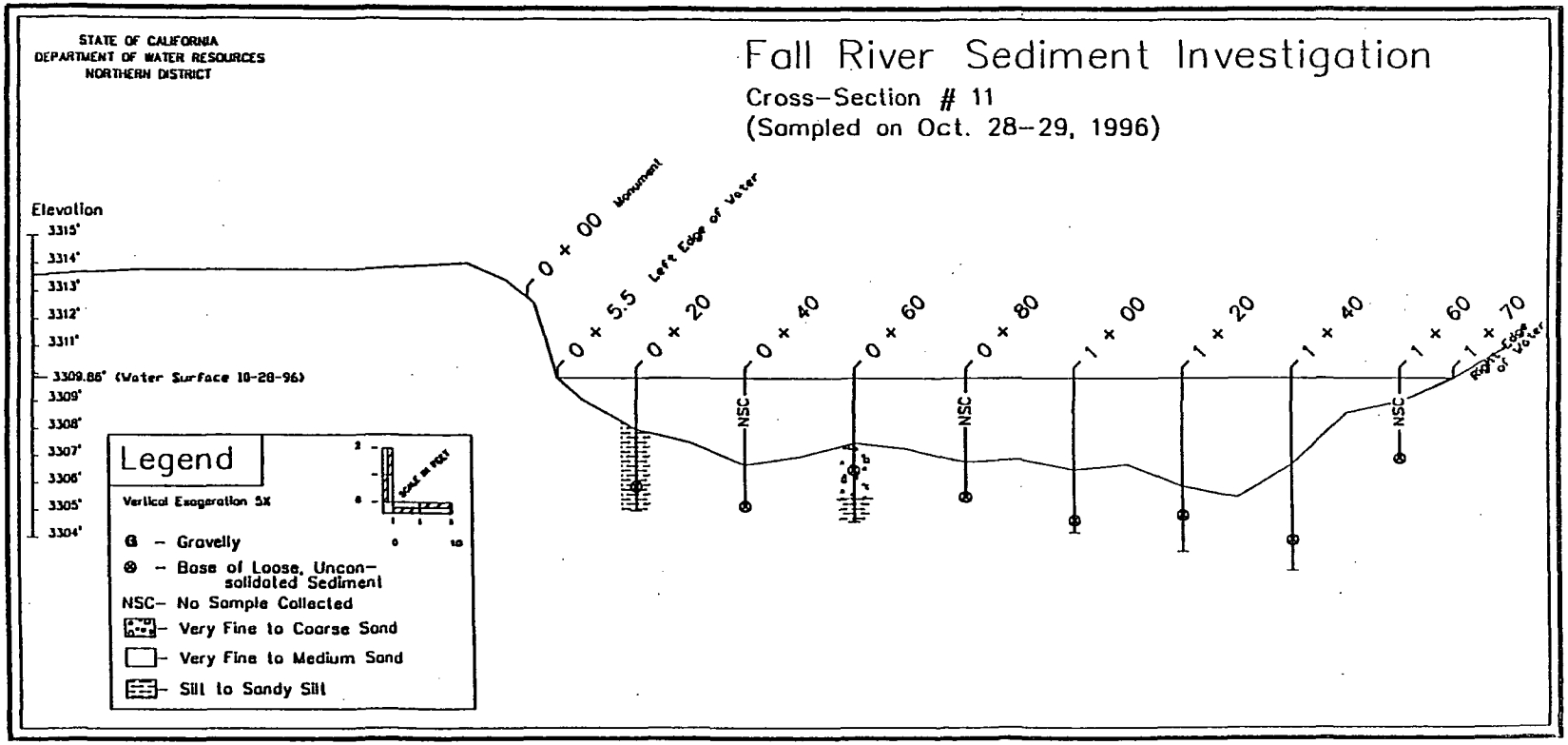
APPENDIX 5

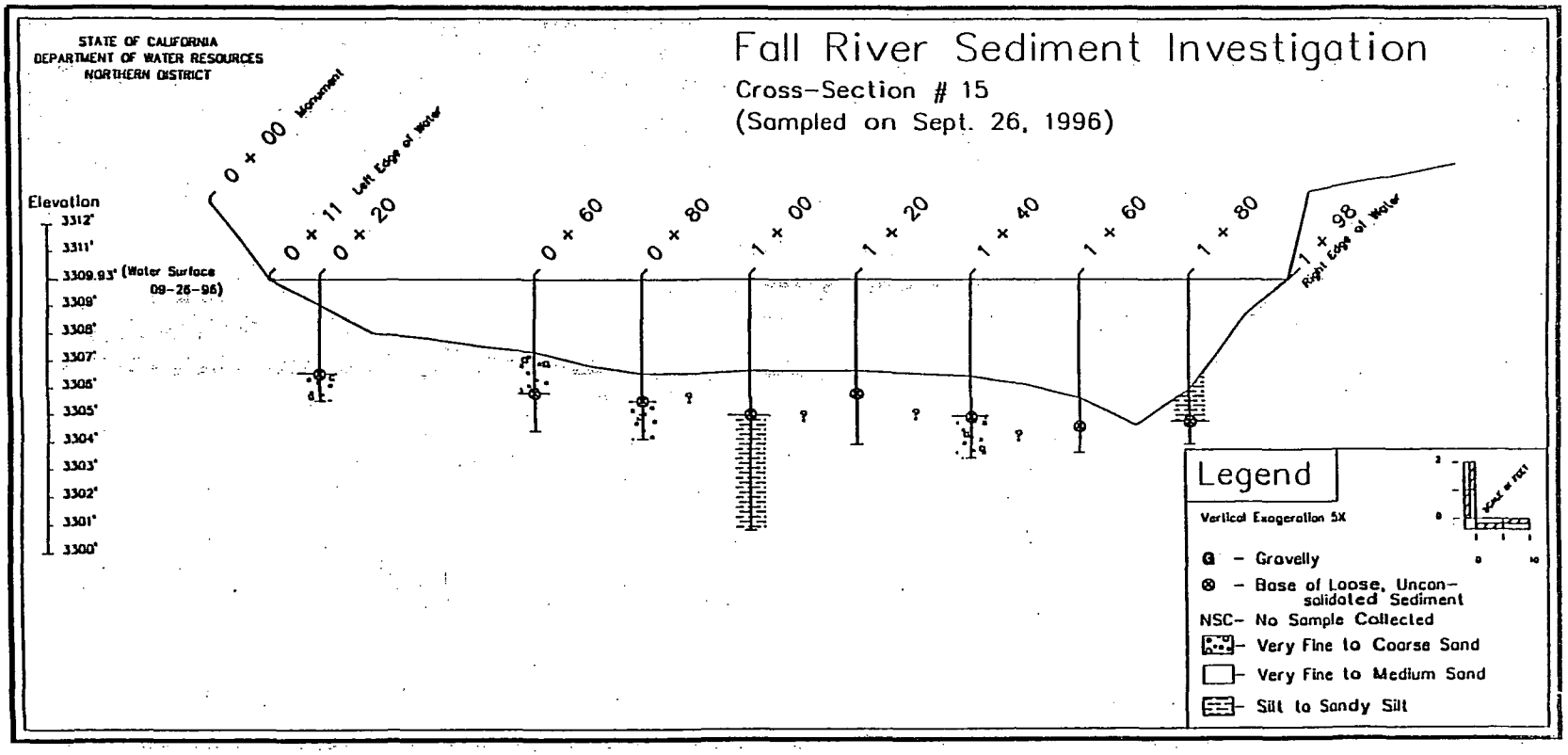

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Fall River Sediment Investigation
Cross-Section # 3 -- Reads Bridge
(Sampled on Sept. 25, 1996)
0 + 00 Monument
0 + 85 Left Edge of Water
0 + 90.2
0 + 93 (Bent of 8" Dia Piers)
0 + 99 (Bent of 12" Dia Piers)
1 + 06.4
1 + 16 (Bent of 12" Dia Piers)
1 + 25
1 + 34 (Bent of 12" Dia Piers)
1 + 42
1 + 52 (Bent of 18" Dia Piers)
1 + 65
1 + 68 (Bent of 16" Dia Piers)
1 + 78
1 + 86 (Bent of 14" Dia Piers)
1 + 89
1 + 95 Right Edge of Water
Elevation
3315'
3314'
3313'
3312'
3311.29' (Water Surface 09-25-96)
3310'
3309'
3308'
3307'
3306'
3305'
3304'
Note: Section Located Upstream of Piers for Reads Bridge (Piers Removed By June 1997)
Legend
Vertical Exageration 5X
G - Gravelly
- Base of Loose, Unconsolidated Sediment
NSC- No Sample Collected
- Very Fine to Coarse Sand
- Very Fine to Medium Sand
- Silt to Sandy Silt

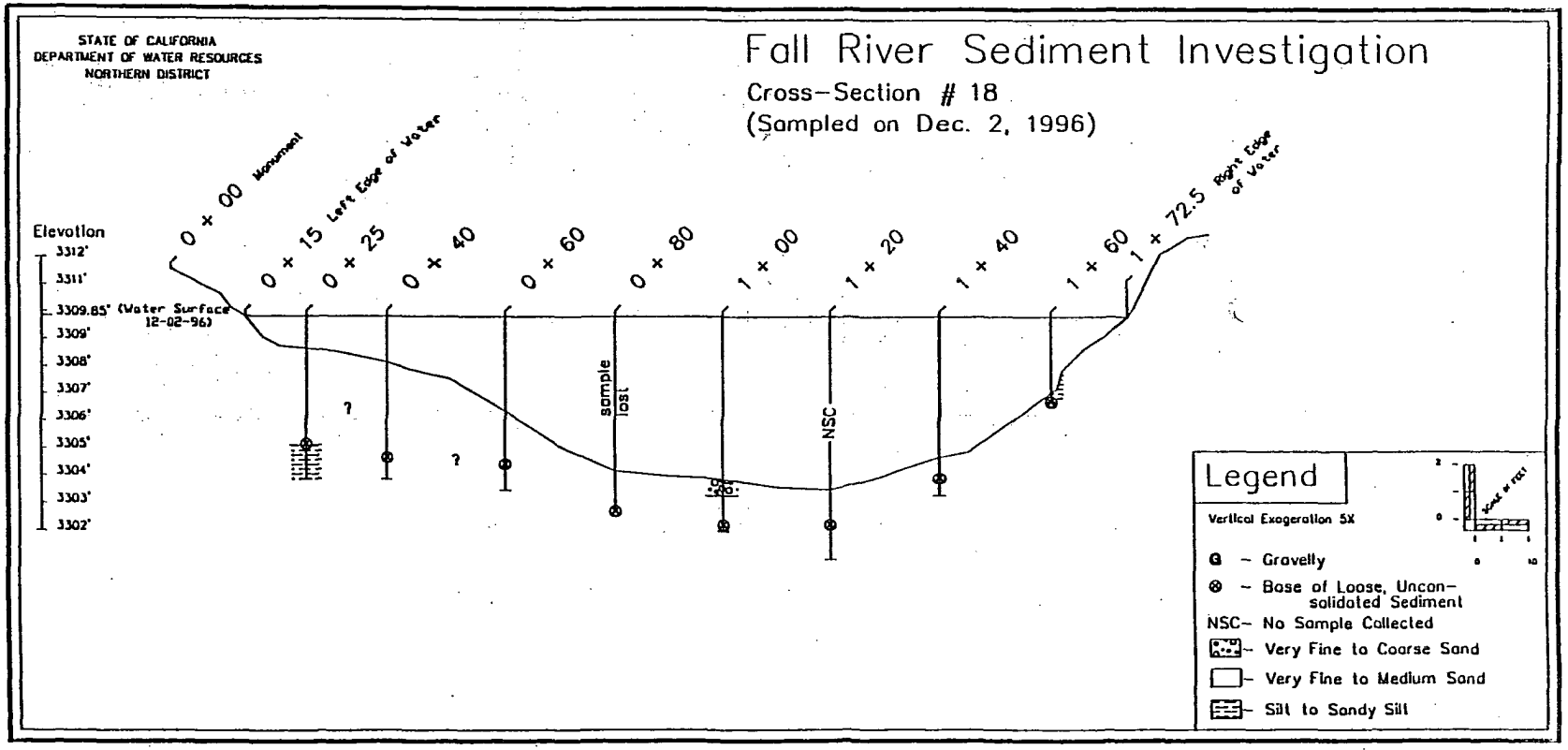

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Fall River Sediment Investigation
Cross-Section # 5
(Sampled on Oct. 28, 1996)
Elevation
3314'
3313'
3312'
3310.71' (Water Surface 10-28-96)
3310'
3309'
3308'
3307'
3306'
3305'
3304'
0 + 00 Monument
0 + 29 Left Edge of Water
0 + 60
0 + 80
1 + 00
1 + 20
1 + 40
1 + 60
1 + 80
1 + 89
2 + 08 Right Edge of Water
NSC
NSC
NSC
Legend
Vertical Exageration 5X
G - Gravelly
⊗ - Base of Loose, Uncon-solidated Sediment
NSC- No Sample Collected
- Very Fine to Coarse Sand
- Very Fine to Medium Sand
- Silt to Sandy Silt

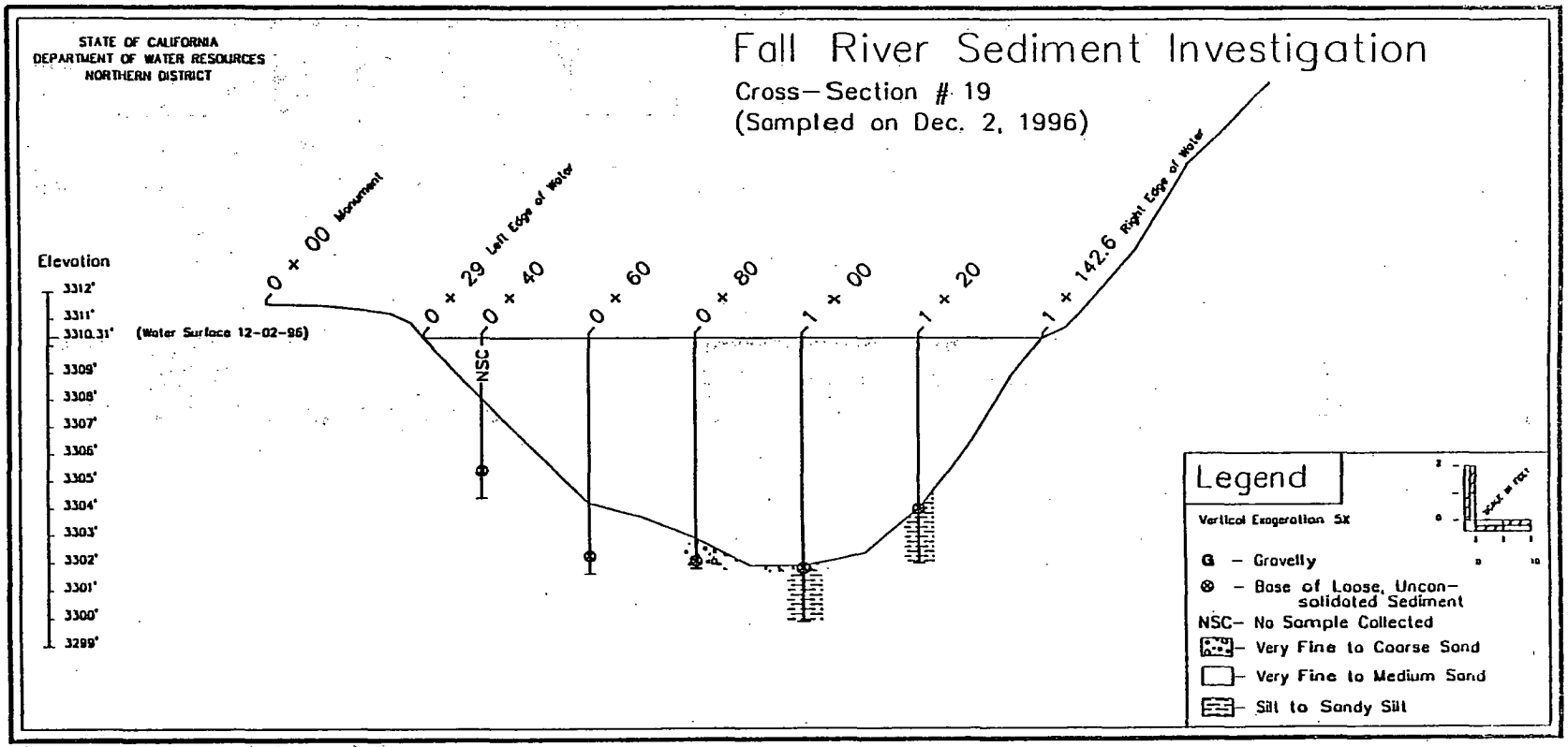

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Fall River Sediment Investigation
Cross-Section # 7
(Sample on Sept. 24, 1996)
0 + 00 Monument
Elevation
3315'
3314'
3313'
3312'
3311'
3310.31' (Water Surface 06-04-97)
3309'
3308'
3307'
3306'
3305'
3304'
0 + 53.9 Left Edge of Water
0 + 55
0 + 75
0 + 95
1 + 15
1 + 35
1 + 55
1 + 75
1 + 95
2 + 09.7 Right Edge of Water
Legend
Vertical Exageration 5X
G - Gravelly
- Base of Loose, Uncon-solidated Sediment
NSC- No Sample Collected
- Very Fine to Coarse Sand
- Very Fine to Medium Sand
- Silt to Sandy Silt

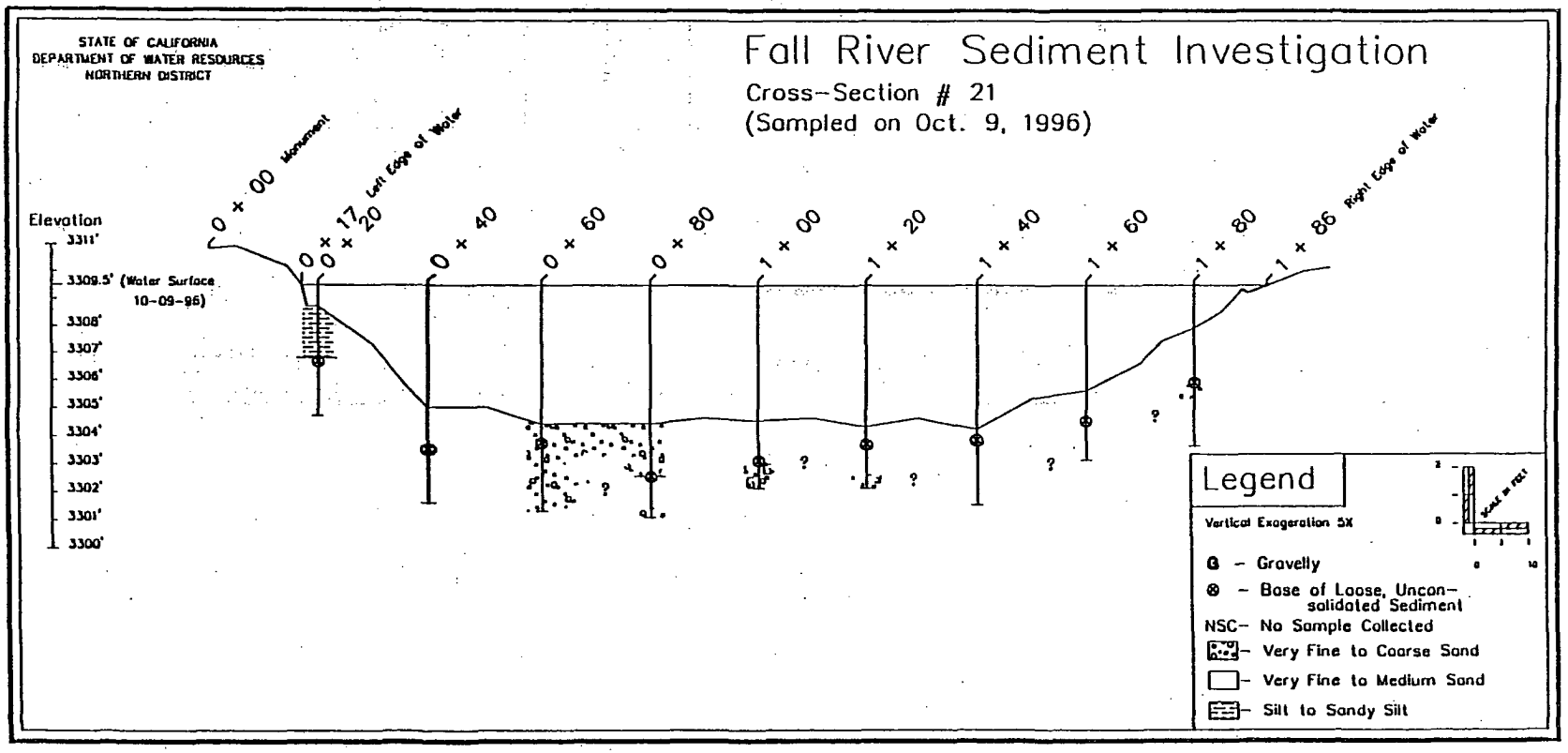

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Fall River Sediment Investigation
Cross-Section # 9
(Sampled on Oct. 28, 1996)
0 + 00 Monument
0 + 19 Left Edge of Water
0 + 40
0 + 60
0 + 80
1 + 00
1 + 20
1 + 36
1 + 56 Right Edge of Water
Elevation
3312'
3311'
3310.2' (Water Surface 10-28-96)
3309'
3308'
3307'
3306'
3305'
3304'
3303'
3302'
3301'
Legend
Vertical Exaggeration 5X
G - Gravelly
⊗ - Base of Loose, Uncon-solidated Sediment
NSC- No Sample Collected
- Very Fine to Coarse Sand
- Very Fine to Medium Sand
- Silt to Sandy Silt

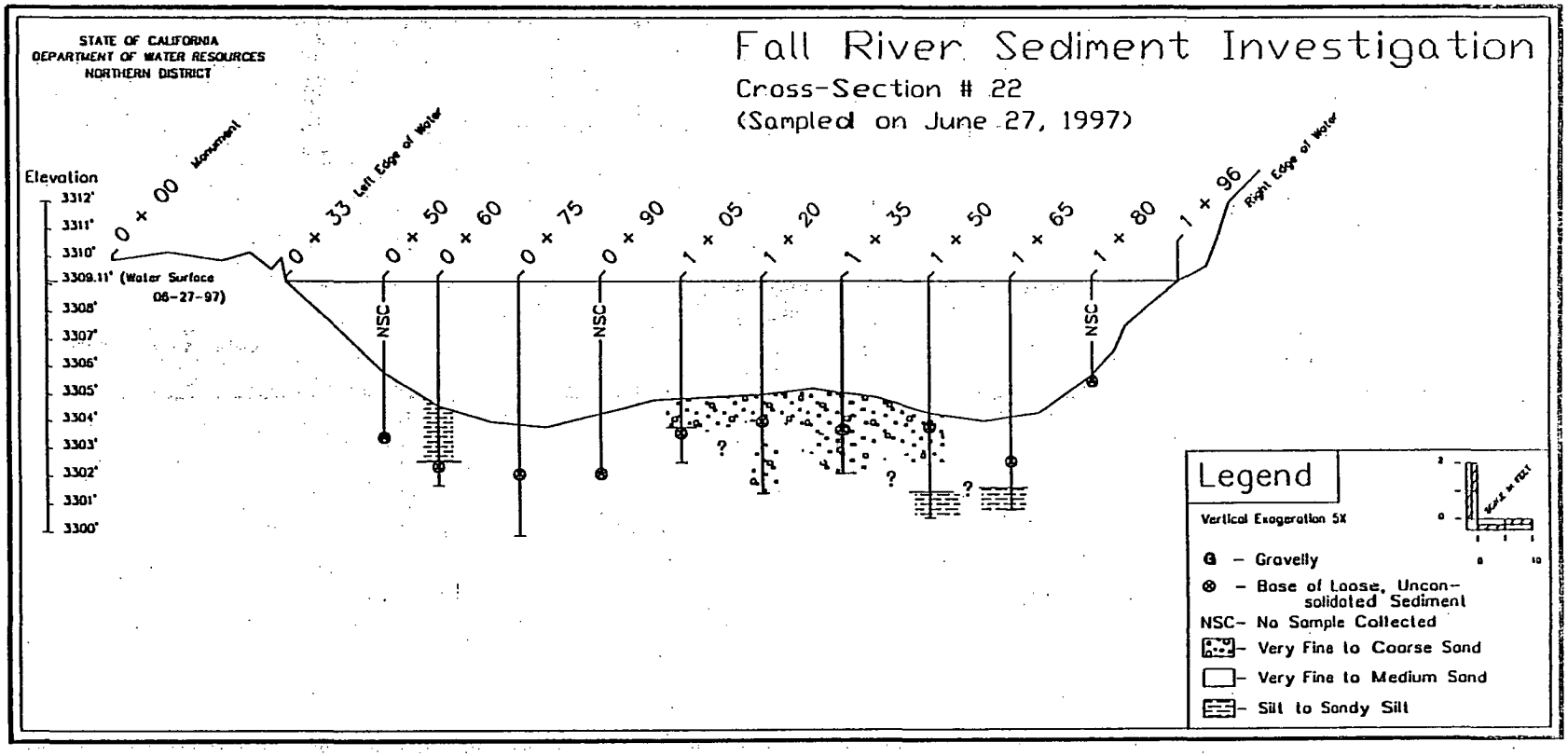

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Fall River Sediment Investigation
Cross-Section # 11
(Sampled on Oct. 28-29, 1996)
Elevation
3315'
3314'
3313'
3312'
3311'
3309.86' (Water Surface 10-28-96)
3309'
3308'
3307'
3306'
3305'
3304'
0 + 00 Monument
0 + 5.5 Left Edge of Water
0 + 20
0 + 40
0 + 60
0 + 80
1 + 00
1 + 20
1 + 40
1 + 60
1 + 70
NSC
Legend
Vertical Exageration 5X
G - Gravelly
⊗ - Base of Loose, Uncon-solidated Sediment
NSC- No Sample Collected
- Very Fine to Coarse Sand
- Very Fine to Medium Sand
- Silt to Sandy Silt

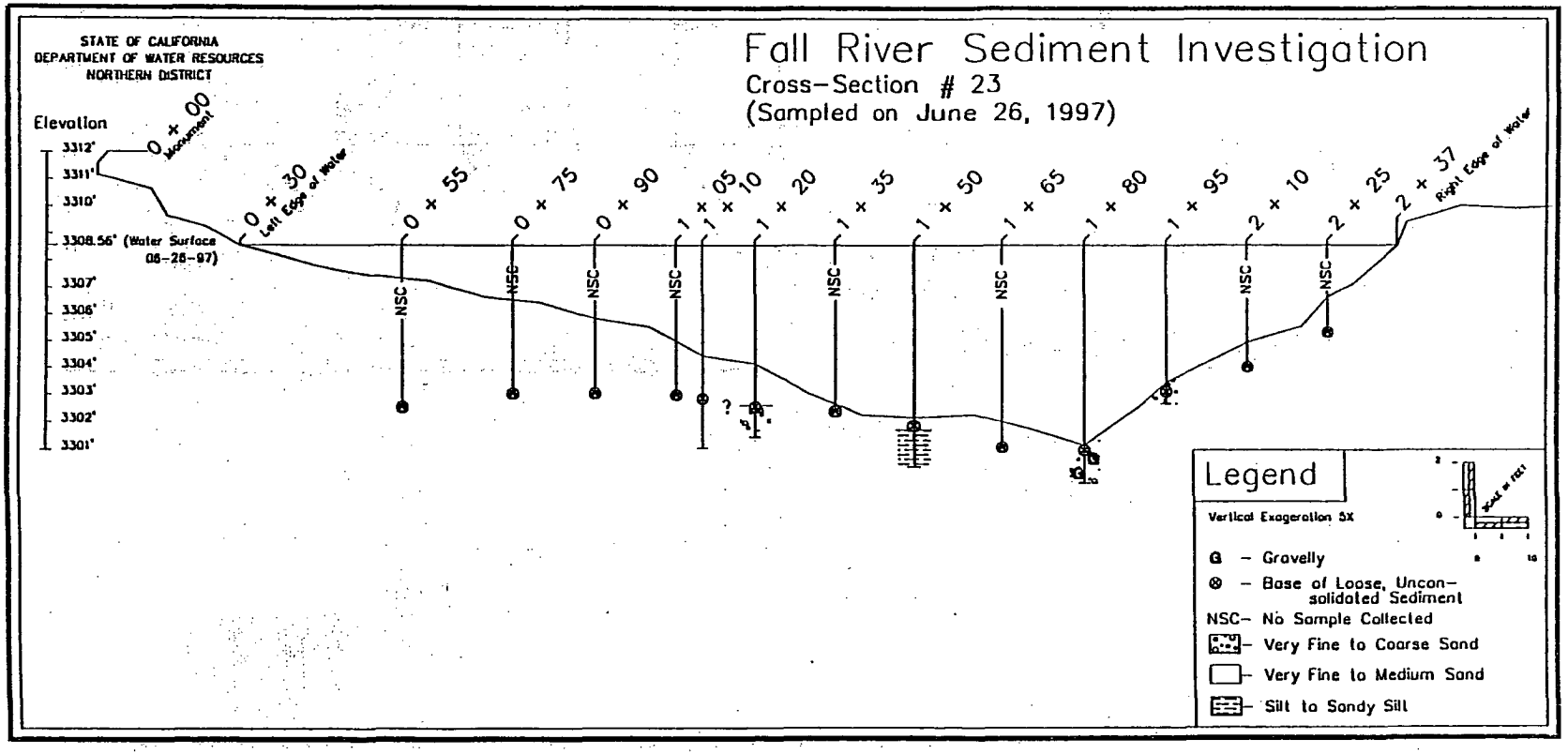

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Fall River Sediment Investigation
Cross-Section # 15
(Sampled on Sept. 26, 1996)
Elevation
3312'
3311'
3309.93' (Water Surface 09-26-96)
3309'
3308'
3307'
3306'
3305'
3304'
3303'
3302'
3301'
3300'
0 + 00 Monument
0 + 11 Left Edge of Water
0 + 20
0 + 60
0 + 80
1 + 00
1 + 20
1 + 40
1 + 60
1 + 80
1 + 98 Right Edge of Water
Legend
Vertical Exageration 5X
SCALE IN FEET
G - Gravelly
⊗ - Base of Loose, Unconsolidated Sediment
NSC- No Sample Collected
- Very Fine to Coarse Sand
- Very Fine to Medium Sand
- Silt to Sandy Silt

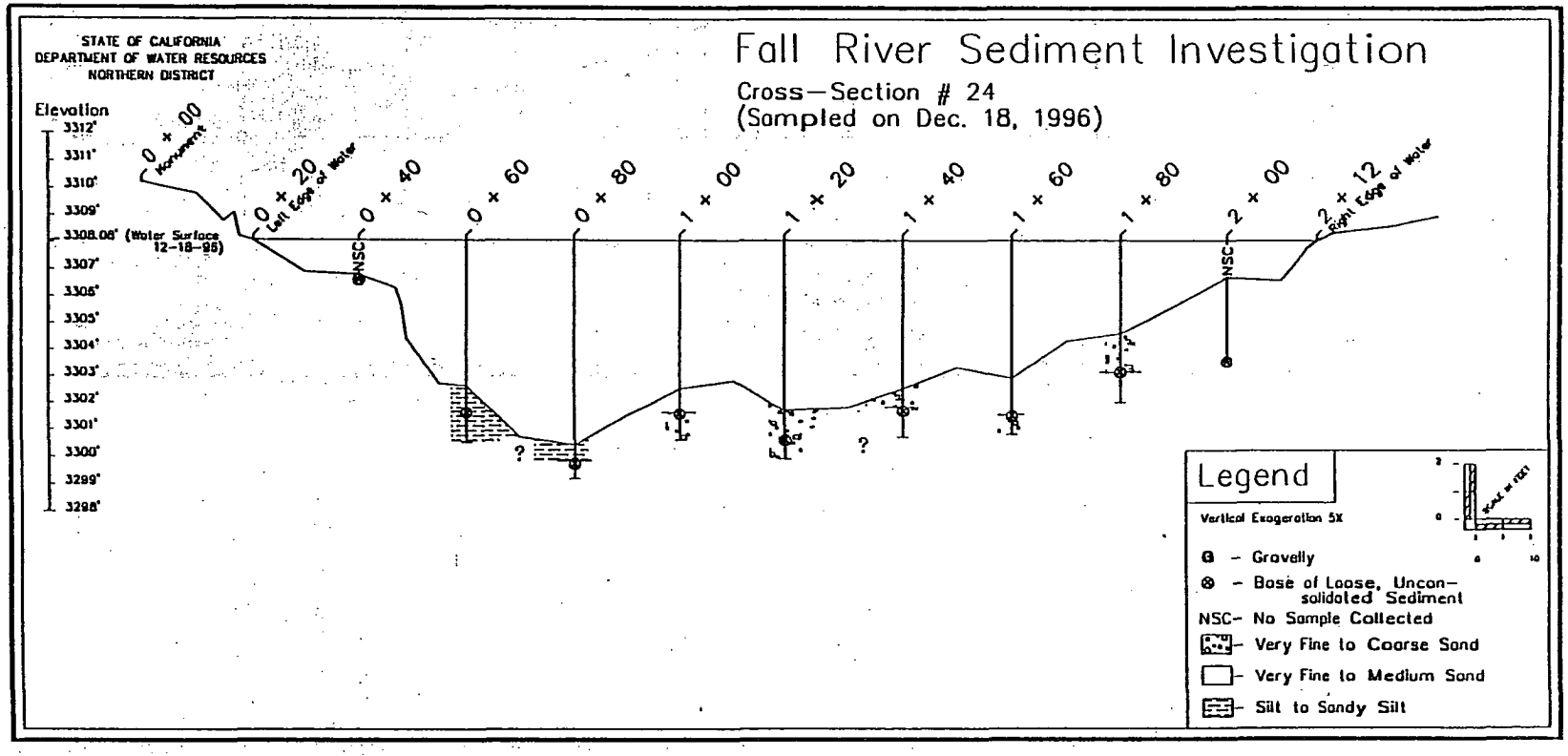

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Fall River Sediment Investigation
Cross-Section # 18
(Sampled on Dec. 2, 1996)
Elevation
3312'
3311'
3309.85' (Water Surface 12-02-96)
3309'
3308'
3307'
3306'
3305'
3304'
3303'
3302'
0 + 00 Monument
0 + 15 Left Edge of Water
0 + 25
0 + 40
0 + 60
0 + 80
1 + 00
1 + 20
1 + 40
1 + 60
1 + 72.5 Right Edge of Water
?
?
sample lost
NSC
Legend
Vertical Exageration 5X
G - Gravelly
- Base of Loose, Unconsolidated Sediment
NSC- No Sample Collected
- Very Fine to Coarse Sand
- Very Fine to Medium Sand
- Silt to Sandy Silt


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Fall River Sediment Investigation
Cross-Section # 19
(Sampled on Dec. 2, 1996)
Elevation
3312'
3311'
3310.31' (Water Surface 12-02-96)
3309'
3308'
3307'
3306'
3305'
3304'
3303'
3302'
3301'
3300'
3299'
0 + 00 Monument
0 + 29 Left Edge of Water
0 + 40
0 + 60
0 + 80
1 + 00
1 + 20
1 + 142.6 Right Edge of Water
NSC
Legend
Vertical Exageration 5X
G - Gravelly
⊗ - Base of Loose, Uncon-solidated Sediment
NSC- No Sample Collected
- Very Fine to Coarse Sand
- Very Fine to Medium Sand
- Silt to Sandy Silt


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Fall River Sediment Investigation
Cross-Section # 21
(Sampled on Oct. 9, 1996)
Elevation
3311'
3309.5' (Water Surface 10-09-96)
3308'
3307'
3306'
3305'
3304'
3303'
3302'
3301'
3300'
0 + 00 Monument
0 + 17 Left Edge of Water
0 + 20
0 + 40
0 + 60
0 + 80
1 + 00
1 + 20
1 + 40
1 + 60
1 + 80
1 + 86 Right Edge of Water
Legend
Vertical Exageration 5X
G - Gravelly
⊗ - Base of Loose, Unconsolidated Sediment
NSC- No Sample Collected
- Very Fine to Coarse Sand
- Very Fine to Medium Sand
- Silt to Sandy Silt


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Fall River Sediment Investigation
Cross-Section # 22
(Sampled on June 27, 1997)
Elevation
3312'
3311'
3310'
3309.11' (Water Surface 08-27-97)
3308'
3307'
3306'
3305'
3304'
3303'
3302'
3301'
3300'
0 + 00 Monument
0 + 33 Left Edge of Water
0 + 50
0 + 60
0 + 75
0 + 90
1 + 05
1 + 20
1 + 35
1 + 50
1 + 65
1 + 80
1 + 96 Right Edge of Water
NSC
NSC
NSC
Legend
Vertical Exageration 5X
G - Gravelly
⊗ - Base of Loose, Unconsolidated Sediment
NSC- No Sample Collected
- Very Fine to Coarse Sand
- Very Fine to Medium Sand
- Silt to Sandy Silt


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Fall River Sediment Investigation
Cross-Section # 23
(Sampled on June 26, 1997)
Elevation
3312'
3311'
3310'
3308.56' (Water Surface 06-28-97)
3307'
3306'
3305'
3304'
3303'
3302'
3301'
0 + 00 Monument
0 + 30 Left Edge of Water
0 + 55
0 + 75
0 + 90
1 + 05
1 + 10
1 + 20
1 + 35
1 + 50
1 + 65
1 + 80
1 + 95
2 + 10
2 + 25
2 + 37 Right Edge of Water
NSC
Legend
Vertical Exageration 5X
G - Gravelly
- Base of Loose, Unconsolidated Sediment
NSC- No Sample Collected
- Very Fine to Coarse Sand
- Very Fine to Medium Sand
- Silt to Sandy Silt


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Fall River Sediment Investigation
Cross—Section # 24
(Sampled on Dec. 18, 1996)
Elevation
3312'
3311'
3310'
3309'
3308.08' (Water Surface 12-18-96)
3307'
3306'
3305'
3304'
3303'
3302'
3301'
3300'
3299'
3298'
0 + 00 Monument
0 + 20 Left Edge of Water
0 + 40
0 + 60
0 + 80
1 + 00
1 + 20
1 + 40
1 + 60
1 + 80
2 + 00
2 + 12 Right Edge of Water
NSC
NSC
?
?
Legend
Vertical Exageration 5X
G - Gravelly
⊗ - Base of Loose, Uncon-solidated Sediment
NSC- No Sample Collected
- Very Fine to Coarse Sand
- Very Fine to Medium Sand
- Silt to Sandy Silt

APPENDIX 6

STATE OF CALIFORNIA - RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES - NORTHERN DISTRICT

DATE - 01/02/98 JPC

STATION NUMBER: A17300
FALL RIVER AT SPRING CREEK NEAR DANA
(ZERO ON GAGE = 0.00 LOCAL)

1997 1997

DISCHARGE, IN CUBIC FEET PER SECOND FOR WATER YEAR OCTOBER 1996 TO SEPTEMBER 1997

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1		612	544	3120	808	686	747	710	537	557	612	530
2		609	536	3060	778	737	728	693	535	557	596	532
3		605	532	2430*	739	738	713	682	540	564	591	540
4		602	533	1780	717	724	711	674	562	569	591	534
5		595	546	1340	697	719	702	661	559	561	594	531
6		590	566	1090	678	721	695	655	550	564	595	527
7		586*	552	948	672	722	695	642	545	568	594	523
8	N	582	623	848	671	724	692	635	543	572	591	520
9		579	765	780	662	725	699	622	549	580	579	518
10	O	575	1200	722	674	728	689	607	554	582	575	515
11		570	1170	686	671	738	689	603	559	578	583	515
12		566	1140*	657	667	742*	696	596	558	578	592	508
13		561	1090	592	655	737	701	591	554	580	584	493
14		557	979	552	653	733	704	588	546	583	580	506
15	R	553	808	559	655	732	698	585	551	591	575	522
16	E	549	735	552	658	759	694	593	553	593	573	514
17		560	692	550	706	831	692	587	552	591	572	512
18	C	574	663	546	716	824	720	576	551	594	572	512
19		716	649	539	700*	793	792	570	550	593	570	507
20	O	868	642	536	707	794	816	567	550	591	574	502
21	R	736	647	554	697	794	820	570	549	593	573*	503
22		774	651	580	694	789	812	569	547	594	567	504
23	D	775	649	548	691	781	823	583	550	595*	556	503*
24		660	643	550	678	776	786	581	548	594	552	503
25		623	638	560	680	770	757	570	553*	597	550	503
26		594	664	690	688	762	742	560	553	595	544	503
27		575	722	922	692	765	735	553	547	606	541	503
28		564	919	921	698	753	728	548	548	606	538	503
29		556	1460	915		744	734	548*	553	611	540	503
30		548	2170*	829		740	720*	546	555	614	532	503
31			2760	784		767		533		613	529	
TOTAL		18414	26888	29740	19402	23348	21930	18598	16501	18164	17715	15392
MEAN		614	867	959	693	753	731	600	550	586	571	513
MAX		868	2760	3120	808	831	823	710	562	614	612	540
MIN		548	532	536	653	686	689	533	535	557	529	493
ACFT		36520	53330	58990	38480	46310	43500	36890	32730	36030	35140	30530

MEAN	INSTANTANEOUS MAXIMUM FLOW			INSTANTANEOUS MINIMUM FLOW			TOTAL AC.FT.
	DATE	TIME	FLOW	DATE	TIME	FLOW	
NR	01/02	0245	3440	09/13	1630	480	NR

Station located at Spring Creek Road Bridge, 3 miles SE of Dana.

STATE OF CALIFORNIA - RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES - NORTHERN DISTRICT

DATE - 01/02/98 JPC

1997

STATION NUMBER: A17200
FALL RIVER NEAR DANA
(ZERO ON GAGE = 0.00 LOCAL)

1997

DISCHARGE, IN CUBIC FEET PER SECOND FOR WATER YEAR OCTOBER 1996 TO SEPTEMBER 1997

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	376	362	394	3770E	667	446	486	477	383	350	341	328
2	376	361	392	3470E	632	485	480	467	382*	349	336	330
3	375	359	390	2490*	595	474	473	460	383	350	336	332
4	375	359	386	1650	574	456	470	454	393	349	338	331
5	375	360	395	1220	553	452	467	447	390	345	339	331
6	373	358	407	971	533	451	463	445	383	345	338	331
7	373	356	400	846	525	452	460	440	378	346	338	329
8	374	355	478	757	517	449	460	435	376	346	338	328
9	372	355	607	700	506	447	465	430	377	348	334	328
10	370	355	1050	646	505	446	459	424	379	349	330	327
11	371	355	914*	613	498	451	455	421	377	346	334	330
12	370	354	911*	582	488	452*	456	417	377	346	340	325
13	370	352	886	522	476	447	454	413	376	344	336	318
14	371	352	734	490	470	448	454	410	371	344	337	327
15	368	355	598	495	468	449	453	407	368	347	333	335
16	367	352	540	485	466	473	452	412	366	348	333	334
17	366	358*	506	483	505	535	450	413	363	347	333	331
18	366	380	481	476	500	526	468	406	362	347	333	333
19	367	505	466	467	485	503	541	401	360	345	334	332
20	366	643*	458	463	484	505	558	399	360	343	336	331
21	362	510	458	467	474	511	558	398	357	343	336	331
22	363	584	455	470	467	507	554	396	354	342	335	331
23	364*	551	450	455	461	503	564	404	354	342	332	333
24	363	464	443	460	456	501	532	407	353	340	331	333*
25	364	441	440	461	453	498	513	400	352	341	330	331
26	364	422	454	602	456	495	500	395	352	339	329	329
27	362	411	490	812	460	499	493	394	350	342	330	329
28	360	403	688	785	455	493	490	391	349	341	329	329
29	362	399	1350	769		486	495*	390	349	343*	329	330
30	363	394	2150*	681		485	482	386	350	345	327	335
31	365		3130	642		497		381		344	328	
TOTAL	11414	12165	21901	28200	14129	14822	14605	12920	11024	10696	10353	9902
MEAN	368	406	706	910	505	478	487	417	367	345	334	330
MAX	376	643	3130	3770E	667	535	564	477	393	350	341	335
MIN	360	352	386	455E	453	446	450	381	349	339	327	318
ACFT	22640	24130	43440	55930	28020	29400	28970	25630	21870	21220	20530	19640

MEAN	INSTANTANEOUS MAXIMUM FLOW			INSTANTANEOUS MINIMUM FLOW			TOTAL AC.FT.
	DATE	TIME	FLOW	DATE	TIME	FLOW	
472	01/01	1815	4370E	09/13	1615	311	341420

Station located at Fletcher's Bridge, 1 mile SE of Dana.

J. Clements
12/97

FALL RIVER NEAR DANA (A17200)

Rating Table No. 1

Current Meter Measurements

PZF = Point of Zero Flow = 0.00

No.	Date	Time (pst)	Flow (cfs)	G. H. (ft)	G.H. - PZF (ft)	Remarks	Method
1	9/24/96	1230	378	3.09	3.09	Used in RT	Waded
2	10/23/96	1015	363	3.09	3.09	Used in RT	"
3	11/17/96	1530	362	3.03	3.03	Used in RT	"
4	11/20/96	1600	645	4.01	4.01	Used in RT	Boat
5	12/11/96	1215	864	4.67	4.67	Used in RT	Bridge
6	12/12/96	1015	983	5.08	5.08	Used in RT	"
7	12/30/96	1100	2118	7.38	7.38	Used in RT	"
8	1/3/97	900	2599	8.71	8.71	Used in RT	"
9	2/19/97	815	642	3.52	3.52	Unused in RT & shift	"
10	3/12/97	1215	450	3.29	3.29	Used in RT	Waded
11	4/29/97	1430	493	3.30	3.30	Used in RT	Waded
12	6/2/97	1030	383	3.08	3.08	Used in RT	Waded
13	7/29/97	830	342	3.32	3.32	Unused in RT	Waded
14	8/21/97	1530	399	3.35	3.35	Unused in RT & shift	Waded
15	9/24/97	815	333	3.40	3.40	Unused in RT	Waded

J. Clements
12/97

FALL RIVER AT SPRING CREEK (A17300)

Rating Table No. 1

Current Meter Measurements

PZF = Point of Zero Flow = 0.00

No.	Date	Time (pst)	Flow (cfs)	G. H. (ft)	G.H. - PZF (ft)	Remarks	Method	
1	11/7/96	1300	588	1.91	1.91	Used in RT	Boat	
2	12/12/96	0830	1233	3.34	3.34	Used in RT	Bridge	
3	12/30/96	1315	2215	4.83	4.83	Used in RT	Bridge	
4	1/3/97	1330	2358	5.77	5.77	Used in RT	Bridge	
5	2/19/97	1100	696	1.37	1.37	Unused in RT	Boat	
6	3/12/97	1000	743	1.21	1.21	Unused in RT	Boat	
7	4/30/97	1030	718	1.35	1.35	Unused in RT	Boat	
8	5/29/97	1515	546	1.45	1.45	Unused in RT	Boat	
9	6/25/97	0845	551	1.72	1.72	Used in RT	Boat	
10	7/23/97	1000	592	2.07	2.07	Unused in RT	Boat	
11	8/21/97	1330	576	2.20	2.20	Unused in RT	Boat	
12	9/23/97	1500	504	2.30	2.30	Unused in RT	Boat	

J. Clements
12/97

FALL RIVER NEAR DANA (A17200)

Rating Table No. 1

Regression Analysis to Determine Curve of Best Fit

PZF = Point of Zero Flow = 0.00

Equation # 1

Date	Time (pst)	Flow (cfs)	Log Flow	G. H. (ft)	G.H. - PZF (ft)	Log G.H. - PZF	Shift
9/24/96	1230	378	2.5775	3.09	3.09	0.4900	-0.05
10/23/96	1015	363	2.5599	3.09	3.09	0.4900	-0.11
11/17/96	1530	362	2.5587	3.03	3.03	0.4814	-0.06
11/20/96	1600	645	2.8096	4.01	4.01	0.6031	0.03
12/11/96	1215	864	2.9365	4.67	4.67	0.6693	0.04
12/12/96	1015	983	2.9926	5.08	5.08	0.7059	-0.03
12/30/96	1100	2118	3.3259	7.38	7.38	0.8681	0.20
1/3/97	900	2599	3.4148	8.71	8.71	0.9400	-0.26
3/12/97	1215	450	2.6532	3.29	3.29	0.5172	0.05
4/29/97	1430	493	2.6928	3.30	3.30	0.5185	0.20
6/2/97	1030	383	2.5832	3.08	3.08	0.4886	-0.02

Q = C(GH-PZF)^N

N=	1.8857	R=	0.9973
C=	46.4284	BP=	8.71

Summary — Q = C(GH-PZF)^N

Eq. No.	C	N	BP	R	PZF
1	46.4284	1.8857	8.7100	0.9973	0.00

* G.H. at highest field measurements

RT 1 Plotting Points

Q	GH	GH - PZF
172	2.00	2.00
3569	10.00	10.00

J. Clements
12/97

FALL RIVER AT SPRING CREEK (A17300)

Rating Table No. 1

Regression Analysis to Determine Curve of Best Fit

PZF = Point of Zero Flow = 0.00

Equation # 1

Date	Time (pst)	Flow (cfs)	Log Flow	G. H. (ft)	G.H. - PZF (ft)	Log G.H. - PZF	Shift
11/7/96	1300	588	2.7694	1.91	1.91	0.2810	-0.06
12/12/96	0830	1233	3.0910	3.34	3.34	0.5237	-0.04
12/30/96	1315	2215	3.3454	4.83	4.83	0.6839	0.38
1/3/97	1330	2358	3.3725	5.77	5.77	0.7612	-0.30
6/25/97	845	551	2.7412	1.72	1.72	0.2355	0.04

Q = C(GH-PZF)^N

N=	1.2831	R=	0.9957
C=	266.7263	BP=	5.77

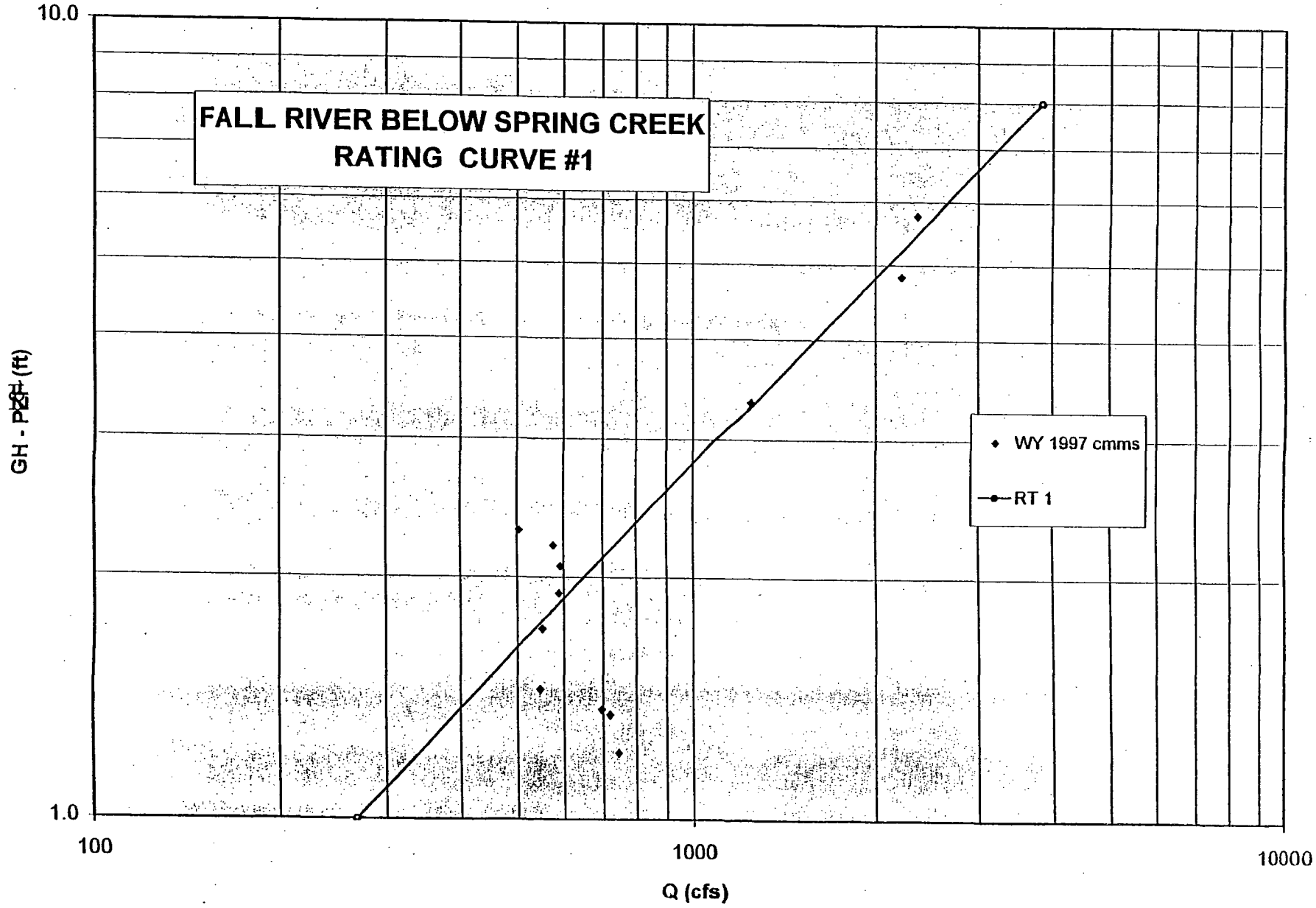
Summary — Q = C(GH-PZF)^N

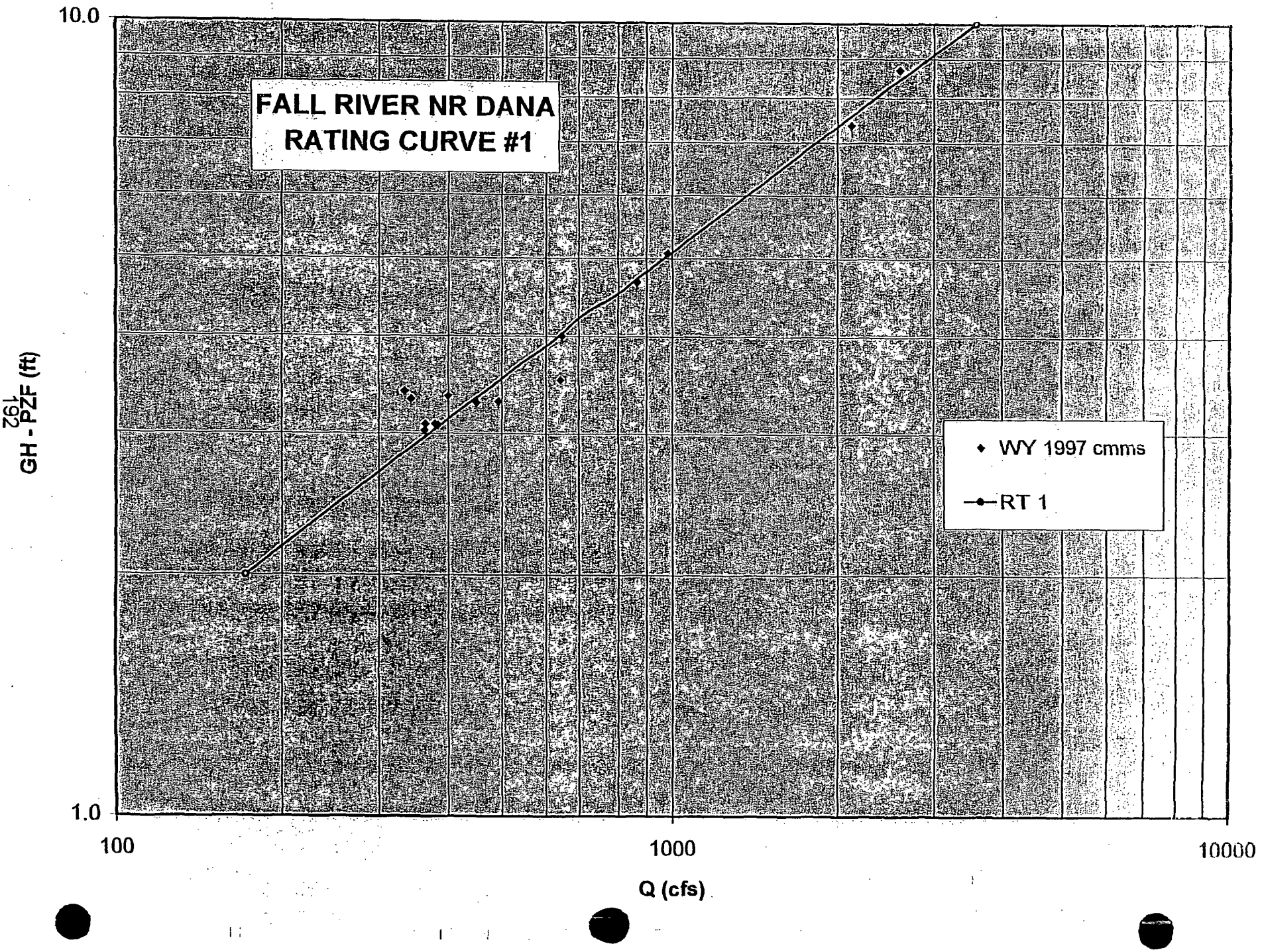
EQS. NO.	C	N	BP	R	PZF
1	266.7263	1.2831	5.77*	0.9957	0.00

* G.H. at highest field measurements

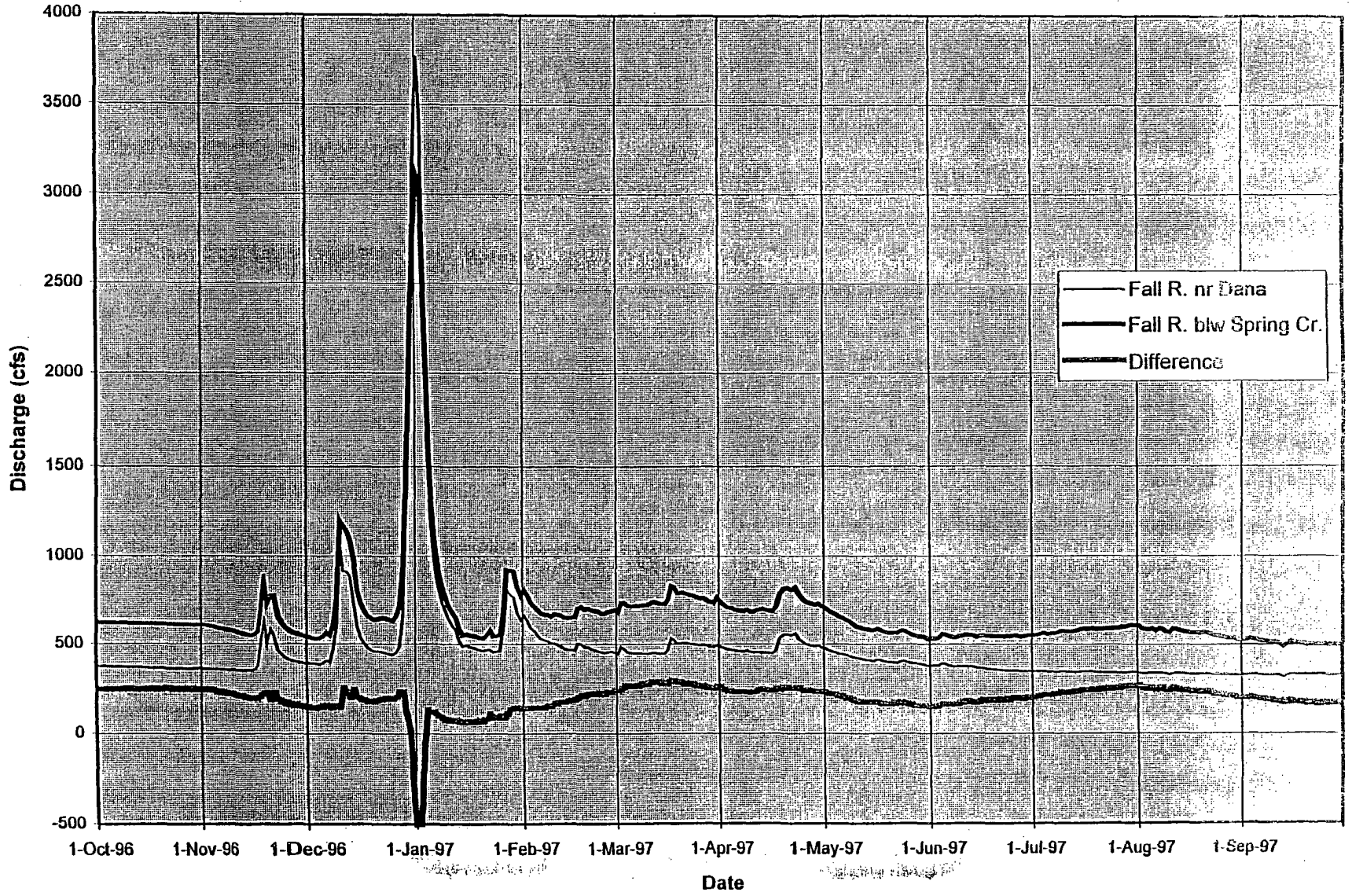
RT 1 Plottting Points

Q	GH	GH - PZF
267	1.00	1.00
3844	8.00	8.00


FALL RIVER BELOW SPRING CREEK
RATING CURVE #1
10.0
1.0
100
1000
10000
GH - PZH (ft)
Q (cfs)
WY 1997 cmms
RT 1


FALL RIVER NR DANA
RATING CURVE #1
10.0
1.0
100
1000
10000
GH - PZF (ft)
192
Q (cfs)
WY 1997 cmms
RT 1

FALL RIVER DAILY DISCHARGE
WATER YEAR 1997





APPENDIX 7

Field Procedure for Collecting Bedload Samples

Equipment Required:

1. Helley-Smith (hand) sampler
2. Handle and extensions
3. USACE WES Sampler Bag with 3.4 ratio and 125 micron opening* netting
4. Tag line, 5' intervals
5. Plastic Bags (1 gallon ziploc)
6. Labels
7. Waterproof Pens
8. Stop Watch
9. Boat with Cable Guide
10. Cable Grabs
11. Field Book
12. Pan (4-gallon)

*Actual opening size, not mesh size

Procedure:

1) Locate a uniform sampling section that has a clear streambed and install a Tag line across the section.

2) The Equal-Transit Rate (ETR) sampling protocol is to be used for all sections.

3) Determine the approximate width of the active section (i.e., transporting bedload). Determine the sample transit stationing increment such that about 20 samples will be collected across the active section of the channel.

4) Record the width between sample transits, the stationing of the first and last sample locations, and (redundantly) the total number of transits employed.

5) Determine and record the time of each sample transit.

6) Collect the sample, in general compliance with the standard U.S. Geological Survey methodology described in the Open File Report 86-531, *Field Methods for Measurement of Fluvial Sediment.*

7) Wash the sample into a plastic ziploc bag (with a 4 gallon pan underneath) and place this bag into a second plastic ziploc bag along with a labeled tag. If any of the sample is lost, the remaining sample is to be discarded and the sampling procedure repeated.

APPENDIX 8

Laboratory Procedure for Analyzing Bed Load Samples

Equipment Required:

1. Electronic scale
2. Drying Container
3. 3-gallon pan
4. Convective drying oven

Total Bedload Sample Mass (including organics)

Procedure:

1. Thoroughly rinse the fines through a US Waterways Experiment Station standard 125 µm Helley-Smith bedload net. Field rinsing at the time of sampling is usually incomplete due to bulking, leaves, etc., and under less than ideal conditions. Large debris should be removed with forceps, insuring that all mineral material is rinsed from the debris first. (Note: The standard USWES bedload net will retain material coarser than #100 and will pass #120 material).
2. Tare a clean, dry porcelain drying dish and record the weight.
3. Remove the retained material and place in tared porcelain drying dish. This will probably require the addition of some rinse water to completely clear the net.
4. After the bedload sample has settled, carefully decant excess water into a pan. If no fines were accidentally poured into the pan, the excess water may be discarded.
5. Oven dry the sample and dish at 107 °C to constant weight (usually overnight due to the large amount of free water present in the sample).
6. Record the weight of the sample plus dish to the nearest 0.1 gram. This should be performed while the sample is still warm to minimize the amount of hygroscopic moisture present.
7. Repeat this weighing after the sample has been slightly reheated in the oven. The weights recorded for the sample plus dish should agree within ±4%.

Total Bedload Sample Mineral Mass

Procedure:

1. Using the final weight of the sample plus dish from above, oven dry the sample plus dish at 150 °C for one hour. This should remove a substantial portion of the organic fraction. Carefully remove the sample plus dish and allow to cool at room temperature (approximately 30 minutes).

2. Record the weight of the sample plus dish to the nearest 0.1 gram. Again, this should be performed while the sample is still warm. Repeat this weighing after the sample has been slightly reheated in the oven. The weights recorded for the sample plus dish should agree within ±4%.

3. This sample weight, less the tare, represents the total inorganic fraction of the bedload sample.

Calculation:

1. Using the following equation (which was developed for a Helley-Smith sampler with a 0.248 foot opening width and that includes the appropriate unit conversions) will yield the Bedload Transport Rate in tons/day:

$$\frac{(\textit{Sample Weight})\ (\textit{Stream Width})}{(\textit{Number Stations})\ (\textit{Time})} = (0.388)$$

Where: the *sample weight* is in grams; the *stream width* is the fluvially active width of the stream, in feet; the *Number Stations* represents the number of ETR sampling points employed; and the sampling *time* is in seconds. The constant also incorporates an adjustment for wetted perimeter, which is generally about 1% greater than the stream width.

APPENDIX 9

Laboratory Procedure for Determining Bedload Grain-size Distribution

Equipment Required:

1. Mechanical Sieve Set
2. Electronic scale
3. Weighing Container

Procedure:

1. Using final weight obtained for the total bedload mineral sample mass, described in Appendix 2, and microsieves, with openings of 0.090, 0.060, 0.040, 0.026, 0.015, and 0.0058 inches, sort sample by size fraction (per steps 2 through 5 below).

2. Tare a weighing container.

3. Sift sample through microsieve using sieve size .090 inch. Weigh amount of sample retained to the nearest 0.01 gram and record on data sheet.

4. Repeat step 2 for the sample fraction that passed with the remaining sieve sizes .060, .040, .026, .015 and .0058 inches.

5. Record all data on bedload sample data sheet.

6. Total the weights retained on each microsieve. This should compare with the total weight obtained from the procedure of Appendix 2 within 4%.

Laboratory Procedure for Determining Suspended Sediment Concentration

Equipment Required:

1. Vacuum filtration unit
2. Gelman sciences glass fiber filters (p/n 61631)
3. Wash bottle and deionized water

Procedure:

1. Record the gross and tare weights of each sample bottle + water/sediment mixture to the nearest gram, assuming that the net sediment + water sample weighs in excess of 200 g.

2. After allowing time for the sediment to settle, decant most of the sediment free water using care not to disturb or remove sediment.

3. Label a Gelman sciences glass fiber filter (p/n 61631) and filter 100 ml of distilled water through the filter with the vacuum assembly. Remove the filter and oven dry at 107 °C for 1 hour. Then desiccate the filter for one hour in the desiccator.

4. Tare and record the weight of desiccated filter.

5. Place the filter in the vacuum assembly, turn on vacuum and wet the filter with distilled water. Slowly pour the sample through the filter, using distilled water to rinse the remainder of the sample from the sample bottle.

6. Clean, air dry, reweigh and repack all used sample bottles while the filter is air drying.

7. After the loss of all visible water, oven dry the filter at 107 °C for 1 hour.

8. Place filters in the desiccator, for 1 hour.

9. Weigh the filter and sample to the nearest 0.0001 g.

10. Repeat (8) & (9) until there is less than 4% weight difference.

11. Compute the net weight of sediment in the filter.
    [Final stabilized weight from (10) - Weight from (4)]

12. Compute the concentration of the sample in parts per million (ppm).
    The concentration of the sediment = 1,000,000 X (net wt. of sediment / net wt. of water & sediment mixture).

Note: 1 ppm ≈ mg/L when the concentration < 16,000 ppm

APPENDIX 11

Laboratory Procedure for Determining Suspended Sand Concentration

Equipment Required:

Vacuum filtration unit
Gelman sciences glass fiber filters (p/n 61631)
Wash bottle and deionized water
Erlenmeyer flask

Procedure:

1) Label a new Gelman sciences glass fiber filter (p/n 61631) and rinse with distilled water. Filter 100 ml of distilled water through the disk with the vacuum assembly. Remove the filter and oven dry at 107 °C for 1 hour, place filter in the desiccator for one hour.

2) Weigh and record weight of filter disk (tare). Set the filter aside for use later.

3) Retrieve the glass fiber filter and residue used for the determination of suspended sediment. Carefully scrape and rinse the sand residue from the filter into a 1-liter, or larger Erlenmeyer flask (rinse with a low water flow rate). Discard the used filter.

4) Gently rinse the remaining clay and silt fractions from the Erlenmeyer flask with a low-pressure, low-flow hose situated approx. 1-2 inches above dispersed sample residue until only clear water is present and only sand remains at the bottom of the flask. This may require some experimental trial runs with placebo samples to insure that the flow rate is low enough such that it does not wash the fine sands out.

5) After rinsing and allowing time for the remaining sands to settle, decant most of the clear water, using care not to disturb the sand.

6) Place a filter on the vacuum assembly, turn on vacuum and pre-wet the filter with distilled water. Slowly pour the sample through the filter, using distilled water to rinse the remainder of sample from the Erlenmeyer flask.

7) After loss of all visible water, oven dry the filter at about 107 °C for 1 hour.

8) Desiccate and cool the filter at room temperature for one hour.

9) Weigh the filter and sand sample to the nearest 0.0001 g, using the analytical balance.

10) Repeat (7), (8) and (9) until there is less than 4% weight difference.

11) Compute the net weight of sand on the filter:.
(Final average weight from (9)) - (Weight from (2))

12) Calculate the % sand fraction, by dividing the weight of the dried, desiccated sand from the previous step by the dry weight of the total suspended sediment and multiply the result by 100.

APPENDIX 12

Date and Time

September 25, 1996 @ 1202-1229 PST

Weather Conditions

Clear, calm, 75° F ±

Streamflow Parameters

Index Stream Discharge, in cfs = 371

Water Temperature, °C = 11.6

Specific Conductance, in μmhos/cm = 133

Suspended Sediment

Sediment Concentration, in ppm = not collected

Suspended Sand Concentration, in ppm = not collected

Bedload

Bedload Transport, in tons/day = 0.69

Bedload Gradation:

Sieve Size U.S. Custom (inches)	Percent Sample	Percent Pass
#8 (0.090)	3.9	96.1
#12 (0.060)	2.0	94.1
#18 (0.040)	4.6	89.5
#24 (0.026)	7.2	82.3
#40 (0.015)	22.2	60.1
#100 (0.0058)	58.8	1.3
<#100(<.0058)	1.3	0.0
Totals:	100	

Comments: Streambed is fine sand w/pebble armor & some longitudinal streaks (visible sand movement on streaks); silt near banks; stable dunes (vegetated) with some ripples.

Date and Time

November 21, 1996 @ 1115-1205 PST

Weather Conditions

Cloudy, cool to cold, calm, approx. 40° F

Streamflow Parameters

Index Stream Discharge, in cfs = 500

Water Temperature, °C = 9.2

Specific Conductance, in μmhos/cm = 58

Slightly Turbid

Suspended Sediment

Sediment Concentration, in ppm = not collected

Suspended Sand Concentration, in ppm = not collected

Bedload

Bedload Transport, in tons/day = 1.1

Bedload Gradation:

Sieve Size		
U.S. Custom (inches)	Percent of Sample	Percent Pass
#8 (0.090)	21.2	78.8
#12 (0.060)	6.6	72.2
#18 (0.040)	5.5	66.7
#24 (0.026)	5.1	61.6
#40 (0.015)	22.3	39.3
#100 (0.0058)	39.3	0.0
<#100(<.0058)	>0.1	0.0
Totals:	100	

Comments: None

Date and Time

December 12, 1993 @ 1610-1810 PST

Weather Conditions

Broken clouds; light windy gusts; 35 °F
Intermittent showers

Streamflow Parameters

Index Stream Discharge, in cfs = 880

Water Temperature, °C = 6.6

Specific Conductance, in μmhos/cm = 80

Moderately turbid

Suspended Sediment

Sediment Concentration, in ppm = 5.7

Suspended Sand Concentration, in ppm = 0.24

Bedload

Bedload Transport, in tons/day = 10.3

Bedload Gradation:

Sieve Size		
U.S. Custom (inches)	Percent of Sample	Percent Pass
#8 (0.090)	9.4	90.6
#12 (0.060)	3.7	86.9
#18 (0.040)	5.2	81.7
#24 (0.026)	8.7	73.0
#40 (0.015)	51.3	21.7
#100 (0.0058)	21.3	0.4
<#100(<.0058)	0.4	0.0
Totals:	100	

Comments: None

Date and Time

January 3, 1997 @ 1505-1555 PST

Weather Conditions

Clear; light breeze; 50 °F

Streamflow Parameters

Index Stream Discharge, in cfs = 2300

Water Temperature, °C = 6.3

Specific Conductance, in μmhos/cm = 55

Turbid to very turbid

Suspended Sediment

Sediment Concentration, in ppm = 49.8

Suspended Sand Concentration, in ppm = 2.0

Bedload

Bedload Transport, in tons/day = 0.76

Bedload Gradation:

Sieve Size		
U.S. Custom (inches)	Percent of Sample	Percent Pass
#8 (0.090)	42.0	58.0
#12 (0.060)	9.9	48.1
#18 (0.040)	4.9	43.2
#24 (0.026)	4.9	38.3
#40 (0.015)	14.8	23.5
#100 (0.0058)	19.8	3.7
<#100(<.0058)	3.7	0.0
Totals:	100	

Comments: Due to excessive depths and velocities, five depth-integrated transits at middle stations of ETR section did not completely reach the streambed. Individual transits were estimated to be within 1 or 2 feet of the streambed. Values cited for suspended sediment and suspended sand are probably too low.

Date and Time

September 24, 1996 @ 1210-1240 PST

Weather Conditions

Clear, calm, approx. 60 °F±

Streamflow Parameters

Index Stream Discharge, in cfs = 380

Water Temperature, °C = 12.0

Specific Conductance, in μmhos/cm = 139

Clear water

Suspended Sediment

Sediment Concentration, in ppm = not collected

Suspended Sand Concentration, in ppm = not collected

Bedload

Bedload Transport, in tons/day = 1.5

Bedload Gradation:

Sieve Size		
U.S. Custom	Percent of	Percent
(inches)	Sample	Pass
#8 (0.090)	27.7	72.3
#12 (0.060)	6.1	66.2
#18 (0.040)	6.1	60.1
#24 (0.026)	4.9	55.2
#40 (0.015)	17.0	38.2
#100 (0.0058)	36.5	1.7
<#100(<.0058)	1.7	0.0
Totals:	100	

Comments: Bottom consists of loose sand & fine sand across cross-section (often sank to knees); ripples.

Date and Time

November 20, 1996 @ 1410-1510 PST

Weather Conditions

not collected

Streamflow Parameters

Index Stream Discharge, in cfs = 660

Water Temperature, °C = 9.5

Specific Conductance, in μmhos/cm = 99

Suspended Sediment

Sediment Concentration, in ppm = not collected

Suspended Sand Concentration, in ppm = not collected

Bedload

Bedload Transport, in tons/day = 8.7

Bedload Gradation:

Sieve Size		
U.S. Custom (inches)	Percent of Sample	Percent Pass
#8 (0.090)	2.9	97.1
#12 (0.060)	2.2	94.9
#18 (0.040)	3.6	91.3
#24 (0.026)	7.0	84.3
#40 (0.015)	43.3	41.0
#100 (0.0058)	40.7	0.3
<#100(<.0058)	0.3	0.0
Totals:	100	

Comments: None

Sediment Sample Summary
Section 7

Date and Time

December 12, 1996 @ 0935-1050 PST

Weather Conditions

Scattered clouds, calm, approx. 35° F

Streamflow Parameters

Index Stream Discharge, in cfs = 990

Water Temperature, °C = 6.5

Specific Conductance, in μmhos/cm = 80

Moderately turbid

Suspended Sediment

Sediment Concentration, in ppm = 16.1

Suspended Sand Concentration, in ppm = 0.50

Bedload

Bedload Transport, in tons/day = 7.9

Bedload Gradation:

Sieve Size		
U.S. Custom	Percent of	Percent
(inches)	Sample	Pass
#8 (0.090)	1.2	98.8
#12 (0.060)	1.8	97.0
#18 (0.040)	1.9	95.1
#24 (0.026)	2.3	92.8
#40 (0.015)	46.2	46.6
#100 (0.0058)	45.6	1.0
<#100(<.0058)	1.0	0.0
Totals:	100	

Comments: None

Date and Time

December 31, 1996 @ 1020-1137 PST

Weather Conditions

Cloudy, windy w/high gusts, light rain, approx. 45 °F

Streamflow Parameters

Index Stream Discharge, in cfs = 3,450

Water Temperature, °C = 5.6

Specific Conductance, in μmhos/cm = 31

Very turbid to muddy

Suspended Sediment

Sediment Concentration, in ppm = 177.6

Suspended Sand Concentration, in ppm = 7.1

Bedload

Bedload Transport, in tons/day = 10.5

Bedload Gradation:

Sieve Size		
U.S. Custom (inches)	Percent of Sample	Percent Pass
#8 (0.090)	41.2	58.8
#12 (0.060)	5.3	53.5
#18 (0.040)	4.2	49.3
#24 (0.026)	3.3	46.0
#40 (0.015)	17.5	28.5
#100 (0.0058)	27.5	.89
<#100(<.0058)	0.9	0.0
Totals:	100	

Comments: None

Sediment Sample Summary
Section 15

Date and Time

September 26, 1996 @ 1230-1350 PST

Weather Conditions

Clear, calm, approx. 70° F±, occasional light breeze

Streamflow Parameters

Index Stream Discharge, in cfs = 415

Water Temperature, °C = 11.1

Specific Conductance, in μmhos/cm = 134

Low turbidity

Suspended Sediment

Sediment Concentration, in ppm = not collected

Suspended Sand Concentration, in ppm = not collected

Bedload

Bedload Transport, in tons/day = 4.05

Bedload Gradation:

Sieve Size		
U.S. Custom (inches)	Percent of Sample	Percent Pass
#8 (0.090)	5.0	95.0
#12 (0.060)	3.3	91.7
#18 (0.040)	3.1	88.6
#24 (0.026)	4.1	84.5
#40 (0.015)	38.5	46.0
#100 (0.0058)	44.7	1.3
<#100(<.0058)	1.3	0.0
Totals:	100	

Comments: Streambed is fine sand & silt w/few gravels; minor vegetation

Date and Time

November 21, 1996 @ 1415-1500 PST

Weather Conditions

Cloudy, calm, 55 °F

Streamflow Parameters

Index Stream Discharge, in cfs = 490

Water Temperature, °C = 9.7

Specific Conductance, in μmhos/cm = 125

Moderately turbid

Suspended Sediment

Sediment Concentration, in ppm = not collected

Suspended Sand Concentration, in ppm = not collected

Bedload

Bedload Transport, in tons/day = 3.0

Bedload Gradation:

Sieve Size		
U.S. Custom (inches)	Percent of Sample	Percent Pass
#8 (0.090)	3.8	96.2
#12 (0.060)	3.3	92.9
#18 (0.040)	8.7	84.2
#24 (0.026)	12.5	71.7
#40 (0.015)	30.8	40.9
#100 (0.0058)	40.9	0.0
<#100(<.0058)	0.0	0.0
Totals:	100	

Comments: None

Date and Time

December 12, 1996 @ 1225-1330 PST

Weather Conditions

Broken clouds, sprinkles, 40 °F, wind later

Streamflow Parameters

Index Stream Discharge, in cfs = 910

Water Temperature, °C = 6.8

Specific Conductance, in μmhos/cm = 81

Moderately turbid

Suspended Sediment

Sediment Concentration, in ppm = 6.2

Suspended Sand Concentration, in ppm = 1.3

Bedload

Bedload Transport, in tons/day = 6.0

Bedload Gradation:

Sieve Size		
U.S. Custom (inches)	Percent of Sample	Percent Pass
#8 (0.090)	2.0	98.0
#12 (0.060)	1.7	96.3
#18 (0.040)	4.4	91.9
#24 (0.026)	8.0	83.9
#40 (0.015)	29.8	54.1
#100 (0.0058)	53.6	0.5
<#100(<.0058)	.5	0.0
Totals:	100	

Comments: None

Sediment Sample Summary
Section 15

Date and Time

January 4, 1997 @ 1415-1505 PST

Weather Conditions

Clear, light clouds, calm, 55 °F

Streamflow Parameters

Index Stream Discharge, in cfs = 1570

Water Temperature, °C = 5.8

Specific Conductance, in μmhos/cm = 71

Suspended Sediment

Sediment Concentration, in ppm = 180.8

Suspended Sand Concentration, in ppm = 122.4

Bedload

Bedload Transport, in tons/day = 56.6

Bedload Gradation:

Sieve Size		
U.S. Custom (inches)	Percent of Sample	Percent Pass
#8 (0.090)	1.7	98.3
#12 (0.060)	2.1	96.2
#18 (0.040)	7.5	88.7
#24 (0.026)	19.8	68.9
#40 (0.015)	52.4	16.5
#100 (0.0058)	16.3	0.2
<#100(<.0058)	0.2	0.0
Totals:	100	

Comments: streambed felt sandy w/some dunes. Bedload sampling was very easy and results should be particularly valid.

Date and Time

June 27, 1997 @ 1130-1240 PST

Weather Conditions

Clear , warm, sunny

Streamflow Parameters

Index Stream Discharge, in cfs = 385

Water Temperature, °C = 12.0

Specific Conductance, in μmhos/cm = 150

Low Turbidity

Suspended Sediment

Sediment Concentration, in ppm = 3.4

Suspended Sand Concentration, in ppm = .85

Bedload

Bedload Transport, in tons/day = 4.1

Bedload Gradation:

Sieve Size		
U.S. Custom (inches)	Percent of Sample	Percent Pass
#8 (0.090)	1.7	98.3
#12 (0.060)	2.6	95.7
#18 (0.040)	10.0	85.7
#24 (0.026)	19.0	66.7
#40 (0.015)	44.8	21.9
#100 (0.0058)	21.5	0.4
<#100(<.0058)	0.4	0.0
Totals:	100	

Comments: None

Date and Time

October 8, 1996 @ 1045 - 1135 PST

Weather Conditions

Clear, approx. 70° F±

Streamflow Parameters

Index Stream Discharge, in cfs = 600 est.

Water Temperature, °C = 12.0

Specific Conductance, in μmhos/cm = 139

Suspended Sediment

Sediment Concentration, in ppm = not collected

Suspended Sand Concentration, in ppm = not collected

Bedload

Bedload Transport, in tons/day = 0.01 est.

Bedload Gradation:

Sieve Size		
U.S. Custom (inches)	Percent of Sample	Percent Pass
#8 (0.090)	5.0	95.0
#12 (0.060)	>0.1	95.0
#18 (0.040)	>0.1	95.0
#24 (0.026)	>0.1	95.0
#40 (0.015)	5.0	90.0
#100 (0.0058)	85.0	5.0
<#100(<.0058)	5.0	0.0
Totals:	100	

Comments: Streambed is fine sand & silt. Extremely dense channel vegetation qualifies bedload sampling & streamflow measurements to estimates of questionable value. Try to locate a better section for future measurements.

Date and Time

December 13, 1996 @ 0945-1045 PST

Weather Conditions

Clear, cool, light breeze; approx. 45° F±

Streamflow Parameters

Index Stream Discharge, in cfs = 1,030

Water Temperature, °C = 7.6

Specific Conductance, in μmhos/cm = 100

Suspended Sediment

Sediment Concentration, in ppm = 46.9

Suspended Sand Concentration, in ppm = 15.6

Bedload

Bedload Transport, in tons/day = 6.9

Bedload Gradation:

Sieve Size		
U.S. Custom (inches)	Percent of Sample	Percent Pass
#8 (0.090)	2.9	97.1
#12 (0.060)	2.9	94.2
#18 (0.040)	10.5	83.7
#24 (0.026)	16.9	66.8
#40 (0.015)	40.1	26.7
#100 (0.0058)	25.4	1.3
<#100(<.0058)	1.3	0.0
Totals:	100	

Comments: Measuring section is ~ 250' u/s of measuring section used last month (10/8) and was generally clear of vegetation.

Date and Time

December 30, 1996 @ 1515-1605 PST

Weather Conditions

Cloudy, light rain, light wind, approx. 40° F±

Streamflow Parameters

Index Stream Discharge, in cfs = 2,200

Water Temperature, °C = 6.6

Specific Conductance, in μmhos/cm = 28

Suspended Sediment

Sediment Concentration, in ppm = 121.5

Suspended Sand Concentration, in ppm = 66.6

Bedload

Bedload Transport, in tons/day = 21.6

Bedload Gradation:

Sieve Size		
U.S. Custom (inches)	Percent of Sample	Percent Pass
#8 (0.090)	15.1	84.9
#12 (0.060)	5.6	79.3
#18 (0.040)	9.8	69.5
#24 (0.026)	13.4	56.1
#40 (0.015)	27.4	28.7
#100 (0.0058)	27.1	1.6
<#100(<.0058)	1.6	0.0
Totals:	100	

Comments: None

APPENDIX 13

1996 Fall River Aquatic Macroinvertebrate Community Data

				Station	Fall River #1	Fall River #3	Fall River #7	Fall River #15	Fall River #19	Fall River #21	Fall River #23
				Location	riffle at lancelne near headwaters	above Reeds Bridge	below Fletcher Bridge	at New Bridge	above Spring Cr.	below Spring Cr. Bridge	Lackey property near pump
				Date Sampled	11/14/96	09/25/96	09/24/96	09/26/96	10/11/96	10/08/96	11/13/96
				Sample Size	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar
Order	**Family**	**y**	**Genus**	**Species**							
Amphipoda											16
	Talitridae		Hyalella	azteca	48		8	48	39	12	40
	Gammaridae		Gammarus								72
Aranae								6			
Colembola							4				
Coleoptera-Terrestrial	Chrysomelidae						4				
	Unid.-A					10					
Coleoptera	Dytiscidae		Unid.-L			10					
			Hydrovatus-A				4				
			Oreodytes-L					6			
	Elmidae		Hetertimnius-L		32						
	Haliplidae		Brychius-A							24	
			Brychius-L			250	4	8		24	8
			Haliplus-L							12	
Diptera -Terrestrial							16				
Diptera	Chironomidae	Chironominae-L				182	32	72	9	144	
		Orthocladiinae-L			48	394	356	714	292	84	80
		Tanypodinae-L				77	48	396	262		
		Unid.-L						36	9		
		Unid.-P				125	28	72	4	72	16
	Empididae		Chelifera-L		32		112				
	Simulidae		Simulium-L		16						
	Tabanidae		Tabanus-L			10		6			
	Tipulidae		Antocha	monticola-L	48						
	Unid.-A				16			6			
	Unid.-L										
Ephemeroptera			Unid.-N		16					12	184
	Baetidae		Baetis-N		16		4			84	16
			Unid.-N			10					
	Ephemerellidae										
			Drunella	doddsil-N							
			Drunella	proserpina-N	32	19	20		4		
			Ephemerella-N		16		192	186	467	300	648
	Heptageniidae		Unid.-N		96						
			Cinygmula-N		256						
			Epeorus-N		32						
			Rhithrogena-N		16						
	Leptophlebiidae		Paraleptophlebia-N							144	
			Unid.-N			10					96
	Tricorythidae		Tricorythodes	fallax-N				6	22	60	
Gastropoda			Unid.			29	28	54		72	72
			Unid. species #1		2480	192	108	168	205	1548	872
			Unid. species #2						62	48	
			Unid species #3								

1996 Fall River Aquatic Macroinvertebrate Community Data

			Station	Fall River #1	Fall River #3	Fall River #7	Fall River #15	Fall River #19	Fall River #21	Fall River #23
			Location	riffle at fencelline near headwaters	above Reeds Bridge	below Fletcher Bridge	at New Bridge	above Spring Cr.	below Spring Cr. Bridge	Lackey property near pump
			Date Sampled	11/14/96	09/25/96	09/24/96	09/26/96	10/11/96	10/08/96	11/13/96
			Sample Size	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar
Order	Family	y	Genus	Species						
			Unid. species #4						96	
	Physidae				16	19				
	Planorbidae		Vorticifex-A			29	4	108	39	84	416
	Pleuroceridae		Juga-A		160	29	12	12	26		
Hemiptera	Corixidae		Unid-L					18	17		8
			Unid-A				12				
Hirudinea	Unid.				16	10	8		4	120	16
	Erpobdellidae		Dina	annoculata						24	72
	Erpobdellidae		Unid-A		1						
	Glossiphoniidae		Helobdella					24	9	84	104
			Helobdella	stagnalis				24		120	104
Hydracarina						10	8	30	13	36	40
Hymenoptera			Unid.-A					6			
Isopoda	Asellidae		Caecidotea							24	352
Megaloptera	Sialidae		Sialis-L			1				1	
Nematoda	Mermithidae					394	36	6	17	156	104
Nematomorpha									22	192	
Odonata	Coenagrionidae		Argia								16
Oligochaeta			Unid (Mangled)		64						
	Naididae		Ophidonais	serpentina	304	432	64	444	74	528	1440
	Tubificidae		Spirosperma	nikolskyi		106		414	135	804	536
	Lumbriculidae		Eclipidrilus	frigidus	224	58			22	336	80
			Unid Species #4								
Pelecypoda			Unid.			163					
	Sphaeriidae		Pisidium-A			125		120	4	276	208
Petromyzontiformes	dae		Lampetra-J			1					
Plecoptera			Unid-N						4		
	Capniidae		Mesocapnia								16
	Chloroperlidae		Unid.-L		32						
			Unid.-N				12				
			Suwallia-N			10					
	Nemouridae		Unid.-N		80						
			Malenka-N			10					
			Zapada-N		208		4		4		
	Perlodidae		Isoperla-N		32				4	348	40
Thysanoptera								6		12	
Trichoptera			Unid.-L			10					
	Apataniidae		Apatania-L		32		12				
	Brachycentridae		Unid.-L			19				12	8
			Amiocentrus-L		96	38					
			Unid.-P			19					
			Unid.-L								
	Goeridae		Goera-L						9		
	Glossosomatidae		Unid.-L		544						
			Unid.-P				24				

1996 Fall River Aquatic Macroinvertebrate Community Data

				Station	Fall River #1	Fall River #3	Fall River #7	Fall River #15	Fall River #19	Fall River #21	Fall River #23
				Location	riffle at fenceline near headwaters	above Reeds Bridge	below Fletcher Bridge	at New Bridge	above Spring Cr.	below Spring Cr. Bridge	Lackey property near pump
				Date Sampled	11/14/96	09/25/96	09/24/96	09/26/96	10/11/96	10/[illegible]/96	11/13/96
				Sample Size	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar
Order	Family	y	Genus	Species							
			Glossosoma-L		1280	10	48				
	Hydroptilidae		Hydroptila-L		48	29	4		39	1[illegible]	24
			Unid.-P			29	12				
	Lepidostomatidae		Lepidostoma-L			19			9	1[illegible]	88
			Unid.-P							1[illegible]	
	Leptoceridae		Mystacides								
	Limnephilidae		Psychoglypha-L				8				
			Unid.-P							[illegible]	
	Rhyacophilidae		Rhyacophila-L (w/gills)		1		8		9		
			Rhyacophila-L (w/o gills)		16						
	Sericostomatidae		Gumaga-L			10					
Tricladida	Planariidae		Dugesia			10					24
A= adult											
J= juvanile			number of organisms		6354	2908	1244	2994	1835	62[illegible]	5818
L= larvae			number of species		34	38	32	27	30	[illegible]	32
N= nymph			Diversity Index		3.2	4.1	3.7	3.5	3.5	[illegible]	3.7
P= pupae			equitability		0.38	0.65	0.60	0.59	0.55	0[illegible]7	0.60
Unid.= unidentified to lower level											

1997 Fall River Aquatic Macroinvertebrate Community Data

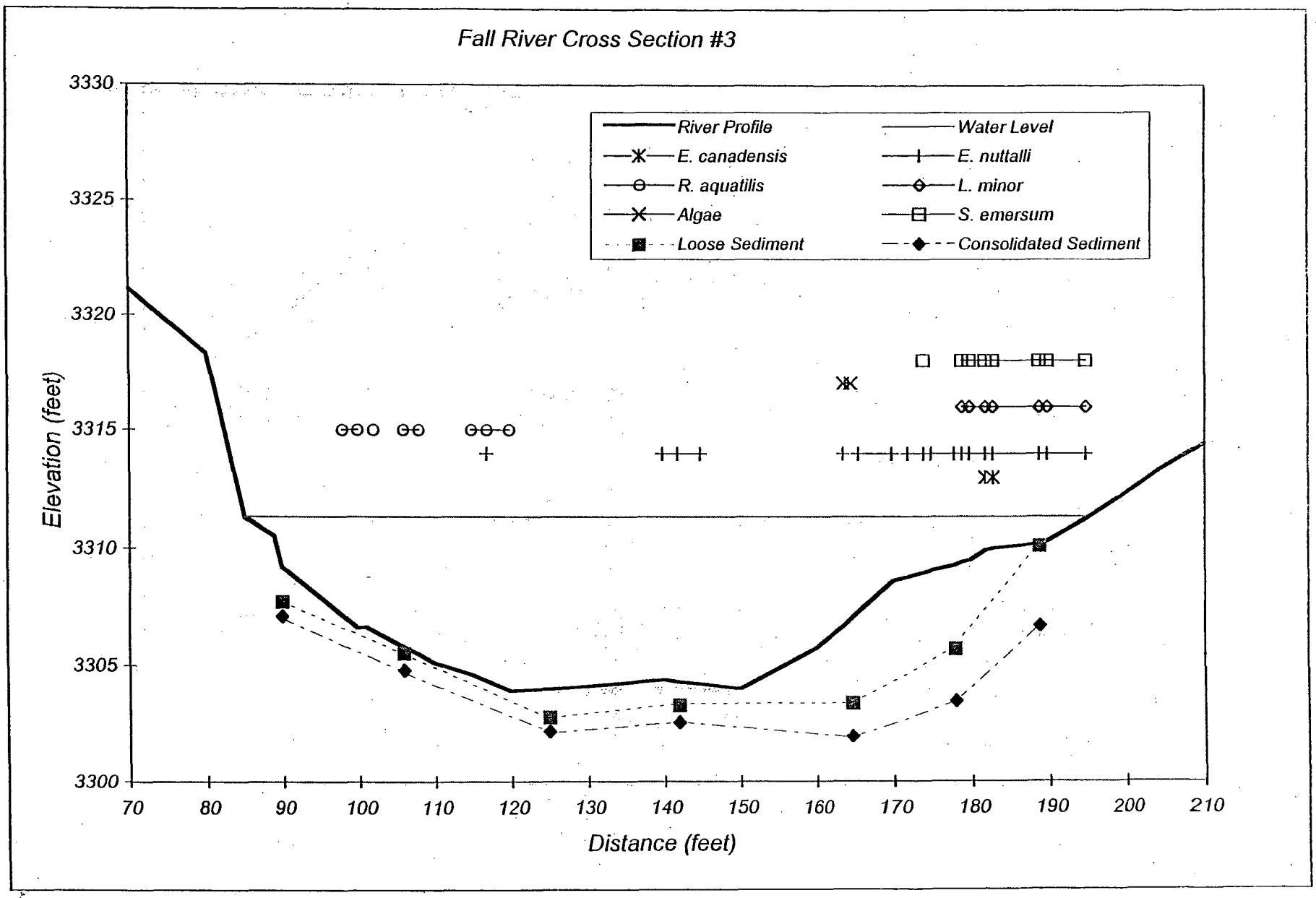
				Station	Fall River #1	Fall River #3	Fall River #7	Fall River #15	Fall River #19	Fall River #21	Fall River #23
				Location	riffle at fenceline near headwaters	above Reeds Bridge	below Fletcher Bridge	at New Bridge	above Spring Cr.	below Spring Cr. Bridge	Lackey property gear pump
				Date Sampled	*not sampled	05/13/97	05/13/97	05/14/97	05/14/97	05/12/97	05/12/97
				Sample Size		2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar
Order	Family	y	Genus	Species							
Amphipoda											
	Talitridae		Hyalella	azteca		4	1	2			18
Coleoptera	Dytiscidae		Oreodytes-L			2			2		
			Unid.-L						2		
	Elmidae		Heterlimnius-L			4	1				
	Haliplidae		Brychius-A						2	11	
			Haliplus-L							5	5
Copepoda	Cyclopidae										5
Decapoda	Astacidae		Pacifasticus								11
Diptera Terrestrial								2	3		
Diptera	Ceratopogonidae		Bezzia/Palpomyia-L						2	11	
			Probezzia-L			6					5
	Chironomi	Chironominae-L				122	88	29	38	27	5
		Orthocladiinae-L				28	175	307	163	789	240
		Tanypodinae-L				24	1	2	14	43	27
		Unid-L					1	4	3		
		Unid-P				6	25	36	38	48	16
	Empididae		Chelifera-L			2	6	2	2		
			Unid.-P				11				
	Tabanidae		Tabanus-L			7					
Ephemerop	Baetidae		Baetis-N				6				21
			Unid.-N						2		
	Ephemerellidae		Drunella	proserpina-N			1				
			Ephemerella-N				32	4	80	112	37
			Unid.-N					4			
	Heptageniidae		Cinygmula-N				1				
	Leptophlebiidae		Unid.-N						2		
	Tricorythidae		Tricorythodes	fallax							5
Gastropoda			Unid. species #1			133	16		37	48	672
			Unid. species #2			4		8	6	75	256
			Unid. species #3					4		21	320
			Unid.				11		3		
	Physidae						1				
	Planorbidae		Vorticifex-A			17					
	Pleuroceridae		Juga-A			6	3	2			
Hemiptera-Terrestrial							1				
Hemiptera	Corixidae		Unid-L								
			Unid-A						2	11	5
Hirudinea	Unid										21
	Erpobdellidae		Dina	anoculata					2	11	5
			Unid-A								64
	Glossiphonidae		Alloglossiphonia								11
			Glossiphonia						2		

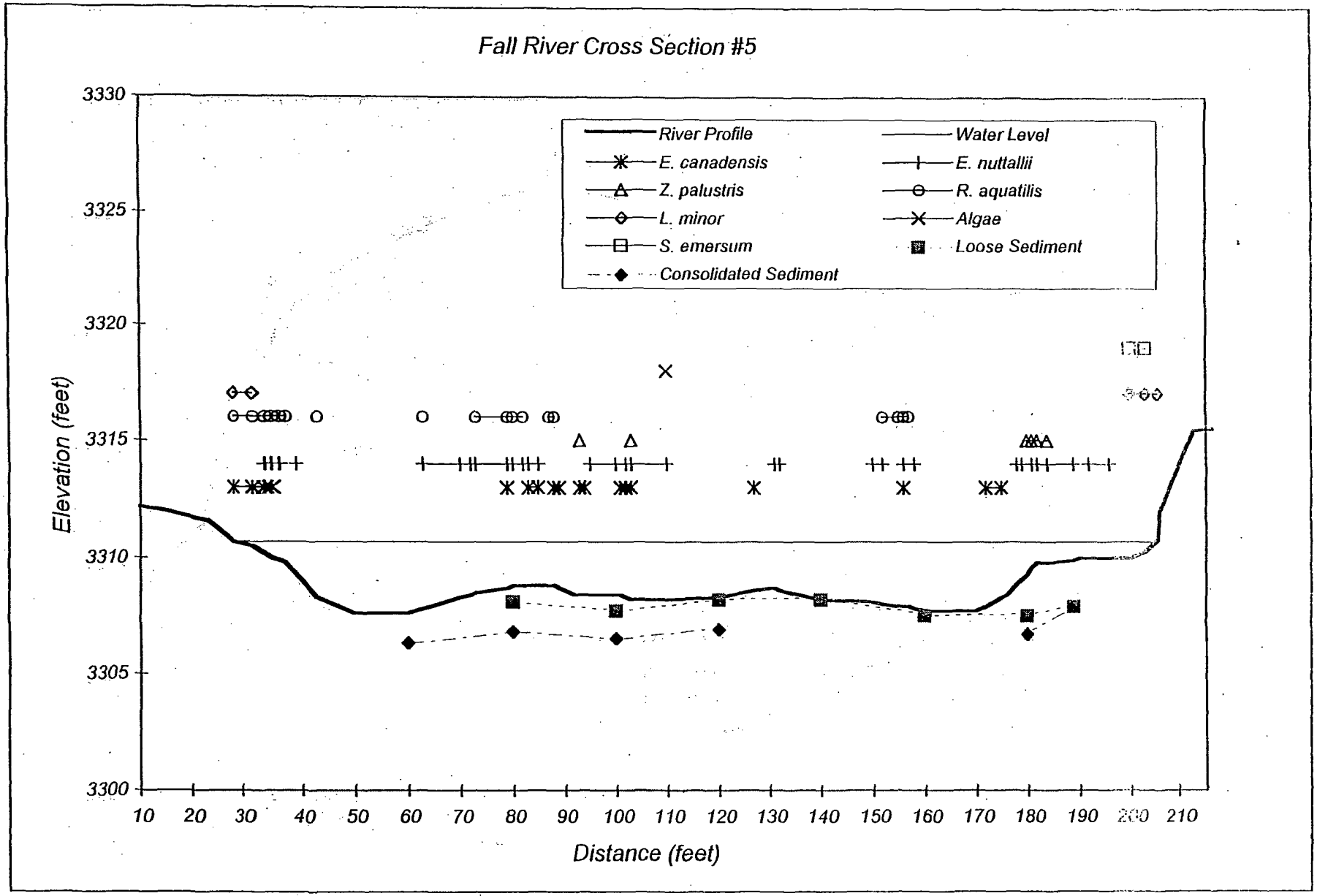
1997 Fall River Aquatic Macroinvertebrate Community Dat

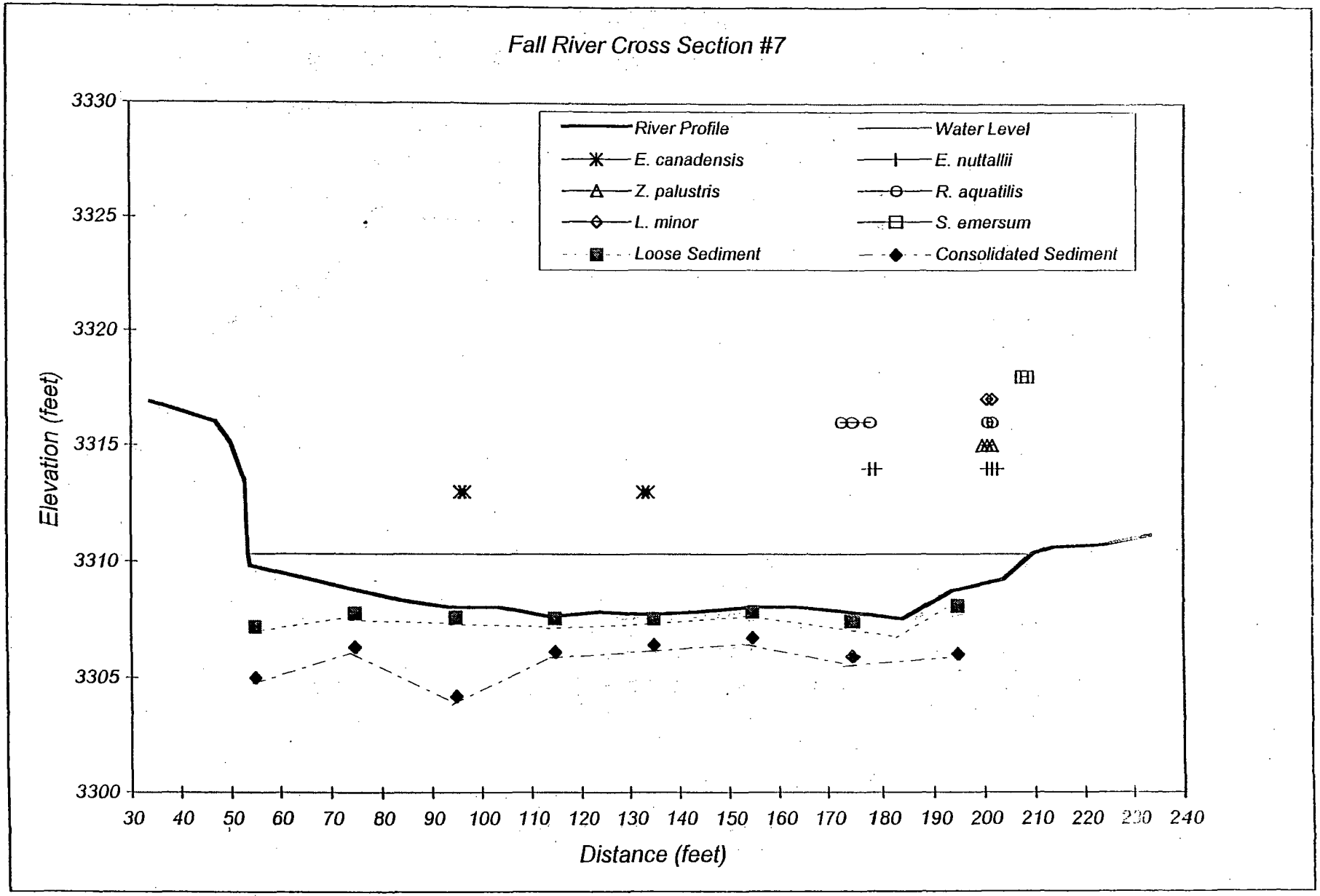
				Station	Fall River #1	Fall River #3	Fall River #7	Fall River #15	Fall River #19	Fall River #21	Fall River #23
				Location	riffle at fenceline near headwaters	above Reeds Bridge	below Fletcher Bridge	at New Bridge	above Spring Cr.	below Spring Cr. Bridge	Lackey property near pump
				Date Sampled	*not sampled	05/13/97	05/13/97	05/14/97	05/14/97	05/12/97	05/12/97
				Sample Size		2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar	2.6 ft² Ponar
Order	Family	Y	Genus	Species							
			Helobdella				1	2		11	176
			Helobdella	stagnalis					2		48
Homoptera-Terrestrial									2		
Hydracarina							3		2		48
Nematoda	Mermithidae					33	28	2		16	5
Nematomorpha									6		203
Oligochaeta			Unid			81					
	Naididae		Ophidonais	serpentina		44	78	84	216	651	843
	Tubificidae		spirosperma	nikolskyi		9	1	152	32	832	112
	Lumbriculidae		Eclipidrilus	frigidus		42	6		16	64	48
			Unid Species #4								619
Ostracoda									2		
Pelecypoda			Unid			28	1			21	53
	Sphaeriidae		Unid							27	
	Sphaeriidae		Pisidium-A			11		10	2	59	69
Plecoptera			Unid.-N				1				
	Chloroperlidae		Unid.-L				14		2		
	Perlodidae		Isoperla-N				3		3		
Trichoptera	Brachycentridae		Amiocentrus-L			2				75	32
			Unid.-L						2		
			Unid.-P			2					
	Glossosomatidae		Glossosoma-L				14				
			Unid.-P				7				
	Lepidostomatidae		Lepidostoma-L							5	
	Leptoceridae		Mystacides								11
	Rhyacophilidae		Rhyacophila-L(w/gills)						2		
	Sericostomatidae		Gumaga-L							11	
	Uenoidae		Neophylax-L				3		2		
*Large and Rare Portion											
A= adult											
L= larvae											
N= nymph											
P= pupae			number of organisms			617	541	656	696	2984	4014
Unid.= unidentified to lower level			number of species			23	31	18	34	24	33

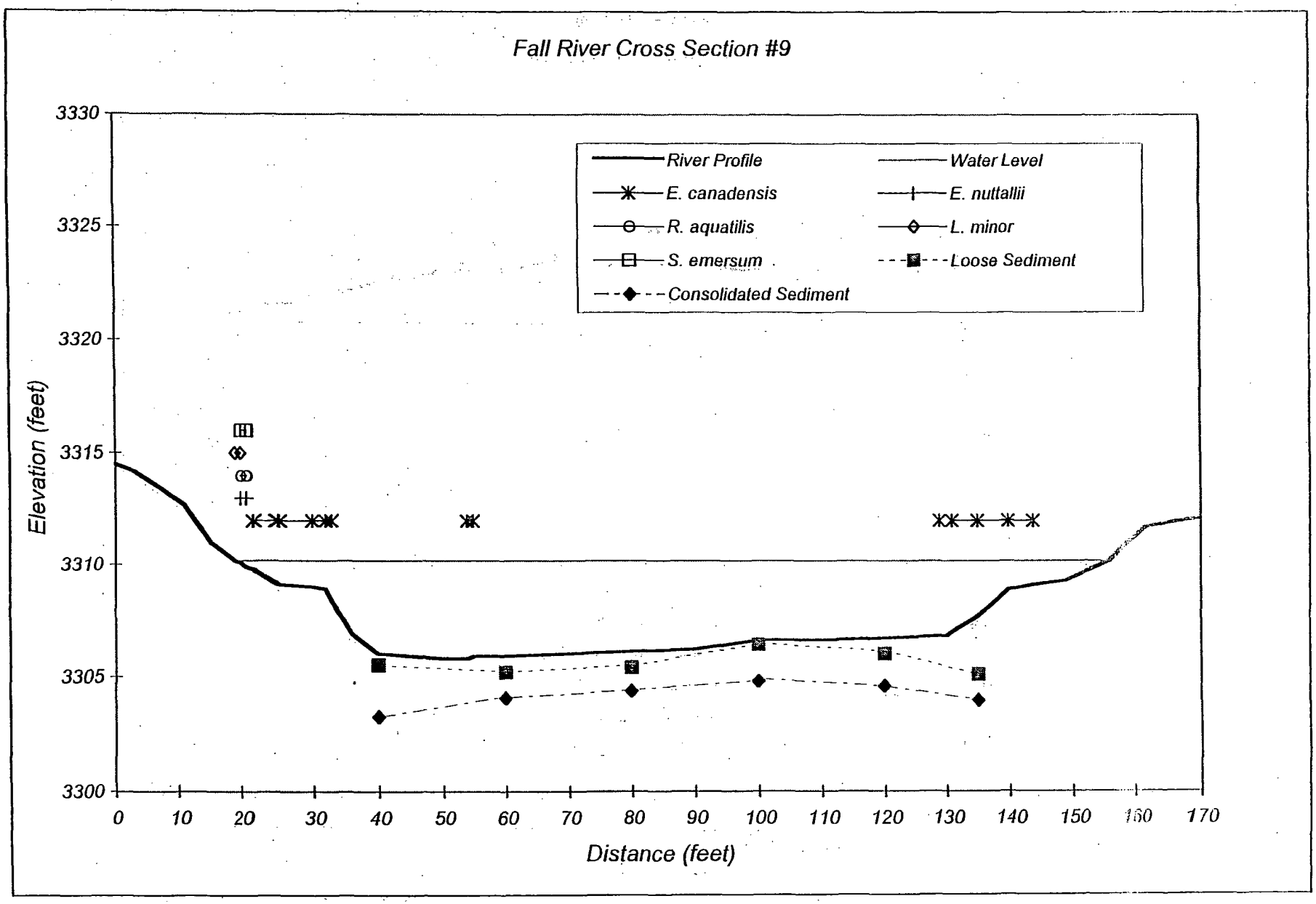


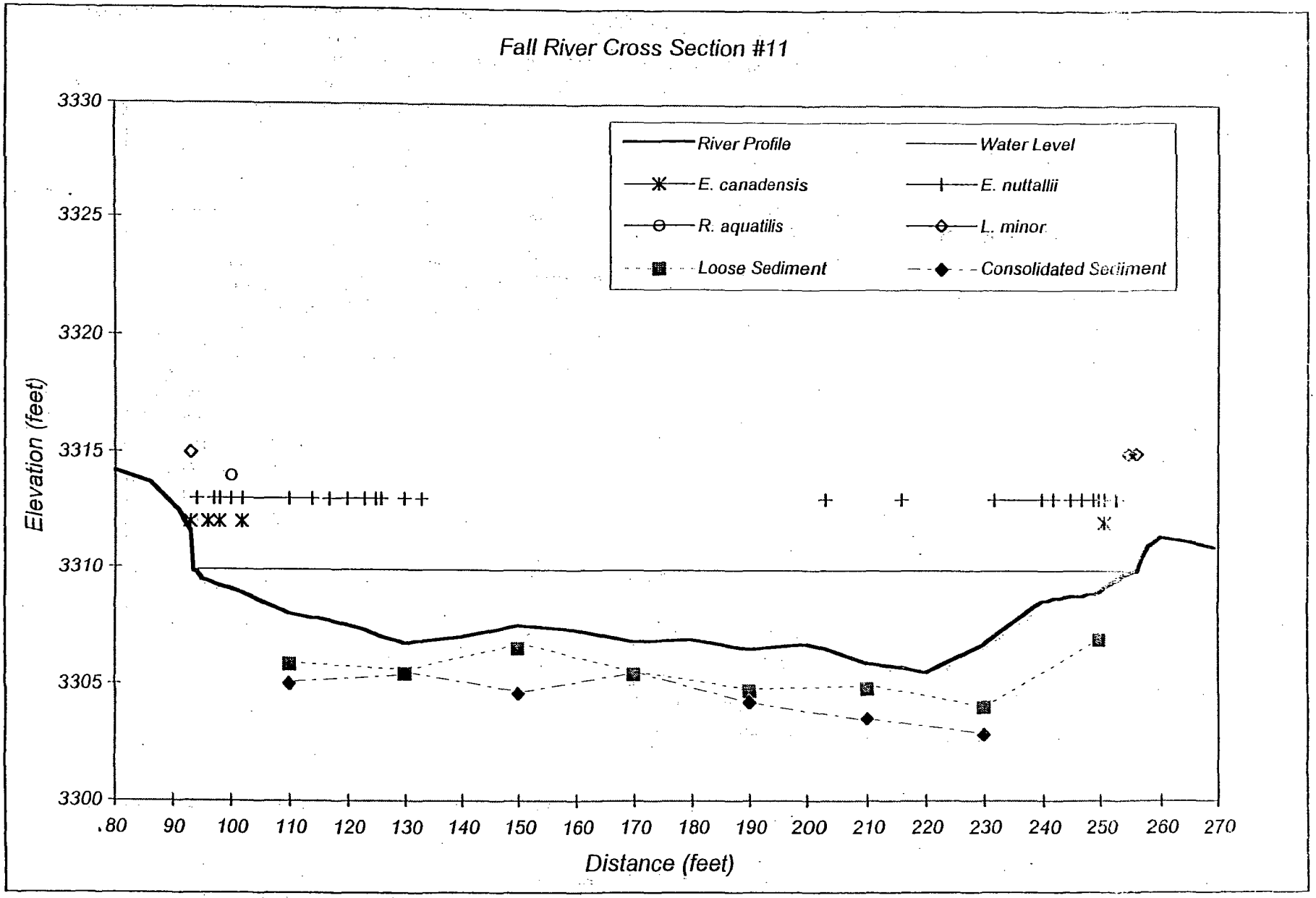
APPENDIX 14

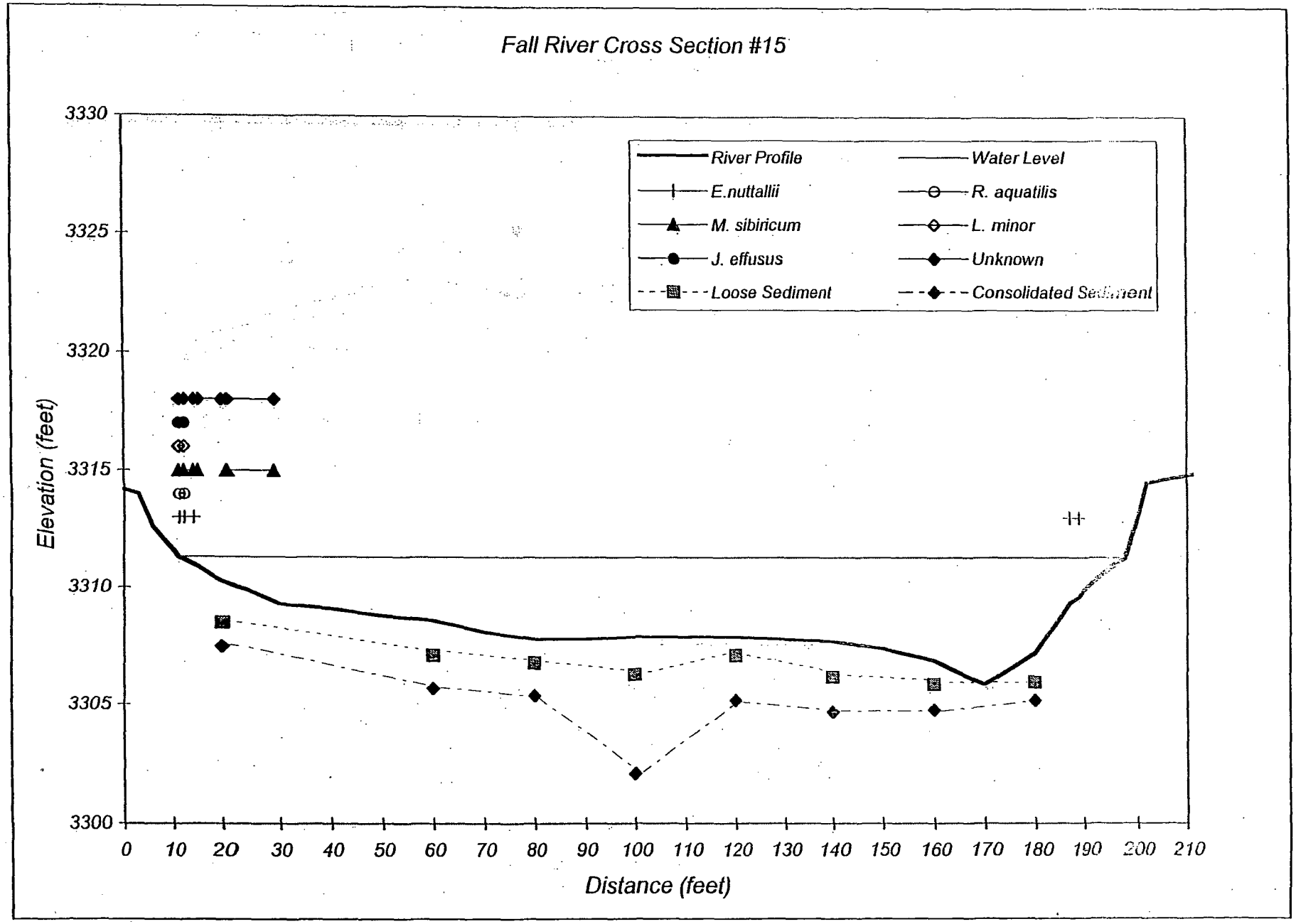

Fall River Cross Section #3
River Profile
Water Level
E. canadensis
E. nuttalli
R. aquatilis
L. minor
Algae
S. emersum
Loose Sediment
Consolidated Sediment
Elevation (feet)
3330
3325
3320
3315
3310
3305
3300
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
Distance (feet)

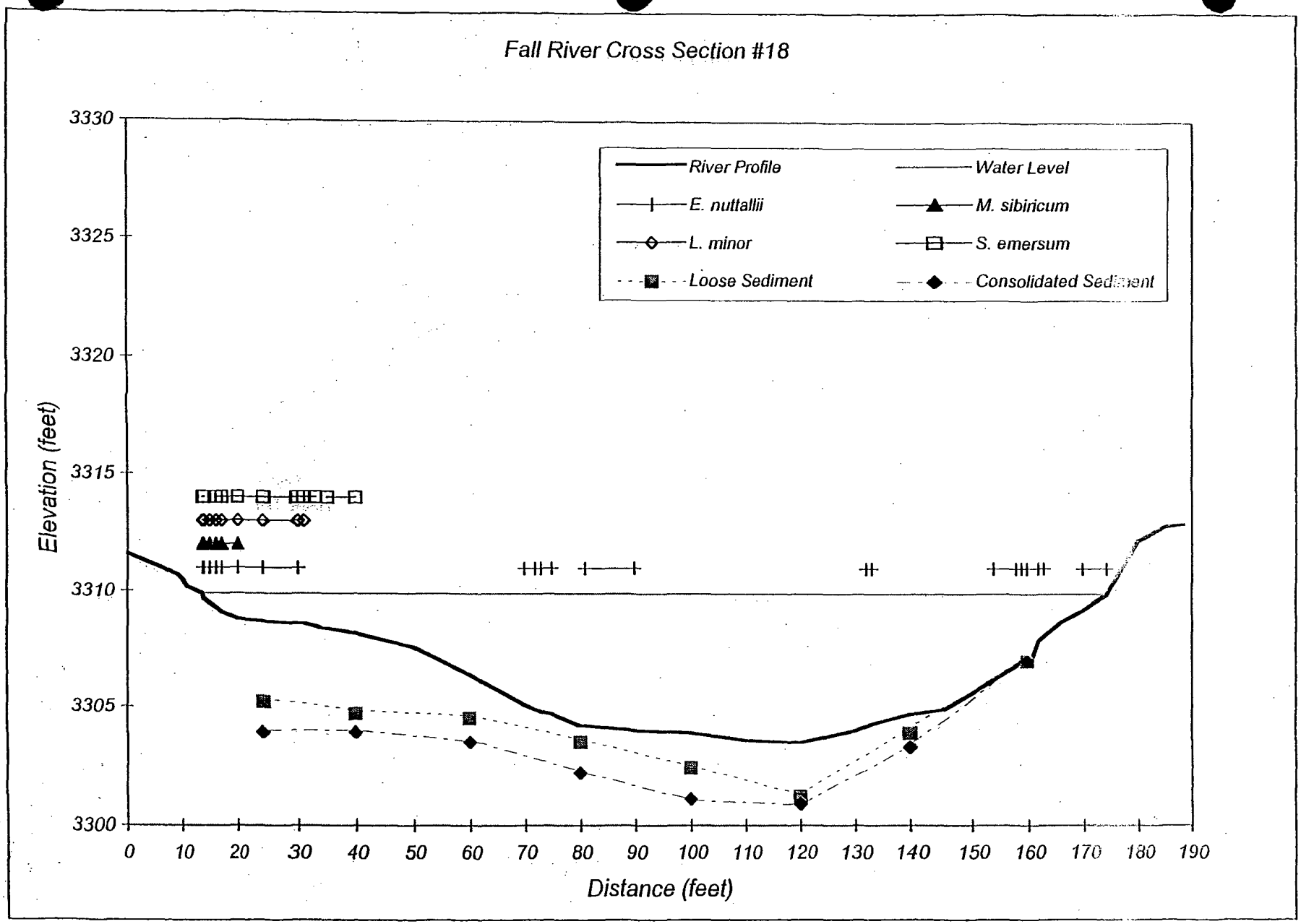

Fall River Cross Section #5
River Profile
Water Level
E. canadensis
E. nuttallii
Z. palustris
R. aquatilis
L. minor
Algae
S. emersum
Loose Sediment
Consolidated Sediment
Elevation (feet)
3330
3325
3320
3315
3310
3305
3300
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210
Distance (feet)

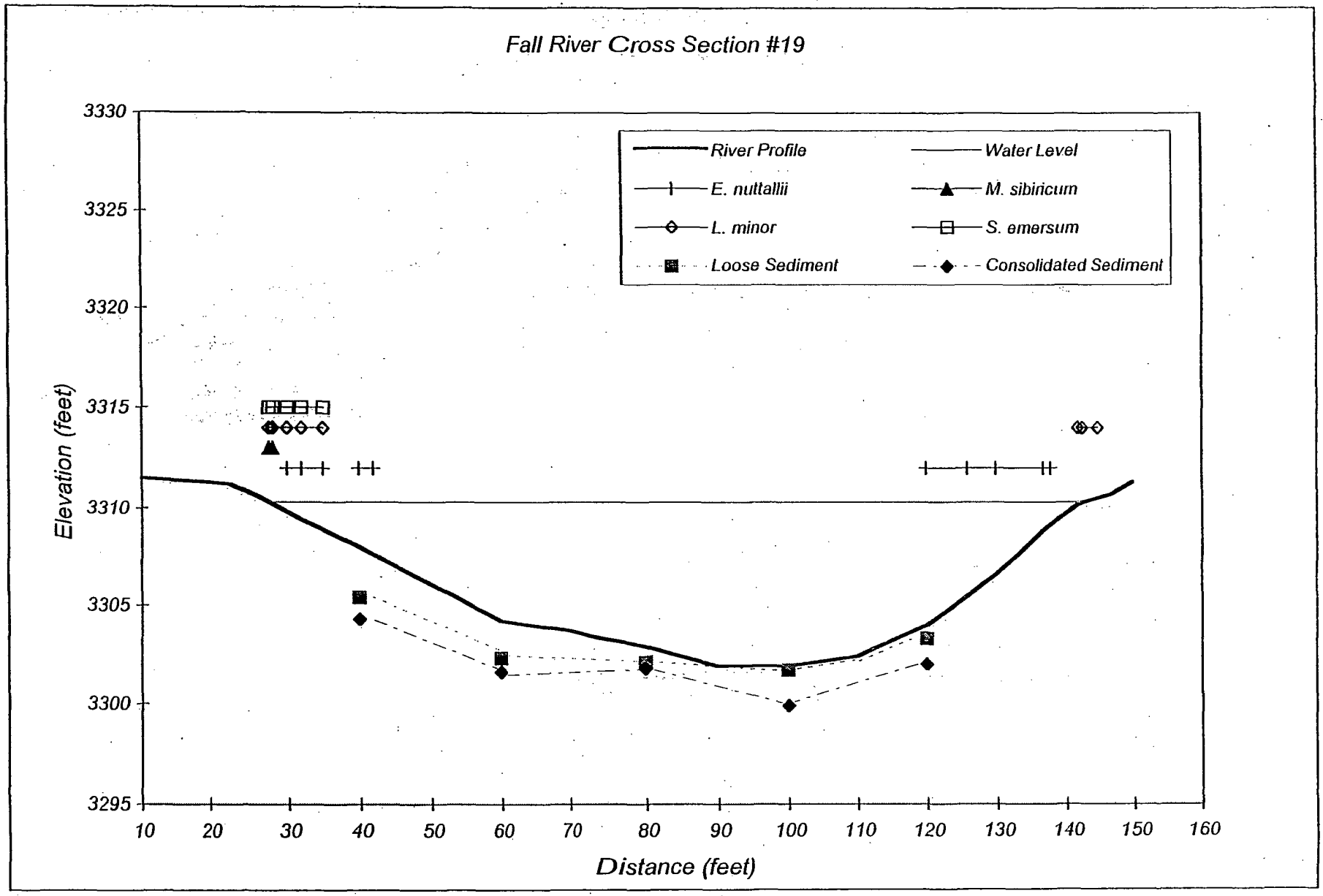

Fall River Cross Section #7
River Profile
Water Level
E. canadensis
E. nuttallii
Z. palustris
R. aquatilis
L. minor
S. emersum
Loose Sediment
Consolidated Sediment
Elevation (feet)
3330
3325
3320
3315
3310
3305
3300
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240
Distance (feet)

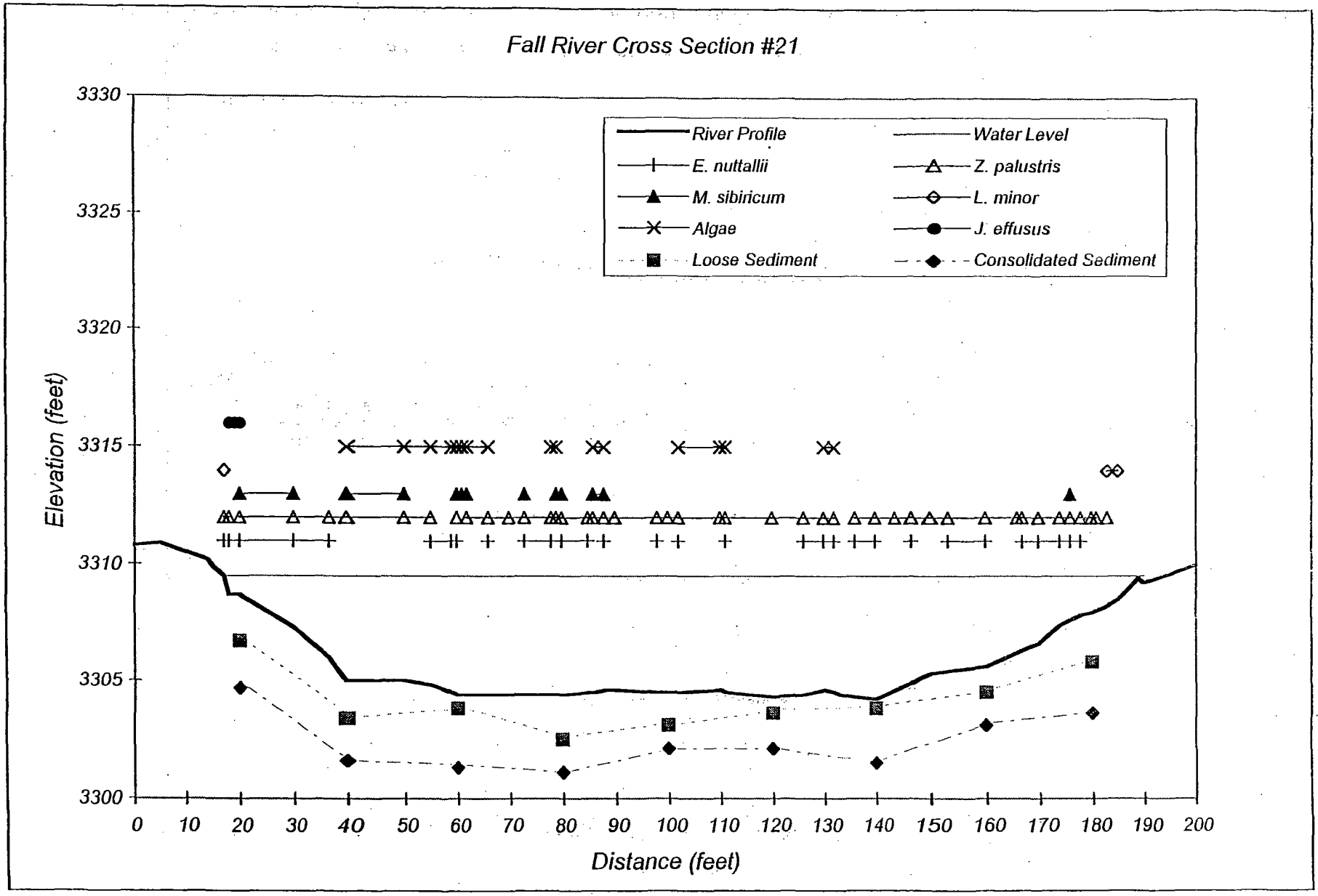

Fall River Cross Section #9
River Profile
Water Level
E. canadensis
E. nuttallii
R. aquatilis
L. minor
S. emersum
Loose Sediment
Consolidated Sediment
Elevation (feet)
3330
3325
3320
3315
3310
3305
3300
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
Distance (feet)

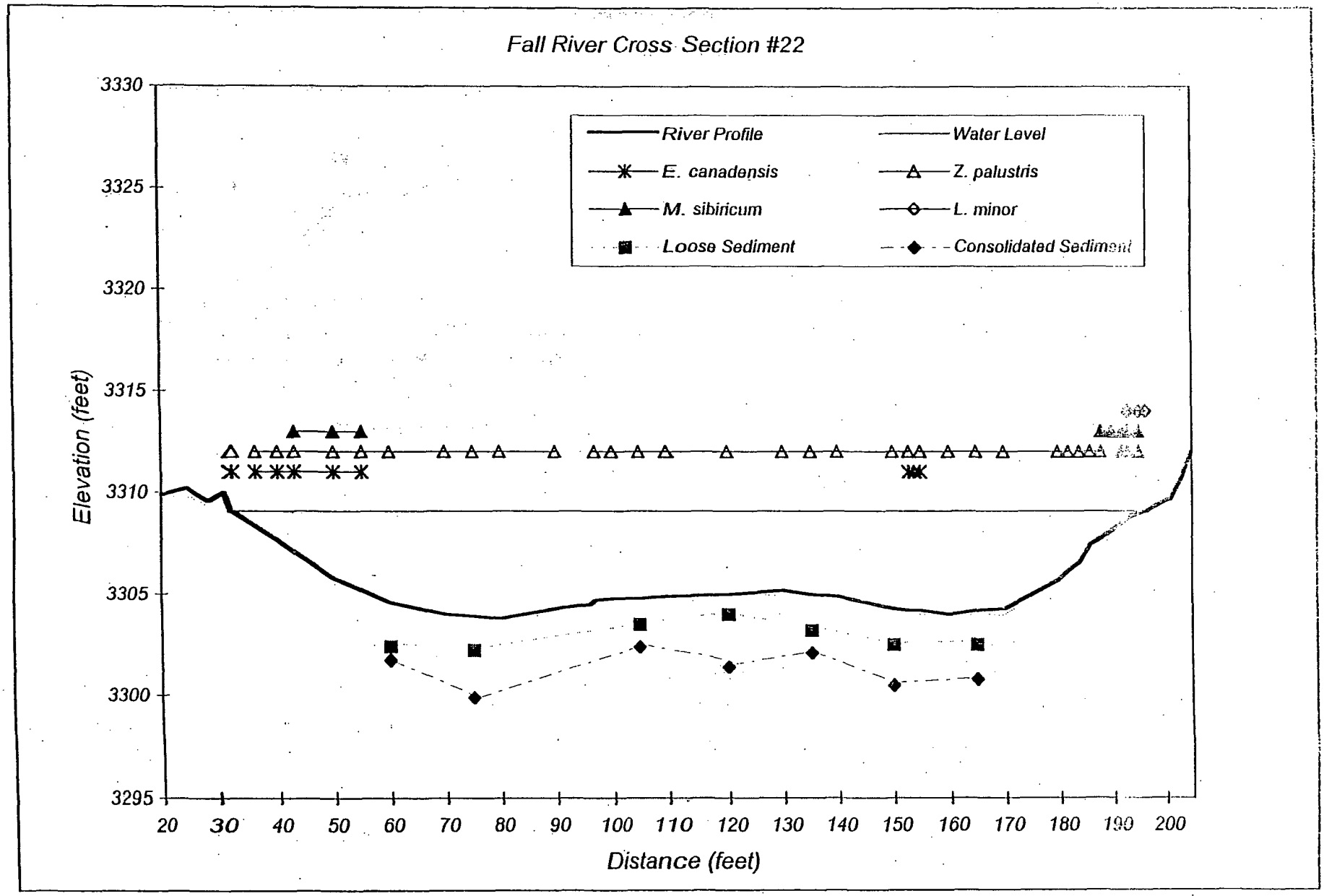

Fall River Cross Section #11
River Profile
Water Level
E. canadensis
E. nuttallii
R. aquatilis
L. minor
Loose Sediment
Consolidated Sediment
Elevation (feet)
3330
3325
3320
3315
3310
3305
3300
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
Distance (feet)

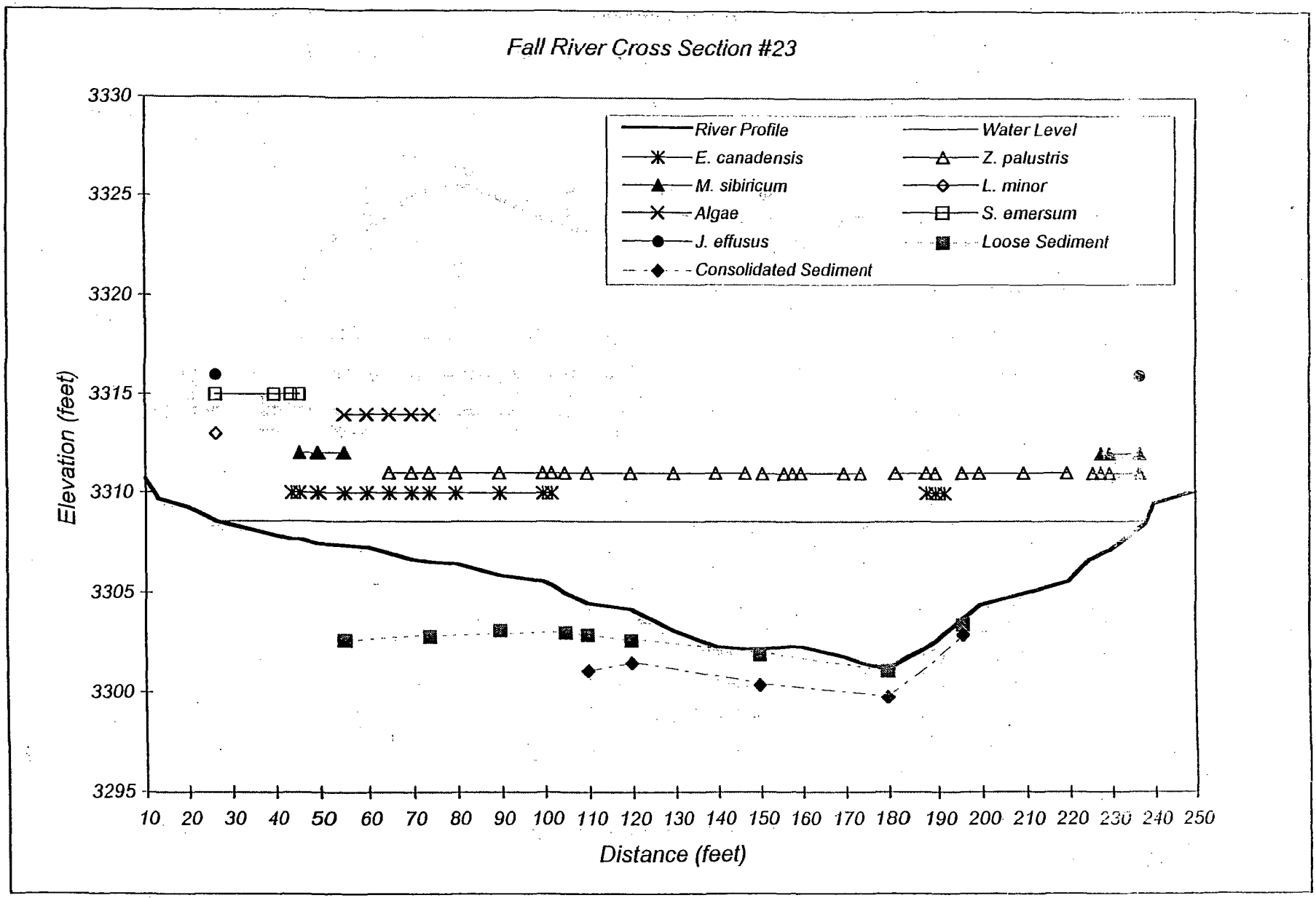

Fall River Cross Section #15
River Profile
Water Level
E.nuttallii
R. aquatilis
M. sibiricum
L. minor
J. effusus
Unknown
Loose Sediment
Consolidated Sediment
Elevation (feet)
3330
3325
3320
3315
3310
3305
3300
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
Distance (feet)

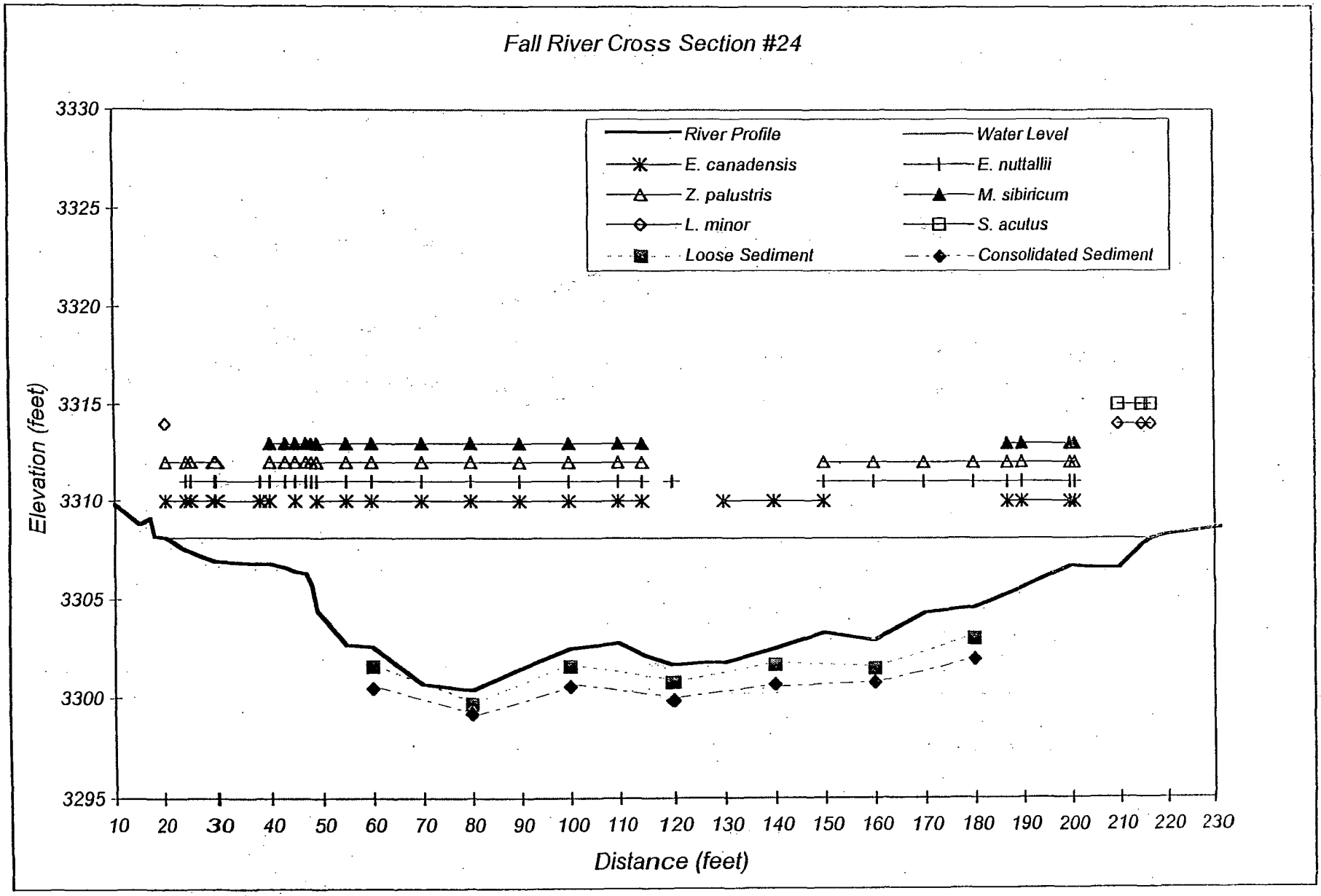

Fall River Cross Section #18
River Profile
Water Level
E. nuttallii
M. sibiricum
L. minor
S. emersum
Loose Sediment
Consolidated Sediment
Elevation (feet)
3330
3325
3320
3315
3310
3305
3300
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
Distance (feet)


Fall River Cross Section #19
River Profile
Water Level
E. nuttallii
M. sibiricum
L. minor
S. emersum
Loose Sediment
Consolidated Sediment
Elevation (feet)
3330
3325
3320
3315
3310
3305
3300
3295
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
Distance (feet)


Fall River Cross Section #21
River Profile
Water Level
E. nuttallii
Z. palustris
M. sibiricum
L. minor
Algae
J. effusus
Loose Sediment
Consolidated Sediment
Elevation (feet)
3330
3325
3320
3315
3310
3305
3300
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance (feet)


Fall River Cross Section #22
River Profile
Water Level
E. canadensis
Z. palustris
M. sibiricum
L. minor
Loose Sediment
Consolidated Sediment
Elevation (feet)
3330
3325
3320
3315
3310
3305
3300
3295
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance (feet)


Fall River Cross Section #23
River Profile
Water Level
E. canadensis
Z. palustris
M. sibiricum
L. minor
Algae
S. emersum
J. effusus
Loose Sediment
Consolidated Sediment
Elevation (feet)
3330
3325
3320
3315
3310
3305
3300
3295
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250
Distance (feet)


Fall River Cross Section #24
River Profile
Water Level
E. canadensis
E. nuttallii
Z. palustris
M. sibiricum
L. minor
S. acutus
Loose Sediment
Consolidated Sediment
Elevation (feet)
3330
3325
3320
3315
3310
3305
3300
3295
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230
Distance (feet)

A Study of the Habitat Characteristics of the Aquatic Vegetation of the Upper Fall River:

Final Report

Prepared for

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8 December, 1997

Acknowledgements

This study is the product of a team effort. Julian Colescott (North State Resources, Inc., Redding, CA) improved our field methods and diligently and conscientiously collected all of the field data. Rick Poore (Thousand Springs Ranch, Fall River Mills, CA) provided key field equipment and carried out the lab work for the sediment-texture and bedload samples. Rick also provided Julian with lodging during the sampling period. Dick Bidtsrup (Fall River Agri-Lab, McArthur, CA) conducted the sediment chemical analyses and made the key suggestion that we include sulphur in our analyses. Kelly Schuler (Fall River Resource Conservation District, McArthur, CA) contributed critical project coordination and provided Julian with the sampling boat. Dale Dennis (Fall River Wild Trout Foundation, Fall River Mills, CA) helped us to refine and improve our field methods. Dr. Fred Hrusa (North State Resources, Inc., Redding CA) provided expert consultations in plant systematics and field ecology. Dr. Steve Towers (North State Resources, Inc., Redding CA) assisted project coordination and budgeting. And together, this team and others (including Bill Fullerton and Dr. Mike Fitzwater) also provided a much-needed sounding board for my wild ideas throughout the project. Fred Hrusa and Steve Towers also provided fruitful commentary on an early draft of this report. Dr. Tyson Holmes designed the study and wrote the final report.

Introduction

The Fall River Resource Conservation District (FRRCD) is interested in assessing how elevated rates of sediment influx into the upper Fall River over the past two decades have affected the river's fishery. Given that aquatic vegetation can serve as an important source of food and cover for fish, of particular concern is the impact of this sedimentation on the river's aquatic plant community. For this reason, the FRRCD has funded this study to address the following three questions central to the ecological health of this fishery.

1. Based on information from previous studies in the Fall River and elsewhere, what environmental factors are likely to influence the distribution of plant cover in the upper Fall River?

2. How does plant cover vary across gradients in these environmental factors within the upper Fall River?

3. Are there differences among plant species in how they are distributed across gradients in these environmental factors within the upper Fall River?

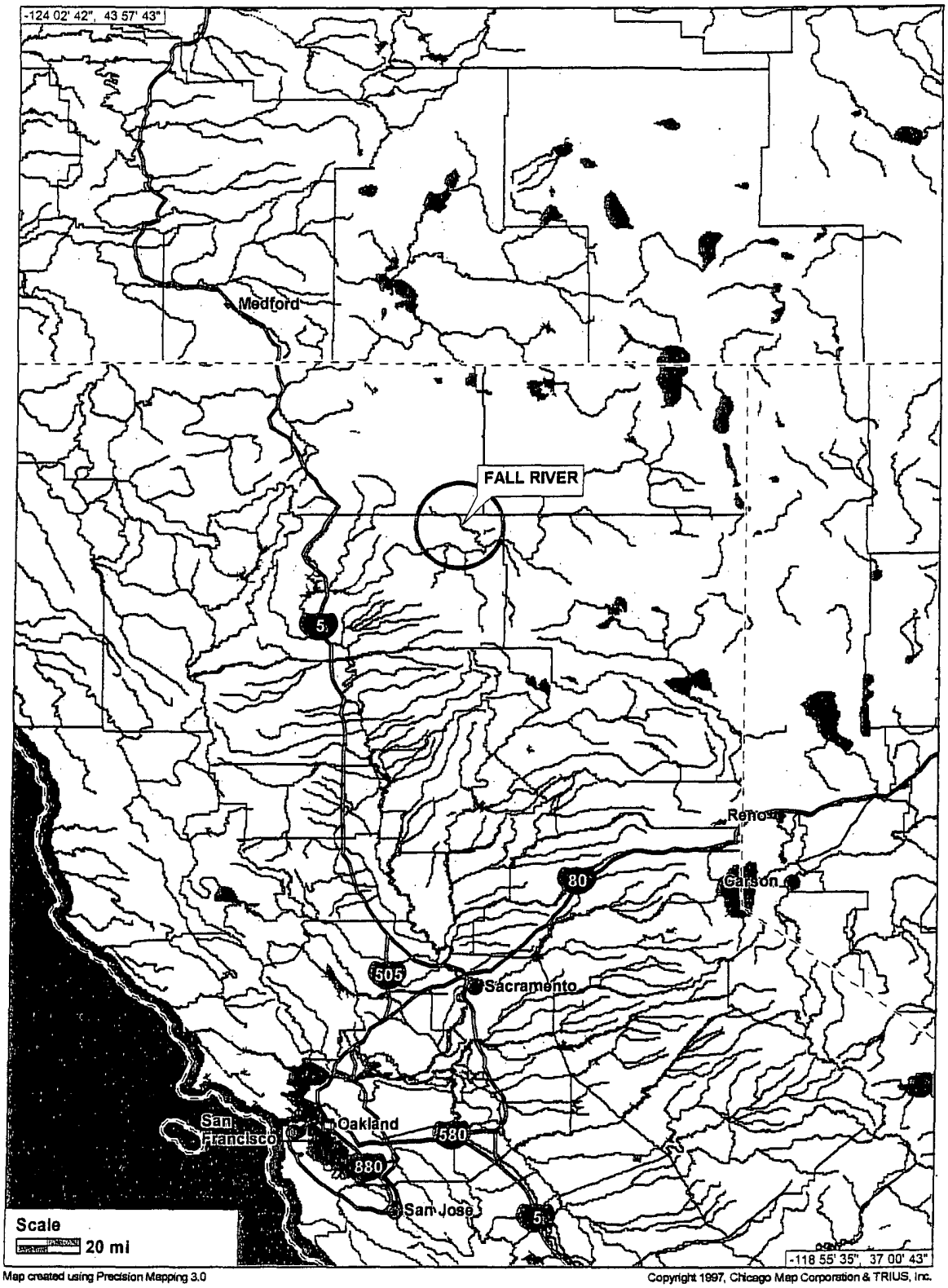
In answer to the first question, a review of the literature identified five environmental gradients that could potentially be related to the distribution of aquatic vegetation in the upper Fall River:

- stream-flow velocity,
- sediment stability,
- sediment fertility,
- sediment texture, and
- depth of sediment[a].

To begin to answer questions 2 and 3, data on the distribution of plant cover across these five gradients was collected within the upper Fall River during September 1997.

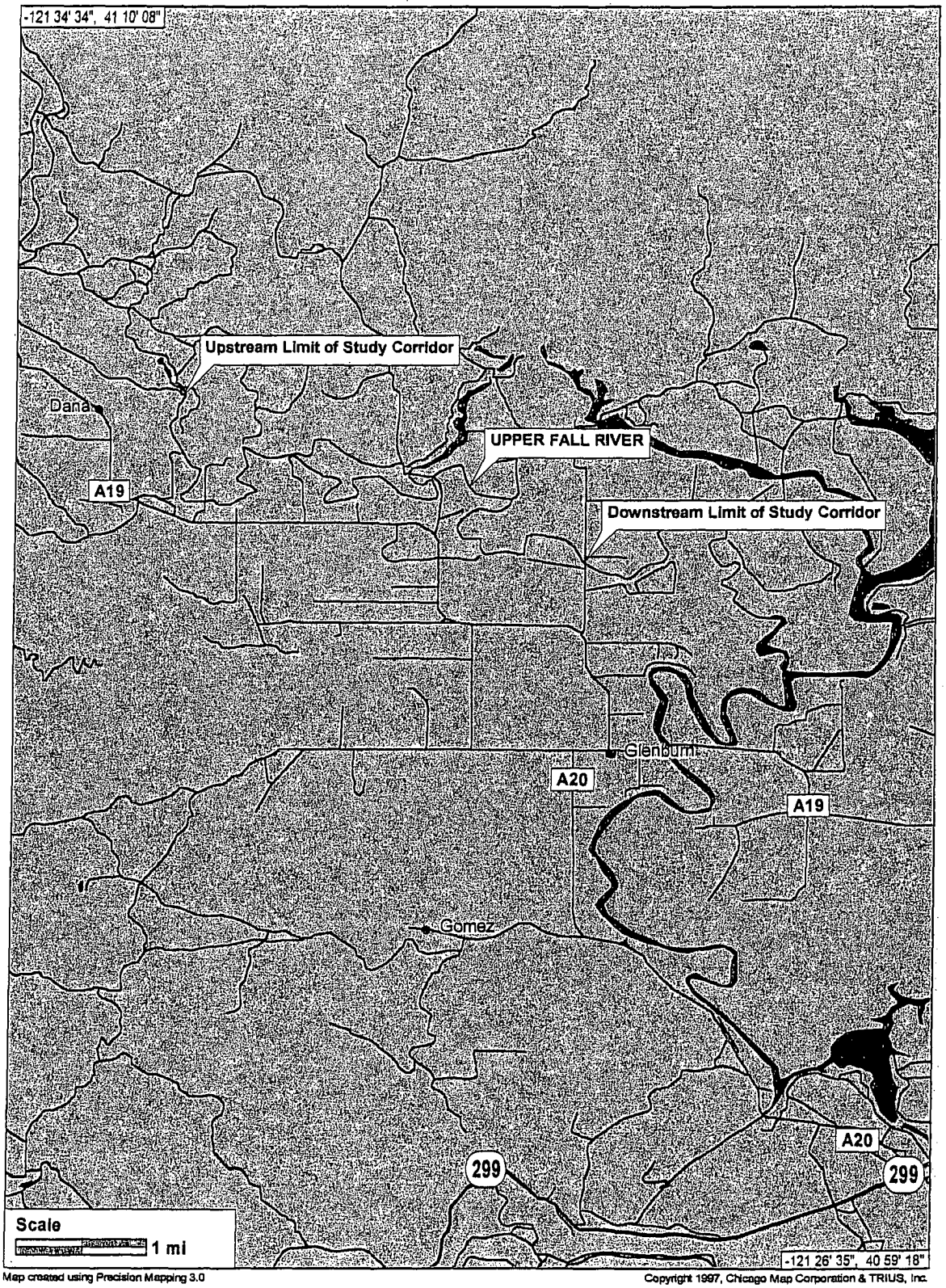
[a] Originally we had planned to use depth of plant burial as the fifth environmental variable, but Dr. Fred Hrusa (North State Resources, Inc.) recommended depth of sediment instead. Depth of sediment and depth of burial could be positively correlated, so that the former may provide an easier-to-measure surrogate of the latter. Moreover, aquatic plant species may vary in the range of sediment depths over which they are distributed because of differences in their requirements for available rooting volume.

Project Vicinity Map



North State Resources, Inc.

Project Location Map



North State Resources, Inc.

Methods

Study Site

The study was conducted within the Fall River between the upriver "navigation barrier" and Island Road Bridge. This "upper" reach encompasses that portion of the fishery that may have been most heavily impacted by recent sediment-deposition events.

Sampling Design

Our sampling design was stratified random. The river was divided into two sampling strata: 1) the reach from the "navigation barrier" to the confluence with Spring Creek and 2) the reach from the confluence with Spring Creek to Island Road Bridge. These strata were selected because during a Phase-I reconnaissance of the river it was observed that vegetation appeared to be much more abundant below the Spring-Creek confluence, which suggested that this confluence marked some type of change in habitat.

Sampling was conducted at fifty sampling locales along the river. Fifteen sampling locales were placed at random positions within each of the two strata described above. These random locales were located by estimating the time it would take to travel down the length of each stratum and then positioning sampling locales at random time points within those travel intervals. In addition to these thirty random positions, five sampling locales were placed in high-cover beds of each of four key aquatic plant species (*Elodea canadensis*, *Elodea nuttalliii*, *Myriophyllum sibiricum*, and *Zanichellia palustris*). High-cover beds were reconnoitered during travel to random locales. A map of our sampling locales is attached.

At each sampling locale along the length of the river, our measurements were made at a single sampling point that was placed at a predetermined random distance (5%, 25%, 50%, 75%, or 95% of channel width) perpendicular to the right bank (heading downstream).

Measurement Techniques

We made the following set of measurements at each sampling point (in the order listed below).

1. Sediment and Water Depth

At the front right boat corner and at a position not disturbed by sediment sampling, a measurement of sediment depth was obtained by pushing a 1/2"-diameter rod into the sediment until hard substrate was encountered. Water depth was measured with a ruled rod.

2. Stream-flow velocity

Stream-flow velocity was measured 6-inches below the water surface and 6-inches above the riverbed with a Marsh-McBirney Flo-Mate 2000 velocity meter. Twelve, consecutive, 5-second averages were obtained at each depth to obtain information on fine-scale variation in flow velocity.

3. Plant Cover

We used schedule-40 PVC to construct a transect on a dipping rod. The transect measured approximately 1.8 m in length. The dipping rod, attached perpendicularly to the transect, allowed the transect to be held horizontally in the water just above the vegetation to measure plant cover. The percentage of this transect intercepted by all vegetation combined and then by each of the four key species (*E. canadensis*, *E. nuttalliii*, *M. sibiricum*, and *Z. palustris*) was estimated ocularly by cover class:

Cover Class	% Plant Cover
0	0
1	>0 to 5
2	>5 to 25
3	>25 to 50
4	>50 to 75
5	>75 to 95
6	>95 to 100

The transect was painted to indicate lengths of 5%, 25% and 50% to facilitate accurate cover classification. Four transects were read at each sample point (one transect at each corner of the sampling boat).

4. Sediment stability

Following velocity measurement, a Helley-Smith Bedload Sampler (3" mouth and 250-mm mesh collector) was lowered to the riverbed at the front, right corner of the boat. The bedload sampler was held in place on the riverbed for 5 minutes (McCarthy et al. 1991). Collected sediment was sealed in a plastic bag, and this bag was labeled with the word "stability", the date of collection, position on the river, and sampling number. Sediment was later sun dried to constant weight[b] and this final weight recorded.

5. Sediment fertility

A sand auger (8.255-cm diameter) was inserted approximately 18 cm into the sediment at the front right corner of the boat. The total volume (ca. 960 cc) of this sample was sealed in a plastic bag. This bag was labeled with the word "fertility", date of collection,

[b] All weighing, here and elsewhere, was performed on a Acculab V1200 scale.

position on the river, and sampling number. The collected sediment was then thoroughly mixed by hand, sealed within its bag, and packed in ice in a cooler for same-day transportation back to a local freezer facility.

Chemical analyses were conducted by Fall River Agri-Labs (McArthur CA). Three 3.75-oz subsamples were removed from each frozen sample for drying to constant weight in a 105°C free-convection oven. Drying typically required 3-4 hrs. Dried subsamples were sieved ("window-screen" mesh) to remove organic debris, gravel, etc. From the three dry, sieved subsamples, 15 g were analyzed for total N, 10 g were analyzed for sulphate, 2.5 g were analyzed for phosphate, and 2.5 g were analyzed for potassium. pH was determined on thawed, wet subsamples using a Chemcadet pH meter. Further details of these analyses can be obtained from Fall River Agri-Labs.

6. Sediment Texture

A second sediment core was collected as above from the left rear boat corner for texture analysis and sealed in a plastic bag labeled with the word "texture", date of collection, position on the river, and sampling number. Texture samples were dried to constant weight in full sun. Each weighed sample was wet-sieved through a 0.5-mm mesh. Sediment collected on the sieve was dried and weighed.

Data Quality Control

An example of one of our completed data sheets is attached to the back of this report.

All original hardcopies were photocopied. Originals were mailed to the FRRCD for archiving. A complete set of copies was mailed Steve Towers (NSR, Inc.) for archiving and to Barry Anderson for data entry into an MS Access database. I examined data for possible erroneous values through multivariate scatterplots.

A complete copy of the database will be kept by Barry (in MS Access) and by myself (in MS Excel). An electronic copy of the database can be provided as ASCII-text or as an MS Excel spreadsheet, whichever is preferred. Interested parties should contact FRRCD.

Statistical Analysis

To aid interpretation of this high-dimensional data set, analysis began by dividing the data into two groups of environmental variables.

Sediment-quality factors

- Phosphate concentration

- Total nitrogen concentration
- Sulphate concentration
- Potassium concentration
- pH
- % coarse fraction

Fluvial factors

- Water velocity 6" below the water surface[c]
- Water depth
- Sediment depth
- Sediment stability[d]

A principal components analysis was run on the sediment-quality variables to see if these several variables could be reduced to a few key environmental gradients. However, the first principal component explained only 30% of the total variance. Bivariate scatterplots revealed that this weak principal component analysis was a result of low correlations among the sediment-quality variables. As a result, further principal component analyses were not pursued.

Regression analyses were also opted against because regression models would express plant abundance as a function of a set of environmental factors, which would too strongly insinuate that these environmental factors in some way **cause** the variation observed in plant abundance. Strictly, we cannot draw conclusions about cause and effect from our mensurative data.

Instead, medians and their 95% confidence intervals[e] were calculated for each of the following data subsets:

- random sampling points above Spring-Creek confluence,
- random sampling points below Spring-Creek confluence,
- sampling points within high-cover beds of *Z. palustris*,
- sampling points within high-cover beds of *M. sibiricum*,
- sampling points within high-cover beds of *E. nuttallii*, and
- sampling points within high-cover beds of *E. canadensis*.

The median, rather than arithmetic mean, was calculated as an estimate of central tendency for each subset, because the arithmetic mean can be strongly influenced by isolated extreme values. Standard errors must be reported because they provide

---

[c] Water velocity 6" above the sediment was dropped from the analysis because we want to identify factors influencing the distribution and abundance of aquatic plants but measurements of water velocity at this depth may largely be influenced by rather than influencing plant abundance.

[d] The bedload measurement for sampling point #11 was 109 g. In contrast, average bedload sample weight was 3.8 g across the remaining 49 measurements. Rick Poore suggested that such a large measurement (109g) could result if a bedload sample had been taken in a high-velocity channel between two patches of aquatic vegetation; but, no vegetation was present at this sampling point. I assumed that this extreme datum was a measurement error and dropped it from the analysis.

[e] Confidence intervals on medians were calculated from the bootstrapped distributions of each sample median.

measures of the uncertainty in our estimates of the medians due to random sampling error.

A pair of boxplots (one boxplot of the data above the Spring-Creek confluence and one of the data below the confluence) was prepared for each sediment-quality, fluvial, and plant-cover variable (most appear in figures below[f]). Comparison of boxplots within a pair allows one to examine how the distributions of sample data differ above and below the Spring-Creek confluence. Medians for high-cover beds of *E. canadensis*, *E. nuttallii*, *M. sibiricum* and *Z. palustris* are also plotted on each sediment-quality or fluvial boxplot pair in order to illustrate how environmental conditions within high-cover beds of each species compare to conditions sampled at random from throughout the upper river.

In addition, some bivariate scatterplots of plant cover variables on environmental variables were constructed in order to explore relationships between vegetation and environmental patterns within the random sample. Correlations are reported as estimates of Spearman's ρ, which ranges in value from 0.0, for no correlation, to 1.0, for perfect correlation. Spearman's ρ was chosen for its robust ability to detect non-linear (but monotonic) relationships among variables.

[f] The caption for Fig. 1 describes how to interpret boxplots.

Results

A complete summary of observations is provided in **Table 1** (Appendix). The most striking results are described here and illustrated in **Figs. 1-12**.

Vegetative Cover

Total vegetative cover seemed to be higher below Spring Creek (median = 76.88, SE = 32.24) than above Spring Creek (median = 9.38, SE = 20.04; **Fig. 1**). Within this pattern for total vegetative cover, species appeared to differ in their distributions. For example, while *Z. palustris* was particularly abundant below the Spring-Creek confluence (median = 44.38, SE = 27.20; **Fig. 2**), *M. sibiricum* did not show up at any of the random sample points in this lower section (**Fig. 3**). *E. nuttallii* (**Fig. 4**) and *E. canadensis* (**Fig. 5**) were found in modest abundance above and below the Spring-Creek confluence.

Sediment-Quality Factors

A fairly narrow range in sediment pH was observed in the river (**Fig. 6**). High-cover beds of *Z. palustris* and *M. sibiricum* were observed in slightly acid sediments (**Fig. 6 MYSI** median = 6.8 and **ZAPA** median = 6.7). In our random sample, abundance of *Z. palustris* peaked at pH's of 7 to 7.1 (**Fig. 6 inset**), while *M. sibiricum* occurred at a median pH of 7.0. Thus *Z. palustris* and *M. sibiricum* appear to have been most abundant at sediment pH's near neutrality.

Sediment sulphate concentrations seemed to be somewhat higher below than above the Spring-Creek confluence (**Fig. 7**). High-cover beds of *M. sibiricum* appeared to have the lowest sediment concentrations of sulphate among the four species (**Fig. 7 MYSI** median = 1.2 ppm). In the random sample, median sulphate concentration was 7.5 ppm in *M. sibiricum* beds compared to overall median of 13.6 ppm for the upper river. In contrast, sediments relatively enriched in sulphate supported the highest cover of *Z. palustris* (**Fig. 7 inset** Spearman's $\rho = 0.50$ and **ZAPA** median = 30 ppm).

In the random sample, the highest cover of *E. canadensis* was observed at lower sediment phosphate concentrations (**Fig. 8 inset**), while, somewhat curiously, sediment phosphate concentrations were quite high in the high-cover beds that we observed of this species (**Fig. 8 ELCA** median = 29 ppm).[g]

[g] This may have resulted if augers hit patches of sediment rich in organics (i.e., "hot spots"). A better sampling procedure would be to auger sediment from multiple places at each sampling point; but this was not an option within our limited sampling time.

Fluvial Factors

In our random sample, we observed the highest cover values of *E. nuttallii, E. canadensis,* and *M. sibiricum* at intermediate water flow velocities (**Fig. 9**). *Z. palustris* appeared to be most abundant at somewhat higher flow velocities (**Fig. 9** Spearman's $\rho = 0.33$ and **Fig. 10 ZAPA** median = 1.11 feet/s). In contrast to the random sample (**Fig. 9**), our measurements in high-cover beds of *E. canadensis* included some very low water flow velocities (**Fig. 10 ELCA** median = 0.04 feet/s).

All species tended to proliferate in shallower rather than deeper waters (**Fig. 11**). High-cover beds of *M. sibiricum* tended to have the shallowest distribution (**Fig. 11 MYSI** median = 2.10 feet) and high-cover beds of *Z. palustris* tended to have the deepest (**Fig. 11 ZAPA** median = 4.5 feet). These results are consistent with the following patterns observed in the random sample: 1) *M. sibiricum* was only found at depths shallower (3.5 feet and 4.0 feet) than the median water depth that we measured in the river (4.7 feet); and 2) percent cover of *Z. palustris* tended to increase with increasing water depth (**Fig. 12**, Spearmans $\rho = +0.30$).

High-cover beds of *E. nuttallii* and *E. canadensis* were observed on the thinnest and thickest sediment deposits, respectively (**Table 1**). Also, among the four species, high-cover beds of *E. canadensis* seemed to be associated with the finest sediments (**Table 1**).

Discussion

Sampling Uncertainty

While some potentially informative patterns exist within this data set, it is important to keep in mind that these data consist in part of a random sample and that they therefore contain some random sampling error. Random sampling error introduces uncertainty into our estimates of median values. One useful measure of uncertainty is a confidence interval on the median. 95% confidence boundaries of the median are reported for all measured variables in **Table 1**. An example will best demonstrate how to interpret these confidence intervals. For instance, for the random sample of water velocity measured above the Spring-Creek confluence, we can be 95% confident that the interval of 0.62 feet/s to 0.88 feet/s contains the true median water velocity for this section of the river. **Table 1** illustrates that some estimates of medians contain more error than others. For example, confidence intervals for pH or potassium concentration were relatively narrow for measurements made below the Spring-Creek confluence, but larger for % cover of *E. nuttallii* above the confluence. All conclusions drawn from these data should be couched in an appreciation of the sampling uncertainty associated with each measure as illustrated in **Table 1**.

Cause and Effect

As was stated in the Phase-I report and eluded to earlier in this report, the results of this study cannot tell us what environmental factors **cause** the observed vegetation patterns because this is an **observational** and thus a correlational study. An example of a pitfall in interpreting correlational results is that two variables may be found to be correlated but that correlation may actually be caused by some third, unmeasured variable. Clear understanding of cause-and-effect relationships can only be achieved by somehow **manipulating** the system under study. One form of manipulation useful for this purpose is scientific experimentation. This is not to say, however, that our understanding of how to best manage the upper river hinges upon elaborate follow-up experiments. Instead, we could use the patterns observed in this study's data, in conjunction with the research of others on the Fall River's vegetation, to plan and implement informed restoration techniques. In this sense, the restoration work itself becomes more experimental in nature. Experimental restoration work should, of course, begin on a restricted scale.

Physical-Habitat Correlates

With the foregoing precautions in mind, along with the additional caveat that data from a single year strictly only apply to the year in which they were obtained, we can draw some tentative conclusions about possible habitat correlates of the aquatic-plant species examined.

In our sample, *M. sibiricum* appeared to be absent or rare below the Spring-Creek confluence and instead restricted to the sulphate-poor sediments above the confluence. This contrasts with *Z. palustris*, which was apparently much more abundant below the confluence, perhaps especially on sediments relatively rich in sulphate. This contrast is even more marked than the sulphate data alone suggest, in that the sulphate chemical analyses were performed on the fine fraction of collected sediments and the percentage of fine particles was higher in high-cover beds of *Z. palustris* than in high-cover beds of *M. sibiricum*. That sulphate concentrations appear to be somewhat higher below than above the Spring-Creek confluence may be worth further investigation, especially since sediment sulphate concentrations are potentially correlated with the distribution of two of the river's key aquatic-plant species. Is Spring Creek a source of sulphate? Are Bear Creek sediments sulphate poor?

Our data seem to suggest that *Z. palustris* may grow more abundantly at some of the higher water flow velocities found in our sample of this river (**Figs. 9** and **10**). Perhaps somewhat higher flow velocities stimulate photosynthesis of *Z. palustris* but depress photosynthesis and/or stimulate dark respiration in the other species (Westlake 1967, Madsen et al. 1993). However, this is not to say that *Z. palustris* prefers high-velocity waters. Other authors cite this species as preferring slow-moving streams and pools (Munz and Keck 1973, Onaindia et al. 1996). In the Fall River, F. Hrusa and I observed upstream edges of clumps of *Z. palustris* that had apparently been uprooted by higher flow velocities. For now, we may tentatively conclude that *Z. palustris* may simply be somewhat tolerant of some of the "less slow" velocities found in this rather **slow-moving** river. Alternatively, the higher water velocities we measured at 6" below the surface could have resulted from water being accelerated up and over dense beds of *Z. palustris*.[h]

Because water attenuates light, it is not surprising that all four species seemed to be most abundant in shallower waters. Of these four species, *Z. palustris* may be able to establish and grow in somewhat deeper waters (**Fig. 11**), and *M. sibiricum* may be most likely to occur where the river is relatively shallow (**Fig. 11**), although one should keep in mind that these differences among species are not especially pronounced.

It is possible that *E. nuttallii* and *E. canadensis* are, respectively, the most and least sensitive to burial by sediment, given that high-cover beds of *E. nuttallii* occurred on the thinnest sediment deposits and high-cover beds of *E. canadensis* occurred on the thickest. Alternatively, one could speculate that *E. canadensis* requires the largest rooting volume and *E. nuttallii* requires the smallest. From one perspective, the latter explanation may be more likely given that measured rates of sediment movement were essentially nil in high-cover beds of both species, suggesting that significant rates of burial were not occurring at the time of measurement in September. On the other hand,

[h] Interestingly, we found some high-cover beds of *E. canadensis* in very slow moving waters—so slow that in places the *E. canadensis* was enveloped in thick layers of filamentous algae.

it may be that species' distributions are most sensitive to rates of burial earlier in the growing season, when plants are first becoming established.

High-cover beds of *E. canadensis* seemed to have the finest sediments and high-cover beds of *M. sibiricum* seemed to have the coarsest sediments (**Table 1**). *E. canadensis* has been reported elsewhere as having an affinity for finer substrates (Bowmer et al. 1995), although it has been reported on sandier substrates as well (Kozhova and Izhboldina 1993).

The Physical Environment versus Population Processes

The focus of this study has been the relationships between physical environmental parameters (i.e., sediment-quality and fluvial factors) and the distribution of aquatic plants. However, correlations may also exist among species. For example, **Fig. 13** illustrates a reciprocal relationship in % cover between the two *Elodea* spp. (Spearman's $\rho = -0.33$), and **Fig. 14** depicts as similar but slightly weaker relationship in % cover between *Z. palustris* and *E. nuttallii* (Spearman's $\rho = -0.29$). These type of relationships could result if species are competitively excluding one another. This seems especially likely for the two *Elodea* spp. given that they appear to have a number of similar habitat preferences (**Figs. 6, 7** and **11**). Given that *E. nuttallii* was found in abundance on thinner sediments that *E. canadensis* and *Z. palustris*, perhaps thin sediments provide a refuge from competition for *E. nuttallii*. However, negative correlations in abundance among species by no means constitute conclusive proof that competition between those species is an important factor underlying their differing distributions; instead, these relationships should send a warning to us that restoration projects cannot ignore the possibility that population processes, such as competition, may be at work among the aquatic-plant species of this ecosystem.

Recommendations for Restoration

General Recommendations

- ☑ As discussed above, any restoration work based on the results of this study should be small-scale and experimental.

- ☑ Restoration efforts should probably not be concentrated on any one species. Instead, projects should seek to produce a mosaic of vegetation that can best support a diversity of riverine wildlife.

- ☑ I am currently planning a pilot test of an in-river planting technique ("ballast buckets") with H.A.R.T., Inc. (Sacramento, CA). If these tests are made and results are positive, then this technique could also be tested in small-scale restoration trials within the Fall River. This technique holds some promise in that it is best suited for establishing stands of perennial plants (all four species in this study are perennial) and it would permit localized sulphate fertilization. Tom Taylor (Entrix, Inc., Walnut Creek, CA) has been able to establish *Elodea* spp. in ponds in small-scale hand plantings.

Specific Recommendations

- ☑ The growth of *E. canadensis* may be promoted by placing some type of mechanical baffles in the river to trap thicker accumulations of fine sediments (**Table 1**) and slow water velocities (**Fig. 9** and **Table 1**). However, excessive slowing of flow velocities may facilitate thick growth of filamentous algae on *E. canadensis* (see footnote "h" above).

- ☑ The creation of mixed stands of *E. nuttallii* and *E. canadensis* or *E. nuttallii* and *Z. palustris* may not be possible due to interspecific competition (**Figs. 13** and **14**)[i] .

- ☑ It may be possible to promote growth of *E. nuttallii* by producing areas of thinner sediments (**Table 1**). Reducing the influx of sediments into the river may also reduce burial of *E. nuttallii* (**Table 1**).

- ☑ Restoration trails for *Z. palustris* in the river above the Spring-Creek confluence should probably be concentrated in areas of somewhat deeper waters (**Figs. 11** and **12**) and higher sediment sulphate concentrations (**Fig. 7**). Creation of these conditions could possibly, but not necessarily, promote the expansion of *Z. palustris*.

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[i] However, a mixed restoration planting could serve as an applied experiment for more definitively examining the nature of competition between these species.

- ☑ Sediments from Spring Creek may be somewhat enriched in sulphate, and/or sediments from Bear Creek could be somewhat sulphate poor (**Fig. 7**). Both of these highly-speculative possibilities should be explored further through sulphate analyses on sediments of these tributaries. If Bear Creek sediments are indeed low in sulphate, then efforts to restore *Z. palustris* to the upper river may require measures to reduce sediment influx from Bear Creek.

- ☑ In contrast to *Z. palustris*, we found high-cover beds of *M. sibiricum* in shallow waters (**Fig. 11**) and sulphate-poor sediments (**Fig. 7**). This does not necessarily indicate that these are the conditions that this species prefers; however, managers could try a mosaic restoration strategy that includes deep-water, sulphate-richer sites for *Z. palustris* and shallow-water, sulphate-poorer sites for *M. sibiricum*.

- ☑ *M. sibiricum* can produce high cover on coarser sediments. Managers could experiment with shallow patches of coarse sediments as restoration sites for this species.

No-Action Alternative

Will the Fall River return to a more desirable vegetative condition without any active restoration? This question asks us to extrapolate and it is unwise to extrapolate with any certainty from data collected at one time of year from just one year. However, the data from this study do tentatively suggest that the future structure and composition of the vegetation community of the Fall River may depend in part upon trends in the quantity, texture, and sulphate concentrations of sediments flowing into the river from Spring and Bear Creeks. Estimates of historical, current and future trends in these three sediment parameters within these two tributaries would provide information useful for assessing the "no-action" alternative.

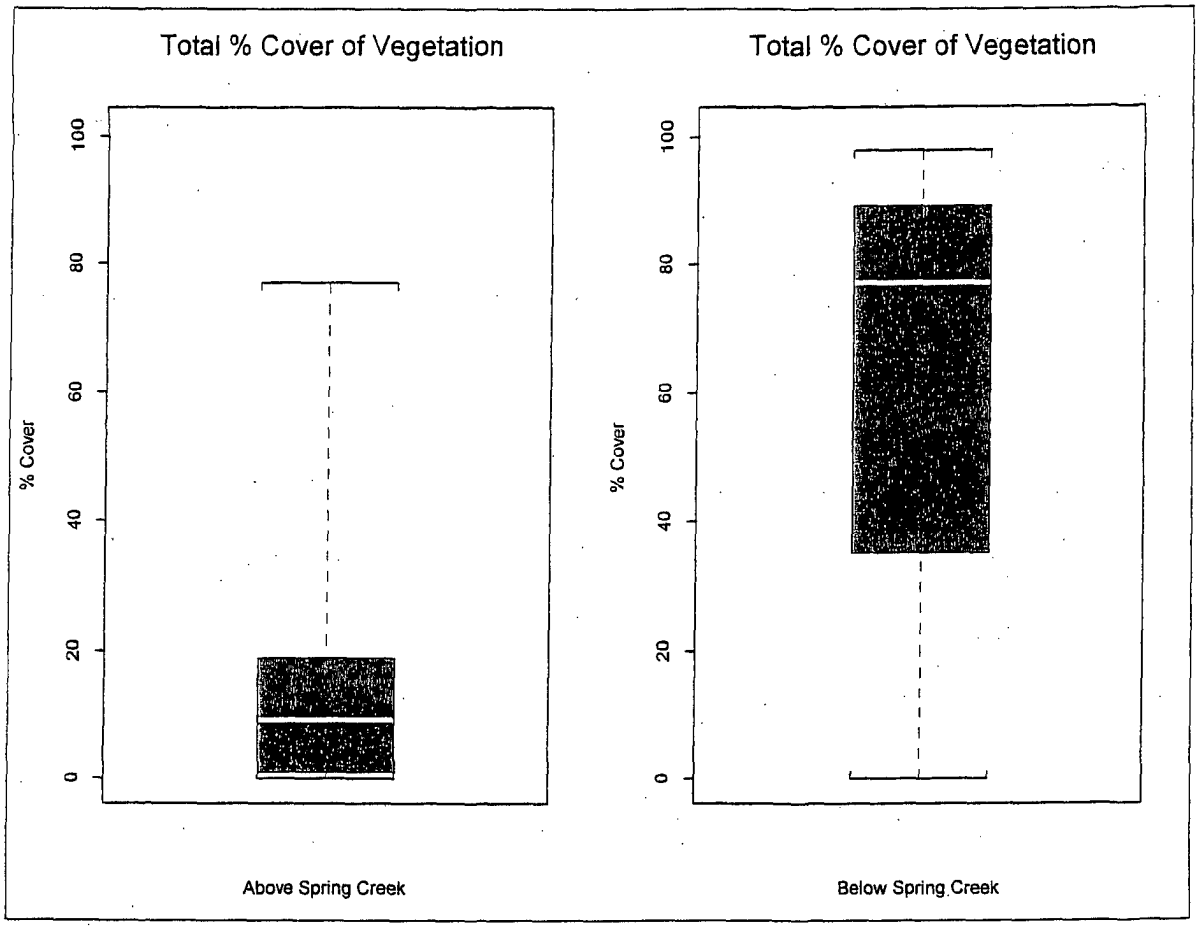

Figure 1: Total percent (%) cover of vegetation above and below the Spring-Creek confluence. The white bar in the center of each shaded area is the median (i.e., half of the measured values lay above the white bar and half lay below). The shaded area contains the central 50% of the measured values. The upper and lower bars in each boxplot are the largest and smallest measured values, respectively.

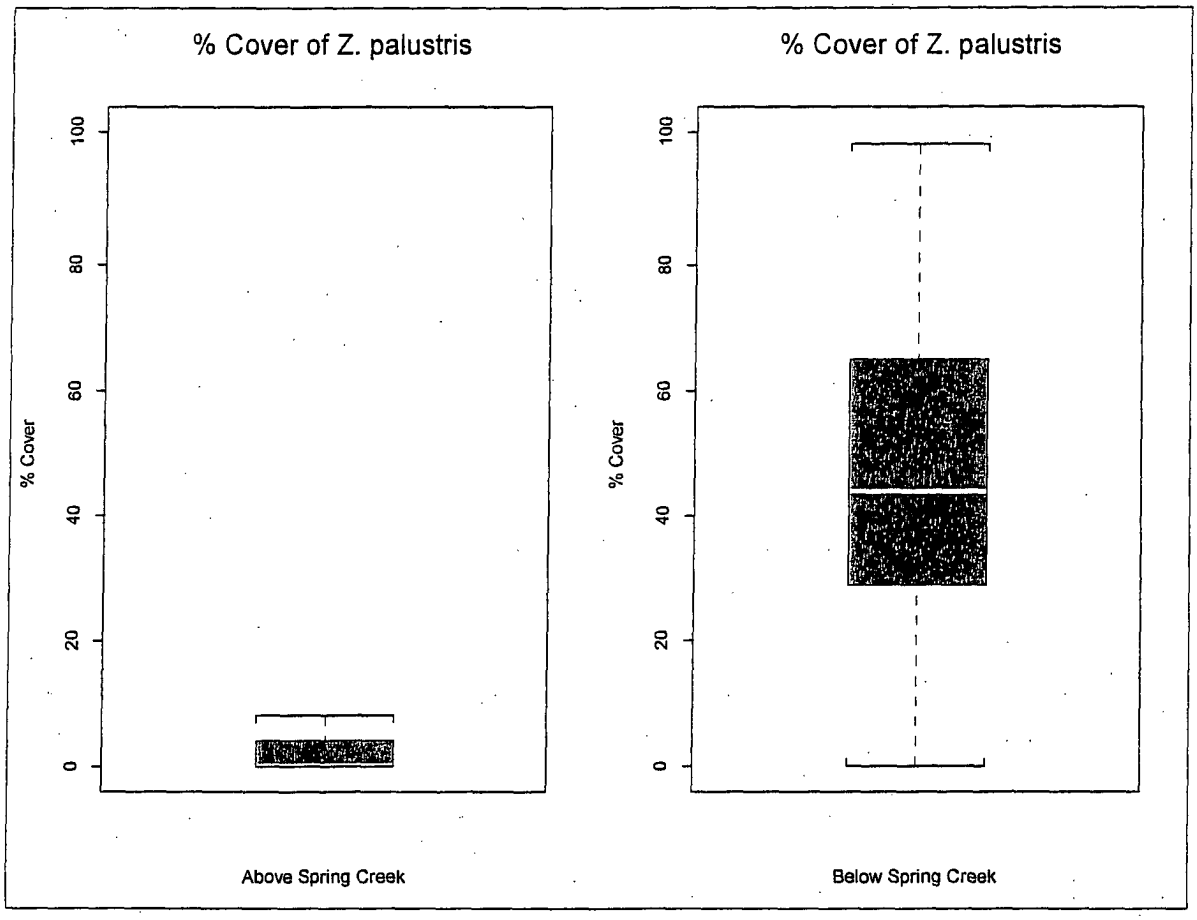

Figure 2: Percent cover of *Z. palustris* above and below the Spring-Creek confluence.

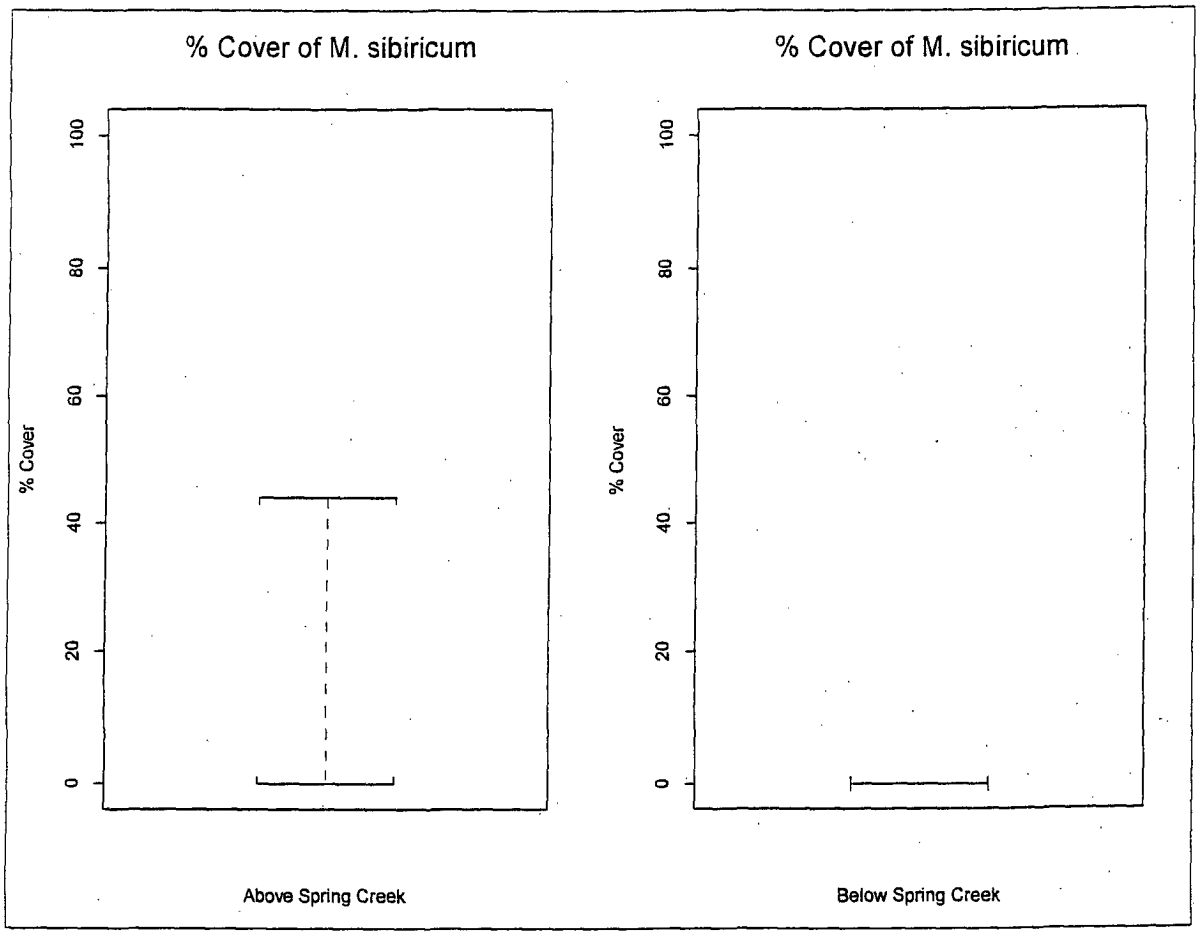

Figure 3: Percent cover of *M. sibiricum* above and below the Spring-Creek confluence.

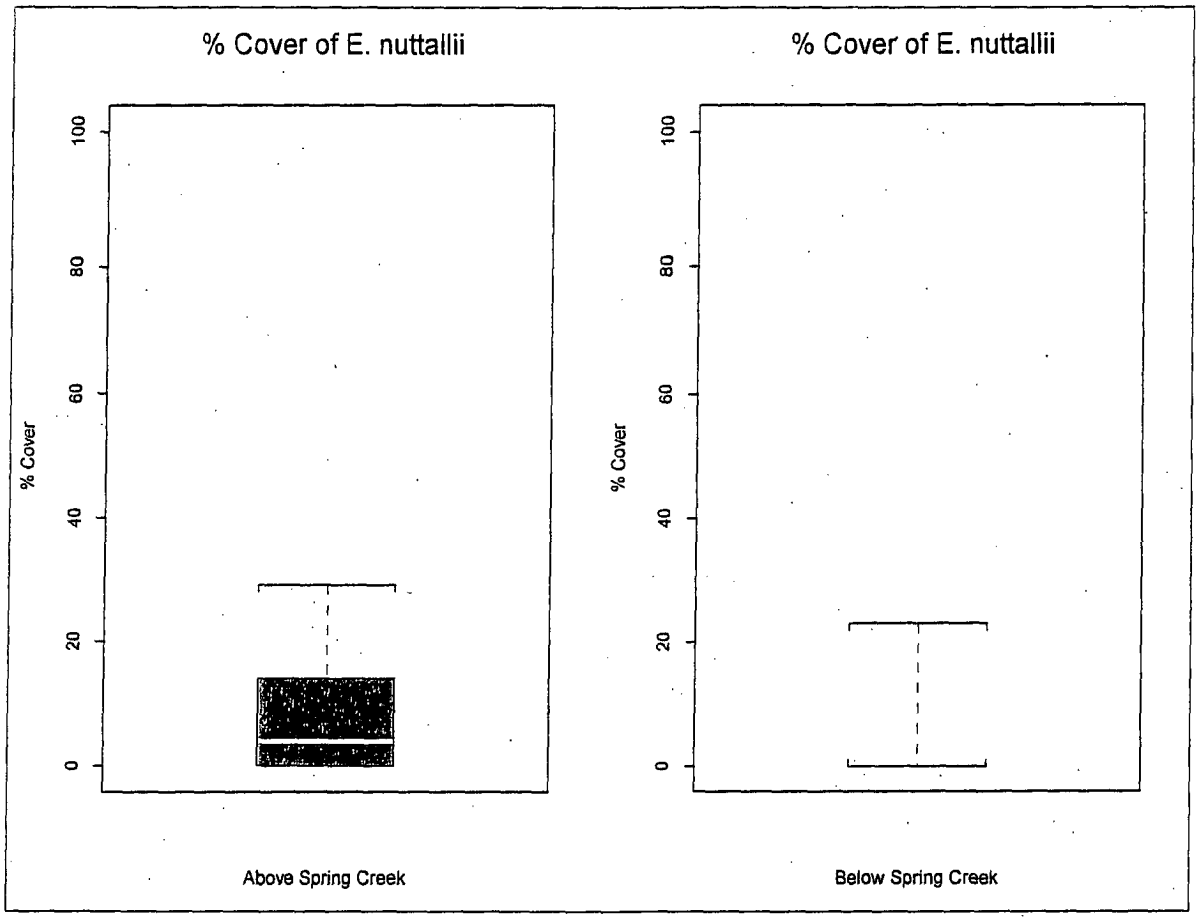

Figure 4: Percent cover of *E. nuttallii* above and below the Spring-Creek confluence.

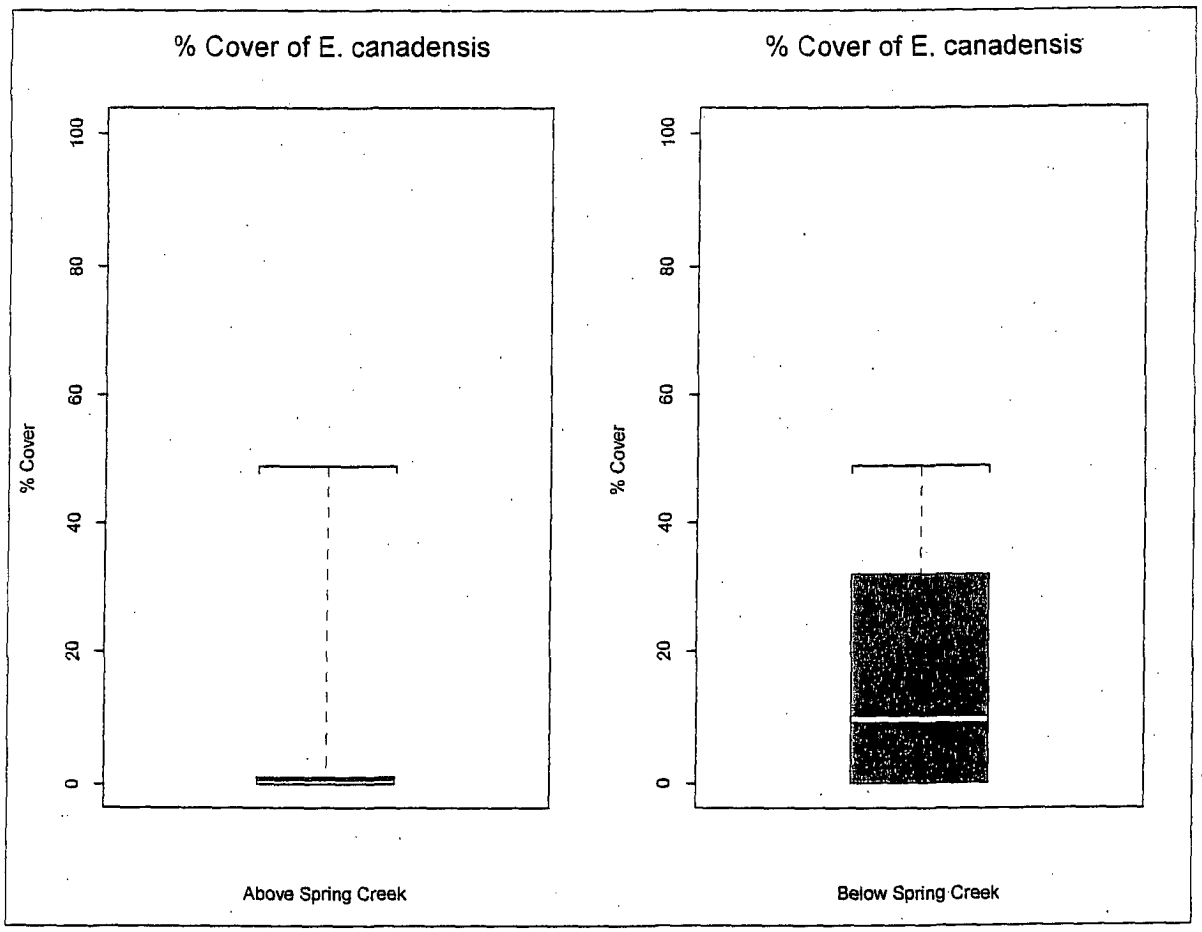

Figure 5: Percent cover of *E. canadensis* above and below the Spring-Creek confluence.

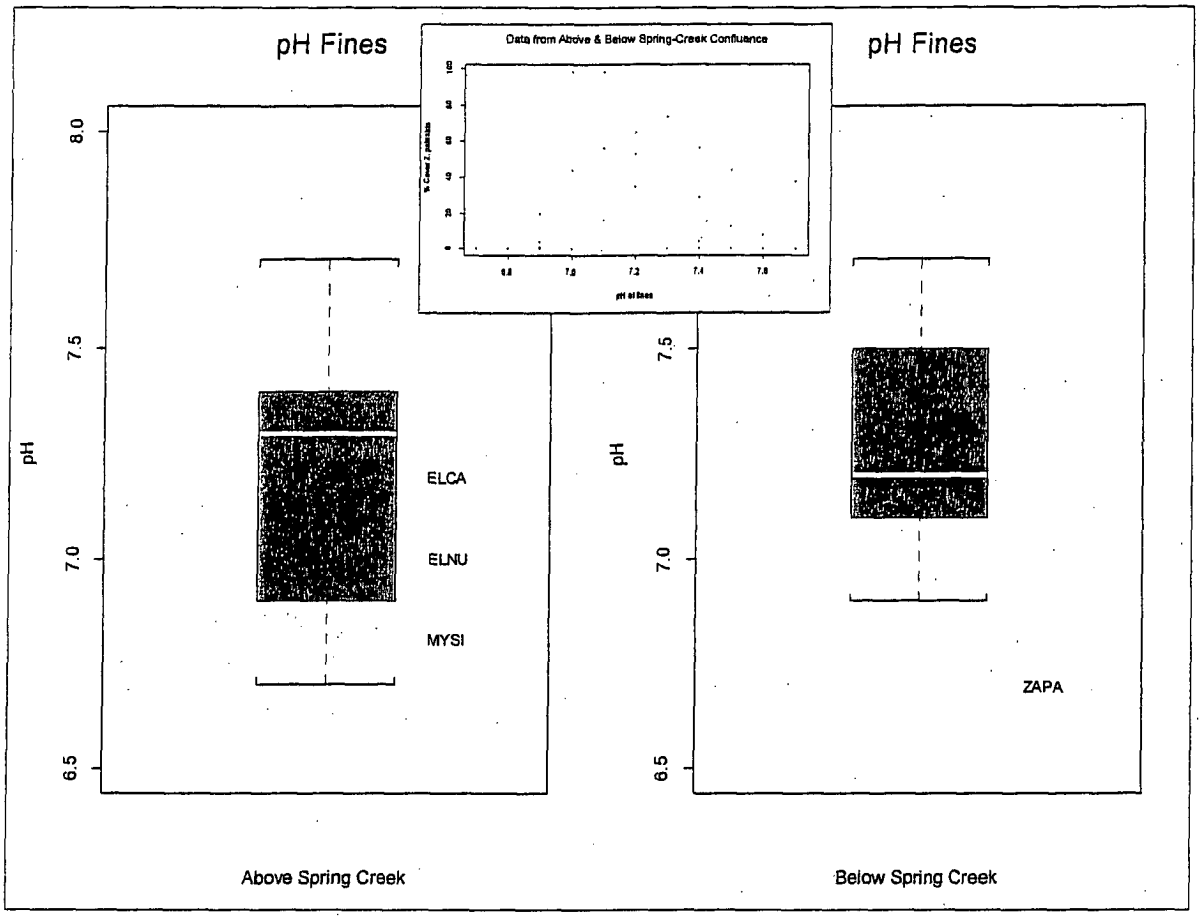

Figure 6: Sediment (fine fraction) pH above and below the Spring-Creek confluence. Inset scatterplot shows relationship between percent cover of *Z. palustris* and sediment pH in the random sample.

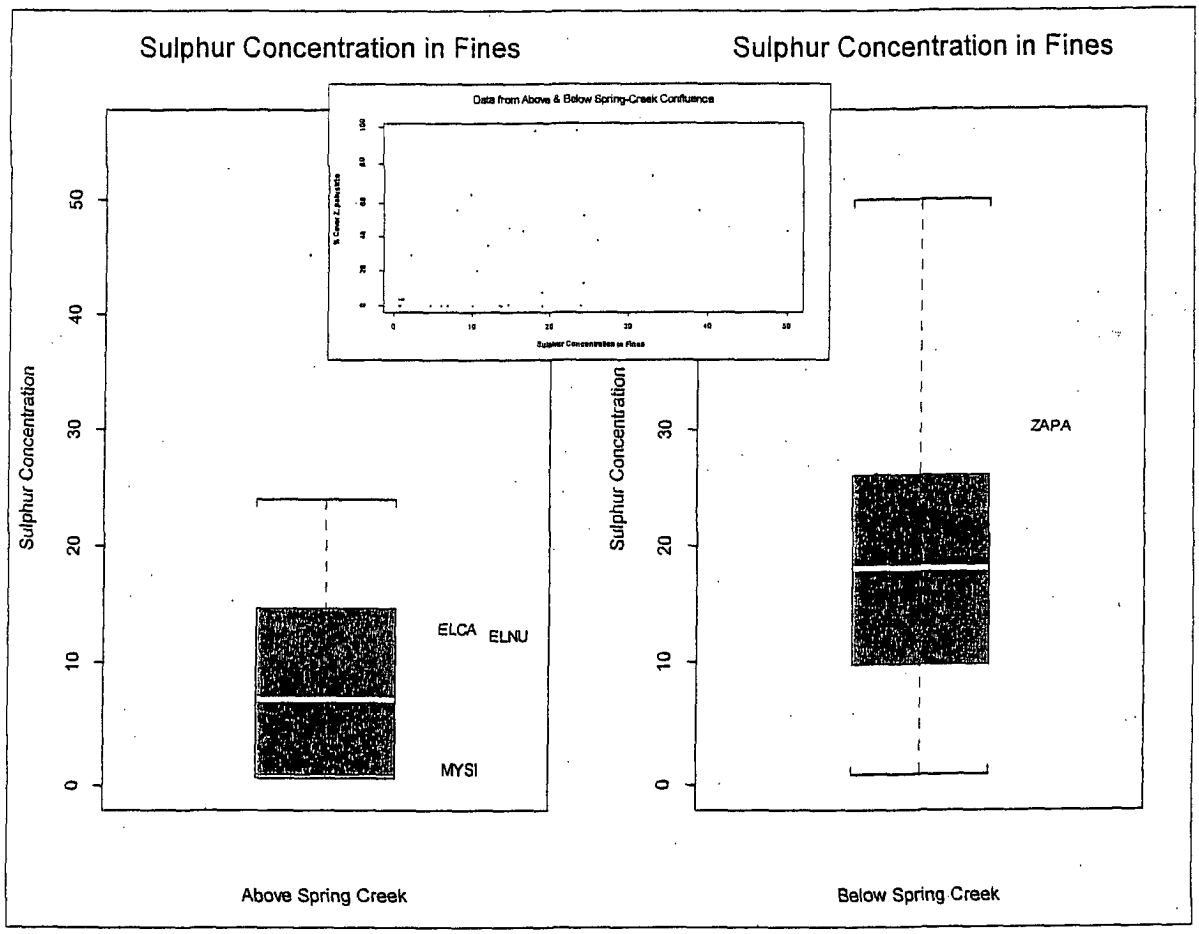

Figure 7: Sediment (fine fraction) sulphate concentration (ppm) above and below the Spring-Creek confluence. Inset scatterplot shows relationship between percent cover of *Z. palustris* and sediment (fine fraction) sulphate concentrations (ppm) in the random sample (Spearman's $\rho = +0.50$).

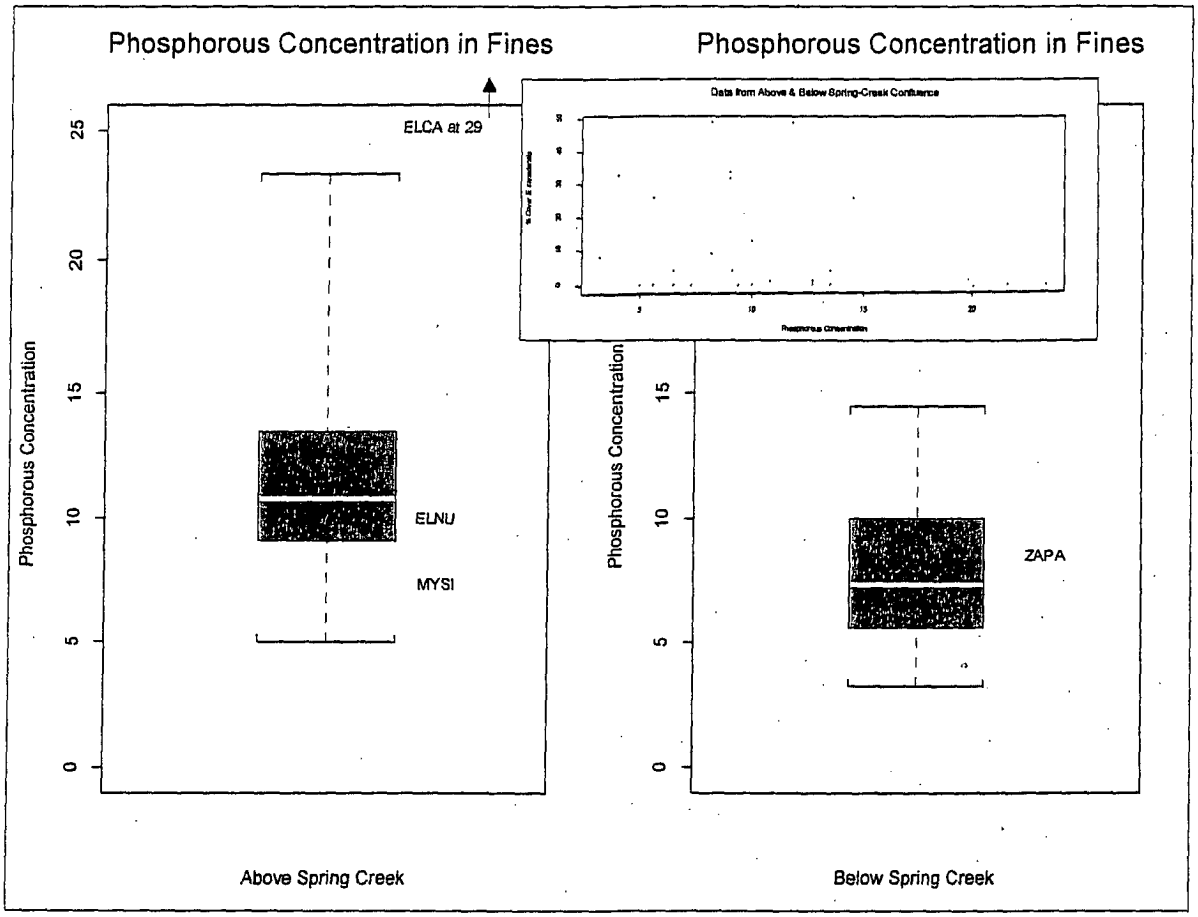

Figure 8: Sediment (fine fraction) phosphate concentrations (ppm) above and below the Spring-Creek confluence. Inset scatterplot shows relationship between percent cover of *E. canadensis* and sediment (fine fraction) phosphate concentrations in the random sample.

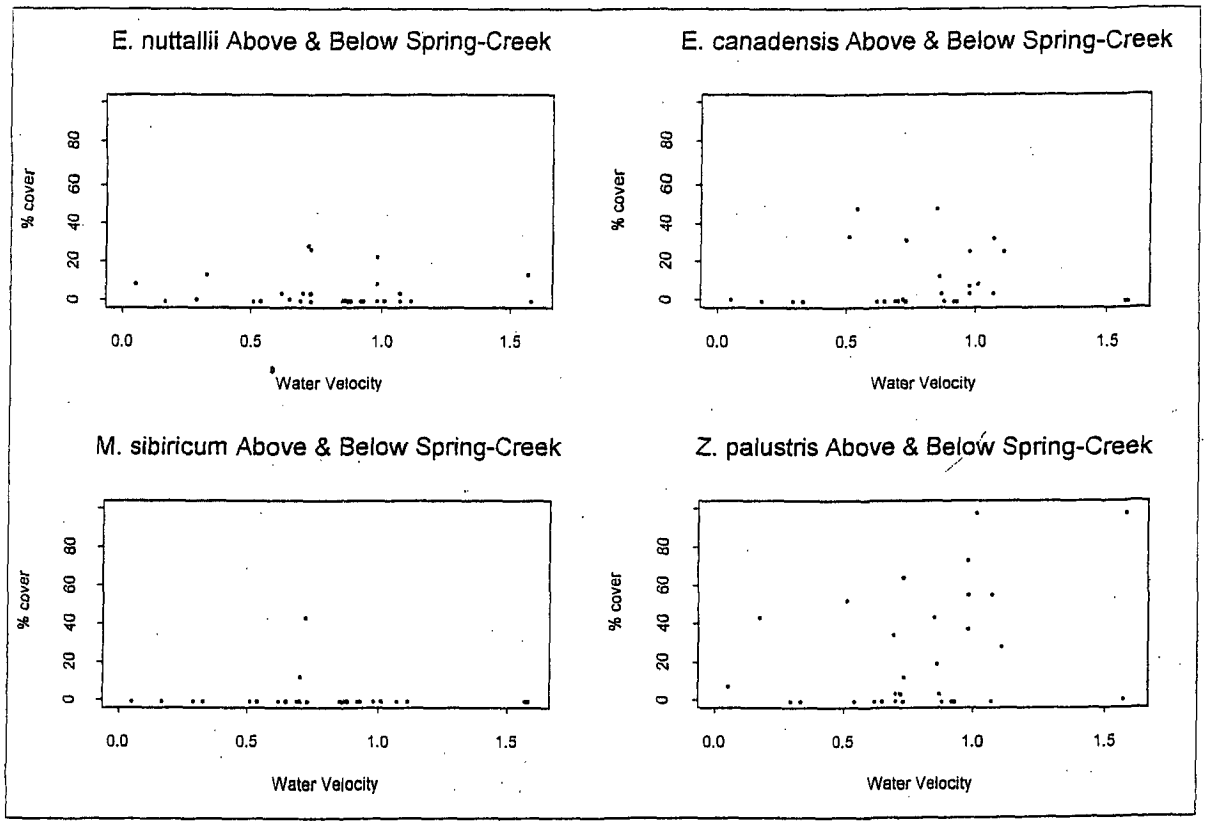

Figure 9: Percent vegetative cover as a function of water-flow velocity (feet/s) in the random sample.

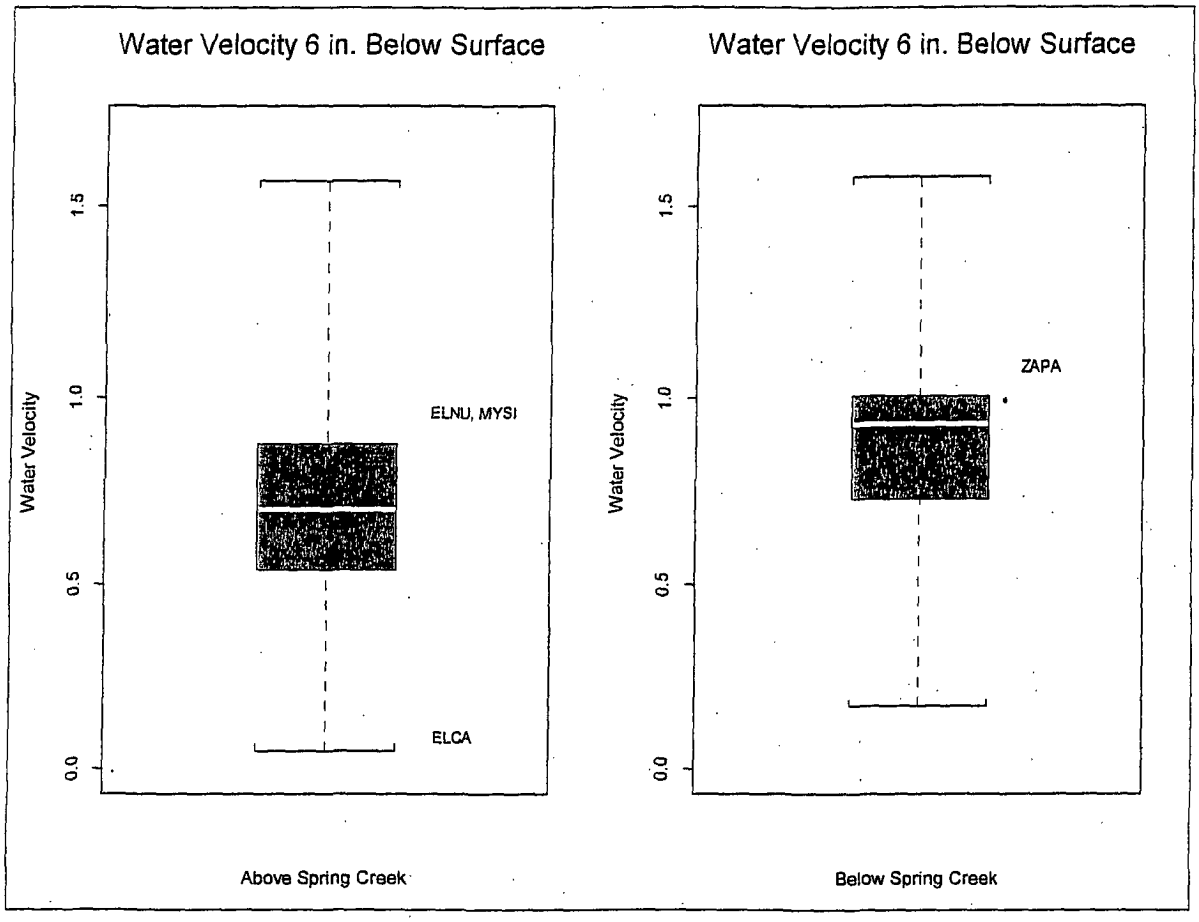

Figure 10: Water-flow velocity (feet/s) above and below the Spring-Creek confluence.

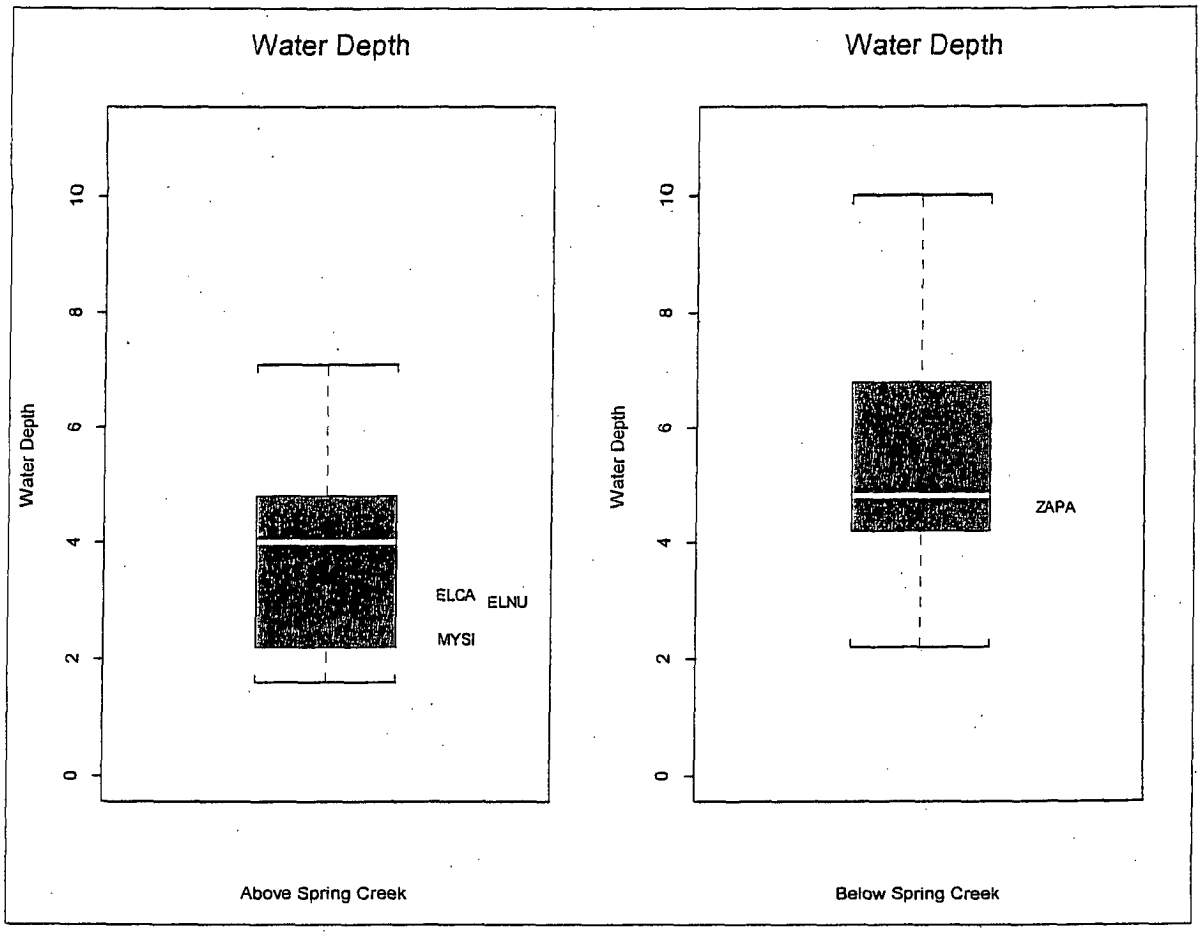

Figure 11: Water depth (feet) above and below the Spring-Creek confluence.

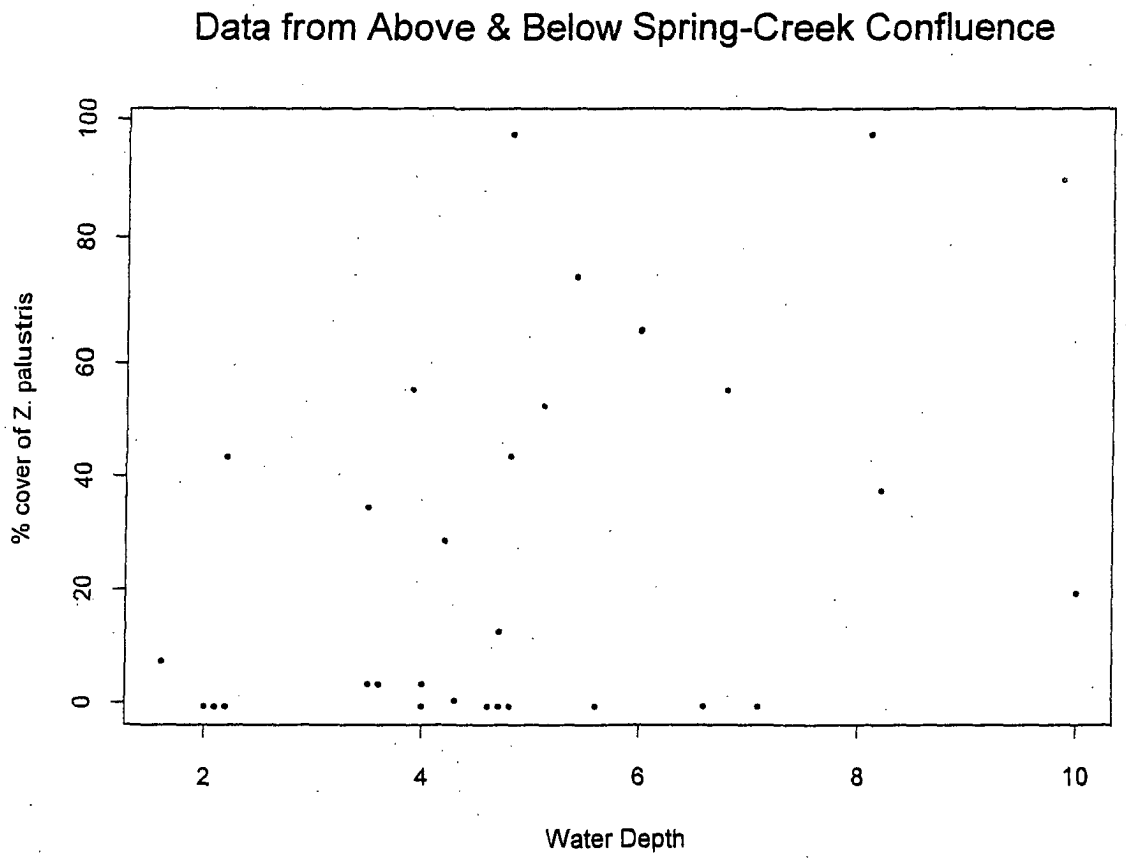

Figure 12: Percent cover of *Z. palustris* as a function of water depth in the random sample.

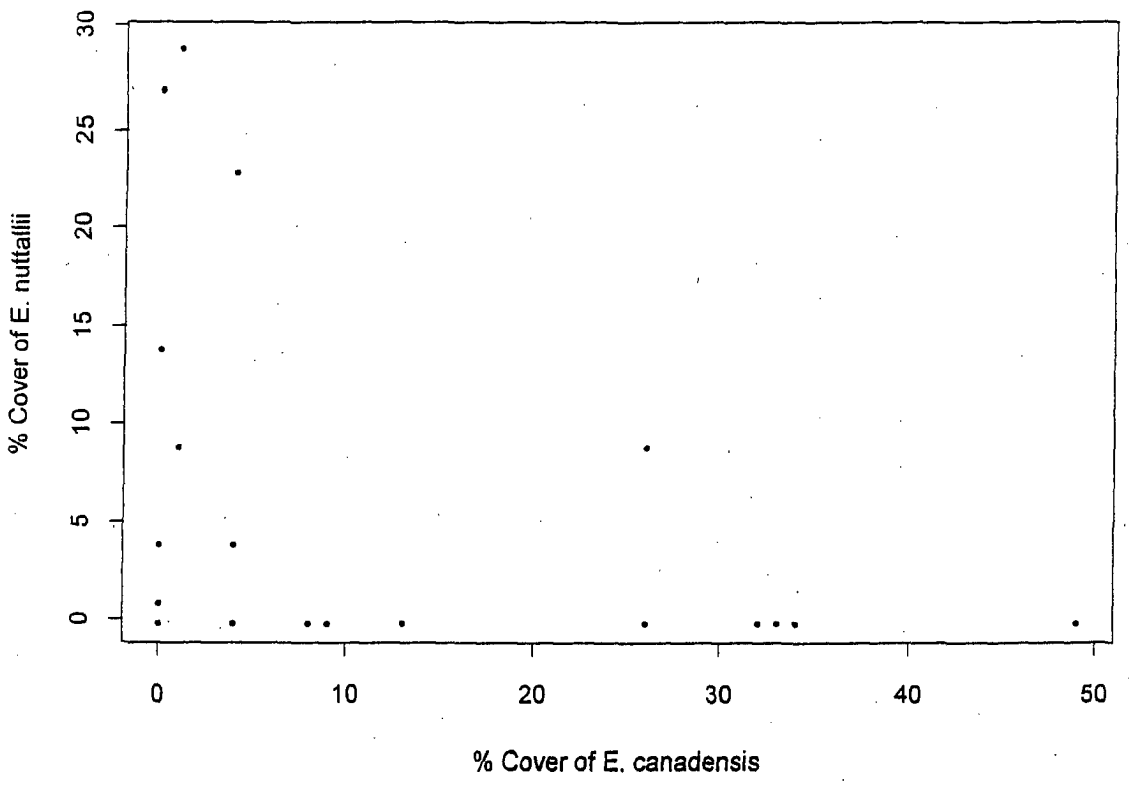

Figure 13: Relationship between percent cover of the two *Elodea* spp. for data above and below the Spring-Creek confluence combined.

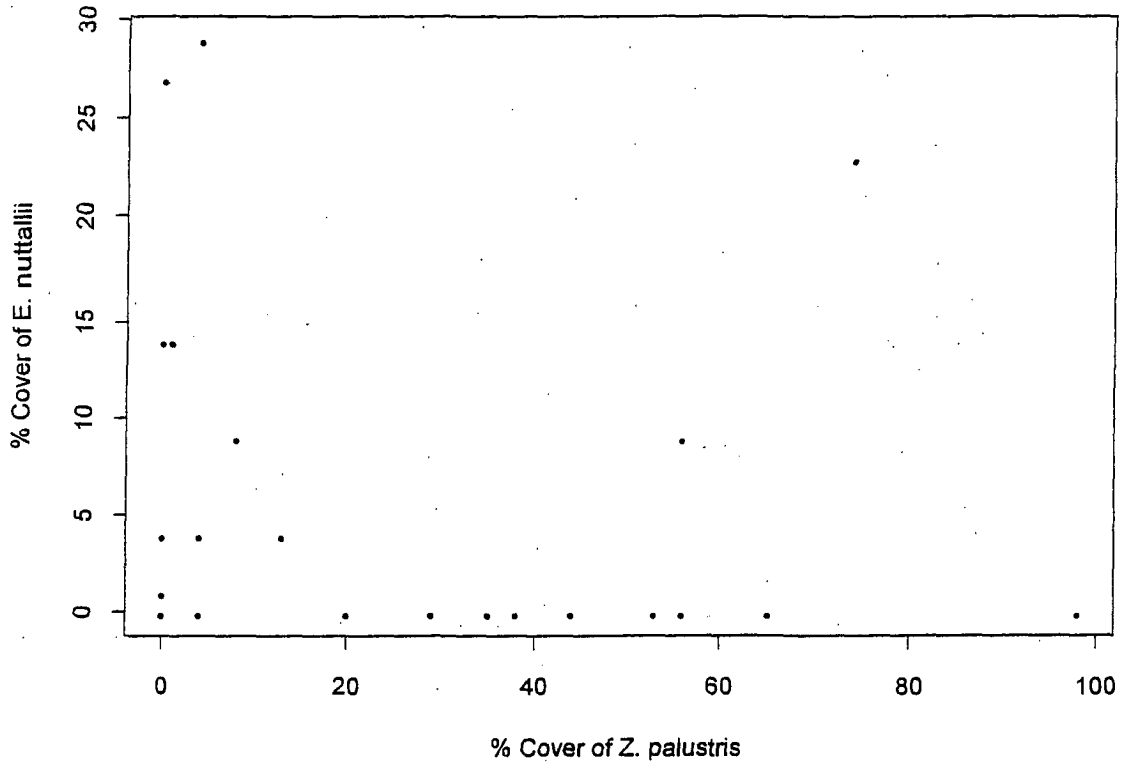

Figure 14: Relationship between percent cover of *E. nuttallii* and *Z. palustris* for data above and below the Spring-Creek confluence combined.

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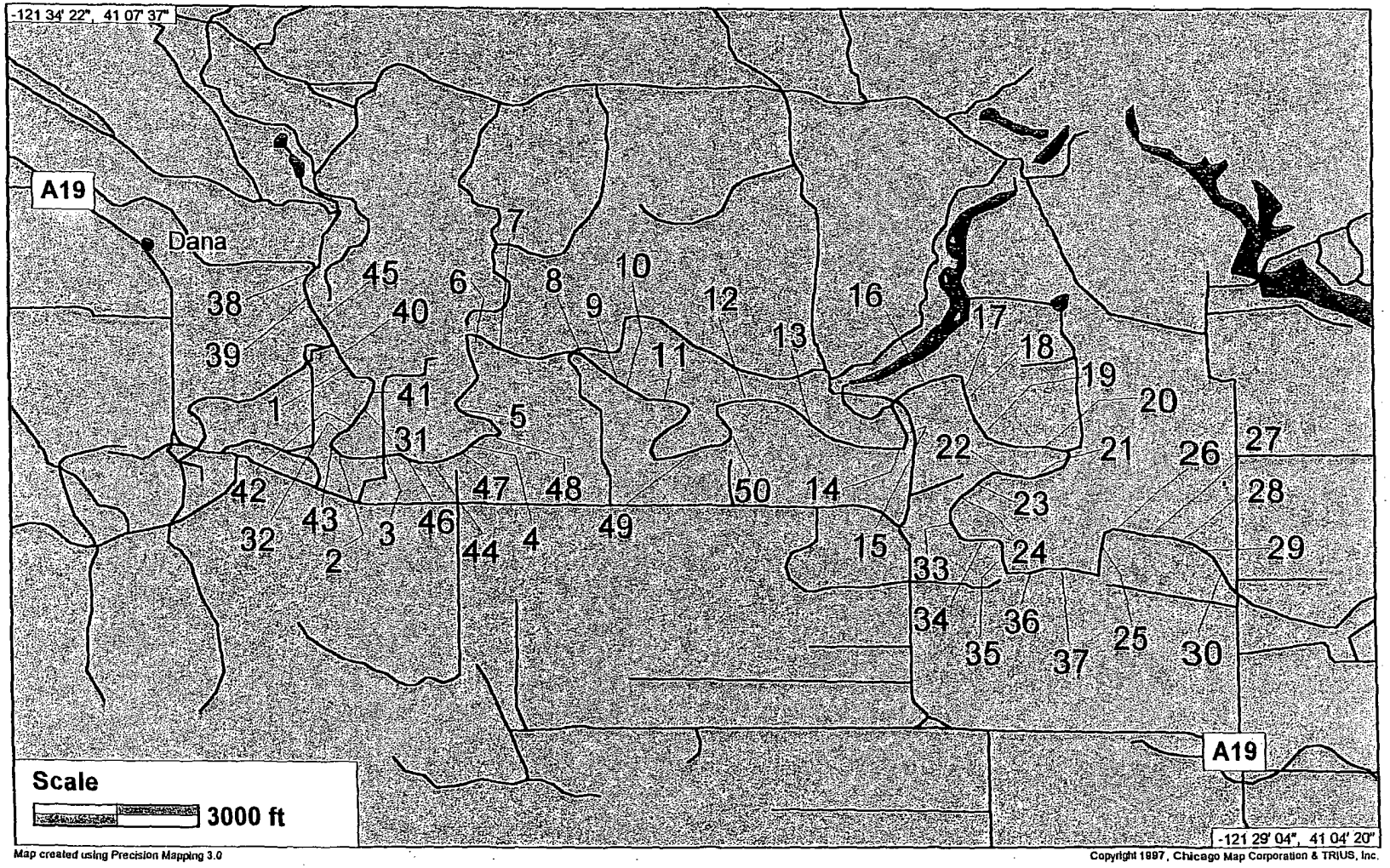
Westlake, D.F. 1967. Some effects of low-velocity currents on the metabolism of aquatic macrophytes. *Journal of Experimental Botany* 55: 187-205.

APPENDICES

Map of Sampling Locales
Sample Data Sheet
Data Summary Table

Sampling Locales



North State Resources, Inc.

START TIME: 1017 END: 1110

Fall River Aquatic-Plant Study

Research-Design Consulting
Tyson Holmes, Principal
(650) 324-8250 tyholmes@aol.com

Date (d/m/y): 10 / 9 / 97 Observer: J. HOLESCOTT

Locale

☒ Above Spring Cr ☐ Below Spring Cr

Sample Point (1-50) 14 67.2 minutes upriver (downriver) of REED'S

Distance from right bank (heading downstream): 5% (25%) 50% 75% 95%

Depth Probe

Water Depth (ft) 4.8 Sediment Base (ft) 4.8 GRAVEL STREAM BED

Velocity Meter

	0-5 sec	5-10 sec	10-15 sec	15-20 sec	20-25 sec	25-30 sec	30-35 sec	35-40 sec	40-45 sec	45-50 sec	50-55 sec	55-60 sec
Velocity 6" below surface	0.33	0.34	0.34	0.34	0.37	0.33	0.30	0.26	0.30	0.33	0.32	0.35
Velocity 6" above sediment	0.16	0.20	0.20	0.29	0.27	0.29	0.29	0.34	0.39	0.30	0.20	0.23

Vegetation Transects

	Transect 1	Transect 2	Transect 3	Transect 4
Total	0 1 (2) 3 4 5 6	(0) 1 2 3 4 5 6	0 (1) 2 3 4 5 6	0 1 2 (3) 4 5 6
Elodea nutallii	0 1 (2) 3 4 5 6	0 1 2 3 4 5 6	0 (1) 2 3 4 5 6	0 1 2 (3) 4 5 6
Elodea canadensis	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Myriophyllum sibiricum	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Zanichellia palustris	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6

Bedload Sampler

	Yes	No
Sample collected?	✓	

ANOTHER TINY SAMPLE!

Sand Auger

	Yes	No
Sample collected?	✓	

Comments

WEATHER: MOSTLY SUNNY, CALM, ~80°F

Cover classes: 1 > 0 to 5; 2 > 5 to 25; 3 > 25 to 50; 4 > 50 to 75; 5 > 75 to 95; 6 > 95 to 100

		Water Velocity 6 in. below surface (feet/s)	Bedload Sampler Weight (g)	P Conc	N Conc	S Conc	K Conc	pH	% of sediment particles ≤ 5 mm	Water depth (m)
Above Spring Creek	median	0.70	3.75	10.80	3.80	6.80	290.00	7.30	69.60	4.00
	se of median	0.35	10.71	5.40	5.94	7.64	88.24	0.31	25.66	1.56
	Lower 95% bound	0.62	0.73	9.10	2.50	1.20	260.00	6.90	46.10	3.50
	Upper 95% bound	0.88	14.20	13.50	7.50	14.60	350.00	7.40	93.10	4.60
Below Spring Creek	median	0.93	0.30	7.30	5.00	18.00	270.00	7.20	69.30	4.80
	se of median	0.31	3.20	2.92	4.57	13.36	82.03	0.22	21.97	2.00
	Lower 95% bound	0.73	0.10	5.60	3.80	10.50	220.00	7.10	48.20	4.20
	Upper 95% bound	1.01	2.20	10.00	7.50	26.00	290.00	7.40	92.70	6.40
ELCA	median	0.04	0.00	29.00	10.00	11.90	290.00	7.20	94.50	3.00
ELNU	median	0.93	0.00	10.00	3.80	11.00	260.00	7.00	80.00	2.80
MYSI	median	0.94	2.50	7.40	5.00	1.20	210.00	6.80	61.00	2.10
ZAPA	median	1.11	0.00	8.20	8.80	30.00	220.00	6.70	70.20	4.50

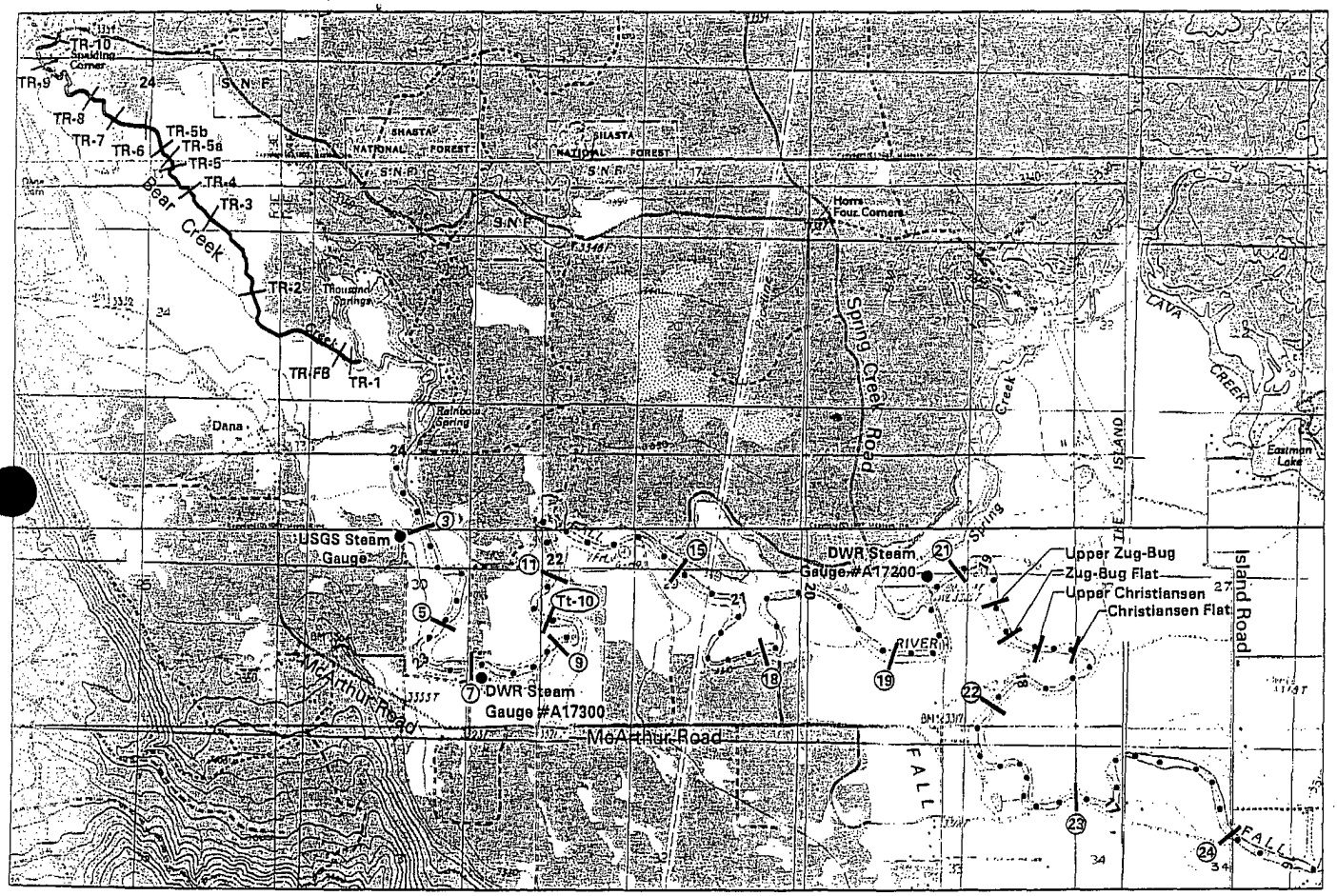
Table 1: Summary of sediment-quality, fluvial, and vegetative-cover measurements for random samples above and below the Spring-Creek confluence and for abundant beds of each aquatic-plant species.

		Sediment depth (m)	Total cover of vegetation (%)	% cover of *E. nuttallii*	% cover of *E. canadensis*	% cover of *M. sibiricum*	% cover of *Z. palustris*
Above Spring Creek	median	2.10	9.38	3.75	0.00	0.00	0.00
	se of median	0.88	20.05	9.18	12.17	10.93	2.37
	Lower 95% bound	1.40	1.00	1.00	0.00	0.00	0.00
	Upper 95% bound	2.60	19.00	14.00	1.00	0.00	2.50
Below Spring Creek	median	1.80	76.88	0.00	9.38	not present	44.38
	se of median	0.89	32.24	6.03	15.54	not present	27.20
	Lower 95% bound	1.00	35.00	0.00	0.00	NA	29.00
	Upper 95% bound	2.10	89.00	0.00	26.00	NA	56.00
ELCA	median	2.20	6.00	0.00	5.50	0.00	0.00
ELNU	median	0.30	4.25	4.25	0.00	0.00	0.00
MYSI	median	1.20	4.75	0.75	0.00	4.00	0.00
ZAPA	median	1.20	6.00	0.00	0.25	0.00	5.75

Table 1: Summary of sediment-quality, fluvial, and vegetative-cover measurements for random samples above and below the Spring-Creek confluence and for abundant beds of each aquatic-plant species.

Analysis of Sedimentation and Action Plan Development for the Upper Fall River, Shasta County, California

Final Draft - May 20, 1998



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EXECUTIVE SUMMARY

The following pages summarize and highlight important aspects of the 205j study of the sedimentation issues in the Upper Fall River. More detailed documentation of the available information, analysis results, alternative evaluations, proposed action plan, conclusions, and recommendations are presented in the main report, "Analysis of Sedimentation and Development of an Action Plan for the Upper Fall River, Shasta County, California." Additionally, the report provides numerous references for persons interested in further investigation of the Upper Fall River and its watershed.

GENERAL

The Fall River, part of the Sacramento River Watershed, is a world-renowned wild trout fishery located in northeastern Shasta County, California. The Upper Fall River is a low-gradient stream, which meanders through a broad, flat floodplain. The native rainbow trout population has thrived in this spring-fed system with nearly constant year-round flows. Bear Creek and Dry Creek watersheds (Figure E.1) provide significant flows to the Upper Fall River during rainfall and snowmelt events. During drier times of the year, these tributaries cease to flow.

Because of the low sediment inflow, historic accounts of Fall River indicate its bed had significant areas of clay, hardpan, or volcanic cobbles exposed. In contrast, a vast majority of the bed currently is covered with sand deposits, and only limited areas of these historic beds are exposed. The exposed historic channel beds typically occur at bends where secondary currents have kept the bed scoured of sand deposits.

The perceived problem in the Upper Fall River is an oversupply of sediment, resulting in two to four feet of sand deposition through much of the stream segment between the Navigation Barrier and Island Road Bridge. It is further

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hypothesized that the influx of sediment has decreased the distribution and density of submerged aquatic vegetation. As a result of these factors, the wild trout fishery is believed to have been adversely affected.

Unfortunately, there is very little data available to establish a baseline against which impacts to the Fall River system can be assessed. The earliest available cross sections for this study date back to 1996. The oldest published sediment transport information on the Fall River was collected in 1996. Therefore, rigorous data to determine changes in sediment volumes and sediment transport rates from pre-impact to the current condition are not available. The presence of the distinct, loosely consolidated sediments that the California Department of Water Resources (DWR) identified by probing is strong evidence implying recent sediment deposition. Additionally, most people familiar with the Fall River over the past decade or more interviewed for this study, believed there has been increased sediment deposition in Fall River. Finally, there have been several events over the past several decades that most likely increased sediment yield to Fall River. This includes large fires in the Bear Creek Watershed, such as the Pondosa Burn in August 1977, and channelization of the Bear Creek Meadow below Spaulding Bridge. Additionally, inspection of the upper watersheds revealed numerous meadows and wetlands, which had been degraded to the point that their natural sediment retention functions had been adversely affected. These features were once an important part of the system that kept sediment delivery to the Fall River at very low levels and permitted the low energy Fall River from being overwhelmed by sediment deposition.

To address concerns over sedimentation in the Fall River, the Fall River Resource Conservation District (FRRCD) applied for and was awarded a 205j grant to investigate the problem and formulate possible solutions. The 205j grant application states the objective of the study as "Address public concerns over the current problem of sedimentation and decline of the trout fishery and initiate a comprehensive watershed management program that will promote and restore the long-term health of the Fall River." Tetra Tech was contracted by the FRRCD to conduct the portions of the 205j study related to sediment transport, geomorphology, and potential restoration measures. For purposes of the study, the reach under consideration is the Upper Fall River, extending from the headwaters at Thousand Springs to Island Road Bridge (Figure E.2).

The FRRCD and Tetra Tech worked together to develop a scope of work for the study, which addressed the needs and budget of the 205j grant. A listing of tasks contained in the scope of work is provided below.

- Task 1 – perform project management and administration (most of this task was performed by the FRRCD);
- Task 2 – provide for public participation;

Table E.1
Upper Fall River,
Reach Average Hydraulic Characteristics

Reach	Flow Designation	Discharge (cfs)	Hydraulic Depth Y_d (ft)	Channel Velocity (fps)	Shear Stress (psf)	Top Width (ft)	Channel Top Width $T_{channel}$ (ft)	Maximum Depth Y_{max} (ft)	W/D T/Y_{max}	W/D $T_{channel}/Y_d$
1	Q_{base}	380	3.48	0.81	0.032	149.04	149.04	5.13	29.03	42.79
1	Q_{10}	1940	6.37	1.51	0.099	362.05	211.54	9.39	38.54	33.21
1	Q_{100}	5880	10.08	2.34	0.197	1042.80	211.67	13.11	79.56	21.00
2	Q_{base}	380	3.47	0.78	0.012	160.56	160.56	5.24	30.67	46.34
2	Q_{10}	1940	6.36	1.47	0.032	753.60	205.31	9.10	82.82	32.30
2	Q_{100}	5880	9.67	2.21	0.063	1898.20	206.36	12.44	152.65	21.35
3	Q_{base}	597	4.08	0.70	0.036	222.75	222.75	6.81	32.69	54.63
3	Q_{10}	2157	7.46	0.72	0.032	2712.56	245.08	10.65	254.79	32.84
3	Q_{100}	6097	10.59	1.04	0.032	6124.83	245.08	13.77	444.75	23.15

- Task 3 - determine existing sediment in the Upper Fall River;
- Task 4 - determine sources of sediment from the Bear Creek and Dry Creek watersheds;
- Task 5 – conduct a mainstream Fall River bank erosion inventory;
- Task 6 – address the lack of historic baseline data (this task was the responsibility of others and outside of Tetra Tech's scope of work);
- Task 7 – develop a quality assurance plan (this task relates to Task 6 and was outside the Tetra Tech scope of work);
- Task 8 – develop an implementation plan; and
- Task 9 – prepare draft and final reports.

The 205j process has included several mechanisms for interested individuals, groups, and agencies to participate. There have been three public meetings at which the project status has been presented and public questions and comments have been solicited. The first public meeting was held on May 6, 1997, and its purpose was to present the scope of the study to the public and to receive input on important issues to be addressed by the 205j study. The second public meeting was held on August 15, 1997, and provided a forum for Tetra Tech and others performing studies on the Fall River to present the status of the work and to answer questions from the public. The third public meeting was held May 8, 1997, and it allowed Tetra Tech to present the draft of the 205j study and to receive public comments.

Additionally, a technical advisory committee (TAC) was developed from representatives of various agencies and private individuals. The TAC represents a collection of people with specific knowledge and interests in Fall River. Purposes of the TAC were to provide access to information that would assist the study to provide personal perspectives on Fall River from individuals who had substantial knowledge and interest in the system, and to provide review and input throughout the study process. TAC meetings were held on June 16, 1997, August 6, 1997, and March 18, 1997. A fourth TAC meeting is scheduled for the week of June 22, 1998.

SEDIMENT SOURCES AND SEDIMENT BALANCE

To assist in developing solutions to control the sedimentation problem in the Upper Fall River and to determine the Upper Fall River's capacity to scour recent sediment deposits, the sedimentation sources were determined and a sediment balance was developed. Sediment sources investigated included sediment yield from the Bear Creek and Dry Creek watershed, Upper Fall River bank erosion and sediment erosion from the Bear Creek Meadow below Spaulding bridge.

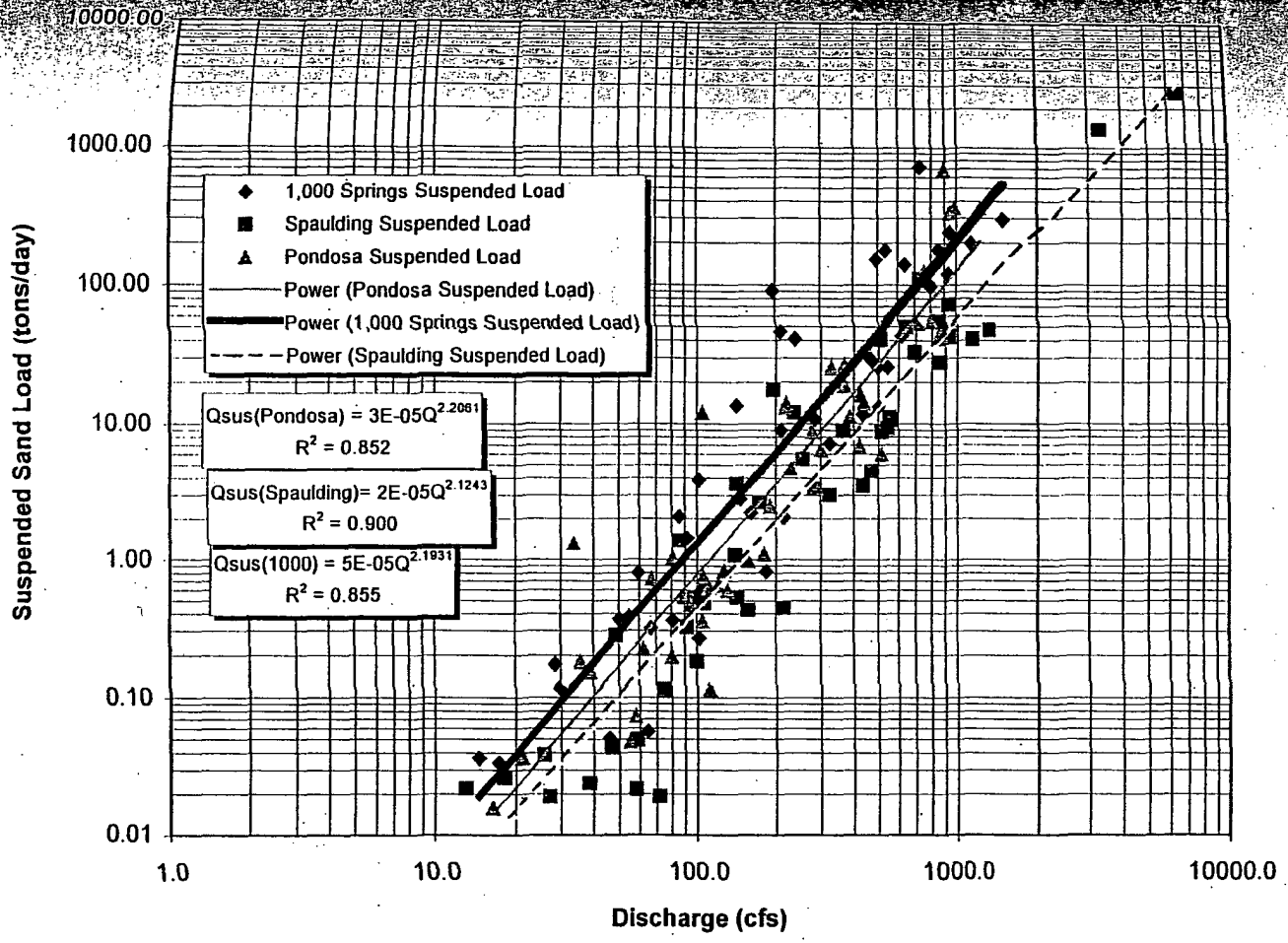


Figure E.5 - Bear Creek Suspended Sand Load Transport Regression Analysis

The provided information was necessary in conducting sediment yield and sediment transport analysis, which also require hydrologic and hydraulic analyses. The hydrologic analysis involved developing 67 years of synthetic records for Bear Creek at Spaulding, Fall River at Dana, and Fall River below Spring Creek. The synthetic records spanned the period from October 1930 to September 1997 and consisted of average daily flows. The synthetic hydrograph was developed from USGS gaging records on Fall River and Hat Creek and DWR gage records at Spaulding Bridge, Fall River at Fletcher's Bridge, and Fall River below Spring Creek (Figure E.1).

The contribution of the springs above Dana (Thousand and Rainbow) is slightly less than 400 cfs. Below Spring Creek, the baseflow increases to approximately 600 cfs. The baseflow constitutes about 80 percent of the average annual flow of Fall River near Dana. At Spring Creek, the baseflow represents 85 percent of the average annual flow. Although baseflows from the springs represent the largest portion of annual flows, rainfall and snowmelt can increase the flow to over ten times the baseflow for short periods. The 10- and 100-year floods have estimated peak discharges on the order of 2,000 and 6,000 cfs in the Upper Fall River.

The hydraulic analysis was performed based on cross-sectional data from DWR and Tetra Tech (Figure E.3). The US Army Corps of Engineers HEC-RAS water surface profile program was used to perform the hydraulic analysis. The model was calibrated using water surface elevations surveyed by Tetra Tech. In order to group lengths of the Upper Fall River into areas containing similar characteristics, the study area was divided into: Reach 1, from the Navigation Barrier to Fletcher's Bridge, Reach 2, from Fletcher's Bridge to Spring Creek, and Reach 3, from Spring Creek to Island Road Bridge. The resulting average hydraulic conditions in the three reaches are presented in Table E.1.

Sediment sources in the Bear Creek and Dry Creek Watersheds were identified through an erosion inventory conducted by the Natural Resource Conservation Service, and analysis of data was provided by Thousand Springs Ranch and the California DWR. Estimates of the sediments in the sand-sized and larger range (greater than 0.062 mm) for various sources were made. Sand-sized sediments were specifically addressed because they are the primary cause of sedimentation in the Upper Fall River.

Based on the suspended and bed load measurements performed by Thousand Springs Ranch, relationships for sediment transport versus discharge were developed. These relationships and data are shown in figures E.4 and E.5. The equations were integrated through the 67-year synthetic hydrograph to estimate average annual yields of 2,700, 600, and 2,500 tons per year for Bear Creek at Pondosa, Spaulding Bridge, and above the Fall River confluence, respectively (Figure E.1 shows locations). Bed load measurements at Spaulding Bridge were extremely low. It was decided to back calculate the annual bed load yield based on

subtracting the current average annual erosion rate of the meadow, between Spaulding Bridge and the Fall River confluence, from the calculated average annual sediment yield for Bear Creek above the Fall River confluence. This resulted in a revised average annual sediment yield at Spaulding Bridge of 1,300 tons per year.

In summary, the watershed above Spaulding Bridge was determined to supply an average of 1,300 tons of sand per year. Based on results of the NRCS watershed sediment inventory, the relative contribution of sediment sources was 85 percent from stream bank erosion, nine percent from hillslopes, and six percent from roads. Sediment delivery from erosion of the Bear Creek channel in the 2.2-mile meadow between Spaulding Bridge and the Fall River confluence was calculated to be 1,200 tons per year.

Tetra Tech conducted a field inventory and aerial photo analysis of bank erosion between the Navigation Barrier and Island Road Bridge. Figure E.6 shows the location of identified bank erosion sites. The aerial photo analysis indicated average annual contributions of sand-sized sediments of 1,400 tons per year from 1939 to 1993 and 400 tons per year from 1964 to 1993. The levels of bank erosion identified are on the order of the resolution of the aerial photographs. Therefore, it is difficult to place a high level of confidence on the results, which most likely represent maximum values. However, it does appear that bank erosion prior to 1964 was more prevalent in Fall River than it is currently experiencing.

The relative contributions of sediment were determined to be 45 percent from the watershed above Spaulding Bridge, 41 percent from the Bear Creek meadow below Spaulding Bridge and 14 percent from bank erosion in the Upper Fall River (primarily below Spring Creek).

Sediment transport relationships (Figure E.7) were developed for the Upper Fall River based on hydraulics, bed material sediment sizes, application of Yang's sediment transport equations, and verification with the DWR sediment transport data. These relationships were used to determine the average annual capacity of the Upper Fall River to transport sand-sized sediments. As was the case for the upstream supply from Bear Creek, the equations were integrated through the 67-year synthetic hydrograph to estimate an average annual transport capacity for sand-sized material. The sediment transport capacity was determined for three reaches. Reach 1 extends from the Navigation Barrier to Fletcher's Bridge and has an estimated sediment transport capacity of 3,200 tons per year. Reach 2 extends from Fletcher's Bridge to Spring Creek and has an estimated sediment transport capacity of 1,200 tons per year. Reach 3 extends from Spring Creek to Island Road Bridge and has an estimated transport capacity of 2,500 tons per year. These low sediment transport rates are approximately equal to or less than the estimated current sediment supply.

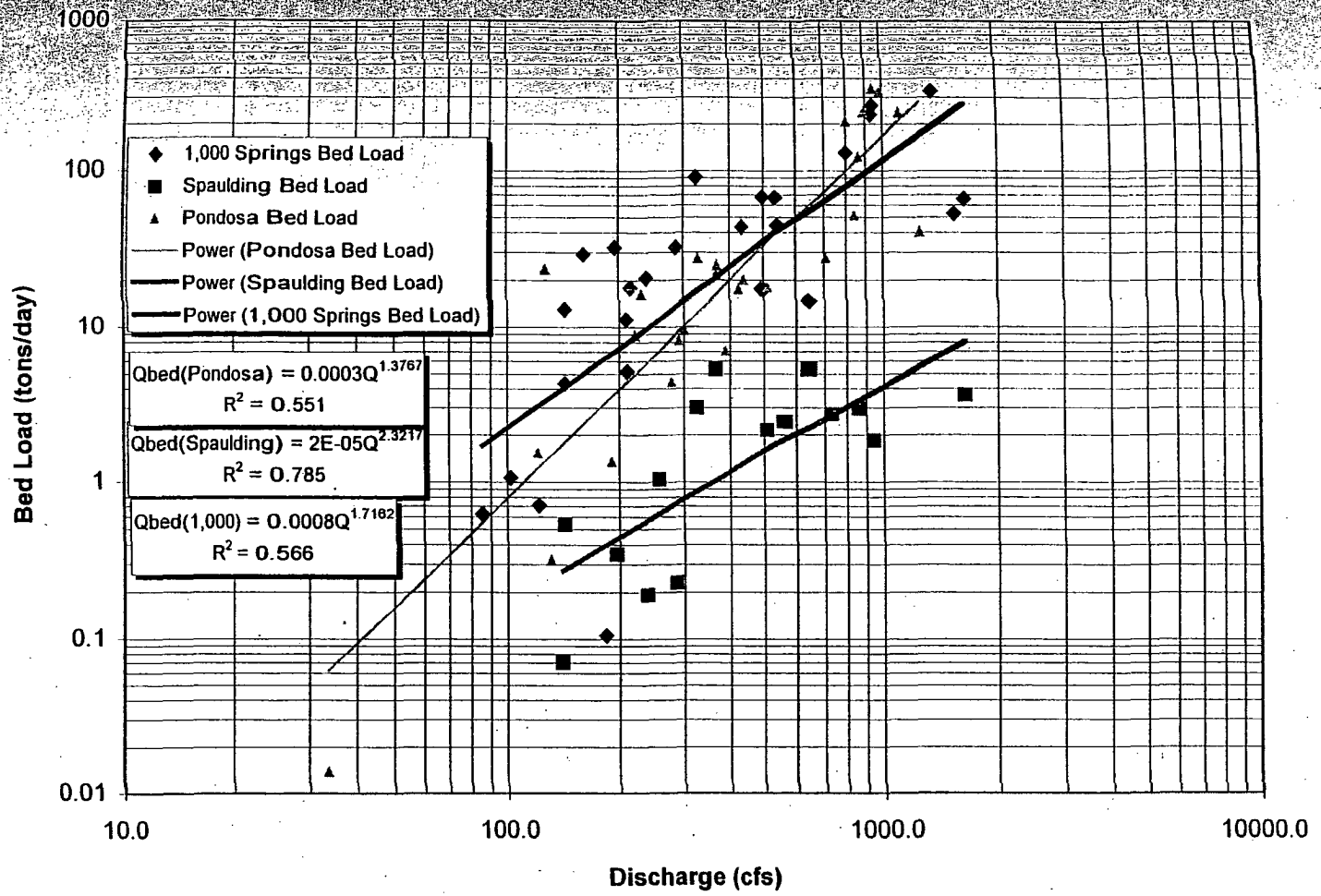
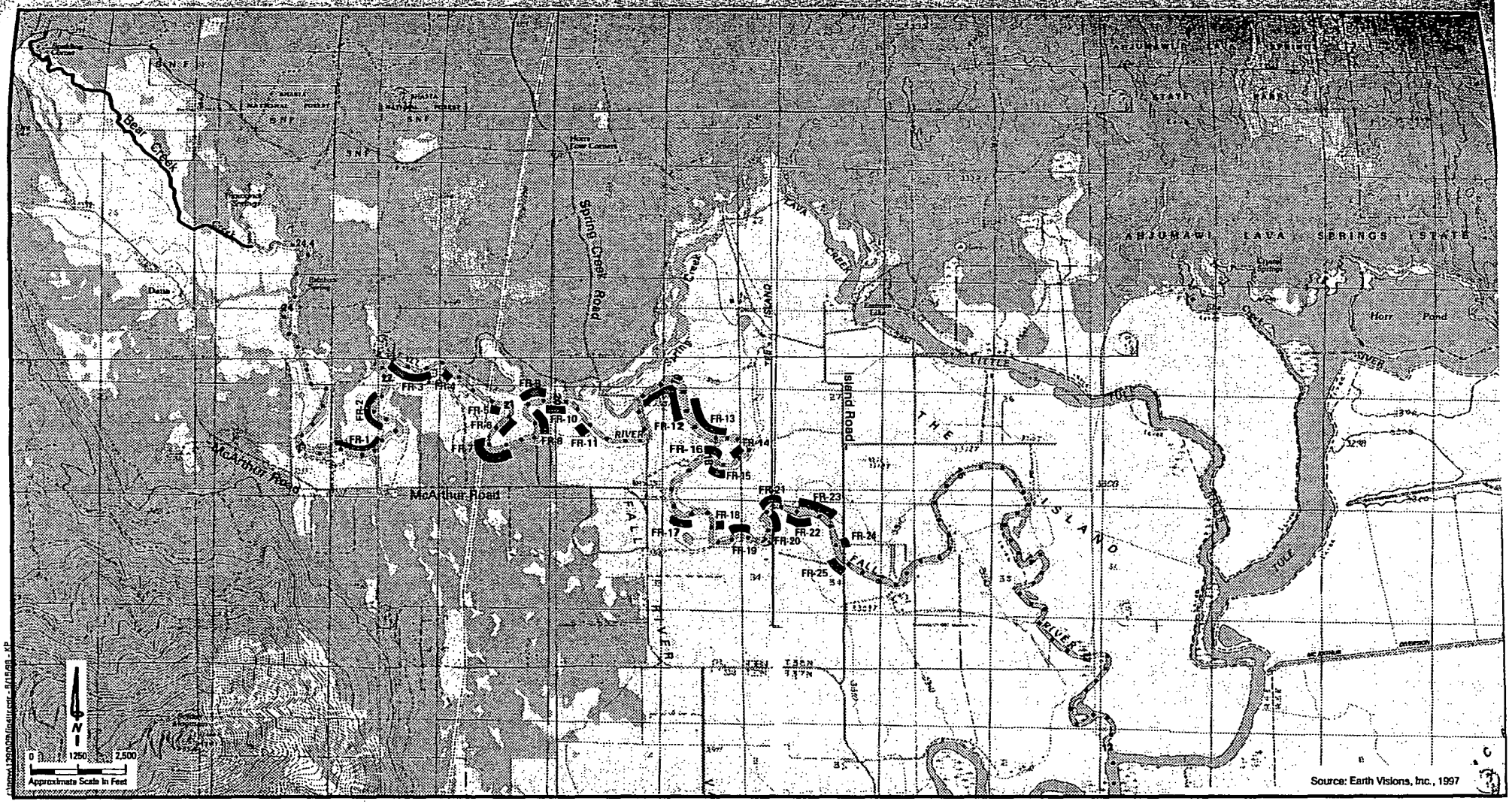


Figure E.4 - Bear Creek Bed Load Transport Regression Analysis



Legend

FR-11 Erosion sites

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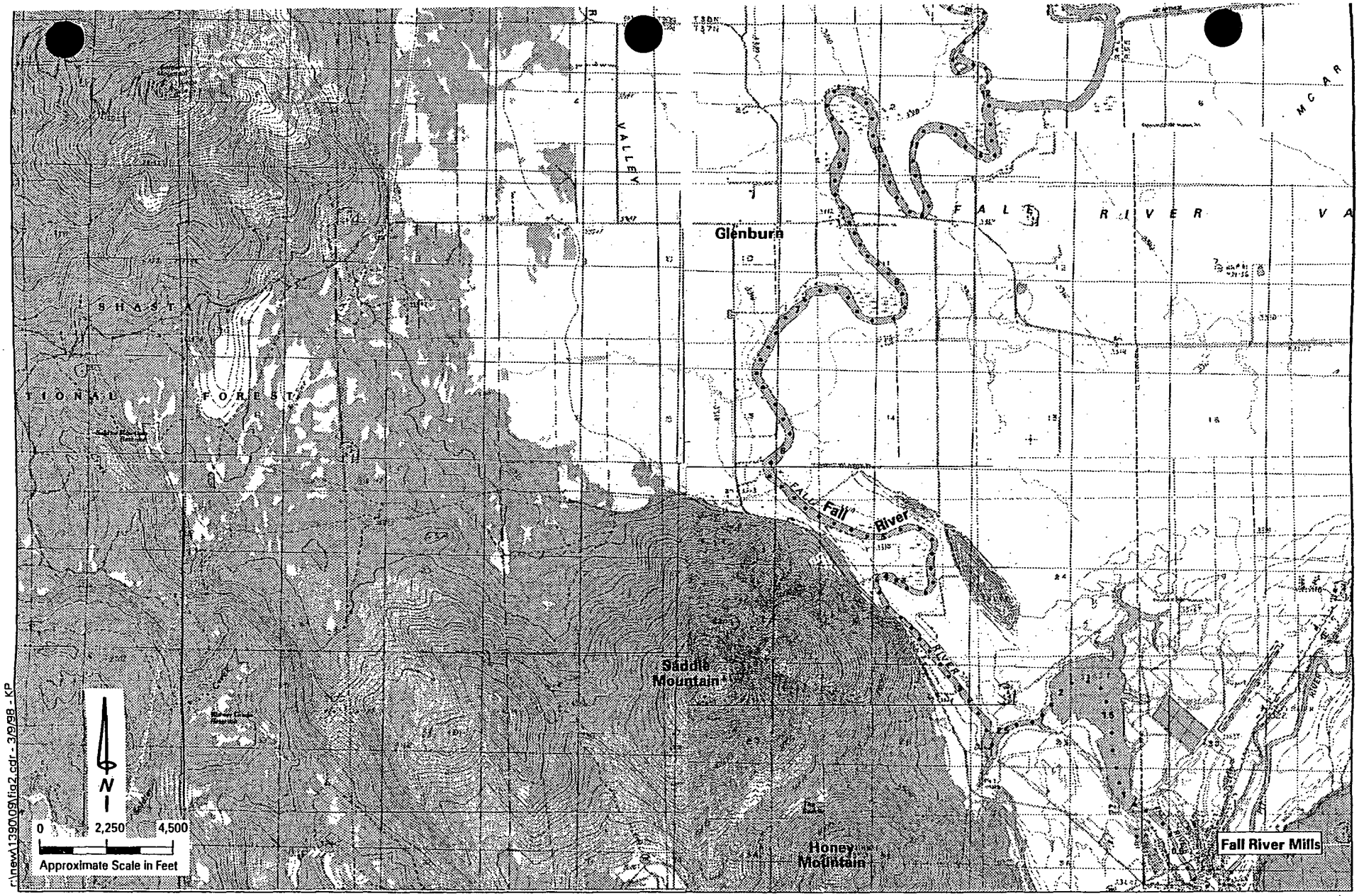
Upper Fall River Erosion Site Locations Map

Northern, California

Tetra Tech, Inc.

Figure E.6



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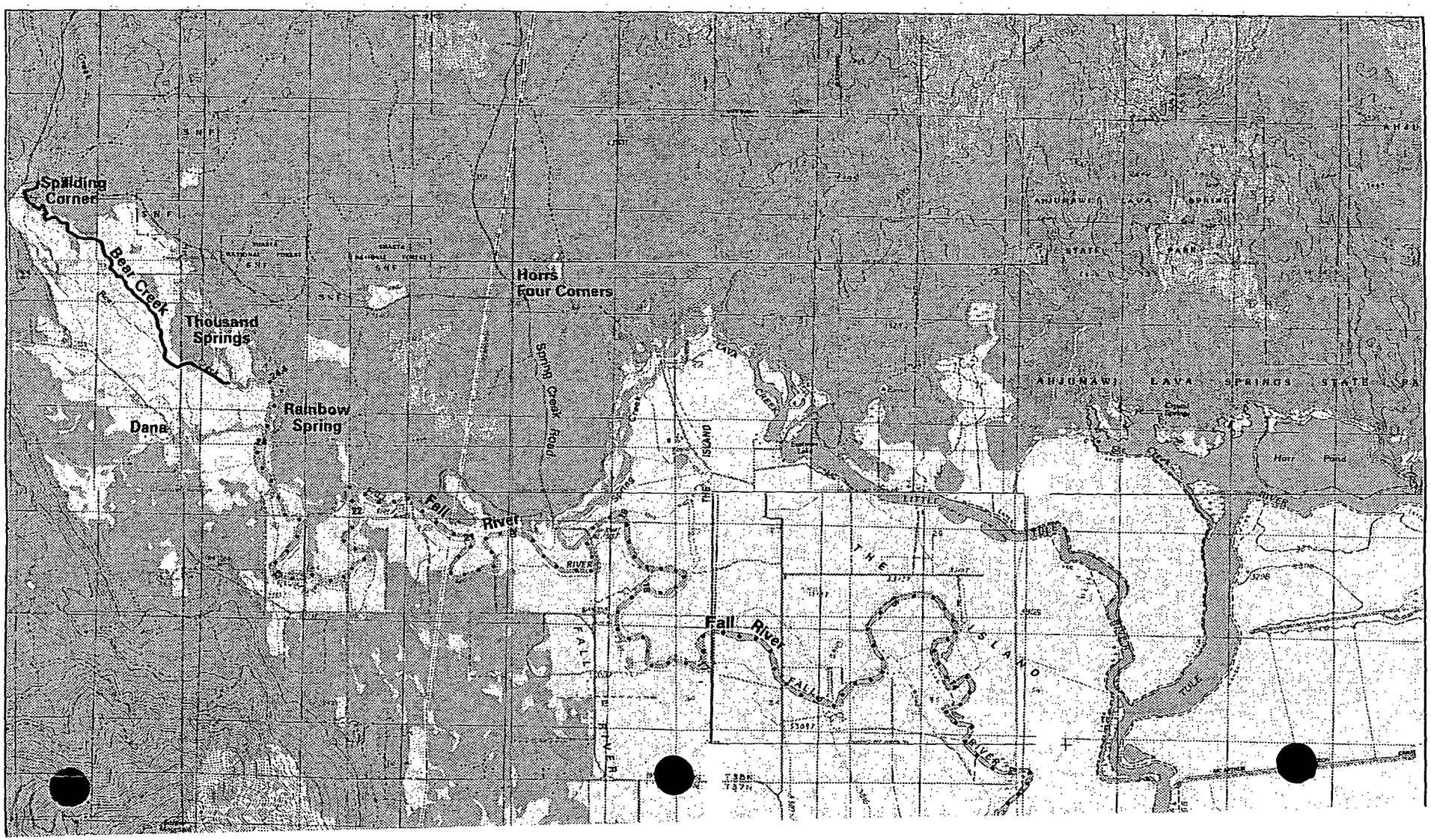
Legend

• 21 • River miles (dots mark 1/10th of rivermile)

Fall River and Bear Creek

Northern California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Bear Creek
Thousand Springs
Horrs Four Corners
Dana
Rainbow Spring
Fall River
Fall River
ISLAND
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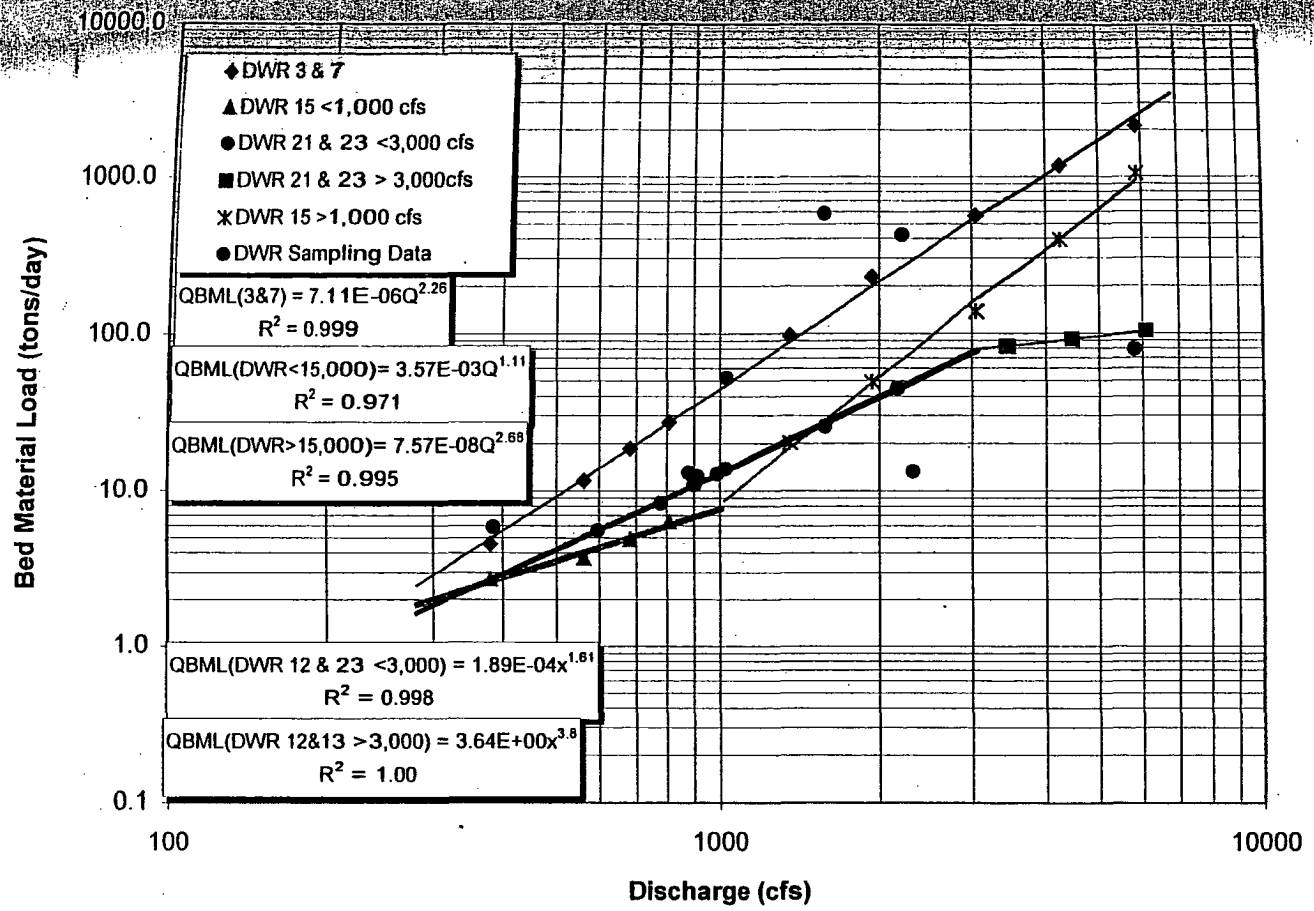


Figure E.7 - Upper Fall River, Bed Material Load (Yang's Equation)

Based on a comparison of current sediment supply and sediment transport capacity, it was concluded that the Upper Fall River has limited capacity to remove the recent sediment deposits. Under current conditions, it would take over 60 years for Reach 1 to be scoured clean; Reach 2 would continue to receive deposits indefinitely, and Reach 3 would require several centuries to scour. To illustrate the low sediment transport capacity of the Upper Fall River, a sediment balance scenario was performed, which assumed all sediment sources were eliminated. Under this condition, the time to scour the recent sediment deposits was 13, 235, and 211 years for Reaches 1, 2, and 3, respectively.

Based on results of the sediment balance calculations, it was concluded that controlling the source of sediment would not in itself allow sediment deposits from Fall River to be removed in a reasonable period. Mechanical removal of sediments needs to be a part of the solution to the sedimentation problem in the Upper Fall River. On the other hand, mechanical removal of sediments does not provide the total solution to the problem. The long-term solution involves an integrated plan to remove sediment deposits and to control sediment sources from the watershed and bank erosion and monitoring to provide a feedback loop that allows an adaptive management approach to resolve the sedimentation problem.

Another important conclusion arrived at from the results of the sediment study is the importance of meadows, wetlands, and floodplains in controlling sediment delivery to Fall River from the Bear Creek and Dry Creek watersheds. Both watersheds have alternating series of relatively steep confined channels and flat unconfined areas occupied by meadows, wetlands, and floodplains. These latter areas trap sediments from upstream sources. These sediment sinks have allowed the low energy Fall River to exist without accumulation of large quantities of sediment. However, the sediment retention capability of many of these areas has been severely degraded due to channel incision and deterioration of vegetative cover. If the loss of these areas continues, sediment transport delivery to the Upper Fall River could increase greatly. Therefore, it is not only important to restore the degraded areas but also to protect the areas that have not been affected.

Alternative Solution Measures

Six alternatives to address the sedimentation problem in the Upper Fall River were evaluated: restoration and protection of streams and meadows in the watershed, control of bank erosion in the Upper Fall River, restoration of the Bear Creek meadow below Spaulding Bridge, selective dredging of recent sediment deposits, geomorphic channel alterations, and no action. A brief description of each alternative follows.

Restoration and Protection of Streams and Meadows in the Watersheds— This alternative involves stream and meadow restoration and protection in the Bear Creek and Dry Creek watersheds. The major actions are livestock exclusion

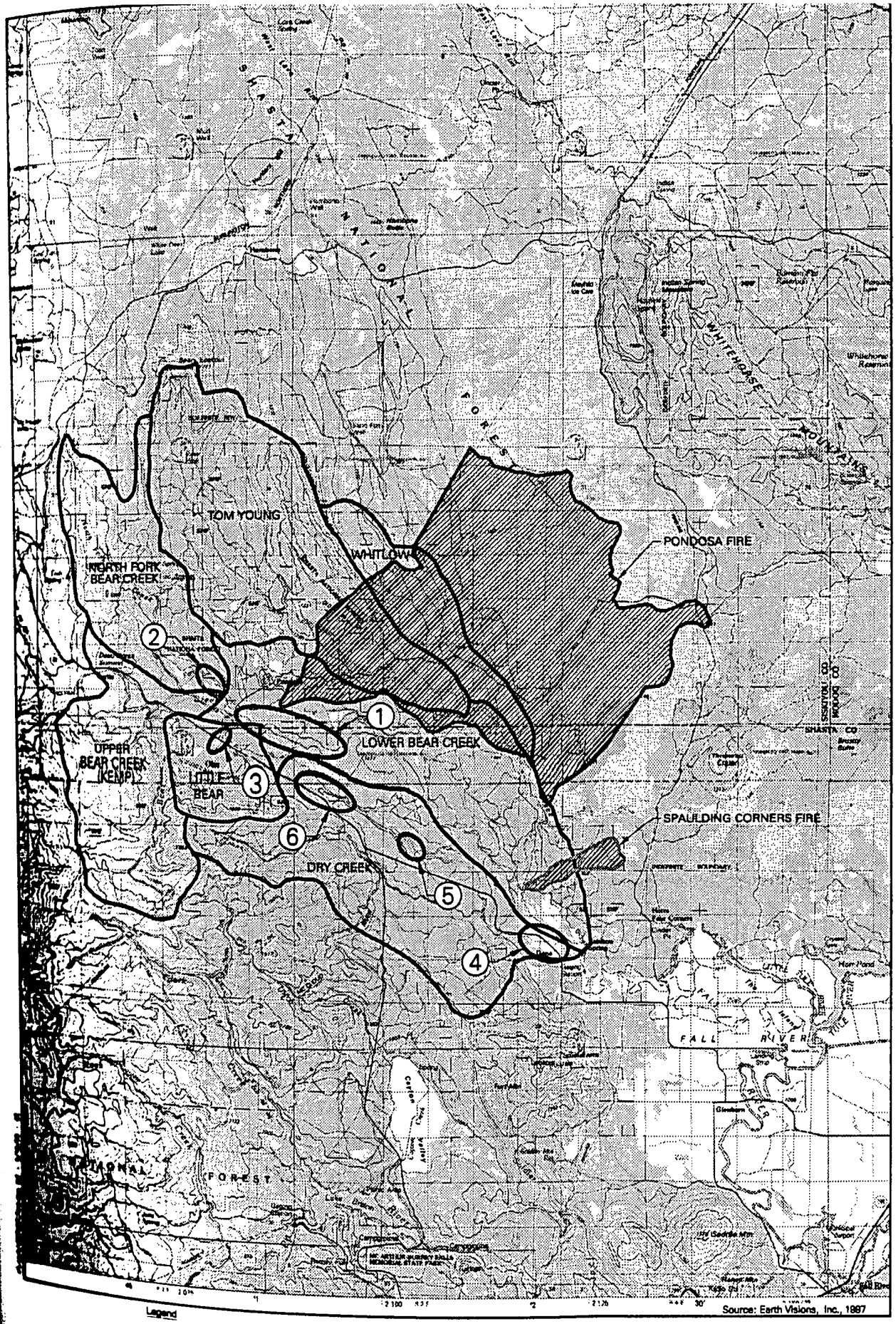
fencing, channel restoration, and meadow revegetation. This alternative has two sub-alternatives: implementation at high priority sites covering about six miles of stream corridor and implementation at a larger number of sites covering 14 miles of stream. The high priority site selection was based on the stream and meadow systems either being in a nondegraded state (protection) or in a state in which deterioration was in its early stages (restoration) and the systems being close to the Upper Fall River so they have the highest opportunity to trap sediments before reaching the Upper Fall River. Figure E.8 shows the location of the six high priority sites.

Control Bank Erosion along the Upper Fall River—Key elements of the Upper Fall River bank erosion control plan include livestock exclusion fencing, muskrat control, and enforcement of boat speed regulations.

Observations on the river and analysis of its hydraulics indicate the bank erosion is caused primarily by a combination of livestock trampling, muskrat burrowing, and wave action. These three factors combine to increase the susceptibility of the bank erosion and increase the hydraulic forces due to wave actions. Two subalternatives were evaluated: a combination of all three components or livestock exclusion fencing only. The second subalternative was considered, due to the large cost to implement a muskrat control plan, which the USDA-Wildlife Service estimated would require a full-time person and two part-time persons. A cost-effective approach could be to monitor areas with livestock exclusion and areas without livestock exclusion and to determine if removing one of the factors contributing to erosion could effectively control bank erosion.

Restoration of the Bear Creek Meadow below Spaulding Bridge—The Bear Creek Meadow restoration project addresses the eroding incised Bear Creek channel through the meadow located between Spaulding Bridge and the Fall River confluence. The length of the project is approximately 2.2 miles. The owner of Thousand Springs Ranch, Mr. Peter Stent, is undertaking the project. Cross section surveys over the past four years indicate a reduction in the sediment delivery rate to about 1,200 tons per year of sand and larger sediments. This current rate represents 41 percent of the 2,900 tons per year of sand-sized sediment Tetra Tech calculated as being delivered annually to the Upper Fall River on average.

The proposed meadow restoration project concept is to create a geomorphically stable channel in the existing floodplain. The restored channel has been designed to have geomorphic characteristics similar to the channels, which existed through the meadow prior to channelization. Whereas the current channel has the capacity to convey 1,200 to 2,000 cfs (return period of five to 15 years), the restored channel will have a capacity of 210 cfs (less than the two-year return period). The change in cross-sectional area will result in flow spreading across the



High-Priority Stream and Meadow Restoration / Protection Sites

Upper Fall River Watershed, California

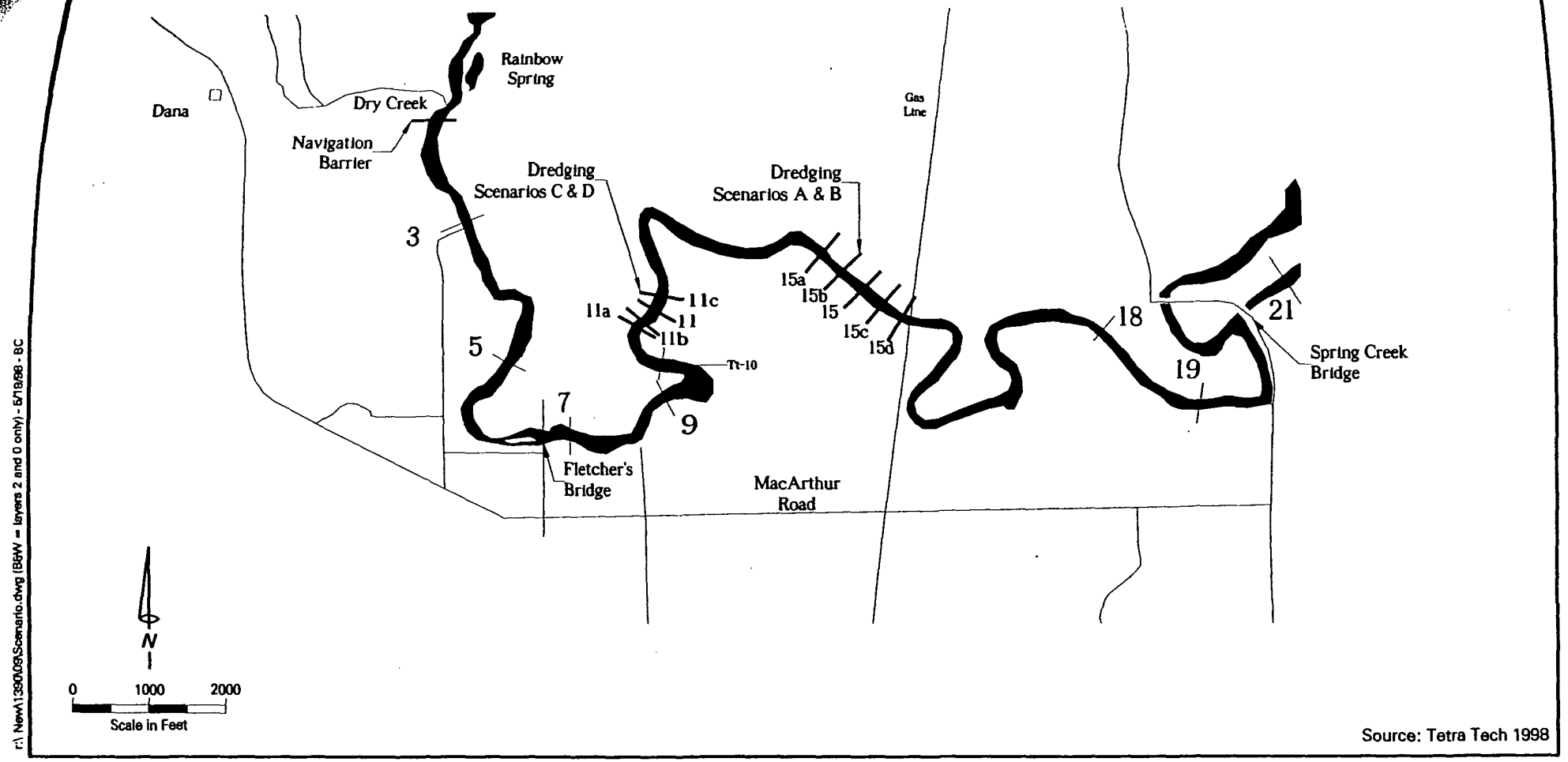
Figure E.8

floodplain more frequently and lower energy in the main channel. Thus, the project is intended to both eliminate bank erosion in this segment of Bear Creek and to restore the sediment retention values of Bear Creek. The project also will include cattle exclusion fencing along the restored channel, restoration of ground water levels in the meadow, and re-vegetation of the meadow.

Mechanical Sediment Removal/Dredging—Recent watershed activities have introduced large sediment deposits into the Fall River. Various dredging scenarios have been created to evaluate different options available for restoring Fall River. Wide-scale and selective dredging of the river are considered. Wide-scale dredging would remove all or a significant percentage of the recent sediment deposits throughout the entire restoration reach. Dredging on this scale can be extremely costly and the risks of unanticipated impacts could be high. Therefore, dredging investigations have concentrated on selective, local removal scenarios that address some of the larger sediment deposits in specific locations. Dredging should not be confused with channelization. Dredging will not change the river's alignment but will change cross-sectional geometry by deepening the river by removing recent sediment deposits. Dredging goals are to remove large local sediment deposits in order to restore aquatic vegetation and fishery habitat. Additionally, local sediment removal will create in-channel sediment traps and will change upstream hydraulics so that additional sediment is pulled into these traps. Selective dredging would provide convenient areas for periodic sediment removal. The selective dredging scenarios are intended to serve as pilot projects to determine the feasibility and effectiveness of dredging as a solution to removing recent sediment deposits. Positive results could warrant expanding dredging to additional areas. Experimental practices to reestablish aquatic vegetation could be performed in these areas.

Tetra Tech analyzed two levels of selective dredging at two sites (Figure E.9). In addition, these scenarios were combined to develop four additional scenarios, which included selective dredging at two locations. For final evaluation two scenarios were selected: the least expensive single location dredging and the most expensive combined location dredging plan. The dredging scenarios evaluated were scenario A, which consisted of removing 2,900 cubic yards of sediment for a 1,100-foot length near the Gas Line crossing, and scenario BD, which consisted of removing 6,600 cubic yards of sediment in an 1,100-foot reach at the Gas Line Crossing and 5,000 cubic yards in the 600-foot reach below Indian Hole.

Geomorphic Channel Alterations - Initially, geomorphic channel alteration was considered as part of the solution possibilities for the Upper Fall River sedimentation problems. However, after reviewing available information and analysis results, Tetra Tech believes that significant geomorphic channel alterations do not address the sedimentation problem and would be counter-productive. We reviewed 60 years of aerial photography and found essentially no change in channel alignment. There has been a slight channel widening, but it has



Source: Tetra Tech 1998

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5 —— Cross Section

Site Locations for Potential Dredging Scenarios

Upper Fall River Watershed, California

Tetra Tech, Inc.

Figure E.9

been minimal. Therefore, it is not productive to propose changes that would disrupt the natural channel configuration established over thousands of years of channel evolution. The significant change is sediment deposition on the channel bed. Channel alterations to address this condition already have been evaluated; they involve either mechanically removing sediments or reducing sediment supply to induce scouring of the recent sediment deposits.

No Action Alternative—The no action alternative represents the status quo. It consists of taking no additional measures to control sediment supply from the upstream watershed and bank erosion along the Upper Fall River. Additionally, measures will not be taken to remove recently deposited sediments; removal will only occur through natural flushing of the stream flows in areas where the sediment transport capacity exceeds supply. The no action alternative does not indicate that nothing is currently being done to control sediment sources. The timber managers in the watersheds follow guidelines and regulations from the California Department of Forestry to minimize sediment contribution to streams from their timber harvest activities. The Long Ranch Meadow on Bear Creek between Pondosa and Spaulding Bridge has had livestock exclusion fencing installed. Similarly, many landowners along the Upper Fall River have installed livestock exclusion fencing along their riverbanks. Sediment problems in Fall River have been monitored and studied, some might argue too much. One should not conclude that nothing has been done or is being done to address the sedimentation problem in the Upper Fall River from the no action alternative; rather, the alternative assumes that no new actions will be taken to control sediment delivery to and sedimentation in the Upper Fall River. None of the alternatives previously described would be implemented under the no action alternative.

Cost estimates for each of the alternatives were developed and are summarized in Table E.2. Numerical ratings for critical evaluation criteria were applied to each alternative. These results are summarized in Table E.3. Each alternative was evaluated in four basic categories: effectiveness in addressing the sedimentation problem, cost, environmental impacts, and private landowner participation. The sedimentation category had three items: controlling sediment sources, removing recent sediment deposits, and maintaining long-term control of sediment deposition. The environmental category also had three items: impacts to the riparian corridor, impact to fisheries, and impacts to endangered species. All items were rated on a scale of 0 to 4, with 0 being the lowest rating and 4 being the highest or best rating.

PRELIMINARY ACTION PLAN

Each alternative was evaluated against several criteria, and the results were presented in Table E.3. In its current state, Table E.3 is intended to provide a comparison among the alternatives on individual criteria. This facilitates

Table E.2
Summary of Cost Estimates for Upper Fall River Restoration

Alternative	Initial Costs	Present Value of Annual Costs	Subtotal of Costs	Design, Administration & Supervision Costs	Contingencies	Total Estimated Cost
High Priority Watershed Stream & Meadow Restoration	$476,000.00	$62,000.00	$538,000.00	$108,000.00	$161,000.00	$807,000.00
Widespread Watershed Stream & Meadow Restoration	$2,228,000.00	$290,000.00	$2,518,000.00	$505,000.00	$754,000.00	$3,777,000.00
Fall River Bank Erosion Control	$52,000.00	$952,000.00	$1,004,000.00	$50,000.00	$301,000.00	$1,355,000.00
Bear Creek Meadow Restoration*	$500,000.00	$350,000.00	$850,000.00	$0.00	$0.00	$850,000.00
Selective Dredging Scenario A	$35,000.00	$0.00	$35,000.00	$7,000.00	$11,000.00	$53,000.00
Selective Dredging Scenario BD	$158,000.00	$0.00	$158,000.00	$32,000.00	$47,000.00	$237,000.00
No Action	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00

Costs for this alternative will be funded by the private landowner.

Table E.3
Summary of Restoration Alternative Evaluation Ratings for the Upper Fall River

Evaluation Criteria	High Priority Watershed Stream & Meadow Restoration	Wide Spread Stream & Meadow	Fall River Bank Erosion Control	Bear Creek Meadow Restoration	Selective Dredging Scenario A	Selective Dredging Scenario BD	No Action
Control of Sediment Source	3	3.5	2	3.5	0	0	0
Removal of Recent Sediment Deposits	1	1	1	1	3	4	0
Long Term Control of Sediment Deposition	3	3.5	2	3.5	2	2	0
Cost	2	0	2	4	4	3	4
Environment Impacts to Riparian Corridor	4	4	4	4	2	3	1
Environmental Impact to Fisheries	3	3	4	3	4	4	1
Environment Impacts to Endangered Species	2	2	3	2	3	3	1
Private Landowner Participation	1.5	1.5	1.5	0	3	3	4

developing an action plan that most completely addresses the issues associated with the restoration of the Upper Fall River. To assist in developing an action plan, Table E.2 provides a summary of the costs for each alternative.

The proposed action plan needs to address two key issues, controlling sediment sources and removing sediment from the Upper Fall River. Evaluation of the sediment balance indicates that the Upper Fall River has extremely low capacity to scour deposited sediments from its bed. The sediment balance performed for a hypothetical case with zero input of sediment indicated some areas in the Upper Fall River would require over 100 years for the flows to remove recent sediment deposits. No sediment input to the Fall River is an unrealistic scenario, but it does illustrate the excessive time frame required for the flows to scour the sediments. On the other hand, a solution plan that included only sediment removal from Fall River would have an immediate positive impact on the current sedimentation problem but would not address long-term sediment supply issues. In fact, an evaluation of the upstream watershed indicated that the current system of meadows, wetlands, and floodplain located in the flatter areas, along the major streams, have a positive influence on sediment delivery to the Upper Fall River by trapping sediments that are produced in portions of the watershed farther upstream. However, many of these areas are deteriorating, and sediment supply from the upstream watershed will increase if these natural sediment sinks continue to degrade. These factors illustrate the need to control sediment supply even though the immediate contribution to remove recent sediment deposits in the Upper Fall River will be small.

With these considerations in mind, the following action plan to address the sedimentation problem in the Upper Fall River is proposed:

- Implement the watershed stream and meadow restoration and protection indicated in the high priority site alternative. This will involve livestock exclusion fencing, channel restoration, and meadow revegetation. Six miles of stream corridor in the Bear Creek and Dry Creek watersheds are targeted. This component addresses current and long-term sediment supply issues.
- Implement the restoration and protection of the Bear Creek Meadow between Spaulding Bridge and the Fall River confluence. This project is considered an extension of the watershed stream restoration and protection activities in the previous item. Bear Creek Meadow represents the last location to trap upstream sediment prior to its introduction into the Upper Fall River. It can control sediment supply from the entire Bear Creek Watershed. This part of the plan addresses both short-term and long-term sediment supply issues.
- Implement a selective dredging plan similar to the plan proposed in the combined BD scenario described in Section 8.4. Additional investigations of alternative locations for such a plan should be performed. The plan presented was for illustrative and approximate cost estimation purposes. Additional investigations should be

performed before actual sites are selected for implementation. To have a noticeable positive impact on the Upper Fall River, a selective dredging alternative should involve removing 10,000 to 20,000 cubic yards of recent sediment deposits. The selective dredging portion of the action plan addresses the removal of sediment from the Upper Fall River. After these pilot dredging areas are evaluated, the program could be expanded to other suitable reaches of the Upper Fall River.

- Implement the livestock exclusion-fencing portion of the Fall River bank erosion control alternative. As part of the plan, monitoring to determine the influence of muskrat burrowing on erosion processes should be performed. Based on cost estimates supplied by the USDA Wildlife Services, the cost of a muskrat control plan is approximately 10 times the cost of the livestock exclusion fencing. The high cost is the result of muskrat control requiring a continued effort from one full-time person and two part-time people during portions of the year. Before such an expensive endeavor is undertaken, a more thorough evaluation of its cost effectiveness is recommended. Livestock exclusion fencing addresses the issues of short-term and long-term supply of sediment to the Upper Fall River.

The costs of implementing the action plan were derived from Table E.2. In addition to the restoration activities identified in the action plan, costs of monitoring the effectiveness of the various measures, as well as the health of Fall River ,need to be included. This cost was estimated as $35,000 per year for 10 years. A 7.5 percent rate of return was assumed to convert the annual costs to present value. The resulting costs are summarized below:

• High Priority Watershed Stream Restoration/Protection	$807,000
• Fall River Bank Erosion Control (without muskrat control)	$105,000
• Bear Creek Meadow Restoration	$850,000
• Selective Dredging Combined BD Scenario	$237,000
• Monitoring for Ten Years	$258,000
• TOTAL	$2,257,000

If the cost estimate for the muskrat control plan is included as part of the project, the total project cost in terms of present value is increased to $3,507,000.

Tetra Tech has developed recommendations as to what actions could be taken to address the sedimentation problem in the Upper Fall River. These recommendations are preliminary. Study results need to be reviewed by the public, TAC, and FRRCD, and comments need to be provided. Based on this input, Tetra Tech will reassess the action plan and make modifications as necessary. The revised results will be included in the final report. It is then up to the public, FRRCD, TAC, and landowners to develop the actual implementation plan. The plan presented by Tetra Tech represents recommendations that should be considered in developing a plan to restore the Upper Fall River. However issues, concerns, community needs and natural events may develop that would warrant adjustments to the action plan. Finally, the plan should be considered

flexible and take an adaptive management approach. This requires continued monitoring of the Fall River to determine what changes may be occurring in the watershed and the river itself. This information should be used as feedback to regularly reevaluate the action plan and to make modifications as necessary.

CONCLUSIONS AND RECOMMENDATIONS

The central issue addressed by the 205j study was the deposition of sediment in the Upper Fall River. Unfortunately, no historic surveys of the river were available to make cross section comparisons to directly assess the amount of sedimentation that occurred. People familiar with Fall River over several decades qualitatively indicate sedimentation has occurred and that it has resulted in burial of logs, hardpans and clays, previously exposed lava cobbles, and aquatic vegetation. DWR performed cross section surveys and collected sediment core samples. Using this information, Tetra Tech established an estimate of 213,000 cubic yards of recent sediment deposits between the Navigation Barrier and the Spring Creek Confluence. Between the Spring Creek Confluence and the Island Road Bridge, an additional 206,000 cubic yards of recent sediment deposits were identified.

Sediment deposition has been an issue because of potential impacts on aquatic vegetation in Fall River and the wild trout fishery. These two parts of the system are intertwined since the wild trout fishery relies heavily on the submerged aquatic vegetation for habitat and for the production of macroinvertebrates. No historic data concerning the distribution or density of submerged aquatic plant beds were available. Fish population counts dating back to 1975 were available, and more recent fish count data were collected in 1993, 1995, and 1997. However, it is difficult to draw any conclusions from this information because the earlier data set was collected by different procedures than the more recent data set. Initial estimations of fish populations showed large decreases and more recently large increases. The Department of Fish and Game could not draw any direct conclusions concerning sedimentation impacts on the wild trout fishery from this information. Thus, the assumption that there has been negative impacts on the aquatic vegetation and wild trout fishery rely on anecdotal accounts of historic conditions and the knowledge that deposition of large quantities of sediment typically have negative impacts on these resources.

Sediment sources in the Bear Creek and Dry Creek watersheds were identified through an erosion inventory conducted by the Natural Resource Conservation Service and analysis of data provided by Thousand Springs Ranch and California DWR. Estimates of the sediments in the sand-sized and larger range for various sources were made. Sand-sized sediments were specifically addressed because they are the primary cause of sedimentation problems in the Upper Fall River. The watershed above Spaulding Bridge was determined to supply 1,300 tons of sand per year. Of this volume, it was estimated that 85 percent originates from stream bank erosion, 9 percent from hill slopes, and 6 percent from roads. Sediment delivery from erosion of the Bear Creek channel in the 2.2-mile meadow between

Spaulding Bridge and Fall River confluence was calculated to be 1,200 tons per year. An additional 400 tons per year of sediment were estimated to be derived from bank erosion within the Upper Fall River study area. The relative contributions of sediment were determined to be 45 percent from the watershed above Spaulding Bridge, 41 percent from the Bear Creek Meadow below Spaulding Bridge, and 14 percent from bank erosion in the Upper Fall River (primarily below Spring Creek).

Sediment transport relationships were used to determine the average annual capacity of the Upper Fall River to transport sand-sized sediments. Sediment transport capacities were determined for three reaches. Reach 1 extended from the Navigation Barrier to Fletcher's Bridge and has an estimated sand transport capacity of 3,200 tons per year. Reach 2 extended from Fletcher's Bridge to Spring Creek and has an estimated sand transport capacity of 1,200 tons per year. Reach 3 extends from Spring Creek to Island Road Bridge and has an estimated sand transport capacity of 2,500 tons per year. These transport capacities are low and are approximately equal to or less than the estimated supply of sand-sized sediments.

Based on a comparison of current sediment supply and sediment transport capacity, it was concluded that the Upper Fall River has limited capacity to remove the recent sediment deposits, and controlling the source of sediment would not in itself allow sediment deposits from the Fall River to be removed in a reasonable period. Mechanical removal of sediments needs to be a part of the solution to the sedimentation problem in the Upper Fall River. On the other hand, mechanically removing sediments does not provide the total solution to the problem. The long-term solution involves an integrated plan to remove sediment deposits, and to control sediment sources from the watershed and bank erosion.

Another important conclusion arrived at is the role of meadows, wetlands, and floodplains in controlling sediment delivery to Fall River from the Bear Creek and Dry Creek watersheds. The sediment retention capabilities of many of these areas have been severely degraded due to channel incision and deterioration of vegetative cover. If the loss of these areas continues, sediment delivery to the Upper Fall River could increase greatly. Therefore, it is not only important to restore the degraded areas but to protect the areas that have not been affected.

A preliminary action plan was developed for addressing the sedimentation problems in the Upper Fall River. The action plan represents Tetra Tech's initial recommendations for solving the sedimentation problems in the Upper Fall River. The components of the plan include the following:

- Control bank erosion by livestock exclusion fencing in the Upper Fall River;

- Restore and protect high-priority stream and meadow systems in the Bear Creek and Dry Creek watersheds;

- Implement the Bear Creek Meadow restoration between Spaulding Bridge and the Fall River confluence; and

- Perform selective dredging at two sites between Fletcher's Bridge and Spring Creek.

The cost of implementing these actions was estimated to be approximately $2,300,000. If a muskrat control plan is included in the plan to control bank erosion in the Upper Fall River, the estimated plan cost is increased to $3,500,000.

In addition to the actual projects to be undertaken, a monitoring plan must be included in the overall approach to solving the sedimentation problems. The annual cost of the monitoring efforts was estimated to be $35,000. The monitoring program should address both assessing the effectiveness of the various components of the action plan and determine the health of Fall River.

An organizational mechanism should be developed to guide the implementation of the action plan and to develop support for the action plan. The proposed efforts will require cooperation with private landowners, permits from agencies, technical assistance from agencies, support of groups and individuals concerned about the health of Fall River, and input from design professionals. To accomplish this synthesis of diverse parties, an organization such as a Coordinate Resource Management (CRM) group should be formed and it should include participation from all the various stakeholders. Without an understanding of the Upper Fall River sediment problems and solutions, public support for the project will be difficult to develop; the CRM group is one method to accomplish this. A CRM will aid in focusing diverse opinions into a plan of action addressing sediment problems and solutions, while providing a much needed communication link to public supporters. Overall project success will rely greatly on this type of resource tool and organization.

CHAPTER 3
GENERAL PHYSICAL SETTING

This chapter presents general information concerning the physical setting for Fall River and its upstream watershed. Detailed information on hydrology, hydraulics, sediment sources, and sediment balance in the Fall River are provided in chapters 4, 5, 6 and 7, respectively.

3.1 LAND USE

Land use along Upper Fall River includes agriculture, recreation, residential, transportation, natural areas, and water supply. The primary agricultural uses are livestock grazing and alfalfa and hay production. Recreational uses include fishing, hunting, and wildlife viewing. Included in the fishing aspect is professional guiding services and lodges. Anglers primarily fish from small boats typically powered by electric trolling motors. Residential uses include the town of Dana near the headwater springs of Fall River and numerous houses along or near the banks of the river. Some of the houses are second homes and have been located along the river corridor because of the corridor's aesthetic and recreational values. Although land ownership along the Upper Fall River corridor is private, there are several natural areas with wetlands, marshes, and woodlands. Transportation uses include county road bridge crossings (Spring Creek and Island Road), numerous private bridge crossings, a major gas line crossing, power and telephone utilities, and boating. Water supply uses include domestic and agricultural for properties in the corridor and domestic, agricultural, and power generation for users further downstream in the Fall River Valley. Power generation consists of PG&E's Pit 1 Project, a 61-MW facility that diverts between 200 and 2,100 cfs from Fall River just upstream of Fall River Mills to the Pit 1 generation facility along Pit River (PG&E 1993).

Primary land uses in the upstream watershed include timber harvest, grazing, recreation, and transportation. Forest products companies own most of the upstream watershed (Bear Creek and Dry Creek); most of the remaining land is part of the Shasta National Forest. There are a few, smaller private holdings.

CHAPTER 1
INTRODUCTION

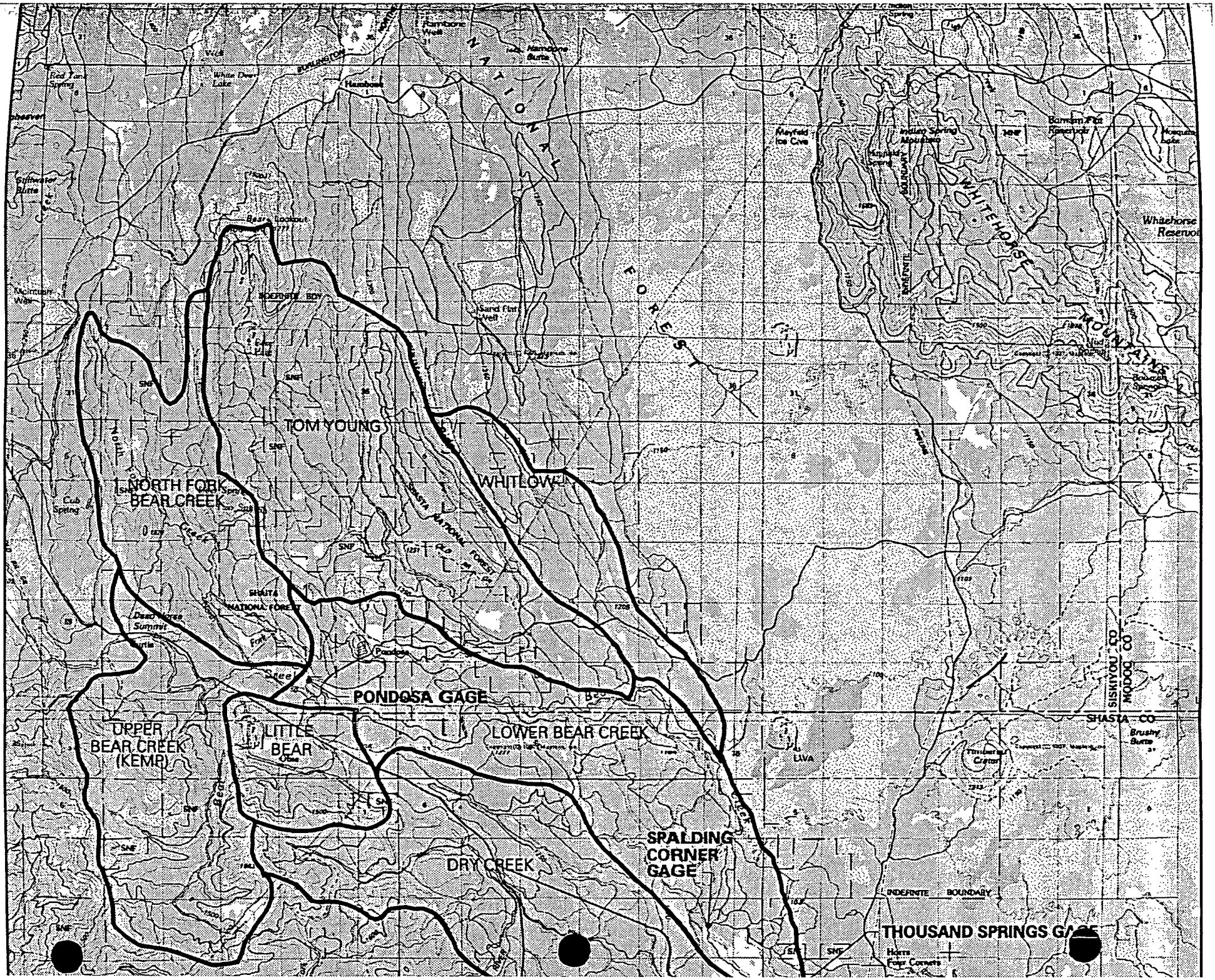
Fall River, part of the Sacramento River Watershed, is a world-renowned wild trout fishery in northeastern Shasta County, California. The native rainbow trout (*species name*) population has thrived in this spring-fed system with its nearly constant year-round flows. From its origins at Thousand and Rainbow springs to its confluence with the Pit River, the river's base flows range from 400 cubic feet per second (cfs) to 1,200 cfs, supplied almost entirely by springs. The 115 square mile Bear Creek and 21 square mile Dry Creek watersheds (see Figure 1-1) provide significant flows to the Upper Fall River during rainfall and snowmelt events. During drier times of year, these tributaries cease to flow.

The Upper Fall River is a low gradient stream, which meanders through a broad, flat floodplain. At a few locations, 10- to 20-foot high terraces confine the river, but in general, the confinement is only on one side of the channel. Because of the low sediment inflow, historic accounts of the Fall River indicate its bed had resistant clay, hardpan, or volcanic cobbles exposed. In contrast, the vast majority of the bed is currently covered with sand deposits, with only limited areas of these historic beds exposed. The exposed clay areas typically occur at bends where secondary currents have kept the bed scoured of sand deposits.

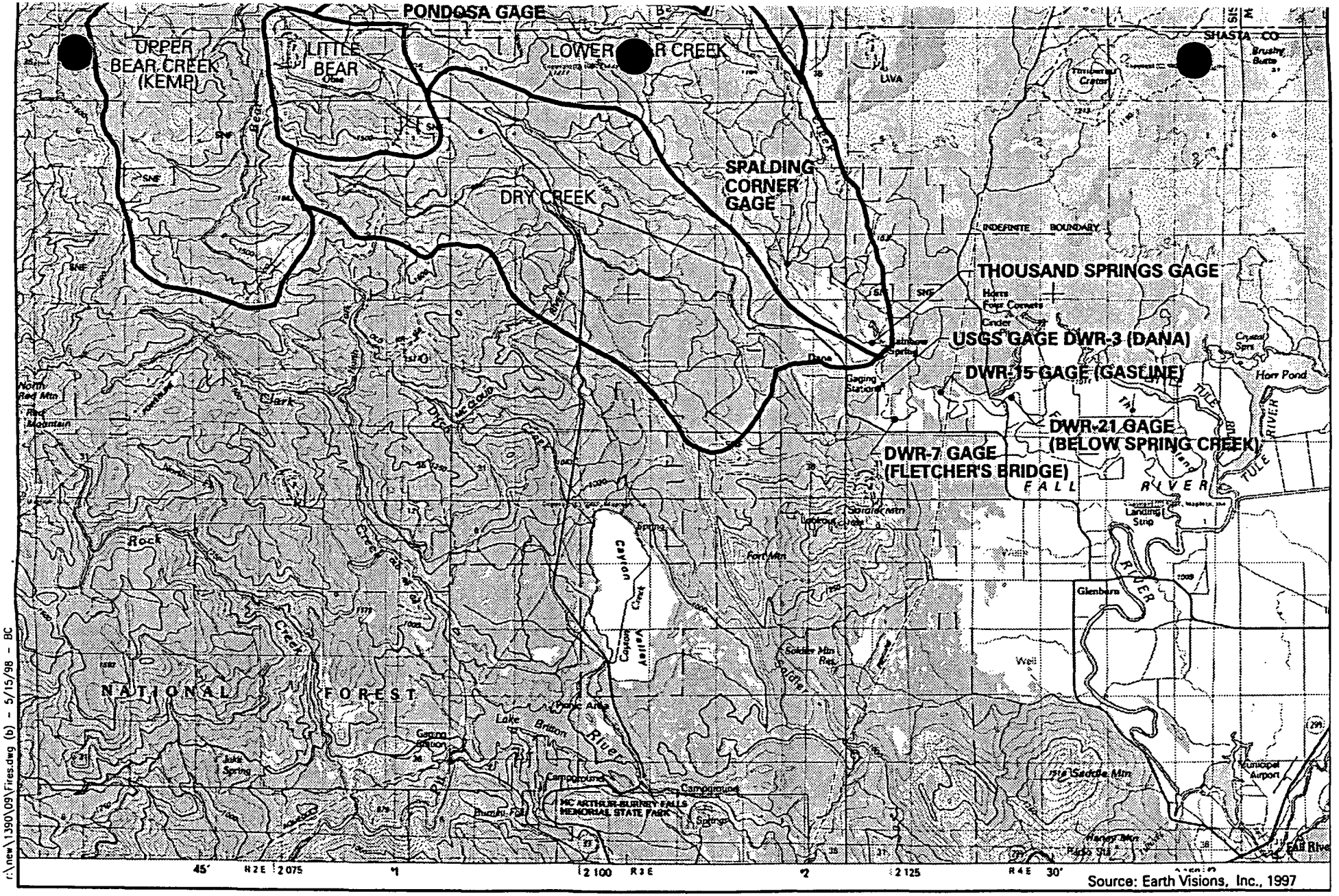
In addition to the wild trout, Fall River supports the Shasta crayfish (*Pacifastacus fortis*), a state and federal endangered species. The river and riparian corridor are used by a variety of migratory waterfowl, shorebirds and other wildlife. Most of the lands within the riparian corridor are privately owned. The principal land use activities along Fall River are livestock grazing, hay and wild rice production, recreation, and residential development (DWR 1998).

1.1 STUDY PURPOSE

To address concerns over sedimentation in Fall River, the Fall River Resource Conservation District (FRRCD) applied for and was awarded a 205j grant from



TOM YOUNG
WHITLOW
NORTH FORK BEAR CREEK
PONDOSA GAGE
UPPER BEAR CREEK (KEMP)
LITTLE BEAR
LOWER BEAR CREEK
DRY CREEK
SPALDING CORNER GAGE
THOUSAND SPRINGS GAGE
NATIONAL FOREST
WHITEHORSE MOUNTAINS
SHASTA NATIONAL FOREST
SHASTA CO
SISKIYOU CO
MODOC CO
INDEFINITE BOUNDARY
Whitehorse Reservoir
Hambone
Sand Flat Well
Mayfield Ice Cave
Indian Spring Mountain
Bamsam Flat Reservoir
Brushy Butte
Timberlake Crater
Horse Four Corners
Cub Spring
Dead Horse Summit
Pondosa
Bear Lookout
Red Tank Spring
White Deer Lake
Stillwater Butte
Mountain Well
Hambone Butte
Hambone Well
Bowman Spring
Lava



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Legend

- Hydrologic boundaries of watershed sub-units
- Stream gage locations

N

0 1 2

Scale in Miles

Hydrologic Watershed Boundary Map

Upper Fall River Watershed, California

Tetra Tech, Inc.

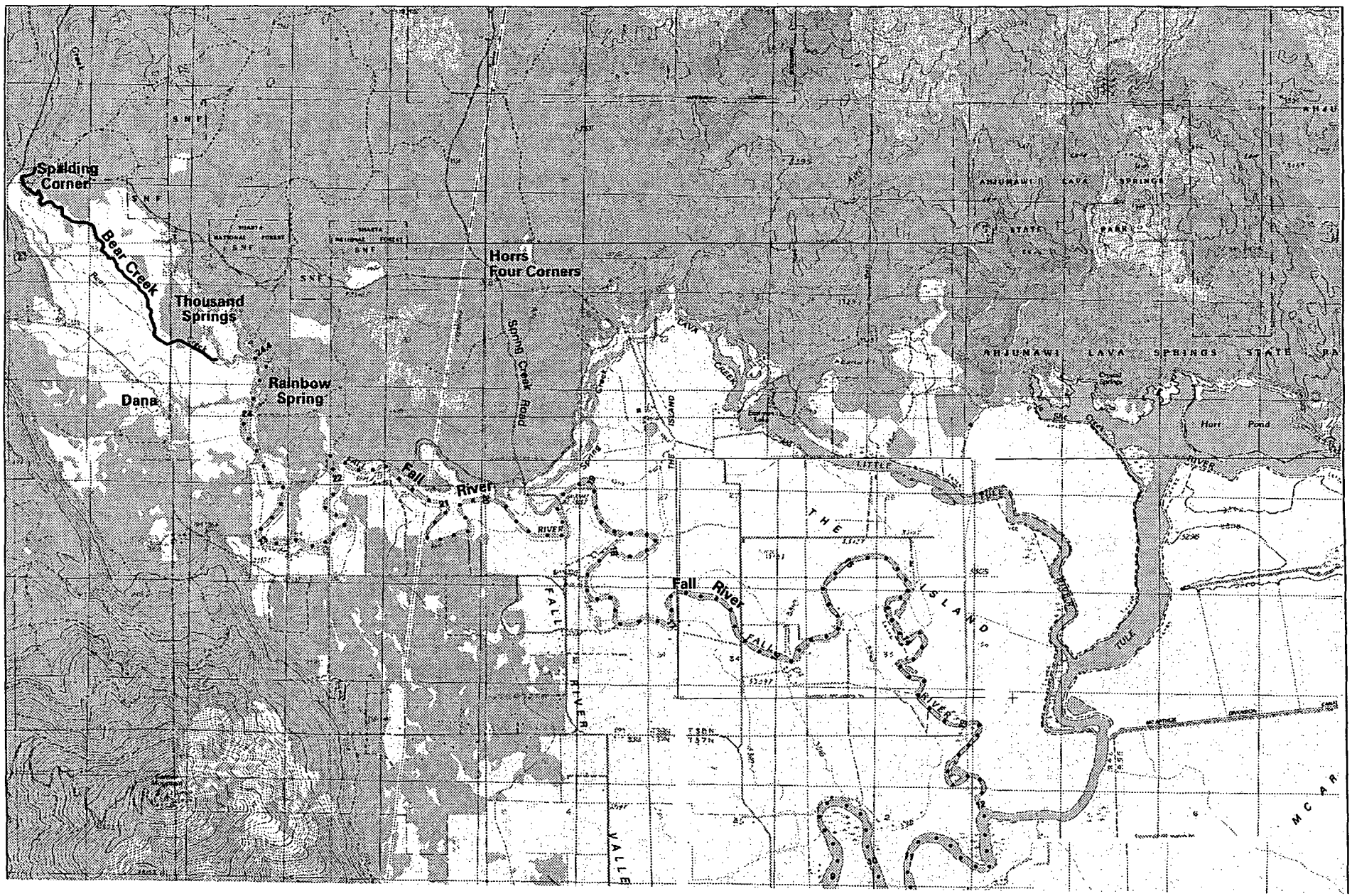
Figure 1.1

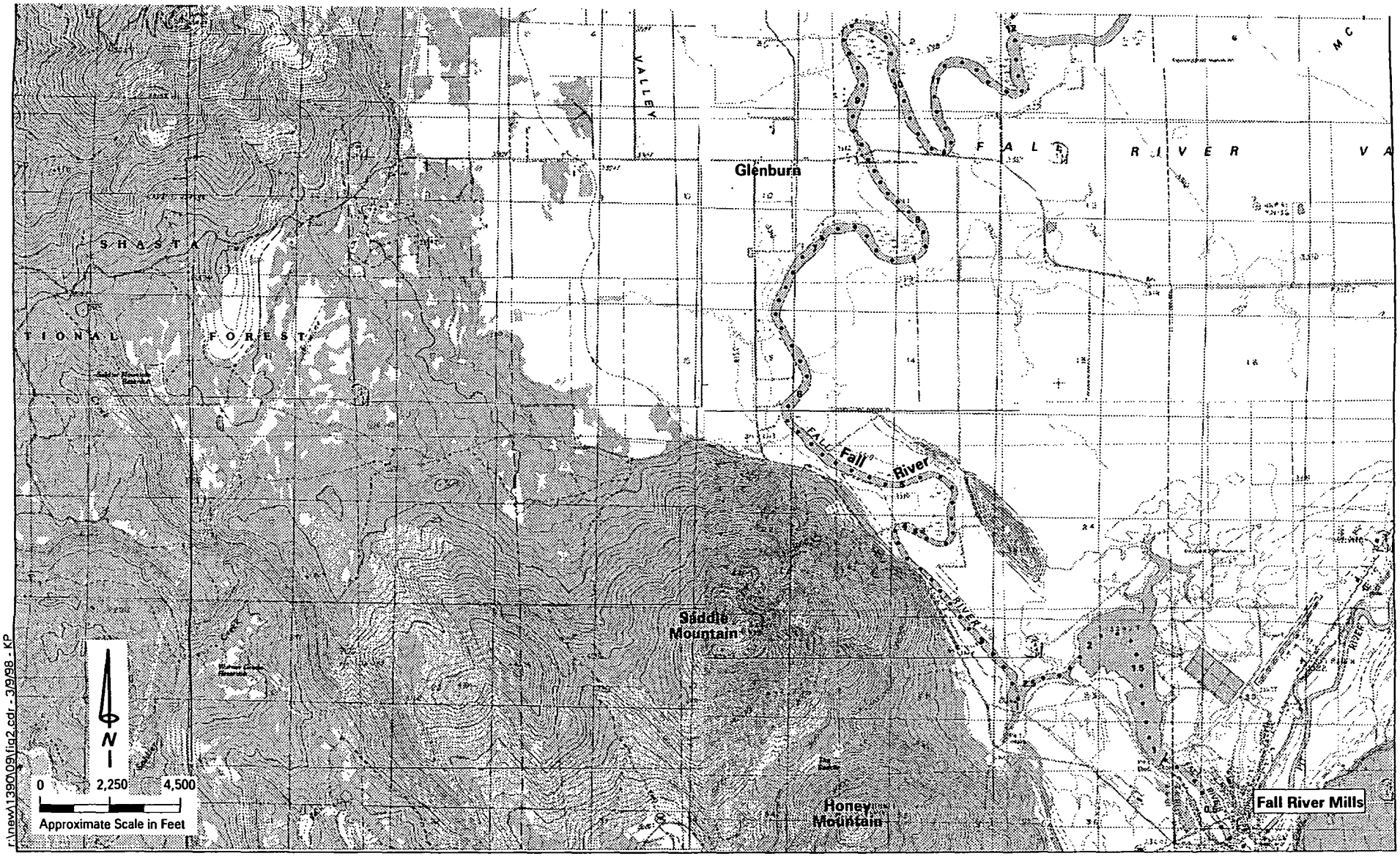
the California RWQCB to investigate the problem and to solutions. The 205j grant application (FRRCD 1995) s study is to "address public concerns over the current proble and decline of the trout fishery and initiate a compr management program that will promote and restore the long Fall River." Tetra Tech was contracted by the FRRCD to con the 205j study related to sediment transport, geomorphol restoration measures. For purposes of the study, the reach un the Upper Fall River, extending from the headwaters at downstream to Island Road Bridge (See Figure 1-2). Thi represents approximately one third of the total length of Fall Ri

1.2 SCOPE OF WORK

The FRRCD and Tetra Tech worked together to develop a sco study, which addressed the needs and budget of the 205j grant. scope of work, the availability of data to perform analyses w summary of the scope of work follows:

- Task 1, project management and administration: m performed by the FRRCD. To support the FR prepared quarterly reports of sedimentation/erosion
- Task 2, public participation: Tetra Tech assisted t public participation process by attending publ ne Technical Advisory Committee (TAC) mee gs, developing responses to public comments.
- Task 3, determine existing sediment in the Upper Tech used available information to provide an opir reasonable estimate of the sediment in the Upper l Tech also recommended future monitoring program the effectiveness of any actions to restore Fall R determine if a sedimentation problem is develo restoration activities were investigated. Specific s quantifying existing sediment in Upper Fall Rive collected by others, describing potential restorat estimating recovery rates and approximate costs of and providing opinions concerning the merits of each
- Task 4, determine sources of sediment from the Bear Creek watersheds: As part of this effort, the Na Conservation Services (NRCS) identified active se within the Bear Creek and Dry Creek watershed evaluated available sediment transport data collecte further identify sediment delivery from the upstre Based on the evaluation of this information


Spalding Corner
Bear Creek
Thousand Springs
Dana
Rainbow Spring
Horrs Four Corners
Spring Creek Road
Fall River
Fall River
THE ISLAND
FALL RIVER VALLE
AHJUMAWI LAVA SPRINGS STATE PA
Horr Pond
LITTLE TULE RIVER
TULE
MCAR



Source: Earth Visions, Inc.1997

Legend

• 21 • River miles (dots mark 1/10th of rivermile)

Fall River and Bear Creek

Northern California

Tetra Tech, Inc.

Figure 1.2

recommended potential measures to address significant sediment sources.

- Task 5, mainstream Fall River bank erosion: Bank erosion is a potential source of sediment into Fall River and as such can contribute to the sediment deposition problems currently identified. Moreover, bank erosion can lead to channel widening and potential reduction in the system's ability to convey sediment. The bank erosion study area extended from Thousand Springs to Island Road Bridge. In this area, bank erosion sites were identified by use of field reconnaissance and aerial photographs. Muskrat burrowing was suggested as a possible significant contributor to bank erosion. The Department of Fish and Game assessed the impact of muskrat burrowing. Specific bank erosion-related sub-tasks included:
  - Identifying current bank erosion sources;
  - Identifying critical bank erosion areas;
  - Estimating bank erosion rates and trends; and
  - Providing opinions concerning bank erosion in Fall River, including the relative contribution to the sediment problems by bank erosion, the causes of bank erosion, and potential ways to control bank erosion.
- Task 6, lack of historic baseline data: This task consisted of developing and implementing monitoring programs addressing sediment transport and quality and quantity, biological conditions and other related data for the mainstream Fall River and tributaries. This task was the responsibility of others and outside of Tetra Tech's scope of work.
- Task 7, quality assurance plan: This task relates to Task 6 and was outside the Tetra Tech scope of work.
- Task 8, implementation plan: Tetra Tech facilitated the TAC's and FRRCD's evaluation and prioritization of the restoration alternatives. Those alternatives considered to have the highest priority were included in an implementation plan. Relevant reports written by other agencies were consulted in this evaluation process. For each of the alternatives included in the implementation plan, Tetra Tech identified permitting requirements, estimated costs, identified potential funding sources and possible institutional constraints, and estimated a timeline that shows the time required for implementation.
- Task 9, final report: Tetra Tech will prepare and submit five copies of a draft report summarizing its work. Tetra Tech will respond to comments by the TAC and RCD on the draft report and will complete and submit one reproducible master and five copies of the final report.

CHAPTER 2
PROJECT BACKGROUND

2.1 DESCRIPTION OF PROBLEMS IN THE UPPER FALL RIVER

The perceived problem in the Upper Fall River is an oversupply of sediment resulting in two to four feet of sand deposition through much of the stream segment between the Navigation Barrier and Island Road Bridge. It is further hypothesized that the influx of sediment has decreased the distribution and density of submerged aquatic vegetation. As a result of these factors, the wild trout fishery has been adversely affected.

Unfortunately, there is very little data available to establish a baseline against which impacts to the Fall River system can be assessed. The earliest available cross sections for this study date back to 1996 (DWR 1998). The oldest published sediment transport information on Fall River was collected in 1996 (DWR 1998). Therefore, rigorous data to determine changes in sediment volumes and sediment transport rates over time are not available. The presence of the distinct, loosely consolidated sediments that were identified by probing (DWR 1998) is strong evidence implying the occurrence of recent sediment deposition. Additionally, many people familiar with Fall River over the past decade or more, who were interviewed for this study, said they believed sediment deposition in the river has increased. Finally, there have been several events over the past few decades that most likely increased sediment yield to the river, including large fires in the Bear Creek Watershed, such as the Pondosa Burn in August 1977, and channelization of the Bear Creek Meadow below Spaulding Bridge. Additionally, the Bear Creek and Dry Creek watersheds contain numerous meadows and wetlands that have had been degraded to the point that their natural sediment retention functions have been adversely affected. These features were once an important part of the system that kept sediment delivery to the Fall River at very low levels and permitted this low energy system from being overwhelmed by deposition.

The key submerged aquatic vegetation within Fall River are *Zanichellia palustris* (referred to as Z-grass by local anglers), *Elodea canadensis*, *Elodea nuttallii*, and *Myriophyllum sibiricum* (NSR 1997). This is no quantitative information dating prior to the 1990s available concerning the occurrence, distribution, or density of these aquatic plant species in Fall River. However, personal accounts of people who have been familiar with the system for two to three decades indicate that extensive beds of Z-grass were found upstream of Spring Creek to the Navigation Barrier. Currently, such extensive Z-grass beds are only found near and below the Spring Creek confluence.

In terms of fishery information, available population estimates for portions of the Upper Fall River date back to 1975. The California Department of Fish and Game (DFG) conducted counts by electroshocking fish in 1975, 1976, 1977, 1978, and 1983 (Rode and Weidlein 1984). Fish counts based on observations also were conducted by DFG divers in 1993, 1995, and 1997 (Dean 1997). Because of the two different procedures, direct comparisons of the two data sets are difficult. In general, the fishery population information is inconclusive but is further discussed in Chapter 3.

It is not unusual to have little or no rigorous data to measure the level of impact that has occurred to a stream, particularly when it involves sedimentation and fisheries habitat. The required information can be expensive to collect and necessitates a long-term commitment of resources to establish a thorough database. Unfortunately, such efforts typically are undertaken only after a problem has been observed by interests personally involved with the system; at this point, it is too late to collect baseline data for prior conditions.

2.2 STUDY AREA

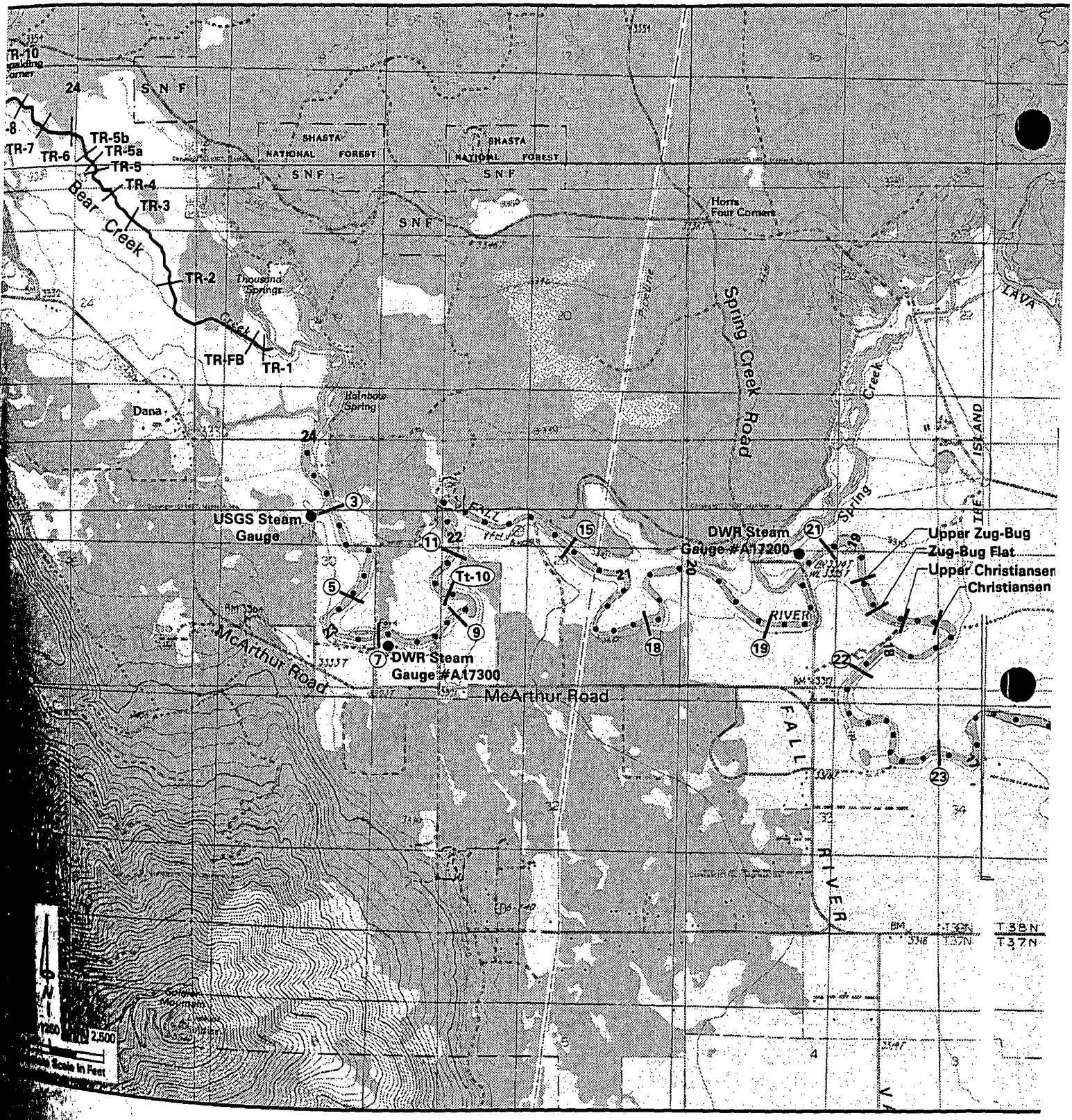
Two distinct areas are included in evaluating sedimentation problems and potential solutions in Upper Fall River. The first area is the reach of Fall River in which the immediate concern is centered. The second area includes the Bear Creek and Dry Creek watersheds upstream of Fall River. The watersheds are a required component of the study due to their potential roles in delivering sediment to Upper Fall River.

2.2.1 Upper Fall River

Upper Fall River is considered to extend from Island Road Bridge upstream to the river's origin at Thousand Springs. This is an 8.3-mile reach starting at river mile (RM) 16.2 and continuing upstream to RM 24.5. (RM is measured moving upstream with RM 0 at the confluence with the Pit River). This section of river in the study area is shown on Figure 2-1.

2.2.2 Bear Creek and Dry Creek Watersheds

The Bear Creek and Dry Creek watersheds are the two major surface water inflows to Fall River. They both contribute to Fall River in the vicinity of



Legend

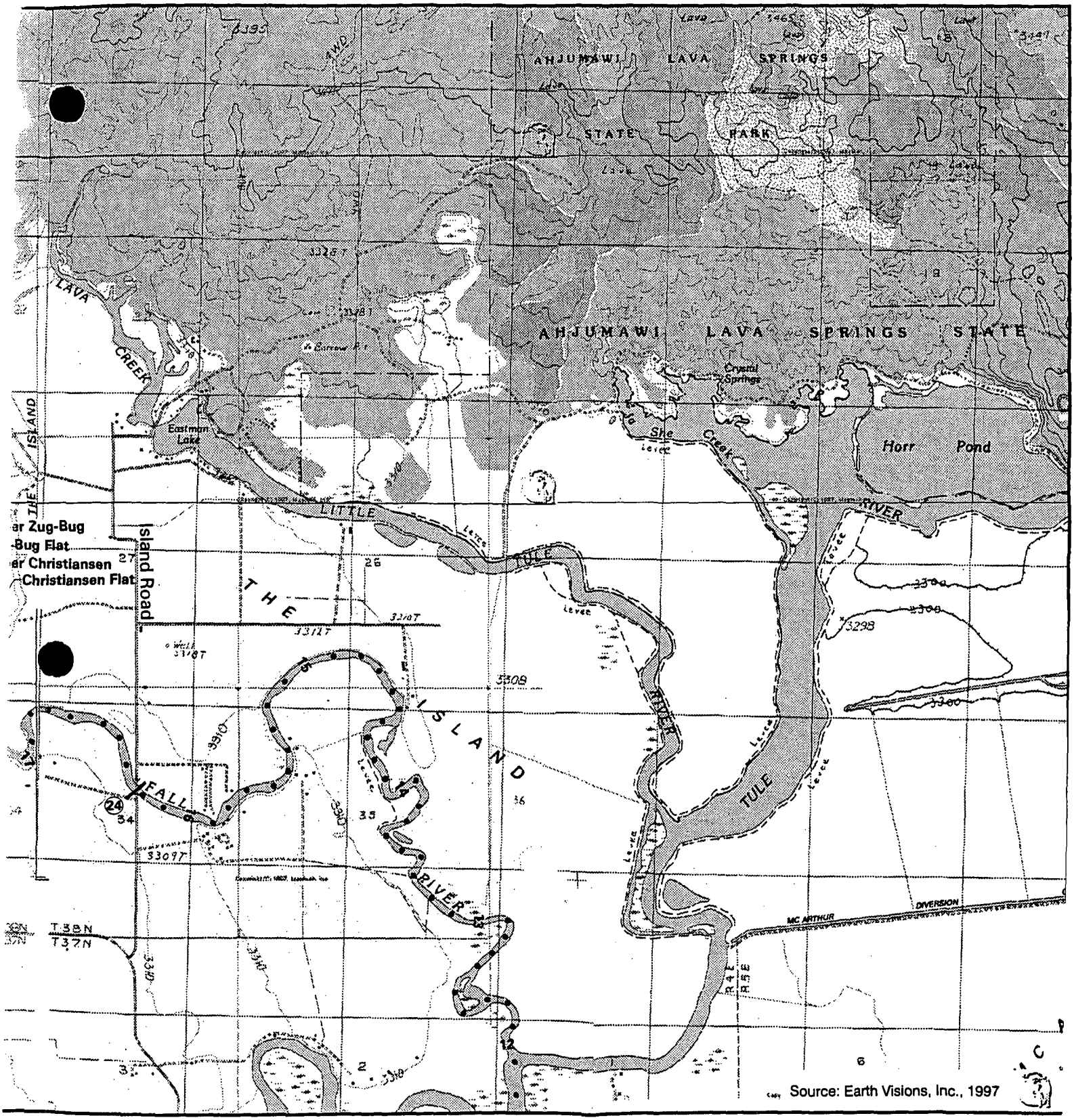
(1) — DWR cross sections

TR-2 — Bear Creek channel transects

(Tt-10) Tetra Tech cross sections

• 21 • River miles (dots mark 1/10th of rivermile)

● Stream gage sites



Source: Earth Visions, Inc., 1997

Upper Fall River Location Map

Northern, California

Figure 2.1

Dana, within several thousand feet of Fall River's origin at Thousand Springs. The Bear Creek watershed has a contributing area of 115 square miles, whereas the smaller Dry Creek watershed represents 21 square miles. These two watersheds are delineated and are shown on Figure 1-1. The Bear Creek watershed often is delineated to encompass a larger area; however, the delineation shown on Figure 1-1 is based on estimates of the actual area that contributes surface flows. Though topographically connected, areas outside of the hydrologic boundaries do not provide surface runoff because the lava flows on the northeastern and eastern portions of the Bear Creek watershed provide no drainage system to convey surface flows. If a hydrologic connection exists between these areas and Fall River, it is through groundwater and springs.

Land use managers in the upstream watersheds use a system of planning units that tend to follow hydrologic boundaries. However, due in part to inclusion of areas that do not appear to contribute runoff, the planning unit boundaries do not directly coincide with the hydrologic watershed boundaries delineated by Tetra Tech.

2.3 Past and Ongoing Studies

A variety of studies have been undertaken within Fall River and its watershed as a result of concerns over the sedimentation problem. Studies specifically undertaken to address sedimentation issues in Fall River and their status are listed below:

- Aquatic Vegetation Study being performed by D.F. Spencer of the USDA, Agricultural Research Service, Weed Science Program at the University of California, Davis. The study is currently undergoing peer review and results are not available.
- Study of the habitat characteristics of the aquatic vegetation of Upper Fall River by North Sate Resources (NSR). Their study was performed as part of the 205j project. The study results are available (NSR 1997).
- Muskrat control plan prepared by the USDA Wildlife Service (USDA-WS), DFG, and Marra Ellis. This report is available (USDA-WS 1997).
- Water quality survey of Upper Fall River by the California Regional Water Quality Control Board (RWQCB). The study period was the summer of 1997. The results are available (RWQCB 1998).
- A study of sediment sources in the Bear Creek and Dry Creek watersheds by the USDA-NRCS. The study was completed and is available (NRCS 1998a and 1998b).
- Aquatic monitoring and assessment study for the Upper Fall River by the California Department of Water Resources (DWR). The project was conducted in 1996 and 1997. A draft report was prepared and is

currently available (DWR 1998). In addition, DWR has made electronic copies of data available to Tetra Tech, which made extensive use of the information in this report.

- Results of discharge, cross section, and sediment transport monitoring performed on the reach of Bear Creek between Spaulding Bridge and the confluence with Fall River. Additionally, discharge and sediment transport data were collected on Bear Creek at Pondosa. This information was collected by Thousand Springs Ranch (TSR) with assistance from W. M. Beaty and Associates (WMBA). A formal report consolidating this information has not been prepared; however, Rick Poore of TSR has made electronic files and hard copies of the information available to Tetra Tech (Poore 1998), which used this information extensively within this report.
- A study of sedimentation and sediment transport characteristics of Upper Fall River by Mike Fitzwater and Dale Dennis. This information has not been published, is proprietary, and is not available for the 205j study.
- Additional sediment transport and flow measurement information collected by Fall River Wild Trout Foundation. This information is being compiled and analyzed and is not available for the 205j study.
- Fish counts to estimate fish populations at several locations in Fall River have been performed by DFG since 1975. DFG plans to continue to perform fish counts in the future. This information is available (Rode & Weilein 1984, Dean 1997).

Of the studies just listed, only the last four are still ongoing. The DWR study was intended to be performed over three years, but funding changes caused the study to be concluded after its first year. The FRRCD currently is seeking funds through several grant applications to continue monitoring efforts. Monitoring activities would include a gaging station, cross section surveys, and sediment transport measurements, additional monitoring in the upstream watersheds, and continued study of the aquatic vegetation in Upper Fall River. Additionally, monitoring efforts would be extended downstream to determine the progression of sediment as it moves through the system.

A number of other studies exist, which provide additional useful information on the natural resources of Fall River, including the following:

- The draft recovery plan for the Shasta crayfish prepared by the US Fish and Wildlife Service (USFWS 1997). This information is currently available.
- The USDA Soil Conservation Service (SCS) performed a study of the Fall River watershed in the early 1980s (SCS 1983). This information is currently available.

- Pacific Gas and Electric Company (PG&E) has performed studies and prepared documents related to the Federal Energy Regulatory Commission (FERC) process for receiving a new license to operate the Pit 1 Project (PG&E 1993). Because the Pit 1 project impounds water on Fall River and diverts it to generating facilities on Pit River, the application provides information about Fall River; this information is currently available.

2.4 PROJECT PARTICIPATION

The 205j process has included several mechanisms for interested individuals, groups, and agencies to participate. There have been three public meetings, at which the project status has been presented and public questions and comments have been solicited. The first public meeting was held on May 6, 1997. Its purpose was to present the scope of the study to the public and to receive general public input as to important issues that should be addressed by the 205j study. The second public meeting was held on August 15, 1997, and provided a forum for Tetra Tech and others performing studies on Fall River to present the status of the work and to answer questions from the public. The third public meeting was held on May 8, 1998. Its purpose was to allow Tetra Tech to present the draft of the 205j study and to receive public comments.

Additionally, a TAC was developed from representatives of various agencies and private individuals. The TAC represents a collection of people with specific knowledge and interests in Fall River. Its purposes were to provide access to information that would assist the study, to provide personal perspective on Fall River from individuals who had substantial knowledge and interest in the system, and to provide review and input throughout the study process. Three TAC meetings were held on March 18, 1997, June 16, 1997, and August 6, 1997. A fourth TAC meeting is scheduled for the week of June 22, 1998.

In addition to the public and TAC meetings, numerous agency staff and private individuals provided assistance and information throughout the study. These participants are identified in the acknowledgments at the front of this report. Finally, the FRRCD board and staff have administered the 205j program and assisted in numerous ways throughout the study from tracking down information to facilitating land access and other logistics associated with field work.

CHAPTER 3
GENERAL PHYSICAL SETTING

This chapter presents general information concerning the physical setting for Fall River and its upstream watershed. Detailed information on hydrology, hydraulics, sediment sources, and sediment balance in the Fall River are provided in chapters 4, 5, 6 and 7, respectively.

3.1 LAND USE

Land use along Upper Fall River includes agriculture, recreation, residential, transportation, natural areas, and water supply. The primary agricultural uses are livestock grazing and alfalfa and hay production. Recreational uses include fishing, hunting, and wildlife viewing. Included in the fishing aspect is professional guiding services and lodges. Anglers primarily fish from small boats typically powered by electric trolling motors. Residential uses include the town of Dana near the headwater springs of Fall River and numerous houses along or near the banks of the river. Some of the houses are second homes and have been located along the river corridor because of the corridor's aesthetic and recreational values. Although land ownership along the Upper Fall River corridor is private, there are several natural areas with wetlands, marshes, and woodlands. Transportation uses include county road bridge crossings (Spring Creek and Island Road), numerous private bridge crossings, a major gas line crossing, power and telephone utilities, and boating. Water supply uses include domestic and agricultural for properties in the corridor and domestic, agricultural, and power generation for users further downstream in the Fall River Valley. Power generation consists of PG&E's Pit 1 Project, a 61-MW facility that diverts between 200 and 2,100 cfs from Fall River just upstream of Fall River Mills to the Pit 1 generation facility along Pit River (PG&E 1993).

Primary land uses in the upstream watershed include timber harvest, grazing, recreation, and transportation. Forest products companies own most of the upstream watershed (Bear Creek and Dry Creek); most of the remaining land is part of the Shasta National Forest. There are a few, smaller private holdings.

Most of the timber is harvested on a 10-year selective cut rotation (NRCS 1998a). The primary grazing activity is cattle and occurs throughout much of the watershed. Recreation uses include hunting, fishing, wildlife viewing, hiking, and mountain biking. Transportation uses include State Highway 89, the McCloud railroad, a major power transmission line, and numerous secondary roads throughout the watershed that serve the timber harvest industry. There are no concentrated residential areas within the watersheds, although there are a few private homes. At one point, the town of Pondosa existed near the center of the watershed, but the town site has largely been abandoned.

3.2 CLIMATE

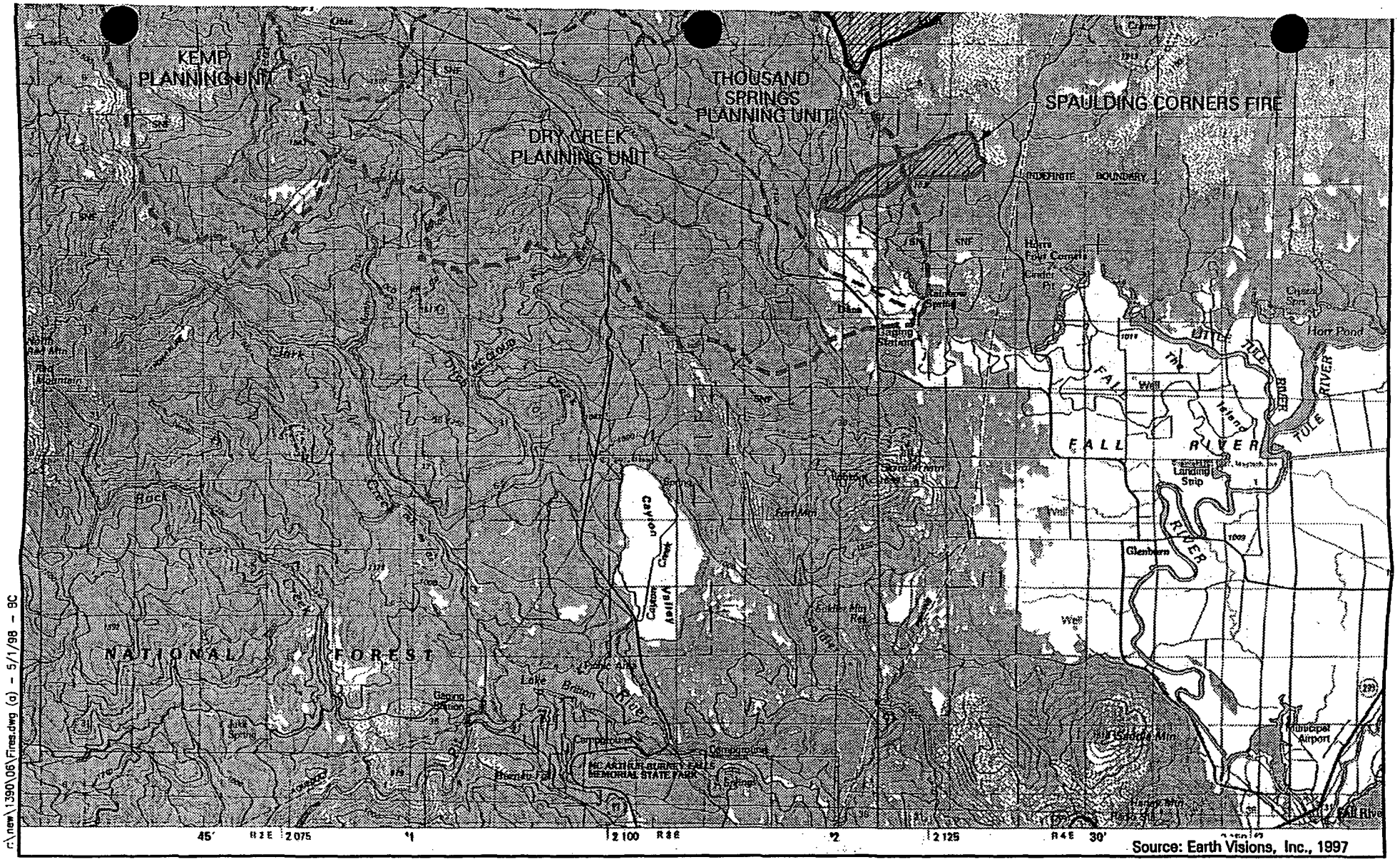
The climate within the study area varies in relation to elevation. Within the Fall River Valley, average annual precipitation is on the order of 20 inches. In the higher elevations of the upper watershed, average annual precipitation can exceed 60 inches. The primary period for precipitation is October through April, during which general storms supply most of the moisture, which may fall as either rain or snow. During the late spring and summer, convective thunderstorms can result in intense but brief rainfall. These storms are usually small and are isolated to a small portion of the watershed at any one time. Precipitation can vary substantially from average values in any given year. In general, precipitation patterns follow "a three-year cycle of wet and dry years within an 11-year cycle of peak or minimum years" (SCS 1983). Summers are generally dry and hot, with temperatures in the high 80s °F. Commonly, subfreezing temperatures occur throughout the winter (Rode & Weidlein 1984).

3.3 GEOLOGY

Information regarding the physical and geological setting of the Fall River Watershed was obtained from the Preliminary Report - Geologic Mapping in the Fall River Valley Region, Northern California by Thomas L.T. Grose, (Grose 1996), the Pit 1 Project FERC No. 2687 Application for New License - Water Use and Quality Report by Pacific Gas and Electric Company (PG&E 1993), and the Fall River Watershed Area Study Technical Report from the USDA Soil Conservation Service (SCS 1983). Information on the geology of the Bear Creek and Dry Creek watersheds was supplemented by the Geology and Mass Wasting Draft Report prepared by Cooksley Geophysics, November 1997, for W. M. Beaty and Associates, Inc. (WMBA 1997).

3.3.1 Physical Setting

The Fall River watershed covers an area of 612 square miles within the volcanic terrain of the Modoc Plateau (SCS 1983) and extends into adjacent Lassen, Modoc, and Siskiyou counties. The Fall River Valley lies just east of the central axis of the southern Cascade Range, trending northwesterly among a string of volcanoes on the west, which include Soldier, Saddle, and Haney mountains, and the Big Valley Mountains on the east. The upper Fall River watershed area, made up of the Bear Creek and Dry Creek watershed areas, contains approximately 87,251 acres (about 136 square miles) of forested land north of the Fall River Valley (Figure 1-1).



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Pondosa and Spaulding Corner Fires in Bear Creek Drainage, Fall River Watershed.

Legend

- Spalding Corners fire boundary - 620 acres - 8/14/73
- Pondosa fire boundary - 20410 acres - 8/3/77
- Bear Creek and Dry Creek watershed boundaries

N

0 1 2

Scale in Miles

Bear Creek Watershed Planning Units and Boundaries of Historic Fires

Shasta and Siskiyou Counties, California

Tetra Tech, Inc.

Figure 3.1

Much of this area lies north of Lake Britton and is transected by Highway 89 (WBA 1997). For planning purposes, the Upper Fall River watershed has been divided into six different planning watersheds (Figure 3-1): Kemp (about 8,845 acres), North Fork Bear Creek (about 9,607 acres), Tom Young (about 24,180 acres), Whitlow (about 24, 466 acres), Thousand Springs (about 6,465 acres), and Dry Creek (about 13,687 acres). Downstream of the confluence with Bear Creek, Fall River flows across a flat floodplain built by sediments deposited in the ancient Lake McArthur (Grose 1996).

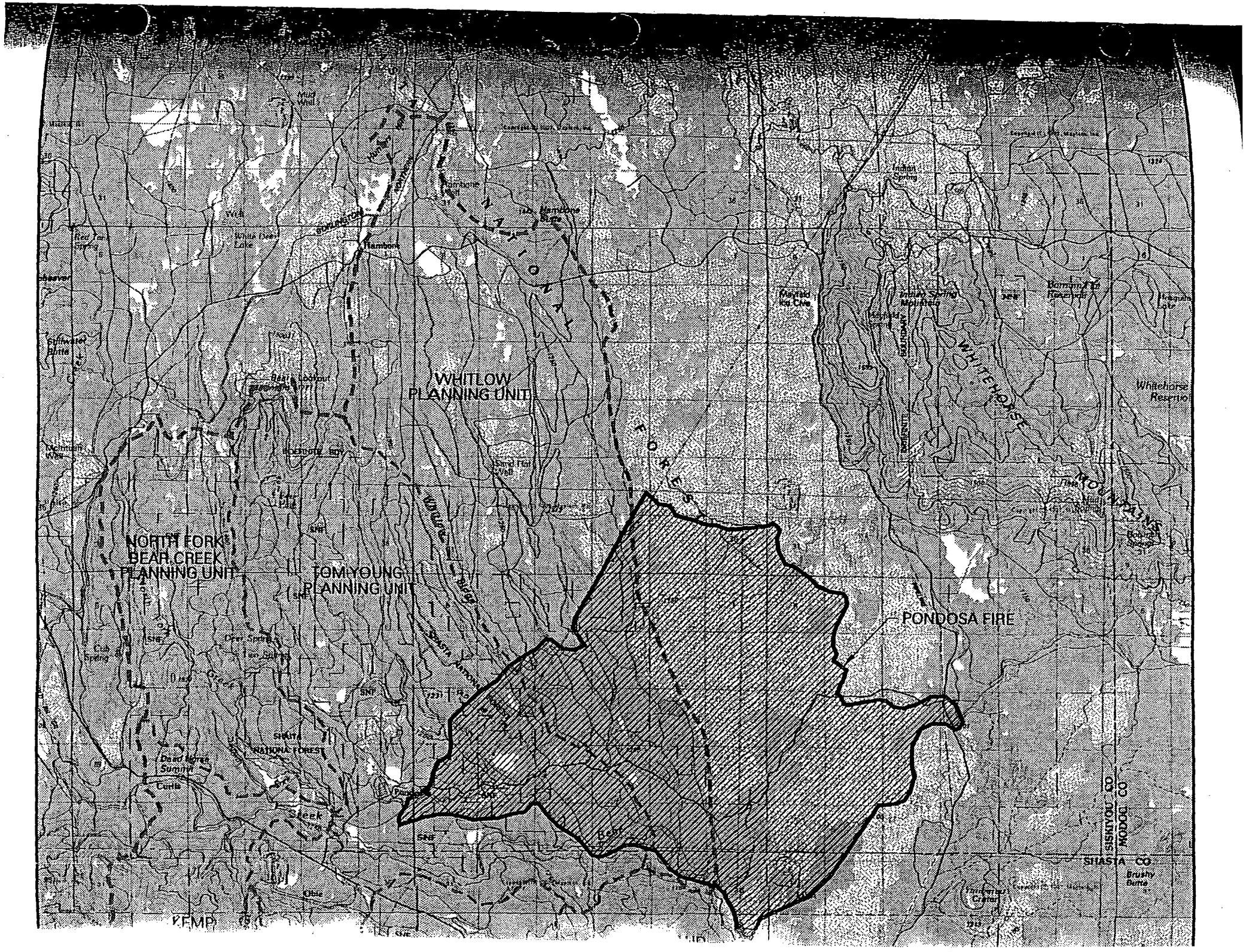
The most recent geologic mapping of the Fall River area was conducted by Dr. Thomas L.T. Grose, a consulting geologist and professor of geology at the Colorado School of Mines, in November 1996 through a contract with the FRRCD. The mapping, which covered about 480 square miles around the Fall River Valley, was conducted using aerial photography and ground truthing in the field. Geologic maps were produced at a scale of 1:24,000 and 1:62,500 and are available at the FRRCD office in MacArthur. Much of the following discussion is based on results from this mapping, which were described in the accompanying preliminary report, Geologic Mapping of the Fall River Valley Region, Northern California (Grose 1996)

Previous geological studies cited by Grose include hydrogeologic mapping and monitoring by the California DWR (1963, 1982) and the USDA Soil Conservation Service (1983), geologic mapping in the adjacent Timbered Crater area (Peterson and Martin 1980). References regarding the geology of the greater area cited include Gay and Aune 1958; Donnelly-Nolan et al. 1990, Wills 1991, Dzurisin et al. 1991, Grose et al. 1992, Grose 1995, Muffler et al. 1994, Champion and Donnelly-Nolan 1994, and Page 1995.

Additional information on soils and fluvial sediments in the Fall River area have been collected by the California DWR (DWR 1998), W. M. Beaty and Associates, and by the USDA NRCS (NRCS 1998).

3.3.2 Structure

The Fall River Valley lies just east of the central axis of the southern Cascade Range and is structurally controlled by a pair of down-dropped fault blocks, or grabens, that trend north by northwest between two uplifted blocks, or horsts (Grose 1996). The town of Fall River Mills lies near the southern end of the graben, which extends about 35 miles north to the summit caldera of the Medicine Lake Highlands volcano. The volcanic peaks of Soldier, Saddle, and Haney mountains make up the western horst, while the Big Valley Mountains make up the eastern horst. Seven major normal faults cut through the valley, creating this classic graben-in-graben rift (Grose ibid). Hat Creek, the next downstream tributary to the Pit River, is also structurally controlled, lying in a graben to the west of the Soldier, Saddle, and Haney mountain horst block.


WHITLOW
PLANNING UNIT
NORTH FORK
BEAR CREEK
PLANNING UNIT
TOM YOUNG
PLANNING UNIT
PONDOSA FIRE
FORKS
WHITEHORSE
SISKIYOU CO
MODOC CO
SHASTA CO
VFMP

Immediately north of the Fall River Valley lies the Giant Crater Lava Field, which contains volcanic flows from both the Medicine Highlands volcano and the Brushy Butte volcano (Grose ibid). Lava flows from the Popcorn Cave volcanic shield also border the southern end of the valley.

According to the Fall River Watershed Technical Report (SCS 1983), Fall River is basically the remains of the outlet channel for the ancient Lake McArthur, which formed in the graben. Lake McArthur began to drain south into the river once the Giant Crater Lava Field essentially dammed the north end of the valley.

The floor of the Fall River Valley is composed of ancient lake sediments that had been deposited into ancient Lake McArthur and subsequently infilled the graben. The sedimentary lake deposits dip slightly to the north and have interbedded hardpan layers that act as impermeable barriers to the vertical migration of groundwater. The structure and lithology of these ancient lake deposits tend to keep the groundwater table less than five feet from the surface in many areas of the valley, creating numerous ponds and wetlands along the north end of the valley. Surface water features are most often structurally controlled; for example, intermittent springs flow from low fault scarps at the base of Saddle Mountain, and sag ponds follow fault traces.

Groundwater is recharged from precipitation (both rain and snow) that falls on the Medicine Lake Highlands and flows southward through the fractured lava flows of the Giant Crater Lava Field. Most of the lava in the area is highly fractured due to the structural deformation in the area, and so the lavas are very permeable and able to transmit water. This groundwater discharges into the many springs, ponds, and lakes of the Fall River area (Grose ibid). Three fourths of the flow in Fall River rises from the springs at the southern end of the lava field (SCS 1983). Lateral groundwater movement also is controlled by the north-south trending faults within the valley and along its east and west margins. These structural features inhibit the east-west movement of groundwater and the development of distinct surface drainage patterns (SCS 1983).

3.3.3 Geologic Formations of the Fall River Area

Forty-four mappable geologic units have been defined in the Fall River Valley area (Grose 1996). Most of these units are either volcanic or sedimentary. Volcanic units include lava flows and pyroclastics, while sedimentary rock units include claystones, siltstones, sandstones, conglomerates, and diatomite deposits. Pyroclastics are deposits of explosive fragmental debris and ashfall, which become welded together after cooling, often forming tuffs or breccias. The formations range in age from approximately 10 Ma (10 million years ago) to the present. Readers are referred to Grose 1996 for a detailed description of the geologic formations of the region.

The main geologic formations found in the Fall River, Bear Creek, and Dry Creek watersheds are listed below. Descriptions are taken from Grose 1996; additional

notes have been made in parentheses stating where they are found within the study area:

Qa - Alluvium. Unconsolidated fluvial deposits of sand, silt, and conglomerate occurring mainly along Bear Creek and in Muck Valley and Widow Valley. (In the study area, this includes the Bear Creek meadow near Thousand Springs and the area around Rainbow Springs.)

Qb - Basalt flows derived from several sources, some many miles northward, such as Giant Crater, and others just north of the Valley, such as Brushy Butte volcano. Most of the lava erupted about 10,600 years ago and was emplaced within a span of less than 30 years (Champion and Donnelly-Nolan 1994). Other flows are undoubtedly thousands of years older. The Qb flows are younger than, and overlie, sediments of Lake McArthur. (In the study area, this includes Giant Crater Lava Field, including Timbered Crater and Brushy Butte volcano.)

Qbcs - Lake sand and silt of Bear Creek deposited as a small delta, a very thin surficial layer over and interbedded with lake clays, Qlms. (In the study area, this includes the Bear Creek meadow near Thousand Springs and the area around Rainbow Springs.)

Qc - Colluvium. Unconsolidated slope creep debris of weathered rock and soil occurring mainly along the base of the Big Valley mountains.

Qlms - Lake clay, silt, and sand deposited in quiet, central areas of ancestral Lake McArthur. Underlies most of the floor of Fall River Valley and occurs an unknown distance northward beneath the flows of Giant Crater Lava Field. (In the study area, this occurs in the flat lands of the valley south of the Giant Crater Lava Field and extends to Fall River Mills and Pit River.)

Qls - Landslide deposit, active or dormant. Fine to coarse debris. May grade into colluvium. Occurs at Soldier Mountain, east of Lake Britton, south of Pit 1 Powerhouse, west of big Valley Mountains, and north of Round Barn. (In the study area, it occurs along steep slopes in some locations within the Bear Creek/Dry Creek watersheds).

Qsb - Basalt and andesite flows preserved on small plateau between Soldier and Saddle mountains. May roughly correlate with Qfrb and project into subsurface of the valley. Age date of 1.22 Ma (Page 1995).

Qfrb - Basalt flows exposed only on benches southwest of Fall River Mills. Interpreted to correlate with prominent flow in the subsurface of Fall River Valley west of the McArthur Fault. Age date of 0.945 Ma (Page 1995). (In the study area, it occurs north of the Pit River and southwest of Fall River Mills.)

Qprd - Lake sand and silt of Pit River deposited as a large delta in ancestral lake McArthur. Occurs in southern and southeastern part of Fall River Valley. Interstratifies and progrades with lake clays, Qlms. (In the study area, it occurs near the Pit River between McArthur and Fall River Mills.)

Tpa - Andesitic and basaltic flows and vent facies from local vents aligned along the Pittville and associated fault zones. Underlies Qdba flows and may be correlated partially with old Tba terrain. Pliocene. (In the study area, it occurs as a few outcrops scattered through the flat lands of the valley.)

Thcb - Basaltic and andesitic flow sequence in area mainly north of Hammond Crossing. Flows occur uniformly over many square miles and are derived from vents to the northwest of map area. Estimated age 2 to 3 Ma. (In the study area, it occurs in the Bear Creek and Dry Creek watersheds.) Note: labeled Thcb on map but apparently mislabeled Thcn in Grose 1996 text.

Tpb - Basaltic and andesite flow sequence in Pondosa area and extending southward to Soldier Mountain. Flows occur uniformly over many square miles and are derived from sources to the northwest. Estimated age 3 to 4 Ma. (In the study area, it occurs in the Bear Creek and Dry Creek watersheds.)

Tsts - Tuff, sandstone, siltstone, and diatomite, massive to well-layered, probably lake deposits. Overlies Tsca (andesite flows and pyroclastics) and underlies Qsb south of Soldier Mountain. Extends into subsurface of the valley. May correlate with Tpps (similar rocktypes exposed in the Pit River canyon) or with Thdl (diatomite and lake clays, silts, sands and tuffs exposed along Hwy 299 at Hat Creek). (In the study area, it is found along the southeastern edge of Soldier Mountain.)

Tspa - Pyroxene andesite of Soldier Mountain volcano. Distinctive crystals of pyroxene and lesser hornblende are common. Individual flows are massive and not obvious in outcrop. Probably all flows were derived from summit intrusive body. Probably earliest Pliocene and older than Tsha andesite.

Tsha - Andesite of Saddle Mountain and Haney Mountain volcanoes. Flows are massive, dense, and relatively indistinct. Estimated age is Early Pliocene, 3 to 5 Ma.

3.4 CHARACTERISTICS OF THE UPPER FALL RIVER

A tributary of the Pit River (which flows into the Sacramento River at Redding), the Fall River is fed by flows from Bear Creek, Dry Creek, and numerous large springs and spring-fed tributaries, including Mallard Creek, Spring Creek, Lava Creek, and Tule River (PG&E 1993). Bear Creek is joined by Mallard Creek about 1,380 feet upstream of the confluence with the Fall River at Thousand Springs. Spring Creek joins the Fall River about 5.2 miles downstream of the Thousand Springs/Bear Creek confluence, and Tule River joins Fall River about

7.3 miles downstream of Spring Creek. The total length of Fall River, from Thousand Springs to the confluence with Pit River, is 24.5 miles. The area referred to as the Upper Fall River extends from Thousand Springs downstream to Island Road Bridge, a distance of 8.3 miles. This reach includes Spring Creek but does not include Tule River (Figure 2-1).

3.4.1 Hydrology

Most flow in the Upper Fall River is derived from Thousand Springs, Rainbows Springs, and Spring Creek, of which Thousand Springs is the largest. Smaller springs and seeps contribute additional flow throughout the reach. The primary surface water tributary is Bear Creek, which has contribution surface drainage area of 115 square miles. Dry Creek is an ephemeral stream with a watershed of 21 square miles and contributes flows only during wetter periods. Bear Creek flows nearly continuously from initiation of the rainy season, through the snowmelt runoff period, and typically into August. Further upstream, Bear Creek flows the entire year; however, there are several miles of stream above Spaulding Corner in which flow infiltrates the porous volcanic material beneath the stream.

The contribution of Thousand, Rainbow, and Mallard springs above Dana is slightly less than 400 cfs. Below Spring Creek, base flow increases to approximately 600 cfs. The base flow constitutes about 80 percent of the average annual flow of the Fall River near Dana. At Spring Creek, the base flow represents 85 percent of the average annual flow.

Although the base flows from the springs represent the largest portion of the annual flows, rainfall and snowmelt can increase the flow to over ten times the base flow for short periods. The 10- and 100-year floods have estimated peak discharges on the order of 2,000 and 6,000 cfs in Upper Fall River.

3.4.2 Planform, Profile, and Cross Section

The Upper Fall River is a low gradient, meandering stream, which occupies a broad, flat floodplain. At a few locations, of 10- to 20-foot high terraces confine the channel on one side, while the opposite side still has a wide floodplain to access. The banks of the river are typically three to six feet above the water surface at base flow conditions. Below Spring Creek, the floodplain is broader and flatter, and at some locations banks may be only two feet or less above the base flow water surface elevation.

Table 3-1 lists some general geomorphic characteristics of the Fall River. Figure 3-2 provides a profile of the channel thalweg (maximum channel depth) and water surface elevations during base flow conditions. DWR (1998) cross sections plus additional cross sections and water surface elevations were surveyed by Tetra Tech and used in the study. Thalweg and water surface elevation values are listed for three separate reaches within the study area. The reaches are defined as follows:

- Reach 1 - Navigation Barrier to Fletcher's Bridge (RM 24.2 to RM 22.8);
- Reach 2: Fletcher's Bridge to Spring Creek (RM 22.8 to RM 19.2); and
- Reach 3: Spring Creek to Island Road Bridge (RM 19.2 to RM 16.2).

The study area was divided into three reaches because of differences in river characteristics among these three areas from thalweg slope and water surface gradient. Several obvious differences became apparent among the reaches. First, the upstream Reach 1 is two to three times steeper than reaches 2 and 3. In fact, the current water surface gradient through Reach 2 is actually flatter than the downstream Reach 3. This also has been the area that many observers of the river indicate has been most affected by sediment deposition and loss of submerged aquatic vegetation. Because of the low energy in this reach, it would be logical that sediment would tend to accumulate in Reach 2.

Channel top widths are noted in Table 3-1 and reflect the addition of discharge below the Spring Creek confluence. Average baseflow and bankfull top widths increase from 150 and 210 feet to 222 and 250 feet from Reach 2 to Reach 3, respectively. Generally, Reach 2 has smaller top widths and less access to the floodplain.

The thalweg for base flow conditions exhibits a similar trend. Reaches 1 and 2 are similar with Reach 3 by being about 30 percent higher. This reflects the higher base flow discharges below Spring Creek. The trend reverses for the bankfull flow, with the values decreasing in the downstream direction. This occurs because of the lower bank heights and less confined nature of Fall River as it flows into an even wider valley below Spring Creek.

3.4.3 Bed Material

Throughout the study reach, the Upper Fall River is a sand bed channel. In Reach 1, there are areas with gravel interspersed with sand. Throughout all three reaches, there are locations with diatomaceous earth, consolidated and hardpan clays exposed. These exposures occur primarily in bends where secondary currents scour the bed free of sands. Often in these areas, there is a scattering of lava cobbles. The areas of lava cobbles are important habitat for the endangered Shasta crayfish (USFWS 1997). Historical accounts of Fall River indicate that a much larger percentage of the Fall River bed consisted of the exposed diatomaceous earth, clay, hardpan, and lava cobbles than under the current condition.

Toward the banks of the river, particularly in slow moving areas or side areas, there are typically deposits of unconsolidated silts, clays, fine sand, and organics. These deposits are so loose that a person will sink several feet trying to walk across them. Also along some banks are erosional benches of clay and sometimes

TABLE 3-1
Planform and Profile Characteristics of the Upper Fall River

Reach #	River Mile		Water Surface Gradient	Base Flow Topwidth	Bankfull Topwidth	Sinuosity	Average Bend Radius	Maximum Channel Depth Baseflow	Maximum Channel Depth Bankfull
	from	to	(ft/mi)	(ft)	(ft)	(ft/ft)	(ft)	(ft)	(ft)
1	24.2	22.8	1	150	210	1.5	310	5.1	8.7
2	22.8	19.2	0.3	160	210	2	460	5.2	8.3
3	19.2	16.2	0.5	220	250	2.1	500	6.8	8.1

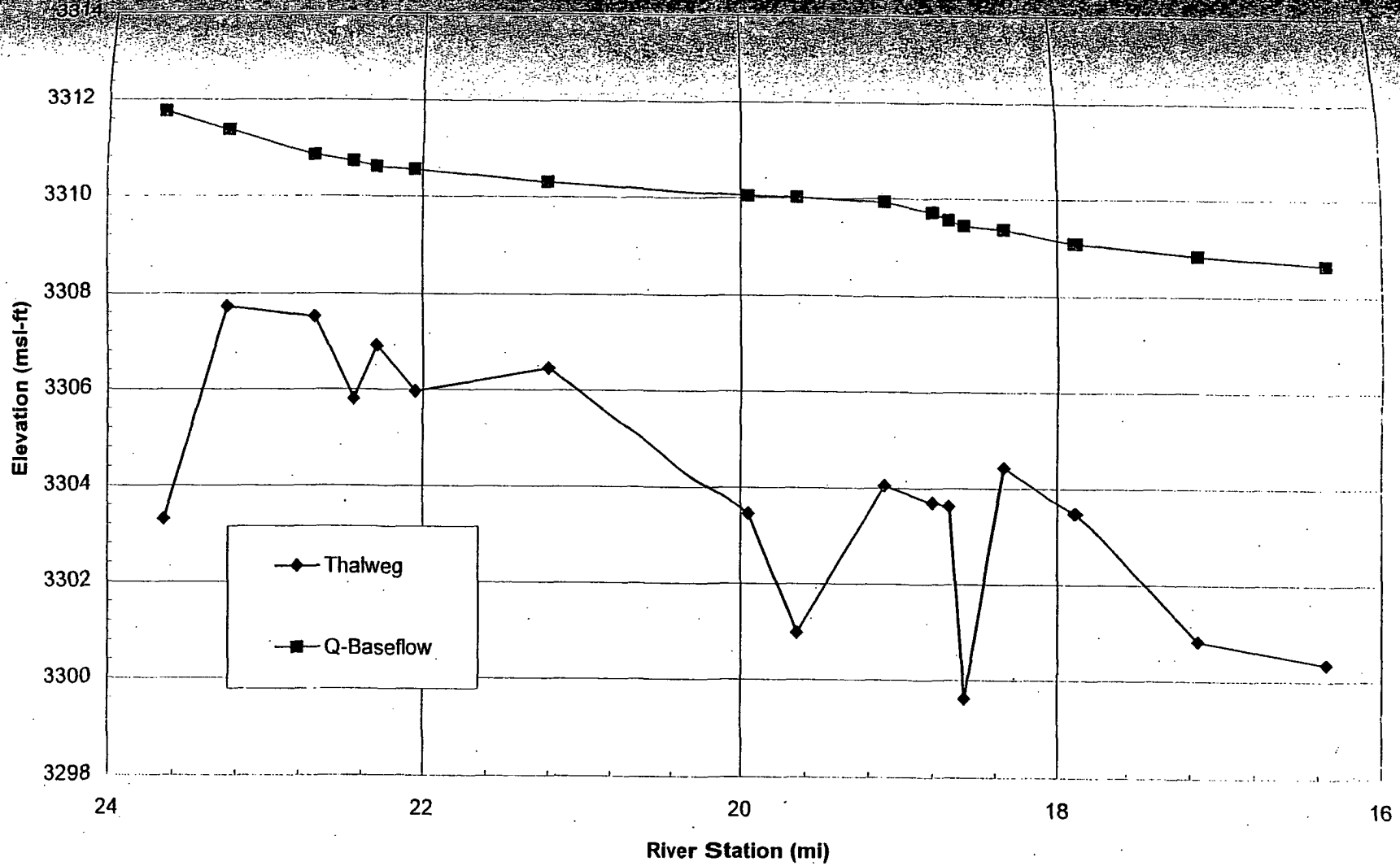


Figure 3-2 Fall River, Baseflow Water Surface and Channel Thalweg Profiles

hardpan. These benches are found primarily downstream of Spring Creek. Oftentimes the benches have burrows dug in them by muskrats. This would indicate that the benches were formed within the 20th century since muskrats are not native to the area. These benches usually project about 10 to 20 feet into the water and are only one to two feet beneath the base flow water surface. This factor indicates that the benches are most likely related to erosion processes at the water surface and above. A probable cause would be a combination of livestock trampling, muskrat burrowing, and wave action.

3.4.4 Aquatic Vegetation and Macro-Invertebrates

Two recent studies of the aquatic vegetation were available as a resource for this subsection: A Study of the Habitat Characteristics of the Aquatic Vegetation of the Upper Fall River (NSR 1997) and Aquatic Monitoring and Assessment for the Upper Fall River (DWR 1998). The DWR report also presented results concerning sampling of macroinvertebrates in the Upper Fall River. Additionally, Draft Recovery Plan for the Shasta Crayfish (USFWS 1997) contains general information on aquatic vegetation and macroinvertebrates throughout the entire length of Fall River and adjacent areas of Pit River. The material in this section was derived almost entirely from the first two sources. DWR (1998) provides information concerning the types and distribution and density of aquatic vegetation found in the Upper Fall River. NSR (1997) concentrated on efforts to relate physical characteristics of the river system to the relative abundance of submerged aquatic vegetation. The NSR study represents the first step in determining strategies to recover submerged aquatic vegetation in Upper Fall River. The following text concerning the aquatic vegetation in Upper Fall River was taken from DWR (1998):

> The Department of Water Resources conducted twelve line-intercept transects across the Fall River to document the species composition and density of submersed aquatic vegetation in relation to several physical parameters. These transects correspond to the cross-sectional transects used for stream width and depth, sediment coring, and benthic macroinvertebrate collection.
>
> Background
>
> Aquatic plants play a key role in maintaining fish productivity in freshwater aquatic ecosystems by providing both essential habitat and refuges and by stimulating invertebrate productivity. The biomass and diversity of invertebrates associated with aquatic plants may exceed that of the fauna in the sediment at the same location. A variety of interacting environmental factors effect both aquatic and terrestrial plant species diversity, abundance, and distribution. These include light, temperature, nutrients, inorganic carbon, and sediment composition (Barko et al. 1986,

Barko et al. 1991). Submersed aquatic vegetation, like all plants, require light for photosynthesis and its availability is important in determining the morphology, abundance, and distribution of the plant species. Temperature also plays an important role in species composition. Rooted aquatic plants obtain their nutrients from sediments as well as from those in solution. Nutrients such as nitrogen and phosphorus and many micronutrients are less available in the surface water and are obtained principally from aquatic plants. Texture of the sediments is important in relation to differing abilities of plant species to physically penetrate the surface. Shifting sediments may affect the plants ability to maintain its portion or to reestablish itself in an area. Some sediments such as very coarse textured or sandy soils may be nutritionally poor. Sediment depth affects the plant's ability for re-establishment by seeds or popagules when new sediments are deposited and rearranged.

Historically, the Fall River is reported to have supported extensive stands of submersed aquatic vegetation both above and below Spring Creek. *Zannichellia palustris* (horned pond weed, locally known as Z-grass) occurs in vast flowing stand below the junction of Fall River and Spring Creek. However, a reported decline in aquatic vegetation, mainly *Z. palustris*, above the Spring Creek bridge and a subsequent decline in the trophy trout fishery are believed by some groups to be a direct result of sediment accumulation in that portion of the Fall River between Bear Creek and the Spring Creek bridge.

No data or documentation has been available on this decline any or change in the submersed aquatic vegetation diversity or abundance. Although the sediment accumulations are believed by some groups to be responsible for the reported degradation of the aquatic invertebrate and plant communities, no data prior to this study was available on sediment depths, their movement, or their relation to aquatic plant distribution. This study of the aquatic plant community proposed to develop a baseline for what is present in relation to the depth of sediment. A multi-year monitoring effort would document the rate of natural recovery or decline of the plant species and aid in developing a management strategy for reestablishing or maintaining plant populations capable of providing essential habitat for invertebrate populations and ultimately increasing fish productivity.

Methods

Twelve channel cross sections were established on the Fall River downstream of the mouth of Bear Creek. Eight cross sections were established between Bear Creek and the Spring Creek Bridge, and are visually impacted by sediment, and four cross sections were established downstream of the Spring Creek Bridge. Permanent end points were established and recorded using a global positioning system (GPS). This will insure accuracy in duplicating sampling sites for long-term monitoring. Aquatic vegetation was surveyed along each cross section to determine species present and their relative abundance within the systems. A line-intercept method was used to identify all plants lying on a straight line across the channel at each transit. A wire tag line was stretched horizontally between each monument with zero being at the left bank monument. A tape measure was stretched along the tag line to determine exact location and abundance of each species. All plants lying below the line were identified with location and distance recorded on data sheets. Plants that were not identifiable in the field were collected and identified in the CSU, Chico Biology Department Herbarium.

Species composition and distribution at each sampling site were graphed in relation to the channel cross section and sediment depth data. Sediment depths were separated into two categories for use in identifying relationships between plant species and sediment depths. Loose sediment included the top layer of sediment in which penetration of the coring tool could easily be done by hand or using less than five blows per foot. The more consolidated sediment included all sediment in which more than five blows per feet was needed to penetrate the soil.

A literature review was conducted for each of the five dominant aquatic plant species within this reach of the Fall River. Aspects of their biology and life history were reviewed as well as seed germination and vegetative reproduction requirements.

Results

Submersed aquatic vegetation in the Fall River system is dominated by five vascular plant species and one species of algae. The most common plant species include *Zannichellia palustris* (horned pondweed, Z grass), *Elodea nuttallii* (Nuttall's elodea), *Elodea canadensis* (common elodea or waterweed), *Ranunculus aquatilis* (Aquatic buttercup), and *Myriophyllum sibiricum* (water milfoil). Common emergent vegetation *include Sparganium*

emersum (bur-reed), *Juncus effusus* (common rush), and *Scirpus acutus* (tule). *Lemna minor* (duckweed), a free-floating aquatic species, is also common along this portion of the river. The species of algae present was not determined but is most likely a species of Chara, a common algae in slow-moving rivers and lake systems.

The riparian zone along the Fall River is not well developed. Agricultural fields or grazing is common up to the immediate bank. Above Spring Creek, some woody riparian vegetation occurs, consisting mainly of willows, ash, and alders. Below Spring Creek and above Island Road Bridge, very little woody riparian vegetation is present. Occasional willows and cottonwoods occur in this stretch. Much of the Fall River has been fenced to restrict grazing along the banks, with open access areas for cattle to reach the water. The banks are heavily degraded and eroded at these access locations, but this area is only a small percentage of the total bank area. Below Spring Creek, less area is fenced to restrict cattle. The banks are gently sloped and erosion due to muskrat or cattle usage is evident.

Results of the vegetation transects indicate a significantly higher percentage of aquatic plant cover in the transects below Spring Creek bridge than those upstream of the bridge during this study. Below Spring Creek Bridge, 78 to 93 percent of each channel cross section was covered with submersed aquatic plants, whereas submersed aquatic plants covered as little as 7 percent of Cross Section #7 below Fletcher's Bridge and up to 46 percent of Cross Section #5 below Reeds Bridge.

Above Spring Creek, *Z. palustris* occurs in only two of the transects and occurs in less than five percent of the length of each one. These plants above Spring Creek tend to be small and widely scattered. However, below Spring Creek *Z. palustris* covers 68 to 93 percent of the length of each of the cross sections. These plants occur in large flowing stands with long stems and are much more robust than the plants in the upper reach. *Z. palustris* is dominant in the first three transects below Spring Creek bridge but is co-dominant with the two elodeas in the last cross section (#24). *E. nuttallii*, *E. canadensis*, and *R. Aquatilis* are the dominant plant species in the upper reach between Reeds Bridge and the Spring Creek Bridge. Although both Elodea species occur below Spring Creek Bridge in as high or higher percentages than above Spring Creek, the large stands of *Z. palustris* at these location clearly dominate most of the cross sections. *R. aquatilis* and *M. sibiricum* were both limited in distribution and abundance in cross

sections. *R. aquatilis* was most abundant in the upper two cross sections near Reeds Bridge and was not encountered in any of the transects below Cross Section #15. *M. Sibiricum* was not seen in the upper cross sections and was not abundant in any except for the most downstream cross section #24 above Island Road Bridge.

Literature on the life history and biology of these five species is somewhat limited. They are common in slow-moving streams, ditches and lakes and tend to be nuisance species in irrigation canals. Thus, much of the literature focuses on factors facilitating their removal instead of the re-establishment. Many submersed aquatic plants reproduce almost exclusively by vegetative reproduction. Seed formation is usually rare in these species. Vegetative reproduction can be accomplished by underground buds on structures such as rhizomes or by the ability to root from nodes on fragmented plant. Rhizomes are underground stems that can invade areas near the parent plant and each node can give rise to a new flowering shoot. This not only aids in reproduction, but also helps to anchor the plant in the substrate.

Z. palustris is a perennial herbaceous species that grows totally submerged in fresh or brackish water. It is distributed worldwide and in California occurs in slow-moving streams, ditches, ponds, and lakes below 6,600 foot elevation. It has slender branching habit with creeping rhizomes. Reproduction in *Z. palustris* is by both seed formation and vegetative growth from the rhizomes. Although fruit set in underwater species is thought to be highly inefficient, studies show a high fruit-set efficiently from self pollination in *Z. palustris* (Guo et al 1990, Hickman 1993).

E. nuttallii and *E. canadensis* are perennial herbaceous species native to North America. Both occur in California in shallow waters of ditches, streams, lakes, and ponds between 1,000 and 9,000 foot elevation. This species has slender unbranched roots from nodes along the stem. The stems easily fragment and these fragments can develop into new plants from axillary or terminal buds. Seed formation is very rare and is not a primary means of reproduction (Mason 1957, Spicer et al. 1988).

R. auqatilis is a perennial herb that has both submersed and floating leaves. This species is native to California and occurs in ponds, lake margins, marshes, and rivers below 10,000 foot elevation. Like the Elodeas, rooting at lower nodes and vegetative reproduction by fragmentation is common (Hickman 1993, Mason 1957).

M. sibiricum is a perennial herbaceous species with both submersed and emergent leaves. It occurs in California in ponds, ditches, lakes, and streams below 9,000 feet. Vegetative reproduction occurs by underground rhizomes (Hickman 1993, Lillie et al. 1992).

Discussion

The submersed aquatic plant community of the Fall River is significantly different between that portion of the river between Bear Creek and Spring Creek and that below the Spring Creek bridge. There is little variation in species composition. However, distribution, density, and coverage of each species varies significantly between the two reaches. The reported change and decline in submersed vegetative coverage above Spring Creek over the last couple of decades could be due to a variety of interacting environmental factors. These include water temperature, light, nutrient availability, and the depth and movement of the sediment.

Temperature and light are both important factors affecting plant abundance and distribution. However, in the Fall River changes in temperature and light have probably not been significant over time. Although no measurements were taken and no prior data are available, the relatively shallow waters and low turbidity should not present photosynthetic problems. The temperature of the spring-fed water of the Fall River remains fairly constant year round and also should not present growth problems or restrictions to the vegetation in this system.

There are several factors determining the impact of sediment on the aquatic plant distribution and coverage. The composition of the sediment and its supply of available nutrients directly affects plant growth. The dominant species, *Z. palustris*, *E. canadensis*, and *E. nuttallii* and the other submersed aquatic species are all rooted species that obtain their nutrient requirements primarily from the sediment. The sediments in the study area are composed primarily of sands with coarser textured gravel and some silt. Typically above Spring Creek the sampled sediments contained very little silt or organic matter with slightly more buildup of silt and organic matter in the sediments downstream below the Spring Creek bridge. No data are available on the nutrient composition of the Fall River sediments nor their ability to support aquatic plan growth. However, extremely sandy or otherwise coarse-textured sediments generally are lacking in important nutrients and thus can inhibit plant growth. The

relatively sandy sediments with few fines in the upper reach of the Fall River may have inadequate nutrients available and may play a part in limiting plant growth in this part of the river. Further studies on the nutrient composition of these sediments both above and below Spring Creek is necessary to determent the relative sterility of these sandy sediments and their ability to support large stands of submersed aquatic vegetation.

Although nutrient availability is important to the submersed aquatic vegetation, the distribution and abundance of the submersed community is linked with the physical characteristics and changes of the substrate and with the general stability of the habitat. A plant's ability to recognize an area varies with the type of deposit and its depth. Seeds of some aquatic species have shown decreased germination when buried under more than two centimeters (.8 inches) of sediment (Hartleb et al. 1993).

The NSR (1997) aquatic plant community study was undertaken to address the following three questions fundamental to the ecological health of the Upper Fall River fishery:

- Based on information from previous studies of the Fall River, what environmental factors are likely to influence the distribution of plant cover in the Fall River?
- How does plant cover vary across gradients in these environmental factors within the Upper Fall River?
- Are there differences among plant species in how they are distributed across gradients in these environmental factors within Upper Fall River?

NSR (1997) identified five environmental gradients that could be related to the distribution of aquatic vegetation on Upper Fall River. These parameters were stream flow velocity, sediment stability, sediment fertility, sediment texture, and sediment depth. NSR conducted data on the distribution of plant cover across these gradients during September 1997. In performing the study, NSR divided Upper Fall River into the reach from the Navigation Barrier to Spring Creek and the reach from Spring Creek to Island Road Bridge. NSR selected these two reaches because reconnaissance indicated vegetation appeared to be much more abundant below Spring Creek. NSR conducted sampling at 50 locations along the Upper Fall River. The number of sites were divided evenly between the two reaches. Measurements were made at five sample points across each transect (five percent, 25 percent, 50 percent, 75percent, and 95 percent of the channel width). At each sampling point, seven measurements were made: sediment depth, water depth, flow velocity, plant cover, sediment stability, sediment fertility, and sediment texture.

Statistical analyses were performed on the results of the sampling program. To aid in interpretating the analysis, NSR divided the environmental variables into sediment-quality factors and fluvial factors. The sediment-quality factors consisted of phosphate concentration, total nitrogen concentration, sulphate concentration, potassium concentration, pH and percent coarse fraction (>0.5 mm sediments). The fluvial factors consisted of water velocity 0.5 feet below the water surface, water depth, sediment depth, and sediment stability. Sediment stability was determined by sampling bed-load movement with a Helley-Smith sampler.

Results, identified as most "striking" by NSR (1997), are summarized below.

Vegetative Cover

Total vegetative cover was higher below Spring Creek than above Spring Creek, 77 percent compared with nine percent. Species also differed in their distribution in the two reaches. *Z. palustris* was abundant below Spring Creek, but *M. sibiricum* did not show up at any points in the lower reach. In contrast, *E. nuttallii* and *E. canadensis* were found in "modest" abundance above and below Spring Creek.

Sediment Quality Factors

The sediment pH in Upper Fall River varied over a narrow range. *Z. palustris* and *M. sibiricum* were most abundant in sediment with pH near neutrality (6.7 to 7.1). Sediment sulphate concentrations were higher below than above Spring Creek. *M. sibiricum* appeared to prefer lower sediment sulphite concentrations, while Z. *palustris* was most abundant in sediment relatively enriched in sulphite. In random samples, the highest cover of *E. canadensis* was observed at lower phosphate concentrates, while, curiously, sediment phosphate concentrates were quite high in the high-cover beds that were observed of this species.

Fluvial Factors

At random sample sites, NSR observed the highest cover value of *E. nuttallii, E. canadensis*, and *M. sibiricum* at intermediate flow velocities. In contrast, Z. *palustris* appeared to be abundant at somewhat higher flow velocities (median 1.1 ft/sec) All species tended to proliferate in shallower rather than deeper waters. High-cover beds of *M. sibiricum* tended to have the shallowest depths (median = 2.1 feet), and high-cover beds of *Z. palustris* tended to have the deepest (median = 4.5 feet). Those results were consistent with patterns observed by NSR in the random samples; *M. sibiricum* was found only at depths shallower than the mean water depth measured in the river (4.7 feet), and percent cover *of Z. palustris* tended to increase with increasing water depth. High-cover beds of *E. nuttallii* and *E. canadensis* were observed by NSR on the thinnest and thickest sediment deposits, respectively. Also, among the four species, high-cover beds of *E. canandensis* were associated with the finest (smallest diameter) sediments.

NSR (1997) further discussed the important results of its aquatic vegetation sampling program but cautioned about such factors as sampling uncertainty and

difficulties in attributing cause and effect between environmental factors and correlation of vegetation patterns. With these cautions in mind, the following paragraphs were taken from the NSR (1997) discussion of the sampling program results:

> In our sample, *M. sibiricum* appeared to be absent or rare below the Spring-Creek confluence and instead restricted to the sulphate-poor sediments above the confluence. This contrasts with Z. *palustris*, which was apparently much more abundant below the confluence, perhaps especially on sediments relatively rich in sulphate. This contrast is even more marked than the sulphate data alone suggest, in that the sulphate chemical analyses were performed on the fine fraction of collected sediments and the percentage of fine particles was higher in high-cover beds of Z. *palustris* than in high-cover beds of *M. sibiricum*. That sulphate concentrations appear to be somewhat higher below than above the Spring Creek confluence may be worth further investigation, especially since sediment sulphate concentrations are potentially correlated with the distribution of two of the river's key aquatic-plant species. Is Spring Creek a source of sulphate? Are Bear Creek sediments sulphate poor?
>
> Our data seem to suggest that Z. *palustris* may grow more abundantly at some of the higher water flow velocities found in our sample of this river. Perhaps somewhat higher flow velocities stimulate photosynthesis of Z. *palustris* but depress photosynthesis and/or stimulate dark respiration in the other species. (Westlake 1967, Madsen et al. 1993). However, this is not to say that Z. *palustris* prefers high-velocity waters. Other authors cite this species as preferring slow-moving streams and pools (Munz and Keck 1973, Onaindia et al. 1996). In the Fall River, F. Hruas and I observed upstream edges of clumps of Z. *palustris* that had apparently been uprooted by higher flow velocities. For now, we may tentatively conclude that Z. *palustris* may simply be somewhat tolerant of some of the "less slow" velocities found in this rather slow-moving river. Alternatively, the higher water velocities we measured at 6" below the surface could have resulted from water being accelerated up and over dense beds of Z. *palustris*.
>
> Because water attenuates light, it is not surprising that all four species seemed to be most abundant in shallower waters. Of these four species, Z. *palustris* may be able to establish and grow in somewhat deeper waters and *M. sibiricum* may be most likely to occur where the river is relatively shallow, although one should

keep in mind that these differences among species are not especially pronounced.

It is possible that *E. nuttallii* and *E. canadensis* are, respectively, the most and least sensitive to burial by sediment, given that high-cover beds of *E. nuttallii* occurred on the thinnest sediment deposits and high-cover beds of *E. canadensis* occurred on the thickest. Alternatively, one could speculate that *E. canadensis* requires the largest rooting volume and *E. nuttallii* requires the smallest. From one perspective, the latter explanation may be more likely since measured rates of sediment movement were essentially nil in high-cover beds of both species, suggesting that significant rates of burial were not occurring at the time of measurement in September. On the other hand, it may be that species' distribution are most sensitive to rates of burial earlier in the growing season, when plants are first becoming established.

High-cover beds of *E. canadensis* seemed to have the finest sediments and high-cover beds of *M. sibiricum* seemed to have the coarsest sediments. *E. canadensis* has been reported elsewhere as having an affinity for finer substrates (Bowmer et al. 1995), although it has been reported on sandier substrates as well (Kozhova and Izhboldina 1993).

The focus of this study has been the relationships between physical environmental parameters (i.e., sediment-quality and fluvial factors) and the distribution of aquatic plants. However, correlations may also exist among species. For example, a reciprocal relationship in percent cover between the two Elodea spp. (Spearman's p+ -0.33) may exist, and similar but slightly weaker relationship in percent cover between *Z. palustris and E. nuttallii.* (Spearman's p = -0.29). These type of relationships could result if species are competitively excluding one another. This seems especially likely for the two Elodea species. Given that they appear to have a number of similar habitat preferences. Given that *E. nuttallii* was found in abundance on thinner sediments that *E. canadensis* and *Z. palustris*, perhaps thin sediments provide a refuge from competition for *E. nuttallii.* However, negative correlation in abundance among species by no means constitute conclusive proof that competition between those species is an importune factor underlying their differing distributions. Instead, these relationships should send a warning to us that restoration projects can not ignore the possibility that population processes, such as competition, may be at work among the aquatic-plant species of this ecosystem.

The Northern District Water Quality and Biology Section of DWR sampled aquatic macroinvertebrates at several sites on two occasions during the fall of 1996 and spring of 1997. Sampled cross sections include DWR #1, #3, #7, #15, #19, #21, and #23. Complete details of field sampling and laboratory processing are provided in DWR, with the raw data provided in Appendix 11 (DWR 1998). The following is a discussion of the macroinvertabrate sampling results presented in DWR (1998):

> Appendix 11 contains aquatic community composition data for 1996 and 1997. It is not possible to accurately describe any long-term trends in the aquatic macroinvertebrate community at a site based on two samples collected over an eight month period. The species collected at each site do, however, represent many of the types of organisms one would normally expect to find in such habitat as is present at these locations. Large numbers, including several species, of substrate dwelling fresh-water snails (Gastropods) were present at some sites. These organisms are bottom dwellers, who feed on vegetation. The dominant food supply for "collectors-gatherers" is the fine particles, decomposing organic matter found in the substrate. Those classified as "scrapers" (Gastropods) derive their food supply by feeding mainly on the periphyton or attached algae and associated materials.

Dominant species at each station (from DWR 1988)

Station Number	Dominant Taxa 1996	Functional Feeding Group	Dominant Taxa 1997	Functional Feeding Group
Fall River #1	Gastropoda	collector-gatherer/scrapers	*station not sampled in 1997	n/a
Fall River #3	Oligochaeta	collector-gatherer	Orthocladiinae	collector-gatherer
Fall River #7	Orthocladiinae	collector-gatherer	Orthocladiinae	collector-gatherer
Fall River #15	Oligochaeta	collector-gatherer	Orthocladiinae	collector-gatherer
Fall River #19	Ephemerella	collector-gatherer/scrapers	Orthocladiinae	collector-gatherer
Fall River #21	Oligochaeta	collector-gatherer	Oligochaeta	collector-gatherer
Fall River #23	Oligochaeta	collector-gatherer	Oligochaeta	collector-gatherer

Also present were a variety of fresh-water leech species (Hirudinea). These organisms are often found in warmer, slow moving streams and ponds and in a variety of habitats. Most are usually found between the shoreline and a depth of two meters. They prefer some form of rough substrate on which to adhere

and therefore are uncommon on pure silty, clay or mud bottoms. Leeches are primarily predatory in nature, with various species showing preference for feeding upon fish, crustaceans, and aquatic insects. Many of these organism are excellent swimmers and others move along the bottom substrate. Some species are parasitic in nature. These organisms provide a food source for aquatic beetles (Dytiscidae), caddisfly larvae (Trichoptera), and fish.

Representatives of another common taxa, segmented worms (Oligochaeta), were found at most sites. These fresh-water relatives of the earthworm are commonly found in the muds and bottom sediments of stagnant ponds and lakes. Some species are especially abundant in areas with plenty of filamentous algae on which to feed. These organisms ingest portions of the substrate and detritus for nutrition. Few oligochaete species are carnivorous, with most preferring decaying vegetation and animal matter.

Various other species of aquatic insects were also collected, particularly in the fall 1996 samples. Data collected in May 1997 indicate fewer species of aquatic insects compared to other macroinvertebrates. The reasons for this might have been high flows in the spring of 1997 which may have flushed free swimming organisms downstream, the sampling time may not have coincided with emergence of these species, or other influencing factors.

The adult mayfly, *Hexagenia limbata* (or "spinner"), has been reported by local residents and fisherman as being extremely abundant during the emergence period for this species. However, not a single specimen was found from the sediment samples. This species normally in streams inhabits quiet back waters with an accumulation of silt (Edmunds et al. 1976). In lakes, they are found from very shallow areas to depths of up to 18 meters, indicating that depths in the Fall River should not adversely affect the distribution of this species. The nymphs burrow to a depth of about 5 inches in the bottom substrate. Tolerant of low dissolved oxygen conditions, the nymphs still require an oxygen concentration above on part per million. The nymphs are usually found in large numbers only in areas where the bottom substrate is composed of soft mud or clay, which is soft enough for burrowing but firm enough to maintain the burrow. They do not normally inhabit sand, gravel, rubble, or peat bottom that are flocculent. The sands and coarse textured gravel bottoms in much of the river above Spring Creek may be responsible for the

absence of this reportedly once common mayfly. If the sands and coarser materials are the result of recent sediment changes in the watershed, an adverse effect to the population of Hexagenia limbata is indicated.

3.4.5 Fisheries

The most recent information regarding fisheries in the Upper Fall River were provided primarily by Mike Dean of the California DFG. This information was provided as various tables and letters documenting recent fish population surveys and interpretations of recent and past surveys. Additional information was obtained from USFWS (1997) and from the "California Wild Trout Management Program - Fall River Management Plan," prepared by DFG (Rode and Weidlein 1984).

Historic Overview of the Fishery

The following description of historic fishing activity on the Fall River was taken from Rodes and Weidlein (1984):

> Prior to 1950, the public was generally permitted fishing access to Fall River. A float trip along its 20-mile course was considered one of California's finest trout angling experiences. In the early 1950's, however, landowners along Fall River began closing the river to the general public, posting their property against trespass, and placing barriers in the stream to prevent boat movement. They even went so far as to place snag wires alongside county roads and bridges, effectively preventing anglers from fishing from these public thoroughfares. Fishing on Fall River thus became restricted to riparian landowners, their guests and those few people who could afford to purchase fishing privileges.
>
> In 1958, a campaign was begun to have the river declared a navigable stream. In 1964, the Shasta County District Attorney filed suite in Shasta County Superior Court to halt the practice of impeding public navigation on the waterway. The court proceedings resulted in a May 1970 Memorandum of Opinion (Appendix) declaring Fall River legally navigable for fishing below the south boundary of Section 19, Township 38 North, Range 4 East (Zereda Jensne property).
>
> In 1971, the Fish and Game Commission established a tow-trout limit for Fall River and Spring Creek to protect the wild trout resource. In December 1972, the Commission designated Fall River for special management and habitat protection as one of the original 16 streams in the state's Wild Trout Program. Another restriction, limiting fishing to flies and artificial lures only upstream from Island Road Bridge was instituted in 1974 to

reduce mortality of fish that were caught and released. A further protective measure that restricts the method of take above Island Road Bridge to single-barbless hooks (with flies and other artificial lures) was instituted in 1982.

Hatchery trout have not been stocked in Fall River above the PG&E Forebay since 1956 and the last experimental plant of hatchery trout in the Big Lake area was made in 1973.

Upper Bear Creek, in the vicinity of Highway 89 and Pondosa, is managed throughout the fishing season with regular plants of catchable-sized hatchery-reared rainbow trout. All Waters within Fall River Valley, except for Fall River, are subject to the general fishing regulations of the Sierra District, including a ten-fish limit but no special gear restrictions. There have been no extensive investigations of wild trout population status in these adjacent waters.

Population Estimates and Trends

Surveys of the fish population in the Upper Fall River have been conducted since 1975. Fish counts were performed by electroshocking in 1975, 1976, 1977, 1978 and 1983 (Rode and Weidlein 1984). DFG personnel used snorkeling gears to conduct fish counts in 1993, 1995, and 1997 (Dean 1997). The earlier counts were conducted within the 1.1-mile long "Gas Line Section" and in the 0.5-mile long "Whipple Section." In the more recent snorkel surveys, fish have been counted in the Gas Line, Whipple, and Island Road sections. Information accompanying the two types of fish count procedures states, "It must be noted that comparisons between statistically valid population estimates and snorkel numbers must be qualified. Snorkel survey counts represent a minimum number of fish present, and the true population almost always exceeds the number of fish counted" (Dean 1997).

Observations and conclusions from Rode and Weidlein (1984) included the following:

- Rainbow trout constitute the major component of the Upper Fall River fish community. They accounted for 91 and 71 percent of the fish sampled at the Gas Line and Whipple sections between 1975 and 1983.
- Brown trout represent only four percent and one percent of the fish populations in the Gas Line and Whipple Ranch sections, respectively.
- Nongame fish represent five percent of the total population number in the Gas Line Section and 29 percent in the Whipple Section. The primary nongame fish are Sacramento suckers and tui chubs.

- Most spawning seems to occur between Rick's Lodge and Thousand Springs. However, anglers in Bear Creek have caught large rainbow trout identified as being of Fall River origin during the early fishing season. This seems to indicate Bear Creek is used by Fall River rainbows for spawning.

Estimates of trout population within the specified reaches of Fall River for Rodes and Weidlein (1984) and Dean (1997) are shown in Table 3-2.

Table 3-2
Upper Fall River, Summary of Rainbow Trout Population Estimates

Reach	Rainbow Trout Population by Years							
	1975	1976	1977	1978	1983	1993	1995	1997
Gas Line	4089	2287	3220	3033	1846	4186	259	5765
Whipple				2300	4745	1523	2448	3900
Island Road						3807	3879	

Notes:
1. 1975 through 1983 estimates are from Rodes & Weidlein (1984).
2. Rodes and Weidlein (1984) estimates are for 6" and larger rainbow trout only.
3. 1993 through 1997 estimates are from Dean (1997).

Source: Rodes & Weilein (1983), Dean (1997)

The following discussion of the trout population in the Upper Fall River was taken from Dean (1997).

> However aesthetically objectionable the existing sediment slug is to all of us, it does not appear to be seriously threatening the wild trout population of the Fall River at this time. It is generally accepted that trout populations undergo normal cyclical variations so drawing conclusions from one or two years of data is unwise and unsound. However, looking at snorkel survey data from a five-year period (1993, 1995, and 1997, inclusive) can provide a sound basis for establishing trends. In the Whipple Ranch section, total trout numbers have increased by over 1000 fish in each of the study years (1200, 2400, 3900, respectively). Young-of-the-year (YOY) numbers have more than tripled and the number of trout greater than 14 inches has increased by more than 60%. In the Island Road Bridge section, trout numbers have been somewhat variable with the only apparent trend being a decrease in the number of YOY. No significant trend is evident for trout larger than six inches. In the Gas-line Crossing section, overall trout numbers dropped dramatically between 1993 and 1995, primarily as a result of extremely low numbers of YOY. The number of fish greater than six inches also decreased in this period. However in 1997, the number of YOY increased by over

50% of the number seen in 1993 and by over 50 times the number seen in 1995. The number of trout over six inches increased by more than six times the number in 1993 and almost three times the number seen in 1995. Based on these data, while the sediment problem is of serious concern, it does not appear to be having significant measurable effects on the overall trout population.

From this data and other observations, it is apparent that trout numbers can vary annually from one river section to another for various reasons. For example the population estimate (trout >6 inches) in 1978 was 3033 in the Gas-line section and 1643 in the Whipple section while five years later (1983) the numbers reversed to 1846 trout in Gas-line and 3390 in Whipple. This is certainly still occurring in the Fall River.

There are several conclusions that can be draws from the snorkel and angler survey data. Recruitment of YOY trout into the next age class (6 to 12 inches) has been fairly constant throughout the period. YOY appear to favor the upper sections of the river. YOY recruitment (production) was poor in 1995 and some YOY were displaced downstream. In 1997, the trout population has increased dramatically over 1995 and in most cases surpassed 1993 numbers. Juvenile recruitment in 1997 was excellent. Trout, especially YOY, are returning to upper river sections. The existing sediment 'slug' has caused the trout population to shift and adapt resulting in an inconsistent fishery in some sections.

Dean (1997) also states, "The resulting sediment load has no doubt negatively impacted trout habitat in the Upper Fall River. The impact is manifested as river shallowing, loss of instream vegetation cover, and possibly a decrease in invertebrate production. However, whether or not this is a serious threat to the trout population in the Fall River is unclear."

In summary, the opinion of Dean (1997) is that the overall population of trout in the Upper Fall River is not being adversely affected by the deposition of sediment, although sediment deposition has caused the trout population to shift and adapt, resulting in an inconsistent fishery in some areas. Dean (1997), however, concludes that the sediment deposition has negatively affected trout habitat in the Upper Fall River. The conclusion that the trout population has not been negatively affected is in sharp contrast to the opinion of most anglers familiar with the stream over the past several decades. These people indicated that there has been a dramatic decrease in the trout population. Their opinions are based on qualitative observations and in some cases may be attributable to the common gripe that things were always better in the "good old days." However, considering the substantial evidence that sediment has been deposited in the Upper Fall River in substantial quantities and the typical negative affects of sediment deposition on

a trout fishery, it is somewhat difficult to conclude that there has not been some negative impact on the fishery. Furthermore, if sediment continues to move downstream and further degrade trout habitat, impacts to the fishery will increase.

CHAPTER 6
SEDIMENT SOURCES

This chapter provides identification and quantification of the major potential sources of sediment inputs to Upper Fall River. Sediment sources investigated include Upper Fall River bank erosion, sediment yield inputs from the Bear Creek and Dry Creek watersheds, and sediment resulting from erosion of the Bear Creek Meadow below Spaulding Corner.

6.1 UPPER FALL RIVER BANK EROSION

Bank erosion in the Upper Fall River was evaluated by identifying bank erosion sites and by comparing historic aerial photographs to determine changes in channel top width. All bank erosion inventories and aerial photograph analyses were performed by Tetra Tech.

6.1.1 Bank Erosion Inventory

Tetra Tech identified bank erosion sites in the field by floating down the length of the Upper Fall River, from the Navigation Barrier to Island Road bridge. Visual clues, such as raw banks without vegetation, fallen trees and shrubs, rill marks, and irregular bank lines, were used to identify bank erosion sites. At each site a field sheet, sketch, and photograph(s) were used to document erosion. A copy of the field sheet is provided in Table 6-1. The extent and location of each site was marked on copies of USGS quad sheets enlarged to a scale of 1" = 1,000'. The quad sheets also had river miles marked, and the river mile associated with each site was documented.

Twenty-five erosion sites were identified, all of which were confined to the area between Fletcher's bridge and Island Road bridge. This area constitutes study reaches 2 and 3. Figure 6-1 shows the location of each of the 25 erosion sites. Table 6-2 summarizes the river mile location, length, and severity of bank erosion at each site. Many of the bank erosion sites had livestock exclusion fencing, which has been installed in the last several years; consequently, these sites generally

CHAPTER 4
HYDROLOGY

The Upper Fall River is a spring-fed system and part of a unique hydrologic system, draining 136 square miles at the Dana gage. To assess sedimentation problems and to develop restoration alternatives for the Upper Fall River, it was necessary to accurately describe and understand the river's surface water hydrology. Surface water hydrology plays a large role in defining channel hydraulics, geomorphic tendencies, sediment transport, and habitat conditions. A detailed understanding of these interactions ultimately will help guide restoration efforts. Upper Fall River hydrologic analysis goals include the following:

- Analyze available data on the study reach for Upper Fall River to determine if alternate hydrologic development methods are needed.
- Understand the need for alternate methods of hydrology development and gather data on local gages and compare them with available data on the Fall River.
- Synthesize a long-term hydrograph to meet the needs of flood frequency and hydraulic and sediment transport analysis.
- Determine a range of flows from the baseflow up to the 100-year peak discharge to be used as a range of representative discharges in a hydraulic model.

Many of the tables and figures used for the Upper Fall River hydrologic analysis are included in Appendix A at the end of this document.

4.1 AVAILABLE INFORMATION

Data available for analysis of the Fall River Dana gage are limited to the period from 1958 to 1967. Downstream gages have periods of record ranging from two to twenty years of data; unfortunately, the dates of record are different from the

Dana gage. Use of data from these gages relies on overlapping periods of record in order for discharge contribution calculations to be made. Since overlapping data were not available for Fall River, other data sources needed to be researched.

Discharge data were gathered from 40 local gages in northern California (Table A-1). The three criteria used for comparison analysis were drainage area, period of record, and overall discharge characteristics (the candidate stream needed to have a dominant spring-fed base-flow component). Gaging stations identified as having a drainage area of between 50 and 250 square miles were analyzed for length and overlapping period of record. An overlapping period of record is essential for comparison analysis of discharge characteristics and volumes. Several gaging stations had overlapping periods of record; however, upon examination of the final criteria comparing discharge volume and characteristics, it was evident that the Hat Creek gaging station was by far the best candidate for comparison analysis and hydrograph synthesis.

The Hat Creek gage is southwest of the Fall River's Dana gage. Hat Creek has a drainage area of 165 square miles and a period of record from April 1930 to September 1994. Hat Creek's strongest attribute is its length of record covering 65 years while overlapping the entire ten years of data for the Dana gage. Initial comparisons of the Fall River and Hat Creek hydrographs show strong similarities in discharge characteristics and less similarity in discharge volumes (Figure A-1). Hat Creek had met all three criteria, and it was determined that, due to the extended length of gaging records, a fairly accurate flood frequency analysis and a synthesized hydrograph for Fall River could be produced.

The California DWR and TSR provided additional data for hydrograph synthesis, including mean daily discharges and peak flood flows from 1995 to 1997 at Spaulding Bridge on Bear Creek. Also available were mean daily discharge data for the Dana gage on the Fall River during the 1997 water year. All data used for periods after 1994 are provisional and may be updated and published by an appropriate agency at a later date.

4.2 HYDROGRAPH SYNTHESIS

Hydrograph synthesis is a technique used to develop hydrologic data not available through stream gaging records on the river of interest. For Fall River discharges, synthesis was accomplished by manipulating overlapping Hat Creek and Fall River discharge records until an accurate representation was achieved. The same treatment or manipulation is then applied to the rest of the Hat Creek record outside of the Fall River record. The major assumption underlying this component of data synthesis is that similar data manipulation on Hat Creek discharges outside of Fall River's period of record will accurately represent unknown discharges for the missing period of record on the Fall River. Further synthesis was created by adding baseflow supplemented discharges to Bear Creek data from 1995 to 1997.

Volume difference analysis was used to treat and manipulate two components of discharge data, the mean daily discharge and the annual flood peak. Volume difference analysis uses the fact that the hydrographs for the comparison rivers are similarly shaped but represent different volumes of water. In general, the Hat Creek hydrograph is fairly representative of the Fall River hydrograph; however, certain flood discharges for Hat Creek experience sharp peaks, implying a flashier flooding nature. A multiplication factor was applied to Hat Creek discharges until the difference in volumes of water discharged between the two rivers was negligible. Peak discharge manipulation was dealt with later in the hydrograph synthesis process.

It was determined that, for the most representative sediment transport calculations, the synthetic hydrograph would be composed of both mean daily discharges and peak annual floods. Data treatment for Hat Creek then would be composed of specific multipliers, derived from volume difference analysis, for both the mean daily and annual peak flow values.

Initial volume adjustments to Hat Creek mean daily discharges were made until the volume difference between Hat Creek and Fall River became negligible. Using a discharge multiplier of 3.22 resulted in a 0.58 percent volume difference and was considered to be negligible compared to actual errors associated with initial assumptions (Figure A-2).

The discharge multiplier then was applied to all Hat Creek flows outside of the period of record available for Fall River. These discharges then were added onto either end of the original Fall River discharge record to create an extended period of record. The synthesized hydrograph spanned water years from 1931 to 1994 while maintaining the original ten years of data within the synthesized hydrograph (Figure A-3).

Additional mean daily discharge synthesis was performed by using comparison analysis between the Spaulding gage on Bear Creek and the Dana gage on the Fall River. The period of record for the additional Spaulding gage data covers the 1995 to 1997 water years. Below Spaulding Bridge most additional discharge contributions to the Upper Fall River are from Thousand, Rainbow, and Mallard springs. Further downstream, Spring Creek, which is discussed later, makes a significant flow contribution. Discharge inputs from the springs essentially provide a consistent baseflow to the Upper Fall River; therefore, the assumption was that adding a consistent baseflow to Bear Creek discharge data would accurately represent Upper Fall River discharges. A baseflow amount of 380 cfs was estimated for the Upper Fall River (Figure A-4). Next the 380 cfs baseflow was added to 1997 Bear Creek data and compared with 1997 Upper Fall River data. Hydrograph comparisons reveal that Fall River discharges and Bear Creek baseflow supplemented discharges are nearly identical (Figure A-5). Supplemented Bear Creek mean daily discharges then were included as part of the synthesized hydrograph for the water years encompassing 1995 through 1997.

The final step in hydrograph synthesis was the addition of annual floods to the hydrograph. Peak floods were included to provide a finer resolution on the discharges, which can transport large quantities of sediment over a short period. Annual peak flow treatment also used volume difference analysis for computing a multiplier on Hat Creek discharges. The derived multiplier for peak flood flows was 1.82, giving a volume difference of 0.00 percent (Figure A-6). Much less confidence was associated with the peak discharge multiplier than with the daily discharge multiplier due to poor correlation between peak flows on both rivers. Data treatment for Hat Creek peak annual flows required engineering judgment for specific cases to determine whether to apply the manipulated peak flood flows based on the Hat Creek multiplier of 1.82 or to use flood peaks generated by applying the mean daily discharge factor of 3.22.

In general, high flood values resulting from Hat Creek's spiked hydrographs, caused by using the mean daily discharge multiplier, were replaced with values generated using the peak annual discharge multiplier. Exceptions occurred when peak discharges were relatively low for a given year. When this was the case, more confidence was placed on the scaled mean daily flow rather than the scaled annual peak flood values. The peak flow adjustments are summarized in Table A-2.

Peak flow adjustments were made to the Fall River data using peak flows for the period of record at the Dana gage. In doing so, discharge peaks were added to the hydrograph while maintaining overall discharge volume integrity. Peak flow treatment also performed in the same manner for discharges originating from Bear Creek data between 1995 and 1997.

One final consideration was addressed concerning flows for Bear Creek and Dana during the 1995 to 1997 period of record. For sediment transport purposes, it is necessary to accurately define total discharges moving within the river and floodplain system. In January 1997, a large flood raged through the Fall River Valley. Discharge recordings were made for the flood at both Spaulding Bridge and the Dana gage. Flows at Spaulding Bridge were confined through the bridge's opening, whereas bank overtopping occurred at the Dana gage. The rating curve for the Dana gage is accurate for in-channel flows, and extrapolation of flows beyond the overtopping point decreases the rating curve's accuracy. The Spaulding gage is considered to be more accurate due to the confinement of flow within the bridge opening, along with the fact that instantaneous measurements also were made at the time of the flood. Arguments have been made for flood attenuation through the Bear Creek meadow and that peak flows were less at Dana than at Spaulding Bridge. However, two important inputs may have been overlooked with the attenuation hypothesis. These are baseflow inputs from the three springs and discharges entering from Dry Creek, all above the Dana gage and below the Spaulding gage. Peak floods may have been attenuated, but considering the lack of accuracy at the Dana gage and other hydrologic inputs to the Fall River, the readings taken at Spaulding Bridge supplemented with spring flows is considered to be the best flow rate estimate available. Synthesized mean daily and

peak annual discharges for Fall River between 1995 and 1997 used baseflow supplemented discharges and peak flows from Bear Creek data.

Various data manipulation using multipliers and scaling factors on available information allowed Tetra Tech to generate the synthesized hydrograph depicted in Figure 4-1 and used for flood frequency analysis, hydraulic analysis, and sediment transport equation development.

4.3 HYDROLOGIC ANALYSIS & RESULTS

Flood frequency analysis was performed using FFAN software (Hydrasoft 1985). Peak annual flood data used with the software generates a flood frequency curve using a Log-Pearson III distribution. Input included peak annual flow data for each of 67 years, along with a generalized skew coefficient. Generalized skew coefficients are provided on a skew contour map of the United States in Guidelines for Determining Flood Flow Frequency (US Water Resources Council 1981). The generalized skew value was chosen as zero based on the skew contours. Output obtained from FFAN provided a frequency distribution curve for mean annual flood flow (Figure 4-2). The flood frequency distribution curve was used to determine the following flow rates for the Fall River at Dana (above Spring Creek):

Return Period (years)	Peak Flow (cfs)
Baseflow	380
1.2	562
1.5	682
2	808
5	1369
10	1940
50	4250
100	5880

Discharges from Spring Creek and other smaller springs between Dana and the Spring Creek confluence were estimated to supplement flows by an average of 217 cfs. The 217 cfs were added to the Fall River at Dana to develop Fall River below Spring Creek flood flows. The resulting flood frequency distribution is provided below:

Return Period (years)	Peak Flow (cfs)
Baseflow	597
1.2	779
1.5	889
2	1025
5	1577
10	2157
50	4467
100	6097

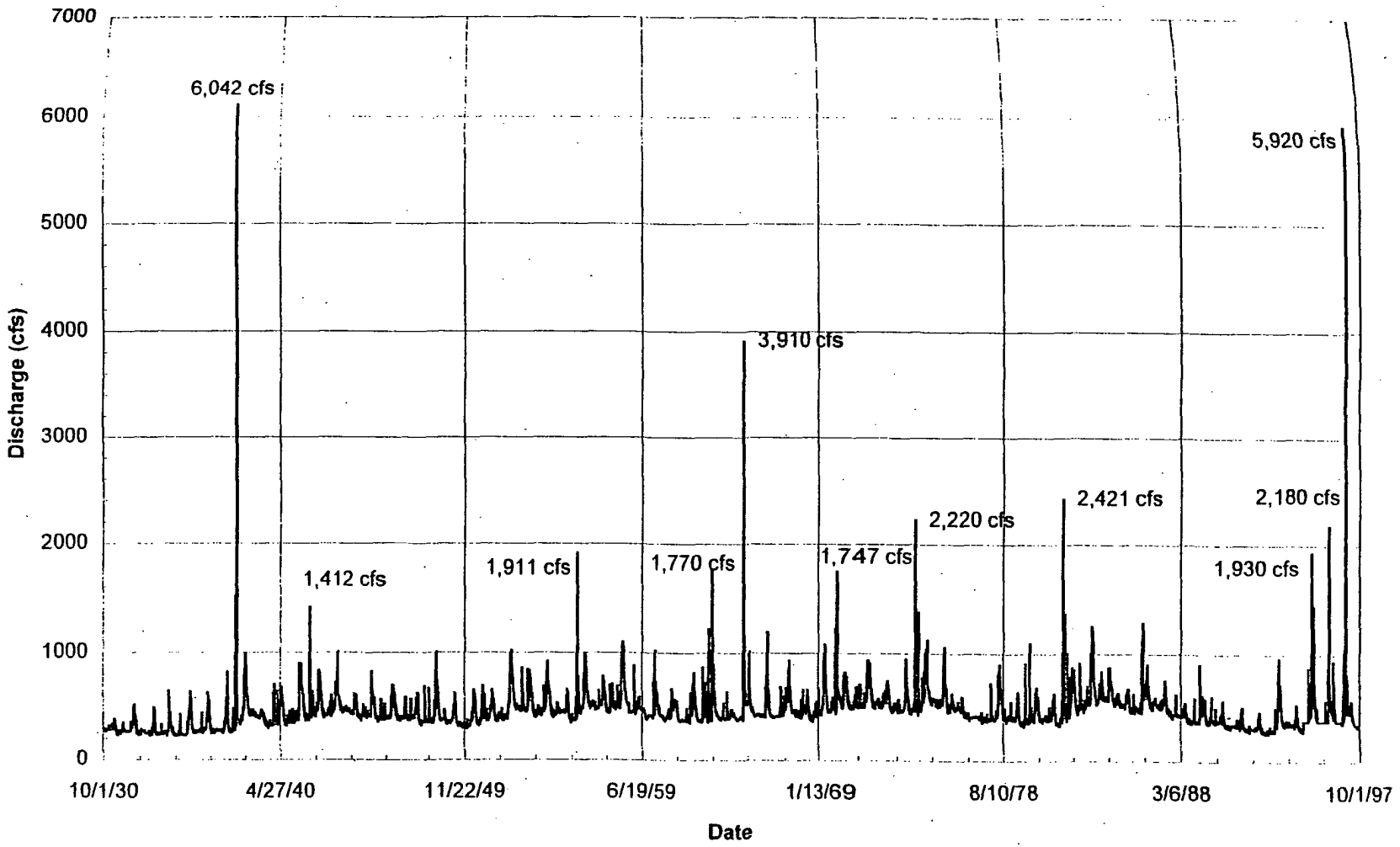
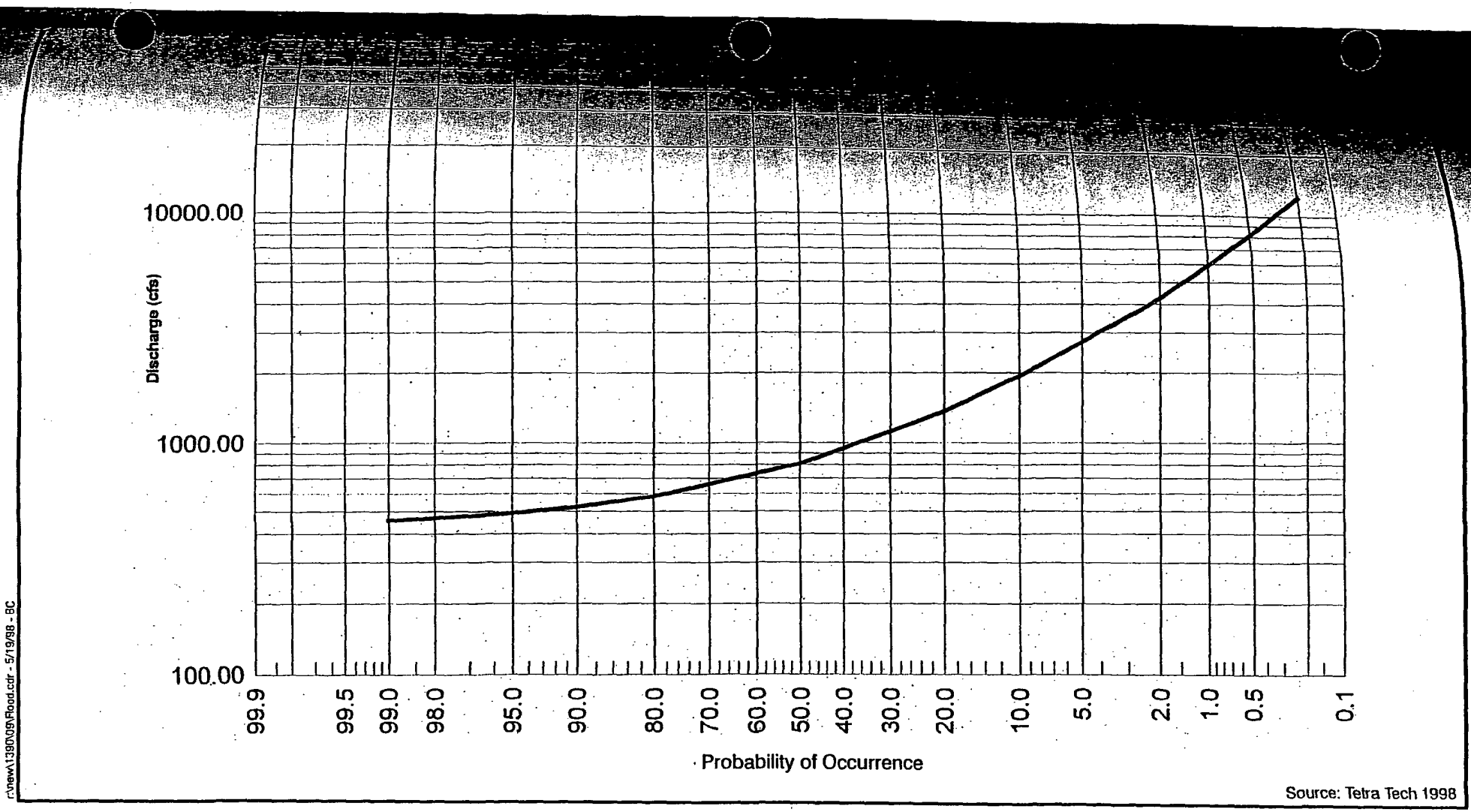


Figure 4-1 Fall River at Dana, Synthesized Hydrograph



Source: Tetra Tech 1998

Fall River @ Dana, Flood Frequency Curve

Upper Fall River Watershed, California

The ranges of flood and baseflow discharges are used as input to the hydraulic model to characterize several hydraulic variables of the Upper Fall River.

Three specific water years were identified as typical high, low, and average water years. Ranking both discharge volume and peak flows allowed for identifying these descriptive flow years. The resulting high, low, and average water years selected were 1970, 1945, and 1990, respectively (Table 4-1).

Table 4-1
High, Low, and Average Water Year Rankings

	Year	Volume Rank	Volume	Flood Rank	Flood
High Water Year	1970	8	417,955	7	2,268
Avg. Water Year	1945	36	324,445	33	827
Low Water Year	1990	54	273,315	56	608

Examination of the yearly hydrographs for these respective years reveals certain hydrologic behavior, namely a bimodal type of discharge distribution. Both higher and average water years experience typical spring runoff, plus additional discharges sometime in late fall or early winter (Figure 4-3). This type of peak flow distribution should be considered when evaluating restoration alternatives, including fishery habitat enhancement and vegetation replacement.

The flow duration curve for the Fall River at Dana was developed using the synthesized hydrology. The resulting flow duration curve is plotted in Figure 4-3. This curve indicates that flows on the order of 1,000 cfs and greater occur less than 0.5 percent of the days. In contrast, flows of 500 cfs or less occur over 70 percent of the time.

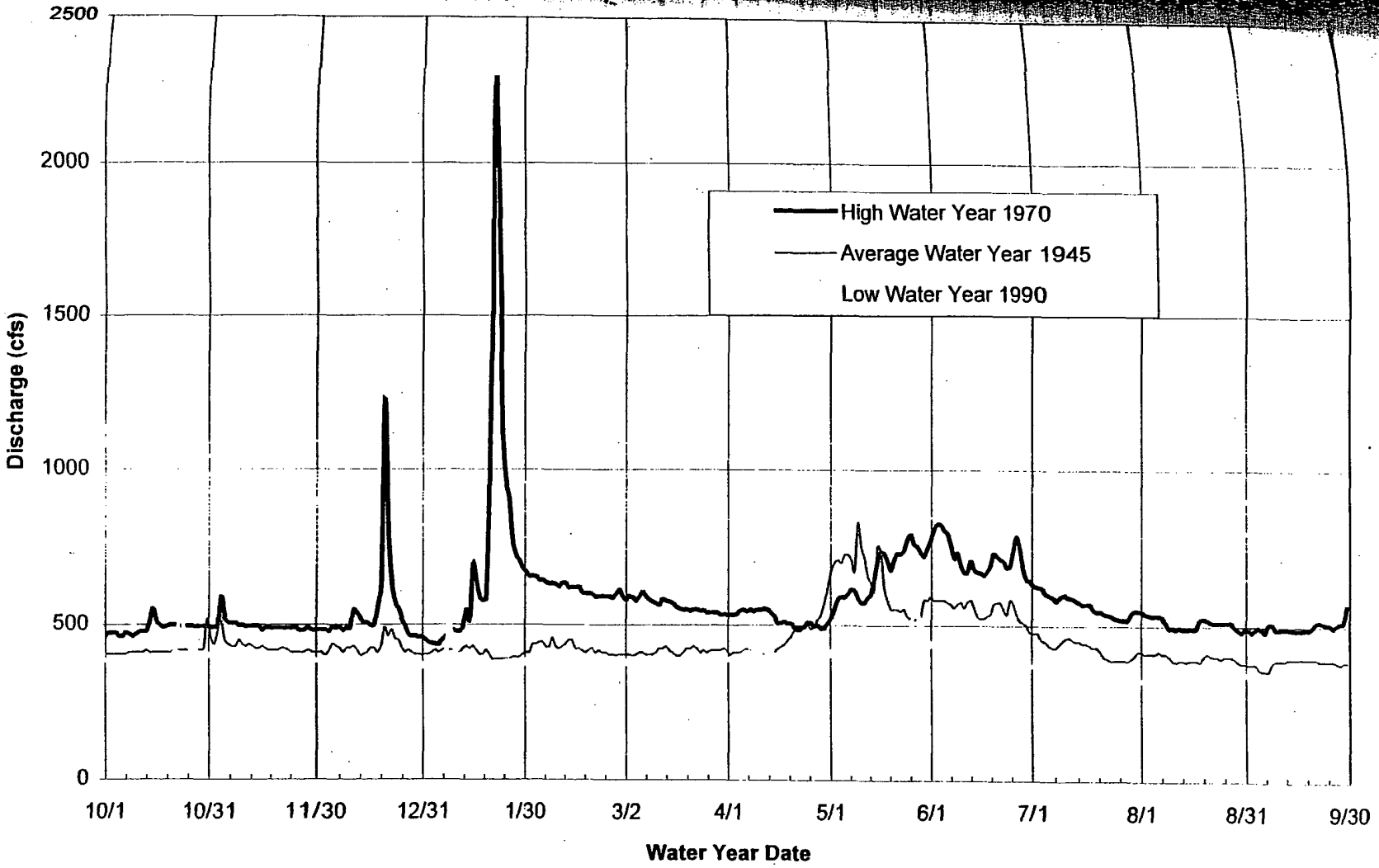
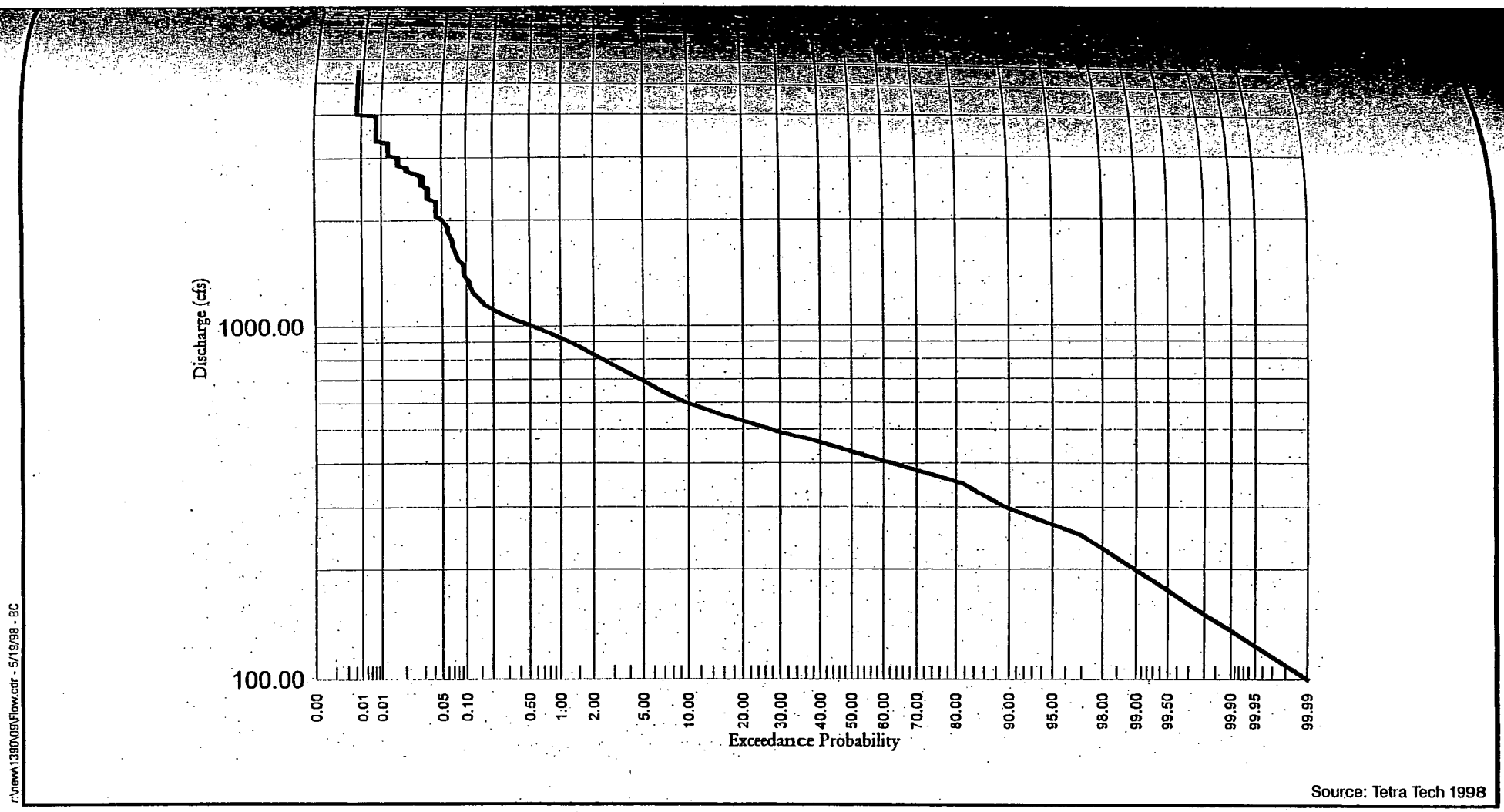


Figure 4-3 Fall River (Dana): High, Average, Low Yearly Hydrographs



Source: Tetra Tech 1998

Fall River @ Dana, Flow Duration Curve

Upper Fall River Watershed, California

Tetra Tech, Inc.

Figure 4.4

CHAPTER 5
HYDRAULIC ANALYSIS

This chapter presents the development and results of a hydraulic analysis performed on Upper Fall River. The hydraulic analysis serves several purposes; primarily, it provides information that is key to understanding sediment transport conditions in the Upper Fall River. More specifically it calculates parameters used in determining sediment transport capacity at various locations in Fall River. Finally, the hydraulic model allows investigators to analyze future hydraulic and sediment transport conditions resulting from channel modifications, such as bank sloping and dredging. The hydraulic model developed will be a useful tool in future analysis, monitoring, and design efforts associated with solving the sedimentation problems in Upper Fall River.

5.1 AVAILABLE INFORMATION

Information and data available for model construction and calibration consisted of 17 cross sections distributed over 7.3 river miles. The hydraulic model extends from immediately upstream of Read's Bridge downstream to Island Road Bridge. Three main reaches are contained within the study area on the Fall River. Cross section 3 through cross section 7 are included in the uppermost reach between Read's Bridge and Fletcher's Bridge, identified as Reach 1. Cross section 7 through cross section 21 are included in Reach 2, ranging from Fletcher's Bridge to Spring Creek. Reach 3 contains cross sections 21 to 24 and ranges from Spring Creek to Island Road Bridge. The cross section locations were shown on Figure 2-1.

DWR provided 12 of 17 surveyed cross sections located along the entire reach of interest (DWR 1998). Cross-sectional data were provided in spreadsheet format, including individual cross section station locations and elevations. Initial end point elevations were obtained by DWR using a global positioning system (GPS), which has a vertical accuracy rating of approximately ± 1.5 feet (DWR 1998). Tetra Tech supplemented the DWR survey with five additional cross sections, four of which are in Reach 3, and a level loop tying all known cross sections together to one known elevation. This level loop had a vertical closure error of

approximately 0.10 feet and also incorporated DWR cross sections. Tetra Tech cross sections provided more accurate vertical control than the GPS elevations and also included water surface elevations at each cross section used in the model's calibration. Benchmark elevation corrections were made and all elevations were adjusted to an updated NGVD 1983 elevation of 3317.46 feet above mean sea level at bench mark 62C (1931). The benchmark is along Spring Creek Road in front of the house that is just east of the volunteer firehouse. The Dana 7.5' USGS quad map was used for distance measurements between cross sections. The combination of the distances and the water surface elevations allowed for slope estimation of the water surface profile. Finally, a photograph log and field assessment provided by Tetra Tech were used to develop initial estimates of roughness coefficients and to confirm model results.

5.2 METHODOLOGY

Hydraulic analysis performed on the Fall River used HEC-RAS Version 2.1 (US Army Corps of Engineers [USACOE] 1997), a one-dimensional, standard step-backwater computation program. The program allows for determining water surface and energy grade elevations as well as other hydraulic variables dependent on channel geometry, slope, roughness, and discharge rates. Hydraulic analysis is performed to attain a general understanding of the river's hydraulic characteristics and to obtain input needed in determining the river's sediment transport capacity. Once resolved, various restoration and enhancement scenarios are developed and are input to the hydraulic model to determine future hydraulic characteristics. Hydraulic design scenarios, including changes in channel geometry, dredging, and bank sloping, can be used to ascertain the viability of the design scenarios.

5.3 MODEL CONSTRUCTION AND CALIBRATION

Model construction used all available information as input for channel geometry, overbank distances, roughness coefficients, floodplain delineation, and boundary conditions. Cross sections based on elevation adjustments from the Tetra Tech survey and overbank distances, estimated using locations identified on the Dana 7.5' USGS quad map, were input to define the channel and floodplain geometry. Initial Manning's roughness coefficients were chosen to be 0.035 and 0.065 for in channel and overbank roughness, respectively. It was known that roughness coefficients would vary throughout the study reach, and the coefficients would be adjusted during the calibration process. The cross section surveys extended less than 100 feet beyond the type of the channel banks. Floodplain definition was attained by adding distances and elevations measured from the USGS quad map to cross section endpoints (Table B-1). Attaching the channel to the floodplain allows for more accurate representation of flood flows, when the river is overtopping its banks. Final input needed to run the hydraulic model were the boundary conditions necessary for determining normal depth using the Manning's Equation (USACOE 1997). Initial slope estimation was assumed to be equal to the slope of the surveyed water surface slope at the downstream end of the study reading equaling 0.3 feet per mile. Considering the fact that Fall River has a subcritical flow regime and an extremely low gradient, the assumption was

considered to be valid. Under an ideal situation, it would be best to have several cross sections established downstream of the study reach. This would allow for errors of water surface slopes assumption to be dampened out in the cross sections below the study reach; however, cross sections downstream of the study reach were not available. The geometry input file for the HEC-RAS model is in Appendix B.1.a - f.

Model calibration was the next step in developing an accurate representation of the true river system. Calibration consisted of matching known water surface elevations to model predicted water surface elevations, at a specific discharge, by adjusting roughness coefficients. Tetra Tech obtained water surface elevations in its August 1997 survey. DWR provided unpublished discharge information for the survey date of August 12, 1997. Model calibrations were considered to be within the range of necessary accuracy when the known and predicted water surface elevations differed by less than 0.10 feet (Table B-2). The calibrated roughness coefficients indicate that rather large Manning n-values occur along the reach between Upper Zug-Bug and Christiansen Flat. This is an area with the thickest beds of Z-grass found within the study area. The Z-grass causes additional frictional losses due to drag and large-scale turbulence.

Errors and model accuracy depend on how well the model represents the physical system. Calibration errors include the assumption that flow resistance is uniform throughout the channel for a variety of flows and that there are no backwater effects. Other possible errors contained within the HEC-RAS hydraulic model are related to the lack of cross-sectional data for bridge crossings. Bridge crossings confine flow and create unique hydraulic effects in the river. The last notable source of error includes the direct link between channel cross sections and contours used to delineate the floodplain from the USGS quad map. Elevations were assumed to be tied linearly to the appropriate elevation contour; however, the floodplain may contain a large flat area adjacent to the channel and then proceed upward toward the next elevation contour farther away from the channel.

If the hydraulic model is to be used for future studies, monitoring programs, and design analysis, certain recommendations are suggested. These include increased floodplain mapping, cross-sectional data for bridge crossings, extending the model farther downstream, and collecting water surface elevations at discharges above baseflow conditions.

5.4 HYDRAULIC MODEL ANALYSIS AND RESULTS

Using multiple discharges determined in the hydrologic analysis (see Chapter 4) that represent flows ranging from the baseflow to the 100-year flood, Tetra Tech resolved solutions for several hydraulic variables, including hydraulic channel depth, velocity, top width, shear stress, maximum channel depth, and water surface elevations. For sediment transport purposes, an average water surface slope and energy gradient was determined. The investigation team used known hydraulic variables to assess overall hydraulic characteristics and sediment

transport capacities and to define specific problem areas along the river. Hydraulic characteristics at each cross section have been charted for the entire range of flows for the full length of the hydraulic model's reach. Reach average values were included so that general descriptions were available for analysis (Table 5-1).

Water surface profiles analysis shows that upstream Reach 1 experiences steeper water surface slopes of approximately 1.0 and 1.6 feet per mile for baseflows and 100-year floods, respectively. Water surface slopes decrease traveling downstream through Reach 2 and are approximately 0.3 and 0.6 feet per mile. Slightly upstream of RM 18 there appears to be a small break in water surface slope for baseflows, tending toward a steeper slope downstream from Reach 2. Water surface slopes are approximately 0.5 and 0.3 feet per mile for baseflow and 100-year flood flows in Reach 3. Note how upstream reaches experience steeper water slopes at larger flows, whereas downstream Reach 2 and Reach 3 experience smaller water slopes (Figure 5-1). Reach 2 has the lowest average water surface slope at baseflows, which occur approximately 75 to 80 percent of the time and influence sediment transport characteristics through this reach.

Hydraulic depth is defined as the ratio of cross-sectional area to top width. For this study, channel-oriented hydraulic depth values were derived using the following equation:

$$Y_d = A_{channel} / T_{channel}$$

Hydraulic depth is used in sediment transport capacity calculations. Most sediment transport occurs within the channel, and using general hydraulic depths, which included the floodplains, would be inaccurate in describing sediment transport when flow overtopped the channel banks. The new hydraulic depth equation emphasizes flow contained between the banks of the channel. Examining the hydraulic depth chart reveals that Cross Section 15 has the smallest hydraulic depth for most of the flows (Figure 5-2). The cross section is on a fairly straight portion of the river and has poor habitat qualities due to sediment deposition and shallow depths throughout this particular reach. Overall hydraulic depths range from approximately 2.0 to 6.0 for baseflow conditions and 9.0 to 12.0 for the 100-year flood. In general, average hydraulic channel depths increase moving in the downstream direction.

Velocity results from the hydraulic model describe a unique relationship within Reach 3 (Figure 5-3). General velocities appear to be much lower than other flow velocities directly downstream from Spring Creek Bridge. Initially the idea is counterintuitive, considering additional flow input from Spring Creek, and the fact that bridge constrictions usually create swifter velocities. However, by examining cross-sectional data immediately downstream of the bridge, it is noted that all flows used in the model above the baseflow were overtopping at Cross

Hydraulic Analysis, Reach Average Values

Reach	Flow Designation	Discharge (cfs)	Hydraulic Depth Y_d (ft)	Channel Velocity (fps)	Shear Stress (psf)	Top Width (ft)	Channel Top Width $T_{channel}$ (ft)	Maximum Depth Y_{max} (ft)	W/D T/Y_{max}	W/D $T_{channel}/Y_d$
1	Q_{base}	380	3.48	0.81	0.032	149.04	149.04	5.13	29.03	42.79
1	Q_{10}	1940	6.37	1.51	0.099	362.05	211.54	9.39	38.54	33.21
1	Q_{100}	5880	10.08	2.34	0.197	1042.80	211.67	13.11	79.56	21.00
2	Q_{base}	380	3.47	0.78	0.012	160.56	160.56	5.24	30.67	46.34
2	Q_{10}	1940	6.36	1.47	0.032	753.60	205.31	9.10	82.82	32.30
2	Q_{100}	5880	9.67	2.21	0.063	1898.20	206.36	12.44	152.65	21.35
3	Q_{base}	597	4.08	0.70	0.036	222.75	222.75	6.81	32.69	54.63
3	Q_{10}	2157	7.46	0.72	0.032	2712.56	245.08	10.65	254.79	32.84
3	Q_{100}	6097	10.59	1.04	0.032	6124.83	245.08	13.77	444.75	23.15

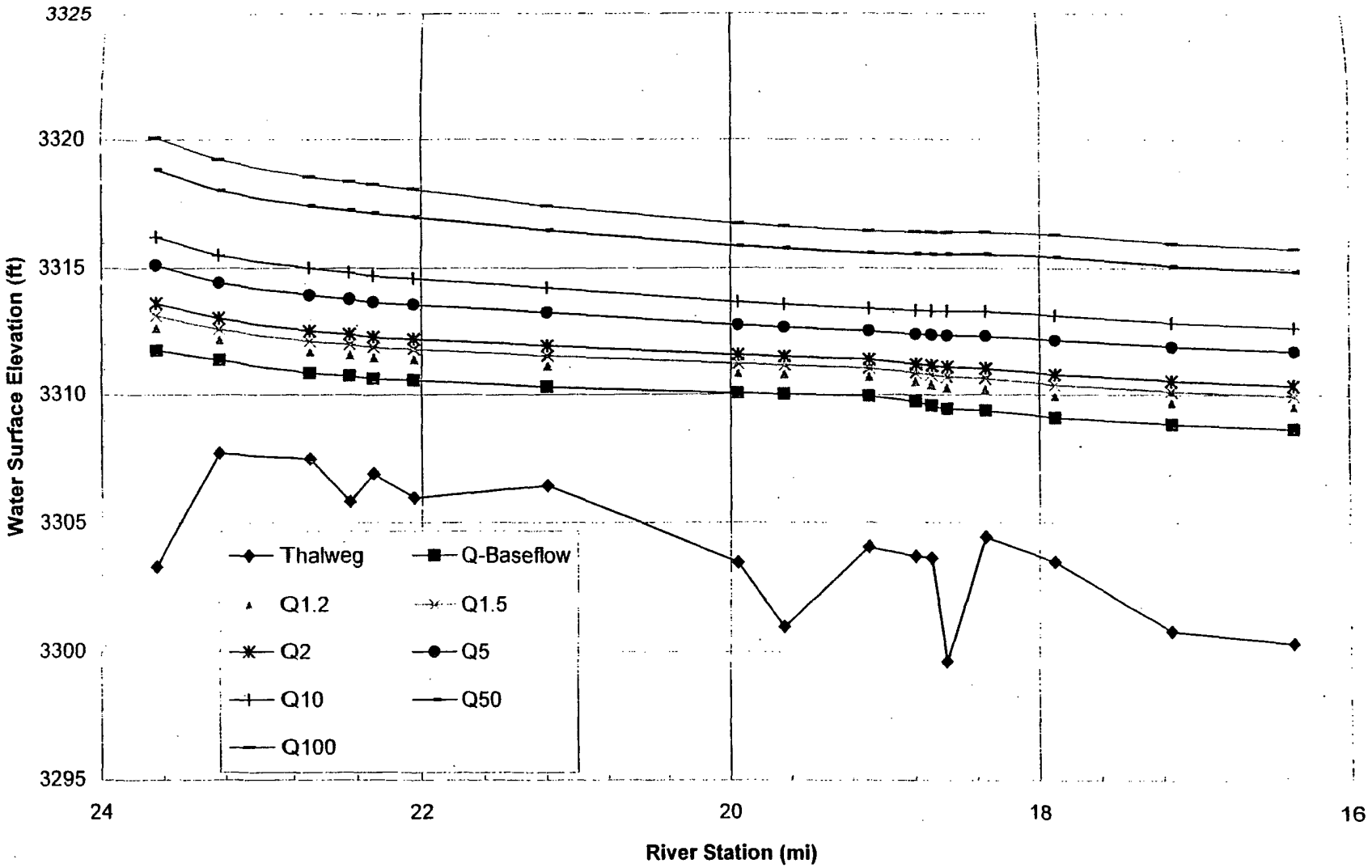


Figure 5-1 Fall River, Water Surfaces Profiles

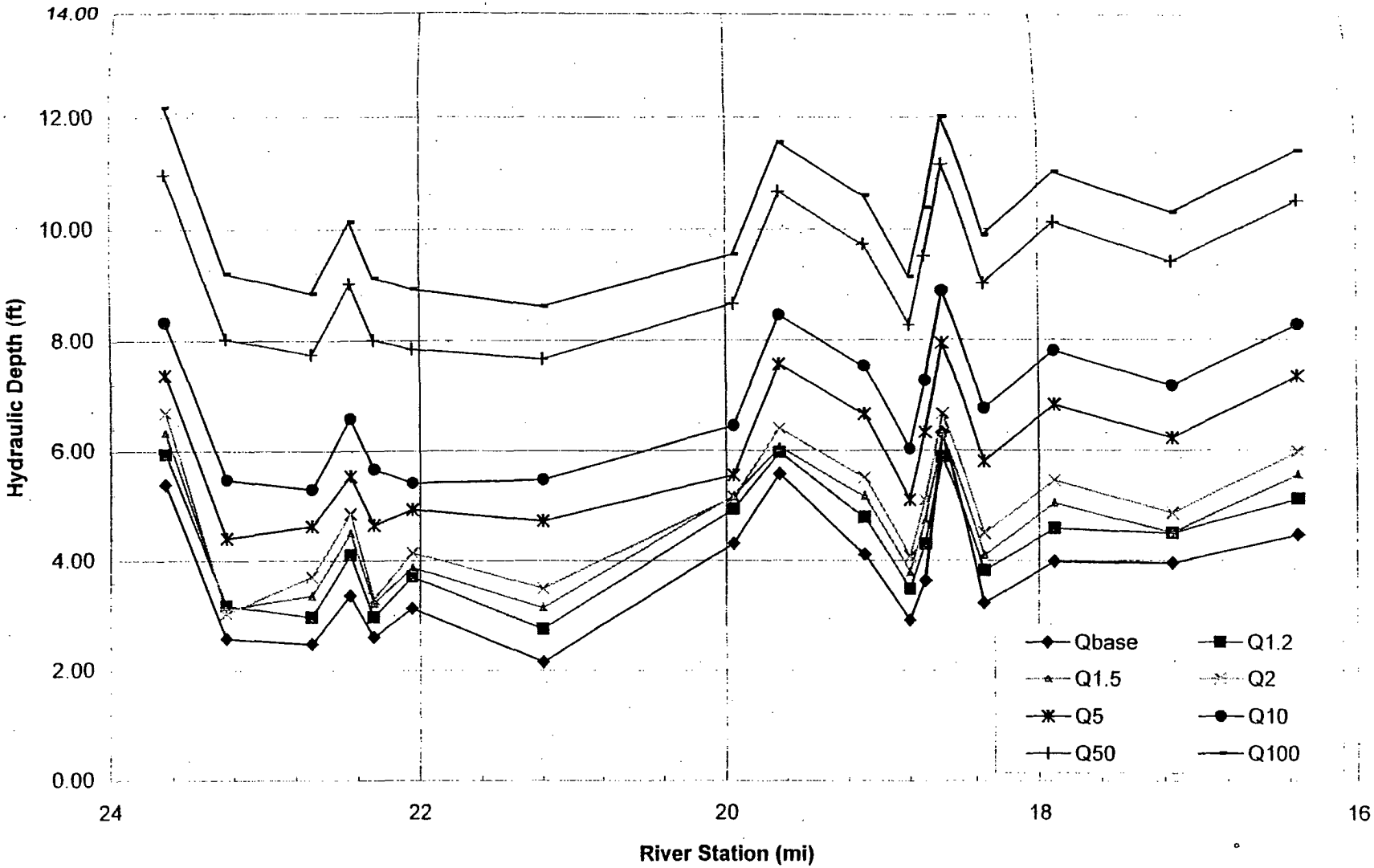


Figure 5-2 Fall River, Hydraulic Depth

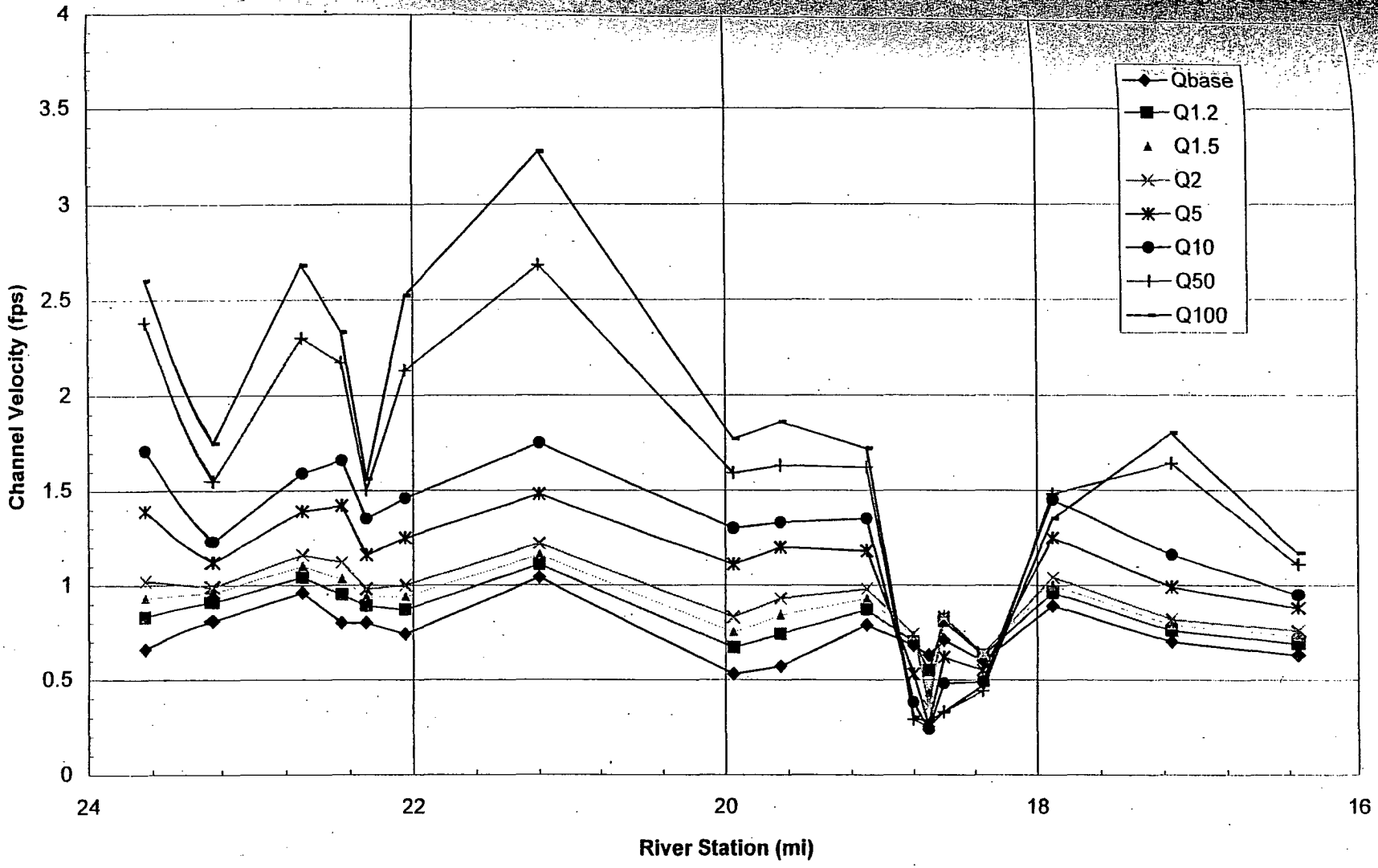


Figure 5-3 Fall River, Channel Velocity

Section 21. Instead of acting as a constriction through the bridge opening, water is actually expanding out onto the floodplain for most flows. Because of the greater access to the floodplain below Spring Creek, velocities decrease throughout Reach 3. The reach of interest also has large amounts of vegetation, Z-grass, sedges, and tules in and around the channel. General habitat conditions are considered to be higher in this particular area (namely Reach 3) than in Reach 2 upstream. Average velocities are higher along Reach 2 compared to the rest of the river. A note of interest is the comparison of sediment deposition with respect to reach average velocities. Reach 3 generally has lower velocities, higher discharges, and a higher level of habitat. What is unique about the hydraulic, geometric, and vegetative interactions throughout this reach are that sediment does not readily accumulate within the thick beds of Z-grass. Local velocities and turbulent forces through the Z-grass appear to remain large enough to transport sediment through the reach. Reach 2 has higher velocities but lower shear stresses and has lower habitat conditions, partially due to its inability to transport sediment. Indications such as these point to the conclusion that Reach 2 could be used as a natural sediment trap and that it is an excellent candidate for mechanical sediment removal strategies. In doing so, preservation of downstream reach integrity through upstream sediment control is the conceptual goal.

Top width analysis confirms initial notions of less floodplain accessibility throughout the middle of Reach 2 (Figure 5-4). In general, top widths are increasing upstream to downstream. At the Gas Line location, top widths are much smaller than values calculated both upstream and downstream. Floodplain mapping or extending cross sections into the floodplain would shed light onto what type of hydraulics and floodplain interactions are taking place along this reach and throughout the river. Channel change possibly due to construction was noted in aerial photography analysis near the Gas Line area. Originally a stand of shrubs and trees extended out into the channel for approximately 150 feet along the bank in 1939; there was no evidence of the vegetation in 1952 photographs.

Analysis of the shear stress chart indicates that, overall, shear stresses are low and decrease in the downstream direction (Figure 5-5). The reach averaged values show that, for all levels of flows in Reach 3, average shear stress values hover around 0.035 psf (Table 5-1). However, some cross sections within Reach 3 experience higher shear stresses at lower flows, which is effectively reversed from the discharge shear stress relationship seen in the rest of the river. Both upstream reaches experience increased levels of shear stress with increases in discharge. Reach 1 experiences the highest levels of shear stress, ranging from approximately 0.03 psf to 0.20 psf. The 0.20 psf value is much higher than all other calculated values throughout the river and is generated by steep water surface slopes and partial confinement of floods to the channel. Reach 2 has extremely low shear stress values of 0.012 psf at baseflows, which contribute to sediment deposition. As discharges increase to the 100-year flow levels, shear stress increases to 0.06 psf

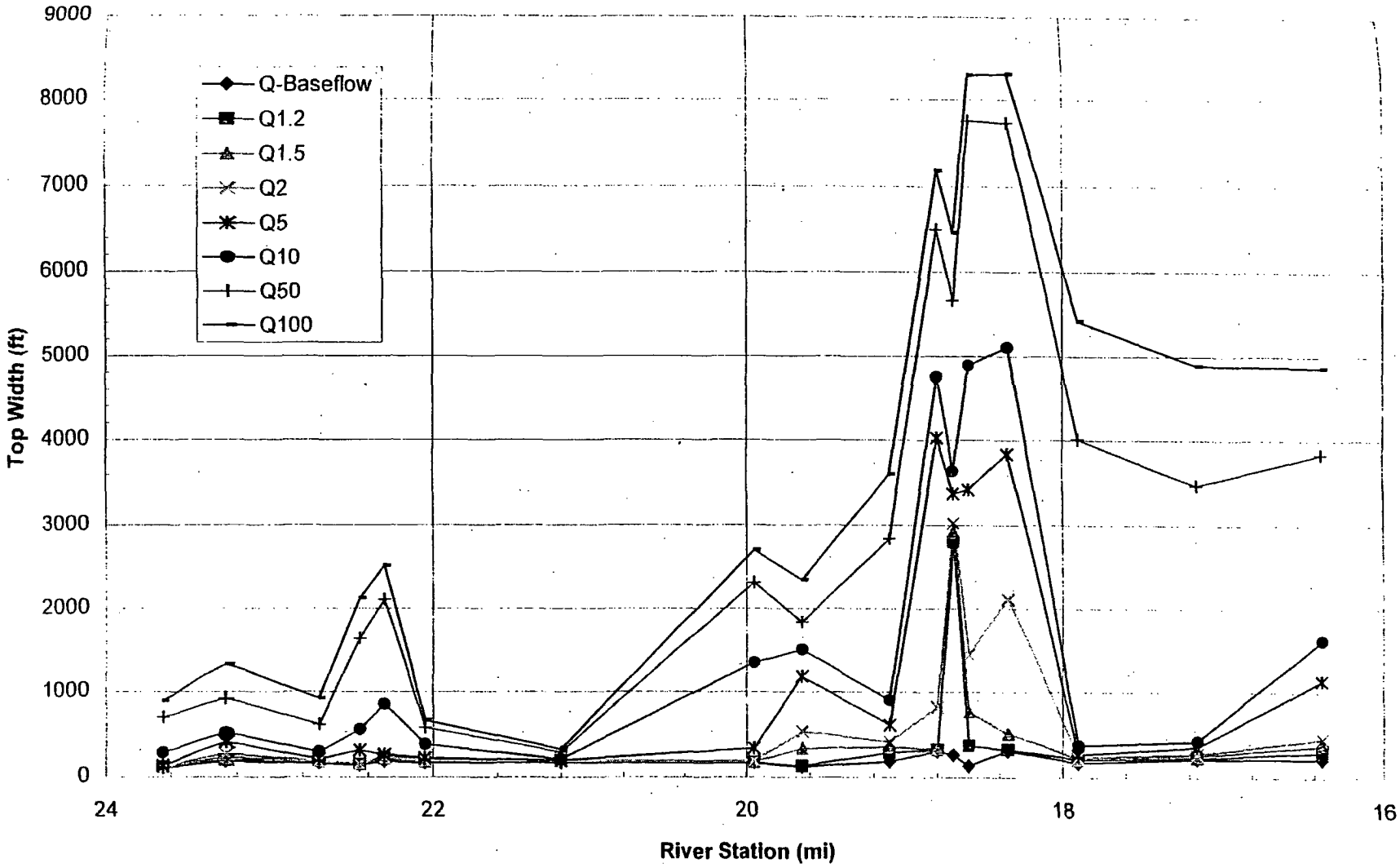


Figure 5-4 Fall River, Top Width

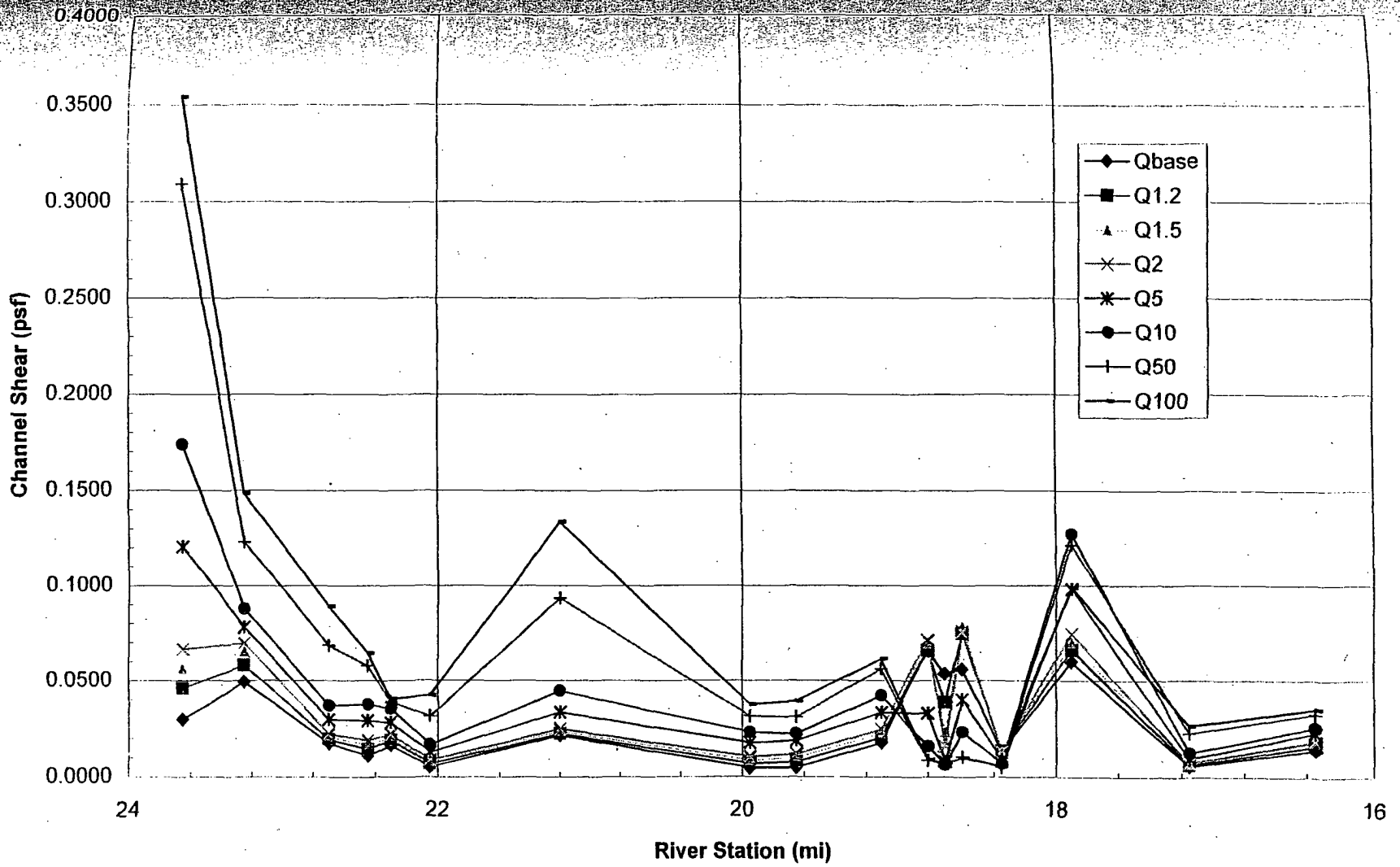


Figure 5-5 Fall River, Channel Shear

due to lack of floodplain access previously mentioned through identification of smaller top widths at higher flows. It is only at higher flows that sediment can be transported through Reach 2.

Maximum channel depths are quite similar throughout the study reach (Figure 5-6). Two notable exceptions stand out: Cross Section 3, containing a large scour hole upstream of Read's Bridge, and Upper Christiansen, which has an extremely deep thalweg tracing the outside bend of a meander. The shallowest depths occur between Cross Section 5 and Cross Section 15. In general, Reach 3 has the highest average maximum depths, while Reach 2 has the shallowest maximum depths. Reach 1 maximum depths are influenced by Cross Section 3 measurements taken at a location with a deep thalweg along the left bank.

In general three distinct reaches can be identified as having general hydraulic characteristics prevalent to each respective reach. Reach 1 experiences steeper water surface profiles, higher channel velocities, and shear stresses. Reach 2 has the lowest channel top widths at flood flows and the lowest maximum depths. Reach 3 has complex hydraulic interactions downstream from Spring Creek Bridge, where there are large amounts of vegetation and floodplain access is readily available. Generally speaking, it has larger top widths and lower velocities, which are directly related to amounts of instream and riparian vegetation and floodplain access.

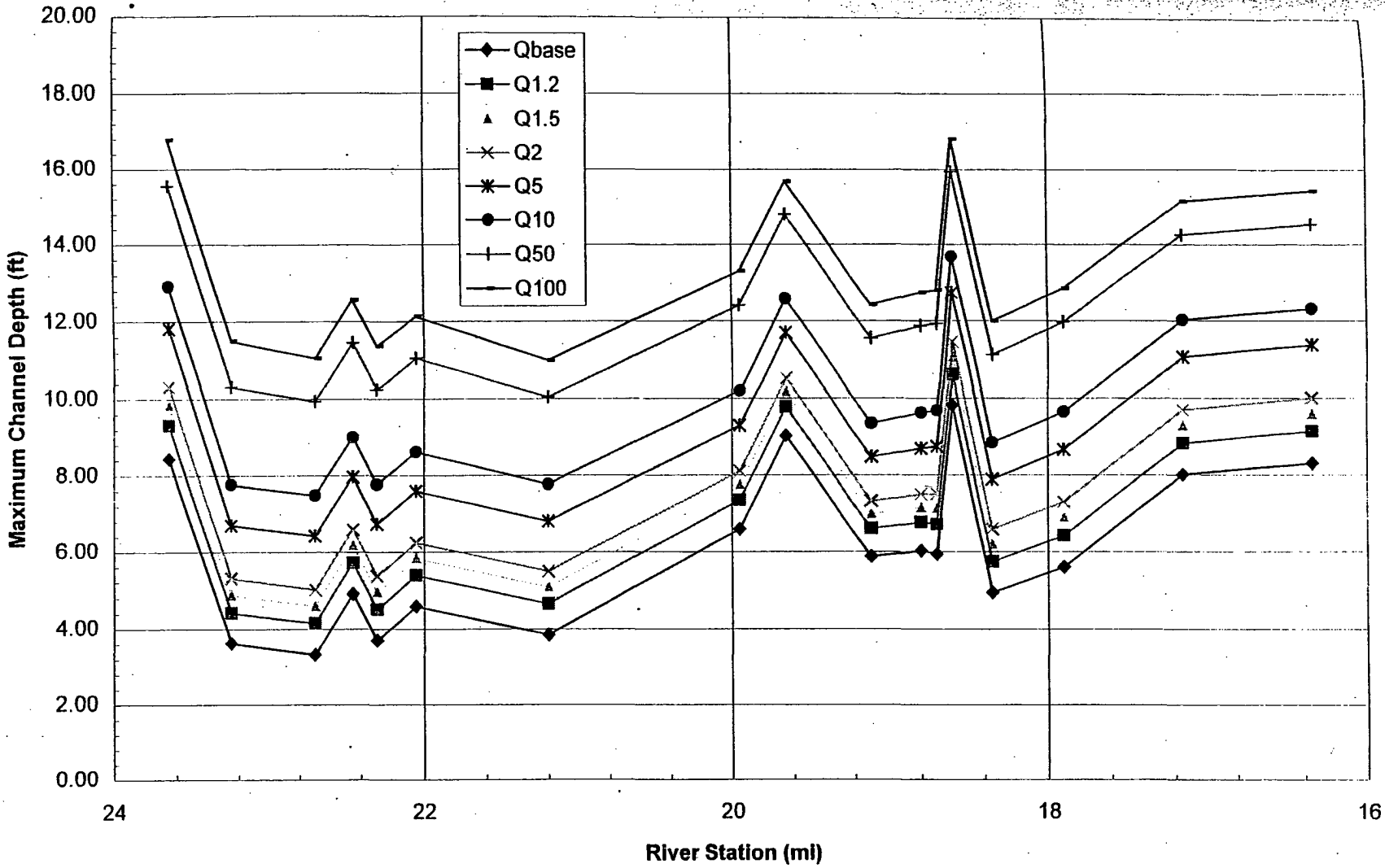


Figure 5-6 Fall River, Maximum Channel Depth

CHAPTER 6
SEDIMENT SOURCES

This chapter provides identification and quantification of the major potential sources of sediment inputs to Upper Fall River. Sediment sources investigated include Upper Fall River bank erosion, sediment yield inputs from the Bear Creek and Dry Creek watersheds, and sediment resulting from erosion of the Bear Creek Meadow below Spaulding Corner.

6.1 UPPER FALL RIVER BANK EROSION

Bank erosion in the Upper Fall River was evaluated by identifying bank erosion sites and by comparing historic aerial photographs to determine changes in channel top width. All bank erosion inventories and aerial photograph analyses were performed by Tetra Tech.

6.1.1 Bank Erosion Inventory

Tetra Tech identified bank erosion sites in the field by floating down the length of the Upper Fall River, from the Navigation Barrier to Island Road bridge. Visual clues, such as raw banks without vegetation, fallen trees and shrubs, rill marks, and irregular bank lines, were used to identify bank erosion sites. At each site a field sheet, sketch, and photograph(s) were used to document erosion. A copy of the field sheet is provided in Table 6-1. The extent and location of each site was marked on copies of USGS quad sheets enlarged to a scale of 1" = 1,000'. The quad sheets also had river miles marked, and the river mile associated with each site was documented.

Twenty-five erosion sites were identified, all of which were confined to the area between Fletcher's bridge and Island Road bridge. This area constitutes study reaches 2 and 3. Figure 6-1 shows the location of each of the 25 erosion sites. Table 6-2 summarizes the river mile location, length, and severity of bank erosion at each site. Many of the bank erosion sites had livestock exclusion fencing, which has been installed in the last several years; consequently, these sites generally

Table 6-1
Upper Fall River Bank Erosion Field Sheet

BANK EROSION EVALUATION SHEET
Upper Fall River Study
Tetra Tech/FLO Engineering Project No. 10637

Location:_____ **Site No.:**_____
Date:_____ **Party:**_____ **Weather:**_____
Access:_____

Channel Form:_____
Top Width (ft):_____
Side Slopes (H:V): Left Bank_____ Right Bank_____
Bank Height (ft): Left Bank_____ Right Bank_____
Control:_____
Adjacent Use Type (agricultural, developed, etc.):
Left Bank:_____
Right Bank:_____
Bed Material:_____

Erosion Description:_____

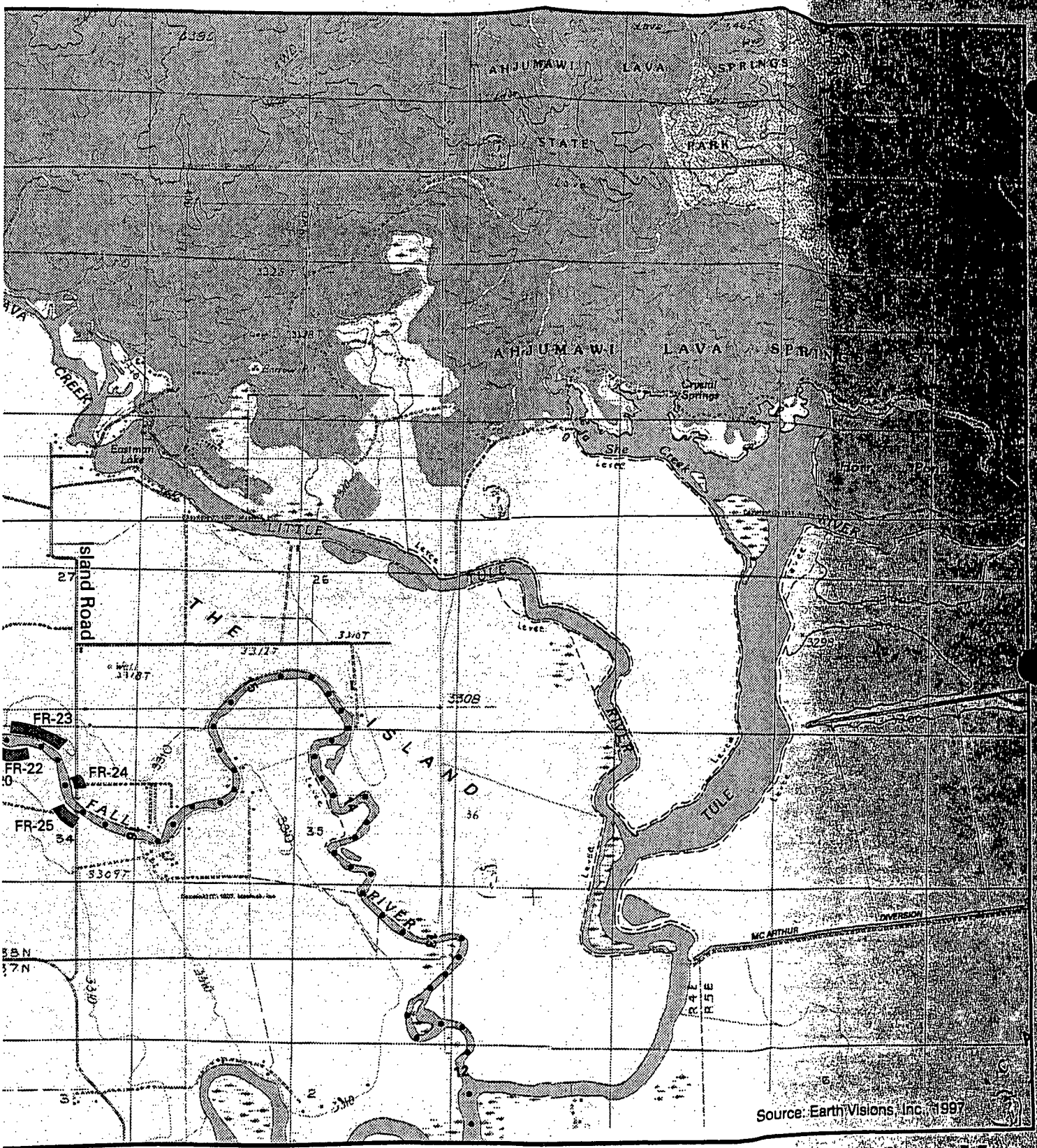
Severity:_____

Photographs (see sketch for location and direction):

Roll #	Picture #	Description

Comments:_____

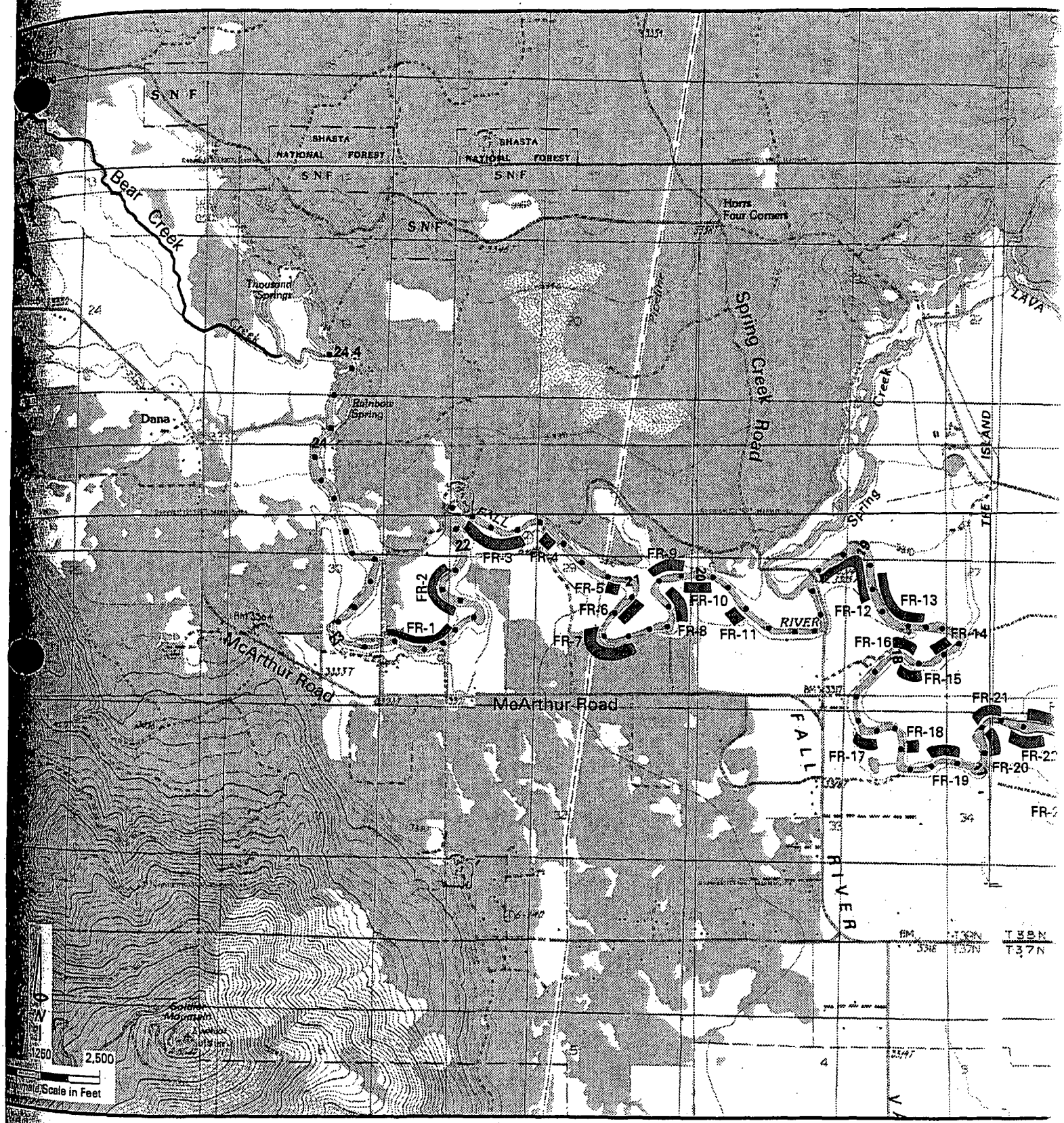
* Left and Right defined looking downstream) Sheet____of____



Upper Fall River Erosion Site Locations Map

Northern, California

Figure 6.1



Legend

FR-11 Erosion sites

• 21 • River miles (dots mark 1/10th of rivermile)

Table 6-2
Summary of Upper Fall River Erosion Sites

Bank Erosion Site	Start River Mile	End River Mile	(L) Left Bank (R) Right Bank	Severity	Length (ft)
FR-1	22.53	22.78	L	Minor	1250
FR-2	22.12	22.25	L	Minor	950
FR-3	21.50	21.70	R	Minor	1100
FR-4	21.35	21.36	R	Moderate	50
FR-5	21.05	21.06	R	Insignificant	50
FR-6	20.80	20.90	L	Minor	500
FR-7	20.57	20.72	R	Minor	1200
FR-8	20.26	20.36	R	Insignificant	550
FR-9	20.10	20.20	L	Minor	550
FR-10	20.00	20.10	R	Minor	450
FR-11	19.78	19.82	R	Minor	200
FR-12	18.78	19.22	R	Minor	2000
FR-13	18.53	18.85	L	Minor	1500
FR-14	18.18	18.27	R	Minor	400
FR-15	18.05	18.09	L	Minor	250
FR-16	17.99	18.04	R	Minor	300
FR-17	17.55	17.63	R	Minor	550
FR-18	17.40	17.41	L	Minor	50
FR-19	17.04	17.14	L	Moderate	700
FR-20	16.81	16.93	R	Moderate	700
FR-21	16.70	16.78	L	Moderate	450
FR-22	16.55	16.63	R	Minor	500
FR-23	16.45	16.63	L	Minor	1300
FR-24	16.33	16.35	L	Minor	100
FR-25	16.20	16.24	R	Moderate	350

appeared to be recovering and may no longer be significant contributors of sediment. However, in order to provide estimates of recent historical sediment delivery from bank erosion, these sites were included in the inventory.

6.1.2 Aerial Photograph Analysis

The aerial photograph analysis focused on the erosion sites identified from the 1997 Tetra Tech field survey. Aerial photographs from 1939 to 1993 were available for analysis. Three sets of photos from 1939, 1964, and 1993 were chosen to conduct the analysis for the following reasons. First, these three sets of photographs were all taken sometime during July, implying that river discharges were reasonably similar. Second, it was important to compare erosion rates over similar periods, specifically 25 and 29 years respectively. Finally, all three sets of photographs were in black and white, as compared to infrared images taken during the 1980s.

Considering the rather small changes in bank location and the inherent inaccuracies in overlaying the photograph tracings, top width change was chosen as a reasonable measurement of bank erosion. Since the purpose of the analysis

was to identify net sediment input from bank erosion, measurement of top width also allowed for consideration of bank accretion.

The following technique was developed to identify top of bank widths while attempting to reduce errors associated with the subjectivity of bank identification and top width measurement: original photographs were nonrectified and had various scales, which needed to be identified and adjusted to one similar scale. A tracing on mylar paper of the 1964 photograph was used as a basemap. The 1964 photograph had scales ranging from 1"= 840' to 1"= 875'. Four distinct scaling sections were used for the 1964 aerial basemap. The 25 erosion sites were located on the mylar basemap tracing and were divided into sections of approximately 275 feet. Each section then was traced onto the mylar map and top widths were measured. Average top widths then were calculated based on the number of sections within each erosion site.

The next step in the process of top width comparisons was adapting several photograph scales to that of the 1964 aerial basemap. Scale adjustments were necessary for the 1993 and 1939 aerial photographs. First, each section of the 1964 aerial basemap was identified on the 1993 and 1939 aerials. Tracings then were made for the section and were reduced or enlarged to the proper scale. Each section was then was linked with photographs from the same year. Once scale differences had been adjusted, erosion sites and sections were traced from the 1964 mylar basemap onto the 1993 and 1939 aerial map tracings. Average top widths then were determined for each erosion site on both sets of aerial maps.

Errors and inaccuracies for these techniques are related to measurement resolution and the ability to identify the river's banks. Measurement resolution is approximately 1/20 of an inch, which represents an error of $\pm$ 20 feet. Multiple measurements of each section along an erosion site were expected to reduce the resolution error by canceling each other out. Other measurement errors are related to the focus of the aerial photographs. For the most part, banks could be identified; however, banks heavily lined with trees, reaches having sun glare, and other darkened and shadowed areas contributed further to the subjectivity of the measurements. Therefore, analysis of results are semiqualitative, due to the inherent margin of error.

General trends and the order of erosion magnitude are of primary interest when determining amounts of sediment input to the river system. Overall results indicate that the river has experienced both erosion and accretion, but in both cases, the magnitudes are small. No major shifts in channel alignment or migration of meander bends were detected. Examination of average top width measurements indicates that erosion activities were present for both periods between 1939 and 1964 and 1964 and 1993 (Figure 6-2). The greatest change in top width for the entire period occurred at erosion sites 11, 12 and 13 (Table 6-3). Sites 12 and 13 are directly downstream of Spring Creek Bridge and do not have cattle exclusion fencing.

Bank erosion was present from 1939 to 1969 throughout much of the entire Upper Fall River area below Fletcher's bridge. All erosion sites were determined to have erosion present except sites FR-5 and FR-20. Even at these two sites the calculated amount of accretion was smaller than the estimated errors, and erosion rather than accretion may have occurred at FR-5 and FR-20. Top width analysis reveals that from 1964 to 1993 many cross sections upstream from erosion site FR-7 experienced lateral accretion. Whereas downstream from FR-7 to FR-13, the river experienced bank erosion and increases in top widths. Most cross sections downstream of FR-13 experienced mild lateral accretion. In general, all erosion sites have widened, according to top width analysis from 1939 to 1993. However, the first 25 years, 1939 to 1964, account for much of the erosion, while in the last 29 years, some lateral accretion has been noted.

Erosion volume and weight estimates were made to determine how much sediment contributed to the Upper Fall River from bank erosion. Estimates were made for both total sediment and for the portion of sand and larger sediments. Soils within the banks were assumed to have sand content of 75 percent and a porosity of 0.35. Contribution amounts were determined from the aerial photograph analysis. The bank height used to estimate the volume was based on the average bank height above water plus half the hydraulic depth at base flow.

Average annual bank erosion contribution rates from 1939 to 1993 were 1,309 cubic yards, as shown by aerial photograph analysis (Table 6-4). The annual sand volume for the period was 982 cubic yards. Annual weight contributions were 1,900 total tons, with 1,425 tons representing the sand contribution. Annual bank erosion volume and weight contribution rates from 1964 to 1993 were 357 cubic yards and 518 tons (Table 6-5), respectively. The portion of the average annual contribution from bank erosion from 1964 to 1993 was made up of sand was estimated to be 268 cubic yards or 389 tons.

Overall results indicate that sediment contributions to the river from bank erosion are small compared to upstream watershed inputs and Bear Creek channel degradation. In both periods, larger contributions of sediment from bank erosion were estimated for the area below Spring Creek than the area above. In fact, from 1964 to 1993, the aerial photo analysis of top widths indicated a net accretion upstream of Spring Creek. Additionally, the estimated rates indicate lower bank erosion rates from 1964 to 1993 than occurred for the entire period of 1939 to 1993. This suggests that there may have been a period of accelerated bank erosion in the earlier part of the century. The SCS (1983) watershed study estimated an average recession rate of 0.05 feet per year for the Fall River and a total contribution from Fall River and Tule River of 170 tons per year. The SCS (1983) bank erosion contribution is smaller than the contribution estimated by Tetra Tech. This is particularly noticeable since the SCS rate was for a much longer river reach.

Erosion Site Top Width Analysis for the Upper Fall River

Cross Section	Top Width				Change in Top Width (ft)		Reach Length (mi)	Reach Length (ft)	1939-1993 Erosion Volume (yd^3)
	1939	1964	1993	1939-1964	1964-1993	1939-1993			
FR-1	161	172	146	11	-26	-15	0.25	1320	-733
FR-2	124	131	135	7	4	11	0.15	792	323
FR-3	115	139	128	24	-11	13	0.20	1056	508
FR-4	76	136	109	60	-27	33	0.05	264	323
FR-5	153	152	120	-1	-32	-33	0.03	158.4	-194
FR-6	112	150	131	38	-19	19	0.10	528	372
FR-7	101	106	123	5	17	22	0.20	1056	860
FR-8	69	91	98	22	7	29	0.15	792	851
FR-9	135	160	175	25	15	40	0.10	528	782
FR-10	138	149	153	11	4	15	0.10	528	293
FR-11	126	158	169	32	11	43	0.05	264	420
FR-12	148	159	174	11	15	26	0.45	2376	2288
FR-13	147	159	196	12	37	49	0.30	1584	2875
FR-14	238	259	249	21	-10	11	0.10	528	215
FR-15	116	158	137	42	-21	21	0.05	264	205
FR-16	116	168	137	52	-31	21	0.07	369.6	287
FR-17	130	165	151	35	-14	21	0.10	528	411
FR-18	110	147	158	37	11	48	0.02	105.6	188
FR-19	133	137	140	4	3	7	0.10	528	137
FR-20	130	123	123	-7	0	-7	0.15	792	-205
FR-21	126	137	126	11	-11	0	0.20	1056	0
FR-22	184	197	194	13	-3	10	0.10	528	196
FR-23	154	184	179	30	-5	25	0.20	1056	978
FR-24	142	168	152	26	-16	10	0.03	132	49
FR-25	152	168	158	16	-10	6	0.05	264	59

Resolution of measurements is +- 20 ft.

Total Erosion Volume (yd^3) 11,487

Fall River Flow Rates	@Dana	@Spring Creek
1939	367	584
1964	411	628
1993	399	616

Estimated Sediment Contribution to the Upper Fall River from Bank Erosion

Erosion Site	1997 Visual Erosion Site Severity	1939-1993 Aerial Erosion Site Severity	1939-1993 Top Width Change (ft)	1939-1993 Aerial Erosion Rate (ft/yr)	Erosion Site Reach Length (ft)	Total Bank Height (ft)	1939-1993 Aerial Erosion Rate Volume (yd³/yr)
FR-1	Minor	Insignificant	-15	-0.3	1250	6.3	-80
FR-2	Minor	Minor	11	0.2	950	6.0	43
FR-3	Minor	Minor	13	0.2	1100	6.8	66
FR-4	Moderate	Moderate	33	0.6	50	3.8	4
FR-5	Insignificant	Insignificant	-33	-0.6	50	6.3	-7
FR-6	Minor	Minor	19	0.4	500	6.0	39
FR-7	Minor	Moderate	22	0.4	1200	9.5	172
FR-8	Minor	Moderate	29	0.5	550	6.8	74
FR-9	Minor	Moderate	40	0.7	550	6.5	98
FR-10	Minor	Minor	15	0.3	450	6.5	30
FR-11	Minor	Moderate	43	0.8	200	7.8	46
FR-12	Minor	Moderate	26	0.5	2000	7.5	267
FR-13	Minor	Moderate	49	0.9	1500	5.8	290
FR-14	Minor	Minor	11	0.2	400	4.5	14
FR-15	Minor	Moderate	21	0.4	250	5.0	18
FR-16	Minor	Moderate	21	0.4	300	7.0	30
FR-17	Minor	Moderate	21	0.4	550	4.5	36
FR-18	Minor	Moderate	48	0.9	50	7.0	12
FR-19	Moderate	Insignificant	7	0.1	700	6.0	20
FR-20	Moderate	Insignificant	-7	-0.1	700	3.5	-12
FR-21	Moderate	Insignificant	0	0.0	450	5.5	0
FR-22	Minor	Minor	10	0.2	500	3.5	12
FR-23	Minor	Moderate	25	0.5	1300	5.5	123
FR-24	Minor	Minor	10	0.2	100	5.5	4
FR-25	Moderate	Insignificant	6	0.1	350	8.0	12
		Total Bank Erosion per Year (yd^3)					1309
		Total Bank Erosion per Year (tons)					1900
		Total Bank Erosion Sand Contribution per Year (yd^3)					982
		Total Bank Erosion Sand Contribution per Year (tons)					1425
		Total Bank Erosion per Year Above Spring Creek (yd^3)					485
		Total Bank Erosion per Year Above Spring Creek (tons)					704
		Bank Erosion Sand Contribution per Year Above Spring Creek (yd^3)					364
		Bank Erosion Sand Contribution per Year Above Spring Creek (tons)					528
		Total Bank Erosion per Year Below Spring Creek (yd^3)					825
		Total Bank Erosion per Year Below Spring Creek (tons)					1197
		Bank Erosion Sand Contribution per Year Below Spring Creek (yd^3)					618
		Bank Erosion Sand Contribution per Year Below Spring Creek (tons)					897

Table 6-5
Upper Fall River Aerial Photograph Bank Erosion Analysis, 1964 - 1993

Erosion Site	1997 Visual Erosion Site Severity	1964-1993 Aerial Erosion Site Severity	1964-1993 Top Width Change (ft)	1964-1993 Aerial Erosion Rate (ft/yr)	Erosion Site Reach Length (ft)	Total Bank Height (ft)	1964-1993 Aerial Erosion Rate Volume * (yd^3/yr)
R1	Minor	Insignificant	-26	-0.9	1250	6.3	-259
R2	Minor	Insignificant	4	0.1	950	6.0	29
R3	Minor	Insignificant	-11	-0.4	1100	6.8	-104
R4	Moderate	Insignificant	-27	-0.9	50	3.8	-6
R5	Insignificant	Insignificant	-32	-1.1	50	6.3	-13
R6	Minor	Insignificant	-19	-0.7	500	6.0	-73
R7	Minor	Minor	17	0.6	1200	9.5	248
R8	Minor	Insignificant	7	0.2	550	6.8	33
R9	Minor	Minor	15	0.5	550	6.5	68
R10	Minor	Insignificant	4	0.1	450	6.5	15
R11	Minor	Minor	11	0.4	200	7.8	22
R12	Minor	Minor	15	0.5	2000	7.5	287
R13	Minor	Moderate	37	1.3	1500	5.8	408
R14	Minor	Insignificant	-10	-0.3	400	4.5	-23
R15	Minor	Insignificant	-21	-0.7	250	5.0	-34
R16	Minor	Insignificant	-31	-1.1	300	7.0	-83
R17	Minor	Insignificant	-14	-0.5	550	4.5	-44
R18	Minor	Minor	11	0.4	50	7.0	5
R19	Moderate	Insignificant	3	0.1	700	6.0	16
R20	Moderate	Insignificant	0	0.0	700	3.5	0
R21	Moderate	Insignificant	-11	-0.4	450	5.5	-35
R22	Minor	Insignificant	-3	-0.1	500	3.5	-7
R23	Minor	Insignificant	-5	-0.2	1300	5.5	-46
R24	Minor	Insignificant	-16	-0.6	100	5.5	-11
R25	Moderate	Insignificant	-10	-0.3	350	8.0	-36
		Total Bank Erosion per Year (yd^3)					**357**
		Total Bank Erosion per Year (tons)					**518**
		Total Bank Erosion Sand Contribution per Year (yd^3)					**268**
		Total Bank Erosion Sand Contribution per Year (tons)					**389**
		Total Bank Erosion per Year Above Spring Creek (yd^3)					**-41**
		Total Bank Erosion per Year Above Spring Creek (tons)					**-59**
		Bank Erosion Sand Contribution per Year Above Spring Creek (yd^3)					**-31**
		Bank Erosion Sand Contribution per Year Above Spring Creek (tons)					**-44**
		Total Bank Erosion per Year Below Spring Creek (yd^3)					**398**
		Total Bank Erosion per Year Below Spring Creek (tons)					**577**
		Bank Erosion Sand Contribution per Year Below Spring Creek (yd^3)					**298**
		Bank Erosion Sand Contribution per Year Below Spring Creek (tons)					**433**

6.1.3 Muskrat, Livestock, and Wave Contributions to Erosion

Review of hydraulic information, presented in Chapter 5, indicates that erosive forces exerted on the banks by stream flow are quite small. Both shear stresses and velocities are well below those considered erosive. However, it is evident from field observations and aerial photograph analysis that some minor bank erosion is occurring. Therefore, other mechanisms besides hydraulic forces created by the flow of Fall River are contributing to bank erosion.

It is the opinion of the Tetra Tech study team that the most likely contributors of bank erosion are a combination of muskrat burrowing, livestock trampling, and wave action. Livestock remove vegetation by grazing and disrupt the structure of the soils when they walk across the moist banks, leaving the banks susceptible to

erosion. Muskrats further increase erosion by burrowing into the banks. The burrows also provide areas for the energy from abrupt changes in water level caused by waves to be concentrated. Finally, wave action increases the local hydraulic forces on the banks and contributes to material piping out of the banks. Waves can be the result of either wind action or boat wakes, either of which increases erosive forces on the banks.

Field observations substantiate the influence of livestock grazing and trampling on bank erosion activity. In locations where exclusion fencing has been installed, there is little evidence of excessive erosion.

6.2 WATERSHED SEDIMENT YIELD

The NRCS conducted a sediment inventory in the Bear Creek and Dry Creek watersheds (NRCS 1998a and 1998b). These are the only two significant surface water contributions to Upper Fall River. The NRCS identified the contributing drainage areas of the Bear Creek watershed as 115 square miles and the Dry Creek watershed as 21 square miles. The Bear Creek watershed was further subdivided into five planning units with the following associated drainage areas:

Thousand Springs	10.1 square miles
Kemp	13.8 square miles
N. Fork Bear Creek	15.0 square miles
Tom Young	37.8 square miles
Whitlow	38.2 square miles

These planning unit watersheds were identified on Figure 3-1 of Chapter 3. The purpose of the NRCS study was to identify and quantify sediment input from the uplands of the Bear Creek and Dry Creek watersheds to the Upper Fall River.

6.2.1 Study Methodology

A general summary of the procedures used to develop the sediment inventory for the watersheds above the Upper Fall River is provided. A complete description of study methodology is provided in NRCS (1998a and 1998b).

The first step in the inventory process was for the NRCS to develop a methodology for identifying erosion sites and for estimating sediment yield from these sites. After development, the procedure was reviewed by Tetra Tech and W. M. Beatty & Associates, Inc., the resource management company responsible for much of the private land in the watershed. Permission to conduct the effort then was sought and granted by the primary landowners in the watershed.

The sediment sources were divided into three main categories: hillslopes, roads, and channels. The next layer of categorization was based on the potential erosion hazard ratings of low, moderate, and high. The final layer of categorization was the land use/cover type. These categories included areas of the Pondosa burn in

various stages of restoration, selectively cut timber lands, clear cut timberlands, brushlands, and grazed meadows.

The analysis procedure called for estimating soil erosion from the various source type using different methods. The Universal Soil Loss Equation (USLE) was used to estimate sheet and rill erosion from hillslopes and road surfaces. Landings used in the timber harvest process were included in the hillslope category. Skid trails were included with roads. Average annual rates of erosion associated with lateral recession of streambanks and road cut and fill slopes were estimated using volumetric calculations combined with general guidelines or field evidence of recession rates. Initial estimates determine how much soil is eroded from a particular site. Depending on conditions between the erosion source and the nearest stream course and conditions within the receiving stream source, only a portion of the eroded material will reach Upper Fall River. To account for sediment deposition and filtering prior to delivery of the sediment to Upper Fall River, the delivery ratio concept was applied. The delivery ratio is an estimate of the percentage of sediment provided on an erosion site that is actually transported to the point of interest. For the NRCS study, two levels of delivery ratios were developed. The first level identified the percentage of sediment that was derived at an erosion site and transported to the nearest stream course. The second level identified the percentage of sediment delivered to the stream channels in an area of the watershed, which was delivered to Upper Fall River. For both ratios, the range of possible values was between 0 and 100 percent.

Prior to conducting sediment inventory fieldwork, the NRCS reviewed aerial photographs of the watershed to assist in identifying potential inventory sites. The NRCS used aerial photographs to select inventory sites that reflected different levels of forestland management, natural disturbance, or vegetative cover type. This analysis was combined with review of the erosion hazard rating (EHR) maps to select field locations, which covered the range of erosion site types, EHR, and cover/land use.

Staff from the NRCS conducted field inventories of 147 erosion sites between June and September 1997. The sites included 60 hillslopes, 38 stream channels, and 49 roads. Field data were entered into spreadsheets and were sorted into hillslope, road, and channel data sets. The data were further sorted based on other parameters, such as watershed, road type, EHR, and stream order, until average results in the sorted categories matched field observations and expected trends. The NRCS staff used professional judgment and experience to develop the final estimates of average annual erosion/sediment production from each of the subcategories. These results then were extrapolated across the entire Bear Creek and Dry Creek watersheds. The final step in the process was modifying the sediment delivery ratios and streambank erosion to bring the average annual sediment yield based on the sediment inventory closer in line with estimates of average annual sediment yield to the Upper Fall River derived from sediment sampling.

Table 6-7
Summary of Sediment Inventory Results, Average Annual Sediment Yield (NRCS 1998b)

Planning Unit	Total Area (acres)	Average Annual Sediment Yield							
		Hillslopes		Roads		Channels		Total All Sources	
		cy/ac-yr	cy/yr	cy/ac-yr	cy/yr	cy/ac-yr	cy/yr	cy/ac-yr	cy/yr
Thousand Springs	6,465	0.04	243	0.02	141	0.47	3,011	0.53	3,395
Dry Creek	13,687	0.002	32	0.002	28	0.02	233	0.02	283
Kemp	8,845	0.006	56	0.004	41	0.05	437	0.06	534
North Fork Bear	9,607	0.003	27	0.003	17	0.02	188	0.02	232
Tom Young	24,180	0.007	164	0.007	91	0.05	1,169	0.06	1,424
Whitlow	24,466	0.002	57	0.002	34	0.01	340	0.02	431
TOTAL	87,250	0.007	579	0.004	352	0.06	5,368	0.07	6,299

Table 6-8
Summary of Sediment Inventory Results, Average Annual Sediment Yield Assuming Restoration of Bear Creek Meadow (NRCS 1998b)

Planning Unit	Total Area (Acres)	Average Annual Sediment Production							
		Hillslopes		Roads		Channels		Total All Sources	
		(cy/ac-yr)	(cy/yr)	(cy/ac-yr)	(cy/yr)	(cy/ac-yr)	(cy/yr)	(cy/ac-yr)	(cy/yr)
Thousand Springs	6,465	0.02	136	0.01	79	0.13	830	0.16	1045
Dry Creek	13,687	0.002	32	0.002	28	0.02	223	0.02	283
Kemp	8,845	0.004	31	0.003	23	0.02	211	0.03	265
North Fork Bear	9,607	0.002	16	0.001	10	0.01	78	0.01	104
Tom Young	24,180	0.004	98	0.002	54	0.02	510	0.03	662
Whitlow	24,466	0.002	38	0.0009	23	0.01	135	0.01	196
TOTAL	87,250	0.004	351	0.002	217	0.02	1987	0.03	2555

year, which is equivalent to 2,849 cubic yards per year at 80 percent. Both values indicate that sediment yield to Fall River per unit area is very low.

- Approximately 85 percent of the total sediment yield to Fall River is derived from eroding stream channels. Hillslopes and roads are estimated to contribute roughly nine and six percent of the total sediment yield.
- Our evaluation suggests that eroding stream channels in the Thousand Springs watershed area are the largest source of sediment delivered to Fall River, accounting for almost 50 percent of the total sediment yield.
- By reducing local streambank erosion and sediment delivery to Fall River from upstream sources, it is roughly estimated that restoring the floodplain function of Bear Creek Meadow would reduce the average annual sediment yield to Fall River by 60 percent.
- Results of the consultants' analysis of Fall River indicate that the transport capacity of Fall River is very low. Reducing what is already a very low sediment yield by restoring the floodplain function of Bear Creek Meadow may not significantly impact movement of recent deposits or the present sediment balance. On the other hand, preserving or restoring the floodplain function of meadows in the Bear Creek system is critical and should help maintain balance by keeping sediment delivery low and providing a buffering effect in the event of catastrophic events, such as wildfire or extreme climatic events, and not contribute large volumes of sediment by channel degradation.

6.3 BEAR CREEK MEADOW

Bear Creek Meadow is on the portion of Bear Creek between Spaulding Bridge and the Fall River confluence and has had recent channel degradation problems, which have contributed sediment to the Fall River. In 1960, Bear Creek was channelized by private landowners and the Soil Conservation Service, resulting in increased sediment transport capabilities. There are also indications that some channelization activity occurred in the early 1950s. The channelization realigned Bear Creek to the northeast side of the meadow and caused the channel to incise approximately six to ten feet deep below the floodplain. Volume estimates of the material eroded, and rates of sediment contribution to the Fall River are therefore considered necessary in determining a sediment balance for the Upper Fall River. Sediment delivery rates are considered for the period from 1960 to 1997 and more recent rates from 1994 to 1997.

6.3.1 Bear Creek Sediment Erosion Volume

Sediment volumes were calculated to determine the amount of sediment Bear Creek has contributed to the Fall River over the last 37 years. Rick Poore of Thousand Springs Ranch has provided all of the information used in the following analysis. Survey data for 1994 to 1997 were provided for 13 cross sections. Cross sections were used to determine annual sediment contribution rates, as well as total sediment volume removed from Bear Creek over the last 37 years.

Cross-sectional data were imported to AutoCad, and cross-sectional cut and fill area calculations were performed for differences between 1994 and 1997 cross section geometry. The plotted cross sections are provided in Appendix C.12. Changes in cross-sectional areas also were determined using the assumption that the original channelization resulted in cross-sectional areas being 30 square feet (ten feet wide by three feet deep, roughly the dimensions of a cut made by a bull-dozer). Area differences were resolved using 1997 cross-sectional data to represent the current condition and a 30 square foot assumed cross section to represent the conditions after channelization. Total cross section degradation or aggradation then was multiplied by a reach length distribution average to determine the change in volume. Annual rates, total volumes and sand fraction calculations were made to determine amounts of sediment contributed to Upper Fall River from Bear Creek. Weight calculations were based on assuming a porosity of 35 percent. The sand contribution was calculated assuming that 85 percent of the banks were made up of sand-sized and larger material.

Analysis of cross-sectional data reveals that Bear Creek has severely degraded over the last 30 years. Annual sediment volumes attributed to channel degradation in Bear Creek were approximately 1,424 tons from 1994 through 1997. The portion of the contribution from the Bear Creek Meadow attributable to sand was 1,210 tons annually over the last three years.

Examining results of Bear Creek Meadow sediment removal by channel bank erosion and incision from the time when it was channelized until the present reveals much larger annual rates in the past than the recent four-year period. This is based on solving for changes in area using the original 30 square foot cross section for 1960 and current 1997 cross sections. The average annual erosion rate over the entire 37 years was 4,520 tons per year, with a sand fraction of 3,842 tons per year. Average erosion rates since 1960 are approximately three times greater than the current average annual rate.

6.3.2 Timing of Sediment Contributions from Bear Creek Meadow

Implications of the higher erosion rate for the entire period compared with current erosion rates are that at one time much larger amounts of sediment were being removed from Bear Creek Meadow than are under the present rate. After channelization, Bear Creek attempted to reach equilibrium through the meadow by eroding its banks and incising. Although Bear Creek has not yet reached the dynamic equilibrium it is seeking, transport rates indicate that it is more stable

than when the channelization first occurred. This is particularly true when recent hydrologic events are considered and that the current time frame represents a period of high flood peaks. All other factors being equal, this would have resulted in higher than average erosion rates from 1994 to 1997. However, the cross-sectional data indicate erosion rates over the current four-year period to be approximately one third of the average historic rate. Thus, during the early stages of channel incision, there may have been periods when the average annual erosion rate was double the overall average annual erosion rate. Under this assumption, the meadow would have made annual sediment contributions to Upper Fall River of approximately 10,000 tons per year.

CHAPTER 7
SEDIMENT BALANCE

In Chapter 6, the major sources of sediment delivery to Fall River were identified, and estimates of their magnitude were presented. To address the key question of what will happen to sediment deposited in Fall River, development of a sediment balance considers the major inflows of sediment, and an evaluation of the river's capability to transport sediment is needed. This latter property of the river, referred to as its "sediment transport capacity," varies with discharge, river location, and sediment size. In general, the larger the sediment, the lower the sediment transport capacity.

Three types of sediment load usually are considered in analyzing the sediment transport characteristics of a river system. These are bed load, suspended bed material load, and wash load. The bed layer is a flow layer, several grain diameters thick, immediately above the bed. Bed load is the material transported in that layer by rolling, sliding, or skipping. Suspended bed material load is the portion of the sediment transport of sizes found within the bed that are carried in suspension above the bed layer by turbulence in the flow. Transport of bed material load, which is made up of both the bed load and suspended bed material load, typically is controlled by hydraulic conditions and the size of the material making up the bed. Changes in the energy available for transporting bed material load can cause major changes in the river's ability to transport bed material; hence, deposition or erosion in the channel bed can result. Wash load is the portion of the sediment transport composed of small particles not found in appreciable quantities in the bed. The transport rate of wash load is governed by the supply of wash load to the river. Once wash load is introduced to the river, it is conveyed downstream until hydraulic conditions change drastically, such as when the gradient lessens considerably, a lake or ocean is encountered, flow is filtered on the floodplain by thick vegetation, or flow is exchanged with relatively quiescent areas along the river channel, such as backwater and side eddies.

In the process of performing the sediment balance, the various sediment inflows are compared with the river's capacity to transport the sediments delivered. If the river cannot transport the sediments delivered, the excess supply is deposited in the channel. However, if the transport capacity exceeds the supply, sediment is removed from the riverbed, and degradation (lowering) of the bed occurs. In the case of the Fall River, degradation would represent removal of the recent sediment deposits. Finally, based on the magnitude of the excess transport capacity, the time frame to remove the excess deposits can be established.

The purpose of the analysis presented in this chapter is to determine if the Upper Fall River has the potential to remove the recent sediment deposits based on a comparison of sediment supply and sediment transport capacity. If there is excess sediment transport capacity, the time frame to remove the recent sediment deposits can be estimated. "What if" scenarios can be investigated to determine the change in the time span required for the flow to remove recent sediment deposits if various reductions in sediment supply are achieved.

For sediment balance, the sediment sizes of concern are sand and gravels. These are the sediment sizes that make up the bed material load. The other sediments (silts and clays) are considered wash load. The primary size of concern is sand, which ranges in diameter from 0.062 mm to 2 mm. There is some gravel in Fall River, particularly upstream of Fletcher's Bridge, but the vast majority of recent sediment deposits are sand-sized.

7.1 Available Sediment Transport Data

Sediment transport data are available from two primary sources, the California DWR (DWR 1998) and the Thousand Springs Ranch (TSR) (Poore 1998). The DWR data were collected in 1996 and 1997 at several locations from just upstream of Island Road Bridge to Read's Bridge. Data collected consisted of bed load measurements and suspended load measurements. DWR sediment transport data are reported in "Aquatic Monitoring and Assessment for the Upper Fall River" (DWR 1998). The TSR sediment transport data were collected by Rick Poore to support analysis and design work associated with the proposed Bear Creek (Dana) Meadow Restoration Project on Thousand Springs Ranch. Mr. Poore's data were collected at three locations on Bear Creek, including the downstream end of Bear Creek Meadow above the confluence with the Fall River, Spaulding Bridge, and the most upstream location at Pondosa Bridge. Data collected at these sites also consisted of suspended sediment and bed load samples. Rick Poore provided Tetra Tech with results of the Thousand Springs Ranch data collection effort in spreadsheet format.

The locations of various sediment data collection sites are shown on figures 1-1 and 2-1. The results of the data collection efforts are reported in Appendix C.1. Table 7-1 provides a summary of the range of conditions, number of samples, and time frame for which sediment transport data were collected.

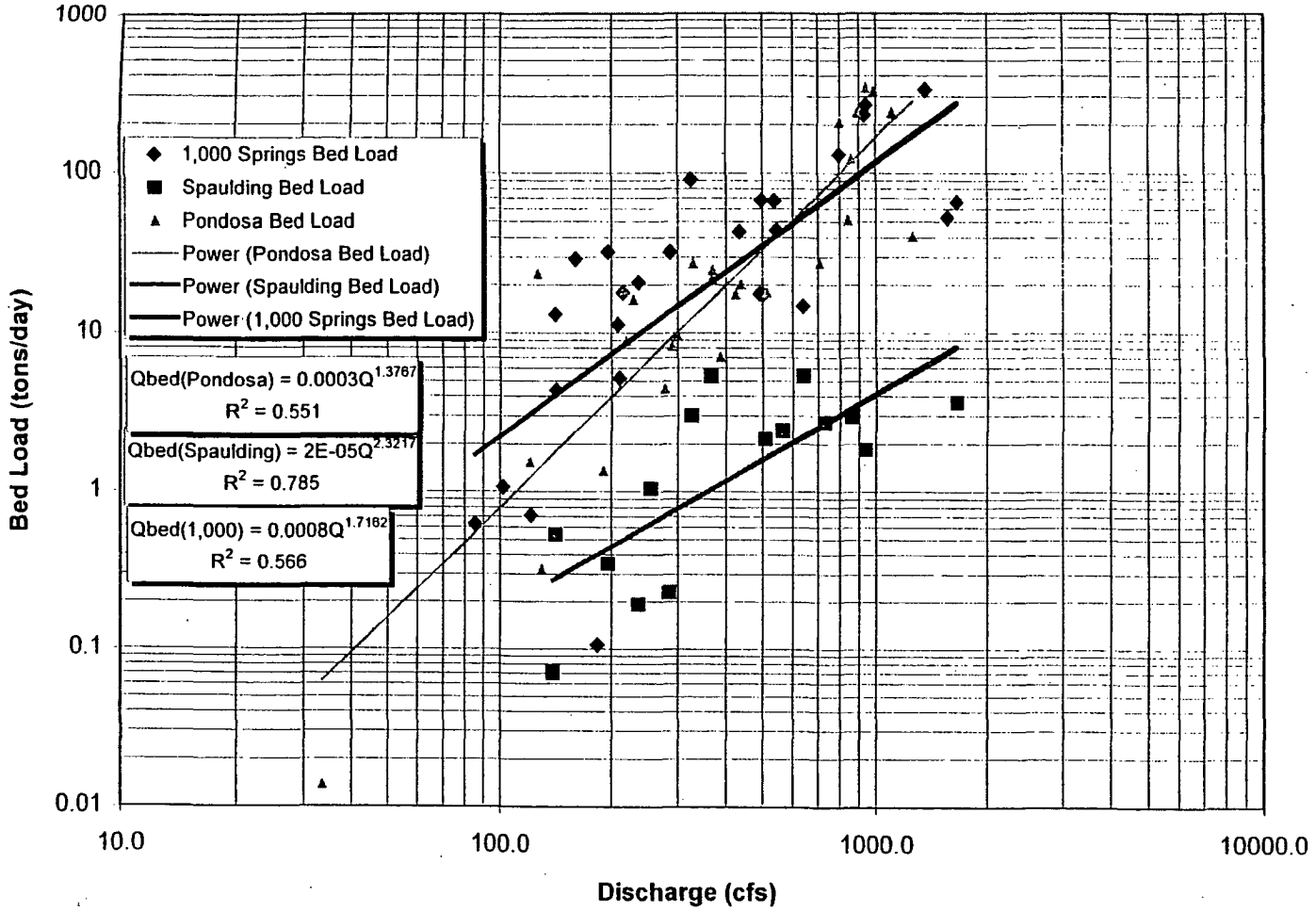


Figure 7-1 Bear Creek Bed Load Transport Regression Analysis

Another important type of information related to sediment transport is the bed material size distribution, which is important because of the differences in the stream's capability to transport sediments of different sizes. In general, all other factors being equal, such as specific gravity and shape, a stream can transport sediment of a smaller size at higher rates than it can larger sediment. The two primary sources of bed material size distribution information were samples collected by Tetra Tech in August 1997 and samples collected by North State Resources and presented in "A Study of the Habitat Characteristics of the Aquatic Vegetation of the Upper Fall River" (NSR 1997). Details of the bed material size distributions are presented in Appendix C.1.

Analysis of Sediment Transport Data

In order to develop sediment transport estimates for extended periods, it was necessary to develop relationships that would relate the sediment transport rate to the flow in the stream. The rating curves typically take the form of a power function, such as:

$$Q_S = aQ^b$$

Q is the water discharge, a is the coefficient, b is an exponent, and Q_S is the sediment transport rate.

Primary concern over sediment in Upper Fall River is for sand and larger sizes, which was defined in section 7.1 as "bed material load." Data were separated to isolate the sand-sized sediment. In the case of the bed load measurements, the sampling procedure traps only sand-sized and larger sediments since samples are collected in a mesh bag. Sizes smaller than the mesh opening are flushed through the bag and are not represented in the sample. The mesh openings for the DWR Helley-Smith bed load sampler was 0.125 mm. For the Helley-Smith bed load samples used by TSR, the collected bag mesh opening was 0.25 mm. Thus the DWR samples do not reflect the portion of the bed material load in the 0.0625 mm to 0.125 mm range and the TSR samples do not reflect the portion of the bed material load in the 0.0625 mm to 0.25 mm range.

In analyzing the suspended load measurements, DWR divided the sample into sand and larger particles (suspended bed material load) and silt and clay particles (wash load). The TSR data were analyzed for total suspended sediment only, combining both suspended bed material load and wash load into a single suspended sediment concentration.

The sediment transport data supplied by DWR and TSR were reviewed and analyzed by Tetra Tech. Since the primary sediment size of interest is sand, the data were manipulated to determine relationships for sand and larger sediment transport. Since there were some differences as to the data collection and the resulting analysis, slightly different procedures were performed to analyze the two

Summary of Sediment Transport Data Collected by California Department of Water Resources

Location	Collected by	Number of Samples by Data Type		Time Frame		Discharge Range (cfs)	
		Suspended	Bed Load	From	To	Low	High
Pondosa Bridge	TSR	47	27	1/8/95	1/27/98	16	1250
Spaulding Bridge	TSR	47	22	1/9/95	1/27/98	13	6520
Thousand Springs	TSR	43	27	1/11/95	1/27/98	14	1544
Read's Bridge (#3)	DWR	2	4	9/25/96	1/3/97	371	2300
Fletcher's Bridge (#7)	DWR	2	4	9/24/96	12/31/96	380	5800
Gasline (#15)	DWR	3	5	9/26/96	6/27/97	385	1570
Spring Creek (#21)	DWR	2	3	10/8/96	12/30/96	600	2200

Notes: All Thousand Springs Ranch (TSR) samples were collected on Bear Creek.
All DWR samples were collected on Upper Fall River.

suspended sand and wash loads. Tables C-4 and C-5 present the bed load and suspended load results for the three TSR sampling sites.

To establish the percentage of the TSR suspended load that was sand, the average percentage of sand in the nine DWR suspended samples was calculated. Sand represented an average of 24 percent of the DWR suspended sediment samples. It was decided to use a factor of 50 percent to represent the portion of sand in the TSR suspended samples. Because the locations along Bear Creek at which the samples were taken are a higher energy environment then the Upper Fall River locations sampled by DWR, it was expected that a higher portion of the suspended load would be composed of bed material load. The 50 percent value is considered a conservatively high estimate of the sand percentage in the suspended load measurements.

Estimation of the portion of the TSR bed load samples that passed through the 0.25 mm mesh bag was based on sieve analysis of five TSR bed load samples showing that approximately 10 percent of the bed load sample was between 0.25 and 0.5 mm. Results range from 5.2 to 12.1 percent. It was assumed that the portion of the bed load in the two smaller intervals, 0.0625 to 0.125 mm and 0.125 mm to 0.25 mm, was the same as for the finest sampled size interval. Based on this assumption, 20 percent of the TSR bed load larger than 0.0625 mm passed through the sample mesh without being collected. To account for this, the TSR bed load samples were multiplied by a factor of 1.2.

Adjusted bed load and suspended load transport rates are provided in tables C-4 and C-5. Regression analysis of data provided the sediment transport equations in figures 7-1 and 7-2. The regression equations developed from the TSR data are listed below.

<u>Bear Creek at Pondosa Bridge</u>

$Q_{ss} = 3.02 \times 10^{-5} Q^{2.21}$
$(R^2 = 0.852)$
$Q_{bl} = 1.8 \times 10^{-5} Q^{2.32}$
$(R^2 = 0.785)$

<u>Bear Creek at Spaulding Corner</u>

$Q_{SS} = 2.35 \times 10^{-5} Q^{2.12}$
$(R^2 = 0.900)$
$Q_{bl} = 0.00031 Q^{1.38}$
$(R^2 = 0.551)$

<u>Bear Creek at Thousand Springs Ranch</u>

$Q_{SS} = 2.72 \times 10^{-5} Q^{2.19}$
$(R^2 = 0.855)$
$Q_{bl} = 0.00082 Q^{1.72}$
$(R^2 = 0.566)$

data sheets. The analysis of the TSR and DWR sediment measurements is presented in the following two subsections.

7.2.1 Department of Water Resources Sediment Data

The DWR sediment transport data consisted of nine measurements of suspended load and sixteen measurements of bed load. The nine suspended load measurements were collected in conjunction with bed load measurements. Since the total load, the combination of both the bed load and suspended load, is the parameter of interest for the sediment balance, only the nine measurements with both suspended and bed load measurements were analyzed.

The DWR suspended samples were analyzed so that the sand portion of the suspended load was determined. This was assumed to be material larger than 0.0625 mm. These results are presented in Table C-1. The bed load samples were analyzed for percentage of material in various class materials ranging from >2.3 mm to <0.15 mm. As previously mentioned, the mesh opening on the bed load sample was 0.125 mm. Therefore, the sample does not effectively collect material finer than the mesh opening and was required to complete the bed load transport rate. It therefore was assumed that the transport in the 0.125 mm to 0.0625 mm (unsampled sizes) was the same as that measured for the 0.38 mm to 0.125mm range. Table C-2 also shows the DWR sample bed load results and the adjustments to account for the finer, unsampled bed load.

The results of combining the suspended and bed load measurements from DWR are presented in Table C-3. This table shows the total sediment load and wash load as well as the total sand load.

Regression equations were not derived for the sediment load verses discharge for the DWR data. This decision was made since the data were collected at four different locations with only two or three samples of both bed load and suspended load at any single cross section. Even if the nine measurements were lumped together as one data set, the data set would be too small for a meaningful regression analysis. Furthermore, it was deemed inappropriate to combine the results at four different locations into a single data set because of the significant difference in hydraulic conditions between the locations. The DWR measurements were used to check the reasonableness of the sediment transport equations developed in section 7.3.

7.2.2 Thousand Springs Ranch Sediment Data

The sediment transport data collected by TSR, similar to the DWR data, consisted of bed load and suspended load measurements. However, there were two significant differences. First, the TSR bed load samples were collected with a 0.25 mm mesh bag sampler, so the TSR data does not include the portion of the bed load between 0.0625 mm and 0.25 mm. Secondly, the TSR suspended load data were not analyzed to determine the portion of the sample composed of sand. These data were reported as a total suspended concentration, which included both

These equations were applied to the 67 years of hydrology developed for Bear Creek to determine bed material yield, which is the sum of the suspended sand load and bed load being transported. The results are summarized in Table 7-2. Calculated yields for each of the 67 years are provided in Table C-6ab.

SEDIMENT TRANSPORT EQUATION DEVELOPMENT

The regression equations presented in Section 7.2 are suitable for analyzing sediment transport rates under existing conditions. However, if channel alterations occur, which change hydraulics or bed material sizes, the transport rates of the bed material load would be altered. Unfortunately, the regression equations developed from the actual data cannot reflect the alteration in sediment transport capacity induced by such changes. In addition, the sediment transport relationships for Upper Fall River were based on a very limited number of samples. Two to four samples were collected at four different locations. Because of these two factors, sediment transport procedures sensitive to changes in the Upper Fall River were necessary. To satisfy this need, a general sediment transport equation available in the literature was chosen for application to Upper Fall River.

7.3.1 Selection of Sediment Transport Relationships

Sediment transport equations found in the literature typically are developed from a combination of fluid mechanics theory and refinements based on actual sediment transport data collected in natural streams or laboratory flumes. Therefore, in selecting a transport equation for a particular stream, it is essential that the transport equation have been developed for conditions similar to those encountered in the stream of interest. To assist in determining the appropriateness of several commonly used sediment transport equations, Williams and Julian (1989) derived a procedure using divisionless parameters to identify the applicability of sediment transport equations to a particular system. The equations addressed by William and Julian (1989) are those of Ackers and White (1973), Shen and Hung (1971), Toffaletti (1968), and Yang (1973). Based on the typical conditions in the Upper Fall River, Yang's (1973) equation was selected as the most appropriate.

7.3.2 Description of Yang's Sediment Transport Equation

Yang (1972) reviewed the basic assumptions used in developing conventional sediment transport equations. He concluded that sediment transport rate assumptions determined from water discharge, average flow velocity, energy slope, and shear stress are questionable. He proposed that a more appropriate parameter was the rate of energy dissipation per unit weight of water. This term is the product of the velocity and water surface slope and is referred to as "unit stream power." Yang proposed that total sediment concentration must be directly related to unit stream power. Yang and Molinas (1982) further developed the theory to show that a direct relationship can be obtained from basic theories in fluid mechanics and turbulence.

Table 7-2
Bear Creek Sediment Yield Summary

Cross Section	Suspended Sand Load			Bed Load			Total Bed Material Load		
	Average (tons/yr)	Total (tons)	Maximum (tons/yr)	Average (tons/yr)	Total (tons)	Maximum (tons/yr)	Average (tons/yr)	Total (tons)	Maximum (tons/yr)
Pondosa	1192	79896	10482	1485	99469	15337	2677	179364	25819
Spaulding	515	34496	3930	79	5281	263	594	39777	4095
Thousand Springs	941	63064	8023	1513	101339	5763	2454	164403	13786

Yang (1973) published an equation for sand transport based on the unit stream power. The resulting dimensionless equation is

$$\log C_{ts} = 5.435 - 0.286 \log\left(\frac{\omega d}{\nu}\right) - 0.457 \log\left(\frac{U_*}{\omega}\right) + \left[1.799 - 0.409 \log\left(\frac{\omega d}{\nu}\right) - 0.314 \log\left(\frac{U_*}{\omega}\right)\right] \log\left(\frac{VS}{\omega} - \frac{V_{cr}S}{\omega}\right) \quad (7\text{-}1)$$

Similarly, Yang developed an equation for gravel transport using the same approach as for sand transport. Yang's (1984) dimensionless gravel transport equation is

$$\log C_{tg} = 6.681 - 0.633 \log\left(\frac{\omega d}{\nu}\right) - 4.816 \log\left(\frac{U_*}{\omega}\right) + \left[2.784 - 0.305 \log\left(\frac{\omega d}{\nu}\right) - 0.282 \log\left(\frac{U_*}{\omega}\right)\right] \log\left(\frac{VS}{\omega} - \frac{V_{cr}S}{\omega}\right) \quad (7\text{-}2)$$

in which C_{ts}, C_{tg} = total sand and gravel concentration in parts per million by weight, respectively; ω = terminal fall velocity of sediment particles; d = median particle diameter; ν = kinematic viscosity of water; U_* = shear velocity; VS = unit stream power; and VS/w = dimensionless unit stream power. The dimensionless critical average flow velocity at incipient motion in Eqs (7-1) and (7-2) can be obtained from Yang's (1973) incipient motion criteria, that is,

$$\frac{V_{cr}}{\omega} = \frac{2.5}{\log\left(\frac{U_* d}{\nu}\right) - 0.06} + 0.66 \quad for \ 1.2 < \frac{U_* d}{\nu} < 70 \quad (7\text{-}3)$$

$$\frac{V_{cr}}{\omega} = 2.05 \quad for \ 70 \le \frac{U_* d}{\nu} \quad (7\text{-}4)$$

The basic forms of Eqs (7-1) and (7-2) are identical except for the numerical values of the coeffiecients, which reflect the difference in particle size between sand and gravel.

7.3.3 Application of Yang's Sediment Transport Equations

Yang's sediment transport equations were applied to three locations within Fall River: Read's Bridge to Fletcher's Bridge, Fletcher's Bridge to Spring Creek confluence, and Spring Creek confluence to Island Road Bridge. These readings

are represented by data collected by DWR at cross sections 3 and 7 and 15 and 21, respectively. They are also referred to as reaches 1, 2, and 3.

The HEC-RAS hydraulic model (see Chapter 5) was used to develop the hydraulic parameters necessary for each reach for a range of flows spanning from the spring fed baseflow up to the 100-year flood peak. For the Read's Bridge to Fletcher's Bridge reach, the hydraulics for cross sections 3 and 7 were averaged. Cross Section 15's hydraulics represented the reach from Fletcher's Bridge to Spring Creek, and cross sections 21 and 23 were averaged to represent the reach from Spring Creek to Island Road Bridge. Except for Cross Section 23, DWR collected sediment transport data at all of these cross sections. Cross Section 23 was included to provide a more representative set of hydraulic parameters for the lower reach. The energy slope at Cross Section 21 decreased by a factor of two between the baseflow and the 100-year discharge. On the other hand, at Cross Section 23, the energy slope increased by about 50 percent over the same range. By combining the two sections, the resulting hydraulics are a better depiction of the typical conditions between Spring Creek and Island Road Bridge. Table C-7 provides the hydraulic variables used in the three reaches.

Bed material size distributions are required for application of Yang's equations. Each size of sediment has a different transport rate. To account for the different transport rates for the various sediment sizes, the transport rate is calculated for each size as if the entire bed is made of that size. Then this value is multiplied by the actual fraction of the material in the bed. The computations are represented by the equation

$$Q_s = \sum_{i=1}^{n} f_i \bullet Q_{si} \qquad (7\text{-}5)$$

where Q_s is the total sediment transport for all sizes, Q_i is the sediment transport for *i*th size interval, and f_i is the fraction of sediment in the *i*th size interval.

Two separate size distributions were used to represent the bed material in the Fall River; these are presented in tables C-8a and C-8b. The coarser distribution in Table C-8a was used for Reach 1 upstream of Fletcher's Bridge, and the finer distribution in Table C-8b was used to represent reaches 2 and 3, between Fletcher's Bridge and Island Road Bridge. The distribution used in the lower reaches was sampled by Tetra Tech at Cross Section Tt-10. D_{50} (median diameter) of the four samples collected by Tetra Tech away from the channel banks was 0.33 mm. The 51 samples collected by NSR (1997) averaged 34.7 percent coarser than 0.5 mm. These values are in very close agreement. Based on qualitative field observations, the bed material upstream of Fletcher's Bridge was obviously coarser, and some areas contained pavement of small gravels. The distribution upstream of Fletcher's Bridge was adjusted, and the bed material sizes sampled by NSR in this area were used. Twelve bed material samples were collected in this

area, two of which were eliminated because they contained primarily organic material. Of the ten samples remaining, an average of 58 percent of the sediment was coarser than 0.5 mm. The D_{50} for the modified distribution is 0.63 mm.

Tables C-9a through C-9c present the computed sediment transport rates for bed material for each of the three reaches. Regression equations were derived for the resulting data. Because several of the reaches exhibited breaks in the slope of the regression equations, two equations were fit for Reach 2 and Reach 3. The equation plots are shown on Figure 7-3, and the equations are listed below:

Read's Bridge to Fletcher's Bridge

$Q_s = 7.1 \times 10^{-6} Q^{2.26}$ (7-6)
($R^2 = 0.999$)

Fletcher's Bridge to Spring Creek

$Q_s = .0036 Q^{1.11}$ for $Q \leq 1{,}000$ cfs (7-7)
($R^2 = 0.971$)

$Q_s = 7.6 \times 10^{-8} Q^{2.68}$ for $Q > 1{,}000$ cfs (7-8)
($R^2 = 0.995$)

Spring Creek to Island Road Bridge

$Q_s = 0.00019 Q^{1.61}$ $Q \leq 3{,}000$ cfs (7-9)
($R^2 = 0.998$)

$Qs = 3.64 Q^{.38}$ $Q > 3{,}000$ cfs (7-10)
($R^2 = 1.00$)

In the above equation, Q_S is the bed material transport rate in tons/day, and Q is the water discharge in cubic feet per second.

To determine the average annual bed material transport in the three Upper Fall River reaches, the daily flows developed in Chapter 4 and the transport equations just presented were used to compute bed material transport rates. These daily values were summed over the 67 years of flow values and the results are listed below:

Read's Bridge to Fletcher's Bridge
67 Year Total Bed Material Transport = 214,000 tons
Average Annual Bed Material Transport = 3,200 tons/year

Fletcher's Bridge to Spring Creek
67 Year Total Bed Material Transport = 82,000 tons
Average Annual Bed Material Transport = 1,200 tons/year

Spring Creek to Island Road Bridge
67 Year Total Bed Material Transport = 168,000 tons
Average Annual Bed Material Transport = 2,500 tons/year

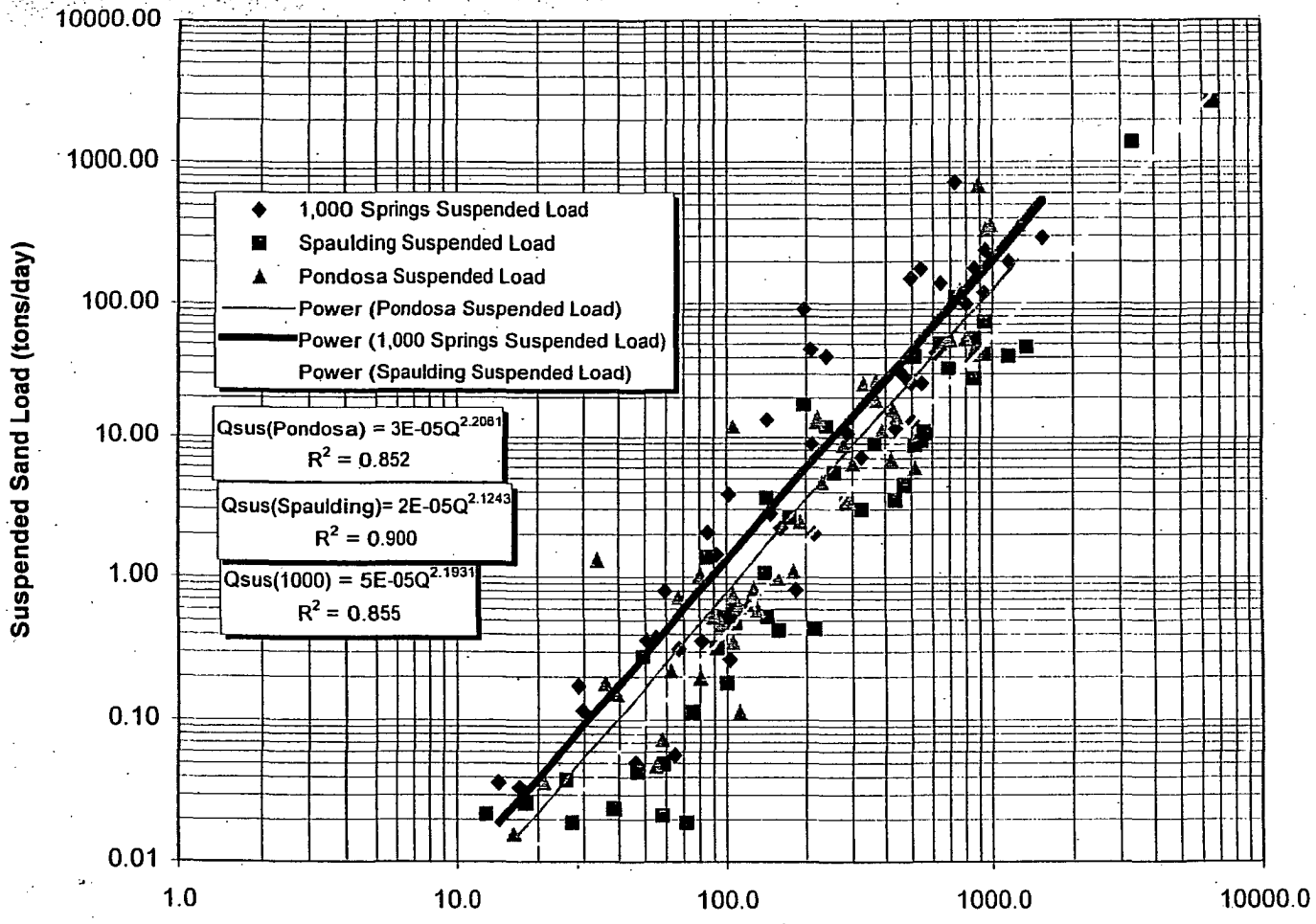


Figure 7-2 Bear Creek Suspended Sand Load Transport Regression Analysis

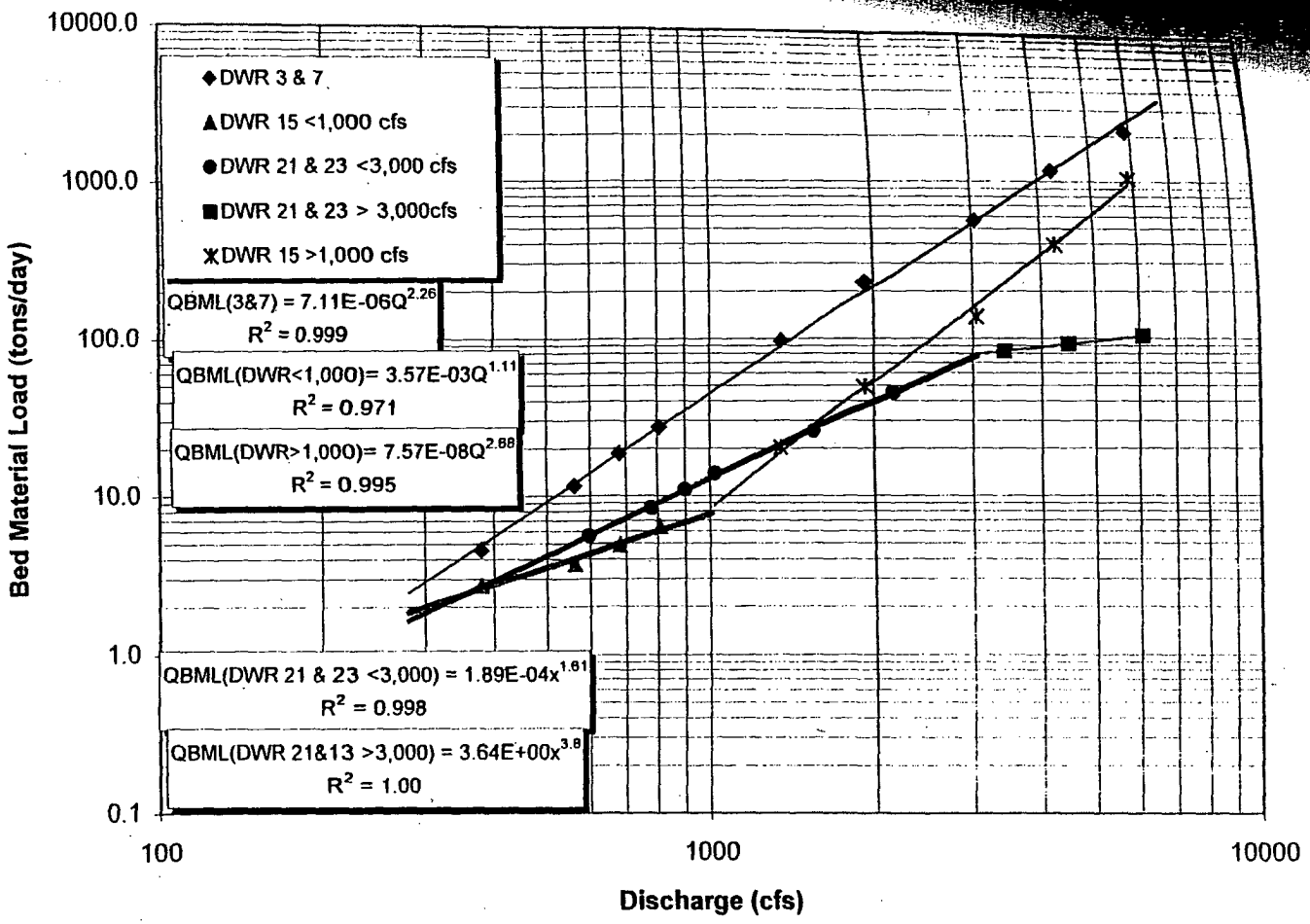


Figure 7-3 Upper Fall River, Bed Material Load (Yang's Equation)

Yearly summaries of sediment yield are provided in Table C-10.

SEDIMENT BALANCE RESULTS

The sediment balance was based on the major sediment inputs or sources to Fall River and its ability to transport sediment. The primary sediment of concern was sand. The sediment balance provides several important pieces of information useful in developing and evaluating potential solutions to the sedimentation problems in the Fall River. The sediment balance allowed the relative contribution of different sediment sources to be evaluated, which in turn helped determine the sources that should be prioritized for control. It allowed for evaluating current sedimentation conditions and evaluating whether the river will continue to experience increased sedimentation or whether trends will reverse and sediment will be flushed from the system.

Also of importance was the time frame required for flushing sediments, if the Fall River actually possesses this capability. The sediment balance addressed this issue. The sediment balance also provided a tool to assess the influence of various solution alternatives on the ability and time frame of Fall River to remove deposited sediments.

Sediment values from various sources were presented in Chapter 6 and the preceding portion of Chapter 7. In this section source volumes were summed and compared with the Fall River's sediment transport capacity to determine the future sedimentation trends in the river. Prior to this analysis, the last component of the sediment balance needed to be determined is the volume of sediment deposited in Fall River.

7.4.1 Recent Sediment Deposits in the Upper Fall River

Depth of sediment deposit data were provided by DWR (1998) for the twelve cross sections also used in the hydraulic model (see Chapter 5). Sediment core samples were taken at ten- to twenty-foot stations across each cross section. Core samples for looser sediments were obtained by advancing the coring device by hand pressure. When more resistive sediments were encountered, the sampling cores were driven through the sediment until the point of refusal was reached. Resistance to sampling was used as layer identification.

Sediments forming the bed of the Fall River are composed of three distinct layers, namely recent, older deposits, and the historic channel bottom. Recent sediment deposits consist of loosely compacted, fine to coarse sand and silt. Older deposits consist of compacted fine to medium sands, silt and some clay. Samples from the loosely consolidated layer were taken using hand strength only and are considered to be the most recent layer of sediment. Older sediments were sampled by hammering the coring device through the more compacted layer until reaching the point of refusal. The historic channel bottom was considered to be at the point of refusal.

Sediment cross-sectional data were imported to AutoCAD. Each imported cross section contained the current channel geometry, water surface elevations, and elevations of the recent sediment and older sediment layers. Figure 7-4 shows an example of a typical cross section and the various sediment layers. A complete set of the cross sections are supplied in Appendix C, figures C-1 through C-12.

Cross-sectional areas for each layer were calculated. The distributed reach length, which depended on cross section location, then was multiplied by the cross-sectional area to determine an individual reach sediment volume. Finally, individual sediment volumes were summed to calculate total sediment volumes for the study reach. The results of the sediment volume determination are presented in Table 7-3.

Recent sediment deposition between the Navigation Barrier and Spring Creek is approximately 213,000 cubic yards of fine to coarse sand and silt. Thirty-two thousand cubic yards of this volume were estimated to be deposited between the Navigation Barrier and Fletcher's Bridge. The remaining 181,000 cubic yards of deposition occurs between Fletcher's Bridge and Spring Creek. From Spring Creek to Island Road Bridge the estimated value of recent sediment deposits is 206,000 cubic yards. Cubic yard values were converted to weight in tons by an assumed porosity of 0.40 and a specific gravity of 2.65 for the sediments.

7.4.2 Significant Sediment Source Contributions

The annual loads of sediment from identified significant sources are listed below. These values are for bed material sediments, sand and larger, and do not include wash load containing silt and clay.

Bear Creek Bed Material Load Supply

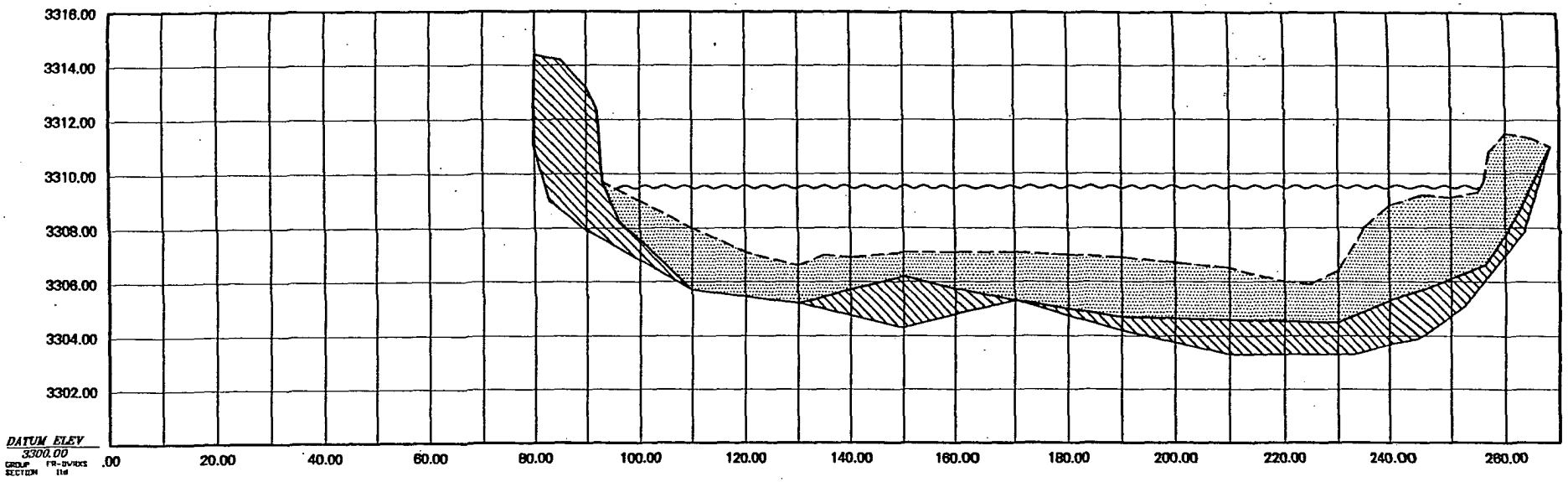
Supply, Bear Creek Above Pondosa: 2,700 tons/year
Storage, Bear Creek between Pondosa and Spaulding: -1,400 tons/year
Resulting Supply, Bear Creek at Spaulding: 1,300 tons/year
Additional Supply from Bear Creek Meadow below Spaulding: 1,200 tons/year
Total Bear Creek to the Fall River: 2,500 tons/year

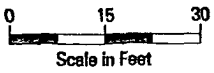
Fall River Bed Material Load Supply

Bear Creek Supply to the Fall River: 2,500 tons/year
Bank Erosion- Thousand Springs to Fletcher's Bridge: 0 tons/year
Bank Erosion- Fletcher's Bridge to Spring Creek: 0 tons/year
Bank Erosion- Spring Creek to Island Road: 400 tons/year
Total Bed Material Load Supply to Fall River: 2,900 tons/year

The annual bed material load at Spaulding Bridge was based on the calculated annual load at Thousand Springs Ranch gaging station minus the average annual contribution from Bear Creek Meadow. This procedure was used since the bed load measurements at Spaulding Bridge were very low. Therefore, it was

Fall River: Cross Section 11





Source: Tetra Tech 1998

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Legend

- Water Surface
- Recent Sediment
- Older Sediment

Typical DWR Sediment Sampling Cross Section

Upper Fall River Watershed, California

Tetra Tech, Inc.

Figure 7.4

Table 7-3
Upper Fall River, Recent Total Sediment Volume

Cross Section	Downstream Distance (ft)	Reach Length Distribution Distance (ft)	Total Cross Section Sediment Area (ft^2)	Recent Cross Section Sediment Area (ft^2)	Total Sediment Volume (ft^3)	Recent Sediment Volume (ft^3)	Older Sediment Volume (ft^3)
1	1408	1408	N/A	N/A	N/A	N/A	N/A
3	2539	2678	404	201	1082781	537642	545139
5	2942	2741	178	27	488905	72897	416008
7	1735	2339	590	101	1379247	237124	1142123
9	2866	2301	472	189	1084916	433874	651042
11	4450	3658	547	388	2000194	1420036	580159
15	6889	5670	584	273	3310988	1550041	1760947
18	1735	4312	428	260	1845536	1121982	723554
19	2741	2238	296	165	662448	369270	293178
21	6109	4425	585	313	2587740	1383255	1204485
22	4827	5468	484	196	2645418	1069541	1575878
23	5501	5164	752	346	3881262	1784678	2096584
24	654	3405	729	389	2481881	1325712	1156168
			Navigation Barrier to Island Bridge	**Total Volume (cu.ft)**	**23451317**	**11306053**	**12145264**
				Total Volume (cu.yd)	**868567**	**418743**	**449825**
				Total Weight (tons)	**1260274**	**607587**	**652687**
			Navigation Barrier to Spring Creek	**Total Volume (cu.ft)**	**11855016**	**5742867**	**6112149**
				Total Volume (cu.yd)	**439075**	**212699**	**226376**
				Total Weight (tons)	**637089**	**308622**	**328467**
			Navigation Barrier to Fletcher's Bridge	**Total Volume (cu.ft)**	**2950934**	**847663**	**2103270**
				Total Volume (cu.yd)	**109294**	**31395**	**77899**
				Total Weight (tons)	**158583**	**45553**	**113030**

7.6 CONCLUSIONS

From the sediment balance, it is possible to develop opinions concerning two issues critical in assessing and developing a plan of action addressing sedimentation problems in Upper Fall River. These issues are the relative contribution of various sources and the ability of Upper Fall River to remove recent sediment deposits.

7.6.1 Relative Contribution of Various Sources

The two largest current sources of sediment to the Upper Fall River are the delivery of sediment from the watershed upstream of Spaulding Bridge and the continued erosion of the incised channel through Bear Creek Meadow below Spaulding Bridge. The Bear Creek watershed was estimated to contribute 1,300 tons/year of bed material load (sand and larger sediments), and Bear Creek Meadow was estimated to contribute 1,200 tons/year of bed material load. The final identifiable current source of bed material supply is bank erosion, which was estimated to provide approximately 400 tons/year of sand and larger sized sediments to Upper Fall River. Bank erosion is primarily a sediment source for the area between Spring Creek and Island Road. The relative percentage of sand and larger sediments attributable to these sources are as follows:

- Watershed above Spaulding Bridge – 45 percent;
- Meadow below Spaulding Bridge – 41 percent; and
- Bank erosion below Spring Creek – 14 percent.

These are estimates of sediment supply for current conditions. At different periods throughout this century, these contributors have varied as land use and natural processes have changed. For example, after major fires in the watershed, such as the Pondosa burn, the contribution from Bear Creek above Spaulding Bridge would be higher. Based on volume calculations of the material eroded from Bear Creek Meadow below Spaulding Bridge, its sediment contribution was higher in the past. Based on the 37-year period since incision of Bear Creek Meadow was initiated, the average contribution of sand and larger sediments was estimated to be 3,800 tons/year. This is in contrast to the 1,200 tons/year for the past three years. finally, analysis of the aerial photographs indicate larger changes from 1936 to 1964 than for the more recent period of 1964 to 1993.

7.6.2 Ability of Upper Fall River to Remove Recently Deposited Sediment

It is clear from the sediment balance that the Upper Fall River's ability to naturally scour recent sediment deposits is limited. The area scouring the quickest is the upper reach from the Navigation Barrier to Fletcher's Bridge. This reach requires 13 to 61 years to remove deposits, depending on assumed sediment supply conditions. In contrast, the estimate for the middle reach from Fletcher's Bridge to Spring Creek is a minimum of over 200 years and, under current conditions, would continue to fill in with sediment indefinitely. The minimum time frame for the lower reach, Spring Creek to Island Road Bridge, is also over 200 years. Even if the sediment transport capacity of the Fall River were increased by a factor

decided to back calculate the bed material load passing Spaulding Bridge based on the procedure just described. If the regression equations developed from the actual measurements are used, then the estimated annual volume of sediment passing Spaulding Bridge is 590 tons/year. This load is approximately half the value calculated by subtracting the Bear Creek Meadow contribution from the Thousand Springs gaging site measurements.

Reviewing the values just listed, most of the bed material-sized sediments entering the Fall River is delivered by Bear Creek. The total sediment supplied to the Fall River, on an average annual basis, is estimated to be 2,900 tons. Of this amount, 2,500 tons (86 percent) is delivered by Bear Creek. The remaining 400 tons (14 percent) is derived from bank erosion between Spring Creek and Island Road Bridge. The 2,500 tons delivered from Bear Creek is divided nearly equally between sediments delivered from upstream of Spaulding Bridge and sediments derived from erosion of Bear Creek Meadow between Spaulding Bridge and the confluence with the Fall River. Over 50 percent of the bed material load passing Pondosa is calculated to be stored (deposited) between Pondosa and Spaulding Corner. Most of the stored sediment is believed to be in several open meadow and wetland areas, such as the Long Ranch.

7.4.3 Time Required for Natural Removal of Sediments

Based on the different sediment sources (sediment supply) and the ability of different segments of the Fall River to transport bed material load, the time frame for the river to naturally remove recently deposited bed material can be estimated. The estimates of the number of years required for flows to remove sediment from the Upper Fall River are calculated for three different reaches. Starting from upstream to downstream, Reach 1 is from the Navigation Barrier to Fletcher's Bridge, Reach 2 is from Fletcher's Bridge to Spring Creek, and Reach 3 is from Spring Creek to Island Road Bridge. In terms of river miles, Reach 1 is from RM 24.0 downstream to RM 22.8, Reach 2 extends from RM 22.8 to RM 19.3, and Reach 3 extends from RM 19.3 downstream to RM 16.2. The sediment removal time frame was determined for five different scenarios and is explained below along with the calculation of the removal time frame for the recently deposited sediments.

Scenario One: Current Estimates of Sediment Supply

Under the current estimate of sediment supply, 1,300 tons/year of bed material are delivered from the Bear Creek Watershed above Spaulding Bridge. An additional 1,200 tons/year are delivered to the Fall River from erosion within the Bear Creek Meadow below Spaulding Bridge. The total average annual supply of bed material load to Reach 1 is the combination of these two sources, or 2,500 tons/year. The sediment contribution from bank erosion in this reach is zero and does not increase the supply. The average annual sediment transport capacity in Reach 1 is 3,200 tons/year. Thus there is an excess transport capacity of 700 tons/year in Reach 1. The 700 tons/year excess transport capacity is satisfied by scouring 700 tons/year of recently deposited sediments. Assuming a porosity of

0.40 for the recent sediments, the 700 tons/year represents 524 cubic yards/year. Based on the volume estimates of recently deposited sediments obtained from the DWR cross sections, there are 32,000 cubic yards of sediment deposited in Reach 1. At an average removal rate of 524 cubic yards/year, 61 years would be required to scour the 32,000 cubic yards of recently deposited sediments.

For the first 61 years, the bed material load supply from Reach 1 to Reach 2 is 3,200 tons/year. The contribution of bank erosion to the bed material load supply is negligible. The bed material transport capacity is 1,200 tons/year. This represents an excess supply of bed material load of 2,000 tons/year or 1,500 cubic yards/year. Consequently, over the first 61 years there is an additional bed material deposition of 91,500 cubic yards. Added to the existing estimate of 181,000 cubic yards of recently deposited sediment results in 273,000 cubic yards of recently deposited sediment in Reach 2. After the recently deposited sediments are scoured from Reach 1, the upstream bed material load supply is reduced to 2,500 tons/year. From year 62 and beyond, Reach 1 delivers the bed material supply only from Bear Creek. The average annual bed material transport of Reach 2 capacity was estimated at 1,200 tons/year. The balance between supply and transport capacity indicates a 1,300 tons/year excess supply. This excess is deposited in Reach 2 at the rate of 973 cubic yards/year. Based on this information, under current sediment supply, Reach 2 continues to experience sediment deposition indefinitely.

For Reach 3, the upstream bed material load supply remains at 1,200 tons/year. Additionally, there is a contribution of 400 tons per year of bank erosion. The total supply of sand and larger sediment is 1,600 tons/year. The bed material load transport capacity is 2,500 tons/year. This results in a predicted deficit of 900 tons/year. At this rate of sediment removal, 305 years will be required to scour the existing estimate of 206,000 cubic yards of recently deposited sediments in Reach 3.

Scenario Two: Current Upstream Sediment Supply from Bear Creek and No Bank Erosion in the Fall River

Under this scenario, sediment scour and deposition conditions remain the same in Reach 2 as for Scenario One since these reaches currently have negligible contributions from bank erosion. Therefore, recently deposited sediments from Reach 1 are scoured clean in 61 years. During this period, sediments in Reach 2 are deposited at the average rate of 1,500 cubic yards/year. After 61 years, the deposition rate is reduced to 973 cubic yards/year. The upstream supply of bed material load to Reach 3 remains constant at 1,200 tons/year. However, there is assumed to be no additional contribution from bank erosion. The 2,500 tons/year transport capacity results in Reach 3 in a sediment deficit of 1,300 tons/year, or 974 cubic yards/year. Under these conditions, 211 years will be required to scour the 206,000 cubic yards of recently deposited sediments in Reach 3.

Scenario Three: Current Sediment Supply from above Spaulding Bridge, No Contributions from Bear Creek Meadow or Fall River Erosion

With the elimination of the 1,200 tons/year of erosion in Bear Creek Meadow below Spaulding Bridge, the total sediment supply to Reach 1 of Fall River is 1,300 tons/year. With a transport capacity of 3,200 tons/year, 1,900 tons/year, or 1423 cubic yards/year, of sediment is removed from the reach. At this rate of sediment removal, 22 years will elapse before the 32,000 cubic yards of recently deposited sediment is removed from Reach 1.

For 22 years the supply to Reach 2 with remain at 3,200 tons/year. After 22 years, the supply to Reach 2 will drop to 1,300 tons/year. For the first 22 years, the supply of bed material load will exceed the transport capacity in Reach 2 by 2,000 tons/year, or 1,500 cubic yards/year. After 22 years, the supply and capacity will be nearly equal, 1,300 tons/year compared to 1,200 tons/year, and the values of sediment deposited in Reach 2 will remain constant. Thus, under Scenario Three, Reach 2 still does not experience natural removal of the sediment deposits.

The Reach 3 response under Scenario Three is the same as for Scenario Two. The supply remains at 1,200 tons/year, there is no contribution from bank erosion, and, considering the sediment transport capacity, 211 years are required to scour to 206,000 cubic yards of recently deposited sediments.

Scenario Four: No Bank Erosion from Bear Creek Meadow below Spaulding Bridge or in Fall River, and 50 Percent of the Bear Creek Sediment Supply above Spaulding Bridge Trapped in Bear Creek Meadow

This scenario represents a reduction of 50 percent from the sediment supplied to Reach 1 under Scenario Three. The average annual supply to Reach 1 for Scenario Four is 650 tons/year. This results in 2,550 tons/year, or 1,910 cubic yards/year, being scoured from Reach 1. A period of 17 years is required for the flow to remove the recent sediment deposits from Reach 1.

Bed material supply for Reach 2 is 3,200 tons/year for the first 17 years and 650 tons/year thereafter. For the first 17 years, Reach 2 experiences deposition at the rate of 1,500 cubic yards/year. At the end of the period, the value of recent sediment deposits increases to 207,000 cubic yards. However, after Reach 1 scours completely, the reduced supply of 650 tons/year to Reach 2 is less than the transport capacity of 1,200 tons/year. From this point on, 412 cubic yards/year of sediment is scoured from Reach 2. At this rate of removal, an additional 502 years is needed to scour the 207,000 cubic yards of recent sediment deposits from Reach 2. Adding the initial 17 years brings the total time frame to scour Reach 2 to 519 years. The Reach 3 sediment supply from Reach 2 remains constant at 1,200 tons/year for over 500 years. The Reach 3 response is the same as for scenarios two and three. A period of 211 years will be required to remove the 206,000 tons of recently deposited sediments.

Scenario Five: Sediment Supply from All Sources is Completely Eliminated

This is the most optimistic sediment supply scenario. A total elimination of all sediment supplied to the river would be impossible. For Scenario One, Reach 1 scours sediment at the transport capacity of 3,200 tons/year, 2,400 cubic yards/year. The time frame required to remove all sediment deposits from Reach 1 is 13 years.

For the first 13 years of Scenario Five, the bed material loading is 3,200 tons/year. After this period, the recent sediment deposit volume has increased by 19,000 cubic yards to 200,000 cubic yards. Starting in the fourteenth year, 1,200 tons/year, or 900 cubic yards/year, are removed from Reach 2. At this rate, an additional 222 years passes before Reach 2 is cleaned of recently deposited sediments. The total elapsed time for flows to remove the sediments from Reach 2 is 235 years.

For Reach 3, the sediment loading is the same as for scenarios two, three, and four. It thus requires 211 years to scour the recently deposited sediment volume of 206,000 cubic yards.

7.4.4 Summary of Sediment Balance Results

The periods required to scour the recent sediment deposits from the three reaches of the Fall River are summarized in Table 7-4. The five sediment loading scenarios represent decreasing sediment supply conditions, with each progressing scenario having one component or a portion of one component of the supply eliminated. The time frame for Reach 1, the navigation barrier to Fletcher's Bridge, ranges from a maximum of 61 years to a minimum of 13 years. For Reach 2, Fletcher's Bridge to Spring Creek, the minimum time frame to scour the recent sediment deposits is 235 years. In the three highest sediment loading scenarios, Reach 2 never scours. The time frame for Reach 3, Spring Creek to Island Road Bridge, varies from 211 years to a maximum of 305 years.

7.5 LIMITATIONS OF ANALYSIS

The analysis of the sediment balance for Upper Fall River was based on the sediment continuity principle. Relationships for the various components of the sediment balance were developed based on available data and analytical techniques. Over the period of each of the five sediment loading scenarios, sediment supply and transport conditions were assumed to remain constant. Additionally, the analysis was based on average annual conditions. More sophisticated analysis procedures, such as sediment routing models, which simulate the scour and deposition of bed material and link the changes in individual cross sections to a hydraulic model, are capable of updating sediment transport conditions as the channel changes. Sediment routing models also simulate actual hydrographs and can be executed on time steps to reflect daily changes in flow conditions. Models that incorporate sediment routing by size fractions adjust the size of the load material at the surface in response to scour or deposition of sediments.

Table 7-1
Summary of Sediment Balance Calculations

Scenario	Reach	Years to Remove Recent Sediment	Comments
1	1	61	
1	2	---	Reach continues to deposit
1	3	305	
2	1	61	Same as Scenario 1
2	2	---	Reach continues to deposit
2	3	211	
3	1	22	
3	2	---	Reach accumulates 33,000 cu. yd. in first 22 years, then remains unchanged.
3	3	211	Same As Scenario 2
4	1	17	
4	2	502	
4	3	211	Same As Scenario 2
5	1	13	
5	2	235	
5	3	211	Same As Scenario 2

Reach 1 – Navigation Barrier to Fletcher's Bridge
Reach 2 – Fletcher's Bridge to Spring Creek
Reach 3 - Spring Creek to Island Road Bridge
Scenario 1 – Current sediment loading condition
Scenario 2 – Current sediment loading minus Fall River Bank Erosion
Scenario 3 – Current sediment loading minus Fall River Bank Erosion and Bear Creek Meadow Erosion
Scenario 4 – Scenario 3 reduced by 50%
Scenario 5 – No sediment supplied to Fall River

In this manner, the routing models can reflect the increase or decrease in bed material size as the system responds to the differential transport capacity of the different sediment sizes that make up the channel bed.

The primary limitations of the sediment balance procedure applied to Upper Fall River, as compared to a sediment routing model, are as follows:

- The sediment balance procedure does not have the resolution to determine scour and deposition at individual cross sections (spatial resolution).
- The sediment balance procedure applied on an average annual basis is not capable of identifying changes during the passage of a single flood event (temporal resolution).
- The sediment balance procedure assumes constant sediment transport capacity throughout the simulation period. It is not sensitive to changes in hydraulic conditions or bed material size distributions in the channel bed.

In contrast to these limitations, a very strong point for the sediment balance performed for the Fall River was the availability of actual measured sediment transport data both within Upper Fall River and in Bear Creek, its primary surface water tributary. Every river system has unique conditions that influence sediment transport conditions. Because of this, to have confidence in a sediment transport analysis, it is essential to have sediment transport data collected within the river system. In the case of Upper Fall River, the data collected by DWR (1998) and TSR (1998) provided an excellent data base to insure that sediment transport rates used in the analysis accurately reflected actual transport rates in the system.

In summary, the sediment balance provides an excellent tool to assess long-term trends related to sediment scour and deposition in the Upper Fall River. It provided a quantitative indication of the period required for changes to occur and to predict how the alteration of sediment supply conditions affect the ability and time frame for deposition and scour to occur. The application of various sediment supply scenarios also serves as a sensitivity analysis to ascertain how an underestimation or overestimation of sediment supply would alter the ability and time frame required for the channel to scour recently deposited sediments. However, the time estimates for sediment removal should be considered "ballpark" values. This is because the sediment balance was performed on an average annual basis and because the procedure does not consider changes in sediment transport capacity as the cross sections and bed material size distribution changes in response to scour or deposition. Finally, the temporal and special resolution of the contributing analysis are such that changes to single flood events or at specific locations in the river cannot be determined.

of five, it would still require several decades for the recent sediment deposits to be flushed.

In contrast, it is also apparent that any increases in sediment supply to Upper Fall River would switch the current sediment balance so that the system would again be experiencing deposition throughout its length. It is also reasonable to infer that the sediment problem in the Fall River did not develop overnight from a single event. This is based on the relatively low rate at which the system can transport sediments. It appears that it would take many decades to deliver the sediments that are currently deposited in the Fall River to their present locations.

CHAPTER 10
CONCLUSIONS AND RECOMMENDATIONS

An extensive effort was conducted to study sedimentation problems in Upper Fall River from the Navigation Barrier to Island Road Bridge. The study involved analyzing data and information supplied by numerous agencies and organizations, including the California DWR, California DFG, California Department of Forestry, California RWQCB, NRCS, USDA Wildlife Service, NSR, WMBA, Thousand Springs Ranch, Fall River Wild Trout Foundation, and the FRRCD. Tetra Tech also conducted site investigations, including establishing and surveying additional Fall River cross sections, inventorying bank erosion sites in Upper Fall River, conducting a reconnaissance of major stream channels in the Bear Creek and Dry Creek watersheds to evaluate their condition, and analyzing historic aerial photographs. A technical advisory committee provided input throughout the project, and three public meetings were held to solicit public involvement. These efforts have been detailed and the results presented in the previous nine chapters. This chapter provides a concise statement of the major conclusions and recommendations developed through the 205j process.

10.1 CONCLUSIONS

The central issue addressed by the 205j study was the deposition of sediment in Upper Fall River. Unfortunately, no historic surveys of the river were available to make cross section comparisons to directly assess the amount of sedimentation that has occurred in the river. Personal observations of those familiar with Fall River for several decades qualitatively indicate sedimentation has occurred and has resulted in burial of logs, hardpans and clays previously exposed, lava cobbles, and aquatic vegetation. DWR (1998) performed cross section surveys and collected core samples. Typically, at the core sampling locations, there was a loose unconsolidated layer of sediments in which the sampler could be advanced by hand. Below this layer, there was a layer of sediment that required striking blows to advance the sampler. Finally, the sampler would reach a layer in which it could no longer be advanced. It was assumed that the loose layer represented the recent sediment deposits. Using the DWR (1998) information, Tetra Tech estimated

213,000 cubic yards of recent sediment deposits between the Navigation Barrier and the Spring Creek confluence. Between the Spring Creek confluence and the Island Road Bridge, an additional 206,000 cubic yards of recent sediment deposits were identified.

Sediment deposition has been an issue because of potential impacts on aquatic vegetation in Fall River and the wild trout fishery. These two parts of the system are intertwined since the wild trout fishery relies heavily on the submerged aquatic vegetation for habitat in the form of cover and production of macroinvertebrates. No historic data concerning the distribution or density of submerged aquatic plant beds were available. Fish population counts dating back to 1975 (Rodes and Weidlein 1984) were available, and more recent data also have been collected (Dean 1997). However, it was difficult to draw any conclusions from this information because the earlier data set was collected by different procedures than the more recent data set. Estimated fish populations showed large decreases and more recently large increases. The Dean study (1997) could not draw any direct conclusions concerning impacts on the wild trout fishery from this information. Thus, the assumption that there have been negative impacts on the aquatic vegetation and wild trout fishery rely on anecdotal accounts of historic conditions and the knowledge that deposition of large quantities of sediment typically have negative impacts on these resources.

The lack of baseline data in terms of sediment deposition, aquatic vegetation, and fisheries points out the need for monitoring as an integral part of any program to address sedimentation problems in Fall River. It also creates the need for an adaptive management approach to development and implementation of solution measures. An adaptive management approach allows for feedback from a monitoring program and adjustment of the project approach as more is learned about the system and the effectiveness of initial measures implemented is evaluated. Fortunately, baseline conditions have been established through the 205j study and data recently collected by agencies, groups and individuals.

Sediment sources in the Bear Creek and Dry Creek watersheds were identified through an erosion inventory conducted by the NRCS (1998a, 1998b) and analysis of data provided by Thousand Springs Ranch (TSR 1998) and DWR (DWR 1998). Estimates of the sediments in the sand-sized and larger range (greater than 0.062 mm) for various sources were made. Sand-sized sediments were specifically addressed because they are the primary cause of sedimentation in Upper Fall River. In summary, the watershed above Spaulding Bridge was determined to supply 1,300 tons of sand per year. Of this volume, it is estimated that 85 percent originates from stream bank erosion, nine percent from hill slopes, and six percent from roads. Sediment delivery from erosion of the Bear Creek channel in the 2.2-mile meadow between Spaulding Bridge and the Fall River confluence was calculated to be 1,200 tons per year. An additional 400 tons per year of sediment were estimated to be derived from bank erosion within the Upper Fall River study area. The relative contributions of sediment were determined to be 45 percent

from the watershed above Spaulding Bridge, 41 percent from the Bear Creek Meadow below Spaulding Bridge, and 14 percent from bank erosion in the Upper Fall River (primarily below Spring Creek).

Sediment transport relationships were developed for the Upper Fall River based on hydraulics, bed material sediment sizes, application of Yang's sediment transport equations and verification with the DWR (1998) sediment transport results. These relationships were utilized to determine the average annual capacity of the Upper Fall River to transport sand-sized sediments. Sediment transport capacities were determined for three reaches. Reach 1 extended from the Navigation Barrier to Fletcher's Bridge and has an estimated sand transport capacity of 3,200 tons per year. Reach 2 extended from Fletcher's Bridge to Spring Creek and has an estimated sand transport capacity of 1,200 tons per year. Reach 3 extends from Spring Creek to Island Road Bridge and has an estimated sand transport capacity of 2,500 tons per year. These transport capacities are very low and are approximately equal to or less than the estimated supply of sand-sized sediments.

Based on a comparison of current sediment supply and sediment transport capacity, it was concluded that the Upper Fall River has very limited capacity to remove the recent sediment deposits. Under current conditions, it would take over 60 years for Reach 1 to be scoured clean; Reach 2 would continue to deposit indefinitely, and Reach 3 would require several centuries to scour. To illustrate the low sediment transport capacity of the Upper Fall River, a sediment balance scenario was performed, which assumed all sediment sources were eliminated. Under this condition, the time to scour the recent sediment deposits was 13, 235, and 211 years for Reaches 1, 2, and 3, respectively.

Based on the results of the sediment balance calculations, it was concluded that controlling the source of sediment would not, in itself, allow sediment deposits from the Fall River to be removed in a reasonable time period. Mechanical removal of sediments needs to be a part of the solution to the sedimentation problem in the Upper Fall River. On the other hand, mechanical removal of sediments does not provide the total solution to the problem. The long-term solution involves an integrated plan to remove sediment deposits and to control sediment sources from the watershed and bank erosion and monitoring to provide for a feedback loop that allows an adaptive management approach to be taken.

Another important conclusion arrived at is the importance of meadows, wetlands, and floodplains in controlling sediment delivery to the Fall River from the Bear Creek and Dry Creek watersheds. Both watersheds have alternating series of relatively steep confined channels and flat unconfined areas occupied by meadows, wetlands, and floodplains. These latter areas trap sediments from upstream sources. These sediment sinks have allowed the low energy Fall River to exist without accumulating large quantities of sediment. However, the sediment retention capabilities of many of these areas have been severely degraded due to

channel incision and deterioration of vegetative cover. If the loss of these areas continues, sediment transport delivery to the Upper Fall River could increase greatly. Therefore, it is not only important to restore the degraded areas but also to protect the areas that have not been affected.

10.2 RECOMMENDATIONS

A preliminary action plan was developed for addressing the sedimentation problems in the Upper Fall River. This is the recommended action to be taken. The components of the plan include the following:

- Controlling bank erosion by livestock exclusion fencing, muskrat control, and boat speed regulations enforcement in the Upper Fall River;
- Restoring and protecting high priority stream and meadow systems in the Bear Creek and Dry Creek watersheds;
- Implementing the Bear Creek (Dana) meadow restoration between Spaulding Bridge and the Fall River confluence; and
- Performing selective dredging at two sites between Fletcher's Bridge and Spring Creek by removing 10,000 to 20,000 cubic yards of sediment.

The cost of implementing these actions is estimated to be approximately $2,400,000.

In addition to the actual projects to be undertaken, a monitoring plan must be included in the overall approach to solving the sedimentation problems. The monitoring plan should include a stream gauge to determine discharges in Fall River, sediment transport measurements in the watershed and the Fall River, monitoring of channel changes through permanent cross sections in the main stem and major tributaries, and extensive monitoring of cross sections that extend downstream of Island Road Bridge to Glenburn. The plan also should include monitoring submerged aquatic vegetation and conducting continued studies of the interaction between aquatic vegetation and sediment in Fall River, monitoring the influence of livestock exclusion fencing and the interaction with the muskrat burrowing, and continuing fish counts in the Upper Fall River. It is assumed that the DFG would continue to perform the fish counts. The annual costs of the remaining monitoring efforts is estimated to be $35,000 per year. The monitoring program should address both assessing the effectiveness of the various components of the action plan and determining the health of the Fall River.

An organizational mechanism should be developed to guide the implementation of the action plan and to develop support for the action plan. The proposed efforts will require cooperation with private landowners, permits from agencies, technical assistance from agencies, support of groups and individuals concerned about the

health of the Fall River, as well as input from design professionals. To accomplish this synthesis of diverse parties, an organization, such as a CRMP group, should be formed. It should include participation from all the various stakeholders. Without an understanding of the Upper Fall River sediment problems and solutions, public support for the project will be difficult to develop; the CRMP group is one method to accomplish this. A CRMP will aid in focusing diverse opinions into a plan of action addressing problems and solutions, while providing a much needed communication link to public supporters. Overall project success will rely greatly on this type of resource tool and organization.

CHAPTER 11
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Appendix A

Tables & Figures for the Upper Fall River Hydrologic Analysis

ID	NAME	STATE	COUNTY	HYDROUNIT	SITECODE	LATITUDE	LONGITUDE	ELEV	DRAIN
11341400	SACRAMENTO R NR MT SHASTA CA	CA	SISKIYOU	18020005	SW	41:16:00	122:18:38		135
11341500	SACRAMENTO R A CASTELLA CA	CA	SHASTA	18020005	SW	41:08:18	122:18:48	1950	256
11353500	BEAR C NR DANA CA	CA	SHASTA	18020003	SW	41:09:25	121:34:09		84
11353600	DRY C NR DANA CA	CA	SHASTA	18020003	SW	41:08:21	121:38:24	0	6.46
11353700	FALL R NR DANA CA	CA	SHASTA	18020003	SW	41:06:20	121:33:00	3340	123
11361400	LK BRITTON NR BURNEY CA	CA	SHASTA	18020003	LK	41:01:20	121:40:32		4607
11362800	NELSON C PP NR BIG BEND CA	CA	SHASTA	18020003	SW	41:01:45	121:53:24	1950	0
11362880	NELSON C OVERFLOW WEIR BL PP DIV NR BIG BEND CA	CA	SHASTA	18020003	SW	41:02:32	121:52:34	2320	13.2
11362890	NELSON C RELEASE WEIR BL PP DIV NR BIG BEND CA	CA	SHASTA	18020003	SW	41:02:32	121:52:34	2320	13.02
11362900	NELSON C BL DIV TO NELSON C PP NR BIG BEND CA	CA	SHASTA	18020003	SW	41:02:32	121:52:34	2320	13.2
11362940	EF NELSON C OVERFLOW WEIR BL PP DIV NR BIG BEND	CA	SHASTA	18020003	SW	41:02:25	121:52:28	2540	8.18
11362945	EF NELSON C RELEASE WEIR BL PP DIV NR BIG BEND C	CA	SHASTA	18020003	SW	41:02:25	121:52:28	2540	8.18
11362950	EF NELSON C BL DIV TO NELSON C PP NR BIG BEND CA	CA	SHASTA	18020003	SW	41:02:25	121:52:28	2540	8.18
11363000	PIT R A BIG BEND CA	CA	SHASTA	18020003	SW	41:01:10	121:54:36		4710
11363500	KOSK C NR HENDERSON CA	CA	SHASTA	18020003	SW	41:03:30	121:55:30		54.8
11363920	IRON CANYON RES NR BIG BEND CA	CA	SHASTA	18020003	LK	41:02:32	121:58:55	2680	11.13
11363930	IRON CANYON C BL IRON CANYON DAM NR BIG BEND CA	CA	SHASTA	18020003	SW	41:02:22	121:59:03	2461.52	11.24
11367200	MCCLOUD R BL BIG SPRINGS NR MCCLOUD CA	CA	SISKIYOU	18020004	SW	41:13:40	122:02:45		322
11367300	ANGEL C NR MCCLOUD CA	CA	SISKIYOU	18020004	SW	41:11:41	122:03:25		17.1
11367500	MCCLOUD R NR MCCLOUD CA	CA	SISKIYOU	18020004	SW	41:11:18	122:03:52	2711.2	358
11367700	MCCLOUD R AB PANTHER C NR MCCLOUD CA	CA	SHASTA	18020004	SW	41:08:10	122:04:40		401
11367740	LK MCCLOUD NR MCCLOUD CA	CA	SHASTA	18020004	LK	41:08:06	122:04:26		403
11367760	MCCLOUD R BL MCCLOUD DAM NR MCCLOUD CA	CA	SHASTA	18020004	SW	41:07:44	122:04:08		404
11367800	MCCLOUD R A AH-DI-NA NR MCCLOUD CA	CA	SHASTA	18020004	SW	41:06:39	122:05:42		427
11517900	EF SCOTT R BL HOUSTON CREEK NR CALLAHAN CALIF	CA	SISKIYOU	18010208	SW	41:24:06	122:39:08		19.7
11517950	EF SCOTT R AB KANGAROO CREEK NR CALLAHAN CALIF	CA	SISKIYOU	18010208	SW	41:20:22	122:43:07		49.5
11518000	EF SCOTT R NR CALLAHAN CALIF	CA	SISKIYOU	18010208	SW	41:19:18	122:43:18		57.5
11518050	EF SCOTT R ALAHAN CA	CA	SISKIYOU	18010208	SW	41:18:14	122:46:32		110
11518200	SOUTH FORK SCOTT RIVER NR CALLAHAN CA	CA	SISKIYOU	18010208	SW	41:17:45	122:48:32	3270	41.5
11518300	SUGAR C NR CALLAHAN CALIF	CA	SISKIYOU	18010208	SW	41:19:42	122:50:24		12
11518310	CEDAR GULCH NR CALLAHAN CALIF	CA	SISKIYOU	18010208	SW	41:20:40	122:49:45		0.99
11523200	TRINITY R AB COFFEE C NR TRINITY CTR CA	CA	TRINITY	18010211	SW	41:06:41	122:42:16	2536.93	149
11523700	COFFEE C NR TRINITY CENTER CA	CA	TRINITY	18010211	SW	41:05:35	122:43:12	2750	107

Table A-2
Upper Fall River Synthetic Peak Discharge Adjustments

Date	Hat Creek Discharge Adjustment(1.82) (cfs)	Dana Discharge (cfs)	Synthesized Peak Flow Dana (cfs)	Applied Peak Flow Adjustment	Previous Discharge (cfs)
06/07/30	322		322	NO	
05/15/31	229		229	NO	
05/14/32	311		311	NO	
05/31/33	320		320	NO	
03/29/34	490		490	NO	
11/15/34	431		431	NO	
05/14/36	369		369	NO	
06/16/37	819		819	YES	804
12/11/37	6042		6042	YES	5501
10/29/38	284		284	NO	
01/02/40	704		704	YES	704
05/24/41	579		579	NO	
12/03/41	1412		1412	YES	1142
06/01/43	604		604	NO	
05/08/44	391		391	NO	
05/16/45	553		553	NO	
10/30/45	564		564	YES	676
06/08/47	411		411	NO	
06/05/48	713		713	NO	
05/13/49	375		375	NO	
06/01/50	408		408	NO	
11/21/50	473		473	NO	
06/09/52	641		641	NO	
01/09/53	602		602	NO	
05/20/54	564		564	NO	
06/09/55	404		404	NO	
12/23/55	1911		1911	YES	2763
05/18/57	783		783	YES	1126
05/24/58	677		677	NO	
01/12/59	553		Record Available		
02/08/60	568		Record Available		
06/15/61	389		Record Available		
06/01/62	351		Record Available		
10/12/62	4313		Record Available		
11/14/63	519		Record Available		
12/23/64	4004		Record Available		
11/18/65	440		Record Available		
06/20/67	703		Record Available		

Table A.2
Upper Fall River Synthetic Peak Discharge Adjustments (Continued)

Date	Hat Creek Discharge Adjustment(1.82) (cfs)	Dana Discharge (cfs)	Synthesized Peak Flow Dana (cfs)	Applied Peak Flow Adjustment	Previous Discharge (cfs)
02/23/68	406		406	NO	
05/26/69	706		706	NO	
01/23/70	1747		1747	YES	2268
06/26/71	735		735	NO	
05/31/72	450		450	NO	
05/25/73	642		642	NO	
11/11/73	2220		2220	YES	3056
6/6/75	684		684	NO	
10/26/75	417		417	NO	
6/6/77	277		277	NO	
12/15/77	724		724	YES	914
5/21/79	389		389	NO	
10/25/79	906		906	YES	872
5/18/81	391		391	NO	
11/16/81	2421		2421	YES	2818
6/10/83	830		830	NO	
11/10/83	723		723	YES	943
11/2/84	442		442	NO	
3/8/86	1278		1278	YES	1776
5/16/87	442		442	NO	
12/2/87	448		448	NO	
3/9/89	622		622	NO	
10/23/89	408		408	NO	
6/11/91	311		311	NO	
6/24/92	297		297	NO	
5/31/93	961		961	YES	1377
5/12/94	329		329	NO	
1/13/59		881	881	YES	738
3/8/60		1020	1020	YES	884
2/11/61		669	669	YES	621
4/28/62		820	820	YES	778
4/7/63		1770	1770	YES	1640
1/20/64		640	640	YES	518
12/23/64		3910	3910	YES	3320
4/10/66		1190	1190	YES	1090
5/23/67		932	932	YES	914
3/11/95	Spaulding	1550	1930	YES	1510
2/19/96	Spaulding	1800	2180	YES	1800
1/1/97	Spaulding	5540	5920	YES	3770

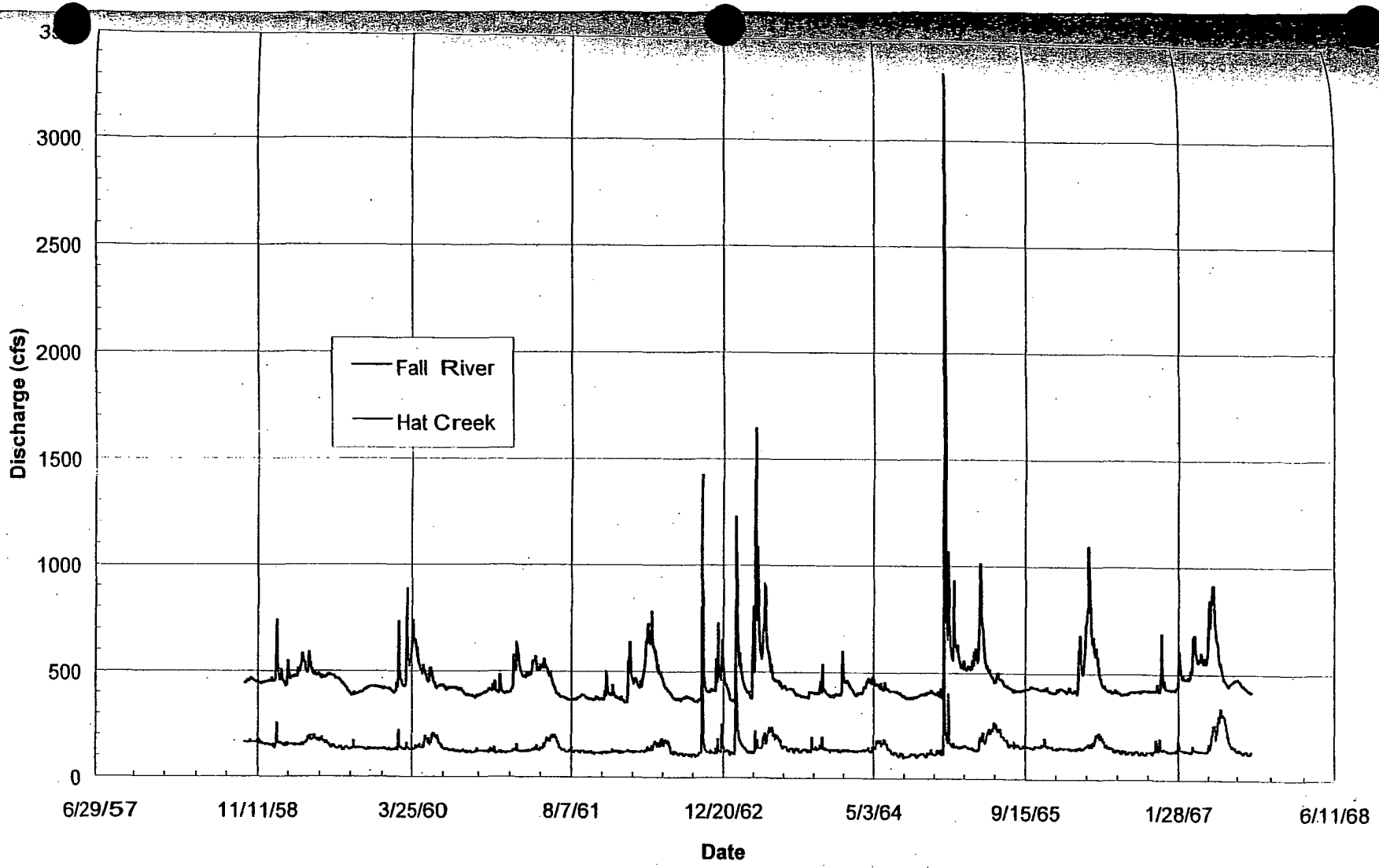


Figure A.1 - Fall River, Hat Creek Hydrograph Comparison

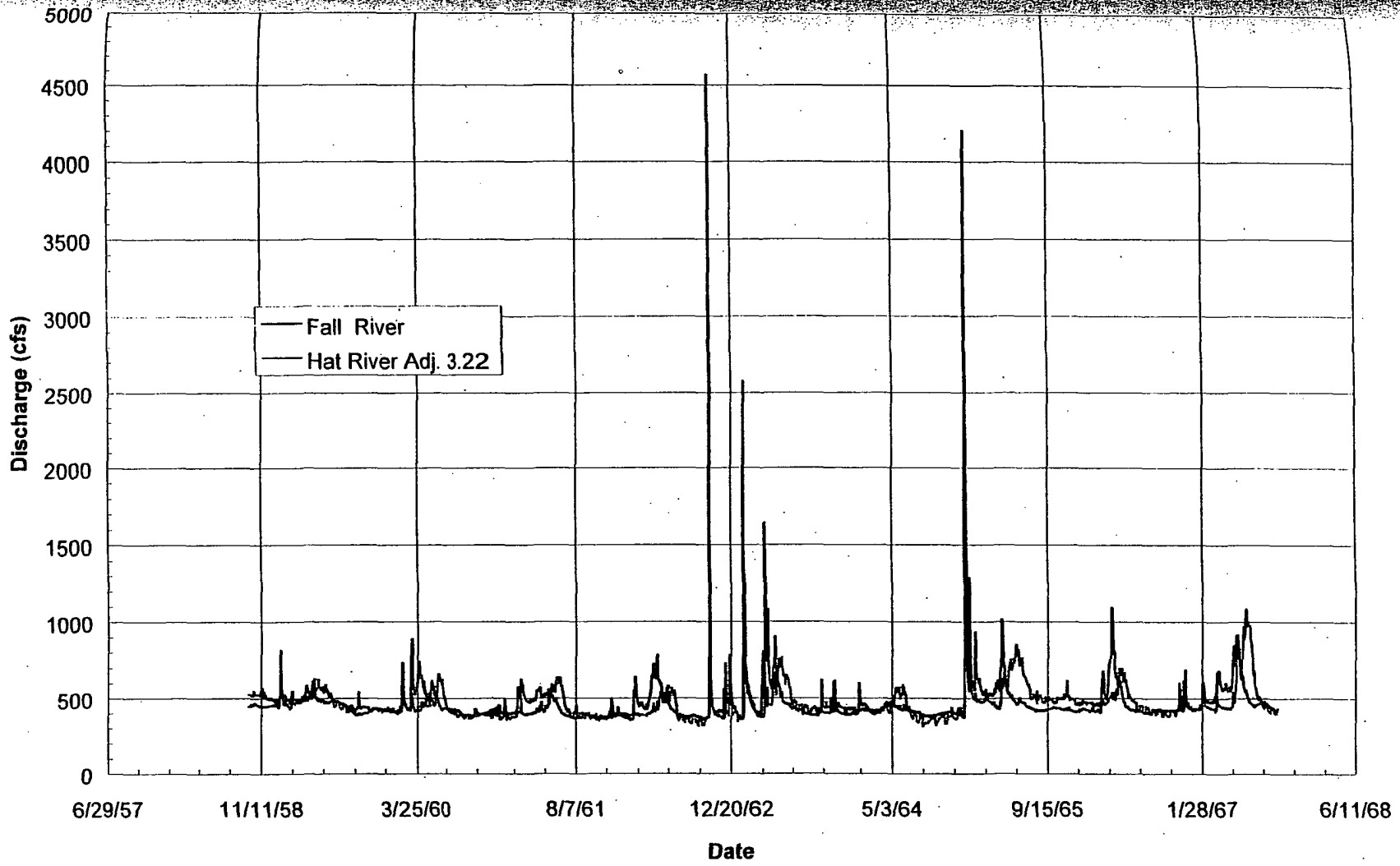


Figure A.2 - Fall River, Hat Creek Hydrology Synthesis Comparison

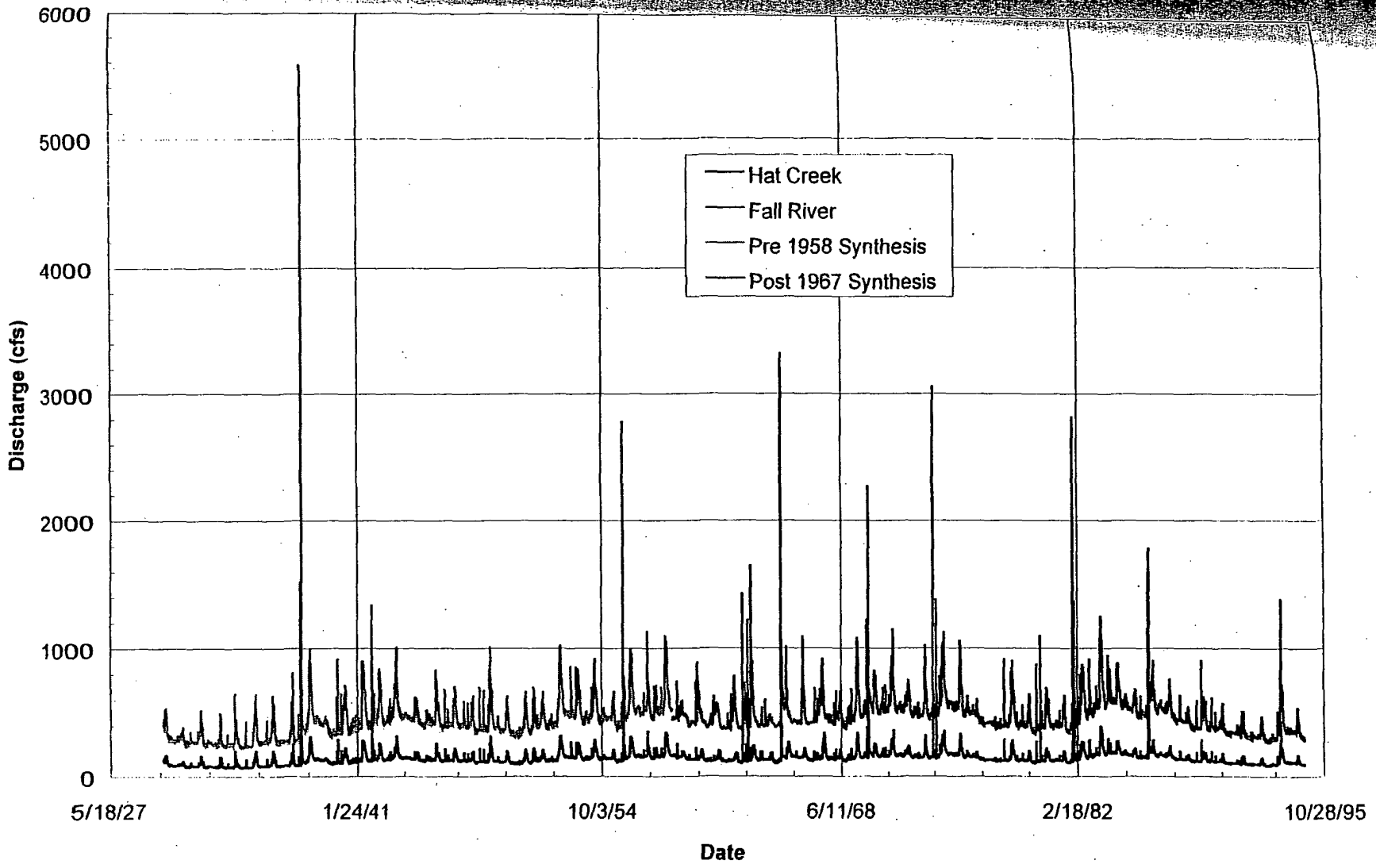


Figure A.3 - Fall River Hydrograph Synthesis

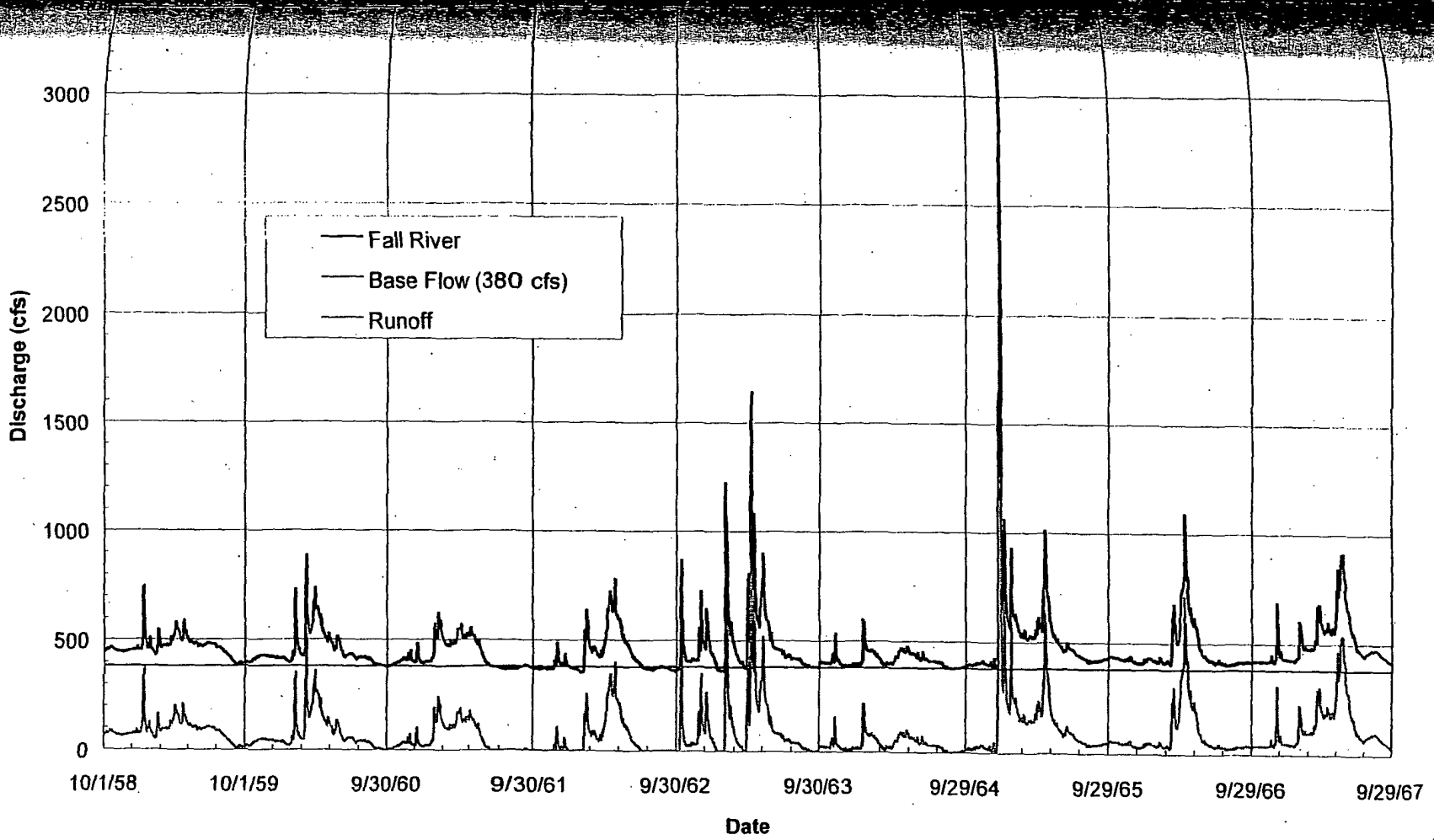


Figure A.4 - Fall River: Hydrograph, Baseflow & Runoff

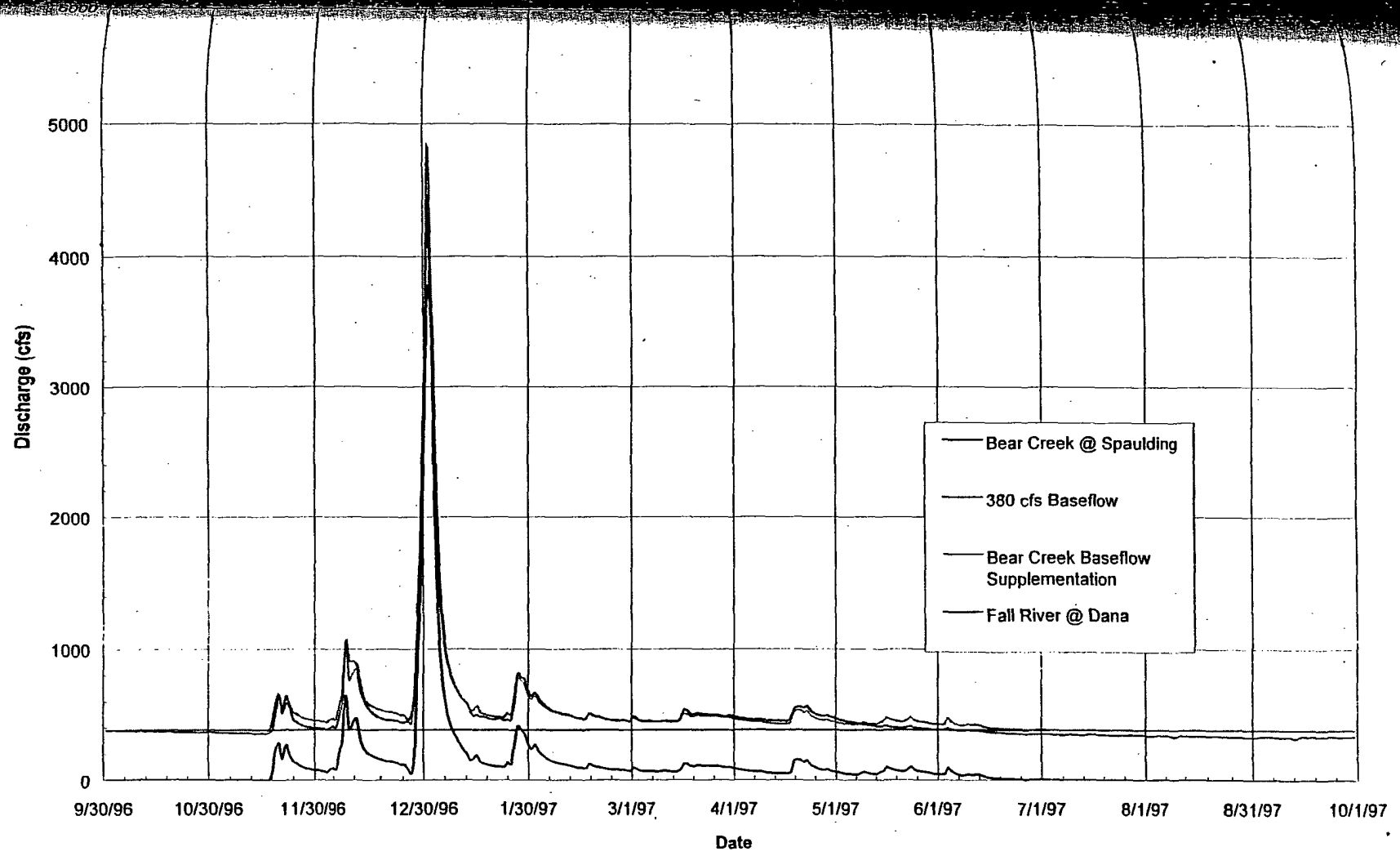


Figure A.5 - Fall River: Bear Creek Baseflow Supplementation

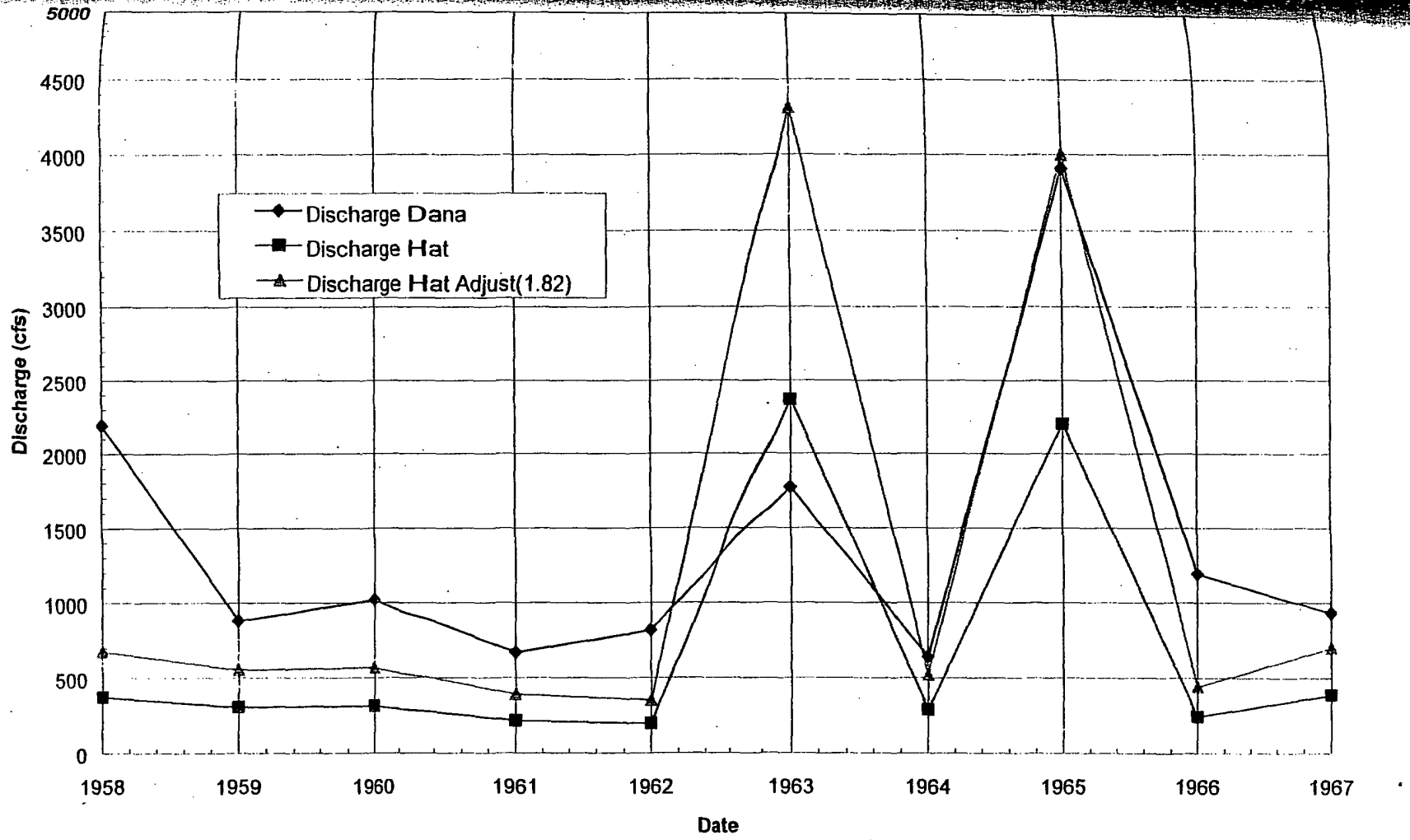


Figure A.6
Fall River & Hat Creek: Peak Discharge Comparison

Appendix B

Tables for the Upper Fall River Hydraulic Analysis

Table B-1a – Fall River, HEC-RAS Cross Section Data

```
Title=Fall River: Original & Calibration Model

Viewing Rectangle= 9.31499266805076E-02 , 0.847972735184612 , 0.936315283341113
0.81492474837009



River Reach=Fall River      ,Rainbow-L.Tule

Junct Up Dn=                ,
Reach XY= 2
     .1158664          .810241        .8215031        .3569277
Junct Text X Y=0.2324707,0.6594786
Reverse River Text= 0

Type RM Length L Ch R = 1 ,23.65   ,2363,2539,2715
BEGIN DESCRIPTION:
XSEC 3
END DESCRIPTION:
Sta/Elev= 31
      0  3333.2    1358 3325.83    1378 3325.11    1398 3323.81    1418 3322.51
   1428 3321.11    1433 3319.71    1443 3315.61    1447 3311.51    1448 3310.51
   1453 3308.21    1458 3306.61    1463 3305.61    1468 3304.61    1473 3304.21
   1478 3303.91    1488 3303.41    1498 3303.31    1508 3303.51    1513 3304.61
   1518 3306.01    1523 3307.81    1528 3308.91    1538 3309.41    1543 3309.71
   1552 3311.51    1558 3312.21    1568 3314.81    1578 3315.21  1582.5 3315.32
 4348.5  3333.2
Mann= 3 , 0 , 0
      0    .065       0    1443    .065       0    1578    .065       0
Bank Sta=1443,1578
Exp/Cntr=.3,.1

Type RM Length L Ch R = 1 ,23.25   ,2816,2942,3067
BEGIN DESCRIPTION:
XSEC 5
END DESCRIPTION:
#Sta/Elev= 43
      0  3323.2    1508  3318.2    20003313.049    2061 3312.41    2071 3312.43
   2081 3311.63    2086 3311.43    2089 3310.95    2096 3310.23    2101 3309.23
   2106 3308.03    2111 3307.73    2121 3307.73    2126 3307.93    2131 3308.23
   2136 3308.93    2141 3308.93    2146 3308.83    2151 3309.03    2161 3308.73
   2171 3308.73    2181 3308.33    2186 3308.33    2193 3309.23    2196 3308.23
   2201 3307.93    2211 3308.13    2216 3307.93    2221 3307.93    2226 3307.73
   2231 3308.13    2241 3308.83    2243 3309.33    2244 3310.13    2251 3310.03
   2261 3310.13  2266.7 3310.99    2268 3312.13    2270 3313.33    2273 3315.13
 2278.5 3315.65  2781.5  3323.2  4541.5  3333.2
#Mann= 3 , 0 , 0
      0    .065       0    2000     .06       0    2270    .065       0
Bank Sta=2000,2270
Exp/Cntr=.3,.1
```

B-1b – Fall River, HEC-RAS Cross Section Data

```
RM Length L Ch R = 1 ,22.7     ,1760,1735,1710
DESCRIPTION:

DESCRIPTION:
Elev= 42
  0  3323.2    1509  3318.2    1861 3316.63    1891 3316.91    1901 3316.71
1906 3316.11    1911 3315.21    1914 3313.51    1915  3310.3    1916 3309.71
1921 3309.41    1931 3309.11    1936 3308.61    1941 3307.91    1946 3308.31
1951 3308.61    1961 3308.31    1971 3308.01    1981 3308.01    1991 3307.61
2001 3307.81    2011 3307.91    2021 3307.81    2031 3307.71    2036 3308.11
2041 3307.51    2051 3308.21    2056 3308.81    2061 3309.11    2066 3309.41
2069 3310.29    2071 3310.71    2076 3311.41    2081 3310.81    2091 3311.01
2101 3312.41    2111 3313.21    2121 3313.91    2141 3314.11    2176 3314.14
2478  3323.2    5118  3333.2
n= 3 , 0 , 0
  0    .065       0    1911     .03       0    2141    .065       0
Sta=1911,2141
Cntr=.3,.1

RM Length L Ch R = 1 ,22.45    ,1157,1533,1911
DESCRIPTION:

DESCRIPTION:
Elev= 30
  0  3323.2    1509  3318.2    2666 3314.49    2671 3313.71    2676 3313.01
2679 3311.31    2681 3310.51  2687.5 3310.01    2691 3309.11    2696 3308.81
2701 3306.71    2706 3305.81    2716 3306.01    2726 3306.31    2736 3306.51
2746 3306.91    2756 3307.11    2766 3306.91    2776 3306.51    2786 3306.31
2796 3306.81    2801 3308.01    2806 3308.91    2816 3309.51  2821.5 3310.01
2825 3312.37    2836 3312.81  2847.8 3312.74  4205.8  3323.2  7423.8  3333.2
n= 3 , 0 , 0
  0    .065       0    2676     .03       0  2847.8    .065       0
Sta=2676,2847.8
Cntr=.3,.1

RM Length L Ch R = 1 ,22.30    ,1458,1333,1207
DESCRIPTION:

DESCRIPTION:
Elev= 50
  0    3320    1509    3315    2666 3314.34    2678 3312.74    2683 3311.35
2696 3310.71    2716 3311.99    2736 3311.99    2750 3310.31    2756 3309.21
2761 3308.31    2766 3308.91    2771 3309.21    2776 3309.31    2781 3309.21
2786 3309.21    2791 3308.91    2796 3308.21    2801 3308.01    2806 3307.71
2811 3307.91    2816 3307.61    2821 3307.61    2826 3307.61    2831 3307.51
2836 3307.41    2841 3307.41    2846 3307.41    2851 3307.51    2856 3307.61
2861 3307.51    2866 3307.61    2871 3307.41    2876 3307.41    2881 3307.41
2886 3307.41    2891 3307.31    2896 3307.11    2901 3306.91    2906 3307.01
2911 3307.01    2916 3307.31    2921 3308.31    2926 3309.51    2928 3310.31
2931 3315.08    2936 3315.82    2943 3316.75    3143    3320    8776    3325
n= 3 , 0 , 0
  0    .065       0    2678    .035       0    2936    .065       0
Sta=2678,2936
Cntr=.3,.1
```

Table B-1c - Fall River, HEC-RAS Cross Section Data

```
Type RM Length L Ch R = 1 ,22.05   ,4777,4450,4123
BEGIN DESCRIPTION:
STC 11
END DESCRIPTION:
Sta/Elev= 40
     0  3333.2    1307  3323.2    1910 3313.74    1930 3314.06    1950 3313.96
  1970 3314.06    1990 3314.46    1995 3314.26    2000 3313.26    2002 3312.46
  2003 3309.78    2010 3309.06    2020 3308.06    2030 3307.16    2040 3306.66
  2045 3307.06    2050 3306.96    2060 3307.16    2070 3307.16    2080 3307.16
  2090 3307.06    2100 3306.96    2110 3306.76    2120 3306.56    2130 3306.06
  2135 3305.96    2140 3306.46    2145 3308.06    2150 3308.86    2155 3309.26
  2160 3309.16    2165 3309.36    2166 3309.78    2167 3310.86    2170 3311.56
  2175 3311.36  2178.4 3311.09  2234.1  3314.5  2378.4  3323.2  8011.4  3328.2
Mann= 3 , 0 , 0
     0    .065       0    1990    .022       0  2234.1    .065       0
Bank Sta=1990,2234.1
Exp/Cntr=.3,.1

Type RM Length L Ch R = 1 ,21.2    ,5839,6889,6939
BEGIN DESCRIPTION:
STC 15
END DESCRIPTION:
Sta/Elev= 37
     0  3333.2    2565  3323.2    2766 3314.09    2770 3313.85    2774 3311.95
  2776 3311.45    2779 3310.76    2786 3310.25    2791 3309.95    2796 3309.35
  2806 3308.85    2816 3308.75    2826 3308.55    2836 3308.05    2846 3308.15
  2856 3308.05    2866 3307.95    2876 3307.85    2886 3308.05    2896 3307.85
  2906 3307.65    2916 3307.55    2926 3307.35    2931 3306.85    2936 3306.45
  2941 3306.45    2946 3307.95    2952 3309.95    2959 3310.78    2962 3311.05
  2966 3313.55    2971 3315.05    2976 3314.95    2986 3315.25    2992 3315.55
  3092  3323.2    8875  3328.2
Mann= 3 , 0 , 0
     0    .065       0    2766     .03       0    2971    .065       0
Bank Sta=2766,2971
Exp/Cntr=.3,.1

Type RM Length L Ch R = 1 ,19.95   ,1710,1735,1760
BEGIN DESCRIPTION:
STC 18
END DESCRIPTION:
Sta/Elev= 34
     0  3323.2    1006  3313.2    1071  3312.1    1107 3311.34    1116 3310.46
  1117 3308.96    1122 3309.16    1124 3308.91    1127 3308.66    1137 3308.26
  1147 3308.06    1157 3307.36    1167 3305.86    1177 3304.66    1187 3303.96
  1197 3303.46    1207 3303.56    1217 3303.46    1227 3303.46    1237 3303.66
  1247 3304.36    1257 3304.96    1262 3305.56    1267 3306.76    1268 3307.76
  1272 3308.36    1277 3308.91    1281 3309.46    1282 3310.56    1287 3312.06
  1292 3312.66  1294.6 3312.72  2148.6  3313.2  5517.6  3323.2
Mann= 3 , 0 , 0
     0    .065       0    1071     .03       0    1292    .065       0
Bank Sta=1071,1292
Exp/Cntr=.3,.1
```

B-1d - Fall River, HEC-RAS Cross Section Data

```
RM Length L Ch R = 1 ,19.65    ,2615,2741,2866
DESCRIPTION:

29
DESCRIPTION:
Elev= 40
.0  3323.2      854  3313.2     2161 3310.83     2171 3310.89     2176 3311.19
181 3310.89    2186 3310.29     2187 3309.79     2191 3309.39  2192.8 3308.83
196 3308.09    2201 3307.09     2206 3306.19     2211 3304.99     2221 3303.79
226 3303.49    2231 3302.79     2236 3302.39     2241 3302.19     2246 3301.99
251 3301.09    2256 3300.99     2261 3301.19     2266 3301.29     2271 3301.79
276 3302.49    2281 3303.39     2286 3304.59     2291 3305.69     2296 3307.89
3 3308.83      2301 3309.19     2306 3309.79     2311 3310.99     2321 3312.76
31 3315.96     2341 3317.96   2346.8 3318.97   2497.8  3315.5   5916.8  3323.2
3 , 0 , 0
0    .065         0    2176      .03         0    2311     .065         0
a=2176,2311
r=.3,.1

RM Length L Ch R = 1 ,19.10    ,1609,1533,1458
DESCRIPTION:

DESCRIPTION:
lev= 40
0  3323.2      3318  3313.2     3338 3310.84     3348 3310.45     3352 3310.25
3309.55        3355 3309.05   3357.1 3308.64     3363 3308.05     3367 3307.45
65 3307.05     3373 3305.95     3378 3305.35     3388 3304.75     3393 3304.75
3304.05        3408 3304.25     3418 3304.85     3428 3304.85     3438 3304.75
3304.45        3458 3304.65     3468 3304.85     3478 3305.15     3488 3305.35
3305.15        3498 3305.85     3503 3305.95     3508 3307.35     3513 3307.65
3308.05        3523 3308.05   3523.8 3308.64     3526 3309.15     3528 3309.65
3309.65        3538 3310.15   3541.1 3310.12   4044.1  3313.2   9525.1  3323.2
, 0 , 0
   .065         0    3352      .04         0    3538     .065         0
3352,3538
.3,.1

ength L Ch R = 1 ,18.80    ,553,578,603
SCRIPTION:
BUG
IPTION:
49
 3320      1408 3311.58     3721 3311.58     3731 3311.54     3735 3310.85
309.94     3739  3309.5     3741  3308.6     3746  3308.1     3751  3307.8
3306.6     3771  3305.3     3781  3304.8     3791  3304.5     3801  3304.2
3304.8     3821  3304.8     3831    3305     3841  3305.2     3851    3305
3304.7     3871    3304     3881  3304.3     3891  3303.7     3901  3304.4
3306.3     3911  3307.4     3916  3307.7     3921    3308     3926  3307.9
3307.9     3936  3307.5     3941  3307.8     3946  3307.8     3951  3308.4
3308.6     3961  3308.9     3966  3308.8     3971 3309.52     3976 3309.73
09.56      4001 3309.61     4021 3309.63     4041 3309.65     4056  3310.4
11.38      4071 3310.89     4373 3310.89     9955    3320
0 , 0
.065         0    3721      .085        0    4067     .065         0
21,4067
.1
```

Table B-1e – Fall River, HEC-RAS Cross Section Data

```
pe RM Length L Ch R = 1 ,18.70    ,603,629,653
IN DESCRIPTION:
BUG FLAT
DESCRIPTION:
/Elev= 53
   0    3315    1408    3310    3822 3309.92    3840 3309.98    3841 3309.33
3842 3308.93    3847 3308.83    3852 3308.73    3857 3308.73    3862 3308.53
3867 3307.93    3870 3307.73    3872 3307.13    3877 3306.73    3882 3306.43
3887 3306.23    3892 3305.93    3902 3305.73    3912 3305.43    3922 3305.23
3932 3305.23    3942 3305.13    3952 3304.73    3962 3304.43    3972 3303.63
3982 3304.33    3992 3304.13    4002 3304.53    4012 3304.23    4022 3304.83
4032 3305.43    4037 3305.53    4042 3305.43    4047 3305.53    4052 3305.53
4057 3306.53    4062 3306.63    4067 3307.13    4072 3307.73    4077 3307.73
4082 3306.83    4085 3307.43    4087 3307.83    4092 3308.33    4095 3308.63
4098 3309.33    4102 3309.91    4104  3309.8    4108 3310.24    4112 3312.21
4117 3313.94    4167 3313.94    9749    3320
   3    0 , 0
   0     .065       0    3840    .085       0    4108    .065       0
La=3840,4108
ntr=.3,.1

RM Length L Ch R = 1 ,18.6    ,804.6,754.3,779.4
DESCRIPTION:
CHRISTIANSEN
SCRIPTION:
lev= 40
   0    3315    3017 3310.72    3118 3310.72    3128 3310.28    3148 3309.68
58 3309.61    3160 3309.22    3163 3308.82    3168 3308.62    3173 3308.22
78 3308.02    3183 3306.52    3188 3303.02    3193 3301.92    3198 3300.72
08 3300.12    3208 3300.12    3213 3300.42    3218 3301.22    3223 3300.32
23 3299.92    3233 3299.62    3238 3299.82    3243 3300.02    3248 3300.32
63 3300.82    3258 3301.92    3263 3301.32    3268 3302.82    3273 3303.42
78 3304.82    3283 3305.62    3288 3308.32    3292 3309.19    3293 3310.03
93313.415     3298 3314.45    3300 3314.54    4406    3310   10440    3320
   2    0 , 0
   0     .065       0    3128    .085       0    3293    .065       0
=3128,3293
=.3,.1

Length L Ch R = 1 ,18.45    ,2715.4,2463.7,2589.6
ESCRIPTION:
ANSEN
CRIPTION:
ev= 42
   0    3315    3017 3310.54    3118 3310.54    3128 3310.53    3148 3309.96
   3309.03    3168 3308.53    3178 3308.38    3188 3307.13    3198 3307.53
   3307.03    3218 3307.03    3228 3307.13    3238 3307.13    3248 3307.13
   3307.23    3268 3307.03    3278 3306.33    3288 3305.93    3298 3305.43
   3304.93    3318 3305.03    3328 3305.03    3338 3304.93    3348 3304.53
   3304.63    3368 3304.83    3378 3304.43    3388 3304.63    3398 3304.53
   3304.43    3418 3304.63    3428 3304.83    3438 3305.93    3448 3307.13
   3308.53    3464 3309.02    3465  3310.1    3468 3310.39    3472 3310.66
   3310.66   10612    3320
   0    0 , 0
   0     .065       0    3128    .043       0    3468    .065       0
3128,3468  Exp/Cntr=.3,.1
```

B-1f – Fall River, HEC-RAS Cross Section Data

```
RM Length L Ch R = 1 ,17.90    ,4526,4827,5129
N DESCRIPTION:

22
DESCRIPTION:
Elev= 43
  0  3318.2     5331   3313.2     5411 3309.64     5421 3309.79     5431 3309.69
5436  3309.89    5441 3309.39     5443 3308.29  5445.8 3308.17     5451 3307.39
5454  3307.19    5456 3306.19     5461 3305.49     5466 3304.59     5471 3304.29
5476  3303.49    5481 3303.69     5491 3304.39     5496 3304.69     5501 3304.69
5511  3304.69    5521 3304.69     5531 3304.69     5536 3304.79     5541 3304.49
5546  3305.09    5551 3304.79     5556 3304.09     5561 3303.99     5571 3303.99
5581  3304.19    5586 3304.49     5591 3305.49     5594 3305.99     5597 3307.29
5604.7  3308.16  5608 3308.49     5611 3309.19     5614 3309.99     5619 3312.59
5622.7  3312.91  5723.7   3313.2 11053.7   3323.2
.3 , 0 , 0
  0     .065        0     5436     .065        0     5614     .065        0
Sta=5436,5614
Mul=.3,.1

M Length L Ch R = 1 ,17.15    ,4526,5501,4475
DESCRIPTION:

DESCRIPTION:
Elev= 42
  0  3318.2     5331   3313.2     5411   3311.2     5421 3310.63     5423 3309.73
5431  3309.33    5436 3308.53     5441 3307.93  5452.8   3307.9     5461 3307.53
5471  3307.13    5481 3306.73     5491 3306.43     5501 3305.93     5511 3305.43
5521  3304.63    5531 3304.13     5541 3303.13     5551 3302.63     5561 3302.03
5566  3301.93    5571 3301.43     5581 3300.83     5591 3301.23     5596 3302.03
5601  3302.53    5606 3303.23     5611 3304.53     5616 3304.93     5621 3305.63
5626  3305.43    5631 3305.43     5636 3306.73     5641 3307.23   5646.2 3307.94
5648  3308.53    5649 3309.23     5656 3309.93     5666 3310.13     5677 3310.07
5678  3313.2    11108   3323.2
.3 , .0 , 0
  0     .065        0     5421     .025        0     5677     .065        0
Sta=5421,5677
Mul=.3,.1

Length L Ch R = 1 ,16.35    ,0,0,0
SCRIPTION:

RIPTION:
ev= 40
  0  3318.2     2514   3313.2     3469   3310.4     3479 3309.95     3486 3309.25
3488  3308.15    3489 3308.15  3494.7 3307.76     3499 3307.35     3509 3307.05
3518  3306.55    3519 3304.25     3524 3302.75     3529 3301.55     3539 3300.65
3549  3300.35    3559 3300.55     3569 3301.75     3574 3302.85     3579 3302.45
3589  3302.65    3589 3302.05     3599 3302.25     3609 3303.15     3619 3303.05
3624  3303.25    3634 3303.95     3639 3304.45     3649 3304.65     3654 3305.55
3664  3305.85    3669 3306.85     3674 3306.85     3680 3307.77     3684 3308.15
3694  3308.25    3699 3308.65  3707.6   3309.1  4411.6   3313.2 10948.6   3323.2
.3 , .0 , 0
  0     .065        0     3486     .045        0  3707.6     .065        0
3486,3707.6
.3,.1
Cuts=-1
```

Table B-2
Hydraulic Model Calibration

River Sta	Cross Section	Known WSE (ft)	Model W.S. Elev. (ft)	Manning's n	Elevation Difference (ft)
23.65	3	3311.48	3311.45	0.065	-0.03
23.25	5	3311.10	3311.10	0.060	0.00
22.70	7	3310.53	3310.54	0.030	0.01
22.45	9	3310.42	3310.42	0.030	0.00
22.30	10	3310.31	3310.31	0.035	0.00
22.05	11	3310.25	3310.24	0.022	-0.01
21.20	15	3309.97	3309.98	0.030	0.01
19.95	18	3309.74	3309.73	0.030	-0.01
19.65	19	3309.70	3309.70	0.030	0.00
19.10	21	3309.61	3309.62	0.040	0.01
18.80	uzb	3309.50	3309.43	0.085	-0.07
18.70	zb	3309.33	3309.28	0.085	-0.05
18.60	uc	3309.22	3309.16	0.085	-0.06
18.45	ch	3309.03	3309.09	0.043	0.06
17.90	22	3308.74	3308.79	0.065	0.05
17.15	23	3308.47	3308.52	0.025	0.05
16.35	24		3308.34	0.045	
				Average Difference	0.00
Calibration Flow Rates (cfs):			Fall River @		
			Dana	325	
			Spring Creek	542	

Appendix C

Tables & Figures for the Upper Fall River Sediment Balance Determination

Date	Time	Location	Discharge	Bed Load	Percent in Size Class (mm)							Estimated	Bed Load
(mm/dd/yy)			(cfs)	Load (tons/day)	>23	2.3 to 1.5	1.5 to 1.0	1.0 to 0.66	.66 to .38	.38 to .15	<0.15	<0.15 Estimated	Bed Load <0.15	Load (tons/day)
09/25/96	12:15	XSEC-3	371	0.69	3.9	2.0	4.6	7.2	22.2	58.8	1.3	58.8	0.4	1.1
11/21/96	11:40	XSEC-3	500	1.10	21.2	6.6	5.5	5.1	22.3	39.3	0.1	39.3	0.4	1.5
12/12/96	15:40	XSEC-3	880	10.30	9.4	3.7	5.2	8.7	51.3	21.3	0.4	21.3	2.2	12.5
01/03/97	15:30	XSEC-3	2300	0.76	42.0	9.9	4.9	4.9	14.8	19.8	3.7	19.8	0.2	0.9
09/24/96	12:25	XSEC-7	380	1.50	27.7	6.1	6.1	4.9	17.0	36.5	1.7	36.5	0.5	2.0
11/20/96	14:40	XSEC-7	660	8.70	2.9	2.2	3.6	7.0	43.3	40.7	0.3	40.7	3.5	12.2
12/12/96	10:10	XSEC-7	990	7.90	1.2	1.8	1.9	2.3	46.2	45.6	1.0	45.6	3.6	11.5
12/31/96	11:00	XSEC-7	5800	10.50	41.2	5.3	4.2	3.3	17.5	27.5	0.9	27.5	2.9	13.4
09/26/96	13:10	XSEC-15	415	4.05	5.0	3.3	3.1	4.1	38.5	44.7	1.3	44.7	1.8	5.9
11/21/96	14:40	XSEC-15	490	3.00	3.8	3.3	8.7	12.5	30.8	40.9	0.0	40.9	1.2	4.2
12/12/96	13:00	XSEC-15	910	6.00	2.0	1.7	4.4	8.0	29.8	53.6	0.5	53.6	3.2	9.2
01/04/97	14:40	XSEC-15	1570	56.60	1.7	2.1	7.5	19.8	52.4	16.3	0.2	16.3	9.2	65.8
06/27/97	12:05	XSEC-15	385	4.10	1.7	2.6	10.0	19.0	44.8	21.5	0.4	21.5	0.9	5.0
10/08/96	11:10	XSEC-21	600	1.00	5.0	0.0	0.0	0.0	5.0	85.0	5.0	85.0	0.9	1.9
12/13/96	10:15	XSEC-21	1030	6.90	2.9	2.9	10.5	16.9	40.1	25.4	1.3	25.4	1.8	8.7
12/30/96	15:40	XSEC-21	2200	21.60	15.1	5.6	9.8	13.4	27.4	27.1	1.6	27.1	5.9	27.5

Date (mm/dd/yy)	Time	Location	Discharge (cfs)	Measured Bed Load (tons/day)	Estimated Bed Load (tons/day)	Measured Susp. Sand Load (tons/day)	Measured Total Sand Load (tons/day)	Estimated Total Sand Load (tons/day)	Measured Wash Load (tons/day)	Measured Total Susp. Load (tons/day)	Measured Total Load (tons/day)	Estimated Total Load (tons/day)
12/12/96	15:40	XSEC-3	880	10.30	12.50	0.57	10.87	13.07	12.95	13.52	23.82	26.02
01/03/97	15:30	XSEC-3	2300	0.76	0.90	12.40	13.16	13.30	296.36	308.76	309.52	309.66
12/12/96	10:10	XSEC-7	990	7.90	11.50	1.33	9.23	12.83	41.63	42.96	50.86	54.46
12/31/96	11:00	XSEC-7	5800	10.50	13.40	66.03	76.53	79.43	2665.76	2731.79	2742.29	2745.19
12/12/96	13:00	XSEC-15	910	6.00	9.20	3.19	9.19	12.39	12.02	15.21	21.21	24.41
01/04/97	14:40	XSEC-15	1570	56.60	65.80	518.02	574.62	583.82	247.16	765.18	821.78	830.98
06/27/97	12:05	XSEC-15	385	4.10	5.00	0.88	4.98	5.88	2.65	3.53	7.63	8.53
12/13/96	10:15	XSEC-21	1030	6.90	8.70	43.31	50.21	52.01	86.91	130.22	137.12	138.92
12/30/96	15:40	XSEC-21	2200	21.60	27.50	394.97	416.57	422.47	325.58	720.55	742.15	748.05

Bear Creek @ Pondosa Bed Load Sampling Data (From Poore, 1998)

Date (mm/dd/yy)	Time	Discharge (cfs)	Width (ft)	Number of Samples	Duration (min.)	Weight (gm)	Transport Rate (tons/day)	Estimated Bed Load (tons/day)
01/08/95	15:00	33.6	18.0	10	1	1.00	0.01	0.01
01/13/95	9:55	219.3	45.0	18	1	460.83	7.32	8.78
01/14/95	10:45	438.8	47.5	10	1	553.83	16.71	20.05
01/16/95	10:00	120.6	47.5	9	1	38.03	1.27	1.53
02/01/95	12:45	328.6	50.0	8	1	572.23	22.71	27.25
02/02/95	23:00	229.3	47.5	8	1	357.23	13.47	16.16
03/03/95	9:30	190.5	49.0	18	1	64.83	1.12	1.34
03/09/95	10:00	890.4	55.0	10	1	5687.69	198.66	238.39
03/11/95	10:15	707.6	55.0	10	1	651.53	22.76	27.31
03/13/95	9:45	387.1	50.0	9	1	166.23	5.86	7.04
03/14/95	13:45	1250.0	55.0	9	1	864.23	33.54	40.25
03/15/95	9:00	840.0	50.0	9	1	1210.93	42.72	51.27
03/18/95	12:00	513.7	50.0	9	1	422.73	14.91	17.90
03/21/95	13:45	425.0	45.0	8	1	406.63	14.53	17.43
04/06/95	9:30	940.0	50.0	9	1	7989.99	281.89	338.26
04/29/95	0:45	860.0	53.0	10	1	3025.23	101.82	122.18
05/01/95	9:30	800.0	53.0	10	1	5120.46	172.34	206.81
05/03/95	13:50	300.0	50.0	9	1	224.63	7.92	9.51
02/05/96	14:45	367.2	48.0	19	1	1123.50	18.02	21.63
02/13/96	14:45	130.0	47.5	9	1	7.90	0.26	0.32
02/18/96	10:30	1104.5	55.0	11	1	6230.40	197.83	237.39
04/01/96	11:15	217.0	50.0	10	1	486.40	15.44	18.53
04/24/96	16:25	277.1	50.0	20	1	232.60	3.69	4.43
05/17/96	11:05	368.4	50.0	20	1	1304.20	20.71	24.85
12/29/96	10:45	984.0	52.0	18	1	14738.80	270.39	324.47
04/21/97	10:00	126.7	47.5	18	1	1163.00	19.49	23.39
01/27/98	10:50	290.0	66.0	10	1	162.60	6.81	8.18

Bear Creek @ Spaulding Bed Load Sampling Data (From Poore, 1998)

Date	Time	Discharge	Width	Number of	Duration	Weight	Transport Rate	Estimated Bed Load
(mm/dd/yy)		(cfs)	(ft)	Samples	(min.)	(gm)	(tons/day)	(tons/day)
01/13/95	11:45	255.7	38.5	16	1	56.82	0.87	1.04
01/14/95	13:15	563.1	38.5	8	1	66.23	2.02	2.43
02/01/95	14:45	365.3	38.5	7	1	127.43	4.45	5.34
02/02/95	12:15	285.3	38.5	7	1	5.48	0.19	0.23
03/09/95	11:30	730.4	38.5	8	1	74.49	2.28	2.73
03/11/95	11:50	1150.0	38.5	7	1	0.00	0.00	0.00
03/14/95	14:45	930.0	38.5	7	1	0.00	0.00	0.00
03/15/95	10:00	1350.0	38.5	7	1	0.00	0.00	0.00
03/18/95	13:45	515.6	38.5	7	1	0.00	0.00	0.00
03/21/95	14:55	545.0	38.5	7	1	0.00	0.00	0.00
04/06/95	11:00	640.0	38.5	7	1	127.43	4.45	5.34
04/29/95	13:40	940.0	38.5	7	1	44.13	1.54	1.85
05/01/95	10:30	690.0	38.5	7	1	0.00	0.00	0.00
02/05/96	16:15	196.0	38.5	7	1	8.30	0.29	0.35
02/13/96	13:15	108.1	38.5	7	1	0.00	0.00	0.00
02/18/96	11:45	1637.6	38.5	7	1	87.10	3.04	3.65
04/01/96	12:15	142.0	38.5	7	1	12.80	0.45	0.54
04/24/96	17:00	236.6	38.5	15	1	9.80	0.16	0.19
05/17/96	14:05	510.0	38.5	15	1	109.70	1.79	2.15
12/29/96	0:00	861.1	38.5	15	1	151.50	2.47	2.96
04/21/97	11:00	139.8	38.5	15	1	3.60	0.06	0.07
01/27/98	13:36	325.1	37.5	8	1	84.00	2.50	3.00

Table C-4c
Bear Creek @ 1,000 Springs Bed Load Sampling Data (From Poore, 1998)

Date	Time	Discharge	Width	Number of	Duration	Weight	Transport Rate	Esitmated Bed Load
(mm/dd/yy)		(cfs)	(ft)	Samples	(min.)	(gm)	(tons/day)	(tons/day)
01/11/95	13:20	85.5	28.0	10	1	29.33	0.52	0.625824
01/13/95	13:25	208.2	36.0	7	1	286.83	9.37	11.24117
01/16/95	13:15	142.7	27.5	11	1	228.23	3.62	4.348055
02/02/95	1:30	286.5	36.0	6	1	707.33	26.95	32.34116
03/02/95	12:00	102.2	26.5	10	1	52.93	0.89	1.068883
03/03/95	11:30	210.0	36.0	14	1	265.03	4.33	5.193401
03/13/95	15:05	493.6	32.5	13	1	924.83	14.68	17.61912
03/14/95	14:40	930.0	35.0	6	1	5188.26	192.19	230.6327
03/15/95	11:30	1350.0	35.0	6	1	7410.96	274.53	329.4379
03/18/95	15:30	497.6	33.0	6	1	1620.33	56.59	67.91231
03/21/95	16:30	545.0	34.0	6	1	1030.43	37.08	44.49677
03/28/95	13:45	183.9	28.0	11	1	5.47	0.09	0.106105
04/06/95	12:00	640.0	32.5	6	1	357.23	12.29	14.7456
04/13/95	16:30	502.0	32.0	7	1	499.23	14.49	17.39142
04/29/95	14:30	940.0	35.0	6	1	5960.06	220.78	264.9414
05/01/95	11:10	800.0	35.0	6	1	2934.23	108.70	130.4347
05/03/95	15:45	435.0	31.0	6	1	1104.23	36.23	43.47627
05/12/95	13:00	215.0	30.0	6	1	470.73	14.95	17.93594
02/05/96	17:00	196.0	38.0	14	1	1564.50	26.97	32.36037
02/13/96	13:45	121.5	28.5	11	1	36.10	0.59	0.712757
02/18/96	13:45	1637.6	43.0	9	1	1816.90	55.13	66.15144
04/01/96	13:45	142.0	38.0	15	1	674.10	10.84	13.01365
04/24/96	17:35	237.0	39.0	15	1	1045.40	17.26	20.71277
05/17/96	15:00	537.0	40.0	16	1	3534.10	56.11	67.32885
12/30/96	0:00	1544.0	42.0	16	1	2656.00	44.27	53.12999
04/21/97	12:05	161.0	30.0	11	1	1405.60	24.34	29.21276
01/27/98	15:00	325.0	39.0	16	1	4914.60	76.07	91.2883

Table C-5a
Bear Creek @ Pondosa Suspended Load Sampling Data (TSR, 1998)

Date	Time	Discharge	Suspended Sediment	Suspended Sediment	Estimated Susp. Sand
(mm/dd/yy)		(cfs)	(ppm)	(T/day)	(T/day)
01/08/95	15:00	33.6	29.00	2.63	1.31
01/09/95	10:30	105.1	85.00	24.09	12.04
01/11/95	10:00	67.0	8.00	1.45	0.72
01/13/95	9:55	219.3	48.00	28.38	14.19
01/14/95	10:45	438.8	24.00	28.39	14.20
01/16/95	10:00	120.6	4.00	1.30	0.65
01/18/95	10:55	57.8	0.94	0.15	0.07
01/23/95	11:45	39.2	2.88	0.30	0.15
01/27/95	10:05	35.7	3.77	0.36	0.18
01/30/95	23:00	80.4	9.52	2.06	1.03
02/01/95	12:45	328.6	57.44	50.88	25.44
02/02/95	23:00	229.3	15.21	9.40	4.70
02/06/95	13:00	111.3	4.16	1.25	0.62
02/12/95	13:30	89.3	4.40	1.06	0.53
02/15/95	13:30	62.5	2.64	0.44	0.22
02/20/95	13:50	54.9	0.65	0.10	0.05
03/01/95	10:20	80.2	1.82	0.39	0.20
03/02/95	10:15	105.5	5.28	1.50	0.75
03/03/95	9:30	190.5	9.60	4.93	2.46
03/04/95	14:30	131.1	3.36	1.19	0.59
03/08/95	9:00	94.9	3.63	0.93	0.46
03/09/95	10:00	890.4	568.84	1365.41	682.70
03/10/95	9:20	758.8	121.08	247.69	123.84
03/11/95	10:15	707.6	55.11	105.12	52.56
03/13/95	9:45	387.1	21.61	22.55	11.27
03/14/95	13:45	1250.0	213.17	718.29	359.14
03/15/95	9:00	840.0	36.46	82.56	41.28
03/18/95	12:00	513.7	8.61	11.92	5.96
03/21/95	13:45	425.0	28.25	32.37	16.18
03/28/95	10:30	156.3	4.69	1.97	0.99
04/06/95	9:30	940.0	261.05	661.48	330.74
04/13/95	15:30	420.0	12.18	13.79	6.89
04/29/95	0:45	860.0	37.64	87.26	43.63
05/01/95	9:30	800.0	50.00	107.83	53.91
05/03/95	13:50	300.0	15.84	12.81	6.41
05/12/95	10:45	180.0	4.55	2.21	1.10
05/30/95	13:20	111.1	0.76	0.23	0.11
06/16/95	9:15	105.0	2.50	0.71	0.35
12/29/95	13:30	16.4	0.71	0.03	0.02
1/26/96	14:15	21.1	1.29	0.07	0.04
2/5/96	14:45	367.2	53.93	53.38	26.69
4/1/96	11:15	217.0	44.57	26.06	13.03
4/24/96	16:25	277.1	23.39	17.47	8.74
5/17/96	11:05	368.4	38.11	37.85	18.92
12/29/96	10:45	984.0	270.94	718.68	359.34
4/21/97	10:00	126.7	4.88	1.67	0.83
1/27/98	10:50	290.0	8.65	6.77	3.38

Table C-5b
Bear Creek @ Spaulding Suspended Load Sampling Data (TSR,1998)

Date	Time	Discharge	Suspended Sediment	Suspended Sediment	Estimated Susp. Sand
(mm/dd/yy)		(cfs)	(ppm)	(T/day)	(T/day)
01/09/95	16:15	85.3	12.00	2.76	1.38
01/11/95	11:45	98.1	4.00	1.06	0.53
01/13/95	11:45	255.7	16.00	11.03	5.51
01/14/95	13:15	563.1	14.00	21.25	10.63
01/18/95	12:15	59.0	0.63	0.10	0.05
01/23/95	13:25	27.1	0.52	0.04	0.02
01/27/95	11:05	25.7	1.11	0.08	0.04
01/30/95	23:45	49.0	4.23	0.56	0.28
02/01/95	14:45	365.3	18.21	17.93	8.97
02/02/95	12:15	285.3	8.69	6.68	3.34
02/06/95	14:00	106.9	3.33	0.96	0.48
02/12/95	14:20	71.8	0.20	0.04	0.02
02/15/95	14:45	46.9	0.69	0.09	0.04
02/20/95	14:40	38.5	0.46	0.05	0.02
03/01/95	11:20	58.3	0.28	0.04	0.02
03/02/95	11:30	105.5	3.85	1.10	0.55
03/03/95	10:30	173.8	11.30	5.30	2.65
03/04/95	15:30	142.6	2.76	1.06	0.53
03/08/95	10:00	75.4	1.12	0.23	0.11
03/09/95	11:30	730.4	112.87	222.23	111.12
03/10/95	11:00	858.7	24.00	55.56	27.78
03/11/95	11:50	1150.0	26.28	81.46	40.73
03/13/95	11:25	555.0	14.95	22.36	11.18
03/14/95	14:45	930.0	33.74	84.59	42.30
03/15/95	10:00	1350.0	26.10	94.97	47.48
03/18/95	13:45	515.6	12.59	17.50	8.75
03/21/95	14:55	545.0	12.70	18.65	9.33
03/28/95	12:30	157.3	2.02	0.86	0.43
04/06/95	11:00	640.0	57.65	99.45	49.73
04/13/95	16:00	470.0	7.12	9.02	4.51
04/29/95	13:40	940.0	57.50	145.70	72.85
05/01/95	10:30	690.0	35.48	66.00	33.00
05/03/95	14:30	435.0	6.00	7.04	3.52
05/12/95	11:20	215.0	1.52	0.88	0.44
05/30/95	14:10	100.0	1.36	0.37	0.18
06/16/95	9:45	92.1	2.59	0.64	0.32
01/02/96	15:30	13.0	1.25	0.04	0.02
01/26/96	15:15	18.1	1.07	0.05	0.03
02/05/96	16:15	196.0	67.23	35.52	17.76
04/01/96	12:15	142.0	19.09	7.31	3.65
04/24/96	17:00	236.6	38.00	24.23	12.12
05/17/96	14:05	510.0	58.77	80.80	40.40
12/29/96	0:00	861.1	47.19	109.54	54.77
12/31/96	8:30	6520.0	301.16	5293.14	2646.57
01/02/97	0:00	3340.0	307.43	2767.97	1383.98
04/21/97	11:00	139.8	5.71	2.15	1.08
01/27/98	13:36	325.1	6.90	6.04	3.02

Table C-5c
Bear Creek, 1,000 Springs Suspended Load Sampling Data (TSR, 1998)

Date	Time	Discharge	Suspended Sediment	Suspended Sediment	Estimated Susp. Sand
(mm/dd/yy)		(cfs)	(ppm)	(T/day)	(T/day)
01/11/95	13:20	85.5	9.00	2.07	1.04
01/13/95	13:25	208.2	82.00	46.03	23.01
01/14/95	15:00	616.0	26.00	43.17	21.59
01/18/95	13:40	59.6	5.00	0.80	0.40
01/23/95	14:20	29.7	1.46	0.12	0.06
01/27/95	13:15	28.6	2.26	0.17	0.09
01/30/95	13:00	50.6	2.69	0.37	0.18
02/01/95	16:00	465.3	23.56	29.55	14.77
02/02/95	1:30	286.5	13.93	10.76	5.38
02/06/95	14:45	107.7	2.21	0.64	0.32
02/12/95	15:15	67.0	1.75	0.32	0.16
02/15/95	15:10	54.8	2.59	0.38	0.19
02/20/95	15:25	46.1	0.41	0.05	0.03
03/01/95	12:45	64.7	0.33	0.06	0.03
03/02/95	12:00	102.2	14.07	3.88	1.94
03/03/95	11:30	210.0	15.92	9.01	4.51
03/04/95	16:00	147.2	7.08	2.81	1.41
03/08/95	11:00	81.3	1.64	0.36	0.18
03/09/95	13:15	730.0	364.90	718.06	359.03
03/10/95	13:00	858.0	77.28	178.74	89.37
03/11/95	13:30	1150.0	64.19	199.00	99.50
03/13/95	15:05	493.6	114.52	152.39	76.19
03/14/95	14:40	930.0	47.98	120.29	60.15
03/18/95	15:30	497.6	19.15	25.69	12.85
03/21/95	16:30	545.0	17.42	25.59	12.80
03/28/95	13:45	183.9	1.65	0.82	0.41
04/06/95	12:00	640.0	81.67	140.89	70.45
04/13/95	16:30	502.0	9.88	13.37	6.68
04/29/95	14:30	940.0	94.15	238.56	119.28
05/01/95	11:10	800.0	45.68	98.50	49.25
05/03/95	15:45	435.0	9.95	11.66	5.83
05/12/95	13:00	215.0	3.53	2.05	1.02
05/30/95	15:00	102.8	0.97	0.27	0.13
6/16/95	10:30	92.0	5.83	1.45	0.72
1/2/96	14:30	14.5	0.94	0.04	0.02
1/26/96	15:50	17.3	0.73	0.03	0.02
2/5/96	17:00	196.0	172.69	91.24	45.62
4/1/96	13:45	142.0	35.66	13.65	6.83
4/24/96	17:35	237.0	64.22	41.03	20.51
5/17/96	15:00	537.0	122.59	177.45	88.73
12/30/96	0:00	1544.0	70.65	294.05	147.03
4/21/97	12:05	161.0	5.13	2.23	1.11
1/27/98	15:00	325.0	8.20	7.18	3.59

Table C-6
Bear Creek Annual Sediment Yield

Water Year	Pondosa Sus. Load (tons/yr)	Bed Load (tons/yr)	Total Load (tons/yr)	Spaulding Sus. Load (tons/yr)	Bed Load (tons/yr)	Total Load (tons/yr)	1,000 Springs Sus. Load (tons/yr)	Bed Load (tons/yr)	Total Load (tons/yr)
1931	0	0	0	0	0	0	0	0	0
1932	12	12	25	6	3	9	10	34	44
1933	6	6	13	3	2	5	5	20	26
1934	12	13	26	6	1	7	10	24	34
1935	76	79	155	37	12	49	62	174	235
1936	26	26	52	13	5	18	21	66	87
1937	61	65	125	29	9	38	49	131	180
1938	8540	12349	20889	3242	171	3413	6554	5232	11786
1939	42	39	81	23	15	38	35	161	196
1940	336	364	700	161	40	201	272	660	932
1941	1063	1211	2274	487	86	574	851	1655	2506
1942	1059	1210	2270	486	94	579	848	1693	2541
1943	896	984	1880	424	102	526	722	1681	2403
1944	247	250	498	125	50	174	202	655	858
1945	363	392	755	174	48	222	293	737	1030
1946	288	308	596	139	39	178	233	600	833
1947	75	76	151	38	16	54	61	205	267
1948	527	589	1115	245	50	296	423	899	1322
1949	70	72	141	35	13	47	57	174	231
1950	151	161	312	73	21	94	123	320	443
1951	229	238	468	113	39	152	187	546	733
1952	1697	1957	3654	771	130	900	1356	2530	3886
1953	1056	1161	2217	499	118	617	851	1967	2818
1954	972	1083	2055	455	101	556	782	1721	2503
1955	255	262	517	127	47	174	208	640	848
1956	3423	4285	7708	1463	180	1642	2697	3896	6593
1957	877	948	1825	420	111	531	709	1765	2473
1958	2764	3208	5972	1250	210	1461	2206	4077	6283
1959	278	286	564	139	52	192	227	708	935
1960	387	421	809	185	51	236	313	778	1091
1961	214	220	434	107	38	144	175	527	702
1962	334	362	697	160	41	201	270	660	930
1963	1531	1825	3356	679	103	782	1217	2063	3280
1964	59	57	116	31	17	48	48	192	241
1965	5710	7754	13464	2281	175	2456	4432	4565	8997
1966	704	804	1508	323	66	389	564	1144	1708
1967	961	1072	2033	449	100	549	773	1701	2473
1968	228	234	462	115	44	158	187	586	772
1969	1798	2099	3897	809	132	942	1434	2584	4018
1970	2660	3207	5867	1172	183	1355	2110	3578	5688
1971	1949	2195	4144	903	180	1083	1564	3254	4818
1972	939	1000	1939	455	125	580	761	1974	2735
1973	1013	1128	2142	474	109	584	815	1822	2637
1974	4975	6189	11165	2136	263	2399	3924	5754	9678
1975	1880	2119	3999	871	176	1047	1509	3152	4660

Table C-6
Bear Creek Annual Sediment Yield (Continued)

Water Year	Pondosa Sus. Load (tons/yr)	Bed Load (tons/yr)	Total Load (tons/yr)	Spaulding Sus. Load (tons/yr)	Bed Load (tons/yr)	Total Load (tons/yr)	1,000 Springs Sus. Load (tons/yr)	Bed Load (tons/yr)	Total Load (tons/yr)
1976	355	360	715	179	67	246	290	922	1212
1977	23	20	43	13	12	25	19	108	127
1978	791	890	1681	366	74	440	635	1317	1952
1979	125	132	257	61	20	81	102	284	386
1980	352	390	741	165	40	205	283	650	933
1981	78	79	156	39	16	56	64	209	273
1982	2795	3470	6265	1204	161	1365	2206	3353	5559
1983	3630	4281	7911	1620	243	1863	2889	4970	7859
1984	2254	2502	4756	1056	218	1273	1813	3922	5735
1985	860	906	1765	420	121	541	698	1872	2570
1986	2197	2555	4752	995	177	1172	1754	3319	5073
1987	715	753	1468	350	104	453	581	1577	2158
1988	104	102	206	54	28	82	86	327	413
1989	248	269	518	119	32	150	200	497	698
1990	21	22	43	11	6	17	18	64	81
1991	11	10	21	6	3	8	9	34	42
1992	3	2	5	1	1	2	2	11	13
1993	582	672	1254	265	47	312	465	889	1354
1994	12	12	25	6	3	9	10	36	46
1995	2039	2511	4550	880	105	984	1611	2350	3961
1996	1474	1872	3346	622	70	692	1158	1563	2721
1997	10482	15337	25819	3930	166	4095	8023	5763	13786
Average	1192	1485	2677	515	79	594	941	1513	2454
Maximum	10482	15337	25819	3930	263	4095	8023	5763	13786
Minimum	0	0	0	0	0	0	0	0	0
Total	79896	99469	179364	34496	5281	39777	63064	101339	164403

Table C-7a
Hydraulic Conditions Read's Bridge to Fletcher's Bridge (DWR-3 and DWR-7 averaged)

Discharge (cfs)	Discharge in Main Channel (cfs)	Velocity in Main Channel (ft/sec)	Hydraulic Depth in Main Channel (ft)	Slope (ft/ft)
380	380	0.85	3.85	0.00019
562	562	0.98	4.33	0.00020
682	682	1.05	4.73	0.00020
808	808	1.12	5.10	0.00021
1,360	1,360	1.42	6.08	0.00023
1,940	1,932	1.68	6.67	0.00026
3,050	2,937	2.08	8.14	0.00028
4,250	3,906	2.44	9.20	0.00032
5,880	5,024	2.77	10.40	0.00035

Table C-8a
Bed Material Size Distribution for the Fall River from Read's Bridge to Fletcher's Bridge

Diameter (mm)			Percent in Interval
Lower	Upper	Mean*	
0.0625	0.125	0.088	2.3
0.125	0.25	0.177	9.7
0.25	0.5	0.354	30
0.5	1	0.707	24
1	2	1.41	15
2	4	2.83	10
4	8	5.66	6
8	16	11.31	3

Table C-8b
Bed Material Size Distribution for the Fall River from Fletcher's Bridge to Island Road Bridge

Diameter (mm)			Percent in Interval
Lower	Upper	Mean*	
0.0625	0.125	0.088	10.5
0.125	0.25	0.177	29.9
0.25	0.5	0.354	26.3
0.5	1	0.707	15.9
1	2	1.41	8.6
2	4	2.83	5.7
4	8	5.66	2.5
8	16	11.31	0.6

*is the geometric mean.

Table C-9a
Computed Sediment Transport for Bed Material Based on Young's Equations, Read's Bridge to Fletcher's Bridge

Discharge (cfs)	Concentration (ppm)	Load (tons/days)
380	4.5	4.6
562	7.6	11.6
682	10.1	18.5
808	12.25	27.1
1360	26.3	96.5
1940	43.6	226.9
3050	71.1	562.6
4250	111.6	1175.1
5880	156.8	2123.4

Table C-9b
Computed Sediment Transport Rates for Bed Material Based on Young's Equations, Fletcher's Bridge to Spring Creek

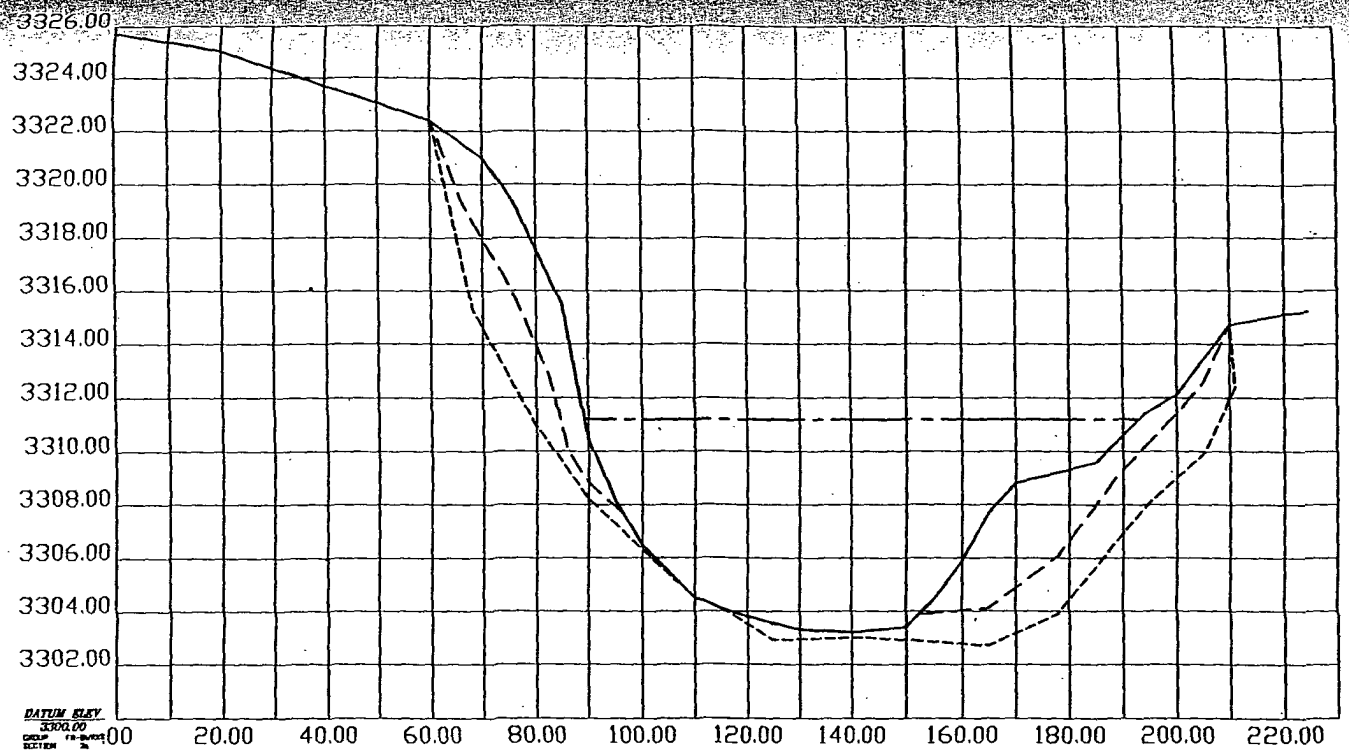
Discharge (cfs)	Concentration (ppm)	Load (tons/days)
380.0	2.7	2.7
562.0	2.4	3.7
682.0	2.7	4.9
808.0	2.9	6.4
1360.0	5.5	20.2
1940.0	9.4	49.1
3050.0	16.7	136.8
4250.0	34.5	392.7
5880.0	67.1	1048.6

Table C-9c
Computed Sediment Transport Rates for Bed Material on Young's Equations,
Spring Creek to Island Road Bridge

Discharge (cfs)	Concentration (ppm)	Load (tons/days)
597.0	3.5	5.6
779.0	4.0	8.3
899.0	4.5	10.9
1025.0	5.0	13.8
1577.0	6.4	25.6
2157.0	8.6	45.0
3430.0	11.3	82.6
4467.0	10.9	91.7
6097.0	10.8	103.0

Table C-10
Upper Fall River, Annual Total Loads for Individual Reaches

Water Year	Reach 1 Annual Total Load Yield	Reach 2 Annual Total Load Yield	Reach 3 Annual Total Load Yield
1931	963	730	1554
1932	1031	744	1583
1933	836	671	1454
1934	813	662	1439
1935	1150	752	1608
1936	1153	779	1649
1937	1175	778	1648
1938	6662	2400	2800
1939	2049	1054	2151
1940	2310	1086	2228
1941	3283	1261	2593
1942	3540	1331	2724
1943	3675	1383	2818
1944	2808	1234	2502
1945	2745	1203	2448
1946	2569	1165	2373
1947	2101	1067	2175
1948	2620	1151	2358
1949	1860	1000	2050
1950	1846	980	2019
1951	2559	1169	2378
1952	4143	1417	2918
1953	3943	1434	2924
1954	3662	1372	2799
1955	2739	1213	2463
1956	5322	1540	3212
1957	3841	1428	2903
1958	5745	1758	3628
1959	2688	1153	2337
1960	2805	1217	2477
1961	2526	1162	2363
1962	2508	1143	2333
1963	3739	1332	2744
1964	2222	1103	2244
1965	5984	1762	3106
1966	3074	1251	2554
1967	3651	1370	2796
1968	2687	1205	2445
1969	4247	1433	2951
1970	5237	1596	3295
1971	4996	1607	3294
1972	4054	1475	2997
1973	3820	1408	2871
1974	6856	1903	3699
1975	4926	1596	3271
1976	3114	1301	2635
1977	2118	1079	2195
1978	3156	1261	2579
1979	2144	1071	2187
1980	2529	1148	2344
1981	2084	1061	2165
1982	4914	1500	3111
1983	6193	1734	3607
1984	5578	1722	3531
1985	3982	1465	2975
1986	5015	1586	3263
1987	3705	1411	2863
1988	2408	1146	2328
1989	2348	1111	2268
1990	1805	993	2033
1991	1407	877	1819
1992	1156	797	1674
1993	2200	1012	2106
1994	1499	904	1869
1995	3814	1298	2697
1996	3265	1221	2522
1997	7267	2581	2759
Average	3207	1265	2518
Maximum	7267	2581	3699
Minimum	813	662	1439
Total	214866	84758	168707



r:\ New\1390\09\X-secs.dwg [layer dwn-03] - 5/18/98 - BC

Source: Tetra Tech 1998

Legend

——— Channel

— - — Water Surface

— — — Recent Sediment

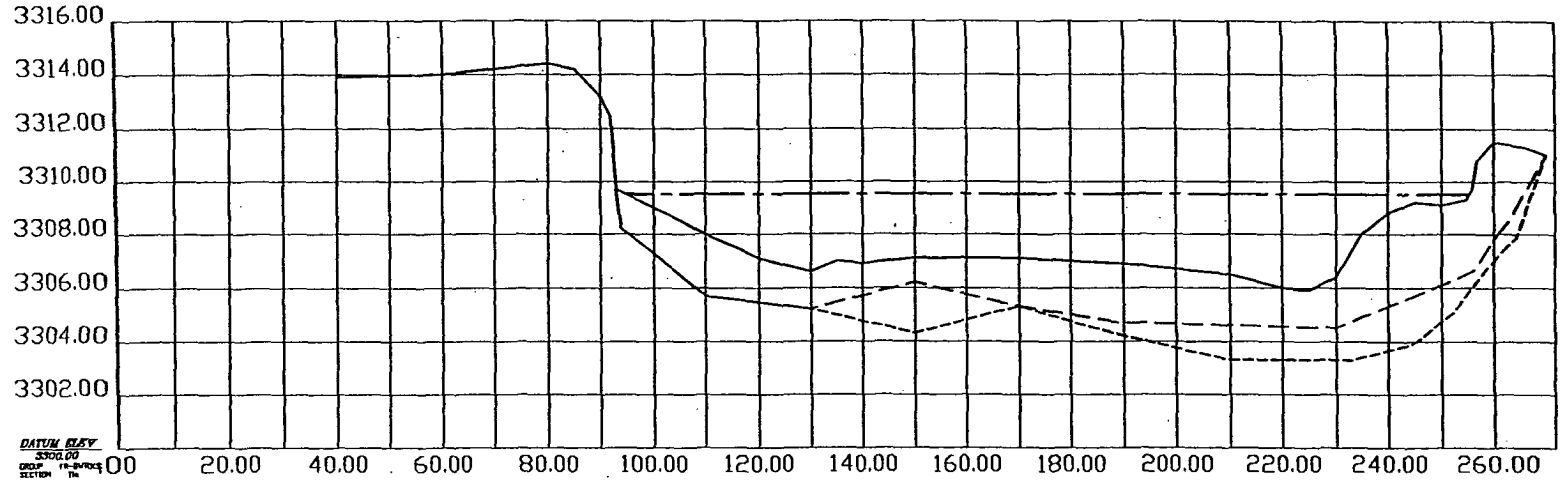
------ Older Sediment

DWR Cross Section 3

Upper Fall River Watershed, California

Appendix C
Figure C-1

Tetra Tech, Inc.



Source: Tetra Tech 1998

Legend

- Channel
- Water Surface
- Recent Sediment
- Older Sediment

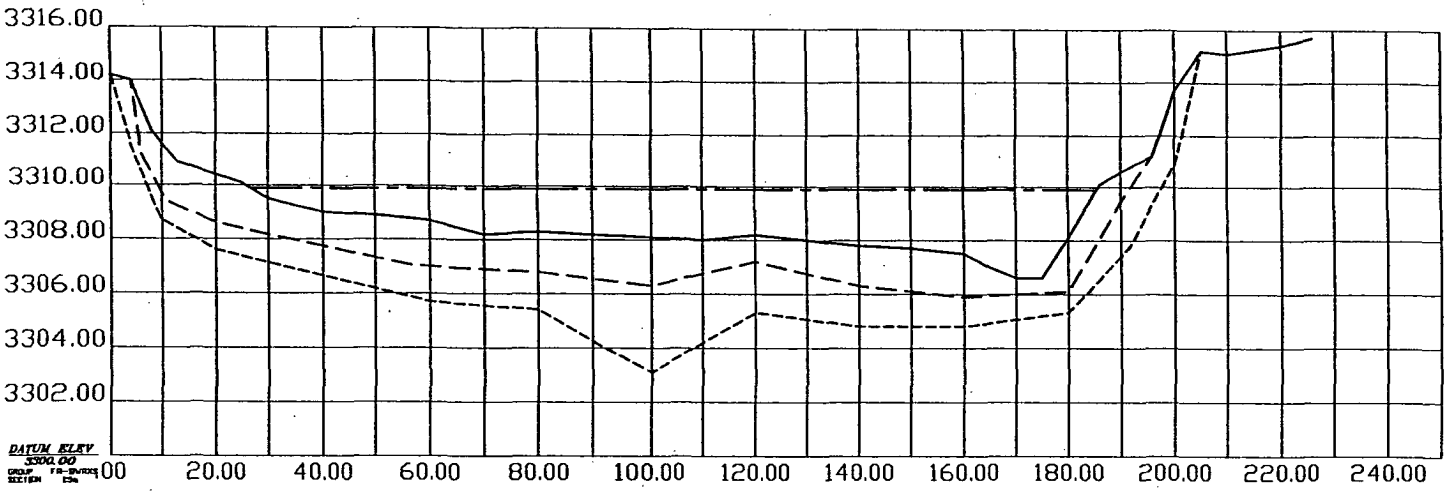
DWR Cross Section11

Upper Fall River Watershed, California

Appendix C
Figure C-5

Tetra Tech, Inc.

r:\ New\1390\03\X-secs.dwg (layer dwn-11) - 5/18/98 - BC



Source: Tetra Tech 1998

Legend

- Channel
- Water Surface
- Recent Sediment
- Older Sediment

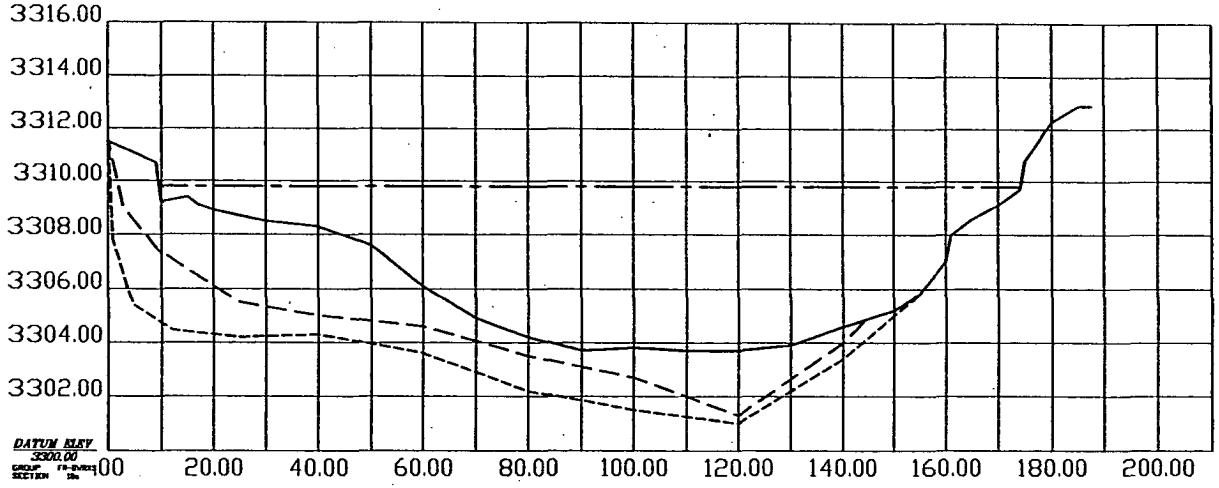
DWR Cross Section 15

Upper Fall River Watershed, California

Appendix C
Figure C-6

Tetra Tech, Inc.

r:\ New\1390\09\X-secs.dwg (layer dwn-15) - 5/18/98 - BC



Source: Tetra Tech 1998

Legend

- Channel
- Water Surface
- Recent Sediment
- Older Sediment

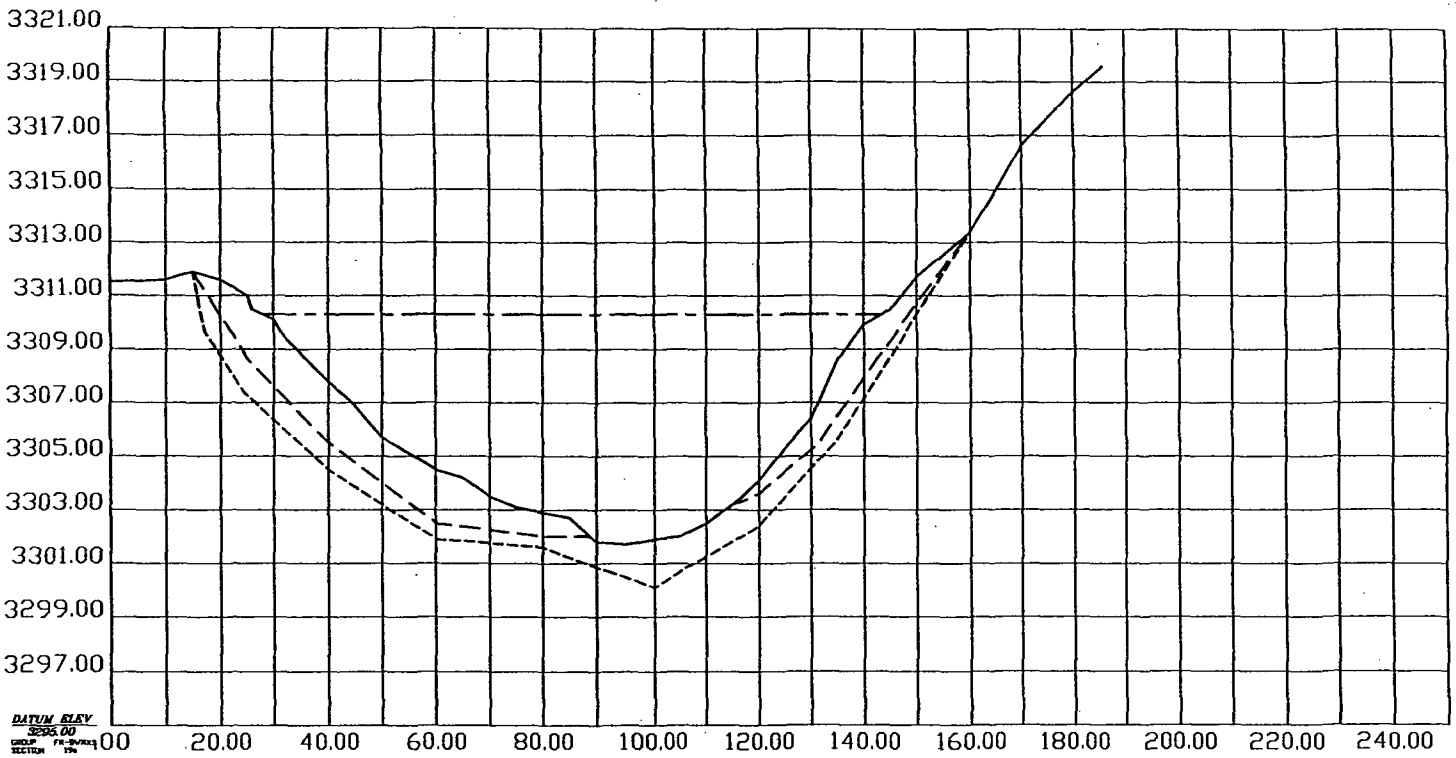
DWR Cross Section18

Upper Fall River Watershed, California

Appendix C
Figure C-7

Tetra Tech, Inc.

r:\ New\1390\03\X-secs.dwg (layer dwn-18) - 5/18/98 - BC



r:\ New\1390\09\X-secs.dwg (layer dwr-19) - 5/18/98 - BC

Source: Tetra Tech 1998

Legend

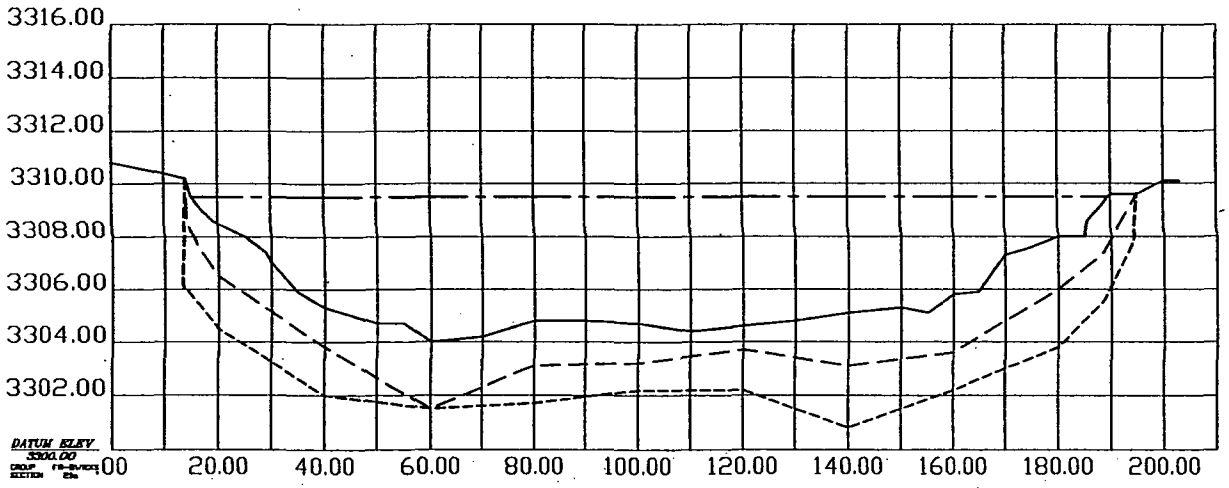
- Channel
- Water Surface
- Recent Sediment
- Older Sediment

DWR Cross Section 19

Upper Fall River Watershed, California

Appendix C
Figure C-8

Tetra Tech, Inc.



Source: Tetra Tech 1998

Legend

- Channel
- Water Surface
- Recent Sediment
- Older Sediment

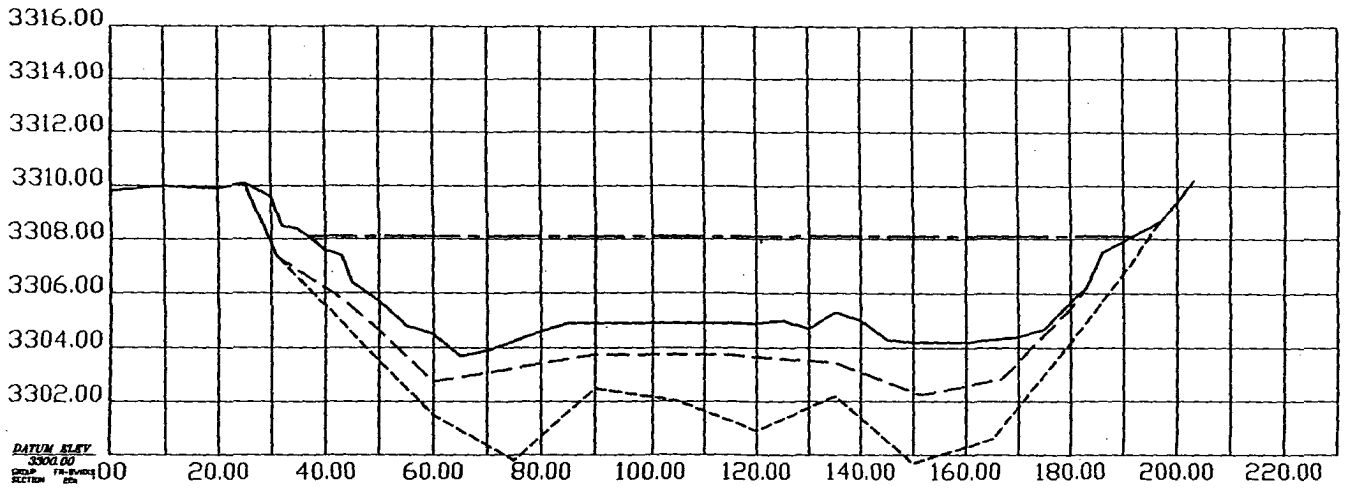
DWR Cross Section 21

Upper Fall River Watershed, California

Appendix C
Figure C-9

Tetra Tech, Inc.

r:\ New\1390\03\X-secs.dwg (layer dwr-21) - 5/18/98 - BC



Source: Tetra Tech 1998

Legend

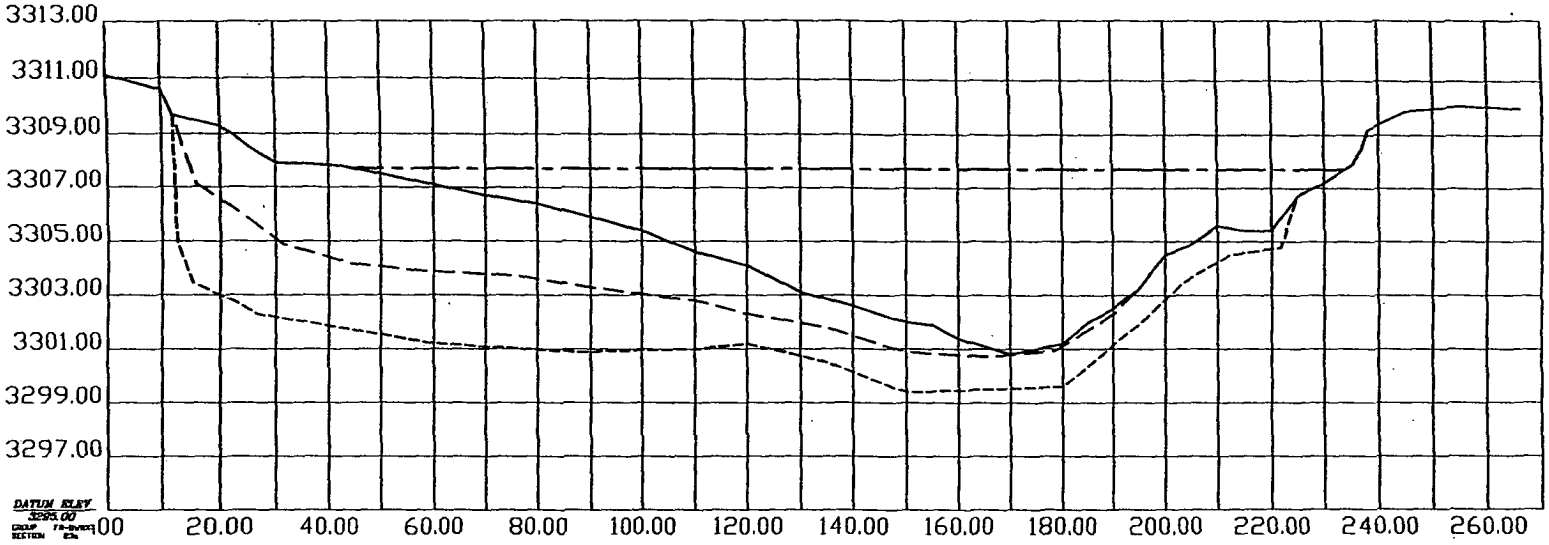
- Channel
- Water Surface
- Recent Sediment
- Older Sediment

DWR Cross Section 22

Upper Fall River Watershed, California

Appendix C
Figure C-10

Tetra Tech, Inc.



Source: Tetra Tech 1998

Legend

- Channel
- Water Surface
- Recent Sediment
- Older Sediment

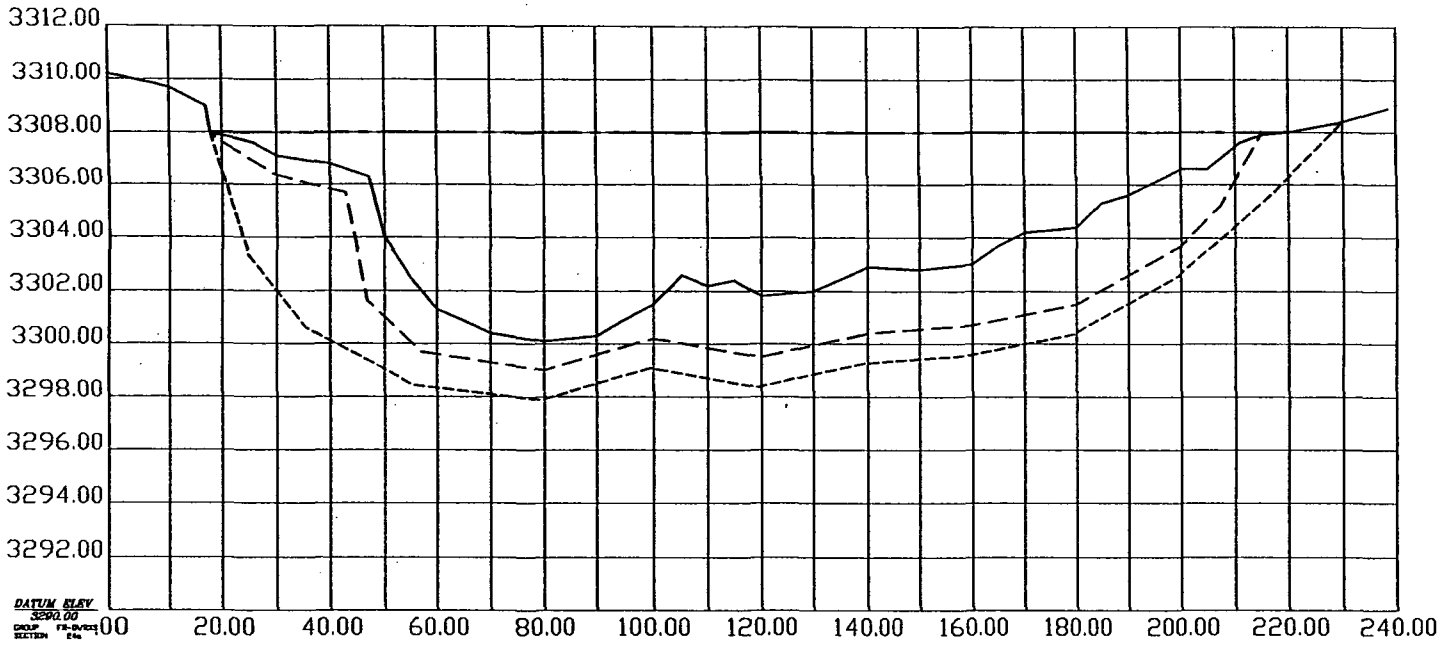
DWR Cross Section 23

Upper Fall River Watershed, California

Appendix C
Figure C-11

Tetra Tech, Inc.

r:\ New\1390\09\X-secs.dwg (layer dwn-23) - 5/18/98 - BC



Source: Tetra Tech 1998

Legend

- Channel
- Water Surface
- Recent Sediment
- Older Sediment

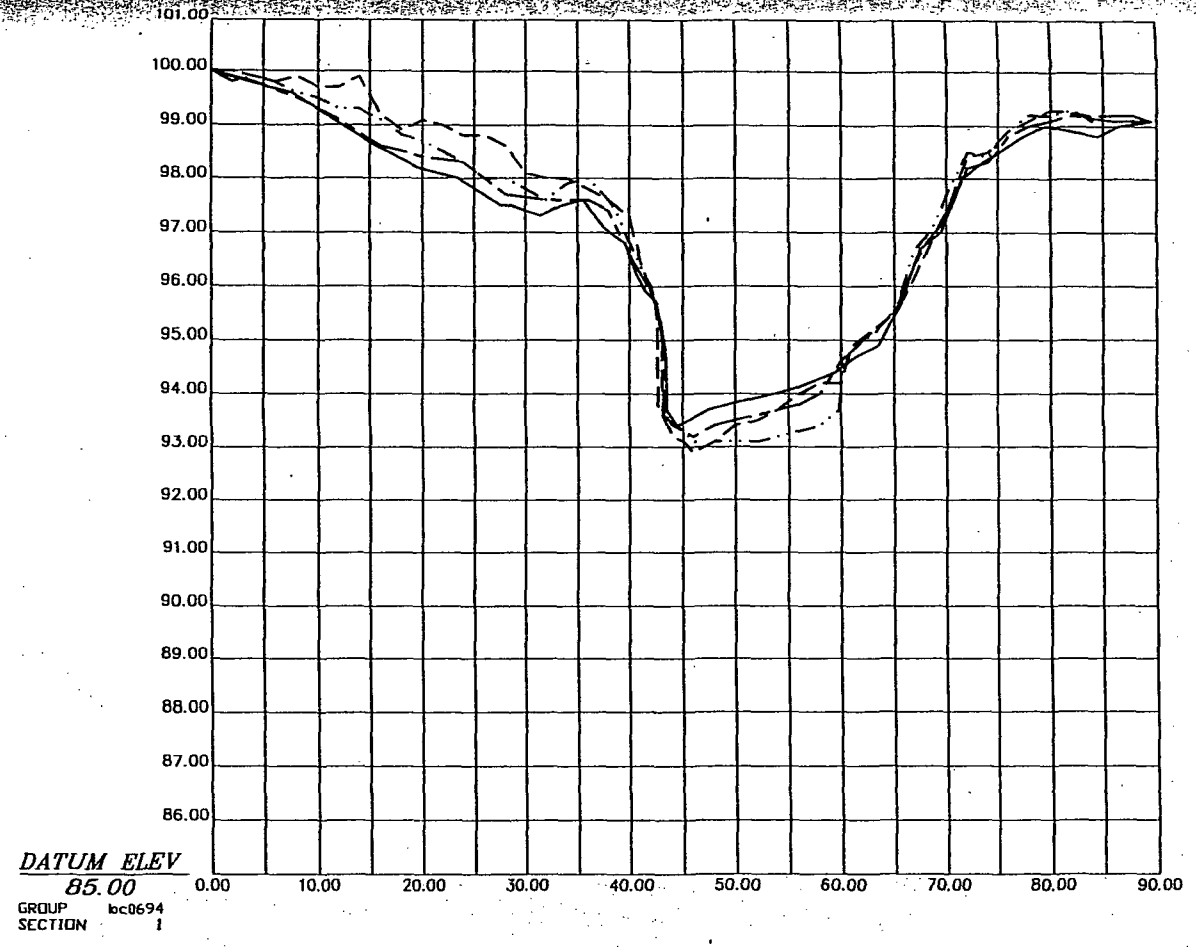
DWR Cross Section 24

Upper Fall River Watershed, California

Appendix C
Figure C-12

Tetra Tech, Inc.

r:\ New\1390\09\X-secs.dwg (layer dwr-24) - 6/18/98 - BC



r:\ New\1390.09\X-secs.dwg (layer tsr-01) - 5/18/98 - BC

Source: Tetra Tech 1998

Legend

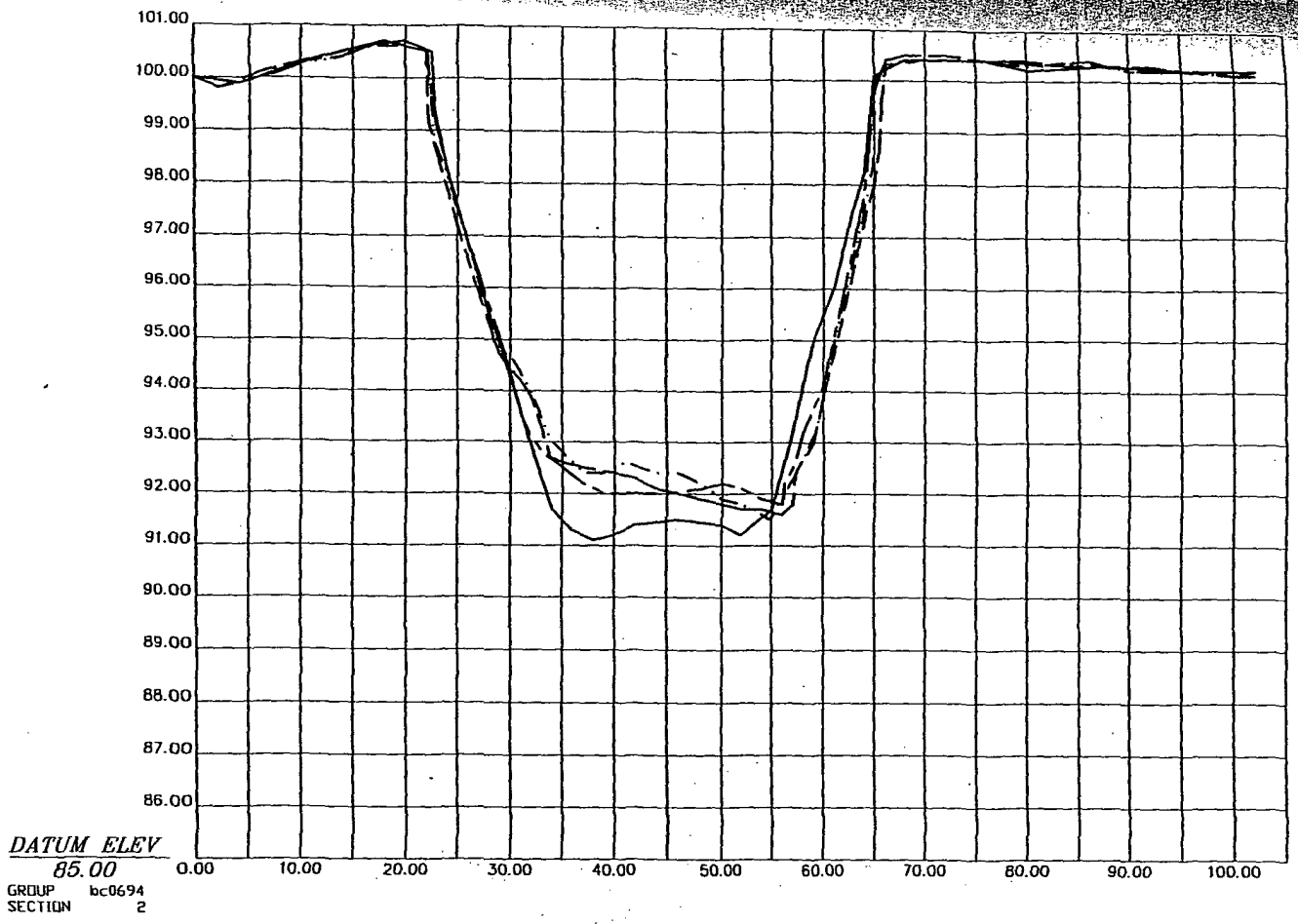
- BC0694
- BC1095
- BC0796
- BC0697

TSR Cross Section 1

Upper Fall River Watershed, California

Appendix C
Figure C-13

Tetra Tech, Inc.



r:\ New\1389\09X-eccs.dwg (layer tsr-02) - 5/18/98 - BC

Source: Tetra Tech 1998

Legend

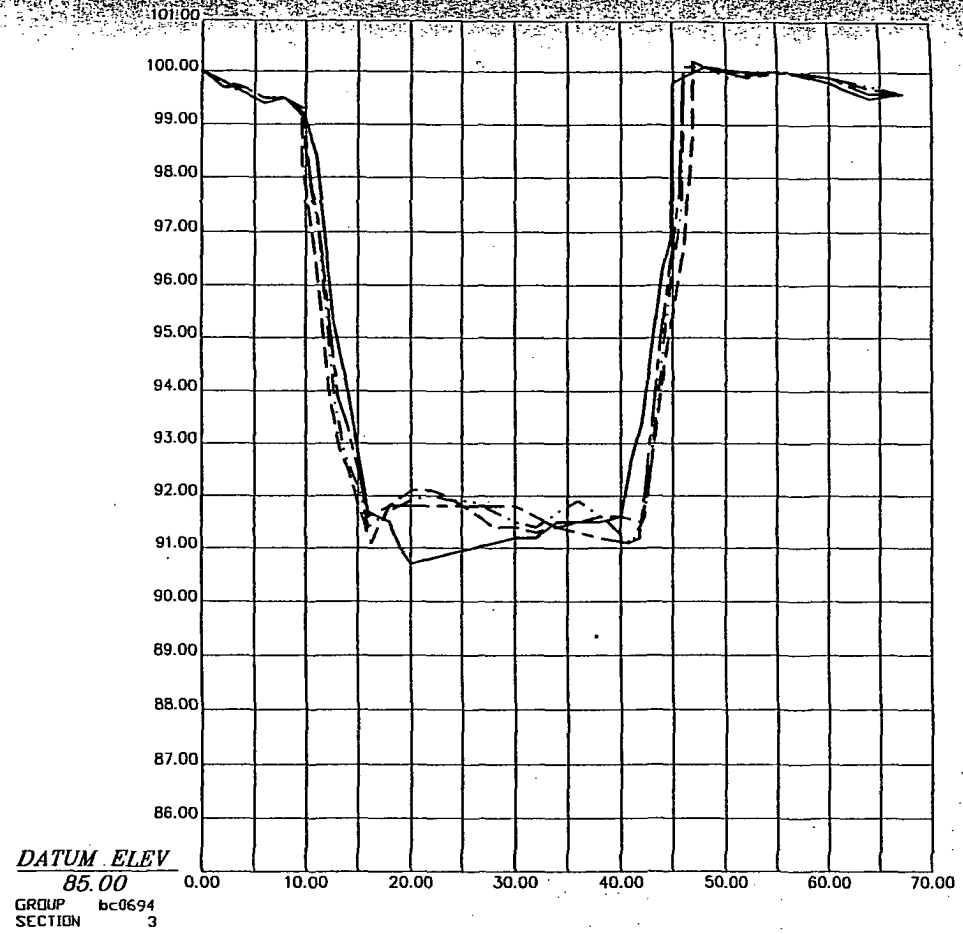
- BC0694
- BC1095
- BC0796
- BC0697

TSR Cross Section 2

Upper Fall River Watershed, California

Appendix C
Figure C-14

Tetra Tech, Inc.



Source: Tetra Tech 1998

r:\ New\1390\08\X-secs.dwg (layer tsr-03) - 5/18/98 - BC

Legend

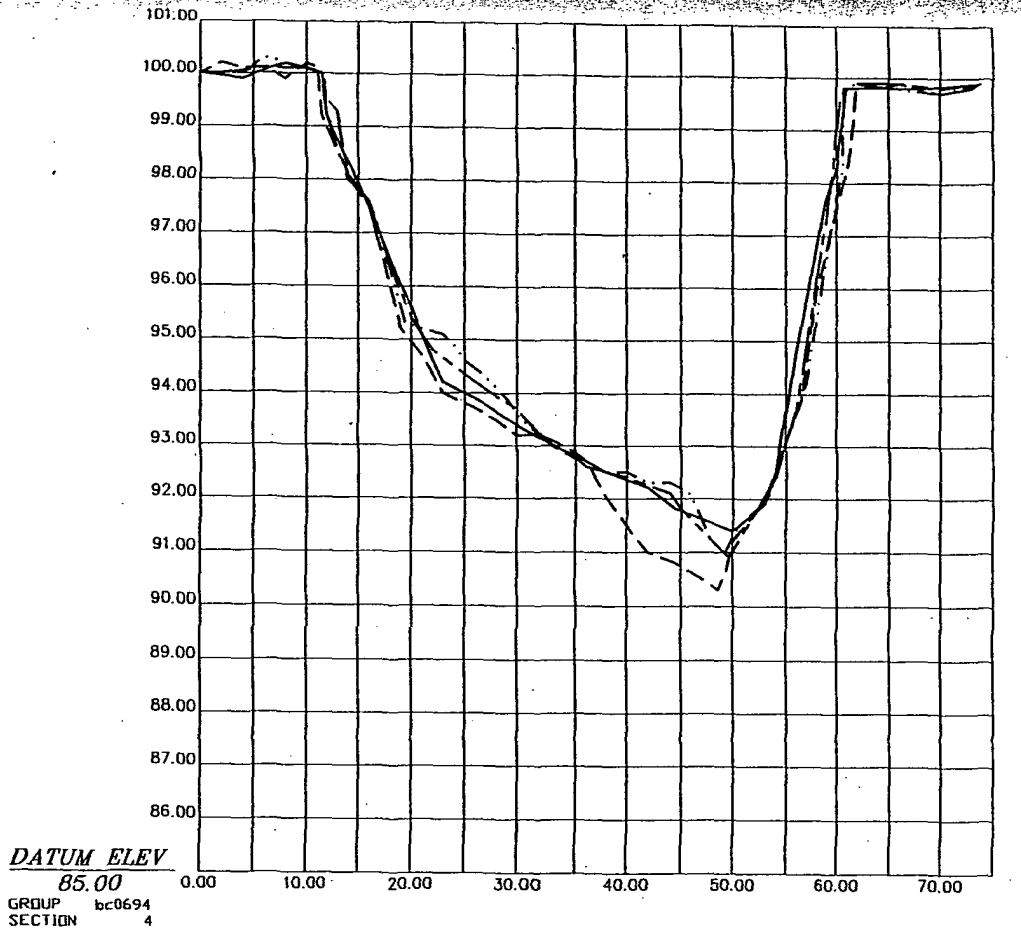
- BC0694
- BC1095
- BC0796
- BC0697

TSR Cross Section 3

Upper Fall River Watershed, California

Appendix C
Figure C-15

Tetra Tech, Inc.



Source: Tetra Tech 1998

Legend

- BC0694
- BC1095
- BC0796
- BC0697

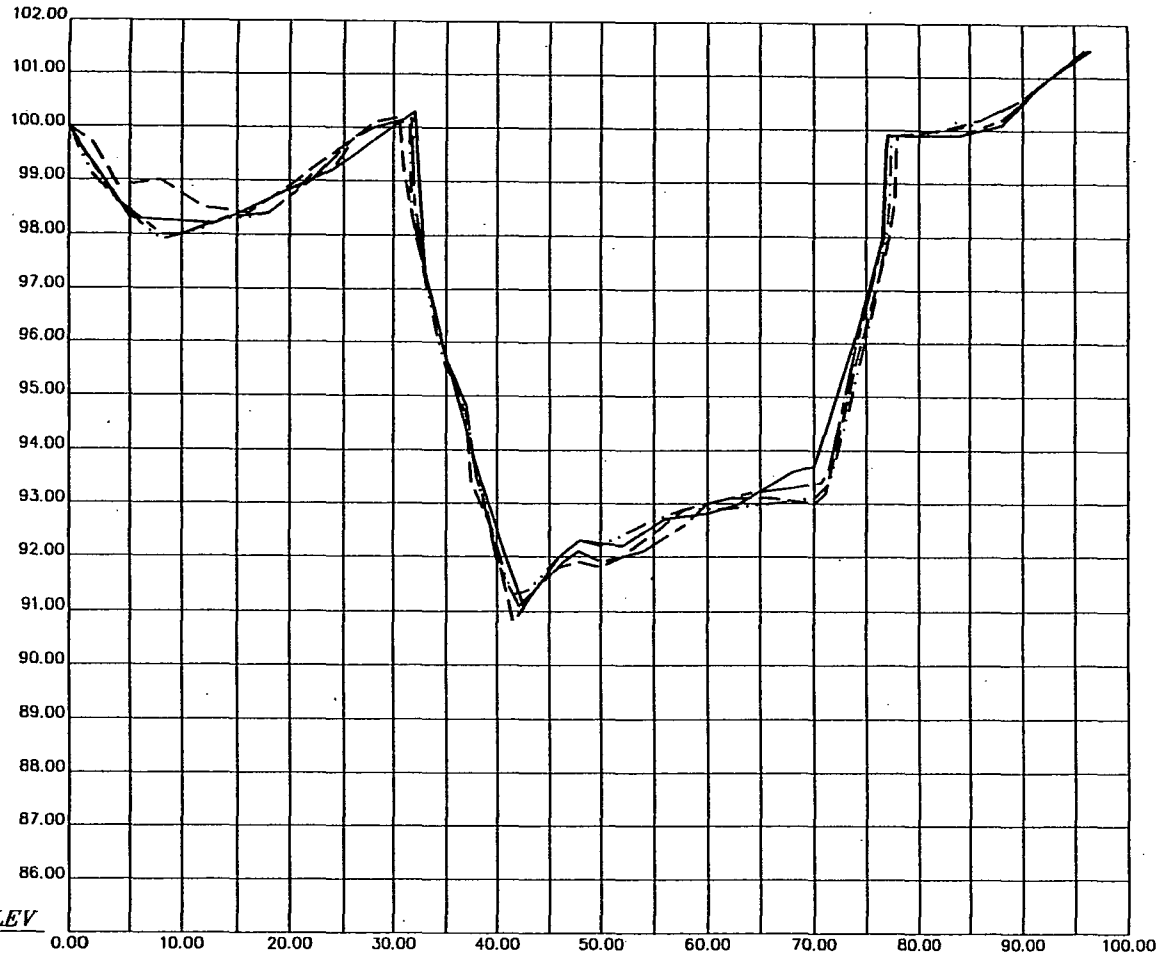
TSR Cross Section 4

Upper Fall River Watershed, California

Appendix C
Figure C-16

Tetra Tech, Inc.

r:\ New\1390\09\X-secs.dwg (layer tsn-04) - 5/18/98 - BC



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Source: Tetra Tech 1998

Legend

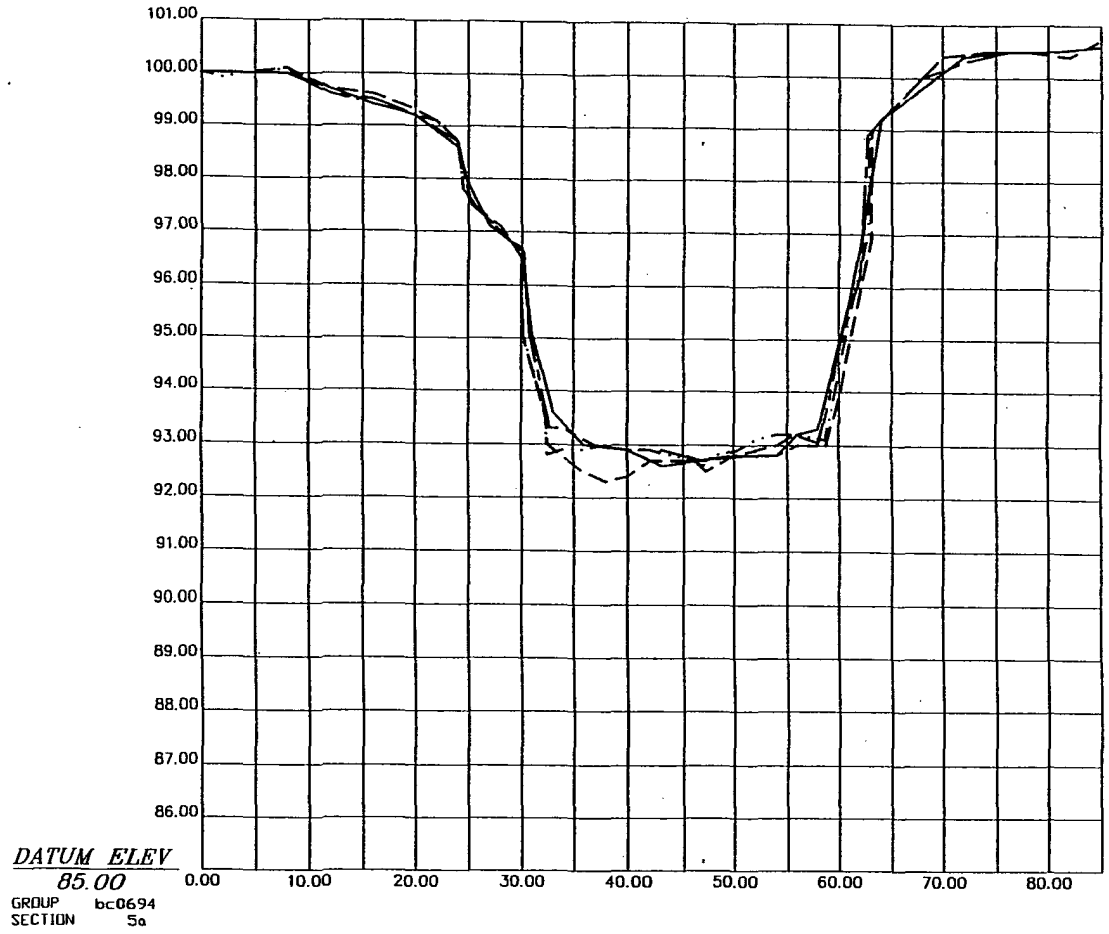
- BC0694
- BC1095
- BC0796
- BC0697

TSR Cross Section 5

Upper Fall River Watershed, California

Appendix C
Figure C-17

Tetra Tech, Inc.



r:\ New\1390\09X-eecs.dwg (layer tsr-05a) - 5/18/98 - BC

Source: Tetra Tech 1998

Legend

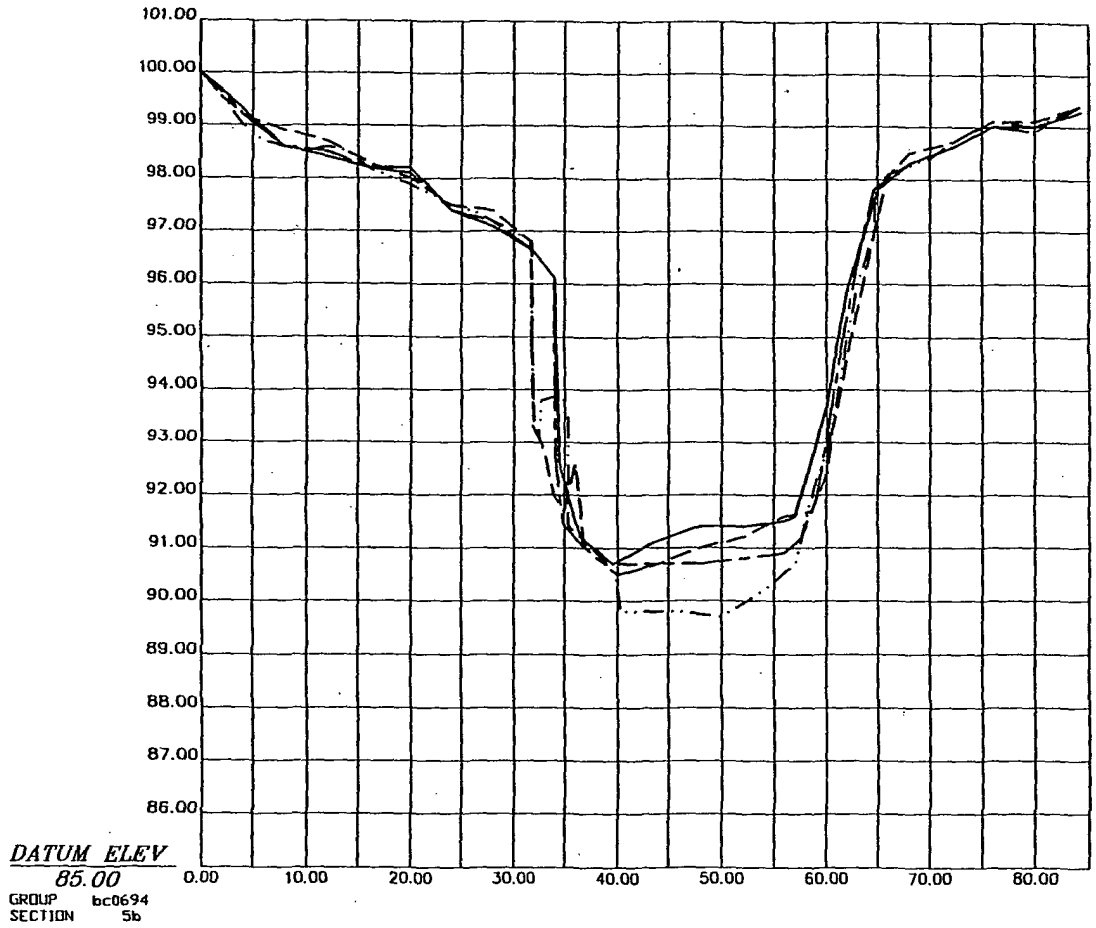
- BC0694
- BC1095
- BC0796
- BC0697

TSR Cross Section 5a

Upper Fall River Watershed, California

Appendix C
Figure C-18

Tetra Tech, Inc.



Source: Tetra Tech 1998

Legend

- BC0694
- BC1095
- BC0796
- BC0697

TSR Cross Section 5b

Upper Fall River Watershed, California

Appendix C
Figure C-19

Tetra Tech, Inc.

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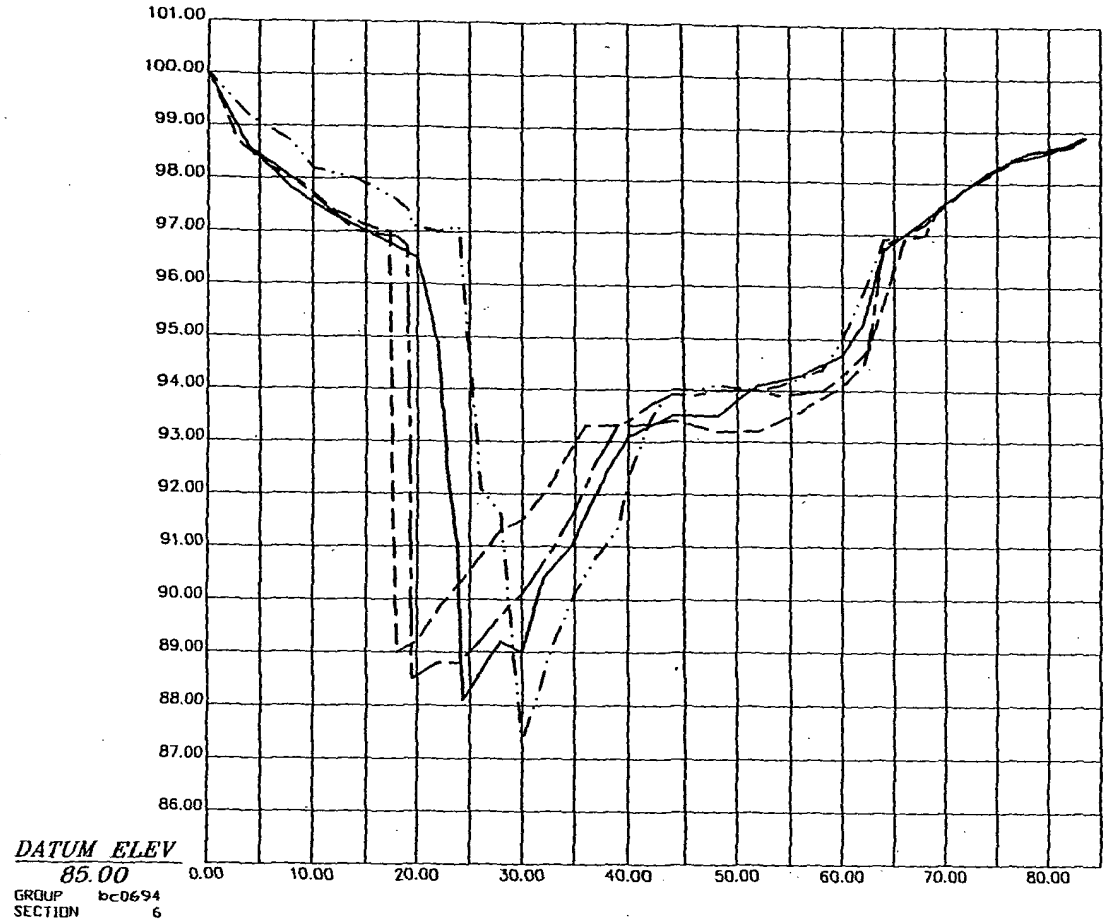

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Source: Tetra Tech 1998

Legend

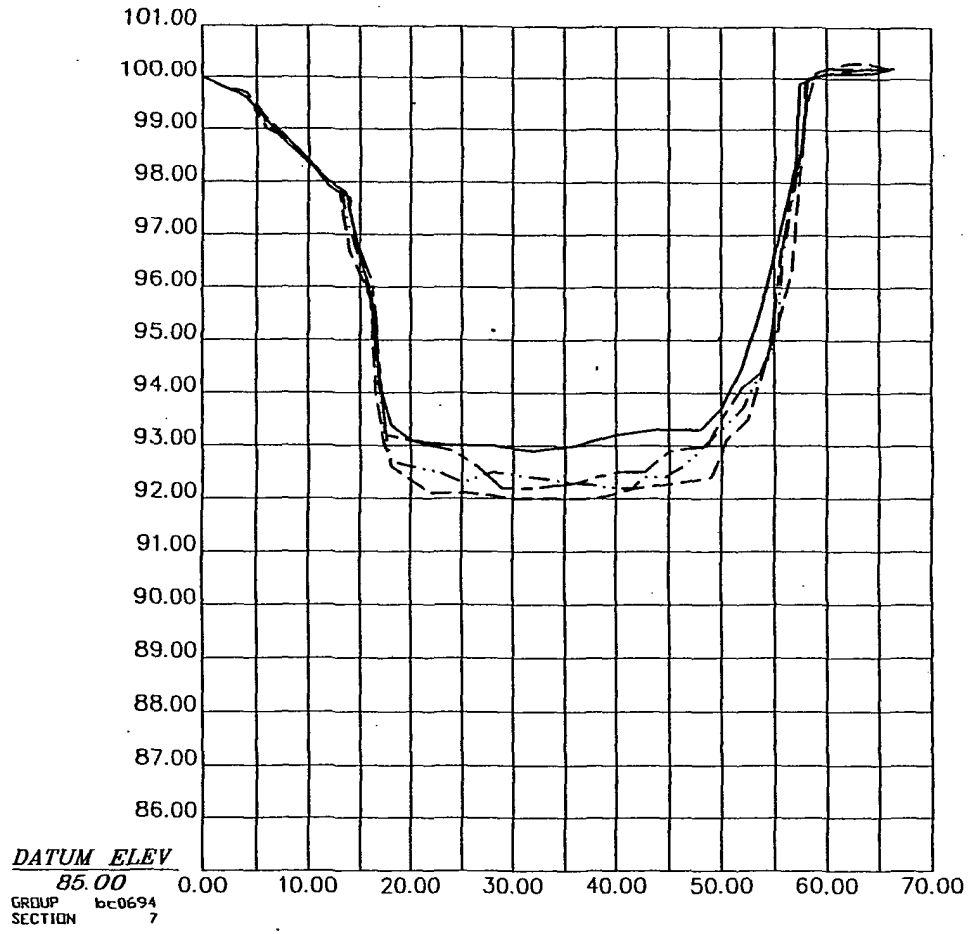
- BC0694
- BC1095
- BC0798
- BC0697

TSR Cross Section 6

Upper Fall River Watershed, California

Appendix C
Figure C-20

Tetra Tech, Inc.



Source: Tetra Tech 1998

Legend

- BC0694
- BC1095
- BC0796
- BC0697

TSR Cross Section 7

Upper Fall River Watershed, California

Appendix C
Figure C-21

Tetra Tech, Inc.

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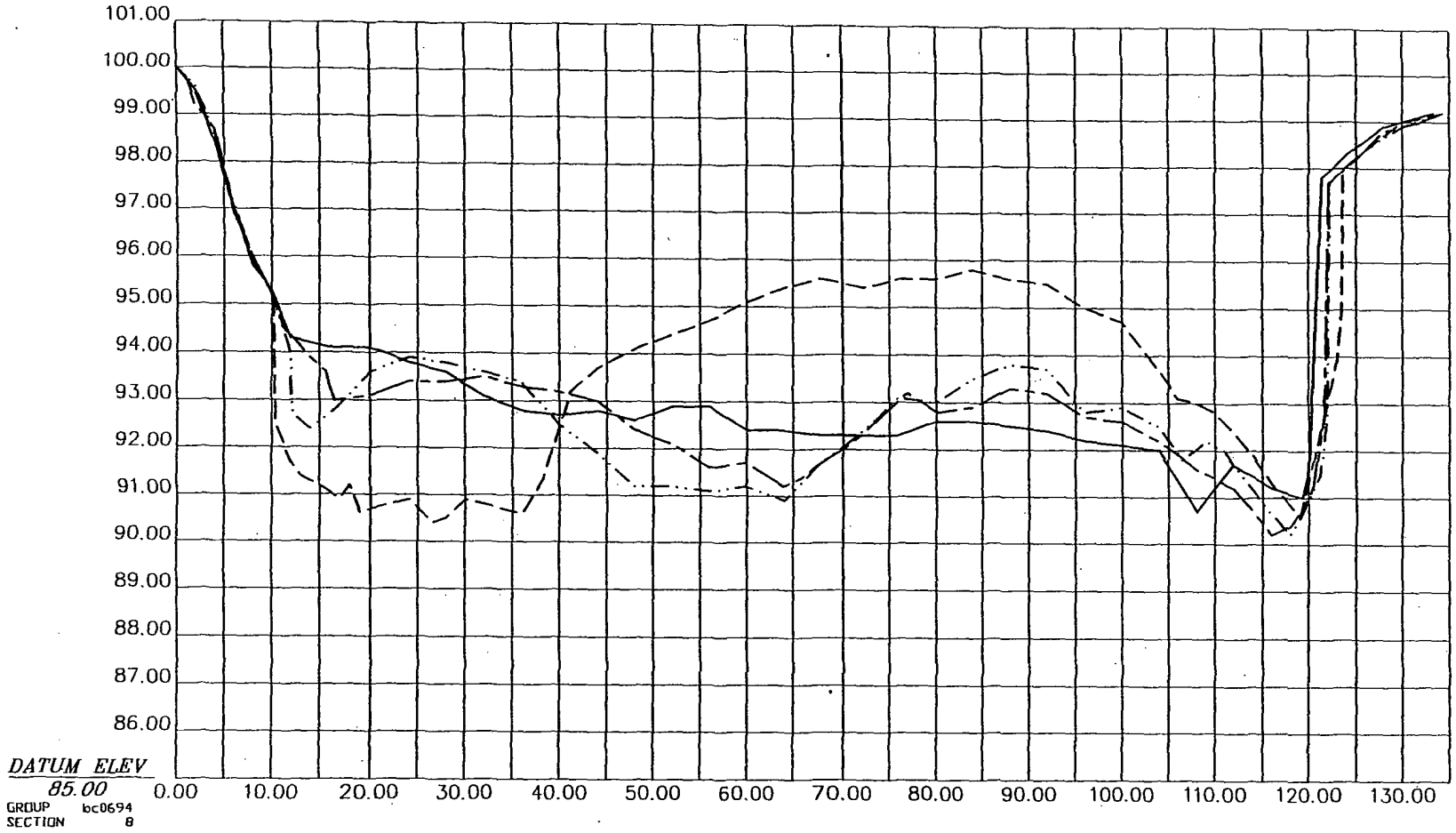

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Source: Tetra Tech 1998

Legend

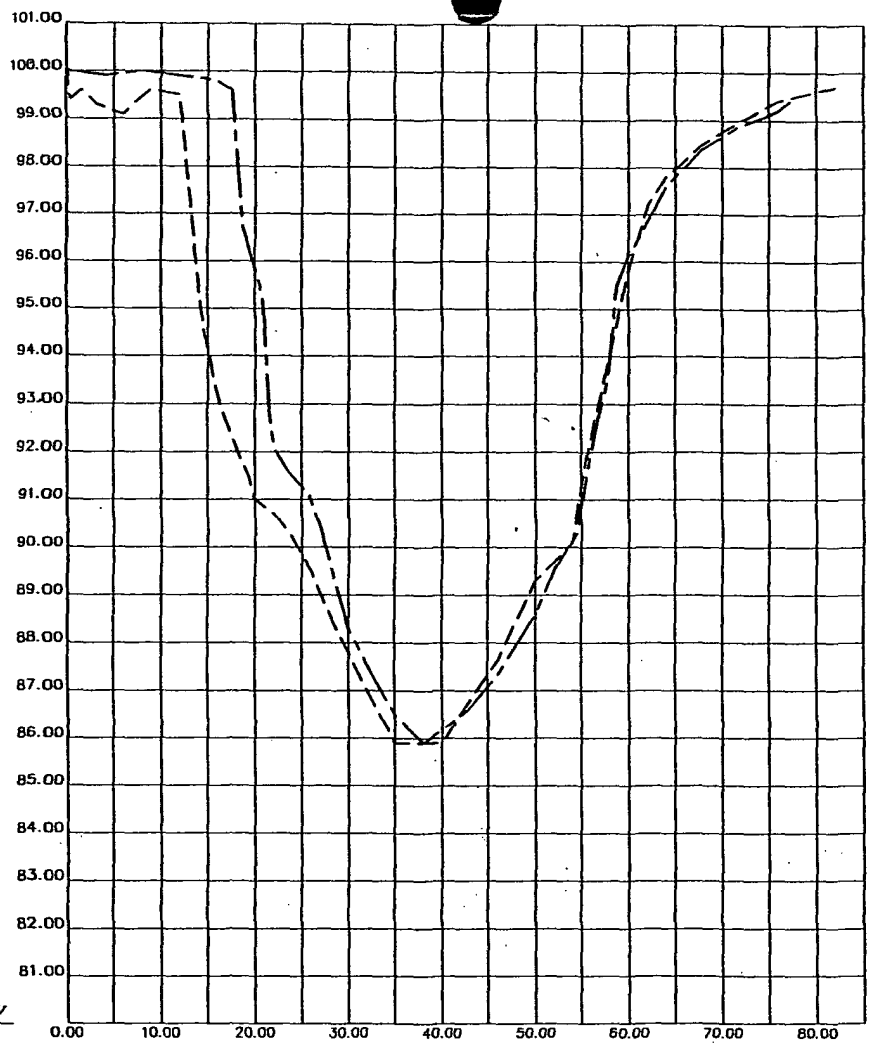
- BC0694
- BC1095
- BC0796
- BC0697

TSR Cross Section 8

Upper Fall River Watershed, California

Appendix C
Figure C-22

Tetra Tech, Inc.



Source: Tetra Tech 1998

Legend

- BC0694
- BC1095
- BC0796
- BC0697

TSR Cross Section 9

Upper Fall River Watershed, California

Appendix C
Figure C-23

Tetra Tech, Inc.

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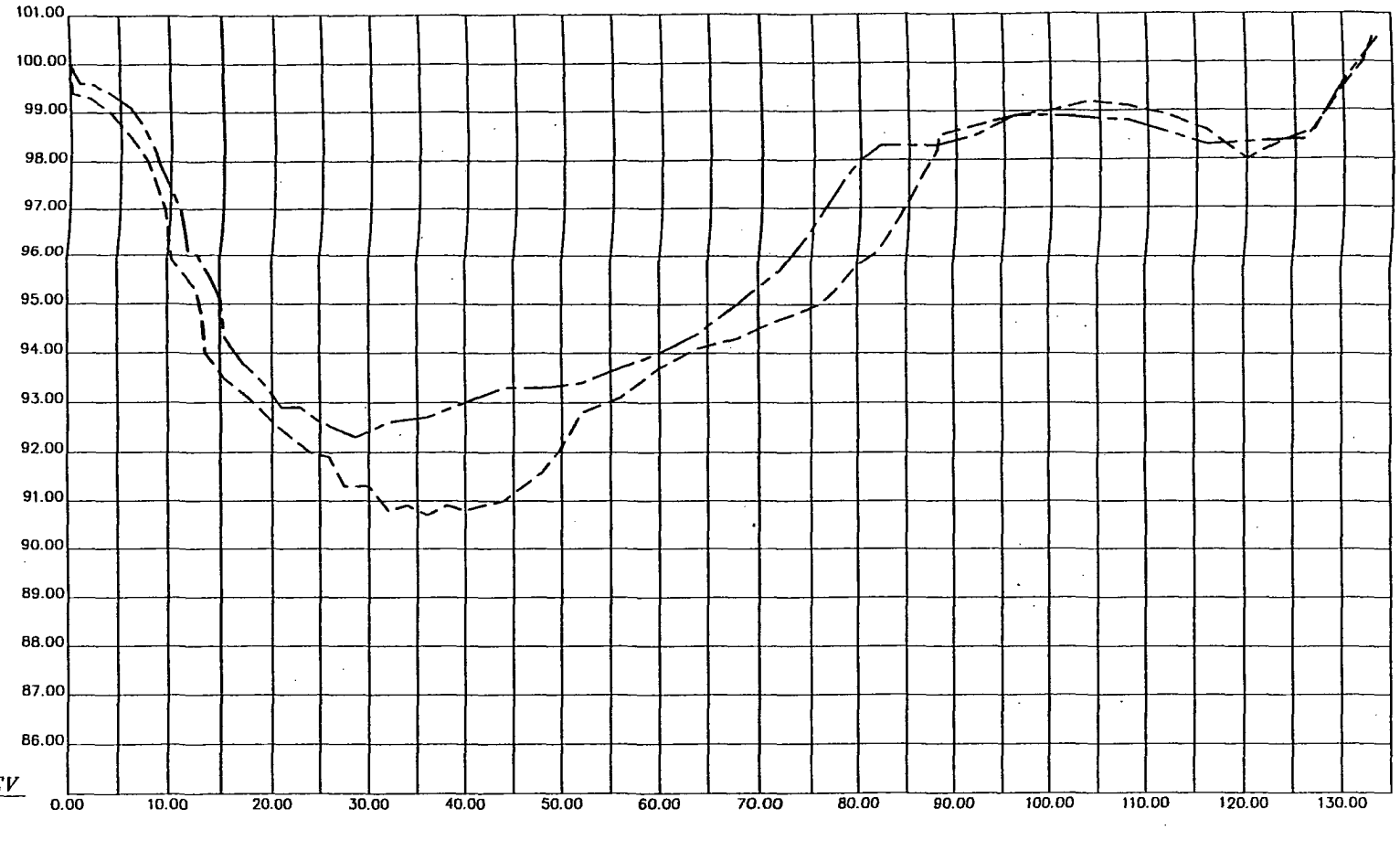

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Source: Tetra Tech 1998

Legend

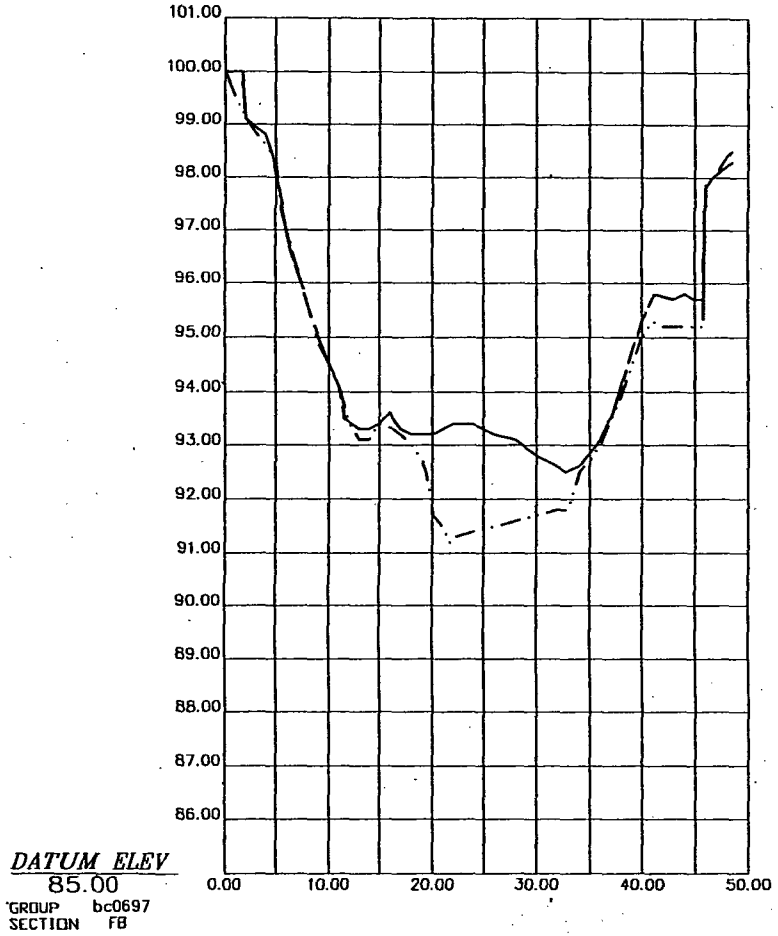
- BC0694
- BC1095
- BC0796
- BC0697

TSR Cross Section 10

Upper Fall River Watershed, California

Appendix C
Figure C-24

Tetra Tech, Inc.



Source: Tetra Tech 1998

Legend

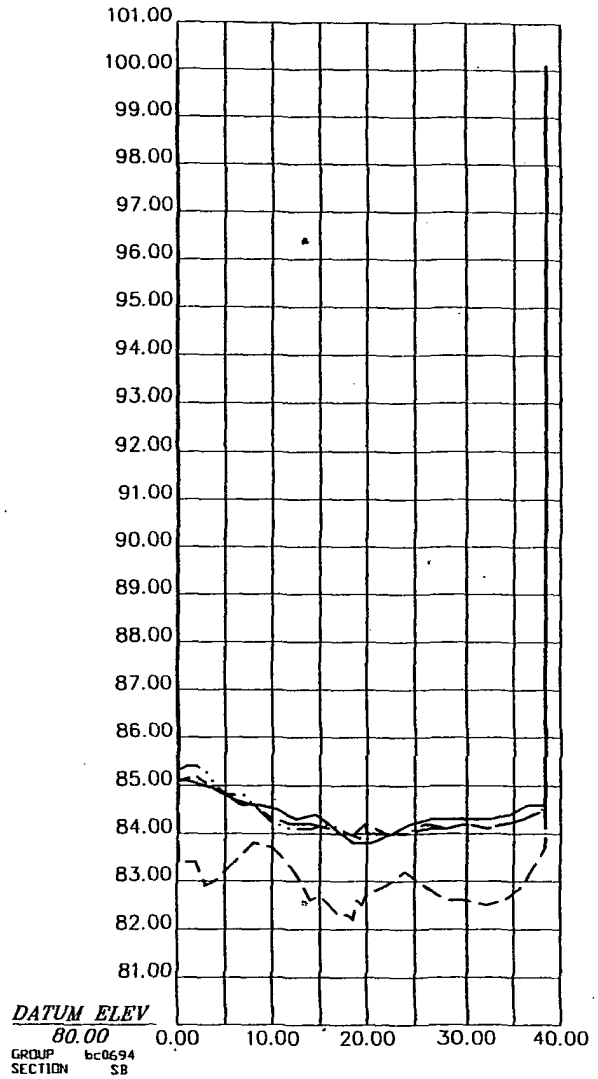
- BC0694
- BC1095
- BC0796
- BC0697

TSR Cross Section FB

Upper Fall River Watershed, California

Appendix C
Figure C-25

Tetra Tech, Inc.



Source: Tetra Tech 1998

F:\ New\1390\09X-eecs.dwg (layer tsr-sb) - 5/18/98 - BC

Legend

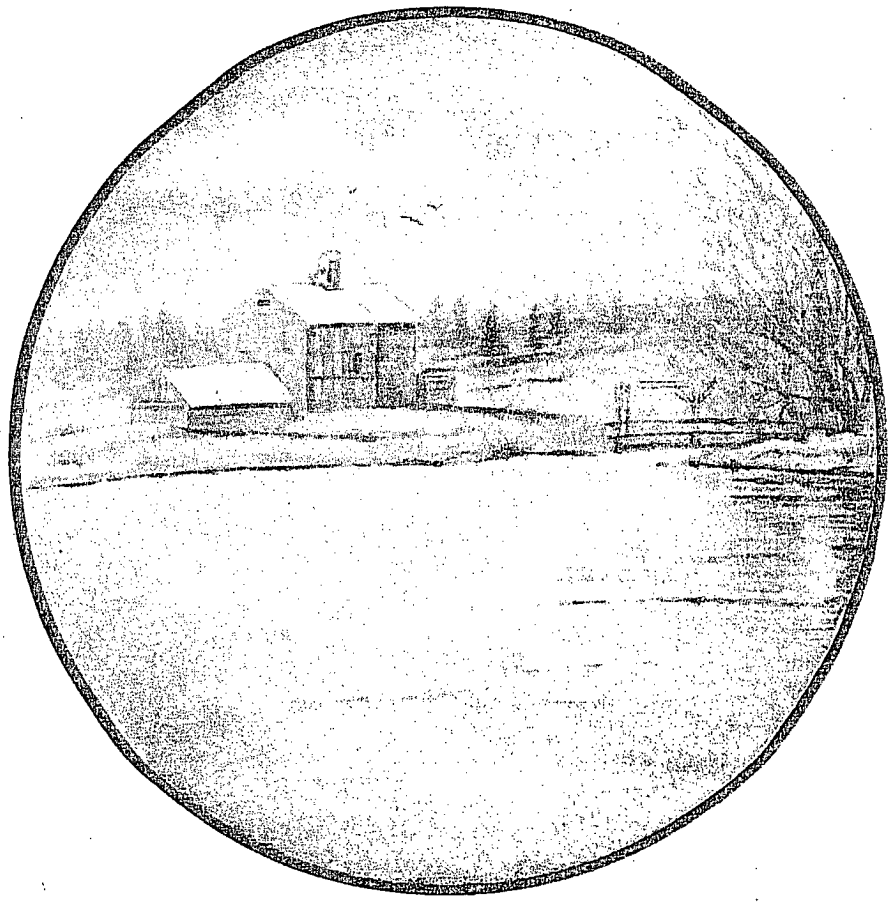
- BC0694
- BC1095
- BC0796
- BC0697

TSR Cross Section SB

Upper Fall River Watershed, California

Appendix C
Figure C-26

FALL RIVER
Watershed Area Study



SUMMARY REPORT

Prepared by:
USDA, River Basin Planning Staff
Soil Conservation Service
Davis, California

In cooperation with:
Fall River Resource Conservation District
Fall River Mills, California

JUNE 1983

PREFACE

The purpose of this study is to assist the requesting agencies in the selection of alternatives based on public involvement and evaluation of adverse and beneficial effects on the study objectives: surface and subsurface drainage, water quality, soil erosion, public health, crop production and other concerns.

This Watershed Area Study was requested by the Fall River Resource Conservation District. Other local agencies endorsed this request through board resolutions and other actions requesting the United States Department of Agriculture to conduct a study of the Fall River Valley area. A Proposal to Study (PTS) was prepared and submitted on January 27, 1981, describing the study area and outlining major problems and needs.

Section 6 of the Watershed Protection and Flood Prevention Act, Public Law 566, 83rd Congress, 68 Stat. 666 as amended, authorizes the United States Department of Agriculture to cooperate with federal, state and/or local agencies in cooperative river basin studies. The responsibility and authority of the Resource Conservation Districts (RCDs) are contained in Division 9 of the State Resource Code. This authority allows RCDs to cooperate with other county, state and federal agencies or districts to develop resource management policies and plans. The California Regional Water Quality Control Board, Central Valley Region, is responsible for developing a Water Quality Management Plan, pursuant to Section 208 of the Federal Water Pollution Control Act, for the nondesignated area of the Central Valley Region.

A Steering Committee formed of local agencies and landowners guided and provided input to the study. The Steering committee reviewed the work outline and data developed during the study, evaluated alternative solutions for effectiveness and acceptability, commented and made recommendations, and conducted public meetings before selecting a plan, providing about 65 person days of time. The steering committee members are: Andy Lakey, Chairman, Pres., Fall River RCD, landowner; Rick Swift, Forester, Beatty and Associates,

landowner; Fred Morrison, Director, Shasta County Department of Health; Richard Stockett, President, Intermountain Haygrowers Association, Landowner; Jim Krause, Central Valley Regional Water Quality Control Board; John Ghiorso, Landowner; Gary Clark, Landowner; Fred Meyer, Landowner; Zereda Jensen, Landowner; and Bill Judge, Landowner.

The California Regional Water Quality Control Board, Central Valley Region, participated in the study by providing about 1/2 person-year of time and water quality laboratory testing for bacteria and nutrients. The Fall River Resource Conservation District assisted by providing about 1/2 person-year of time to collect data, take samples and interview people residing in the study area. The California Department of Fish and Game provided 10 person-days of time to collect and review data and to make recommendations. The Shasta County Health Department collected and tested water quality samples on 25 wells and assisted in locating contamination sources. The California Department of Water Resources, USDI-Indian Health Services and Pacific Gas and Electric provided water quality and supply information.

This study augments other studies previously done for water quality by the Department of Fish and Game, the RCD, county and state agencies and the Community Services District. Groundwater and geology have been studied by the Department of Water Resources. Hydrology and geohydrology for power purposes and structure safety studies have been done by PG&E.

Concurrent studies are the Big Valley Soil Survey, a water quality management plan by the Regional Water Quality Control Board, and checking domestic well contamination by the Shasta County Public Health Department. Applicable concurrent study data is included in this study report.

The location map shows the entire 612 square mile watershed. In subsequent maps, the upper watershed is not displayed, only the 98-square mile Fall River Valley portion is shown as the main study area. This division was made because of the few feasibly treatable problems occurring in the upper watershed that effect the Fall River. The 374 square miles of lava beds have problems associated with off-road vehicles and road erosion (erosion and destruction of tree seedlings). The 140-square mile Bear Creek watershed has

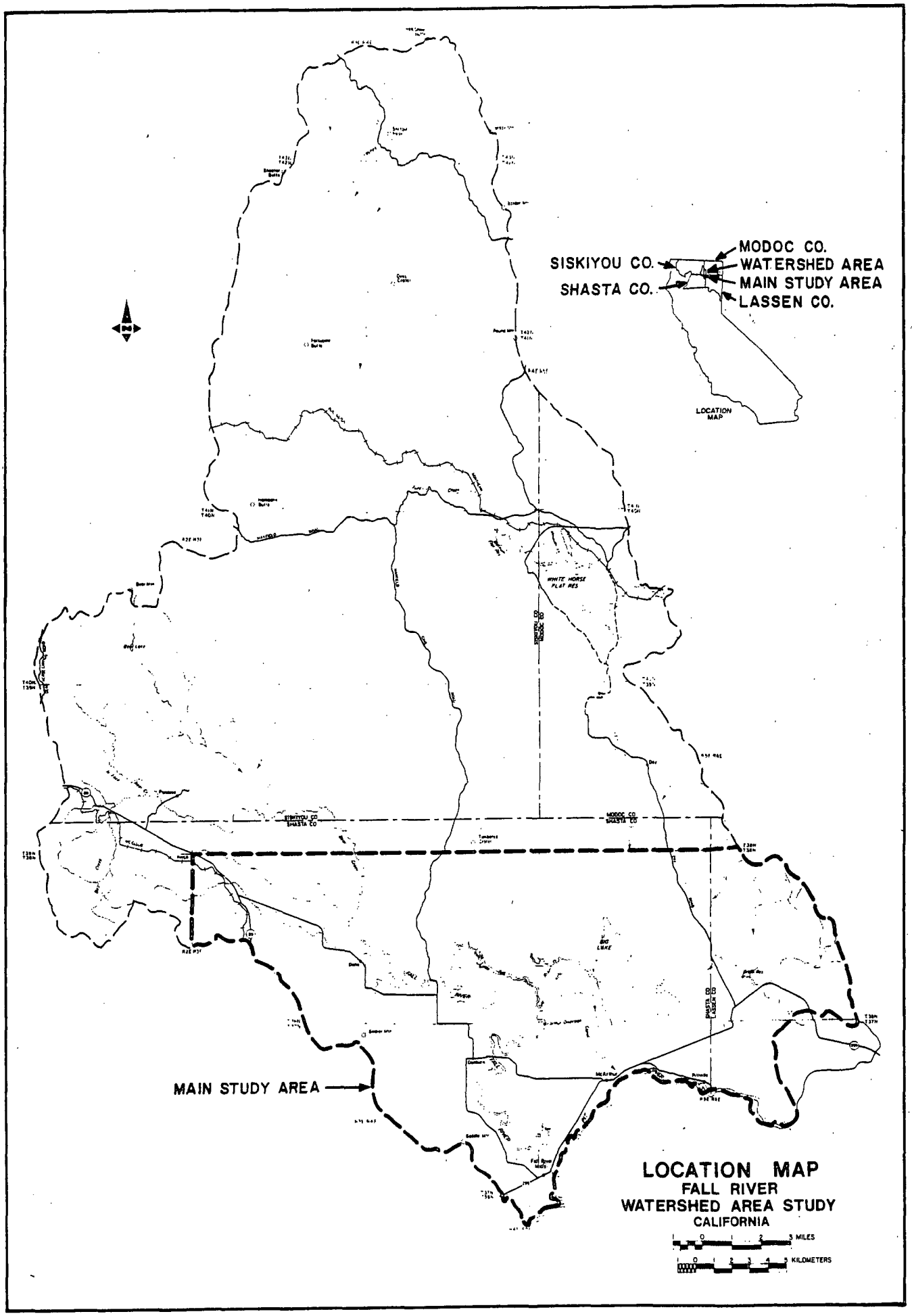
problems with road erosion and streambank erosion. The upper watershed problems are discussed briefly in the section on Problems.

This Summary Report is for general distribution. The Technical Report, including appendices, map descriptions and legends, and references, has been developed to use as a reference document by those who need additional information.

Copies of the Summary Report, Technical Report and documentation for the Fall River Watershed Area Study are on file at the Fall River Mills Field Office, Soil Conservation Service. Copies of he Technical Report are on file at the Fall River Resource conservation District, the Public Library, Shasta County offices and other locations designated by the Steering Committee. Additional copies of the Summary Report may be requested from the Steering Committee.

Copies of the Summary Report Fall River Watershed Area Study and documentation are on file at the Fall River Field Office, Soil Conservation Service.

Copies of the Summary Report are on file at the Fall River Resource Conservation District, the Public Library, Shasta County offices and other locations designated by the Steering Committee.


MODOC CO.
WATERSHED AREA
MAIN STUDY AREA
LASSEN CO.
SISKIYOU CO.
SHASTA CO.
LOCATION MAP
MAIN STUDY AREA
LOCATION MAP
FALL RIVER
WATERSHED AREA STUDY
CALIFORNIA
MILES
KILOMETERS

SUMMARY REPORT

The study area is located in the northeastern corner of Shasta County and adjoining portions of Lassen, Modoc and Siskiyou Counties. Of the 612 sqaure miles of watershed, 97 square miles at the southwestern end comprise the main study area and includes the Fall River Valley. The watershed is located in the volcanic terrain of the southern Cascade Range.

Land use acreage is grouped as follows:

Land Use	Total Watershed (Acres)	Main Study Area (Acres)
Forest Land, Grazed (timber, grazing recreation)	345,710	21,720
Agriculture (pasture, alfalfa, grain, berries)	28,040	26,380
Natural Areas (wetlands, native pasture, parks)	5,530	5,530
Water (lakes, rivers, ponds)	2,260	2,260
Urban (towns, resident areas)	3,600	3,500
Railroads, Roads, Utilities	5,900	2,630
Other (cemetaries, waste ponds, quarries)	150	150
Totals	391,190	62,170

Land ownerships is split almost equally between private and nonprivate, though most of the federal lands lie in steeper watershed lands. In the 62,170-acre main study area, about 15.8 percent is utility owned, 8.3 percent state owned, about 11.0 percent federal owned, and 64.9 percent privately owned.

PURPOSE, OBJECTIVES AND SCOPE

This study was to assist the sponsors in the selection of alternatives to treat problems. The study objective was to assess and provide solutions to maintain water quality, provide a coordinated surface drainage system, improve agricultural productivity and maintain environmental quality.

PROBLEMS

The principal problems in this study area were contaminated domestic water supplies, septic tank failures, siltation of ditches and waterways, loss of farm income from flooding or ponding, high water table, and the loss of wetlands. Other problems were flooding damages to homes and roads, erosion along stream and road banks and losses of cultural values.

Contamination of Water: Water quality of surface water in the Fall River Valley is presently bacteriologically not acceptable for untreated domestic water use and may not be acceptable part of the year, in some areas, for water contact sports. It is acceptable for agricultural uses, fish and wildlife, and hydroelectric generation.

Groundwater quality may not be generally bacteriologically acceptable for domestic uses unless treated, but is acceptable for other uses. Deep groundwater, below 120 feet, was not sampled for fecal coliform bacteria contamination. Domestic wells sampled and found contaminated may have been contaminated through inadequate well seals or well head openings. Approximately 203 wells may need sealing.

Septic tank failure causes contamination of both surface and subsurface water bodies. 73 septic tanks are over a dense slowly and very slowly permeable clay or silica-cemented hardpan, 171 lie in high water table areas and 153 are subject to flooding.

Contamination levels of coliform bacteria were higher in the fall than in the spring, both in surface and ground water.

Nutrients, nitrogen and phosphorous, are presently at acceptable levels in both surface and ground water.

Because the Fall River Valley is a closed and limited basin, the continuing and increasing residential and agricultural contaminant loading will degrade the quality of both surface and groundwater.

Siltation: Soil erosion and sediment are not presently serious problems in the study area. Rates of erosion are generally low, except where the vegetative cover has been removed and where unsurfaced roads are used during the rainy season.

Problems with excessive erosion occurs in the watersheds from unsurfaced roads. Roadways need proper design and construction and maintenance practices applied for water control. New residential properties on the sloping lands, adjacent to the valley and along the Day Bench, need erosion control practices for disturbed areas and adequate water control and drainage structures installed. Sediment delivered to ditches, ponds and streams amount to an estimated 7,170 tons per year from unsurfaced roads and 9,400 tons per year from residential and urban areas.

Agricultural improvements and cultivation practices remove vegetative cover from the land during the winter season. Estimated sediment delivered to the Fall River is 610 tons per year.

Stream or river bank erosion occurs along 90 of the 327 streambank miles. Where vegetative cover has been removed or is heavily grazed, or a large population of muskrats exist, bank erosion is occurring. An estimated 1,600 tons of sediment per year are being delivered to the Fall River from streambank erosion.

Sediment removal costs from drainage ditches, stream channels, and the Fall River are $60,130 per year.

Damages from High Water Table and Septic Tank Failure: Subsurface drainage is restricted, leading to a high water table under about 17,370 acres of the Fall River Valley. The high water table causes about 71 septic tanks to fail or operate improperly each year and reductions in crop yields on 14,940 acres.

A dense slowly and very slowly permeable clay or silica-cemented hardpan layer one to six feet below the ground surface is one restriction on about 14,330 acres. The valley soils are slowly permeable and stratified. High water surface elevations in the lakes and Fall River prevent drainage of land nearby and slows the flow of water from higher elevations. Springs along the north edge of the valley also contribute to the high water table.

Estimated loss in agricultural production is $717,100 per year and increased septic tank costs amount to $22,000 per year from inadequate subsurface drainage.

Damages from Ponding and Flooding: A lack of surface drainage is a problem for agriculture and residences over about 24,120 acres of the valley. Inadequate drainage ways, potholes and flat land contribute to surface ponding and flooding. Flooding from the Fall River occurs frequently, but at shallow depths, because of low banks and flat slopes. Most of the ponding and flooding is discontinuous and less than two feet deep.

Ponding and flooding damages usually are limited to agricultural lands (crops), road inundation and septic tank failures (overflow). Only four to 31 dwellings may have water inside at maximum flooding depths and about 196 garages, barns and outbuildings may receive damages to contents. Surface water contaminates domestic wells and causes driving hazards, both are considered health damages.

The ponding and flooding damages per year are estimated to be $257,500 to agricultural production, $57,300 to roads and $13,900 to dwellings.

Loss of Wetlands and Upland Wildlife Habitat, Recreation and Cultural Resources: Agricultural and residential developments are removing valuable wetland and upland wildlife habitat and special use areas. The development land changes and modernization are also removing or destroying archaeological and historical resources. About 14,900 acres in the Fall River Valley are mapped as wetlands.

Changes in habitat, land form, travelways, human proximity and water quality affect at least three area important nonthreatened and as many as four threatened/rare or endangered water and land dwelling animal species. No plant species were found to be threatened/rare or endangered within the main study area.

Increased recreational activities may affect wildlife through proximity of use and impact the native fish population through increased pollution. Aesthetic values may be reduced by the increase of residential developments and intensified agricultural operations.

SELECTED PLAN

Table 1 summarizes the solutions, costs and impacts of the Selected Plan. The Selected Plan reflects the Sponsor's view of ultimate development and is slightly more ambitious than recommended by the Soil Conservation Service staff, especially in wetland areas.

This alternative would retain the present level of development, with some protective measures, and would provide practices to increase agricultural production in the Fall River Valley. Practices and actions are those that would reduce erosion and sedimentation, provide surface drainage to reduce flooding and ponding damages, provide limited subsurface drainage to increase crop yields and reduce septic tank problems, and, provide irrigation water management to reduce irrigation costs and maintain the existing water balance.

Project proposals shown on the Project Map are approximately located to fit land form and ownership and are intended only as guidelines to future development or actions.

Water quality is addressed by installing 14 miles of filter strip along waterways, installing 4 livestock waste management systems, extending 203 domestic well casings, and providing 60 acres of upland and wetland habitat, treating domestic water in 11 dwellings, installing 46 domestic sewage treatment

systems for individual dwellings and low water fixtures in 360 dwellings. The estimated installation cost for these practices is $1,605,700, the annual cost is $309,900 and the annual direct benefits is $215,500.

Reduction of erosion and sedimentation are addressed by practices installed on 2,560 acres of residential area, 162 miles of (mostly unsurfaced forest) roads, 9,900 acres of agricultural land, and 18 miles of streambank, establishing a muskrat trapping program and by restricting off road vehicle (ORV) use. The estimated installation cost for these practices is $731,000, the annual cost is $204,300 and the annual direct benefits is $269,600.

The drainage practices shown in the plan treat surface waters. Some soil profile drainage will occur to ditches. Lowered water tables will result mostly from reduced surface percolation originating from surface ponding. The drainage may cause a short-term increase in contamination of surface water.

Drainage practices installed are 144 miles of ditches or swales to reduce flooding or ponding on 11,980 acres and drainage for 16,740 acres, chiseling and subsoiling for 9,140 acres and irrigation water management for 20,100 acres. The estimated installation cost for these practices is $3,798,400 the annual cost is $451,800 and the annual direct benefits is $587,700.

Wetlands and upland wildlife habitat loss is addressed by mitigation practices establishing potholes, shallows, channels and surround levees on 280 acres along the Fall River system and establishing trees, shrubs and herbs on 716 acres along channels and ditches. The work would also include fencing, weirs and habitat developments in the drain filter basins. The estimated installation cost of these practices is $3,081,000 and the annual cost is $315,700.

Legislative and planning actions address flood plain zoning, continued enforcement of existing rules, monitoring of fish and aquatic plants, protection of cultural resources, erosion and water quality. These actions assist in making the plan complete. No costs have been estimated for legislative and planning actions.

IMPLEMENTATION OPPORTUNITIES

Implementation of the Selected Plan, or portions of it, should be made only after careful consideration of effects on wetlands and wildlife and the needs for mitigation of those effects. Consideration should also be made of resultant net income; extensive agricultural intensification may not be economically feasible in the Fall River Valley, especially when wetlands mitigaton is needed.

The Fall River Resource Conservation District and the Soil Conservation Service, with assistance from the Shasta County Department of Health and the University Extension Service could set up an education and information program. The program would discuss problems, actions and sources of assistance. The program would use available information and would be carried out by providing speakers at schools, meetings and group activities and by working with individuals on specific problems.

The State Water Resources Board could set water quality objectives for the Fall River. The Regional Water Quality Control Board and Shasta County could maintain a monitoring program to follow up on practices installed to reduce contamination and on growth of aquatic vegetation. Monitoring would also help determine practice effectiveness or establish a need for additional or different practices to be used.

The Fall River Resource Conservation District and the present steering committee should work through public meetings to set goals and priorities for practices and actions to meet the goals. The priorities of work will have to be revised over the next ten years as changes occur in both problems and needed practices. As installation of proposed practices is voluntary, information and technical assistance will have to be readily available to achieve satisfactory results.

On-farm conservation or practices are eligible for cost-sharing through the ACP program, funded by the Agricultural Stabilization and Conservation Service (ASCS). Technical assistance is available through the local Soil Conservation Service office to provide analysis and solutions to site specific problems.

Long-term loans may be available from the Farmers Home Administration (FmHA) for the drainage, flood control and land treatment practices. The FmHA loans would require a planned project.

The agricultural drainage and related land treatment practices is eligible for assistance through a P.L. 83-566 program or watershed plan. Federal cost-sharing could be up to about 65 percent. The required mitigaton would cause the land treatment project to be not economically feasible.

TABLE I
COST AND EFFECTS OF SELECTED PLAN
FALL RIVER WATERSHED AREA STUDY

COMPONENTS, ALTERNATIVES, OR ACTION BY CONCERN[1/]	INSTALLATION UNITS	INSTALLATION COST[2/] ($)	AVERAGE ANNUAL COST[2/3/] ($)	AVERAGE ANNUAL DIRECT BENEFITS[2/] ($)	BENEFICIAL EFFECTS	ADVERSE EFFECTS
CONTAMINATION OF WATER						
Monitor water quality and aquatic species (biannually)	1 unit	(7,100)	(3,900)	0	Provide record of Fall River water quality. Maintain quality of Fall River water. Identify problem areas.	
Recreation Area Development; Install portable comfort stations and waste receptacles along river access.	5 units	(6,500)	(1,400)	Unknown	Provides five locations along system to dispose of waste. Improves recreation experience.	Increases waste loading on district liquid and solid waste sites. Requires continual servicing. Requires 1/5 acre of land, adjacent to roads (total).
Domestic Water; Individually treatwater for consumption.	11 dwellings	(10,900)	(2,200)	0	Improves health and safety.	Adds chlorine to effluent.
Strict enforcement of existing zoning and test regulations.	1 unit	--	(7,700)	0	Improves water quality. Reduces septic system failures Reduces housing costs and maintenance. Provides 1/5 person-year employment.	Energy use for enforcement. Reduces building area. Increases housing first costs.
Sewage Treatment; install individual dwelling mound system leach beds.	40 each	(223,600)	(28,200)	0	Improves water quality and safety and health.	Requires 2 sites on 1/2 acre.
Sewage Treatment; install individual dwelling evaporation pond.	5 each	(85,100)	(10,200)	0	Improves water quality and safety and health.	May produce odors. High cost.
Sewage Treatment; install autothermal digester for group use (4-8 dwellings)	1 unit (6 dwellings)	(18,200)	(10,200)	0	Improves water quality and safety and health.	May produce odors. High cost. Requires professional maintenance.
Fertilization; application timing to reduce fall and winter fertilization or manure spreading	Unknown	--	--	Unknown; based on value of fertilizer	Improves water quality. Reduces nutrient losses. Protects fishery.	May interfere in normal operations.
Irrigation Water Management; Timed Water Application	20,100 acres	--	74,400	75,400	Reduces water use, increases efficiency. Increases crop production. Reduces over-irrigation, nutrient losses, underirrigation, saline problems or plant stress.	
Irrigation Water Management; Apply measured water volumes.	20,100 acres	982,400	140,700	140,100	Reduces water use. Increases efficiency of irrigation.	
Waste Management System; Livestock concentrations	4 each	(47,700)	(5,400)	(4,300)	Reduces nutrient losses. Retains nutrients for beneficial use.	Improves water quality. Removes 4 acres from production or use.
Domestic water conservation (low water use fixtures)	360 res.	(14,400)	(3,600)	(2,900)	Reduces liquid waste volume. Improve surface water quality Reduce domestic pumping cost for 360 dwellings. Enhances operations of sewage treatment facilities.	May increase sewerage maintenance costs.
Domestic wells, sanitary seal. Extend casing to two feet above average ground.	203 each	(196,900)	(19,300)	0	Improves health and safety. Improves water quality. Reduces costs of well decontamination.	
Domestic water; individually treat water for consumption where continued contamination occurs.	13 wells	(12,900)	(2,700)	0	Improves health and safety.	Adds chlorine to effluent.
SILTATION						
Retain vegetation on ground surface through winter on construction sites, disturbed areas and cropland.	1,260 acres	--	--	3,000	Reduces ditch and channel maintenance costs. Improves water quality. Reduces erosion by 3,360 T/yr., sediment by 1,910 T/yr. Improves wildlife habitat.	May interfere with normal operations.
Planning; continue strict enforcement of timber harvest rules and plans	1 unit	--	--	Unknown	Improves water quality. Reduces erosion. Improves aesthetics. Improves wildlife habitat and protects fishery.	May increase timber harvest costs.
Emergency seeding of burned areas	300 acres (avg. ann.)	21,400	3,200	4,800	Improves water quality. Reduces erosion. Improves aesthetics. Improves wildlife habitat nad protects fishery. Increases grazing. Reduces erosion by 1,500 T/yr, sediment by 120 t/yr.	Cost to landowner and taxpayer

TABLE I
COST AND EFFECTS OF SELECTED PLAN
FALL RIVER WATERSHED AREA STUDY

COMPONENTS, ALTERNATIVES, OR ACTION BY CONCERN[1]/	INSTALLATION UNITS	INSTALLATION COST[2]/ ($)	AVERAGE ANNUAL COST[2/3]/ ($)	AVERAGE ANNUAL DIRECT BENEFITS[2]/ ($)	BENEFICIAL EFFECTS	ADVERSE EFFECTS
Planning; restrict ORV use to designated areas	1 unit	--	12,500	31,000	Improves water quality. Reduces erosion. Improves wildlife habitat. Improves vegetative regeneration Provides 0.30 person year employment. Protects 185,000 acres. Reduces erosion by 1,000 T/yr., sediment by 50 T/yr.	Cost to landowner and taxpayer. Increased damages to designated areas. Reduced opportunity of use. Increases use on 23,000 acres.
Contour Farming (Cross Slope, >3 percent)	2,600 acres	--	4,700	15,600	Reduces erosion and sedimentation. Reduces main-nutrient losses. Improves sediment by 160 T/yr.	Cost increase for point rows. Energy cost. May tion system.
Conservation Cropping System (includes Conservation Tillage and Crop Residue Use)	7,300 acres	--	65,700	71,000	Reduces erosion and sedimentation. Reduces maintenance costs. Reduces nutrient losses. Improves water quality. Improves soil tilth. Increases water intake. Increases production. Reduces erosion by 7,300 T/yr., sediment by 360 T/yr.	Energy cost. May require change in planting equipment. May "carry over" plant disease.
Use Conservation Tillage (Minimum Tillage)	1,300 acres	0	0	31,200	Reduces energy use. Increases efficiency of irrigation.	
Planning; plan existing road maintenance and new roads to include erosion and drainage measures	1 unit	Unknown	Unknown	Unknown	Reduces erosion and sedimentation. Reduces maintenance costs. Increases structure life. May reduce transportation costs.	
Access Roads; construct all road fill and cut slopes to be not steeper than 1-3/4:1, seed with grass	22 miles	74,400	9,100	11,500	Reduces erosion and sedimentation. Reduces maintenance costs. Improves aesthetics. Reduces erosion by 3,585 T/yr., sediment by 2,510 T/yr.	Energy costs. Landrights costs. Removes 20 acres from timber production or uses other than road or minor grazing.
Access Roads; design, install and maintain rolling dips or waterbars on unsurfaced roads	112 miles	42,000	7,600	8,000	Reduces erosion and sedimentation. Reduces maintenance costs. Improves health and safety. Reduces erosion by 2,510 T/yr, sediment by 1,750 T/yr.	Energy costs. Increases travel time slightly.
Streambank Protection; Slope and install vegetation; willows and blackberries	5 miles	163,200	30,200	30,200	Improves fishery. Reduces sediment by 170 T/yr. Improve water quality. Improves wildlife habitat. Improves health and safety. Reduces erosion by 640 T/yr.	High cost. Removes 22 acres from other uses.
Streambank Protection; Plant only; willows and blackberries; and/or prevent removal	12 miles	161,400	41,600	50,800	Improves fishery. Reduces erosion by 770 T/yr. Improves water quality. Improves wildlife habitat. Reduces sediment by 120 T/yr.	Restricts land use on 97 acres (filterstrip).
Streambank Protection, Rock Riprap, severe problem areas.	1 mile	(171,800)	(18,300)	(7,900)	Improves fishery. Reduces erosion by 1,160 T/yr. Improves water quality. Improves health and safety. Increases production of benthic organisms and improves fishery. Reduces sediment by 460 T/yr.	Restricts land use on 2 acres.
Planning; establish Muskrat trapping program	1 Unit	Unknown	Unkown	Unknown	Reduces erosion and sedimentation. Improves fishery habitat	
Clearing and Snagging (debris removal)	Job	--	2,100	Unknown	Reduces bank erosion by roiling. Improves health and safety.	Reduces fishery habitat.
Filter Strip; install or retain vegetative bufferstrips to retain nutrients and reduce erosion and sediment, including livestock access	14 miles	96,800	9,300	12,500	Retains farmland. Reduces erosion and sedimentation. Improves water quality. Improves wildlife habitat. Improves fishery. Reduces bank sloughing of about 1/2 acre per year. Reduces dredging costs. Reduces erosion by 1,300 T/yr., sediment by 390 T/yr.	Restricts land use on 170 acres. Fence may obstruct visual. Strip averages 100-feet wide.
Planning; Require minimum vegetative disturbance and erosion/sediment control plan for each construction site.	1 unit	0	0	Unknown	Reduces erosion and sediment. Decreases road maintenance costs.	Increases construction costs.

TABLE I
COST AND EFFECTS OF SELECTED PLAN
FALL RIVER WATERSHED AREA STUDY

COMPONENTS, ALTERNATIVES, OR ACTION BY CONCERN[1/]	INSTALLATION UNITS	INSTALLATION COST[2/] ($)	AVERAGE ANNUAL COST[2/3/] ($)	AVERAGE ANNUAL DIRECT BENEFITS[2/] ($)	BENEFICIAL EFFECTS	ADVERSE EFFECTS
DAMAGES FROM HIGH WATER TABLE AND SEPTIC TANK FAILURE						
Surface drain; install deep ditch drainage system, including existing ditches.	16,740 acres (52 miles)	1,581,300	182,500	220,500	Reduce flooding and ponding damages. Improves water quality. Improves health and safety. Reduces septic tank failure. Improves wildlife habitat. Increases building life. Increases crop production. Removes salts. Provides drainage for 16,740 acres; flooding or ponding reduction for 3,880 acres and assists in reduction for 8,000 acres.	Decreases health and safety. Removes 205 acres from production or use. Removes wildlife habitat and wetlands. May decrease water quality.
Chiseling and Subsoiling (Rip hardpan layer)	9,140 acres	1,096,800	100,500	153,800	Increases crop production in shallow soils. Reduces water logging. Provides surface drainage (percolation). Increases rooting depth.	May overdrain fragile soils. May cause groundwater contamination. Removes wetlands.
DAMAGES FROM FLOODING AND PONDING						
Planning, floodplain zoning	1 unit	--	--	Unknown	Reduce potential flooding damages. Improves health and safety.	Increases building costs. Restricts uses in floodplain.
Surface Drains; improve existing drainage system and install wetlands basins/ponds	11,900 acres (56 mi. ditch)	481,000	79,800	110,800	Increases crop production. Provides flood protection to 3,690 acres and reduction for 5,580 acres. Improves wildlife habitat.	Removes 136 acres from production or use. Removes wildlife habitat.
Surface drain; install ditches, swales or channels (residential area)	2,560 acres (8 mi. ditch)	68,700	11,400	20,600	Reduce flooding and ponding damages. Improves water quality. Improves health and safety. Improves wildlife habitat.	Removes land from production or use (19 acres). Removes wildlife habitat. May cause short-term increase in contamination of surface water.
Design, install, protect and maintain adequate and continuous road ditches and appurtenant structures; Surface Drain	28 miles	570,600	77,600	96,400	Reduces maintenance costs. Increased road life. Improves health and safety.	Energy costs. Landrights costs. Removes 40 acres from production or use.
LOSS OF WETLAND AND UPLAND WILDLIFE HABITAT, RECREATION AND CULTURAL RESOURCES						
Wildlife Wetland Habitat Management; improve existing wetlands, route drain water into.	1 each (serves 3,400 acres)	(270,000) (Land) (247,200) (Install.)	(43,300)	0	Improves water quality. Protects fishery. Provides wildlife habitat and mitigates wetland habitat losses. Provides recreation opportunities.	Removes 60 acres from production. High costs.
Habitat Mitigation in permanently protected wetlands and along Fall River system.	1 Unit	1,110,000	144,900	Unknown	Mitigates habitat losses. Protects fishery.	High costs. Requires 1,081 acres (including purchased 800 acres).
Habitat Mitigation along surface ditches	716 acres	813,800	71,000	Unknown	Mitigates habitat losses from drainage	Removes 716 acres from other uses.
Locate cultural resources, restrict improvements or developments at identified sites.	Unknown	--	Unknown	Unknown	Retain historic or archaeological values in-situ.	May hamper orderly development or improvement. May increase building costs.
Allow supervised salvage of threatened cultural sites	Unknown	--	Unknown	Unknown	Retain recorded and evaluated historic or archaeological values.	Salvage costs. Increases building costs.
Provide permanent protection for wetlands (legislation and/or purchase of surface rights, in addition to those presently available)	800 acres	(640,000)	(56,500)	0	Protects wetlands. Improves wildlife habitat. Provides mitigation.	Cost. Precludes most other uses.
SUBTOTALS						
CONTAMINATION OF WATER		$ 982,400	$ 215,100	$ 215,500		
		(623,300)	(94,800)	--		
SILTATION		559,200	186,000	269,600		
		(171,800)	(18,300)	--		
DAMAGE FROM HIGH WATER TABLE AND SEPTIC TANK FAILURE		2,678,100	283,000	359,900		
DAMAGES FROM FLOODING AND PONDING		1,120,300	168,800	227,800		
LOSS OF WETLAND AND UPLAND WILDLIFE HABITAT, RECREATION AND CULTURAL RESOURCES		1,923,800	215,900	--		
		(1,157,200)	(99,800)	--		
TOTALS		7,263,800	1,068,800	1,087,200		
		(1,952,300)	(212,900)	--		

NOTE: (1) Solutions shown may effect more than one problem. The solutions have been located with the problem they will havethe greater effect on.
(2) Water quality, environmental, wildlife, safety and health, etc., benefits are assumed to equal costs, though theremay be no direct monetary benefit. Costs for these intangible items are shown in brackets and are not included in total project costs. Incidental direct monetary benefits are also not shown.
(3) Interest rate used is 7 5/8 percent, practice life varies, 50-year project life. Price base 1981.

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B.3.4 Delta Waterways, Dissolved Oxygen— Change in Total Size and Size Affected

Summary of Proposed Actions

The California Regional Water Quality Control Board, Central Valley Region, recommends a change to California's Clean Water Act Section 303(d) list for the impairment of the Delta due to impairment organic enrichment/low dissolved oxygen. The Regional Board recommends that the identified total size change from 480,000 acres to 48,000 acres and that the size affected be changed from 75 acres to 1,461 acres. The basis for the recommended change is described below.

Watershed Characteristics

The Delta waterways (Sacramento-San Joaquin Delta) encompass 1,153 square miles, with approximately 1,000 linear miles of waterway and a total waterbody size of approximately 48,000 acres. The Delta waterways form the lowest part of the Central Valley, lying between the Sacramento and San Joaquin Rivers and extending from the confluence of the two rivers inland as far as Sacramento and Stockton. Incoming flows vary widely from season to season and year to year, greatly affecting hydrology and habitat.

Total Waterbody Size and Extent of Impairment

The total waterbody size of the Delta is approximately 48,000 acres. This was misprinted in the final listing of the 1998 303(d) list as 480,000 acres. Therefore, the total size of the Delta should be changed to 48,000 acres for all pollutants. The area of the Delta impacted by low dissolved oxygen is the San Joaquin River from the Stockton Deep Water Ship Channel to Disappointment Slough (Lee and Jones-Lee, 2000b). This area is 1,461 acres.

B.3.5 Delta Waterways, Chlorpyrifos, DDT, Diazinon, Group A pesticides, Mercury, Unknown Toxicity, and Electrical Conductivity — Change in Total Size and Size Affected

Summary of Proposed Actions

The California Regional Water Quality Control Board, Central Valley Region, recommends changes to California's Clean Water Act Section 303(d) list for the Delta due to impairment by Chlorpyrifos, DDT, Diazinon, Group A pesticides, Mercury, Unknown Toxicity, and Electrical Conductivity (EC). The Regional Board recommends that the identified total size change for Chlorpyrifos, DDT, Diazinon, Group A pesticides, Mercury, and Unknown Toxicity from 480,000 acres to 48,000 acres and that the extent of impairment change 480,000 acres to 48,000 acres. The identified total size of the Delta associated with electrical conductivity should be changed to 48,000 acres. The basis for the recommended change is described below.

Watershed Characteristics

The Delta waterways (Sacramento-San Joaquin Delta) encompass 1,153 square miles, with approximately 1,000 linear miles of waterway and a total waterbody size of approximately 48,000 acres. The Delta waterways form the lowest part of the Central Valley, lying between the Sacramento and San Joaquin Rivers and extending from the confluence of the two rivers inland as far as Sacramento and Stockton. Incoming flows vary widely from season to season and year to year, greatly affecting hydrology and habitat.

Total Waterbody Size and Extent of Impairment

The total waterbody size of the Delta is approximately 48,000 acres. This was misprinted in the final listing of the 1998 303(d) list as 480,000 acres. Therefore, the total size of the Delta should be changed to 48,000 acres for all pollutants. Chlorpyrifos, DDT, Diazinon, Group A pesticides, Mercury, and Unknown Toxicity impair the entire area of the Delta, and their extent of impairment should be changed from 480,000 acres to 48,000 acres.

B.3.8 French Ravine, Bacteria - Change in Total Size and Size Affected

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, recommends changes to California's Clean Water Act Section 303(d) list for the impairment of French Ravine due to impairment by bacteria. The Regional Board recommends that the identified total length change from 1 mile to 4 miles. The basis for the recommended change is described below.

Watershed Characteristics

French Ravine is located in western Nevada County, approximately 4 miles southwest of Grass Valley. It flows for approximately 4 miles before entering Wolf Creek, a tributary to Bear River. McCourtney Road Landfill is located along two drainages approximately ½ mile upslope from French Ravine. The drainages enter French Ravine approximately 2.5 miles upstream from the confluence of French Ravine and Wolf Creek. McCourtney Road Landfill operated as a burn dump from 1950 to 1973, as a landfill for residential and commercial solid refuse and for septic tank pumping from 1973 to 1992, and as a transfer station between 1992 and 1998. The landfill was closed and effectively sealed in 1998.

Total Waterbody Size Extent of Impairment

French Ravine has a length of approximately 4 miles from its headwaters to its confluence with Wolf Creek (Horizons Technology, Inc., 1997). The historic McCourtney Road Landfill is located along French Ravine approximately half way between its headwaters and its confluence. Water samples tested for bacteria indicate that high levels of bacteria would be present for approximately one mile below the inflow of water from McCourtney Road Landfill.

B.3.16 Mosher Slough, Diazinon and Chlorpyrifos - Change in Total Size

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, recommends changes to California's Clean Water Act Section 303(d) list for the impairment of Mosher Slough due to impairment by diazinon and chlorpyrifos. The Regional Board recommends that the identified total length change from 3 to 5 miles. The basis for the recommended change is described below.

Watershed Characteristics

Mosher Slough is a small urban creek located entirely within San Joaquin County in the northern part of Stockton. The confluence of Mosher Slough, Bear Creek, and Pixley Slough flows west and converges with Disappointment Slough, which flows to the Sacramento-San Joaquin Delta (Horizons Technology, Inc., 1997). Land use in the Mosher Slough watershed is predominately commercial and residential.

Total Waterbody Length

Mosher Slough is approximately 5 miles in length (Horizons Technology, Inc., 1997; DeLorme, 1998).

B.3.18 Lower Stanislaus River - Change in Total Size and Size Affected

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, recommends changes to California's Clean Water Act Section 303(d) list for the impairment of the Stanislaus River due to impairment by diazinon, Group A pesticides, and unknown toxicity. The Regional Board recommends that the identified total length change from 48 to 58 miles and the size affected from 48 to 58 miles. The basis for the recommended change is described below.

Watershed Characteristics

The Stanislaus River is located on the east side of the San Joaquin River Basin and has a total basin area of 1,144 square miles. The Lower Stanislaus River subbasin, covering the area from Goodwin Dam to the San Joaquin River, encompasses approximately 102,550 acres, of which around 52,151acres is used for agriculture.

Total Waterbody Length and Extent of Impairment

USGS topographic maps indicate that the total length of the lower Stanislaus River is approximately 58 miles, from Goodwin Dam to San Joaquin River (USGS, 1958-2000). The Regional Board had previously indicated on the 303(d) list that the entire length is impaired by diazinon, Group A pesticides, and unknown toxicity. The size affected should also be changed to 58 miles for those pollutants.

B.3.19 Lower Tuolumne River, Diazinon - Change in Total Size and Size Affected

Summary of Proposed Actions

The California Regional Water Quality Control Board, Central Valley Region, recommends changes to California's Clean Water Act Section 303(d) list for the impairment of the lower Tuolumne River due to impairment by diazinon. The Regional Board recommends that the identified total length change from 32 to 54 miles and the size affected from 32 to 42 miles. The basis for the recommended change is described below.

Watershed Characteristics

The lower Tuolumne River flows for approximately 54 miles, from New Don Pedro Dam and drains into the San Joaquin River west of Modesto. This sub-basin encompasses approximately 161,268 acres, of which 52,715 acres is used for agriculture.

Total Waterbody Length and Extent of Impairment

Topographic maps provided by the USGS indicate that the total length of the lower Tuolumne River is approximately 54 miles, from New Don Pedro Dam to San Joaquin River (USGS, 1958-2000). Chemical analysis of water samples and land use along the Tuolumne River (the presence of crops) indicate that the lower 42 miles (from Turlock Lake State Park to the San Joaquin River) is impaired by diazinon.

Lower Tuolumne River, Group A pesticides and Unknown Toxicity - Change in Total Size and Size Affected

Summary of Proposed Actions

The California Regional Water Quality Control Board, Central Valley Region, recommends changes to California's Clean Water Act Section 303(d) list for the impairment of the lower Tuolumne River due to impairment by Group A pesticides and unknown toxicity. The Regional Board recommends that the identified total length change from 32 to 54 miles and the size affected from 32 to 54 miles. The basis for the recommended change is described below.

Watershed Characteristics

The lower Tuolumne River flows for approximately 54 miles, from New Don Pedro Dam and drains into the San Joaquin River west of Modesto. This subbasin encompasses approximately 161,268 acres, of which 52,715 acres is used for agriculture.

Total Waterbody Length and Extent of Impairment

USGS topographic maps indicate that the total length of the lower Tuolumne River is approximately 54 miles, from New Don Pedro Dam to San Joaquin River (USGS, 1958-2000). Chemical analysis of water samples from the lower Tuolumne River indicate that the entire length is impaired by Group A pesticides. Toxicity tests, using water from lower Tuolumne River, indicate that the entire length is impaired by an unknown toxin.

Changes: Mines

B.3.1 Cache Creek, Mercury and Unknown Toxicity, Change in Total Size and Size Affected

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, recommends changes to California's Clean Water Act Section 303(d) list for the impairment of Cache Creek due to impairment by mercury and unknown toxicity. The Regional Board recommends that the identified total length change from 60 to 81 miles and that the extent of impairment change from 35 miles to 81 miles. The basis for the recommended change is described below.

Watershed Characteristics

The Cache Creek watershed is located primarily within Lake and Yolo counties with a small portion in Colusa County. Cache Creek flows for approximately 81 miles from the Clear Lake dam to the Cache Creek Settling Basin adjacent to the Yolo Bypass (USGS, 1958-1992). The upper Cache Creek watershed (above Rumsey) flows through undeveloped chaparral and shrub oak habitat and is primarily used as rangeland (Foe and Croyle, 1998). The gradient of the creek in the 33-mile reach between Clear Lake (~1,320 feet above sea level [asl]) and Rumsey (420 feet asl) is steep, dropping approximately 27 feet per mile. Large areas are highly erosive. There are three inactive mercury-mining districts in the upper watershed area, Clear Lake, Sulfur Creek, and Knoxville mining districts (Montoya and Pan, 1992; Buer *et al*, 1979). The Sulfur Bank Mercury Mine at Clear Lake is a U.S. Environmental Protection Agency (USEPA) Superfund site. The lower Cache Creek watershed (downstream of Rumsey) is intensely farmed, primarily row, orchard, and rice cultivation (Foe and Croyle, 1998).

Total Waterbody Size and Extent of Impairment

Foe and Croyle (1998) indicated that the total length of Cache Creek is 81 miles. There are three inactive mercury-mining districts in the upper watershed area, Clear Lake, Sulfur Creek, and Knoxville mining districts (Montoya and Pan, 1992; Buer *et al*, 1979). Water quality and fish tissue data from the upper watershed (North and South forks, and Cache Creek Canyon) and the lower watershed (at Rumsey, Capay Dam, and Road 102) indicate mercury impairs the entire waterbody. Toxicity tests conducted using samples collected in Cache Creek at Road 102, at Rumsey, and from the North Fork were toxic to Ceriodaphnia, indicating that a toxin impairs the entire length of Cache Creek.

B.3.9 Horse Creek, All Metals - Change in Size Affected

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, recommends changes to California's Clean Water Act Section 303(d) list for the impairment of Horse Creek due to impairment by metals (cadmium, copper, lead, and zinc). The Regional Board recommends that the identified extent of impairment change from 2 miles to 1 mile. The basis for the recommended change is described below.

Watershed Characteristics

Horse Creek is located in Shasta County, south of the city of Lakehead. It flows for approximately 2 miles before entering the East Squaw Creek Arm of Shasta Lake. Rising Star Mine, which was historically operated for multiple metal extraction, is located along Horse Creek. Rising Star Mine is surrounded by reactive, highly acidic waste rock on steeply graded slopes, and discharges cadmium, copper, lead, and zinc into the Horse Creek.

Total Waterbody Length, and Extent of Impairment

Montoya and Pan (1992) indicate that Horse Creek is located in Shasta County, south of the city of Lakehead. It flows for approximately 2 miles before entering the East Squaw Creek Arm of Shasta Lake.

Rising Star Mine, which was historically operated for multiple metal extraction, is located approximately 1 mile downstream from the headwater of Horse Creek. Water quality data indicates that metals impair Horse Creek downstream from Rising Star Mine.

B.3.10 Humbug Creek, Sedimentation/Siltation, Mercury, Copper and Zinc - Change in Size Affected

Summary of Proposed Action

The California Regional Water Quality Control Board-Central Valley Region (Regional Board) recommends changes to California's Clean Water Act Section 303(d) list for the impairment of Humbug Creek due to impairment by sediment and silt, mercury, copper, and zinc. The Regional Board recommends that the identified extent of impairment change from 9 miles to 3 miles. The basis for the recommended change is described below.

Watershed Characteristics

Humbug Creek is located in the Sierra foothills, approximately 8 miles northeast of Nevada City in Nevada County. It flows for approximately 9 miles before entering South Yuba River. Malakoff Diggins, an historic hydraulic mine (currently a State Historic Park), is located along Humbug Creek. Hydraulic mining has left barren slopes and unstable soil (primarily clay) exposed to erosional forces for the past hundred years. Erosion of soil materials from the Malakoff Diggins area results in the discharge of sediment into Humbug Creek. Discharges of sediment and silt and metals from Malakoff Diggins impair the water quality of Humbug Creek.

Extent of Impairment

Montoya and Pan (1992) indicated that the total length of Humbug Creek is approximately 9 miles. Malakoff Diggins, a historically operated mine, is located approximately 3 miles upstream Humbug Creek's confluence with the Yuba River. Water quality data indicates that metals impair Humbug Creek downstream Malakoff Diggins (Montoya and Pan, 1992), and several studies indicate that sediment and silt impair Humbug Creek downstream Malakoff.

B.3.11 James Creek, Nickel and Mercury - Change in Total Size and Size Affected

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, recommends changes to California's Clean Water Act Section 303(d) list for the impairment of James Creek due to impairment by nickel and mercury. The Regional Board recommends that the identified total length change from 6 mile to 9 miles, and the impaired length from 6 to 8.5 miles. The basis for the recommended change is described below.

Watershed Characteristics

James Creek is located in Napa County, approximately 10 miles northwest of Lake Berryessa. James Creek flows for approximately 9 miles before joining with Swartz Creek to form Pope Creek, an eight-mile creek that flows into Lake Berryessa (USGS, 1958-2000). The creek has a steep gradient, falling from approximately 2,400 feet above sea level at its headwaters to approximately 720 feet at its confluence with Pope Creek – a drop of approximately 1,680 feet over 6 miles. A fish survey reported both trout and suckers as present inhabitants of the creek in the impacted area (Montoya and Pan, 1992). Several historic mercury mines are located within the James Creek watershed. Corona, Oat Hill, Oat Hill Extension, Aetna Extension, Grenada, and Toyon mines are all located within the watershed. In addition, Twin Peaks Mine is located on Bateman Creek, a tributary to James Creek. Corona Mine is considered to contribute the highest amount of mercury to James Creek. It is located in the headwaters area of the James Creek watershed (Buer *et al*, 1979; Montoya and Pan, 1982). During the late 1980s, James Creek was coated with an orange gelatinous floc that extending up to 2 miles downstream from Corona Mine (Montoya and Pan, 1992).

Total Waterbody Length and Extent of Impairment

Buer *et al* (1979), Montoya and Pan (1992), and the USGS (1980, 1987a, 1987b, & 1997) indicate that the total length of James Creek is approximately 9 miles. Several historic mercury mines are located within the James Creek watershed. Corona, Oat Hill, Oat Hill Extension, Aetna Extension, Grenada, and Toyon mines are all located within the watershed. In addition, Twin Peaks Mine is located on Bateman Creek, a tributary to James Creek. The inflow of mine drainage originates approximately 0.5 miles downstream from the headwaters of James Creek (Buer *et al*, 1979; and Montoya and Pan, 1992).

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INVENTORY AND ASSESSMENT OF WATER QUALITY PROBLEMS RELATED TO ABANDONED AND INACTIVE MINES IN THE CENTRAL VALLEY REGION OF CALIFORNIA

by

Stein M. Buer, Stanley R. Phillippe
and Thomas R. Pinkos - Staff Engineers

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I. INTRODUCTION

Inactive and abandoned mines are an important source of heavy metals pollution and have severely degraded water quality in receiving stream segments within the Central Valley Region of California. The absence of effective regulations and abatement technology have hindered efforts to eliminate the mine drainage problems. In accordance with Section 208 of Public Law 92-500, the Regional Board is in the process of identifying the mine related sources of pollution and developing an effective legal and institutional framework for abatement of mine drainage problems.

The Regional Board's Workplan, issued in August 1977, specified that the planning be conducted as follows: Technical studies were to be undertaken to inventory the mine related pollution problems in the region, to rank the identified mine sites according to their impact on beneficial uses of receiving waters, and to develop best management practices (BMP's) at selected sites for application throughout the region.

The objectives of this work are to document the impact of abandoned and inactive mines in the region and to gather the information necessary to develop an effective abatement program. This report describes the inventory and assessment phase of the planning process.

II. INVENTORY OF THE PROBLEM MINES

Only a small fraction of the mine sites within the Central Valley Region are discharging acids, heavy metals, or sediments to receiving waters. If a presently operating mine is creating such problems, the discharge may be monitored and regulated through existing programs such as the N.P.D.E.S. or W.D.R. permit programs. However, if a mine continues to generate pollutants after it has been abandoned or ceased operating, it becomes difficult to assign responsibility for clean-up and abatement work and to obtain the funding necessary for such work. Such mines are classified as "problem mines" requiring a special reclamation program.

Several agencies have previously investigated the abandoned and inactive mine pollution problems in the Central Valley Region. Each agency has focused on a portion of the problem, and applied its own qualitative or quantitative criteria to determine whether or not a mine is creating a significant pollution problem. The Regional Board's goal is to include in the present inventory all the mines which have been earlier identified as creating significant pollution problems, regardless of the particular criteria used. These mine sites, as well as sites identified by the Regional Board staff on a continuing basis, may then be ranked in terms of impact on receiving waters by the procedure proposed in this report. As more information becomes available, the list may be expanded to accommodate newly identified problem sites.

To compile an inventory of abandoned and inactive mines in the Central Valley Region, existing data and information were reviewed by Regional Board staff using publications by the California Division of Mines and Geology, the E.P.A., special reports, and information from Regional Board files. A tentative list of 41 mine pollution sources was developed.

Table 1 lists the abandoned mines in California which are known to be polluting the surface waters of their respective watersheds. Information regarding ownership of the mines is not readily available. The listed CDMG map number refers to the reference number assigned to each mine in the course of the 1972 study by CDMG entitled Principal Areas of Mine Pollution. In most cases, the location in terms of latitude and longitude was also determined by CDMG.

The mines are grouped according to the watersheds within which they occur and the watersheds are in turn listed alphabetically. The watersheds were labeled according to the U.S.G.S. map of California watersheds, compiled in 1968, with one exception. For this study, the Redding watershed and the Red Bluff watersheds were treated as one entity, and labeled the Upper Sacramento River watershed. Within each watershed grouping the mines are listed alphabetically by name. A cross reference to the mines by name in alphabetical order is provided in Appendix A. Figure 1 shows the location of each mine.

TABLE 1. INVENTORY OF PROBLEM MINES

Watershed	Mine Name	County	CDMG Map No.	USGS Map	Latitude	Longitude	Commodity Mined	Type of Operation	Receiving Stream
American River, SF	Alhambra Shumway	El Dorado	5A-733	Georgetown	38 49.54'	120 47.37'	Gold	Undergrnd	Mosquito Trail Glch—Rock Crk—SF American R
Bear River	Dairy Farm	Placer	5A-633	Cmp Far W	39 1.81'	121 17.25'	Copper	Undergrnd	Camp Far West Reservoir
	Lava Cap-Banner	Nevada	5A-571	Chicago Pk	39 13.64'	120 58.19'	Gold	Undergrnd	L.Clipper Crk—Greenhorn Crk—Rollins Res—Bear R
Butte Creek	Cherokee	Butte	5A-278	Cherokee	39 38.20'	121 37.70'	Gold	Hyd Placr	Sawmill Ravine—Dry Creek—Butte Crk
	Mineral Slide	Butte	(none)	Paradise	39 47.14'	121 37.63'	Gold	Undergrnd	L.Butte Crk—Butte Crk
Cache Creek	Abbott	Lake	5A-645	Wilbur Spg	39 1.23'	122 26.63'	Mercury	Undergrnd	Harley Glch—Cache Crk
	Manzanita	Colusa	5A-644	Wilbur Spg	39 2.30'	122 25.82'	Mercury	Undergrnd	Sulfur Crk—Bear Crk—Cache Crk
	Reid	Yolo	5A-656	Knoxville	38 51.88'	122 22.20'	Mercury	Undergrnd	Davis Crk—Cache Crk
	Sulfur Bank	Lake	5A-650	Clr Lk Hi	38 59.90'	122 40.35'	Merc,Sul	Open Pit	Clear Lake—Cache Crk
Cosumnes River	Copper Hill	Amador	5B-044	Latrobe	38 30.13'	120 58.00'	Copper	Undergrnd	Cosumnes River
Feather River	China Gulch	Plumas	(none)	Greenvlle	40 12.74'	120 45.17'	Copper	Undergrnd	Lights Crk—Wolf Crk—NF Feather R
	Engel	Plumas	5A-076A	Greenvlle	40 12.20'	120 46.41'	Cop,Silv	Undergrnd	Lights Crk—Wolf Crk—NF Feather R
	Iron Dyke	Plumas	5A-080	Greenvlle	40 3.90'	120 50.60'	Cu,Ag,Au	Undergrnd	Taylor Crk—Indian Crk—Wolf Crk—NF Feather R
	Walker	Plumas	5A-159	Mt Inglls	39 58.70'	120 39.80'	Copper	Undergrnd	L.Grizzly Crk—Indian Crk—Wolf Crk—NF Feather R
Fresno Slough	New Idria	San Benito	5D-045	Idria	36 24.85'	120 40.39'	Mercury	OPit&Undg	San Carlos Crk—Silver Crk—Panoche Crk
Mokelumne River	Argonaut	Amador	5B-105	Jackson	38 21.77'	120 47.10'	Gold	Undergrnd	Jackson Crk—Dry Crk—Mokelumne R
	Newton	Amador	5B-089	Ione	38 20.45'	120 53.20'	Copper	Undergrnd	Copper Crk—Sutter Crk—Dry Crk—Mokelumne R
	Penn	Calaveras	5B-223	Vlly Spg	38 13.97'	120 52.50'	Copper	OPit&Undg	Mokelumne River (Camanche Res)
Putah Creek	Aetna	Napa	5A-785	Aetna Spg	38 39.43'	122 29.51'	Mercury	Surf&Undg	Swartz Crk—Pope Crk—Putah Crk—Lake Berryessa
	Anderson	Lake	5A-652	Whisp Pne	38 46.35'	122 42.40'	Mercury	Undergrnd	Anderson Crk—Bear Canyon Crk—Putah Crk—Lk. Berry.
	Big Injun	Lake	5A-650A	Whisp Pne	38 45.85'	122 42.40'	Mercury	Surf&OPit	Bear Canyon Crk—Putah Crk—Lake Berryessa
	Corona	Napa	5A-790	Detert Spg	38 40.21'	122 32.47'	Mercury	Undergrnd	James Crk—Pope Crk—Putah Crk—Lake Berryessa
	Great Western	Lake	5A-795	Mt St Hel	38 42.87'	122 38.44'	Mercury	OPit&Undg	Hoodoo Crk—Dry Crk—Putah Crk—Lake Berryessa
	Knoxville	Napa	5A-659	Knoxville	38 49.61'	122 20.34'	Mercury	OPit&Undg	Knoxville Crk—Eticuera Crk—Lake Berryessa
	Oat Hill	Napa	5A-789	Detert Spg	38 40.50'	122 21.65'	Mercury	Surface	James Crk—Pope Crk—Putah Crk—Lake Berryessa
Sacramento River	Afterthought	Shasta	5A-019	Millville	40 44.10'	122 4.10'	Cu,Ag,Au	Undergrnd	L.Cow Crk—Sacramento R
	Balaklala	Shasta	5A-033	Shasta Dam	40 43.59'	122 29.79'	Cu,Zn,Ag	Undergrnd	West Squaw Crk—Shasta Lake
	Bully Hill	Shasta	5A-017	Bllbkka Mt	40 47.80'	122 12.20'	Cu,Zn,Pb	Undg&Surf	First Crk, Town Crk—Shasta Lake
	Golinsky	Shasta	5A-014	Lamoine	40 45.84'	122 27.40'	Cu,Zn,Au	Undergrnd	L.Backbone Crk—Shasta Lake
	Greenhorn	Shasta	5A-055	Frnch Glch	40 39.75'	122 41.65'	Cu,Au,Ag	Undergrnd	Willow Crk—Clear Crk—Whiskeytown Lake
	Iron Mountain	Shasta	5A-041	Frnch Glch	40 40.39'	122 31.47'	Cu,Zn,Au	Undg&Surf	Spring Crk—Keswick Res (Sacramento R)
	Keystone	Shasta	5A-037	Frnch Glch	40 43.10'	122 30.32'	Cu,Au,Ag	Undergrnd	West Squaw Crk—Shasta Lake
	Mammoth	Shasta	5A-013	Lamoine	40 45.84'	122 27.40'	Cu,Zn,Au	Undergrnd	L.Backbone Crk—Shasta Lake
	Shasta King	Shasta	5A-035	Shasta Dam	40 43.80'	122 29.80'	Cu,Au,Ag	Undergrnd	West Squaw Crk—Shasta Lake
San Joaquin Delta	Mount Diablo	Contra Costa	(none)	Antioch So	37 53.87'	121 52.54'	Mercury	Undergrnd	Marsh Crk—Marsh Crk Res—San Joaquin Delta
Stanislaus River	Empire	Calaveras	5C-072	Copperopls	37 58.60'	120 38.30'	Copper	OPit&Undg	Copper Crk—Black Crk—Tulloch Res (Stanislaus R)
	Keystone	Calaveras	5C-073	Copperopls	37 59.20'	120 38.90'	Copper	Undergrnd	Penny Crk—Sawmill Crk—Black Crk—Tulloch Res
Yuba River	Kenton	Sierra	5A-357	Alleghany	39 27.31'	120 51.52'	Gold	Undergrnd	Kanaka Crk—M Yuba R
	Malakoff Diggings	Nevada	5A-345	Pike,NBlmf	39 22.20'	120 55.00'	Gold	Surf Hydr	Humbug Crk—SF Yuba R
	Plumbago	Sierra	5A-384	Alleghany	39 27.17'	120 48.74'	Gold	Undergrnd	Buckeye Ravine—M Yuba R
	Sixteen to One	Sierra	5A-367	Alleghany	39 27.92'	120 50.53'	Gold	Undergrnd	Kanaka Crk—M Yuba R

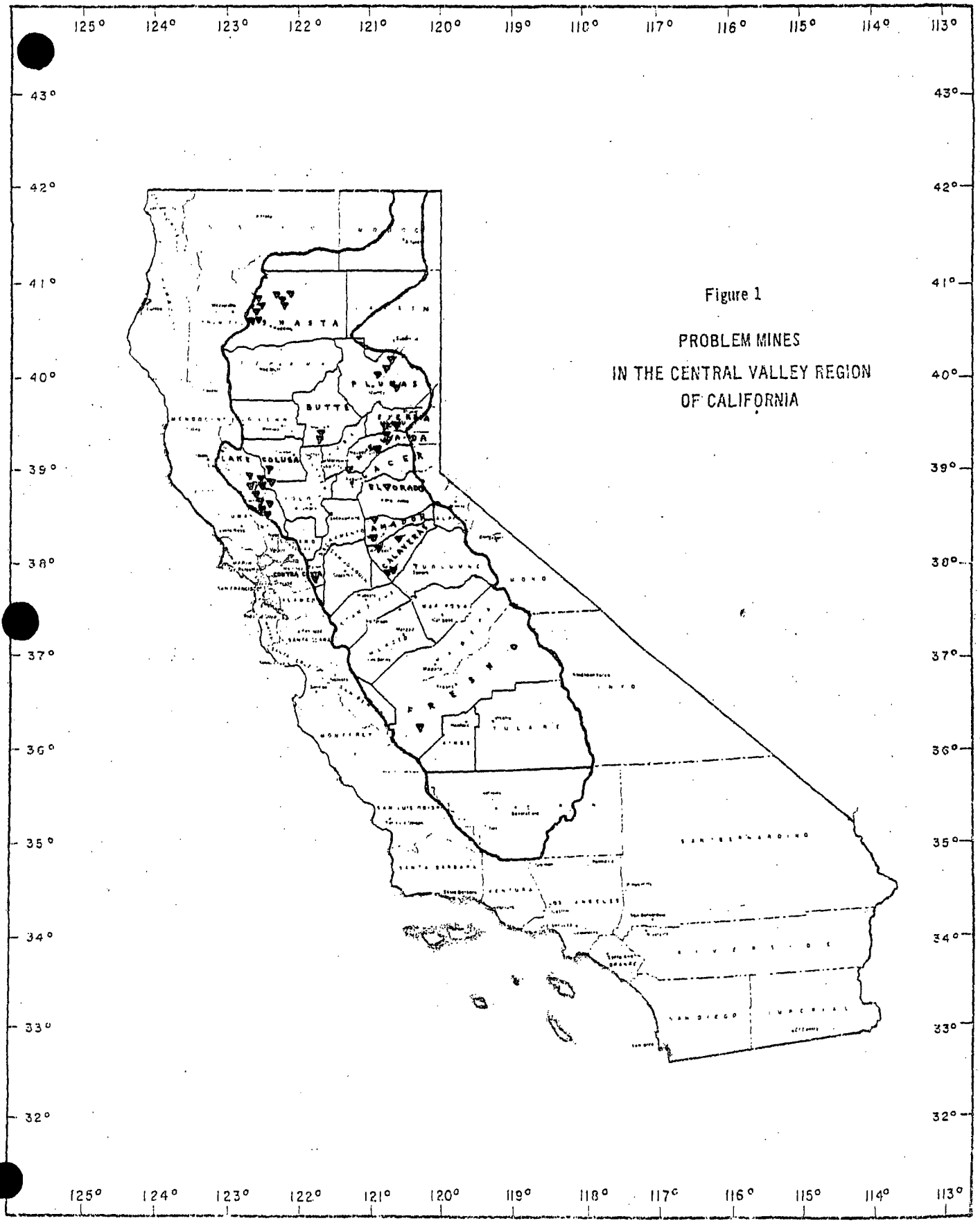


Figure 1

PROBLEM MINES
IN THE CENTRAL VALLEY REGION
OF CALIFORNIA

III. ASSESSMENT OF THE PROBLEM MINES: RANKING METHODOLOGY

A. General Description

The priority of a mine pollution problem depends, first, on the direct physical impacts (chemical and biological) in receiving waters and, second, on additional factors such as mine geology and topography, impairment of land-related aesthetic qualities, proximity to population centers, cost effectiveness of abatement projects, and land ownership status. The most effective way to deal with these complexities is to separately evaluate the physical and additional factors (Skelly and Loy, 1975).

The ranking process described in this report is based on the direct physical impacts of acid mine drainage in receiving streams. These impacts are measured chemically and biologically. (Sedimentation problems, arising from steep, exposed cuts, excavation pits, and slides, will be evaluated separately because both the formative mechanisms and the effect on receiving waters are fundamentally different).

If biological data of the receiving stream, such as species diversity indices, benthic surveys, or visual evaluation of stream biota are available, they are used as the primary data source for the ranking process because they provide the most direct indication of downstream impact (EPA, 1977).

In the absence of biological data, chemical analyses of the receiving stream are evaluated to estimate the impact on the aquatic ecosystem, (EPA, 1977). This represents a formidable and complex problem if the evaluation is to be exhaustive. On the other hand, a highly simplified procedure, ignoring synergistic and antagonistic effects and basing the impact assessment on the most sensitive resident species, is adequate for estimating the gross impact of a mine discharge.

Once biological and chemical data are used to rank the stream, the additional factors are consulted to adjust priorities. Mine geology and topography are most influential,

since pollution impact may be roughly estimated on the basis of the past history of the mine, the tailings area, volume, and composition as well as tunnel extensiveness, orientation, permeability, and geology.

The mines are ranked into three categories: HIGH, MODERATE, and LOW. Mines ranked HIGH or MODERATE will be more carefully evaluated thereafter to better quantify their impacts in terms of beneficial use impairment.

B. Procedure

1. Biological Analysis

Biological data are more useful than chemical analyses because biological data provide a direct indication of the impact which a pollutant discharge has on the receiving stream, whereas water quality data must be further interpreted to estimate the impact on the aquatic ecosystem (EPA, 1977). Moreover, a single biological sampling is more indicative of the stream condition over time than a single chemical analysis at one location at one moment. The chemical character of the stream may be a transient condition at the time of sampling, whereas the biological character is most likely the result of cumulative effects.

A modest goal of identifying three levels of degradation may be achieved on the basis of available biological data and a visual inspection of the stream segment under consideration. The criteria by which the degree of degradation can be classified are given in Table 2.

The damaging impact of acid mine drainage is most pronounced where the toxic water first enters the receiving stream. Further downstream the effects may be milder due to mixing, dilution, precipitation, aeration, or detoxification. The rank of a particular mine, representing its overall impact on downstream beneficial uses, should reflect the various levels of degradation downstream, ranging from severe to slight. In addition, the rank should depend on the importance of the stream to the region. A crude but direct measure of this importance is the streamflow, Q. The streamflow provides a direct measure of the stream's importance in the water budget of the Region and the magnitude of the potential downstream beneficial uses.

TABLE 2. STREAM SEGMENT DEGRADATION CRITERIA

CLASSIFICATION	DESCRIPTION
SEVERE DEGRADATION ls	$\bar{d}$, < 1.0 $\bar{d}$ < 2.0, low to nonexistent benthic biomass, fish absent or repeatedly killed off in reach, pH < 4.5 high EC, extensive iron compound precipitates, absence of chlorophyta, chrysophyta, discolored or highly turbid water, water usually exceeds water quality standards.
MODERATE DEGRADATION lm	1.0 < $\bar{d}$, <2.0 2.0 < $\bar{d}$ <3.0, low to moderate benthic biomass and diversity, 4.5 < pH < 6.5, moderate discontinuous iron compound precipitates, some tolerant fish and invertebrates, low chlorophyta, chrysophyta, occasional fish kills, toxic constituents frequently above water quality standards.
SLIGHT DEGRADATION lo	$\bar{d}$, > 2.0 $\bar{d}$ >3.0, benthic biomass and diversity near normal, pH > 6.5, normal fish population toxic constituents rarely above water qaulity standards, minor to insignificant iron precipitates.

$\bar{d}$ = Wilhm and Davis (1968) diversity index
= Shannan-Weimar diversity index

To rank a mine from biological data and visual inspection:

- Determine the length of stream below the mine which corresponds to the degradation classification of severe (ls), moderate (lm), or slight (lo) from Table 2.
- Determine the flow of the stream (Q) along that length.
- Enter the matrix of Table 3 with l and corresponding Q to determine rank.

TABLE 3: BIOLOGICAL RANKING MATRIX: R_B

Q (cfs)	ls miles			lm miles			lo miles
	.0-.5	.6-1	>1	0-.5	.6-1	>1	0
0-.5	L	M	H	L	L	M	L
.6-5	M	H	H	L	M	H	L
>5	H	H	H	M	H	H	L

- Use only one value of Q and one value of l to retrieve one rank from the matrix. If in a given stream length, more than one classification of l are present, or Q varies, determine the several rankings from the corresponding data, and rank the mine on the basis of the highest rank attained.

B.2. Chemical Analysis

When biological stream survey data are not available water quality data may be utilized to estimate the effects of mine drainage on receiving streams. The chemical composition of natural streams varies throughout the year in response to rainfall intensity and duration, temperature, groundwater flow, and many other factors. In addition, the toxicities of heavy metals, acids, and iron compounds are profoundly influenced by changes in environmental variables such as dissolved oxygen concentration, temperature, hardness, and alkalinity while synergistic and antagonistic interactions between the various pollutants further complicate the problem.

Most toxic substances become more lethal to fish in water as the dissolved oxygen concentration is reduced (Katz, 1971). Lloyd (1960) found that trout had a significantly reduced tolerance to the zinc ion in water with reduced dissolved oxygen. Lloyd and Herbert (1962) found that lead and copper were also more toxic under such conditions.

The water temperature strongly affects the toxicity of most substances. With increasing temperature the toxicity increases (Katz, 1971).

The concentrations of sodium, calcium, potassium, magnesium, bicarbonate, and sulfate ions have a profound effect on heavy metals toxicity; in most cases high alkalinity and hardness are associated with a reduced toxicity. Katz (1971) found that concentrations of heavy metals which could be extremely toxic in fresh water were harmless in hard fresh water or dilute sea water.

When various toxic constituents are mixed, they may interact to either augment or counteract their individual effects on aquatic organisms. For example, the addition of acid to water polluted with ammonia will reduce its toxicity to fish (Wuhrmann; et al 1947), whereas the toxicity of a nickel cyanide complex will increase under the same conditions (Doudoroff, 1956, and Doudoroff, et al, 1966). Heavy metals may interact in unexpected ways; for example, Bandt (1946) found that zinc sulfate and copper sulfate were synergistic in their effects upon fish, whereas zinc sulfate and cadmium sulfate were simply additive.

Not all organisms of the aquatic ecosystem are equally susceptible to the destructive effects of acid mine drainage. Rainbow trout (Salmo gairdneri) may be killed by 20 ug/l copper in soft water (Chapman, 1976), while bluegills (Lepomis macrohirus) require 55 times this concentration for a comparable effect (Benoit, 1975). Similarly profound differences in vulnerability have been documented for benthic invertebrates, algae, and unicellular organisms.

In many cases, the greatest pollutant load and fish mortality occur during high flows. A report by the California Department of Water Resources (1969) concluded that the most significant fish kills in Lake Shasta occurred during the period of high flow (November through April) when the copper discharge was greatest. Sampling in streams affected by lead mining in Missouri showed that concentrations of lead, cadmium, zinc, and copper were highest during the peak runoff periods (Wixson, et al, 1974).

These variations in streamflow, water composition, environmental conditions, constituent toxicities, and biotic susceptibility all influence the downstream impact of a mine discharge. Regardless of this complexity, crude but adequate estimates of the relative effects of various mine discharges on receiving waters may be obtained through simple chemical analysis. However, such a ranking procedure requires a few preliminary assumptions and simplifications.

First, assume that stress on the receiving stream increases with increasing pollutant concentration, and that pollutant concentration is the sole determinative ranking factor. This allows one to ignore variations in streamflow and thus to ignore the additional adverse effects of low dissolved oxygen and high temperatures which normally occur during low flow periods.

Second, rather than evaluate mine drainage effects on the entire aquatic ecosystem, establish impact criteria according to the requirements of the most sensitive resident species in the receiving stream (EPA, 1976).

Finally, ignore synergistic and antagonistic effects in the ranking process. The major justifications for this are that the mine drainages are similar in nature throughout the region, consisting essentially of various concentrations of heavy metals, sulfuric acid, and iron compounds and that simple additive combination of these constituents is sufficient to categorize impacts into three broad classes ranging from low to high.

Once again, since rank should depend on the importance of the receiving stream and its beneficial uses, streamflow will be utilized with pollutant concentration to determine mine rank.

To rank a mine from chemical analysis of the receiving stream:

- At a point in the receiving stream below the confluence with the mine discharge determine flow, pH, Fe (total), hardness, and one or more of the following heavy metals: As, Cd, Cu, Pb, Hg, Ag, Zn.
- From Table 4, select the appropriate factor from 0 to 3 for heavy metals (hm), acid (ac), and iron compounds (fe); where more than one heavy metal is present, select the highest hm-factor which results.

TABLE 4. STREAM EVALUATION FACTORS: CHEMICAL ANALYSIS

FACTOR	soft water hm heavy metals ug/l	hard water hm heavy metals ug/l	ac acid	fe iron compound
3	As, ▷ 4000 Cd, ▷ 4 Cu, ▷ 20 Pb, ▷ 500 Hg, ▷ 1.0 Ag, ▷ 20 Zn, ▷ 500	As, ▷ 4000 Cd, ▷ 12 Cu, ▷ 400 Pb, ▷ 500,000 Hg, ▷ 1.0 Ag, ▷ 20 Zn, ▷ 5000	pH◁4.5	▷ 10.0 mg/l
2	As, 2000-4000 Cd, 2-4 Cu, 10-20 Pb, 250-500 Hg, 0.3-1.0 Ag, 10-20 Zn, 200-500	As, 2000-4000 Cd, 6-12 Cu, 200-400 Pb, 250,000 - 500,000 Hg, 0.3-1.0 Ag, 10-20 Zn, 2000-5000	pH 4.5 - 5.5	5-10 mg/l
1	As, 500-2000 Cd, 0.4-2 Cu, 2-10 Pb, 5-250 Hg, 0.05-0.3 Zn, 5-200 Ag, 2-10	As, 500-2000 Cd, 1.2-6.0 Cu, 40-200 Pb, 5000-250,000 Hg, 0.05-0.3 Zn, 50-2000 Ag, 2-10	pH 5.5 - 6.5	1-5 mg/l
0	As, ◁ 500 Cd, ◁ 0.4 Cu, ◁ 2 Pb, ◁ 5 Hg, ◁ 0.05 Ag, ◁ 2 Zn, ◁ 5	As, ◁ 500 Cd, ◁ 1.2 Cu, ◁ 40 Pb, ◁ 5000 Hg, ◁ 0.05 Ag, ◁ 2 Zn, ◁ 50	Soft Water 9.0▷pH▷6.5 Hard Water pH▷6.5	◁ 1.0 mg/l

- Calculate ℂ = 5hm + 3ac + 2fe. ℂ represents the concentration factor of pollutants in the stream due to the mine. The coefficients 5, 3, and 2 are arbitrarily assigned to the pollutant factors to reflect the relative importance of the three major constituent classes of acid mine drainage. The heavy metals are ranked most important because even in low concentrations they may be highly toxic to aquatic organisms and may accumulate in sediments and the food chain. Precipitated heavy metals may persist indefinitely in sediments, creating potentially long-term contamination problems. Acids are ranked second in importance both because a low pH directly limits the growth of organisms and because it maintains a medium in which poisonous heavy metals may remain in solution. To a lesser extent, iron compounds limit the development of normal aquatic life through direct toxicity at high concentrations and by coating stream bottoms with insoluble ferric hydroxide which smothers the benthic life.

- To determine rank, enter the matrix of Table 5 with ℂ and the corresponding Q, where Q is the receiving streamflow below the mine discharge, preferably at the time pollutant concentrations were determined.

TABLE 5. CHEMICAL RANKING MATRIX: Rc

Q (cfs) \ ℂ	<2	2-10	11-20	21-30
<.1	L	L	L	L
.1-5	L	L	L	M
.6-5	L	L	M	H
>5	L	M	H	H

If sufficient receiving stream water quality data are unavailable, mine discharge characteristics may be used as an indication of reasonable mine rank. The problem is simply one of mixing two streams and calculating the effect of dilution of the receiving stream on the mine discharge. Once the pollutant concentrations in the receiving stream are calculated, their impact on the stream biota may be determined as before.

The buffering capacity of natural streams, due mostly to the carbonate system (Stumm and Morgan, 1970), will partly neutralize incoming acids, resulting in a higher final pH than would be predicted by dilution alone, but the alkalinity of the receiving water must be known before this neutralization can be accounted for. In light of other uncertainties in the method, due to seasonal variations in streamflow, mine discharge, and pollutant concentrations, correction for alkalinity does not seem justified.

To rank a mine from chemical analysis of the mine discharge:

- Determine, for the mine discharge, flow, pH, Fe (total), hardness, and one or more of the following heavy metals: As, Cd, Cu, Pb, Mg, Ag, Zn.
- Determine receiving streamflow, and assume that the concentration of all constituents in the receiving stream, before mixing with the mine discharge, is zero.
- Calculate constituent concentrations in the receiving stream after mixing with the mine discharge.

$$C_s = \frac{Q_m}{Q_m + Q_s} \times C_m$$

$$pH_s = -\log_{10}\left[\frac{Q_m}{Q_m + Q_s} \times 10^{-pH_m}\right]$$

Where

Cs = downstream pollutant concentration
Cm = pollutant concentration in mine drainage
Qs = receiving streamflow
Qm = mine flow
pHs = downstream pH
pHm = mine discharge pH

. Use the calculated receiving stream concentrations to enter Table 4, to calculate C, to enter Table 5, and to determine ranking as discussed previously.

3. Additional Factors

Mine ranking by chemical and biological analysis, as outlined above, is extremely simplified and crude. Its purpose is a first-cut priority list which may be refined by incorporating additional factors.

These additional factors include mine geology and topography, aesthetic values, proximity to population centers, cost effectiveness of clean-up and abatement projects, and land ownership status. The first of these, mine geology and topography, is directly related to the physical impacts of the mine on the stream, and is thus foremost as an additional factor in the ranking process. On the basis of the hydrology, geology, topography, and past history of a mine site, probable pollution impact from that mine may be estimated.

According to the EPA (1977), climate, and especially rainfall, is often the most important factor in the production of non-point source pollution. In particular, rainfall will dislodge and transport particulates from tailings dumps and exposed cuts. An important indication of its erosive capacity is the energy intensity of a given storm or the rainfall-erosivity index calculated for a given location. The EPA (1977) demonstrated that there are large variations in this index for various locations in the country. In this study the erosivity index was not considered because the whole region is under the influence of a relatively uniform climatic regime. The description given by Rantz (1968) for the north coastal region of California is applicable to the whole study region:

> "Precipitation in the region is distinctly seasonal, very little occurring from June through September. Roughly three-fourths of the total annual precipitation occurs during the five months, November through March. The bulk of the precipitation occurs during general storms of several days duration and relatively moderate intensity."

Therefore, a reasonable assumption is, for the purpose of ranking the mines, that the storm pattern is uniform, although annual precipitation received at each mine site may vary greatly, depending on the local altitude, topography, orientation with respect to the moisture-bearing winds, and distance from the ocean (Rantz, 1968).

In addition to directly eroding exposed surfaces, rainfall is the ultimate source of water seeping through the underground passages and tailings dumps left by mining activities, where it both participates in the oxidation of sulfides to sulfuric acid and free metallic cations and transports the oxidation products to receiving streams.

On the basis of these arguments, a reasonable assumption is that the pollutant load generated at a mine site will be proportional to the available water expressed as annual rainfall.

Equally important are the physical characteristics of the mine site which determine the mine's deleterious effects. Historical reports describing the mine's production history, ore processing methods, disposal sites, tunnel configurations, and local geology are a vital source of information for this purpose. (Franks, 1978). Such historical data and a field investigation of present surface conditions may be utilized to estimate the mines' pollution potential. The required information may be subdivided into the characteristics of the surface waste piles and the characteristics of the underground workings.

Potter (1976) identified three types of waste piles associated with heavy metals and sulfide mining in Shasta County, California - tailings piles from processed ore, waste piles predominantly composed of sulfide with minor country rock, and waste piles composed primarily of waste rock with little or no sulfide present - and found that the weathering processes were different in each. Three mine locations were studied which were essentially alike in their quality. Potter concluded that the most important inorganic factors were the grain size of the sulfide material, the presence of sulfides other than pyrite, the porosity and permeability of the tailings material, and the residence time of the water contact with the sulfides.

These conclusions, if assumed applicable for other mines in the region, may be utilized to support or modify a ranking based on direct physical impacts. Moreover, in the absence of chemical or biological stream analysis, mine geology and topography may provide a third procedure in itself for ranking the various contributing sites.

An exposed tailings pile will intercept rainfall in proportion to its projected horizontal areas; its effluent dissolved solids will depend on permeability, average grain size, heavy metal and pyrite concentration, and average depth.

The pollutant load discharged from tunnels may be expected to depend on the surface area exposed underground, on the orientation of the tunnels, on the fracturing and permeability of the rock, and on the extensiveness of sulfide ore bodies underground.

These considerations may be expressed in a simple formula:

$$G = 5hm + 3p + r + a + h + g + t + n + w$$

Where, expressed as factors, 0 to 3,

hm = heavy metals concentration in tailings or ore deposits
p = pyrite (or other sulfide) concentration in tailings or ore deposits
r = average annual rainfall at mine site
a = projected horizontal area of tailings
h = depth of tailings
g = grain size of tailings
t = extensiveness of tunnel network
u = updrift or orientation of tunnels
w = water flux or permeability of tunneled area

Heavy metals and pyrites are arbitrarily weighted by 5 and 3, respectively, because of their deemed importance relative to the remaining variables. Values for each factor, from 0 to 3, are obtained from Table 6. Upon calculating G, a rank may be assigned from Table 7, or, as previously noted, G may be used best as support or modification of a ranking based on chemical or biological analysis of the receiving stream.

TABLE 7. MINE GEOLOGY RANKING: R_g

G	R_g
31-45	H
16-30	M
0-15	L

TABLE 6. MINE GEOLOGY FACTORS

FACTOR	hm heavy metals	p pyrites and other sulfides	r rainfall	a area of tailings	h depth of tailings
3	evidence of high heavy metals concentration in tailings or ore deposits	very high concentration of sulfides in tailings or extensive sulfide deposits in tunneling area	▷ 40"	▷ 5 acres	▷ 30 ft.
2	moderate heavy metals concentration in heavy metals or ore deposits	moderate sulfide concentrations or deposits	25-40"	2-5 acres	10-30 ft.
1	low heavy metals concentration in tailing or ore deposits	low sulfide concentrations minor deposits or exposure underground	10-25"	½-2 acres	5-10 ft.
0	insignificant heavy metals in tailings or ore deposits	insignificant sulfides in tailings or underground	0-10"	½ acre	◁ 5 ft.

TABLE 6. MINE GEOLOGY FACTORS

FACTOR	g grain size of tailings	t tunnel extensiveness	u updrift, orientation of tunnels	w water flux, permeability of tunnel area
3	predominantly fine grained and porous or evidence of extensive leaching	extensive, deep, multiple level tunneling, horizontal and vertical development, multiple adits	tunnel above adits and water table, free drainage from mine containment difficult	rock well fractured or highly porous or known water bearing formation
2	moderate permeability moderate grain size, moderate leaching, potential or activity	moderate tunnel develop one or more adits	moderate drainage potential; mine at or above water table elevation	rock moderately fractured or porous
1	low permeability or coarse material, some evidence of chemicals leaching	low tunnel development usually only 1 or 2 adits, minor geologic disturbance	workings mostly flooded or minor drainage from adits possible	rock slightly fractured or porous
0	either very impermeable or very coarse material insignificant water contact potential	negligible shaft development geological structure essentially undisturbed	negligible drainage from mine, working below lower water table elevation essentially no discharge	nonfractured nonporous rock horizontal bedding

C. Application

Reduction of mine-caused water pollution to a simple rank or single number is fraught with risk. Misunderstanding, misinterpretation, and false conclusions are easy products of a simplified procedure for dealing with a complex problem. The mine list and ranking are neither permanent nor inflexible. Mines may be added or subtracted and ranks may change as better information and more reliable data are acquired.

The ranking methodology was applied to each of the 41 mines of the initial inventory, resulting in a first-cut priority list. In Table 8, the mines are ranked in order of decreasing adverse impact of the mine on the receiving stream, from HIGH (H) to MODERATE (M), to LOW (L). Where the pollution problem of the mine did not fit the methodology (i.e., sedimentation problem) or when no data existed upon which a ranking could be computed, the mine rank was either SPECIAL (S) or UNKNOWN (U), respectively.

Although the mines could have been ranked according to one of three procedures, and although biological analysis is preferable to either chemical analysis or geological evaluation, chemical analysis was used exclusively to rank the mines, for several reasons.

First, chemical analyses were more readily available, as in STORET and field reports, while biological and geological data were not. Second, water samples are more rapidly analyzed for chemical constituents than benthic samples are for diversity of species or water samples are for biologic life. Third, field personnel may retrieve water samples for subsequent chemical analyses without the expertise required to biologically evaluate the streambed or geologically evaluate the mine. Fourth, numeric chemical analysis lends itself more readily to a numeric ranking, whereas the qualitative aspects of both biological and geological analyses hinder a simplified reduction to a single number.

Rank based on biological analysis was attempted three times. Only for the Mammoth Mine was sufficient biological information available to adequately determine a rank. Biological information for the Manzanita Mine was more from a cursory visual inspection than thorough analysis, and for the Golinsky Mine, the information was incomplete. Thus, each of the latter two mines was ranked by alternate means.

TABLE 8. MIN[illegible]NKING

Mine Name	Rank	Chemical C	Chemical Q	Pollution Problem	Data Source
Iron Mountain	H	30	5-70	acid,Cu,Zn,Fe from tailings and adits to creeks	USGS WRI78-32, CDFG, CDMG reports, and CVRWQCB inspections
Mammoth	H	30	3	acid,Cu,Zn,Fe from adits to creek	USGS WRI78-32
Penn *	H	26	680	acid,Cu,Zn,Fe from tailings and shafts to river	CDFG and CVRWQCB reports and inspections
Balaklala	H	26	5	acid,Cd,Cu,Zn from adits and dump to creek	USGS WRI78-32 and DWR report
Keystone	H	26	5	acid,Cd,Cu,Zn from adits and dump to creek	USGS WRI78-32 and DWR report
Afterthought	H	24	68	acid,Cd,Cu,Zn from main portal to creek	CDFG report
Mount Diablo	H	23	.6-1	acid,Hg,Fe from tailings and overburden to creek	CVRWQCB and DWR inspections and reports
Bully Hill	H	21	1.8	acid,Cd,Cu,Zn from mine to creek	USGS WRI78-32
Walker	H	17	11	Cu,Zn from tailings and portal to creek	CVRWQCB, CONOCO, and AMAX inspections and sampling
Sulfur Bank	H	15	5	Hg from open pit to lake	USGS and DWR reports
Newton	M	30	.3	acid,Cu,Fe from tailings to creek	CVRWQCB inspections
Greenhorn	M	19	.6-5	Cu,Zn,Fe from tailings to creek	CDFG inspection
New Idria	M	19	.6-5	Hg,Fe from mine to creek	CVRWQCB inspection
Corona	M	17	1.2	acid,Hg,Fe from adits to creek	CVRWQCB inspections
Manzanita	M	15	3.5	Hg from mine area to creek	CVRWQCB inspection
Cherokee	M	15	.6-5	Hg from mine area to creek	CVRWQCB inspection
Copper Hill	M	5	474	Cu,Zn from mine area to river	STORET and USGS-DWR data
Empire	L	20	.3	Cu from tailings to creek	CVRWQCB inspection
Abbott	L	15	.1	Hg from tailings to creek	CVRWQCB inspections
Knoxville	L	10	2	Hg from mine area to creek	CVRWQCB inspection
Keystone	L	4	2	none observed but Cu suspected, perhaps Fe	CVRWQCB inspection
Lava Cap-Banner	L	3	1.3	none detected in creek but As,Ag,Hg are possible	CVRWQCB inspection
Great Western	L	3	1	none detected but Hg suspected	CVRWQCB inspection
Alhambra Shumway	L	2	1	none detected and sedimentation suspected	CVRWQCB inspection
Anderson	L	0	13	none detected but Hg suspected	CVRWQCB inspection
Big Injun	L	0	8	none detected but Hg suspected	CVRWQCB inspection
Kenton	L	0	5	none detected but As possible	STORET data and CVRWQCB inspections of creek
16 to 1	L	0	5	none detected but As possible	STORET data and CVRWQCB inspections of creek
Engel	L	0	3	none detected but Cu suspected	STORET data
China Gulch	L	0	3	none detected but Cu suspected	STORET data
Ost Hill	L	0	3	none detected in creek but mine runoff high in Hg,Fe	CVRWQCB inspections
Aetna	L	0	.5	none detected but Hg suspected	CVRWQCB inspection
Shasta King	L	0	.1	none detected in creek but mine water high in acid,Cu	USGS WRI78-32 and DWR report
Golinsky	L	0	0	none observed (no flow from mine) but Cu,Zn are possible	USGS WRI78-32
Iron Dyke	L	0	0	none observed (no flow from mine) but Cu is possible	CVRWQCB inspections
Argonaut	L	0	0	none observed (no flow from mine) but acid is possible	CVRWQCB inspection
Dairy Farm	L	0	0	none observed but acid,Cu are possible	CVRWQCB communication with S. Sutter Water District
Plumbago	U N K N O W N			no inspection due to remote location, As suspected	
Reid	U N K N O W N			no inspection due to inaccessibility, acid,Hg suspected	
Malakoff Diggings	S P E C I A L			high sediment and turbidity from mine area to creek	CVRWQCB inspection
Mineral Slide	S P E C I A L			sediment and turbidity from mine area to creek	CVRWQCB observation

*Rank based on conditions existing prior to abatement measures presently being installed.

Rank based solely on geological analysis was not used. Rather, geological, topographical, and hydrological information were deemed better utilized as additional factors in refining the initial priority list.

All of the mines were ranked on the basis of chemical analysis. The ranking was done without an extensive data acquisition program, for which neither time nor money was available. Data and information were obtained from California Department of Fish and Game reports, California Department of Water Resources reports, U.S. Geological Survey reports, STORET computer printouts, and, primarily, Central Valley Regional Water Quality Control Board files. Where these sources fell short, field inspections for sampling and analysis were undertaken by Regional and State Board staff as a last resort. The primary data source for each mine is listed in Table 8.

Because of the variety of sources, chemical data ranged from fairly extensive and in-depth to isolated and superficial. For example, Walker Mine and Iron Mountain Mine have been frequently investigated and rather thoroughly studied, whereas Great Western Mine and Reid Mine are remote operations of which little is known. Mines like the former may have numerous analyses of the mine discharge and the receiving water, as well as detailed reports of mine geology, tunnel orientation, and tailings characteristics. On the other hand, mines like the latter may have but one chemical analysis at a downstream station.

This disparity in weight of data among the mines does not necessarily detract from the sufficiency of the data to compute mine ranks. As readily as one sample may represent an instantaneous aberration of the norm, so also may it reflect general conditions persisting over time. Although degree of confidence in a rank may increase with repeated sampling, lack of extensive data does not prohibit a fair rank computation.

Ranking was based, if at all possible, on examination of the receiving stream, as opposed to examination of the mine. Emphasis on the former accords with the stated goal of mine ranking by impact on beneficial uses of receiving waters. Ideally, data at three locations - upstream, the mine discharge, and downstream - were obtained, so that downstream pollution, or increase thereof, could be attributed to the mine.

Flow is important as a ranking factor because it indicates the magnitude of the stream and hence the importance of its beneficial uses, and because by relating flow to concentration, the magnitude of the pollutant loading is obtained.

Typically, streamflow used for ranking was the streamflow at the time of sampling, rather than average annual streamflow, low flow, or peak flow. Matching streamflow to its corresponding pollutant concentration was preferred as more representative of actual conditions because, usually, one or only a few samples for chemical analysis were taken at a given location, and because concentration is likely dependent on flow, i.e., an increase in streamflow would probably decrease pollutant concentration. However, where streamflow at time of sampling was unknown, average streamflow, or some representative value, was used.

Division of flow in Tables 3 and 5 is based primarily on policy -- that is, what flow is significant enough, coupled with stream degradation and pollutant concentrations, to warrant investigation and enforcement? Considered was the fact that flows are often less than 5 cfs during late summer, when sampling often occurs, and that mines are often located in the foothills or mountains at the headwaters where flow is relatively low.

An explanation of how each mine's rank was computed is provided in Appendix B.

A. CROSS INDEX LIST

Name of Mine	Watershed Affected
Abbott	Cache Creek
Aetna	Putah Creek
Afterthought	Sacramento River (Upper)
Alhambra Shumway	American River, South Fork
Anderson	Putah Creek
Argonaut	Mokelumne River
Balaklala	Sacramento River (Upper)
Big Injun	Putah Creek
Bully Hill	Sacramento River (Upper)
Cherokee	Butte Creek
China Gulch	Feather River (North Fork)
Copper Hill	Consumnes River
Corona	Putah Creek
Dairy Farm	Bear River
Empire	Stanislaus River
Engel	Feather River, North Fork
Golinsky	Sacramento River (Upper)
Greenhorn	Sacramento River (Upper)
Iron Dyke	Feather River, North Fork
Great Western	Putah Creek
Iron Mountain	Sacramento River (Upper)
Kenton	Yuba River, Middle Fork
Keystone	Sacramento River (Upper)
Keystone	Stanislaus River
Knoxville	Putah Creek
Lava-Cap Banner	Bear River
Malakoff Diggings	Yuba River, South Fork
Mammoth	Sacramento River, (Upper)
Manzanita	Cache Creek
Mineral Slide	Butte Creek
Mt. Diablo	San Joaquin Delta
New Idria	Fresno Slough
Newton	Consumnes River
Oat Hill	Putah Creek
Penn	Mokelumne River
Plumbago	Yuba River, Middle Fork
Reid	Cache River
Shasta King	Sacramento River (Upper)
Sixteen to One	Yuba River, Middle Fork
Sulphur Bank	Cache Creek
Walker and Walker Tailings	Feather River, North Fork

ALHAMBRA SHUMWAY MINE

Alhambra Shumway Mine drains to Mosquito Trail Gulch which is tributary to Traverse Creek, thence to Rock Creek, thence to South Fork American River. An inspection 1 March 1979 by CVRWQCB obtained the following:

Station	cfs Q	pH	µg/l As	mg/l Fe	umhos/l Ec
#1 - drainage on road into mine area	.1	--	10	30	50
#2 - runoff below mine area	1	7	10	1.4	200

Arsenic was sampled because gold occurs at the mine free and associated with arsenopyrite. The drainage sampled is not one continuous stream, and Station #1 is more an indication of natural background than any contribution from mine drainage.

Entering Table 4, for soft water, hm and ac equal zero, and fe = 1, resulting in C = 2. Therefore, from Table 5, with Q = 1cfs, Rc = L.

Based on chemical analysis of runoff below the Alhambra Shumway Mine, the rank of the mine is LOW.

DAIRY FARM MINE

Dairy Farm Mine is located along the high water line of Camp Far West Reservoir on the Bear River.

Camp Far West Reservoir is owned and operated by the South Sutter Water District. By phone conversation with District representative, it was learned that the Dairy Farm Mine is not submerged, but is rather above the high water line and dry; that the District has never detected a water quality problem with respect to the mine; that, to their knowledge, there has been no discharge from the mine.

Based on these initial findings, although with no hard data, assume initially for the mine that $Q = 0$ and therefore, $C = 0$, resulting in zero rank, or LOW.

LAVA CAP-BANNER MINE

Lava Cap Mine is located approximately 6000 feet south and lower in elevation from the Banner Mine. Since the two mines are connected through the subsurface, water discharging from Lava Cap includes water from Banner.

Both mines have been inactive since 1943, when they were closed by Presidential order. The current lessees of the property propose to dewater the mines and evaluate the feasibility of resuming gold production.

As a presently "abandoned" mine, water discharges from a tunnel out of the Lava Cap mine to Little Clipper Creek, thence Clipper Creek, thence Little Greenhorn Creek, thence Greenhorn Creek, and finally NID's Rollin Reservoir on the Bear River.

In view of plans to reopen the mines, inspections were conducted by CVRWQCB and SWRCB staff with respect to application for NPDES permit. Results of sampling follow:

			µg/l							mg/l	mg/l as CO_3 Ca
STATION	DATE	pH	As	Cd	Cu	Pb	Hg	Ag	Zn	Fe	Hdns
Little Clipper Crk., above tunnel discharge	4-3-78	6.3	<5								
Lava Cap mine tunnel discharge	8-16-77	6.9	660	3	3	10	.3	12	9	1.2	215
Lava Cap mine water in shaft	11-30-78		<5								
	12-1-78		<6								
Little Clipper Crk. below tunnel discharge	4-3-78	6.3	39								

Flow in Little Clipper Creek in the fall of 1977 consisted entirely of mine overflow, which is estimated at approximately 35 gpm (.08cfs). Little Clipper Creek above the mine runs only during winter and spring months, but below the mine the Creek often runs year-round. Using very liberal assumptions, a crude estimate of flow in Little Clipper

Creek may be calculated using the formula:

$$C_{creek} = \frac{C_{mine} \times Q_{mine}}{Q_{(creek)} + Q_{(mine)}}$$

where C = concentration of element and
Q = flow in cfs

Using arsenic concentrations and the known mine flow,

$$39 = \frac{660 \times .08}{Q_{creek} + .08} \Rightarrow Q_{creek} = 1.27 \text{ cfs}$$

Using the data for the tunnel discharge and entering Table 4, hm (max) = 2 from the Ag concentration. Again, using the same very liberal assumptions as above, the Ag concentration in the creek would be:

$$C_{creek} = \frac{12 \times .08}{1.27 + .08} = .71 \text{ mg/l, resulting in hm} = 0$$

Therefore, using the data for Little Clipper Creek below the tunnel discharge and entering Table 4, hm = 0, ac = 1, and fe = 0, resulting in a ℂ - factor of 3. Therefore, with ℂ = 3 and Q = 1.27, Rc = L.

Based on a chemical analysis of Little Clipper Creek, the rank of Lava Cap-Banner Mine is <u>LOW</u>.

CHEROKEE MINE

Cherokee Mine discharges to Sawmill Ravine, thence to Dry Creek which is tributary to Butte Creek.

CVRWQCB inspection and sampling on 6 May 1976 yielded the following results:

Station	As	Hg	Fe	Ec
Drainage from mine adit	0.0	< 1 mg/l	0.1 mg/l	450 µmhos
Sawmill Ravine, downstream from adit	0.0	< 1 mg/l	0.3 mg/l	520 µmhos

This data, and the degree of accuracy of the mercury analysis, are insufficient for an adequate ranking. However, assume that the mercury concentration yields hm = 3 from Table 4, and that pH is high enough for ac = 0; fe = 0, and therefore, C = 15. Flow is unknown, but a fair assumption is that flow may well be in the .6 - 5cfs range. On this basis, from Table 5, Rc = M.

Based on chemical analysis of Sawmill Ravine, the rank of Cherokee Mine is MODERATE.

MINERAL SLIDE

Mineral Slide is an abandoned mining area along Little Butte Creek south of Magolia Reservoir near Paradise.

The area has had but cursory inspections from CVRWQCB staff and information from other sources is lacking. Underground mines are at the site, and gold is presumed to have been mined.

Water quality problems are mainly as a result of unstable hillsides which slump into the creek, causing excessive siltation and turbidity. However, no hard data are available.

Because problems at Cherokee do not conform to the ranking procedure, no rank will be assigned on that basis. At best, a SPECIAL rank may be assigned to indicate that the problem has been noted.

ABBOTT MINE

Abbott Mine is located along Highway 20 in Lake County, and drains to Harley Gulch and thence to Cache Creek. Inspections by CVRWQCB obtained the following:

Station	Date	cfs Q	pH	ppb µg/l Hg	ppm mg/l Fe	µmhos/cm Ec
¼ mile above waste pile	2-8-73	-	--	0	--	--
¼ mile below waste pile	2-8-73	-	--	21	--	--
	3-8-79	0.1	7.5	2	0.2	5000

Entering Table 4, for hard water (Cache Creek, North Fork, 39° 07'09"/122°34'04", reports hardness of 174 mg/l as $CaCO_3$), ac and fe equal zero, and hm =3 for downstream sampling, resulting in C = 15. Therefore, from Table 5, with Q = 0.1cfs, Rc = L.

Based on chemical analysis of unnamed tributary to Harley Gulch, the rank of Abbott Mine is LOW.

Abb.H

MANZANITA MINE

The Manzanita Mine was listed as a "potential mercury contamination problem" in the 1972 CDMG report, Principal Areas of Mine Pollution. To evaluate this possibility, a field trip was undertaken by J. Henao, A. Franks, and S. Buer on 15 May 1978.

The field investigation included water sampling, visual inspection of the mine area, and visual inspection of Sulfur Creek, which receives any discharge which might issue from the mine area. The results may be summarized as follows:

The receiving water is normally high in mineral content and has a very noticeable hydrogen sulfide odor. The DWR sampled the creek on 15 April 1952 and characterized the water "sodium chloride-bicarbonate water", with an EC value of 3640.

The stream was tepid, supported abundant algae, large numbers of flies (Diptera), including Calliphoridae, abundant Gerridae and unidentified flies and larvae. Grasses grew vigorously on the stream banks and into the water along the creek. The stream flow was estimated to be 2-5cfs.

A ravine draining the east portion of the mine area carried a minor stream flow of about 5 gpm. As with Sulfur Creek, vegetative growth in the water was abundant, and large numbers of benthic larvae were noted.

No evidence of acid mine drainage or heavy metals toxicity was found in the stream downstream from the mine: No precipitates, no iron staining, no evidence of reduced biota downstream.

Using Table 1, the observations above indicate that the stream may be classified l_o. Entering the matrix of Table 2 with Q = ≃3.5cfs and l_o greater than 264 feet, the resulting R_v = L.

Based on a visual inspection of Sulfur Creek, the rank of Manzanita Mine is LOW.

An inspection of the mine area supported this judgment: The mine was separated from the creek by a horizontal bench 100-150 feet wide, with very little evidence of sediment transport or minerals drainage from the mine. Very little erosion was observed at the mine site, and no sulfide bearing minerals were noted (by A. Franks).

The history of the mine also suggests that the pollution potential of the mine is negligible. The ore was found near the surface, so only shallow adits and surface cuts were developed and the ore was generally low grade and dispersed in narrow veins within the mineralized zone. (CDMG, 1929)

At this writing, (7-5-78), the water samples have not yet been analyzed but all available evidence supports the conclusion that the Manzanita Mine represents a negligible mine pollution problem.

Water samples taken during the aforementioned 5-15-78 field trip were analyzed 7-7-78. Results follow:

Sample Location	Hg (µg/l)	pH	Flow
1. Sulfur Creek [downstream] from Manzanita Mine	3.4	8.45	2-5 cfs
2. Unnamed creek ½ mile south of Manzanita Mine	12.4	8.45	1-2 gpm (.003cfs)
3. Manzanita Mine discharge	32.1	8.40	NA

Using Table 4 for hard water, hm = 3, ac = 0, and fe = 0; therefore, C = 15, and, with Q = ≃3.5cfs, Rc = M from Table 5.

Based on a chemical analysis of Sulfur Creek, the rank of Manzanita Mine is MODERATE.

REID MINE

Reid Mine is located northwest of Knoxville along Davis Creek, which is tributary to Cache Creek.

An attempt 8 March 1979 by CVRWQCB to inspect the mine was unsuccessful, as access was denied by a locked gate, and no mine personnel were about for assistance.

Although no problems are suspected, until data are available, Reid Mine must be ranked UNKNOWN.

SULFUR BANK MINE

Sulfur Bank Mine is located on the eastern shore of Clear Lake at the lower southeast end of the lake. The mine is an open pit covering approximately two acres.

No analyses of water directly discharged from the mine area to the lake are available. Water quality of the lake in the vicinity of the mine area was determined by DWR in Bulletin 143-2 "Clear Lake Water Quality Investigation", March 1966.

Summary of DWR results, range of values:

pH	7.3 - 8.8
Hdns	131 mg/l
SO_4	8.1 - 30 mg/l
B	0.4 - 1.8 mg/l
Cu	0.01 - 11.0 mg/l
Cd	<3.3 mg/l
Pb	0.01 - <3.3 mg/l
Zn	0.02 - <13 mg/l
Fe (total)	.05 - .25 mg/l; 57 mg/l; 87 mg/l

USGS is currently studying Clear Lake to determine the relation of mercury concentrations in the sediments to such concentrations in fish. Preliminary results of a core sample of the lake bottom in the vicinity of the Sulfur Bank Mine area show an average mercury concentration (for a 387 cm sample, 11 points) of approximately 22 mg/l.

This information -the DWR and USGS reports- show than any conclusions regarding the contribution of Sulfur Bank Mine to the pollution of Clear Lake are tenuous at best. Table 5 of the DWR report demonstrates that other portions of the lake, far removed from the influence of Sulfur Bank Mine, are a quality as poor as near the mine.

Clear Lake, due to its hydrology, geology, and development, is too complex of a system to isolate one factor for blame. In short, without a thorough investigation of Sulfur Bank Mine, a determinate ranking is impossible.

However, certainly based on visual observation (photos, in file), past history (rescinded Resolution No. 153), and chemical analyses available, the influence of Sulfur Bank Mine on Clear Lake is not positive, nor benign. A fair judgment is that, probably, the mine contributes mercury in concentrations sufficient enough for hm = 3; since pH of the lake is constantly above 6.5, ac = 0; iron concentrations in the lake, although sporadically very high, generally range less than 1.0 mg/l, resulting in fe = 0. On these bases, C = 15. Regarding Clear Lake as the receiving stream flow (Q), Rc = H and the rank is HIGH; at best, regarding Q as mine discharge, a probable range is .5-5cfs, and the rank is MODERATE.

COPPER HILL MINE

Copper Hill Mine discharges, if at all, to the Consumnes River in Amador County approximately 4 miles upstream from Michigan Bar. Extensive water quality data for the Consumnes River at Michigan Bar are available in STORET and USGS-DWR publications (see Copper Hill file). Pertinent data for ranking the mine are summarized below:

Station	cfs Q	pH	µg/l As	Cd	Cu	Pb	Hg	Zn	mg/l Fe	mg/l $CaCO_3$ Hdns
Consumnes River at Michigan Bar	474	7.5	0.7	0.0	3.7	0.0	0.0	14.7	.08	32

All values are mean values

Entering Table 4, for soft water, hm = 1 (for Cu and Zn, which are indicative of mine drainage), ac = 0, and fe = 0, resulting in $\mathbb{C}$ = 5. With Q = 474cfs and $\mathbb{C}$ = 5, Rc = M.

Based on a chemical analysis of the Consumnes River, the rank of Copper Hill Mine is possibly MODERATE.

Note: The mine is ranked "possibly" moderate because there is no proof that the Copper Hill Mine is in fact discharging to the Consumnes River and is responsible for the copper and zinc concentrations.

ENGEL MINE
CHINA GULCH MINE

Engel and China Gulch Mines discharge, if at all, to Lights Creek which is tributary to Indian Creek near Taylorsville in Plumas County. Water quality data are available in STORET at two stations on Lights Creek, and are summarized below:

Station	cfs Q	pH	µg/l Cd	µg/l Cu	µg/l Pb	µg/l Hg	µg/l Zn	mg/l Fe	mg/l as Hdns CaC
Lights Crk. near Taylorsville	.306	7.8	0.0	2.3	1.3	0.0	7.3	.027	--
Lights Crk. Station 1	3.28	6.7	--	5.7	--	--	7.8	.025	61.7

All values are mean values. Both stations are located below the Engels and China Gulch Mines and above the Lights Creek confluence with Indian Creek.

Entering Table 4, for hard water, hm, ac, and fe each equal zero, resulting in $\mathbb{C} = 0$. Therefore, from Table 5, the rank is zero, or LOW.

Based on chemical analysis of Lights Creek the rank of Engel and China Gulch Mines is LOW.

IRON DYKE MINE

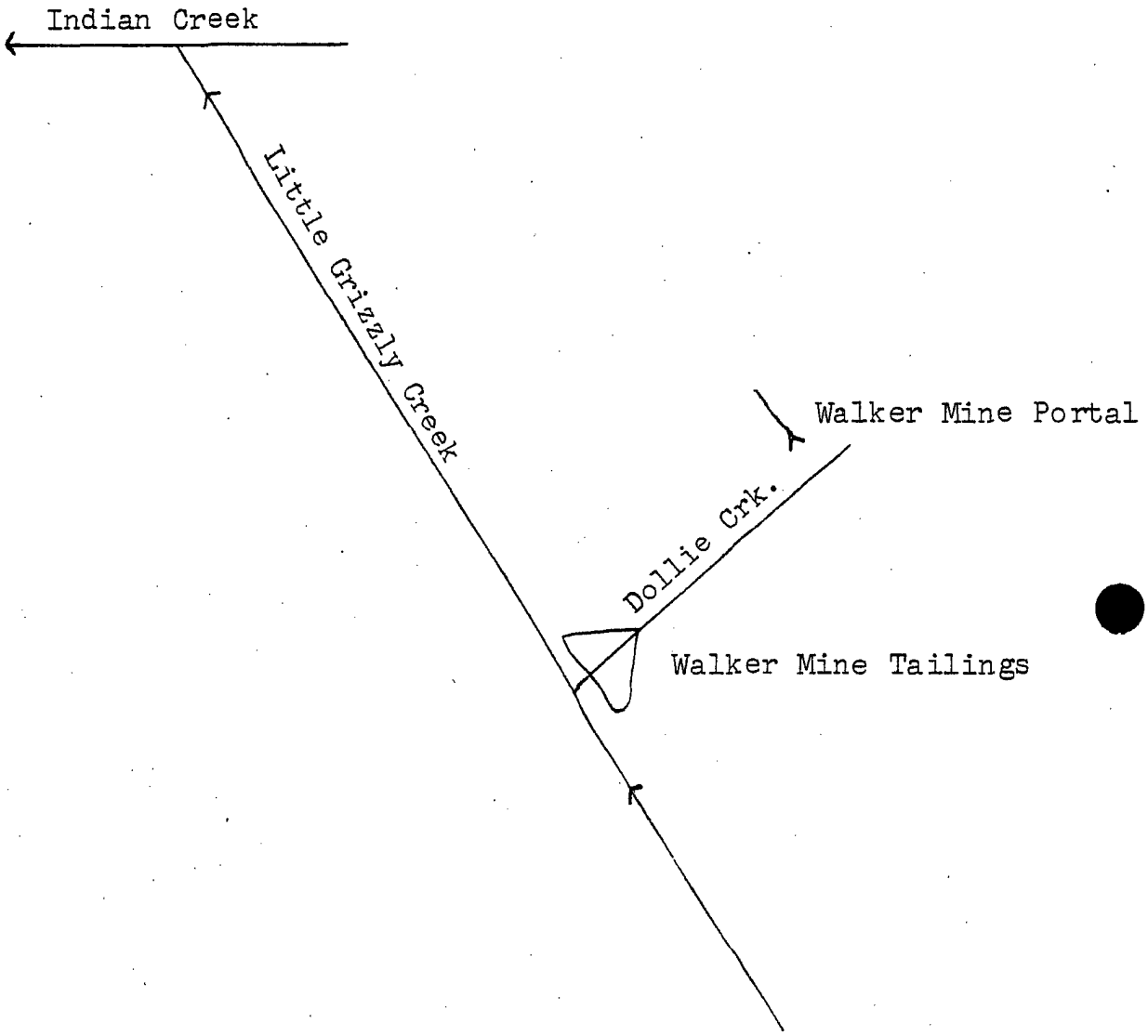
Iron Dyke Mine drainage is to Taylor Creek, thence to Indian Creek, thence to Wolf Creek, and finally to NF Feather River.

CVRWQCB has inspected the mine area four times since 1958. Never was a mine discharge to the Creek observed; mine flow of less than 0.1cfs was noted as percolating into the ground before reaching the Creek. One sample of the mine discharge (15 August 1974) had 610 µg/l of copper.

Based on these findings, the mine does not appear to impact the stream, i.e., mine Q to the stream = 0, resulting in C = 0, and therefore, in effect zero rank, or LOW.

WALKER MINE

The situation at Walker Mine in Plumas County is illustrated in the following schematic:



Water quality data and descriptions of the mine and environs are available in Case File #355 - "Walker Mine", and the Walker Mine 208 file. Because the data are relatively numerous, and the time over which collection has taken place is relatively long, <u>average</u> values are believed to fairly represent the mine for ranking purposes.

For Dollie Creek, and using Table 4, for soft water, hm = 3 as a result of the copper concentrations, ac = 0, and fe = 1, resulting in C = 17. With Q probably generally less than 5cfs but greater than 0.5cfs, Rc = M.

Based on chemical analyses of Dollie Creek, the rank of Walker Mine is MODERATE.

For Little Grizzly Creek, using Table 4, hm = 3 due to the copper concentrations, ac = 0, and fe = 1, again resulting in ℂ = 17. Q was measured once at 7.2cfs at the mine site; the downstream USGS gaging station recorded monthly mean values for water year 1975-76 (drought) ranging from 3.68cfs to 27.0cfs, with an annual mean that year of 11.5cfs. It is fair to assume that normal flows in Little Grizzly Creek are generally greater than 5cfs. Therefore, from Table 5, Rc = H.

Based on chemical analyses of Little Grizzly Creek, the rank of Walker Mine is HIGH.

WALKER MINE (cont'd.)

Station	Data Source	Period of Record	µg/l Cu	Zn	Cd	Pb	Ag	pH	cfs Q	mg/l Fe
Little Grizzly Creek, above tailings	CONOCO	1978	13	14	<10	<100		7.6		.42
	AMAX	1976-1977	2	18	<10	<50	<10	7.4		.59
	RWQCB	1958-1978	<10	12				7.4	4.6	.55
Dollie Creek below mine discharge	CONOCO	1978	724	323	18	<50	<30	5.6		1.24
	AMAX	1976-1977	1400	155	<10	<50	<10	7.2		1.21
	RWQCB	1960-1978	2317	116				7.5	1.2	2.2
Little Grizzly Creek, below tailings, first station	CONOCO	1978	1602	94	<2	<50		7.8		1.22
	AMAX	1976-1977	360	34	<10	<50	<10	7.8		0.7
	RWQCB	1957-1978	372	40				7.7	7.2	1.1

NOTES: "Period of Record" only means that samples were obtained at certain times during the years listed. At most, eight samples were collected in a given year.

NEW IDRIA MINE

New Idria Mine discharges to San Carlos Creek in the town of Idria. Information used to rank the mine is from a CVRWQCB inspection of April 8, 1975.

			µg/l				mg/l	mg/l (as $CaCO_3$)
	Station	pH	As	Cd	Cu	Pb	Hg	Fe	Hdns
#3	San Carlos Crk. upstream from mine discharge	8.5	0.0	0.0	20	10	2.7	7.4	724
#4	Runoff from mine area before entering Creek	2.8	20	0.0	450	10	4.0	9.7	2900
#5	San Carlos Crk. 1 3/4 mi. downstream from mine discharge	7.7	20	0.0	110	20	7.8	9.6	1350

Flow observation: "At the time of inspection, the water draining from the mine area made up approximately ¼ of the total volume of water flowing in San Carlos Creek below mine property." Otherwise no estimate of flow is available; no gaging stations are located downstream. The closest flow measurement is on Panoche Creek below Silver Creek (San Carlos Creek is tributary to Silver Creek). The average flow at that station during 1965-67 was 26cfs, ranging from 1.3cfs to 108cfs.

Although upstream water quality is degraded, the runoff from the mine clearly aggravates the problem. Using the data for Station #5 and entering Table 4, for hard water, hm = 3, ac = 0, and fe = 2, resulting in C = 19. Flow is unknown, but an estimate of from 0.6cfs to 5cfs is reasonable, resulting in Rc = M.

Based on a chemical analysis of San Carlos Creek, the rank of New Idria Mine is MODERATE.

ARGONAUT MINE

Argonaut Mine is located west of Hwy. 49 above the road grade. Mine drainage or discharge, if any, would flow to Jackson Creek.

Inspection of the mine area by CVRWQCB 12 March 1979 discovered no evidence of mine pollution or any drainage from the mine. Since for the mine Q = 0, C = 0, and based on this single inspection, there is in effect zero rank. Therefore, the rank is LOW.

Note: STORET data in Jackson Creek at 38°20'40.0"/ 120°46'56.0" above City of Jackson sewage treatment plant:

Q (mean instant flow 11-28-73 to 11-5-75) = 7.6cfs
Ec = 180 µmhos
pH = 7.6

NEWTON MINE

Newton Mine, located along Highway 88, drains to Copper Creek, thence to Sutter Creek, Dry Creek, and finally the Mokelumne River.

The mine has been visited by CVRWQCB personnel at least nine times since 1965. Usual observations include no actual discharge from the mine, but degradation of the stream, i.e., discoloration, precipitate and increases in acid and copper, as it courses through the tailings. Sampling 12 March and 10 April 1979 yielded the following results:

Station	Q (cfs)	pH	Cu (g/l)	Fe (mg/l)
Upstream of mine	0.3	7.1	< 10	0.24
Downstream of mine	0.3	3.2	11,400	106

Entering Table 4 (assuming soft water since streamflow composed of runoff from recent rains), for the downstream station, hm = ac = fe = 3, resulting in C = 30. From Table 5, with Q = .3, Rc = M.

Based on chemical analysis of Copper Creek, the rank of Newton Mine is MODERATE.

PENN MINE

Penn Mine is located along the Mokelumne River between Pardee and Camanche Reservoirs. Downstream pollution as a result of drainage from the Penn Mine is succintly explained in CDFG Environmental Services Branch Administrative Report No. 78-1 by Finlayson and Rectenwald, which may be found in the mine file labeled "Penn Mine".

Water quality problems due to Penn Mine have been abated by diversion works and containment facilities constructed in 1978 (see also Case File #166 - Penn Mine). If these measures suffice to eliminate further downstream pollution due to the mine, a rank of LOW will be warranted, or perhaps a non-rank, i.e., elimination from the list. However, should the measures prove inadequate, a HIGH rank is justified, particularly if downstream fishkills are a direct result of the mine discharge.

Data to date are summarized below. No data sufficient to judge the effectiveness of the abatement measures are yet available. Therefore, Penn Mine will be tentatively ranked on the basis of its impact on the stream without effective abatement measures.

		cfs		µg/l				mg/l
Station	Date	Q	pH	As	Cu	Pb	Zn	Fe
Upstream from mine discharge, below Pardee Reservoir	2/10,11/58 [1]	650	6.9	0	10	0	10	.13
	10/6/77 [3]		7.28	-	<10	-	250	--
	4/11/78 [4]		--	-	--	-	<10	--
	5/9/78 [4]		--	-	--	-	<10	--
Mine Run Creek, near confluence with Mokelumne River	2/10,11/58 [1]	1.4	2.7	10	59,000	310	1,640,000	178
Shoreline near Penn drainage Mokelumne River	5/5/77 [2]		--	-	30	-	120	.09
Downstream from mine discharge above Camanche Reservoir	2/10,11/58 [1]	680	3.4	0	3,800	0	37,600	1.3
	10/6/77 [3]		6.96	-	40	-	1,120	--
	4/11/78 [4]			-	--	-	50-960	--
	5/9/78 [4]						10-30	

Mokelumne River water is soft (total hardness ≃ 18 mg/l as $CaCO_3$)

1/ Cordone, CDFG unpublished data, 1960, in Finlayson and Rectenwald, CDFG ESB Admin. Rep. 78-1 (Oct. 78)

2/ Memorandum, CVRWQCB, S. Phillippe to J. Del Conte (June 27, 1977)

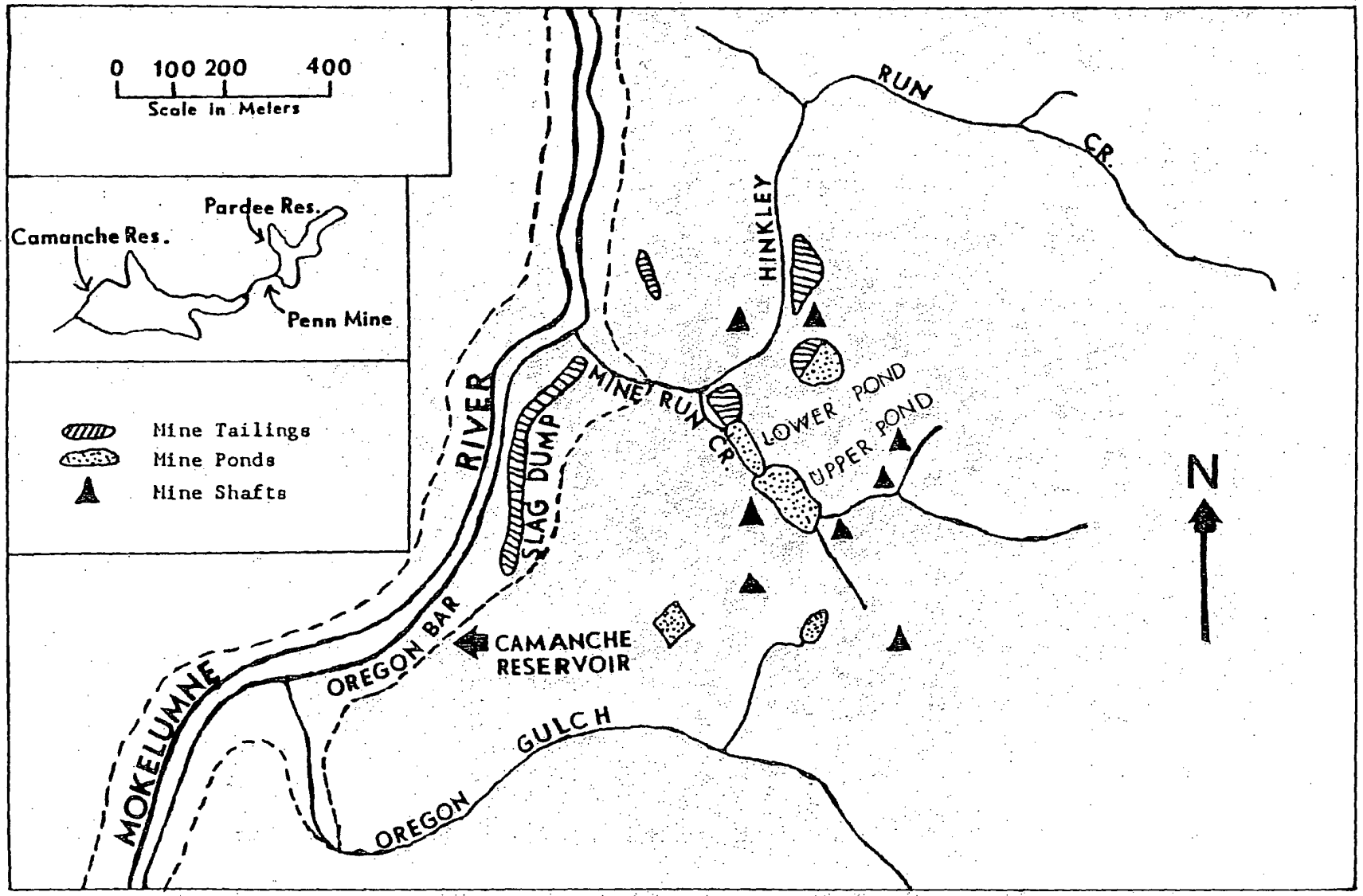
3/ Memorandum, re: Kill of Steelhead Trout at Mokelumne River Hatchery Beginning October 6, 1977, CDFG, R. Hanson to B. Lassen (Oct. 19, 1977)

4/ Memorandum re: Analysis of Water Samples for Zinc, Camanche Lake, CDFG (May 1 and 22, 1978)

Using the 1958 data for the Mokelumne River downstream from the mine, and above Camanche Reservoir, ac and hm equal 3, and fe = 1, resulting in C = 26; since streamflow is greater than 5cfs, Rc = H. Using more current data, the high zinc levels result in hm = 3, producing C = 15, and again, with the high Q in the river, Rc = H.

Using the 1958 data for Mine Run Creek, which discharges to the Mokelumne, hm = ac = fe = 3, resulting in C = 30, and with Q = 1.4, Rc = H.

Therefore, based on chemical analysis of either the Mokelumne River or Mine Run Creek, <u>without</u> effective abatement measures, the rank of Penn Mine is <u>HIGH</u>.



The Penn Mine Watershed, Mokelumne River Basin, California.

AETNA MINES

Aetna Mine drains to Swartz Creek, thence to Pope Creek which is tributary to Putah Creek. Aetna Extension Mines drain to James Creek, thence to Pope Creek.

Unnamed tributaries below Aetna Mine and Aetna Extension Mine, respectively, were inspected and sampled 21 March 1979 by CVRWQCB. Both unnamed tributaries were clear and clean, and were analyzed as follows:

Station	cfs Q	pH	µg/l Hg
Unnamed tributary below Aetna Mine	.5	7.4	0.0
Unnamed tributary below Aetna Extension Mine	.04	7.8	0.0

Entering Table 4, ac and hm equal zero; assume from appearances that iron concentration was negligible, and therefore fe = 0. As a result, C = 0, and from Table 5, Rc = L.

Based on chemical analysis of unnamed tributaries draining below Aetna and Aetna Extension Mines, their respective ranks are LOW.

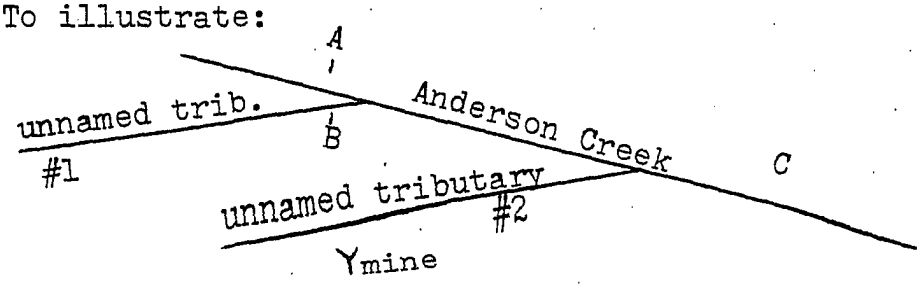
ANDERSON MINE

According to CDMG coordinates, Anderson Mine is located in the SE ¼ of the SE ¼ of Section 26, T11N, R8W, and apparently would drain into an unnamed tributary to Anderson Creek.

CVRWQCB sampled Anderson Creek and another unnamed upstream tributary on 15 March 1979 with the following results:

	Station	cfs Q	pH	µg/l Hg	mg/l Fe
A.	Anderson Crk., upstream from mine	7	7.0	0.0	0.0
B.	Unnamed tributary to Anderson Crk. (mine is not located on this tributary).	5	5.8	1	25
C.	Anderson Crk., below unnamed tributary #1 and below unnamed tributary on which mine is located	13	7.2	0.0	7.4

To illustrate:



Using the data at Station C, and entering Table 4 (assume soft water as flow was high due to recent storm), hm and ac equal zero, and fe = 2, resulting in $\mathbb{C} = 4$.

From Table 5, with $\mathbb{C} = 4$ and Q~13cfs, Rc = M. However, since tributary #1 is contributing excessive iron and mercury which dilutes downstream, a fair judgment is that the pollutants measured at Station C are not due to Anderson Mine, but rather "solely" to unnamed tributary #1. Therefore, for ranking purposes, assume that $\mathbb{C}$ as a result of Anderson Mine is practically zero, resulting in the zero rank, or LOW.

Based on chemical analysis of Anderson Creek and an unnamed upstream tributary, the rank of Anderson Mine is LOW.

BIG INJUN MINE

Big Injun Mine drains to Bear Canyon Creek, thence to Anderson Creek which is tributary to Putah Creek above Lake Berryessa.

CVRWQCB sampled Bear Canyon Creek downstream of the mine on 15 March 1979, with the following results:

Q	pH	Hg	Fe
~8cfs	6.6	0.0 µg/l	0.0 mg/l

Entering Table 4, hm = ac = fe = 0 and therefore, $\mathcal{C}$ = 0, resulting, effectively, in zero rank, or LOW.

Based on chemical analysis of Bear Canyon Creek, the rank of Big Injun Mine is LOW.

CORONA MINE

Corona Mine is located near the headwaters of James Creek, which is tributary to Pope Creek, which in turn discharges to Putah Creek.

Corona Mine has been visited by CVRWQCB staff at various times since the late 1950's. A summary of sampling results follows:

			cfs		←——— µg/l ———→				mg/l	mg/l ($CaCO_3$)
	Station	Date	Q	pH	Hg	Cu	Pb	Zn	Fe	Hdns
(1)	James Crk. above Corona Mine	2-17-77		7.9	0.1				.7	175
		3-15-79	.15-.2	6.4	0.0				.4	
(2)	Corona Mine, lower adit	7-29-70	.17	3.0	150				263	
		3-15-79	.7-.8	5.0	0				620	
(3)	James Crk. below lower adit	3-15-79	1.0-1.2	5.4	0	0		100	110	
(4)	Corona Mine upper adit	7-29-70	.02	3.8	160				132	
		2-17-77		3.2	0	0		200	7	
		3-15-79	.1-.15	5.6	0				80	
(5)	James Crk(?) below both mine adits	10-9-58	.013	2.9		100	10	130	2.6	572
(6)	James Crk., approx. 1½ mi. below mine adits	3-21-79	3	7.0	0	0		0	13	
(7)	James Crk. at Aetna Sprgs. Golf Course Road	3-15-79	4-5	6.6	0	0		0	6.3	
(8)	Pope Crk. at Butts Canyon Road	7-29-70	.3	8.2	60				.07	
		3-15-79	10-12	7.2	0				1.2	

The effect of the mine on James Creek is noticed first at Station (3). Based on this Station, hm = 1, ac = 2, and fe = 3, resulting in ℂ = 17; with Q = 1.2, Rc = M.

The inspection of 7-29-70 observed that at the time, flows from the Corona Mine adits were the only discharges to James Creek and that there was no upstream flow. As a result, James Creek at the mine had a flow of .19 cfs, a pH at best of 3.8, and mercury and iron concentrations at best of 150 mg/l and 132 mg/l, respectively. Based on this information, hm = ac = fe = 3, resulting in ℂ = 30, and, with Q = .19, Rc = M. Further downstream on Pope Creek that same day, ac and fe = 0, and hm = 3, resulting in ℂ = 15. Here, with Q = 3, Rc = L.

The next most representative indication of the effect of the mine is at Station (6). There, hm and ac = 0, and fe = 3, resulting in ℂ = 6; therefore, with Q = 3, Rc = L.

Considering all the data, and the suspicion that the zero values for mercury concentrations reported 3-15-79 and 3-21-79 are perhaps in error (detectable mercury concentrations were expected, in view of past results and the nature of the mines), a rank of MODERATE is believed fair.

[To place numbers on the ranking, average the above values for ℂ (17, 30, 15, 6) and Q (1.2, .19, .3, 3), resulting in ℂ = 17 and Q 1.17, from which Rc = M]

1 Corona

GREAT WESTERN MINE

Great Western Mine drains to Hoodoo Creek, thence to Dry Creek which is tributary to Putah Creek above Lake Berryessa.

CVRWQCB sampled Hoodoo Creek downstream of the mine on 15 March 1979, with the following results:

Q	pH	Hg	Fe
~1cfs	6.4	0.00 µg/l	0.0 mg/l

Entering Table 4, ac and fe equal zero; and ac = 1, resulting in C = 3. From Table 5, with Q ~1cfs, Rc = L.

Based on chemical analysis of Hoodoo Creek, the rank of Great Western Mine is LOW.

KNOXVILLE MINE

Knoxville Mine drains, if at all, to Knoxville Creek, tributary to Eticuera Creek, thence to Lake Berryessa. An inspection on 8 March 1979 by CVRWQCB obtained the following:

	Station	cfs Q	pH	µg/l Hg	mg/l Fe	Ec
#1	upstream of general mine area	~≤1	7.6	0.1	0.2	--
#2	downstream of mine	2	7.5	0.4	0.2	1500

Entering Table 4, for hard water (Hunting Creek near Knoxville reports hardness of 355 mg/l as $CaCO_3$), ac and fe equal zero, and hm = 2 for the downstream sampling, resulting in ℂ = 10. Therefore, from Table 5, with Q ~2cfs, Rc = L.

Based on chemical analysis of Knoxville Creek, the rank of Knoxville Mine is LOW.

OAT HILL MINE

Oat Hill Mine is located along James Creek below Corona Mine. James Creek discharges to Pope Creek which is tributary to Putah Creek.

Oat Hill Mine and James Creek were inspected by CVRWQCB personnel March 15 and 21, 1979. Runoff from the Oat Hill Mine, and downstream flow in James Creek (which includes Corona Mine discharge) were sampled, with the following results:

	Station	cfs Q	pH	µg/l Hg	mg/l Fe	Appearance
1.	Runoff from Oat Hill Mine	.02	7.0	120	63	turbid, light brown
2.	James Crk. approx. 2500' below Oat Hill Mine (includes Corona Mine discharge)	3	7.0	0.0	13	opaque, yellow brown
3.	James Crk. at Aetna Spgs. Golf Course Rd. crossing, approx. 2½ miles below Oat Hill Mine	4-5	6.6	0.0	6.3	light orange

For comparison, theoretical receiving stream concentrations due to Oat Hill Mine may be computed as follows:

$$\text{for Hg, } Cs = \frac{.02}{3 + .02} \times 120 = .79\ \mu g/l$$

$$\text{for Fe, } Cs = \frac{.02}{3 + .02} \times 63 = .42\ mg/l$$

To determine the rank of Oat Hill Mine, a fair evaluation may be obtained by combining the above data, and allowing for the upstream influence of Corona Mine.

Assume that for Hg, the actual result at Station (2) is representative, and that mercury from Oat Hill Mine is diluted in the receiving stream so as to be negligible. For Fe, assume that the result at Station (2) is primarily due to the upstream Corona discharge, and therefore the theoretical computation of Fe = 0.42 mg/l is more representative of the Oat Hill Mine contribution.

Entering Table 4 with this data, hm and fe, as well as ac, equal zero, resulting in $\mathbb{C}$ = 0, and from Table 5, Rc = L.

Based on a chemical analysis of the Oat Hill Mine discharge and James Creek, the rank of Oat Hill Mine is LOW.

Oat Hill Mine

AFTERTHOUGHT MINE

Afterthought Mine discharges to Little Cow Creek which is east of the Shasta Lake drainage. The information used to rank the mine is from a California Department of Fish and Game Memorandum Report dated July 10, 1978, by Dana Finney, Seasonal Aid (see file). Flow data for Little Cow Creek was obtained from a seasonal watermaster gage operated by DWR from May to September. The gage is located approximately 3/4 mile upstream from the mine discharge into the Creek.

Data considered pertinent to the ranking are summarized below:

				µg/l			mg/l	mg/l as CaC
Station	Date	Q	pH	Cu	Cd	Zn	Fe	Hdns
Ingot ~½ mile below mine discharge	2/23,24/78	-	--	20	<10	210	.05	38
	6/9,12/78	~68 cfs	7.3	<10	--	70	--	32
150 yds. below mill site	2/23,24/78	-	--	--	--	--	--	34
	6/9,12/78	~68 cfs	--	<10	--	70	--	34
Plume: worst condition at outfall next to bank	5/11/78	-	3.0	4,780	120	28,000	--	--
Plume: second worst condition 50 yds. below outfall, next to bank	5/11/78	-	4.8	10	<10	340	--	--
Mine discharge	3/1/78	-	--	16,500	440	96,500	90.3	--
	5/11/78	-	2.85	19,400	580	127,000	106	--
First upstream station	2/23,24/78		--	<10	<10	20	.02	32
	6/9,12/78		7.1	<10	--	<10	--	32

Flow in Little Cow Creek for July, August, and September of 1978 was generally a uniform 10cfs.

The mine discharges a highly acid effluent rich in iron and heavy metal concentration. There is little immediate mixing as the discharge plume hugs the inner bank as it disperses downstream. Upstream water quality is good.

The worst stream condition is within the plume in the stream at the outfall next to the bank. Using Table 4, for soft water, hm = 3, and ac = 3. Ignoring fe for the moment, C = 24 and with Q = 68, Rc = H.

If we allow for mixing, i.e., if we rank the stream outside the plume, by using the data 50 yards below the outfall, we have hm = 2, ac = 2, and fe = unknown. Assuming iron is not significantly present at this point (giving benefit of doubt and comparing characteristics here to other stations), C = 16, and with Q > 5cfs, Rc = H. Therefore, even though outside the plume the concentrations of pollutants are moderated, the flow is significant enough to retain a HIGH ranking.

Based on a chemical analysis of the plume in Little Cow Creek, the rank of Afterthought Mine is <u>HIGH</u>.

BULLY HILL MINE

Bully Hill Mine is situated north of the Squaw Creek Arm of Shasta Lake between Town Creek and First Creek. Data used to rank the mine were reported in USGS WRI 78-32 by Fuller et al (May 1978). The data are summarized as follows:

				µg/l			mg/l
Station	Date	Q	pH	Cd	Cu	Zn	Fe
First Creek	11-6-74	0.13	6.96	<.05	1.2	.54	.007
	4-2-75	5.32	7.30	.05	1.6	1.4	.005
Town Creek	11-6-74	no flow					
	4-2-75	1.84	4.70	130	4,500	12,000	.085

From the USGS topographic map (Bollibokka Mtn.), Bully Hill Mine appears as the only influence of either of these creeks. Although First Creek is unaffected at high and low flows, Town Creek is adversely impacted when flow is present in the spring of the year.

Using the Town Creek data of 4-2-75 and entering Table 4, for soft water, hm = 3, ac = 2, and fe = 0, resulting in C = 21. With Q = 1.84cfs, Rc = H from Table 5.

Based on chemical analysis of Town Creek when flow is present, the rank of Bully Hill Mine is HIGH.

KEYSTONE MINE
BALAKLALA MINE
SHASTA KING MINE

Keystone, Balaklala, and Shasta King Mines discharge to West Squaw Creek which is tributary to Shasta Lake. Pollution from the mines has been reported in:

- "Squaw Creek Copper Investigation", a memorandum report of the DWR Northern District (Nov 1969); and in
- "An Evaluation of Problems Arising from Acid Mine Drainage in the Vicinity of Shasta Lake, Shasta County, California", Water Resources Investigation 78-32 by Fuller et al, USGS (May 1978)

These reports are available in the mine file under "Squaw Creek". DWR concluded that:

"2. At least 50 and possibly 70 percent of the total copper comes from the mine drainage of the Balaklala and Keystone Mines.

3. The remainder of the copper comes from water percolating through dump material, springs which are interconnected with mineralized zones, and the Shasta King Mine.

4. Although the highest concentrations of copper recorded were in drainage from the Shasta King Mine, its observed discharges were of such a limited quantity that the total contribution of copper was insignificant compared to the other two mines. Either the configuration of the mine workings or the structural geology is such that the amount of mineralized drainage flowing into the South Fork is minimized."

Therefore, Balaklala's and Keystone's contributions to pollution in Squaw Creek far outweigh that of Shasta King's. In fact, USGS also reported little or no effluent from Shasta King during their investigation. On this basis, we will assume the flow from Shasta King is .1cfs and assign it a rank of LOW. However, as both reports indicate, water in Shasta King is highly acidic and rich in copper, thereby posing a very serious threat should it ever discharge to the Creek. Should such discharge ever occur, a HIGH ranking is most probable.

BALAKLALA MINE
SHASTA KING MINE

Keystone, Balaklala, and Shasta King Mines discharge to West Squaw Creek which is tributary to Shasta Lake. Pollution from the mines has been reported in:

- "Squaw Creek Copper Investigation", a memorandum report of the DWR Northern District (Nov 1969); and in
- "An Evaluation of Problems Arising from Acid Mine Drainage in the Vicinity of Shasta Lake, Shasta County, California", Water Resources Investigation 78-32 by Fuller et al, USGS (May 1978)

These reports are available in the mine file under "Squaw Creek". DWR concluded that:

"2. At least 50 and possibly 70 percent of the total copper comes from the mine drainage of the Balaklala and Keystone Mines.

3. The remainder of the copper comes from water percolating through dump material, springs which are interconnected with mineralized zones, and the Shasta King Mine.

4. Although the highest concentrations of copper recorded were in drainage from the Shasta King Mine, its observed discharges were of such a limited quantity that the total contribution of copper was insignificant compared to the other two mines. Either the configuration of the mine workings or the structural geology is such that the amount of mineralized drainage flowing into the South Fork is minimized."

Therefore, Balaklala's and Keystone's contributions to pollution in Squaw Creek far outweigh that of Shasta King's. In fact, USGS also reported little or no effluent from Shasta King during their investigation. On this basis, we will assume the flow from Shasta King is .1cfs and assign it a rank of LOW. However, as both reports indicate, water in Shasta King is highly acidic and rich in copper, thereby posing a very serious threat should it ever discharge to the Creek. Should such discharge ever occur, a HIGH ranking is most probable.

KEYSTONE MINE, BALAKLALA MINE
SHASTA KING MINE

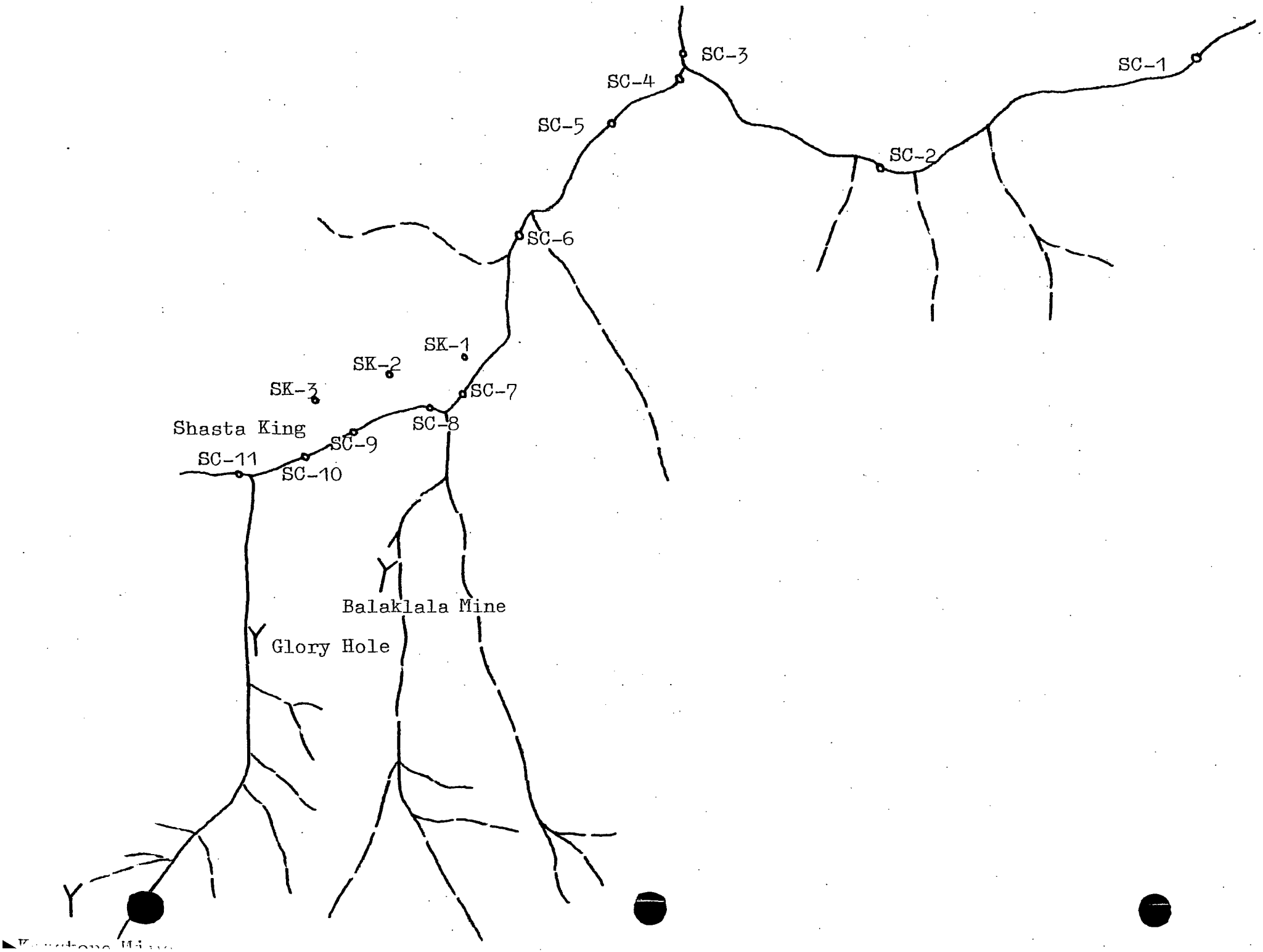
Therefore, for all practical purposes, the copper concentration in the Creek is due "solely" to the Balaklala and Keystone mines.

Using the above data for Squaw Creek and entering Table 4, for soft water, the factors on the whole receive the following values: hm = 3 due to copper concentrations from 650 to 15,800 µg/l ac = 3 for pH generally below 4.5; and fe = 1 for iron concentrations of 0.65 to 3.5 mg/l. Therefore, ℂ = 26. Flow is greater than 5cfs throughout most of the year (see DWR report and calculations of S. Buer in file). From Table 5, Rc = H.

Based on chemical analysis of Squaw Creek, the rank of the Balaklala-Keystone mine complex is HIGH.

Notes of Stein M. Buer - 7-21-78:

The oxidation of pyrites is a complex process which becomes more rapid as the pH drops. According to Al Franks, (Personal communication, 4-12-78), it has the character of an exponential or power function: Beginning with neutral water and native pyrite, the reaction is slow at first, then becomes more rapid with increased oxidation product concentration. Therefore, there is no simple way to separate the effects of the Balaklala and Keystone mine drainages. For example, if the Keystone mine drainage is diverted from the Balaklala glory hole, the Balaklala drainage concentrations might drop much more than would be expected by simple subtraction of the Keystone drainage mass loading. It is most reasonable, therefore, to treat the two mines as a single complex rather than to attempt to separate the effects of the two mines on Squaw Creek.


SC-3
SC-4
SC-5
SC-6
SC-1
SC-2
SK-1
SK-2
SK-3
SC-7
SC-8
Shasta King
SC-9
SC-11
SC-10
Balaklala Mine
Glory Hole

USGS-WRI 78-32 (listed above) was used to rank the Iron Mountain Mine Complex. The pertinent data from that report are summarized below.

		cfs		←——— µg/l ———→			mg/l
Station	Date	Q	pH	Cd	Cu	Zn	Fe
Spring Creek	4-3-75	75.4	2.72	80	1780	1120	108
Spring Creek	11-8-74	4.91	2.95	200	4300	8000	125

Using Table 4, for soft water, hm, ac, and fe each equal 3 on both dates; therefore, $\mathbb{C}$ = 30 and, since Q $\gtrsim$ 5 cfs, R_c = H from Table 5.

Based on chemical analysis of Spring Creek, the rank of the Iron Mountain Mine Complex is HIGH.

Further justification for a HIGH ranking is supplied by the photos, reports, and commentary in the files.

IRON MOUNTAIN MINE COMPLEX

The Iron Mountain Mine Complex drains into Boulder and Slickrock Creeks, both tributary to Spring Creek which flows into the Keswick Reservoir (see map attached). Water quality problems in Spring Creek due to the Iron Mountain Mines have been extensively reported. The following sources of information should be consulted for a thorough understanding of the Iron Mountain Mine - Spring Creek problems:

- "Recommended Flow Releases from Spring Creek Debris Dam for the Protection of Salmonid Fishes in the Sacramento River", unpublished report by Robert H. Lewis, CDFG (1963)
- "Siltation and Pollution Problems in Spring Creek, Shasta County, California" by Nikola P. Prokopovich, JAWWA, V. 57 N. 8 (Aug 1965)
- "Pollution of Spring Creek by the Iron Mountain Mine, Shasta County", field trip summary by Evans and Stinson, CDMG (1970)
- "Toxins Exiting Spring Creek, a Sacramento River Tributary Near Redding, California", proposal to CVRWQCB by USGS (1973)
- WDR for Iron Mountain Mines, Inc., Shasta County, Order No. 77-225, CVRWQCB
- Iron Mountain Mines Tour, transcript of field notes (Sept 1977)
- "An Evaluation of Problems Arising from Acid Mine Drainage in the Vicinity of Shasta Lake, Shasta County, California", Water Resources Investigation 78-32 by Fuller et al, USGS (May 1978)
- "Safe Zinc and Copper Levels from the Spring Creek Drainage for Steelhead Trout in the Upper Sacramento River Basin, California, and Their Use in Water Quality Management", report by Finlayson and Ashuckian, CDFG (1978)

All of these reports, plus correspondence, photos, maps, and miscellaneous notes and data are in our mine files under "Iron Mountain", except for USGS WRI 78-32, which is filed under "Squaw Creek" and under "Mammoth".

MAMMOTH MINE
GOLINSKY MINE (cont'd.)

Since the mine effluent at the Friday-Loudon Tunnel discharges to Shoemaker Gulch and not Little Backbone Creek, it must be excluded from the ranking of Mammoth Mine with respect to the Little Backbone Creek watershed.

In the summer and autumn of 1975 - i.e., during the 9-18-75 sampling - no effluent was observed at the Golinsky Mine (Fuller et al p. 17). Therefore, the chemical analysis of Little Backbone Creek on 9-18-75 could be assumed to result solely from the contribution of Mammoth Mine. This is in fact contravened by the benthic sampling and analyses also reported for autumn of 1975. As noted in Figure 3 of Fuller et al, sampling site 7, which is upstream from the mines, exhibits stream degradation as evidenced by a pH of 3.6.

Further evidence of pollution from an unknown upstream source may be demonstrated as follows: Assume for the moment that the flow in the Creek, 3.0 cfs, is clear, and that Mammoth Mine is the sole contributor of pollutants. Compare, then, the calculated downstream concentrations with those actually recorded on 9-18-75.

$$\underset{\text{(mine)}}{Q_M\ C_M} + \underset{\text{(creek)}}{Q_C\ C_C} = \underset{\text{(mine + creek)}}{Q_{M+C}\ C_{M+C}}$$

Where,

$$C_c = 0 \text{ and } Q_M + Q_C + Q_{M+C}$$

Therefore,

$$C_{M+C} = \frac{Q_M}{Q_{M+C}} \cdot C_M = \frac{.64}{3.0} \times C_M = 0.2133\ C_M$$

and,

$$pH_{M+C} = -\log_{10} \left[0.1233 \times 10^{-pH_m} \right]$$

MAMMOTH MINE
GOLINSKY MINE

Mammoth and Golinsky Mines discharge to Little Backbone Creek above Shasta Lake. The watershed area draining into the creek upstream from the Mammoth Mine discharge is approximately 3.1 square miles, as calculated from the 15' USGS topographic map (Lamoine). For all practical purposes, the two mines are apparently the only significant contributors of pollution to the Creek. The mines are located as shown in the figure attached.

CDFG reported a fishkill in Little Backbone Creek on April 8, 1969. Fifteen fish were killed, including trout, crappie, bass, carp, squawfish, and salmon.

The information used for ranking the mines is from USGS Water Resources Investigations 78-32 - "An Evaluation of Problems Arising from Acid Mine Drainage in the Vicinity of Shasta Lake, Shasta County, California" by Fuller et al, May, 1978. The pertinent data from that report are summarized below:

		cfs		µg/l				
Station	Date	Q	pH	Fe	Cd	Cu	Pb	Zn
Little Backbone Creek just above Shasta Lake	9-18-75	3.0	3.0	7600	60	4700	20	11,000
	4-10-75	31.2	3.61	6000	14	1400	--	1,900
	11-05-74	1.19	3.15	11,700	60	3900	14	9,500
Mammoth Mine effluent 470 ft. level (2820 ft. elev) discharge to L. Backbone Crk.	9-18-75	0.64	2.8	110,000	180	15,000	62	30,000
Mammoth Mine ponded effluent on beach at 2820 ft. elev.	9-18-75	--	2.8	110,000	180	15,000	62	30,000
Mammoth Mine effluent Friday-Loudon tunnel 870 ft. level (2426 ft. elev) discharge to Shoemaker Gulch	9-18-75	0.30	5.3	360	20	420	2	5,100

> species of organisms are present. Of these species, 98.9 percent are the chironomid (Orthocladius sp.), which has been noted as being acid tolerant. The highly acid water entering Little Backbone Creek from the Mammoth Mine resulted in decreased diversities for samples from stations 6, 8, and 9. The most notable change was the small diversity of 0.043 at station 12. This probably is due to the vast numbers of the chironomid (Thienemanniella sp.), which constituted 99.5 percent of the organisms and accounted for the largest density of organisms present at any site on the creek. The large numbers of Thienemanniella sp. probably were owing to the lack of competition and predation as a result of water quality conditions in which other organisms could not survive. In addition, site 12 may have been more nearly a pool than a riffle, which may account for some of the increase in density." (Fuller et al, p. 27)

Although Sites 11 and 12 are influenced by both Mammoth Mine and the unknown source above Site 7, we will assume for ranking purposes that the mine discharge (Site 10) is the primary reason the downstream is severely degraded.

Using Table 1, the information indicates that 0.52 miles of stream is severely degraded (ls). Entering the matrix of Table 2 with Q = 3cfs and ls = 0.52, the resulting R_V = H.

Based on a biological analysis of Little Backbone Creek, the rank of Mammoth Mine is HIGH.

For the Golinsky Mine, no effluent was observed in the summer and autumn of 1975, and therefore, no ranking on the basis of chemical analysis can be computed. Moreover, no ranking may be attempted with the benthic data provided in Fuller et al.

One benthic sampling station, No. 9, is located upstream from Mammoth and downstream from Golinsky. Three stations, Nos. 6, 7, and 8, are located upstream from Golinsky. The data are summarized in Figure 3 (attached), and the following is provided from Fuller et al, (pgs. 26-27):

> "Samples from Sites 6 and 8 were used as standards for comparison with samples from the other sites, because the water in the North Fork was of good chemical and biological quality (Fig. 3). Samples from Site 6 had 25 species of organisms, and samples from Site 8 had 18 species. Diversities were 2.751 and 2.577, respectively.

MAMMOTH MINE
GOLINSKY MINE (cont'd.)

Results and comparisons of downstream concentration in Little Backbone Creek:

	μg/l calculated	actual		conclusions
Fe	23,467	7,600	⇒	Fe has precipitated out
Cd	38	60	⇒	Actual > calculated implies that these constituents are being added to the Creek from an upstream source
Cu	3,200	4,700		
Pb	13	20		
Zn	6,613	11,000		
pH	3.47	3.0		

With this information in mind, we will rank Mammoth on the basis of the calculated downstream concentrations (i.e., as if the mine discharge were diluted with a clear stream), thus allowing for background and upstream contributions. Using Table 4, for soft water, hm, ac, and fe each equal 3; therefore, $\mathbb{C}$ = 30, and with Q = 3cfs, R_c = H from Table 5.

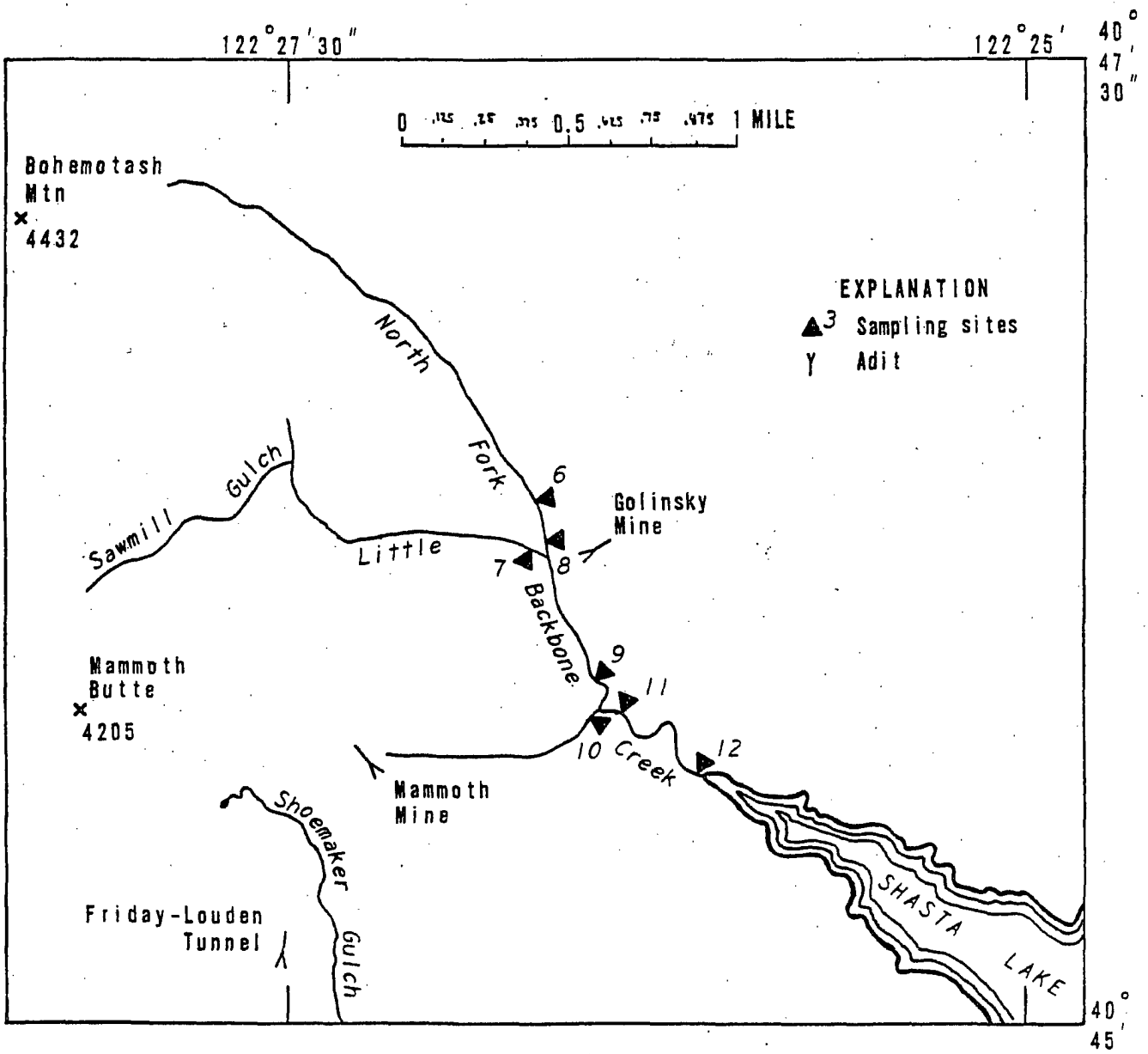
Based on a chemical analysis of Little Backbone Creek, the rank of Mammoth Mine is HIGH.

Because there is no additional data on 4-10-75 and 11-5-74 other than for Little Backbone Creek - i.e., no data on the three possible pollution contributors, Mammoth, Golinsky, and unknown upstream - no ranking may be calculated for those dates.

We may attempt an alternative ranking for Mammoth Mine with the benthic data provided in Fuller et al. Three benthic sampling sites on the Creek are located downstream from Mammoth - 10, 11, and 12. One site, 9, is located immediately upstream from Mammoth. The data are summarized in Figure 3 (attached).

Site 10 is the Mammoth Mine discharge. Site 11 is 0.12 miles from Site 10, and Site 12 is 0.52 miles from Site 10. Assume that the streamflow equals the 3.0cfs recorded 9-18-75.

> "Water from Site 10, on the acid effluent from the Mammoth Mine, has the lowest pH, 2.4, of any site on Little Backbone Creek (Fig. 3). It has a low diversity, 0.101, and only four



	Sampling site						
	6	7	8	9	10	11	12
Diversity	2.751	2.108	2.577	0.975	0.102	0.784	0.043
Number of species	25	6	18	6	4	2	3
Number of individuals per square meter	2096.3	123.8	1044.1	236.8	3326.2	322.9	9068.9
pH	6.5	3.6	6.5	4.00	2.4	2.75	2.7

FIGURE 3.-- Benthic sampling sites, and analyses of sampling on Little Backbone Creek.

(from Fuller et al, May 1978)

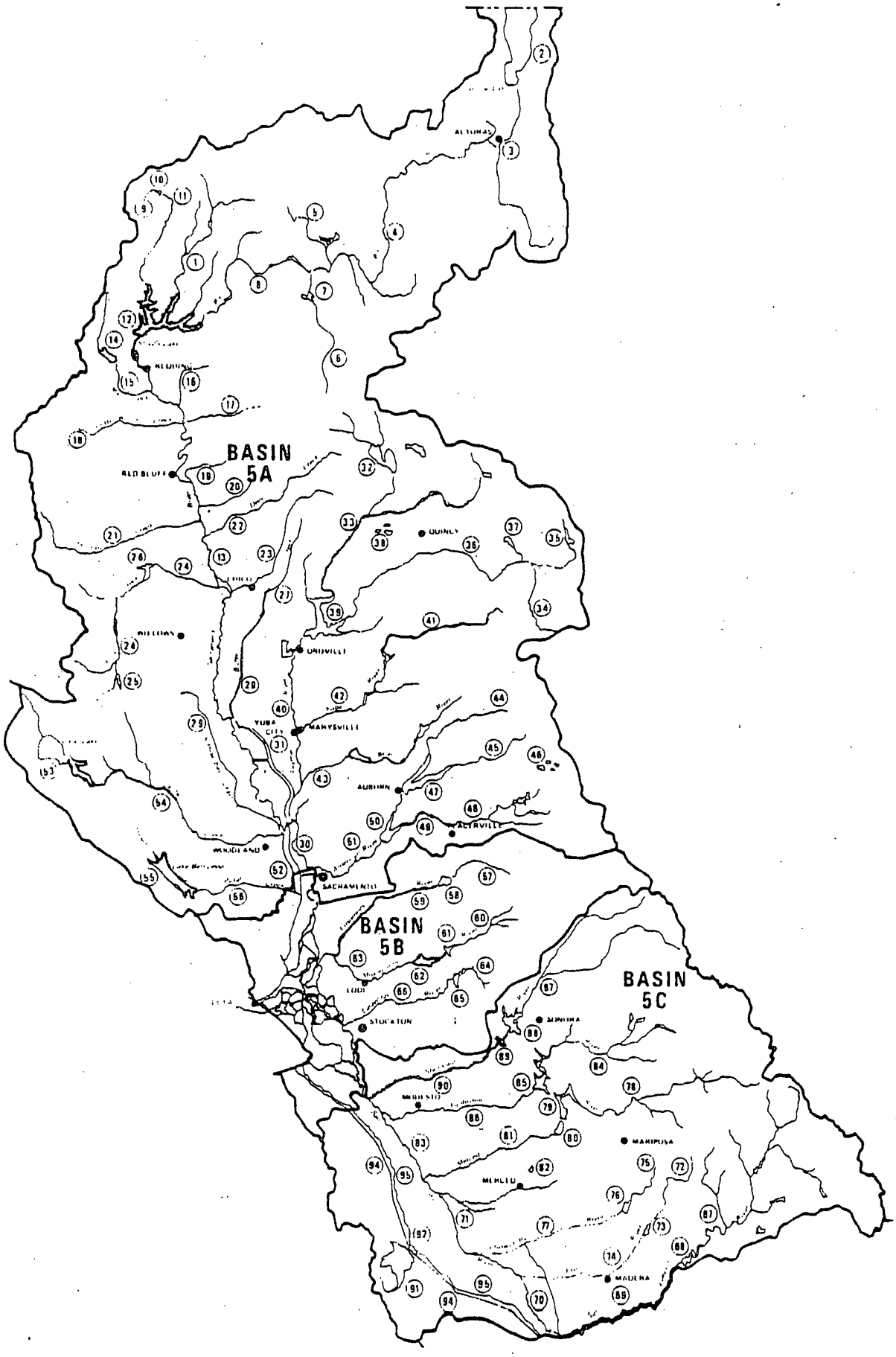
Sites 6 and 8 contained insects which represent all trophic levels. Shredders included the choronomid (Cricotopus sp.), a chewer and miner living on vascular plants; collectors, which feed by gathering material by filtering suspended material in water, included chironomids (Thienemanniella sp., Orthocladius sp., and Eukiefferiella sp.), Simuliidae, and Tricoptera (Wormaldia sp., Polycentropus sp., and Hydropsyche sp.). Scrubbers included Ephemeroptera (Baetis sp., Iron sp., and Hydropsyche sp.), and predators included Neuroptera (Protochauliodes sp.), Odonata (Paltothemis lineatus), Plecoptera (Alloperla sp.), and a chironomid (Pentaneurini).

The creek water at Site 7 (Fig. 3) has already suffered some degradation as indicated by a pH of 3.6 and a diversity of 2.108. Only six species of organisms were found at this site. Of these, only four Ephemeroptera were present as compared to an average of 127 at Sites 6 and 8.

Water at Site 9, downstream from the confluence of the main stream and the North Fork of Little Backbone Creek, is heavily influenced by the water flowing past Site 7 and polluting the flow from the North Fork. Site 9 water has a pH of 4.0, a diversity of 0.975, and only six species of organisms." (Emphasis supplied)

As the underlined portion indicates, the degradation at Station 9 is heavily influenced by water not discharging from Golinsky Mine. Therefore, the rank of the Golinsky Mine is presently UNKNOWN, or, in the alternate, or the basis of no effluent, the rank at worst is tentatively LOW.

C. SURFACE WATER BODIES AND BENEFICIAL USES



PLUMBAGO MINE

Plumbago Mine is located along Buckeye Ravine which is tributary to the Middle Yuba River.

The mine has not been inspected for water quality problems, and no problems are known to exist. The only water quality information is from STORET at latitude 39°26'19.0" and longitude 120°48'40.0" on the Middle Yuba River approximately one mile below the Buckeye Ravine tributary.

Date	Flow	pH	SO_4	Hdns
8-11-59	19cfs	7.4	0.04 mg/l	50 mg/l as $CaCO_3$

Until further information is obtained, Plumbago Mine is UNKNOWN, and therefore must be ranked no higher than LOW.

MALAKOFF DIGGINGS

Malakoff Diggings is an abandoned hydraulic gold mine which is now part of the State Park system. Hydraulic mining left barren and unstable soil. Erosion and slides carry suspended material through Hiller Tunnel to Humbug Creek, which is tributary to the South Yuba River. Turbidities as high as 1750 JTU and flows to 10 cfs have been recorded at Hiller Tunnel. No heavy metal, acid, or iron problems are suspected, and sampling has focused on sediment and turbidity. For example, results of April 25, 1978 inspection:

Station	pH	mg/l TSS	NTU Turbidity	mg/l TDS
Humbug Creek, upstream from Diggings	7.0	38	1	44
Malakoff Diggings, below Hiller Tunnel	7.15	1504	350	174
Humbug Creek, downstream from Diggings	7.2	544	120	150

Beginning July 1978, a 12-month study of the sedimentation problem was begun by the Nevada County Resource Conservation District under a contract executed by California Department of Parks and Recreation.

Because the problems at Malakoff Diggings do not conform to the ranking procedure, no rank will be assigned on that basis. At best, we might assign a SPECIAL rank to indicate that we have noted the problem and are proceeding to understand and correct it.

9-22-77	CVRWQCB inspection:	16 to 1 Mine observed as inactive.
1-10-78	CVRWQCB inspection:	16 to 1 Mine - or Tightner Mine - appearing to have activity.
2-23-78	CVRWQCB inspection:	Gold Crown Mine operational. Mine discharge sampled: Ph = 7.7, As = 120 µg/l, T = 51°F, Ec = 460 µmhos, milky-gray appearance.

All of the arsenic concentrations result in hm = 0 from Table 4, and the sole iron concentration and few pH values also result in zero factors for ac and fe. Therefore, although water quality problems of turbidity and sedimentation have been documented along the subject stretch of Kanaka Creek, data to date show no pollutant concentrations significant enough to rank any of the mines - particularly Kenton and 16 to 1- any higher than LOW.

KENTON MINE

16 to 1 MINE

Kenton Mine and 16 to 1 Mine are located along Kanaka Creek. Accurate ranking of each mine is complicated by the location along Kanaka Creek of several other mines, some of which are "operating". Proceeding upstream toward Alleghany from the Kenton mine are the Oriental Mine (active), Gold Crown Mine (active), 16 to 1 Mine (active?), and El Dorado Mine (inactive).

Oriental Mine is under WDR Order No. 76-81, and CVRWQCB Case File #1747 - "Oriental Mine-Sierra County" should be consulted for details.

Various data about Kanaka Creek and the mines may be summarized as follows:

9-20-67 STORET, Kanaka Creek below Alleghany, 39°27'16.0"/ 120°51'36.0" near Oriental Mine:

pH	As	Cd	Cu	Pb	Zn	Fe	Hdns
8.35	31 mg/l	0	0	0	0	.034 mg/l	58 mg/l as $CaCO_3$

4-10-68 California Department of Fish and Game observed Kanaka Creek to be clear and clean above Oriental Mine and opaque, gray, and turbid below it.

2-9-76 CVRWQCB inspection:

	Q cfs	As µg/l	Pb µg/l
Kanaka Creek at El Dorado Mine	10	20	0
Kanaka Creek at Kenton Mine Lodge	15	0	10

5-24-77 CVRWQCB inspection:

Kanaka Creek at El Dorado Mine	5	0	7.5
Kanaka Creek at Kenton Mine Lodge	5	40	7.8

El Dorado Mine observed as inactive.
Gold Crown Mine observed as inactive.

EMPIRE MINE
KEYSTONE MINE

Empire and Keystone designate two groups of abandoned mines in Copperopolis. Empire includes the Empire, Discovery, and McCarty which consist of extensive tailings piles which drain to Copper Creek, thence to Black Creek and the Tulloch Reservoir. Keystone includes the Keystone, North Keystone, and Keystone-Union which drain to Penny Creek, thence to Sawmill Creek, Black Creek, and Tulloch Reservoir.

CVRWQCB inspected and sampled downstream of each group on 12 March 1979 with the following results:

	cfs		µg/l	mg/l
Station	Q	pH	Cu	Fe
Penny Creek, below Keystone tailings	2	7.3	0.0	9.5
Copper Creek, below Empire tailings	0.3	6.4	4,200	1.5

Entering Table 4, for Penny Creek, ac and hm equal zero, and fe = 2, resulting in ℂ = 4. Therefore, from Table 5, with Q ~2cfs, Rc = L. Based on chemical analysis of Penny Creek, the rank of Keystone Mine is LOW.

Entering Table 4, for Copper Creek, ac and fe = 1, and hm = 3, resulting in ℂ = 20. From Table 5, with Q ~0.3cfs, Rc = L. Based on a chemical analysis of Copper Creek, the rank of Empire Mine is LOW.

During the sampling, flow was not specifically measured. The flow on 4-16-75 was determined by:

1. Obtaining from USGS Water Resources Data for California (CA-75-3) the recorded flow at the gaging station on Marsh Creek (Station 3), which is 17cfs (p. 364).
2. Adjusting the 17cfs at Station 3 according to watershed area to reflect the average flow at Station 2 - i.e., from EXHIBIT 1 (in file)

watershed area above Station 3 = 40.1 mi^2

watershed area above Station 2 = 1.5 mi^2

therefore, the estimated flow at Station 2 = $Q_2 = \frac{Q_3 (A_2)}{(A_3)}$

$$Q_2 = 17\text{cfs} \frac{(1.5\ mi^2)}{(40.1\ mi^2)} = 0.6\text{cfs}$$

At Station 2, for the four sampling times, hm = fe = 3 in all instances; ac = 0 on 1-29-75 and 4-16-75, ac = 3 on 2-4-77, and ac = 1 on 7-20-78. The resulting values for ℂ for the four dates are 21, 15, 30, and 24, respectively, which equals an average of 23. Entering Table 5, with ℂ = 23 and Q = 6.1, Rc = H.

Based on a chemical analysis of Dunn Creek (Marsh Creek) the rank of Mt. Diablo Mine is HIGH.

MT. DIABLO MINE

Mt. Diablo Mine is located along Dunn Creek which is tributary to Marsh Creek above Marsh Creek Reservoir.

CVRWQCB inspections observed a substantial volume of toxic mud and precipitate retained on the mine property by an earth fill dam which may be breached under adverse weather conditions.

Although water quality samples have been collected at various locations during different field inspections, there are three primary sampling stations noted in a May 22, 1975 DWR Report:

Station I: Marsh (Dunn) Creek at the intersection of Marsh Creek Road and Morgan Territory Road upstream of Mt. Diablo mine.

Station 2: Marsh (Dunn) Creek at Morgan Territory Road bridge, downstream from Mt. Diablo mine.

Station 3: Marsh Creek at gaging station on Marsh Creek Road above Marsh Creek Reservoir, approximately 10 miles downstream from Mt. Diablo mine.

These stations were sampled 1-29-75 and 4-16-75. The 2-4-77 sample taken at the "discharge from pipe thru dam to Dunn Creek" and the 7-20-78 sample taken at "No. 002" are assumed comparable to Station 2. Because it is a first point downstream from the confluence of the several streams around the mine, Station 2 will be regarded as the primary location for chemical analysis of receiving water for ranking purposes.

Water quality data are summarized below:

				µg/l						mg/l	(as CaCO3) mg/l
Station	Date	cfs Q	pH	As	Cu	Pb	Hg	Ag	Zn	Fe	Hdns
1	1-29-75		8.1		10		1.6			2.1	250
	4-16-75		8.3		0		0				137
2	1-29-75		7.2		30		72			42	2620
	4-16-75	.6	7.2	10	30		4.2				405
	2-4-77	<1	4.3		40		97		380	33	
	7-20-78	<1	6.1	10	60	20	4	4	410	40	3400
3	4-16-75	17	8.3	0	0		.1				261

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SURFACE WATER BODIES[1]	MUN	AGRI-CULTURE		INDUSTRY			RECREATION			FRESHWATER HABITAT[3]		MIGRATION		SPAWNING		WILD	NAV
		AGR		PROC	IND	POW	REC 1		REC 2	WARM	COLD	MIGR		SPWN			
	MUNICIPAL AND DOMESTIC SUPPLY	IRRIGATION	STOCK WATERING	PROCESS	SERVICE SUPPLY	POWER	CONTACT	CANOEING AND RAFTING[2]	OTHER NONCONTACT	WARM	COLD	WARM[4]	COLD[5]	WARM[4]	COLD[5]	WILDLIFE HABITAT	NAVIGATION
52 YOLO BYPASS		•	•				•		•	•	C	•	•	•		•	
CACHE CREEK																	
53 CLEAR LAKE	•	•	•				•		•	•	O			•		•	
54 CLEAR LAKE TO YOLO BYPASS		•	•	•	•		•	•	•	•	O			•	•	•	
PUTAH CREEK																	
55 LAKE BERRYESSA	•	•	•			O	•		•	•	•			•		•	
56 LAKE BERRYESSA TO YOLO BYPASS	•	•	•				•	•	•	•	O			•		•	
OTHER LAKES AND RESERVOIRS IN BASIN 5A[7]	•	•	•	•		•	•		•	•	•				•	•	
COSUMNES RIVER																	
57 SOURCES TO NASHVILLE RESERVOIR (PROPOSED)	•	•					•		•		•				•	•	
58 NASHVILLE RESERVOIR (PROPOSED)	O					O	O		O	O	O	O		O	O	O	
59 PROPOSED NASHVILLE RESERVOIR TO DELTA	•	•	•				•	•	•	•	•	•	•	•	•	•	
MOKELUMNE RIVER																	
60 SOURCES TO PARDEE RESERVOIR	•					•	•	•	•	•	•	•		•	•	•	
61 PARDEE RESERVOIR[8]	•					•	•		•	•	•			•	•	•	
62 CAMANCHE RESERVOIR	•	•	•				•		•	•	O	•		•	•	•	
63 CAMANCHE RESERVOIR TO DELTA		•	•				•	•	•	•	•	•	•	•	•	•	
CALAVERAS RIVER																	
64 SOURCE TO NEW HOGAN RESERVOIR							•	•	•	•	•	•		•	•	•	
65 NEW HOGAN RESERVOIR							•		•	•	•	•		•	•	•	
66 NEW HOGAN RESERVOIR TO DELTA	•	•	•	O	O		•	•	•	•	•	•	•	•	•	•	
OTHER LAKES AND RESERVOIRS IN BASIN 5B[7]	•	•	•	•		•	•		•	•	•				•	•	
SAN JOAQUIN RIVER																	
67 SOURCES TO MILLERTON LAKE	•	•	•			•	•	•	•	•	•					•	
68 MILLERTON LAKE	O	•	•				•		•	•	O					•	
69 FRIANT DAM TO MENDOTA POOL	•	•	•	•			•	•	•	•	•	•	•	•	O	•	
70 MENDOTA DAM TO SACK DAM	O	•	•	•			•	•	•	•		•	•	•	O	•	
71 SACK DAM TO MOUTH OF MERCED RIVER	O	•	•	•			•	•	•	•		•	•	•	O	•	
FRESNO RIVER																	
72 SOURCE TO HIDDEN RESERVOIR (PROPOSED)	O	•	•				•		•	•	•					•	
73 HIDDEN RESERVOIR (PROPOSED)	O		O				O		O	O						O	
74 HIDDEN RESERVOIR TO SAN JOAQUIN RIVER	O	•	•				•	O	•	•						•	
CHOWCHILLA RIVER																	
75 SOURCE TO BUCHANAN RESERVOIR							•		•	•	•					•	
76 BUCHANAN RESERVOIR (UNDER CONSTRUCTION)	O	O	O				O		O	O						O	
77 BUCHANAN DAM TO SAN JOAQUIN RIVER	O	•		•			•	O	•	•						•	
MERCED RIVER																	
78 SOURCE TO McCLURE LAKE	O	•				•	•	•	•	•	•					•	
79 McCLURE LAKE	O	•				•	•		•	•	•					•	
80 McSWAIN RESERVOIR	O	•				•	•		•	•	•					•	
81 McSWAIN RESERVOIR TO SAN JOAQUIN RIVER	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	
82 YOSEMITE LAKE							•		•	•	•					•	
83 MOUTH OF MERCED RIVER TO VERNALIS	O	•	•	•			•	•	•	•		•	•	•		•	
TUOLUMNE RIVER																	
84 SOURCE TO DON PEDRO RESERVOIR	•	•	•			•	•	•	•	•	•					•	
85 DON PEDRO RESERVOIR	O					•	•		•	•	•					•	
86 DON PEDRO DAM TO SAN JOAQUIN RIVER	O	•	•				•	•	•	•	•		•	•	•	•	
STANISLAUS RIVER																	
87 SOURCE TO NEW MELONES RESERVOIR (PROPOSED)	•	•	•			•	•	•	•	•	•					•	
88 NEW MELONES RESERVOIR (PROPOSED)	O	O	O			O	O		O		O					O	
89 TULLOCH RESERVOIR	O	•	•			•	•		•	•						•	
90 GOODWIN DAM TO SAN JOAQUIN RIVER	O	•	•	•	•	•	•	•	•	•	•		•	•	•	•	
91 SAN LUIS RESERVOIR	•	•	•		•	•	•		•	•						•	
92 O'NEILL RESERVOIR	•	•	•				•		•	•							
93 OTHER LAKES AND RESERVOIRS IN BASIN 5C[7]	•					•	•		•	•	•				•	•	
94 CALIFORNIA AQUEDUCT	•	•	•	•	•	•	•		•							•	
95 DELTA MENDOTA CANAL	•	•	•				•		•	•						•	
96 SACRAMENTO SAN JOAQUIN DELTA[9]	•	•	•	•	•		•		•	•	•	•	•	•		•	•

(1) Those streams not listed have the same beneficial uses as the streams, lakes, or reservoirs to which they are tributary.

(2) Shown for streams and rivers only, with the implication that certain flows are required for this beneficial use.

(3) Resident does not include anadromous. Any segments with both COLD and WARM beneficial use designations will be considered COLD water bodies for the application of water quality objectives.

(4) Striped bass, sturgeon, and shad.

(5) Salmon and steelhead.

(6) As a primary beneficial use.

(7) The indicated beneficial uses are to be protected for all waters except in specific cases where evidence indicates the appropriateness of additional or alternative beneficial use designations.

(8) Sport fishing is the only recreation activity permitted.

(9) Beneficial uses vary throughout the Delta and will be evaluated on a case-by-case basis.

	SURFACE WATER BODIES[1]	MUN	AGRI-CULTURE		INDUSTRY			RECREATION			FRESHWATER HABITAT[3]		MIGRATION		SPAWNING		WILD	NAV
			AGR		PROC	IND	POW	REC 1		REC 2	WARM	COLD	MIGR		SPWN			
		MUNICIPAL AND DOMESTIC SUPPLY	IRRIGATION	STOCK WATERING	PROCESS	SERVICE SUPPLY	POWER	CONTACT	CANOEING AND RAFTING [2]	OTHER NONCONTACT	WARM	COLD	WARM[4]	COLD[5]	WARM[4]	COLD[5]	WILDLIFE HABITAT	NAVIGATION
1	McCLOUD RIVER	•					•	•	○	•		•				•	•	
2	GOOSE LAKE		•	•				•		•	•	•					•	
	PIT RIVER																	
	NORTH FORK, SOUTH FORK, PIT RIVER	•	•	•				•	○	•	•	•			•	•	•	
3	CONFLUENCE OF FORKS TO HAT CREEK	•	•	•			•	•		•	•	•			•		•	
4	FALL RIVER	•	•	•			•	•	•	•	•	•					•	
5	HAT CREEK		•				•	•		•	•	•				•	•	
6	BAUM LAKE						•	•		•		•				○	•	
7	MOUTH OF HAT CREEK TO SHASTA LAKE	•	•	•			•	•	•	•	○	•			•	•	•	
8	SACRAMENTO RIVER																	
	SOURCE TO BOX CANYON RESERVOIR		•	•				•		•		•					•	
9	LAKE SISKIYOU							•		•	•	•				○	•	
10	BOX CANYON DAM TO SHASTA LAKE		•	•				•	•	•		•				•	•	
11	SHASTA LAKE	•	•				•	•		•	○	•			•	•	•	
12	SHASTA DAM TO COLUSA BASIN DRAIN	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•
13	WHISKEYTOWN RESERVOIR	•	•	•			•	•		•	•	•			•		•	
14	CLEAR CREEK BELOW WHISKEYTOWN RESERVOIR	•	•	•				•	•	•	•	•		•	•	•	•	
15	COW CREEK	○	•	•			•	•	○	•		•		•	•	•	•	
16	BATTLE CREEK		•	•			•	•	•	•	•	•		•	•	•	•	
17	COTTONWOOD CREEK	•	•	•	○	○	○	•	•	•	•	•		•	•	•	•	
18	ANTELOPE CREEK	•	•	•				•		•	•	•		•	•	•	•	
19	MILL CREEK	•	•	•				•		•	•	•		•	•	•	•	
20	THOMES CREEK		•	•			•	•		•	•	•		•	•	•	•	
21	DEER CREEK	•	•	•				•	•	•	•	•		•	•	•	•	
22	BIG CHICO CREEK		•	•				•	•	•	•	•		•	•	•	•	
23	STONY CREEK		•	•				•	•	•	•	○		•	•	•	•	
24	EAST PARK RESERVOIR							•		•	•	○			•		•	
25	BLACK BUTTE RESERVOIR		•	•				•		•	•				•		•	
26	BUTTE CREEK																	
	SOURCES TO CHICO	•	•	•			•	•			•	•		•	•	•	•	
27	BELOW CHICO, INCLUDING BUTTE SLOUGH		•	•				•	•		•	•		•	•		•	
28	COLUSA BASIN DRAIN		•	•				•	•		•	○	•		•		•	
29	COLUSA BASIN DRAIN TO EYE STREET BRIDGE	•	•					•	•	•	•	•	•	•	•	•	•	•
30	SUTTER BYPASS		•					•			•			•		•	•	
31	FEATHER RIVER																	
	LAKE ALMANOR						•	•			•	•			•		•	
32	NORTH FORK, FEATHER RIVER	•					•	•	•	•		•				•	•	
33	MIDDLE FORK, FEATHER RIVER																	
	SOURCE TO LITTLE LAST CHANCE CREEK		•	•				•	•	•	•	•				•	•	
34	FRENCHMAN RESERVOIR							•		•	○	•				•	•	
35	LITTLE LAST CHANCE CREEK TO LAKE OROVILLE	•						•	•	•	•	•				•	•	
36	LAKE DAVIS							•		•	○	•				•	•	
37	LAKES BASIN LAKES							•		•		•				•	•	
38	LAKE OROVILLE	•	•				•	•		•	•	•			•	•	•	
39	FISH BARRIER DAM TO SACRAMENTO RIVER	•	•					•	•	•	•	•	•	•	•	•	•	
40	YUBA RIVER																	
	SOURCES TO ENGLEBRIGHT RESERVOIR	•	•	•			•	•	•	•		•				•	•	
41	ENGLEBRIGHT DAM TO FEATHER RIVER		•	•			•	•	•	•	•	•	•	•	•	•	•	
42	BEAR RIVER	•	•	•			•	•	•	•	•	•	○	○	○	○	•	
43	AMERICAN RIVER																	
	NORTH FORK, SOURCE TO FOLSOM LAKE	•	•					•	•	•	○	•				•	•	
44	MIDDLE FORK, SOURCE TO FOLSOM LAKE	•	•	•			•	•	•	•	○	•				•	•	
45	DESOLATION VALLEY LAKES							•		•		•				•	•	
46	AUBURN RESERVOIR (UNDER CONSTRUCTION)	○	○				○	○		○		○				○	○	
47	SOUTH FORK																	
	SOURCE TO PLACERVILLE	•					•	•	•	•	○	•				•	•	
48	PLACERVILLE TO FOLSOM LAKE	•	•				•	•	•	•	•	•					•	
49	FOLSOM LAKE	•	•			○	•	•		•	•	•			•		•	
50	FOLSOM DAM TO SACRAMENTO RIVER	•	•			•	•	•	•	•	•	•	•	•	•	•	•	
51																		

LEGEND

● EXISTING BENEFICIAL USES

○ POTENTIAL BENEFICIAL USES

NOTE:

Surface waters with the beneficial uses of Groundwater Recharge (GWR), Freshwater Replenishment (FRSH), and Preservation of Rare and Endangered Species (RARE) have not been identified in this plan. Surface waters of Basins 5A, 5B, and 5C falling within these beneficial use categories will be identified in the future as part of the continuous planning process to be conducted by the State Water Resources Control Board.

Change:
Mt Diablo

B.3.6 Dunn Creek, Mercury and Metals - Change in Total Size and Size Affected

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, recommends changes to California's Clean Water Act Section 303(d) list for the impairment of Dunn Creek due to impairment by mercury and metals. The Regional Board recommends that the identified total length change from 9 to 3 miles and that the extent of impairment change from 9 miles to 1 mile. The basis for the recommended change is described below.

Watershed Characteristics

Dunn Creek is located along the east slope of Mount Diablo in Contra Costa County. It flows for approximately 3 miles before entering Marsh Creek, which flows into the San Joaquin Delta. The Mount Diablo Mine (Mt. Diablo Mine), which was historically operated for mercury extraction, is located between Dunn Creek and Horse Creek (a tributary to Dunn Creek). The tailings from the Mt. Diablo Mine are highly acidic and contain numerous metals and mercury.

Total Waterbody Length and Extent of Impairment

Slotton *et al* (1996a) and Iovenitti *et al* (1989) indicated that the total length of Dunn Creek is approximately 3 miles. Mt. Diablo Mine, which was historically operated for mercury extraction, is located between Dunn Creek and Horse Creek (a tributary to Dunn Creek), approximately 1 mile upstream from the confluence of Dunn and Marsh Creeks (Iovenitti, *et al* 1989; Slotton *et al*, 1996a; Buer *et al*, 1979). Water quality data indicates that mercury and metals impair Dunn Creek downstream Mt Diablo Mine.

B.3.14 Marsh Creek, Mercury – Change in Total Size and Size Affected

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, recommends changes to California's Clean Water Act Section 303(d) list for Marsh Creek due to impairment by mercury. The Regional Board recommends that the identified impaired length change from 24 mile to 16.5 miles and the extent of impairment from all of Marsh Creek to Marsh Creek, from Dunn Creek to Marsh Creek Reservoir. The basis for the recommended change is described below.

Watershed Characteristics

Marsh Creek is located in Contra Costa County. It flows for approximately 24 miles, with its water ultimately entering the San Joaquin Delta. The Mount Diablo Mine (Mt. Diablo Mine), which was historically operated for mercury extraction, is located between Dunn Creek and Horse Creek (a tributary to Dunn Creek), approximately 7.5 miles downstream from the headwaters of Marsh Creek. The tailings and outflow from the Mt. Diablo Mine are highly acidic and contain numerous metals, including mercury.

Extent of Impairment

Mt. Diablo Mine, which was historically operated for mercury extraction, is located between Dunn Creek and Horse Creek (a tributary to Dunn Creek) (Iovenitti, *et al* 1989; Slotton *et al*, 1996a; Buer *et al*, 1979). Dunn Creek discharges into Marsh Creek approximately 7.5 miles downstream from the headwaters of Marsh Creek. Water quality, fish tissue, and invertebrate data collected above and below the inflow of Dunn Creek indicate that Marsh Creek is impaired downstream of Dunn Creek. The impaired length of Marsh Creek is approximately 16.5 miles, from Dunn Creek through Marsh Creek Reservoir to the furthest extent of Marsh Creek.

B.3.15 Marsh Creek, Metals - Change in Total Size and Size Affected

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, recommends changes to California's Clean Water Act Section 303(d) list for the impairment of Marsh Creek due to impairment by metals. The Regional Board recommends that the identified impaired length change from 24 mile to 8.5 miles and the extent of impairment from all of Marsh Creek to Marsh Creek, from Dunn Creek to Marsh Creek Reservoir. The basis for the recommended change is described below.

Watershed Characteristics

Marsh Creek is located in Contra Costa County. It flows for approximately 24 miles, with its water ultimately entering the San Joaquin Delta. The Mount Diablo Mine (Mt. Diablo Mine), which was historically operated for mercury extraction, is located between Dunn Creek and Horse Creek (a tributary to Dunn Creek), approximately 7.5 miles downstream from the headwaters of Marsh Creek. The tailings and outflow from the Mt. Diablo Mine are highly acidic and contain numerous metals (CRWQCB-CVR, 1978).

Extent of Impairment

Mt. Diablo Mine, which was historically operated for mercury extraction, is located between Dunn Creek and Horse Creek (a tributary to Dunn Creek) (Iovenitti, *et al* 1989; Slotton *et al,* 1996; Buer *et al,* 1979). Dunn Creek discharges into Marsh Creek approximately 7.5 miles downstream from the headwaters of Marsh Creek. Water quality data was collected upstream and downstream from the Dunn Creek inflow to Marsh Creek contains high levels of metals below the confluence of Dunn Creek. However, downstream of Marsh Creek Reservoir, there is no data to indicate that metals impair Marsh Creek (Iovenitti *et al* 1989; Slotton *et al,* 1996; Buer *et al,* 1979). The impaired length of Marsh Creek is approximately 8.5 miles, from Dunn Creek to Marsh Creek Reservoir.

B.3.16 Mosher Slough, Diazinon and Chlorpyrifos - Change in Total Size

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, recommends changes to California's Clean Water Act Section 303(d) list for the impairment of Mosher Slough due to impairment by diazinon and chlorpyrifos. The Regional Board recommends that the identified total length change from 3 to 5 miles. The basis for the recommended change is described below.

Watershed Characteristics

Mosher Slough is a small urban creek located entirely within San Joaquin County in the northern part of Stockton. The confluence of Mosher Slough, Bear Creek, and Pixley Slough flows west and converges with Disappointment Slough, which flows to the Sacramento-San Joaquin Delta (Horizons Technology, Inc., 1997). Land use in the Mosher Slough watershed is predominately commercial and residential.

Total Waterbody Length

Mosher Slough is approximately 5 miles in length (Horizons Technology, Inc., 1997; DeLorme, 1998).

MOUNT DIABLO MINE

SURFACE IMPOUNDMENT TECHNICAL REPORT

prepared for
CENTRAL VALLEY REGION
REGIONAL WATER QUALITY CONTROL BOARD

by

J. L. Iovenitti, Weiss Associates and J. Wessman

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30 June 1989

EXECUTIVE SUMMARY

This technical report has been prepared on the Mount Diablo Mine surface impoundment as part of the application to qualify for an exemption from the Toxic Pit Cleanup Act of 1984 provided in California Health and Safety Code 25208.20(c). This impoundment is located on the northeast flank of Mount Diablo in Contra Costa County.

The Mount Diablo Mine produced mercury intermittently from about 1870 to the 1970s. Mr. and Mrs. Wessman, the property owners, purchased the mine property as part of a larger land purchase in 1974. The property was purchased for residential use. In 1978, Order No. 78-114, Waste Discharge Requirements for the Mount Diablo Quicksilver Mine, was issued to Mr. and Mrs. Wessman, prohibiting the direct discharge of mine waste to surface waters or surface water drainage courses. That same year, a Cleanup and Abatement Order was issued ordering the Wessmans to, among other things, (1) "...redivert the springs from the mine overburden...back to the storage reservoir [surface impoundment] to abate further discharge", and (2) "...complete the repair of the storage reservoir...". In compliance with this order, the surface impoundment was rebuilt in 1978/1979 by the Wessmans.

The water in this surface impoundment collects acid mine discharge, spring discharge, rainfall and other surface waters. The impoundment waters exceed the Soluble Threshold Limit Concentration for mercury and nickel, as defined in Section 66699 of Title 22 CCR. It also exceeds many of the primary drinking water standards. The sediment in the impoundment exceeds the Soluble Threshold Limit Concentration for mercury and nickel.

This study has reviewed (1) the geohydrochemical setting of the surface impoundment, (2) the source of the hazardous constituents in the surface impoundment, and (3) various waste control alternatives and preliminary cost estimates for each. A proposed operation plan has been developed to reduce the quantity of water entering the surface impoundment. This plan appears to be the most feasible alternative to mitigate surface and/or ground water pollution.

A two-step plan is proposed to reduce the quantity of water entering the surface impoundment. First, waters from the pond immediately north of the surface impoundment would be diverted to the adjacent stream. Second, a portion of the surface runoff currently collecting in the impoundment would also be diverted to this stream. The quality of the waters to be diverted would be confirmed and monitored. This plan should minimize the release of surface impoundment waters to waters of the State.

8.2 Discussion

The literature review conducted has provided an understanding of some of the processes operative at the Mount Diablo Mine by which hazardous constituents are generated. The following discussion describes what we believe is the dominant process.

It appears that during the 1938 deepening of the mine shaft, a (reduced-?) Na-Cl dominated, low pH water was encountered. This water was pumped out of the mine and discharged to Dunn Creek. Williams (1988b) reported that oak trees which lined the creek died shortly after the pumping started.

As mining operations progressed, the acidic waters from the mine reacted with sulfides in an oxidizing environment to produce sulfuric acid and dissolved Fe. Hence, the pond effluent which is believed to be derived largely from mine drainage became more SO4 and Fe dominated.

Waters seeping from the mine were, and we believe still are of two types. One water is the characterized by low pH, SO4-Fe-Cl-Na dominated and high TDS. The other water has low pH, is relatively dilute, and is SO4 dominated. The horizontal and vertical distribution of these waters are not known.

An additional, naturally occurring SO4-Fe-Cl-Na water in the ore body can be inferred on the basis of Knox (1938). He reported the widespread occurrence of sulfates and oxidized sulfur gases along with the observation that the leaching was in part responsible for the loss of marcasite (iron sulfide) in parts of the deposit. The oxidized, low pH water is responsible for leaching the heavy metals from the ore body and precipitating the metal-rich sulfates in the mine. Knox's (1938) study was placed in the University of California library in May 1938. Williams (1988b) reports the water encountered in the mine was pumped and discharge to the creek in the fall of 1938. The extent to which this inferred naturally occurring SO4-Fe-Cl-Na water existed prior to mining activity is not known.

8.3 Summary

There is some evidence that the acid waters seeping from the mine are natural in origin. There is some evidence that also the heavy metals contained in the SO4-Fe-Cl-Na water are also naturally occurring. This is supported by the reported heavy metal content in the sulfates precipitated in the mine (Ross, 1940).

However, the presence of the mine workings undoubtedly exacerbated the condition by creating a greater reservoir for this type of fluid than previously existed. This greater reservoir and the mine openings themselves may allow for (1) acid water discharge if it did not previously exist, and (2) an increased volume of this acid water discharge.

With respect to the hazardous constituents in the pond, there are three possible sources: (1) from the acid waters in the mine, (2) from acid mine waters traversing the mine tailings pile, and (3) from rainfall interacting with the tailings pile. The available data suggests that the acid mine waters traversing the tailings pile is not a significant source (see discussion in Section 7.1.3.1). If acid waters interacting with the mine tailings pile do not dissolve significant quantities of hazardous metals, then it is unlikely that rainfall with a pH closer to neutrality would dissolve significant quantities of metals.

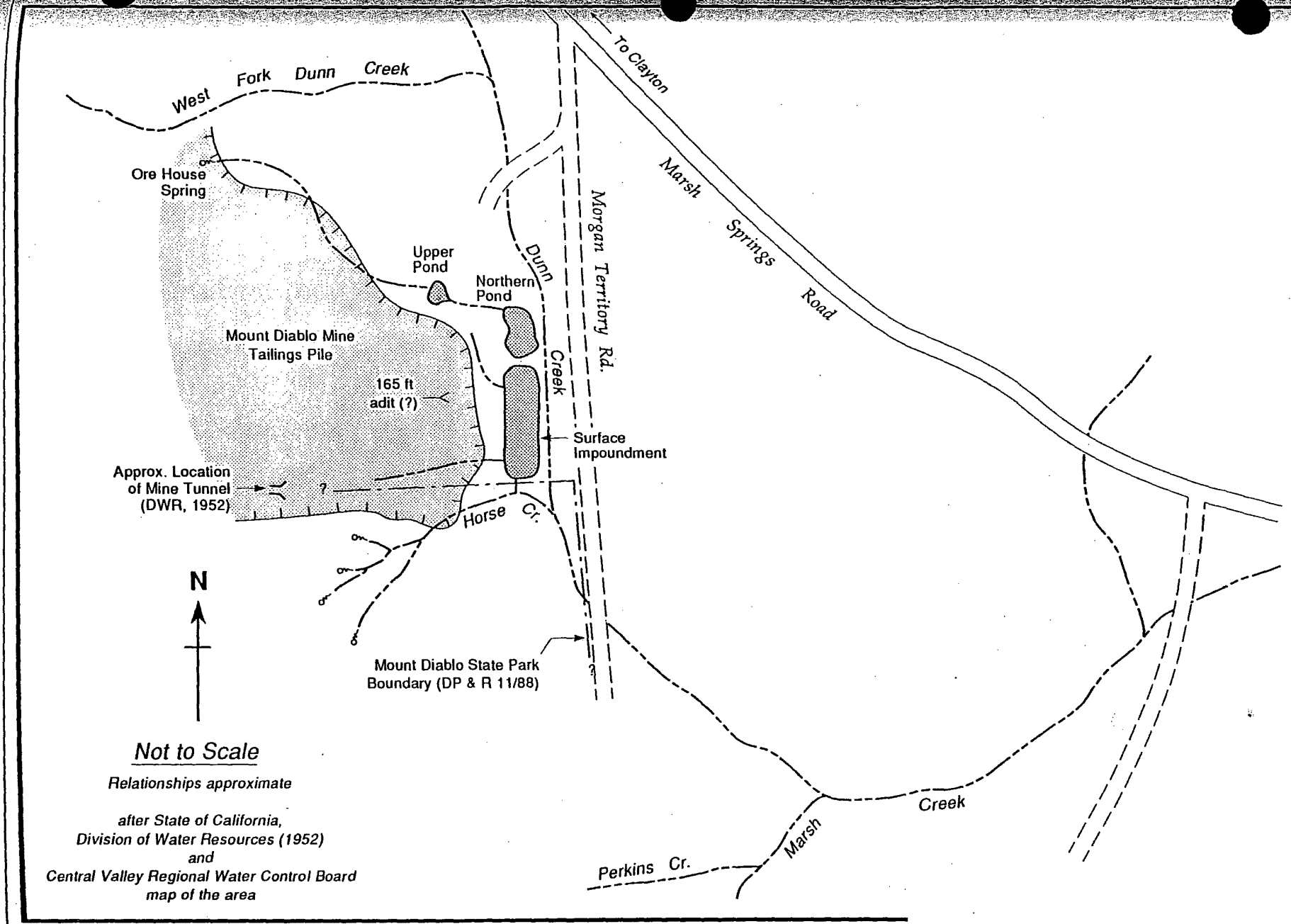

Figure 1. Schematic Map of the Mount Diablo Mine Surface Impoundment and Surrounding Features.

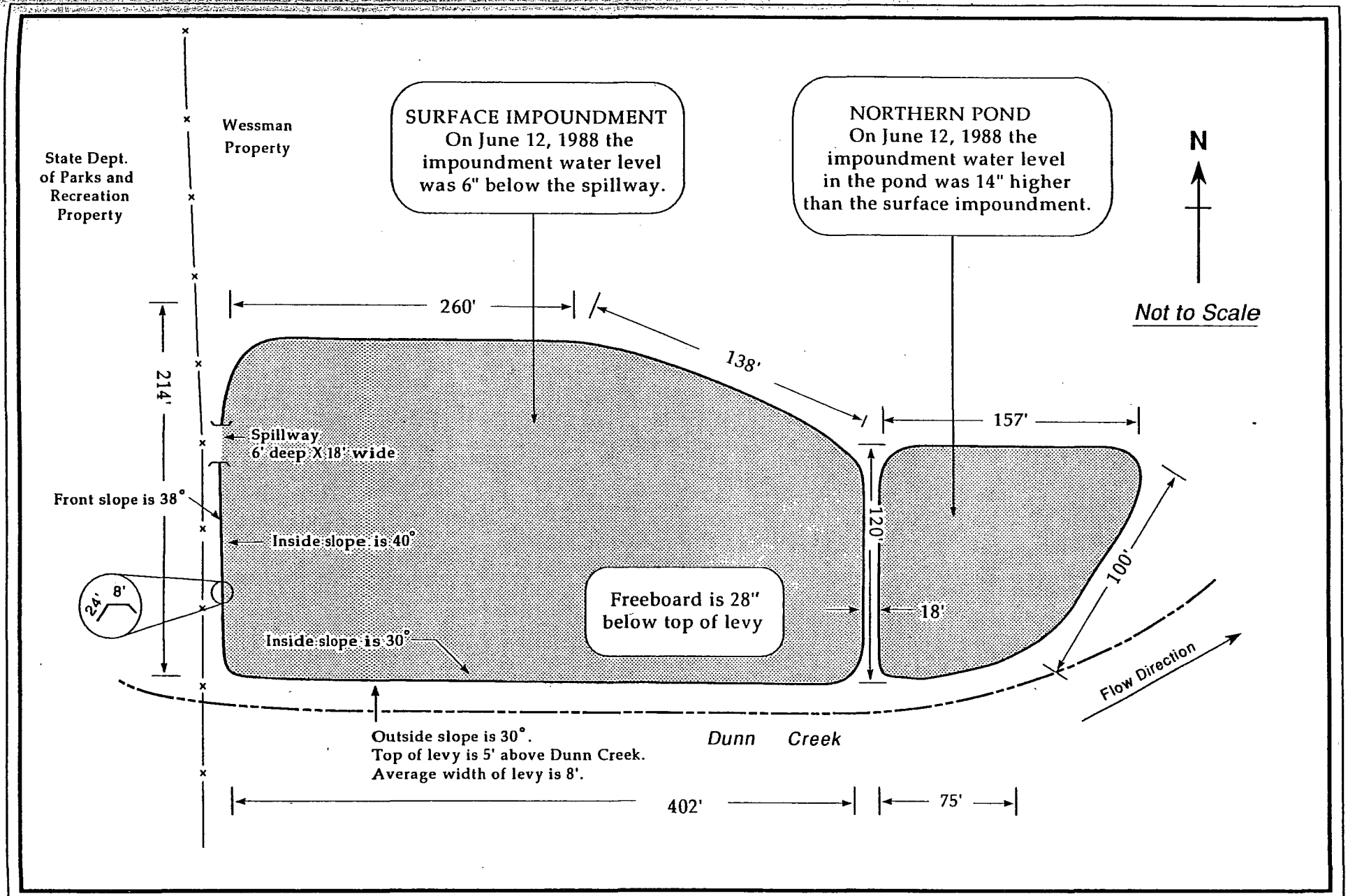

Figure 2. Mount Diablo Mine Surface Impoundment and Northern Pond Dimensions. Measurements provided by Mr. Wessman.

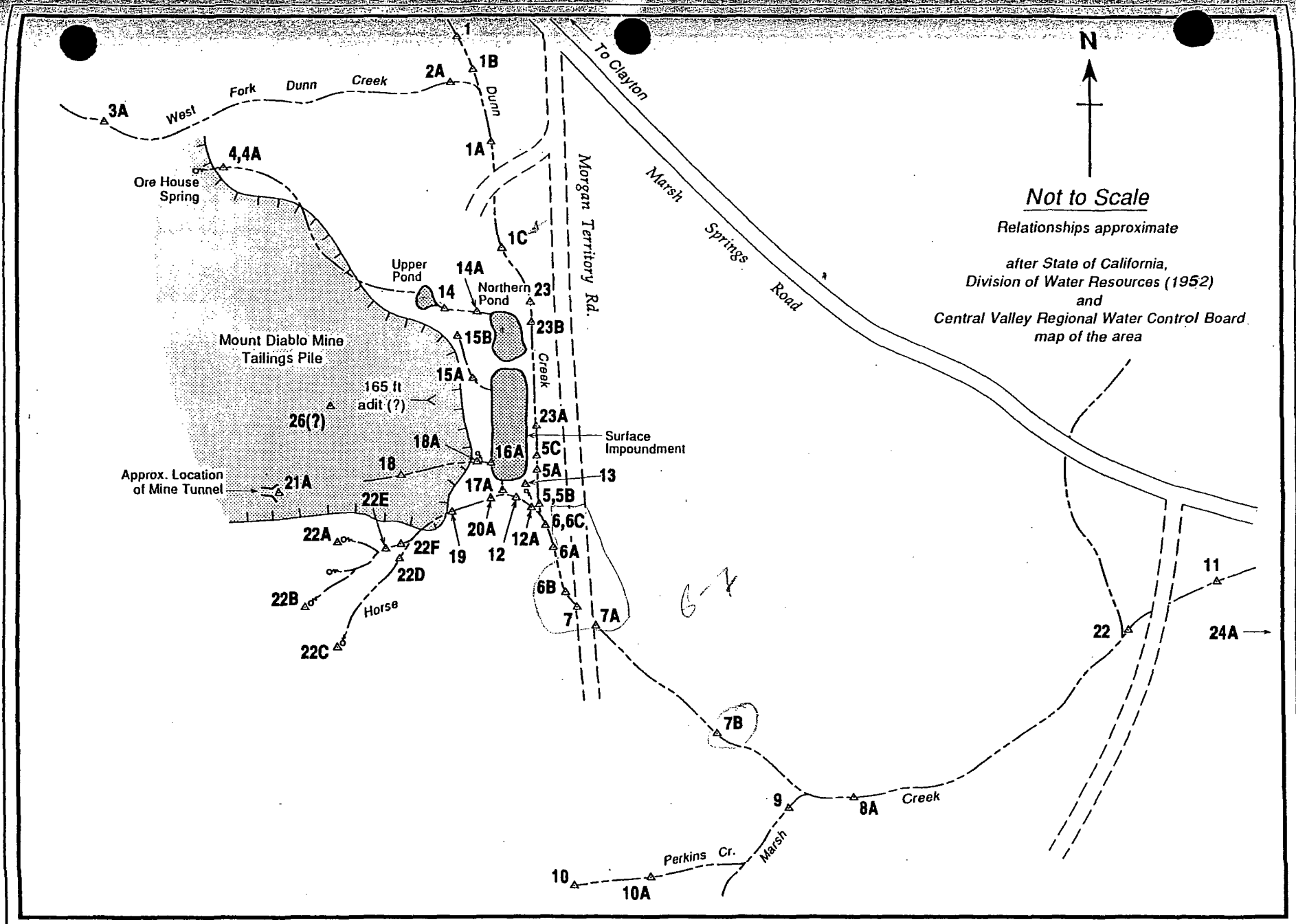

Figure 3. Location Map for Surface Water Samples Collected Near the Mount Diablo Mine Surface Impoundment

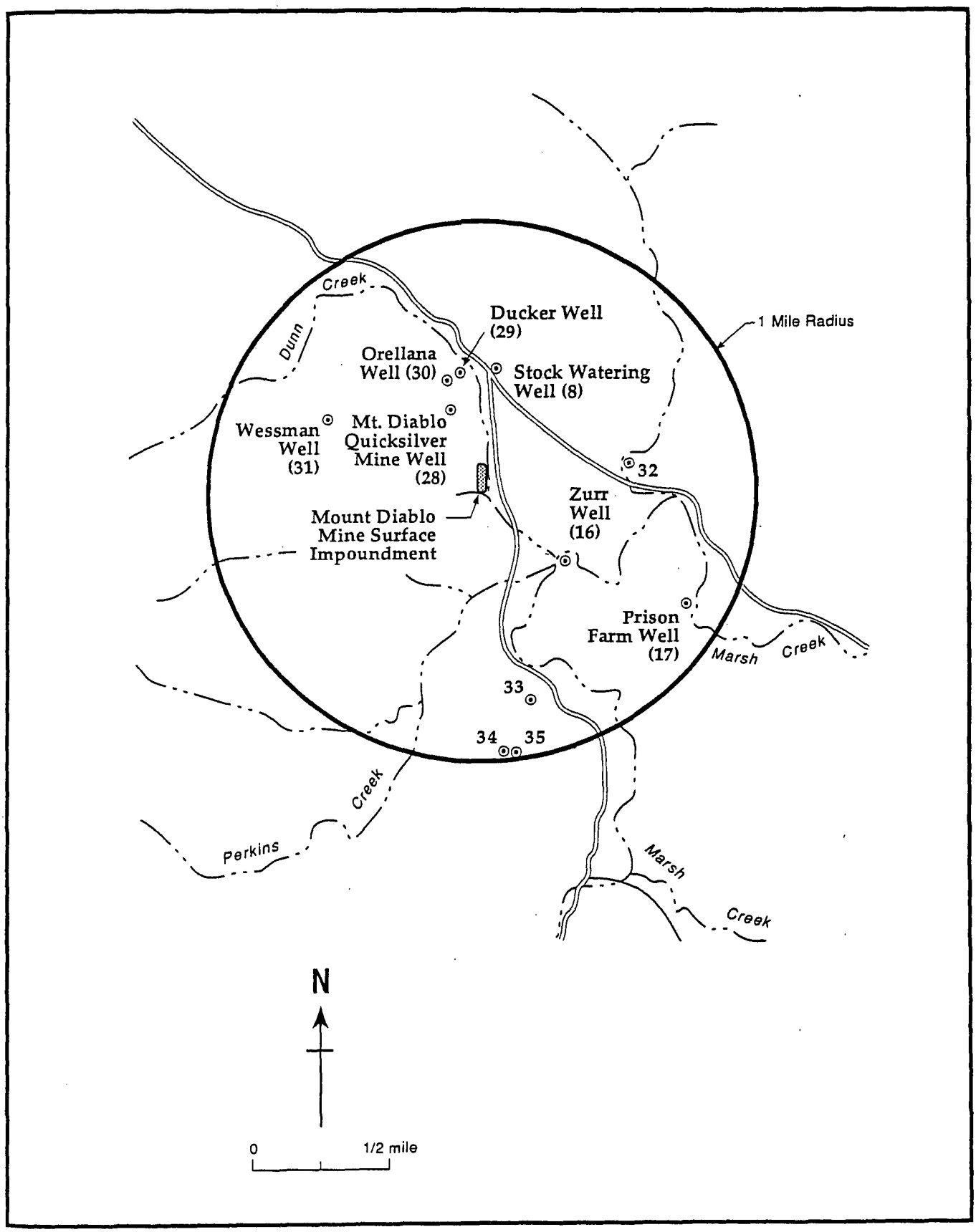

Figure 6. Wells within One Mile of the Mount Diablo Mine. Well Numbers are keyed to Table 3.

Table 1. Water Chemistry Data for Pond Waters within the Mount Diablo mine area. See text for pre-1953 Data.

Sample ID	Map Location[1]	Location Description	Date	pH	Total Solids (ppm)	EC (μmhos x10⁶)	Hardness (Total ppm $CaCO_3$)	NC Hardness	Turbidity	HCO_3 (ppm)	CO_3 (ppm)	CO_2	Alkalinity (ppm $CaCO_3$)	Acidity	H_2SO_4 (ppm)	PO_4 (ppm)	NH_3 (ppm)	NO_3 (ppm)
P-1-1[a]	NA	Upper Pond[2]	9-1-50	2.4	21430	25500	10000											
P-2-1[b]	NA	Surface Impoundment	2-2253	3.3														
P-2-2[g]	NA	Surface Impoundment	2-59	3.0														
P-2-3[c]	NA	Surface Impoundment	3-16-61	3.0		10600												2.4
P-2-4[i]	NA	Surface Impoundment	11-9-71	4.0														
P-2-5[g]	NA	Surface Impoundment	7-78	6.7	11900	12400	4430						209					4.3
P-2-6[m]	NA	Surface Impoundment	10-25-84	2.7	22000	18400	10000		18	0	0					0.17	15	2.9
P-2-7[m]	NA	Surface Impoundment	10-25-84													0.18		
P-2-8[g]	NA	Surface Impoundment	10-84	2.7	22000	18400	1000						0					2.9
P-2-9[g]	NA	Surface Impoundment	3-87	2.9	10000	9500												
P-2-10[o]	NA	Surface Impoundment	7-30-87	2.4	24000	32000	12528									0.12	56	51.8
P-2-11[h]	NA	Surface Impoundment	3-9-88	3.1														
P-3-1[u]	NA	Northern Pond	5-17-89	6.6	3600	4000				27	ND		210					ND

Table 1: Cont'd.

Sample ID	Map Location[1]	Date	Cl	SO_4	Ca	Mg	Na	K	Fe	B	SiO_4	Cu	As	Al	Zn	Hg	Pb	Sb	Ba	Be	Cd	Cr^{+6}	Cr^{+3}	Co	Ag	Mo	Ni	Se	Th	V	Li	Mn	F	H	As_2O_3	Color	%Na	Specific Gravity
			(ppm)																																				
P-1-1[a]	NA	9-1-50							849	>100																												
P-2-1[f]	NA	2-2253																																				
P-2-2[g]	NA	2-59																																				
P-2-3[k]	NA	3-16-61	1610	4546	360	523				80																												
P-2-4[i]	NA	11-9-71																																				
P-2-5[g]	NA	7-78	1790	5590	412	826	1740	82	78	120		0.15	0		0.33	.004	.13								.07						10						
P-2-6[m]	NA	10-25-84	1500	14000	413	1720	1300	17.6	273	73	<1	0.41	.1	640	3.23	.152	.38														47						
P-2-7[m,j]	NA	10-25-84			430	1800	1400	<.04	250	39	31	.33	<.057	610	2.9		.28	<.03	.02	<.0005	1.8		2.0	6.6	<.002	<.002	130	.72		<.003	4.7	42						
P-2-8[j,4]	NA	10-84	1500	14000	413	1720	1300	9.16	273	73	<1	.40	<.01	440	3.06	.152	.33	<.03	.02	<.0005	1.8		2.0	6.6	<.002	<.002	130	.72	<.09	<.003		47						
P-2-9[f]	NA	3-87										.18	.02			.083	.19		.02		.002		.76	4.7			59			<.01							
P-2-10[o]	NA	7-3087	4200	22400	493	2756	2649	13.3	137	224	101	.64	<.1	1100	5.1	.017	<.2	.16	<.005	.033	.026		2.7	12	.022	<.04	250	<.2		<.04	16	97						
P-2-11[k]	NA	3-88														.11	<.01				.0011		.68	2.09			49											
P-3-1[u]	NA	5-1789	410	1800	230	280	540	4.2	54		15	ND	.01		.01	ND	ND	ND	.04	ND	ND		ND	.03	ND	ND	.56	ND	ND	ND	6.0		2.2				

Table 2. Water Chemistry for Surface Waters within One Mile of the Mount Diablo Mine Surface Impoundment.

Sample ID	Map Location[1]	Location Description	Date	pH	Total Solids (ppm)	EC (μmhos x10⁶)	Hardness (Total ppm $CaCO_3$)	NC Hardness	Turbidity	HCO_3 (ppm)	CO_3 (ppm)	CO_2	Alkalinity (ppm $CaCO_3$)	Acidity (ppm)	H_2SO_4 (ppm)	PO_4 (ppm)	NH_3	NO_3
S-1-1[a]	1 (?)	Dunn Creek above mines; exact loc. unknown	3-6-42	6.0														
S-1-2[a]	"	"	2-28-49	8.3	236		116			181								
S-1-3[b]	1A	"	2-5-52	7.9		467	208	100		132	0							0.8
S-1-4[b]	1A	Dunn Creek above mine waste;	4-28-52	7.9		792	320	156		200	0							0.8
S-1-5[c]	1A	Dunn Creek 150 ft above road to homes + mines	2-4-54	8.4	197	339	146			154	8		170					2.9
S-1-6[d]	1B	Dunn Creek at intersection of Marsh Creek & Morgan Terr. Rd	4-17-75	8.3	174	294	137			160	0		160					0.1
S-1-7[e]	1C	Dunn Creek above northern pond	4-10-89	7.1	390	450												
S-2-1[b]	2A	West Fork of Dunn Creek ~100 ft above confluence with Dunn Creek	4-29-52	7.8		1520	668	551		142	0							4.4
S-3-1[b]	3A	" ~3/4 mile	4-29-52	8.0		727	318	152		202	0							1.6
S-4-1[b]	4	Seepage Through Furnace Plant	4-29-52	2.75	2400	3130	2060	2060		0	0							0.3
S-4-2[a]	4(?)	Spring in mine waste in Franciscan Fm	9-1-50	2.5	16270	20100	6640							190				
S-4-3[a]	4(?)	"	11-24-50	2.4	57980	28900	15800											
S-4-4[e]	4A	Ore House spring	4-10-89	3.0	740	1200				ND	ND							
S-5-1[a]	5	Dunn Creek below mine	3-6-42	3.4														
S-5-2[a]	5	"	2-28-49	4.9	2162		1190			15			12					
S-5-3[a]	7B	"	11-24-50	3.4	1901	2190	1170			0								
S-5-4[b]	7A	"	2-5-52	4.1	1420	1820	864	864		0	0				4.0			0.4
S-5-5[c]	7A	"	4-28-52	8.2	515	900	360	217		174	0							0.9
S-5-6[b]	5	Dunn Creek above confluence with Horse Creek	2-27-53	7.6														
S-5-7[a]	5B	"	2-59	7.0														
S-5-8[e]	5A	"	3-9-88	8.6	490	766	256			198	16							
S-5-9[e]	5C	"	3-9-88	7.6		1000												
S-5-10[e]	5C	Dunn Creek east of surface impoundment	11-9-71	3.0														
S-5-11[f]	5A	"	7-13-76	6.95	280	1180	416					289						9.5
S-6-1[b]	6A	Dunn Creek 100 ft below confluence with Horse Creek	2-27-53	6.8														
S-6-2[a]	6	Dunn Creek below confluence with Horse Creek	2-59	5.2														
S-6-3[e]	6A	"	3-16-61	7.3		2630												5.7
S-6-4[e]	6A	"	9-70															
S-6-5[e]	6C	Dunn Creek just below confluence with Horse Creek	11-9-71	8.0														
S-6-6[d]	6B	Dunn Creek 300 feet below "	1-29-75	7.2	8170	9830	2620		300	81	0							9.3
S-6-7[f]	6A	Dunn Creek just below "	7-13-78	6.9	11500	12800	3400						59					10

Sample ID	Map Location [1]	Date	Cl	SO_4	Ca	Mg	Na	K	Fe	B	SiO_2	Cu	As	Al	Zn	Hg	Pb	Sb	Ba	Be	Cd	Cr^{+6}	Cr^{+2}	Co	Ag	Mo	Ni	Se	Th	V	Li	Mn	F	H	As_2O_3	Color	%Na	Specific Gravity
S-1-1[a]	1(?)	3-6-42	798	69	16	114																																
S-1-2[a]	"	2-28-49	11	32	35	7	37		0.3																													
S-1-3[b]	"	2-5-52	18	100	37	28	17	1.1	0.32	0.78	12	0.37	0.04	0.7																		0.42	0.1					
S-1-4[b]	"	4-28-52	60	160	56	44	41	1.7	0.00	2.4	11	0.00	0.00	0.4																		0.00	0.1					
S-1-5[c]	1A	2-4-54	7.5	23	37	13	15	0.8	0.01	0.2	12	0.0	0.00	0.03	0.00		0.08					1.00					0.01					0.00						
S-1-6[d]	1B	4-17-75	44	17	35	12	9	0.4		0.1		0.00	0.00			0.0000																						
S-1-7[d]	1C	4-10-89	18	59	45	23	21	0.84			7.8																												
S-2-1[b]	2A	4-29-52	178	467	106	98	86	3.0	0.00	9.6	9.2	0.00	0.00	0.07	0.00																	0.00	0.2					
S-3-1[b]	3	4-29-52	78	100	65	38	29	0.9	0.00	4.7	18	0.00	0.00	0.1	0.00																	0.00	0.1					
S-4-1[b]	4	4-29-52	108	1660	57	27	55	5.3	115	3.5		0.00	0.04	269	0.84																	2.4						
S-4-2[a]	4(?)	9-1-50	1451	5980	336	358			991	>1000																												
S-4-3[a]	4(?)	11-24-50	2540	6198	556	1720			2640	121	78																											
S-4-4[a]	4A	4-10-89	15	640	60	47	25	1.8	6.0		44	0.07	.03		0.10	.013	ND	ND	0.02	ND	ND		0.04	0.14	ND	ND	3.0	ND	ND	ND		.49	.46					
S-5-1[a]	5	3-6-42	848	3362	341	94			300																													
S-5-2[a]	5	2-28-49	510	1197	155	197	378		3.0																													
S-5-3[a]	7B	11-24-50	140	1180	80	122			253	39	24																											
S-5-4[b]	7A	2-5-52	76	929	26	83	60	1.7	160	5.1		0.31	0.01	30																		2.5	0.3					
S-5-5[b]	7A	4-28-52	84	219	65	48	56	2.1	0.00	4.9	9.5	0.00	0.00	0.4	0.00																	0.00	0.2					
S-5-6[b]	5	2-27-53																																				
S-5-7[b]	5B	2-59																																				
S-5-8[h]	5A	3-9-88	40.1	108	41.4	37.1	46.4		40.1			<.05			<.05	<.001	<0.01				<.001		<.01	<.10			<.05					.032						
S-5-9[k]	5B	3-9-88																																				
S-5-10[c]	5C	11-9-71																																				
S-5-11[b]	5A	7-13-78	87	332	66	61	100	3.3	0.11	4.7		0	0		0.05	.0003	0.2								0							0.01						
S-6-1[b]	6A	2-27-53																																				
S-6-2[b]	6	2-59																																				
S-6-3[k]	6A	3-16-61	360	680	98	131				1.7																												
S-6-4[l]	6A	9-70														0.05																						
S-6-5[c]	6	11-9-71																																				
S-6-6[a]	6B	1-29-75	1440	3610	262	478	1480	49	42	515		0.03				.072																						
S-6-7[b]	6A	7-13-78	2080	4930	324	630	2060	75	40	140		0.06	0.01		0.41	.004	0.02								0.04							5.9						

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Table 2. Cont'd.

Sample ID	Map Location	Location Description	Date	pH	Total Solids (ppm)	EC (µmhos x10⁶)	Hardness (Total ppm $CaCO_3$)	NC Hardness	Turbidity	HCO_3 (ppm)	CO_3 (ppm)	CO_2 (ppm)	Alkalinity (ppm $CaCO_3$)	Acidity (ppm)	H_2SO_4 (ppm)	PO_4 (ppm)	NH_3 (ppm)	NO_3 (ppm)
S-6-8[m,g]	6A	Dunn Creek just below confluence with Horse Creek	10-84	7.0	15000	19000	5600						320					5.1
S-6-9[h]	6A	"	3-9-88	7.5		2800												
S-7-1[c]	7	Dunn Creek 100 ft below surface impoundment	2-4-54	7.3	1560	2500	636	508		156	0							1.7
S-7-2[d]	7A	" at Morgan Territory Rd Bridge	4-17-75	7.2	970	1360	405			64	0							1.6
S-7-3[g]	7	Dunn Creek at Morgan Territory Road	2-59	5.8														
S-8-1[b]	8A	Marsh Creek 300 ft below confluence with Dunn Creek	2-5-52	6.9	374	590	235	120		140	0							1.5
S-8-2[b]	"	"	4-28-52	8.1	463	744	300	65		286	0							0.4
S-9-1[a]	9	Marsh Creek above confluence with Dunn Creek	3-6-42	8.2														
S-9-2[a]	"	"	5-6-43	6.2														
S-9-3[a]	"	"	3-7-46	7.2														
S-9-4[a]	"	"	2-28-47	7.6														
S-9-5[a]	"	"	11-24-50	8.1	303	490	192			182								
S-9-6[h]	"	"	3-16-61	8.3		381												0.3
S-10-1[b]	10A	Dunn Creek ≈ 150 ft above confluence with Marsh Creek	2-5-52	8.4	166	280	128	9		146	0							0.2
S-10-2[b]	10A	"	4-28-52	8.2	288	438	187	20		204	0							0.5
S-11-1[a]	11	Marsh Creek at Sunshine Creek	1-60	7.8		2940				191	94							28
S-12-1[o]	12	Horse Creek above confluence with Dunn Creek	10-87	7.7	14775	19700	4739						577				9.8	38.5
S-12-2[h]	12	" " below confluence with surface impoundment	3-9-88	7.0		710000												
S-12-3[h]	12A	" " just above confluence with Dunn Creek	3-9-88	7.5		710000												
S-13-1[a]	13	Seepage below surface impoundment	9-1-50	3.3	23360	27000	10800			0								
S-13-2[b]	13	"	2-27-53	3.1														
S-13-3[g]	13	Spring below & east of surface impoundment	2-59	7.6														
S-13-4[h]	13	"	3-16-61	8.0		15690												14
S-14-1[c]	14	Near tailings on Creek feeding northend of surface impoundment	11-9-71	5.0														
S-14-2[g]	14(?)	Drainage from ponded area north of tailings	7-13-78	4.1	6700	6730	3310											2.8
S-14-3[c]	14A	Creek above northern pond	4-10-89	5.0	2400	3500				ND	ND							

Table 2. Cont'd.

Sample ID	Map Location [1]	Date	Cl	SO_4	Ca	Mg	Na	K	Fe	B	SiO_4	Cu	As	Al	Zn	Hg	Pb	Sb	Ba	Be	Cd	Cr^{+6}	Cr^{2}	Co	Ag	Mo	Ni	Se	Th	V	Li	Mn	F	H	As_2O_3	Color	%Na	Specific Gravity
																	(ppm)																						
S-6-8[m,9]	6A	10-84	3100	2300	510	896	2200	137	0.7	180	4	0.03	.008	0.9	0.11	.007	0.24														10.8						
S-6-9[k]	6A	3-9-88																																			
S-7-1[c]	7	2-4-54	440	525	100	94	392	0.8	0.05	18	8.2	0.0	0.00	0.05	0.01		0.00					0.00				0.0					3.3	0.1					
S-7-2[d]	7A	4-17-75	125	448	57	64	117	3.1		8.8		0.03	0.01			0.04																					
S-7-3[g]	7A	2-57																																			
S-8-1[b]	8A	2-5-52	26	153	48	28	31	1.6	2.4	0.7	13	0.0	0.0	0.6																	0.31	0.1					
S-8-2[b]	"	4-28-52	44	112	64	34	50	1.8	0.00	0.9	16	0.00	0.00	0.00	0.00																0.00	0.2					
S-9-1[a]	9	3-6-42	45	29.2	49	22			0.2																												
S-9-2[a]	"	5-6-43	40	134	69	36																															
S-9-3[a]	"	3-7-46	58	207	70	35			0.3																												
S-9-4[a]	"	2-28-49	51	49	46	21	40		0.2																												
S-9-5[a]	"	11-24-50	36	54	44	28			0.16	0.65	16																										
S-9-6[k]	"	3-6-61	24	23	35	16				0.2																											
S-10-1[b]	10A	2-5-52	90	16	30	13	8.2	0.8	0.00	0.30	17	0.00	0.00	0.00																	0.01	0.00					
S-10-2[b]	"	4-28-52	48	24	42	20	31	1.0	0.00	1.9	19	0.00	0.00	0.00	0.00																0.00	0.00					
S-11-1[n]	11	1-60	665	300	188	115	241	5.6		22	16																										
S-12-1[o]	12	10-67	4220	1320	484	861	2180	190	<0.1	289	18.9	<.006	<.1	<.05	<.01	<.0002	<.05	<.05	.027	<.001	<.005		<.01	.016	<.005	<.02	0.63	<0.2	<0.4	<.01	11	3.2					
S-12-2[k]	"	3-9-88																																			
S-12-3[k]	12A	3-9-88																																			
S-13-1[a]	13	9-1-50	6692	9702	559	1480			17	7100				64.7																							
S-13-2[f]	"	2-27-53																																			
S-13-3[g]	"	2-59																																			
S-13-4[i]	"	3-16-61	4230	1480	163	295				233																											
S-14-1[k]	14	11-9-71																																			
S-14-2[f]	14(?)	7-13-78	530	3810	253	651	444	22	36	38		0.12	0.01		0.44	0.01	0								0						17						
S-14-3[e]	14A	4-10-81	270	2320	180	260	280	24	2.2		26	<.01			0.44	.003	<1	<.1	.04	<.01	<.01			0.52	<.01	<.03	10	<.01	<.2	<.01		7.6					

Table 2. Cont'd.

Sample ID	Map Location [1]	Location Description	Date	pH	Total Solids (ppm)	EC (μmhos x10⁶)	Hardness (Total ppm $CaCO_3$)	NC Hardness	Turbidity	HCO_3 (ppm)	CO_3 (ppm)	CO_2	Alkalinity (ppm $CaCO_3$)	Acidity	H_2SO_4	PO_4 (ppm)	NH_3	NO_3
S-15-1[c]	15	Spring (below tailings)	11-9-71	7.0														
S-15-2[d]	15B	Tailings drainage north of South acid spring	7-13-78	6.15														
S-15-3[a]	15A	North acid spring	10-87	5.7	8975	11700	2897						NIL				40	2.1
S-16-1[e]	?	Surface impoundment inlet	8-3-39	8.2									1432					
S-16-2[h]	16B	Surface impoundment inlet	3-9-88	2.7		710000												
S-17-1[a]	17A	Surface impoundment outlet	8-3-39	8.2									1120					
S-17-2[a]	"	"	2-19-40	3.5									208					
S-17-3[a]	"	"	5-17-40	3.8														
S-17-4[a]	"	"	7-26-40	2.8														
S-17-5[a]	"	"	1-22-42	3.2														
S-17-6[b]	"	"	2-26-42	3.2														
S-17-7[a]	"	"	3-7-46	3.0						0								
S-17-8[a]	"	"	9-1-50	3.85	24350	27900	10700			0								
S-17-9[a]	"	"	11-24-50	3.2	1846	2180	1130											
S-17-10[g]	"	"	3-26-56	8.0	827	1370	471	348	20	150	0							40
S-17-11[c]	"	"	11-9-71	4.0														
S-17-12[d]	"	"	7-13-78	5.85	11900	12400	4430						209					4.3
S-17-13[h]	"	"	3-11-87		100000	9500												
S-17-14[h]	"	"	3-9-88	3.1	710000													
S-18-1[c]	18	Drainage from tailings pile	11-9-71	1.0														
S-18-2[d]	"		7-13-78	2.35	89300	30700												320
S-18-3[a]	18A	South acid spring [3]	10-87	2.4	11400	15200	3797										6.1	284
S-18-4[h]	18A	South acid spring [3]	3-9-88	2.2	23200	34400	5004			NIL	NIL							
S-18-5[a]	"	"	4-10-89	2.3	20000	20000?				<2.5	<2.5							
S-19-1[c]	19	Horse Creek at travertine springs	11-9-71	8.0														
S-19-2[d]	"	"	7-13-78	6.76	18500	20700	4020						1300					30
S-19-3[h]	"	State Park drainage in tailings	3-9-88	6.6	11076	17100	4388			<.05	NIL							
S-20-1[m]	20A	Horse Creek above Confluence with Surface Impoundment outflow	10-84	7.7	15200	18600										0.02	66	2.8
S-20-2[h]	"	"	3-9-88	7.9	710000													
S-21-1[b]	21A	Seepage from mine tunnel	2-5-52	3.5	43100	24400	28500	28500		0	0							4.1

Table 2. Cont'd.

Sample ID	Map Location	Date	Cl	SO_4	Ca	Mg	Na	K	Fe	B	SiO_2	Cu	As	Al	Zn	Hg	Pb	Sb	Ba	Be	Cd	Cr^{+6}	Cr^{+2}	Co	Ag	Mo	Ni	Se	Th	V	Li	Mn	F	H	As_2O_3	Color	%Na	Specific Gravity
			(ppm)																																			
S-15-1[k]	15	11-9-71																																				
S-15-2[d]	15B	7-13-78																																				
S-15-3[o]	15A	10-87	1770	7490	308	5.9	558	455	136	53.7	19.3	<.0006	<.1	23	0.99	.004	<.05	<.05	<.005	.011	.007		0.03	26	0.01	<.02	41	<.2	<.4	0.028	3.2	33						
S-16-1[p]	?	8-3-39	1450	228	83	208	515		10																													
S-16-2[k]	16A	3-4-88																																				
S-17-1[a]	17A	8-3-39	7900	670	90	214	5226		2																													
S-17-2[a]	"	2-19-40	300	1150					60																													
S-17-3[a]	"	5-17-40	798	192					150																													
S-17-4[a]	"	7-16-40	1599	1787					80																													
S-17-5[a]	"	1-22-42	1645	492	343	191			500																													
S-17-6[a]	"	2-26-42	1652	448	312	189			500																													
S-17-7[a]	"	3-7-46	3288	5860	417	604			100																													
S-17-8[a]	"	9-1-50	9121	9680	639	1040			>100		21		95.1																									
S-17-9[a]	"	11-24-50	115	1165	80	113			238	6.2	19																											
S-17-10[a]	"	3-26-56	215	257	87	62	100	26	0.08	13	12																											
S-17-11[k]	"	11-9-71																														.2					
S-17-12[d]	"	7-13-78	1790	5590	412	826	1740	82	78	120		.15	0		.33	.0018	.12								.07						10					
S-17-13[n]	"	3-11-87										.18	0.038			.084	.19		.02		.0021		.76	4.7			59			<.01						0.18
S-17-14[k]	"	3-9-88																																				
S-18-1[c]	18	11-9-71																																				
S-18-2[d]	"	7-13-78	685	3140	290	240	296	3.0		38	2.3	.61			10	.014	1.4								.4						64					
S-18-3[o]	18A	10-87	394	1650	214	796	235	1.8	1300	25.2	99.1	1	<.1	1500	5.4	0.12	<.05	0.23	.009	.034	.031		4.8	14	<.01	<.08	280	<.2	<.4	0.4	2.1	56					
S-18-4[k]	18A	3-9-88	442	1149	218	1088	291		1385			0.81			5.0	0.17	0.04				0083		5.83	10.10			235					462					
S-18-5[e]	18A	4-10-89	420	2400	300	1108	310	0.28			79					0.19											200					37					
S-19-1[c]	19	11-9-71																																				
S-19-2[d]	"	7-13-78	374	6620	378	747	4330	165	2550	280		0	0		.28		.01																				
S-19-3[h]	"	3-9-83	2318	3311	498	367	1725		1.1			<.05			<.05	.17	<.01								0												
S-20-1[m]	20A	10-84	3200	6600	508	338	2700	148	1.02	180	5	.03	.008	<.05	.02	.010	.22				<.001		.016	2.1			4.62					7.38					
S-20-2[k]	"	3-9-88																														6.9					
S-21-1[t]	21A	2-5-52	1770	2900	100	504	1070	52	8320	112		0.5	1.05	2030	13																	27					

Table 2. Cont'd.

Sample ID	Map Location	Location Description	Date	pH	Total Solids (ppm)	EC (μmhos x10^3)	Hardness (Total ppm $CaCO_3$)	NC Hardness	Turbidity	HCO_3 (ppm)	CO_3 (ppm)	CO_2	Alkalinity (ppm $CaCO_3$)	Acidity	H_2SO_4 (ppm)	PO_4 (ppm)	NH_3	NO_3
S-21-2[b]	21A	Seepage from mine tunnel	4-29-52	2.75	26400	22800	15600	15800		0	0							58
S-21-3[c]	21A(?)	Pipe at mouth of mine tunnel	2-4-54	3.6	22600	21800	3480	3480		0	0							
S-22-1[k]	22	Horse Creek uphill from mine tailings	11-9-71	7.0														
S-22-2[m]	22A	Piedmont State Park Spring	10-84	6.2	14000	17600	5200		50	440						.13		0.07
S-22-3[o]	22B	Red spring, State Park Land	10-87	6.4	11550	15400	3348						104				74	5
S-22-4[o]	22C	Bedrock Spring, State Park Land	10-87	7.6	15225	20300	2919						1179				76	31.6
S-22-5[k]	22D	Horse Creek above park drainage	3-9-88	7.6	15338	23000	4942			962	NIL							
S-22-6[k]	22E	Park drainage in tailings, upper road	"	6.7	12682	20500	3857			965	NIL							
S-23-1[k]	23	Dunn Creek above surface impoundment	3-16-61	7.5		1260												1.8
S-23-2[a]	23A	Dunn Creek 300 ft above confluence w/ Horse Creek	1-29-75	8.1	3.90	622	250	15		200	0							0.3
S-23-3[k]	23B	Dunn Creek above confluence with Horse Creek	3-9-88	8.2		720												
S-24-1[a]	24A	Marsh Creek at prison farm	8-3-39	7.8									276					
S-24-2[a]	"	"	5-6-43	7.0														
S-24-3[a]	"	"	12-7-45	7.2														
S-24-4[a]	"	"	3-7-46	7.2														
S-24-5[b]	"	"	2-28-49	7.8	667			304	0				132					
S-24-6[a]	"	"	6-14-50	7.7	830			215	0									0.9
S-24-7[k]	"	"	3-16-61	7.6		2270												7.7
S-25-1[b]	25	Marsh Creek - 50 ft above confluence with Dunn Creek	2-5-52	8.4	562	332		38		226	6.0							2.1
S-25-2[b]	"	" confluence with Perkins Creek	4-28-52	8.1	732	285		49		288	0							0.6
S-26-1[o]	26(?)	Mine drainage	8-3-39	3.0									1540					

Table 2. Cont'd.

Sample ID	Map Location	Date	Cl	SO_4	Ca	Mg	Na	K	Fe	B	SiO_2	Cu	As	Al	Zn	Hg	Pb	Sb	Ba	Be	Cd	Cr^{+6}	Cr^{+2}	Co	Ag	Mo	Ni	Se	Th	V	Li	Mn	F	H	As_2O_3	Color	%Na	Specific Gravity
S-21-2[b]	21A	4-29-52	4260	3300	243	507	2640	15	4250	92		0.00	0.06	933	12																25						
S-21-3[c]	21A(?)	2-4-54	5760	9200	352	632	3240	113	2530	221		0.6	0.01	173	6.7		0.0					0.00					505					24						
S-22-1[c]	22	11-9-71																																				
S-22-2[m]	22A	10-84	2700	6700	527	882	2000	130	28.3	160	1.5	.03	<.004	<.5	0.05	<.001	0.24															458						
S-22-3[o]	22B	10-87	3515	6105	490	518	1182	122	34.5	258	18.7	<.01	<.1	<.05	.031	<.0002	<.05	<.05	.022	.005	<.005		<.01	.26	<.01	<.02	10	<.2	<.4	.013	5.5	6.6						
S-22-4[o]	22C	10-87	5070	6370	197	592	1970	149	<.1	205.4	45.9	<.01	<.1	.069	<.01	<.0002	<.05	<.05	.022	<.001	<.005		<.01	<.019	<.005	<.02	0.34	<.02	<.4	<0.01	11	2.2						
S-22-5[k]	22D	3-9-88	2507	4121	521	888	2357		4.0			<.05			<.05	.016	<.001				<.001		.020	<.1			1.66					6.71						
S-22-6[k]	22E	"	1822	4145	382	708	2444		4.1			<.05			<.05	.20	<.01				<.001		.015	.19			4.51					9.58						
S-23-1[k]	23	3-16-61	67	506	90	98				2.4																												
S-23-2[d]	23A	1-29-75	27	107	55	27	32	2.7	2.1	0.6		.01				.0016																						
S-23-3[k]	23B	3-9-88																																				
S-24-1[a]	24A	8-3-39	900	164	228	142	260		0.2																													
S-24-2[a]	"	5-6-43	245	350	83	66			6.0																													
S-24-3[a]	"	12-7-45	240	207	83	47			1.0																													
S-24-4[a]	"	3-7-46	58	175	68	35			0.3																													
S-24-5[a]	"	3-28-49	110	239	53	43	106		0.6																													
S-24-6[a]	"	6-14-50	135	210	86	42	104		0																													
S-24-7[k]	"	3-16-61	363	462	150	93			14																													
S-25-1[b]	25	2-5-52	25	72	52	25	33	1.4	.20	0.45	20	0.16	0.02	0.5																		0.00	.2					
S-25-2[b]	"	4-8-52	40	111	40	45	49	1.7	0.00	0.60	17	0.00	0.00	0.00	0.0																	.00	.2					
S-26-1[k]	26(?)	8-3-39	755	82	168	195	5379		5.0																													

[illegible] Chemistry Data for Wells [illegible] Mount Diablo Mine Surface Impoundment

Sample ID	Map Location	Location Description	Date	pH	Total Solids (ppm)	EC (µmhos x10⁶)	Hardness (Total ppm $CaCO_3$)	NC Hardness	Turbidity	HCO_3 (ppm)	CO_3 (ppm)	CO_2 (ppm)	Alkalinity (ppm $CaCO_3$)	Acidity (ppm)	H_2SO_4 (ppm)	PO_4 (ppm)	NH_3 (ppm)	NO_3
W-8-1[a]	8	Stock Watering Well, completed in the Cretaceous Fm	9-1-50	7.6	2830	4980	57			724								1.9
W-8-2[b]	"	"	4-29-52	7.5	370	605	36	0		98	0							3.7
W-29-1[o]	29	Ducker Well - Cretaceous shale	7-30-87	7.5	3675	4900	199						564			<0.1	<0.1	4
W-30-1[o]	30	Orellana Well	7-30-87	8.2	1440	2000	19						950				2.2	5
W-28-1[a]	28	Mt Diablo Mine Well, completed in Alluvium	11-24-50	7.8	205	335	139			179								1.24
W-28-2[b]	"	"	4-29-52	7.8	273	445	214	3		258	0							1.2
	"	"																
W-16-1[P]	16	Zurr Well, completed in Alluvium	6-14-50	7.4	675		330				0		270					0.4
W-16-2[a]	"	"	9-1-50	7.6	1850	3000	1170			376			376					4.96
W-16-3[a]	"	"	11-24-50	7.4	954	1670	406			179								5.58
W-16-4[b]	"	"	2-5-52	7.8	200	338	108	0		148	0							1.7
W-16-5[b]	"	"	4-29-52	8.1	314	516	210	24		226	0							0.8
W-16-6[s]	"	"	7-18-55	7.1	5820	8960	3850	3690		140	0							41
W-17-1[a]	17	Shallow Well at Prison Farm, completed in Alluvium	8-3-39	7.3						244			200					
W-17-2[a]	"	"	2-19-40							256			208					
W-17-3[a]	"	"	5-17-40															
W-17-4[a]	"	"	7-26-40															
W-17-5[a]	"	"	2-26-42										252					
W-17-6[a]	"	"	5-6-43															
W-17-7[a]	"	"	12-7-45															
W-17-8[a]	"	"	2-28-49	7.0	1162		549			264			216					
W-17-9[a]	"	"	6-14-50	7.8	770		365			208								1.8
W-17-10[a]	"	"	9-1-50	7.7	771	1220	422			273			277					1.9
W-17-11[a]	"	"	11-24-50	7.2	861	1380	470			302								4.3

Sample ID	Map Location[1]	Date	Cl	SO_4	Ca	Mg	Na	K	Fe	B	SiO_2	Cu	As	Al	Zn	Hg	Pb	Sb	Ba	Be	Cd	~~Cr~~[6]	Cr^{+2}	Co	Ag	Mo	Ni	Se	Th	V	Li	Mn	F	H	As_2O_3	Color	%Na	Specific Gravity
			(ppm)																																			
W-8-1[a]	8	9-1-52	1320	3.8	15.0	4.6			0.57	>5	11																											
W-8-2[b]	11	4-29-52	58	121	6.8	4.6	113	3.5	0.18	2.9	7.3	0.00	0.02	0.01	2.3																0.00					
W-29-1[b]	29	7-30-87	1335	123	41.5	23.3	868	10.9	<.1	8.5	9.5	0.086	<.1	<.05	.042	<.002	<.05	<.05	0.3	<.001	<.05		<.01	<.01	<.005	<.02	<.04	<.2	<.4	<.01	.48	.23				
W-30-1[b]	30	7-30-87	108	36.4	2.5	3.1	385	8.6	<.1	9.3	5.5	<.001	<.1	<.05	<.01	<.0002	<.05	<.05	0.72	<.001	<.05		<.01	<.01	<.02	<.02	<.04	<.2	<.4	<.01	.71	.009				
W-28-1[a]	28	11-24-52	9.9	19.2	40.1	9.48			0.12	0.8	14																										
W-28-2[b]	11	4-29-52	11	22	58	17	13	0.7	0.10	0.05	23	0.00	0.04	0.00	2.1																0.00					
W-16-1[a]	16	6-14-52	110	91	72	39	88		0																												
W-16-2[a]	11	9-1-52	620	425	242	137			0.04	>5	23																										
W-16-3[b]	11	11-24-52	288	237	89.9	44			0.04	1.0	24																										
W-16-4[b]	11	2-5-52	70	29	21	13	31	0.7	0.00	0.85	15	0.27	0.01	0.00	0.00																						
W-16-5[b]	11	4-9-52	42	32	42	23	30	1.5	0.00	3.8	19	0.00	0.00	0.00	0.00																						
W-16-6[c]	11	7-18-52	2380	1140	79	838	633	9.0	0.04	83	28																										
W-17-1[a]	17	8-3-39	1312	164	360	191	216		4.0																												
W-17-2[a]	11	2-19-43	1939	191																																	
W-17-3[a]	11	5-17-43	780	53					0																												
W-17-4[a]	11	7-26-43	200	83					0.1																												
W-17-5[a]	11	2-26-42	355	159	118	57																															
W-17-6[a]	11	5-6-43	59	170	48	32																															
W-17-7[a]	11	12-7-45	195	118	85	41																															
W-17-8[a]	11	2-23-49	335	193	120	61	158		0.4																												
W-17-9[a]	11	6-11-50	135	209	79	41	115		0.4																												
W-17-10[a]	11	9-1-50	153	207	95	45			0.04	25	18																										
W-17-11[a]	11	11-24-50	160	250	101	53			0.15	7.4	17																										

DWS

pH 6.5 - 8.5 2° proposed
EC 900 μhmos/cm 2°
TDS 500 ppm 2°
Cl 250 ppm 2°
SO_4 250 ppm 2°
Mn 0.05 ppm 2°
Fe 0.3 ppm 2°
Cu 1 ppm 2°
1.3 ppm 1° proposed
Zn 5 ppm 2°
NO_3 45 ppm 1°
Al 1.0 ppm 1°

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REPORT OF LABORATORY ANALYSIS

Joe Ivonetti
Page 3

June 14, 1989
PACE Project Number: 490517600

PACE Sample Number:			730610
Parameter	Units	MDL	MDM-589-1S
INORGANIC ANALYSIS			
CAM METALS, TOTAL CONCENTRATIONS			
Antimony	mg/kg wet	50	ND
Arsenic	mg/kg wet	10	42
Barium	mg/kg wet	1	230
Beryllium	mg/kg wet	1	ND
Cadmium	mg/kg wet	1	1.4
Chromium	mg/kg wet	1	110
Cobalt	mg/kg wet	1	36
Copper	mg/kg wet	1	39
Lead	mg/kg wet	10	ND
Mercury	mg/kg wet	0.02	24
Molybdenum	mg/kg wet	2	ND
Nickel	mg/kg wet	4	650
Selenium	mg/kg wet	10	ND
Silver	mg/kg wet	1	ND
Thallium	mg/kg wet	50	ND
Vanadium	mg/kg wet	1	28
Zinc	mg/kg wet	1	66

TTLC (mg/kg) for constituents

As	500
Ba	10,000
Cd	100
Cr+3	2500
Co	8000
Cu	2500
Hg	20
Ni	2000
V	2400
Zn	5000

ND Not detected at or above the MDL.
MDL Method Detection Limit

The data contained in this report were obtained using EPA or other approved methodologies. All analyses were performed by me or under my direct supervision.

Stephen F. Nackord
Director, Sampling and Analytical Services

Douglas E. Oram, Ph.D.
Organic Chemistry Manager

ciates
re Street
:A 09

June 14, 1989
PACE Project Number: 490517600

. Joe Ivonetti

) Mine

le(s) Collected: 05/17/89
)le(s) Received: 05/17/89

)le Number: 730600

	Units	STLC mg/l	MDL	MDM-589-1W	DWS mg/l
C ANALYSIS					
AL PARAMETERS					
nce (Cations:Anions)				107%	
LS, IN WATER					
	mg/L	15	0.1	ND	—
	mg/L	5	0.01	0.01	0.05 (1°)
	mg/L	100	0.01	0.04	1.0 (1°)
um	mg/L	0.75	0.01	ND	—
	mg/L	1.0	0.01	ND	0.01 (1°)
m	mg/L	5/560	0.01	ND	0.05(+6) — (+3)
	mg/L	80	0.01	0.03	—
	mg/L	25	0.01	ND	1.0 (2°)
	mg/L	5	0.1	ND	0.05 (1°)
y	mg/L	0.2	0.0002	ND	0.002 (1°)
enum	mg/L	350	0.02	ND	—
	mg/L	20	0.02	0.56	—
ium	mg/L	1.0	0.01	ND	0.01 (1°)
	mg/L	5	0.01	ND	0.05 (1°)
tum	mg/L	7	0.2	ND	—
um	mg/L	24	0.01	ND	—
	mg/L	250	0.01	0.01	5.0 (2°)
ry Prep-Aqueous				ND	
NS AND GENERAL METALS					
um	mg/L		0.05	230	
sium	mg/L		0.05	280	
sium	mg/L		0.1	4.2	
n	mg/L		0.1	540	

Method Detection Limit
Not detected at or above the MDL.

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REPORT OF LABORATORY ANALYSIS

Mr. Joe Ivonetti
Page 2

June 14, 1989
PACE Project Number: 490517600

PACE Sample Number:			730600	
Parameter	Units	MDL	MDM-589-1W	
INORGANIC ANALYSIS				
CATIONS AND GENERAL METALS				DWS (mg/l)
Iron	mg/L	0.05	54	0.3 (2°)
Manganese	mg/L	0.01	6.0	0.05 (2°)
Silicates, by ICAP	mg/L	0.05	15	
GENERAL PHYSICAL PARAMETERS				
pH (Units at 25 Degrees Celsius)		0.1	6.6	6.5-8.5 (2°)
Specific Conductance, umhos/cm @ 25oC		1.0	4000	900 (2°)
Solids, Total Dissolved	mg/L	1	3600	500 (2°)
Alkalinity, Total as CaCO3	mg/L	2.5	270	
Alkalinity, Bicarbonate as CaCO3	mg/L	2.5	270	
Alkalinity, Carbonate as CaCO3	mg/L	2.5	ND	
ORGANIC ANALYSIS				
ANIONS BY EPA METHOD 300 (ION CHROM.)				
Chloride	mg/L	10	410	250 (1°)
Fluoride	mg/L	0.5	2.2	4.0 (1°)
Nitrate, as N	mg/L	0.1	ND	45 (1°)
Nitrite, as N	mg/L	10	ND	
Phosphate, as P	mg/L	20	ND	
Sulfate	mg/L	20	1800	250 (2°)

MDL Method Detection Limit
ND Not detected at or above the MDL.

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MOUNT DIABLO MINE

INACTIVE MINE CHECKLIST

I. LOCATION OF MINE AND DISCHARGES

A. COUNTY AND STREAMS INVOLVED

The Mount Diablo Mine is in Central Costa County about ten miles southeast of Concord. The mine is in the upper reaches of the Marsh Creek watershed. Mine discharges flow into Dunn Creek, thence Perkins Creek, thence Marsh Creek. Below the confluence with Perkins Creek, Marsh Creek flows through a State farm and several resorts, then to the Marsh Creek Reservoir. This reservoir is approximately 12 miles downstream and east of the Mount Diablo Mine.

B. DISCHARGE TO SURFACE WATER COVERED BY NPDES PERMITTING

A NPDES permit has never been formulated or adopted for discharges from the Mount Diablo Mine.

C. PRIVATE OR PUBLIC LANDS

Surface and mineral rights of property incorporating the Mount Diablo Mine are privately owned. However, some areas containing mine tailings are owned by the State of California. Detailed information is presented in Section V.

D. IMPACT OF DISCHARGE UPON PUBLIC LAND, IF ANY: IDENTIFCATION OF LAND MANAGEMENT AGENCY

Dunn Creek is severely impacted by toxic heavy metal concentrations. Contra Costa County is the responsible land management agency.

E. SOURCES OF DISCHARGES

The major source of pollution is a discharge from the mine that flows across waste rock piles thence into a holding reservoir. The holding

reservoir, when empty, is designed to contain the runoff from storms of 25 year intensity; periodic discharges occur when insufficient capacity in the holding pond exists.

Alkaline springs occur naturally within a couple hundred yards from the waste rock piles and holding reservoir. When the alkaline waters mix with the mine discharge, salts of heavy metals and iron precipitate. This chemical process would occur naturally with the neutral waters in Dunn Creek and Marsh Creek if the alkaline springs were not present. However, because the alkaline spring waters are diverted into the holding reservoir, the precipitates settle in the reservoir. Periodically the reservoir fills with precipitate, so cleaning is a necessary maintenance operation.

F. INFORMATION NEEDED CONCERNING HYDROLOGY OF MINE AREA

Factors that may need to be investigated and compiled in one comprehensive technical document include hydrology, geology, and itemization of discharge locations.

II. SEVERITY OF POLLUTION PROBLEM

A. DESCRIPTION OF DISCHARGE OF ITS TOXICITY

Waters issuing from the Mount Diablo Mine are generally acidic and contain a variety of dissolved sulfate ~~salts~~ salts heavy metals including iron, copper, and boron. Results of some past sampling listed in Regional Board files (not inclusive) are presented in Table 1.

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

ORDER NO. 78-114

WASTE DISCHARGE REQUIREMENTS
FOR
MOUNT DIABLO QUICKSILVER MINE
CONTRA COSTA COUNTY

The California Regional Water Quality Control Board, Central Valley Region, (hereafter Board), finds that:

1. The Board on 27 February 1953 adopted Resolution No. 53-21 which prescribed requirements for a discharge from Mount Diablo Quicksilver Mine to Dunn Creek.

2. Surface and mineral rights of the mine are presently owned by Jack and Carolyn Wessman.

3. Present waste discharge requirements established by Resolution No. 53-21 are not adequate nor consistent with present plans and policies of the Board.

4. Mount Diablo Quicksilver Mine discharges mine drainage from the mine tailings and overburden to Dunn Creek near its confluence with Marsh Creek a tributary of the San Joaquin River a water of the State.

5. Mount Diablo Quicksilver Mine is located in the NE 1/4, SE 1/4 of Section 29, T1N, R1E, MDB&M (assors parcel #78060008-6) with surface water drainage to Dunn Creek.

6. The beneficial uses of Marsh Creek and Marsh Creek reservoir are: water-contact recreation, non-water contact recreation, freshwater habitat, wildlife habitat, and the preservation of rare and endangered species.

7. The beneficial uses of the groundwater are: domestic supply, irrigation, and stockwatering.

8. The Board, on 25 July 1975, adopted a Water Quality Control Plan for the Sacramento-San Joaquin Delta Basin.

9. Mining operations ceased in 1971, however, the mine area continues to discharge mineralized water and sediment to Dunn Creek.

10. The action to revise waste discharge requirements for this facility is exempt from an environmental review in accordance with Sections 15101, 15107, and 15108 of the CEQA regulations.

11. The Board has notified the discharger and interested agencies and persons of its intent to prescribe waste discharge requirements for this discharge.

12. The Board in a public meeting heard and considered all comments pertaining to the discharge.

DISCHARGE REQUIREMENTS
MT. DIABLO QUICKSILVER MINE
CONTRA COSTA COUNTY

IT IS HEREBY ORDERED, that Resolution No. 53-21, be rescinded and Jack and Carolyn Wessman shall comply with the following:

A. Discharge Prohibitions:

1. The direct discharge of wastes to surface waters or surface water drainage courses is prohibited.

2. Previously deposited sediment in the reservoir shall not be discharged.

B. Discharge Specifications:

1. The discharge shall not cause a pollution or nuisance as defined by the California Water Code.

2. The discharge shall not cause degradation of any water supply.

3. The discharge shall remain within the designated disposal area at all times.

4. The discharger shall implement erosion control practices to minimize erosion of mine overburden and worked areas.

C. Provisions:

1. The discharger may be required to submit technical or monitoring reports as directed by the Executive Officer.

2. The discharger shall follow the following time schedule to comply with discharge prohibition A1:

Action	Compliance Date	Compliance Report Due
Conceptual Plan	1 Nov 1978	15 Nov 1978
Complete Construction Plan	1 Jan 1979	15 Jan 1979
Begin Construction	1 Apr 1979	15 Apr 1979
Progress Construction Report	1 Jun 1979	15 Jun 1979
Full Compliance	1 Jul 1979	15 Jul 1979

3. The discharger shall follow the following time schedule to comply with Provision A.2:

TABLE 1

SUMMARY OF WATER QUALITY DATA
VICINITY OF MOUNT DIABLO MINE
5 February 1980

	1	2	3	4	5
pH	7.9	4.1	3.5	8.5	2.75
EC x 10^6 at 25°C	467	1,820	24,400	280	3,130
Percent Na	15	13	8	12	5
Total Hardness, ppm	208	864	28,500	128	2,060
NC Hardness, ppm	100	864	28,500	9	2,060
Discharge, sec-ft	3.82	0.10	3.74	8.14	0.08
Constituents, ppm					
Ca	37	26	100	30	57
Mg	28	83	504	13	27
Na	17	60	1,070	8.2	22
K	1.1	5.2	1.7	0.8	5.3
CO_3	0	0	0	0	0
HCO_3	132	0	0	146	0
SO_4	100	979	29,100	16	1,660
Cl	18	76	1,770	9.0	108
NO_3	0.8	0.4	4.1	0.2	0.3
Boron	0.75	5.1	112	0.30	3.5
Sum	279	1,420	43,100	166	2,400
Si	12	- -	- -	17	- -
Cu	0.32	160	8,320	0.00	115
Al	0.7	30	2,030	0.00	2.69
Mn	0.42	2.5	2.7	0.01	2.4
Fl	0.1	0.3	- -	0.00	- -
Zn	- -	- -	13	- -	0.84
As	0.01	0.01	0.05	0.00	0.04
H_2SO_4	- -	4.0	15	- -	- -

Station

1 Dunn Creek, above mine waste

2 Dunn Creek, below mine waste

3 Seepage from mine adit

4 Perkins Creek, approximately 150 feet above confluence of Marsh Creek

5 Seepage from furnance plant (sample taken 29 April 1952)

B. SENSITIVITY OF AREA OF DISCHARGE

1. Beneficial Uses:

Beneficial uses of Marsh Creek and Marsh Creek Reservoir are water contact and noncontact recreation, flood control, stock watering, ground water recharge, and preservation and enhancement of fish and wildlife including rare and endangered species. Beneficial uses of areal ground water are domestic supply, irrigation, and stock watering.

2. Present Evidence of Impacts on Beneficial Uses; Description of Additional Evidence Needed:

The Marsh Creek Reservoir was built for the purpose of providing a recreational fishery. However, the mercury levels in fish tissue has caused the closure of the area for this purpose.

Additional evidence that would be helpful to determine a solution is whether the mercury in the fish is due to the current discharge or due to precipitates on the bottom of the reservoir.

III. HISTORY OF MINE

A. AGE OF MINE AND TIME SINCE MINE OPERATED

Little is known about the early history of the Mount Diablo Mine. The adjacent Ryne mine was producing from 1875 to 1877.

During this time some prospecting work was done at the Mount Diablo site, but no mining for metacinnabar was undertaken.

In 1929, both mine sites were leased by Mr. Vic Blomberg of the Mount Diablo Quicksilver Mines Company. In 1930-31 they produced nine flasks of quicksilver, being the first in the district to utilize metacinnabar.

In 1933 the property known as the Mount Diablo Mine was leased to C.W. Ericksen, who in a year and a half is said to have produced 730 flasks of quicksilver from an ore shoot which opened up in a glory hole above the adit level, a few hundred feet west-southwest of the present mill site. The ore in this shoot was quite rich in metacinnabar as well as cinnabar, and is said to have once yielded 48 flasks of quicksilver in 48 hours.

During 1934-35 Ericksen built a 40-ton Gould-type furnace plant, and in 1936 sold the lease to the Bradley Mining Company. The Bradleys then laid out an underground mining program, together with a little surface work, to develop the ground adjacent to the glory hole. Ore taken from these workings yielded 10,455 flasks of quicksilver between 1937 and 1948, making the Mount Diablo quicksilver district rank ninth in U.S. production for the period 1940-1952, and twenty-ninth for total production during the period 1950-52.

Quicksilver mining was interrupted in 1947, when the price of quicksilver dropped to less than $90 per flask. The Bradleys then installed rock crushers near the mill and began to produce crushed and broken stone from indurated graywacke of the Franciscan formation quarried near the Ryne Mine.

In September 1951 the Mount Diablo Mine was leased to R.B. Smith, who developed an open-pit operation over the underground workings near the mill. During the 55-day period from November 15, 1951 to January 17, 1952, this operation yielded 123 flasks of quicksilver. On the latter date, after prolonged rainstorms, landslides from the south face of the pit terminated operations on the productive benches.

Early in 1953 a DMEA (Defense Minerals Exploration Administration) exploration contract was awarded to Mr. Smith for exploring the Mount Diablo Mine and some ground below its lowest level. A 330-foot shaft was sunk and a crosscut was driven towards the old workings. The project was terminated in 1954 before completion. In 1955 the exploration project was completed by the Cordero Mining Company without DMEA assistance. Between the end of 1955 and June 1958, a few minor drilling and sampling projects were conducted in the open pit, but no mining was done.

In June 1958 the Mount Diablo Mine was leased by J.E. Johnson, who installed a washing and concentrating plant, about 250 feet south of the furnace, to concentrate low-grade mineralized rock from the dumps and the open pit. In October 1958 a trial run of the plant yielded a concentrate containing 20 pounds of quicksilver per ton, but the operation was terminated shortly afterward because of Mr. Johnson's untimely death, without having produced any quicksilver.

In the summer of 1960 the Victoria Resources Corporation took an option to purchase the Mount Diablo Quicksilver Mine. During the mid-60's the Welty and Randal Mining Company worked the mine tailings and ore dumps from previous operations. In 1970 the Guadalupe Mining Company purchased the mine and reintitiated mining and retorting of mercury ore.

By 1975 the property transferred to Mr. Jack Wessman. Mr. Wessman has not continued mining operations, but works through a local real estate brokerage firm. The mine is currently inactive.

B. MINERALS MINED, AND TYPE AND SIZE OF MINE

The Mount Diablo Mine is in an area of serpentine and Franciscan strata typical of many of the quicksilver belts of the state. Ore deposition has taken place in a zone of opalized porous rock, commonly called "quicksilver rock". Cinnabar and metacinnabar have been deposited within this rock in about equal quantities, with the metacinnabar occurring in rather massive form closely associted with pyrite and marcasite. There is not indication of mineralization having taken place beyond the zone of opalized porous rock. Table 2 presents production figures for the Mount Diablo Mine from 1875 to 1957:

TABLE 13... [illegible] mercury and base-metal deposits, in parts per million

(Ionization state or species of complex not distinguished)

	Temp. collected (°C)	pH	Na	K	NH_4	Ca	Mg	Fe	Mn	HCO_3[a]	Cl	SO_4	H_2S[b]	B	SiO_2	Others	Analyst, Reference
Waters associated with mercury deposits																	
1. Sulphur Bank, Lake Co., Calif.	69½	6.8	1,190	23	464	20	55	[d]0.1	[e]0.2	3,290	644	598	12	620		42 [d]As, 0.00; [d]Cu, 0.01; [e]As, Sb, Hg <0.02	C. E. Roberson (White and Roberson, 1962, table 1)[c]
2. Wilbur Springs district, Colusa Co., Calif.																	C. E. Roberson (White and others, 1963, table 23)[c]
a. Abbott mine	~35	7.1	1,500	39	22	64	443	[d]0.04	0.0	2,710	1,900	467	<1	56		16 [d]As, 0.00; [d]Cu, 0.006	
b. Wilbur Springs (Sulphur Creek group)	57	7.2	9,140	460	303	1.4	58	0.1	0.3	7,390	11,000	23	178	292		190 As, Sb 0.0; [d]W 9; [d]Pb 1; [e]Hg 0.22 (BL)W	W. W. Brannock (White and others, 1963, table 15)[c]
c. Elgin mine[c,f]	68½	7.4	9,110	506	243	5.9	29	0.04	0.0	7,240	11,000	6.8	170	240		244 [d]W, 7; [d]Cu, 0.03; [e]Hg 0.04 (BL)	C. E. Roberson, U. S. Geological Survey[c,f].
3. Mayacmas district, Calif.																	
a. Valley mine, Napa Co.	32	6.5	476	8.2	2.5	19	90	0.6	0.1	1,490	229	16	<1	67		95 As, 0.00; [d]Cu 0.2	J. P. Schuch (White and others, 1963, table 23)[c]
b. Big Injun mine, Lake Co.[e]	~21	6.8	26	0.9	—	34	142	—	—	708	2	154	—	0.7		74 Sr, 0.1; Li, 0.0	C. E. Roberson, U.S. Geological Survey[e]
c. The Geysers, Sonoma Co.	~100	~1.8	12	5	1,400	47	281	63	1.4	—	0.5	5,710	—	3.1		225 Cr, 2; [e]Hg 0.07 (BL)	E. T. Allen (White and others, 1963, table 20)
4. Skaggs Springs, Sonoma Co., Calif.	54	7.2	912	33	—	14	5.4	—	—	2,480	58	6.5	<1	92		74 [e]Sb, 0.01; [e]As, Hg < 0.02; [e]Hg 0.06 (BL)	R. N. Martin (White, 1957*b*, p. 1676)
5. Altoona mine, Trinity Co., Calif.[c,e]	12½	7.0	3,710	220	18	28	39	0.07	0.01	8,060	1,560	352	18	121		60 As, 0.05	H. C. Whitehead, U.S. Geological Survey[c,e].
6. Beaver Creek district, Siskiyou Co., Calif.																	
a. West Cinnabar Spring[e] near HG prospect	14	6.5	2,070	53	Present	124	92	—	—	4,280	1,540	8	—	89		— Li, 4.9	C. E. Roberson, U.S. Geological Survey[e]
7. Mt. Diablo mine, Contra Costa Co., Calif.	21	7.7	3,100	53	57	431	12	0.3	0.1	203	5,770	1.6	0.4	191		16 As, 0.00; [d]Cu, 0.1	C. E. Roberson (Pampeyan, 1963, table 4)[c]
8. Steamboat Springs, Washoe Co., Nevada[c,h]	60	6.1	637	61	<1	16	1.0	—	—	314	824	107	8	48		220 As, 1.7; Sb, 0.3; [e]Hg 0.00; 0.10(BL)	W. W. Brannock, U.S. Geological Survey[c,h]
9. Cordero mine, Humboldt Co., Nevada[c,i]	56	8.1	115	2.4	0.3	3.2	0.2	0.06	0.01	199	26	59	0.2	0.7		60 As, 0.07; [d]Mo, 0.02	H. C. Whitehead, U.S. Geological Survey[c,i].
10. Amedee Springs, Lassen Co., Calif.[j]	92	8.5	227	6.8	0.5	16	0.0	0.01	0.00	37	160	288	<1	4.1		96 [e]As, 0.15, [e]Sb, 0.01	J. P. Schuch (White and others, 1963, table 23)[c,j]
11. Boiling Springs, Valley Co., Idaho	88	9.2	74	1.9	—	2.2	0.0	0.4	0.004	[k]106	14	12	<1	0.1		81 As, Sb < 0.1	Henry Kramer (White and others, 1963, table 23)
12. Apapel'sk Springs, Kamchatka, U.S.S.R.	96	8.1	372	22	0	16	5.2	0.7	0	174	168	499	—	16		182 As, 1.6	(Ivanov, 1958, p. 204)
13. Ngawha Springs, New Zealand	48	6.4	830	63	148	7.8	2.5	—	—	340	1,250	347	6	912		178 As, 0.2; Hg, 0.1	A. J. Ellis (written communication, 1964)[f]
14. Toya Springs, Hokkaido, Japan	47	7.3	—	—	—	267	—	—	—	204	2,142	588	0	28		Evap. res. 5,000	M. Nishimura (written communication, 1965)
15. Cymric Oilfield, Kern Co., Calif.	~81	7.5	5,820	132	51	373	115	1.2	0.08	535	9,840	1.6	0	140		47 As, 0.0; [d]Cu, 0.04; Hg, 0.1 to 0.4 (BL)	C. E. Roberson (Bailey and others, 1961)[e]

Gary Johnson has book

Geochemistry of Hydrothermal Ore deposits

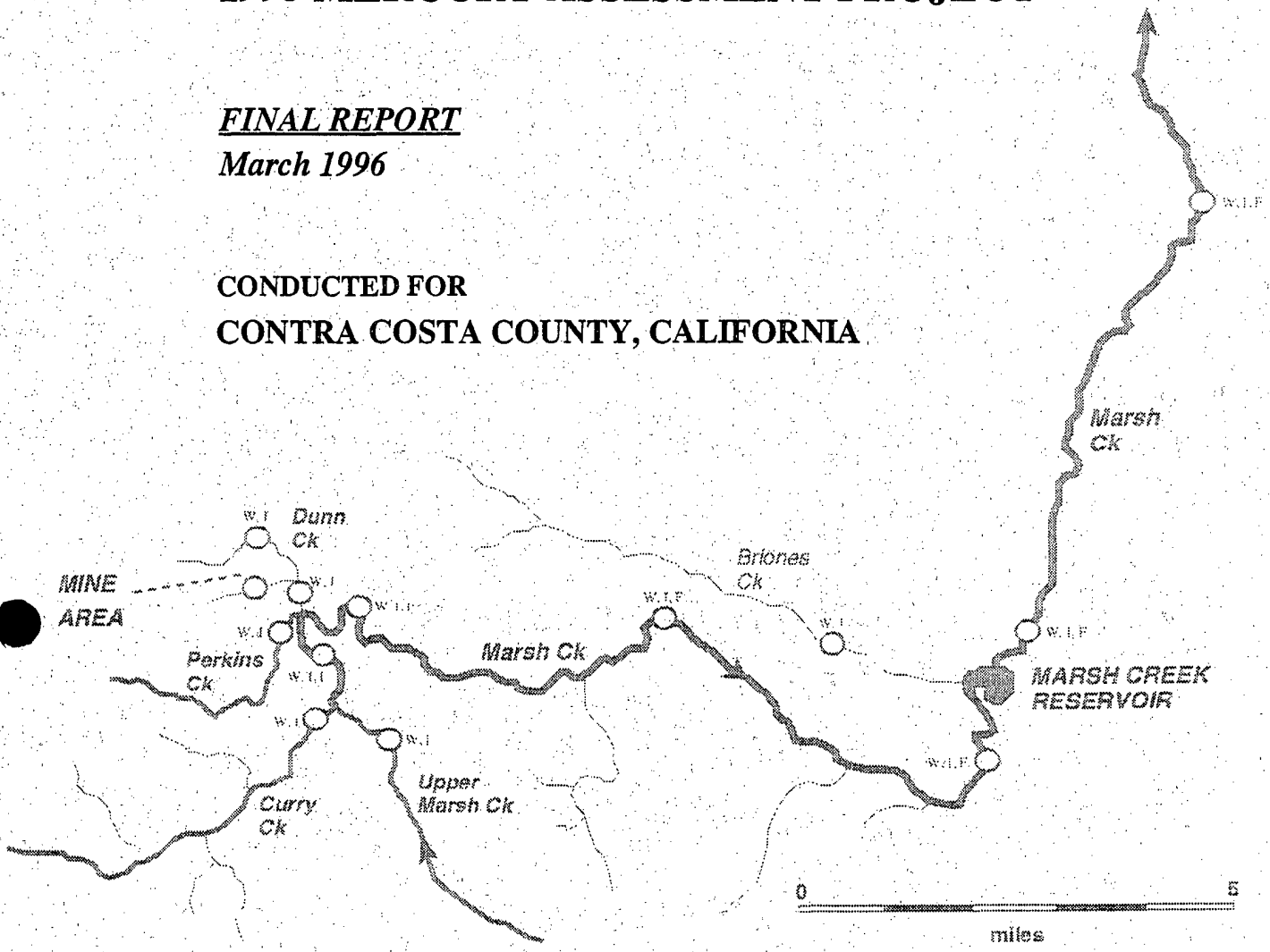
Barnes 1967 and later (1979)

Table 13-1
Chemical analyses of waters associated with mercury and base-metal deposits, in parts per million

MARSH CREEK WATERSHED
1995 MERCURY ASSESSMENT PROJECT

FINAL REPORT
March 1996

CONDUCTED FOR
CONTRA COSTA COUNTY, CALIFORNIA



STUDY AND REPORT BY

Darell G. Slotton, Ph.D.
Shaun M. Ayers
John E. Reuter, Ph.D

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1. INTRODUCTION

The Marsh Creek watershed, in eastern Contra Costa County, is fed primarily by seasonal tributaries from the eastern slope of Mt. Diablo. Flows in the watershed range from zero in many upstream tributaries during the dry season to hundreds of cubic feet per second in downstream Marsh Creek during winter storm runoff. Marsh Creek flows through the towns of Brentwood and Oakley, ultimately emptying into the San Joaquin Delta east of Antioch.

A flood control dam was built on Marsh Creek in 1963, approximately five miles upstream of Brentwood. The resulting Marsh Creek Reservoir is now a shallow water body with extensive riparian, marsh, and aquatic weed growth, providing habitat for a variety of wildlife including resident populations of fish. The surrounding land is currently used for cattle grazing. The primary function of the reservoir is flood control. Operated by the Contra Costa Department of Public Works, it has been closed to the public throughout recent years.

An extensive residential development is planned for the area surrounding Marsh Creek Reservoir. As the existing reservoir may be incorporated into these development plans, information regarding its water quality and that of the watershed in general is of particular current interest. One potential area of concern involves mercury. The California Department of Fish and Game analyzed fish from the reservoir in 1980. These fish were found to be above existing health standards for mercury (Contra Costa County 1994).

A large, abandoned mercury mine site is present on the northeast slope of Mt. Diablo. The Mt. Diablo Mercury Mine is located within the Marsh Creek watershed, adjacent to Dunn Creek, which is a small tributary to Marsh Creek. A substantial area of exposed tailings is present at the site and, while this region contributes only a small fraction of the total flow in the watershed, it has been assumed for many years to be a major contributor to the downstream mercury accumulations. A series of sediment settling ponds were constructed in ~1980 to intercept suspended sediment from the tailings and related springs. Water collections made in the vicinity of the mine by the Central Valley Regional Water Quality Control Board demonstrated significantly elevated mercury concentrations (CVRWQCB 1994). However, these tests did not include the entire watershed and did not have a low enough level of analytical detection to obtain useful data from any but the most extremely contaminated samples. Consequently, this earlier work could not determine the relative loading of mercury to the watershed from the mine on a mass balance basis.

In early 1995, our mercury biogeochemistry research group was contracted by the Contra Costa County Department of Public Works to undertake a comprehensive

assessment of mercury throughout the Marsh Creek watershed. It was our strong recommendation that a relatively thorough and up-to-date understanding of mercury dynamics throughout the watershed as a whole be obtained before mitigation plans were made. We felt that it was critical to determine the relative importance of the exposed mine site to the watershed's total mercury loading.

Mercury is naturally enriched throughout extensive areas of the Mt. Diablo region, which is why mercury was historically mined here (Ross 1940). Mercury is similarly enriched throughout much of the California Coast Range. As the majority of the water flow and associated transported material in the Marsh Creek watershed appeared to derive from tributaries other than the one containing the Mt. Diablo mine, it was quite conceivable that a significant proportion of the total mercury budget might come from more generalized watershed sources. Despite the locally contaminated nature of the mine vicinity itself, if the majority of total mercury loading came from elsewhere in the watershed, mitigation work at the mine could be relatively ineffectual.

In the first phase of our mercury assessment, we developed a sampling plan that accounted for all important watershed tributaries, major source flows at the mine site, and included stations along downstream Marsh Creek to the reservoir and well beyond. We waited for a period of high but relatively steady flows following a major storm series, when suspended material was being transported in abundance and the sites could be inter-calibrated. These conditions occurred in late March 1995 and we were able to successfully collect samples throughout the watershed within a short period of consistent flow. At each of the 18 sites, water samples were taken for analysis of mercury in both raw and filtered fractions, as well as for suspended solids concentration. The mercury samples were taken using ultra-clean techniques and were analyzed by the foremost aqueous mercury analytical laboratory in the world, providing above-detection mercury concentration data for all samples. At each site, the water flow was determined as well. With concentration and flow data for each site, it was then possible for us to calculate the total loads of mercury moving through each stretch and to compare the tributaries on a relative basis.

To supplement these water-based mercury measurements, we looked at bioindicator organisms within the watershed. At 12 collection sites, we sampled localized benthic invertebrates of several types. These invertebrates integrate the bioavailable fraction of mercury that they are exposed to over their lifetimes. In-stream fish were collected at the 6 stations where they were present. All of these samples were analyzed for mercury, to provide time-integrated information on the relative mercury trends among the different tributaries.

A second piece of essential information was the determination of current mercury conditions in Marsh Creek Reservoir, particularly within the fish populations. As the only data to have been collected there had been taken 15 years earlier, in 1980, and the actual data themselves were apparently unavailable (Contra Costa County 1994), a new survey of the reservoir was warranted.

Therefore, in a second phase of our assessment, we conducted a study of mercury in Marsh Creek Reservoir sediments and biota in September 1995. We collected surficial sediments from throughout the reservoir and obtained a record of historical sediment mercury deposition over the 30+ year history of the reservoir through sediment core samples. The reservoir's current fish populations were assessed, with tissue mercury analyses conducted on extensive samples from all types with significant representation at this time.

Table 1 summarizes the mercury analytical samples collected for both phases of this project. A total of 48 aqueous mercury analyses were made, half in raw water and half in corresponding filtered water. Total mercury was analyzed in 170 individual biotic and sediment samples, including 46 individual fish analyzed for muscle mercury from Marsh Creek Reservoir. Additional analytical samples for the project included suspended solids samples from all stream sites (22, including duplicate samples), and moisture and organic percentage analyses in 30 reservoir bottom sediment samples.

Throughout this report, the data for each major watershed parameter is generally presented both in tabular and graphic form. Map figures of each of the major data parameters are included for the watershed as a whole, as well as for the immediate mine vicinity where appropriate.

With the data collected in the two phases of the study, this report provides the County with information on current mercury levels throughout the Marsh Creek watershed and Marsh Creek Reservoir. Further, the relative importance of the various upstream source regions to the overall mercury loading in the system can be estimated. Finally, in the event that new mercury mitigation work is initiated within the watershed, a comprehensive, accurate data base has been initiated, describing mercury conditions throughout the major components of the system, including water, suspended sediment, and aquatic biota from the entire watershed and depositional sediment and biota from Marsh Creek Reservoir. Baseline data, taking into account natural inter-annual variability, can be compared to mercury levels in future collections to guide and assess the effectiveness of mitigation efforts.

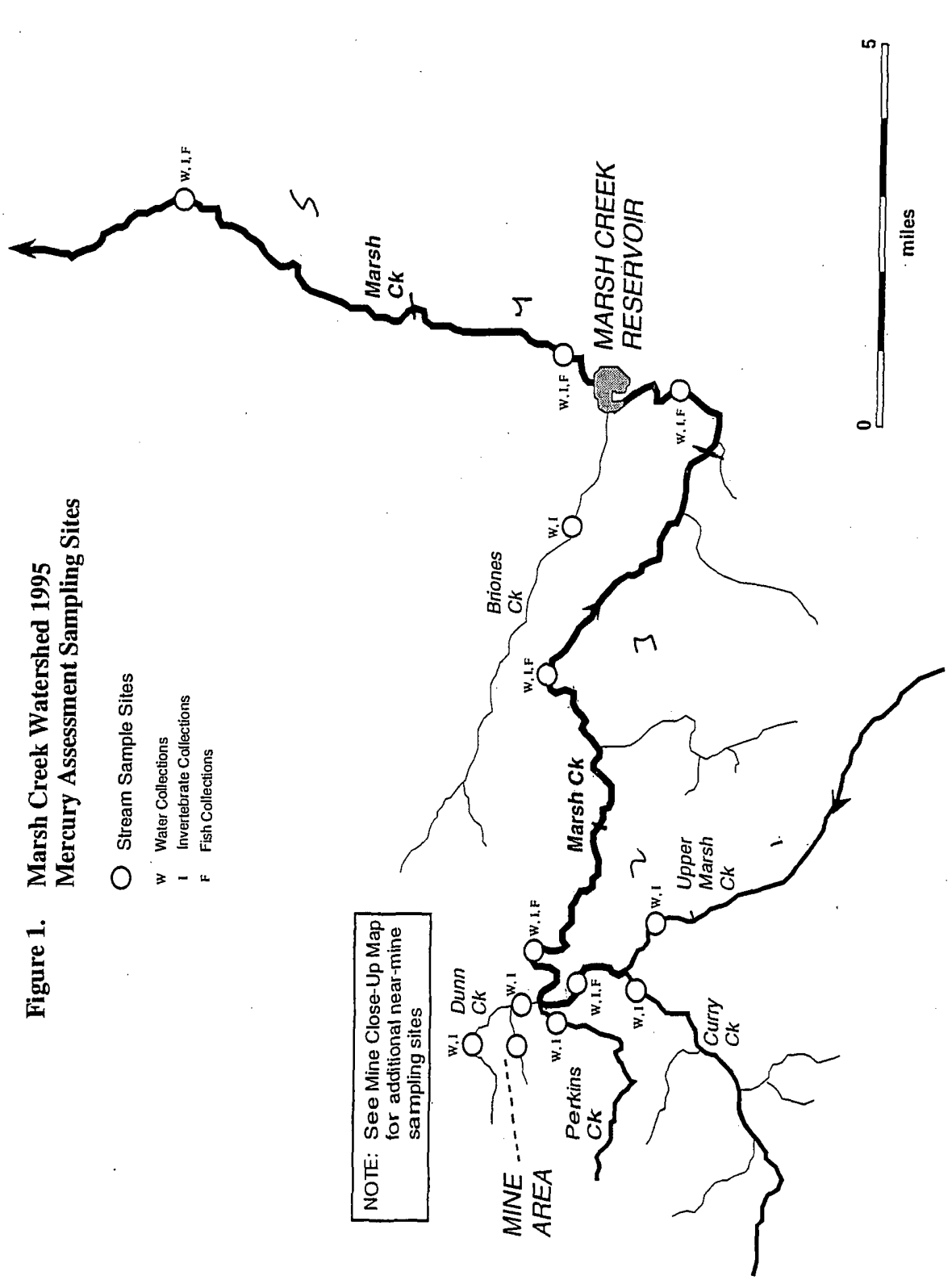


Figure 1. Marsh Creek Watershed 1995 Mercury Assessment Sampling Sites

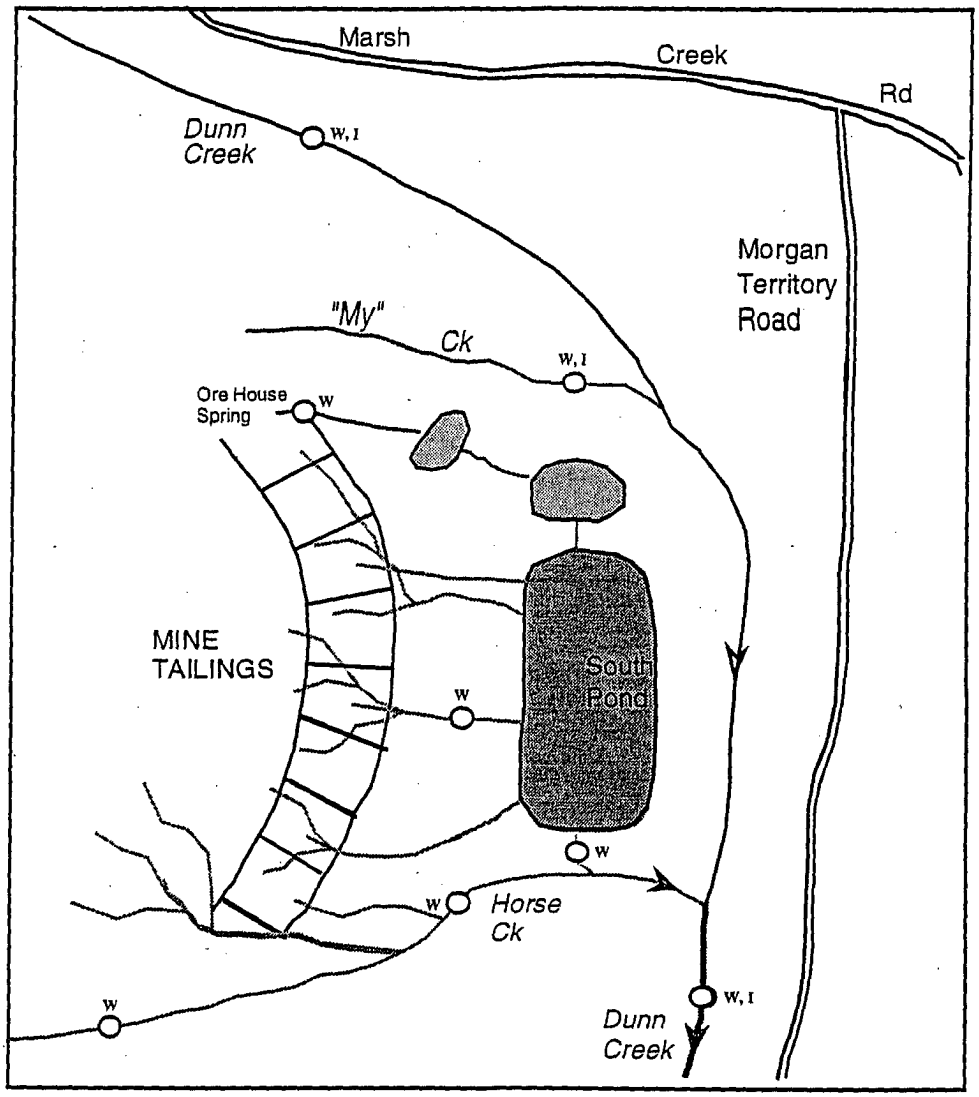


Figure 2. **1995 Mercury Assessment Sampling Sites in the Vicinity of the Mt. Diablo Mine**

○ Sample Sites

W Water Collections

I Invertebrate Collections

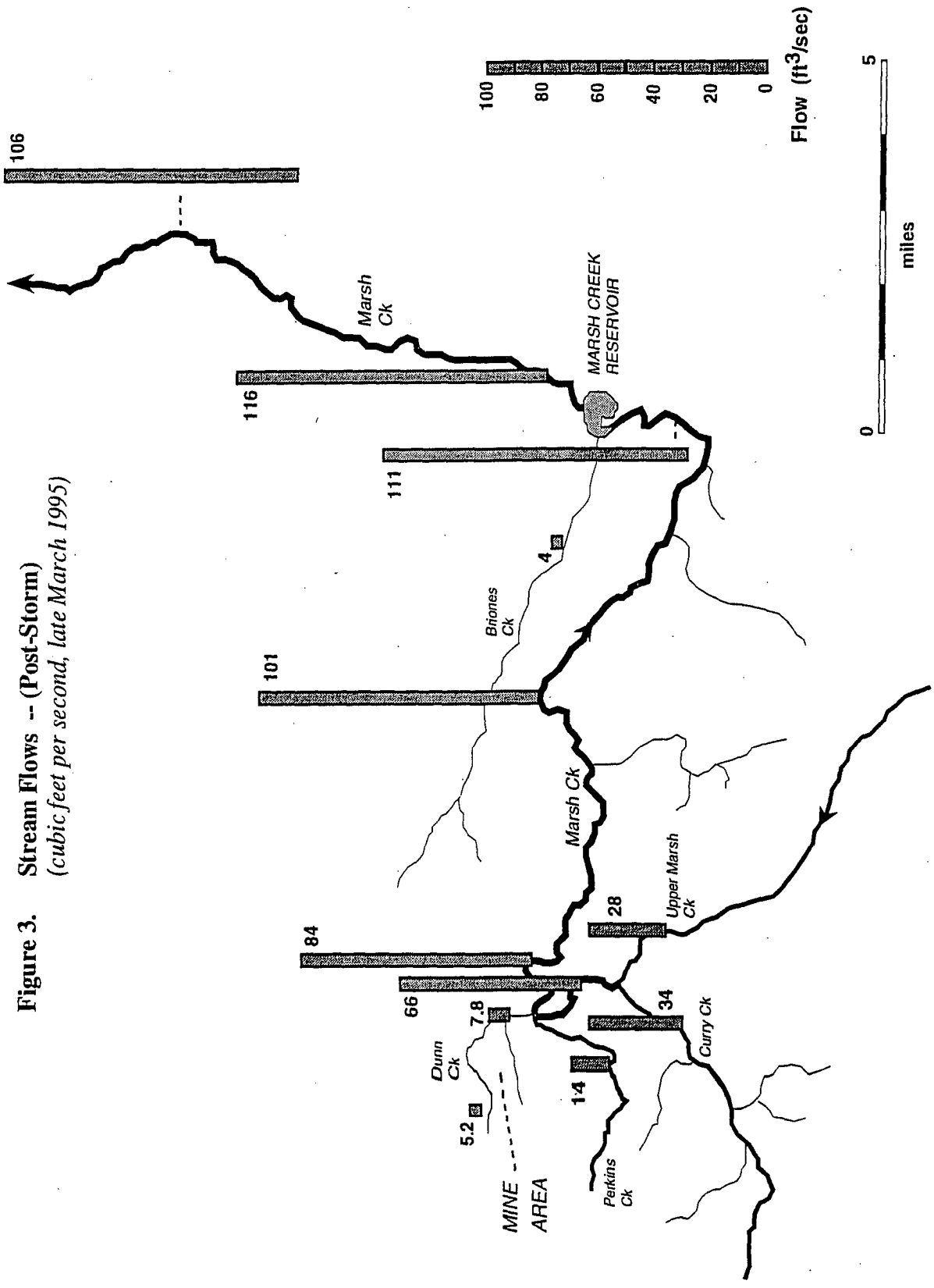


Figure 3. Stream Flows -- (Post-Storm)
(cubic feet per second, late March 1995)

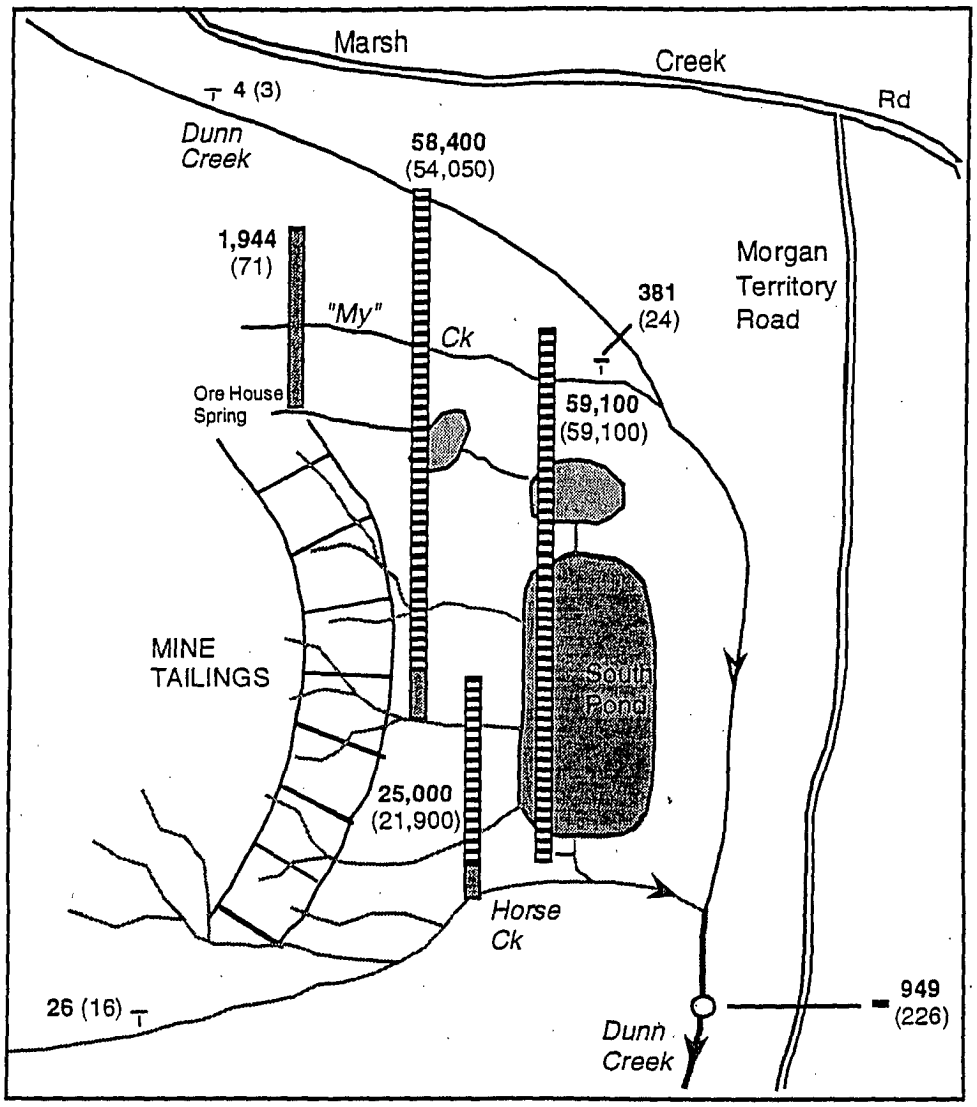


Figure 6. **Aqueous Mercury Concentrations in the Vicinity of the Mt. Diablo Mine** *(Late March 1995)*

The mercury concentrations found in the other main tributaries, at 3.2-8.9 ng L^{-1}, were two orders of magnitude lower than the 949 ng L^{-1} concentration found in Dunn Creek below the mine. The great impact of the mine-region Dunn Creek flows to Marsh Creek is apparent in the large increase in Marsh Creek aqueous mercury concentrations below the Dunn Creek confluence. Upstream levels of 3.2-8.9 ng L^{-1} increased to 79.3 ng L^{-1}, measured one mile below the confluence. Aqueous mercury concentrations remained elevated below this point in the watershed, at > 37 ng L^{-1} as far downstream as the town of Oakley.

The close-up map of aqueous mercury concentrations in the immediate vicinity of the Mt. Diablo mine (Fig. 6) demonstrates that the very high mercury levels seen in Dunn Creek are clearly derived from the mine itself. The stream "My" Creek, which borders the north extent of the tailings region, was quite high in mercury at 381 ng L^{-1}, while flows emanating from the tailings themselves were massively contaminated, with levels ranging from 25,000 - 60,000 ng L^{-1}. The Orehouse spring was also quite high, though far lower in mercury than the downslope tailings flows, at 1,944 ng L^{-1}. This small spring, however, contributed very little to the overall water volume from the site, with its flow at this time measured at just 0.01 cubic feet per second (Fig. 4).

Previous water sampling in the region by the Central Valley Regional Water Quality Control Board utilized less sensitive analytical techniques that placed most watershed samples below the 0.00002 mg L^{-1} (20 ng L^{-1}) level of detection (CVRWQCB 1994). However, above detection results were obtained from 4 of the earlier samples, including a Dunn Creek sample directly below the mine inflows (600 ng L^{-1}) and 3 sites in the direct vicinity of the tailings and settling pond (16,000 - 70,000 ng L^{-1}). These December 1994 levels were quite similar to the corresponding concentrations we found in our 1995 work.

In addition to the maximally contaminated flows from the mine tailings themselves, it is notable that all of the Marsh Creek watershed tributaries which showed any significant elevation in mercury concentration, relative to the entire data base, derived from the same slope of Mt. Diablo; i.e. the region between Perkins Creek and "My" Creek.

It is a very important observation that nearly all of the mercury detected in the heavily contaminated, near-tailings flows was found to be in the *filtered* fraction; i.e. the "dissolved" state. The sample of representative tailings seepage moving into the settling pond was found to contain 58,400 ng L^{-1} total mercury, with 54,050 ng L^{-1} (93%) measured in the filtered fraction. Water leaving the settling pond had 59,100 ng L^{-1} total mercury, with an identical concentration (a full 100%) measured in the filtered fraction. The somewhat diluted but higher volume flow in Horse Creek had a total mercury concentration of 25,000 ng L^{-1}, with 21,900 ng L^{-1} (88%) accounted for by the filtered

Table 5. Watershed Aqueous Mercury and Suspended Solids Bulk Loading Data

Site	*Aqueous Total Hg* Raw	Filtered	*Suspended Solids* (TSS)
	(grams/day)		*(kilograms/day)*
Upper Marsh Creek	0.224	0.089	1,110.0
Curry Creek	0.427	0.123	2,640.0
Marsh Ck above Perkins Ck	0.753	0.215	5,160.0
Perkins Creek	0.302	0.140	102.0
Upper Dunn Creek	0.046	0.035	18.4
Upper Horse Creek	0.005	0.003	0.2
"My" Creek	1.960	0.146	55.9
OreHouse Spring	0.048	0.002	0.3
Trickle coming from tailings	4.290	3.970	5.7
South Pond outlet	7.230	7.230	3.2
Horse Creek @ tailings	19.600	17.100	81.2
Dunn Ck below mine confluence	18.100	4.310	257.0
Marsh Ck below Dunn Ck conf.	16.200	4.380	3,960.0
Mid Marsh Ck @ rd. crossing	13.100	2.500	6,070.0
Marsh Ck above Reservoir	10.200	2.380	6,250.0
Briones Ck @ Deer Valley Rd.	0.059	0.020	614.0
Marsh Ck below Reservoir	12.390	2.120	9,800.0
Marsh Ck @ Delta Rd.	9.880	1.680	14,100.0
	Aqueous Methyl Hg Raw	Filtered	
	(grams/day)		
Marsh Ck above Reservoir	0.055	0.030	

upper Dunn Creek (0.05 g/day) totaled 28.8 grams per day, while the load measured in Dunn Creek just below the mine site was considerably lower at 18.1 grams per day. The load in downstream Marsh Creek one mile below the Dunn Creek confluence was still lower at 16.2 grams per day. The decline in the mercury load suspended in the water column continued, moving downstream, with 13.1 g/day measured at the site halfway down to the reservoir and 10.2 g/day measured just above the reservoir. This consistent pattern indicates that a portion of the mercury load was falling out of the current along with sedimenting particulates. However, we note that much or all of the previously suspended sediment that settles out within the channel itself during post-storm and lower flow conditions may ultimately be transported downstream to the reservoir and beyond under higher flow conditions, particularly with the spike increases in flow typical during large storm events.

The bulk load data additionally indicates that all significant mercury loading to the Marsh Creek watershed is accounted for by the upper watershed tributaries. The steady drop in aqueous mercury loads measured in Marsh Creek, from the Dunn Creek confluence

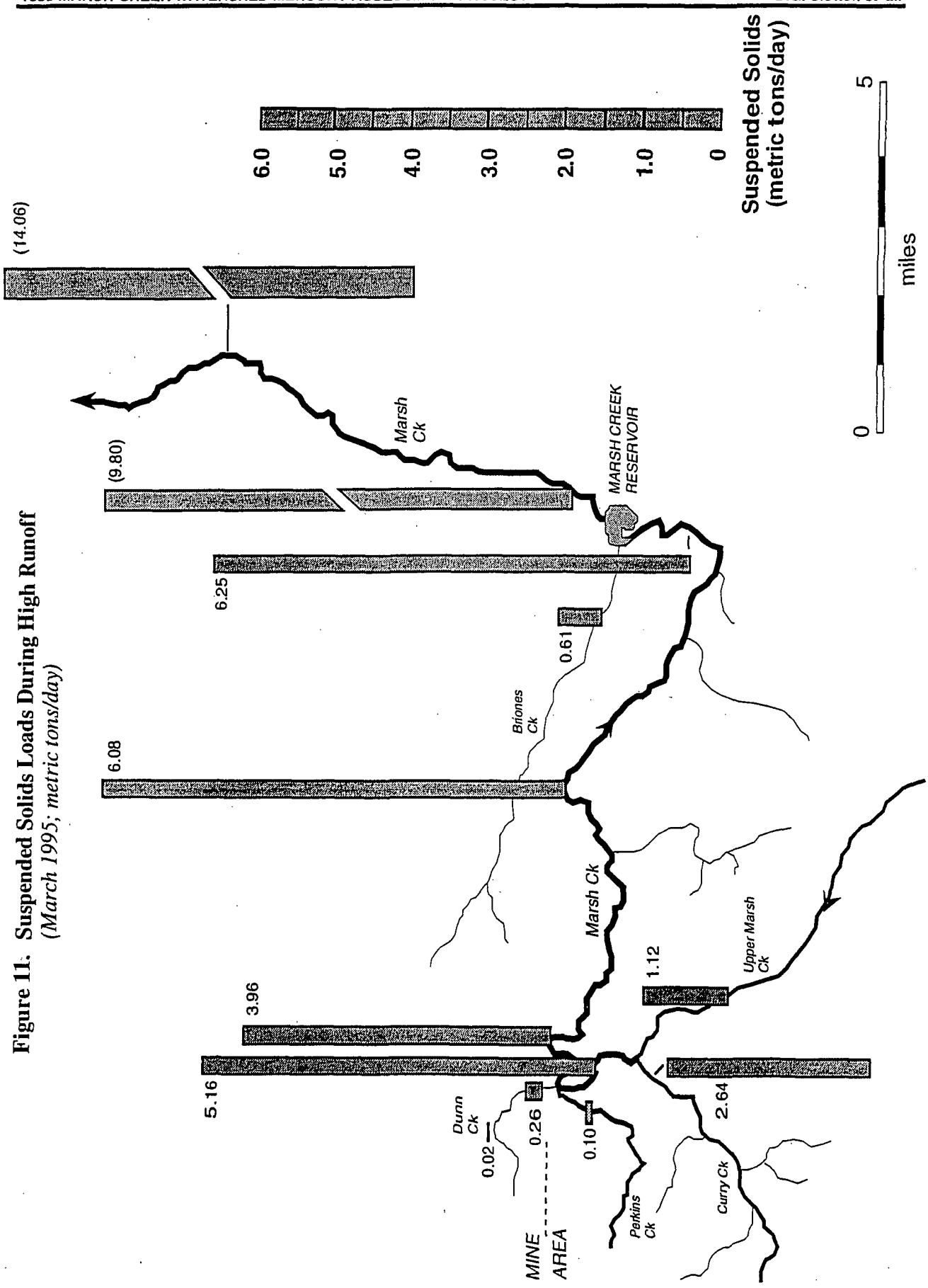


Figure 11. Suspended Solids Loads During High Runoff
(March 1995; metric tons/day)

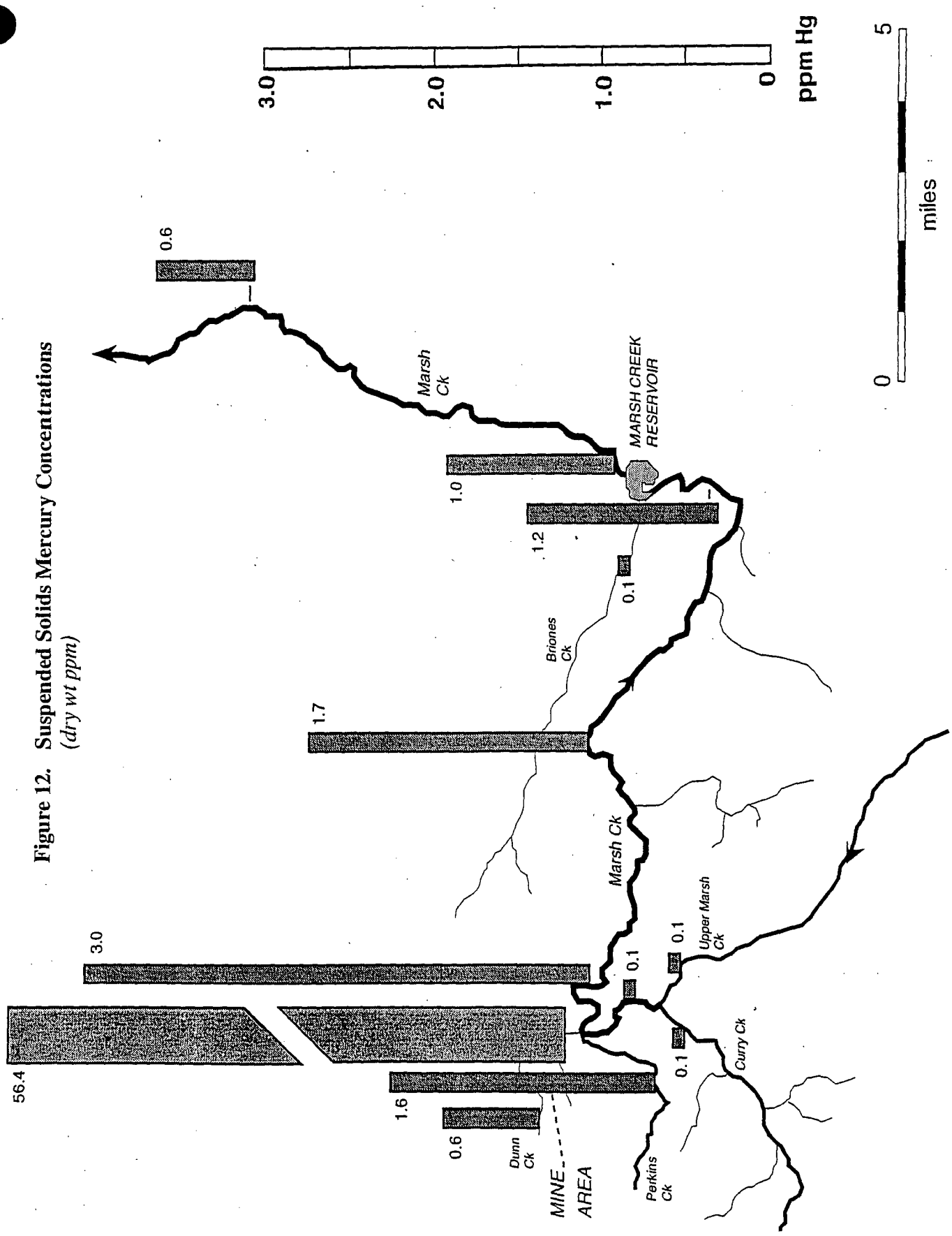


Figure 12. Suspended Solids Mercury Concentrations *(dry wt ppm)*

storm seasons should plummet in average mercury concentration, as the great majority of sediment transported in this drainage has been shown to be quite low in mercury content. This material can then form a natural, lower mercury "treatment" for the Marsh Creek Reservoir bottom sediments in future years.

3.1.2 Stream Invertebrates

Stream invertebrates that were analyzed for this project are illustrated in Figure 13. The mercury data for the watershed invertebrate samples are presented in Table 7 and in Figures 14 and 15. Native in-stream invertebrate species have proven to be excellent monitors of mercury bioavailability in California streams and rivers (Slotton et al. 1995a). Because they incorporate mercury into their bodies throughout their lives, they can provide a time-integrated measure of stream conditions, as compared to standard "point-in-time" grab sampling for water. The mercury incorporated into local aquatic biota is, by definition, specifically the bioavailable fraction, which can be of paramount importance for management considerations. Additionally, many of these species are ideal indicators of highly localized conditions, as compared to fish which can and often do migrate extensively. The benthic invertebrate species we focused on in this work typically remain within a very limited area throughout their lives. They thus function as relatively static biological probes of the fraction of mercury in the water that is bioavailable.

At the majority of sampling stations, we were able to collect specimens from three distinct trophic feeding levels of invertebrates in sufficient quantity for mercury analysis. Macro-invertebrates were not present in the smaller, more ephemeral flows in the immediate mine region. Near the base of the aquatic food chain were mayfly nymphs (Ephemeroptera) from several herbivorous genera. Perlodid stoneflies were also taken at most of the sites. These are medium-sized invertebrate predators which feed on small to medium invertebrates. At the top of the invertebrate food chain in the upper watershed are the large-jawed hellgrammites (Corydalidae), which can reach several inches in length and are voracious predators of all other co-occurring species. We additionally took samples of aquatic "hair worms" of the order Nematomorpha. These organisms have a complex life cycle, deriving from the terrestrial ecosystem, and do not feed while in the stream. They thus provide limited information, presumably linked to direct uptake of mercury from the water. The majority of biotic mercury is typically accumulated through the food chain in the diet, particularly in the higher trophic levels (Lindberg et al. 1987, Gill and Bruland 1990).

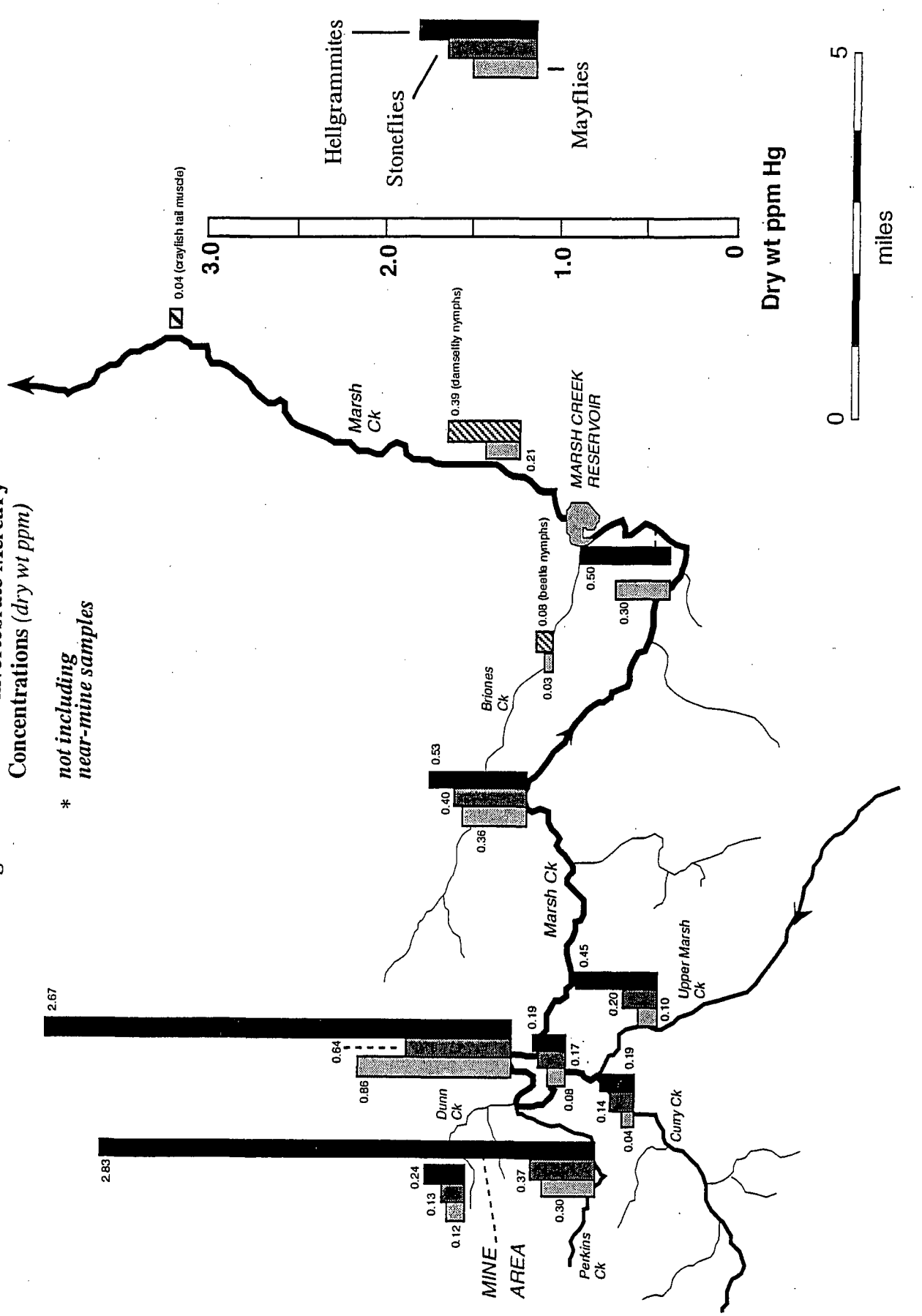
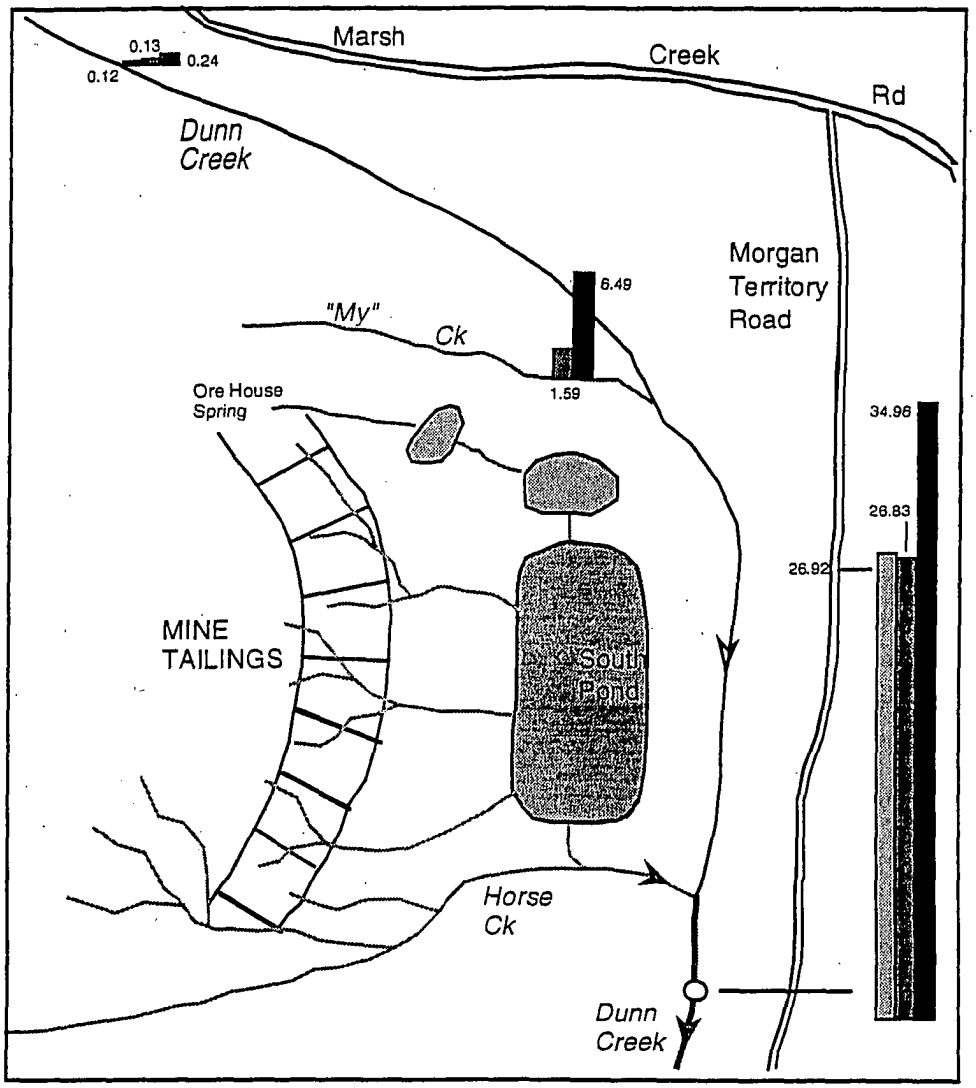
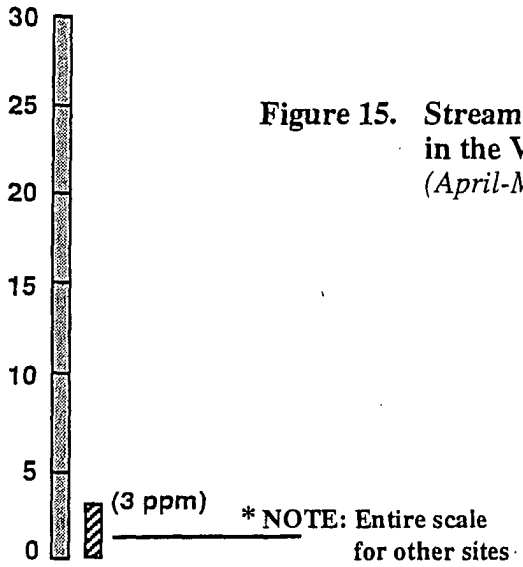


Figure 14. Stream Invertebrate Mercury Concentrations *(dry wt ppm)*

* ***not including near-mine samples***





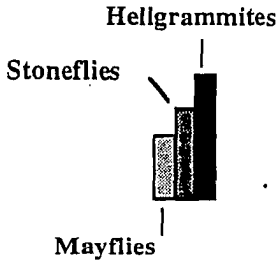


Figure 15. Stream Invertebrate Mercury in the Vicinity of the Mt. Diablo Mine *(April-May, 1995)*

Table 7. Stream Invertebrate Mercury Concentrations *(dry weight ppm)*

SITE	Nematomorpha	Ephemeroptera	Plecoptera	Megaloptera
	Horsehair Worms	Mixed Mayflies	Perlodid Stoneflies	Medium Hellgrammites
	Water Uptake Only	*Herbivores*	*First Order Predators*	*Second Order Predators*
Upper Marsh Creek	0.06	0.10	0.20	0.45
Curry Creek	0.10	0.04	0.14	0.19
Marsh Ck above Dunn Ck	0.06	0.08	0.17	0.19
Perkins Creek	0.38	0.30	0.37	2.83
Upper (clean) Dunn Creek	0.06	0.12	0.13	0.24
"My" Creek	0.32		1.59 §	6.49
Dunn Creek below Mine		13.80	16.00	23.80
Marsh Ck below Dunn Ck	0.29	0.52	0.64	2.67
Middle Marsh Creek	0.09	0.36	0.40	0.53
Briones Creek		0.05	0.08 ¥	
Marsh Ck above Reservoir		0.30		0.50
Marsh Ck below Reservoir		0.21	0.39 †	

Alternate 1° predators: § Rhyacophyllid caddis larvae
¥ Predaceous beetle nymphs
† Damselfly nymphs

The invertebrate mercury data indicate that the trend within the watershed for bioavailable mercury generally parallels that seen for aqueous mercury concentrations (section 3.1.1). Massive spike concentrations were apparent in Dunn Creek invertebrates immediately below the inflows from the mine site (27-35 ppm, dry weight). Biota from "My" Creek and Perkins Creek were also relatively elevated, though to a lesser degree, as were aqueous mercury concentrations in these streams. In particular, the hellgrammite samples from Perkins Creek (2.83 ppm) and "My" Creek (6.49 ppm) were significantly elevated. Concentrations were low throughout the invertebrate food chain at most sites upstream and away from the mine influence. Samples from upper Dunn Creek, above the mine, were two orders of magnitude lower in accumulated mercury than near-mine samples, at 0.06-0.24 ppm. Levels from upper Marsh Creek, Curry Creek, and Briones Creek were in a similar low range.

Along Marsh Creek, invertebrate mercury concentrations were dramatically higher downstream of the Dunn Creek confluence as compared to the relative "control" levels seen upstream of this point. Concentrations generally declined with increasing distance downstream from the mine. Comparable samples were not available at the downstream site near Oakley, though we were able to take several crayfish, which we analyzed for tail

muscle mercury (Table 9, Fig. 14). These were quite low at ~0.04 ppm wet wt, ~0.18 ppm dry wt.

Within each site, mercury concentrations in the various trophic groups generally increased with feeding level, with predatory stoneflies typically containing higher levels than herbivorous mayflies, and the large predatory hellgrammites generally having the greatest concentrations.

We again point out that both the aqueous concentration data and these data from bioindicator stream organisms provide information on relative localized water quality in the various tributaries. For questions of absolute, bulk contributions of mercury from each of the streams to the entire watershed, the bulk loading/mass balance types of information are more relevant (section 3.1.1.4 - 3.1.1.5). Both approaches provide important, though potentially very different, information.

3.1.3 Stream Fish

Illustrations of the stream fishes collected in this project can be found in Figure 16. Data collected from the in-stream fish samples are presented in Tables 8 and 9 and Figure 17. Fish were present at a subset of the sampling sites, primarily in the main channel of Marsh Creek downstream of Dunn Creek. Fish were not present in smaller upstream tributaries, presumably due to annual dry-season losses of water. While larger fish were found in Marsh Creek within a mile above the reservoir, upstream fish were limited to "minnows". These small species consisted of California roach (*Hesperoleucus symmetricus*), mixed with juvenile hitch (*Lavinia exilicauda*) closer to the reservoir. Below the reservoir, the character of the creek changes such that roach and hitch are no longer present. Fish taken downstream of the reservoir consisted of small bluegill (*Lepomis macrochirus*), together with a collection of juvenile (parr) Chinook salmon (*Oncorhynchus tshawytscha*) taken near Oakley.

The California roach and juvenile hitch were prepared for mercury analysis in the form of whole fish, multiple individual composites (Table 8). This is the technique typically used for roach in other metals biomonitoring work in California (Hellawell 1986, Reuter et al. 1989,1995, Bodega Research Associates 1995). Composites were made of similar sized individuals, with up to five different size classes composited separately for each site, depending on the range of sizes taken. The much larger hitch individuals taken just upstream of the reservoir were analyzed for muscle mercury rather than whole body composite concentrations. A subset of the fish taken downstream of the reservoir were also analyzed for muscle mercury, in addition to whole fish composite mercury. Muscle

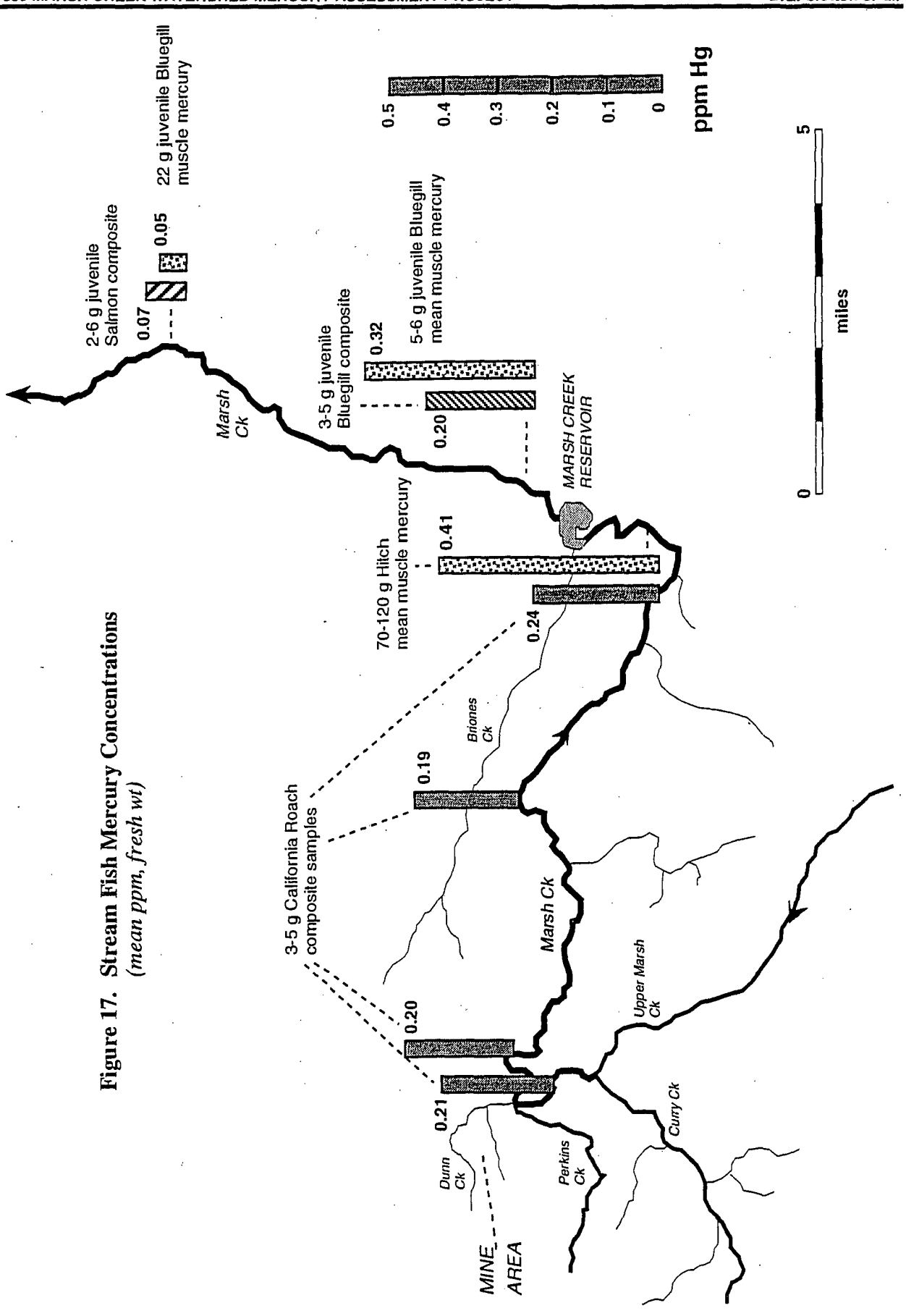


Figure 17. Stream Fish Mercury Concentrations *(mean ppm, fresh wt)*

mercury analyses (Table 9) were conducted on those fish for which the majority of comparative information exists in the form of muscle mercury concentrations.

Because fish were basically absent in the watershed upstream of the Dunn Creek confluence, it was not possible to use them as indicators of water quality differences between mine-impacted and control waters. Also, because fish are free to migrate up and down the creeks on each side of the reservoir, their accumulated mercury cannot be definitively linked with the location of capture. Additionally, the presence of different fish species above as compared to below the reservoir introduces a level of uncertainty to comparisons of fish mercury levels between these two areas. Consequently, the information provided by the stream fish data is somewhat limited. Because of these considerations, we supplemented fish collections with the invertebrate mercury work, described in section 3.1.2. However, some useful conclusions may be drawn from the stream fish data.

Mercury concentrations in the composite fish samples from spring 1995 (Table 8) were quite similar among the Marsh Creek sites between upper Marsh Creek and just below the reservoir. Among similar sized fish (2-5 g) including California roach, juvenile hitch, and juvenile bluegill, mercury concentrations were within the comparatively narrow range of 0.13-0.25 ppm. Except for a single, anomalously higher mercury individual roach from upper Marsh Creek, composites of all sizes (2-19 g) from these sites had mercury concentrations that fell within this range. There is no indication of a size vs mercury trend in this small-fish composite data.

Only a single individual roach was collected upstream of the Dunn Creek confluence, approximately one half mile upstream of Perkins Creek in Marsh Creek, despite repeated sampling efforts over several days. The similar mercury level in this fish (0.21 ppm) as compared to the range of levels seen downstream (0.13-0.25 ppm) suggests that this fish may have been a migrant from downstream. The lack of additional fish here indicates that the site was above the normal range of fish in the creek, a function of the annual disappearance of surface water each dry season. Therefore, it is likely that the individual roach taken here may have been a relatively recent migrant--and its mercury content may not reflect local conditions. Based on the aqueous mercury concentration data and the stream invertebrate findings, fish residing throughout the year in Marsh Creek above the Dunn Creek confluence would be expected to have significantly lower mercury than downstream fish.

Of the minnow composite samples, only a single individual roach exhibited a mercury concentration greater than 0.25 ppm. This 9 g individual had anomalously higher mercury concentration, at 0.71 ppm, nearly three-fold greater than the next highest values. As this

fish was collected from the site 1 mile below the Dunn Creek confluence, we hypothesize that it may have lived much of its life within the immediate influence of the Dunn Creek mine-impacted flows.

Table 8. Marsh Creek Fish Composite Samples (Whole Fish) Mercury Concentrations *(fresh/wet weight ppm Hg)*

Species	Weight (g)	Length (mm)	Individuals in Comp.	Hg (wet wt ppm)
1 mile above Dunn Ck Confluence				
California Roach	4.2	72	n=1	0.21
1 mile below Dunn Ck Confluence				
California Roach	4.1	72	n=2	0.20
" "	9.0	93	n=1	0.71
~5 miles below Dunn Ck confluence				
California Roach	1.5	52	n=11	0.25
and	2.2	63	n=16	0.23
juvenile Hitch	4.0	72	n=19	0.19
" "	7.5	85	n=5	0.18
" "	19.2	115	n=1	0.24
1 mile above Marsh Ck Reservoir				
California Roach	2.8	65	n=5	0.13
" "	4.0	76	n=3	0.24
" "	6.9	84	n=2	0.15
0.5 mile below Marsh Ck Reservoir				
juvenile Bluegill	1.7	50	n=9	0.24
" "	3.4	61	n=3	0.19
" "	5.4	70	n=3	0.21
Downstream near Oakley				
juvenile Salmon	3.6	70	n=5	0.07

A collection of larger hitch individuals (72-117 g, 1-3 yrs) was made one mile above the reservoir. We also noted several large goldfish in the creek at this location, which were likely the grown results of earlier releases by the public. Large fish were not found in the creek upstream of this region. Muscle mercury concentrations in the 8 larger hitch taken upstream of Marsh Creek Reservoir, at 0.29-0.51 ppm (Table 9), were very similar to levels measured in adult hitch within the reservoir (section 3.2.3, Table 11).

The juvenile bluegill samples taken immediately below the reservoir were similar in both size and mercury concentration to upstream roach and juvenile hitch, on a whole body

Table 9. Marsh Creek Fish Muscle (Fillet) Mercury Concentrations
(fresh/wet weight ppm Hg)

Identification	Weight (g)	Length (mm)	Muscle Hg (wet wt ppm)
1 mile above Marsh Ck Reservoir			
Hitch	72	177	0.44
"	73	181	0.30
"	88	194	0.40
"	90	196	0.35
"	97	197	0.51
"	106	208	0.51
"	114	205	0.46
"	117	205	0.29
0.5 mile below Marsh Ck Reservoir			
juvenile Bluegill	5.2	68	0.22
" "	5.3	71	0.35
" "	5.8	71	0.40
Downstream near Oakley			
juvenile Salmon	2.2	60	0.01
" "	2.5	63	0.01
" "	3.9	72	0.06
" "	4.0	72	0.06
" "	5.6	80	0.02
1 yr Bluegill	22	113	0.05
Crayfish (tail meat)	8.5	39¥	0.04
" "	12.2	39¥	0.03
" "	16.8	41¥	0.04

¥ Lengths for crayfish are standard carapace lengths, not total lengths.

composite basis (1.7-5.4 g, 0.19-0.24 ppm Hg). While these are quite different fish species, at this small size their feeding habits are relatively similar, with food items dominated by small in-stream invertebrates. The similar mercury concentrations measured at this time indicate that bioavailable mercury had been moving out of and/or through the reservoir in previous months. The aqueous mercury data (section 3.1.1.2) indicates that this was clearly the case under post-storm, high flow conditions. In addition to whole body composites, we analyzed muscle mercury in several 5-6 g juvenile bluegill taken downstream of the reservoir (Table 9). Muscle concentrations were somewhat higher than the whole body levels (0.22-0.40 ppm muscle vs 0.19-0.24 whole body). This is often the case. In ongoing research at the University of California, we repeatedly find muscle tissue to be the major repository for mercury in fish (Reuter et al. 1989, Slotton 1991, Suchanek et al. 1993, Slotton et al. 1996).

The samples taken from downstream Marsh Creek near Oakley provide some interesting comparative information. Here, we collected five small parr salmon (2-6 g), a one year old bluegill (22 g), and several adult crayfish. Muscle mercury in all of these samples, as well as composite mercury in the parr salmon, was significantly lower than that seen in fish from upstream Marsh Creek and the reservoir. Concentrations were all ≤ 0.07 ppm Hg. Once again, while the upstream roach and juvenile hitch are very different fish than the juvenile salmon, at this small size they are quite similar in body form and in the diet imposed by their size. Salmon parr such as these were almost certainly born in the only gravel spawning areas available on Marsh Creek downstream of the reservoir; i.e. just below the reservoir. As they only migrate downstream at this life stage (Moyle 1976), they could not have originated from outside of the watershed. Therefore, the mercury in these samples provides a reasonable measure of mercury bioavailability in downstream Marsh Creek, as compared to upper watershed roach and juvenile hitch of the same size. The levels were approximately one third of concentrations seen upstream.

While the direct comparison between parr salmon and roach of the same size may be complicated by the fact that roach of the same size can be considerably older, we found the same trend in the other samples. The bluegill taken near Oakley was also very low in mercury (0.05 ppm), despite being considerably larger than the comparative samples from just below the reservoir. Similarly, the crayfish tail meat samples were all very low, at 0.03-0.04 ppm Hg. These organisms are relatively sedentary as compared to fish, and can thus provide a good measure of localized conditions, integrated over their lifespans. In our work with crayfish throughout the Sierra Nevada, we have consistently found them to contain mercury at levels greater even than co-occurring hellgrammites, with concentrations generally similar to those of local fish (Slotton et al. 1995a). This results from their consumption of dead fish, the preferred food of these scavengers. On a comparable dry weight basis, the crayfish tail meat concentrations near Oakley were 0.15-0.20 ppm Hg. This is considerably lower than invertebrate samples of any trophic level taken between the Mt. Diablo mine area and the reservoir, and much lower than the hellgrammite mercury concentrations, which ranged from 0.50 ppm to far greater levels.

mercury at 0.63 ppm, intermediate between the adult hitch and adult largemouth bass levels. As hitch consume low trophic level foods (primarily algae and zooplankton), they will generally accumulate less mercury than the piscivorous (fish eating) largemouth bass. The bluegill diet consists mainly of small invertebrates, which are trophically intermediate relative to the diets of the other two species.

Table 11. Marsh Creek Reservoir Adult Fish Tissue Mercury Concentrations *(fresh/wet weight ppm Hg)*

	Weight (g)	Length (mm)	Muscle Hg (wet wt ppm)	Liver Hg
Hitch				
	285	266	0.26	0.33
	298	280	0.37	
	310	270	0.31	
	313	283	0.33	
	346	292	0.50	
	350	290	0.46	
	350	301	0.41	
	370	295	0.48	
	380	303	0.41	
	402	309	0.48	
	406	316	0.47	
	420	310	0.55	
	437	301	0.43	0.45
	480	322	0.48	
Bluegill				
	215	196	0.63	0.77
Largemouth Bass				
	412	283	0.64	0.55
	480	295	0.66	
	560	302	0.59	
	815	348	0.86	
	870	344	0.71	0.36
	930	343	0.72	
	1,030	372	0.84	
	1,040	362	0.90	0.58
	1,160	387	0.92	
	1,155	403	1.04	1.21

The U.S. FDA health standard for mercury in fish flesh is 1.0 ppm. However, the criterion recommended by the U.S. Academy of Sciences, the California Department of Health Services, and the great majority of other nations internationally is 0.5 ppm (TSMP 1990). In Fig. 20, the reservoir fish muscle mercury concentrations are compared to the 0.5 ppm criterion. The levels clearly straddle the line, with the "keeper" sized bluegill and largemouth bass all being well above the 0.5 ppm level. The bass ranged up to and even

The young-of-year bass and small bluegill will be particularly useful (Table 12, Fig. 24). Muscle mercury concentrations in these small fish were quite consistent across the range of sizes present, falling between 0.30 ppm and 0.43 ppm in all 10 of the sampled juvenile bass (mean = 0.36 ppm) and in 10 of the 11 sampled small bluegill (mean = 0.37 ppm). One bluegill was somewhat higher, at 0.51 ppm. Because the young-of-year fish can have only accumulated mercury in the year they are sampled, these consistent 1995 levels can be compared in future years to corresponding levels in new young-of-year fish, to determine relative changes in exposure.

Table 12. Marsh Creek Reservoir Juvenile Fish Muscle (Fillet) Mercury Concentrations *(fresh/wet weight ppm Hg)*

Juvenile Bluegill Muscle Mercury			Juvenile Largemouth Bass Muscle Mercury		
Weight *(g)*	Length *(mm)*	Hg *(ppm)*	Weight *(g)*	Length *(mm)*	Hg *(ppm)*
6.9	72	0.41	6.4	78	0.33
19.4	99	0.35	6.4	80	0.43
19.8	100	0.32	7.0	80	0.41
22.0	104	0.42	7.1	80	0.31
24.9	104	0.30	7.3	82	0.33
30.0	112	0.51	8.5	87	0.35
31.7	114	0.43	8.6	89	0.33
34.3	117	0.38	8.7	89	0.32
35.4	118	0.31	12.9	98	0.42
40.7	124	0.40	18.2	111	0.32
55.4	131	0.33			

In addition to the small fish muscle mercury samples, we made composite, whole body samples of young-of-year bass and mosquito fish (Table 13). These composites, grouped by size class for each species, provide additional measures of short term reservoir mercury bioavailability. They also can be compared to the composite small fish data generated in the watershed work (section 3.1.3). As seen for muscle, whole body mercury concentrations in the juvenile bass were very similar among the range of sizes present, at 0.23-0.29 ppm. The levels in whole body composites were somewhat lower than those analyzed in muscle tissue. This is frequently the case, as muscle is the major site of mercury accumulation in fish (Reuter et al. 1989, Slotton 1991, Suchanek et al. 1993, Slotton et al. 1996). The tiny mosquito fish were also consistent in their whole body composite mercury levels, at 0.15-0.20 ppm among the dominant range of sizes. A single much larger individual, potentially several years old, had anomalously higher mercury concentration, at 0.57 ppm.

4. DISCUSSION AND CONCLUSIONS

Prior to this study, the Mt. Diablo Mercury Mine was generally assumed to be the dominant source of mercury to the Marsh Creek watershed. However, data was not available to quantify this input, rank the mine against other potential mercury sources, or rule out the possibility of a generalized source of mercury in this mercury-enriched watershed. Now, with the 1995 watershed mercury information assembled here, we can establish that the mine site does indeed represent the overwhelming source of mercury to the watershed. By collecting consistent, above detection aqueous mercury concentration data, together with accompanying flow information, from all major source areas, it has been possible to rank the various inputs on a mass balance basis. While the various loading values measured were specific to the particular flow regime during the sampling period, the relative contributions are of greater importance.

Both the aqueous mercury data and those from the invertebrate bioindicator organisms strongly implicate the mine region as being the dominant source of mercury in the Marsh Creek watershed. The aqueous mercury mass balance calculations indicate that approximately 95% of the total input of mercury to the upper watershed derives from Dunn Creek. The mine area itself was the clear source region for the mercury, with an estimated 88% of the total input of mercury to the upper watershed traceable specifically to the current exposed tailings piles. This is a remarkably high percentage, particularly in light of the geologically mercury-rich nature of the watershed in general, and indicates that the mercury in exposed, processsed, cinnabar tailings material is exceptionally available for aqueous transport downstream.

The data indicates that the great majority of the mercury load eminating from the tailings is initially mobilized in the dissolved state. This dissolved mercury rapidly partitions onto particles as it moves downstream. The bulk of downstream mercury transport is thus particle-associated.

In marked contrast to the massive mercury loads carried by lower Dunn Creek, this small tributary delivered less than 7% of the watershed's total flow and less than 4% of the suspended solids load. As downstream mercury accumulations are greatly dominated by the sediment burden, a lowering of mercury concentrations in the downstream surficial sediments would almost certainly help to drive down both the aqueous mercury concentrations and the corresponding flux of mercury into biota. With 95% of the mercury originating from the Mt. Diablo Mine area, but 95% of the watershed's suspended sediment load deriving from non-mine, low mercury source regions, any significant decrease in the export of mercury from the immediate mine site should result in a corresponding decline in

surficial sediment mercury concentrations downstream and in Marsh Creek Reservoir. With an estimated 88% of the currently exported mercury linked directly to the tailings piles themselves, mercury source mitigation work within the watershed would clearly be best directed toward this localized source.

Though mitigation recommendations were not a part of our scope of work, we have several comments on the subject that may help to both clarify the task and direct the planning process:

1. In order to reduce the downstream export of mercury from the Mt. Diablo Mercury Mine, we believe that the major mitigation focus should be directed toward source reduction from the tailings piles themselves, with subsequent containment of the remaining mobile mercury fraction being a secondary consideration.

2. The data we have assembled here indicate that source reduction of mobile mercury from the tailings will best be accomplished by diminishing the flow of water through the tailings. Rather than being a problem of direct erosion of tailings material, in solid particle form, to downstream, it appears that the predominant mode of mercury mobilization from the tailings involves the acidification of runoff/seepage water by the processed, high sulfur ore material, and the subsequent dissolution of mercury from the ore into the acidic water. Very similar trends are concurrently being found at the EPA Superfund site at Clear Lake's Sulfur Bank Mercury Mine.

3. Lowering the flow of water through the tailings can be accomplished by (a) diverting any runoff that originates from outside of the tailings zone and (b) diminishing the movement of direct precipitation into and through the tailings. Diversion of upslope surface and groundwater flows away from the tailings will likely be the simplest and most cost-effective procedure to begin with. As part of this operation, upper Horse Creek should be diverted directly to Dunn Creek, bypassing the tailings (Fig. 26).

4. Direct water inputs to the tailings from precipitation are more problematical, but can be significantly lessened with a variety of revegetation schemes. Central to the most effective of these techniques is the application of a soil cover over the tailings that is sufficiently thick and porous to hold the average winter precipitation. Through the careful revegetation of the slope with appropriate, hardy plant species, much of this soil water can be annually soaked up and removed to the atmosphere through evapotranspiration. While grasses may be most efficient at initially stabilizing the slope, perennial shrubs and trees exhibit the greatest rates of evapotranspiration and

have thus been found to be the most effective in removing accumulated soil water (Mary Ann Showers, California Department of Conservation, personal communication).

5. Any containment/treatment scheme for the remaining mobile mercury eminating from the tailings region will be enhanced by source reduction. Because the current principal sediment settling basin does not appear to be providing the desired level of effectiveness, we would suggest some modifications (also shown in Fig. 26):

   (a) As lower Horse Creek contained the majority of the mercury loads eminating from the tailings, it should be diverted into the pond.

   (b) Because much of the tailings inflow enters the pond near the southwest corner, the outflow should be relocated to a part of the pond distant from the inflow, i.e. to the east side of the pond. This will be even more essential if lower Horse Creek is diverted into the pond.

   (c) Consider deepening the pond, making more room for the deposition of precipitating solids and rendering them less susceptible to sediment resuspension.

   (d) Consider periodic liming of the pond to lower the acidity of the water and promote the rapid precipitation and deposition of dissolved metals.

   (e) Occasional dredging out of the accumulated depositional material may be necessary. This could be accomplished with minimal consequences to downstream by working in the dry season and temporarily sealing the outflow for the operation.

   Again, all aspects of secondary containment will be enhanced by source reduction of water, sediment, and associated mercury from the tailings.

Mercury in Marsh Creek Reservoir edible fish flesh was above the health standard concentration of 0.5 ppm in all samples of "keeper" sized bass and bluegill, with the larger bass ranging up to and slightly over 1.0 ppm muscle mercury. Fish accumulate mercury in their muscle (fillet) tissue almost entirely in the methyl form. Methyl mercury is naturally produced from inorganic mercury mainly as a metabolic byproduct of certain bacteria (Gill and Bruland 1990). As methyl mercury was measured to be quite low in storm runoff inflows to the reservoir (0.20 ng/L, Table 4), it is likely that a significant proportion of the methyl mercury accumulating in Marsh Creek Reservoir fish is produced within the reservoir from inorganic mercury associated with depositional sediments. Any lowering of the reservoir depositional sediment mercury concentration, through upstream mine site mitigation work, should act to reduce the rate of mercury methylation in the reservoir.

warranted, it may be possible to further reduce mercury methylation rates within the reservoir through water column manipulation to minimize anoxia. This is an area that we are currently investigating in our mercury biogeochemical research work.

With this 1995 watershed mercury assessment, a comprehensive, accurate data base has been initiated for the County, describing mercury conditions throughout the major components of the system. This includes mercury concentration, loading, and relative mass balance data for water and suspended sediment from all major tributaries, biota mercury levels from throughout the watershed, and depositional sediment and biota mercury concentrations from Marsh Creek Reservoir. The utility of these data for use as a general baseline could be substantially increased with the sampling of selected parameters in the current water year (1996), prior to any mitigation work, to help account for natural inter-annual variability. We note that 1995 was an extremely wet, high-runoff year, while 1996 is more of an average water year. It is our strong recommendation that the County obtain as extensive and varied a baseline data record as possible prior to mitigation, and maintain selective monitoring of key sites and parameters throughout and following mitigation work. Ongoing monitoring of carefully chosen indicator samples, both at the mine and in downstream receiving waters, will play an integral role in guiding and assessing the effectiveness of any mitigation efforts.

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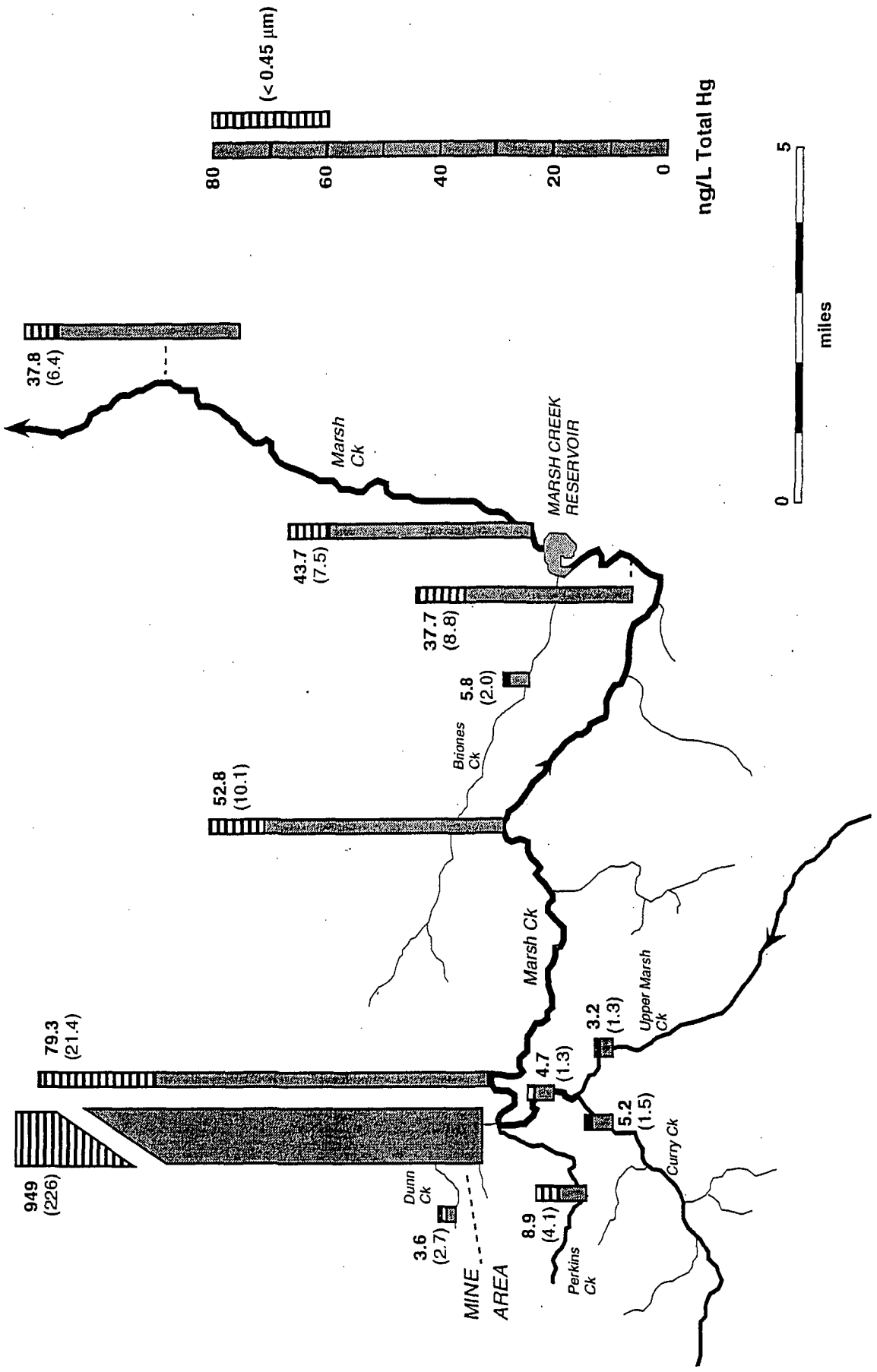

Figure 5. Marsh Creek Watershed Aqueous Mercury Concentrations *(ng/L, late March 1995)*

MARSH CREEK WATERSHED
1995 MERCURY ASSESSMENT PROJECT

FINAL REPORT
March 1996

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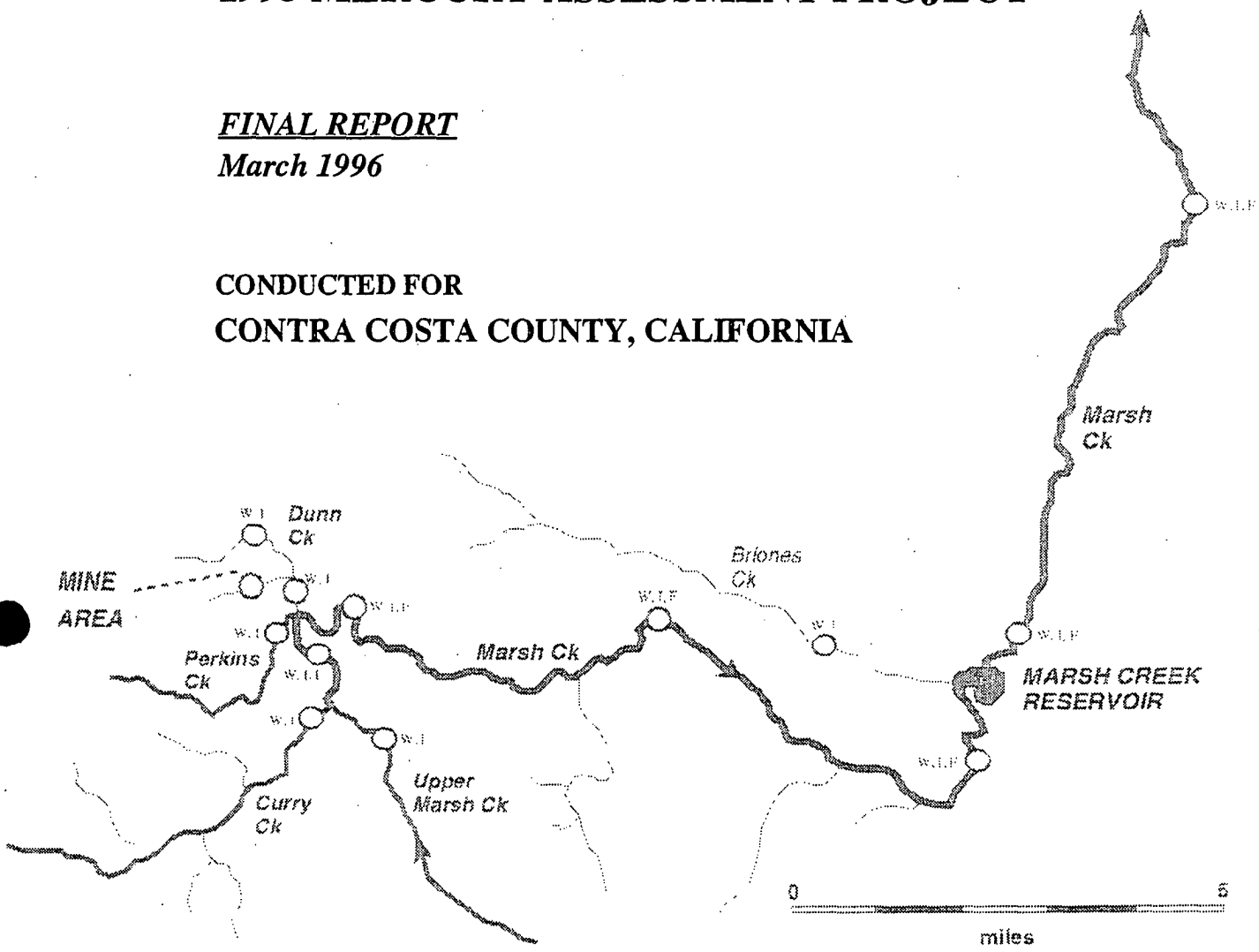

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3. RESULTS

3.1 Watershed

3.1.1 Water

We determined flows and collected water samples for mercury and suspended solids at 18 individual sampling sites distributed throughout the Marsh Creek watershed. These collections were made within a 48 hour period during high runoff flow conditions in late March 1995, following an extensive series of storms. A considerable effort was made to obtain these samples within as close a time period as possible, during high but relatively stabilized flow conditions. Flow values are presented in Table 4 and Figures 3 and 4. Concentration data for suspended solids and aqueous mercury are presented in Table 4 and Figures 5 and 6. Calculated bulk mercury loads, on a grams per day basis for each site, can be found in Table 5 and Figures 7 and 8. Mass balance data quantifying the overall proportional mercury contributions of the various source tributaries to downstream receiving waters are presented in Table 6 and Figures 9 and 10.

Table 4. Watershed Flow; Aqueous Mercury and Suspended Solids Concentration Data

Site	Flow	*Aqueous Total Mercury* Raw	Filtered	*Suspended Solids* All (TSS)	Solids Hg
	(cfs)	*(ng/L)*		*(mg/L)*	*(dry ppm)*
Upper Marsh Creek	28.30	3.24	1.29	16.10	0.10
Curry Creek	33.70	5.18	1.49	32.00	0.12
Marsh Ck above Perkins Ck	65.60	4.69	1.34	32.10	0.10
Perkins Creek	13.90	8.89	4.11	3.00	1.59
Upper Dunn Creek	5.20	3.60	2.73	1.50	0.60
Upper Horse Creek	0.08	25.50	16.00	1.10	8.64
"My" Creek	2.10	381.00	28.40	10.90	32.41
OreHouse Spring	0.01	1,940.00	71.00	11.40	164.00
Trickle coming from tailings	0.03	58,400.00	54,100.00	77.20	56.37
South Pond outlet	0.05	59,100.00	59,100.00	26.10	0.00
Horse Creek @ tailings	0.32	25,000.00	21,900.00	104.00	29.8
Dunn Ck below mine confluence	7.80	949.00	226.00	13.50	53.60
Marsh Ck below Dunn Ck conf.	83.60	79.30	21.40	19.40	2.99
Mid Marsh Ck @ rd. crossing	101.00	52.80	10.10	24.60	1.74
Marsh Ck above Reservoir	111.00	37.67	8.80	23.10	1.25
Briones Ck @ Deer Valley Rd.	4.10	5.84	2.03	61.20	0.06
Marsh Ck below Reservoir	116.00	43.70	7.47	34.60	1.05
Marsh Ck @ Delta Rd.	107.00	37.80	6.44	53.80	0.58

	Aqueous Methyl Mercury Raw	Filtered
	(ng/L)	
Marsh Ck above Reservoir	0.204	0.112

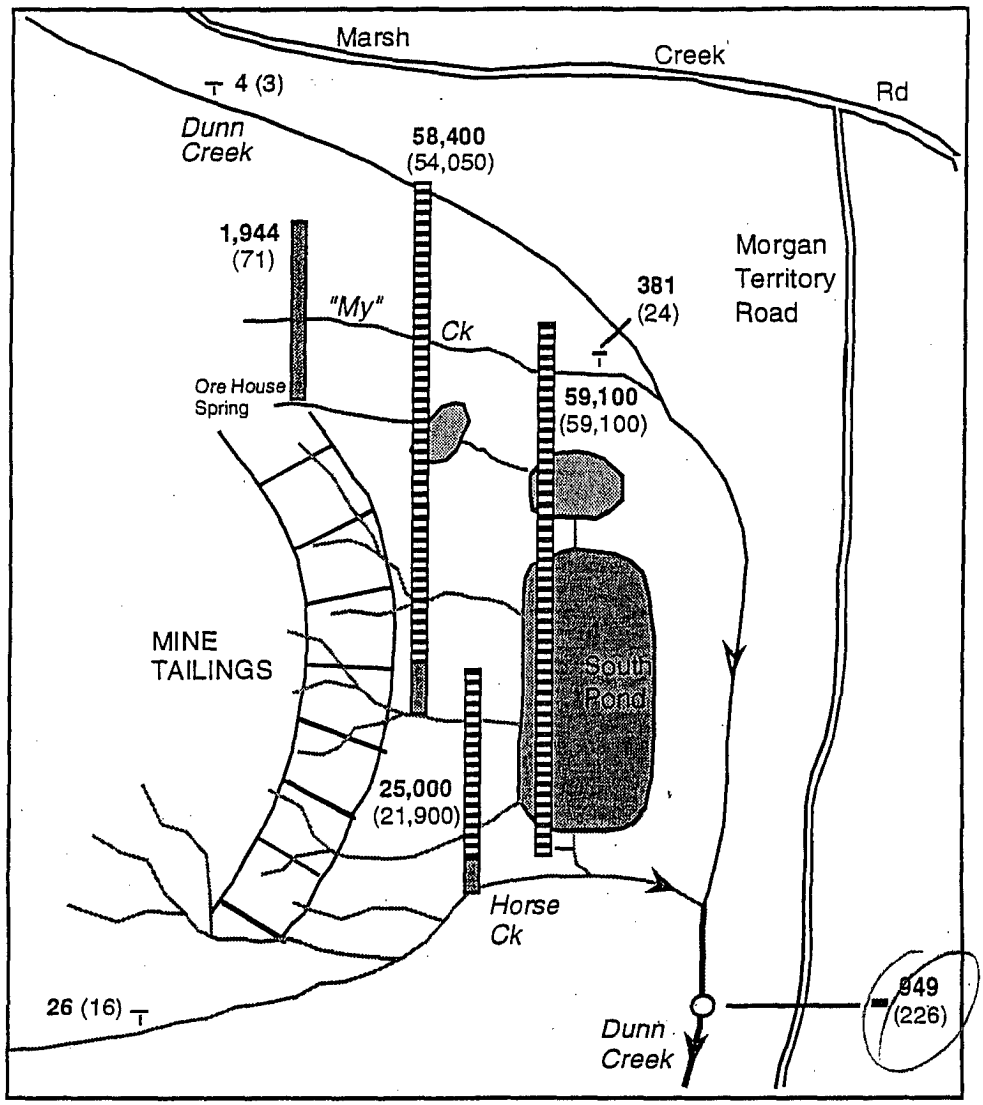


Figure 6. **Aqueous Mercury Concentrations in the Vicinity of the Mt. Diablo Mine** *(Late March 1995)*

STATE OF CALIFORNIA - Environmental Protec Agency PETE WILSON, Governor

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION
3443 Routier Road, Suite A
Sacramento, CA 95827-3098
PHONE: (916) 255-3000
FAX: (916) 255-3015

27 December 1994

Mr. Jack Wessman
P.O Box 949
Clayton, CA 94517

MT. DIABLO MERCURY MINE, CONTRA COSTA COUNTY

Enclosed are the results of the analyses for mercury and nickel on samples collected by Regional Board staff during our inspection on 1 December 1994. This completes the inspection report previously sent to you. This project is being turned over to Mr. Isaac Kaing of our office. Any future correspondence and questions should be directed to him. His telephone number is (916) 255-3022. Mr. Kenneth Landau is his supervisor whom attended the recent task force meeting regarding the mine. It has been my pleasure working with you during the past several years.

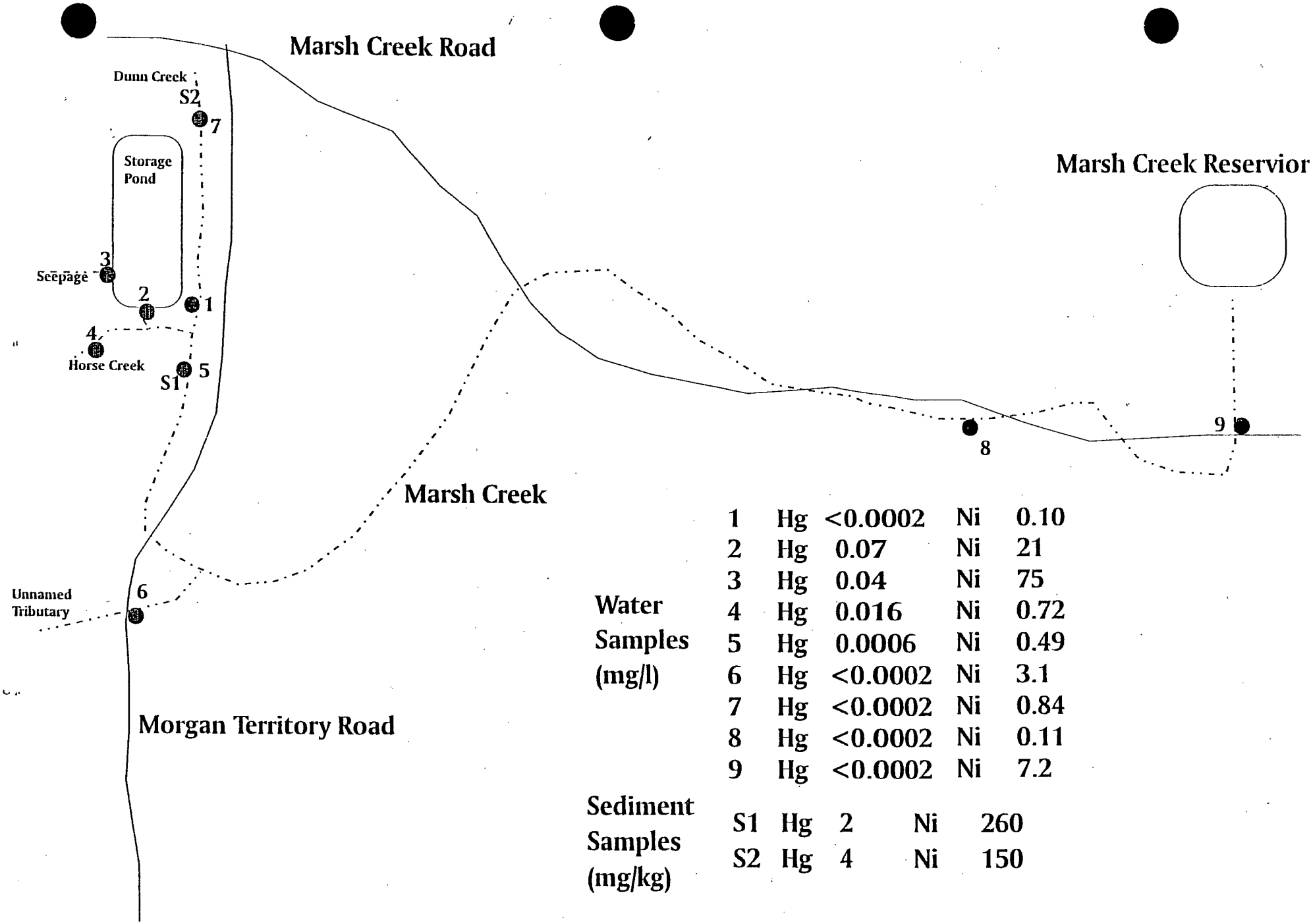
If you have any questions regarding this matter, please call me at (916) 255-3025.

ALEXANDER MACDONALD
Project Engineer

AMM

Enclosure

cc: Contra Costa County Health Services Department, Martinez



Water Samples (mg/l)	1	Hg	<0.0002	Ni	0.10
	2	Hg	0.07	Ni	21
	3	Hg	0.04	Ni	75
	4	Hg	0.016	Ni	0.72
	5	Hg	0.0006	Ni	0.49
	6	Hg	<0.0002	Ni	3.1
	7	Hg	<0.0002	Ni	0.84
	8	Hg	<0.0002	Ni	0.11
	9	Hg	<0.0002	Ni	7.2
Sediment Samples (mg/kg)	S1	Hg	2	Ni	260
	S2	Hg	4	Ni	150

Mount Diablo Mercury Mine Sampling by Regional Board staff on 1 December 1994

Change:
New Idea

B.3.17 San Carlos Creek, Mercury - Change in Total Size and Size Affected

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, recommends changes to California's Clean Water Act Section 303(d) list for the impairment of San Carlos Creek due to impairment by mercury. The Regional Board recommends that the identified total length change from 1 mile to 9 miles and that the extent of impairment change from 1 mile to 4 miles. The basis for the recommended change is described below.

Watershed Characteristics

San Carlos Creek is located in the Tulare Lake Basin in San Benito County (USGS, 1969-1981). It is a tributary to Panoche Creek (*via* Silver Creek). San Carlos Creek has a length of approximately 9 miles from its headwaters at San Benito Mountain to its confluence with Silver Creek. It derives from marine sediments, is highly mineralized, and is intermittent, with sustained flows only after extended wet periods (CRWQCB-CVR, 1995). Several small historic mines (such as the San Carlos, Aurora, and Molina mines) are located in the upper portion of the San Carlos watershed. However, the historic New Idria Mine, located along San Carlos Creek approximately 4 miles upstream of the San Carlos Creek – Silver Creek confluence, is by far the largest mine in the region (USGS, 1958-2000). The New Idria Mine has acid mine drainage containing mercury that likely impairs the water quality of the downstream segment of San Carlos Creek (CRWQCB-CVR, 1995).

Total Waterbody Length and Extent of Impairment

San Carlos Creek has a length of approximately 9 miles from its headwaters at San Benito Mountain to its confluence with Silver Creek (CRWQCB-CVR, 1995; USGS, 1958-2000). The historic New Idria Mine is located along San Carlos Creek approximately 4 miles upstream of the San Carlos Creek – Silver Creek confluence (USGS, 1958-2000). Water quality samples indicate that high levels of mercury are present below the mine, indicating that that the lower four miles are impaired by mercury.

San Carlos CR

MEETING MEMO

File: Panoche/Silver Creek CRMP
Subject: TAC Water Quality Report
Date: 29 February 1996

Attendees: Tim Hatten, Tim Moore, Chris Eacock, Al Vargas, Betty Yee

Tim Moore reported on the status of the Bylaws: They have been drafted but not signed. The last steering committee meeting was in Mendota on 2/15/96.

Discussion of report:

Introduction - Runoff does not go directly into the Lower San Joaquin River, the sentence should be rewritten to make this clearer. Tim Moore wanted more discussion on the meaning of "elevated" concentrations of metals, salts and sediment. Tim Moore has a concern with the theory that the runoff is adding fresh selenium to the grasslands watershed. However, Al Vargas felt that this theory should be included. Compromised on stating that this is a Regional Board theory. The note that there is "biannual" large rainfalls should be removed since the large rainfalls are not that predictable. The tables should note that high concentrations may be from background and not caused by man.

General comment on the standards tables - Al thinks that this data is too much information and hides the important facts - that the committee needs to work on reducing contaminant movement instead of debating the standards.

General comment on format: Tim Moore thinks all narratives need to be brought forward and tables should come at the end of the report.

General comment on interpretation of data - Tim Moore thinks that the data needs to be interpreted at some time although not necessarily in this report.

Table IA: The stats at the bottom of the table need to be checked. Also, Tim Moore thinks that the methodology should be described such as the method that was used for "Total Recoverable". The footnote that "high flow sediment was not included" is confusing - what does it mean? Does it mean that all the other results include the sediment?

Table IB - Define TALK and HDNS. The boron numbers shouldn't be marked as exceeding standards since we haven't established the applicable boron criteria. pH result for sampling date 2/20/87 appears incorrect.

Table IC - The first half of the table doesn't identify the samplers.

Table IIA - Need a description of what sediment content means and how to interpret these results. The high concentrations under Dissolved Se need to be highlighted.

Table IIB - Need to spell out the methodology for dissolved and total mercury.

Section II (Mendota Pool) - Chris Eacock will provide flood flow pathways.

Table V - Need to correlate flood events with water quality in Mendota Pool.

Next mtg: 3/14/96 after regular P/SC gen'l mtg.

B

DRAFT DRAFT

Purpose

To compile surface water quality data for the Panoche-Silver Creek watershed and to identify exceedances in federal and state water quality standards.

Introduction

During large rainfall events ~~(biannual)~~ runoff waters from the Panoche-Silver Creek (P-SC) watershed outlet into the Fresno Slough/Mendota Pool and ~~the~~ Lower San Joaquin River. Because runoff waters contains elevated concentrations of metals, salts and sediment there is concern that the beneficial uses of these important water bodies are being degraded. During such events large areas on the Panoche Alluvial Fan are flooded. As transported selenium (Se) concentrations are also elevated there is additional concern that flooding events are aggravating Se reduction efforts in the Grassland's watershed by replenishing the fan's agricultural soils and groundwater with fresh Se (Westcott & Vargus, pers comm).[1]

In 1993 a Coordinated Resource Management (CRM) effort was initiated to address these concerns. In order to formulate a CRM Plan (CRMP) the CRM Steering Committee has directed a Technical Review Committee (TRC) to compile all pertinent surface water quality data for the P-SC watershed including its receiving waters. The TRC was also directed to compile federal water quality standards and state water quality objectives pertinent to the watershed, and to identify exceedances in these standards. This report is a presentation of the TRC's findings.

It must be noted that discussion concerning the causes of identified exceedances are outside the scope of this report. Readers should keep in mind that elevated constituent concentrations do not necessarily constitute violations of water quality standards as they may result from natural (background) causes.

TRT Objectives

1. Compile surface water quality data for Panoche, Silver and San Carlos Creeks.
2. Compile surface water quality data for Panoche Creek's recieving water - the Delta-Mendota Pool.
3. Compile pertinent federal and state water quality standards applicable to the Panoche-Silver Creek watershed and receiving waters.
4. Briefly discuss findings.

[1]The grasslands watershed extends from the Mendota Pool to the confluence of the Merced and San Joaquin Rivers and includes Panoche, CCID, Broadview, Firebaugh, and the Grassland's Water Districts. Agricultural drainage water from this area is thought to contribute the majority of selenium to the Lower San Joaquin River.

SECTION I

WATER QUALITY DATA

for

PANOCHE, SILVER AND SAN CARLOS CREEKS

I. Surface water quality data for Panoche and Silver Creeks (May 1930 - March 1993)

Table IA: Trace element data for Panoche Creek at Interstate 5 (Site 6) - 3/84 to 3/93

Table IB: Mineral data for Panoche Creek at Interstate 5 (Site 6) - 5/30 to 2/85

Table IC: Trace element data for Silver Creek @ County bridge (Site 4) - 3/84 to 3/93

Table ID: Mineral data at Silver Creek @ County bridge (Site 4) - 5/30 to 3/88

II, III, IV: Surface water quality data for Panoche, Silver and San Carlos Creeks(March 1995)

Table IIA: Se and sediment data for upper and lower Panoche-Silver Creek watershed - March 9 &10, 1995.

Sites:

1	San Carlos @ County Rd
2	Panoche Creek @ County Road
3	Panoche Creek downstream of Griswold
4	Silver @ County bridge
6	Panoche Creek @ I-5
7	Panoche Creek @ Fairfax Avenue

Table IIB: Trace Element and Mineral Water Quality Data for San Carlos Creek @County Rd (Site 1), San Benito County -March 9, 1995.

Table IIIA: Se and sediment data for lower Panoche watershed - March 23, 1995.

Sites:

8	Firebaugh Canal Water Districts (FCWD) Main Lift @ Mendota Pool (site 8)
6	Panoche Creek @ I5 (Site 6)

Table IIIB: Mineral data for Panoche flood waters in FCWD (Site 8) - March 23, 1995.

Table IV: Se and sediment data for lower and upper Panoche watershed - March 31, 1995.

Sites:

6	Panoche Creek @ I5
5	Ranch upstream of I5
4	Silver Creek @ bridge
2	Panoche Creek @ County bridge

Table IA: Total Recoverable Trace Element Water Quality Data - March 1984 through March 1993 - For Panoche Creek, I-5 location (Site 5), Fresno County.

Sampling Location: 1/4 mi N of Panoche Rd, 1 mi W of I-5

what is this?

Date	Flow (cfs)	Hg	Se	Mo	Cu	Cr	Ni	Pb	Zn	U	Samp
			Total Recoverable(ug/L)								
			6.0	9	9	7	16	3			USBR
3/22/84			6.0								USBR
5/25/84			6.0	18	3	2	23	<1			USBR
6/19/84			6.0	15	5	<1	13	<1			USBR
7/27/84			2.0	8			23	<1			USBR
8/22/84			2.0	2		1	<1	2			USBR
9/26/84			3.0	8	2	4	7	1			USBR
10/15/84			3.0	13	4	2	26	2			USBR
11/14/84			4.0	4	3	1	11	<1			USBR
12/12/84			5.0	7	8	3	30	<1			USBR
01/16/85			5.0	9	2	2	25	<1			USBR
02/11/85			5.0	5	1	3	15	1			USBR
03/11/85			3.0	7	2	<2	15	2			USBR
04/08/85			2.0	3	<1	<2	15	6			USBR
05/06/85			<1	3	4	7	24	<1			USBR
06/03/85			<1	7	1	<1	13	3			USRB
12/12/85			2.0	7	5	4	7	2			USRB
01/06/86			2.0	4	2		12				USRB
*2/15/86			17	13	420	7000	2300	8			RB
02/25/86			10	11	20	36	89	<5			RB
02/27/86			10	8	9		29				USRB
*3/13/86			23	12	140	53	280	11			RB
05/19/86			3	8	<4		16				USBR
11/21/86			2.1	<5	<1	<1	<5	<5	<1		RB
12/17/86			2.0	17	<1	<1	<5	<5	<1		RB
01/14/87			2.5								RB
01/15/87			2.6	9	8	2	13	<5	2		RB
02/20/87			2.3								RB
03/18/87			1.9	11	<5	2.1	34	<1	9	39	RB
04/16/87			2.4								RB
10/29/87	25cfs		44								USGS
11/19/87			2.8								RB
12/15/87			2.6								RB
01/17/88	85cfs		56								USGS
03/23/88			4.1								RB
03/25/91		45	75	76	1400	1800	2900	140	3200	90	DWR
02/09/93			22.8								RB
03/17/93			7.7								RB
Minimum			<1	2	<1	<1	<1	<1	<1	39	
Median		*45*	*3*	*8*	*4*	*2.1*	*20*	*2*	*2*	*49.5*	
Maximum			10	18	20	36	89	8	9	90	
# Data		1	38	28	26	24	28	23	6	2	

check these

* Does not include high flow sediment ?2 what does this mean?

Note: Shaded text represents an exceedance of either federal or state water quality standards - see Section III and IV.

May '30 March '85

Table IB: Mineral Water Quality Data - ~~September '31~~ through ~~February '85~~ - for Panoche Creek (Site 5)*, Fresno County.

Total Alkalinity

What are these?

Sampling location: 1/4 mi N of Panoche Rd, 1 mi W of I-5
* See Sampling Site Location Map (Sites 1-9)

Date	Time	Flow	pH	EC	B	Cl	SO4	Ca	Mg	Na	K	HCO3	TALK	HDNS	TDS	Sampler
		cfs		umhos/cm	----------					Mg/L						
05/22/30		2.0		2530	4.9	172	1070	142	114	364		317	317		2020	USGS
09/09/31		2.0		3000	6.5	202	1070	112	110	423		311	311		2070	USGS
01/09/52		4.0		5600	6.1	305	2210	299	212	700		382	382		3960	USGS
01/30/52		0.5		4300	4.8	170	1680	268	147	500		432	432		3030	USGS
03/19/52		5.0		2170	1.5	48	882	178	55	237		192	192		1520	USGS
01/27/53		0.5		3670	3.3	220	1330	183	143	442		434	434		2570	USGS
01/27/54		1.2		7600	8.6	460	2990	332	296	935		410	410		5250	USGS
01/26/56		33		1750	1.6	48	685	136	54	170		184	184		1210	USGS
03/19/57	1220	0.2	8.0	9340	13	720	4050	358	444	1440	14	550	550	2720	7320	USGS
02/10/58	1230	1.8	7.8	6830	6.1	364	3840	384	443	905	22	444	444	2780	6210	USGS
03/17/58		200		2020	1.5	42	753	133	74	179		200	200		1310	USGS
04/15/58	1150	26	7.8	2950	3.0	110	1402	34	278	314	9	408	408	1230	2370	USGS
04/22/59	1400	0.01	7.9	11600	23	1040	6450	474	735	2040	16	502	502	4210	11000	DWR
06/08/60	1600	0.01			20											DWR
02/27/62				5740	10	325	2920	224	419	760	10	408	422	2280	4890	DWR
04/03/63	1700	5.0	8.2	8400	13	615	4805	233	552	1400	14	320	320	2950	8080	DWR
03/14/84				6700	9.1											USBR
03/22/84	1530	0.3					3300	270	470	1100	11					RB
05/17/84	800			8400	10	510	2700	196	544	520	17.2	408	408			RB
05/25/84				9250	12											USBR
06/19/84				10500	15											USBR
07/27/84					16											USBR
08/22/84				12830	18											USBR
09/26/84				12200	18											USBR
10/15/84				11360	16											USBR
11/14/84				9230	14											USBR
12/12/84				9890	13											USBR
01/16/85				9270	12											USBR
02/11/85				9050	12											USBR
03/11/85				8950	12											USBR
04/08/85				9340	12											USBR

Continued on following page.

Need to establish applicable criteria before marking acceptance.

May '86 March '88

Table IB: (Continued)**Mineral Water Quality Data - ~~September '81~~ through ~~February '85~~ - for Panoche Creek (Site 5)*, Fresno County.**

Sampling location: 1/4 mi N of Panoche Rd, 1 mi W of I-5
* See Sampling Site Location Map (Sites 1-9)

Date	Time	Flow cfs	pH	EC umhos/cm	B	Cl	SO4	Ca	Mg	Na	K	HCO3	TALK	HDNS	TDS	Sampler
										Mg/L						
05/06/85				11340	**14**											USBR
06/03/85				11120	**15**											USBR
12/12/85				10550												USBR
01/06/86				10240												USBR
02/15/86	1440		8.1	2200	1.9	60	1400	195	73	244	10.2	150	150	780	1800	RB
02/25/86	1615	1.0	9.0	4500	**5.9**	240	2400	199	319	540	13.2	400	400	1840	4000	RB
02/27/86				4820	**6.0**											USBR
03/13/86	830	12		2500	**2.6**	100	1200	168	126	288	7.9	240	240	880	2000	RB
05/19/86				11240	**15**											USBR
11/21/86	1500	1.0	8.1	10000	**18**	750	7600	600	920	2000	25.0	310	310	4400	12000	RB
12/17/86	1100	2.0	8.4	10000	**19**	800	6200	450	800	1400	19.0	220	220	3800	6500	RB
01/14/87	1540		8.2	10700	**13**	680	4700									RB
01/15/87	1100	4.0	7.7	10000		650	3700	380	720	1700	14.0			3500		RB
02/20/87	915	1.5	1.5 ? this correct ?	10000	**14**	360	2500									RB
03/18/87	900	2.0	8.1	10800	**12.5**	730										RB
04/16/87	1030	1.5	9.2	12000	**17**	770										RB
10/29/87	1000	25		3790	1.6	84	2220	472	116	362	24		127	1660	3730	RB
11/19/87	1445	0.8		12000	**17**	920	6200					480	480			RB
12/15/87	1615		8.1	11350	**14**	800	5100									RB
01/14/88	1200	85	7.9	4270	**2.0**	127	2380	412	170	496	17		125	1730	4160	RB
03/23/88	1000		8.4	11900	**16**	940	7200					230	230			RB
Minimum				1750	1.5	42	685	34	54	170	7.9	150	150	780	1210	
Median				*9250*	*12*	*345*	*2600*	*230*	*278*	*500*	*14*	*382*	*382*	*2700*	*3350*	
Maximum				12000	23	1040	7600	600	920	2040	25	550	550	4400	12000	
# Data				51	51	31	30	25	25	25	16	23	23	14	22	

Note: Emboldend numbers within the 'B' column represents an exceedance of either federal or state water quality standards - see Section III and IV.

Table IC: Total Recoverable Trace Element Water Quality Data - March '84 through March '95 - for Silver Creek (Site 4)*, Fresno County.

Sampling Location: Latitude 36° 34' 47", Longitude 120° 40' 35"
NW 1/4, NW 1/4, SW 1/4, Sec. 31, T.15S, R.12E
6.5 mi W of I-5 on Panoche Rd.

* See Sampling Site Location Map (Sites 1 - 8)

DATE	FLOW	Hg	Se	Mo	Cu	Cr	Ni	Pb	Zn	U	Samp
			Total Recoverable (ug/L)								
03/22/84			4.0								
12/17/85			18	14	9	4	120	10			
01/15/86			3.0	15	8	5	47	12			
02/25/86			10.0	14	21	18	55	<5			
04/25/86			8.0	9.0	9	2	11	<5			
05/15/86			5.0	<5	3	2	13	<5			
01/15/87			1.0	9.0	6	3	23	<5	7		
02/20/87			8.6								
03/18/87			5.4	9.6	<5	6.1	24	<1	14	27	
04/16/87			2.0								
11/19/87			1.7								
12/15/87			2.2								
01/14/88			3.2								
03/23/88			6.4								
01/17/88			56.0								USGS
03/25/91			72.0	70.0						90	DWR
03/17/93			6.2								RB
03/23/95			22.0								RB
03/31/95			15.2								RB
Minimum			1.0	<5	3.0	2	11	<1	7	27	
Median			*7.5*	*9.6*	*8.0*	*4*	*24*	*<5*	*10.5*	*58*	
Maximum			72.0	70.0	21.0	18	120	12	14	90	
#Data			19.0	8.0	7.0	7	7	7	2	2	

Who are the samp

Note: Shaded text represents an exceedance of either federal or state water quality standards - see Section III and IV.

Table ID: Mineral Water Quality Data - May '30 through March '85 - for Silver Creek (Site 4)*, Fresno County.

Sampling location: 1/4 mi N of Panoche Rd, 1 mi W of I-5
* See Sampling Site Location Map (Sites 1-9).

Date	Time	Flow	pH	EC	B	Cl	SO4	Ca	Mg	Na	K	HCO3	TALK	HDNS	TDS	Sampler
		cfs		umhos/cm	----------					mg/L	----------					
05/22/30		0.03		9950	**8.8**	528	4270	391	515	1090		348	348		6970	USGS
09/09/31		0.03		13000	**13**	918	5220	397	494	1820		290	290		9000	USGS
03/19/52		4		2620	**2.6**	68	1040	146	135	235		360	360		1820	USGS
01/28/53		2		7200	**7.0**	270	3090	227	397	790		396	396		5010	USGS
03/14/57	1230		8.3	6630	**11**	345	3590	210	448	930	15	216	216	2370	5680	DWR
01/07/59	1055	2	8.0	4950	**7.8**	222	2520	188	321	672	12	421	421	1790		DWR
07/06/59					**20**										9290	DWR
04/03/63	1630	5	8.1	5900	**11**	310	3293	158	423	938	13	412	412	2135	5350	DWR
03/22/84	1600	0.6		4600	**7.6**		2490	120	390	620	6.5					RB
12/17/85	1630		8.1	14000	**23**	1000	9100	518	1150	2210	36.5	700	700		16000	RB
01/15/86	1600		7.5	1000	**20**	940	7600					480	480			RB
2/25/86	1600	3.5	9.1	3600	**4.5**	120	1900	143	289	380	11.0	380	380	1480	3200	RB
04/25/86	1300	1.0	9.0	4000	**5.1**	130	2100		270	400	12.0	280	280	1620	3400	RB
01/15/87	1120	2.0	7.5	9100		400	3100	310	670	1300	17.0			3200		RB
02/20/87	940	3.0	8.0	7800	**11**	240	3000									RB
03/18/87	845	3.0	8.1	7500	**10**	370										RB
04/16/87	1050	0.5	9.1	9650	**17**	550										RB
11/19/87	1515			11800	**18**	870	6000					660	660			RB
12/15/87	1550		8.3	12100	**18**	900	5300									RB
01/14/88	1505		8.1	10900	**16**	670	4400									RB
03/23/88	1035		8.3	12100	**19**	1000	6800					320	320			RB
Minimum				1000	2.6	68	1040	120	135	235	6.5	216	216	1480	1820	
Median				*7650*	*11*	*380*	*3450*	*210*	*400*	*850*	*13.0*	*396*	*396*	*1965*	*5515*	
Maximum				14000	23	1000	9100	518	1150	2210	36.5	700	700	3200	16000	
# Data				20	20	17	18	11	12	12	8	13	13	6	10	

Note: Emboldend numbers within the 'B' column represents an exceedance of either federal or state water quality standards - see Section III and IV.

Table IIA: Se and sediment data for upper and lower Panoche-Silver Creek watershed (March 9 &10, 1995).*

* See Sampling Site Location Map (Sites 1 - 8)

what is the meaning of these and how do they relate to each other?

Sample site	Date	Time	Flow/ stage (Ft)	Sed Content (mg/L)	Se/sed Content (ug/g)	Se Dissolved (ug/L)	Se Total (ug/L)	Sampler
San Carlos	3/9/95	1950	2.5	42,000	1.97	5.45	46.9	RB
@ County Rd		2000	2.25	38,000	1.00	5.34	36.7	RB
(Site 1)								
Median				*40,000*	*0.98.5*	*5.40*	*41.8*	
Panoche @	3/9/95	1750	3	16,000	0.82	0.72	24.7	RB
County Rd		1820	5.25	17,000	1.30	1.32	26.3	RB
(Site 2)		1905	5.7	19,000	1.62	1.46	26.5	RB
		1945	5.9	24,000	1.5	1.34	44.7	RB
		2005	5.9	24,000	1.73	1.26	29.1	RB
		2025	5.7	28,000	1.42	1.20	38.7	RB
		2045	5	26,000	1.42	1.48	30.5	RB
Median				*24,000*	*1.42*	*1.34*	*29.1*	
Panoche@	3/9/95	1925	2	52,000	1.52	8.43	102	RB
Griswold		1940	2.7	40,000	1.42	7.79	94.3	RB
(Site 3)		2010	3.2	52,000	1.19	12.0	118	RB
		2045	2.2	54,000	1.34	9.58	95.1	RB
		2105	2.8	48,000	1.3	10.8	102	RB
Median				*52,000*	*1.34*	*9.58*	*102*	
Silver @	3/9/95	1930	2.8	69,000	1.77	35.9	264	RB
Panoche		2100	7.7	71,000	1.70	8.22	151	RB
(Site 4)		2245	5.1	59,000	1.55	8.44	106	RB
Median				*69,000*	*1.70*	*8.44*	*151*	
Panoche @	3/09/95	1830	450cfs	59,000	2.59	15.1	205	RB
I-5		2000	550cfs	130,000	2.22	44.8	489	RB
(Site 6)		2030	350cfs	110,000	1.86	44.3	463	RB
	3/10/95	1430	5500cfs	95,000	1.67	19.5	194	RB
		1500	7000cfs	110,000	1.51	19.0	206	RB
		1530	10000cfs	98,000	1.46	19.3	241	RB
			12000cfs	130,000	1.51	26.4	270	RB
Median				*110,000*	*1.67*	*19.5*	*241*	
Panoche @	3/9/95	2315	rising	120,000	1.46	43.2	460	RB
Fairfax Rd	3/10/95	0057	high flow	73,000	2.11	15.7	144	RB
(Site 7)								
Median				*96,500*	*1.78*	*30.0*	*302*	

Note: Shaded text represents an exceedance of either federal or state water quality standards - see Section III and IV.

Table IIB: Trace Element and Mineral Water Quality Data for San Carlos Creek @County Rd (Site 1)*, San Benito County (March 9, 1995).

what are the methods? total recov.

* See Sampling Site Location Map (1 - 8)

Date	Time	Cu	Cr	Ni	Pb	Zn	Hg	Hg	Bo	Hardnes	sampler
					Dissoved (ug/L)			(total)	mg/L	mg/L	
3/9/95	2015	13.3	<1	4.8	<3	99	<0.2	207	10.6	1921	RB

Total Recoverable & Total Dissolved are described in SW-846 and these definitions describe the sample prep for above.

Table IIIA:- Se and sediment data for upper and lower Panoche-Silver Creek watershed (March 23, 1995).*

* See Sampling Site Location Map (1 - 8); see Table IIIB for mineral water quality data at this site.

Sample site	Date	Time	Flow/ stage	Sed Content		Se/sed	Se Dissolved	Total	Sampler
FC Main Lift @	3/23/95	0730	----	----		2.0	22.0	----	chedster
Men Pool		0730	----	----		<1	22.0	----	
(Site 8)		0730	----	----		<1	----	----	
Median						*<1*	*22.0*	—	
Panoche @	3/23/95	1430	----	----	----	----	----	21	RB
I-5		1700	----	----	----	----	----	14	RB
(Site 5)									
Median								*17.5*	

Table IIIB: Trace element and mineral data - March 23, 1995 - for Panoche Creek flood waters in Firebaugh Canal Water District's Main Lift Canal @ the Mendota Pool, Fresno County.

Date	Time	Flow	Se/sed Content (ug/g)	Se Dissolved (ug/L)	Se Total	Boron (mg/L)	Calcium (mg/L)	pH (mg/L)	Sodium (mg/L)	Sulfate	Sampler
3/23/95	0730		2.0	22.0	N/A	2.7	240	7.9	360	1600	Chedster
3/23/95	0730		<1	22.0	N/A	1.5	260	8.0	220	1300	
3/23/95	0730		<1	----		---	---	---	---	-----	
Median			*<1*	*22.0*		*2.1*	*250*	*7.95*	*290*	*1450*	

Note: Shaded text represents an exceedance of either federal or state water quality standards - see Section III and IV.

* According to Betty Lee, the 3/9/95 sample was collected during a storm flow event approximately 1 mile downstream of New Idria Mine (MLW, 3/16/01)

Table IV: Se and sediment data for upper and lower Panoche-Silver Creek watershed (March 31, 1995).*

* See Site Sampling Location Map (1 - 8)

Sample site	Date	Time	Flow/ stage	Sed Content (Mg/L)	Se/sed (mg/kg)	Se Dissolved (ug/L)	Total (ug/L)	Sampler
Panoche @ I-5 (Site 5)	3/31/95	1430	----	----	----	----	21.4	RB
Ranch @ Panoche (Site 6)	3/31/95	0815	----	----	----	----	16	RB
		0815	----	----	----	----	16.2	RB
Silver @ Bridge (Site 4)	3/31/95	0845	----	----	----	----	15.2	RB
Panoche @ County Rd (Site 2)	3/31/95	930		----	----	----	38.0	RB

Note: Shaded text represents an exceedance of either federal or state water quality standards - see Section III and IV.

SECTION II

WATER QUALITY DATA

for the

MENDOTA POOL & DELTA MENDOTA CANAL

I. Surface water quality data for the Mendota Pool

Figure 1 - Schematic diagram of Central Valley Project and Non-project water deliveries

Table Va: Total Recoverable Trace Element Water Quality and Salinity Data for Delta-Mendota Canal and Mendota Pool

Table Vb: Summary of Water Quality Monitoring in the Delta-Mendota Canal and Mendota Pool conducted by the Bureau of Reclamation

Chris Eacock will provide flood flow pathways.

~~SECTION III~~

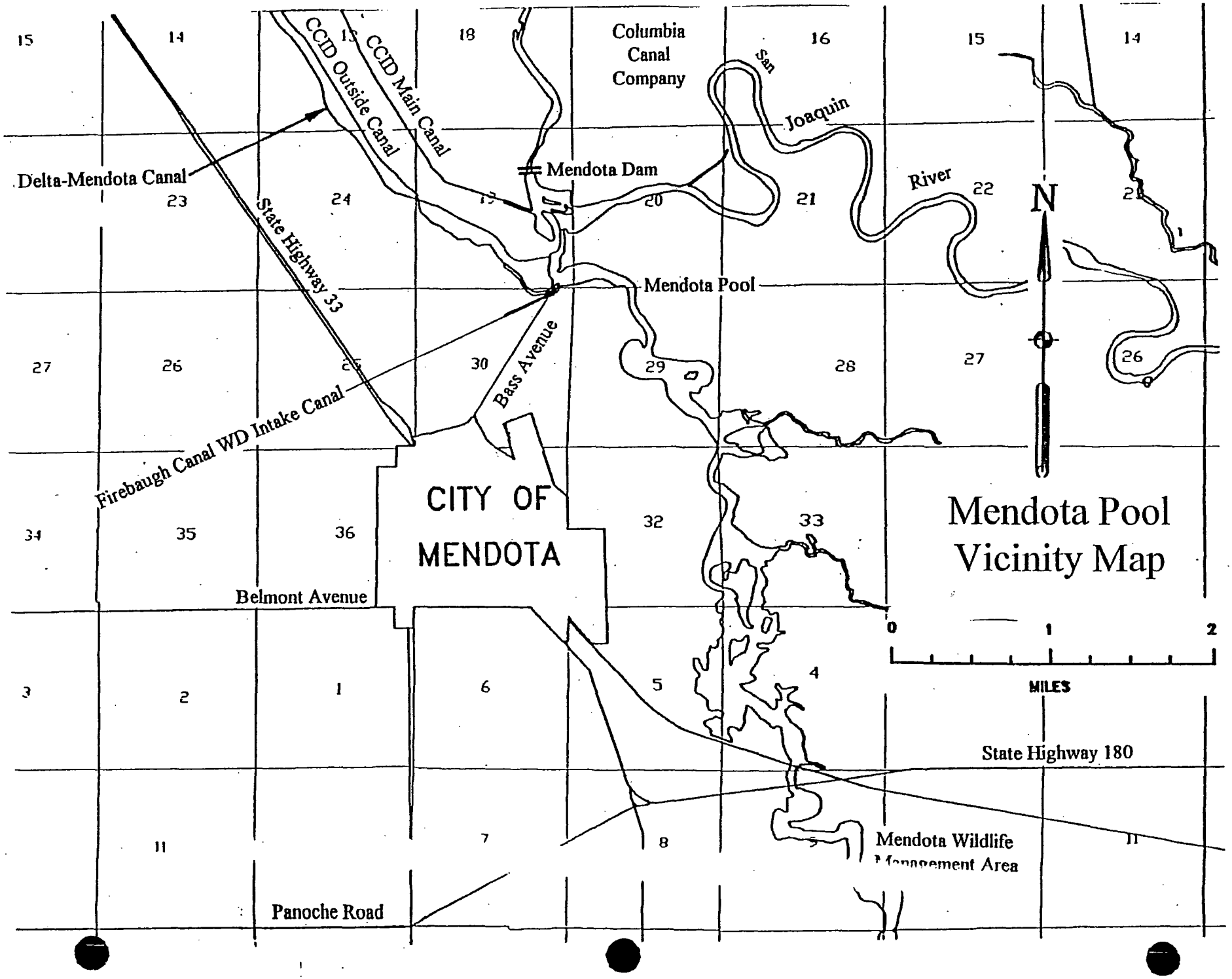
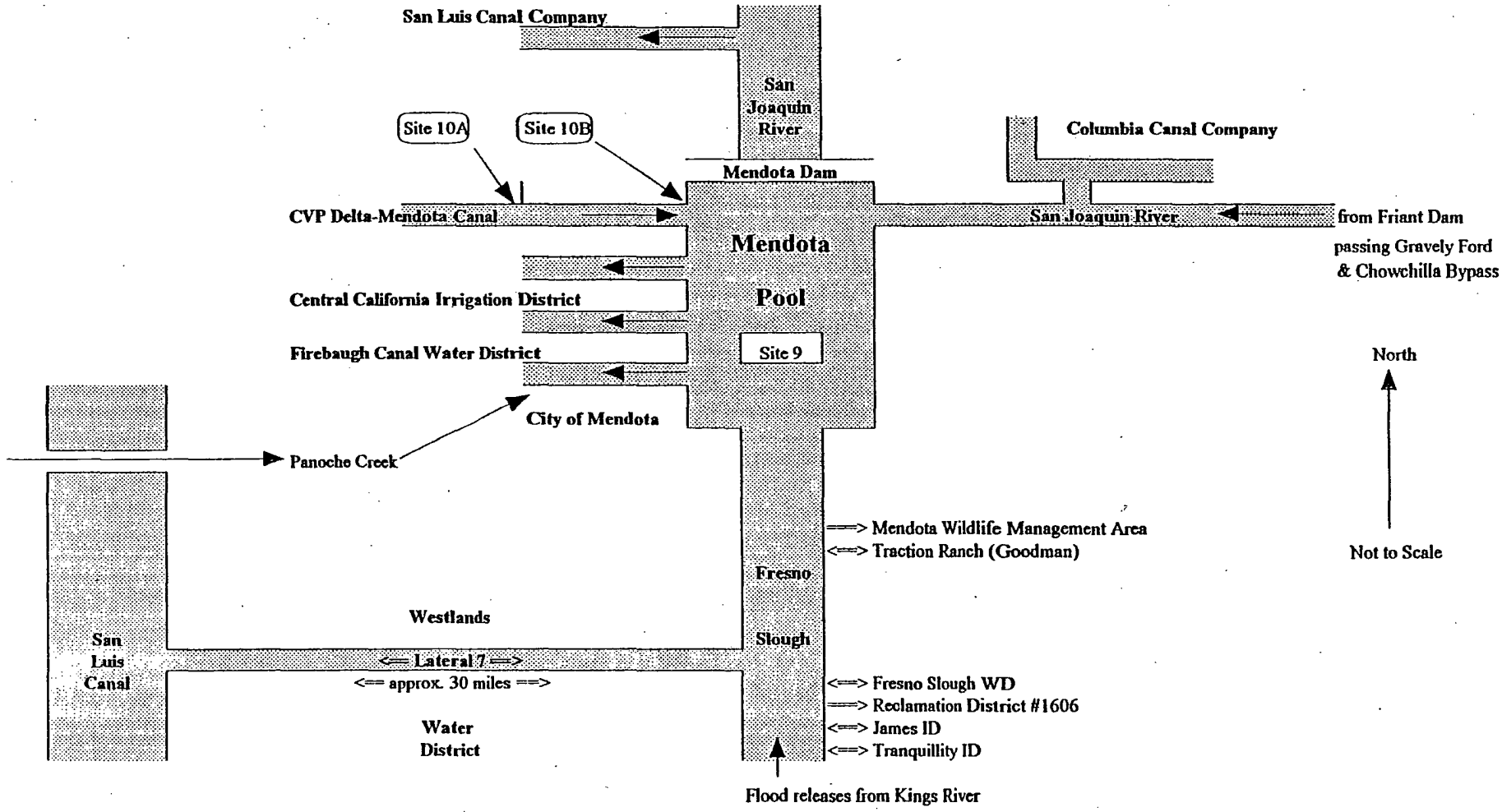

Columbia Canal Company
CCID Outside Canal
CCID Main Canal
Delta-Mendota Canal
State Highway 33
Mendota Dam
San Joaquin River
Mendota Pool
Bass Avenue
Firebaugh Canal WD Intake Canal
CITY OF MENDOTA
Belmont Avenue
Panoche Road
State Highway 180
Mendota Wildlife Management Area
N
0 1 2
MILES
Mendota Pool Vicinity Map

Figure 1 - Schematic diagram of Central Valley Project and Non-project water deliveries



Prepared by M.C.R. Hacock, Bureau of Reclamation, Fresno CA.

G:\DATA\USERS\FRO420BVP3SCRMP\FLOWDIA2.WK4 12/14/95 Sheet A

This data should be correlated with flood flows.

Table V_ : Total Recoverable Trace Element Water Quality and Salinity Data for Delta-Mendota Canal and Mendota Pool

PSCCRMP Site #	Site 10A				Site 10B					Site 9			
Sampling Location:	DMC Check 20 @ Firebaugh				DMC Check 21 @ Mendota					Mendota Pool @ wooden Bridge			
	Boron	Selenium	EC	TDS	Boron	Mercury	Selenium	EC	TDS	Boron	Mercury	Selenium	TDS
	mg/L	ug/L	uS/cm	mg/L	mg/L	ug/L	ug/L	uS/cm	mg/L	mg/L	ug/L	ug/L	mg/L
02/05/91					0.5		<0.002						
05/10/91			630	405	0.3		<2						
05/19/92			624	402	0.4		<5						
06/22/92			700	449	0.3		<5						
07/13/92			693	444	0.3		<5						
08/19/92			739	473	0.3		<5						
09/24/92			798	509	0.4		<5						
10/21/92			768	491	0.4		<1						
11/23/92			831	530	0.1		<1	887	539				
12/03/92			864	550			<1	858	527				
01/05/93			1154	729			5	1080	683				
02/03/93			923	586	0.6		8	1084	686				
03/03/93			690	442	0.5		2	770	492	0.4		17	
03/24/93			840	535	0.3		<5	779	497				
04/29/93			617	397	0.4		<5	603	389				
06/08/93			532	345	0.4		<5	548	355				
07/14/93	0.5	3	573	370	0.3		<5	562	363				
08/04/93	0.2	<1	451	295			<1	417	274			<1	
09/13/93	0.2	<1	384	253	0.2		<1	395	260	0.2		<1	
10/05/93	0.2	<1	369	244	0.1		<1	468	305	0.2		<1	
11/10/93	0.5	1	540	350	0.2		<1	563	364	0.2		<1	
12/08/93	0.5	1	576	372	0.3		<1	593	382	0.4		[redacted]	
01/13/94	0.4	3	722	462	0.4		1	722	462	0.3		<1	
02/07/94	0.5	1	689	442	0.6		2	689	442	0.7		2	
03/10/94	0.7	2	910	578	0.9		3	910	578	0.8		3	
04/13/94	0.8	2	817	521	0.9		1	817	521	0.9		2	
05/18/94	0.6	1	744	476	0.9		1	744	476	0.9		1	
06/15/94	0.8	1	652	419	0.8		2	652	419	0.7		2	
07/14/94	0.3	<1	1185	748	0.4		1	1185	748	0.4		<1	
08/10/94	0.2	<1	619	399	0.4		2	619	399	0.4		<1	
09/14/94	0.2	<1	583	376	0.2		1	583	376	0.2	<0.2	1	311
10/04/94	0.1	<1	663	426	NS		NS	663	426	0.3	<0.2	1	453
11/07/94	0.2	1	703	450	0.2	<0.2	<1	703	310	0.2	<0.2	<1	309
12/06/94	0.2	2	755	483	0.3	<0.04	1	755	427	0.3	<0.04	1	410
01/04/95	0.5	6			0.6	<0.05	7	907	625	0.4	0.1	5	532
02/01/95					0.4	<0.05	5	769	430	0.4	0.2	5	408
02/28/95					0.4	0.08	3		334	0.4	<0.05	3	327
04/06/95					0.5	0.2	6		425	<0.1	0.1	<1	83
05/04/95					0.6	0.1	9		427	<0.1	<0.04	<1	47
06/07/95					<0.1	<0.04	<1		61	<0.1	<0.04	<1	40
07/05/95					<0.1	0.06	<1			<0.1	<0.04	<1	
08/02/95													
09/06/95													
10/04/95													
Minimum	0.1	0	369	244	0.0	0.00	0	395	61	0.0	0.00	0	40
Median	0.5	1	707	453	0.4	0.05	1	726	438	0.4	0.04	2	292
Maximum	2.9	6	1,185	748	0.9	0.23	9	1,185	748	0.9	0.20	17	532
# Data	45	19	33	33	38	9	41	28	32	24	11	25	10

G:\DATA\USERS\FRO420\PSCRMP\HDOTEST.WK4 12/14/95

Table V__: Summary of Water Quality Monitoring in the Delta-Mendota Canal, Mendota Pool, and San Joaquin River

Location	Agency	Schedule	Analyses	Remarks
Delta-Mendota Canal				
MP 111.26 Check 20 @ Firebaugh	Reclamation	Continuous	Electrical conductivity	Daily max, min, avg and est. TDS
MP 116.48 Check 21 @ Mendota	Reclamation	Monthly, first Wednesday	List A	
Mendota Pool				
Mendota Pool	Reclamation	Monthly, first Wednesday	List A	
Columbia - Mowry Intakes	Columbia Canal Company	Continuous	Electrical conductivity	
Outside Canal	Central California ID	Continuous	Electrical conductivity	
Main Canal	Central California ID	Continuous	Electrical conductivity	
Firebaugh Inlet Canal	Firebaugh Canal WD	Continuous	Electrical conductivity	
Mendota Wildlife Mgt Area	Cal. Dept. Fish & Game	Occasional	Electrical conductivity	
Lateral 7	Westlands WD	Occasional	List B	
Tranquillity	Tranquillity ID	Occasional	M & I deliveries	
San Joaquin River & tributaries				
Temple Slough	San Luis Canal Company	Continuous	Electrical conductivity	

Table V__: List of Routine Water Analyses conducted by the Bureau of Reclamation

List A (Monthly)		List B (Occasional)
Antimony	Molybdenum	Arsenic
Arsenic	Nickel	Boron
Beryllium	Nitrates (as N)	Nitrates
Boron	Selenium	Selenium
Cadmium	Silver	Chlorides
Calcium	Sodium	Manganese
Chlorides	Sulfates	Sulfates
Chromium	Thallium	TDS
Copper	Total dissolved solids	Electrical conductivity
Electrical conductivity	Zinc	
Lead	pH	
Magnesium	Gross alpha	
Mercury		

Table V__: Summary of Water Quality Monitoring in the Delta-Mendota Canal and Mendota Pool conducted by the Bureau of Reclamation

	Mendota Pool	Delta-Mendota Canal	
	Wooden bridge	Check 20 MP 111.26	Check 21 MP 116.48
PSCCRMP Sample Site #	Site 9	Site 10-A	Site 10-B
Aluminum	USBR		
Antimony	Monthly		Monthly
Arsenic	Monthly		Monthly
Barium			
Beryllium	Monthly		Monthly
Boron	Monthly		Monthly
Cadmium	Monthly		Monthly
Calcium	Monthly		Monthly
Chlorides	Monthly		Monthly
Chromium	Monthly		Monthly
Copper	Monthly		Monthly
Cyanide			
Electrical conductivity	Monthly	Continuous	Continuous
Fluoride			
Iron			
Lead	Monthly		Monthly
Magnesium	Monthly		Monthly
Manganese			
Mercury	Monthly		Monthly
Molybdenum	Monthly		Monthly
Nickel	Monthly		Monthly
Nitrates (as N)	Monthly		Monthly
Selenium	Monthly		Monthly
Silver	Monthly		Monthly
Sodium	Monthly		Monthly
Sulfates	Monthly		Monthly
Thallium	Monthly		Monthly
Total dissolved solids	Monthly		Monthly
Zinc	Monthly		Monthly
pH	Monthly		Monthly
Gross alpha	Monthly		Monthly
Pesticides (19)			
Ethylene glycol			
Oil & grease			
Total hydrocarbons			
THM Potential			
Flow	Continuous		Continuous

SECTION III

APPLICABLE WATER QUALITY STANDARDS

for

PANOCHE and SILVER CREEK

The purpose of this section (III) is to provide a brief summary on:

1) Federal law enacted to protect the Nation's water quality;
2) State law enacted to protect California's water quality, and;
3) specific federal and state standards/objectives established to protect the beneficial uses of the waters within the Panoche-Silver Creek watershed and its receiving waters.

Clean Water Act and Porter Cologne: California's water quality is protected from point and nonpoint source (NPS) impacts by federal and state laws. The overarching federal law requiring States to adopt water quality standards for all "waters of the United States"[2] is the Clean Water Act (CWA). The CWA defines water quality standards to be comprised of designated beneficial uses and water quality criteria. Examples of beneficial uses include aquatic life, fishing, drinking water, etc... Criteria are specific limits for individual pollutants, depending upon the designated use, which should not be exceeded in waters of the United States. The State law protecting California's waters specifically is the Porter-Cologne Water Quality Control Act. Consistant with the CWA, Poter Cologne requires beneficial use designations and water quality objectives for California's water bodies. Porter Cologne also requires an implementation program for achieving water quality objectives.

The Porter-Cologne Act designated the State Water Resources Control Board (SWRCB) as the water quality planning agency for California and established 9 Regional Water Quality Control Boards (RWQCB). The Porter-Cologne Act designated the SWRCB to be responsable for developing statewide water quality plans, the regional boards for developing Regionwide Water Quality Control Plans (Basin Plans). Both statewide and regional plans are part of the SWRCB's Nonpoint Source Management Plan.

Central Valley RWQCB ~~CVWQCB~~ Basin Plans **In 1975**, The CVWQCB adopted ~~its first~~ two Basin Plans for the ~~northern portion of the~~ Central Valley. The plans were approved by the State Board and the EPA within the following year. ~~This~~ northern ~~portion contained~~ plan covered 3 hydrologic basins: The Sacramento

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[2] "All other waters such as intrastate lakes, rives, streams (including intermittent streams), mudflats, sandflats, "wetlands," sloughs, prairie potholes...degradation, or destruction of which would affect...Tributaries of waters identified in paragraphs (a) through (d) of this definition;" (40 CFR Ch. I (7-1-94 Edition).

River Basin; the Sacramento-San Joaquin Delta Basin; and the San Joaquin River Basin. The Tulare Lake Basin is ~~also under the juristiction of the CVWQCB, but has its own basin plan - The Tulare Lake Basin Plan (TLBP). The TLBP was also first apporved in 1975 by the SWRCB and the EPA~~. Both plans have had several revisions since their adoption.

- More on Basin Plans...**1988 Amendment**...EPA dissapproval of specific objectives for Selenium and boron...EPA promulgation of standards for Se and Bo in the San Joaquin River....

- **1995/96** Basin Plan Amendments...

California Inland Surface Waters Plan (ISWP): In **April, 1991** the SWRCB adopted the ISWP. The ISWP is a statewide water quality control plan designed to protect inland surface waters from toxic pollutants.[3] To accomplish this the ISWP established narrative, toxicity and numerical water quality objectives to protect aquatic life and human health.

The ISWP was in response to the U.S. EPA's promulgation of numeric water quality criteria for 14 states which were not complying with Section 303(c)(2)(B) of the CWA. Section 303(c)(2)(B) requires criteria for priority toxic pollutants in state water quality standards. On December 22, 1992 these federal criteria were promulgated under the National Toxics Rule. As California had already adopted the ISWP and EBEP, only a few criteria for priority pollutants and water bodies were promulgated for California.

In July 1994 all portions of the ISWP were rescinded by the California Superior Court for not being in compliance with the California Administrative Procedures Act. As a result, the State of California has been without numeric water quality criteria for most priority pollutants and has therefore been out of compliance with section 303(c)(2)(B) of the Clean Water Act.

Consequently, the EPA is in the process of promulgating new federal standards for ~~these~~ water bodies (CA Toxics Rule), and the SWRCB is in the process of reestablishing objectives in a new statewide plan. June ~~of~~ 1997 is the target completion date for the federal promulgation. Promulgated water quality standards will be withdrawn when the State of California re-adopts water quality objectives.

Standards applicable to Panoche Watershed and Receiving Waters: The beneficial uses and protective water quality objectives for Panoche Creek and its tributaries within the P-SC watershed are described in the ~~Draft~~ TLBP. The beneficial uses and protective water quality objectives for the principal receiving waters of Panoche Creek, the Mendota Pool, are described in ~~CVWQCB Basin Plan.~~ For the purposes of this report, these uses and objectives are outlined in Table VIa (Stds for Panoche-Silver Crks) and briefly described in VIb (Narrative for Stds as Presented in Table VI). For a complete description of the beneficial uses refer to Appendix I, for a complete desription of the water quality objectives refer to Appendix II.

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[3] Inland refers to all surface waters of the State which do not include the ocean, enclosed bays, or estuaries.

Table VI
Stds for Panoche-Silver Crks

	TLBP (Westside Streams) - no MUN BU	SJRBP (SJR)	MCL DHS/USEPA	USEPA SNARL	Ag. WQ Goal	USEPA 4-Day Amb. WQ Criteria	USEPA 1-hr Amb. WQ Criteria	USEPA Non-Cancer Public Health
Selenium		12 ug/l (2 ug/l for wetlands)	10/50 ug/l		20 ug/l for plants 50 ug/l for livestock	5 ug/l	20 ug/l	
Boron	1 mg/l over Class I water, 2 mg/l over Class II water	2.0 mg/l Mar - Sep 0.8 mg/l monthly mean Mar - Sep 2.8 mg/l Sep - Mar 1.0 mg/l monthly mean Mar - Sep 1.3 mg/l monthly mean critical year		0.6 mg/l	0.7 mg/l			
Sediment	No adverse affects to BUs	No adverse affects to BUs						
Turbidity	20% increase if < 50 NTU, 10% increase if > 50 NTU	1 NTU increase bet. 0-5 NTU, 20% increase if bet. 5-50 NTU, 10 NTU if bet 50-100 NTU, 10% increase if > 100 NTU	5 NTU*/1 NTU monthly average or 5 NTU for two consutive days					
Mercury			2/2 ug/l	2 ug/l		0.012 ug/l	2.4 ug/l	0.14/0.15 ug/l (Fish & Water/Fish Consumption)
Molybdenum		0.015 mg/l 0.010 mg/l monthly mean		0.040 mg/l	0.010 mg/l			
Toxicity	All water shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life.							
Applicable BUs	AGR, IND, PRO, REC-1. REC-2, WARM, WILD, RARE, GWR	MUN, AGR (Irrigation & stock watering), PRO, REC-1. REC-2, WARM, MIGR (Warm & Cold), SPWN (Warm), WILD						

TLBP = Water Quality Control Plan for the Tulare Lake Basin
SJRBP = Water Quality Control Plan for the San Joaquin River
SJR = San Joaquin River from the mouth of the Merced R. to Vernalis
SNARL = Suggested No-Adverse Response Level
* DHS MCL for Turbidity is a secondary standard

Criteria for mineral quality of irrigation water:

Constituent	Class I	Class II	Class III
TDS (mg/l)	<700	700-2000	>2000
EC (umhos/cm)	<1000	1000-3000	>3000
Chlorides (mg/l)	<175	175-350	>350
Sodium % Base Constituents	<60	60-75	>75
Boron (mg/l)	<0.5	0.5-2	>2

Developed by the Regional Salinity Laboratories of the U. S. Department of Agriculture in cooperation with the University of California

to. Boron obj — there is a boron effluent limit which is that there should not be more than 1 mg/l boron in discharges to surface waters which recharge good quality

TLBP = Standards from the Water Quality Control Plan (Basin Plan) for the Tulare Lake Basin. The Panoche and Silver Creeks fall under Westside Streams as described in the Basin Plan. Westside streams have the following beneficial uses: Agricultural Supply, Industrial Service Supply, Industrial Process Supply, Contact Water Recreation, Non-Contact Water Recreation, Warm Water Habitat, Wildlife Habitat, Preservation of Rare and Endangered Species, and Ground Water Recharge.

SJRBP = Standards from the Water Quality Control Plan for the San Joaquin River. Panoche Creek may affect the quality of the San Joaquin River through surface flows from the Fresno Slough or through subsurface flows. The Panoche Creek may not adversely affect the beneficial uses of the San Joaquin River. The objectives listed in the table are for the San Joaquin River at Vernalis because that is where there are standards for boron and selenium. The San Joaquin River at Vernalis has the following beneficial uses: Municipal Supply, Agricultural Supply (for irrigation and stock watering), Industrial Process Supply, Contact Water Recreation, Non-Contact Water Recreation, Warm Water Habitat, Fish Migration (for both warm water and cold water species), and Fish Spawning (for warm water species), and Wildlife Habitat. The beneficial uses at Mendota Pool include the above and Cold Water Spawning.

Sediment Objective (as found in both the San Joaquin River and the Tulare Lake Basin plans) = The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.

Toxicity Objective (as found in both the San Joaquin River and the Tulare Lake Basin plans) = All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life. This objective applies regardless of whether the toxicity is caused by a single substance or the interactive effect of multiple substances. Compliance with this objective will be determined by analyses of indicator organisms, species diversity, population density, growth anomalies, biotoxicity tests of appropriate duration, or other methods as specified by the Regional Water Board. The Regional Water Board will also consider all material and relevant information submitted by the discharger and other interested parties and numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U. S. Food and Drug Administration, the National Academy of Sciences, the U. S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective.

The survival of aquatic life in surface waters subjected to a waste discharge or other controllable water quality factors shall not be less than that for the same water body in areas unaffected by the waste discharge, or, when necessary, for other control water that is consistent with the requirements for "experimental water" as described in Standard Methods for the Examination of Water And Wastewater. As a minimum, compliance with this objective as stated in the previous sentence shall be evaluated with a 96-hour bioassay.

In addition, effluent limits based upon acute biotoxicity tests of effluents will be prescribed where appropriate; additional numerical receiving water quality objectives for specific toxicants will be established as sufficient data become available; and source control of toxic substances will be encouraged.

MCL = Maximum Contaminant Level for drinking water. The State standards are set by the Department of Health Services and the federal standards are set by EPA. All standards are primary (prolonged exposure may cause health effects) except for the state turbidity standard. That standard is secondary (consumer acceptance standard based on taste, odor, or appearance). These standards are used for waters with a MUN beneficial use.

USEPA SNARL = EPA Suggested No Adverse Response Level. These criteria are for human health effects and apply to waters with a MUN beneficial use.

Ag. WQ Goal = these are from Ayers, R. S. and D. W. Westcot, "Water Quality for Agriculture", Food and Agriculture Organization of the United Nations - Irrigation and Drainage Paper No. 29, Rev. 1, Rome (1985). These levels are recommended to avoid harmful effects and loss of productivity of crops and stock. These apply to waters with an AGR beneficial use.

USEPA 4-day Ambient and 1-hr Ambient Water Quality Criteria - These apply to waters with either WARM or COLD beneficial uses.

USEPA Non-Cancer Public Health - These values apply to waters with either WARM or COLD beneficial uses.

Criteria for mineral quality of irrigation water = These classes of water were developed to define the quality of water needed for certain crops. The downstream crops should be assessed to determine the mineral quality class of water necessary.

SECTION IV

FINDINGS

The following section compares the compiled water quality data with State water quality objectives and Federal water quality criteria to determine whether exceedances in these "standards" exist.

Water Quality Assessments: Under authority of Section 319 of the CWA, the Environmental Protection Agency (EPA) has oversight responsabilty to ensure that states's protect their surface waters from nonpoint source impacts. Section 319 requires that each state assess the quality of its surface waters, identify impairments due to NPS pollution and to develop appropriate NPS management programs for these waters.

Panoche Creek and its principal tributary Silver Creek have been listed by the Central Valley Water Quality Control Board (CVWQCB) as impaired by selenium and sediment (1993 Water Qaulity Assessment, 303d list). The listing is based upon water quality monitoring and identified beneficial use impairments. The same report identified San Carlos Creek, a tributary to Silver Creek, as impaired by mercury.

- More.....

- **Findings.....Table VII**
  Disscussion

Table VII: Exceedances In Federal Standards/Criteria or State Numeric/Narrative H2O Qual. Objectives @ Sampling Sites

Sites	TLBP Objectives	SJRBP Objectives	MCL DHS/USEPA	SNARL USEPA	Ag.WQ (goal)	4-Day Amb. WQ Standard or Criteria 3/	1-hr Amb. WQ Crit.	USEPA Non-Can Pu.Health
1						Hg		Hg?
2					Se		Se	
3					Se		Se	
4	Toxicity 2/				Se,Mo,Bo	Se, Mo, Cu, Cr	Se	
5							Se	
6	Toxicity 2/				Se,Mo,Bo	Se, Hg, Cu, Cr	Hg, Se	Hg?
7	Sed 1/						Se	
8	Sed 1/						Se	
9		Sed 1/ Toxicity 2/ Bo,Se 4/	Se	Se	Bo, Mo(?)	Se, Hg		Hg dissovd(?)

1/ Beneficial uses impaired due to sediment deposition during flooding
2/ Exceedances in established federal criteria implies a violation of the basin plan's narrative toxicity objective.
3/ National criteria for the protection of aquatic life (EPA National Criteria, CFR, 12/22/92).
4/ Numeric Objectives

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Removed:
A.R. - GAP

B.2.1 American River, Lower, Group A Pesticides

Summary of Proposed Action

The California Regional Water Quality Control Board, Central Valley Region, (Regional Board) recommends the removal of the lower American River from California's Clean Water Act Section 303(d) list due to impairment by Group A Pesticides. Information available to the Regional Board on Group A Pesticides levels indicates that water quality objectives are being attained. The description for the basis for this determination is given below.

Watershed Characteristics

The lower American River flows from Folsom Dam, approximately 30 miles east of Sacramento, through the greater Sacramento area to its confluence with the Sacramento River, near downtown Sacramento.

Water Quality Objectives Attained

The narrative objective for pesticides and toxicity are being attained for Group A pesticides in the American River. The narrative objective for pesticides states, "No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses." It further states "discharges shall not result in pesticide concentrations in bottom sediments or aquatic life that adversely affect beneficial uses." The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective (CRWQCB-CVR, 1998; http://www.swrcb.ca.gov/~rwqcb5/bsnplnab.pdf)."

The toxicity and pesticide narrative objectives were evaluated for the American River by comparing Group A pesticides concentrations measured in the American River to freshwater fish and marine organism guidelines and criteria that have been developed for both human health and wildlife protection. Group A pesticides consist of a total concentration from the following organochlorine pesticides: aldrin, dieldrin, endrin, heptachlor, heptachlor epoxide, chlordane (total), lindane, hexachlorocyclohexane (total), endosulfan (total), and toxaphene. Group A pesticides bind tightly to soil and break down slowly. They are either insoluble or have low solubility in water, but are lipid soluble thereby accumulating in the fatty tissue of consumers. The Environmental Protection Agency (USEPA) classifies Group A pesticides as toxins, carcinogens, or both (USEPA, 2000b). The National Academy of Sciences-National Academy of Engineering (NAS) numeric Group A pesticides guideline of 100 ng/g (nanograms per gram, or parts per billion (ppb)), applies to whole fish for the protection of fish-eating wildlife (NAS, 1973). The United States Food and Drug Administration (USFDA) set 300 ppb as its numeric action level for the edible portion (filet) of commercial freshwater and marine fish (USFDA, 1984).

Evidence of Attainment

The American River was originally placed on the 303(d) list based on Group A pesticide fish tissue concentrations reported by the Toxic Substances Monitoring Program (TSMP) (SWRCB, 1995). The TSMP analysis of Group A pesticides included aldrin, chlordane (total), dieldrin, endosulfan (total), endrin, hexachlorocyclohexane (total), heptachlor, heptachlor epoxide, and toxaphene. Three out of fifteen fish filet samples had total Group A pesticide concentrations greater than 100 ppb. The average Group A pesticide concentration of all samples, when weighted by the number of fish in each composite sample, was 56.2 ppb. When only considering the total dieldrin and chlordane concentration, the weighted average concentration was 55.7 ppb. Dieldrin and chlordane, therefore, account for almost all of the Group A pesticides historically found in fish in the American River.

Dieldrin and chlordane concentrations in fish tissue were recently analyzed in the American River as part of the Sacramento River Watershed Program (Larry Walker and Associates, 2001b). Seven different composites of fish filets (which included a total of 33 individual fish) were analyzed for total chlordane and dieldrin. Fish tissue data was collected for the SRWP between 1997 and 1999. None of the samples

analyzed exceed fish tissue criteria established by NAS and USFDA (Larry Walker and associates, 2001b). Data from the earlier TSMP studies and the more recent SRWP studies are presented in Table B-1.

Since the earlier TSMP study, upon which the original 303(d) listing was based, showed that dieldrin and chlordane were the dominant Group A pesticides found in fish tissue in the American River, a direct comparison between the TSMP studies and the more recent SRWP studies can be made. The more recent SRWP information indicates that dieldrin/total chlordane concentrations have been reduced by approximately a factor of 7 and that available criteria are not being exceeded.

Table B-1. Summary of Group A Pesticide Concentrations in Fish Tissue Samples

Data Source	Sample Years	# of Composites/ Individuals Analyzed (Total # of Fish)	Mean Dieldrin & Chlordane Pesticide Concentration	Range Dieldrin/ Chlordane Pesticide Concentration	Criteria[a]		Percent of Samples Above Criteria
TSMP[b]	1979 - 1990	15 (74)	55.7 ppb	nd – 191.3 ppb	USFDA	300 ppb	0%
					NAS	100 ppb	20%
SRWP[c]	1997 - 1999	7 (33)	7.5 ppb	nd – 25.47 ppb	USFDA	300 ppb	0%
					NAS	100 ppb	0%

[a] USFDA-AL = United States Food and Drug Administration action level. NAS = National Academy of Sciences guideline

[b] Sampling locations include American River downstream of the Highway 160 Bridge and American River downstream of Watt Avenue Bridge

[c] Sampling locations include American River at Discovery Park and American River at J Street Bridge

nd = not detected

Extent of Attainment

The entire length of the lower American River, Nimbus Dam to the Sacramento River confluence, attains water quality objectives for Group A pesticides and no longer need be identified on the 303(d) list. In the TSMP studies, fish were collected from the American River at Highway 160 (about river mile 2) and downstream of the Watt Avenue Bridge (about river mile 9.5). In the SRWP studies, fish were collected from the American River at Discovery Park (about river mile 0.2) and J Street (about river mile 6.5). The spatial coverage of the sampling sites for the two studies overlaps sufficiently so that the fish tissue concentrations are comparable.

JANUARY 7, 2001
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SACRAMENTO RIVER
WATERSHED
PROGRAM

Annual Monitoring Report: 1999–2000

Prepared for:

Sacramento River Watershed Program

By:

Larry Walker Associates

DRAFT

F. Organochlorine Pesticides and PCBs in Fish Tissue

i. Background and Available Data Overview

In September and October of 1997-1999, the SRWP monitoring program collected fish from 14 locations and analyzed tissue for concentrations of organochlorine pesticides (DDTs, chlordanes, aldrin, dieldrin, endrin, hexachlorocyclohexanes, hexachlorobenzene, endosulfans, methoxychlor, mirex, and oxadiazinon) and PCB compounds. Monitoring in the Sacramento River watershed for these compounds in fish tissue has been performed previously by the Toxic Substances Monitoring Program (administered by the State Water Resources Control Board) between 1977 and 1996. Studies of these pollutants in fish tissue were also performed in San Francisco Bay in 1994 (Table 25).

The locations of sites monitored in 1997–1999 by the SRWP are illustrated in Figure 29.

Table 25. Fish Contamination Monitoring programs in the Sacramento River Watershed

Program	Monitoring Period	Parameters	# of locations & geographic reference
SRWP	Sep-Oct '97, Sep-Oct '98, Sep-Oct '99	▪ Organochlorine pesticides and PCBs in edible fish tissue	14 fish tissue sites, distributed throughout the watershed
TSMP (SWRCB)	1977–1996	▪ metals, organics, and pesticides in fish	Many sites distributed throughout the watershed
SFBRWQCB	1994	▪ mercury and organochlorines in fish	San Francisco Bay
SF Estuary RMP (SFEI)	1997	▪ mercury and organochlorines in fish	San Francisco Bay

ii. Spatial Distribution & Patterns

The concentrations of organochlorines accumulated in fish tissue are dependent on a number of factors in addition to exposure to these compounds, including species and trophic level, age, size, and tissue lipid concentrations. The species and size of fish analyzed for this study varied by location, and it is difficult to describe purely spatial variation independent of these factors. The results of SRWP 1997 monitoring for organochlorines in fish tissue are summarized in Table 26 and Figure 30, and summarized below.

Aroclors: Aroclors were detected in 56% of all samples analyzed, and were most frequently detected in samples from the Sacramento River at River Mile 44 and from the American River at Discovery Park. Aroclor concentrations tended to be lower in fish from upper watershed sites, and were not detected in samples from the Sacramento River

above Bend Bridge and Colusa, and Sacramento Slough. Aroclor concentrations tended to be highest in white catfish, lowest in the two carp samples, and similar in the other four species captured (rainbow trout, largemouth bass, Sacramento pikeminnow, and Sacramento sucker). The highest single tissue concentration of aroclors reported was in a white catfish sample from the American River at Discovery Park.

Chlordanes: Chlordanes were detected in 50% of all samples analyzed, and were most frequently detected in samples from the lower Sacramento River (Veterans Bridge and River Mile 44). Concentrations tended to be lower in fish from upper watershed sites, and were not detected in samples from the Sacramento River at Colusa and above Bend Bridge, or from Colusa Basin Drain. The highest chlordane concentrations were reported in white catfish and Sacramento pikeminnow. Chlordane concentrations were lower and similar in the other four species. The highest single concentration reported was in a Sacramento pikeminnow sample from the American River at Discovery Park.

DDTs: DDTs were detected in all samples analyzed. The highest DDT concentrations were reported in common carp and white catfish. The highest tissue concentration reported was in a single carp sample collected from the Colusa Basin Drain. Concentrations tended to be lower in fish from upper watershed sites. The next highest single concentration was in a white catfish sample from the Sacramento River at Mile 44. The lowest mean concentrations were observed in the Sacramento River at Bend Bridge and Hamilton City, and in the American river at J Street..

Dieldrin: Dieldrin were detected in only 27% of samples analyzed. It was not detected in samples from Natomas East Main Drain, Putah Creek, or the American River at J Street, and was detected in only one of nine samples from the Sacramento River from Keswick to Colusa. The highest dieldrin concentration was reported in a single carp sample from Colusa Basin Drain. Concentrations were much lower and in the other five species, and were lowest in trout and Sacramento sucker.

iii. Temporal Distribution & Patterns

There are currently insufficient data available to assess seasonal or long-term temporal trends in the concentrations of organic chemicals in fish tissue.

iv. Attainment of Beneficial Uses and Potential Impairment

Concentrations of organochlorine compounds in fish tissue were compared to FDA Action Levels (applicable to commercially-caught fish) and USEPA national screening values (SFRWQCB *et al.* 1995, USEPA 1995, USEPA 1998) adjusted for a fish consumption rate of 30 g/day and an updated PCB cancer slope factor (SFEI 1999). Exceedance of screening values is considered an indication that more intensive site-specific monitoring or evaluation of human health risks should be conducted (SFEI 1999). Note that these risk-based human health limits are based on assumptions of specific fish consumption rates that are typically averages for the general population. For individuals or populations (e.g. sport fisherman or some ethnic populations) consuming

more fish than assumed for a specific limit or screening value, the risk of adverse health effects is increased.

Concentrations of all organochlorines in SRWP-collected fish were well below FDA Action Levels for these compounds (Table 26). Concentrations of aroclors exceeded the SFRWQCB screening value (23 ng/g wet weight) in 15% of all samples, including samples from four of the fourteen sites, and in three of the six species analyzed. The screening value for chlordanes (18 ng/g wet weight) was not exceeded in any sample. The screening value for DDTs (69 ng/g wet weight) was exceeded in 10% of all samples, including samples from three of fourteen sites, and in three of the six species analyzed. Dieldrin exceeded the screening value (1.5 ng/g) in 16% of all samples, including samples collected from five of fourteen sites and in four of the six species analyzed. Samples collected from the Sacramento River from Keswick to Colusa exceeded screening values in only one sample (aroclors in one Rainbow trout sample from the Sacramento River below Keswick). In general, exceedances of screening values were more frequent in the lower watershed.

There are several waterbodies included on the 1998 California 303(d) list for organochlorine compounds (Table 27). Levels of organochlorines in SRWP samples from the Feather River and American River suggest levels of these chemicals may not be sufficiently high in fish tissue to warrant 303(d) listing at these sites, but additional data are required to fully evaluate potential human health risks. Results from the monitoring conducted in 2000 and planned for 2001 will provide additional data. This monitoring has been designed in concert with OEHHA to provide the more complete data needed to evaluate attainment of beneficial uses and the need for fish consumption advisories in the lower Sacramento River watershed.

vi. Conclusions and Recommendations

- Data collected by the SRWP indicated the need for continued monitoring to assess the potential for human health risks related to consumption of fish, particularly in the lower Sacramento River watershed.
- Although concentrations of organochlorines did not exceed FDA Action Levels in any samples, concentrations of aroclors, DDTs, and dieldrin exceeded screening values in fish collected from eight locations, primarily in the lower watershed.
- Monitoring of organochlorine compounds in fish tissue has been continued for 2000-2001 monitoring.

Table 26. Organochlorines in Fish Tissue: Regulatory Limits, Screening Values, and Summary of SRWP Data (1997-1999)

	PCBs (Sum of Aroclors)	Sum of Chlordanes	Sum Of DDTs	Dieldrin
Updated USEPA Screening Values[a] (SFRWQCB *et al.* 1995)	23 ng/g	18 ng/g	69 ng/g	1.5 ng/g
FDA Action Levels[b]	2000 ng/g	300 ng/g	5000 ng/g	300 ng/g
Total number of samples analyzed (1997 – 1999)	48	48	48	48
Number of samples exceeding screening value	7	0	5	8
Percent of samples exceeding screening value	15%	0%	10%	16%
Species exceeding screening value	Carp, trout, white catfish	None	Carp, largemouth bass, Sacramento sucker, white catfish	Carp, largemouth bass, Sacramento pikeminnow, white catfish
Sites[(c)] exceeding screening value	SRBKR NEMDR ARDPK SRRMF	None	COLDR PUTAH SRRMF	COLDR SACSL ARDPK SRRMF CCHSL
Sites exceeding no screening values	SRABB, SRHAM, SRCOL, SRVET, FRNIC, ARJST			

(a) Screening value is based on a consumption rate of 30 g/day.
(b) FDA Action Level is based on a consumption rate of 6.5 g/day.
(c) Sites in downstream order: SRBKR–Sac. River below Keswick; SRABB–Sac. River at Bend Bridge; SRHAM–Sac. River at Hamilton City; SRCOL–Sac. River at Colusa; SRVET–Sac. River at Vets Bridge; COLDR–Colusa Basin Drain; SACSL–Sacramento Slough; Feather River near Nicolaus; ARJST–Amercian River at J Street; NEMDR–Natomas East Main Drain; ARDPK–American River at Discovery Park; PUTAH–Putah Creek; SRRMF–Sac. River at Mile 44; CCHSL–Cache Slough near Ryers Ferry.

Table 27. Waterbodies Cited On California's 1998 303(D) List For PCBs And Organochlorine Pesticides.

Water Body	Cause for 303(d) Listing	Source of Pollution	Size Affected	Unit
Delta Waterways	DDT	Agriculture	480000	Acres
Delta Waterways	Group A Pesticides[(a)]	Agriculture	480000	Acres
American River, Lower	Group A Pesticides	Urban Runoff	23	Miles
Colusa Basin Drain	Group A Pesticides	Agriculture	70	Miles
Feather River, Lower	Group A Pesticides	Agriculture	60	Miles
Natomas East Main Drain	PCBs	Industrial Point Source	12	Miles
Natomas East Main Drain	PCBs	Urban Runoff	12	Miles

(a) Group A pesticides: aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexanes (including lindane), endosulfan, and toxaphene

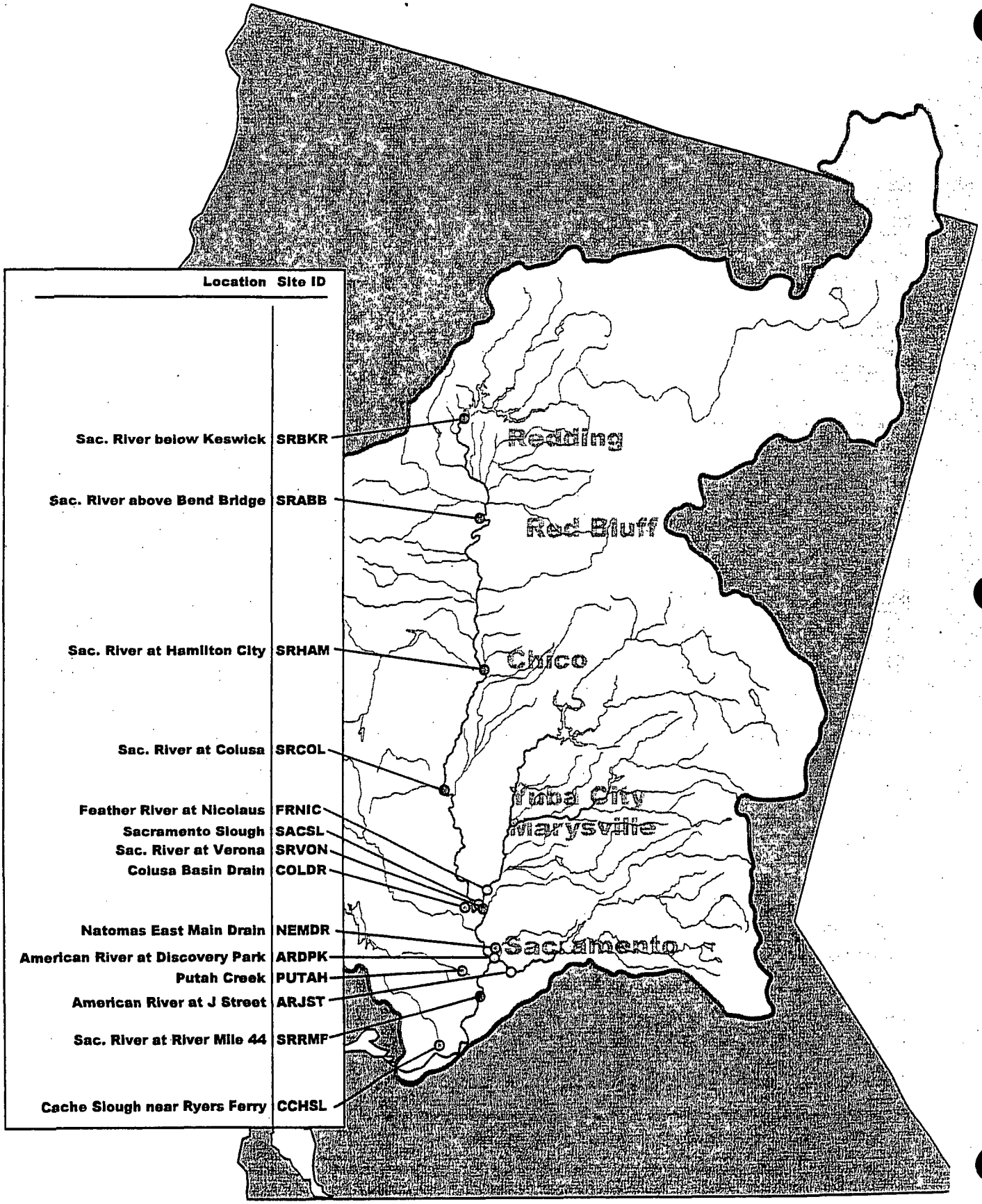

Figure 29. SRWP Monitoring for OrganoChlorines in Fish Tissue: 1997, 1998, and 1999 Monitoring Locations

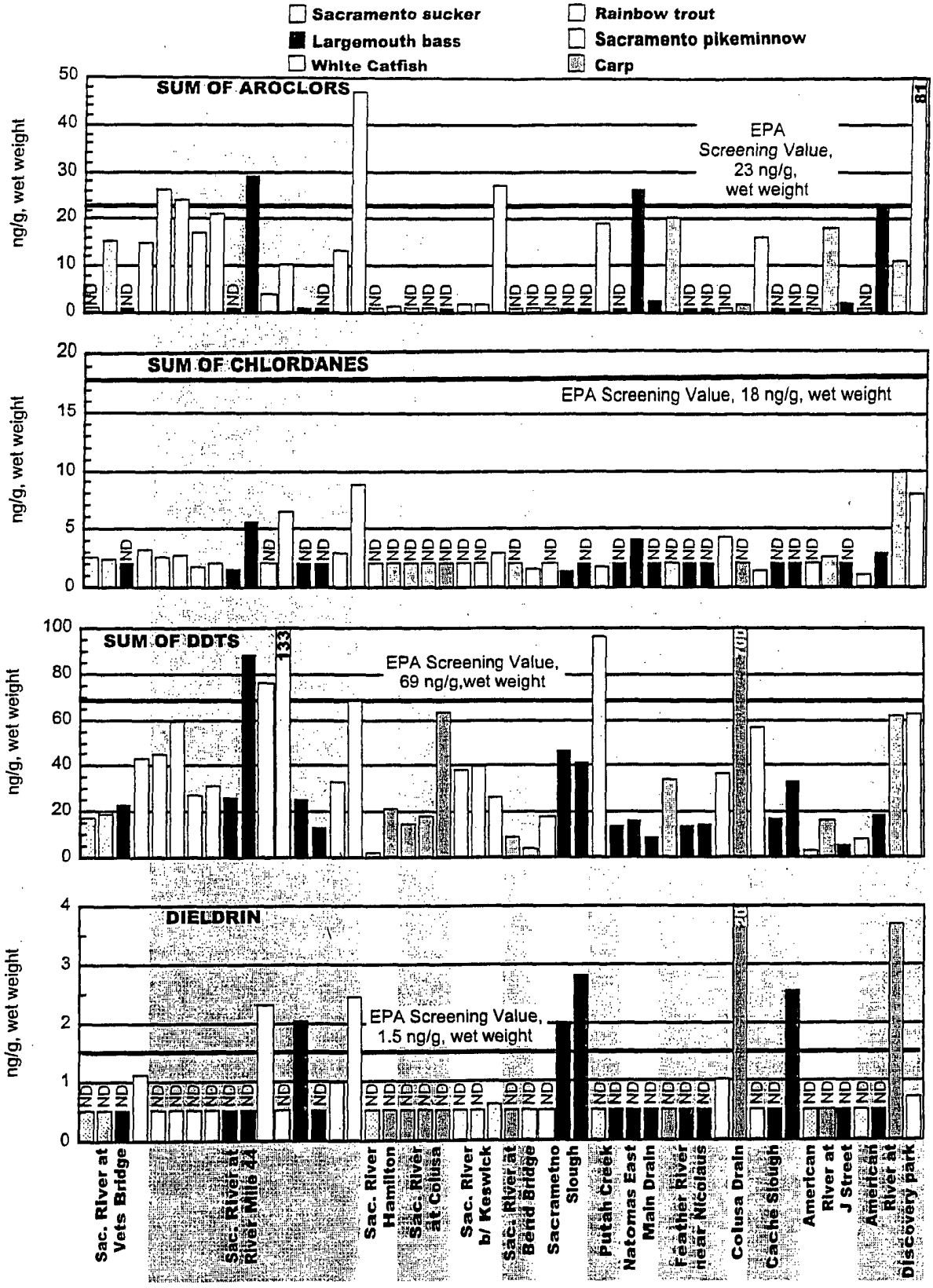

Figure 30. Organochlorines in Fish Tissue: SRWP Data, 1997 - 1999

G. Sediment Toxicity

i. Background and Available Data Overview

Sediment toxicity monitoring was implemented by the SRWP as a pilot project to evaluate sediment toxicity testing as a monitoring tool. This monitoring was performed in September of 1998, April and November of 1999, and May of 2000, at 9 SRWP sites selected to match USGS NAWQA sediment monitoring sites in the Sacramento River watershed. Sediment toxicity monitoring was also performed at an additional 10 sites as part of DWR's intensive tributary monitoring program. Toxicity testing was performed in elutriates of sediment samples with *Ceriodaphnia* (daphnid or water flea) and in bulk sediment samples with *Hyalella* (an amphipod). Sediment collection methods were consistent with USGS methods for collecting surface sediment samples from depositional areas.

There were no other sediment toxicity monitoring efforts in Sacramento River watershed.

ii. Spatial Distribution

No significant mortality to *Hyallela* or *Ceriodaphnia*, or reduction in *Ceriodaphnia* reproduction was observed for any of the sediment elutriate toxicity tests conducted in 1999-2000. The only pattern identifiable in the available data is a general lack of detectable significant sediment toxicity using these methods.

iii. Temporal Distribution

There are insufficient monitoring data to evaluate seasonal or long-term temporal trends in sediment toxicity.

iv. Attainment of Beneficial Uses and Potential Impairment

No Sacramento River watershed waterbodies are listed on the California 1998 303(d) list of impaired waterbodies due to concerns regarding sediment toxicity. Because currently available data cover only a limited time period and spatial scope, they do not provide conclusive information regarding the attainment of beneficial uses affected by sediment toxicity. However, within the limitations of this monitoring effort, the preliminary results indicate that sediments collected from depositional zones from the Sacramento River mainstem and major tributaries generally did not cause toxicity to test organisms. While this result can not be considered conclusive and can not be readily extrapolated to all of the watershed, this result is generally consistent with the attainment of related beneficial uses, and clearly does not indicate widespread impairment of beneficial uses.

V. Conclusions, Recommendations

- No sediment toxicity was observed in any samples from mainstem Sacramento River sites. Only one sample (collected at the Feather River at Nicolaus site in September

1998) was found to be toxic to *Hyallela* in bulk sediment tests. Although not conclusive, the available data provide no evidence that suggests potential impairment of beneficial uses in the Sacramento River watershed.

- No spatial or temporal patterns of sediment toxicity were identified in the available data.
- This monitoring element was undertaken as a pilot project designed to evaluate the value of sediment toxicity testing in identifying potential sources of toxic pollutants, and to assess the occurrence and distribution of sediment toxicity. Based on the results of the 1998–2000 monitoring efforts, it was concluded by the Monitoring Sub-committee that data from this type of monitoring was difficult to interpret on a local or regional scale. Therefore, sediment toxicity testing was not ranked as a high priority tool for assessing the attainment of beneficial uses in the watershed. This pilot program was not continued in 2000-2001.

Comments

303dlist - Head

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by gwgate.swrcb.ca.gov; Mon, 01 Oct 2001 20:25:25 -0700
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by swrcb10.swrcb.ca.gov (8.9.3+Sun/8.9.3) with SMTP id QAA07309
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Mon, 1 Oct 2001 16:56:14 -0700 (PDT)
(envelope-from msexton@minasianlaw.com)
Message-ID: <01c101c14ad4$fc0cbd20$07fea8c0@Newedgenetworks.com>
Reply-To: "Michael Sexton" <msexton@minasianlaw.com>
From: "Michael Sexton" <msexton@minasianlaw.com>
To: <303dlist@rb5s.swrcb.ca.gov>
Cc: "Steve Chedester" <sjrecwa@inreach.com>
Subject: 303d comments
Date: Mon, 1 Oct 2001 16:58:35 -0700
MIME-Version: 1.0
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X-MSMail-Priority: Normal
X-Mailer: Microsoft Outlook Express 5.00.2615.200
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303dlist - Part.(

I submitted comments by fax on May 15, 2001 on behalf of the Exchange Contractors. I do not see their comments in the staff report available on line. Are you able to confirm that the comments were received and, if so, why weren't they included?

Michael Sexton
Minasian, Spruance, Baber, Meith, Soares & Sexton, LLP
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From: "Michael Sexton" <msexton@minasianlaw.com>
To: <303dlist@rb5s.swrcb.ca.gov>
Date: Mon, Oct 1, 2001 8:26 PM
Subject: 303d comments

I submitted comments by fax on May 15,2001 on behalf of the Exchange Contractors. I do not see their comments in the staff report available on line. Are you able to confirm that the comments were received and, if so, why weren't they included?

Michael Sexton
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CC: "Steve Chedester" <sjrecwa@inreach.com>

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by gwgate.swrcb.ca.gov; Thu, 04 Oct 2001 13:20:37 -0700
Received: from fw1ro7.r1.fws.gov (fw1ro7.r1.fws.gov [164.159.11.19])
by swrcb10.swrcb.ca.gov (8.9.3+Sun/8.9.3) with SMTP id LAA07058
for <303dlist@rb5s.swrcb.ca.gov>; Thu, 4 Oct 2001 11:51:11 -0700 (PDT)
From: Steven_Schwarzbach@fws.gov
Subject: California Clean Water Act Section 303(d) list
To: 303dlist@rb5s.swrcb.ca.gov
Cc: William_Beckon@fws.gov, Daniel_Russell@fws.gov, Thomas_Maurer@fws.gov
X-Mailer: Lotus Notes Release 5.0.6a January 17, 2001
Message-ID: <OFD0043049.7200B26E-ON88256ADB.00677483@r1.fws.gov>
Date: Thu, 4 Oct 2001 11:53:11 -0700
X-MIMETrack: Serialize by Router on FW1RO7/R1/FWS/DOI(Release 5.0.7 |March 21, 2001) at
10/04/2001 11:53:16 AM
MIME-Version: 1.0
Content-type: text/plain; charset=us-ascii

From: <Steven_Schwarzbach@fws.gov>
To: <303dlist@rb5s.swrcb.ca.gov>
Date: Thu, Oct 4, 2001 1:20 PM
Subject: California Clean Water Act Section 303(d) list

Attn.: Joe Karkoski

We have reviewed proposed changes to the California Clean Water Act Section 303(d) list (draft staff report of 27 September 2001). We find no justification for the proposed reduction in priority for selenium in Mud Slough from "high" to "medium." In fact, in the last five years selenium contamination in lower Mud Slough (north) has worsened compared to previous years (see Grassland Bypass Project annual reports). We would also like to point out that the work on Silversides reported by Slotton, et al. (in the EIP Newsletter, 2000) and our own data on mercury concentrations in various fish suggest that Mud Slough may also be impaired with respect to mercury. Because a likely source of mercury in Mud Slough is the New Idria Mercury Mine via San Carlos Creek and Panoche Creek, those creeks should have a higher priority with respect to mercury (see Panguli, et al., 2000. "Mercury speciation in drainage from the New Idria Mine, California." Environ. Sci. & Technol.) and we believe the TMDL end date for them should match that for the San Joaquin River into which mercury from these tributaries eventually discharges at least during flood events.

If you have further questions about this data please contact Bill Beckon of my staff.

As we continue to review the list we may have additional comments.

Steven Schwarzbach, Ph.D.
Chief, Environmental Contaminants Division
Sacramento Fish and Wildlife Office
2800 Cottage Way
room W-2605
Sacramento, California 95825-1846

phone: (916) 414-6591
fax :(916) 414- 6713
email: Steven_Schwarzbach@fws.gov

Contact information for Beckon:

Bill Beckon
U.S. Fish and Wildlife Service
2800 Cottage Way, Suite W-2605
Sacramento, CA 95825-1846

(916) 414-6597

CC: <William_Beckon@fws.gov>, <Daniel_Russell@fws.gov>, <Thomas_Maurer@fws.gov>

303dlist - Head

Received: from swrcb10.swrcb.ca.gov
by gwgate.swrcb.ca.gov; Thu, 04 Oct 2001 14:30:05 -0700
Received: from InterJet.westlandswater.org (Westlands-Water-District.cust-rtr.pacbell.net
[209.232.140.18])
by swrcb10.swrcb.ca.gov (8.9.3+Sun/8.9.3) with SMTP id OAA16302
for <303dlist@rb5s.swrcb.ca.gov>; Thu, 4 Oct 2001 14:27:58 -0700 (PDT)
Received: (from daemon@localhost)
by InterJet.westlandswater.org (8.8.5/8.8.5) id OAA27495;
Thu, 4 Oct 2001 14:29:12 -0700 (PDT)
Received: from UNKNOWN(200.0.0.111), claiming to be "rmmrhodes"
via SMTP by InterJet.westlandswater.org, id smtpdA27490; Thu Oct 4 21:29:03 2001
Reply-To: "Mark Rhodes" <mrhodes@westlandswater.org>
From: "Mark Rhodes" <mrhodes@westlandswater.org>
To: <303dlist@rb5s.swrcb.ca.gov>
Cc: "Thaddeus Bettner" <tbettner@westlandswater.org>
Subject: 303(d) List Draft Report on Recommended Changes: San Luis Reservoir Addition
Date: Thu, 4 Oct 2001 14:29:01 -0700
Message-ID: <NEBBJCLMAMHOMOIJJFDOIEJCCGAA.mrhodes@westlandswater.org>
MIME-Version: 1.0
Content-Type: multipart/alternative;
boundary="----=_NextPart_000_0004_01C14CE0.E91B4BB0"
X-Priority: 3 (Normal)
X-MSMail-Priority: Normal
X-Mailer: Microsoft Outlook IMO, Build 9.0.2416 (9.0.2910.0)
Importance: Normal
X-MimeOLE: Produced By Microsoft MimeOLE V5.50.4522.1200

303dlist - Part.(

The draft report Table 1 and Table 2 include the San Luis Reservoir to be added to the list of impacted bodies of water for 2002.

The following appendix contains no fact sheet to support this addition: Appendix B -

Unless I have overlooked it, I could find no information supporting or detailing why San Luis should be listed as an impacted body of water. Can you provide a link or source that documents why San Luis has been recommended for addition and or a report or data that indicates the source for "copper" contamination. Best Regards Mark Rhodes Associate Resources Analyst Westlands Water District

From: "Mark Rhodes" <mrhodes@westlandswater.org>
To: <303dlist@rb5s.swrcb.ca.gov>
Date: Thu, Oct 4, 2001 2:30 PM
Subject: 303(d) List Draft Report on Recommended Changes: San Luis Reservoir Addition

The draft report Table 1. and Table 2. include the San Luis Reservoir to be added
to the list of impacted bodies of water for 2002.

The following appendix contains no fact sheet to support this addition:

Appendix B - Fact Sheets for Recommended Changes to the 303(d) List

Unless I have overlooked it, I could find no information supporting or detailing
why San Luis should be listed as an impacted body of water. Can you provide a link or source that documents why San Luis has been recommended for addition
and or a report or data that indicates the source for "copper" contamination.

Best Regards

Mark Rhodes
Associate Resources Analyst
Westlands Water District
mrhodes@westlandswater.org

CC: "Thaddeus Bettner" <tbettner@westlandswater.org>

303dlist - Head

Received: from swrcb10.swrcb.ca.gov
by gwgate.swrcb.ca.gov; Mon, 08 Oct 2001 10:57:27 -0700
Received: from InterJet.westlandswater.org (Westlands-Water-District.cust-rtr.pacbell.net
[209.232.140.18])
by swrcb10.swrcb.ca.gov (8.9.3+Sun/8.9.3) with SMTP id KAA06038
for <303dlist@rb5s.swrcb.ca.gov>; Mon, 8 Oct 2001 10:55:16 -0700 (PDT)
Received: (from daemon@localhost)
by InterJet.westlandswater.org (8.8.5/8.8.5) id KAA23713
for <303dlist@rb5s.swrcb.ca.gov>; Mon, 8 Oct 2001 10:55:08 -0700 (PDT)
Received: from UNKNOWN(200.0.0.111), claiming to be "rmmrhodes"
via SMTP by InterJet.westlandswater.org, id smtpdb23704; Mon Oct 8 17:55:05 2001
From: "Mark Rhodes" <mrhodes@westlandswater.org>
To: "303dlist 303dlist" <303dlist@rb5s.swrcb.ca.gov>
Subject: RE: 303(d) List Draft Report on Recommended Changes: San LuisReservoir Addition
Date: Mon, 8 Oct 2001 10:55:05 -0700
Message-ID: <NEBBJCLMAMHOMOIJJFDOGEJKCGAA.mrhodes@westlandswater.org>
MIME-Version: 1.0
Content-Type: text/plain;
charset="iso-8859-1"
Content-Transfer-Encoding: 7bit
X-Priority: 3 (Normal)
X-MSMail-Priority: Normal
X-Mailer: Microsoft Outlook IMO, Build 9.0.2416 (9.0.2910.0)
Importance: Normal
X-MimeOLE: Produced By Microsoft MimeOLE V5.50.4522.1200
In-Reply-To: <sbbd67df.038@gwgate.swrcb.ca.gov>

From: "Mark Rhodes" <mrhodes@westlandswater.org>
To: "303dlist 303dlist" <303dlist@rb5s.swrcb.ca.gov>
Date: Mon, Oct 8, 2001 10:57 AM
Subject: RE: 303(d) List Draft Report on Recommended Changes: San LuisReservoir Addition

Did DWR identify the contamination source? Did USBR comply or recognize the problem area?

Is a copy or the report available from DWR?

Mark Rhodes

-----Original Message-----
From: 303dlist 303dlist [mailto:303dlist@rb5s.swrcb.ca.gov]
Sent: Friday, October 05, 2001 7:57 AM
To: mrhodes@westlandswater.org
Subject: Re: 303(d) List Draft Report on Recommended Changes: San LuisReservoir Addition

The San Luis Reservoir was mistakenly left on the draft 303(d) list for impairment due to elevated copper levels. We will not include it in our final recommendations to the State Water Resources Control Board. Our original solicitation for information included a cutoff date of May 15, 2001 for submittal of information. We received information from the Department of Water Resources after May 15, 2001, which indicated that copper levels were above US EPA standards. Since the information was received after the cutoff date, we can not use it as the basis for our recommendations for changes to the 303(d) list. If you have any other questions, you may contact me at (916) 255-3368.

Joe Karkoski

Received: from swrcb10.swrcb.ca.gov
by gwgate.swrcb.ca.gov; Thu, 01 Nov 2001 16:44:34 -0800
Received: from nccn6.nccn.net (nccn6.nccn.net [209.79.220.19])
by swrcb10.swrcb.ca.gov (8.9.3+Sun/8.9.3) with SMTP id QAA13163
for <303dlist@rb5s.swrcb.ca.gov>; Thu, 1 Nov 2001 16:42:05 -0800 (PST)
Received: from nccn3.nccn.net (IDENT:root@nccn3.nccn.net [209.79.220.13])
by nccn6.nccn.net (8.11.6/8.11.6/*rGs*A1* NO SPAM! Ver: Tue Aug 21 12:25:34 PDT 2001) with ESMTP id fA20iVd25621
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by nccn3.nccn.net (8.11.6/8.11.6/*rGs*A1* NO SPAM! Ver: Tue Aug 21 17:07:25 PDT 2001) with SMTP id fA20iU808651
for <303dlist@rb5s.swrcb.ca.gov>; Thu, 1 Nov 2001 16:44:30 -0800
Received: by localhost with Microsoft MAPI; Thu, 1 Nov 2001 16:44:29 -0800
Message-ID: <01C162F4.79DF8AC0.chatigny@nid.dst.ca.us>
From: Jim Chatigny <chatigny@nid.dst.ca.us>
Reply-To: "chatigny@nid.dst.ca.us" <chatigny@nid.dst.ca.us>
To: "'303dlist@rb5s.swrcb.ca.gov'" <303dlist@rb5s.swrcb.ca.gov>
Subject: California Clean Water Act Section 303(D) list
Date: Thu, 1 Nov 2001 16:44:28 -0800
Organization: Nevada Irrigation District
X-Mailer: Microsoft Internet E-mail/MAPI - 8.0.0.4211
MIME-Version: 1.0
Content-Type: text/plain; charset="us-ascii"
Content-Transfer-Encoding: 7bit

The Nevada Irrigation District files the following comments concerning the proposed changes to California Clean Water Act Section 303(D) Draft Staff Report.

The District would urge the Board and staff that as studies are implemented to more closely define The constituents suspected of water quality degradation that qualified scientific methods be used To verify specific levels that are purported to be the primary causes for water quality concerns.

It would be extremely important that any scientific data collected would meet a peer review by a Panel with credentials within the scope of the contaminant species and a definitive corrective process For the findings. Review, data collection and analyses need to be of a suitable duration to make the Study creditable, which would make the peer review fully identifiable.

Thank you for the opportunity to submit this short comment and district staff will be available to offer Whatever support may be necessary to complete studies of waters used by the Nevada Irrigation District.

James P Chatigny, General Manager
Nevada Irrigation District
P.O. Box 1019
Grass Valley CA 95945
530/273-6185

From: Jim Chatigny <chatigny@nid.dst.ca.us>
To: "'303dlist@rb5s.swrcb.ca.gov'" <303dlist@rb5s.swrcb.ca.gov>
Date: Thu, Nov 1, 2001 4:44 PM
Subject: California Clean Water Act Section 303(D) list

The Nevada Irrigation District files the following comments concerning the proposed changes to California Clean Water Act Section 303(D) Draft Staff Report.

The District would urge the Board and staff that as studies are implemented to more closely define The constituents suspected of water quality degradation that qualified scientific methods be used To verify specific levels that are purported to be the primary causes for water quality concerns.

It would be extremely important that any scientific data collected would meet a peer review by a Panel with credentials within the scope of the contaminant species and a definitive corrective process For the findings. Review, data collection and analyses need to be of a suitable duration to make the Study creditable, which would make the peer review fully identifiable.

Thank you for the opportunity to submit this short comment and district staff will be available to offer Whatever support may be necessary to complete studies of waters used by the Nevada Irrigation District.

James P Chatigny, General Manager
Nevada Irrigation District
P.O. Box 1019
Grass Valley CA 95945
530/273-6185

JKark

MINASIAN, SPRUANCE, BABER, MEITH, SOARES & SEXTON, LLP

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WILLIAM H. SPRUANCE, INC.
WILLIAM H. BABER III INC.
JEFFREY A. MEITH
M. ANTHONY SOARES
MICHAEL V. SEXTON

LISA A. GRIGG

TELEPHONE: (530) 533-2885
FACSIMILE: (530) 533-0197

ATTORNEYS
A Partnership Including Professional Corporations

1681 Bird Street
P.O. Box 1679
Oroville, CA 95965-1679

Writer's E-MAIL: msexton@minasianlaw.com

October 23, 2001

Joe Karkoski, 303(d) List Update Coordinator
California Regional Water Quality Control Board
Central Valley Region
3443 Routier Road, Suite A
Sacramento, California 95827-3003

Re: ***Notice of Availability of Draft Staff Report on Recommended Changes to California's Clean Water Act §303(d) List and Request for Comments***

Dear Mr. Karkoski:

This responds to the Regional Water Quality Control Board's September 27, 2001, Notice of Availability of Draft Staff Report on Recommended Changes to California's Clean Water Act §303(d) List and Request for Comments.

On May 15, 2001, in response to the Regional Board's public solicitation of water quality information, we submitted comments on behalf of the San Joaquin River Exchange Contractors Water Authority and its members Central California Irrigation District, San Luis Canal Company, Firebaugh Canal Water District and Columbia Canal Company.

On October 2, 2001, in response to my inquiry, you confirmed that the Regional Board had received our comments. You stated, however, that our comments, "appeared to address a number of issues outside of the scope of the solicitation for information for the 303(d) list. Your comments have been forwarded to staff working on the salinity issues in the San Joaquin Basin and they will prepare a response to the issues you have raised."

While we thank you for your response to our inquiry, we are forced to take issue with your characterization that our comments should be considered outside of the scope of the 303(d) list. Quite the contrary, the comments pointed to the anomaly that we feel must be addressed. That is, the Regional Board, and USEPA cannot, in our view, ignore the fact that, in the 1930's, Congress approved the development of the Central Valley Project and the Friant Unit almost 30 years before Congress adopted the Clean Water Act. We pointed to this anomaly in our May 15, 2001, comments and, with all due respect, we say again that blind adherence to a 303(d) submission for the San Joaquin River without acknowledging the role of Congress in the significant manmade changes to the San Joaquin River makes little sense.

We intend to make similar comments to USEPA and we respectfully request that the Regional Board tell us why it feels it must blindly include the San Joaquin River on its 303(d) submission to USEPA without acknowledging the role of Congress in the development of the CVP, the purchase of Miller and Lux water rights on the San Joaquin River, and the construction of Friant Dam all of which Congress knew would remove over 1.5 million acre-feet of water a year from the mainstem of the San Joaquin River, and dry up a portion of the river between Friant Dam and Gravelly Ford.

Very truly yours,

MINASIAN, SPRUANCE, BABER, MEITH, SOARES & SEXTON, LLP.

By: _____
MICHAEL V. SEXTON

MVS/bgt
cc: Senator Dianne Feinstein
Senator Jim Costa
Senator Dick Monteith
Assembly Member Dennis Cardoza
Christine Todd Whitman, USEPA Administrator
Kirk Rodgers, Acting Regional Director, United States Bureau of Reclamation
Arthur Baggett, Chairman, State Water Resources Control Board
Gary Carlton, Executive Officer, Central Valley RWQCB
Rudy Schnagl, Central Valley RWQCB
Steve Chedester, Executive Director, San Joaquin River Exchange Contractors
Chris White, Manager, Central California Irrigation District
Jeff Bryant, Manager, Firebaugh Canal Water District
Randy Houk, Manager, Columbia Canal Company
Hank White, Manager, San Luis Canal Company

201 North Civic Drive
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JK

BROWN AND CALDWELL

October 31, 2001

Joe Karkoski
303(d) List Update Coordinator
California Regional Water Quality Control Board
Central Valley Region
3443 Routier Road, Suite A
Sacramento, California 95827-3003

21347-009

Subject: Draft Staff Report

Dear Mr. Karkoski:

As representatives of the Turlock Irrigation District (TID), we would like to comment on the Draft Staff Report on Recommended Changes to California's Clean Water Act Section 303(d) List (Report). In particular, we disagree with the addition of Don Pedro Lake and the Lower San Joaquin River to the 303(d) List due to impairment by mercury. We also have issue with continued listing of the Harding Drain as impaired, since the drain is not a water of the U.S. and since uses and water quality objectives have not been appropriately designated for those waters. The final 303(d) List should not include listings for Don Pedro Lake and San Joaquin River for mercury, nor listing of the Harding Drain for any constituents.

A brief summary of our position follows, with a detailed presentation below,

Don Pedro Lake listing for mercury is flawed for several reasons:

- Data used to support the listing are outdated and are not spatially representative of the entire Lake.
- Only a portion of the available data were actually used (Trophic Level 4), which erroneously skewed the results.
- The EPA methyl mercury criterion has been applied arbitrarily, without any consideration of site-specific factors and in violation of federal and state substantive and procedural requirements.

- There is no evidence of impairment because no health or environmental agency has issued a fish consumption advisory for Don Pedro Lake.

Lower San Joaquin River listing for mercury is also flawed.

- The data used to support the listing are limited.
- The EPA methyl mercury criterion has been applied arbitrarily, without any consideration of site-specific factors and in violation of federal and state substantive and procedural requirements.

There was never a basis for including the Harding Drain on the 303(d) list and it should be removed.

- The Harding Drain is not a water of the U.S.
- Beneficial uses were inappropriately assigned to Harding Drain without substantive or procedural legal process.

I. Don Pedro Lake Listing

Don Pedro Lake should not be included on the 303(d) List because the evidence to support such a listing is outdated and inconclusive and there is no evidence of use impairment. In addition, arbitrary application of EPA mercury guidance values as numeric mercury standards for the Lake is erroneous and violates legal requirements.

For Don Pedro Lake, the Report presents data collected from the northernmost arm of the Lake (Moccasin Creek, the Tuolumne River, and Woods Creek) between 1981 and 1987 during the Toxic Substances Monitoring Program or TSMP (SWRCB, 1995). Data from a very limited area of the Lake have been extrapolated to the entire 12,960-acre Lake, under the juxtaposition that other tributaries to the Lake are also mercury sources. In addition, the mercury data collected from Don Pedro Lake are 14 to 20 years old. Other states have rejected 303(d) listings based on such outdated evidence, ruling that sufficient evidence of current impairment must exist to justify the listing. [*See Sierra Club v. United States E.P.A.,* (D.C. Md) CV:WMN-97-3838 (Sept. 2001), which denied petitioner's request to list additional waters as impaired based on data from a 1984 toxic hot spots list because there was no evidence of current impairment.] Further, requirements that each state provide an updated

303(d) list every two years indicates an intent that 303(d) listings be based upon current data evidencing such impairment.

In the Report, a subset of the TSMP mercury data was used to define "evidence of impairment" for the Lake. The Report used data for 32 Trophic Level 4 fish (largemouth bass) that were selected out of the 67 Trophic Level 3 and 4 fish collected from the Lake in 1981 and 1984-1987. By using a subset of the available data, the Report determined an average mercury concentration of 0.54 ppm, versus an average concentration of 0.41 ppm for all the data. The Report compares the average 0.54 mg/kg total mercury concentration to the recent U.S. EPA value for tissue residue criterion (TRC) of 0.3 mg-methyl mercury/kg fish. In making comparisons to the EPA criterion, it would be more appropriate to take an approach similar to the one EPA used to derive the 0.3 mg/kg criterion for methyl mercury, where data from Trophic Levels 2, 3, and 4 were combined. Using Trophic Level 4 fish only is overly conservative, as they tend to concentrate mercury more than lower trophic level fish. So, even if EPA guidance were appropriate, it has been misinterpreted and misapplied to Don Pedro Lake fish data. In addition, there was no effort made in the Report to correlate total mercury measurements with the methyl mercury criterion.

The application of the EPA TRC to waters in California is arbitrary. The EPA value was based on a number of assumptions about reference dose and fish ingestion rate, which vary depending on the location. In the criteria document, it states "the EPA strongly encourages States . . . to consider developing a criterion using local or regional data over default values if they believe that they would be more appropriate for their target population." In fact, the State of Georgia Department of Natural Resources (DNR) has proposed a site-specific method that determines a weighted tissue residue (TRw) for trophic levels present at a given location (Hern, Linda, personal communication, 2001). The Georgia DNR compares TRw results to a criteria range of 0.3 to 2.0 mg/kg. The Report arbitrarily applies the 0.3 mg/kg target, without considering site-specific characteristics.

The Report has presumptively adopted water quality objectives for mercury in violation of federal and state substantive and procedural requirements. The Report states that U.S. EPA's criterion of 0.3 ppm mercury in edible fish tissue will be utilized to determine attainment of the narrative objective. This effectively establishes a numeric methyl mercury objective for this Lake without considering, among other factors, site specific conditions, environmental characteristics, economics, etc. Consideration of these factors, in establishing water quality standards, is required by the Clean Water Act and Porter-Cologne Water Quality Act ("Porter-Cologne"). The utilization of the 0.3 mg/kg numeric mercury level to determine attainment of water quality standards violates federal and state water quality substantive requirements. Because there was no public participation in the development of this numeric mercury

standard, the action also violates federal and state procedural and rulemaking requirements.

Finally, there is no evidence of use impairment for Don Pedro Lake. According to Tuolumne County, there has never been a fish consumption advisory on Don Pedro Lake. A representative of the Tuolumne County Health Department indicated in a recent conversation that he was aware of the proposed 303(d) listing of Don Pedro Reservoir, but was "very surprised" because he did not think that existing data warranted listing (Cruz, Walt, personal communication, October 2001).
A representative from the Office of Environmental Health and Hazard Assessment (OEHHA) indicated that the TSMP data are not intended for health risk analysis and that they had not performed any risk analysis on the Lake (personal communication with Bob Brodberg, October 2001).

The rationale in the Report and the data used are so fatally flawed that the recommended listing for Don Pedro Lake must be stricken. The legal errors, substantive and procedural, mandate Don Pedro Lake not to be included in the 303(d) List of impaired waters.

II. Lower San Joaquin River Listing

The foregoing concerns and rationale about applying an arbitrary standard of 0.3 mg/kg methyl mercury to Don Pedro Lake are also relevant for the San Joaquin River. The Lower San Joaquin River should not be added to the 303(d) List, because there is no evidence of current impairment, no evidence of use impairment and the proposed listing would establish numeric water quality standards for this River without adhering to substantive and procedural requirements.

III. Harding Drain Listing

The Harding Drain is not a water of the U.S., so should not be included on the 303(d) List. The "beneficial uses" purportedly assigned to Harding Drain were adopted "*sub rosa*," without substantive or procedural legal process, and, therefore, are void *ab initio* so the Harding Drain cannot be listed due to impairment of illegally designated uses.

A. Description of Waters. The Report incorrectly presumes that the Harding Drain is the same as "Turlock Irrigation District Lateral No.5 (TID 5)." This is not accurate. TID 5 and the Harding Drain are separate, distinct elements of the TID irrigation system. Turlock Irrigation District Lateral #5 is a lined canal that discharges into the Ceres Main, which then discharges at Drop 32 into the Harding Drain, an un-lined

ditch. The Report's description of the water body purportedly impaired as either the Harding Drain or TID #5 is erroneous, rendering it impossible to determine which water is actually intended to be listed. The listing is vague and ambiguous and, therefore, neither the Harding Drain nor TID #5 should be included on the 303(d) List.

B. Harding Drain Is Not A Water Of The U.S. Assuming, arguendo, that the proposed 303(d) listing is for Harding Drain, we submit numerous additional factual, scientific and legal errors which warrant delisting the Harding Drain. (Many of the same facts and rationale also would apply if TID #5 were proposed for listing.) The Harding Drain is part of TID's irrigation system. TID's water releases into the canals fluctuate greatly, depending upon grower's actual needs and demands for water during the irrigation season. The Harding Drain was designed to intercept and convey irrigation return flows and high groundwater. Accordingly, the flows in the Harding Drain fluctuate depending upon irrigation return flows, stormwater or groundwater drainage present. The United States Supreme Court has limited Clean Water Act jurisdiction to navigable waters. *See Solid Waste Agency of Northern Cook County v. United States Army Corps. of Eng'rs*, 531 U.S. 159 (2001). Even the Ninth Circuit Court limited jurisdictional waters to irrigation canals that were interconnected with natural streams, and even used natural streams as part of the conveyance system so that the manmade features could not be distinguished from the natural features. *See Headwaters, Inc. v. Talent Irrigation Dist.*, 243 F.3d 526 (Mar. 2001).

The Harding Drain is entirely manmade. TID's irrigation system was not created in waters of the U.S. The Central Valley Regional Board has previously recognized that the Harding Drain was a manmade agricultural drainage facility, designed and constructed by TID for drainage purposes. *See City of Turlock NPDES Permit, Central Valley Regional Board Order No. 5-01-122 and Cease and Desist Order No. 5-01-123 ("City's Permit") (2001).* Because the Harding Drain is a manmade irrigation system, which is ***not*** intertwined with natural streams, it is ***not*** a tributary of the San Joaquin nor a water of the U.S. The Harding Drain is not a water of the U.S., not subject to Clean Water Act jurisdiction or its regulatory programs, including 303(d) requirements. The Harding Drain must be removed from the 303(d) List because there is no federal regulatory authority under the Clean Water Act over the Harding Drain.

C. Beneficial Use Designations And Water Quality Objectives For Harding Drain Are Void.

(1) *Designation Through Discharge Permit Process.* The Central Valley Regional Board has attempted designation of beneficial use classifications for the Harding Drain that violated substantive and procedural requirements. TID, its members and the public were denied due process. The purported adoption of beneficial uses for the Harding Drain was accomplished as part of the Central Valley

Regional Board's issuance of a discharge permit for the City of Turlock. *(See Central Valley Regional Board Order No. 5-01-122 and Cease and Desist Order No. 5-01-123.)* Designation of beneficial use must be accomplished through an amendment to the Central Valley Regional Water Quality Control Plan. *(See Porter-Cologne Water Quality Control Act, Cal. Water Code §§ 13000, 132241, et seq.)* At a minimum, federal regulations require public notice, opportunity for comment and testimony, and public hearings *before* adoption of beneficial uses and water quality objectives. *(See 40 CFR §§ 25.4 and 25.10.)* And, Porter-Cologne requires that the Central Valley Regional Board adopt its water quality plan, and amendments thereto, *including* designation of beneficial uses and water quality objectives, only after notice and a public hearing. *No* notice was provided of the Central Valley Regional Board's intent to consider, or ever adopt beneficial uses and water quality objectives for the Harding Drain. The Central Valley Regional Board's purported adoption of water quality standards through the City of Turlock's discharge permit fails to comply with the procedural and due process requirements of state or federal laws. This *sub rosa* adoption of water quality standards for the Harding Drain is void and therefore cannot establish the basis for determinations pursuant to 303(d) that the waters are impaired.

(2) *Designation Via Tributary Rule.* The assignment of beneficial uses is the critical, initial step for water quality regulatory programs so it should not, and legally cannot, be undertaken without adequate consideration of the existing and potential beneficial uses for the water. In summary, the classification of the Harding Drain via the "Tributary Rule" for beneficial uses failed to adequately consider, if at all, the factors and evidence in support (or derogation) of such beneficial uses.

Language in the Central Valley Basin Plan referred to as the "Tributary Rule" states that the beneficial uses assigned to a water body shall also apply automatically to all tributary streams to that water body. *Central Valley Basin Plan at II-2.00 (4th ed. 1998).* That is, the beneficial uses associated with major California rivers are deemed to apply to each tributary stream to such rivers. The text of the "Tributary Rule" is:

> The beneficial uses of any specifically identified water body generally apply to its tributary streams. In some cases a beneficial

use may not be applicable to the entire body of water. In these cases the Regional Water Board's judgment will be applied.

Central Valley Basin Plan at II-2.00 (4th ed. 1998). The Central Valley Regional Board found that the Harding Drain, into which the City discharges, "is a manmade agricultural drainage facility designed and maintained by TID for drainage purposes." *City's NPDES Permit, ¶ 2 at 1.* Further, the Central Valley Regional Board found that the Central Valley Basin Plan did not identify any beneficial uses for the Harding Drain. *City's NPDES Permit, ¶ 12 at 3.* However, pursuant to the "Tributary Rule," the Central Valley Regional Board applied and assigned to the Harding Drain the beneficial use classifications of the San Joaquin River downstream water. *City's NPDES Permit, ¶¶ 12-13 at 3-4.* By applying the Tributary Rule to the Harding Drain, the Central Valley Regional Board assigned water contact recreation, warm water fish, fish migration, and municipal water supply uses to the Harding Drain.

As a threshold matter, the *automatic* attribution of beneficial uses from a major river to its tributaries violates the substance of the Clean Water Act and Porter-Cologne. Federal regulations require that "the classification of the waters of the State must take into consideration the use and value of water" for several purposes, including "agricultural, industrial, and other purposes." *40 CFR § 131.10(a).* There is little or no evidence that the Central Valley Regional Board had adequate facts to sufficiently evaluate the physical and economic condition of the Harding Drain before assigning beneficial *uses* for the Harding Drain. Similarly, *Porter-Cologne* requires that several factors must be considered in establishing water quality objectives, including "past, present and probable future beneficial uses of water." *Cal. Water Code § 13241(a).* These prerequisites for assigning beneficial uses are to ensure that classified uses are appropriately designated and that the water quality objectives adopted protect those beneficial uses. Porter-Cologne itemizes the specific factors that the regional board considers in adopting water quality objectives. To wit:

a. Past, present and probable beneficial uses of water.

b. Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto.

c. Water quality conditions that could reasonably be achieved through the coordinated control of all factors that affect water quality in the area.

d. Economic considerations.

e. The need for developing housing within the region.

f. The need to develop and use recycled water.

Cal. Water Code § 13241. An analysis of the findings demonstrates that the Central Valley Regional Board failed to adequately consider these factors. The Central Valley Regional Board adopted beneficial uses for the Harding Drain, stating as follows:

> The beneficial uses of any specifically identified water body generally apply to its tributary streams. The [Central Valley Regional] Board finds that, based on hydraulic continuity, aquatic life migration, existing and potential water rights, and the reasonable potential for contact recreational activities, that the beneficial uses of the San Joaquin River apply to the Harding Drain.

City's NPDES Permit, ¶ 13 at 5. The Central Valley Regional Board did not evaluate evidence pertaining to these factors. The Fact Sheet accompanying the City's NPDES Permit *only*, like the Tributary Rule, imputes the beneficial uses to the Harding Drain because the uses exist in the downstream San Joaquin River.

a. *Past, present and probable future uses.* There is *no* basis for assuming that the Harding Drain is used for municipal purposes. TID, the owner of the water rights in the drain, does *not* use the waters for municipal water supplies nor has it authorized or licensed any third parties to use TID's waters for municipal purposes. The Central Valley Regional Board relied upon the fact that the San Joaquin River downstream of its confluence with Harding Drain is used as a municipal water supply and information on San Joaquin dilution factors. Municipal water is *not* a past or present use of the Harding Drain, although it is a use of the San Joaquin.

   Classifying the Harding Drain for aquatic life uses was based *solely* upon the existence and designation of those beneficial uses in the San Joaquin River.

   The designation of recreational use classifications for the Harding Drain are purportedly made because (1) the public has access and (2) the public has been observed fishing and swimming near the Harding Drain. *See City's NPDES Fact Sheet at 2-3.* TID warns the public not to swim or dive in the Harding Drain. The physical characteristics of the Harding Drain discourage recreational uses. The Central Valley Regional Board's action would provide water quality protections for a few individuals who unadvised and without consideration of safety, occasionally could use the

Harding Drain for recreation. This is gross misinterpretation of the type of beneficial uses, and presumably legal uses, which Congress or the State intended to protect.

b. *Environmental characteristics of the Harding Drain.* The Central Valley Regional Board presented no evidence that it considered or evaluated the physical, chemical or biologic characteristics of the Harding Drain, which would effect determinations of beneficial uses. Nor does the Central Valley's Basin Plan's discussion of the Tributary Rule contain information regarding the physical, chemical or biologic characteristics of the Harding Drain.

c. *Water quality conditions reasonably achievable.* In adopting the beneficial uses, the Central Valley Regional Board did not adequately consider the water quality conditions reasonably achievable for the Harding Drain. The Central Valley Regional Board only considered the wastewater treatment 'reasonably' achievable by the City of Turlock, the reasonableness of which is now disputed. There is no evaluation of the environmental characteristics affecting water quality in the Harding Drain and whether the adopted water objectives could be attained through coordinated controls.

d. *Economic considerations.* The Central Valley Regional Board limited its economic considerations to the City's anticipated costs for wastewater treatment. Such a limited and focused economic analysis is insufficient to support adoption of water quality objectives for the Harding Drain. Adoption of beneficial uses and water quality objectives for the Harding Drain will have broad and far-reaching economic effects. It will certainly effect TID, the owner of the Harding Drain and its waters; however, *no* consideration was given to the economic effects on TID or its agricultural growers who use TID's water to irrigate 150,000 acres. The Central Valley Regional Board's limited economic considerations are insufficient to support adoption of beneficial uses and water quality objectives for the Harding Drain.

e. *The need for developing housing within the region and the need to develop and use recycled water.* This criteria is not applicable since the Harding Drain is not used for these purposes.

f. *Rationale for invalidating designations pursuant to the Tributary Rule.* It is likely that the Central Valley Regional Board will contend that consideration of these factors was *not* required because they merely applied the Tributary Rule. Such argument fails because the Central Valley Basin Plan does not

indicate that these factors were considered for effected waters and, in particular, were not considered for the Harding Drain when the Central Valley Basin Plan was adopted or amended.

The regional boards may not require a regulated entity to meet standards that are not supported by actual facts. *So. California Edison Co. v. State Water Resources Control Bd.*, 116 Cal.App.3d 751, 760 (4th Dist. 1981) (addressing the issue in the context of Ocean Plans adopted by the State Board for ocean waters of California).

Rather than assigning each water body individually the beneficial uses appropriate to it, a rule of broad application was articulated. In fact, several interested parties recently expressed their concern with the 'rule' to the State Board, based on such grounds. In a March 27, 2001 letter sent to the State Board from the California Association of Sanitation Agencies (CASA), the Southern California Alliance of POTWs, and three other parties,[1] these parties stated, "Regional boards should be instructed to discontinue the *rote* application of the so-called Tributary Rule, under which upstream waters are required to meet all of the requirements of the designated downstream waters, *without regard to the past, present and probable future uses in the actual receiving water.*" *March 27, 2001 letter of CASA and other parties to Arthur G. Baggett, Jr. at 2 ("CASA Letter").* There is no record of the Central Valley Regional Board's considering the factors enumerated under the Clean Water Act and Porter-Cologne when it adopted the Tributary Rule or when it applied the Tributary Rule to the Harding Drain. The Central Valley Regional Board automatically applied the beneficial uses of the San Joaquin River to the Harding Drain. The Central Valley Regional Board's designation of beneficial uses and adoption of water quality objectives for the Harding Drain pursuant to the Tributary Rule was an abuse of its discretion.

IV. Relief Requested

TID has identified factual and legal bases for removing these waters from the proposed 303(d) List. The listing is not warranted under federal law because current impairment of valid uses of water quality objectives has not been evidenced. Therefore, the Central Valley Regional Board should not add Don Pedro Lake or the

[1] These parties were the Central Valley Wastewater Managers Association, League of California Cities, and Tri-TAC. The letter may be viewed at http://www.casaweb.org/committee/tritac/pdfs/letters/032701.pdf.

Lower San Joaquin to the 303(d) List for mercury and should remove the Harding Drain from the 303(d) List.

Please feel free to contact me at (925) 210-2477, or Ronda Sandquist at (303) 674-4031 if you have any further questions.

Very truly yours,

BROWN AND CALDWELL

Cynthia Paulson, Ph.D., P.E.
Vice President

Ronda L. Sandquist, Esq.
Baker & Hostetler LLP

CP:gm

Cc: Mr. Bob Nees, Turlock Irrigation District
Ms Debra Liebersbach, Turlock Irrigation District

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by gwgate.swrcb.ca.gov; Fri, 02 Nov 2001 16:45:57 -0800
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for <303dlist@rb5s.swrcb.ca.gov>; Fri, 2 Nov 2001 16:43:24 -0800 (PST)
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Date: Fri, 02 Nov 2001 16:45:29 -0800
From: "Bob Murdoch" <Bob.Murdoch@ci.stockton.ca.us>
To: <303dlist@rb5s.swrcb.ca.gov>
Subject: City of Stockton Comments on Draft 303d list
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Attached in Word format you will find the City of Stockton's comments on
the draft 303(d) list. A hard copy will follow in the mail.

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November 2, 2001

Mr. Joe Karkoski
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COMMENTS ON RECOMMENDED CHANGES TO THE CLEAN WATER ACT SECTION 303(D) LIST

The City of Stockton is submitting the following comments on the Recommended Changes to California's Clean Water Action Section 303(d) List dated September 27, 2001.

The United States Environmental Protection Agency has set forth guidance to the states when identifying impaired and threatened waterbodies (Quality-based Decisions: The TMDL Process (Second Edition); Chapter 2, *Identifying Impaired and Threatened Waterbodies and Setting Priorities for Establishing TMDLs*. In that guidance document, EPA emphasizes that:

> "It is very important that 303(d) listing decisions be based on sound, high-quality, scientific information. As a reflection of this, EPA is requiring States...to document their level of information quality (rigor) used in making decisions". (Quality-based Decisions, Chapter 2, page 14)

In addition, EPA further notes:

> "Listed waterbodies can vary in size from stream segments of a few miles to entire watersheds. The geographic extent of the listing should correspond to whether water quality is impaired or threatened". (Quality-based Decisions, Chapter 2, page 16).

The need to have good solid data that is representative of the water quality of a listed segment is imperative. Listing of waterbodies as impaired with questionable and/or limited data would not be incompliance with the guidance noted above.

With this guidance in mind, the City of Stockton has the following comments on the subject List:

Lower Calaveras River, Diazinon

The data attributed to CDM at the Sutter Street and West Lane locations are not from samples taken in the Calaveras River. This sampling was done by the City of Stockton as part of its Storm Water NPDES requirements. The City took these samples from its storm drain system prior to discharge to the Calaveras River. Therefore, these samples are not representative of the conditions in the Calaveras River. In addition, these samples were taken during discreet storm events and cannot be compared to the chronic diazinon criteria which is a 4-day average.

In addition, the City objects to relying on the Lee and Jones-Lee 2001 data which does not specify a sampling location in the Calaveras River. Data cannot be considered to be "sound, high-quality, and scientific information" if the sampling location can not be identified.

Given the questionable nature of the data noted above, there is insufficient information to support listing the Lower Calaveras River as impaired for diazinon.

Lower Calaveras River, Low Dissolved Oxygen

It is proposed that a five mile segment of the Calaveras River be listed as impaired for dissolved oxygen based on sampling results from one location. Data from a single location can not be considered representative of the water quality in a five mile segment. Additional data must be gathered to support listing of a waterbody segment.

In addition, the water quality criteria of 5mg/L is currently being examined as part of the San Joaquin River TMDL. Because dissolved oxygen varies significantly depending on the time of day and the location sampled in the water column, Regional Board staff are trying to determine how to apply the noted criteria. For example, should the criteria be a daily average or perhaps averaged over several samples taken at various locations in the water column?

Since how to apply the criteria in question is still to be resolved, a listing of impairment from discreet samples taken at one location is not warranted.

Lower Calaveras River, Pathogens

The evidence for impairment notes that two sample locations were used. One location was "near the mouth" of the Calaveras River (i.e. near the confluence with the San Joaquin River). Obviously, water quality at this location will be greatly influenced by the San Joaquin River and tidal flows. This brings into

question if the data is representative of the Calaveras River, or a mixture of the Calaveras River and the San Joaquin River. In addition, the noted exceedence of the E. Coli single sample criteria was of a draft criteria from CDHS. The City objects to a draft criteria being used to justify an impairment listing.

If the downstream sampling is discounted, the data available to support the noted impairment is from a single location. It is not valid to use data from a single location to justify the listing of an 8 mile segment of the Calaveras River. Additional data from various locations within the waterbody is needed to support a listing of impairment.

Five Mile Slough, Low Dissolved Oxygen

The City objects to a listing of impairment based on data from a single location in a waterbody. For data to be sound and of high-quality, samples from representative locations in a waterbody must be taken to insure that the listing of impairment is justified.

The water quality criteria of 5mg/L is currently being examined as part of the San Joaquin River TMDL. Because dissolved oxygen varies significantly depending on the time of day and the location sampled in the water column, Regional Board staff are trying to determine how to apply the noted criteria. For example, should the criteria be a daily average or perhaps averaged over several samples taken at various locations in the water column?

Since how to apply the criteria in question is still to be resolved, a listing of impairment from samples taken at one location is not warranted.

Mormon Slough, Low Dissolved Oxygen

The City objects to a listing of impairment based on data from a single location in a waterbody. For data to be sound and of high-quality, samples from representative locations in a waterbody must be taken to insure that the listing of impairment is justified.

The water quality criteria of 5mg/L is currently being examined as part of the San Joaquin River TMDL. Because dissolved oxygen varies significantly depending on the time of day and the location sampled in the water column, Regional Board staff are trying to determine how to apply the noted criteria. For example, should the criteria be a daily average or perhaps averaged over several samples taken at various locations in the water column?

Since how to apply the criteria in question is still to be resolved, a listing of impairment from samples taken at one location is not warranted.

Mormon Slough, Pathogens

The City objects to a listing of impairment based on data from a single location in a waterbody. For data to be sound and of high-quality, samples from representative locations in a waterbody must be taken to insure that the listing of impairment is justified.

Mosher Slough, Low Dissolved Oxygen

The City objects to a listing of impairment based on data from a single location in a waterbody. For data to be sound and of high-quality, samples from representative locations in a waterbody must be taken to insure that the listing of impairment is justified.

The water quality criteria of 5mg/L is currently being examined as part of the San Joaquin River TMDL. Because dissolved oxygen varies significantly depending on the time of day and the location sampled in the water column, Regional Board staff are trying to determine how to apply the noted criteria. For example, should the criteria be a daily average or perhaps averaged over several samples taken at various locations in the water column?

Since how to apply the criteria in question is still to be resolved, a listing of impairment from samples taken at one location is not warranted.

Walker Slough, Diazinon

The data from the Western Park Industrial Center is from the City's NPDES sampling within the storm drainage system prior to being discharged to the basin and, therefore, prior to being discharged to receiving waters. This data can not be used to characterize the condition of Walker Slough. Also, the data provided that does not provide a location can not be considered sound.

Without the noted data, there is no information available that supports the impairment listing.

If you have any question concerning the City's comments, please contact Bob Murdoch at (209) 937-8734.

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November 2, 2001

Mr. Joe Karkoski
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Subject: **Comments on *Draft Staff Report on Recommended Changes to California's Clean Water Act Section 303(d) List* Prepared by the Staff of the Central Valley Regional Water Quality Control Board**

Mr. Karkoski:

Thank you for the opportunity to provide comments on the proposed 303(d) list for the Central Valley Region, Region (5). This letter is written in response to your letter of September 27, 2001, soliciting public comment on the *Draft Staff Report on Recommended Changes to the Clean Water Act Section 303(d) List* for the Central Valley Region.

As you are aware, the Sacramento Regional County Sanitation District is very interested in the 303(d) listing process, given the significance of effort and commitment of state and local resources involved in the development and implementation of TMDLs for each listed water body. The District is very supportive of scientifically sound TMDLs as a valuable water quality management tool in California. The District believes that the 303(d) list should be used to identify and prioritize major water quality problems that have been clearly identified through a rational process. The District also believes that adherence to the existing legal framework provided by the California Water Code and Clean Water Act in the 303(d) listing process is extremely important.

In the District's letters to the Regional Board (January 20, 1998) and State Board (March 17 and May 26, 1998) regarding the 1998 303(d) list (which are included herein by reference), two fundamental issues were raised:

1. Lack of appropriate documentation prior to the listing decision to explain the basis of listings and/or impairment determinations.

2. Use of un-adopted numeric "criteria" and other bases identified in the August 11, 1997 SWRCB memorandum entitled "1998 Clean Water Act (CWA) Section 303(d) Listing Guidelines for California" as the basis for numerous 303(d) listings.

We commend you and your staff on the obvious effort that has gone into the documentation for the proposed 2002 listings. The Draft Staff Report contains a much more detailed description of the basis for listing recommendations.

Technology in balance with nature

Our remaining concerns with the proposed 303(d) list are therefore with the issues described in item 2 above. These concerns are explained in greater detail below.

Major Concerns with 303(d) listings

Use of unadopted numeric values as surrogates for numeric water quality objectives in the 303(d) listing process. Numeric values (e.g. advisory criteria and guidelines) continue to be used in the listing process as surrogates for properly adopted numeric water quality objectives. The California Water Code establishes a clear process for the adoption of water quality objectives in Sections 13000, 13241 and 13242. The use of numeric values as surrogate water quality objectives without having formally adopted these values through the process described in the California Water Code is inconsistent with State Law, specifically the Porter Cologne Act and the Administrative Procedures Act.

Examples of the use of numeric surrogate values in the proposed listings include:

- Listings based on specific numeric fish tissue "criteria". For most pollutants, no enforceable state or federal fish tissue objective/standard has been adopted. Listings based on un-adopted tissue "criteria" are problematic because those "criteria" were never adopted as standards/objectives through a formal public process. Examples include listings for mercury using the USEPA 304(a) advisory fish tissue criterion of 0.3 mg/kg and use of National Academy of Science guideline of 100 nanogram/gram fish tissue value for Group A pesticide listings.

- Listings based on USEPA 304(a) advisory criteria and/or guidelines. The USEPA adopted a number of 304(a) criteria as federal standards in California through the National Toxics Rule and the California Toxics Rule. The proposed and continued use of other USEPA advisory criteria or guidelines (which have not been adopted as standards in the NTR or CTR) in the 303(d) listing process imparts the same weight to those numeric values as is given to CTR and NTR standards, in the absence of a proper administrative and legal process. Examples include listings based on use of the USEPA 304(a) fish tissue criterion for mercury (as listed above), use of USEPA 1986 guidelines for pathogens, use of a USEPA advisory criterion for aluminum, USEPA 1976 advisory criteria for azinphos-methyl and USEPA advisory criteria for parathion.

- Listings based on Department of Fish and Game or Department of Health Services criteria or guidelines which have not otherwise been adopted as standards or objectives under the California Water Code or Clean Water Act. Such listings effectively convey standard setting authority to outside agencies and bypass the standard setting processes identified in the Clean Water Act, USEPA regulations and the California Water Code. Examples of such listings include use of Department of Fish and Game advisory criteria for diazinon, chlorpyrifos, and ammonia and use of DHS criteria and draft guidelines for pathogens.

- Listings based on existence of a health advisory imposed outside the Clean Water Act process. Such listings effectively convey standard setting authority to outside agencies and bypass the standard setting processes identified in the Clean Water Act, USEPA regulations and the California Water Code. A number of listings refer to the existence of health advisories, although it does not appear that the advisories comprised the basis for those listings.

Certainly, any of these advisory criteria or guidelines could be considered for adoption as water quality objectives in the Basin Plan. Under those circumstances, interested parties would be afforded the opportunity to comment on the appropriateness of the criteria as objectives for a given water body in light of the factors specified in the Porter Cologne Act, the technical basis for the criteria, potential adverse environmental impacts and other important factors. However, to effectively incorporate the criteria de facto into the Basin Plan, and for all waters, through the 303(d) process, is improper. The consequence is that at any given time, anywhere in the world, a person or agency may be issuing a number that effectively becomes a water quality objective, rendering the Basin Planning process irrelevant. Additionally, we note that the Office of Administrative Law, in its review of the State Implementation Plan for toxics adopted by the State Water Resources Control Board, disapproved of the practice of prospective incorporation by reference (see Notice and Decision Re Approval and Partial Disapproval of a Rulemaking Action: OAL File No. 00-0317-15). We assert that the practice of prospective incorporation (e.g. using present and future criteria and guidelines developed by other agencies to interpret the narrative toxicity objective) that has been disapproved by OAL is clearly being used in the proposed 303(d) listing process.

The argument has been made that the use of adopted narrative toxicity objectives to impose numeric objectives is acceptable because such an approach was previously approved in the Basin Planning process. The implied assertion is that this approach was advertised and evaluated in accordance with appropriate requirements in the California Water Code at the time that the narrative objectives were adopted into the Basin Plan. If such evaluation occurred in the Basin Planning process, documentation must exist to corroborate compliance with California Water Code requirements. The District requests that copies of such documentation be made available for inspection to assist in resolution of this matter.

In addition, under the Clean Water Act, a "translator" must be developed to describe to the public the means by which narrative objectives would be implemented. The Regional Board has not adopted such a translator.

The language in the Basin Plan describing the Toxicity objective (Page III-8.00) states

> *"All waters shall be maintained free of toxic substances that produce detrimental physiological responses in human, plant, animal or aquatic life. This objective applies regardless of whether toxicity is caused by a single substance or the interactive effect of multiple substances. Compliance with this objective will be determined by analyses of indicator organisms, species diversity, population density, growth anomalies, and biotoxicity tests of appropriate duration or other methods as specified by the Regional Water Board.*
>
> *The Regional Water Board will also consider all material and relevant information submitted by the discharger and other interested parties and numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the US Food and Drug Administration, the National Academy of Sciences, the US Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective... "*

Careful reading of the above language indicates that compliance determinations *will be made* through the *combined use of biological and toxicological information.* The language also indicates that other information will be *considered* in the evaluation of compliance. The District believes that above

language carries a mandatory requirement to use both biological and toxicological information in any compliance evaluation and a discretionary action to use other information to supplement the biological and toxicological information.

The commitment to "consider" other information, including numerical criteria, in evaluating compliance with the narrative objective carries no obligation to use any or all of the available criteria or guidelines as specific thresholds for compliance determinations. The District believes that this wording is often misinterpreted in discussions of this topic.

The above language also does not address use of specific numeric values or other methods as the means of determining compliance with the narrative toxicity objective. To satisfy the specific requirements of the California Water Code (e.g. Section 13241) for the establishment of water quality objectives, the use of specific numeric values or other methods would require fulfillment of those requirements. The past and proposed action to use specific numeric values as the major determinant of compliance with the toxicity objective represents a bypassing of the water quality standard setting process. To the degree this approach has been used in the existing and recommended 303(d) listings for the Central Valley, the District asserts that such actions are improper as a matter of law and policy.

Categorical Listings which Do Not Meet the Letter or Intent of Section 303(d) of the Clean Water Act

Examples of categorical (i.e. non-pollutant specific) listings in the draft staff report for the proposed 303(d) list include:

- Group A pesticides
- Unknown Toxicity

Categorical listings do not lend themselves to treatment under the TMDL program. The TMDL program relies on the identification of specific pollutants which do not meet water quality standards. Categorical groupings of multiple or unknown pollutants confounds the TMDL approach, as currently advertised in USEPA rules and guidance.

Such listings also create major problems in NPDES permitting. For instance, for lindane, a Group A pesticide, the 303(d) listing of Group A pesticides led to a determination by Regional Board permitting staff for the SRCSD permit that a dilution credit could not be considered in the derivation of effluent limits, based on a blanket assumption that the river had no assimilative capacity for any of the Group A pesticides. In fact, specific water quality data in the Sacramento River at Freeport that lindane had never been detected. The result is an overly stringent effluent limit for lindane in the SRCSD permit. This problematic effluent limit is a direct result of the use of the categorical Group A pesticide listing.

Similar NPDES permitting problems exist for Unknown toxicity. It has been alleged that because of the 303(d) listing for Unknown Toxicity in Delta Waters, (a) no dilution factor should be considered for WET and (b) all toxic pollutants present in a surface water discharge should be deemed to have reasonable potential to cause or contribute to violation of the toxicity standard, since the cause of Unknown Toxicity is unknown. This creates significant NPDES permit liability for the District.

Categorical listings are more appropriately included in Section 303(d)(3) list and in Table 2 of Draft Staff Report, Parameters for Further Assessment. For example, further assessment is required before a TMDL can move forward for Unknown Toxicity. The State must first determine the pollutants or other stressors causing observed toxicity to test organisms before embarking on the TMDL-required tasks of source identification, load assessment, waste load and load allocations, and linkage analysis. Until the causative agent(s) are clearly identified, these TMDL tasks cannot be completed. As such, a firm schedule for completion of a TMDL for Unknown Toxicity or for attainment of the toxicity water quality objective cannot be set with appropriate confidence. The current and recommended continued listing for Unknown Toxicity places the Regional Board and regulated community in a position of predictable failure in meeting TMDL commitments in the eyes of the public, environmental advocacy groups and other the USEPA.

Temperature Listing for the Sacramento River between Hamilton City and the I Street Bridge in Sacramento

The District questions whether consideration has been given to including this portion of the Sacramento River on the 303(d) list for temperature. Available information from various sources (e.g. CMP and SRWP monitoring data) indicates that the temperature of the river in this reach exceeds the Basin Plan numeric temperature objective of 68 degrees F for portions of the year. The Basin Plan objective states that the temperature in the river shall not exceed 68 degrees F during periods of the year when temperature increases will be detrimental to the fishery. The District requests that documentation be provided which explains the basis for not including this section of the river on the proposed 303(d) list.

Request

The District requests that the recommended 303(d)(1) list be modified to include only those listings derived from documented violations of adopted numeric water quality objectives. In addition, the District requests documentation which explains the basis for not listing temperature on the proposed 303(d) list for the Sacramento River between Hamilton City and the I Street bridge.

The District recommends that the Regional Board create a second list (the 303(d)(3) list) which includes the waters which are on the existing and proposed 303(d) list on the basis of consideration of the un-adopted criteria and numeric threshold values described above. These waters would be retained for future listing pending completion of a standard-setting process to validate the use of the numeric threshold values as a basis for listing. The District also recommends that categorical listings (e.g. Unknown Toxicity and Group A pesticides) be included on this second list, for the reasons cited above.

We appreciate the opportunity to provide these comments.

Sincerely,

Robert F. Shanks
District Engineer

RFS/WHK/MJ:gjl (303(d) List Comments 11/01/01.doc)

cc: SWRCB
USEPA Region IX

SAN JOAQUIN FARM BUREAU FEDERATION
MEETING TODAY'S CHALLENGES / PLANNING FOR TOMORROW

JK

November 6, 2001

Mr. Joe Karkoski
303(d) List Update Coordinator
Regional Water Quality Control Board
Central Valley Region
3443 Routier Road, Suite A
Sacramento, CA 95827-3003

Re: Comments on 303(d) List Update

Mr. Karkoski:

These comments are submitted on behalf of the San Joaquin Farm Bureau Federation to the Draft Staff Report on Recommended Changes to California's Clean Water Act Section 303(d) List dated September 27, 2001

We would like to reference comments sent to you by Stockton East Water District on October 19. 2001 (attached). It is vital that the EPA guidance document be adhered to. That staff recommended changes for the Calaveras River and the Mormon Slough listings be based on sound, high quality, scientific information.

Regards,

Joe Petersen
Program Director
San Joaquin Farm Bureau Federation

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P.O. BOX 8444 • 3290 NORTH AD ART ROAD • (209) 931-4931 • STOCKTON, CALIFORNIA 95208

HERUM CRABTREE BROWN
Attorneys At Law

Jeanne M. Zolezzi
jzolezzi@herumcrabtree.com

October 31, 2001

Mr. Joe Karkoski
303(d) List Update Coordinator
Regional Water Quality Control Board
Central Valley Region
3443 Routier Road, Suite A
Sacramento, CA 95827-3003

Re: Stockton East Water District/Comments on 303(d) List Update

Dear Mr. Karkoski:

These comments are submitted on behalf of the Stockton East Water District to the Draft Staff Report on Recommended Changes to California's Clean Water Act Section 303(d) List dated September 27, 2001.

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Further, EPA notes that :

> "Listed waterbodies can vary in size from stream segments of a few miles to entire watersheds. The geographic extent of the listing should correspond to whether water quality is impaired or threatened". (Quality-based Decisions, Chapter 2, above, at page 16).

This guidance should be kept in mind when reviewing the staff recommendations for the Calaveras River.

RECEIVED
NOV 01 2001
STOCKTON EAST WATER DISTRICT

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A Professional Corporation

Calaveras River - Diazinon

The staff report recommends that the Calaveras River be added to the list as impaired for **diazinon** for the entire thirty-mile stretch of the river within San Joaquin County. However, there is no factual or technical support provided for the staff conclusion at p. B-17 that: "the water quality objectives for pesticides and toxicity are not being attained for diazinon in the lower Calaveras River."

Regional Board staff relies on 22 water samples as evidence of impairment. (See Table B-2 attached, which lists 23 tests) However, 78% of these tests (18 of 23) were taken **within a stretch of River less than 1.5 miles long**, exclusively within the city limits of Stockton. Actual impairment was shown in only two of the three identified sampling locations, comprising a stretch of river approximately 2/3 of a mile, again, exclusively within the city limits of Stockton. The remaining 22% of the samples (an additional five samples) were taken at a location designated as "not identified", and should not be relied upon at all as a basis for the staff's recommendation.

Those samples that were identified were taken at West Lane, Sutter Street and Pacific Avenue. The enclosed map identifies the location of those identified tests in relation to the stretch of river that the staff is recommending for listing as impaired, and visually illustrates the lack of connection between the limited geographic evidence of impairment and the staff's broad recommendation.

Despite such limited sampling, the staff report recommends listing the entire 30-mile stretch of the Calaveras River lying within San Joaquin County as impaired. The staff report reveals that "most of the samples were collected from sites within the City of Stockton" (at p. B-18), but nevertheless concludes that "it is likely that the entire lower Calaveras River is impaired by diazinon." This is an unwarranted and irresponsible conclusion; there is absolutely no evidence to conclude that "it is likely".

Several other factors also undermine staff's recommendation:

(1) The two locations within the City of Stockton that did test positive for diazinon are subject to tidal influence from the Delta, thus no conclusion can be drawn that the contamination is from upstream.

(2) The staff report identifies potential sources, concluding that: "Diazinon is commonly used as a dormant spray on almonds and stonefruits during the winter months. . . . It is likely that these applications are the source of diazinon in the lower Calaveras River." The staff has done no investigation as to the potential sources, as the fact is that there are no almonds and insignificant stone fruit plantings along the Calaveras River.

(3) The San Joaquin County Agricultural Commissioner's office has confirmed that the largest diazinon use in San Joaquin County is for structural pest control in the urban area.

(4) The Stockton East Water District tested water in the Calaveras River at Belotta for diazinon in 1993, 1995 and 1996 and the results were non-detectable.

(5) There is no discussion of the fact that the use of diazinon is being phased out, with retail sales of diazinon for household ending by December 2002, and all sales and distribution ending by August 2003. Of what use is a TMDL in 2015 for a chemical that may no longer be manufactured after 2003?

At most the Calaveras River should be listed for diazinon within the 2/3 mile stretch identified as impaired within the urban area. More appropriately, give the phase out of the chemical, the Calaveras River should be included in Table 2 as one of the suggested sites for further assessment for diazinon. There is no legal support for listing the entire 30-mile stretch of the Calaveras River for diazinon without actual evidence of impairment.

Mormon Slough

Staff recommends that Mormon Slough be added to the list for **dissolved oxygen** and **pathogens**. The river would be listed for dissolved oxygen in a one-mile segment from Commerce Street to the Stockton Deep Water Ship Channel within the urban area.

SEWD would respectfully request that the segment of the slough designated be referred to as **Lower Mormon Slough** to differentiate it from the larger portion of Mormon Slough upstream.

San Joaquin River

The San Joaquin River continues to be included for Boron, Chlorpyrifos, DET, Diazinon, Group A Pesticides, Electrical Conductivity, Selenium and Unknown Toxicity, and it is recommended that Mercury be added.

The current 303(d) list provides that a TMDL will be presented to the SWRCB for adoption in December of 1999, which obviously did not happen. Staff recommends that the date be changed to 2002. This recommendation only serves to highlight the Regional Board's continued delays in taking any action with regard to the San Joaquin River water quality. Stockton East Water District and other San Joaquin County entities are on record that such continued delays are unacceptable and will not be tolerated.

Very truly yours,

JEANNE M. ZOLEZZI
Attorney-at-Law

JMZ:rl
Enclosures
cc: Mr. Kevin Kauffman Mr. Morris Allen

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JKark



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California 96158

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October 31, 2001

RECEIVED
NOV 5 - 2001
CA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

Joe Karkoski, 303(d) List Update Coordinator
California Regional Water Quality Control Board
Central Valley Region
3443 Routier Rd #A
Sacramento CA 95827-3003

President
Bill Center
Camp Lotus

Vice President
Stan Weidert
Biologist

Secretary
Scott Kruse
Biophysical Geographer

Treasurer
Bob Kelso

Executive Director
Laurel W. Ames

Board of Directors:

Randy Barrow
Attorney

Carole Combs
Sierra Los Tulares Land Trust

Cal French

Ray Griffiths
Georgetown Divide Resource Conservation District

Lynn Sadler
Mountain Lion Foundation

Advisory Council:

Martha Davis, Chair
Inland Empire Utilities Agency

Dear Mr. Karkoski:

The Sierra Nevada Alliance is deeply disappointed that the updated 303(d) list does not include any new listings on the west side of the Sierra Nevada. In conversations with SWRCB staff two years ago we were assured that the Sierra watersheds would be reviewed and included as appropriate.

Now we learn that there is not enough data for decisions to include west side streams in the list. If you needed new or existing but not immediately available data to include the streams, it is unclear why, in the past two years, there has been no effort to collect such data. To those of us who live in the Sierra and read our local newspapers, there is widespread information about MTBE, mercury, pathogens and sediment degradation of our waters available in local communities and from local water districts.

Last year the Governor announced the SWAMP program to monitor surface waters. The Sierra is clearly in line to receive a healthy amount of that programs' funds in order to undertake the monitoring that will qualify Sierra streams for being listed in the 303(d) list.

The Alliance is concerned that another two years will have gone by before the next 303(d) list is released, and again no Sierra streams will have been monitored and thus no Sierra streams will be proposed for the list.

The Alliance proposes that the State Water Resources Control Board target the west side of the Sierra for a research and monitoring program to establish the level of impairment in west side Sierra streams. The Alliance will be very happy to work with the SWRCB to identify areas with known contaminants and to set up monitoring programs that collect data acceptable to the agency.

We recognize the heavy workload and the enormous amount of problems that exist throughout the state, but we are very concerned that no monitoring or data collection efforts were spent on the Sierra in the past two years. We remind you that the Sierra provides 65% of the water used by Californians. This water should be first in your line of defense against pollution and degradation.

Very truly yours,

Laurel W. Ames
Executive Director

JK

HERUM CRABTREE BROWN
Attorneys At Law

Jeanne M. Zolezzi
jzolezzi@herumcrabtree.com

October 31, 2001

RECEIVED
CENTRAL VALLEY REGION
01 NOV -1 PM 1:25

Mr. Joe Karkoski
303(d) List Update Coordinator
Regional Water Quality Control Board
Central Valley Region
3443 Routier Road, Suite A
Sacramento, CA 95827-3003

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Very truly yours,

JEANNE M. ZOLEZZI
Attorney-at-Law

JMZ:rl
Enclosures
cc: Mr. Kevin Kauffman
Mr. Morris Allen

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Table B-2. Diazinon in Water Samples Collected from the Lower Calaveras River

Data Source	Location	Sample Years	Number of Samples	Range of Diazinon Concentrations	Criteria[a]		Number of Samples Equal to or Above Criteria	Percent Samples Equal to or Above Criteria
Lee, G.F., and A. Jones-Lee. 2000	Pacific Ave	1996	1	0.036 µg	chronic	0.05 µg/L	0	0%
					acute	0.08 µg/L	0	0%
CDM, 1999; Lee and Jones-Lee, 2001	Sutter Street	1996 - 1998	8	nd - 1.7 µg	chronic	0.05 µg/L	6	75%
					acute	0.08 µg/L	6	75%
CDM, 1999; Lee and Jones-Lee, 2001	West Lane	1996 - 1998	9	nd - 1.3 µg	chronic	0.05 µg/L	4	44%
					acute	0.08 µg/L	4	44%
Lee and Jones-Lee, 2001	Not identified	1994 - 1998	5	nd - 0.45 µg	chronic	0.05 µg/L	4	80%
					acute	0.08 µg/L	4	80%
Sum	Sum	1994 - 1998	23	nd - 1.7 µg	chronic	0.05 µg/L	18	78%
					acute	0.08 µg/L	18	78%

a) California Department of Fish and Game Water Quality Criteria for Diazinon (Siepmann and Finlayson, 2000)
nd = not detected

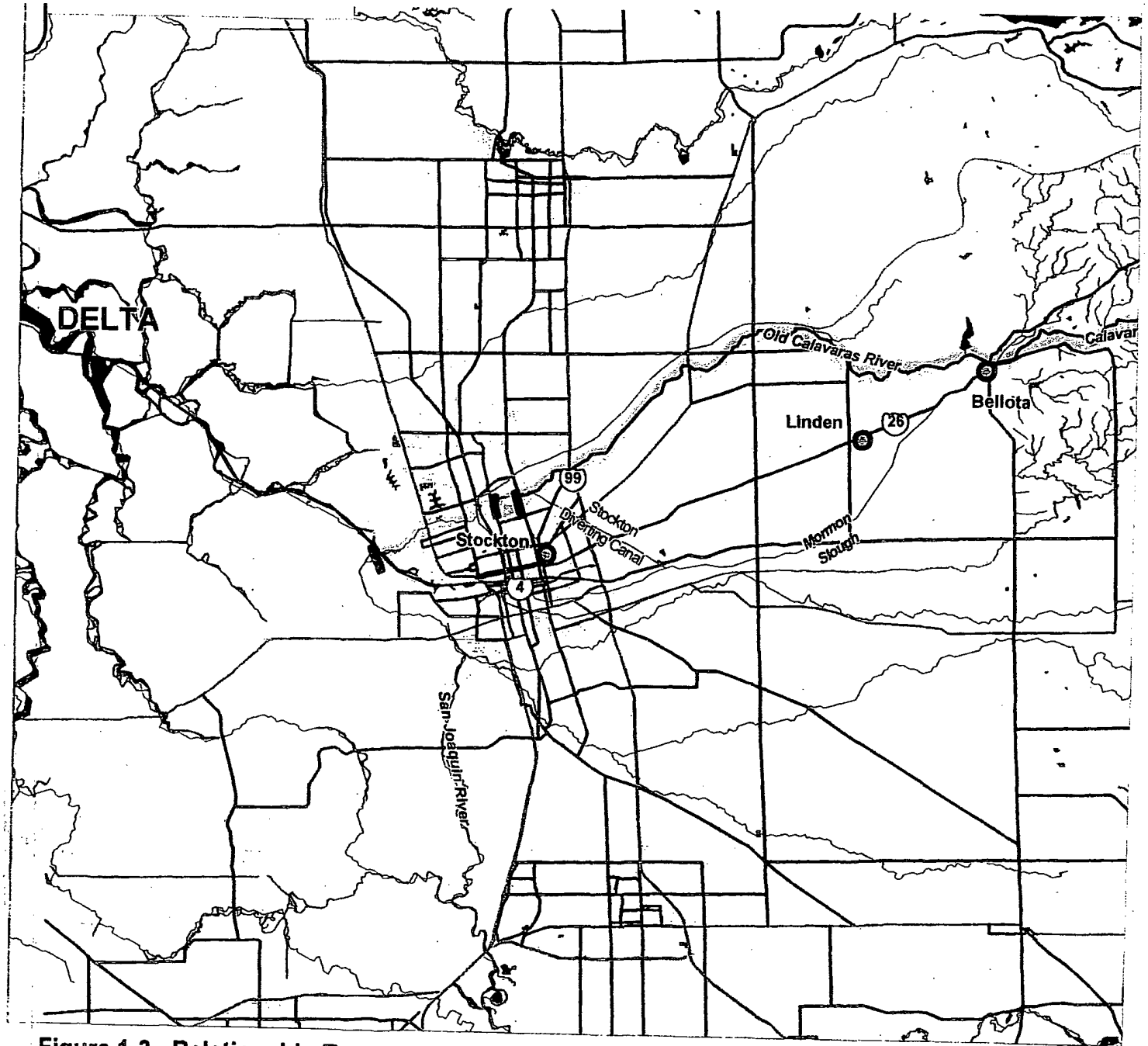

Figure 1-3. Relationship Between Calaveras River and San Joaquin River Delta

From: Gene Davis
To: Wilson, Craig J.
Date: 2/7/02 8:47AM
Subject: TRANSMITTAL OF PUBLIC COMMENTS TRACKING LIST FOR THE REGIONAL 5'S 303(d) LIST ADMIN. RECORD

This transmittal accompanies a Table of Contents ("Tracking List", as an Excel file) for public comments received on the "Draft Staff Report of Recommended Changes to California's Clean Water Act Section 303(d) List".

Copies of the public comments were forwarded to the State Water Resources Control Board (SWRCB) under separate transmittal letter dated 10 January 2002 and are not included with this missive. The public comments were included in Binder 3 of the Central Valley Regional Board's administrative record for the "Final Staff Report on Recommended Changes to California's Clean Water Act Section 303(d) List." The Table of Contents (tracking table) should be inserted behind the Table of Contents for the administrative record in the front of Binder 3. The Table of Contents (tracking table) for the public comments includes the date each comment was received, the comment author and/or contact name, and the contact information.

If you have any questions, please have your staff contact Gene Davis at (916) 255-3387.

Gene Davis
Sacramento River TMDL Unit
Central Valley Region Water Quality Control Board
3443 Routier Road, Suite A
Sacramento, CA 95827-3003
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(916) 255-0752 (FAX)
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The energy challenge facing California is real. Every Californian needs to take immediate action to reduce energy consumption. For a list of simple ways you can reduce demand and cut your energy costs, see our Web-site at http://www.swrcb.ca.gov

CC: Bruns, Jerry; Daniels, Debbie; Karkoski, Joe