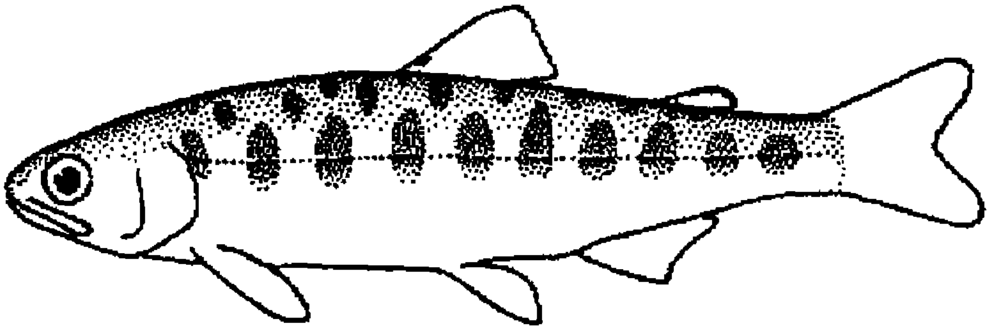
FLOW-HABITAT RELATIONSHIPS FOR CHINOOK SALMON REARING IN THE SACRAMENTO RIVER BETWEEN KESWICK DAM AND BATTLE CREEK



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CVPIA INSTREAM FLOW INVESTIGATIONS
SACRAMENTO RIVER BETWEEN KESWICK DAM TO BATTLE CREEK
CHINOOK SALMON REARING

PREFACE

The following is the final report for the U. S. Fish and Wildlife Service's investigations on salmonid rearing habitat in the Sacramento River between Keswick Dam and Battle Creek. These investigations are part of the Central Valley Project Improvement Act (CVPIA) Instream Flow Investigations, a 7-year effort which began in February, 1995. Title 34, Section 3406(b)(1)(B) of the CVPIA, P.L. 102-575, requires the Secretary of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U. S. Fish and Wildlife Service after consultation with the California Department of Fish and Game (CDFG). The purpose of these investigations are to provide scientific information to the U. S. Fish and Wildlife Service Central Valley Project Improvement Act Program to assist in developing such recommendations for Central Valley rivers.

Written comments or questions about this report or these investigations should be submitted to:

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INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act requires the doubling of the natural production of anadromous fish stocks, including the four races of chinook salmon (fall, late-fall, winter, and spring runs), steelhead, and white and green sturgeon. For the Sacramento River, the Central Valley Project Improvement Act Anadromous Restoration Plan calls for October through April flows ranging from 3,250 to 5,500 cfs, with the recommended flow varying with the October 1 carryover storage in Shasta Reservoir (U. S. Fish and Wildlife Service 1995). In December 1994, the U. S. Fish and Wildlife Service prepared a study proposal to identify the instream flow requirements for anadromous fish in certain streams within the Central Valley of California, including the Sacramento River. The purpose of this report is to produce models predicting the hydraulic and structural characteristics of rearing sites for chinook salmon in the Sacramento River between Keswick Reservoir and Battle Creek over a range of streamflows.

A 2-dimensional hydraulic and habitat model (RIVER2D) was used for this modeling, instead of the Physical Habitat Simulation (PHABSIM[1]) component of the Instream Flow Incremental Methodology (IFIM). The 2-D model uses as inputs the bed topography and substrate of a site, and the water surface elevation at the downstream end of the site, to predict the amount of habitat present in the site. The 2-D model avoids problems of transect placement, since the entire site can be modeled. The 2-D model also has the potential to model depths and velocities over a range of flows more accurately than PHABSIM because it takes into account upstream and downstream bed topography and bed roughness, and explicitly uses mechanistic processes (conservation of mass and momentum), rather than Manning's n and a velocity adjustment factor. Other advantages of 2-D modeling are that it can explicitly handle complex habitats, including transverse flows, across-channel variation in water surface elevations, and flow contractions/expansions. The model scale is small enough to correspond to the scale of microhabitat use data with depths and velocities produced on a continuous basis, rather than in discrete cells. The 2-D model does a better job of representing patchy microhabitat features, such as gravel patches. The data can be collected with a stratified sampling scheme, with higher intensity sampling in areas with more complex or more quickly varying microhabitat features, and lower intensity sampling in areas with uniformly varying bed topography and uniform substrate. Bed topography and substrate mapping data can be collected at a very low flow, with the only data needed at high flow being water surface elevations at the top and bottom of the site and flow and edge velocities for validation purposes. In addition, alternative habitat suitability criteria, such as measures of habitat diversity, can be used.

The results of this study are intended to support or revise the flow recommendations above.

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[1] PHABSIM is the collection of one dimensional hydraulic and habitat models which are used to predict the relationship between physical habitat availability and streamflow over a range of river discharges.

METHODS

Study Site Selection

We divided the Sacramento River study area into six stream segments (Figure 1), based on hydrology and other factors: Grimes to Colusa (Segment 1); Deer Creek to Red Bluff Diversion Dam (Segment 2); upstream of Lake Red Bluff to Battle Creek (Segment 3); Battle Creek to Cow Creek (Segment 4); Cow Creek to Anderson-Cottonwood Irrigation District (ACID) dam (Segment 5); and ACID to Keswick Dam (Segment 6). Segment 1 addresses green and white sturgeon, while the other segments address chinook salmon.

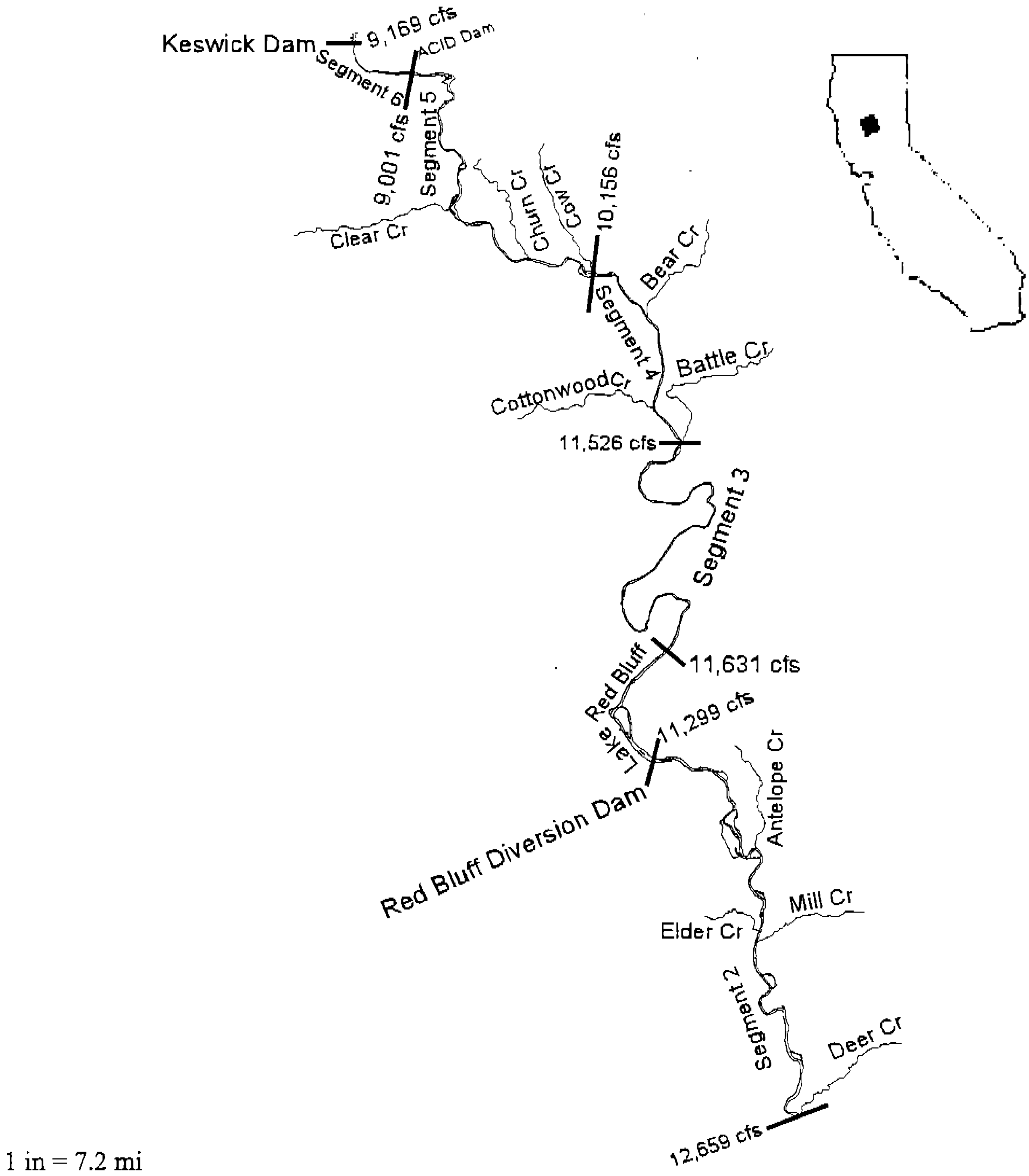
CDFG conducted mesohabitat mapping of the Sacramento River between Keswick Dam and Battle Creek. CDFG used 13 mesohabitat types: bar complex glides, bar complex pools, bar complex riffles, bar complex runs, flatwater glides, flatwater pools, flatwater riffles, flatwater runs, side channel glides, side channel pools, side channel riffles, side channel runs, and off-channel areas (Snider et al 1992). The only mesohabitat types found in Segment 6 are Flatwater pool, Flatwater glide, run and pool. In Segment 5, there are no side channel glides, and there are no side channels in Segment 4. Off-channel areas were not modeled because our snorkel survey data in FY-96 indicated that they were rarely used by juvenile chinook salmon, compared to other mesohabitat types (U. S. Fish and Wildlife Service 1996), and because the amount of habitat in off-channel areas is not sensitive to flow.

We selected one site of each mesohabitat type in Segments 4 through 6 (Table 1). To minimize duplication of effort, we first selected for use spawning sites (Lower Lake Redding, Upper Lake Redding, Salt Creek, Posse Grounds, Above Hawes Hole, Powerline Riffle and Price Riffle). For the mesohabitat types present in each segment which were not found in a spawning site, we used a random number generator to randomly select a mesohabitat unit. In January 1998, we conducted a reconnaissance of the sites in Segments 4 through 6 to confirm their viability as study sites. Each site was evaluated based on morphological and channel characteristics which facilitate the development of reliable hydraulic models. Also noted were riverbank and floodplain characteristics (e.g. steep, heavily vegetated berms or gradually sloping cobble benches) which might affect our ability to collect the necessary data to build these models. The landowners along both riverbanks of the sites were identified and temporary entry permits were sent, accompanied by a cover letter, to acquire permission for entry onto their property during the course of the study.

Transect Placement (study site setup)

Study sites (Appendix A) were established in March and April of 1998. A PHABSIM transect was placed at the up- and downstream end of each study site. The downstream transect was modeled with PHABSIM to provide water surface elevations as an input to the 2-D model. The upstream transect was used in calibrating the 2-D model - bed roughnesses are adjusted until the water surface elevation at the top of the site matches the measured water surface elevation. For

Figure 1
Sacramento River Stream Segments 2-6[2]



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[2] Flows are the average flows for the period October 1974 to September 1993 at the upstream end of each segment.

Table 1
Mesohabitat Units Selected for Modeling Chinook Salmon Rearing

Stream Segment	River Mile	Location	Mesohabitat Type(s)
6	298.7-298.8	Lower Lake Redding Site	Flatwater Pool
6	299-299.3	Upper Lake Redding Site	Flatwater Glide
6	300.6	Salt Creek Site	Run
5	297.7-297.8	Posse Grounds Site	Flatwater Riffle
5	296.6-296.8	Site 130	Bar Complex Pool
5	294.9-295	Site 112	Bar Complex Riffle
5	291.6-291.7	Site 96	Side Channel Run
5	298.4-298.8	Site 81	Bar Complex Glide
5	298.4-298.5	Site 80	Side Channel Pool
5	287.5-288	Site 61/63	Side Channel Riffle/Bar Complex Run
5	286.1-286.2	Site 52	Flatwater Run
5	282.7-282.8	Above Hawes Hole Site	Flatwater Glide/Flatwater Pool
4	279.8-280	Site 28	Bar Complex Pool
4	279.2-279.4	Powerline Riffle Site	Flatwater Glide
4	276.9-277.4	Site 15/17	Flatwater Pool/Flatwater Run/Flatwater Riffle
4	272.8-273	Site 9	Bar Complex Run
4	271.5-271.7	Price Riffle Site	Bar Complex Glide/Bar Complex Riffle

Site 61/63, an additional transect was placed in the middle of the site across the entrance to a side channel (which is not part of the site). This transect was also modeled with PHABSIM to provide water surface elevations as an input to the 2-D model. Transect pins (headpins and tailpins) were marked on each river bank above the 30,000 cfs water surface level using rebar driven into the ground and/or lag bolts placed in tree trunks. Survey flagging was used to mark the locations of each pin.

In most cases, the study site boundaries (up- and downstream ends) were selected to coincide with the upstream and downstream ends of the mesohabitat unit. The exceptions to the above were: 1) Salt Creek; 2) Upper Lake Redding; 3) Lower Lake Redding; 4) Posse Grounds; 5) Site 81; 6) Site 61/63; 7) Powerline; and 8) Price. The mesohabitat units that Salt Creek, Upper Lake Redding, Lower Lake Redding and Powerline were located in were extremely long (on the order of a mile), and thus it was impractical to model the entire mesohabitat unit. We decided to model 800 feet for Salt Creek and Powerline sites, since the average length of the other sites was 800 feet. Since Salt Creek only had one transect, the transect was used as the downstream end of the site; it was also located a short distance (approximately 200 feet) upstream of the downstream end of the mesohabitat unit. Powerline Transect 2 was located at the downstream end of the mesohabitat unit, and was thus used as the bottom end of this site. The two transects of the Upper Lake Redding site were selected as the up- and downstream end of this site to reduce the amount of additional data that needed to be collected; in addition, this resulted in a 729-foot-long site (i.e. almost as long as the average length of other sites). ACID dam (the downstream boundary of this mesohabitat unit) was selected as the downstream end of the Lower Lake Redding site, while the transect at this site, located 469 feet upstream of ACID dam, was selected as the upstream boundary of the site, again to reduce the amount of additional data that needed to be collected. Posse Grounds Transect 7 was selected as the upstream study site boundary, since it was located near the upstream boundary of the mesohabitat unit on the left bank, while Posse Grounds Transect 1 was selected as the downstream boundary to once again reduce the amount of additional data that needed to be collected. Approximately 80 percent of the mesohabitat unit that Site 81 was located in was selected for modeling for logistical reasons (so that there would be the same flow throughout the site). Mesohabitat unit 61 consisted of several channels; we only chose to model the channel which was located adjacent to (and discharged from and into) mesohabitat unit 63 to most efficiently collect data. All of mesohabitat unit 63 was included in the study site. Price Transects 2 through 5 are located in two mesohabitat units, with the mesohabitat boundary crossing the river at an extreme angle. Price Transect 2, located at the downstream end of one of the mesohabitat units, was selected as the downstream boundary of the site, while the upstream boundary of the site is at the upstream boundary of the other mesohabitat unit.

Hydraulic and Structural Data Collection

Vertical benchmarks were established at each site to serve as the reference elevations to which all elevations (streambed and water surface) were tied. Vertical benchmarks consisted of lag bolts driven into trees. In addition, horizontal benchmarks (rebar driven into the ground) were established at each site to serve as reference locations to which all horizontal locations (northings and eastings) were tied.

The data collected on the upstream and downstream transect included: 1) water surface elevations (WSELs), measured to the nearest 0.01 foot at a minimum of three significantly different stream discharges using standard surveying techniques (differential leveling); 2) wetted streambed elevations determined by subtracting the measured depth from the surveyed WSEL at a measured flow; 3) dry ground elevations to points above bankfull discharge surveyed to the nearest 0.1 foot; 4) mean water column velocities measured at a mid-to-high-range flow at the points where bed elevations were taken; and 5) substrate and cover classification at these same locations and also where dry ground elevations were surveyed. In between these transects, the following data were collected: 1) bed elevation; 2) horizontal location (northing and easting, relative to horizontal benchmarks); 3) substrate; and 4) cover. These parameters were collected at enough points to characterize the bed topography, substrate and cover of the site. For the spawning sites with PHABSIM transects within the sites, these transects were used as an additional data source to characterize the bed topography and substrate of the sites. Hydraulic and structural data collection began in March 1998 and was completed in March 2000. See U. S. Fish and Wildlife Service 1999 for details on the hydraulic and structural data collection on the spawning site PHABSIM transects.

Water surface elevations were measured at all sites at the following flow ranges: 4,000-6,500 cfs, 8,000-10,500 cfs, 13,500-15,500 cfs, and 29,000-36,000 cfs. Water surface elevations were also collected at a range of 11,000-13,000 cfs (Above Hawes Hole, Powerline and Price Riffles, Sites 28, 15/17 and 9), and 22,000-26,500 cfs (Sites 130, 112, 61/63 and Above Hawes Hole). Depth and velocity measurements were collected at all sites for the flow range of 13,000-15,500 cfs.

Depth and velocity measurements in portions of the transects with depths greater than 3 feet were made with a 600 kHz Broad-Band Acoustic Doppler Current Profiler (ADCP), while depths and velocity measurements in shallower areas were made by wading with a wading rod equipped with a Marsh-McBirney^R model 2000 or a Price AA velocity meter. The ADCP settings used are shown in Table 2. Starting at the water's edge, water depths and velocities were made at measured intervals using the wading rod and Marsh-McBirney^R model 2000 or Price AA velocity meter until the water became sufficiently deep to operate the ADCP (approximately 3 feet). The distance intervals of each depth and velocity measurement from the headpin or tailpin were measured using a hand held laser range finder[3]. At the location of the last depth and velocity measurement made while wading, a buoy was placed to serve as a starting point for the ADCP. The boat was then positioned so that the ADCP started operation at the buoy, and water depth and velocity data were collected across the transect to the location near the opposite bank where water depths of approximately 3 feet were reached. A buoy was placed at the location where ADCP operation ceased and the procedure used for measuring depths and velocities in shallow water was repeated until the far bank water's edge was reached. Additional details on the ADCP operation are given in Gard and Ballard (2003).

Substrate and cover classification was accomplished using underwater video equipment along the deepwater portion of the transects and visually in shallow water. The underwater video equipment consists of two waterproof remote cameras mounted on an aluminum frame with two 30-lbs. bombs. One camera was mounted facing forward, depressed at a 45° angle from the horizontal, and the second camera was mounted such that it faced directly down at a 90° angle from the horizontal. The camera mounted at a 45° angle was used for distinguishing changes in substrate size and cover types, while the camera mounted at 90° was used for assessing substrate size and cover type. The frame is attached to a cable/winch assembly, while a separate cable from the remote cameras is connected to two TV monitors on the boat. The two monitors are

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[3] The stations for the dry ground elevation measurements were also measured using the hand held laser range finder.

Table 2
CFG Files[4] Used for ADCP Data

CFG File	Mode	Depth Cell Size (ft)	Depth Cell Number	Max Bottom Track Depth (ft)	Pings	WT[5]	First Depth Cell (ft)	Blanking Dist. (ft)
MD8A	8	0.66	15	26	4	5	1.61	0.33
MD4C	4	0.33	30	26	4	5	1.51	0.33
MD4E	4	0.66	30	26	4	5	1.84	0.33
MD4G	4	0.66	50	39	4	5	1.84	0.33
MD4H	4	0.66	100	52	4	5	1.84	0.33
D45D	8	0.66	30	26	4	5	1.94	0.66

used by the winch operator to distinguish changes in substrate size and cover type and determine the substrate size and cover type. Substrates and cover were visually assessed (using a calibrated grid[6] on the monitor connected to the 90° camera for the deep water substrates) for the dominant particle size range for substrate (e.g., range of 2-4 inches) and for cover type. Table 3 gives the substrate codes and size classes used in this study, while Table 4 gives the cover codes and types used in this study. The substrate sizes and cover types were visually assessed from the headpin or tailpin to the location along the transect where the water became too deep for further visual assessment. At each change in substrate size class or cover type, the distance from the headpin or tailpin was measured using a hand held laser range finder. A buoy was placed at the location where visual assessment stopped and assessment from that point was continued across the transect by boat using the video camera assembly, with the distances where substrate size or cover type changed again measured with the hand held laser range finder. A buoy was again dropped at the location along the transect near the opposite shore where shallow water depth prevented further progress by boat. The substrate and cover over the remaining distance from the buoy to the end of the transect was assessed using the same visual methods used on the opposite bank.

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[4] The first four characters of the ADCP traverses designates which CDG file (containing the ADCP settings) was used for the traverses.

[5] WT is the water track transmit length.

[6] The grid was calibrated so that, when the camera frame was 1 foot off the bottom, the smallest grid corresponded to a 2-inch substrate, the next largest grid corresponded to a 4-inch substrate, etc.

Table 3
Substrate Descriptors and Codes

Code	Type	Particle Size (inches)
0.1	Sand/Silt	< 0.1
1	Small Gravel	0.1 - 1
1.2	Medium Gravel	1 - 2
1.3	Medium/Large Gravel	1 - 3
2.3	Large Gravel	2 - 3
2.4	Gravel/Cobble	2 - 4
3.4	Small Cobble	3 - 4
3.5	Small Cobble	3 - 5
4.6	Medium Cobble	4 - 6
6.8	Large Cobble	6 - 8
8	Large Cobble	8 - 10
9	Boulder/Bedrock	> 12
10	Large Cobble	10-12

In between the upstream and downstream transect, the following data were collected: 1) bed elevation; 2) horizontal location (northing and easting, relative to horizontal benchmarks); 3) substrate; and 4) cover. These parameters were collected at enough points to characterize the bed topography, substrate and cover of the site. There were two techniques used to collect the data within the site: 1) for areas that were dry or shallow (less than 3 feet), bed elevation and horizontal location of individual points were obtained by sighting from a total station to a stadia rod and prism, while the substrate and cover were visually assessed at each point; and 2) in portions of the site with depths greater than 3 feet, the ADCP was used in concert with the total station to obtain bed elevation and horizontal location. Specifically, the ADCP was run across the channel at 50 to 150 foot intervals, with the initial and final horizontal location of each traverse recorded by the total station. Initially, WSELs were measured down the site using differential leveling, with the distance down the site measured with the hand held laser range finder. Subsequently, we found that it was more efficient to measure the WSEL of each ADCP traverse.

Table 4
Cover Coding System

Cover Category	Cover Code
no cover	0.1
cobble	1
boulder	2
fine woody vegetation (< 1" diameter)	3
fine woody vegetation + overhead cover	3.7
branches	4
branches + overhead cover	4.7
log (> 1' diameter)	5
log + overhead cover	5.7
overhead cover (> 2' above substrate)	7
undercut bank	8
aquatic vegetation	9
aquatic vegetation + overhead cover	9.7
rip-rap	10

Velocities at each point measured by the ADCP were used to validate the 2-D model. To validate the velocities predicted by the 2-D model for shallow areas within a site, depth, velocity, substrate and cover measurements were collected along the right and left banks within each site by wading with a wading rod equipped with a Marsh-McBirney^R model 2000 or a Price AA velocity meter. The horizontal locations and bed elevations were determined by sighting from a total station to a prism held at each point where depth and velocity were measured. A minimum of 25 representative points were measured along the length of each side of the river per site. For the spawning sites with PHABSIM transects within the sites, the velocities measured on these transects were also used to validate the 2-D model.

For the collection of the substrate and cover data on the ADCP traverses for the first several sites, the initial and final locations of each deep bed elevation traverse were located using the previously-measured horizontal angle and slope distance, and marked with buoys. The underwater video and hand held laser range finder were then used to determine the substrate and cover along each traverse, so that substrate and cover values could be assigned to each point of the traverse. However, subsequently it was determined that it was more efficient to collect the deep substrate and cover data immediately following the completion of the deep bed elevation data collection for a site, with buoys placed prior to the collection of the deep bed data and used during the collection of the deep substrate and cover data.

By determining the horizontal location of the head and tail pins of the transects at the spawning sites and collecting cover data on these transects, we have used all of the points on these transects to determine at least part of the bed topography and cover/substrate of these sites. The number and density of data points collected for each site is given in Table 5.

Hydraulic Model Construction and Calibration

All data were compiled and checked before entry into PHABSIM data decks for the upstream and downstream transects. ASCII files of each ADCP traverse were produced using the Playback feature of the Transect program[7]. Each ASCII file was then imported into the Riverine Habitat Simulation (RHABSIM)[8] Version 2.0 to produce the bed elevations, the component of the average water column velocities perpendicular to the transect, and stations (relative to the start of the ADCP traverse). RHABSIM was then used to output a second ASCII file containing this data. The second ASCII file was input into a QuattroPro spreadsheet and combined with the velocity, depth, and station data collected in shallow water. We defined a statistic (R) to provide a quality control check of the velocity measured by the ADCP at a given station n, where $R = Vel_n/(Vel_{n-1} + Vel_{n+1})/2$ at station n[9]. R was calculated for each velocity where Vel_n, Vel_{n-1} and Vel_{n+1} were all greater than 1 ft/s for each ADCP data set. Based on data collected using a Price AA velocity meter on the Lower American River, the acceptable range of R was set at 0.5-1.6. All verticals with R values less than 0.5 or greater than 1.6 were deleted from each ADCP data set[10]. Discharges were calculated for each ADCP traverse, including the data collected in shallow water. For those sites which included the entire Sacramento River flow, the traverse for

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[7] The Transect program is the software used to receive, record and process data from the ADCP.

[8] RHABSIM is a commercially-produced software (Payne and Associates 1998) that incorporates the modeling procedures used in PHABSIM.

[9] n - 1 refers to the station immediately before station n and n + 1 refers to the station immediately after station n.

[10] We also deleted velocities where Vel_n was less than 1.00 ft/s and Vel_{n-1} and Vel_{n+1} were greater than 2.00 ft/s, and where Vel_n had one sign (negative or positive) and Vel_{n-1} and Vel_{n+1} had the opposite sign (when the absolute value of all three velocities were greater than 1.00 ft/s); these criteria were also based on the Lower American River dataset (Gard and Ballard 2003).

Table 5
Number and Density of Data points Collected for Each Site

Site Name	Number of Points			Density of Points (points/100 m^2)
	Points on Transects	Points Between Transects Collected with Total Station	Points Between Transects Collected with ADCP	
Salt Creek	76	140	306	3.5
Upper Lake	330	72	156	1.7
Lower Lake	211	68	213	1.8
Posse Grounds	727	70	0	3.6
Site 130	105	56	158	2.4
Site 112	163	69	151	1.1
Site 96	65	50	66	3.0
Site 81	111	82	192	0.6
Site 80	64	139	246	3.8
Site 61/63	107	324	567	0.9
Site 52	66	60	188	1.7
Hawes	561	362	400	1.1
Site 28	75	50	160	1.9
Powerline	568	36	407	2.8
Site 15/17	95	96	1146	1.3
Site 9	84	61	624	1.6
Price	431	89	0	1.1

each transect which had the flow closest to the actual flow, determined from gage readings[11] (Table 6), was selected for use in the PHABSIM decks. For the remaining sites, the traverse for each transect which had the flow closest to the average of the flows from all of the traverses for that site was selected for use in the PHABSIM decks, except for Site 96 transect 2, where the ADCP traverse that resulted in the best match to the transect length was used.

Flow/flow regressions were performed for sites which did not include the entire Sacramento River flow (Sites 130, 96, 81, 80 and 61/63), using the flows measured either in the site or in an adjacent side channel, and the corresponding total flows from Table 6. The regressions were developed from three sets of flows, typically with the entire river discharge around 5000 cfs, 10000 cfs and 15000 cfs. For Site 130, the flows used in the regression were the average of the ADCP traverses at Site 130 at the highest flow, and the flows measured with a wading rod and Price AA or Marsh-McBirney meter on an adjacent side channel for the other two flows, where the total river flow was the sum of the Site 130 flow and the adjacent side channel flow. For Sites 96 and 80, the flows used in the regression were the average of the ADCP traverses at the sites at the highest flow and the flows measured with a wading rod and Price AA or Marsh-McBirney meter at the sites for the other two flows. Since the sum of the Site 80 and 81 flows was the entire river flow, the flows for Site 81 were determined by subtraction. For transect 3 at Site 61/63, the flows used in the regression were the average of the ADCP traverses on transect 3, while for transect 2 at Site 61/63, the flows used in the regression were those measured on transect 2 with a wading rod and Price AA or Marsh-McBirney meter. The flow for transect 1 at Site 61/63 was the difference between the flows for transects 3 and 2. The flow/flow regressions used are given in Table 7. Calibration flows for Sites 130, 96, 81, 80 and 61/63 (Table 8) were computed from the total discharge in Table 6 and the appropriate regression equation in Table 7.

The ADCP traverses selected for use are shown in Table 9.[12]

See U. S. Fish and Wildlife Service 1999 for details on the hydraulic model construction and calibration on the spawning site PHABSIM transects.

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[11] As shown in Table 5, the flow calculated at Bend Bridge from upstream and tributary gage readings often differed from the gage reading at Bend Bridge by less than 5% and never differed by more than 10%. Similarly, as shown in Table 8, the measured discharge usually differed from the flow in Table 5 or 7 by less than 5% and never differed by more than 13.5%. Flows could be calculated using either USBR or USGS flows measured at Keswick Dam; the flows selected for use were those which had the smaller Bend error.

[12] Velocities for Site 61/63 transect 2 were measured entirely with a wading rod and Price AA or Marsh McBirney velocity meter.

Table 6
Sacramento River Flows at Study Sites[13] (cfs)

Date	Sites 130 & 112	Sites 96, 81 & 80	Sites 52 & 61/63	Hawes Hole	Site 28 & Powerline	Site 15/17	Price & Site 9	Bend err	Keswick Flow Used
3/30/98	29200							6.94%	USGS
3/31/98	29000	29000	29455					2.75%	USGS
4/1/98			29918	30864	32594	32774	35704	3.93%	USGS
4/2/98							30886	5.90%	USGS
4/29/98	10128	10068	10300					1.50%	USGS
4/30/98		10369	10598					1.66%	USGS
5/1/98				11248	12288	12413	14573	0.73%	USGS
6/10/98			13109					1.49%	USBR
6/16/98		14510						0.98%	USBR
6/17/98			14414					0.35%	USBR
7/22/98			14673					1.02%	USGS
8/10/98	14577							1.68%	USGS
8/11/98					14999	15028	15206	2.71%	USGS
8/12/98		14703	14917	14934	15079			2.30%	USGS
9/3/98		13520						1.43%	USGS
9/22/98				9898				1.84%	USGS
10/14/98	6152							9.19%	USGS
10/15/98		5885	6091	6112				9.10%	USGS
10/16/98					6149	6178	6301	8.30%	USBR
12/8/98								1.58%	USGS
12/9/98			22294					6.14%	USGS
12/10/98		22200	22444	26100				2.21%	USGS
12/11/98	22200							2.65%	USGS
4/20/99					9922	10026	12576	0.69%	USBR
5/3/99					11136			3.40%	USBR
5/4/99						11084		3.30%	USGS

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[13] These flows are the same as the study site flows for those sites that include all of the Sacramento River flow (Sites 112, 52, 28, 28, 15/17, 9, Hawes Hole, Powerline and Price).

Table 6 (continued)

Date	Sites 130 & 112	Sites 96, 81 & 80	Sites 52 & 61/63	Hawes Hole	Site 28 & Powerline	Site 15/17	Price & Site 9	Bend err	Keswick Flow Used
5/5/99						10976	12126	3.18%	USGS
5/13/99							11790	0.60%	USGS
11/15/99	6250							3.99%	USGS
12/7/99	8406							0.59%	USBR
12/8/99	8036	8036	8247		8490	8527	8756	0.12%	USBR
1/3/00	5020							8.30%	USGS
1/4/00		5010	5219		5375	5404		8.47%	USGS
1/10/00	4500							9.87%	USBR
1/11/00					5847		6075	4.79%	USGS
1/12/00		4440	4666					9.11%	USGS
1/13/00				4670				5.49%	USGS
2/16/00						44643		6.51%	USBR

A table of substrate and cover ranges/values was created to determine the substrate and cover for each vertical/cell (e.g, if the substrate size class was 2-4 inches on a transect from station 50 to 70, all of the verticals with station values between 50 and 70 were given a substrate coding of 2.4). Dry bed elevation data in field notebooks were entered into the spreadsheet to extend the bed profile up the banks above the WSEL of the highest flow to be modeled. An ASCII file produced from the spreadsheet was run through the FLOMANN program (written by Andy Hamilton, USFWS) to get the PHABSIM input file and then translated into RHABSIM files. RHABSIM was used rather than PHABSIM because the number of verticals per transect exceeded 100.

All of the measured WSELs were checked to make sure that water was not flowing uphill. Those WSELs that showed water flowing uphill were not used in the decks or were modified before being used in the decks[14]. A total of four to seven sets of WSELs at widely spaced flows were used; if WSELs were available for several closely spaced flows, the WSEL that corresponded with the velocity set or the WSEL collected at the lowest flow was used in the decks. Calibration flows in the data decks (Appendix B) were the flows calculated from gage readings or the flows calculated from gage readings and the regression equations in Table 6.

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[14] The only WSELs that showed water running uphill were those measured at Site 52. For these flows, the WSEL at transect 1 was 0.02 to 0.07 foot higher than the WSEL at transect 2. We attribute this to eddies along the banks. For these flows, we set the WSEL for transect 2 equal to the WSEL at transect 1.

Table 7
Flow/Flow Regression Equations

Study Site	XS #	Flow Range	Regression Equation[15]	R^2-value
Site 130	all	3250-31000	Site 130 Q = 242 + 0.805 x Q	0.998
Site 96	all	3250-31000	Site 96 Q = 10 ^ (-0.906 + 1.089 x log (Q - 3111))	0.986
Site 81	all	3250-31000	Site 81 Q = Q - Site 80 Q	N/A
Site 80	all	3250-3308	Site 80 Q = 0	N/A
Site 80	all	3309-15000	Site 80 Q = 10 ^(-5.85 + 2.258 x log (Q - 3308))	0.99999
Site 80	all	17000-31000	Site 80 Q = -2499 + 0.308 x Q	1 [16]
Site 61/63	3	3250-31000	XS 3 Q = -800 + 0.661 x Q	0.999
Site 61/63	2	3250-21000	XS 2 Q = 10 ^(-2.491 + 1.25 x log(Q))	0.89
Site 61/63	2	23000-31000	XS 2 Q = -511 + 0.755 x Q	1 [16]
Site 61/63	1	3250-31000	XS 1 Q = XS 3 Q - XS 2 Q	N/A

A separate deck was constructed for each study site. In addition, a separate deck was constructed for each transect at Site 61/63. The WSELs used in the decks, along with the distances between transects, were then used to compute the slope to be used for each transect, as follows. For each transect, two slopes were computed at each measured flow, one using the difference in WSELs between the transect and the next transect downstream divided by the distance between the two, and the other in the same fashion using the next transect upstream. Each of these two slopes were averaged for all measured flows, and these two averages were then averaged again to determine the final slope used in the velocity simulation. For transects at either end of a study site (where either an adjacent upstream or downstream transect was absent), slopes were calculated minus the final averaging step.

The stage of zero flow (SZF), an important parameter used in calibrating the stage-discharge relationship, was determined for each transect and entered. In habitat types without backwater effects (e.g., riffles and runs), this value generally represents the lowest point in the streambed across a transect. However, if a transect directly upstream contains a lower bed elevation than

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[15] Q is the total river flow, Site 130 Q is the flow in Site 130, etc.

[16] Since only two flows were used in these regressions, the R^2-values, by definition, were one.

Table 8
Calibration Flows for Study Sites 130, 96, 81, 80 and 61/63 (cfs)

Date	Site 130	Site 96	Site 81	Site 80	Site 61/63 XS 3	Site 61/63 XS 2	Site 61/63 XS 1
3/30/98	23739						
3/31/98		7983	22560	6440	18687	1711	16976
4/29/98	8392	1907	9440		6014	334	5680
4/30/98				693			
6/16/98		3266	12546				
6/17/98					8736		8227
7/22/98						520	
8/10/98	11972						
8/12/98				2041	9069		8538
9/3/98		2958	11926				
10/14/98	5192						
10/15/98		700	5814	71	3229	173	3056
12/8/98			7756				
12/9/98					13949	877	13072
12/10/98					14048	885	13163
12/11/98	18106						
12/8/99	6708						
1/3/00	4281						
1/4/00			4982		2653		2510
1/12/00			4429			124	

the adjacent downstream transect, the SZF for the downstream transect applies to both. In some cases, data collected in between the transects showed a higher thalweg elevation than either transect; in these cases the higher thalweg elevation was used as the SZF for the upstream transect. For Sites 130, 52 and 28, we made a series of ADCP traverses across the channel below the site, with a WSEL measured for each traverse to compute bed elevations for each traverse. The highest thalweg bed elevation from the traverses was used as the SZF for these sites. For Site 80, we were able to survey in, at a low flow, the highest thalweg elevation downstream of transect 1; since this was higher than the thalweg elevation at transect 1, this elevation was used as the SZF for Site 80 transect 1. The SZFs used for each transect are given in Appendix B.

Table 9
ADCP Files Used in PHABSIM Decks

Site Name	XS Number	File Name	Measured Q	% Difference
Site 130	1	MD4E028	12375	2.3%
Site 130	2	MD4E030	11650	2.9%
Site 112	1	MD4C110	13386	8.2%
Site 112	2	MD4C107	14388	1.3%
Site 96	1	MD4C119	2763	0.1%
Site 96	2	MD4C115	3138	13.5%
Site 81	1	MD8A190	11758	1.6%
Site 81	2	MD8A192	12282	2.8%
Site 80	1	MD8A188	2215	9.0%
Site 80	2	MD8A182	2024	0.4%
Site 61/63	1	MD4C114	8424	1.4%
Site 61/63	3	MD4E038	9195	1.8%
Site 52	1	MD4G003	13405	2.3%
Site 52	2	MD4G004	14602	11.4%
Hawes Hole	7	MD8A178	14945	0%
Site 28	1	MD4H001	15413	2.2%
Site 28	2	MD4E034	15209	0.9%
Powerline	7	MD8A176	15041	0.28%
Site 15/17	1	D45D038	15300	1.8%
Site 15/17	2	MD8A171	14780	1.65%
Site 9	1	D45D035	15912	4.6%
Site 9	2	MD8A168	15591	2.5%
Price	6	MD8A165	15028	2%

The first step in the calibration procedure was to determine the best approach for WSEL simulation. Initially, the *IFG4* hydraulic model (Milhous *et al.*, 1989) was run on each deck to compare predicted and measured WSELs. This model produces a stage-discharge relationship using a log-log linear rating curve calculated from at least three sets of measurements taken at different flows. Besides *IFG4*, two other hydraulic models are available in PHABSIM to predict stage-discharge relationships. These models are: 1) *MANSQ*, which operates under the assumption that the condition of the channel and the nature of the streambed controls WSELs; and 2) *WSP*, the water surface profile model, which calculates the energy loss between transects to determine WSELs. *MANSQ*, like *IFG4*, evaluates each transect independently. *WSP* must, by nature, link at least two adjacent transects. *IFG4*, the most versatile of these models, is considered to have worked well if the following criteria are met: 1) the beta value (a measure of the change in channel roughness with changes in streamflow) is between 2.0 and 4.5; 2) the mean error in calculated versus given discharges is less than 10%; 3) there is no more than a 25% difference for any calculated versus given discharge; and 4) there is no more than a 0.1 foot difference between measured and simulated WSELs[17]. *MANSQ* is considered to have worked well if the second through fourth of the above criteria are met, and if the beta value parameter used by *MANSQ* is within the range of 0 to 0.5. The first *IFG4* criterion is not applicable to *MANSQ*. *WSP* is considered to have worked well if the following criteria are met: 1) the Manning's n value used falls within the range of 0.04 - 0.07; 2) there is a negative log-log relationship between the reach multiplier and flow; and 3) there is no more than a 0.1 foot difference between measured and simulated WSELs. The first three *IFG4* criteria are not applicable to *WSP*. For a majority of the transects for at least a portion of the measured flows, *IFG4* met the above criteria for *IFG4* (Appendix B). *MANSQ* worked successfully for a number of transects, meeting the above criteria for *MANSQ* (Appendix B). *WSP* worked successfully for the remaining transects, meeting the above criteria for *WSP*.

For most of the transects, we needed to simulate low and high flows with different sets of calibration WSELs (Appendix B) to meet the above criteria. For transects where we had measured five or more sets of WSELs, *IFG4* could be run for low flows using the three or four lowest calibration WSELs, and run for high flows using the three highest calibration WSELs. For transects where we had only measured four sets of WSELs, we typically used *IFG4* with the three highest or three lowest flows to simulate, respectively, the high or low flows, and used *MANSQ* or *WSP* with the two lowest or two highest flows to simulate the remaining flows. For Site 61/63 transect 1, where we had measured seven sets of WSELs, we used *IFG4* to simulate low flows with the three lowest sets of WSELs, the middle-range flows with the three middle sets of WSELs, and the high flows with the three highest sets of WSELs.

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[17] The first three criteria are from U.S. Fish and Wildlife Service 1994, while the fourth criterion is our own.

For those transects/flow ranges modeled with *IFG4*, the mean error and calculated-given discharge criteria were met in all cases, and the measured-simulated WSEL difference criterion for *IFG4* was met in all cases except for Site 80 transect 1 (11,000-31,000 cfs), Site 61/63 transect 2 (15,000-31,000 cfs) and Site 52 transect 1 and 2 (14,000-31,000 cfs). We still used *IFG4* for these transects because *MANSQ* gave much greater errors and *WSP* could not be used because they were the downstream-most transects in the site[18]; in addition, the difference between measured and simulated WSELs for all 4 transects was less than 0.14 foot. For Site 130 transect 1 (15,000-31,000 cfs), *MANSQ* met the mean error and calculated-given discharge criterion but did not meet the measured-simulated WSEL difference criterion. We still used *MANSQ* for this transect because *IFG4* gave much greater errors and *WSP* could not be used because it was the downstream-most transect in the site; in addition, the difference between measured and simulated WSELs was less than 0.14 foot. As shown in Appendix B, the beta coefficient values were less than 2.0 for the following transects calibrated with *IFG4*: 1) Site 96 transect 1 and 2 (all flows); 2) Site 61/63 transect 2 (all flows) and 3 (15,000 to 31,000 cfs); 3) Site 52 transect 1 and 2 (3,250 to 14,000 cfs); and 4) Powerline Riffle transect 7 (10,000 to 31,000 cfs). In addition, the Velocity Adjustment Factors (VAF) for Site 96 transect 1 and Site 61/63 transect 2 (Appendix C) decreased with increasing flow at low flows. VAFs typically increase monotonically with increasing flows as higher flows produce higher water velocities. The model, in mass balancing, was obviously decreasing water velocities at high flows so that the known discharge would pass through the increased cross-sectional area. We concluded that both of these phenomena were caused by channel characteristics which form hydraulic controls at some flows but not at others (compound controls), thus affecting upstream water elevations. Specifically, at lower flows the channel at these transects controlled the water surface elevations, while at higher flows the water surface elevations were controlled by downstream hydraulic controls. Accordingly, the performance of *IFG4* for these transects was considered adequate despite the beta coefficient criterion not being met.

The final step in simulating WSELs was to check whether water was going uphill at any of the simulated WSELs. This occurred at Site 61/63 transect 3 at 3,250 and 3,500 cfs and at Powerline Riffle transect 7 at 3,250 to 9,000 cfs. It appears that there is a very low WSEL gradient at these transects and flow ranges; accordingly, we used *WSP* for these transects by setting the simulated WSELs for the transect equal to the WSEL at the next-most downstream transect.

VAFs were examined for all of the simulated flows (Appendix C). The only transects that deviated significantly from the expected pattern of VAFs were Site 112 transect 1, Site 96 transect 1 and Site 61/63 transect 2. Site 15/17 transect 1 and 2 and Price Riffle transect 6 had minor deviations from the expected pattern of VAFs. We conclude that for all of the transects with major or minor deviations in the expected pattern of VAFs, the deviations were due to

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[18] Site 61/63 transect 2 was on an outflow side-channel and thus did not have a transect below it. Site 52 transect 2 could not be modeled separately from transect 1 because the measured WSELs for both transects at all flows were the same (see footnote 13).

compound controls, and thus the patterns of VAFs for all transects was acceptable. In addition, the VAF values (ranging from 0.002 to 3.77) were all within an acceptable range except for Site 96 transect 2, Site 80 transect 1 and 2 at low flows.[19] The low VAF values for the above sites are due to strong backwater effects, and is acceptable in this case since RHABSIM is only being used to simulate WSELs and not velocities.

The data from the ADCP traverses made to characterize the bed topography of the sites between the transects for input to the 2-D model were processed for input into a QuattroPro spreadsheet in the same manner described above for the ADCP data on the transects. We applied the same quality criteria to the velocities from these ADCP traverses as described above for the velocity data collected on the transects, with the velocities not meeting the quality control criteria deleted from each ADCP data set.

For the initial sites where we collected deep bed topography data, the procedure to determine the WSEL of each traverse was as follows: 1) a WSEL profile down the site was computed from the measured WSELs and measured distances down the site; and 2) the initial and final locations of each traverse was used to determine the distance down the site of each traverse, so that the WSEL of each traverse could be determined from the WSEL profile. This step was not necessary for the later sites, since we directly measured the WSEL of each ADCP traverse. The bed elevation of each point along the traverse was calculated as the difference between the WSEL of the traverse and the depth at each point. The distance along each ADCP traverse, in concert with initial and final horizontal locations, was used to compute the horizontal location of each point along the traverse. The station along each PHABSIM transect, in concert with the horizontal locations of the headpins and tailpins of the transects, was used to compute the horizontal location of each vertical of the PHABSIM transects. Substrate and cover was assigned to each point along each ADCP traverse in the same manner as described above for the transects.

The data from the ADCP traverses were combined in QuattroPro with the dry/shallow total station data and the PHABSIM transect data to create the input files (bed, substrate and cover) for the 2-D modeling program. An artificial extension one channel-width-long was added upstream of the top of the site to enable the flow to be distributed by the model when it reached the study area, thus minimizing boundary conditions influencing the flow distribution at the upstream transect and within the study site. For Salt Creek site, Posse Grounds site, and Site 28, we also had to add an artificial extension a half-channel-width-long downstream of the bottom of the site to enable a stable solution, for Salt Creek site and Site 28, and to get a different WSEL for each channel at the bottom of the site, for Posse Grounds site. For Site 61/63, we had to add an artificial extension downstream of transect 2, extending to transect 1, to get flow going downstream at transect 2. The bed files contain the horizontal location (northing and easting), bed elevation and initial bed roughness value for each point, while the substrate files contain the horizontal location, bed elevation and substrate code for each point and the cover files contain

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[19] VAFs are considered acceptable if they fall within the range of 0.2 to 5.0.

the horizontal location, bed elevation and cover code for each point. The initial bed roughness value for each point was determined from the substrate and cover codes for that point and the corresponding bed roughness values in Table 10, with the bed roughness value computed as the sum of the substrate bed roughness value and the cover bed roughness value. The bed roughness values for substrate in Table 10 were computed as five times the average particle size. The bed roughness values for cover in Table 10 were computed as five times the average cover size, where the cover size was measured in the field on a representative sample of cover elements of each cover type. The bed, substrate and cover files were exported from QuattroPro as ASCII files.

A utility program, R2D_BED (Steffler 2001b), was used to define the study area boundary and to refine the raw topographical data TIN (triangulated irregular network) by defining breaklines[20] following longitudinal features such as thalwegs, tops of bars and bottoms of banks. Breaklines were also added along lines of constant elevation. The bed topography of the sites is shown in Appendix D.

An additional utility program, R2D_MESH (Steffler 2001a), was used to define the inflow and outflow boundaries and create the finite element computational mesh for the River2D model. R2D_MESH uses the final bed files as an input. The first stage in creating the computational mesh was to define mesh breaklines[21] which coincided with the final bed file breaklines. Additional mesh breaklines were then added between the initial mesh breaklines, and additional nodes were added as needed to improve the fit between the mesh and the final bed file and to improve the quality of the mesh, as measured by the Quality Index (QI) value. The QI is a measure of how much the least equilateral mesh element deviates from an equilateral triangle. An ideal mesh (all equilateral triangles) would have a QI of 1.0. A QI value of at least 0.2 is considered acceptable (Steffler 2001a). As shown in Appendix E, the meshes for all sites had QI values of at least 0.28. The percentage of the original bed nodes for which the mesh differed by less than 0.1 foot (0.03 m) from the elevation of the original bed nodes ranged from 61% to 88%, except for Salt Creek site (Appendix E). Salt Creek site, located in a bedrock channel, had

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[20] Breaklines are a feature of the R2D_Bed program which force the TIN of the bed nodes to linearly interpolate bed elevation and bed roughness values between the nodes on each breakline and force the TIN to fall on the breaklines (Steffler 2001b).

[21] Mesh breaklines are a feature of the R2D_MESH program which force edges of the computation mesh elements to fall on the mesh breaklines and force the TIN of the computational mesh to linearly interpolate the bed elevation and bed roughness values of mesh nodes between the nodes at the end of each breakline segment (Steffler 2001a). A better fit between the bed and mesh TINs is achieved by having the mesh and bed breaklines coincide.

Table 10
Initial Bed Roughness Values[22]

Substrate Code	Bed Roughness (m)	Cover Code	Bed Roughness (m)
0.1	0.05	0.1	0
1	0.1	1	0
1.2	0.2	2	0
1.3	0.25	3	0.11
2.3	0.3	3.7	0.2
2.4	0.4	4	0.62
3.4	0.45	4.7	0.96
3.5	0.5	5	1.93
4.6	0.65	5.7	2.59
6.8	0.9	7	0.28
8	1.25	8	2.97
9	0.05	9	0.29
10	1.4	9.7	0.57
		10	3.05

very irregular topography, which resulted in only 42% of the original bed nodes for which the mesh differed by less than 0.1 foot (0.03 m) from the elevation of the original bed nodes, despite having 12,740 nodes in the mesh. In most cases, the areas of the mesh where there was greater than a 0.1 foot (0.03 m) difference between the mesh and final bed file were in steep areas; in these areas, the mesh would be within 0.1 foot (0.03 m) vertically of the bed file within 1 foot (0.3 m) horizontally of the bed file location. Given that we had a 1-foot (0.3 m) horizontal level of accuracy, such areas would have an adequate fit of the mesh to the bed file. The final step with the R2D_MESH software was to generate the computational (cdg) files.

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[22] For substrate code 9, we used bed roughnesses of 0.71 and 1.95, respectively, for cover codes 1 and 2. Bed roughnesses of zero were used for cover codes 1 and 2 for all other substrate codes, since the roughness associated with the cover was included in the substrate roughness.

The cdg files were opened in the RIVER2D software, where the computational bed topography mesh was used together with the WSEL at the bottom of the site, the flow entering the site, and the bed roughnesses of the computational mesh elements to compute the depths, velocities and WSELs throughout the site. The basis for the current form of RIVER2D is given in Ghanem *et al* (1995).The computational mesh was run in RIVER2D to steady state at the highest flow for which WSELs were measured, and the WSELs predicted by RIVER2D at the upstream end of the site were compared to the WSELs measured at the upstream-most transect. The bed roughnesses of the computational mesh elements were then modified by multiplying them by a constant bed roughness multiplier (BR Mult) until the WSELs predicted by RIVER2D at the upstream end of the site matched the WSELs measured at the upstream-most transect. For sites with PHABSIM transects within the sites, the bed roughnesses downstream of each transect were also modified by multiplying them by a constant BR Mult so that the WSELs predicted by RIVER2D matched the WSELs measured at these transects[23]. The values of all other River2D hydraulic parameters were left at their default values (upwinding coefficient = 0.5, minimum groundwater depth = 0.05 m, groundwater transmissivity = 0.1, groundwater storativity = 1, and eddy viscosity parameters epsilon 1 = 0.01, epsilon2 = 0.5 and epsilon3 = 0.1).

An additional calibration step was needed for the three sites which had downstream extensions to develop a relationship between the WSEL at the downstream boundary and the WSEL predicted by PHABSIM at the downstream-most transect for the calibration flows. For these sites, we tried different WSELs for the downstream boundary at the highest flow for which WSELs were measured until we found a WSEL for the downstream boundary that resulted in a WSEL predicted by RIVER2D at the downstream end of the site which matched the WSELs measured at the downstream-most transect. The same process was repeated at flows of 15,000 and 3,250 cfs, with the WSEL predicted by RIVER2D at the downstream end of the site compared to the WSEL predicted by PHABSIM at the downstream-most transect for these two flows. We then developed a log-log relationship between flow and the difference between the WSEL specified at the downstream boundary and the WSEL at the downstream-most transect, using the data from these three flows. This relationship was then used to determine what to subtract from the WSEL predicted by PHABSIM for each simulation flow to generate the WSEL to be used for the downstream boundary for each simulation flow.

A stable solution will generally have a solution change (Sol Δ) of less than 0.00001 and a net flow (Net Q) of less than 1% (Steffler and Blackburn 2001). In addition, solutions for low gradient streams should usually have a maximum Froude Number (Max F) of less than one[24]. Finally, the WSEL predicted by the 2-D model should be within 0.10 foot (0.031 m) of the

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[23] Different BR Mults were used for different transects and for different split channels of transects.

[24] This criteria is based on the assumption that flow in low gradient streams is usually subcritical, where the Froude number is less than one (Peter Steffler, personal communication).

WSEL measured at the upstream transect[25]. The calibrated cdg files all had a solution change of less than 0.00001, with the net Q for all sites less than 1% (Appendix E). The calibrated cdg file for Upper Lake Redding (ACID boards out), Lower Lake Redding (ACID boards in), Posse Grounds, Powerline Riffle and Price Riffle sites and Site 61/63 had a maximum Froude Number of greater than one (Appendix E). Posse Grounds site was a higher gradient site with a limited area of supercritical flow, where a Max Froude value of greater than one would be expected. Similarly, Lower Lake Redding site would have been expected to have supercritical flow at the ACID Dam. In addition, we considered the solutions for all six sites to be acceptable since the Froude Number was only greater than one at a few nodes, with the vast majority of the site having Froude Numbers less than one. Furthermore, these nodes were located either at water's edge or where water depth was extremely shallow, typically approaching zero. A high Froude Number at a very limited number of nodes at water's edge or in very shallow depths would be expected to have an insignificant effect on the model results.

Thirteen of the 17 sites had calibrated cdg files with WSELs that differed by more than 0.1 foot (0.031 m) from the measured WSELs (Appendix E). For nine of these sites (Salt Creek, Lower Lake Redding Boards Out, Powerline Riffle, Sites 130, 112, 81, 80, 61/63 and 28), the predicted WSELs near the water's edge, where the WSELs were measured, were all within 0.1 foot (0.031 m) of the measured WSELs. For much of the Sacramento River, the WSEL going across the river will differ by more than 0.1 foot (0.031 m), with up to a 3-foot (0.91 m) measured difference in WSEL between the two banks in some areas, such as the Posse Grounds site. Accordingly, we conclude that the calibration for these nine sites was acceptable. Three of the remaining sites (Posse Grounds, Above Hawes Hole and Price Riffle) had five to seven relatively closely spaced transects. In calibrating these sites, we had to make tradeoffs in the accuracy of one transect versus another transect in matching measured WSELs. In large part, the calibration was successful in matching measured WSELs near the water's edge (for example, for all but one transect at the Above Hawes Hole site). The resulting calibration of these sites represented the best overall match to the observed patterns of WSELs, and thus we conclude that the calibration for these sites was acceptable. For the last site (Site 52), the simulated WSEL on the left bank fell within 0.1 foot (0.031 m) of the measured WSEL, while the simulated WSEL on the right bank only differed by 0.15 foot (0.046 m) from the measured WSEL. There was little effect of the bed roughness multiplier on the simulated WSELs for this site, due to the large depths of this site. We attribute the inaccuracy of the right bank simulated WSEL to aspects of the bed topography that were not captured by the data collection. The complexity of the topography of this site was evidenced by eddies which were observed along both banks. Given the above discussion, we conclude that the WSEL calibration of Site 52 was acceptable.

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[25] We have selected this standard because it is a standard used for PHABSIM (U. S. Fish and Wildlife Service 2000).

Velocity validation is the final step in the preparation of the hydraulic models for use in habitat simulation. Velocities predicted by RIVER2D were compared with measured velocities to determine the accuracy of the model's predictions of mean water column velocities. The measured velocities used were the velocities measured on the upper and lower transects, the velocities measured during collection of the deep bed topography with the ADCP, and the 50 velocities per site measured in between the upper and lower transects. See Appendix F for velocity validation statistics. Although there was a strong correlation between predicted and measured velocities, there were significant differences between individual measured and predicted velocities. In general, the simulated and measured velocities profiles at the upper and lower transects and deep bed ADCP traverses (Appendix F[26]) were relatively similar in shape. Differences in magnitude in most cases are likely due to: (1) operator error during data collection, i.e., the probe was not facing precisely into the direction of current; (2) range of natural velocity variation at each point over time resulting in some measured data points at the low or high end of the velocity range averaged in the model simulations; (3) aspects of the bed topography of the site that were not captured in our data collection; (4) the effect of the velocity distribution at the upstream boundary of the site[27]; and (5) the measured velocities being the component of the velocity in the downstream direction, while the velocities predicted by the 2-D model were the absolute magnitude of the velocity[28]. As shown in the figures in Appendix F, we attribute most of the differences between measured and predicted velocities to noise in the measured velocity measurements; specifically, for the transects, the simulated velocities typically fell within the range of the measured velocities of the three or more ADCP traverses made on each transect. The 2-D model integrates effects from the surrounding elements at each point. Thus, point measurements of velocity can differ from simulated values simply due to the local area integration that takes place. As a result, the area integration effect noted above will produce somewhat smoother lateral velocity profiles than the observations.

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[26] Velocities were plotted versus easting for transects that were orientated primarily east-west, while velocities were plotted versus northing for transects that were orientated primarily north-south.

[27] River2D distributes velocities across the upstream boundary in proportion to depth, so that the fastest velocities are at the thalweg. In contrast, the bed topography of a site may be such that the fastest measured velocities may be located in a different part of the channel. Since we did not measure the bed topography above a site, this may result in River2D improperly distributing the flow across the top of the site. As discussed above, we added artificial upstream extensions to the sites to try to address this issue.

[28] For areas with transverse flow, this would result in the 2-D model appearing to overpredict velocities even if it was actually accurately predicting the velocities.

Overall, the simulated velocities for Sites 112 and 28 were relatively similar to the measured velocities for all transects and deep bed ADCP traverses, with some differences in magnitude that fall within the amount of variation in the ADCP velocity measurements. Except as noted below, the simulated velocities for the remaining sites were relatively similar to the measured velocities for the transects and deep bed ADCP traverses, with some differences in magnitude that fall within the amount of variation in the ADCP velocity measurements.

River2D overestimated velocities near the banks for some transects and/or deep bed traverses (Lower Lake Redding Deep Bed C, Site 96 transect 1, Site 81 transect 2, Above Hawes Hole Deep Bed G, Powerline Riffle transect 6 and Deep Beds A, B and D, Site 9 Deep Beds A, B, D, F, H, I and K and Price Riffle transect 2). We attribute this to the area integration effect of River2D, where the model was not able to capture the rapid decrease in velocities approaching the banks.

For the Salt Creek site transect 1, River2D overpredicted velocities on the south bank and underpredicted velocities on the north bank (Appendix F). A similar but lower magnitude effect was seen for the first deep bed ADCP traverse above transect 1, where the simulated velocities on the south bank were significantly higher than the measured velocities. We attribute this to the bed topography downstream of transect 1, where a bedrock outcropping on the south bank downstream of transect 1 resulted in low velocities on the south side of the channel. Because this feature was outside of the site and not included in the model, the simulated velocities reflect a lack of any slowing influences in this part of the channel.

For Upper Lake Redding Deep Beds C, Site 81 Deep Beds G and Site 9 transects 1 and 2, the velocities simulated by River2D in the middle of the channel were significantly less than the measured velocities. We attribute this to errors in the ADCP velocity measurements (being too high). For example, the calculated discharge for Upper Lake Redding Deep Bed C, which did not include the total river discharge, was 13,884 cfs, versus the actual total river discharge of 13,568 cfs. Further, the calculated discharges for the Site 9 transects of 15,912 and 15,591 cfs were greater than the actual river discharge of 15,206 cfs.

For Posse Grounds transect 3 through 7, the velocities simulated by River2D on either side of a central bar were greater than the measured velocities. We attribute these differences to the measured velocities being the component of the velocity in the downstream direction, while the velocities predicted by the 2-D model were the absolute magnitude of the velocity. In the vicinity of this central bar, the current was almost perpendicular to the downstream direction, so it would be expected that the downstream component of the velocity would be much less than the absolute magnitude of the velocity.

For Site 130 transect 2, River2D underestimated the velocities on the south side of the channel and overestimated the velocities in a portion of the north side of the channel. We conclude that the lower simulated velocities on the south side of the channel and higher velocities in a portion of the north side of the channel were likely an artifact of the flow distribution from the upstream extension. The River2D model acts to increase velocities with depth. At the location of the higher simulated velocities on transect 2, the depths were shallow, while at the location of the lower simulated velocities, the depths were large. The use of the upstream extension longitudinally extended both the shallow and deep areas upstream of transect 2. The increased length of these shallow and deep areas above transect 2 likely acted to slow the water velocities more on the south side and increase it more in a portion of the north side than actually occurred at transect 2. We conclude that the topography upstream of the site resulted in relatively high velocities on the south side and lower velocities on the north side. Because this topography was outside of the site and thus not included in the model, the velocities on the south side of the site reflected only the shallow depths that were present on that portion of the transect, while the velocities in a portion of the north side of the site reflected only the large depths that were present on that portion of the transect.

For Site 80, River2D overestimated velocities on the east side of the channel for Deep Beds A and B, on the west side of the channel for Deep Bed E, and on both sides of the channel for Deep Bed G. For the first three deep bed traverses, we attribute the overestimation of velocities to some aspects of the bed topography that were missed during data collection, which resulted in lower velocities in these portions of the channel. For Deep Bed G, we attribute the differences to errors in the ADCP velocity measurements (low values), since the discharge calculated from the ADCP depths and velocities would be much less than the actual discharge of the site[29].

For Site 61/63 transect 3, River2D underestimated the velocities on the north side of the channel and overestimated the velocities on the south side of the channel. We conclude that the lower simulated velocities on the north side of the channel and higher velocities on the south side of the channel were likely an artifact of the flow distribution from the upstream extension. The River2D model acts to increase velocities with depth. At the location of the higher simulated velocities on transect 3, the depths were shallow, while at the location of the lower simulated velocities, the depths were large. The use of the upstream extension longitudinally extended both the shallow and deep areas upstream of transect 3. The increased length of these shallow and deep areas above transect 3 likely acted to slow the water velocities more on the north side and increase it more on the south side than actually occurred at transect 2. We conclude that the topography upstream of the site resulted in relatively high velocities on the north side and lower velocities on the south side. Because this topography was outside of the site and thus not included in the model, the velocities on the north side of the site reflected only the shallow depths that were present on that portion of the transect, while the velocities on the south side of the site reflected only the large depths that were present on that portion of the transect. We attribute differences between simulated and measured velocities for transect 2 and Deep Beds B, C, E, J, M and N of Site 61/63 to some aspects of the bed topography that were missed during data collection, which resulted in measured velocities in these portions of the channel which deviated from the simulated velocities.

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[29] The deep bed traverses for this site included most of the discharge of the site.

The measured velocities for Site 52 showed lower velocities on the north side of the upper portion of the site (transect 2 and Deep Beds F, G and H) and lower velocities on the south side of the lower portion of the site (transect 1 and Deep Beds A, B, C and D). In contrast, the simulated velocities for the site showed higher velocities in the middle of the channel, with velocities dropping off near the banks. We conclude that there must have been some feature of the bed topography in the vicinity of Deep Bed E, which was not captured during data collection, that caused the main flow to shift from the north side to the south side of the channel. Since this aspect of the bed topography was not captured in the data we collected, River2D was unable to correctly distribute flow across the channel going down through the site.

For Site 15/17 Deep Beds G and H, River2D predicted that velocities approaching the west bank of the channel would drop off closer to the west bank than shown in the measured velocities. We attribute this to some feature of the bed topography between Deep Beds F and G, which was not captured during data collection, that produced the observed velocity distribution. Since this feature was not captured in the data collection, River2D was unable to accurately capture the cross-section distribution of velocities at Deep Beds G and H. Similarly, we conclude that River2D's overestimation of the velocities on the east side of Deep Bed O was due to some feature of the bed topography upstream of this traverse which was not captured in the data collection.

The flow and downstream WSEL in the calibrated cdg file were changed to simulate the hydrodynamics of the sites at the simulation flows (3,250 cfs to 5,500 cfs by 250 cfs increments, 5,500 cfs to 8,000 cfs by 500 cfs increments, 8,000 cfs to 15,000 cfs by 1,000 cfs increments, and 15,000 cfs to 31,000 cfs by 2,000 cfs increments). The cdg file for each flow contained the WSEL predicted by PHABSIM at the downstream transect at that flow. Each discharge was run in RIVER2D to steady state. Again, a stable solution will generally have a Sol Δ of less than 0.00001 and a Net Q of less than 1%. In addition, solutions will usually have a Max F of less than one. The production cdg files all had a solution change of less than 0.00001, but the Net Q was greater than 1% for the lowest 10 flows for Site 112, the lowest 2 flows for Site 96, 1 flow for Site 80, 10 flows for Powerline Riffle, and 1 flow for Price Riffle (Appendix G). We still considered these sites to have a stable solution since the net Q was not changing and the net Q in all cases was less than 5%. In comparison, the accepted level of accuracy for USGS gages is generally 5%. Thus, the difference between the flows at the upstream and downstream boundary (net Q) is greater than the accuracy for USGS gages, and is considered acceptable. The maximum Froude Number was greater than 1 for 14 simulated flows for Salt Creek Boards In, 13 simulated flows for Salt Creek Boards Out, 2 simulated flows for Upper Lake Redding Boards Out, 1 simulated flow for Upper Lake Redding Boards In, 7 simulated flows for Lower Lake Redding Boards Out, 11 simulated flows for Lower Lake Redding Boards In, all but 1 simulated flows for Posse Grounds, 5 simulated flows for Site 130, 16 simulated flows for Site 112, 1 simulated flow for Site 96, 7 simulated flows for Site 80, all simulated flows for Site 61/63, 8 simulated flows for Site 52, 16 simulated flows for Above Hawes Hole, 3 simulated flows for Site 28, the 7 highest simulated flows for Powerline Riffle, 13 simulated flows for Site 15/17, 1 simulated flow for Site 9, and 24 simulated flows for Price Riffle (Appendix G); however, we considered these production runs to be acceptable since the Froude Number was only greater than 1 at a few nodes, with the vast majority of the area within the site having Froude Numbers less than 1. Also, as described previously, these nodes were located either at water's edge or where water depth was extremely shallow, typically approaching zero and would be expected to have an insignificant effect on the model results, and the Lower Lake Redding and Posse Grounds sites had limited areas of supercritical flow, where a Max Froude value of greater than 1 would be expected.

Habitat Suitability Criteria (HSC) Development

Habitat suitability criteria are used within both PHABSIM and 2-D habitat modeling to translate hydraulic and structural elements of rivers into indices of habitat quality (Bovee 1986). The collection of chinook salmon fry and juveniles (YOY) rearing HSC data began in April 1996 and was completed in August 2001. The sampling dates and Keswick releases are shown in Table 11. We were unable to sample from December 1996 to August 1997, from December 1997 to June 1998 and from January to March 1999 due to high turbidity.

In 1996 to 1998, most of the sampling was conducted in areas adjacent to the bank, since the river channel away from the banks was thought to be inhospitable for young salmon due to high velocities. However, we did do some sampling in this portion of the river in 1996 to 1998. One method employed the use of a grappling anchor attached to a 150 ft length of rope. The anchor was set 30 to 60 feet out from the bank. Snorkelers used a hand ascender to pull themselves up the rope, angling their bodies to move laterally. This method worked well in water up to 6 feet deep with velocities up to 4 ft/s. Similar areas were also sampled by snorkelers drifting down through a section of river. Deeper pools were sampled using SCUBA gear with free diving. As discussed below, greater effort was spent SCUBA diving in 1999 to 2001 to try to equalize overall sampling effort between shallow and deep areas.

When conducting snorkeling surveys adjacent to the bank, one person snorkeled upstream along the bank and placed a weighted, numbered tag at each location where YOY chinook salmon were observed. The snorkeler recorded the tag number, the cover code[30] and the number of individuals observed in each 10-20 mm size class on a PVC wrist cuff. Cover availability in the area sampled (percentage of the area with different cover types) and the length of bank sampled (measured with a 300-foot tape) was also recorded. Another individual retrieved the tags, measured the depth and mean water column velocity at the tag location, and recorded the data for each tag number. Depth was recorded to the nearest 0.1 foot and average water column velocity was recorded to the nearest 0.01 ft/s. An adjacent mean water column velocity was also

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[30] If there was no cover elements (as defined in Table 3) within 1 foot horizontally of the fish location, the cover code was 0.1 (no cover).

Table 11
Chinook Salmon YOY HSC Sampling

Sampling Dates	Keswick Release (cfs)
April 10-12, 1996	5,456
April 24-26, 1996	5,629
May 6-8, 1996	7,089
June 13-14, 1996	14,258
June 25-28, 1996	12,434
September 16-17, 1996	7,539
September 24-25, 1997	6,815
October 1-2, 1997	5,928
July 8-10, 1998	15,135
November 2-4, 1998	6,016
May 17-20, 1999	9,222
July 20-23, 1999	13,122
September 13-16, 1999	8,034
January 18-20, 2000	4,043
April 11-14, 2000	8,461
July 18-21, 2000	14,928
October 10-13, 2000	6,284
March 26-28, 2001	4,170
May 21-24, 2001	10,571
August 14-17, 2001	15,077

measured within 2 feet[31] on either side of the tag where the velocity was the highest. This measurement was taken to provide the option of using an alternative habitat model which considers adjacent velocities in assessing habitat quality. Adjacent velocity can be an important habitat variable as fish, particularly fry and juveniles, frequently reside in slow-water habitats adjacent to faster water where invertebrate drift is conveyed (Fausch and White 1981). Both the residence and adjacent velocity variables are important for fish to minimize the energy expenditure/food intake ratio and maintain growth. Data taken by the snorkeler and the measurer were correlated at each tag location.

Scuba surveys of deep water mesohabitat areas in 1999 to 2001 were conducted by first anchoring a rope longitudinally upstream through the area to be surveyed to facilitate upstream movement by the divers and increase diver safety. Two divers entered the water at the downstream end of the rope and proceeded along the rope upstream using climbing ascenders. One diver concentrated on surveying the water below and to the side, while the other diver concentrated on surveying the water above and to the side. When a juvenile salmon was observed, a weighted buoy was placed by the divers at the location of the observation. The cover code and the number of individuals observed in each 10-20 mm size class was then recorded on a PVC wrist cuff. Cover availability in the area sampled (percentage of the area with different cover types) and the length of river sampled (measured with the electronic distance meter) were also recorded. After the dive was completed, individuals in the boat retrieved each buoy and measured the water velocity and depth over that location with the ADCP. For each set of data collected using the ADCP for a juvenile fish observation, the average depth and velocity are considered the depth and velocity, while the maximum velocity is considered the adjacent velocity.

All YOY chinook salmon observed were classified by race according to a table provided by CDFG correlating race with life stage periodicity and total length. Data were also compiled on the length of each mesohabitat and cover type sampled to try to have equal effort in each mesohabitat and cover type and that each location was only sampled once at the same flow (to avoid problems with pseudo-replication).

We conducted an analysis of snorkel survey data that we collected in 1996 (U. S. Fish and Wildlife Service 1996) to determine if the cover codes could be simplified. Specifically, we used Pearson's test for association (chi-squared test) to determine if there were statistically significant differences between cover codes for YOY chinook salmon presence versus absence. The statistical tests are presented in Tables 12 and 13. For Table 12, an asterisk indicates that

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[31] Two feet was selected based on a mechanism of turbulent mixing transporting invertebrate drift from fast-water areas to adjacent slow-water areas where fry and juvenile salmon reside, taking into account that the size of turbulent eddies is approximately one-half of the mean river depth (Terry Waddle, USGS, personal communication), and assuming that the mean depth of the Sacramento River is around 4 feet (ie., 4 feet x ½ = 2 feet).

presence/absence of fish for those cover codes were significantly different at p = 0.05. For Table 13, an asterisk indicates that fish presence/absence for the cover codes in Group A were significantly different than fish presence/absence for the cover codes in Group B at p = 0.05. Our analysis indicated that there are two distinct groups of cover types; cover codes within the groups were not significantly different in fish presence versus absence, while the two groups were significantly different from each other in fish presence versus absence. The first cover group (cover group code 0) includes cover codes 0.1, 1, 2, 3, 5, 8, 9 and 10. The other cover group (cover group code 1) included cover codes 3.7, 4.7, 5.7, 9.7, 4 and 7.

Table 12
Statistical Tests of Difference Between Cover Codes

Cover Codes	**c-value**
3.7, 4.7, 5.7, 9.7, 4, 7	6.68
0.1, 1, 2, 3, 5, 8, 9, 10	8.52
3.7, 4.7, 5.7, 9.7, 4, 7, 0.1, 1, 2, 3, 5, 8, 9, 10	237.9 *

Table 13
Statistical Tests of Differences Between Cover Code Groups

Cover Codes in Group A	**Cover Codes in Group B**	**c-value**
3.7, 4.7, 5.7, 9.7	7	3.37
3.7, 4.7, 5.7, 9.7	4	1.25
3.7, 4.7, 5.7, 9.7, 4, 7	0.1, 1, 2, 3, 5, 8, 9, 10	221.9 *
0.1, 1, 2, 3, 9, 10	5	2.55
0.1, 1, 2, 3, 9, 10	8	2.84

We collected 999 measurements of cover, 998 measurements of depth, 996 measurements of velocity and 994 measurements of adjacent velocity where YOY chinook salmon were observed. All but 36 of these measurements were made near the river banks. There were 515 observations of fish less than 40 mm, 632 observations of 40-60 mm fish, 171 observations of 60-80 mm fish and 54 observations of fish greater than 80 mm[32]. According to the race classification table, these numbers account for 493 fall-run, 483 late fall-run, 6 spring-run, and 273 winter-run YOY chinook salmon observations. A total of 14.4 miles of near-bank habitat and 10.0 miles of mid-channel habitat were sampled. Table 14 summarizes the number of feet of different mesohabitat types sampled and Table 15 summarizes the number of feet of different cover types sampled. We sampled 54,827 feet of cover group 0 and 21,307 feet of cover group 1 in near-bank habitats, and 50,640 feet of cover group 0 and 2,625 feet of cover group 1 in mid-channel habitats. Depths at locations where YOY chinook salmon were observed ranged from 0.2 to 23.7 feet, while velocities ranged from 0 to 3.92 ft/s and adjacent velocities ranged from 0 to 4.53 ft/s.

Starting with the April 2000 surveys, we also collected depth, velocity, adjacent velocity and cover data on locations which were not occupied by YOY chinook salmon (unoccupied locations). This was done so that we could apply a method presented in Rubin *et al* (1991) to explicitly take into account habitat availability in developing HSC criteria, without using preference ratios (use divided by availability). Traditionally criteria are created from observations of fish use by fitting a nonlinear function to the frequency of habitat use for each variable (depth, velocity, cover, adjacent velocity). One concern with this technique is what effect the availability of habitat has on the observed frequency of habitat use. For example, if cover is relatively rare in a stream, fish will be found primarily not using cover simply because of the rarity of cover, rather than because they are selecting areas without cover. Rubin *et al* (1991) proposed a modification of the above technique where depth, velocity, cover and adjacent velocity data are collected both in locations where fish are present and in locations where fish are absent. Criteria are then developed by using a nonlinear regression procedure (suited to data with a Poisson distribution) with number of fish as the dependent variable and depth, velocity, cover and adjacent velocity as the independent variables, and all of the data (in both occupied and unoccupied locations) are used in the regression. An alternative approach is to use a logistic regression procedure, with the only difference being that the dependent variable is the presence or absence of fish. The HSC sampling methods presented above were modified as follows to allow for the collection of juvenile HSC data from both occupied locations (same method as above) and unoccupied locations.

Before going out into the field, a data book was prepared with one line for each unoccupied location where depth, velocity, cover and adjacent velocity would be measured. Each line had a distance from the bank, with a range of 0.5 to 10 feet by 0.5 foot increments, with the values produced by a random number generator.

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[32] These numbers total much more than 999 because most of the observations included YOY of several size classes and only one measurement was made per group of closely associated individuals.

Table 14
Distances (feet) Sampled for Juvenile Chinook Salmon HSC Data - Mesohabitat Types

Mesohabitat Type	Near-bank habitat distance sampled	Mid-channel habitat distance sampled
Bar Complex Glide	6385	5370
Bar Complex Pool	5756	5215
Bar Complex Riffle	8796	1230
Bar Complex Run	8770	2126
Flatwater Glide	10923	8391
Flatwater Pool	3534	1500
Flatwater Riffle	5712	1200
Flatwater Run	8286	11713
Off-Channel Area	900	0
Side-Channel Riffle	7995	270
Side-Channel Run	3700	0

Table 15
Distances (feet) Sampled for Juvenile Chinook Salmon HSC Data - Cover Types

Cover Type	Near-bank habitat distance sampled	Mid-channel habitat distance sampled
None	15100	13153
Cobble	20734	16127
Boulder	3473	2259
Fine Woody	8782	222
Branches	11541	841
Log	2126	365
Overhead	1476	0
Undercut	1766	0
Aquatic Vegetation	4852	1143
Rip Rap	908	6
Overhead + instream	15230	667

One person snorkeled upstream along the bank in the same method as described above dropping tags at locations of juvenile salmon. Two additional items were recorded by the snorkeler: the average and maximum distance from the water's edge that was sampled. A 300-foot tape was put out with one end tied at the location where the snorkeler finished and the other end loose with a small buoy attached. Three people went up the tape, one with a stadia rod and data book and the other two with a wading rod and velocity meter. At every 10-foot increment along the tape, the person with the stadia rod measured out the distance from the bank given in the data book. If there was a tag within 3 feet of the location, "tag within 3'" was recorded on that line in the data book and the people proceeded to the next 10 foot increment on the tape, using the distance from the bank on the next line. If the location was beyond the sampling distance, based on the information recorded by the snorkeler, "beyond sampling distance" was recorded on that line and the recorder went to the next line at that same location, repeating until reaching a line with a distance from the bank within the sampling distance. If there was no tag within 3 feet of that location, one of the people with the wading rod measured the depth, velocity, adjacent velocity and cover at that location. A fourth person followed behind and measured the depth, velocity and adjacent velocity at each tag location.

For areas that were sampled with SCUBA, the ADCP was turned on as we started to pull in the rope after the dive. The boat followed the course of the dive as the rope was pulled back into the boat. If there were any observations during the dive, the ADCP was stopped three feet before the location of the observation and started again three feet after the location of the observation. The ADCP was turned off at the location where the dive ended. A random number generator was used to select ADCP measurements of depth and velocity for unoccupied locations. The number of unoccupied cells selected for each site was the lesser of either 10% of the total distance (feet) sampled or 30% of the total number of ADCP points. For the SCUBA data, cover was assigned to all of the observations in proportion to which they were observed during the dive. The adjacent velocity for each unoccupied location was the largest of the three following values: the velocity at the location immediately prior to the unoccupied location, the velocity at the unoccupied location, and the velocity at the location immediately after the unoccupied location.

We made 1,789 measurements for unoccupied locations (592 in shallow areas and 1,197 in deep areas). Depth and velocity were measured at all 1,789 locations, and adjacent velocity was measured at 1,787 of the locations. The data for both occupied and unoccupied locations described above were combined with the previously-collected data on habitat use.

Separate chinook salmon YOY rearing HSC are typically developed for different size classes of YOY (typically called fry and juvenile). Since we recorded the size classes of the YOY, we were able to investigate three different options for the size used to separate fry from juveniles: <40 mm versus > 40 mm, <60 mm versus >60 mm, and <80 mm versus >80 mm. We used Mann-Whitney U tests to test for differences in depth, velocity and adjacent velocity, and Pearson's test for association to test for differences in cover, for the above categories of fry versus juveniles. The results of these tests, as shown in Table 16, showed significant differences (at $p = 0.05$)

between fry and juvenile habitat use for all four variables for all three different options for the size to use to separate fry from juveniles. However, there was the greatest difference between fry and juvenile habitat use for depth, velocity and adjacent velocity for the <60 mm versus >60 mm criteria to separate fry from juveniles (see Z values in Table 16), while there was the greatest difference between fry and juvenile habitat use for cover for the <40 mm versus > 40 mm criteria to separate fry from juveniles (see c values in Table 16). Since there was the greatest difference between fry and juvenile habitat use for the <60 mm versus >60 mm criteria for three of the four parameters, we selected 60 mm as the criteria to separate fry from juveniles. Hereafter, fry refers to YOY less than 60 mm, while juvenile refers to YOY greater than 60 mm.

Table 16
Differences in YOY Habitat Use as a Function of Size

Variable	<40 mm versus > 40 mm	<60 mm versus > 60 mm	< 80 mm versus > 80 mm
Depth	$Z = -7.95$, $p < .000001$, $n = 515, 709$	$Z = -10.55$, $p < .000001$, $n = 921, 186$	$Z = -7.48$, $p < .000001$, $n = 984, 53$
Velocity	$Z = -5.43$, $p < .000001$, $n = 515, 707$	$Z = -7.56$, $p < .000001$, $n = 919, 185$	$Z = -3.86$, $p = .000115$, $n = 982, 52$
Adjacent Velocity	$Z = -5.01$, $p = .000001$, $n = 515, 705$	$Z = -7.31$, $p < .000001$, $n = 917, 185$	$Z = -4.23$, $p = .000023$, $n = 980, 52$
Cover	$c = 34$, $p < .005$, $n = 517, 711$	$c = 29$, $p < .01$, $n = 920, 189$	$c = 26$, $p < .025$, $n = 985, 54$

Separate fry and juvenile HSC could be developed for each race (fall, late-fall and winter-run) of chinook salmon. To determine if there were difference between races, we used Kruskal-Wallis and Median tests to test for differences in depth, velocity and adjacent velocity, and used Pearson's test for association to test for differences in cover, for fry and juveniles. The results of these tests, as shown in Table 17, was that there were significant differences (at $p = 0.05$) between races for fry for depth, velocity and adjacent velocity (See χ^2 and H values in Table 17) and for cover (see C values in Table 17), but there were no significant differences (at $p = 0.05$) between races for juveniles for depth, velocity, adjacent velocity and cover. Accordingly, we developed separate criteria for fall-run, late-fall-run and winter-run fry rearing, but only one set of criteria for juvenile rearing, based on the data from all runs.

Based on the CDFG race table, fall-run fry are present between December 1 and June 29, late-fall-run fry are present between April 1 and September 28, and winter-run fry are present between July 1 and January 13. As a result, we only used unoccupied data collected between December 1 and June 29 (897 observations) to develop fall-run fry depth, velocity and adjacent velocity criteria; only used unoccupied data collected between April 1 and September 28 (1,011 observations) to develop late-fall-run fry depth, velocity and adjacent velocity criteria; and only used unoccupied data collected between December 1 and June 29 (892 observations) to develop

Table 17
Differences in YOY Habitat Use as a Function of Race

Variable	Test	< 60 mm fish	> 60 mm fish
Depth	Median Test	$\chi^2 = 13$, df = 2, p = 0.0013	$\chi^2 = 0.39$, df = 2, p = 0.82
Depth	Kruskal-Wallis	H = 11, p = 0.0046	H = 1.8, p = 0.40
Velocity	Median Test	$\chi^2 = 27$, df = 2, p < 0.0001	$\chi^2 = 0.29$, df = 2, p = 0.86
Velocity	Kruskal-Wallis	H = 24, p < 0.0001	H = 0.64, p = 0.73
Adjacent Velocity	Median Test	$\chi^2 = 23$, df = 2, p < 0.0001	$\chi^2 = 2.37$, df = 2, p = 0.30
Adjacent Velocity	Kruskal-Wallis	H = 27, p < 0.0001	H = 1.29, p = 0.52
Cover	Pearson's	C = 57, df = 26, p < 0.005	c = 27, df = 26, p > 0.25

winter-run fry depth, velocity and adjacent velocity criteria[33]. We used all of the unoccupied observations for juveniles, since juveniles are present year-round. The number of occupied and unoccupied locations for each parameter, race and life-stage are shown in Table 18.

We then used a polynomial logistic regression (SYSTAT 2002), with dependent variable frequency (with a value of 1 for occupied locations and 0 for unoccupied locations) and independent variable depth or velocity, to develop depth and velocity HSI for each race of fry and for juvenile chinook salmon. The logistic regression fits the data to the following expression:

$$\text{Frequency} = \frac{\text{Exp}\,(I + J * V + K * V^2 + L * V^3 + M * V^4 + N * V^5)}{1 + \text{Exp}\,(I + J * V + K * V^2 + L * V^3 + M * V^4 + N * V^5)}, \qquad (1)$$

where Exp is the exponential function; I, J, K, L, M and N are coefficients calculated by the logistic regression; and V is velocity or depth. The logistic regressions were conducted in a sequential fashion, where the first regression tried was a fourth order regression (where $N = 0$). If any of the coefficients or the constant were not statistically significant at $p = 0.05$, the associated terms were dropped from the regression equation, and the regression was repeated. If the result of the regression demonstrated behavior that was not reflected in the observed data (for example the computed frequency reaching one at a large depth or fast velocity), a fifth order (where $N \neq 0$) regression was used. The coefficients for the final logistic regressions for depth and velocity for each run and for juveniles are shown in Table 19. The p values for all of the non-zero coefficients in Table 19 were less than 0.05, as were the p values for the overall regressions.

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[33] We used all of the unoccupied data in developing cover criteria, because, as discussed below, we ended up combining together fry and juveniles for developing cover criteria. Either fry or juveniles of each race are present year-round.

Table 18
Number of Occupied and Unoccupied Locations

Variable	Fall-run fry		Late-fall-run fry		Winter-run fry		Juvenile	
	Occupied	Unoccupied	Occupied	Unoccupied	Occupied	Unoccupied	Occupied	Unoccupied
Depth	409	897	442	1011	266	892	187	1789
Velocity	408	897	440	1011	266	892	186	1789
Adjacent Velocity	407	894	439	1007	266	890	186	1787
Cover	408	1789	442	1789	266	1789	189	1789

Table 19
Logistic Regression Coefficients[34]

race/life stage	parameter	I	J	K	L	M	N
fall fry	depth	0	0.9276	-0.3694	0.03185	-0.000830	0
fall fry	velocity	0.3960	4.0616	-10.5521	5.76002	-0.995520	0
late-fall fry	depth	0	1.4292	-0.7928	0.10571	-0.005370	0.00009
late-fall fry	velocity	0.5959	0	-1.7495	0.29436	0	0
winter fry	depth	-0.7621	2.4024	-1.5174	0.23218	-0.010701	0
winter fry	velocity	0	0	-1.8235	0.26964	0	0
juvenile	depth	-2.6596	1.6249	-0.4828	0.04443	-0.001647	0.000021
juvenile	velocity	-1.9213	4.9697	-7.8887	3.2658	-0.412316	0

The results of the regression equations were rescaled so that the highest value of suitability was 1.0. The resulting HSC were modified by truncating at the slowest/shallowest and deepest/fastest ends, so that the next shallower depth or slower velocity value below the shallowest observed depth or the slowest observed velocity had a SI value of zero, and so that the next larger depth or faster velocity value above the deepest observed depth or the fastest observed velocity had an SI value of zero; and eliminating points not needed to capture the basic shape of the curves.

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[34] A coefficient or constant value of zero indicates that term or the constant was not used in the logistic regression, because the p-value for that coefficient or for the constant was greater than 0.05. The coefficients in this table were determined from Equation 1.

The final depth and velocity criteria, along with the frequency distributions of occupied and unoccupied locations, are shown in Figures 2 through 9 and Appendix H. It should be noted that the regressions were fit to the raw occupied and unoccupied data, rather than to the frequency histograms shown in Figures 2 through 9. In general, the criteria track the occupied data, but drop off slower than the occupied data due to the frequency of the unoccupied data also dropping over the same range of depths and velocities.

Because adjacent velocities were highly correlated with velocities (Table 20), a logistic regression of the following form was used to develop adjacent velocity criteria:

$$\text{Frequency} = \frac{\text{Exp}\,(I + J * V + K * V^2 + L * V^3 + M * V^4 + N * AV)}{1 + \text{Exp}\,(I + J * V + K * V^2 + L * V^3 + M * V^4 + N * AV)}, \qquad (2)$$

where Exp is the exponential function; I, J, K, L, M and N are coefficients calculated by the logistic regression; V is velocity and AV is adjacent velocity. For fall-run fry adjacent velocity, the constant (I) and [K * V] terms were dropped from the regressions because the p-values for the constant and K were greater than 0.05. For late-fall-run fry adjacent velocity, the [K * V] and [M * V^4] terms were dropped from the regressions because the p-values for K and M were greater than 0.05. For winter-run fry adjacent velocity, the constant (I), [K * V^2], [L * V^3], and [M * V^4] terms were dropped from the regressions because the p-values for the constant, K, L and M were greater than 0.05. The p-values for the remaining coefficients, and for the coefficients for juveniles, were less than 0.05, as were the overall p values for the four logistic regressions. The I and N coefficients from the above regression (Table 20) were then used in the following equation:

$$\text{HSI} = \frac{\text{Exp}\,(I + N * AV)}{1 + \text{Exp}\,(I + N * AV)}. \qquad (3)$$

We then computed values of the above equation for the range of occupied adjacent velocities, and then rescaled the values so that the largest value was 1.0. We then used a linear regression on the rescaled values to determine, using the linear regression equation, HSI_0 (the HSI where the AV is zero) and AV_{LIM} (the AV at which the HSI is 1.0). The range of values was restricted at the upper end for fall-run, late-fall-run, and winter-run fry to only include the linear portion of the computed values (Figures 10 to 13). For fall-run, this resulted in a regression on adjacent velocities between 0 and 1.9 ft/s; 93% of the occupied locations had adjacent velocities less than 1.9 ft/s. For late-fall-run, this resulted in a regression on adjacent velocities between 0 and 2.1 ft/s; 95% of the occupied locations had adjacent velocities less than 2.1 ft/s. For winter-run, this resulted in a regression on adjacent velocities between 0 and 1.3 ft/s; 93% of the occupied locations had adjacent velocities less than 1.3 ft/s. The final adjacent velocity criteria (Appendix H) started at HSI_0 for an adjacent velocity of zero, ascended linearly to an HSI of 1.0 at an adjacent velocity of AV_{LIM} and stayed at an HSI of 1.0 for adjacent velocities greater than AV_{LIM}.

Figure 2
Chinook Salmon Fall-run Fry Rearing Depth HSC

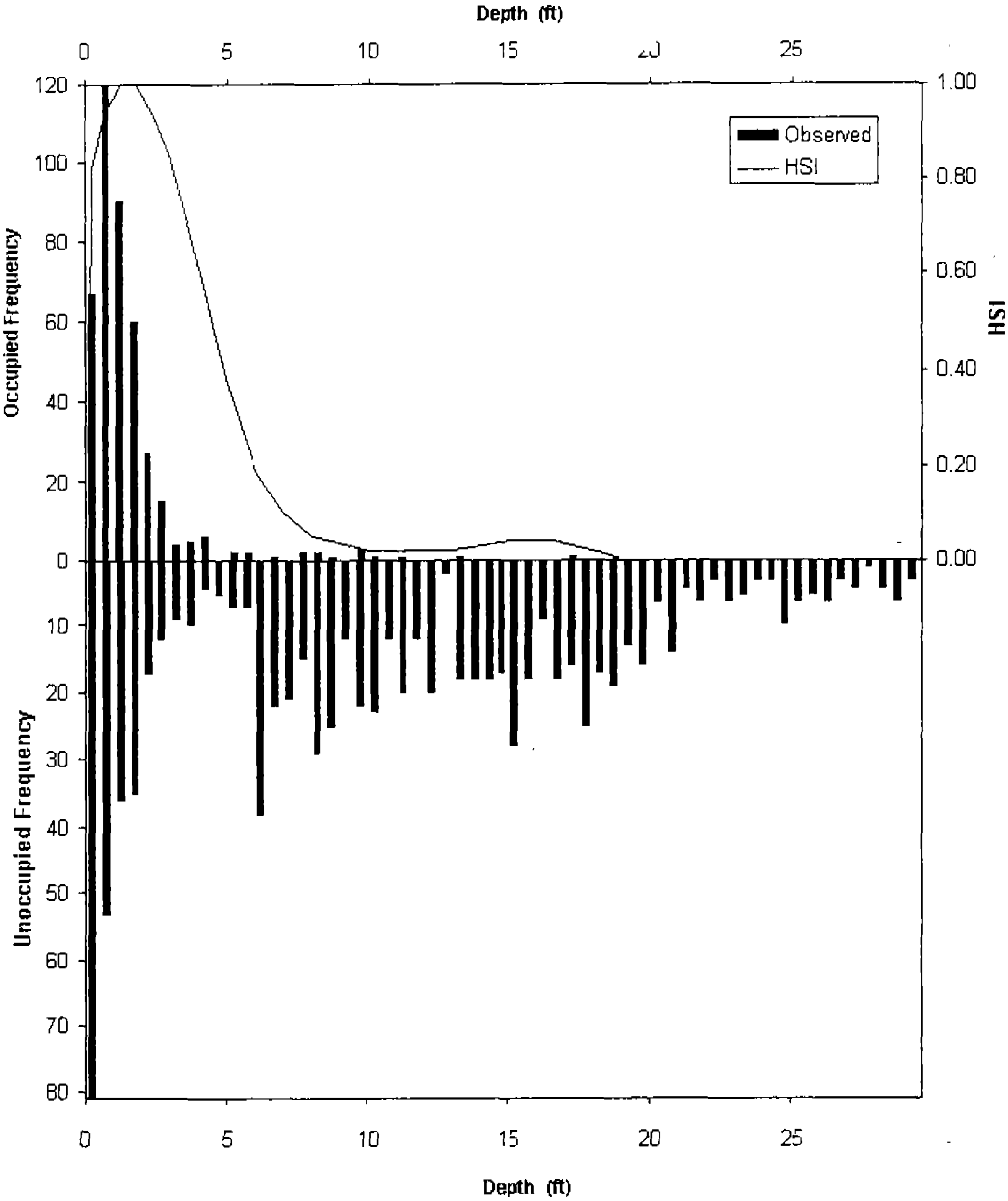


Figure 3
Chinook Salmon Fall-run Fry Rearing Velocity HSC

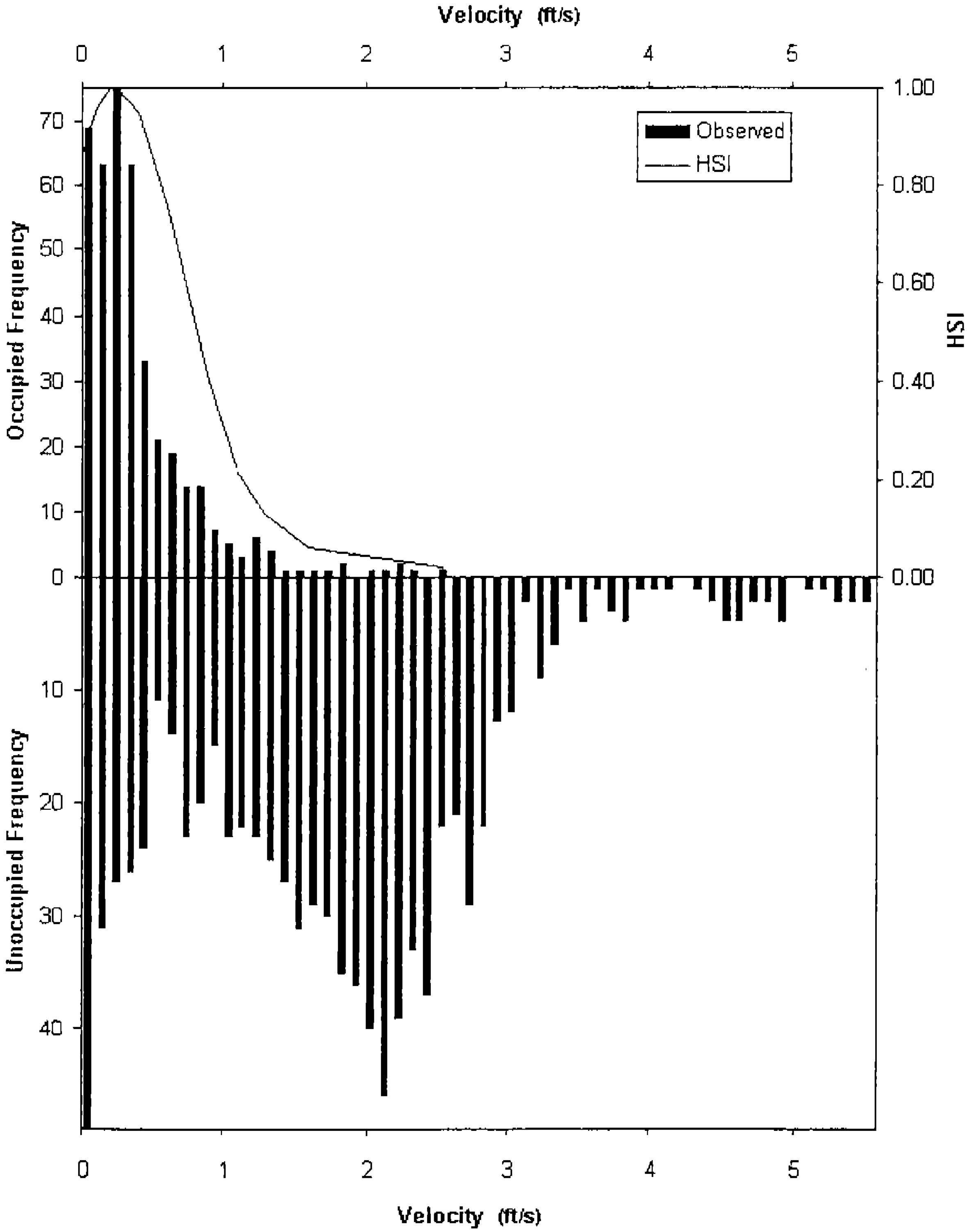


Figure 4
Chinook Salmon Late-fall-run Fry Rearing Depth HSC

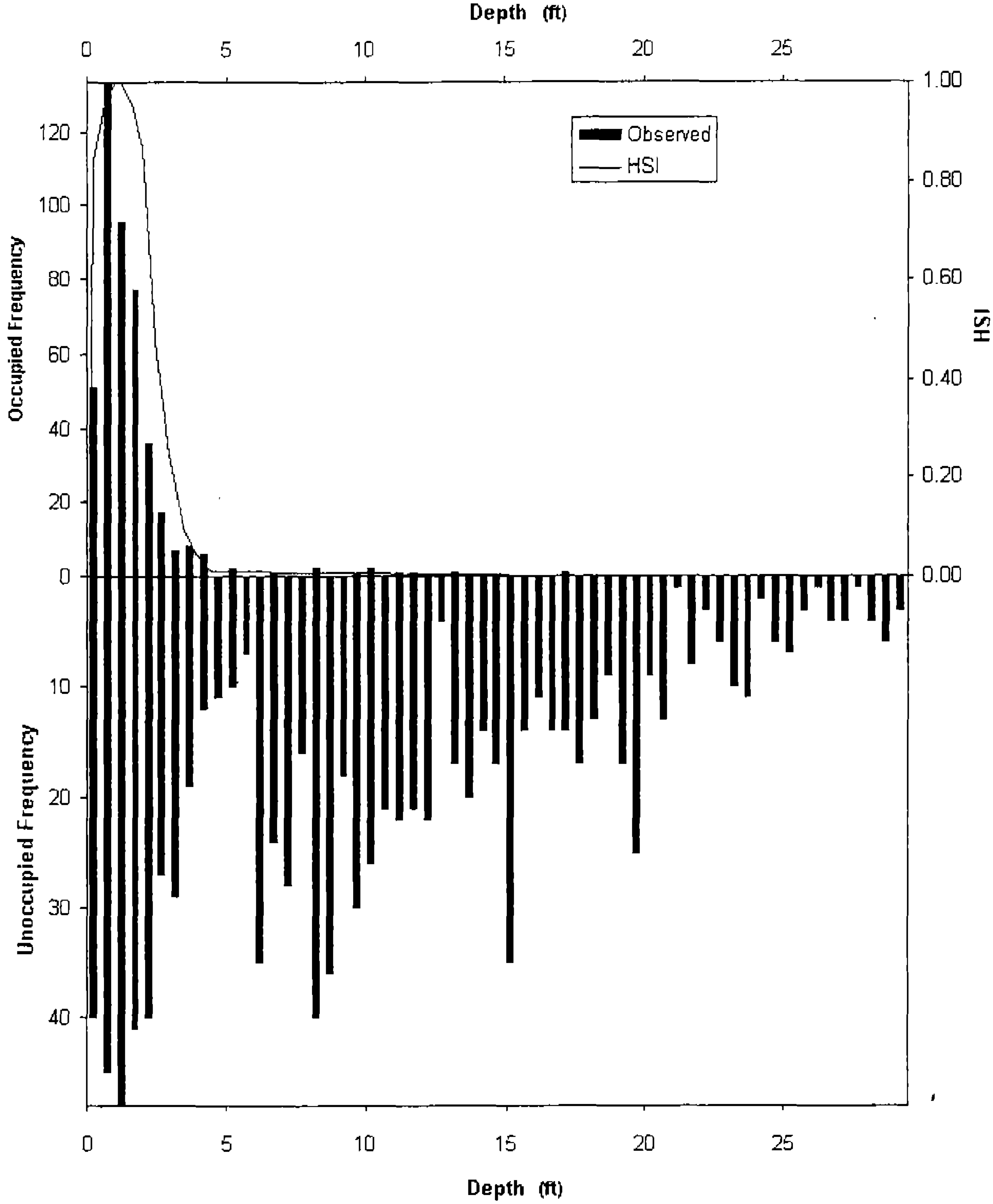


Figure 5
Chinook Salmon Late-fall-run Fry Rearing Velocity HSC

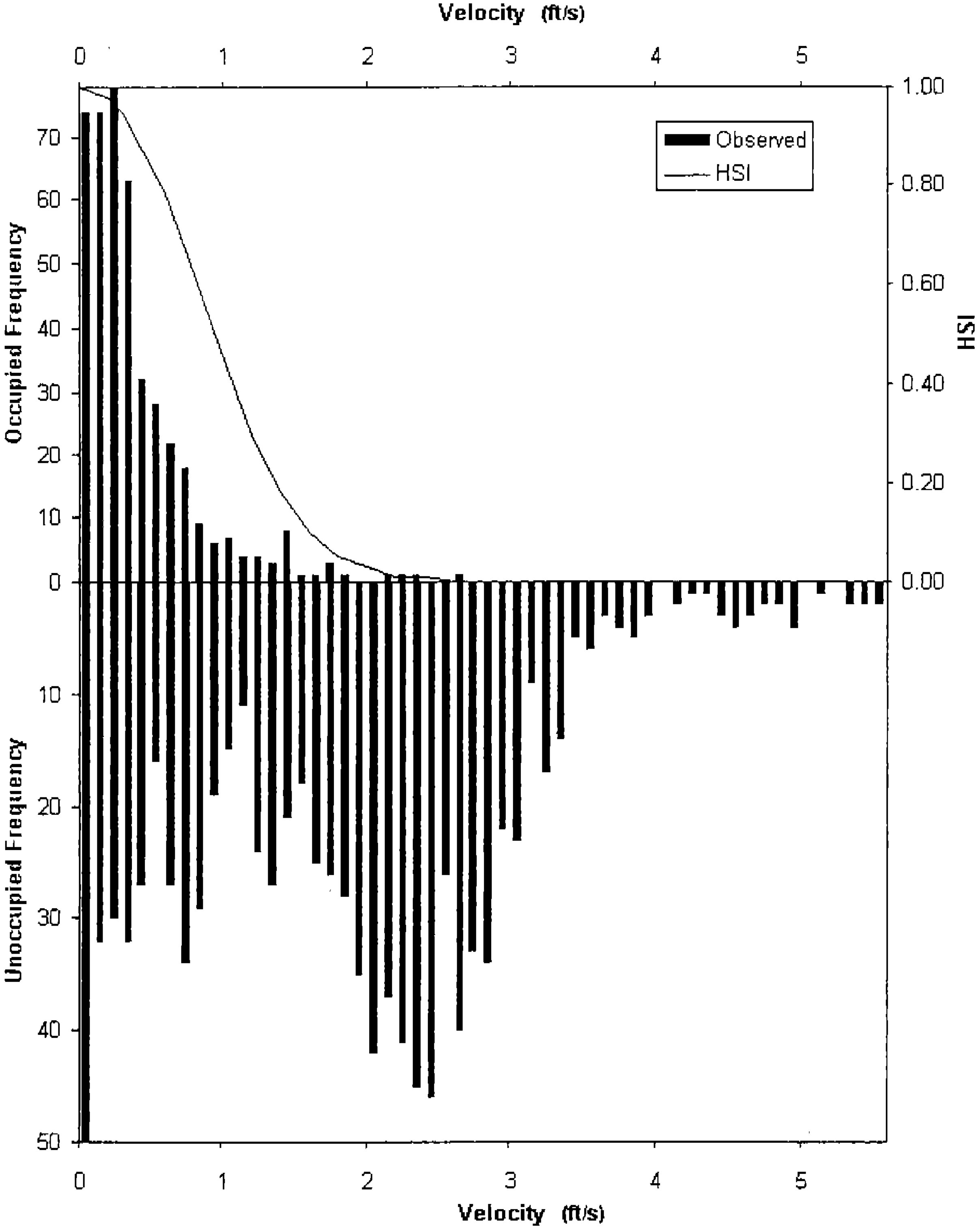


Figure 6
Chinook Salmon Winter-run Fry Rearing Depth HSC

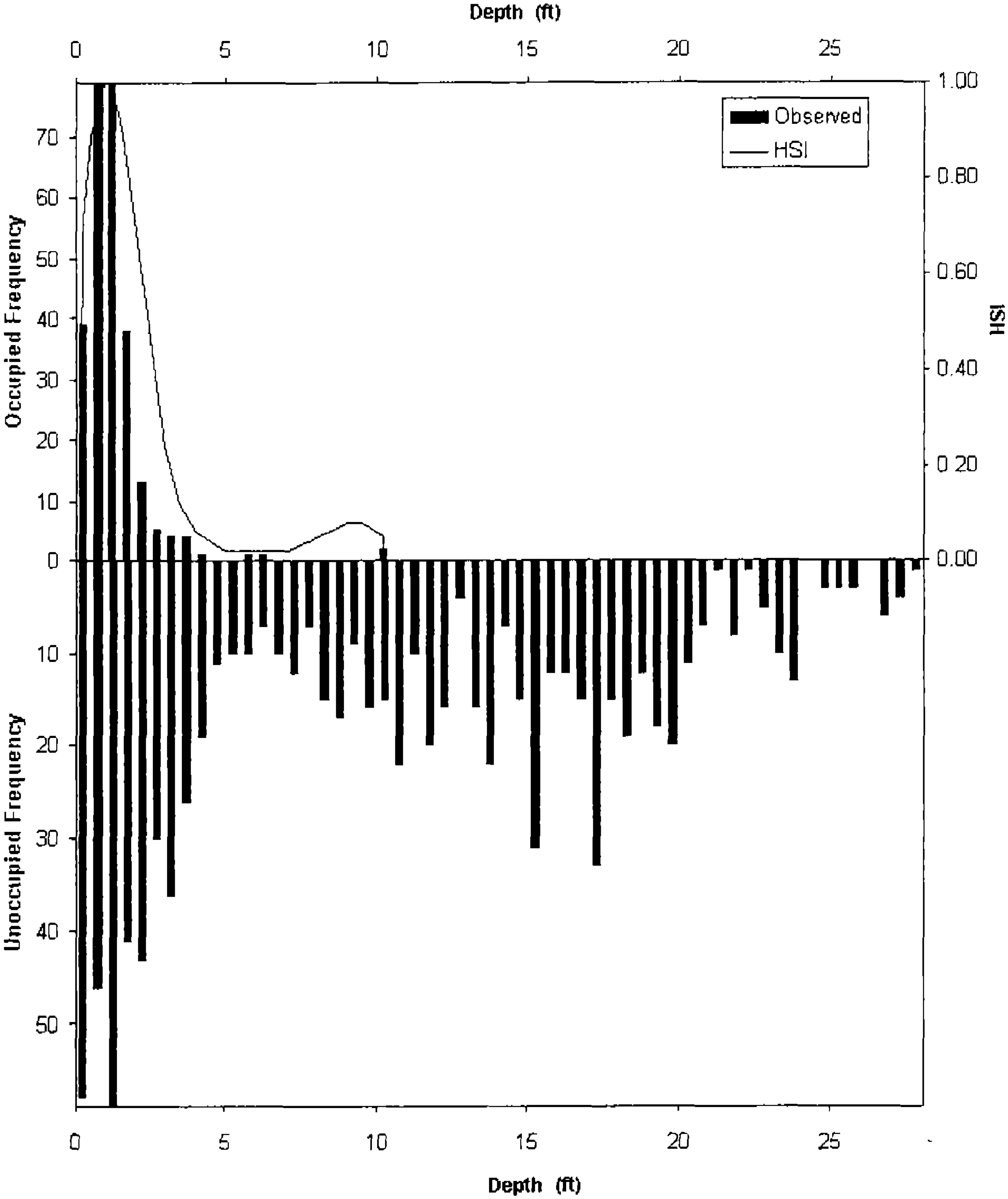


Figure 7
Chinook Salmon Winter-run Fry Rearing Velocity HSC

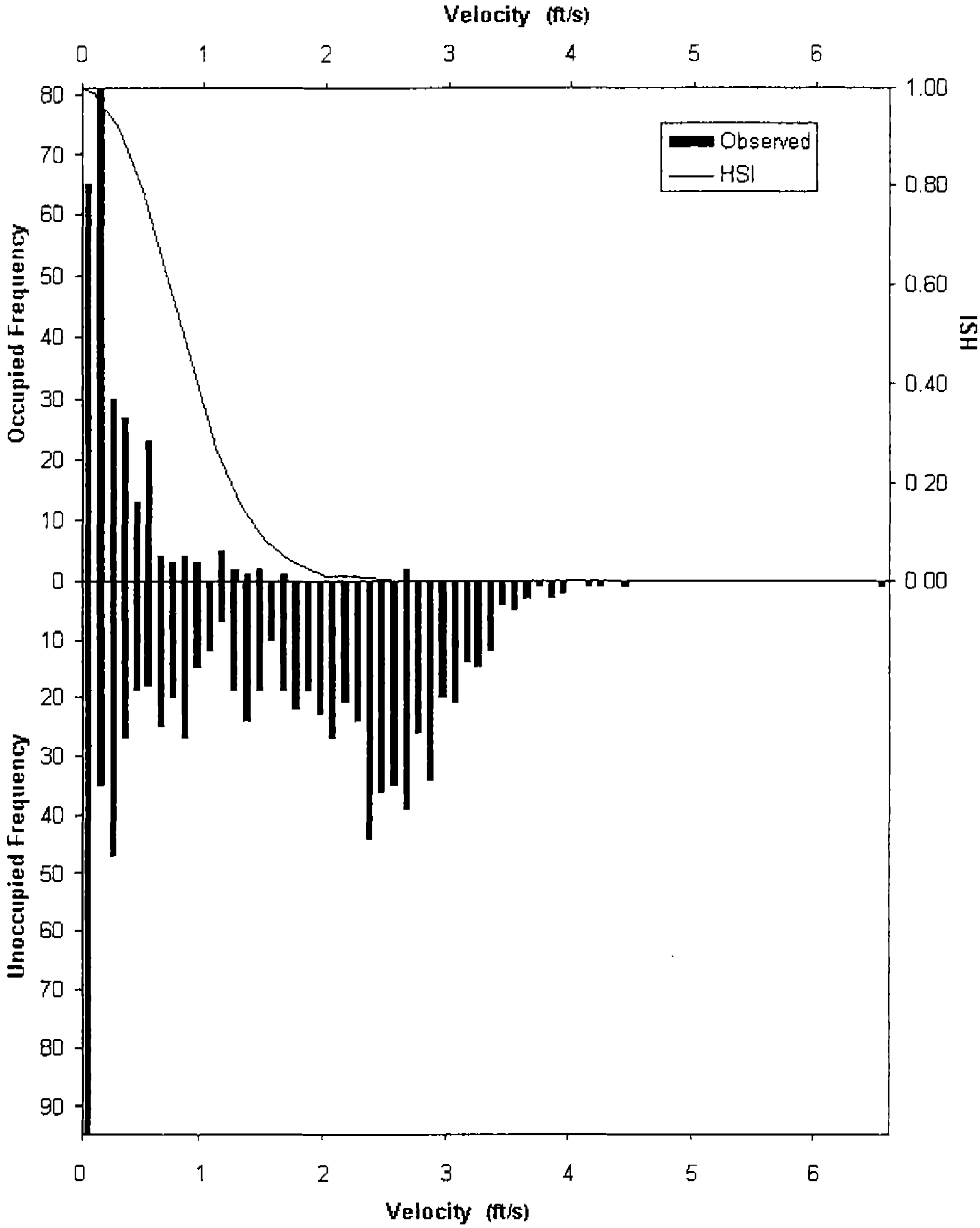


Figure 8
Chinook Salmon Juvenile Rearing Depth HSC

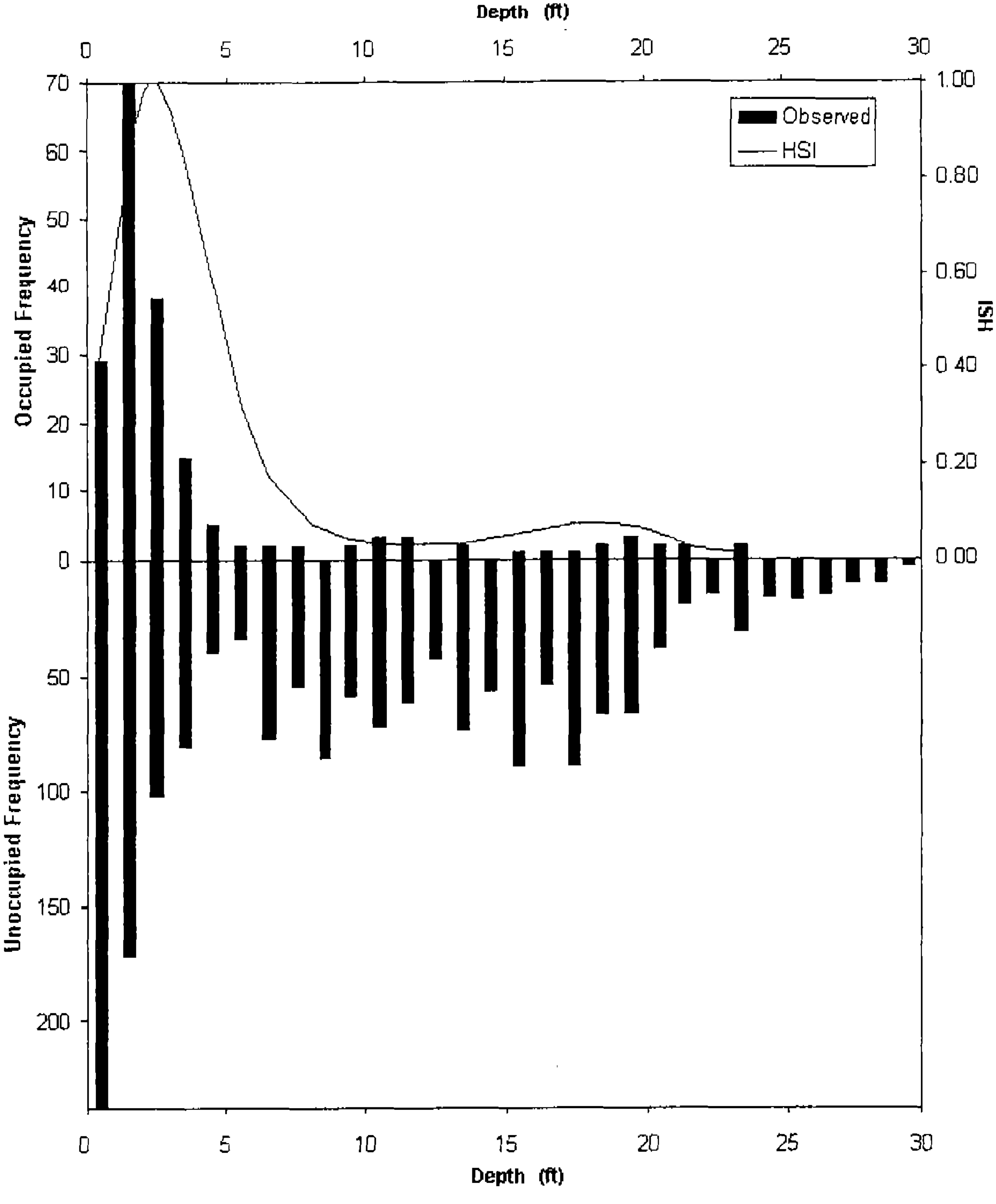


Figure 9
Chinook Salmon Juvenile Rearing Velocity HSC

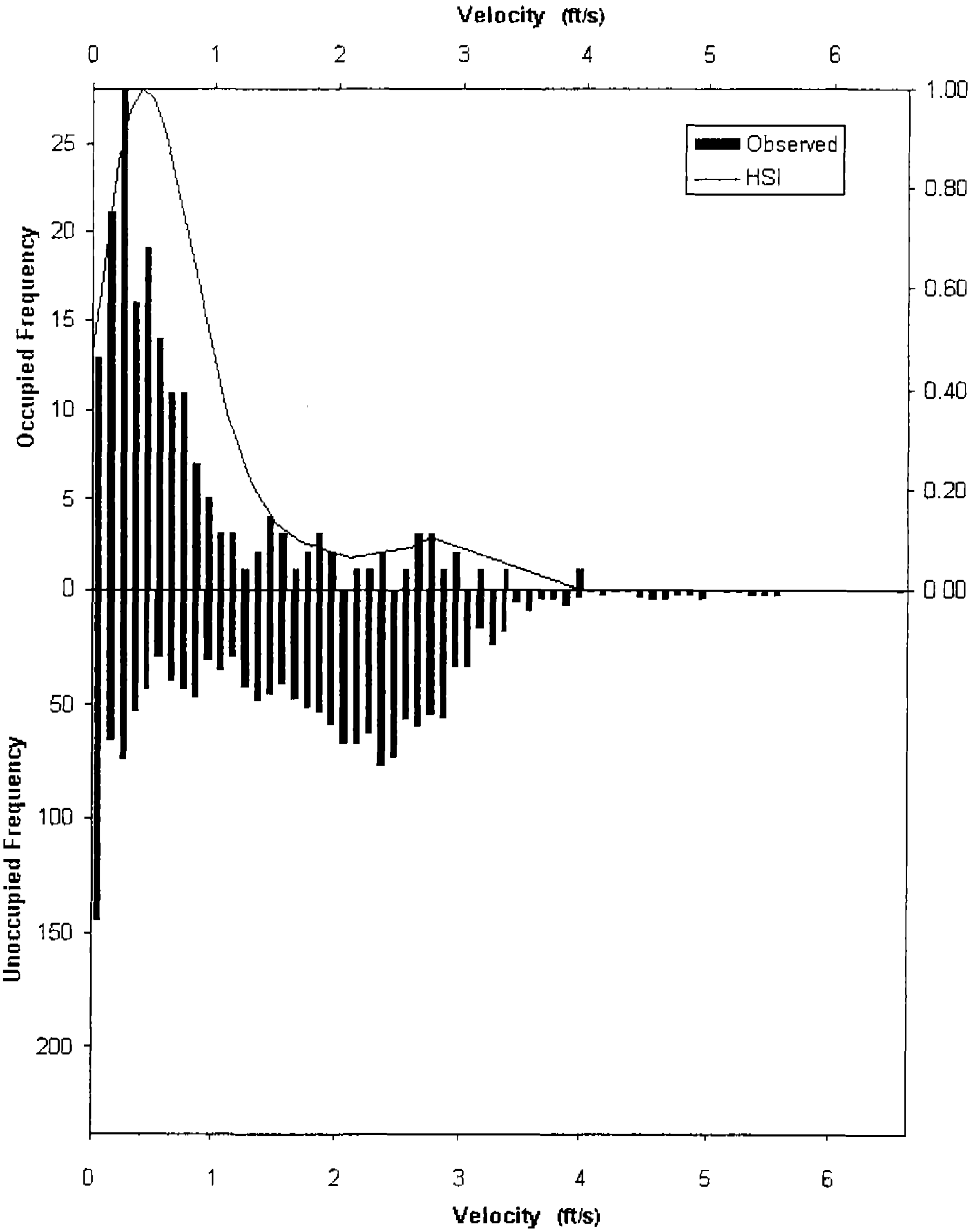
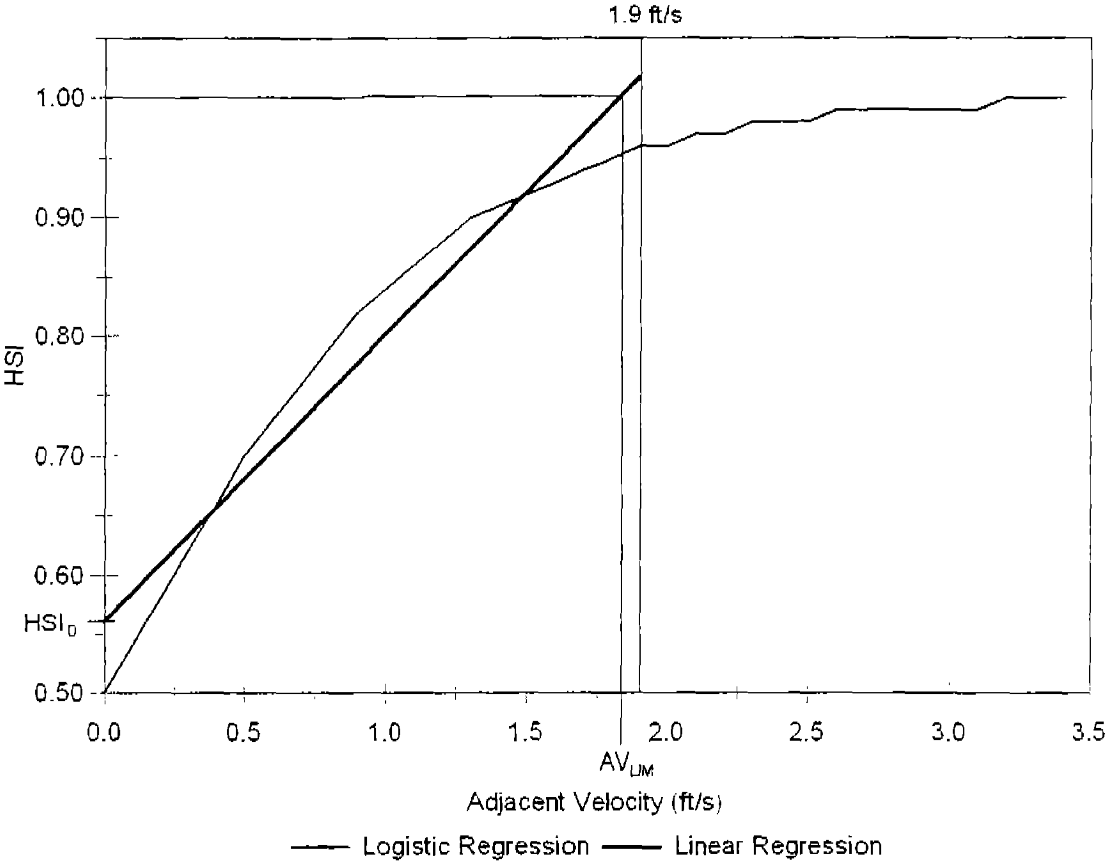


Table 20
Adjacent Velocity Coefficients[35]

Race/Life Stage	Velocity/Adjacent Velocity Correlation	I	N
fall fry	0.95	0	1.6570
late-fall fry	0.94	0.3863	0.4346
winter fry	0.95	0	-2.9372
juvenile	0.94	-2.1112	1.0929

Figure 10
Chinook Salmon Fall-run Fry Rearing Adjacent Velocity HSC



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[35] The coefficients in this table were determined from Equation 2.

Figure 11
Chinook Salmon Late-fall-run Fry Rearing Adjacent Velocity HSC

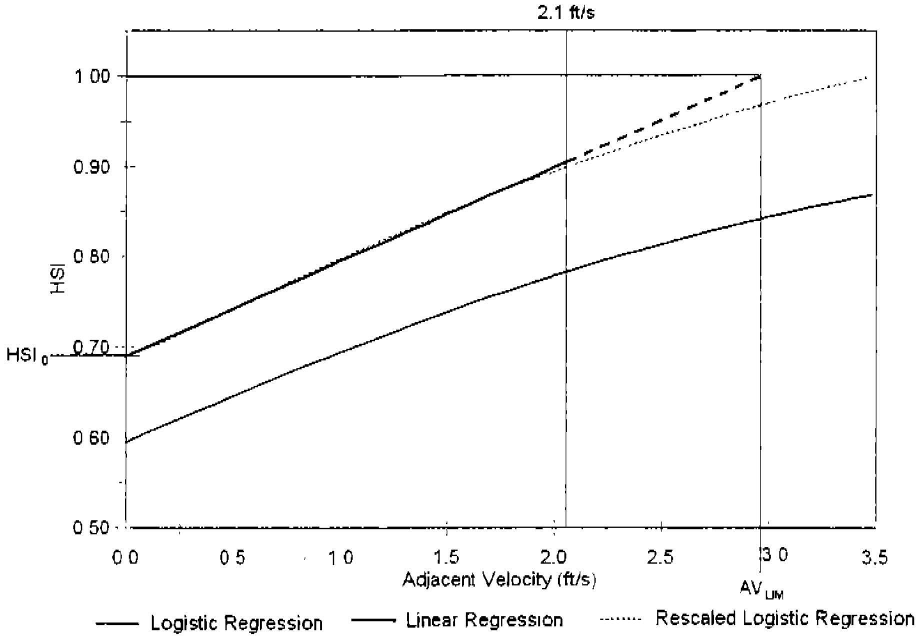


Figure 12
Chinook Salmon Winter-run Fry Rearing Adjacent Velocity HSC

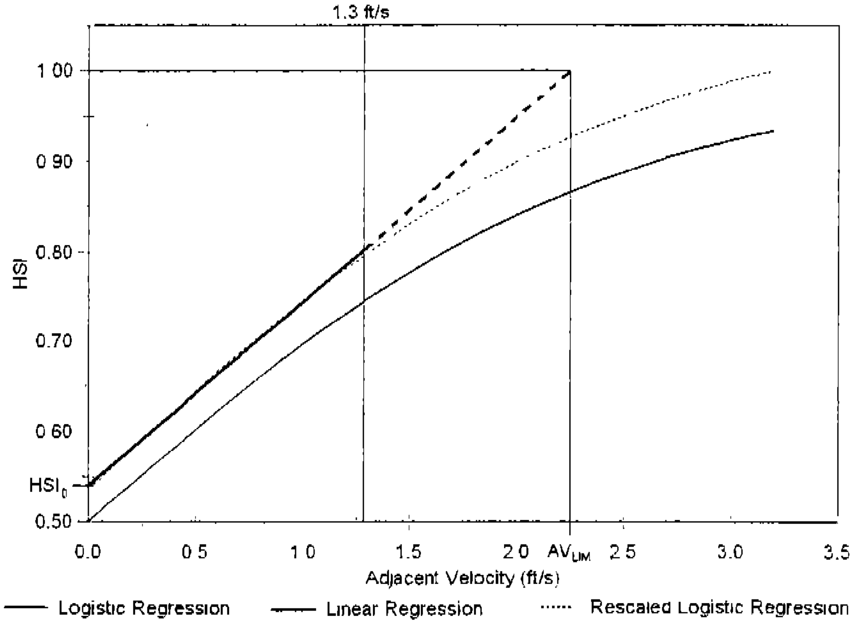
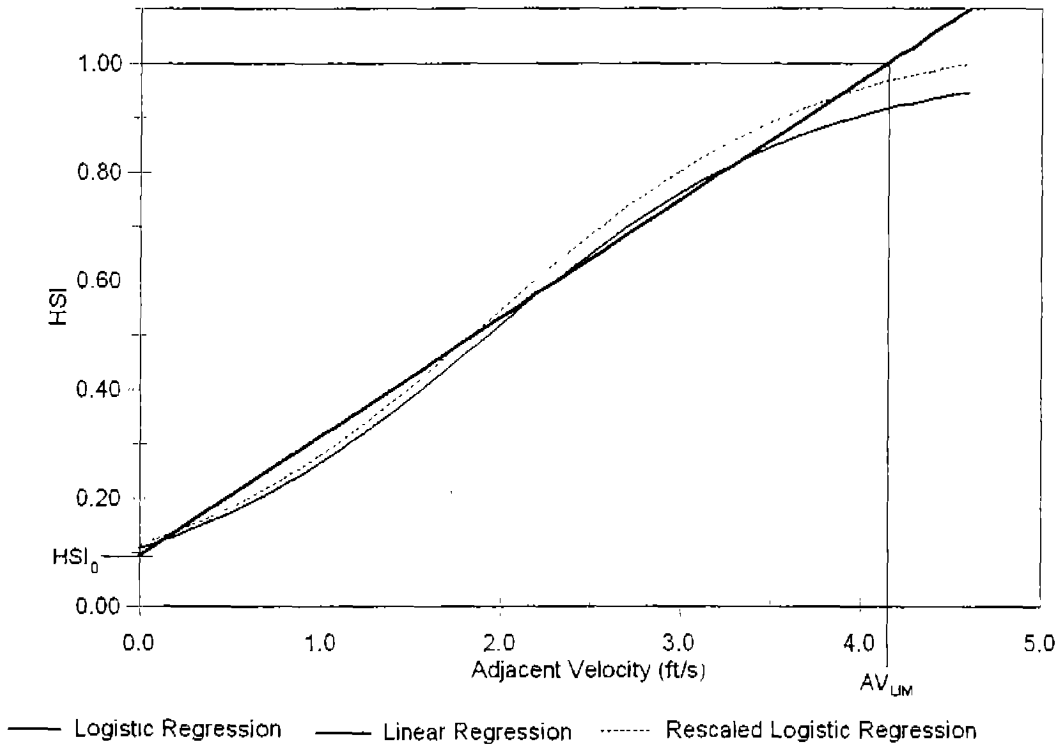


Figure 13
Chinook Salmon Juvenile Rearing Adjacent Velocity HSC



We started the development of the cover criteria by ranking the sites sampled in descending order by the percentage of cover group 1. We then calculated the cumulative feet sampled of cover groups 0 and 1 going down through the sites until we reached an equal number of cumulative feet of cover groups 0 and 1 sampled. We then continued our development of cover criteria using only the above subset of sites. This process allowed us to maximize the amount of area sampled to include in development of the cover criteria while equalizing the amount of area sampled in cover groups 0 and 1. This subset of sites consisted of a total of 41,614 feet of channel (20,803 feet of cover group 0 and 20,811 feet of cover group 1), or 32% of the total area sampled. The subset of sites included 3,826 feet of mid-channel habitat and 37,788 feet of near-bank habitat. The subset of sites included 707 occupied locations (71% of the total number of occupied locations). For this subset of sites, there was not significant difference between YOY <60 mm and YOY > 60 mm for cover (Pearson's test for association, c = 16, df = 13, p > 0.1). As a result, we did not develop separate cover criteria for fry and juvenile chinook salmon. For all fish (fry and juveniles) in this subset of sites, there was a significant difference between races (Pearson's test for association, c = 43, df = 26, p < 0.025). As a result, we developed separate sets of cover criteria for fall-run, late-fall-run and winter-run chinook salmon, with the cover criteria for each race used for both fry and juveniles.

The next step in the development of the cover criteria was to group cover codes within each race, so that there were no significant differences within the groups and a significant difference between the groups, using Pearson's test for association. This analysis used the occupied locations from the above subset of sites, and the 1,789 unoccupied observations. The statistical tests are presented in Tables 21 and 22. For Table 21, an asterisk indicates that presence/absence of fish for those cover codes were significantly different at p = 0.05. For Table 22, an asterisk indicates that fish presence/absence was significantly different between Groups at p = 0.05. Our analysis indicated that there were three distinct groups of cover types for fall-run, four distinct groups for late-fall-run and four distinct groups for winter-run. We then combined together the fish observations in each of the above groups of cover types and calculated the HSI for each group by dividing the number of observations in each group by the number of observations in the most frequent group. This procedure normalized the HSI, so that the maximum HSI value was 1.0. For fall-run, the initial HSI value for the group including cover codes 0.1, 1, 9, 9.7 (0.26) was slightly greater than the initial HSI value for the group including cover codes 2, 3, 7 and 10. Since it would not be expected that some type of cover, such as 3 or 7, would have a lower suitability than no cover, we averaged the two initial HSI values for a final HSI value to use for both groups. Similarly, for late-fall-run, the initial HSI value for the group including cover codes 9 and 9.7 (0.14) was lower than the initial HSI value for the group including cover codes 0.1 and 1 (0.28); for the same reason, we averaged the two initial HSI values for a final HSI value to use for both groups. For winter run, there were small difference in initial HSI values for the group containing cover codes 9 and 9.7 (0.03), and the initial HSI values for cover codes 0.1 (0.07) and 1 (0.12); for the same reason, we averaged these three initial HSI values for a final HSI value to use for all four cover codes. The final cover HSI values for all races are given in Appendix H.

Habitat Simulation

The final step was to simulate available habitat for each site. An preference curve file was created containing the digitized criteria. The final cdg files, the cover file and the preference curve file were used in RIVER2D to calculate the combined suitability of depth, velocity and cover for each site. The resulting data was exported into a comma-delimited file for each site, flow, race and life stage. These files were then run through a Geographic Information System (GIS) postprocessing software[36] to incorporate the adjacent velocity criteria into the habitat suitability, and to calculate the WUA values for each site over the desired range of flows (3,250 cfs to 5,500 cfs by 250 cfs increments, 5,500 cfs to 8,000 cfs by 500 cfs increments, 8,000 cfs to 15,000 cfs by 1,000 cfs increments, and 15,000 cfs to 31,000 cfs by 2,000 cfs increments). The

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[36] The software calculates the adjacent velocity for each node, then uses the adjacent velocity criteria to calculate the adjacent velocity suitability index for that node. This index is then multiplied by the combined depth, velocity and cover suitability indices. This product is then multiplied by the area represented by each node to calculate the WUA for each node, with the WUA for all nodes summed to determine the total WUA for each habitat unit, flow, life stage and race.

Table 21
Statistical Tests of Difference Between Cover Codes

Race	Cover Codes	c-value
Fall-run	3.7, 4.7, 5.7, 9.7, 4, 7, 0.1, 1, 2, 3, 5, 8, 9, 10	633 *
Fall-run	3.7, 4, 4.7, 5, 5.7, 8	6.8
Fall-run	2, 10, 3, 7	0.9
Fall-run	0.1, 1, 9, 9.7	0.7
Late-fall-run	3.7, 4.7, 5.7, 9.7, 4, 7, 0.1, 1, 2, 3, 5, 8, 9, 10	632 *
Late-fall-run	3.7, 4.7, 5, 5.7, 8	3.4
Late-fall-run	4, 7, 2, 10, 3	2.0
Late-fall-run	0.1, 1	0.2
Late-fall-run	9, 9.7	1.2
Winter-run	3.7, 4.7, 5.7, 9.7, 4, 7, 0.1, 1, 2, 3, 5, 8, 9, 10	427 *
Winter-run	2, 10, 3, 3.7, 4, 4.7, 5, 5.7, 7, 8	13.1
Winter-run	9, 9.7	0.6

Table 22
Statistical Tests of Differences Between Cover Code Groups

	Cover Codes In Group				
Race	Group A	Group B	Group C	Group D	c-value
Fall-run	3.7, 4, 4.7, 5, 5.7, 8	2, 10, 3, 7	0.1, 1, 9, 9.7		609 *
Late-fall-run	3.7, 4.7, 5, 5.7, 8	4, 7, 2, 10, 3	0.1, 1	9, 9.7	611 *
Winter-run	2, 10, 3, 3.7, 4, 4.7, 5, 5.7, 7, 8	9, 9.7	0.1	1	397 *

WUA values calculated for each site and criteria set are contained in Appendix I. We then multiplied the WUA values for each habitat unit modeled by the ratios in Table 23 (calculated by dividing the total length of each habitat type present in a given reach by the length of each habitat type that was modeled in that reach), and then summed the resulting products to calculate the total WUA for each reach (Appendix J).

Table 23
Ratio of Habitat Lengths in Reach to Habitat Lengths in Modeled Sites[37]

Habitat Type	Reach 6	Reach 5	Reach 4
Flatwater Glide	5.77	32.50	31.43
Flatwater Pool	6.87	1.88	1.00
Flatwater Riffle	*	7.41	5.97
Flatwater Run	*	14.55	4.63
Bar Complex Glide	*	11.54	2.89
Bar Complex Pool	*	3.64	2.42
Bar Complex Riffle	*	35.44	5.91
Bar Complex Run	*	19.56	2.18
Side Channel Pool	*	2.00	*
Side Channel Riffle	*	16.23	*
Side Channel Run	*	4.92	*
Run	15.03	*	*

We then conducted a limiting-life-stage analysis using the data in Appendix J, spawning habitat data from U.S. Fish and Wildlife Service 2003, and the parameters in Table 24. The habitat requirements in Table 24 for fry and juvenile were determined as the 90th percentile of fry and juvenile densities observed in our habitat suitability criteria data, assuming that largest groups of fish occupied 1 square meter and that the largest groups of juveniles occupied 4 square meters. The habitat requirement in Table 24 for spawning is from Gallagher and Gard (1999). The adult equivalent for spawning and survival for fry and juvenile are from Hallock (1987), while the number of eggs/redd is from a personal communication with Scott Hamelberg, U.S. Fish and Wildlife Service. The adult equivalents for fry and juveniles were calculated from the other data in Table 24 as follows:

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[37] Entries with an asterisk indicate that the habitat type was not present or used in that reach.

$$380 \text{ fry/adult} = \frac{3.800 \text{ eggs/redd x } 25\% \text{ egg to fry}}{2.5 \text{ adults/redd}} \text{ and}$$

$$228 \text{ juveniles/adult} = \frac{3,800 \text{ eggs/redd x } 15\% \text{ egg to juvenile}}{2.5 \text{ adults/redd}} .$$

Table 24
Limiting Life Stage Analysis Parameters

Life Stage	Habitat Requirement	Survival	Adult Equivalent
Spawning	48 ft^2/redd [38]	3800 eggs/redd	2.5 adults/redd
Fry	10 fry/ft^2	25% egg to fry	380 fry/adult
Juvenile	5 juveniles/ft^2	15% egg to juvenile	228 juveniles/adult

For each race and segment, we used the parameters in Table 24 to convert spawning, fry and juvenile rearing WUA into adult equivalents. The life stage with the lowest adult equivalents would be the limiting life stage.

RESULTS

The flow-habitat relationships for fall-run, late-fall-run and winter-run fry and juvenile rearing are shown in Figures 14 to 27 and Appendix J. The results from this study and from U.S. Fish and Wildlife Service (2003) could be used as inputs to the SALMOD salmonid population model (Bartholow 2002) to assess the effects of alternative flow regimes on salmonid production. For fall-run, this analysis will also require the results of our ongoing modeling of fall-run spawning habitat in Segments 2 and 3.

The limiting life stage analyses are shown in Figures 28 to 39. The limiting life stage analyses indicated that in most cases, juvenile habitat is limiting. In some cases (fall-run and late-fall-run in Segment 5) spawning habitat is limiting at higher flows. The main purpose of presenting this analysis is to determine whether to model fry and juvenile rearing habitat in the Sacramento River downstream of Battle Creek. An important limitation of this analysis is that it does not take into account fry and juvenile rearing habitat in the Sacramento River below Battle Creek or in the Sacramento/San Joaquin Delta.

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[38] This number is based on the egg pocket area, per Bartholow (2002).

Figure 14
Fall-run Chinook Salmon Fry Rearing Flow-Habitat Relationships

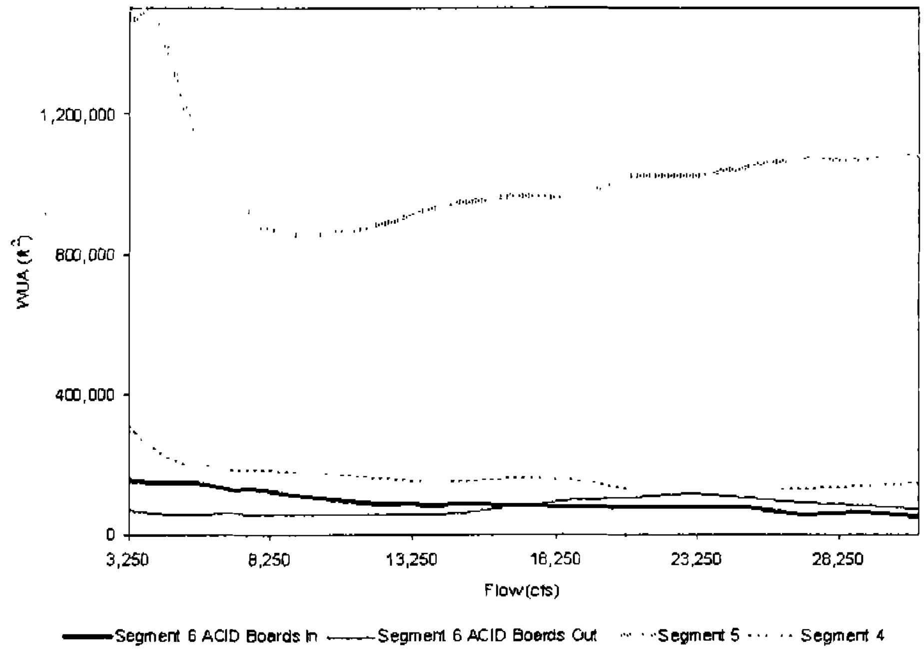


Figure 15
Fall-run Chinook Salmon Juvenile Rearing Flow-Habitat Relationships

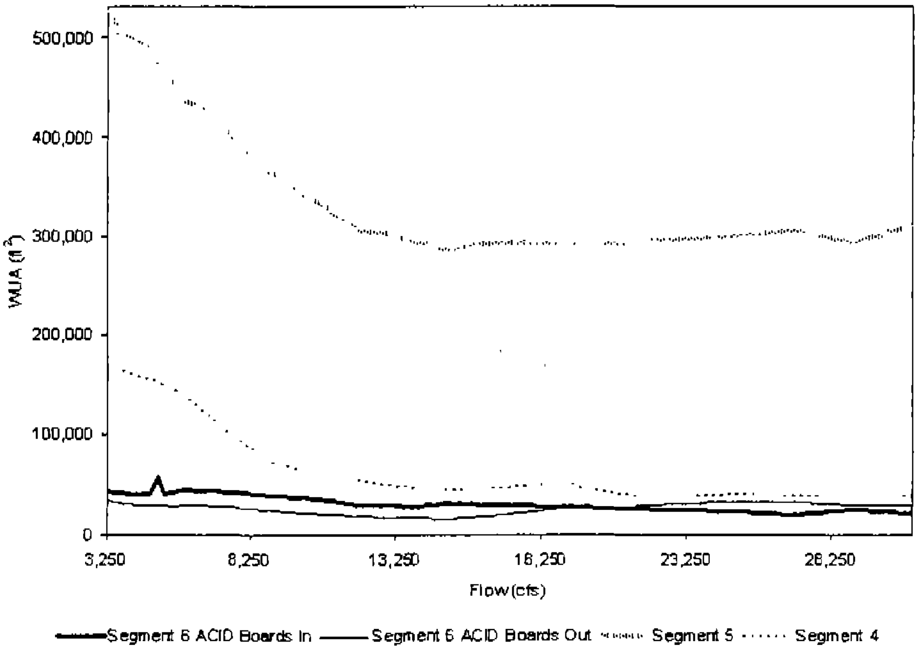


Figure 16
Late-fall-run Chinook Salmon Fry Rearing Flow-Habitat Relationships

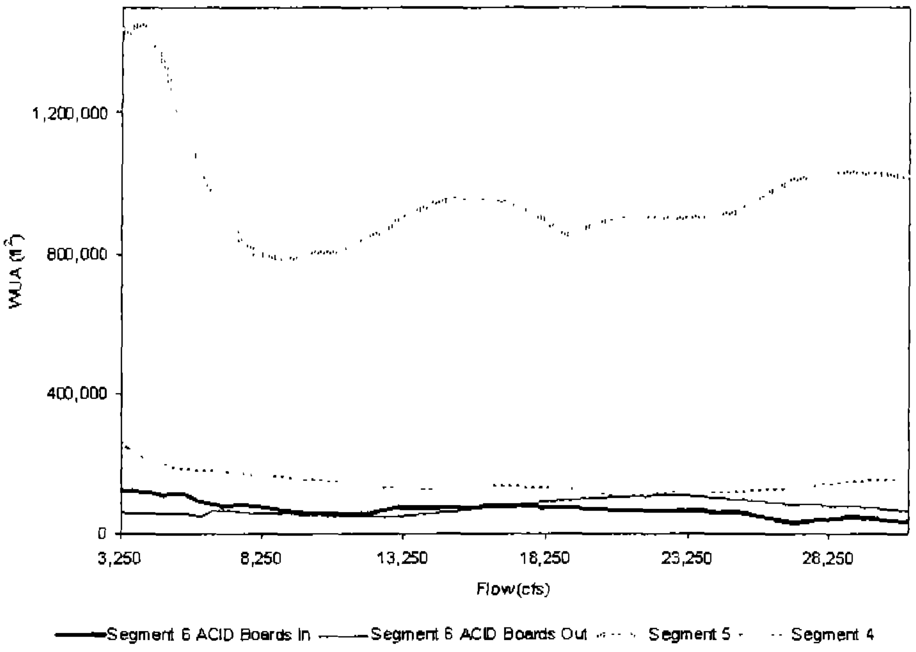


Figure 17
Late-fall-run Chinook Salmon Juvenile Rearing Flow-Habitat Relationships

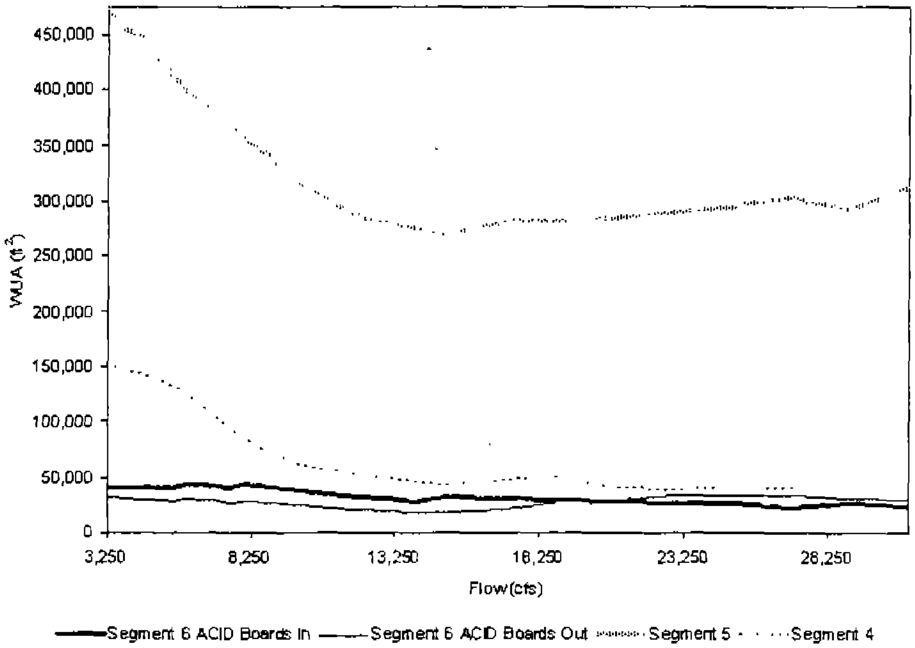


Figure 18
Winter-run Chinook Salmon Fry Rearing Flow-Habitat Relationships

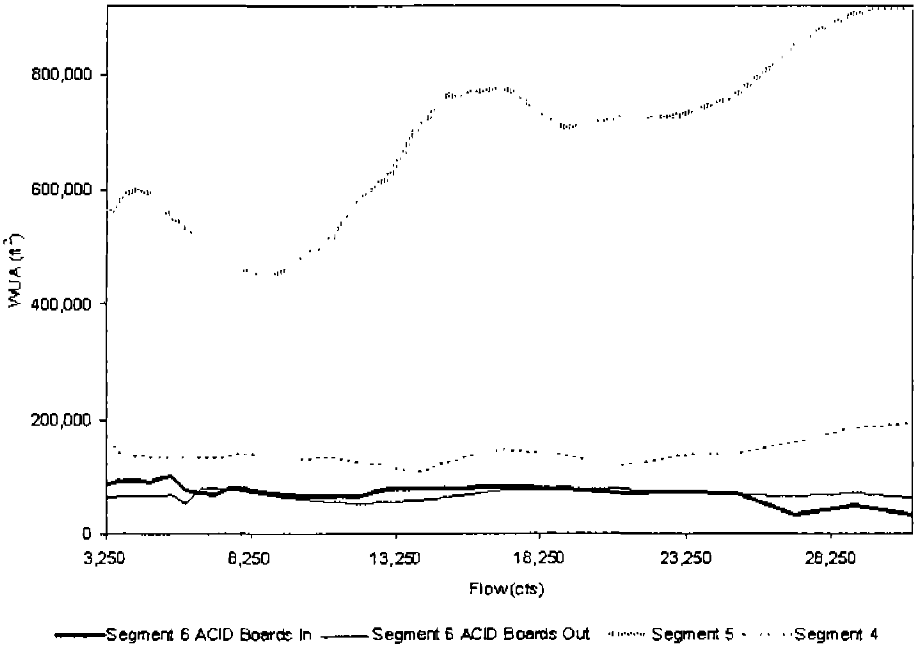


Figure 19
Winter-run Chinook Salmon Juvenile Rearing Flow-Habitat Relationships

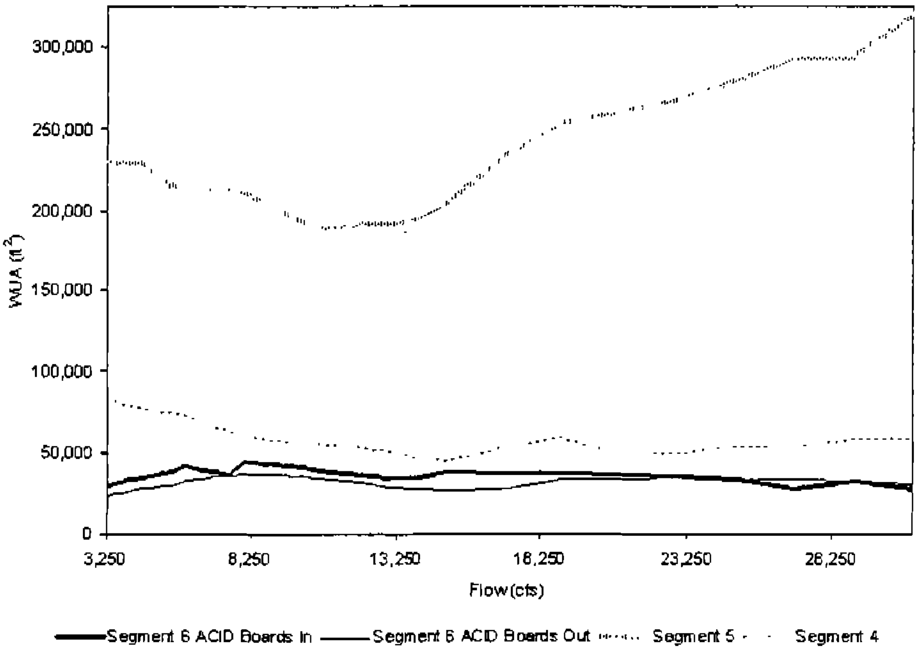


Figure 20
Fry Rearing Flow-Habitat Relationships For Segment 6 ACID Boards In

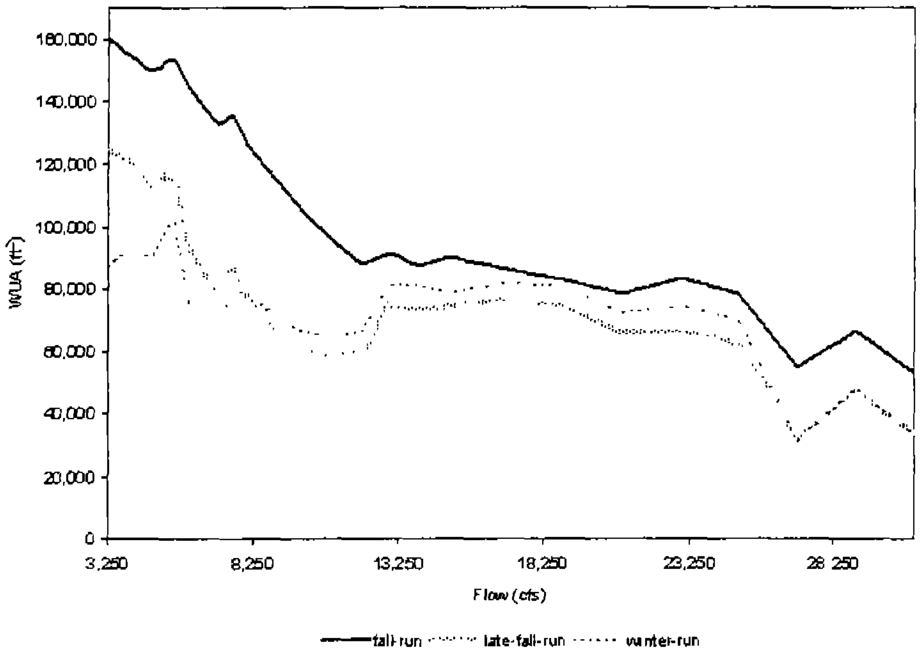


Figure 21
Juvenile Rearing Flow-Habitat Relationships For Segment 6 ACID Boards In

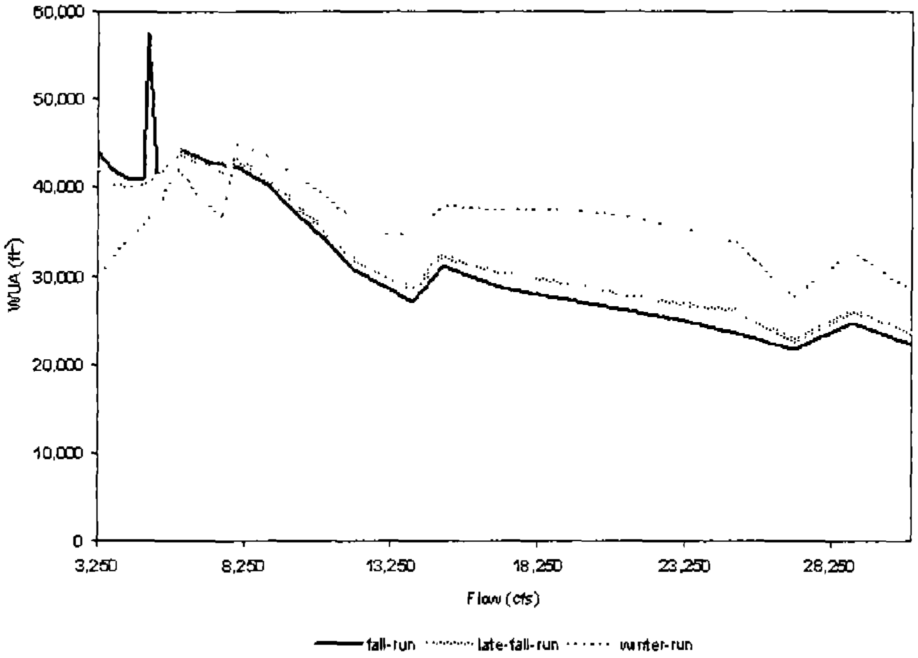


Figure 22
Fry Rearing Flow-Habitat Relationships For Segment 6 ACID Boards Out

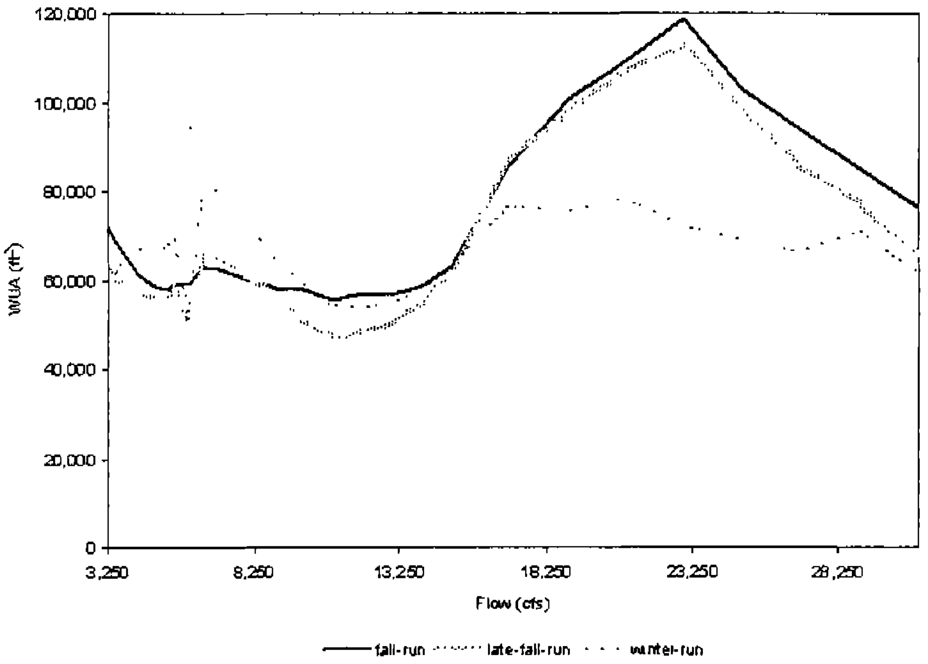


Figure 23
Juvenile Rearing Flow-Habitat Relationships For Segment 6 ACID Boards Out

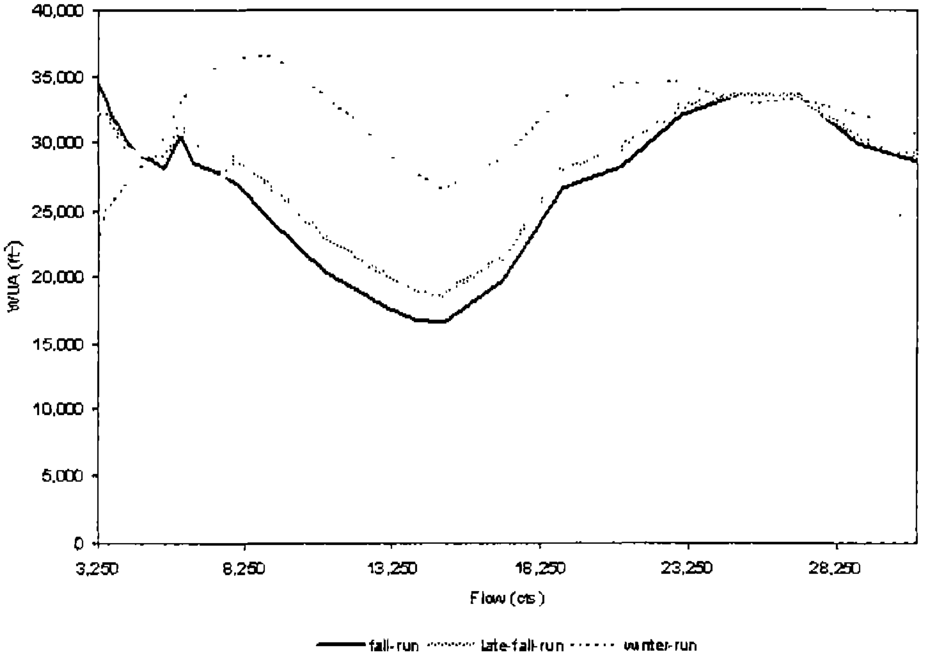


Figure 24
Fry Rearing Flow-Habitat Relationships For Segment 5

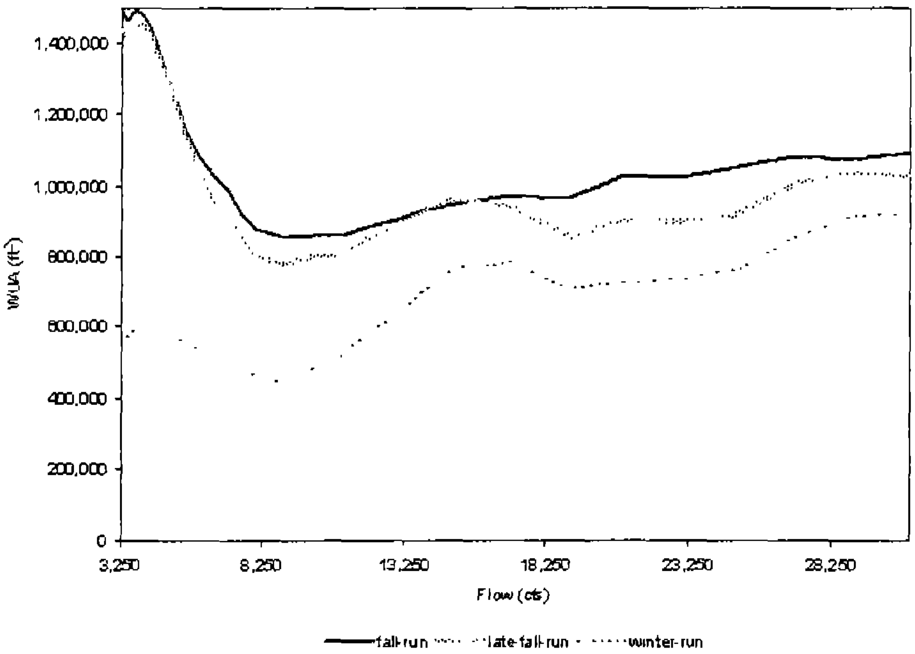


Figure 25
Juvenile Rearing Flow-Habitat Relationships For Segment 5

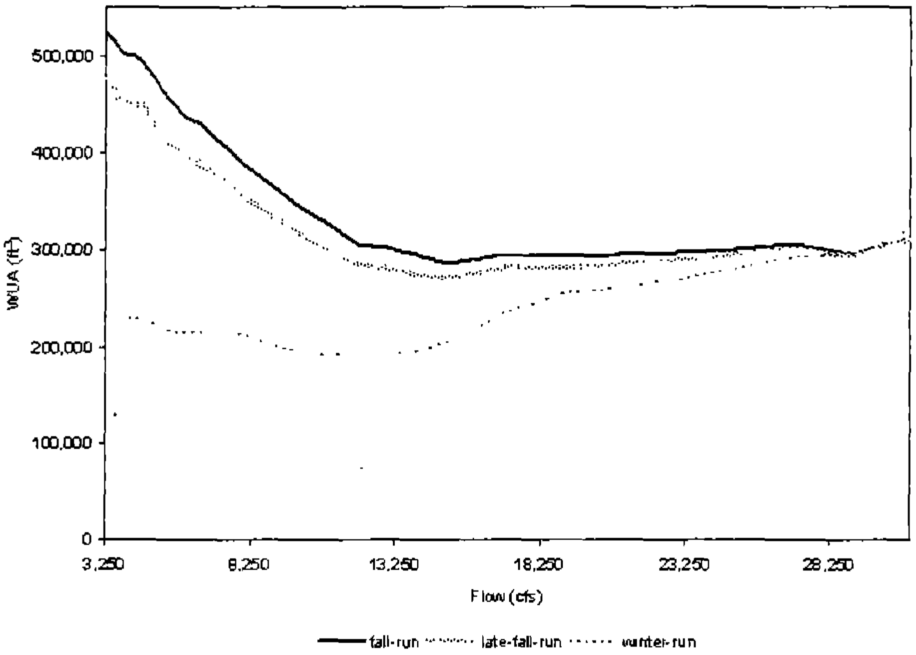


Figure 26
Fry Rearing Flow-Habitat Relationships For Segment 4

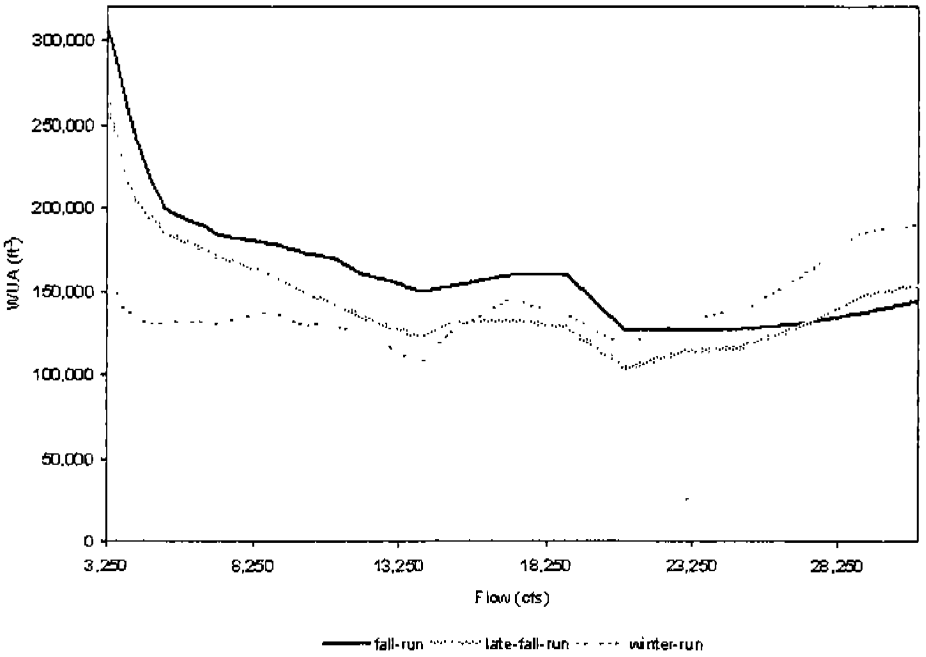


Figure 27
Juvenile Rearing Flow-Habitat Relationships For Segment 4

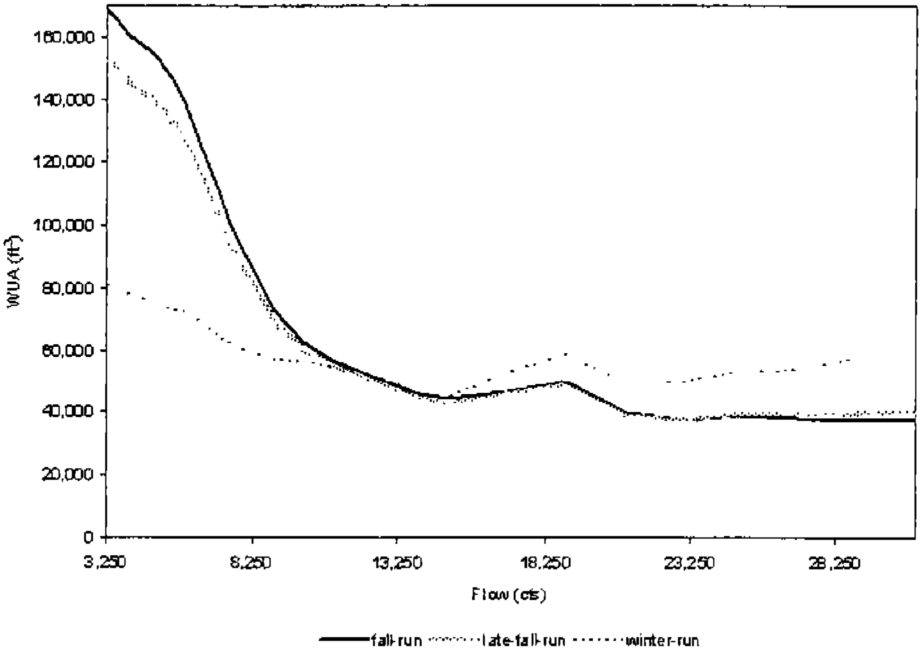


Figure 28
Limiting Life Stage Analysis for Fall-run Chinook Salmon for Segment 6 ACID Boards In

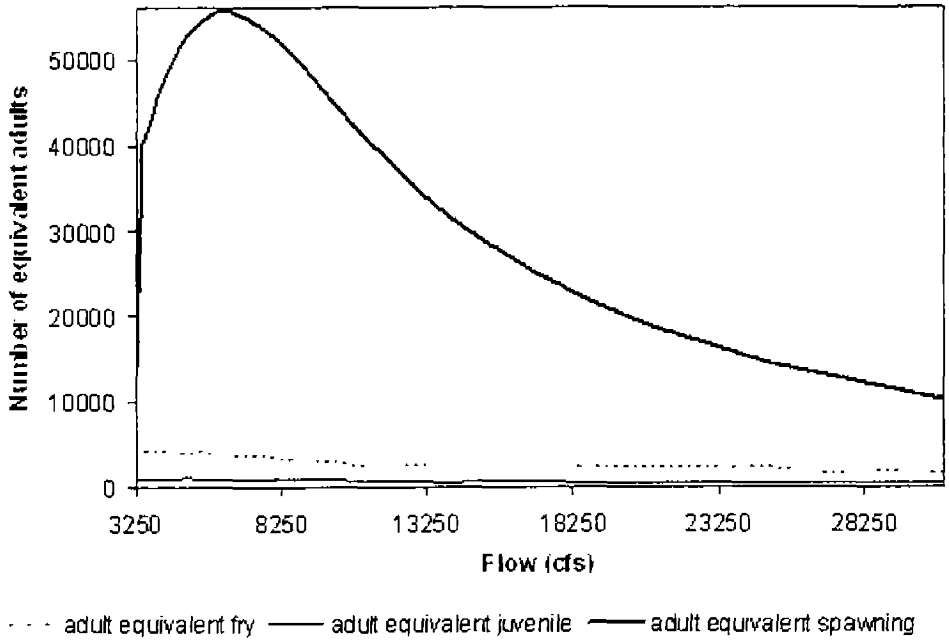


Figure 29
Limiting Life Stage Analysis for Fall-run Chinook Salmon for Segment 6 ACID Boards Out

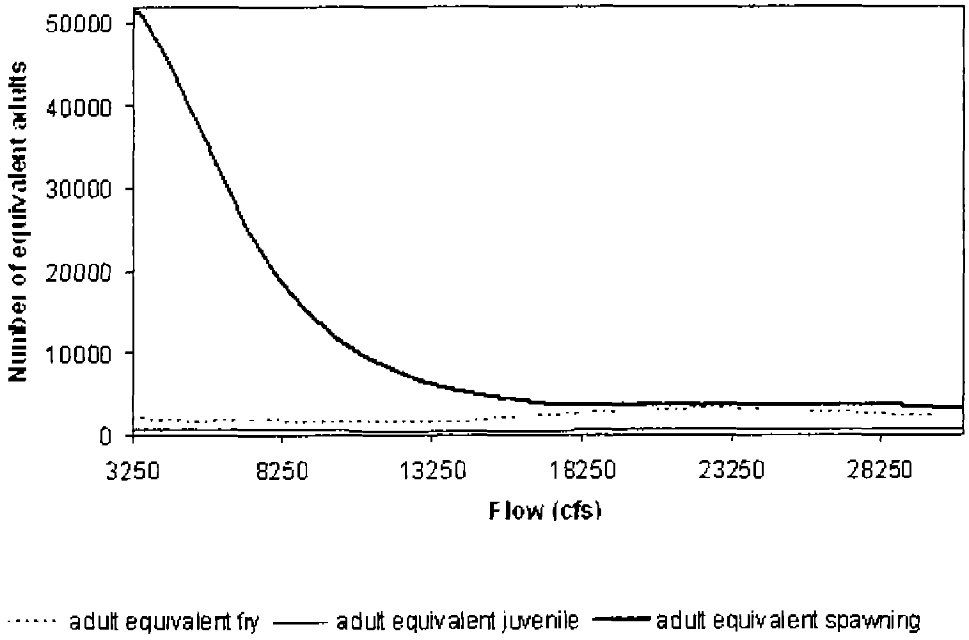


Figure 30
Limiting Life Stage Analysis for Fall-run Chinook Salmon for Segment 5

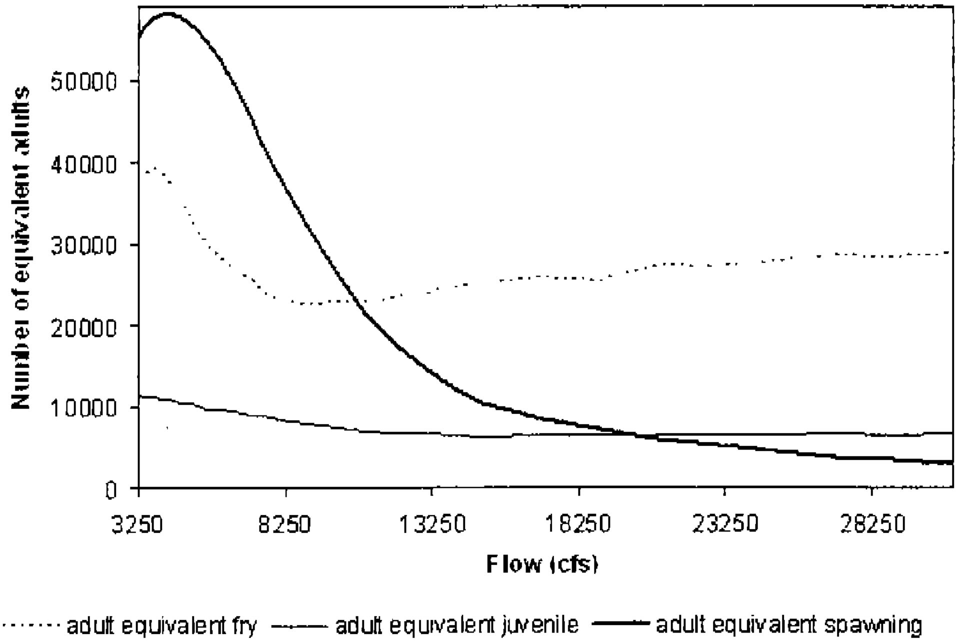


Figure 31
Limiting Life Stage Analysis for Fall-run Chinook Salmon for Segment 4

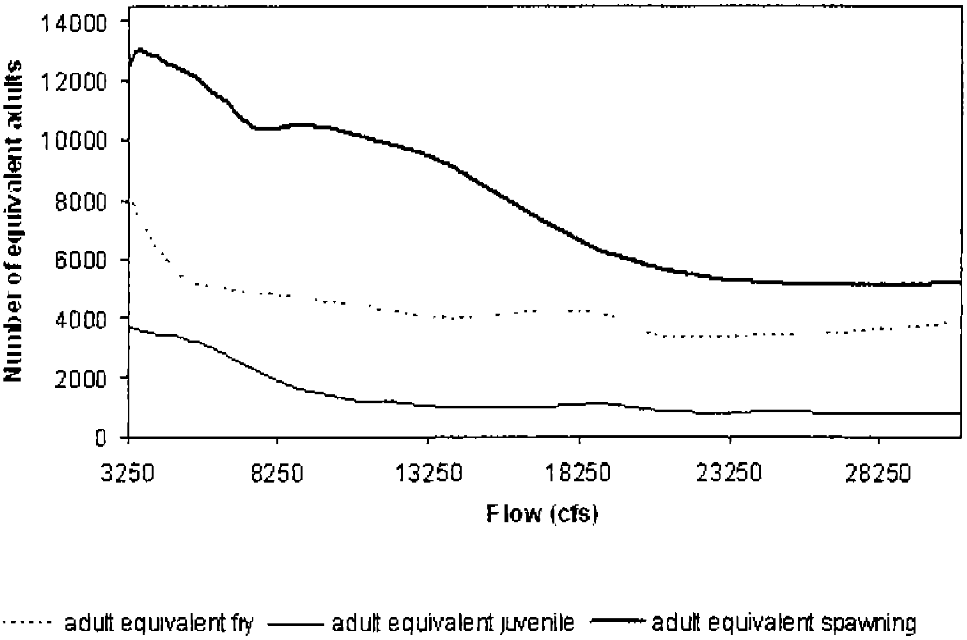


Figure 32
Limiting Life Stage Analysis for Late-fall-run Chinook Salmon for Segment 6 ACID Boards In

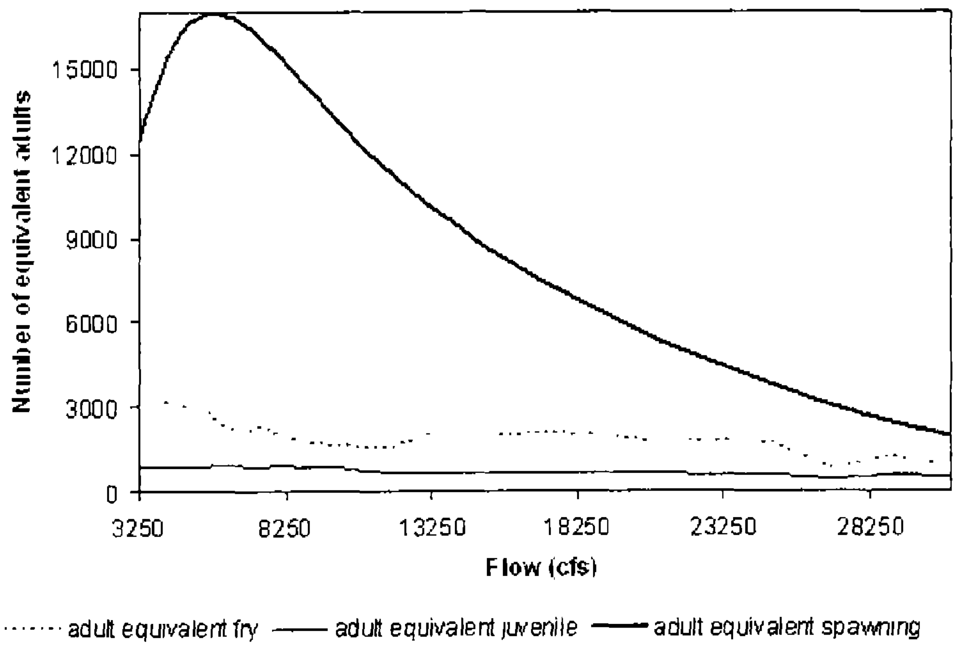


Figure 33
Limiting Life Stage Analysis for Late-fall-run Chinook Salmon for Segment 6 ACID Boards Out

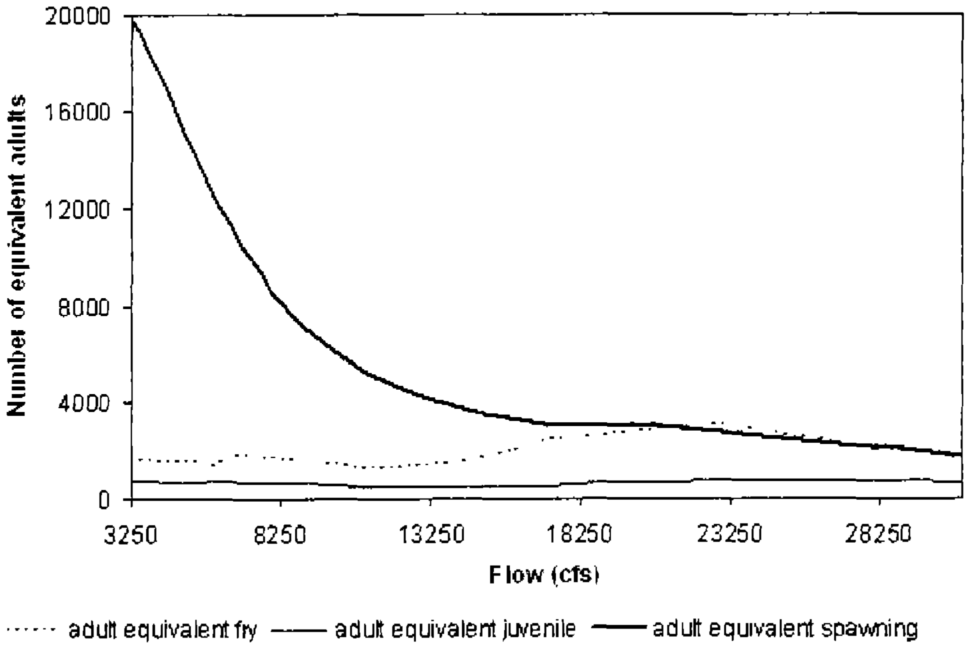


Figure 34
Limiting Life Stage Analysis for Late-fall-run Chinook Salmon for Segment 5

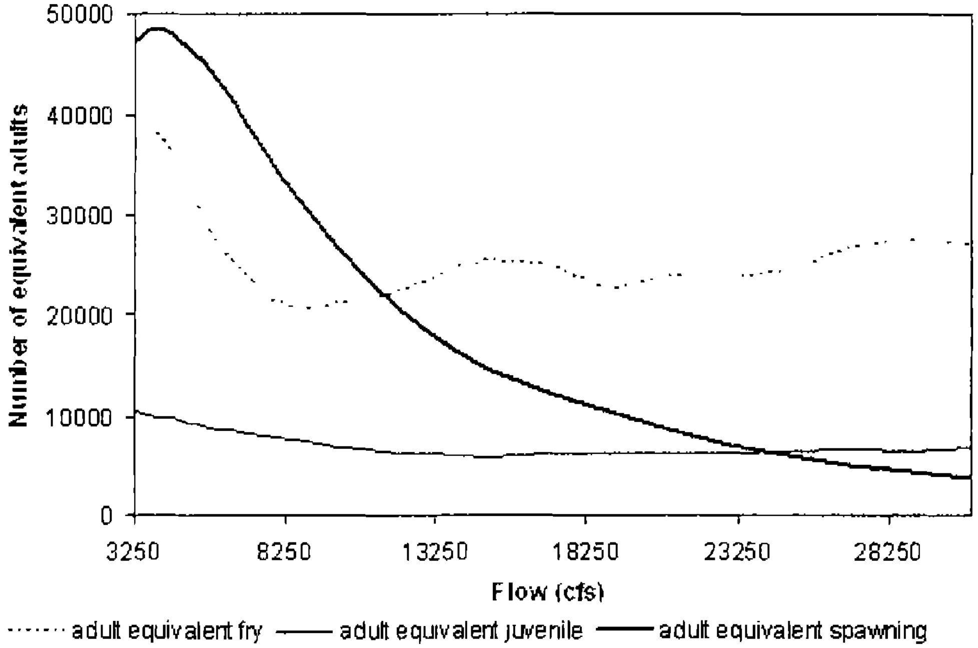


Figure 35
Limiting Life Stage Analysis for Late-fall-run Chinook Salmon for Segment 4

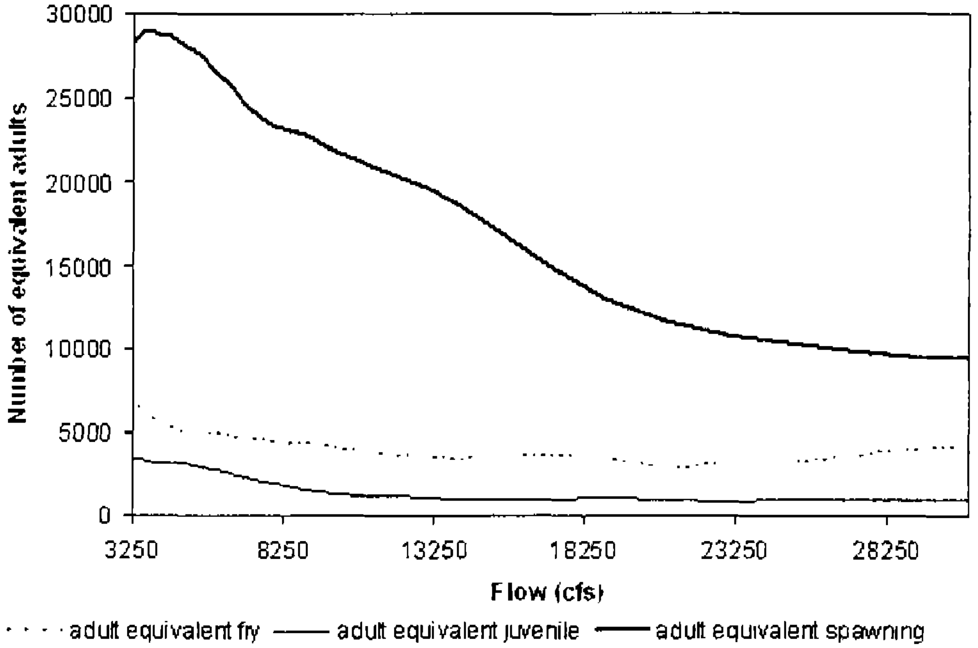


Figure 36
Limiting Life Stage Analysis for Winter-run Chinook Salmon for Segment 6 ACID Boards In

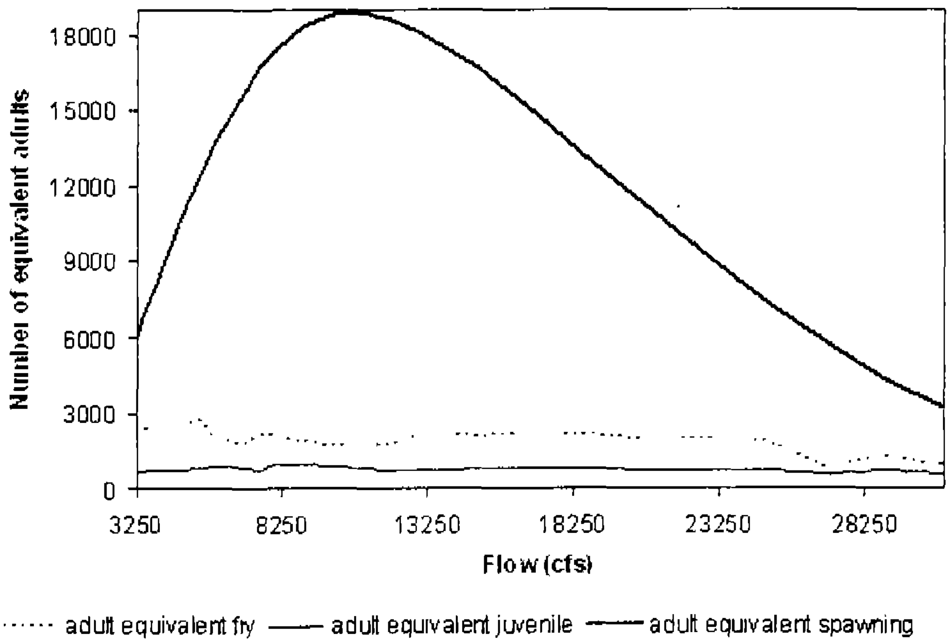


Figure 37
Limiting Life Stage Analysis for Winter-run Chinook Salmon for Segment 6 ACID Boards Out

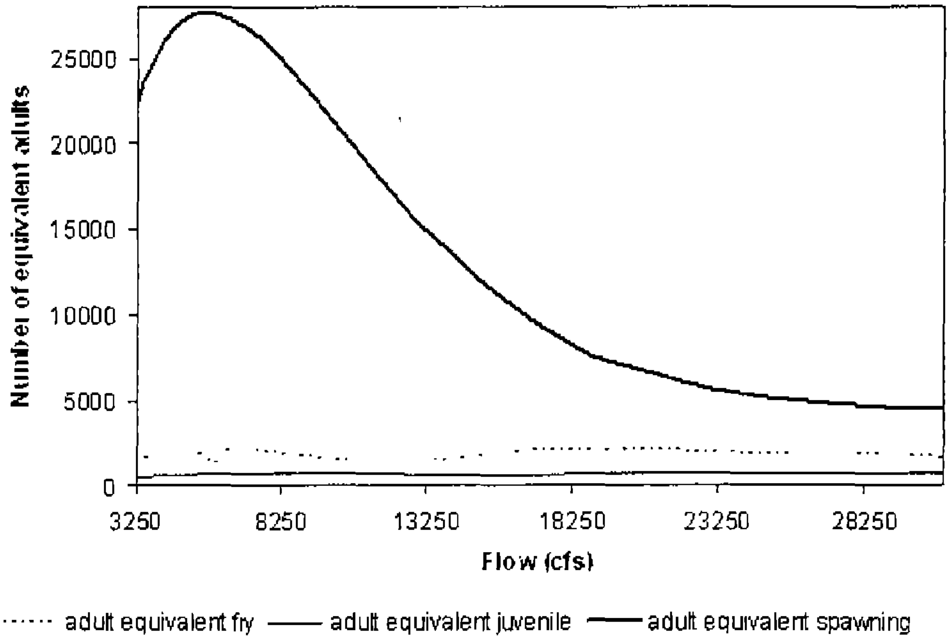


Figure 38
Limiting Life Stage Analysis for Winter-run Chinook Salmon for Segment 5

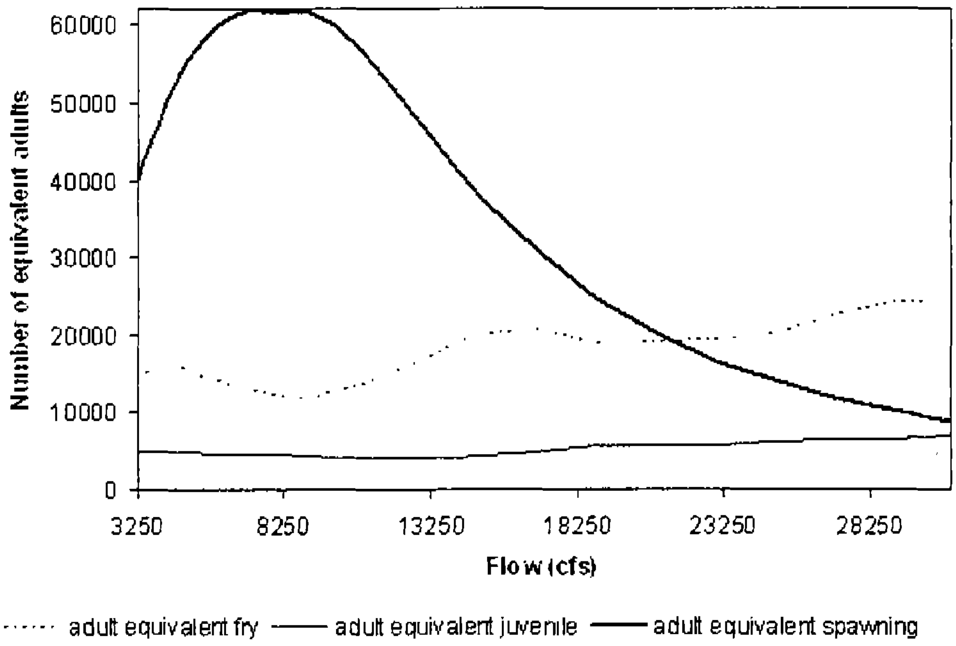
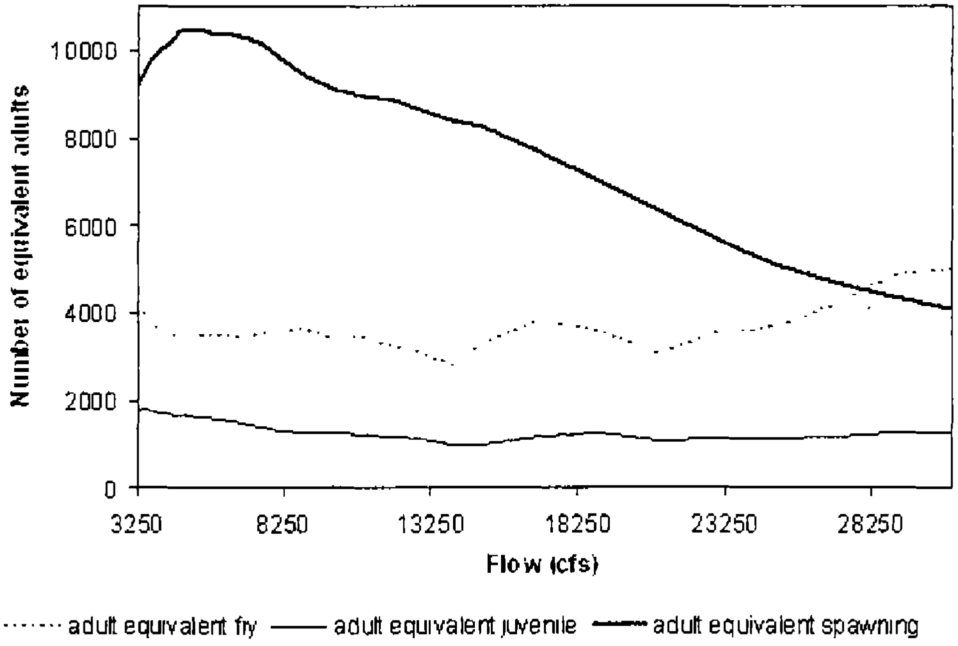


Figure 39
Limiting Life Stage Analysis for Winter-run Chinook Salmon for Segment 4



The flow-habitat relationships presented in this report differ from the flow-habitat relationships found in an earlier flow study on the Sacramento River (California Department of Water Resources 1993). The differences between the results of the two studies can primarily be attributed to the following: 1) the use of preference HSC (calculated by dividing use by availability), versus HSC derived using logistic regression; 2) use of a representative reach approach, versus a mesohabitat mapping approach; 3) the use of a more simplified cover coding (4 categories versus 14 categories used in this study); 4) the use of adjacent velocity HSC in this study; and 5) the use of PHABSIM, versus two-dimensional modeling. While the methods used in the earlier study were the accepted approaches when the California Department of Water Resource study was conducted, they are no longer the state of the art for conducting instream flow studies.

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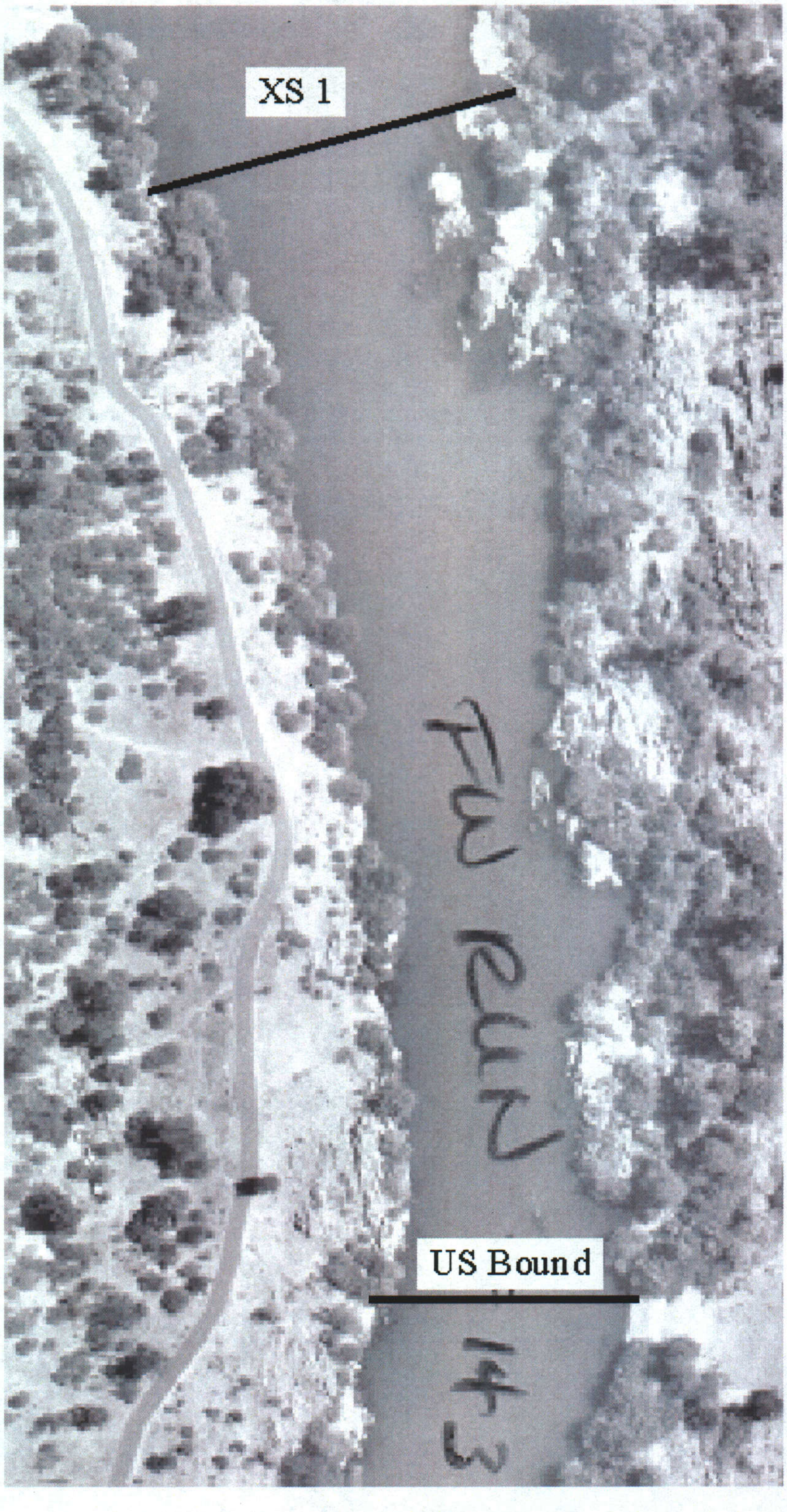
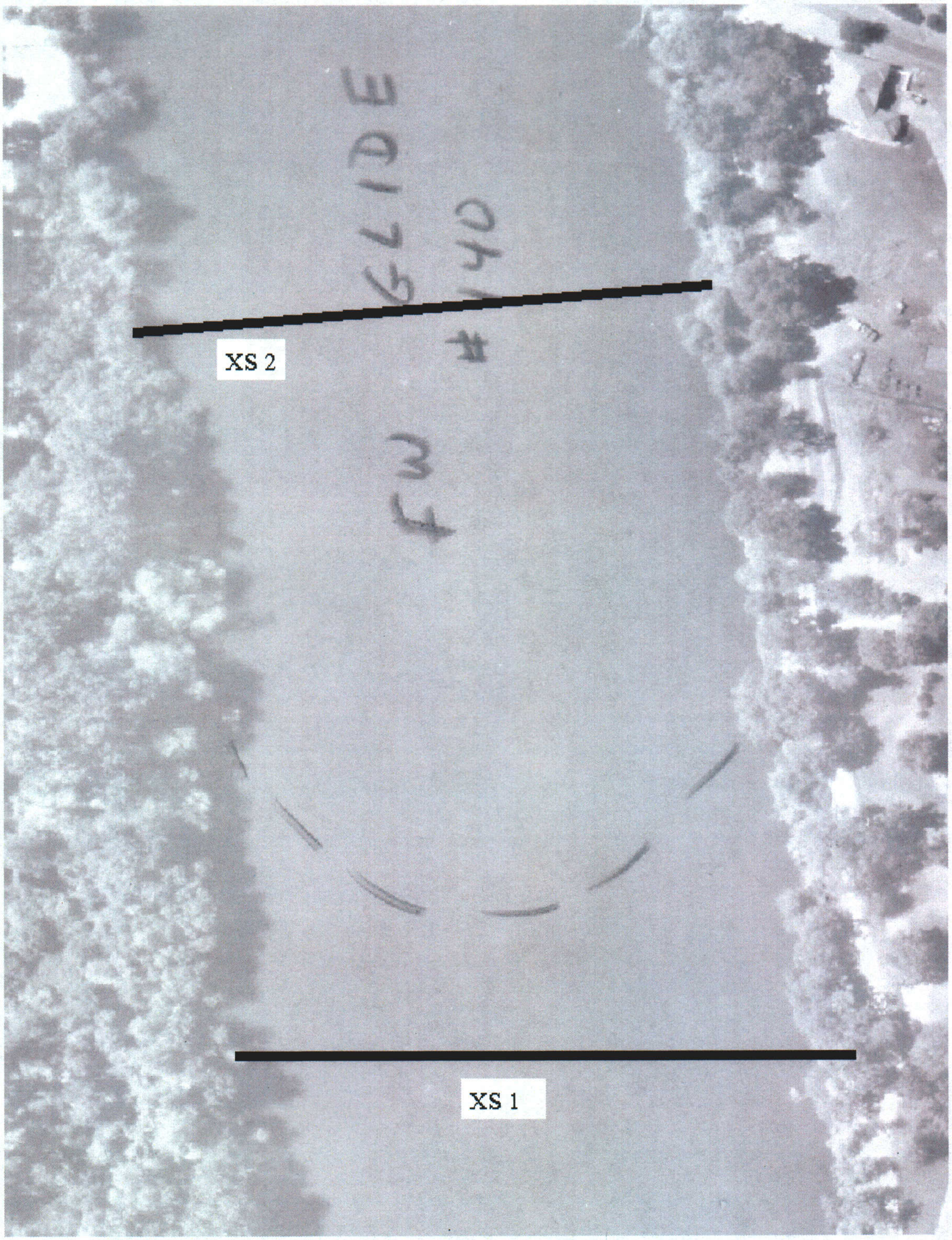
APPENDIX A
STUDY SITE AND TRANSECT LOCATIONS

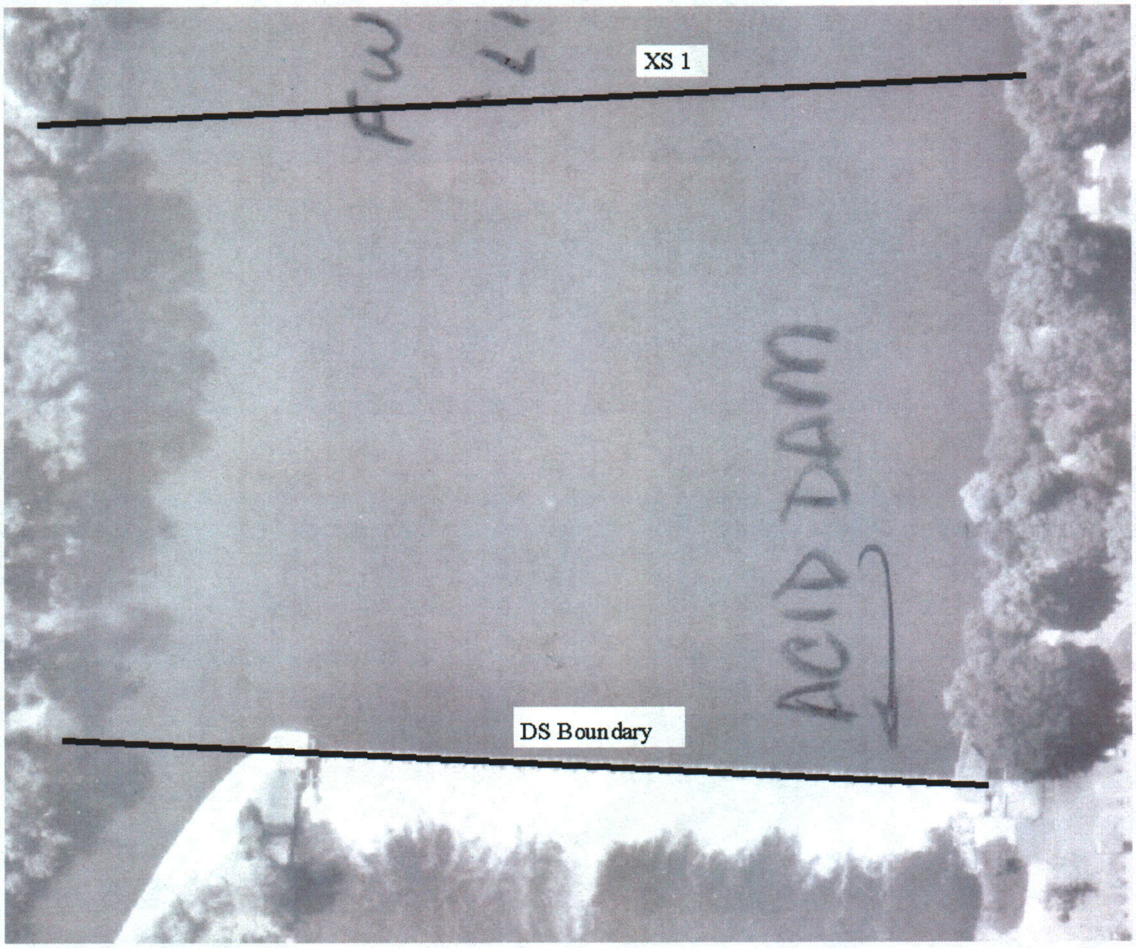
Salt Creek Study Site



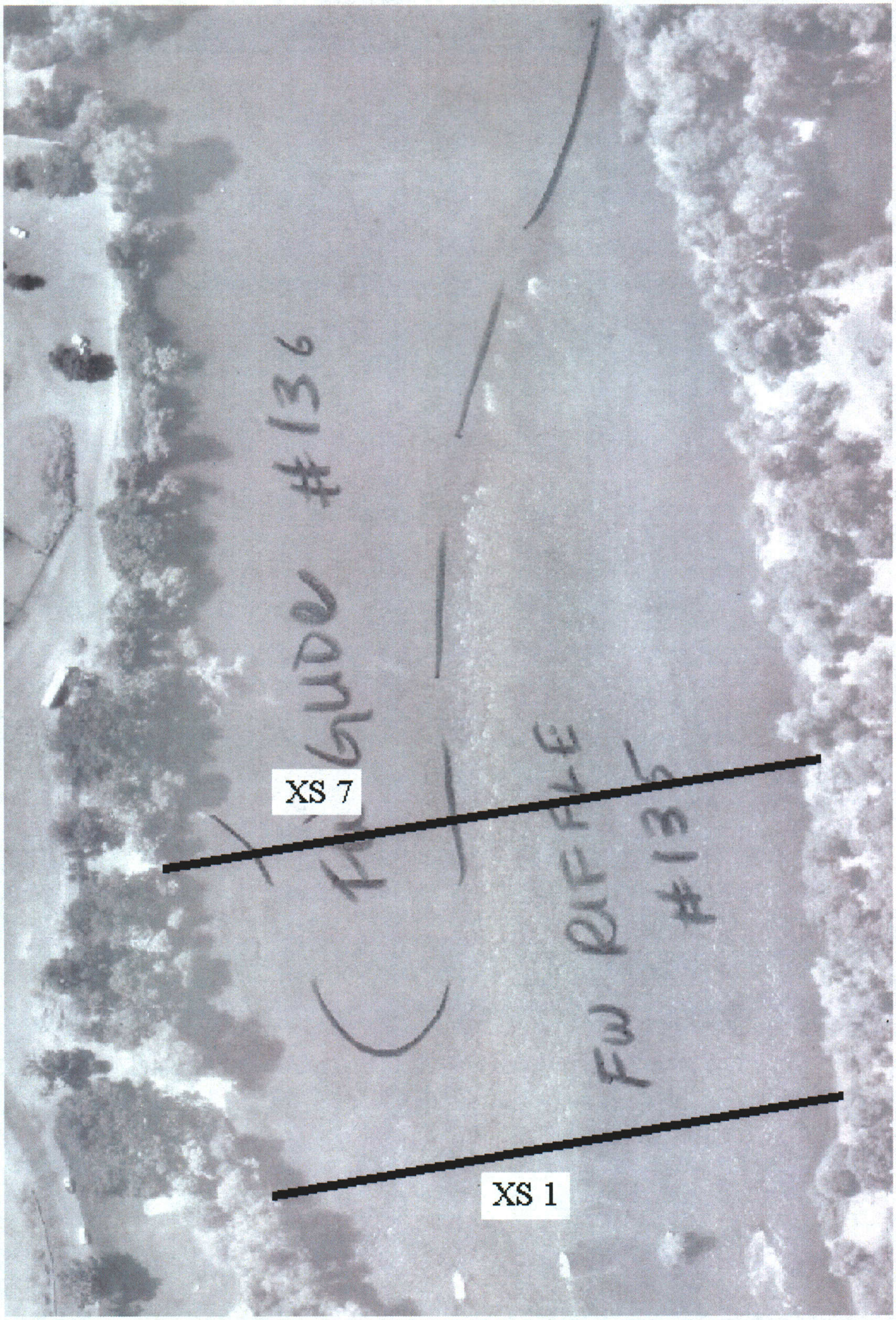
Upper Lake Redding Study Site



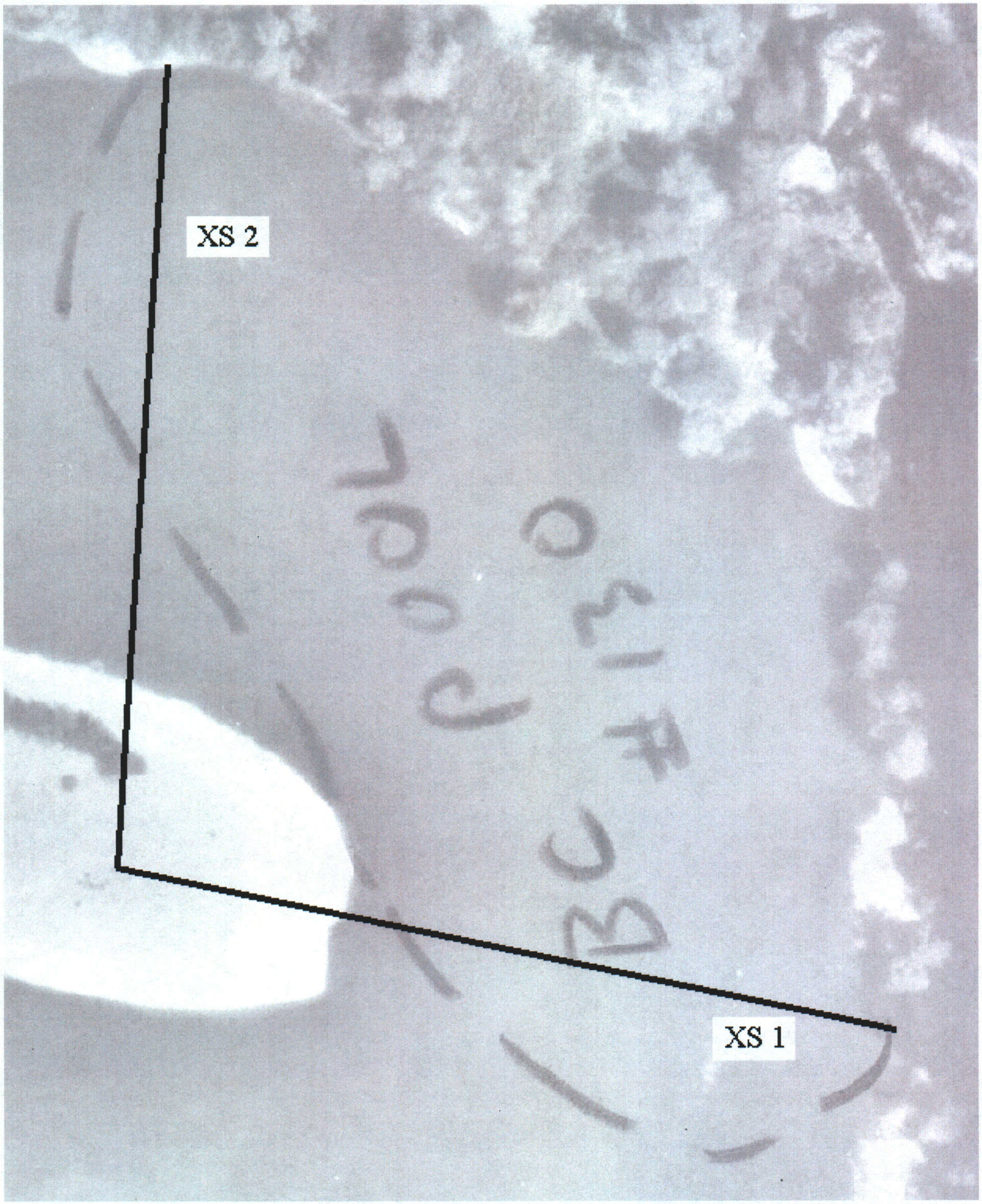
Lower Lake Redding Study Site



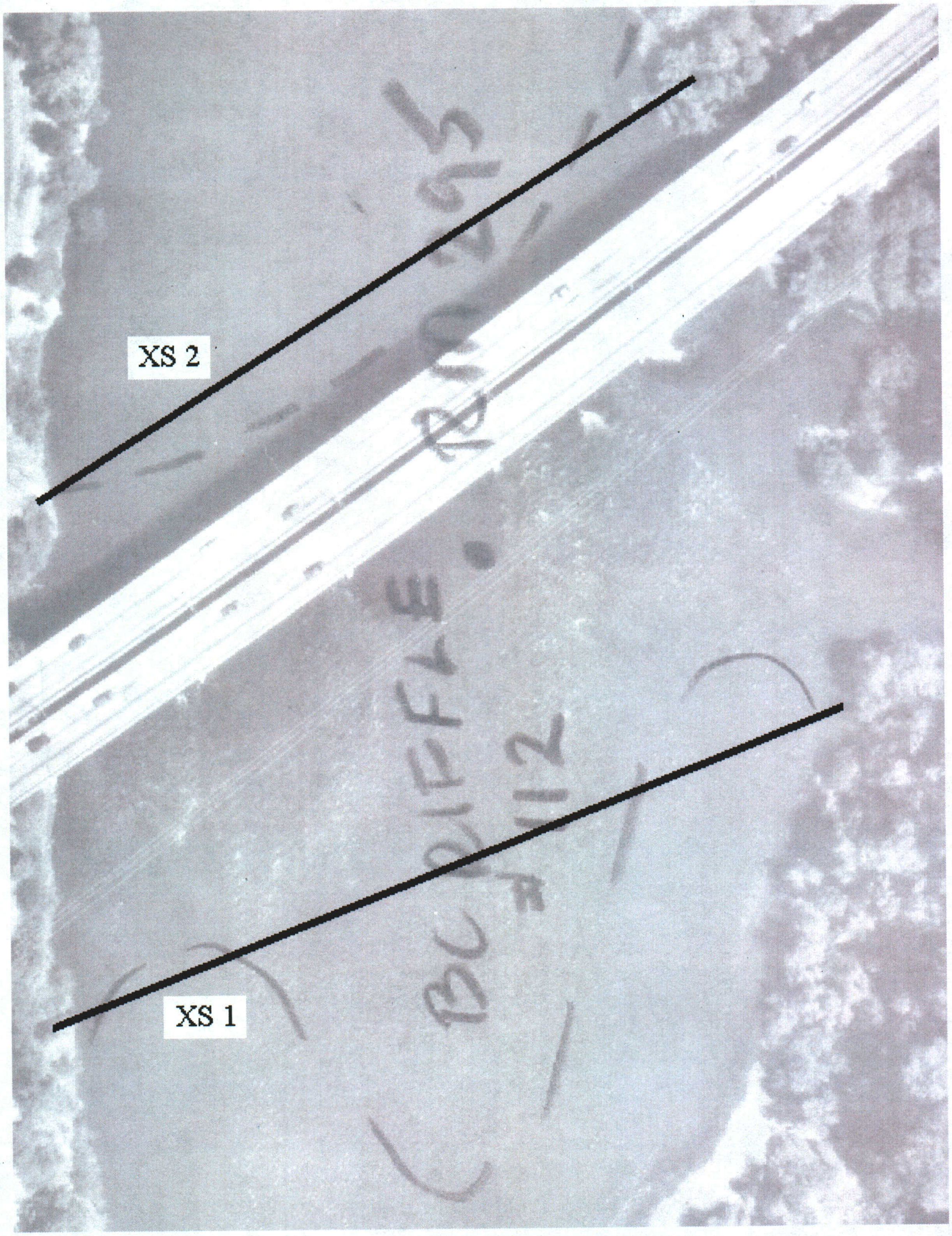
Posse Grounds Study Site



Study Site 130



Study Site 112



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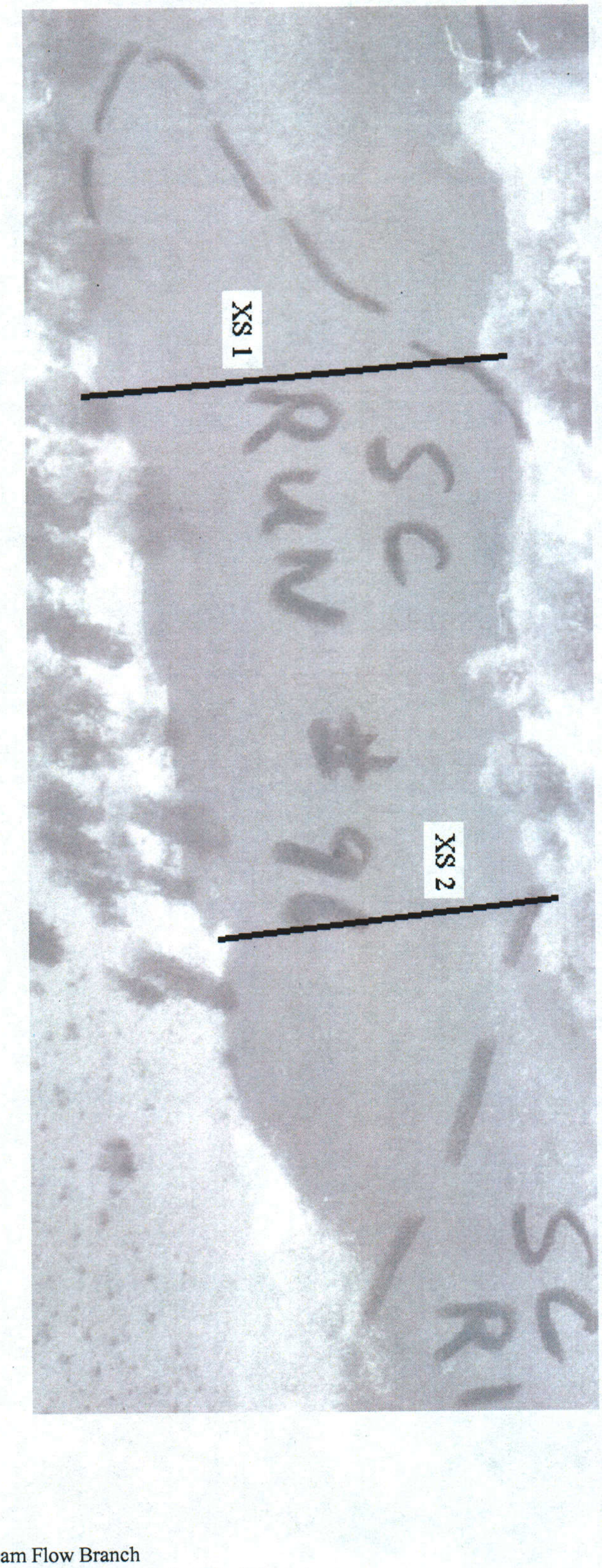

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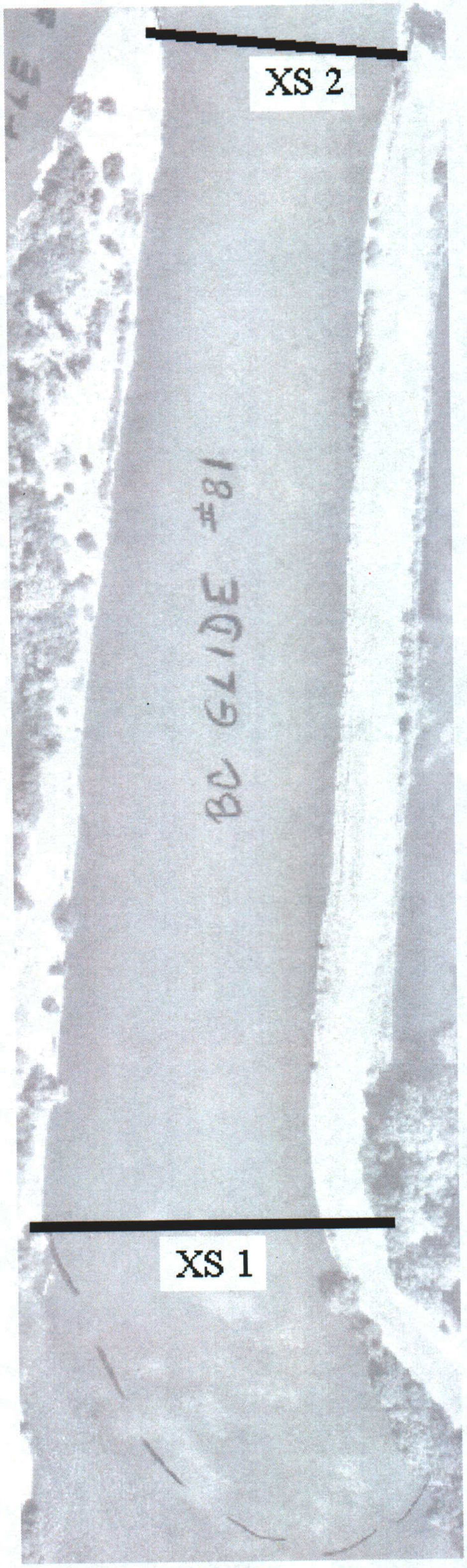
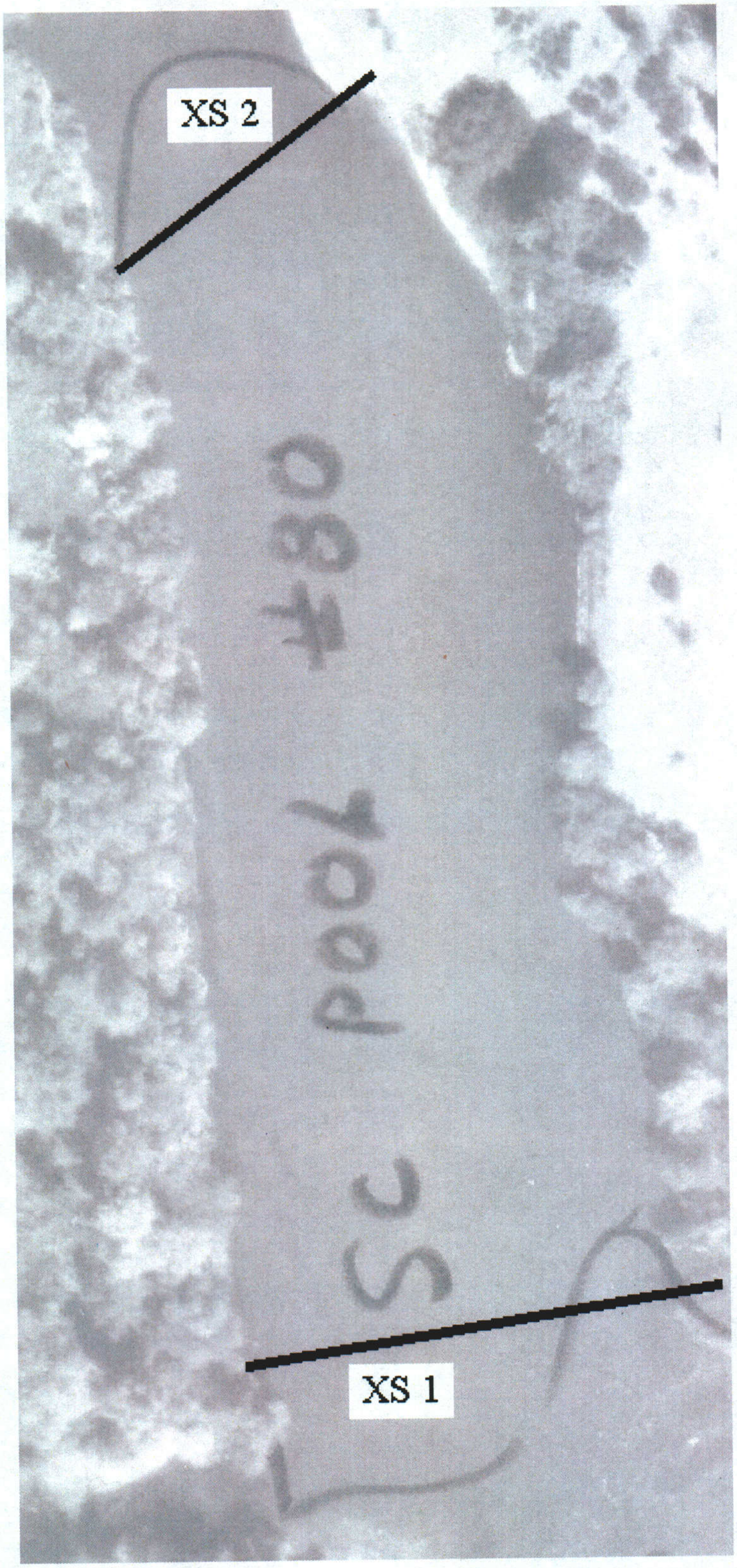
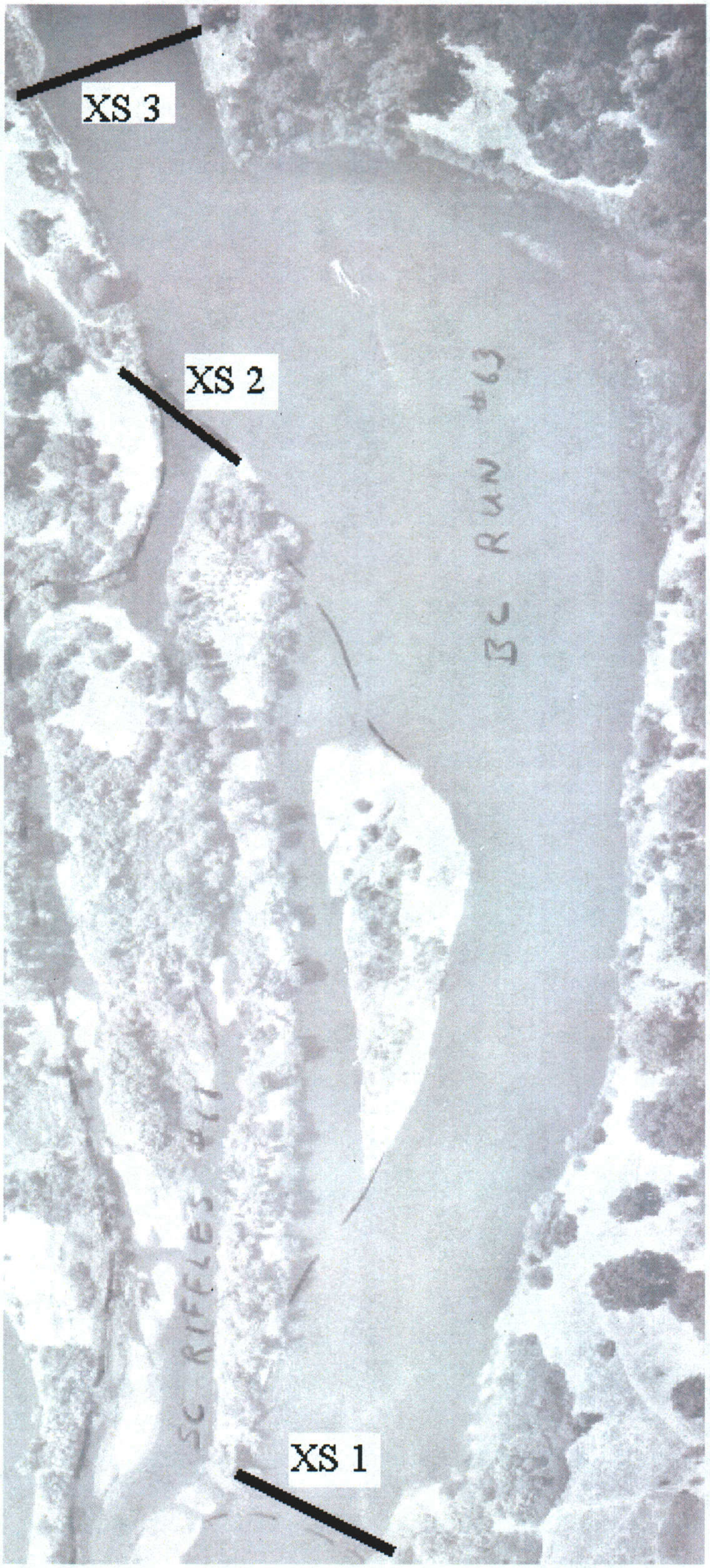


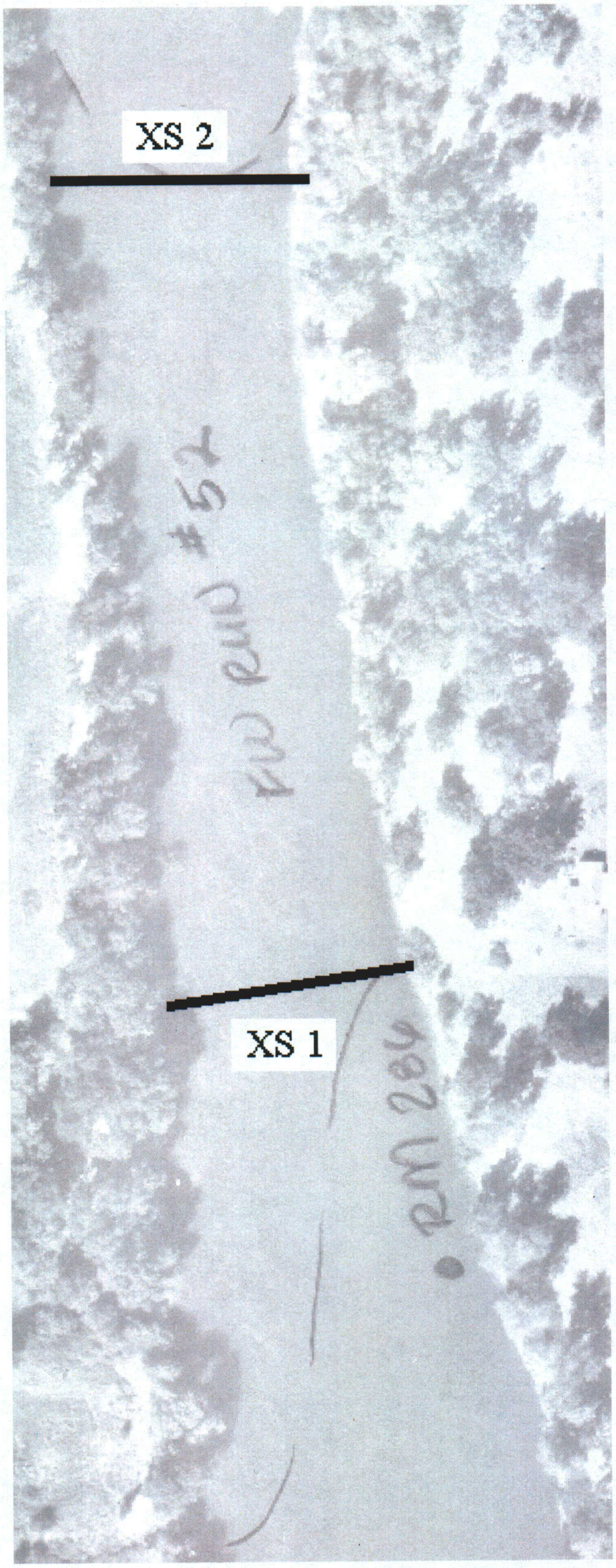
Study Site 80



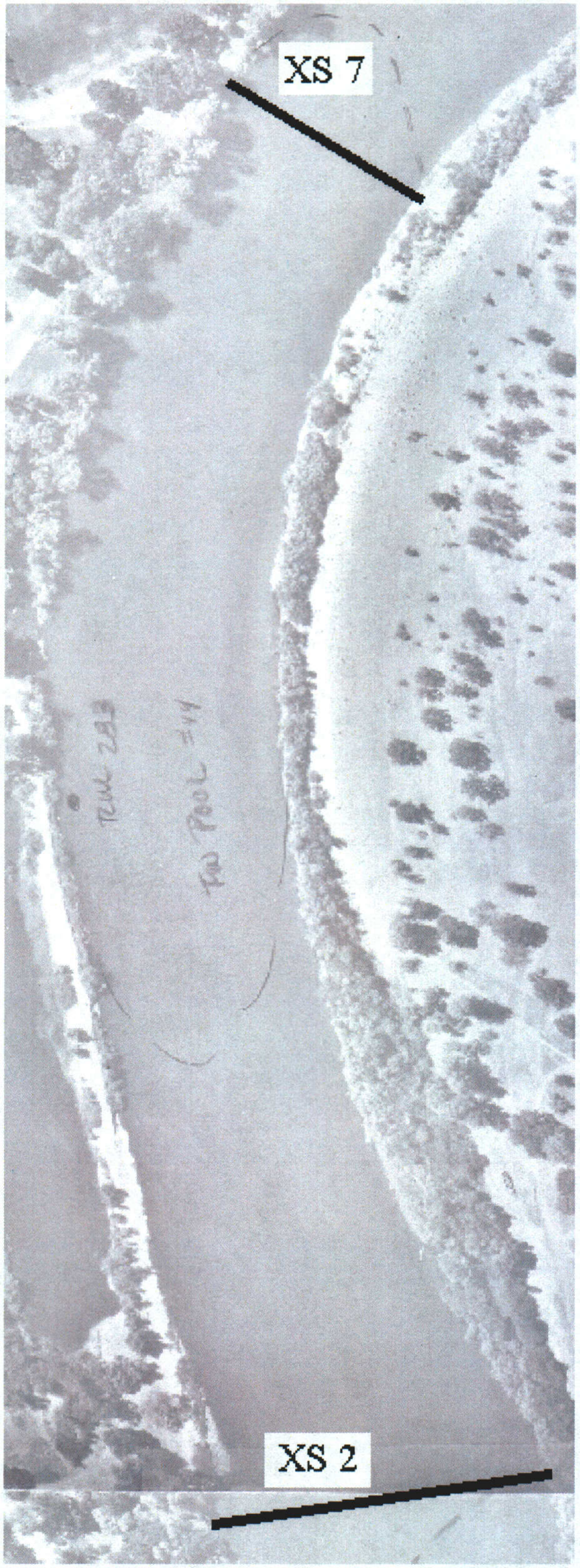
Study Site 61/63



Study Site 52

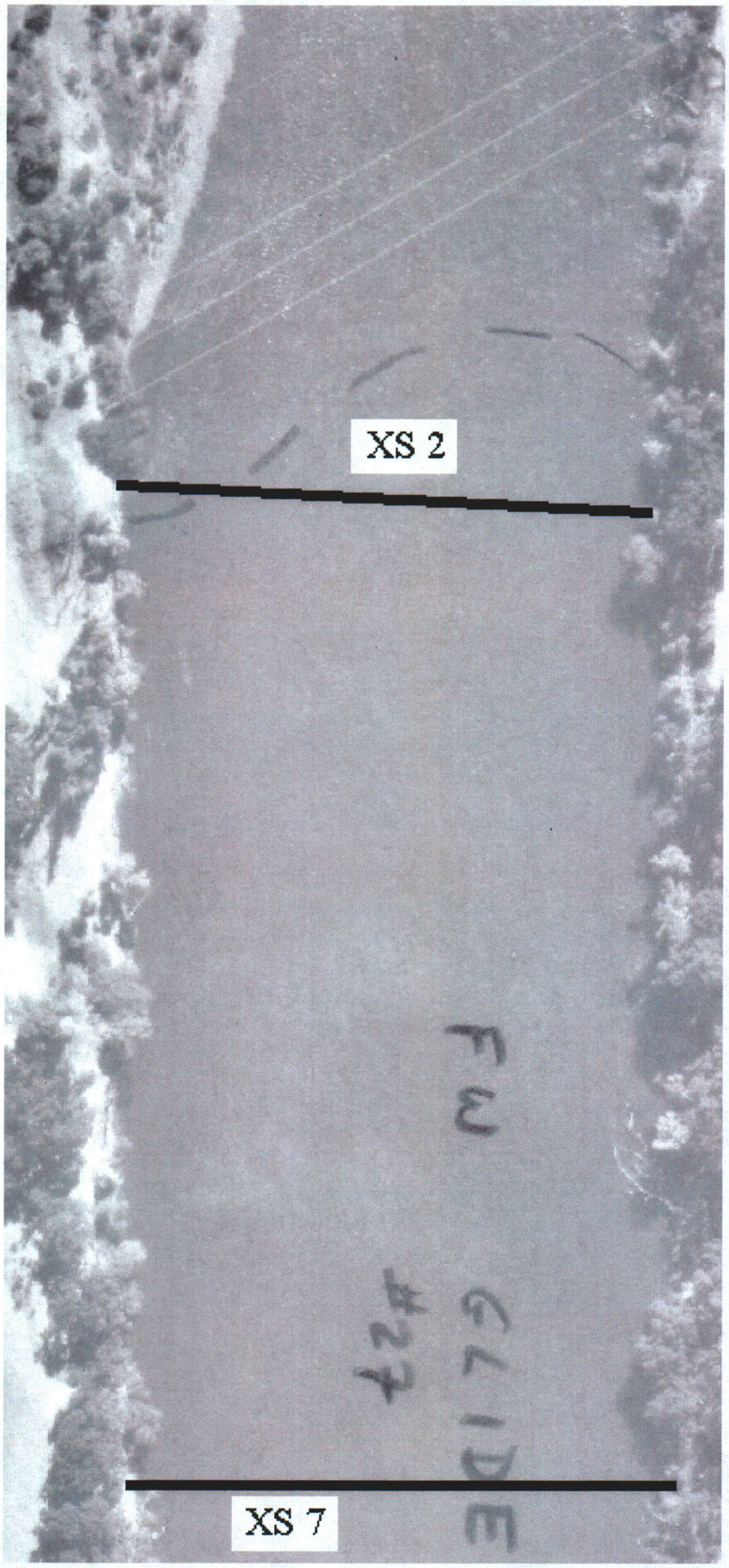


Above Hawes Hole Study Site

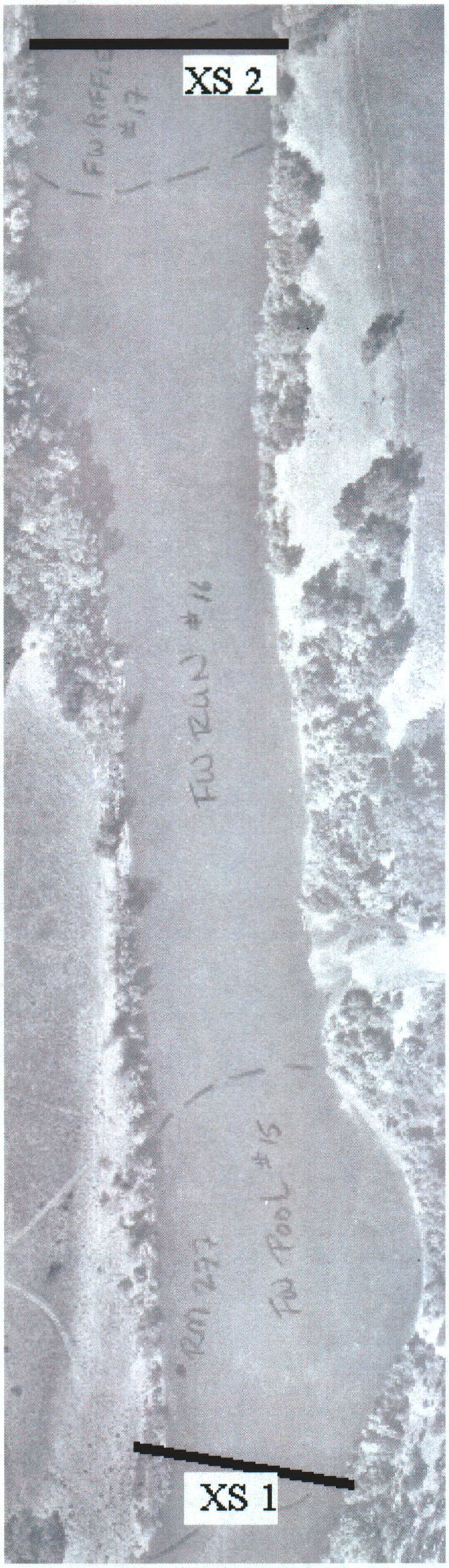


Study Site 28

Powerline Riffle Study Site

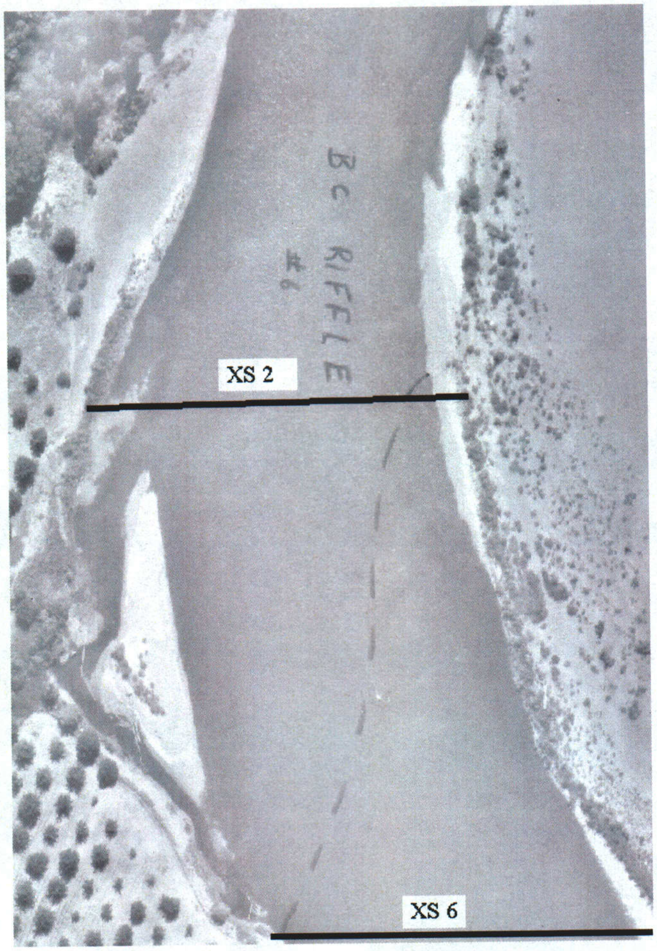


Study Site 15/17



Study Site 9

Price Riffle Study Site



APPENDIX B
PHABSIM WSEL CALIBRATION

Stage of Zero Flow Values

Study Site	XS #	SZF
Site 130	1, 2	86.2
Site 112	1, 2	84.3
Site 96	1, 2	89.9
Site 81	1, 2	75.6
Site 80	1	89.0
Site 80	2	89.5
Site 61/63	1	80.8
Site 61/63	2	92.0
Site 61/63	3	90.3
Site 52	1, 2	82.5
Hawes	6	89.1
Site 28	1, 2	72.9
Powerline	7	88.2
Site 15/17	1	74.1
Site 15/17	2	82.5
Site 9	1	76.3
Site 9	2	80.7
Price	6	83.4

Calibration Methods and Parameters Used

Study Site	XS #	Flow Range	Calibration Flows	Method	Parameters
Site 130	1, 2	3250-14000	5020, 8036, 10128, 14577	IFG4	—
Site 130	1	15000-31000	14577, 22200, 29200	MANSQ	β = 0.49, CALQ = 29200
Site 130	2	15000-31000	14577, 22200, 29200	MANSQ	β = 0.445, CALQ = 14577
Site 112	1	3250-14000	5020, 10125, 14577	IFG4	—
Site 112	2	3250-14000	6152, 10125, 14577	IFG4	—
Site 112	1, 2	15000-31000	14577, 22200, 29000	IFG4	—
Site 96	1	3250-13000	5885, 10068, 13520	IFG4	—
Site 96	1	14000-31000	13520, 14510, 29000	IFG4	—
Site 96	2	3250-31000	5885, 10068, 13520, 14510, 29000	IFG4	—
Site 81	1	3250-31000	5885, 10068, 13520, 14510, 29000	IFG4	—
Site 81	2	3250-13000	5885, 10068, 13520	IFG4	—
Site 81	2	14000-31000	14510, 29000	MANSQ	β = 0.235, CALQ = 14510
Site 80	1	3750-10000	4440, 5885, 10369	IFG4	—
Site 80	2	3750-10000	5885, 10369	WSP	n = 0.04, RM = 1
Site 80	1, 2	11000-31000	10369, 14703, 29000	IFG4	—
Site 61/63	1	3250-8000	5219, 6091, 8247	IFG4	—
Site 61/63	1	9000-14000	8247, 10300, 14414	IFG4	—
Site 61/63	1	15000-31000	14414, 22444, 29455	IFG4	—
Site 61/63	2	3250-14000	4666, 10300, 14673	IFG4	—
Site 61/63	2	15000-31000	14673, 22444, 29455	IFG4	—
Site 61/63	3	3250-3500	5219	WSP	XS 3 WSEL = XS 2 WSEL
Site 61/63	3	3750-14000	5219, 10300, 14917	IFG4	—
Site 61/63	3	15000-31000	14917, 22444, 29455	IFG4	—

Study Site	XS #	Flow Range	Calibration Flows	Method	Parameters
Site 52	1, 2	3250-13000	6091, 10596, 13109	IFG4	—
Site 52	1, 2	14000-31000	10159, 13109, 29918	IFG4	—
Hawes	7	3250-25000	6104, 9898, 14934, 26106	IFG4	—
Hawes	7	27000-31000	26106, 30864	MANSQ	β = 0.44, CALQ = 26106
Site 28	1	3250-31000	5375, 8490, 12288, 15079, 32594	IFG4	—
Site 28	2	3250-12000	5375, 8490, 12288	IFG4	—
Site 28	2	13000-31000	15079, 32594	WSP	n = 0.0589, RM = 1.03
Powerline	7	3250-9000	9922	WSP	XS 7 WSEL = XS 6 WSEL
Powerline	7	10000-31000	9922, 12288, 14999, 32594	IFG4	—
Site 15/17	1	3250-12000	5404, 8527, 10026, 12413	IFG4	—
Site 15/17	2	3250-12000	5404, 10026, 12413	IFG4	—
Site 15/17	1	13000-31000	12413, 15028, 32774	IFG4	—
Site 15/17	2	13000-31000	12413, 15028, 32774	WSP	n = 0.04, 12413 RM = 0.81, 15028 RM = 0.81, 32774 RM = 0.8
Site 9	1, 2	3250-12000	6301, 8756, 12576	IFG4	----
Site 9	1, 2	13000-31000	12576, 15206, 35704	IFG4	----
Price	6	3250-12000	6301, 12576	MANSQ	β = 0.27, CALQ = 6301
Price	6	13000-31000	14573, 15206, 30886	IFG4	----

Site 130

	BETA	%MEAN	Calculated vs. Given Disch. (%)				Difference (measured vs pred. WSELs)			
XSEC	COEFF.	ERROR	5020 cfs	8036 cfs	10128 cfs	14577 cfs	5020 cfs	8036 cfs	10128 cfs	14577 cfs
1	2.94	2.1	2.3	4.3	0.8	1.1	0.05	0.10	0.02	0.03
2	2.77	1.2	2.2	2.5	0.7	0.5	0.03	0.06	0.02	0.02

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	14577 cfs	22200 cfs	29200 cfs	14577 cfs	22200 cfs	29200 cfs
1	—	2.8	3.5	2.7	2.3	0.13	0.11	0.10
2	—	1.4	0.0	2.2	2.0	None	0.10	0.10

Site 112

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	5020 cfs	10128 cfs	14577 cfs	5020 cfs	10128 cfs	14577 cfs
1	2.18	1.7	0.8	2.5	1.8	0.02	0.10	0.08

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	6152 cfs	10128 cfs	14577 cfs	6152 cfs	10128 cfs	14577 cfs
2	4.39	0.4	0.3	0.6	0.3	None	0.01	0.01

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	14577 cfs	22200 cfs	29000 cfs	14577 cfs	22200 cfs	29000 cfs
1	2.64	1.3	0.8	1.9	1.1	0.03	0.08	0.05
2	3.13	1.1	0.6	1.7	1.1	0.02	0.06	0.05

Site 96

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	5885 cfs	10068 cfs	13520 cfs	5885 cfs	10068 cfs	13250 cfs
1	1.67	2.0	0.8	2.9	2.2	0.01	0.05	0.05

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	13520 cfs	14510 cfs	29000 cfs	13520 cfs	14510 cfs	29000 cfs
1	1.78	1.5	1.0	2.2	0.3	0.04	0.05	0.01

	BETA	%MEAN	Calculated vs. Given Disch. (%)					Difference (measured vs. pred. WSELs)				
XSEC	COEFF.	ERROR	5885	10068	13520	14510	29000	5885	10068	13250	14510	29000
2	1.78	2.1	1.5	1.6	1.7	3.5	2.1	0.02	0.03	0.04	0.09	0.09

Site 81

	BETA	%MEAN	Calculated vs. Given Disch. (%)					Difference (measured vs. pred. WSELs)				
XSEC	COEFF.	ERROR	5885	10068	13520	14510	29000	5885	10068	13250	14510	29000
1	3.66	2.5	3.4	1.6	4.7	0.1	2.6	0 06	0.03	0.10	None	0.07

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	5885 cfs	10068 cfs	13520 cfs	5885 cfs	10068 cfs	13250 cfs
2	3 49	1.7	0.7	2.5	1.9	0.01	0.06	0.05

	BETA	%MEAN	Calculated vs Given Disch. (%)		Difference (measured vs. pred. WSELs)	
XSEC	COEFF	ERROR	14510 cfs	29000 cfs	14510 cfs	29000 cfs
2	—	0.0	0.0	0.0	None	None

Site 80

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	4440 cfs	5885 cfs	10369 cfs	4440 cfs	5885 cfs	10369 cfs
1	2.75	0.8	1.2	0.5	0.6	None	0.01	None

	BETA	%MEAN	Calculated vs. Given Disch. (%)		Difference (measured vs. pred WSELs)	
XSEC	COEFF	ERROR	5885 cfs	10369 cfs	5885 cfs	10369 cfs
2	—	—	—	—	0.01	0.04

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	10369 cfs	14703 cfs	29000 cfs	10369 cfs	14703 cfs	29000 cfs
1	3.09	7.1	6.1	11.3	4.3	0.06	0.13	0.08
2	2.70	2.6	2.1	4.0	1.8	0.02	0.05	0.04

Site 61/63

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	5219 cfs	6091 cfs	8247 cfs	5219 cfs	6091 cfs	8247 cfs
1	4.50	1.9	2.9	1.7	1.2	0.02	0.05	0.02

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	8247 cfs	10300 cfs	14414 cfs	8247 cfs	10300 cfs	14414 cfs
1	2.31	0.6	0.6	0.9	0.4	0.02	0.03	0.02

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	4666 cfs	10300 cfs	14673 cfs	4666 cfs	10300 cfs	14673 cfs
2	1.82	0.0	0.0	0.0	0.0	None	None	None

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	5219 cfs	10300 cfs	14917 cfs	5219 cfs	10300 cfs	14917 cfs
3	2.84	2.2	1.2	3.3	2.0	0.01	0.05	0.04

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	14414 cfs	22444 cfs	29455 cfs	14414 cfs	22444 cfs	29455 cfs
1	2.34	0.1	0.1	0.2	0.1	None	0.01	0.01

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	14673 cfs	22444 cfs	29455 cfs	14673 cfs	22444 cfs	29455 cfs
2	1.93	4.3	4.0	6.7	2.3	0.06	0.11	0.06

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	14917 cfs	22444 cfs	29455 cfs	14917 cfs	22444 cfs	29455 cfs
3	1.87	1.3	0.7	1.9	1.2	0.02	0.07	0.05

Site 52

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	6091 cfs	10596 cfs	13109 cfs	6091 cfs	10596 cfs	13109 cfs
1	1.97	1.5	0.7	2.3	1.5	0.02	0.09	0.07
2	1.97	1.5	0.7	2.3	1.5	0.02	0.09	0.07

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	10596 cfs	13109 cfs	29918 cfs	10596 cfs	13109 cfs	29918 cfs
1	2.10	2.1	2.3	3.0	0.8	0.09	0.13	0.05
2	2.10	2.1	2.3	3.0	0.8	0.09	0.13	0.05

Above Hawes Hole Site

	BETA	%MEAN	Calculated vs Given Disch. (%)				Difference (measured vs. pred. WSELs)			
XSEC	COEFF.	ERROR	6104 cfs	9898 cfs	14934 cfs	26106 cfs	6104 cfs	9898 cfs	14934 cfs	26106 cfs
7	2.31	2.4	2.6	2.4	2.5	2.1	0.07	0.07	0.09	0.10

	BETA	%MEAN	Calculated vs. Given Disch. (%)		Difference (measured vs. pred. WSELs)	
XSEC	COEFF.	ERROR	26106 cfs	30864 cfs	26106 cfs	30864 cfs
7	—	0.0	0.0	0.0	None	None

Site 28

	BETA	%MEAN	Calculated vs. Given Disch. (%)					Difference (measured vs. pred. WSELs)				
XSEC	COEFF.	ERROR	5375	8490	12288	15079	32594	5375	8490	12288	15079	32594
1	2.04	1.3	1.4	2.6	0.4	2.0	0.4	0.04	0.09	0.02	0.09	0.02

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	5375 cfs	8490 cfs	12288 cfs	5375 cfs	8490 cfs	12288 cfs
2	2.10	1.6	1.2	2.5	1.2	0.03	0.08	0.05

	BETA	%MEAN	Calculated vs. Given Disch. (%)		Difference (measured vs. pred. WSELs)	
XSEC	COEFF.	ERROR	15079 cfs	32594 cfs	15079 cfs	32594 cfs
2	—	—	—	----	0.09	0.08

Powerline Riffle Site

	BETA	%MEAN	Calculated vs. Given Disch. (%)	Difference (measured vs. pred. WSELs)
XSEC	COEFF.	ERROR	9922 cfs	9922 cfs
7	—	—	----	None

	BETA	%MEAN	Calculated vs. Given Disch. (%)				Difference (measured vs. pred. WSELs)			
XSEC	COEFF.	ERROR	9922 cfs	12288 cfs	14999 cfs	32594 cfs	9922 cfs	12288 cfs	14999 cfs	32594 cfs
7	1.97	0.7	1.0	0.9	0.5	0.3	0.04	0.04	0.02	0.02

Site 15/17

	BETA	%MEAN	Calculated vs. Given Disch. (%)				Difference (measured vs. pred. WSELs)			
XSEC	COEFF.	ERROR	5404cfs	8527 cfs	10026 cfs	12413 cfs	5404 cfs	8527 cfs	10026 cfs	12413 cfs
1	4.27	2.1	1.7	2.5	1.7	2.4	0.04	0.07	0.05	0.07

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	5404cfs	10026 cfs	12413 cfs	5404 cfs	10026 cfs	12413 cfs
2	2.68	1.3	0.6	1.9	1.3	0.01	0.05	0.03

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	12413 cfs	15028 cfs	32774 cfs	12413 cfs	15028 cfs	32774 cfs
1	2.73	0.5	0.6	0.7	0.1	0.03	0.04	0.01
2	—	—	—	—	—	None	None	None

Site 9

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	6301cfs	8756 cfs	12576 cfs	6301 cfs	8756 cfs	12576 cfs
1	4.22	0.7	0.6	1.1	0.5	0.02	0.03	0.02
2	2.87	0.8	0.6	1.2	0.5	0.02	0.04	0.02

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	12576 cfs	15206 cfs	35704 cfs	12576 cfs	15206 cfs	35704 cfs
1	3.35	0.0	0.0	0.0	0.0	None	None	None
2	2.38	1.4	1.7	2.2	0.5	0.07	0.10	0.03

Price Riffle Site

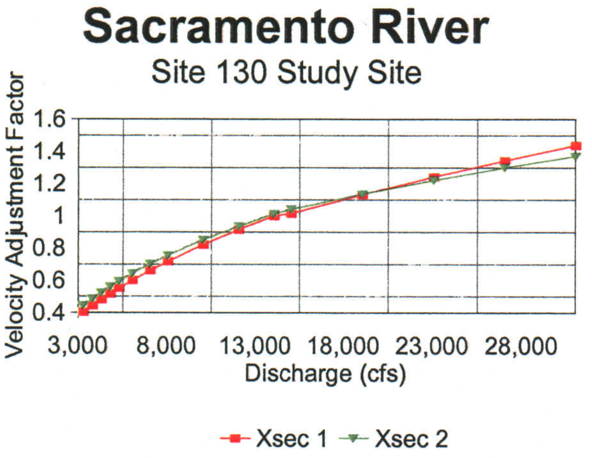
	BETA	%MEAN	Calculated vs. Given Disch. (%)		Difference (measured vs. pred. WSELs)	
XSEC	COEFF.	ERROR	6301 cfs	12576 cfs	6301 cfs	12576 cfs
6	----	0.0	0.0	0.0	None	None

	BETA	%MEAN	Calculated vs. Given Disch. (%)			Difference (measured vs. pred. WSELs)		
XSEC	COEFF.	ERROR	14573 cfs	15206 cfs	30886 cfs	14573 cfs	15206 cfs	30886 cfs
6	2.04	0.3	0.5	0.5	0.0	0.02	0.02	None

APPENDIX C
VELOCITY ADJUSTMENT FACTORS

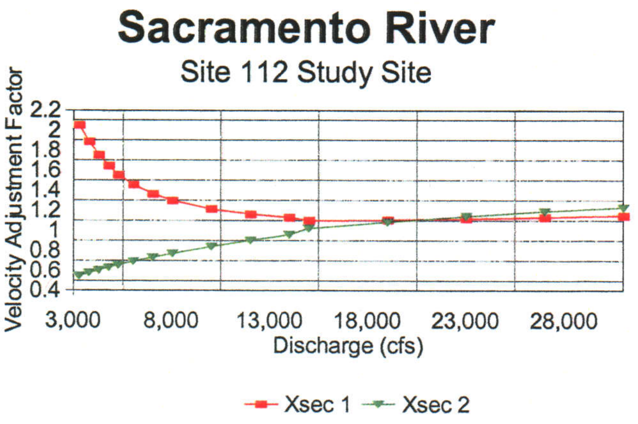
STUDY SITE 130

Discharge	Velocity Adjustment Factors Xsec 1	 Xsec 2
3250	0.41	0.45
3750	0.45	0.49
4250	0.48	0.52
4750	0.52	0.56
5250	0.55	0.59
6000	0.60	0.64
7000	0.66	0.70
8000	0.72	0.75
10000	0.82	0.85
12000	0.92	0.94
14000	1.00	1.01
15000	1.02	1.04
19000	1.13	1.14
23000	1.24	1.22
27000	1.34	1.30
31000	1.44	1.37



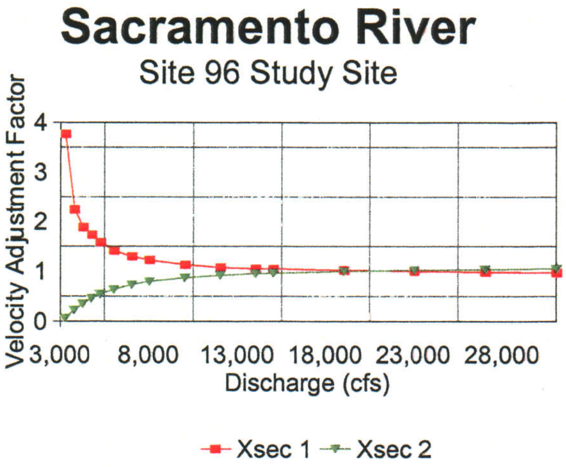
STUDY SITE 112

Discharge	Velocity Adjustment Factors Xsec 1	 Xsec 2
3250	2.05	0.55
3750	1.89	0.58
4250	1.75	0.60
4750	1.64	0.63
5250	1.55	0.66
6000	1.46	0.69
7000	1.37	0.73
8000	1.30	0.77
10000	1.21	0.84
12000	1.16	0.90
14000	1.13	0.96
15000	1.10	1.02
19000	1.10	1.08
23000	1.11	1.14
27000	1.13	1.18
31000	1.15	1.22



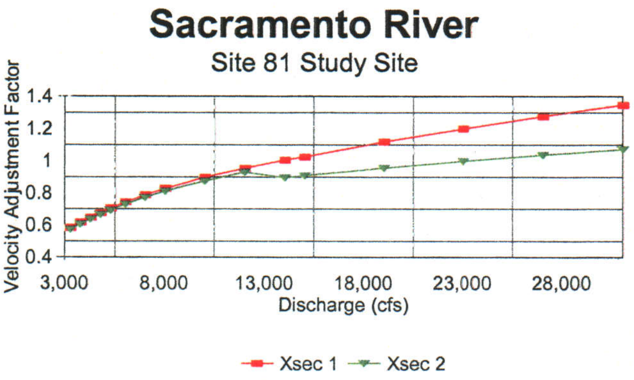
STUDY SITE 96

	Velocity Adjustment Factors	
Discharge	Xsec 1	Xsec 2
3250	3.77	0.06
3750	2.24	0.22
4250	1.88	0.35
4750	1.73	0.45
5250	1.58	0.54
6000	1.41	0.63
7000	1.29	0.73
8000	1.22	0.79
10000	1.13	0.87
12000	1.07	0.92
14000	1.05	0.95
15000	1.04	0.96
19000	1.01	0.99
23000	0.99	1.01
27000	0.97	1.03
31000	0.96	1.04



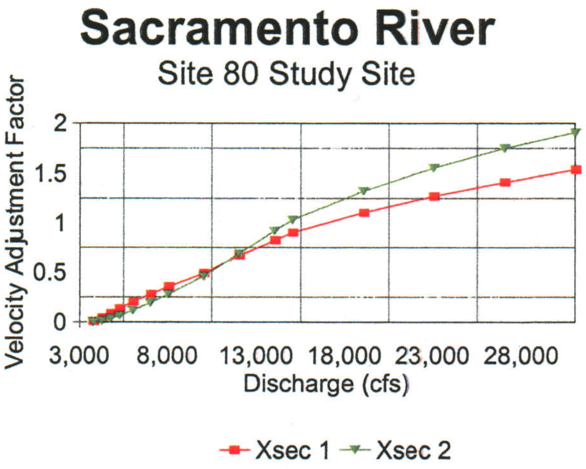
STUDY SITE 81

	Velocity Adjustment Factors	
Discharge	Xsec 1	Xsec 2
3250	0.58	0.57
3750	0.62	0.60
4250	0.65	0.63
4750	0.68	0.66
5250	0.70	0.69
6000	0.74	0.73
7000	0.79	0.77
8000	0.83	0.81
10000	0.90	0.87
12000	0.96	0.93
14000	1.01	0.89
15000	1.03	0.91
19000	1.12	0.95
23000	1.20	1.00
27000	1.28	1.03
31000	1.34	1.07



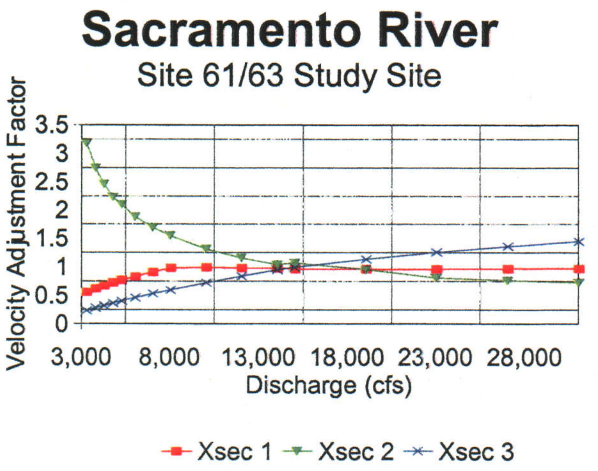
STUDY SITE 80

Discharge	Velocity Adjustment Factors Xsec 1	Xsec 2
3750	0.01	0.002
4250	0.04	0.02
4750	0.09	0.04
5250	0.14	0.06
6000	0.21	0.12
7000	0.28	0.19
8000	0.36	0.28
10000	0.49	0.46
12000	0.67	0.69
14000	0.82	0.92
15000	0.90	1.03
19000	1.10	1.32
23000	1.27	1.55
27000	1.41	1.75
31000	1.53	1.90



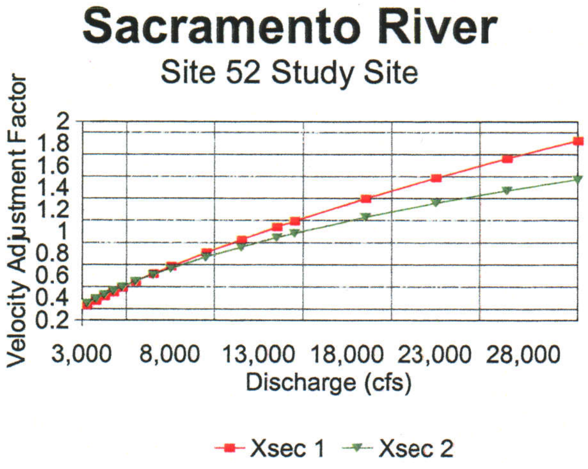
STUDY SITE 61/63

Discharge	Velocity Adjustment Factors Xsec 1	Xsec 2	Xsec 3
3250	0.56	3.18	0.23
3750	0.62	2.74	0.28
4250	0.67	2.46	0.32
4750	0.72	2.23	0.36
5250	0.77	2.09	0.40
6000	0.83	1.88	0.46
7000	0.91	1.69	0.53
8000	0.98	1.54	0.59
10000	0.99	1.31	0.72
12000	0.98	1.15	0.83
14000	0.97	1.04	0.94
15000	0.96	1.06	0.99
19000	0.96	0.95	1.13
23000	0.96	0.80	1.25
27000	0.96	0.76	1.35
31000	0.96	0.72	1.44



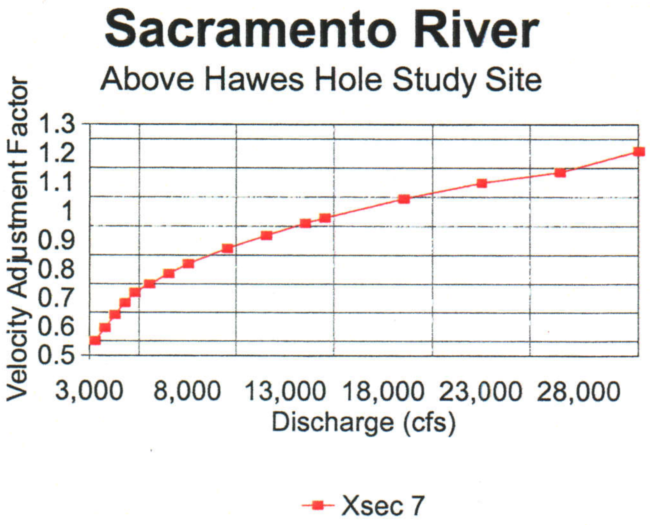
STUDY SITE 52

	Velocity Adjustment Factors	
Discharge	Xsec 1	Xsec 2
3250	0.33	0.35
3750	0.38	0.39
4250	0.42	0.43
4750	0.45	0.46
5250	0.49	0.50
6000	0.55	0.55
7000	0.62	0.61
8000	0.68	0.66
10000	0.81	0.77
12000	0.93	0.86
14000	1.04	0.94
15000	1.10	0.98
19000	1.30	1.13
23000	1.49	1.26
27000	1.66	1.37
31000	1.83	1.47



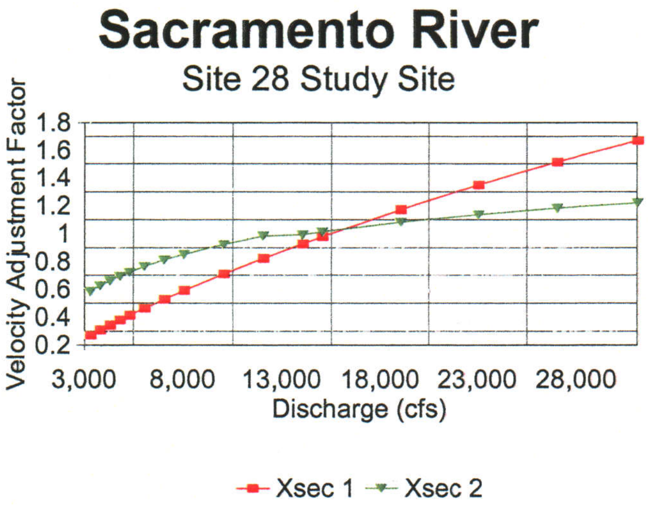
ABOVE HAWES HOLE STUDY SITE

	Velocity Adjustment Factors
Discharge	Xsec7
3,250	0.55
3,750	0.60
4,250	0.64
4,750	0.69
5,250	0.72
6,000	0.75
7,000	0.79
8,000	0.82
10,000	0.87
12,000	0.92
14,000	0.96
15,000	0.98
19,000	1.04
23,000	1.10
27,000	1.13
31,000	1.21



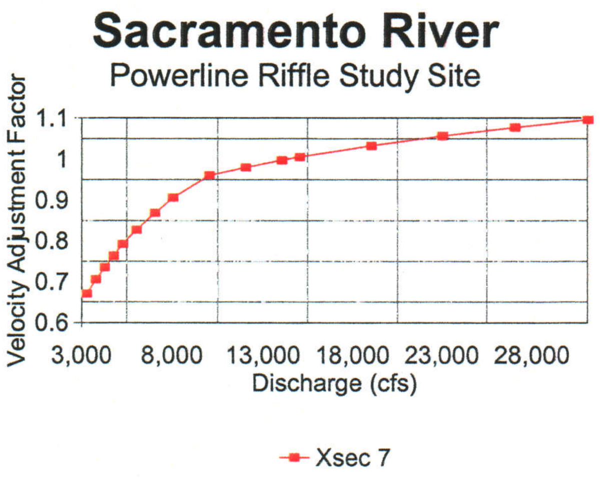
STUDY SITE 28

	Velocity Adjustment Factors	
Flow	XS 1	XS 2
3250	0.27	0.58
3750	0.31	0.62
4250	0.34	0.66
4750	0.38	0.69
5250	0.41	0.72
6000	0.46	0.76
7000	0.53	0.81
8000	0.59	0.85
10000	0.71	0.92
12000	0.82	0.98
14000	0.93	0.99
15000	0.98	1.01
19000	1.17	1.08
23000	1.35	1.13
27000	1.51	1.18
31000	1.67	1.22



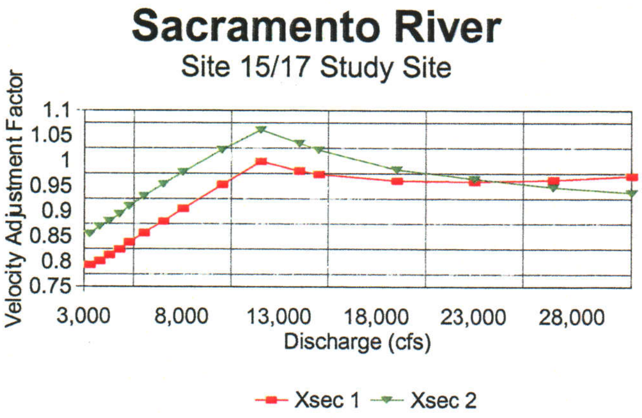
POWERLINE RIFFLE STUDY SITE

	Velocity Adjustment Factors
Discharge	Xsec 7
3,250	0.67
3,750	0.71
4,250	0.73
4,750	0.76
5,250	0.79
6,000	0.83
7,000	0.87
8,000	0.91
10,000	0.96
12,000	0.98
14,000	1.00
15,000	1.00
19,000	1.03
23,000	1.06
27,000	1.08
31,000	1.09



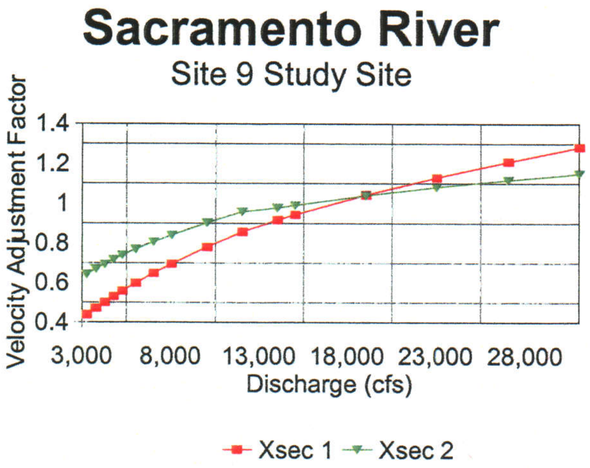
STUDY SITE 15/17

	Velocity Adjustment Factors	
Discharge	XS 1	XS 2
3250	0.79	0.85
3750	0.80	0.87
4250	0.81	0.88
4750	0.82	0.89
5250	0.84	0.91
6000	0.86	0.93
7000	0.88	0.95
8000	0.91	0.98
10000	0.95	1.02
12000	1.00	1.06
14000	0.98	1.03
15000	0.97	1.02
19000	0.96	0.98
23000	0.96	0.96
27000	0.96	0.95
31000	0.97	0.94



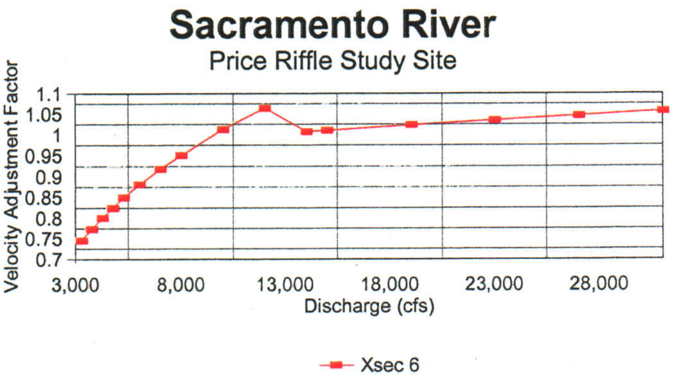
STUDY SITE 9

	Velocity Adjustment Factors	
Discharge	Xsec 1	Xsec 2
3250	0.44	0.64
3750	0.47	0.67
4250	0.50	0.69
4750	0.53	0.72
5250	0.56	0.74
6000	0.60	0.77
7000	0.65	0.81
8000	0.70	0.84
10000	0.78	0.90
12000	0.86	0.96
14000	0.92	0.98
15000	0.95	0.99
19000	1.04	1.04
23000	1.13	1.08
27000	1.21	1.12
31000	1.28	1.15



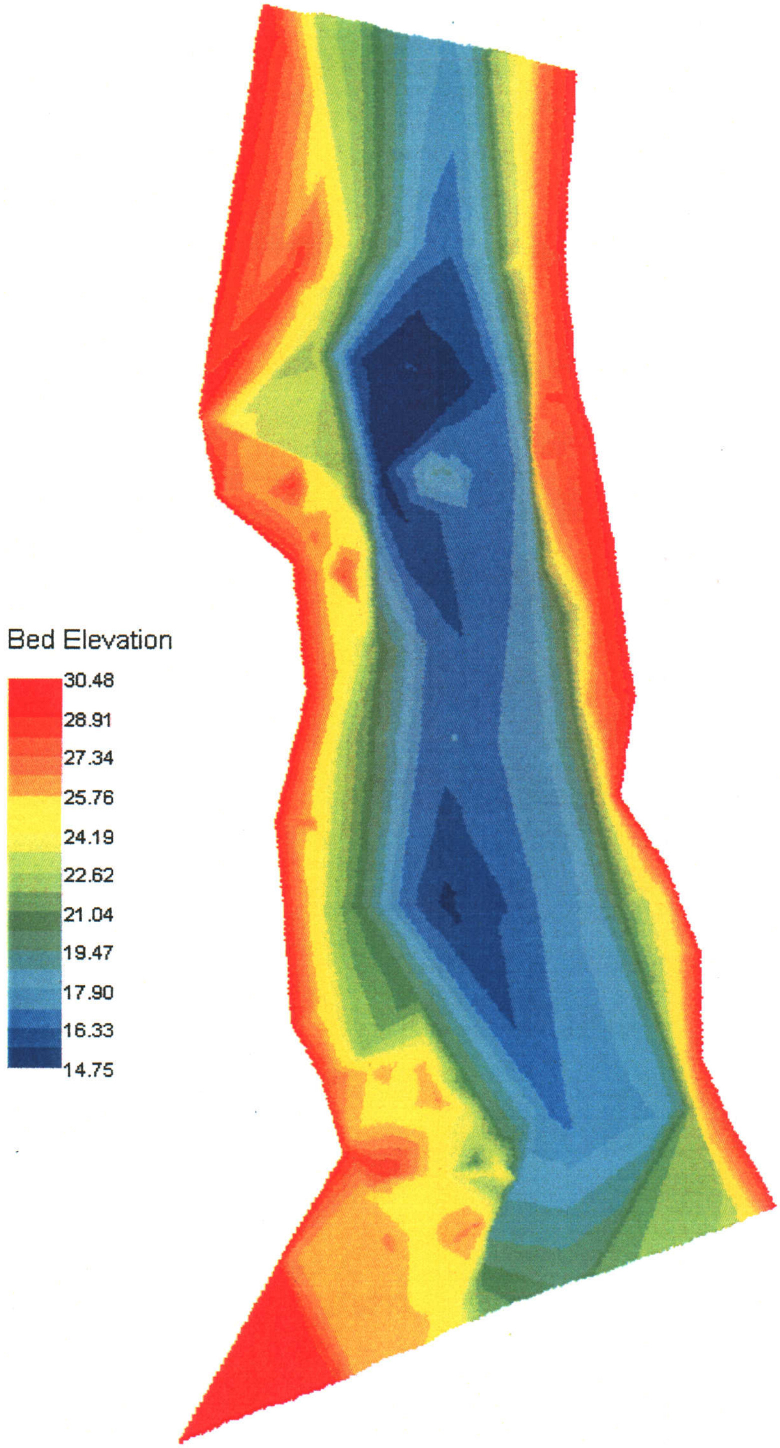
PRICE RIFFLE STUDY SITE

	Velocity Adjustment Factors
Discharge	Xsec 6
3,250	0.75
3,750	0.77
4,250	0.80
4,750	0.83
5,250	0.85
6,000	0.88
7,000	0.92
8,000	0.95
10,000	1.01
12,000	1.07
14,000	1.01
15,000	1.01
19,000	1.02
23,000	1.04
27,000	1.05
31,000	1.06



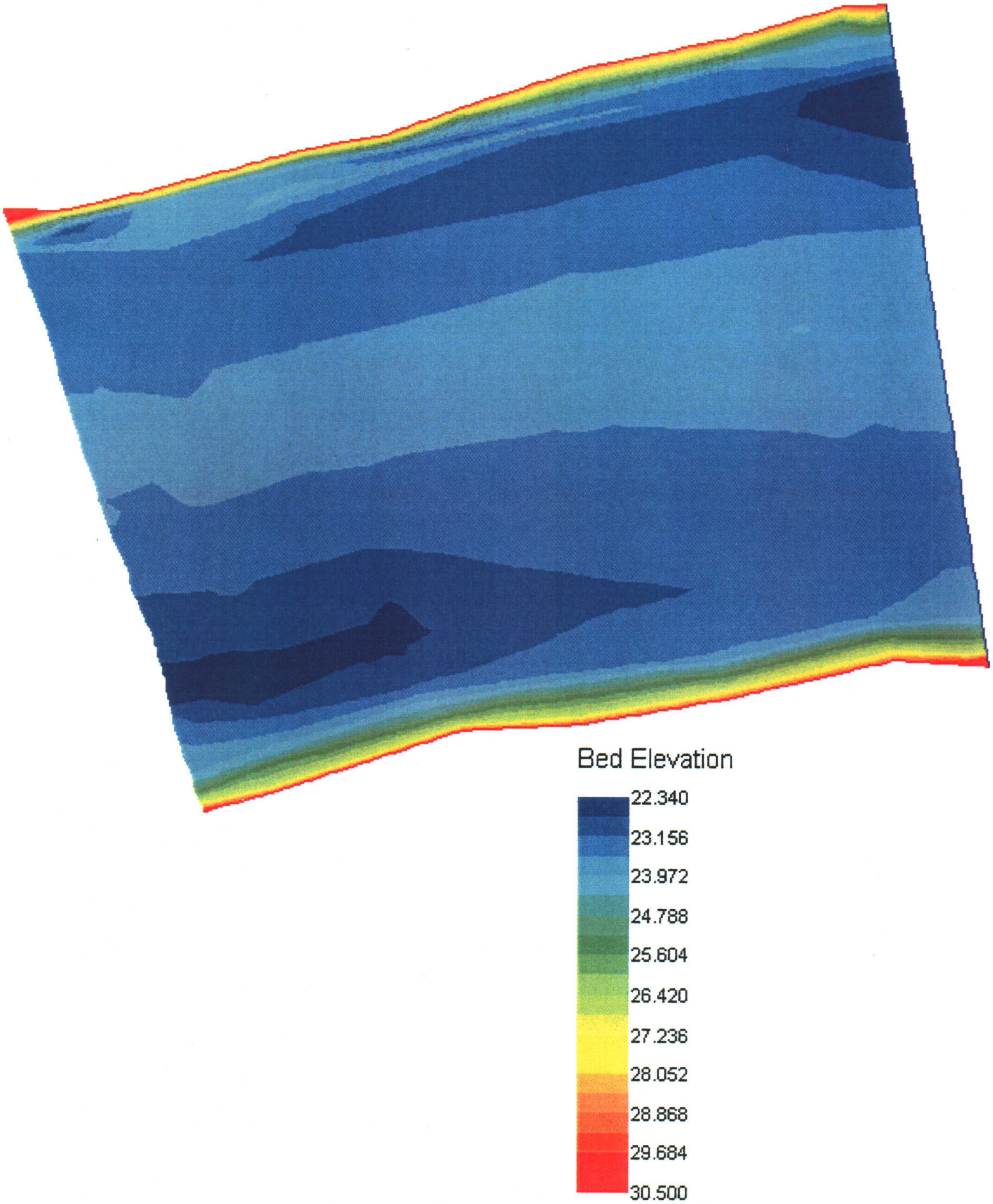
APPENDIX D
BED TOPOGRAPHY OF STUDY SITES

SALT CREEK STUDY SITE



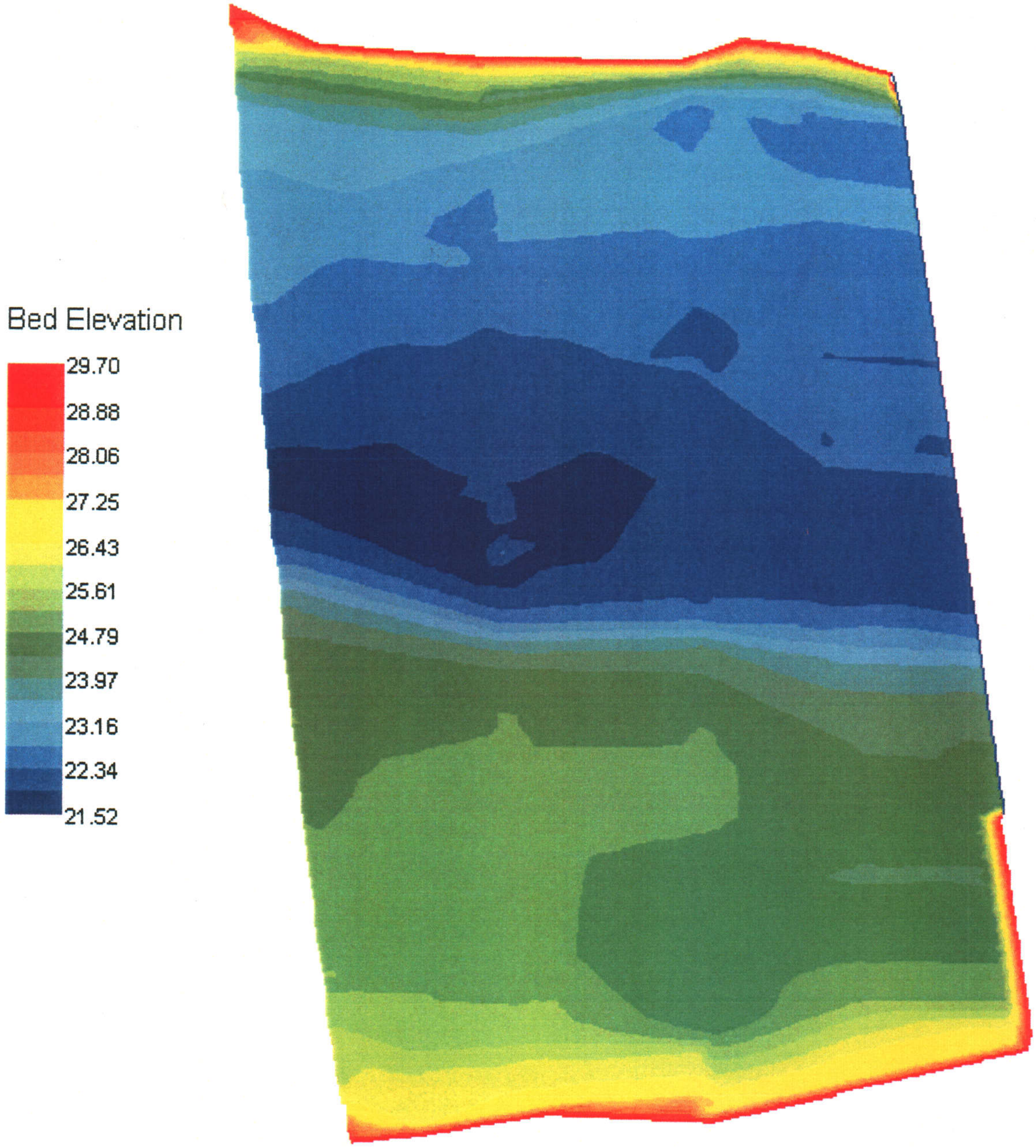
Units of Bed Elevation are meters.

UPPER LAKE REDDING STUDY SITE



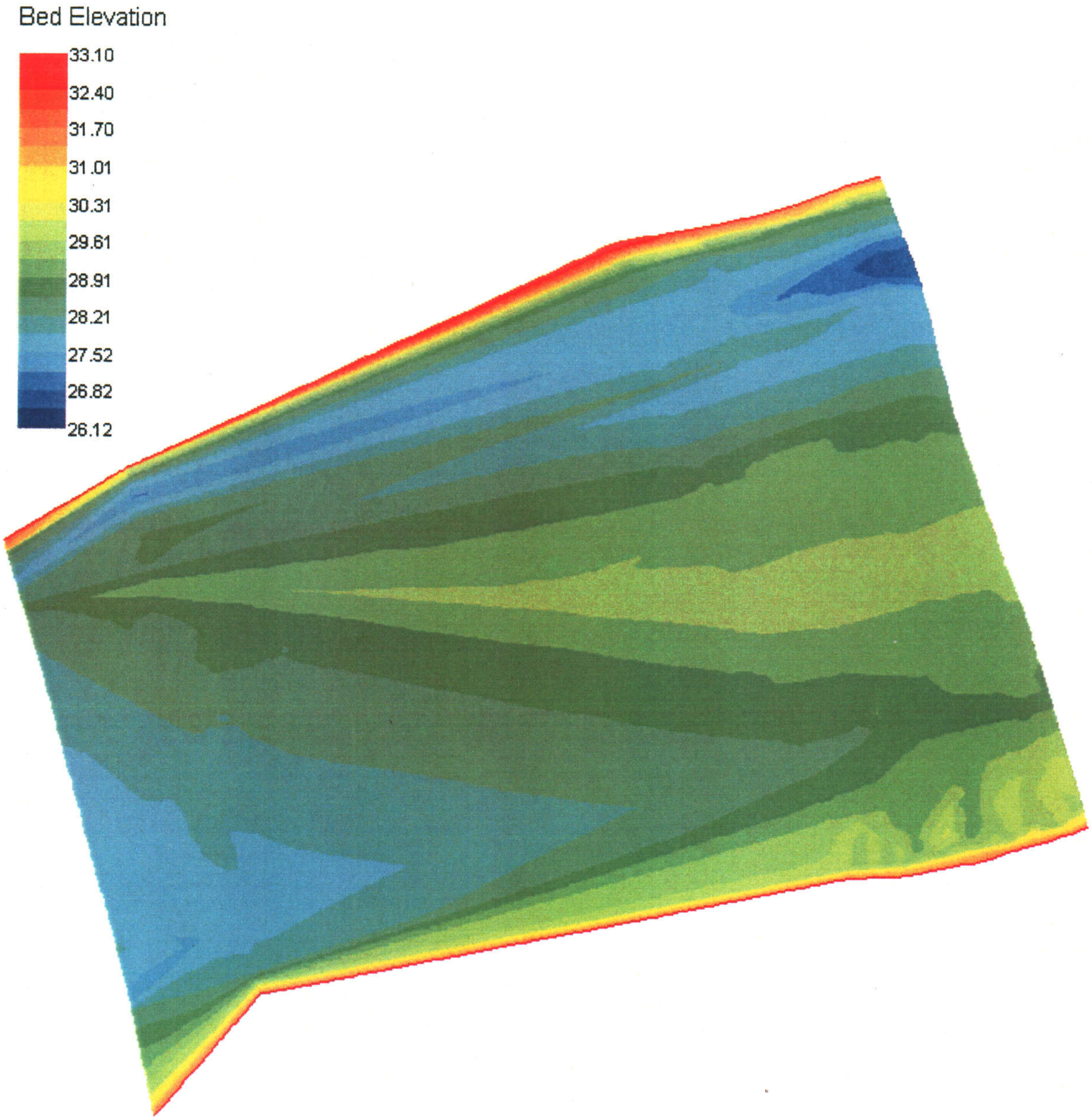
Units of Bed Elevation are meters.

LOWER LAKE REDDING STUDY SITE



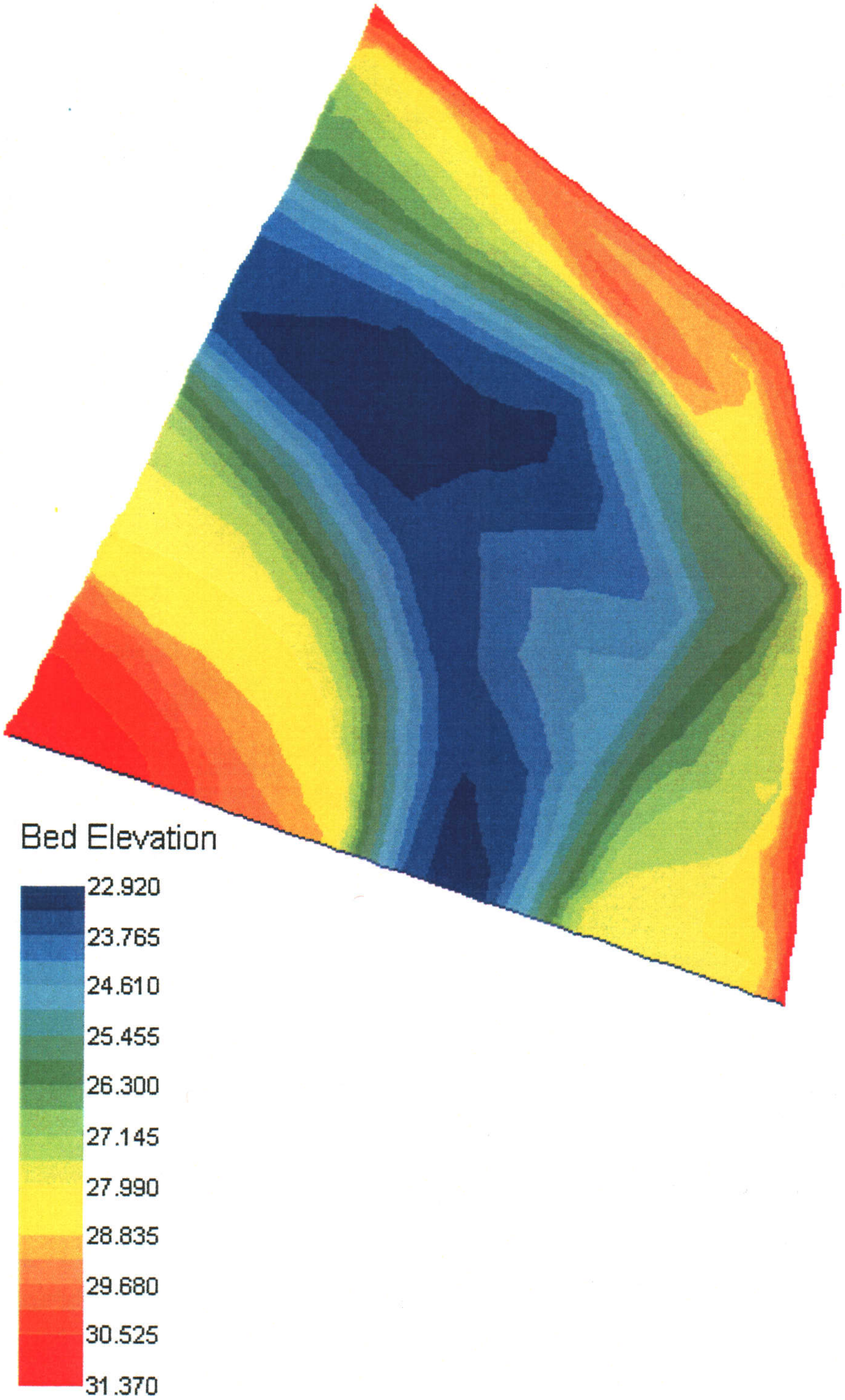
Units of Bed Elevation are meters.

POSSE GROUNDS STUDY SITE



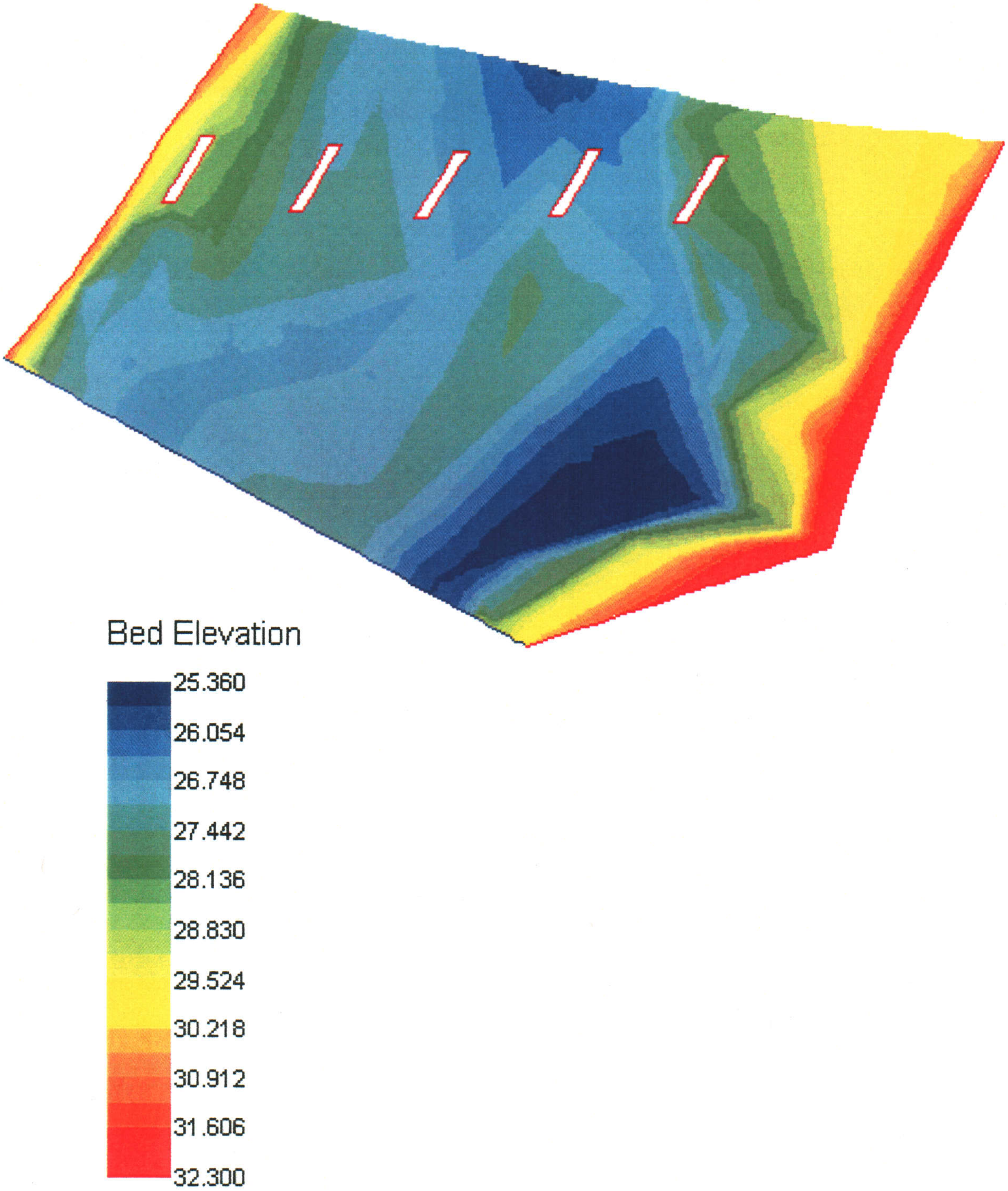
Units of Bed Elevation are meters.

STUDY SITE 130



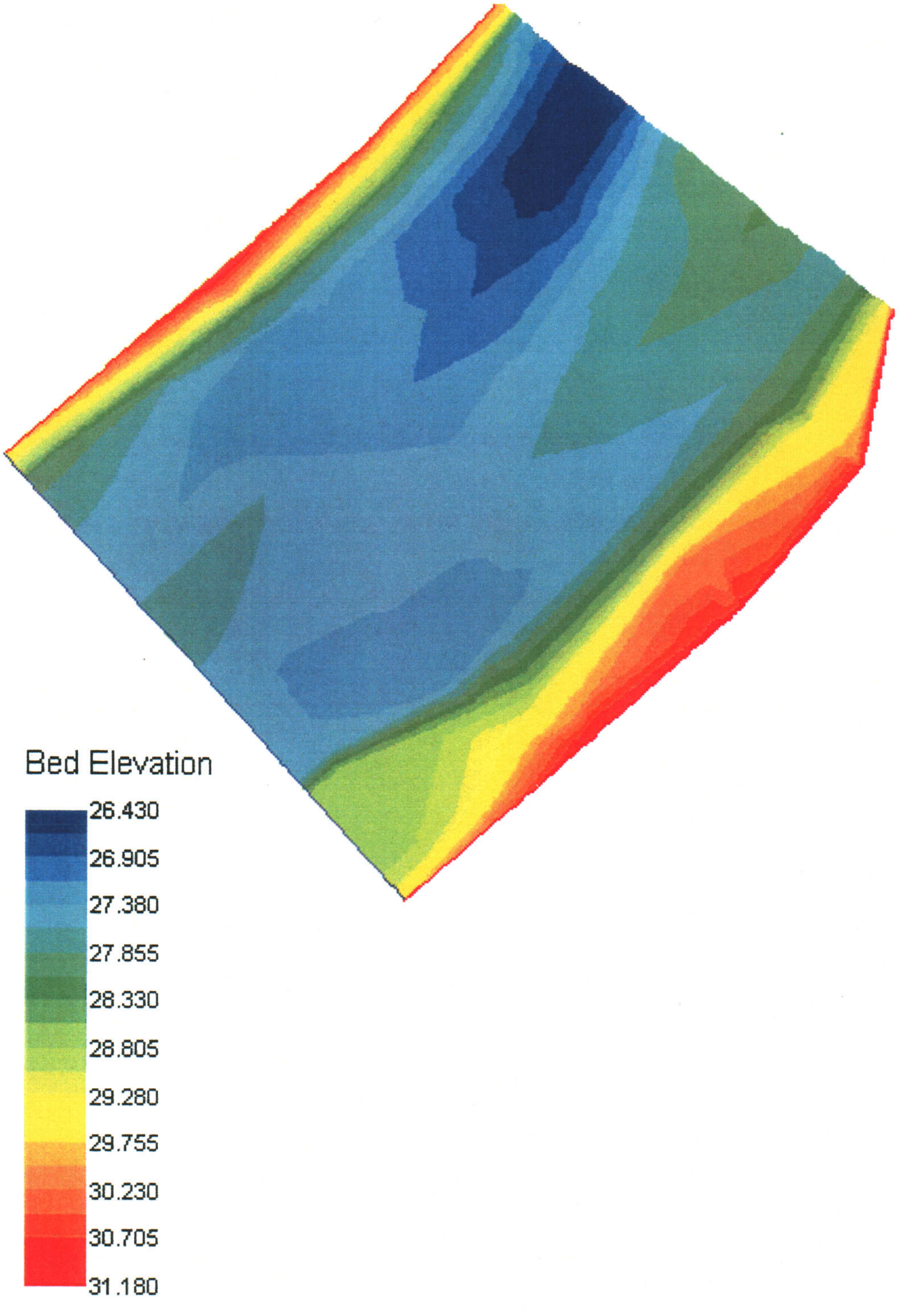
Units of Bed Elevation are meters.

STUDY SITE 112



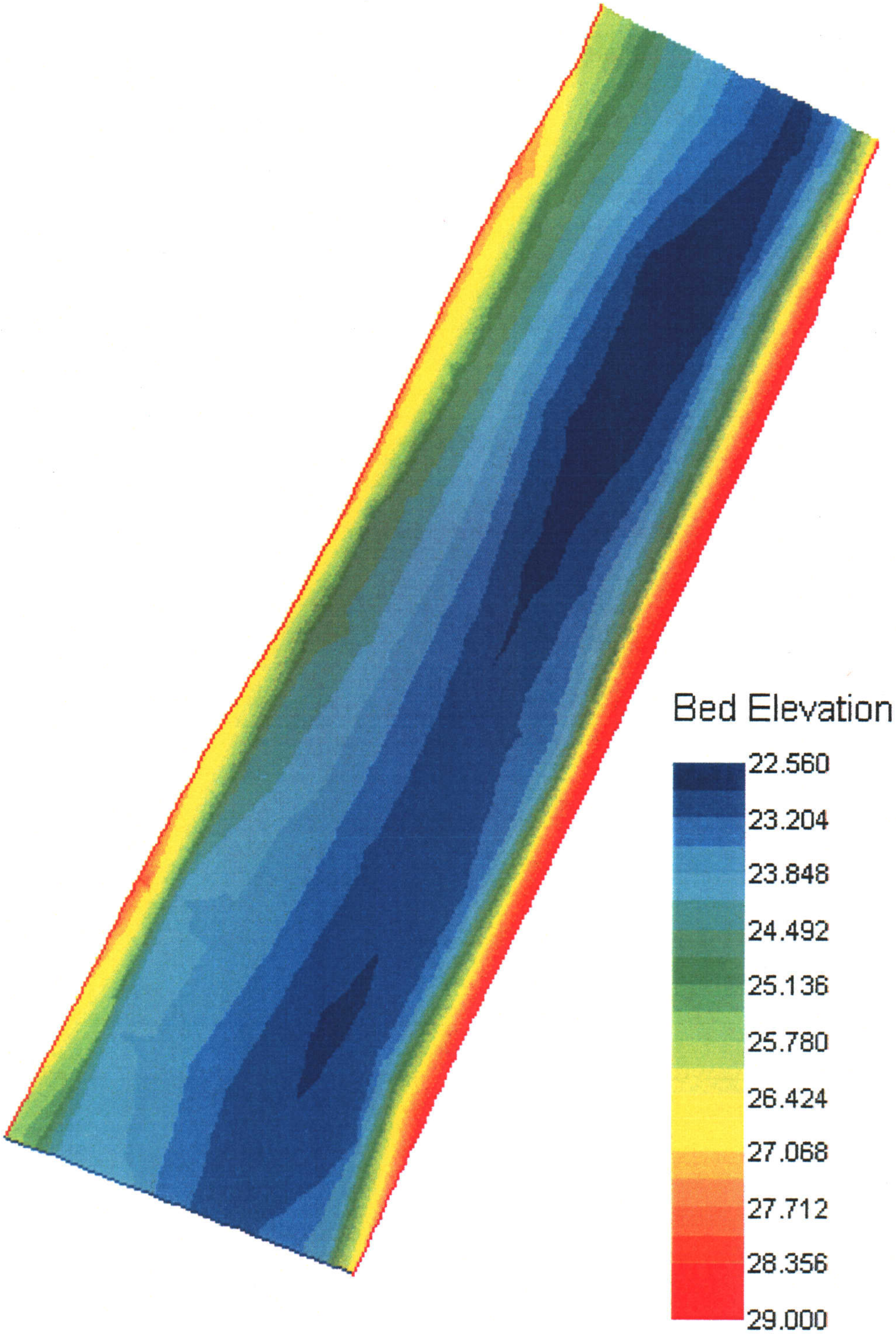
Units of Bed Elevation are meters.

STUDY SITE 96



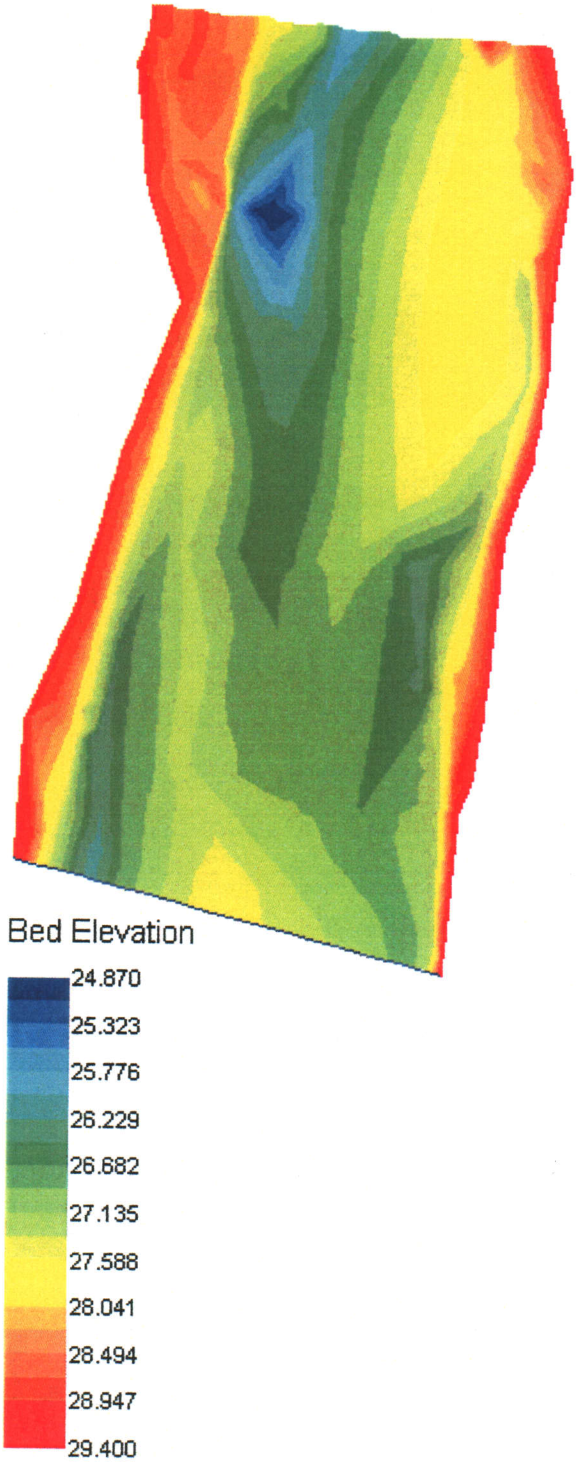
Units of Bed Elevation are meters.

STUDY SITE 81



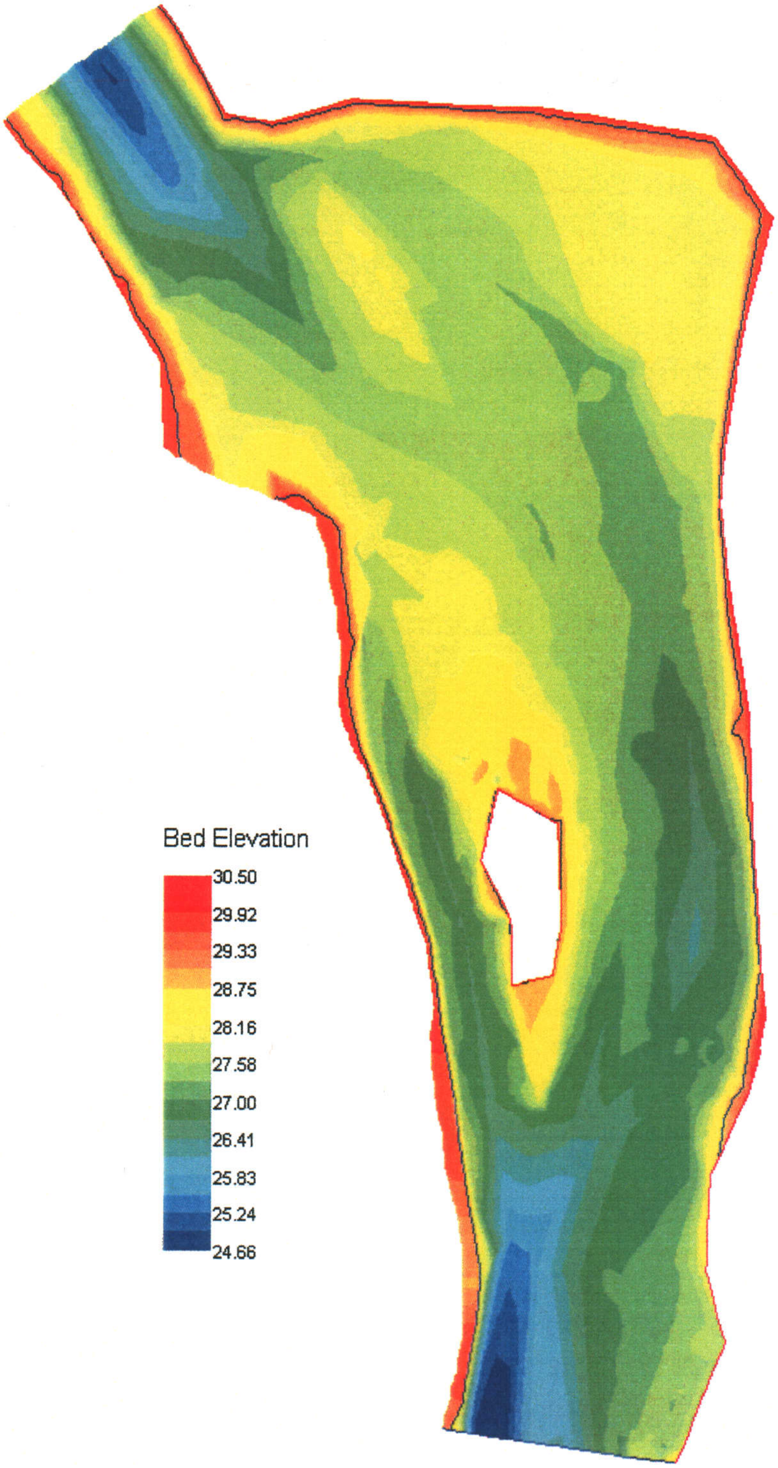
Units of Bed Elevation are meters.

STUDY SITE 80



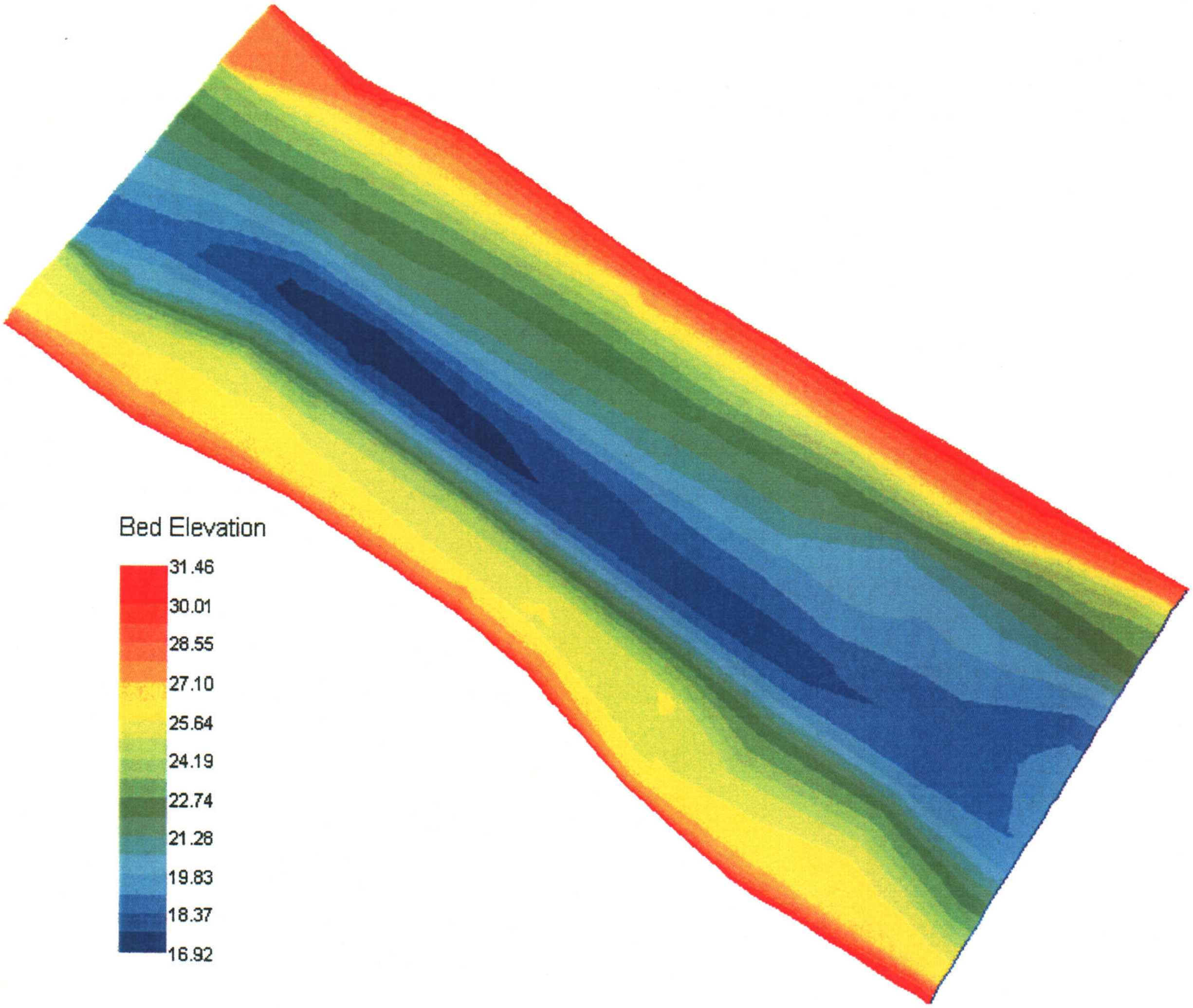
Units of Bed Elevation are meters.

STUDY SITE 61/63



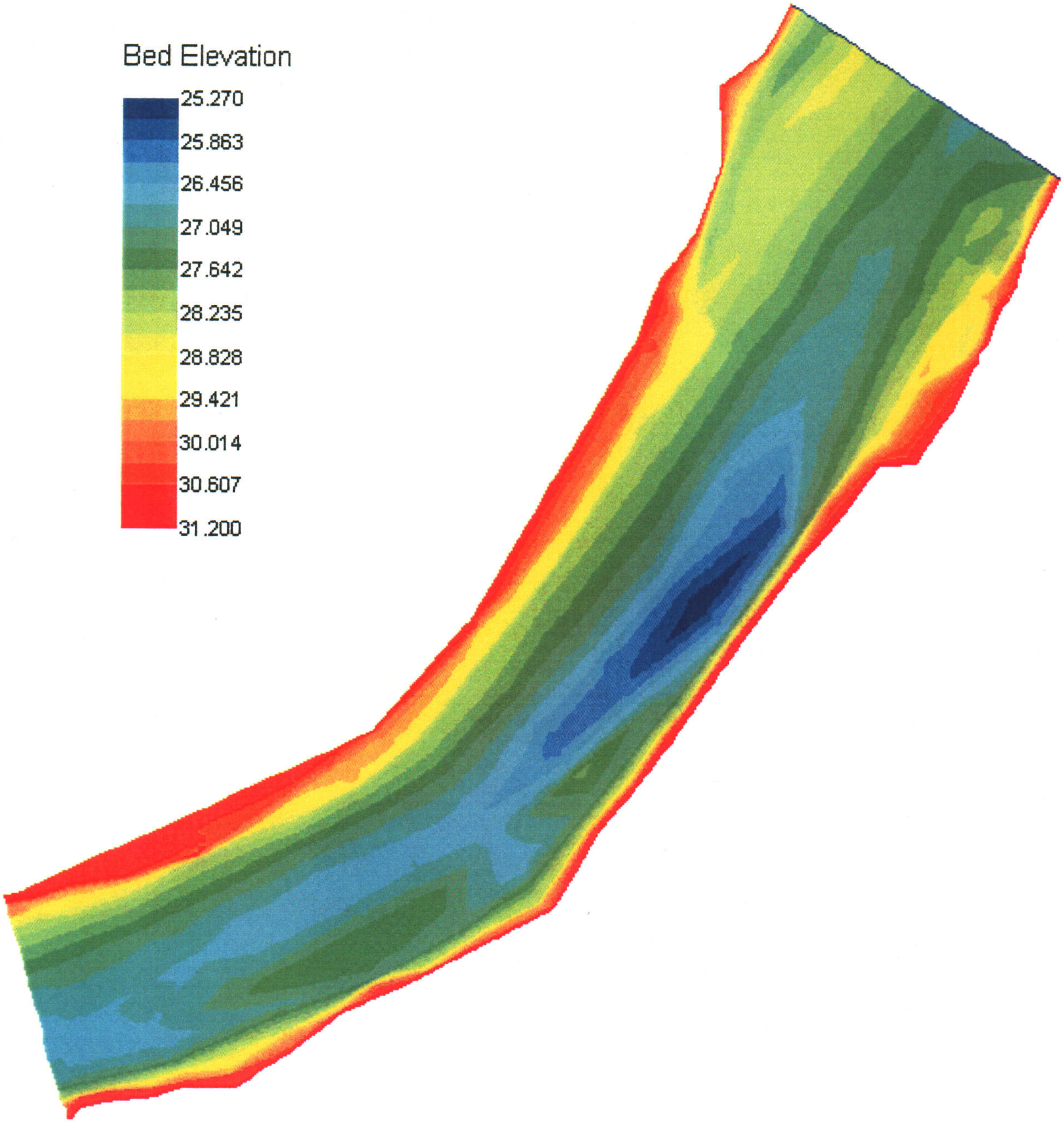
Units of Bed Elevation are meters.

STUDY SITE 52



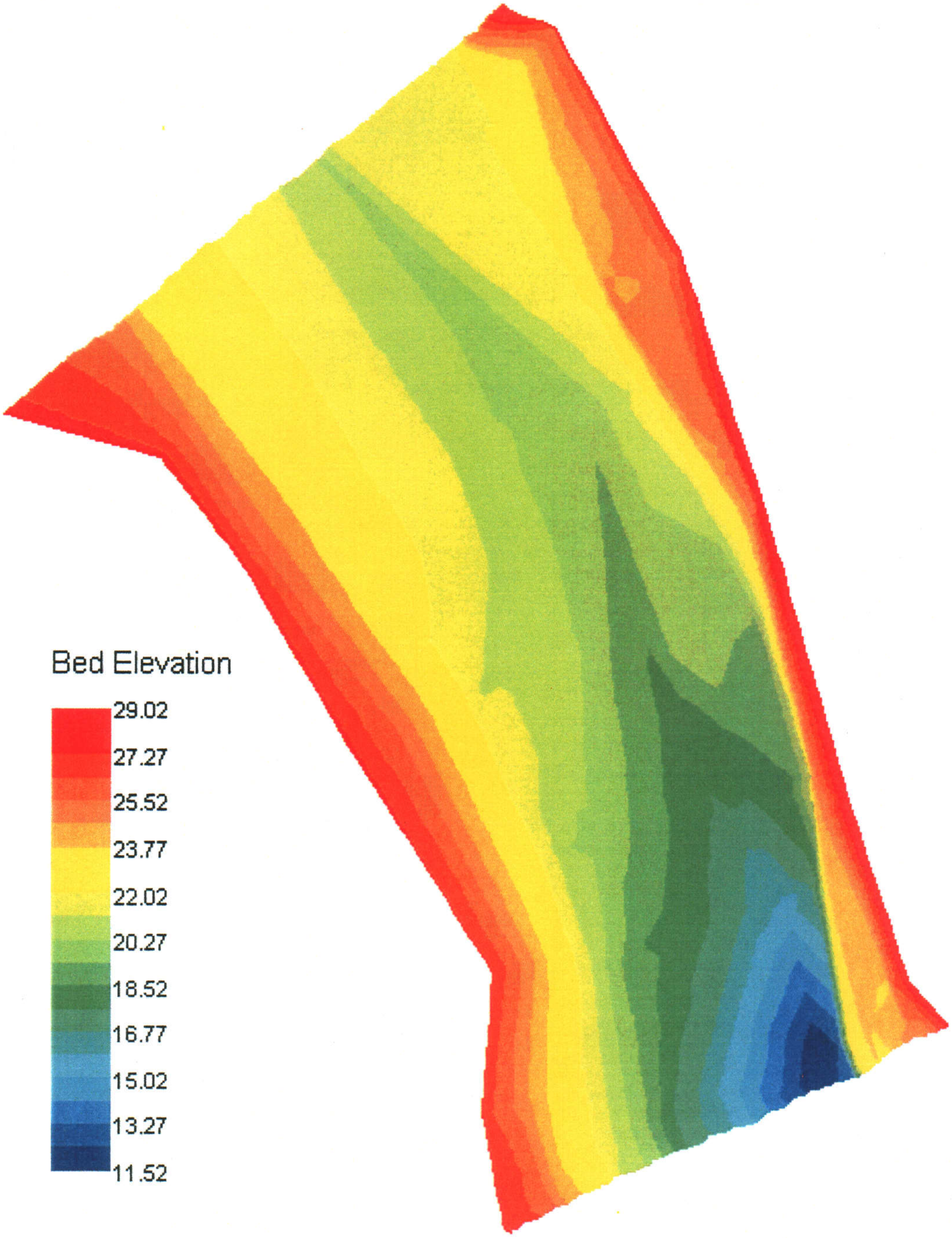
Units of Bed Elevation are meters.

ABOVE HAWES HOLE STUDY SITE



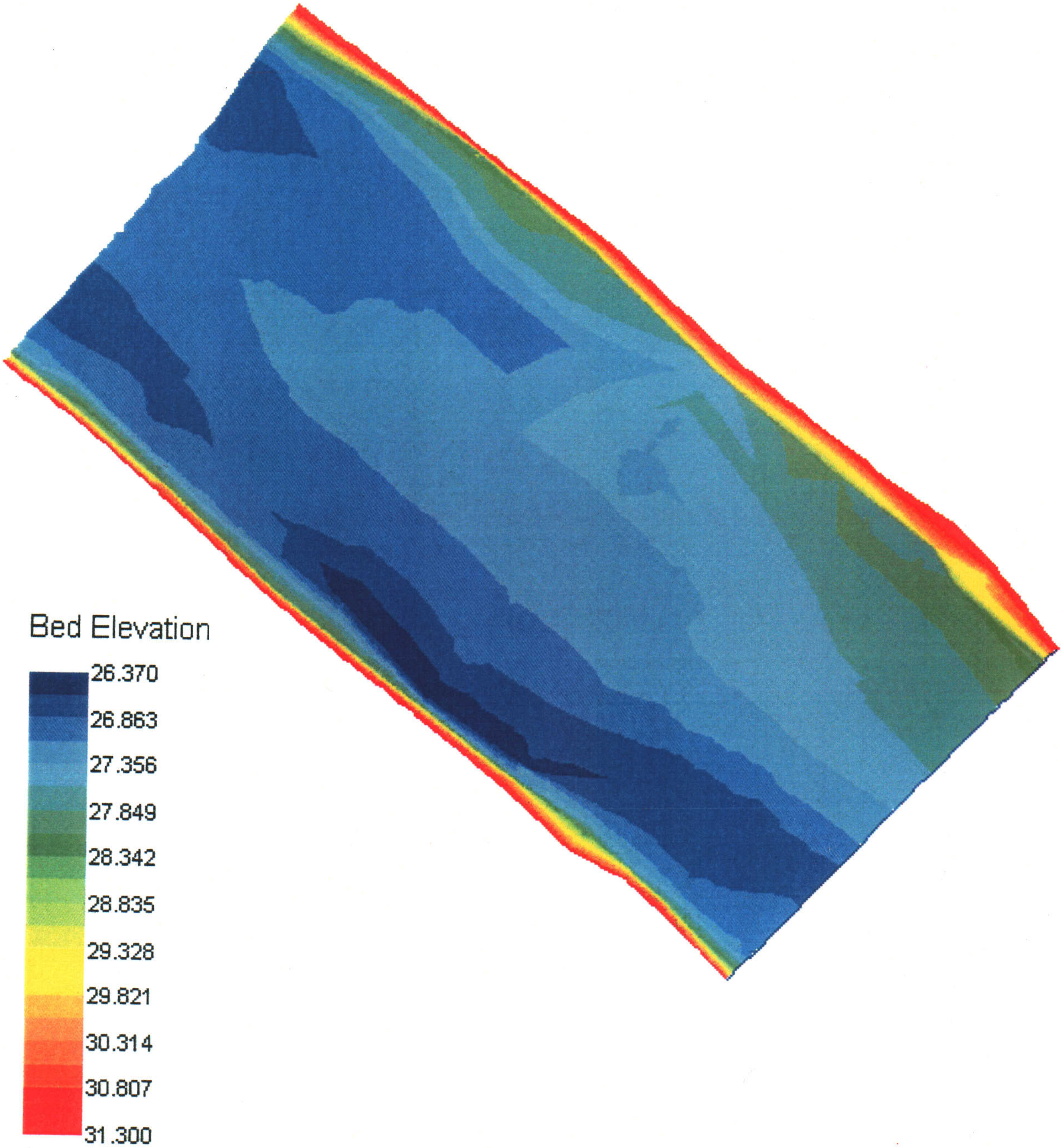
Units of Bed Elevation are meters.

STUDY SITE 28



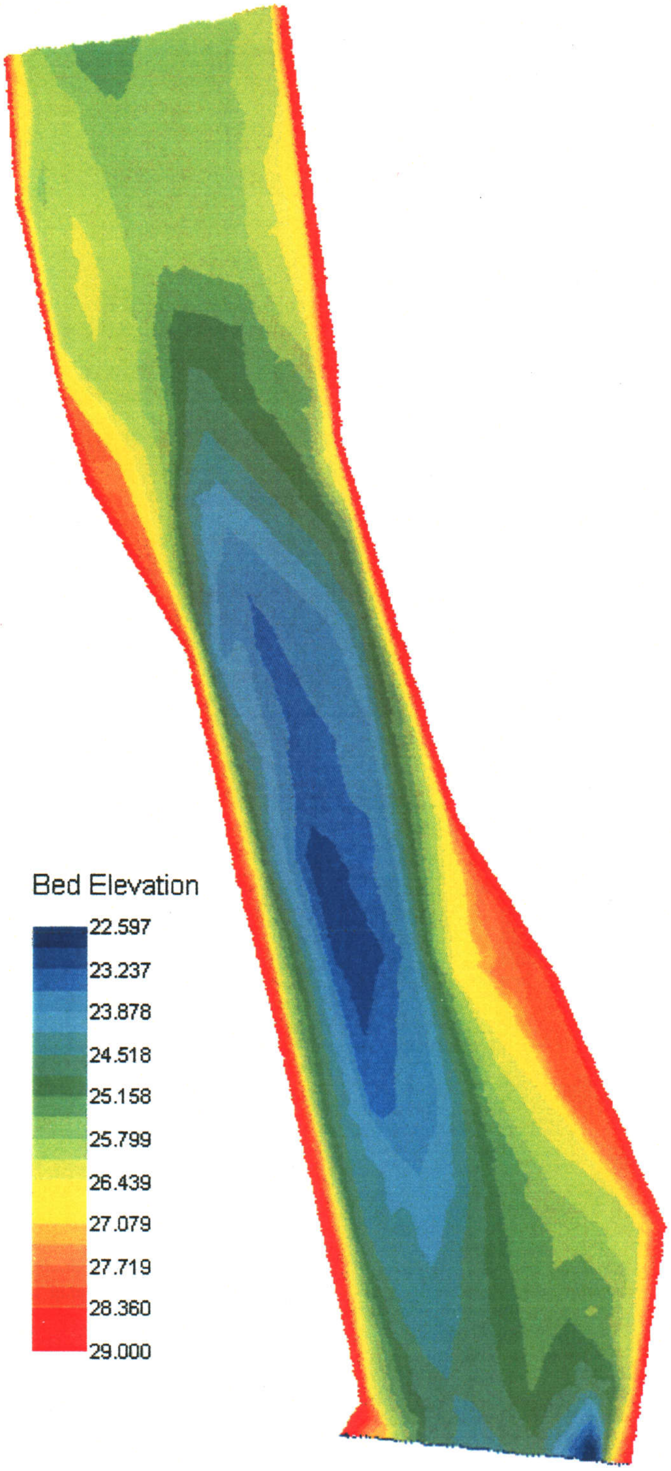
Units of Bed Elevation are meters.

POWERLINE RIFFLE STUDY SITE



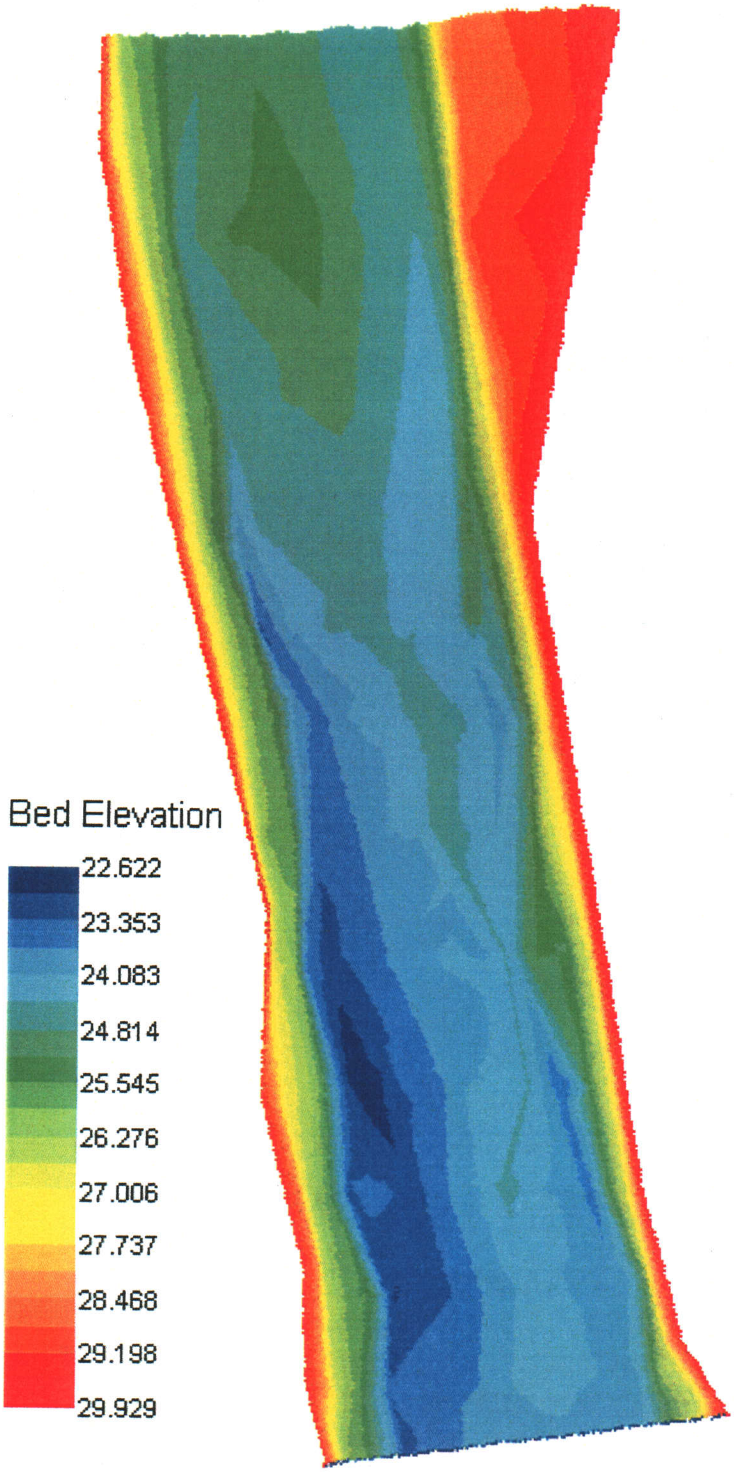
Units of Bed Elevation are meters.

STUDY SITE 15/17



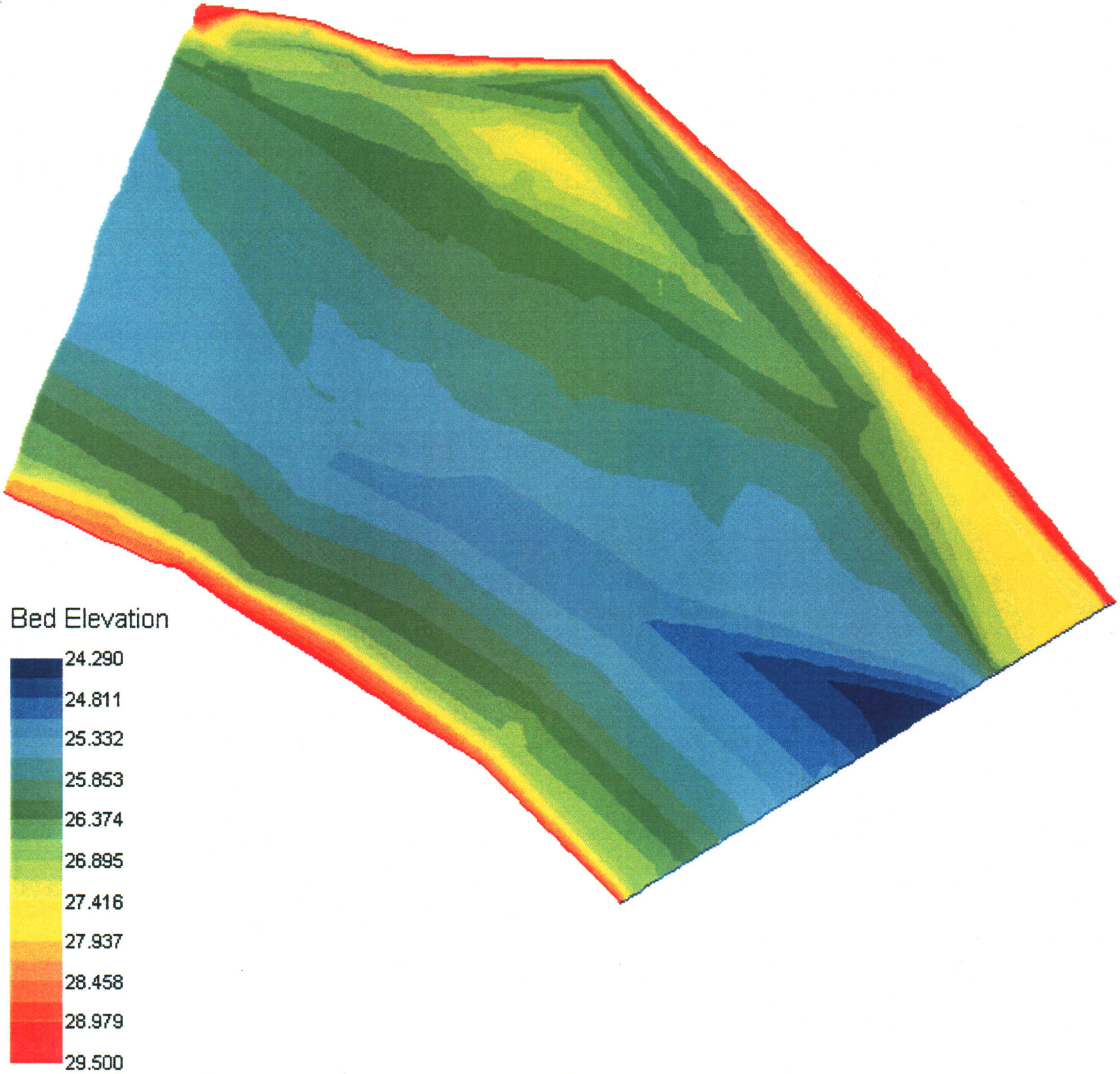
Units of Bed Elevation are meters.

STUDY SITE 9



Units of Bed Elevation are meters.

PRICE RIFFLE STUDY SITE



Units of Bed Elevation are meters.

APPENDIX E
2-D WSEL CALIBRATION

Calibration Statistics

Site Name	% Nodes within 0.1'	Nodes	QI	Net Q	Sol Δ	Max F
Salt Creek	42%	12740	0.30	0.01%	<.000001	0.86
Upper Lake Redding Boards in	84%	8320	0.29	0.1%	<.000001	0.28
Upper Lake Redding Boards out	84%	8320	0.29	0.1%	<.000001	1.54
Lower Lake Redding Boards in	72%	5861	0.30	0.2%	<.000001	1.19
Lower Lake Redding Boards out	66%	6335	0.30	0.003%	<.000001	0.73
Posse Grounds	77%	9768	0.28	0.04%	<.000001	2.03
Site 130	87%	4515	0.31	0.1%	<.000001	0.99
Site 112	78%	5675	0.30	0.1%	.000005	0.94
Site 96	86%	5854	0.29	0.03%	<.000001	0.83
Site 81	85%	9294	0.30	0.02%	<.000001	0.84
Site 80	87%	6373	0.30	0.4%	<.000001	0.79
Site 61/63	67%	10402	0.30	0.02%	<.000001	2.29
Site 52	75%	9309	0.30	0.5%	.000004	0.50
Above Hawes Hole	75%	7739	0.30	0.2%	.000006	0.97
Site 28	61%	6789	0.30	0.07%	.000002	0.86
Powerline Riffle	88%	7956	0.30	0.1%	.000001	1.00
Site 15/17	74%	10083	0.30	0.3%	.000003	0.82
Site 9	70%	7838	0.30	0.1%	<.000001	0.63
Price Riffle	80%	5438	0.30	0.1%	<.000001	1.40

Salt Creek Site

XSEC	BR Mult	Difference (measured vs. pred. WSELs) Average	Standard Deviation	Maximum
US	3	0.15	0.06	0.26
US LB	3	0.09	0.01	0.10

Upper Lake Redding Site Boards In

XSEC	BR Mult	Difference (measured vs. pred. WSELs) Average	Standard Deviation	Maximum
2	1	0.01	0.01	0.02

Upper Lake Redding Site Boards Out

XSEC	BR Mult	Difference (measured vs. pred. WSELs) Average	Standard Deviation	Maximum
2	0.8	0.03	0.03	0.10

Lower Lake Redding Site Boards Out

XSEC	BR Mult	Difference (measured vs. pred. WSELs) Average	Standard Deviation	Maximum
1	0.7	0.34	0.23	0.72
1 RB	0.7	0.08	0	0.08

Lower Lake Redding Site Boards In

XSEC	BR Mult	Difference (measured vs. pred. WSELs) Average	Standard Deviation	Maximum
1	1	0.03	0.02	0.07

Posse Grounds Site

XSEC	BR Mult	Difference (measured vs. pred. WSELs) Average	Standard Deviation	Maximum
1 LC	0.3	0.07	0.08	0.22
1 LB	0.3	0.04	0.004	0.04
1 RC	0.3	0.39	0.06	0.45
1 RB	0.3	0.15	0	0.15
2 LC	0.3	0.06	0.10	0.37
2 LB	0.3	0.02	0.03	0.08
2 RC	0.3	0.44	0.12	0.68
2 RB	0.3	0.67	0	0.67
3 LC	0.3	0.07	0.09	0.32
3 LB	0.3	0.02	0.04	0.10
3 RC	0.3	0.39	0.06	0.50
3 RB	0.3	0.47	0.002	0.47
4 LC	0.3	0.07	0.08	0.32
4 LB	0.3	0.04	0.04	0.09
4 RC	0.3	0.22	0.07	0.32
4 RB	0.3	0.32	0	0.32
5 LC	3.0	0.24	0.12	0.54
5 LB	3.0	0.05	0.01	0.07
5 RC	3.0	0.05	0.03	0.13
5 RB	3.0	0.13	0	0.13
6 LC	3.0	0.22	0.11	0.51
6 LB	3.0	0.08	0.01	0.10
6 RC	3.0	0.18	0.03	0.22
6 RB	3.0	0.19	0	0.19
7 LC	3.0	0.10	0.08	0.37
7 LB	3.0	0.06	0.02	0.10
7 RC	3.0	0.21	0.04	0.26
7 RB	3.0	0.14	0	0.14

Site 130

		Difference (measured vs. pred. WSELs)		
XSEC	BR Mult	Average	Standard Deviation	Maximum
2	1.15	0.65	0.44	1.17
2 LB	1.15	0.02	0.06	0.08

Site 112

		Difference (measured vs. pred. WSELs)		
XSEC	BR Mult	Average	Standard Deviation	Maximum
2	0.5	0.24	0.17	0.50
2 LB	0.5	0.03	0.04	0.09

Site 96

		Difference (measured vs. pred. WSELs)		
XSEC	BR Mult	Average	Standard Deviation	Maximum
2	0.6	0.03	0.04	0.09

Site 81

		Difference (measured vs. pred. WSELs)		
XSEC	BR Mult	Average	Standard Deviation	Maximum
2	0.5	0.15	0.12	0.27
2 RB	0.5	0.01	0.04	0.09

Site 80

		Difference (measured vs. pred. WSELs)		
XSEC	BR Mult	Average	Standard Deviation	Maximum
2	0.7	0.01	0.10	0.18
2 RB	0.7	0.04	0.02	0.08

Site 61/63

XSEC	BR Mult	Difference (measured vs. pred. WSELs) Average	Standard Deviation	Maximum
2	Bed roughness = 0.1	0.003	0.08	0.17
2 RB	Bed roughness = 0.1	0.06	0	0.06
3	0.5	0.04	0.05	0.09

Site 52

XSEC	BR Mult	Difference (measured vs. pred. WSELs) Average	Standard Deviation	Maximum
2	0.5	0.14	0.09	0.35
2 LB	0.5	0.05	0.02	0.07
2 RB	0.5	0.15	0	0.15

Above Hawes Hole Site

XSEC	BR Mult	Difference (measured vs. pred. WSELs) Average	Standard Deviation	Maximum
2	0.15	0.04	0.08	0.21
2 LB	0.15	0.01	0.06	0.10
3	0.6	0.08	0.06	0.28
3 LB	0.6	0.05	0.03	0.10
4	0.01	0.07	0.03	0.14
4 LB	0.01	0.14	0	0.14
5	1.3	0.0008	0.05	0.11
5 LB	1.3	0.10	0	0.10
6	1.5	0.09	0.10	0.37
6 LB	1.5	0.04	0.04	0.10
7	0.05	0.09	0.08	0.22
7 LB	0.05	0.07	0	0.07

Site 28

		Difference (measured vs. pred. WSELs)		
XSEC	BR Mult	Average	Standard Deviation	Maximum
1	1.25	0.01	0.26	0.47
1 RB	1.25	0.09	0.01	0.09
2	1.25	0.03	0.05	0.10

Powerline Riffle Site

		Difference (measured vs. pred. WSELs)		
XSEC	BR Mult	Average	Standard Deviation	Maximum
2	0.6	0.12	0.10	0.60
2 RB	0.6	0.04	0.05	0.10
3	0.2	0.08	0.11	0.47
3 RB	0.2	0.05	0.002	0.05
4	0.6	0.07	0.05	0.13
4 RB	0.6	0.05	0.03	0.10
5	0.5	0.002	0.02	0.07
6	0.5	0.02	0.04	0.09
7	0.01	0.06	0.01	0.08

Site 15/17

		Difference (measured vs. pred. WSELs)		
XSEC	BR Mult	Average	Standard Deviation	Maximum
2	0.3	0.04	0.03	0.08

Site 9

		Difference (measured vs. pred. WSELs)		
XSEC	BR Mult	Average	Standard Deviation	Maximum
2	1.05	0.01	0.07	0.10

Price Riffle Site

		Difference (measured vs. pred. WSELs)		
XSEC	BR Mult	Average	Standard Deviation	Maximum
2	0.05	0.03	0.17	0.39
2 RB	0.05	0.29	0	0.29
3 MC	0.2	0.01	0.05	0.12
3 MC RB	0.2	0.01	0.03	0.06
3 SC	0.15	0.02	0.01	0.03
4 MC	0.8	0.01	0.02	0.05
4 SC	2	0.11	0.05	0.19
4 SC RB	2	0.05	0.03	0.10
5 MC	0.1	0.15	0.07	0.27
5 MC RB	0.1	0.06	0.06	0.11
5 SC	5	0.17	0.06	0.28
5 SC RB	5	0.10	0.01	0.11
6	0.25	0.09	0.03	0.13
6 RB	0.25	0.09	0	0.09

APPENDIX F
VELOCITY VALIDATION STATISTICS

Measured Velocities less than 3 ft/s

Difference (measured vs. pred. velocities, ft/s)

Site Name	Number of Observations	Average	Standard Deviation	Maximum
Salt Creek	281	1.03	1.16	5.24
Upper Lake Redding	259	0.56	0.54	2.43
Lower Lake Redding	370	0.46	0.36	1.65
Posse Grounds	277	0.96	0.77	5.11
Site 130	107	0.74	0.70	3.11
Site 112	100	1.22	1.02	5.92
Site 96	85	1.06	1.01	3.87
Site 81	106	0.86	0.62	2.46
Site 80	318	0.51	0.34	1.46
Site 61/63	158	1.71	1.58	8.55
Site 52	177	1.06	0.91	3.48
Above Hawes Hole	389	0.73	0.67	3.26
Site 28	132	0.81	0.64	2.79
Powerline Riffle	210	1.56	0.83	4.05
Site 15/17	346	1.24	1.07	5.53
Site 9	311	0.92	0.61	2.52
Price Riffle	95	1.13	1.21	5.04

All differences were calculated as the absolute value of the difference between the measured and simulated velocity.

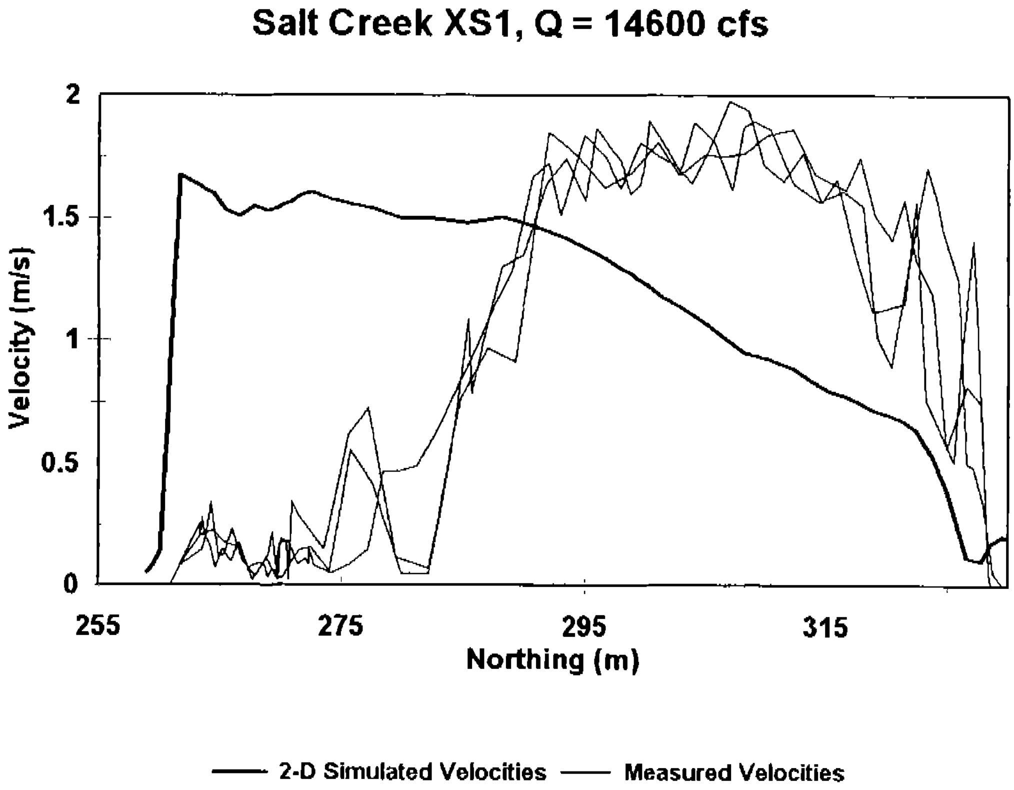
Measured Velocities greater than 3 ft/s

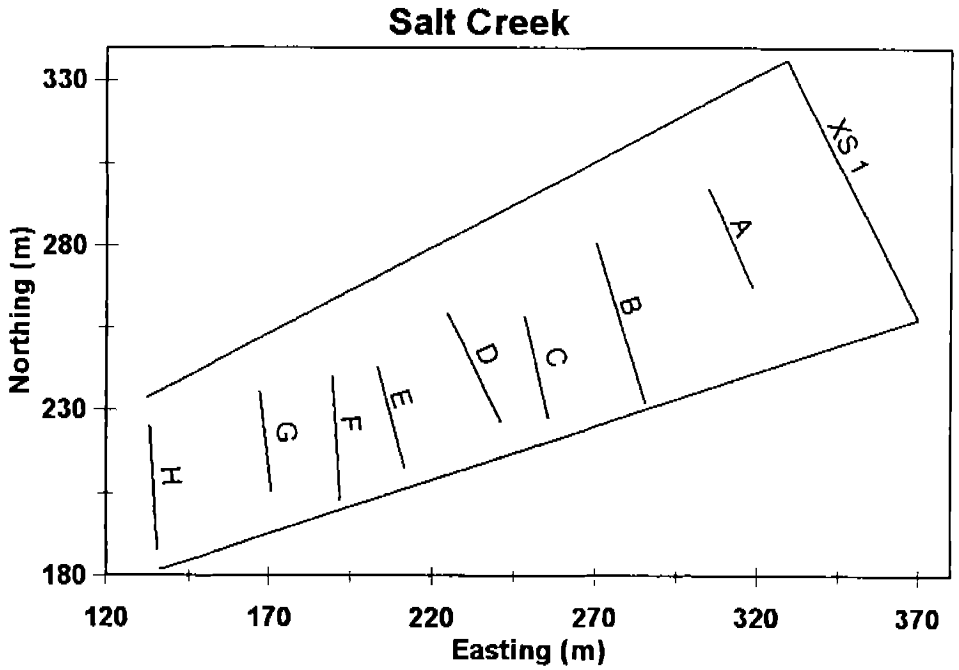
Percent Difference (measured vs. pred. velocities)

Site Name	Number of Observations	Average	Standard Deviation	Maximum
Salt Creek	133	24%	14%	57%
Upper Lake Redding	256	17%	8%	36%
Lower Lake Redding	71	16%	16%	72%
Posse Grounds	333	15%	14%	104%
Site 130	169	19%	17%	95%
Site 112	168	21%	21%	95%
Site 96	62	22%	15%	59%
Site 81	226	13%	12%	62%
Site 80	17	21%	13%	40%
Site 61/63	541	20%	20%	182%
Site 52	108	35%	23%	98%
Above Hawes Hole	537	13%	12%	76%
Site 28	131	15%	13%	62%
Powerline Riffle	885	13%	9%	63%
Site 15/17	870	19%	19%	157%
Site 9	400	10%	7%	33%
Price Riffle	388	20%	19%	121%

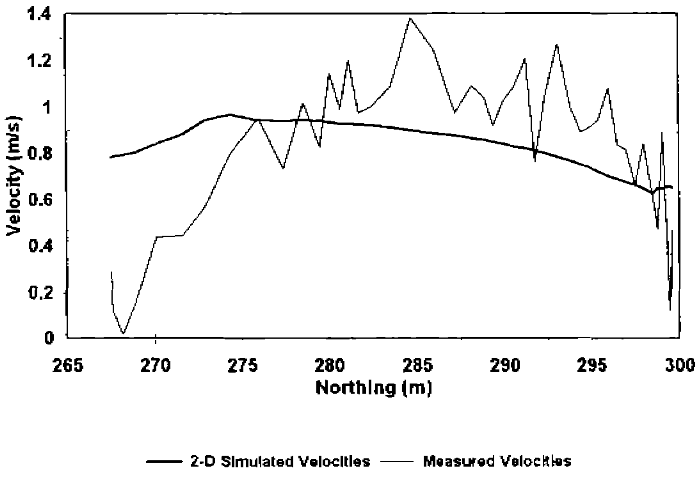
All differences were calculated as the absolute value of the difference between the measured and simulated velocity.

Salt Creek Study Site

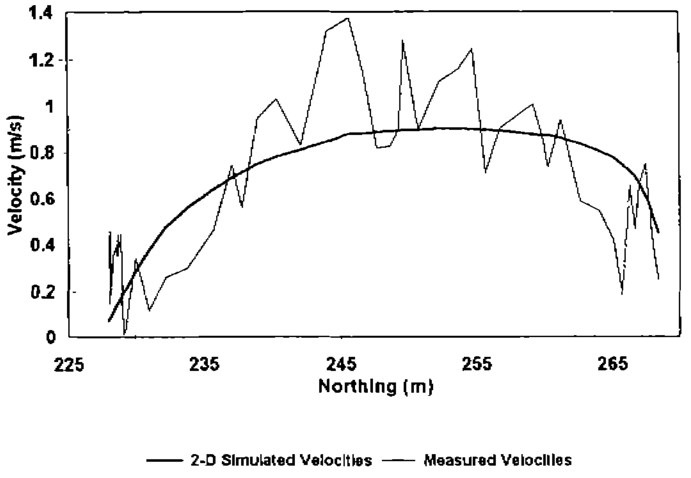




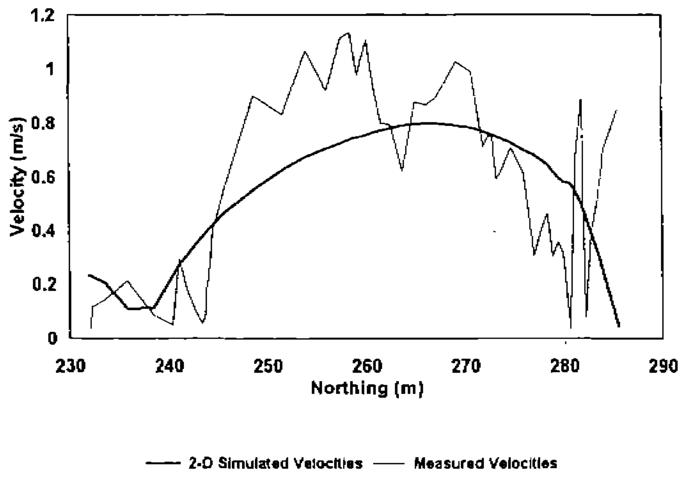
Salt Creek Deep Beds A, Q = 9506 cfs



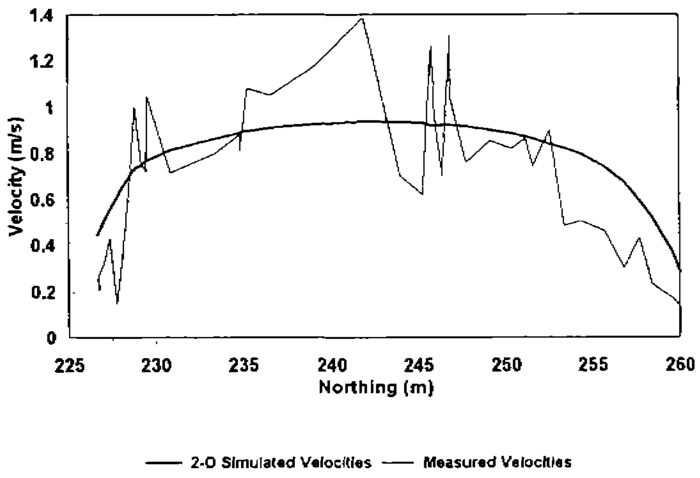
Salt Creek Deep Beds C, Q = 9506 cfs

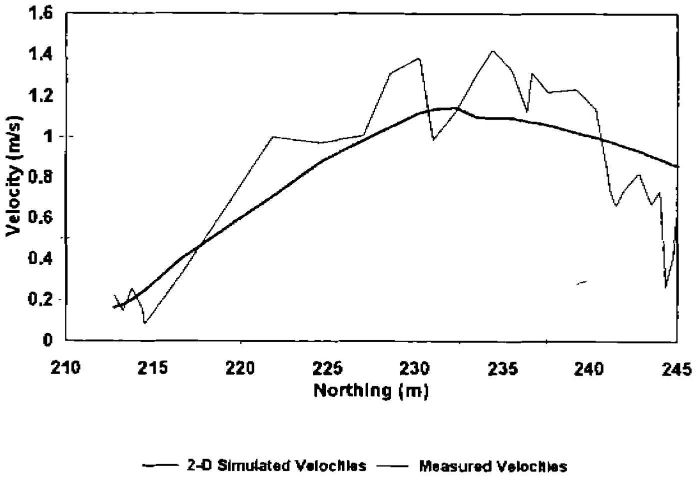


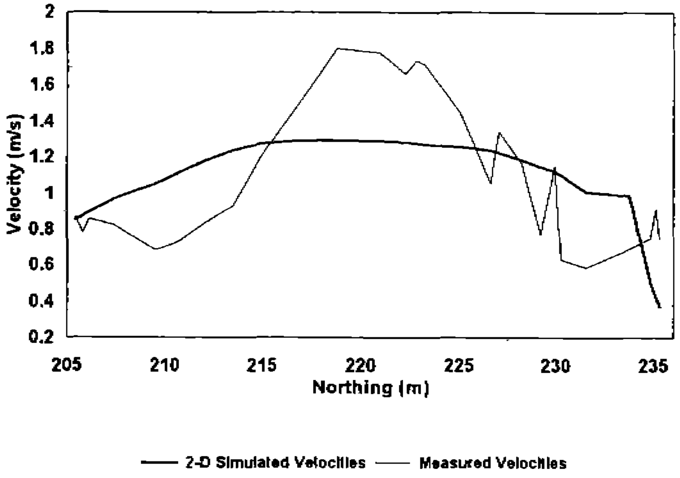
Salt Creek Deep Beds B, Q = 9506 cfs

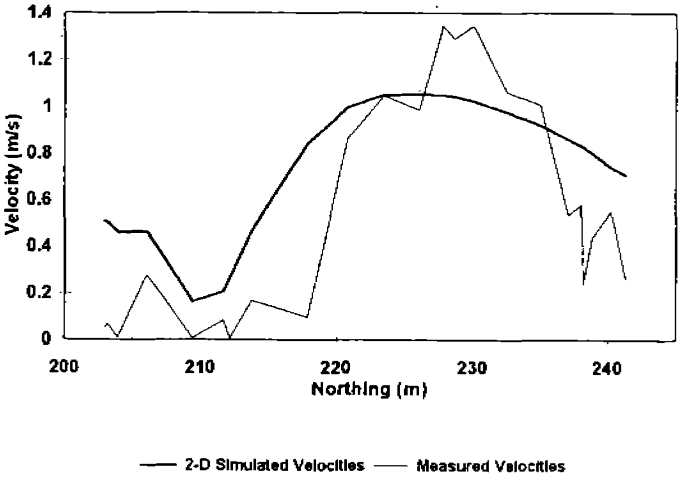


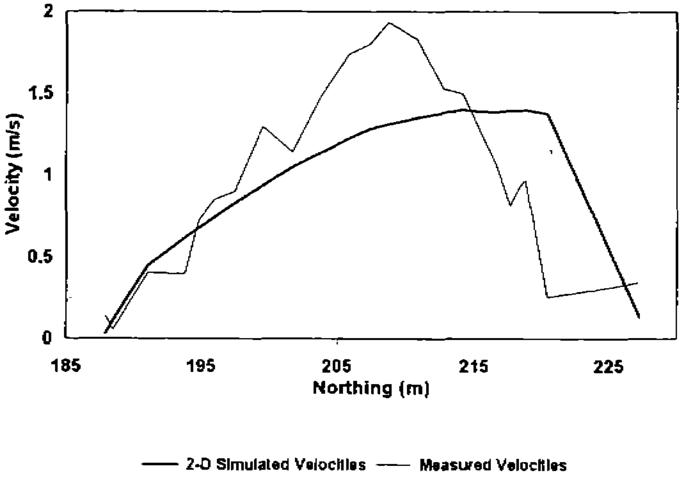
Salt Creek Deep Beds D, Q = 9506 cfs



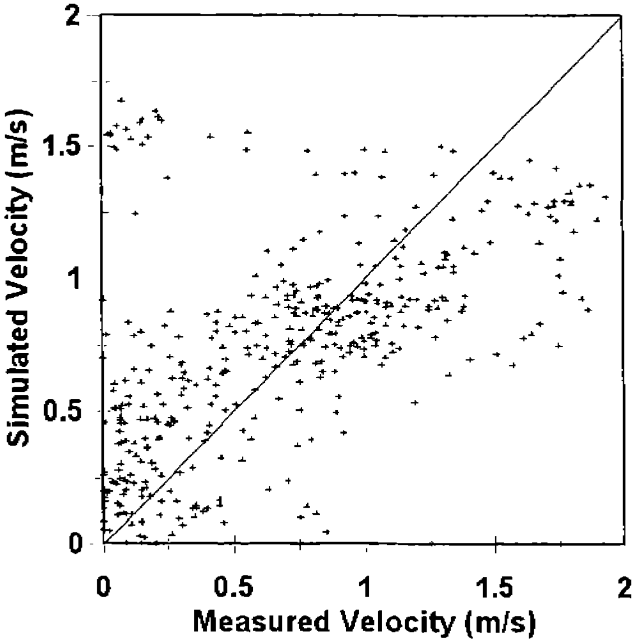

Salt Creek Deep Beds E, Q = 9506 cfs


Salt Creek Deep Beds G, Q = 9497 cfs

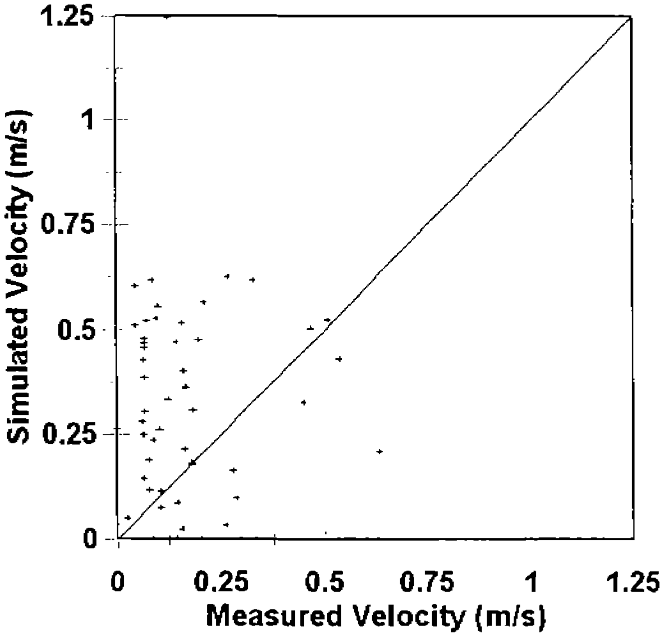

Salt Creek Deep Beds F, Q = 9497 cfs


Salt Creek Deep Beds H, Q = 9497 cfs

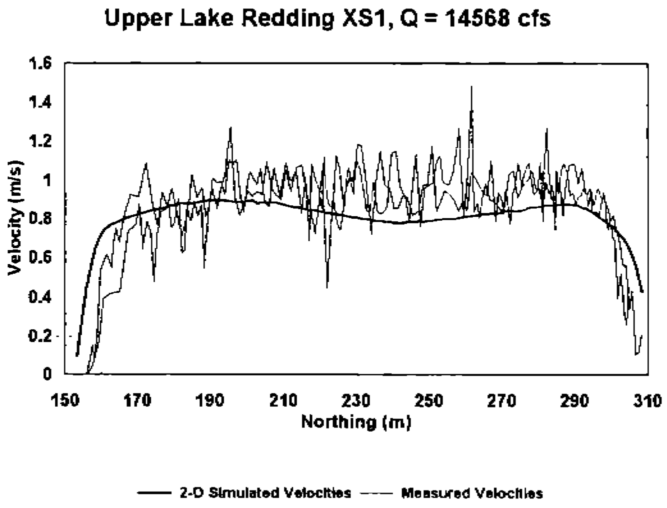
Salt Creek
All Validation Velocities

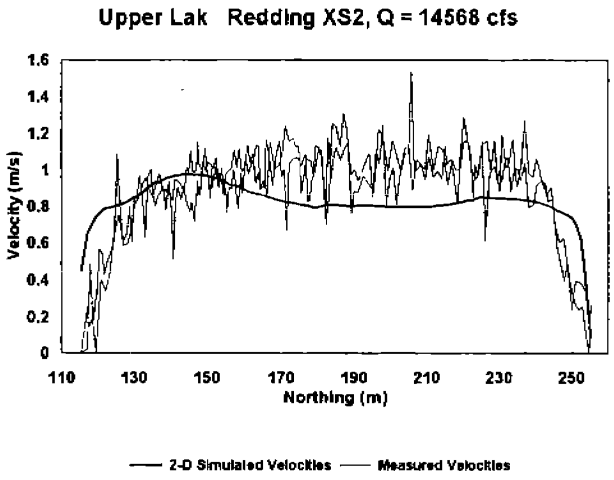


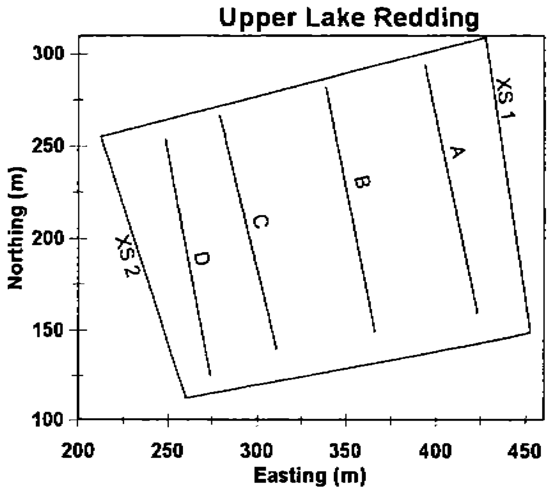
Salt Creek
Between Transect Non-ADCP Velocities



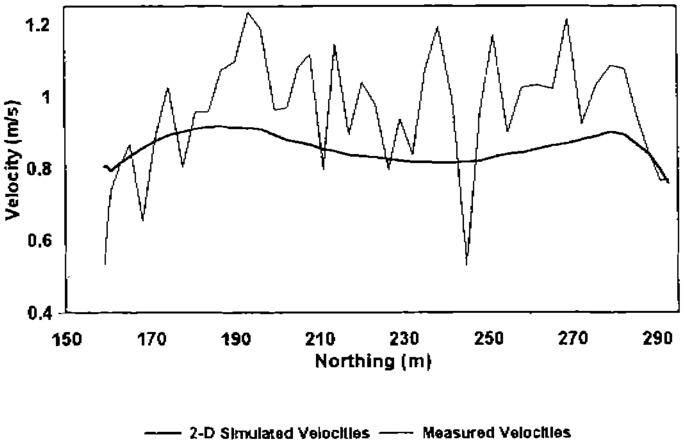
Upper Lake Redding Study Site


Upper Lake Redding XS1, Q = 14568 cfs

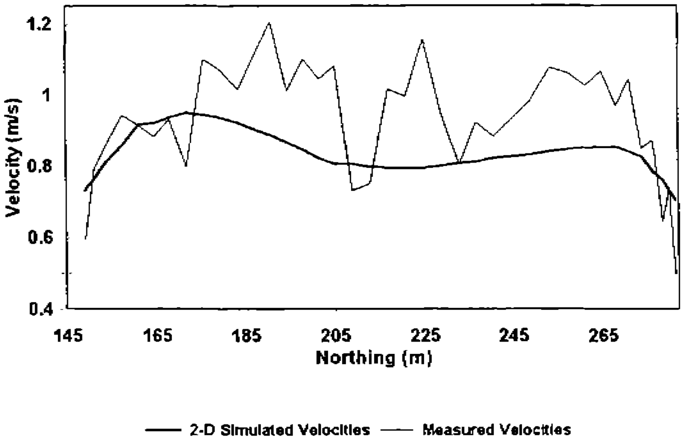

Upper Lak Redding XS2, Q = 14568 cfs


Upper Lake Redding

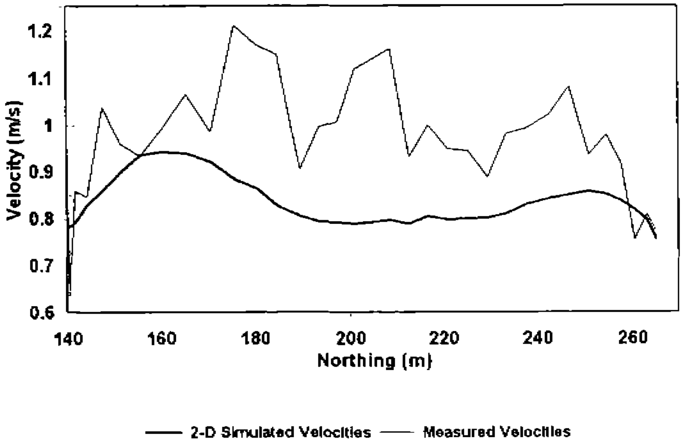
Upper Lake Redding Deep Beds A
Q = 13568 cfs



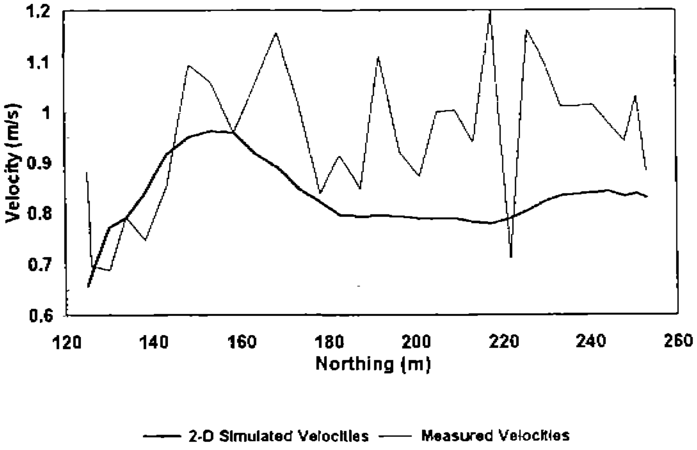
Upper Lake Redding Deep Beds B
Q = 13568 cfs

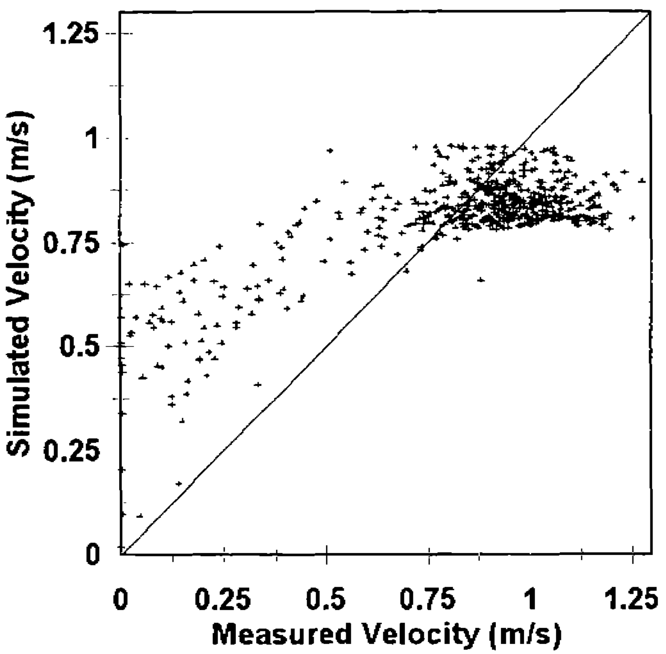


Upper Lake Redding Deep Beds C
Q = 13568 cfs



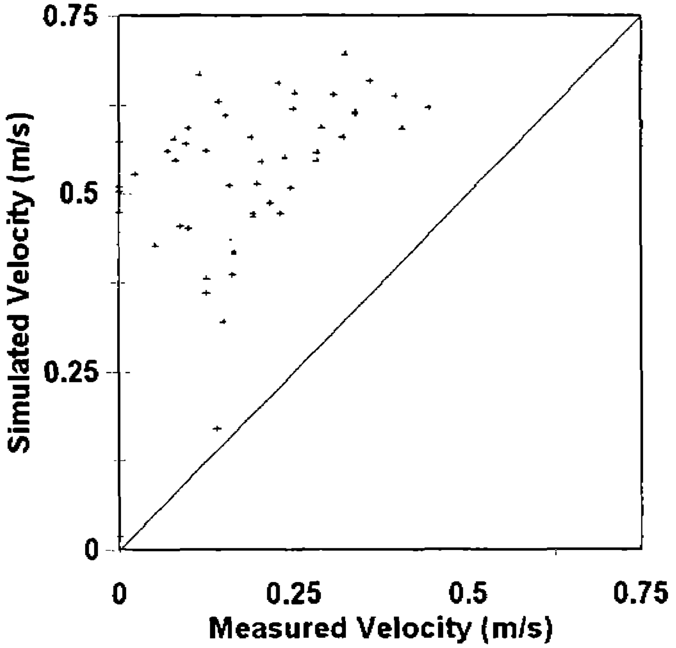
Upper Lake Redding Deep Beds D
Q = 13568 cfs





Upper Lake Redding

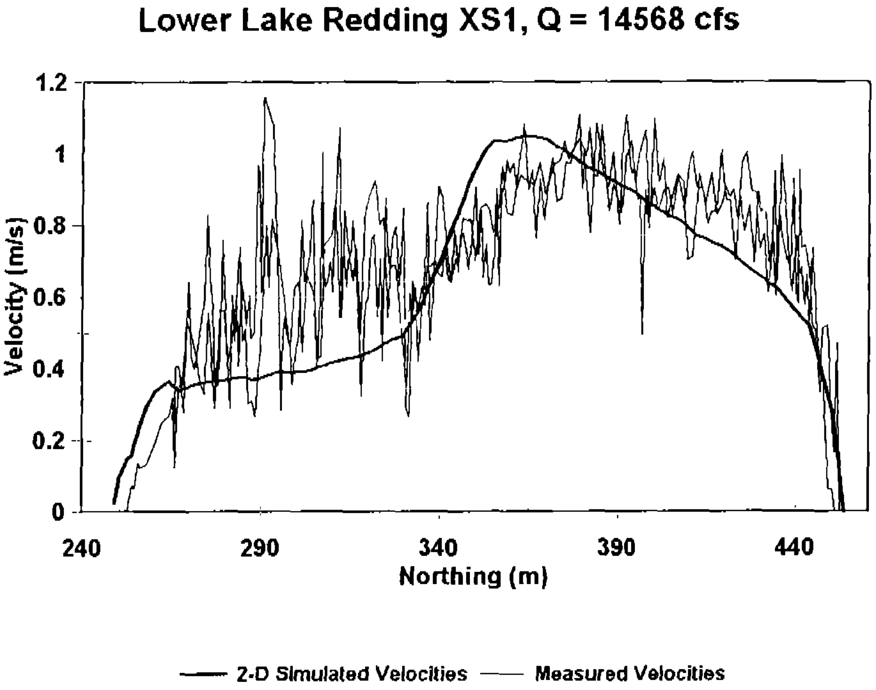
All Validation Velocities

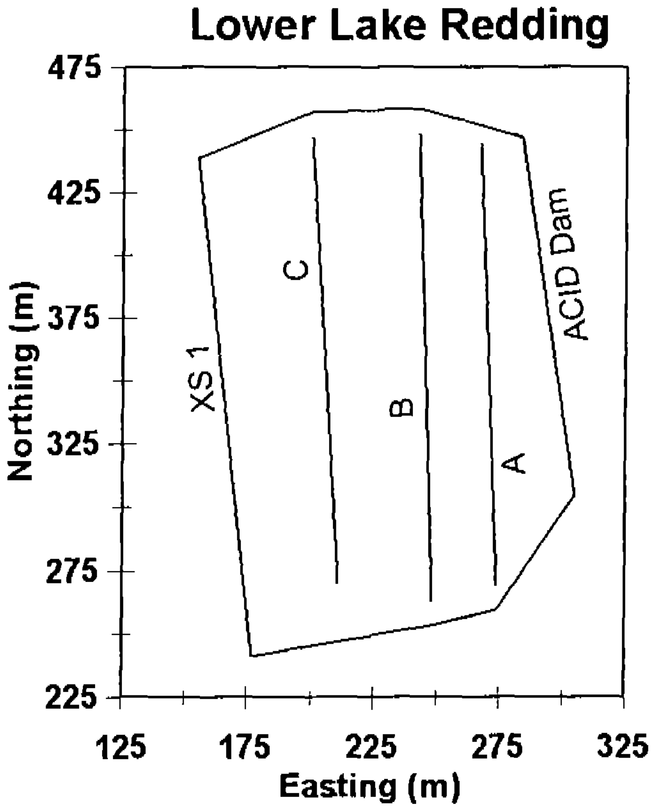


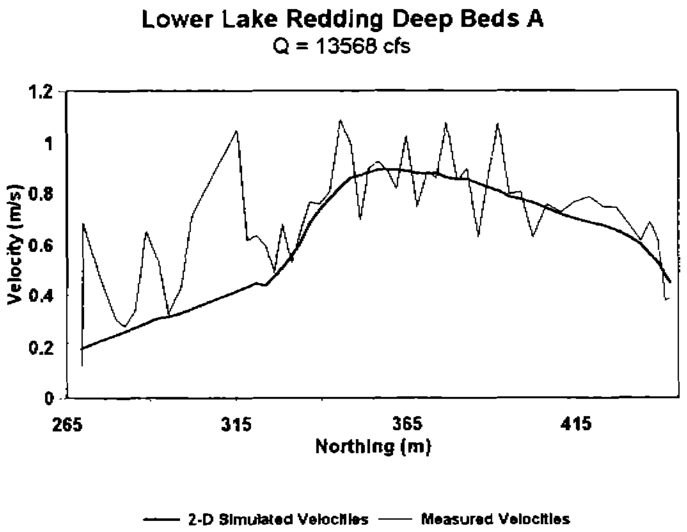
Upper Lake Redding

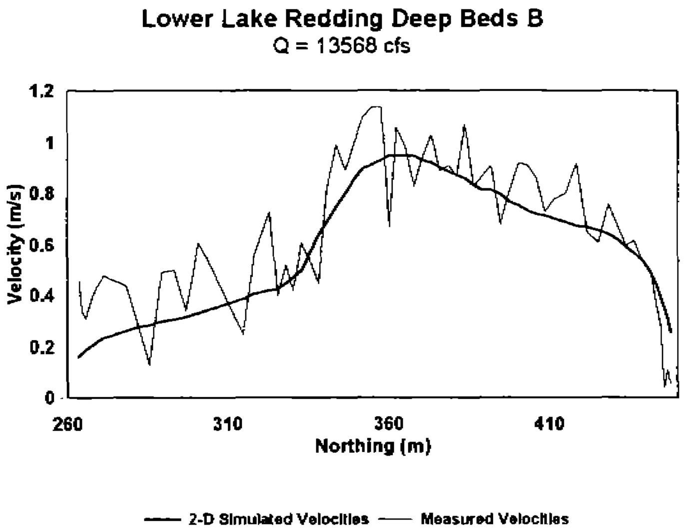
Between Transect Non-ADCP Velocities

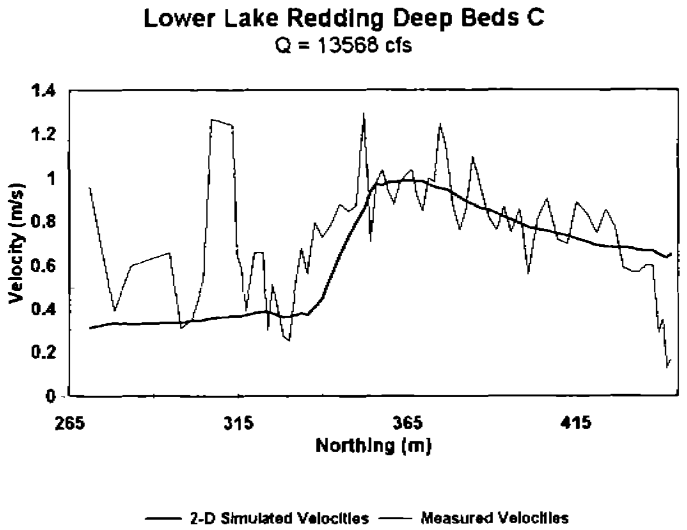
Lower Lake Redding Study Site



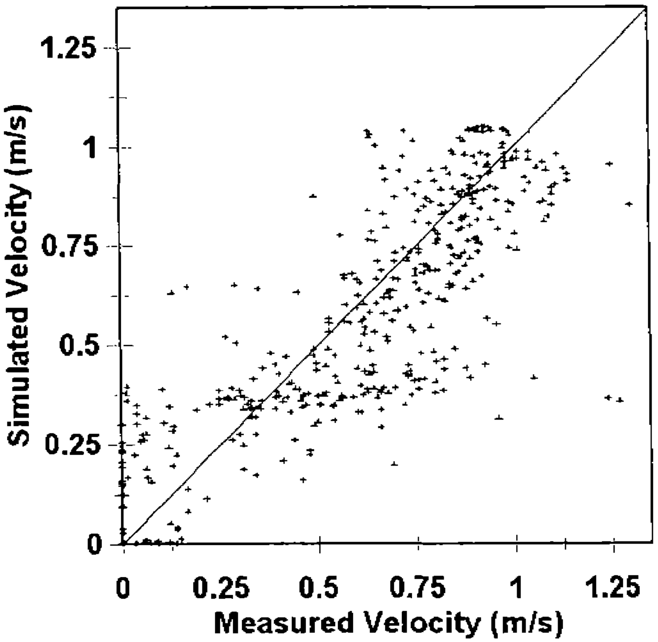



Lower Lake Redding Deep Beds A
Q = 13568 cfs

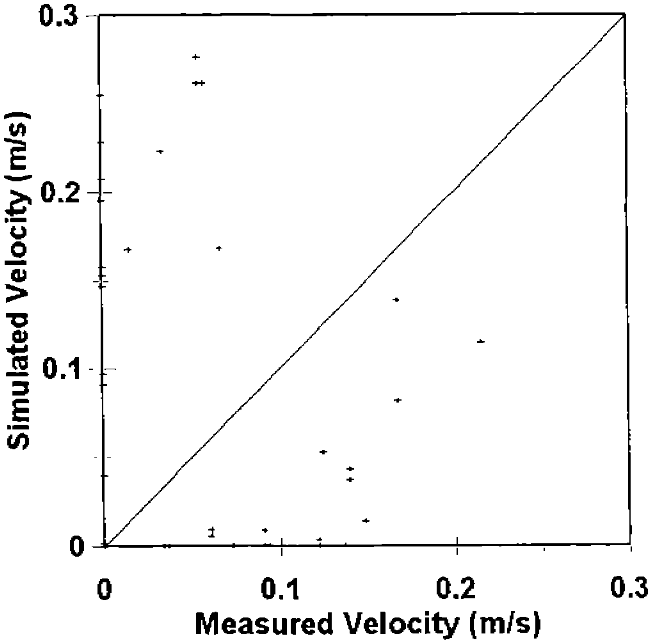

Lower Lake Redding Deep Beds B
Q = 13568 cfs


Lower Lake Redding Deep Beds C
Q = 13568 cfs

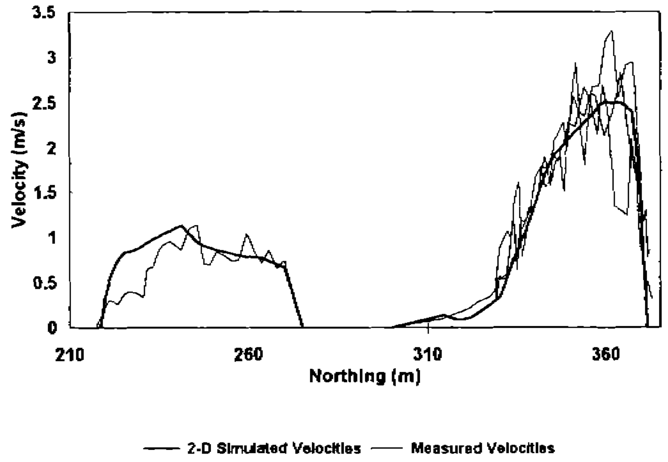
Lower Lake Redding
All Validation Velocities

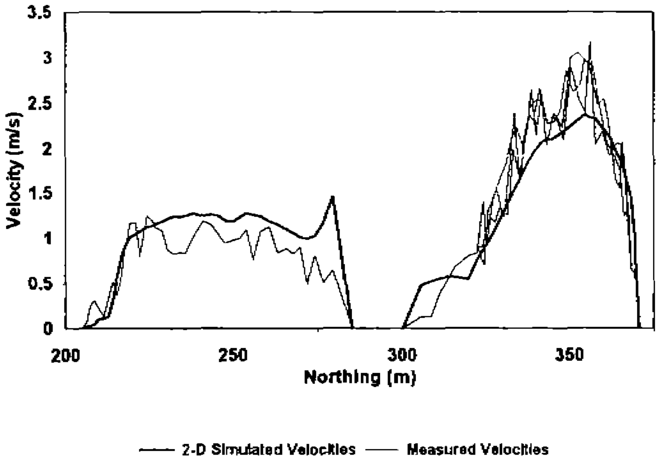


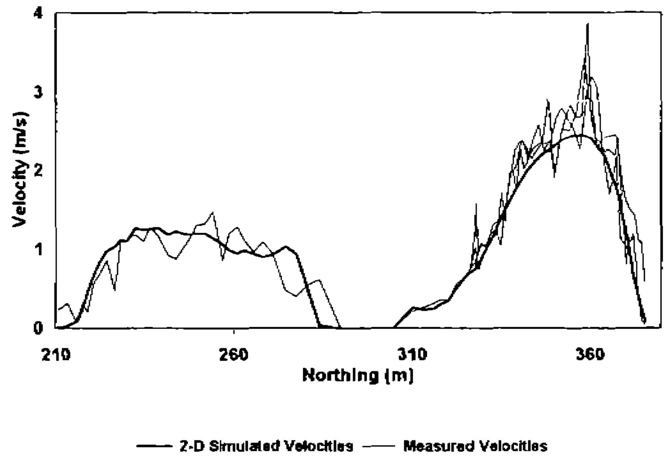
Lower Lake Redding
Between Transect Non-ADCP Velocitie

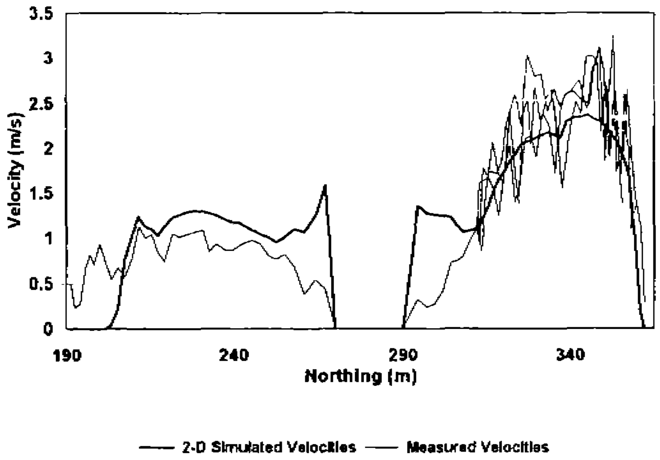


Posse Grounds Site

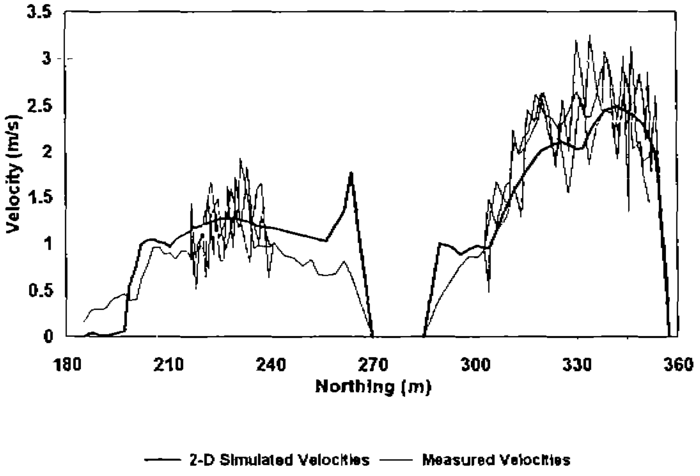

Posse Grounds XS1, Q = 7629 cfs


Posse Grounds XS3, Q = 8364 cfs

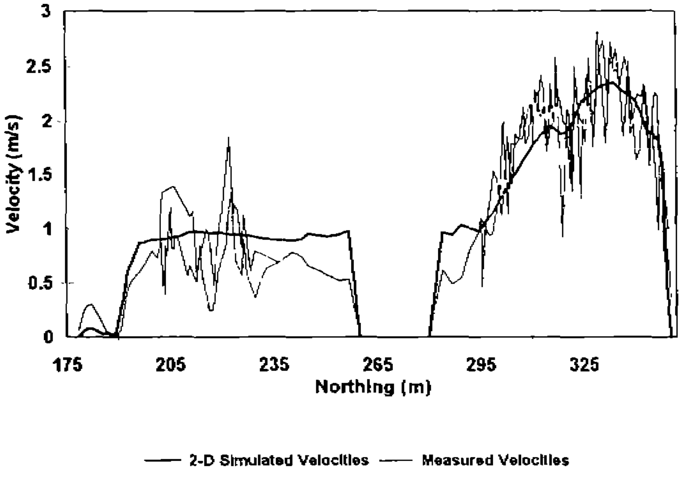

Posse Grounds XS2, Q = 8364 cfs


Posse Grounds XS4, Q = 8364 cfs

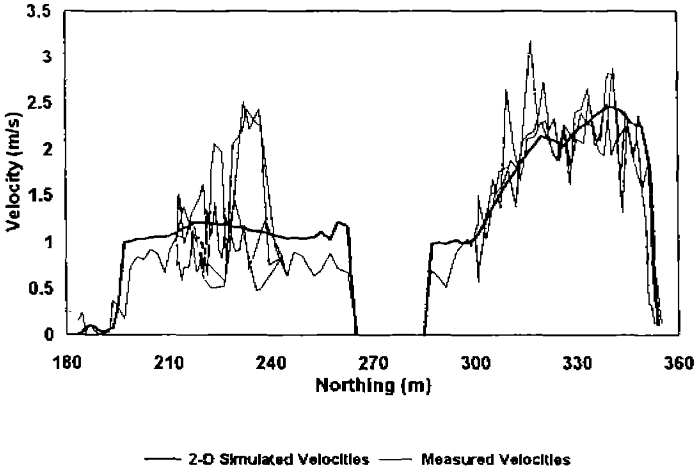
Posse Grounds XS5, Q = 8422 cfs



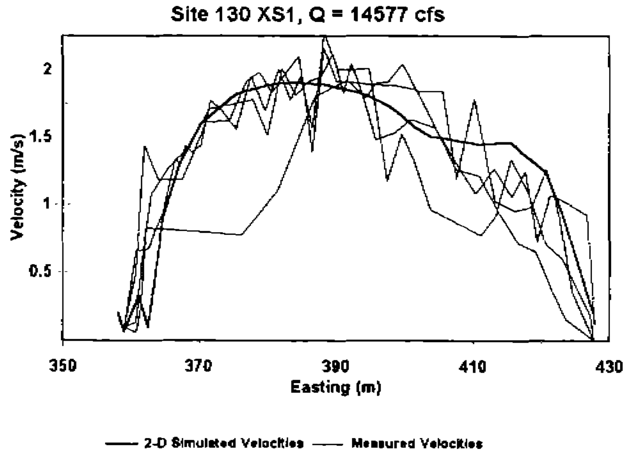
Posse Grounds XS7, Q = 7815 cfs

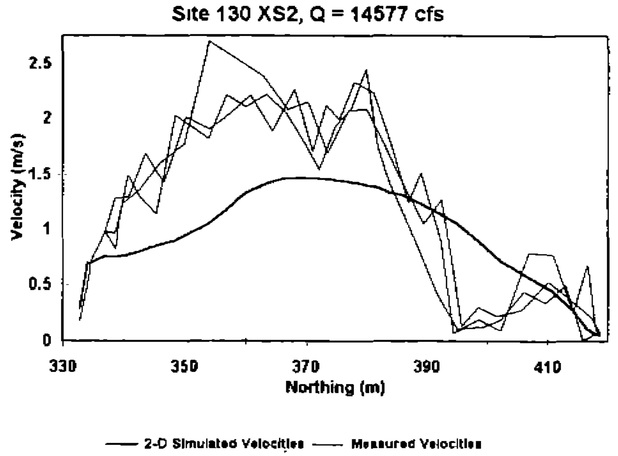


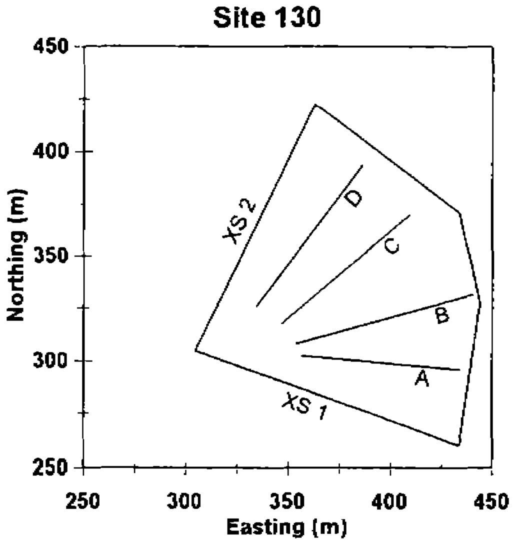
Posse Grounds XS6, Q = 8422 cfs



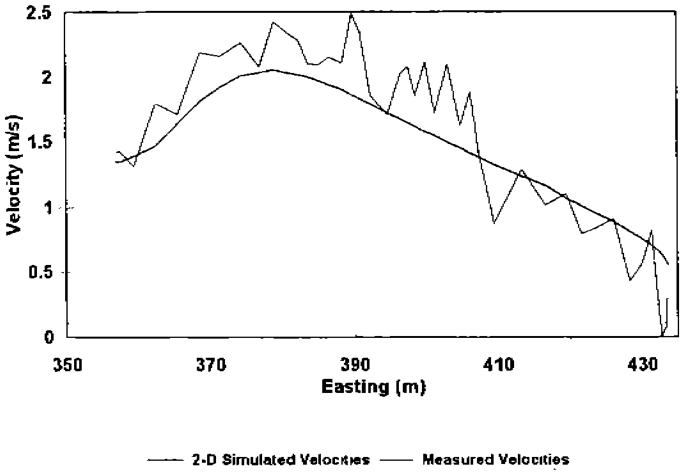
Study Site 130



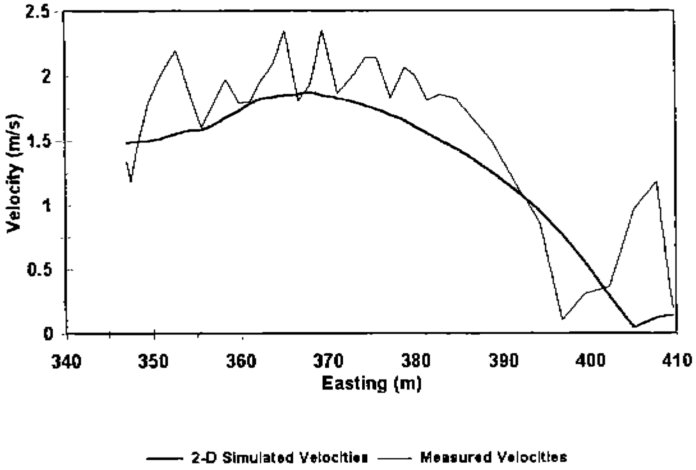




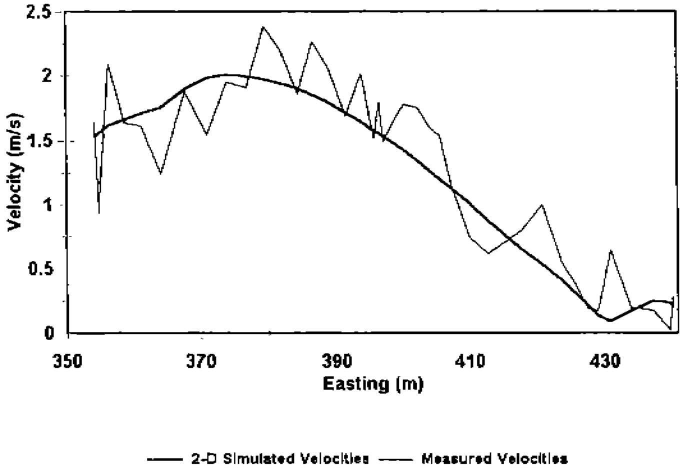
Site 130 Deep Beds A, Q = 18106 cfs



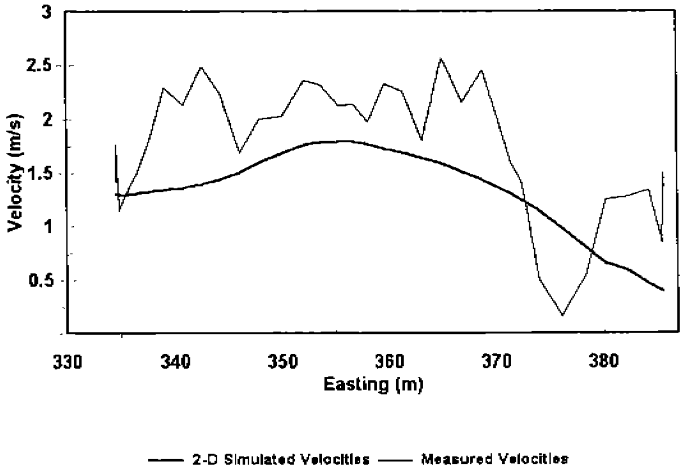
Site 130 Deep Beds C, Q = 18106 cfs



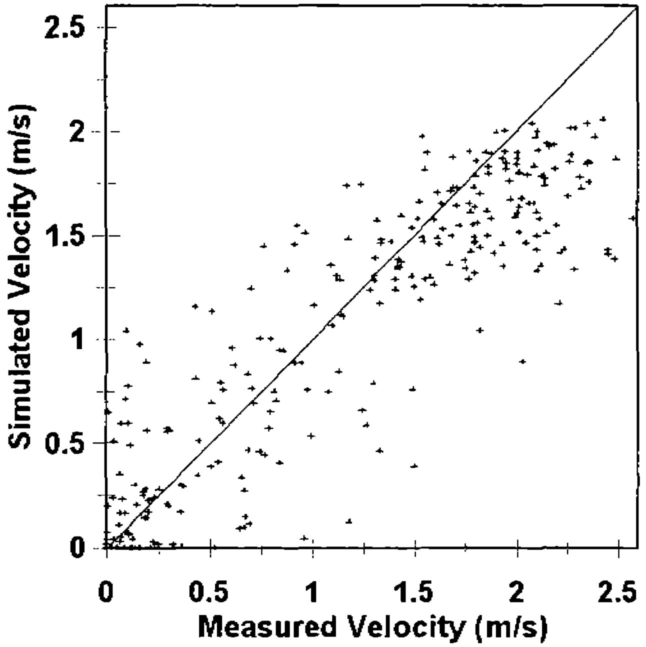
Site 130 Deep Beds B, Q = 18106 cfs



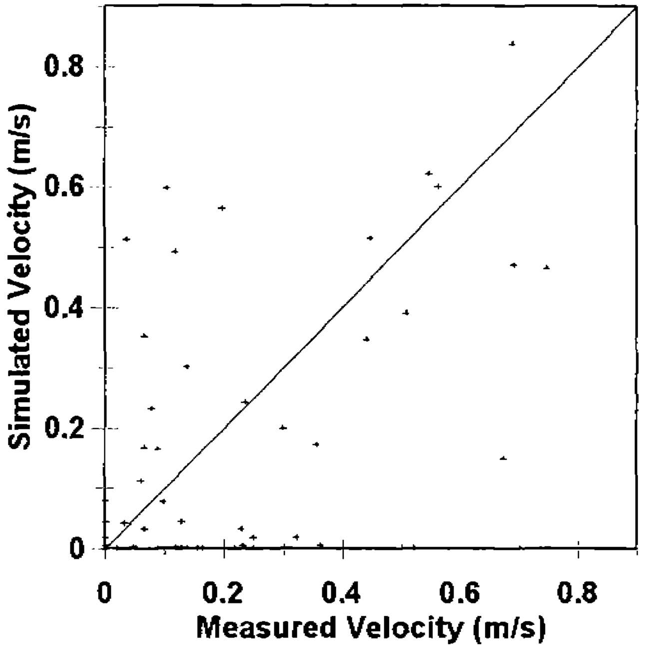
Site 130 Deep Beds D, Q = 18106 cfs



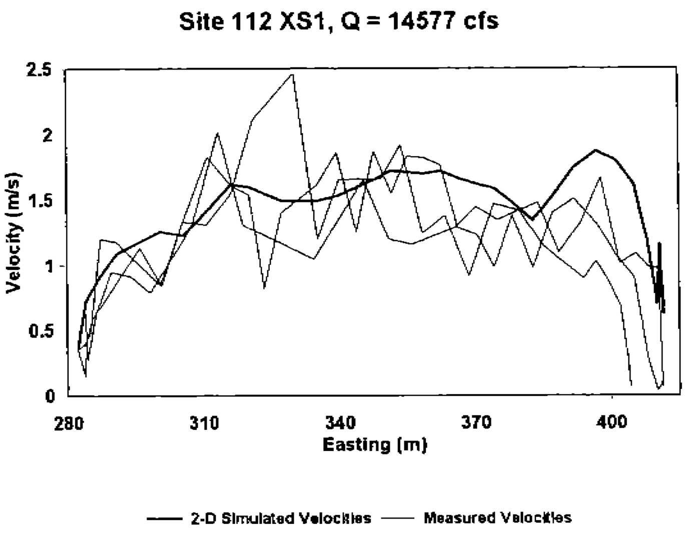
Site 130
All Validation Velocities

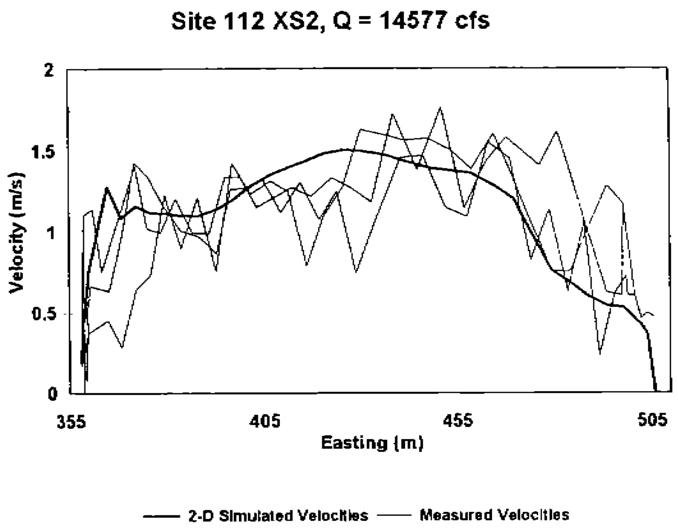


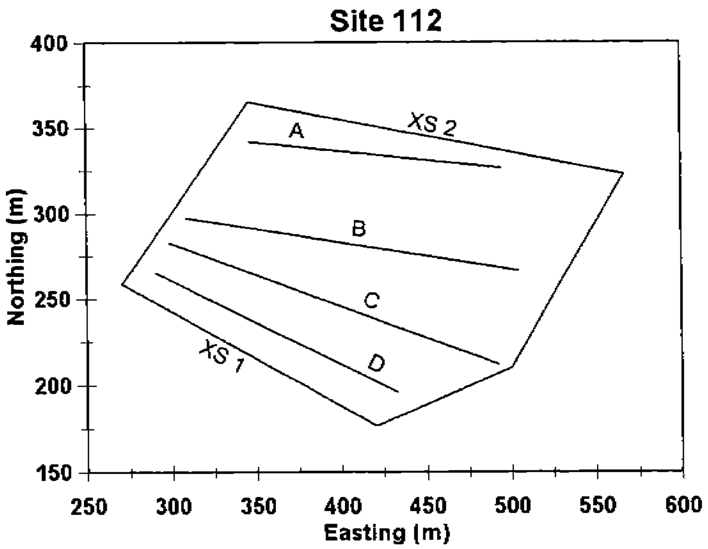
Site 130
Between Transect Non-ADCP Velocitie



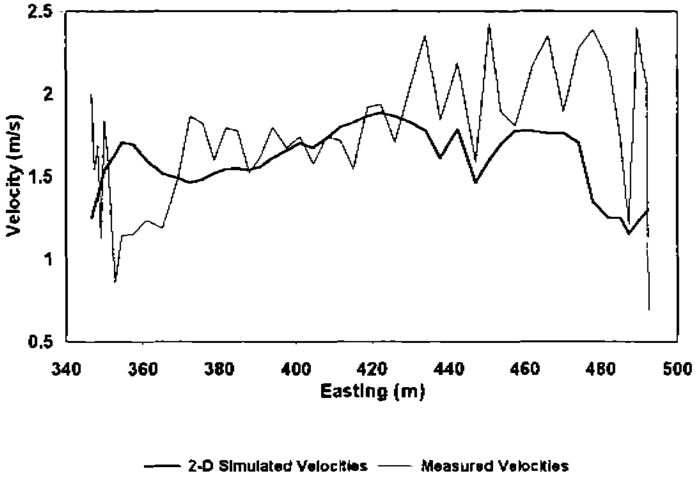
Study Site 112



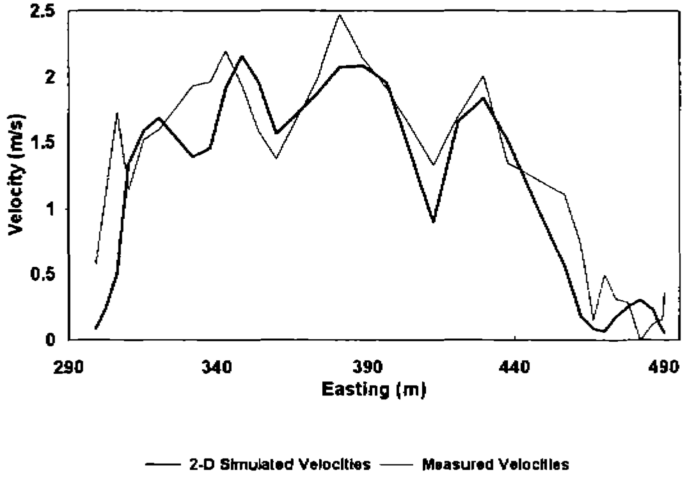




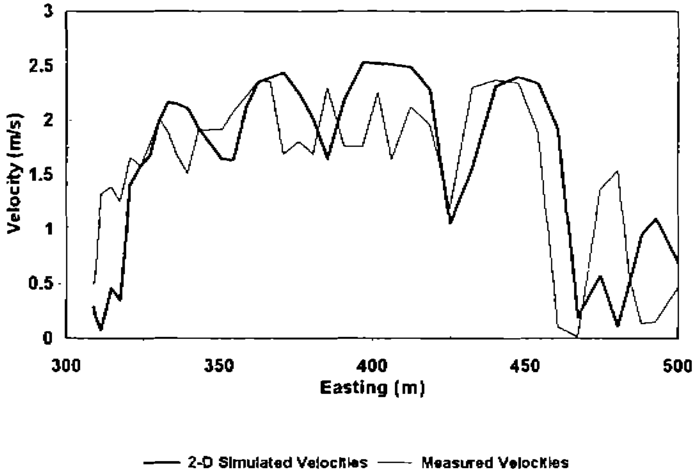
Site 112 Deep Beds A, Q = 22200 cfs



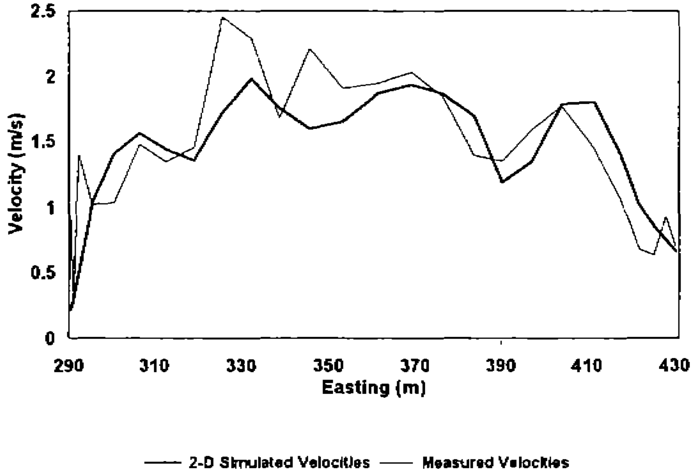
Site 112 Deep Beds C, Q = 22200 cfs



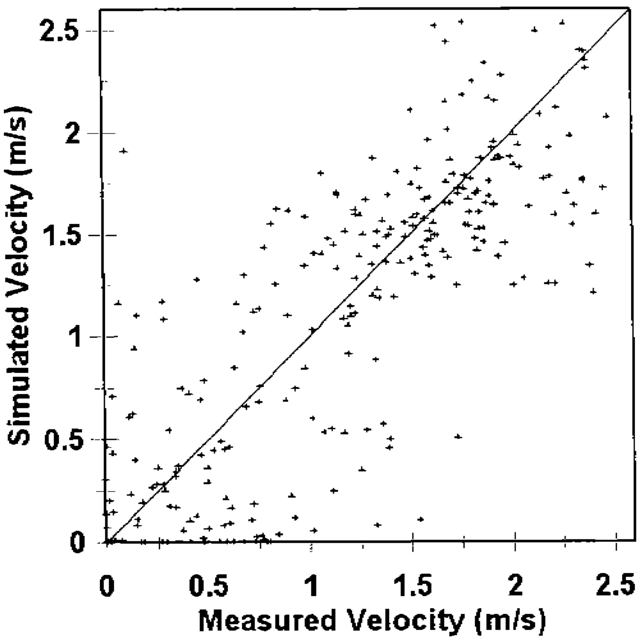
Site 112 Deep Beds B, Q = 22200 cfs



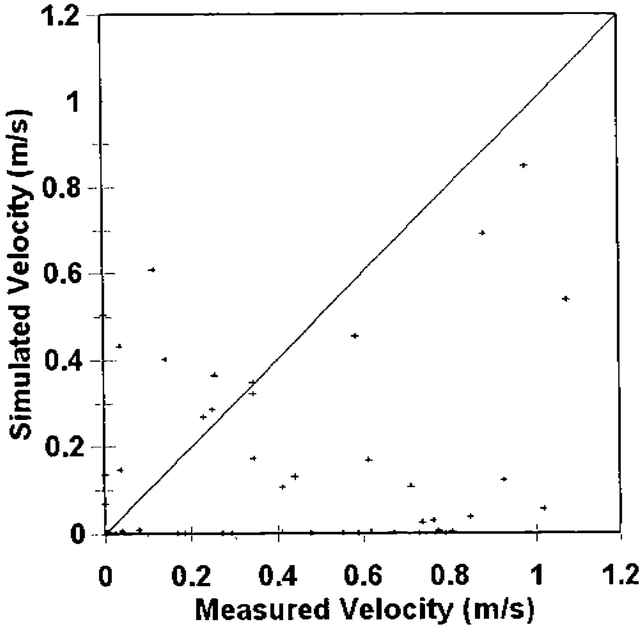
Site 112 Deep Beds D, Q = 22200 cfs



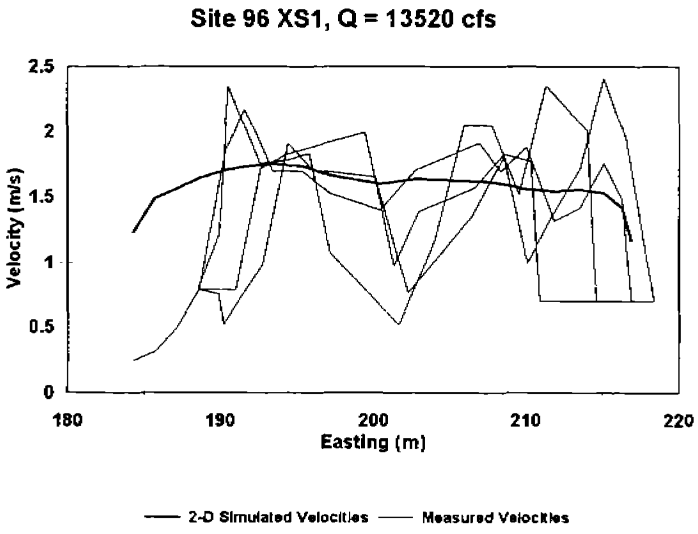
Site 112
All Validation Velocities

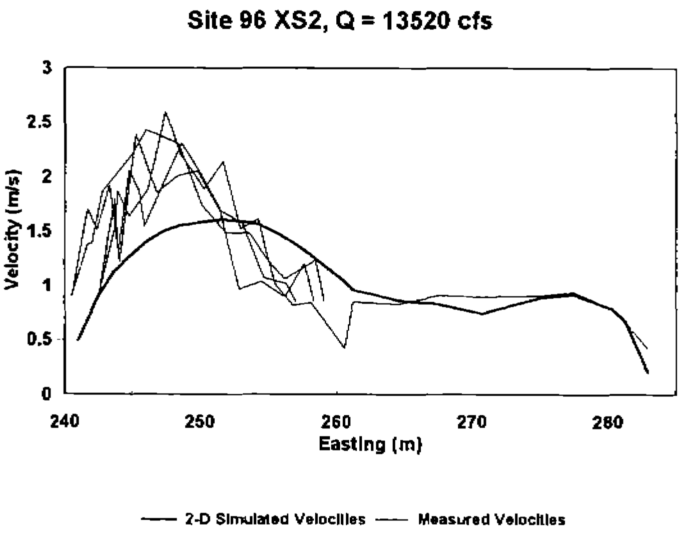


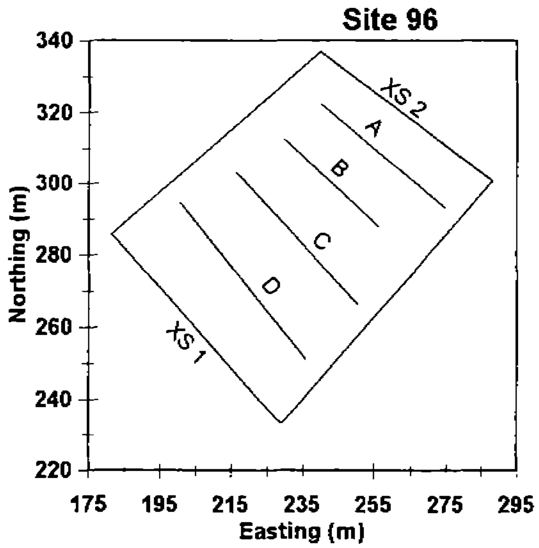
Site 112
Between Transect Non-ADCP Velocities



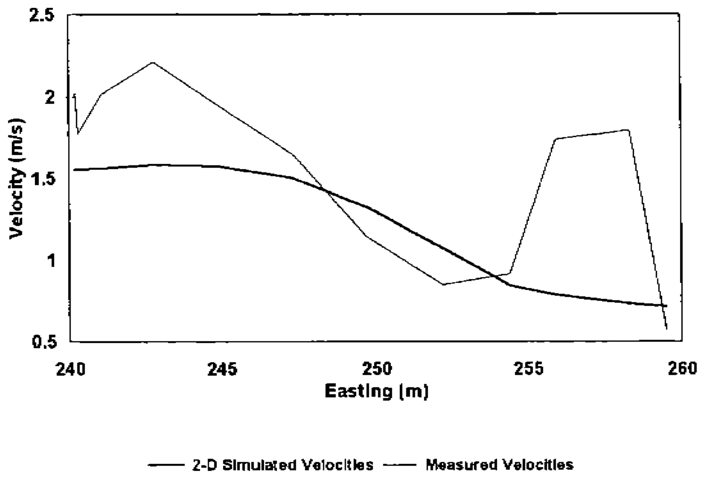
Study Site 96



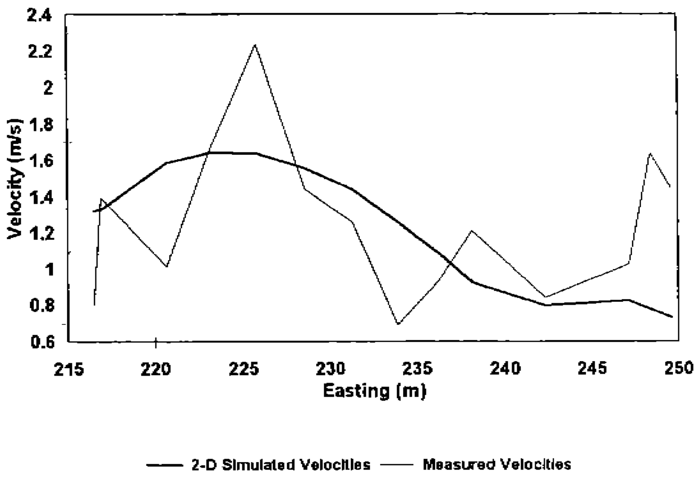




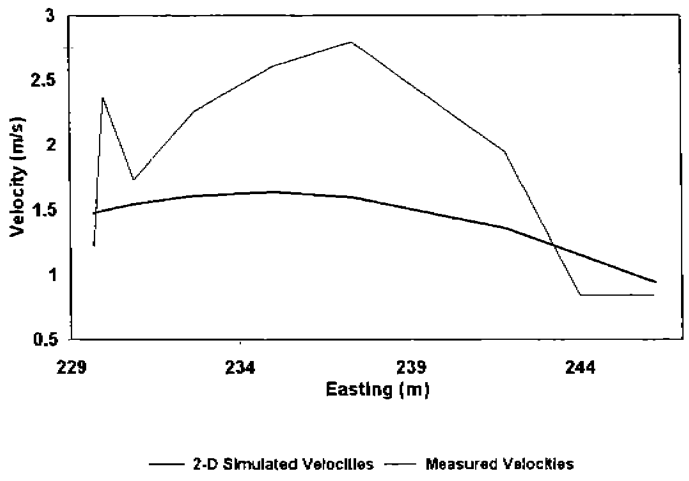
Site 96 Deep Beds A, Q = 13520 cfs



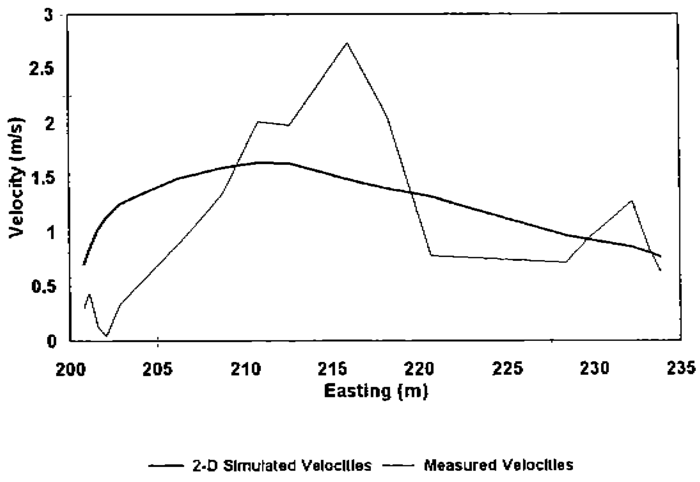
Site 96 Deep Beds C, Q = 13520 cfs



Site 96 Deep Beds B, Q = 13520 cfs

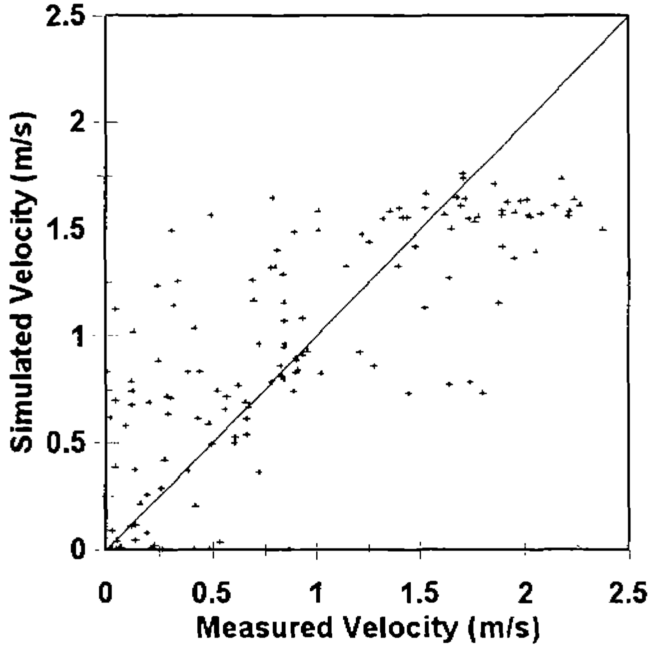


Site 96 Deep Beds D, Q = 13520 cfs



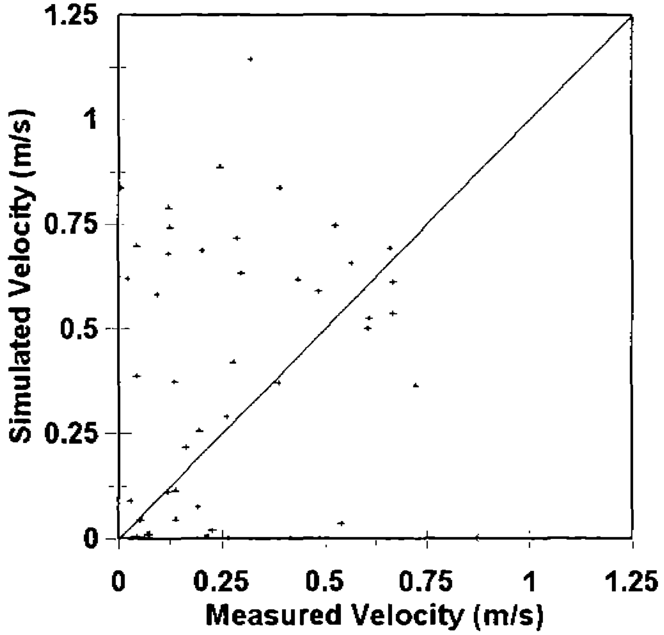
Site 96

All Validation Velocities

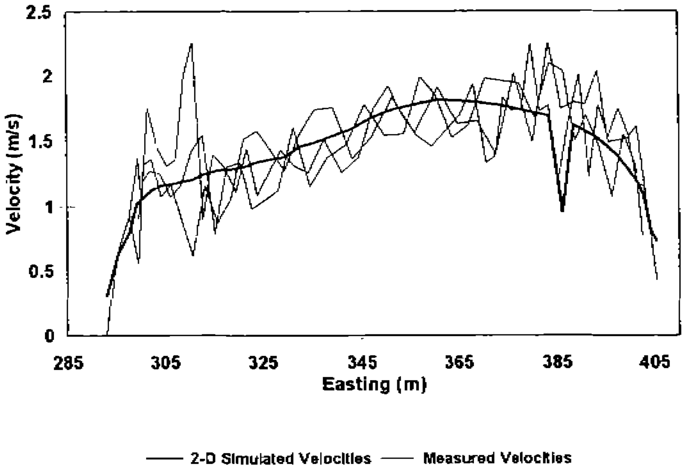


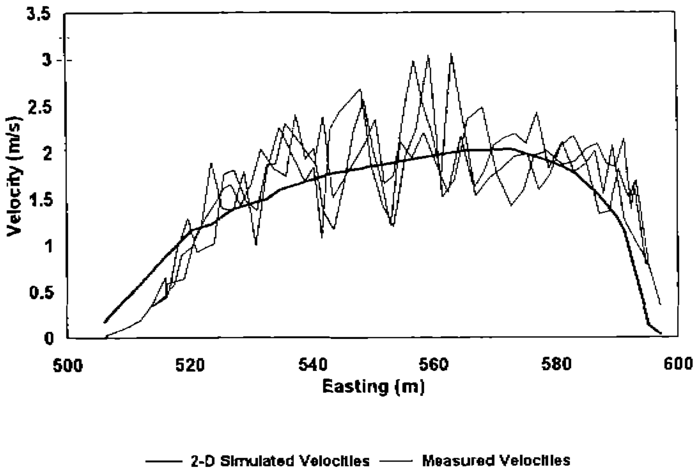
Site 96

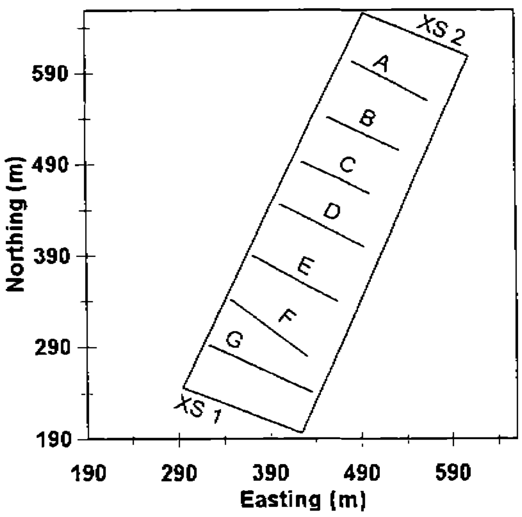
Between Transect Non-ADCP Velocities



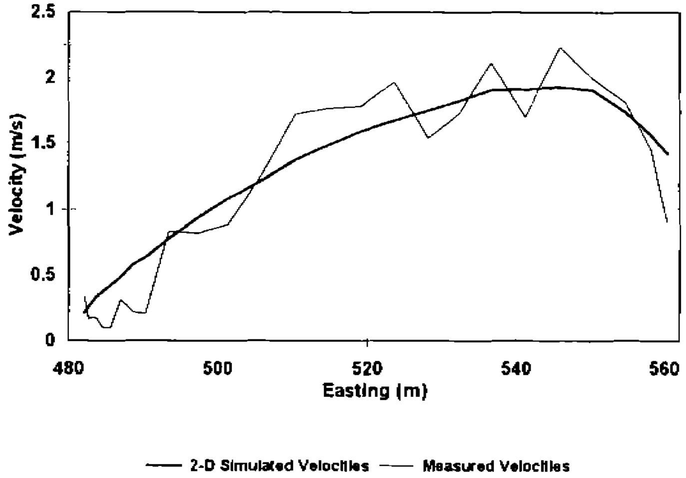
Site 81


Site 81 XS1, Q = 13520 cfs

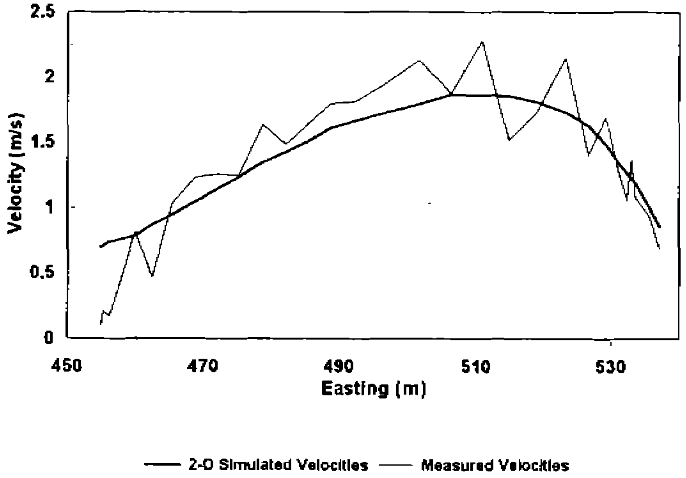

Site 81 XS2, Q = 13520 cfs


Site 81

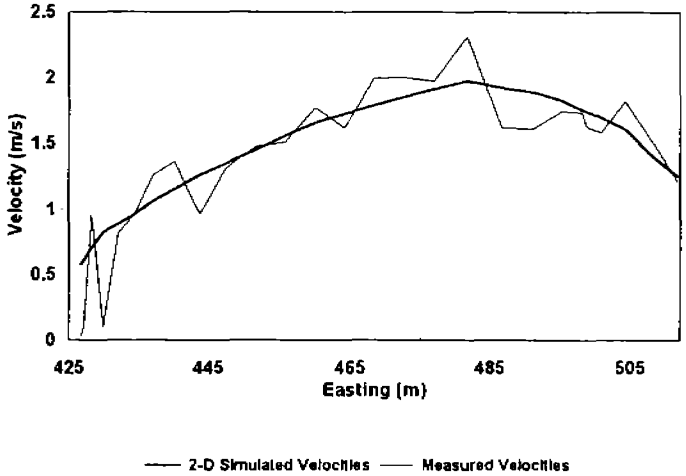
Site 81 Deep Beds A, Q = 13520 cfs



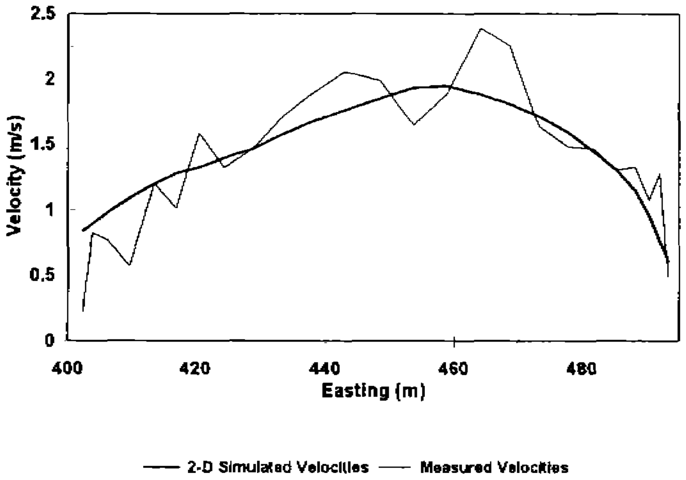
Site 81 Deep Beds B, Q = 13520 cfs



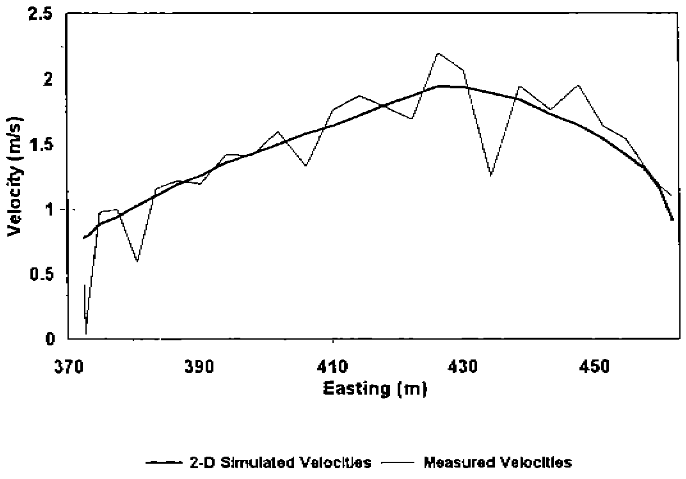
Site 81 Deep Beds C, Q = 13520 cfs



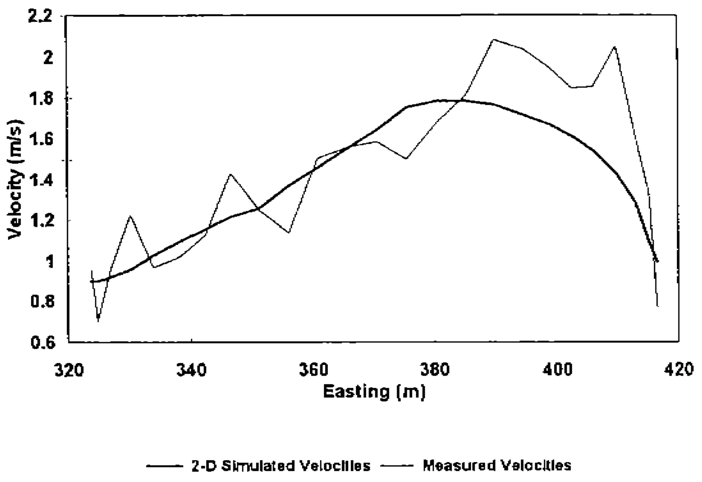
Site 81 Deep Beds D, Q = 13520 cfs



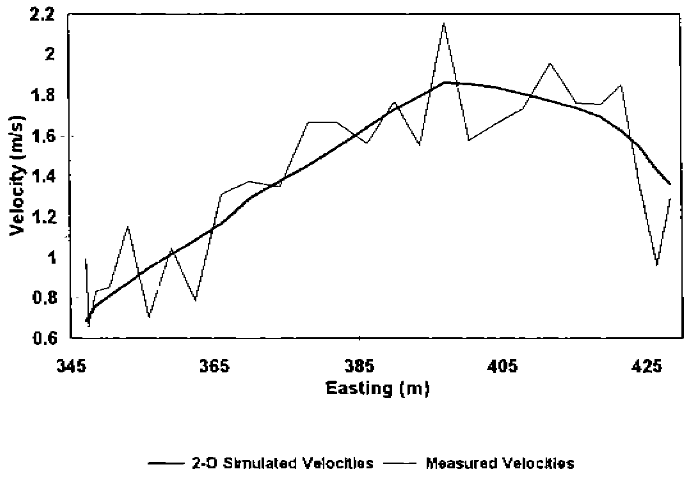
Site 81 Deep Beds E, Q = 13520 cfs



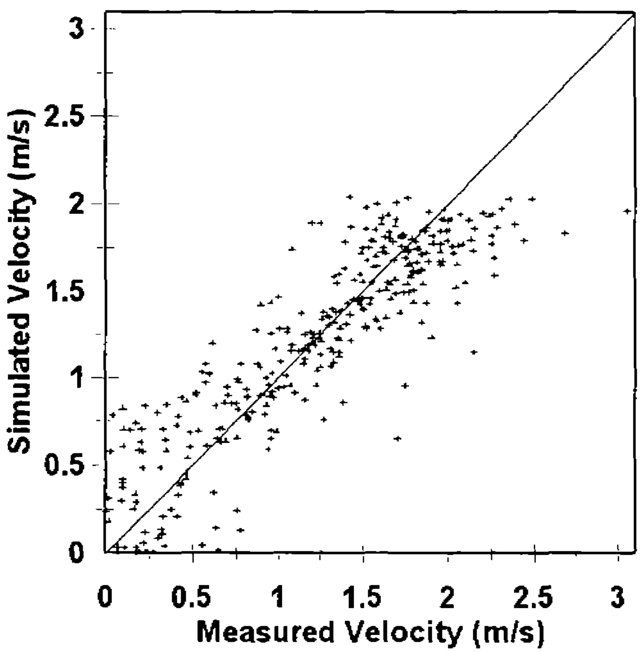
Site 81 Deep Beds G, Q = 13520 cfs



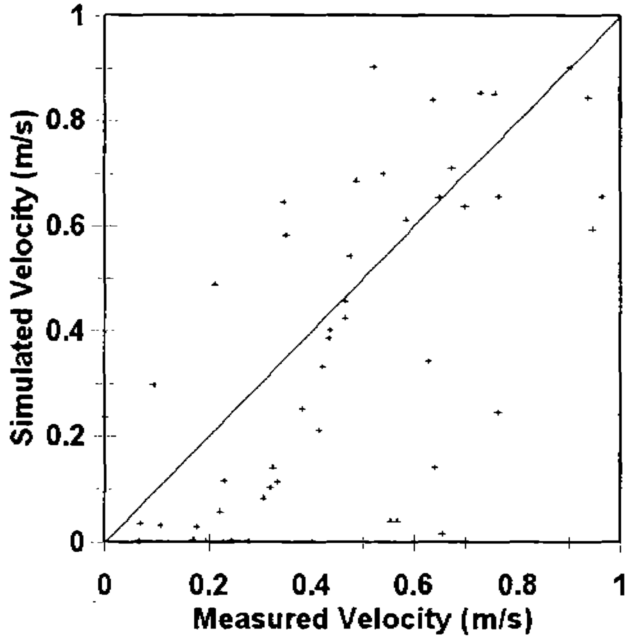
Site 81 Deep Beds F, Q = 13520 cfs



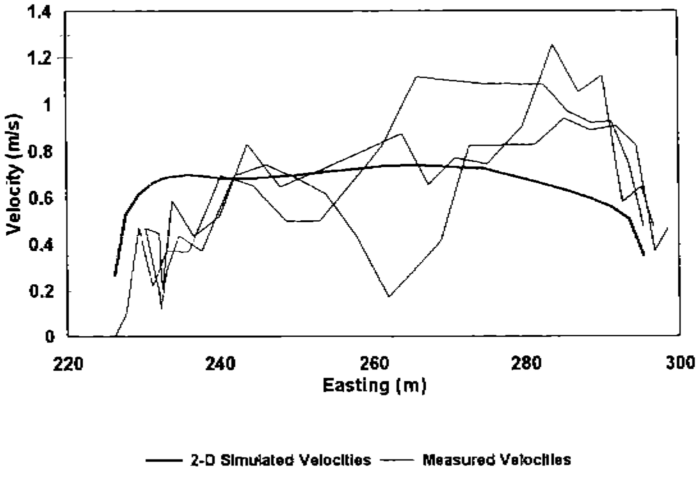
Site 81
All Validation Velocities

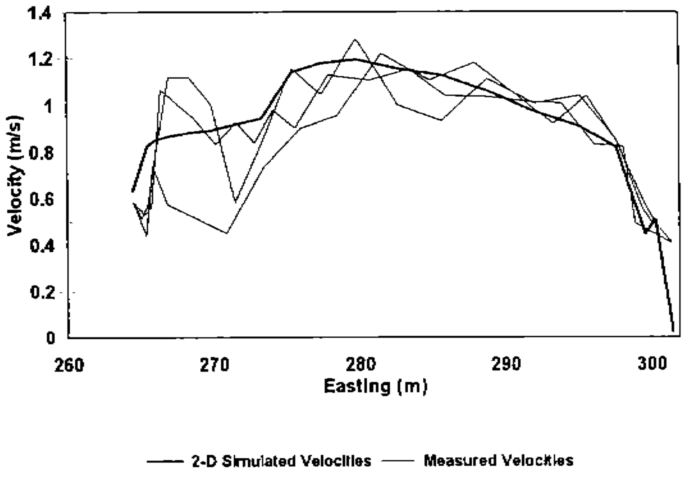


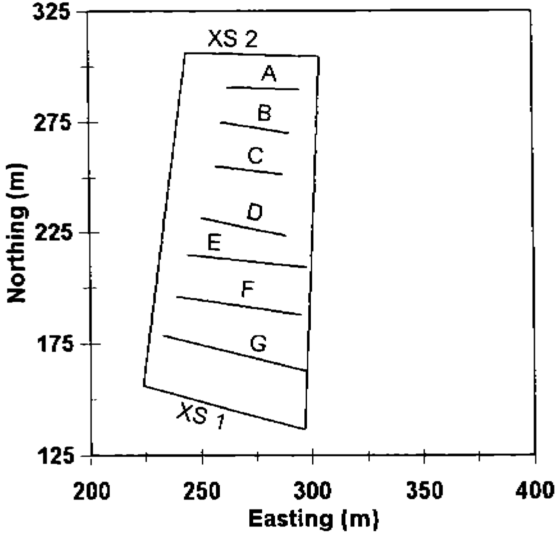
Site 81
Between Transect Non-ADCP Velocities

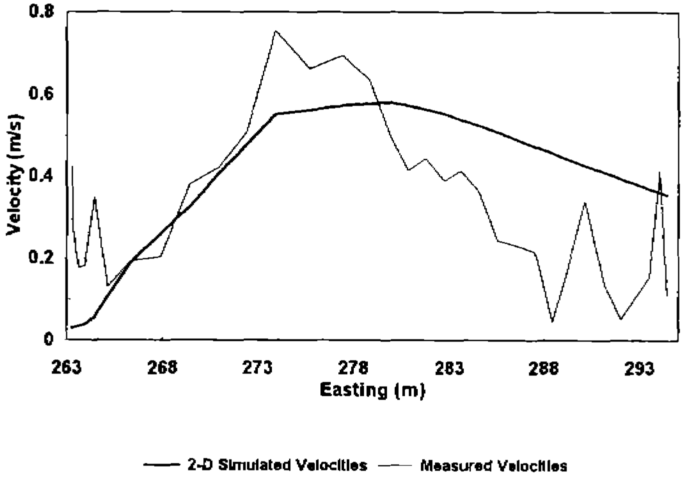


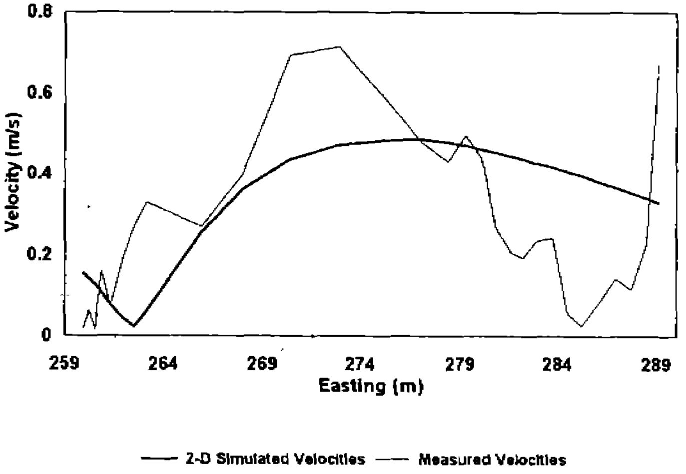
Study Site 80

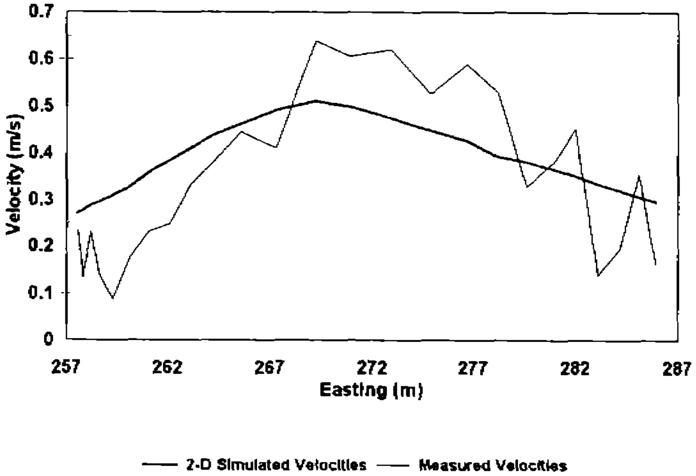

Site 80 XS1, Q = 14703 cfs

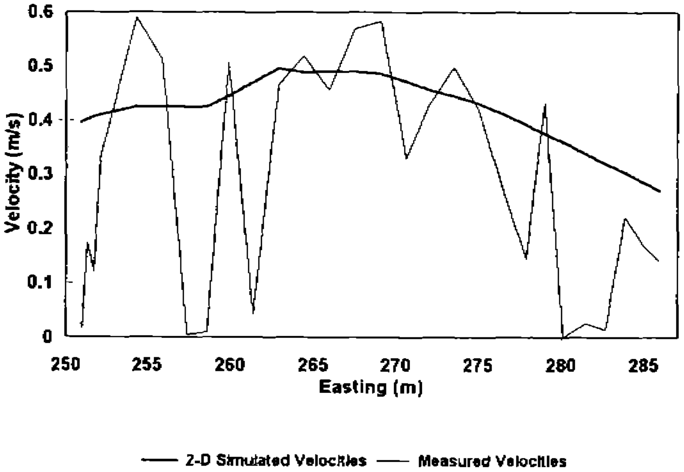

Site 80 XS2, Q = 14703 cfs


Site 80

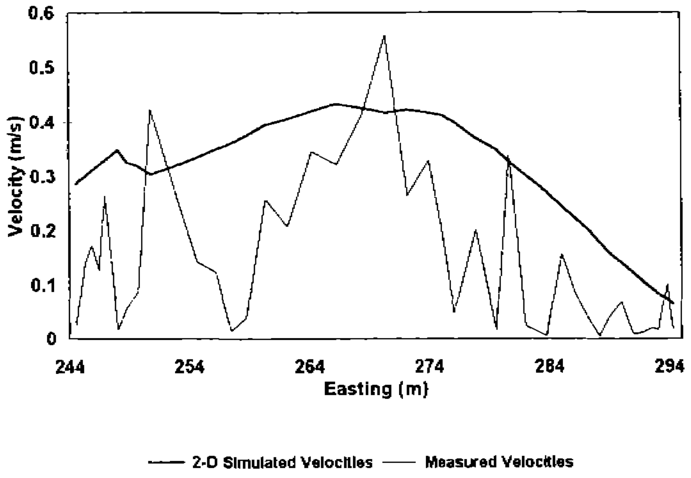

Site 80 Deep Beds A, Q = 10369 cfs


Site 80 Deep Beds B, Q = 10369 cfs

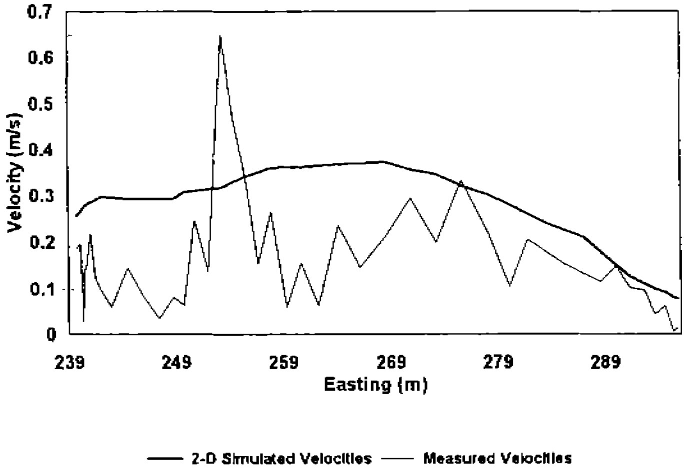

Site 80 Deep Beds C, Q = 10369 cfs


Site 80 Deep Beds D, Q = 10369 cfs

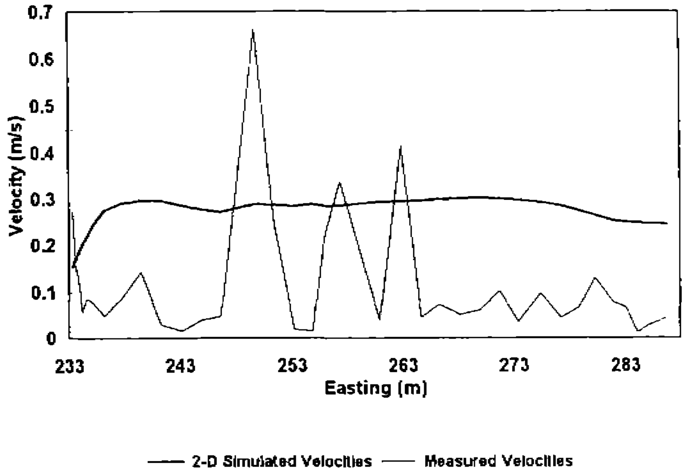
Site 80 Deep Beds E, Q = 10369 cfs



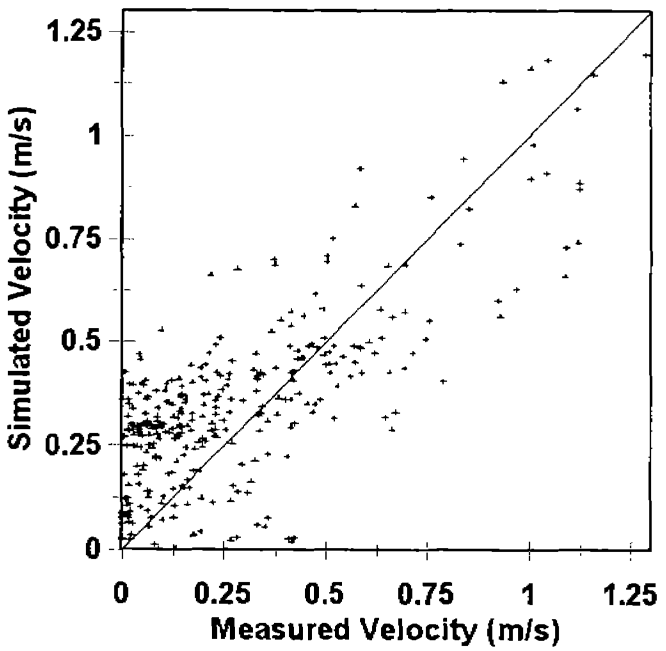
Site 80 Deep Beds F, Q = 10369 cfs



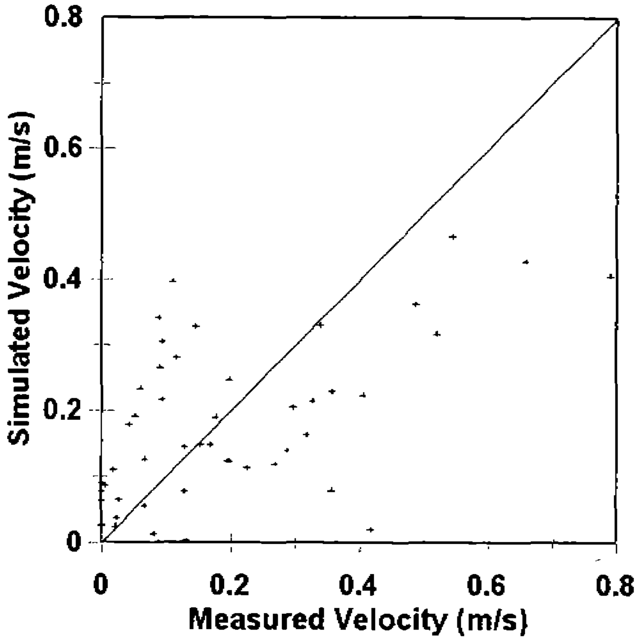
Site 80 Deep Beds G, Q = 10369 cfs



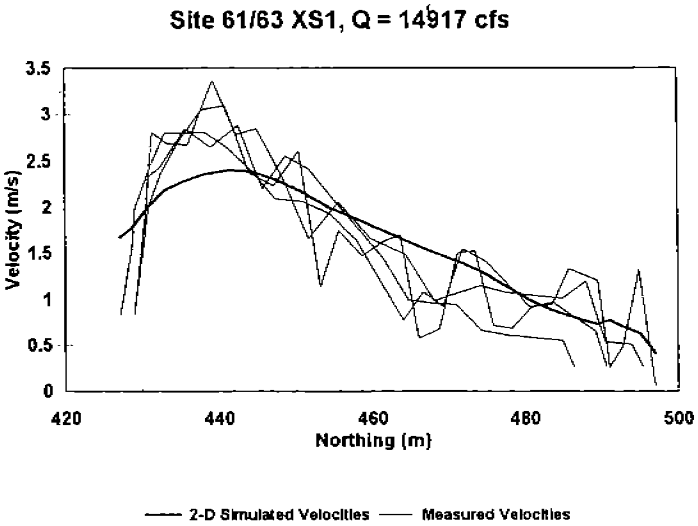
Site 80
All Validation Velocities

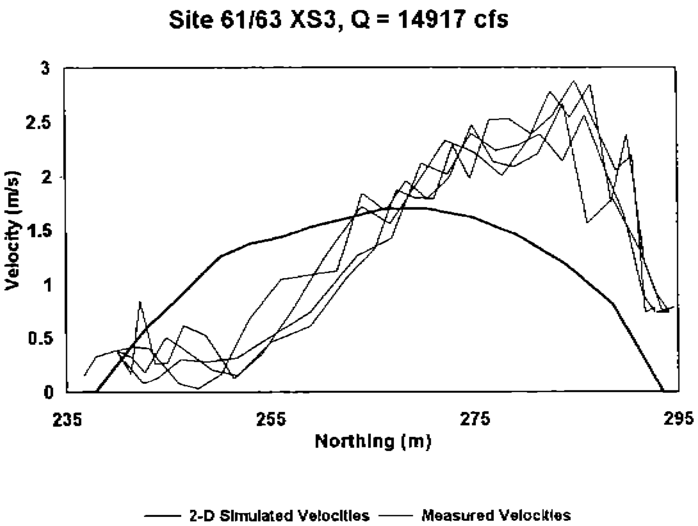


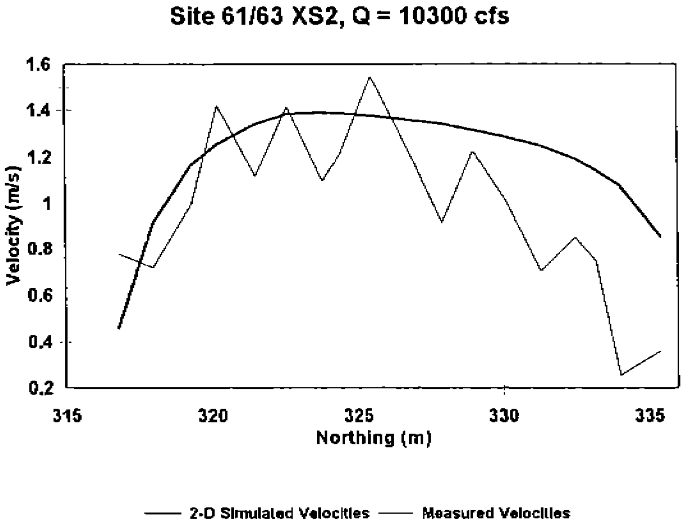
Site 80
Between Transect Non-ADCP Velocities

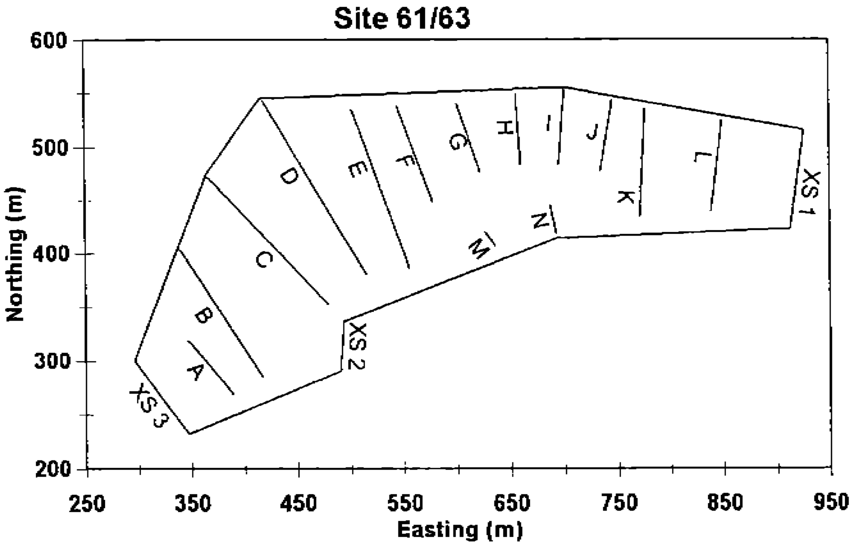


Study Site 61/63

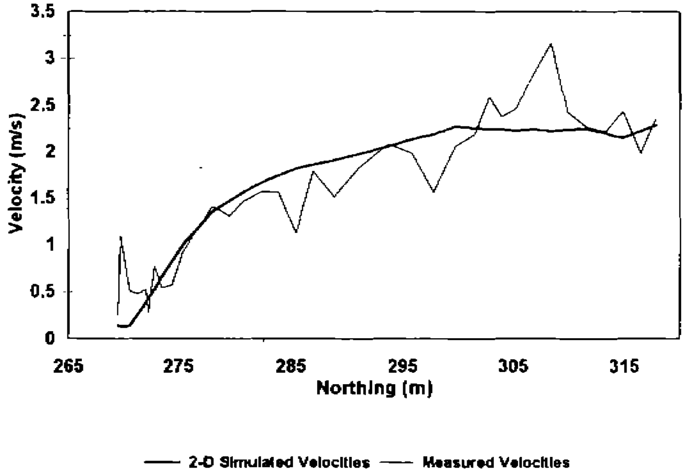

Site 61/63 XS1, Q = 14917 cfs


Site 61/63 XS3, Q = 14917 cfs

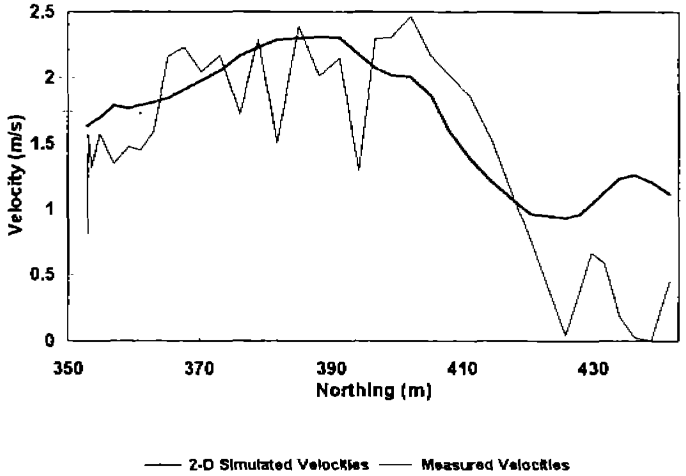

Site 61/63 XS2, Q = 10300 cfs


Site 61/63

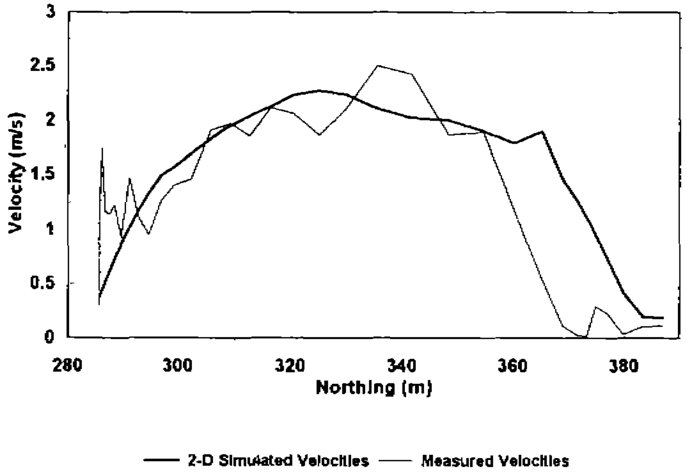
Site 61/63 Deep Beds A, Q = 22444 cfs



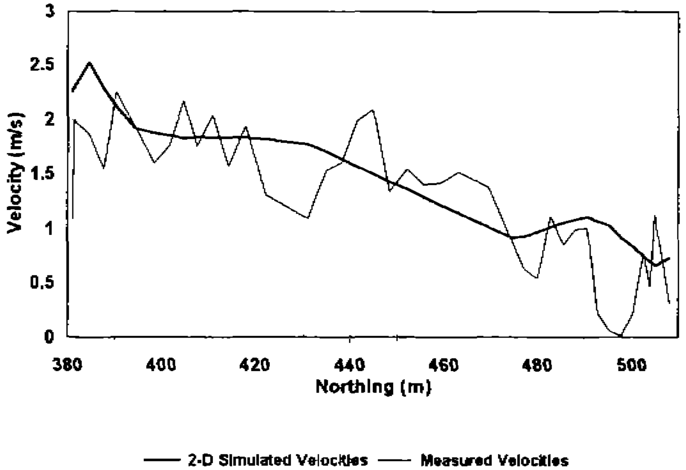
Site 61/63 Deep Beds C, Q = 22444 cfs

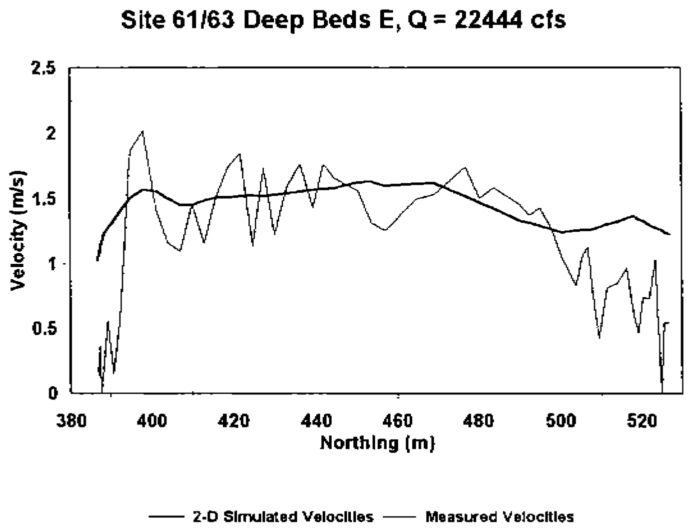


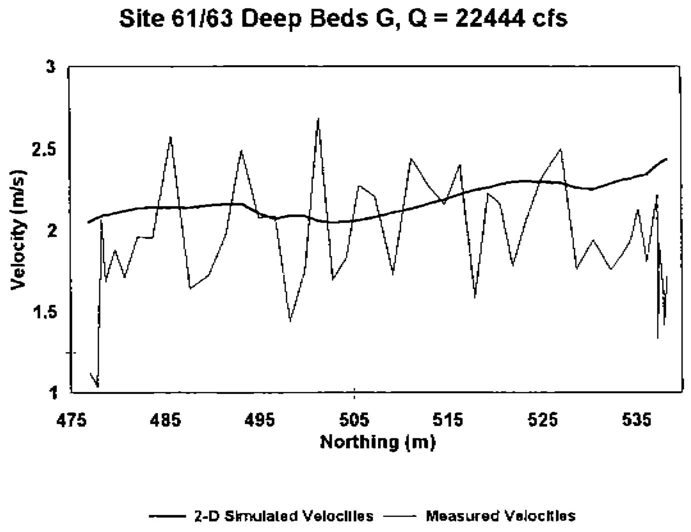
Site 61/63 Deep Beds B, Q = 22444 cfs

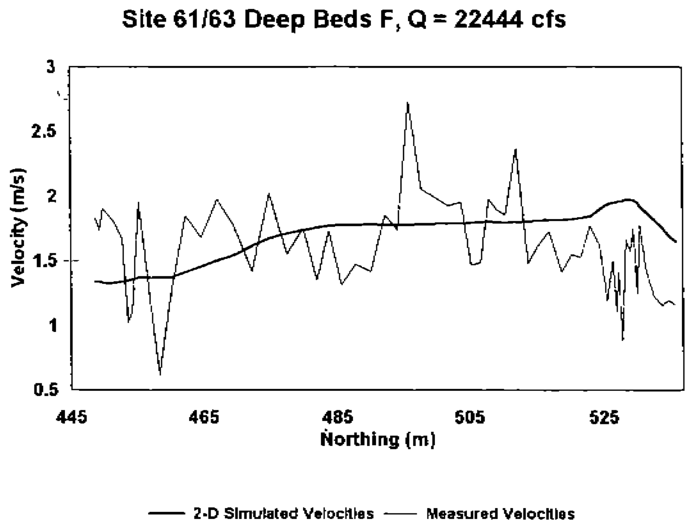


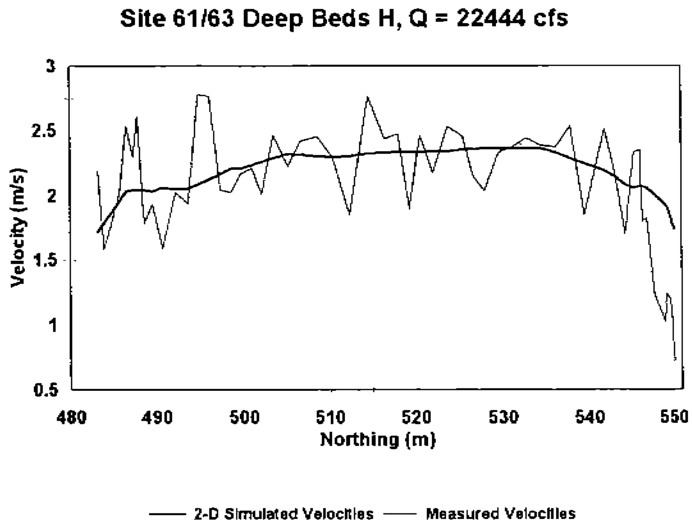
Site 61/63 Deep Beds D, Q = 22444 cfs



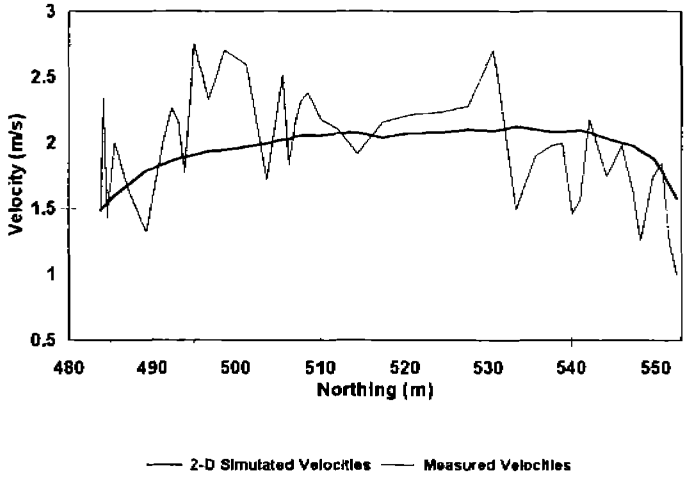

Site 61/63 Deep Beds E, Q = 22444 cfs


Site 61/63 Deep Beds G, Q = 22444 cfs

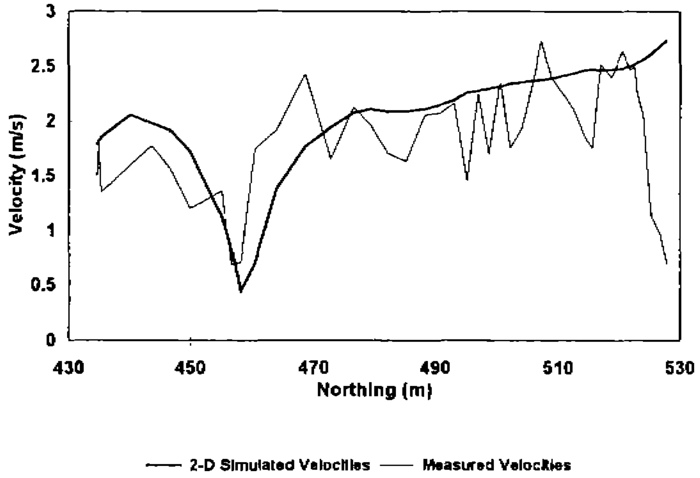

Site 61/63 Deep Beds F, Q = 22444 cfs


Site 61/63 Deep Beds H, Q = 22444 cfs

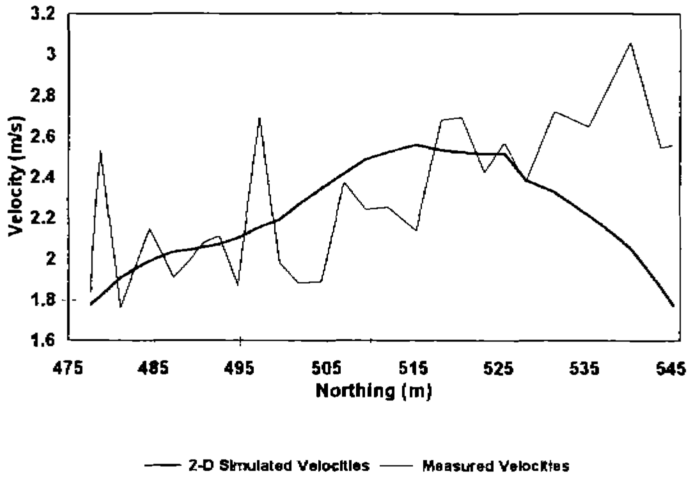
Site 61/63 Deep Beds I, Q = 22444 cfs



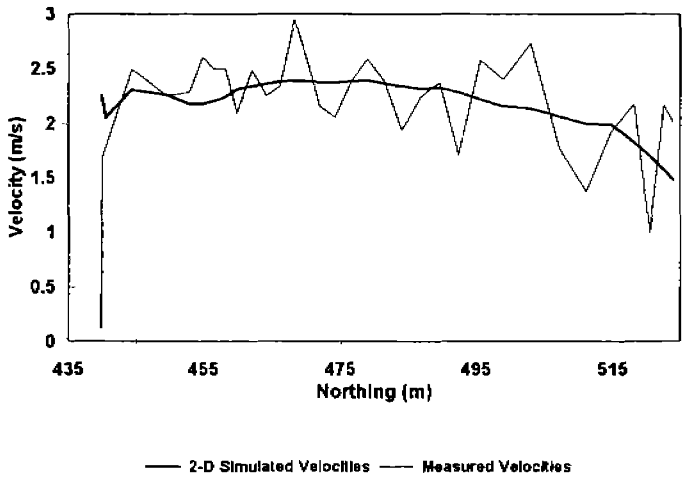
Site 61/63 Deep Beds K, Q = 22444 cfs



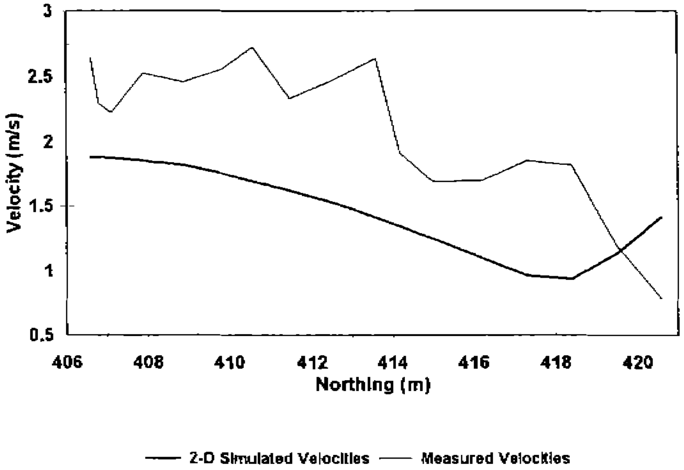
Site 61/63 Deep Beds J, Q = 22444 cfs



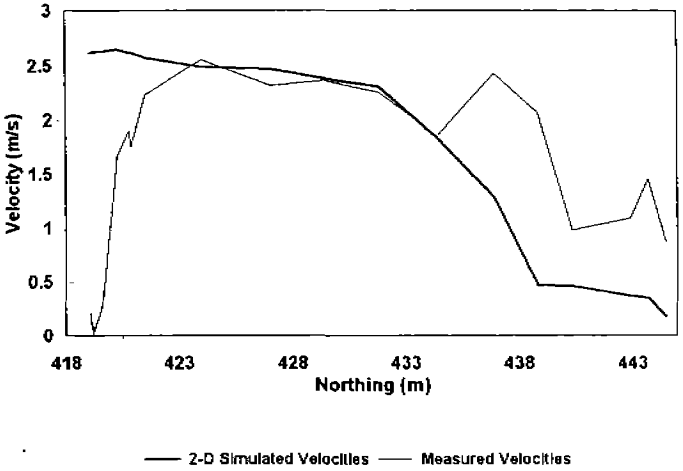
Site 61/63 Deep Beds L, Q = 22444 cfs



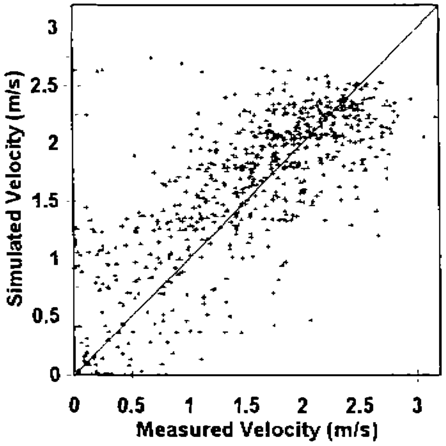
Site 61/63 Deep Beds M, Q = 22444 cfs



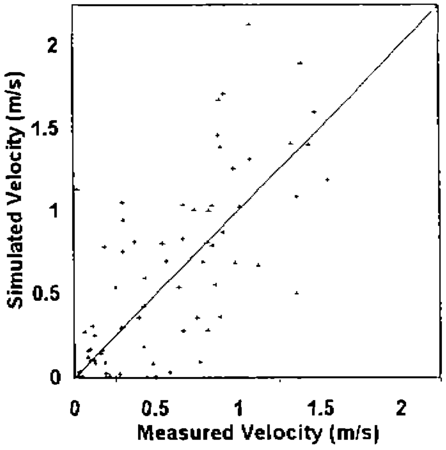
Site 61/63 Deep Beds N, Q = 22444 cfs



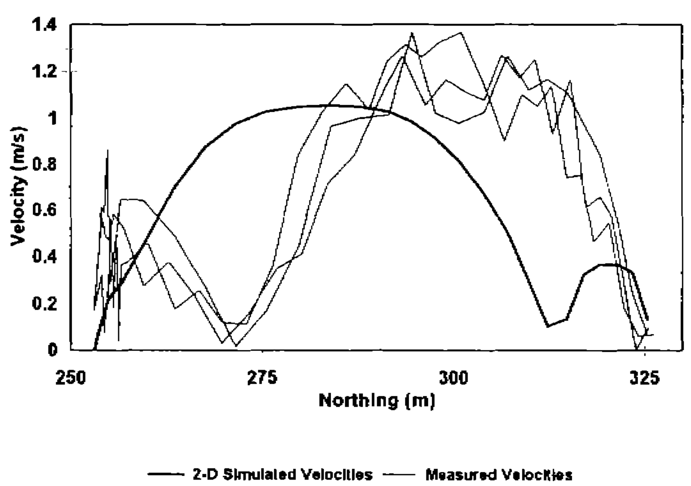
Site 61/63
All Validation Velocities

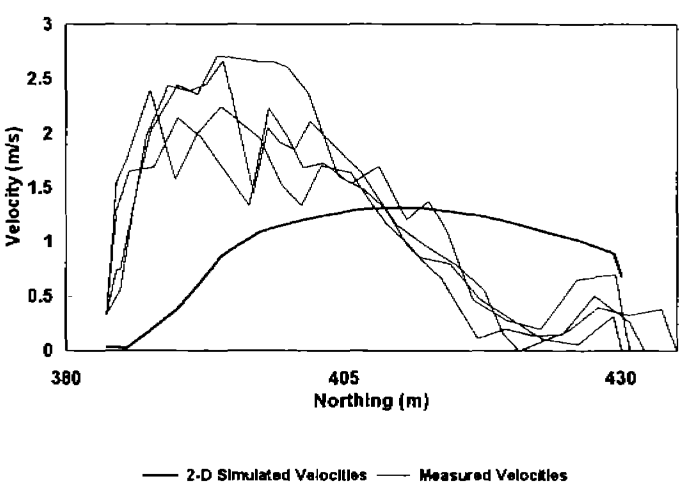


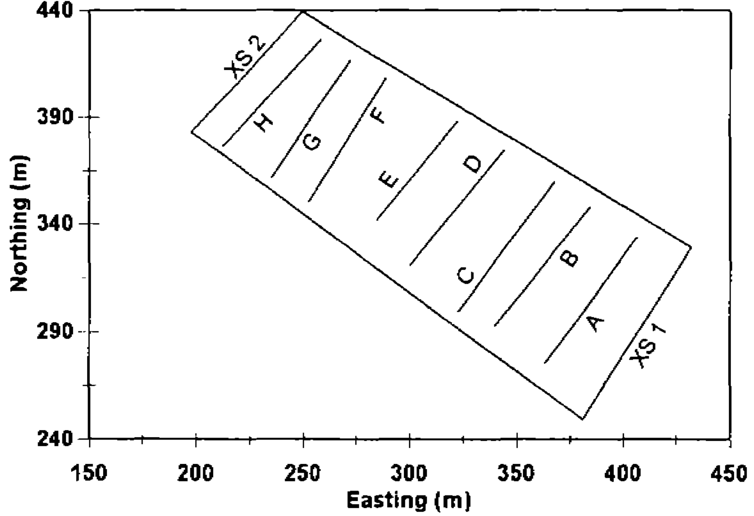
Site 61/63
Between Transect Non-ADCP Velocities



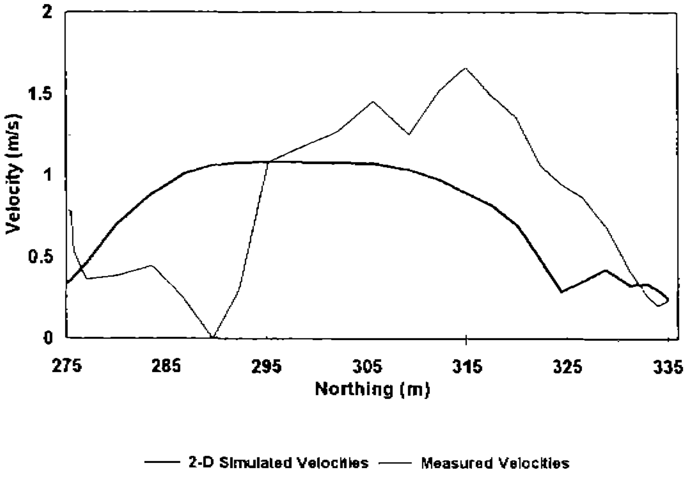
Study Site 52


Site 52 XS1, Q = 13109 cfs

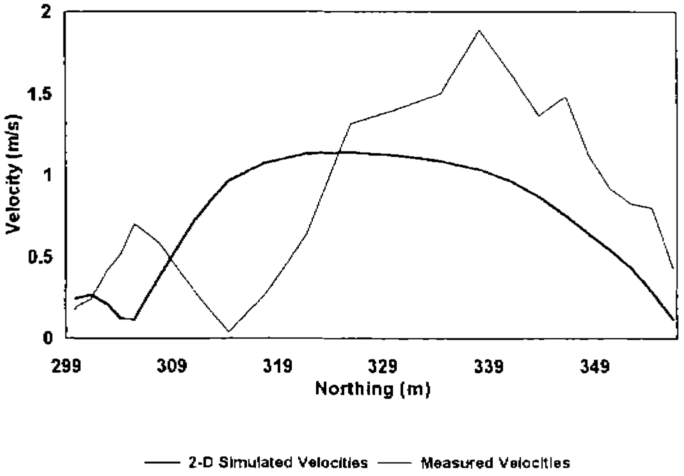

Site 52 XS2, Q = 13109 cfs


Site 52

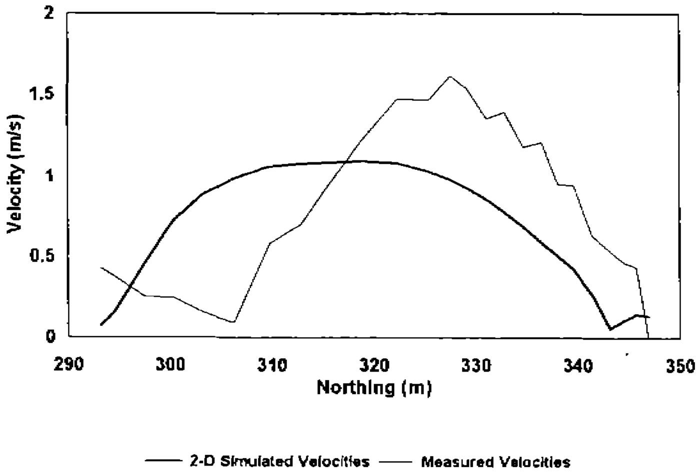
Site 52 Deep Beds A, Q = 13109 cfs



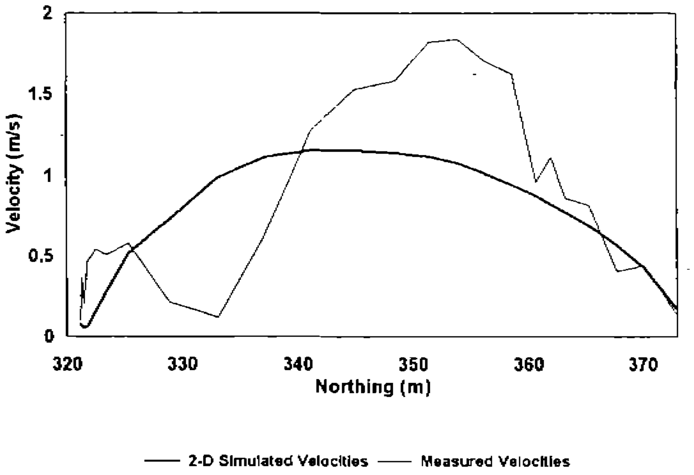
Site 52 Deep Beds C, Q = 13109 cfs



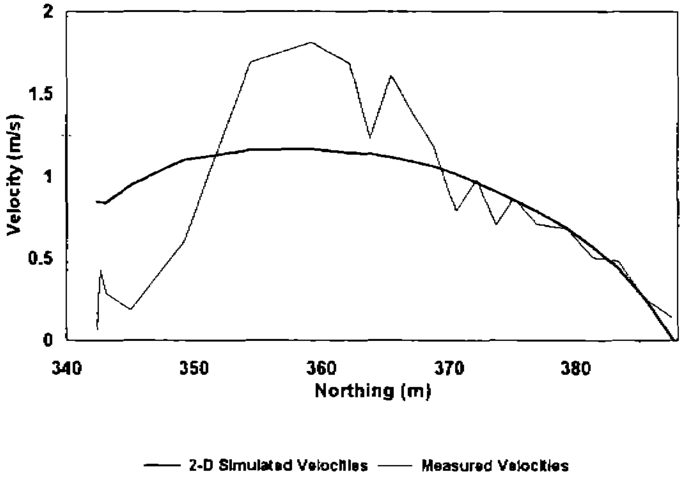
Site 52 Deep Beds B, Q = 13109 cfs



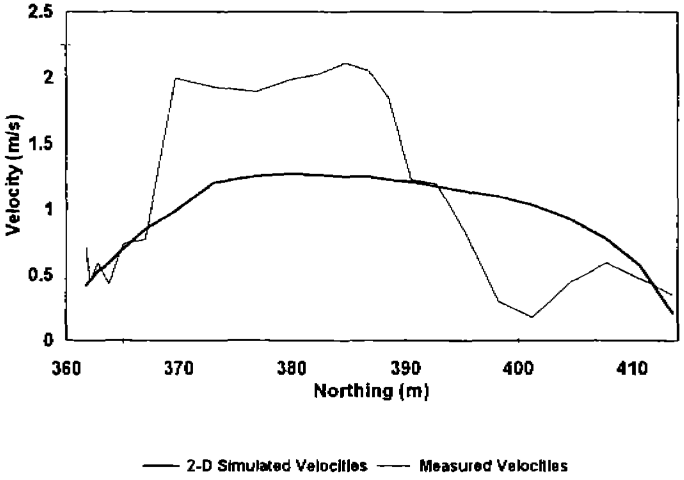
Site 52 Deep Beds D, Q = 13109 cfs



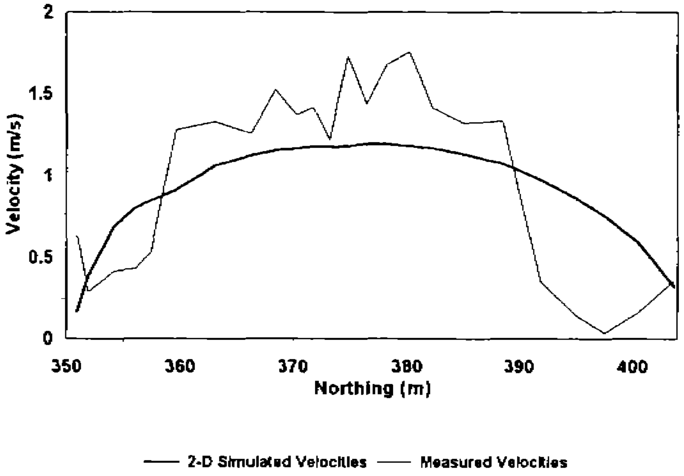
Site 52 Deep Beds E, Q = 13109 cfs



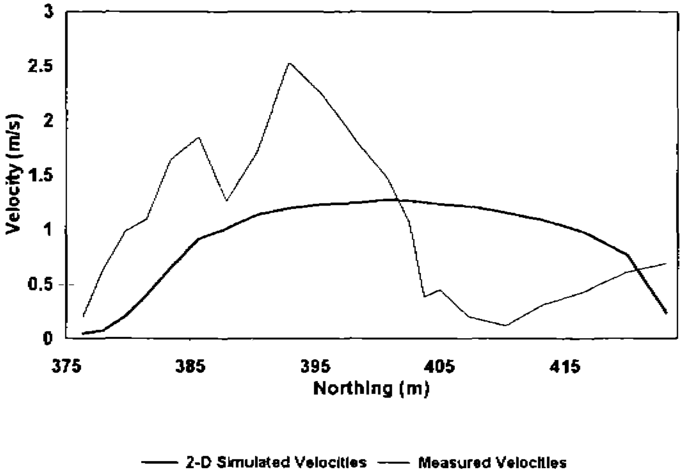
Site 52 Deep Beds G, Q = 13109 cfs



Site 52 Deep Beds F, Q = 13109 cfs

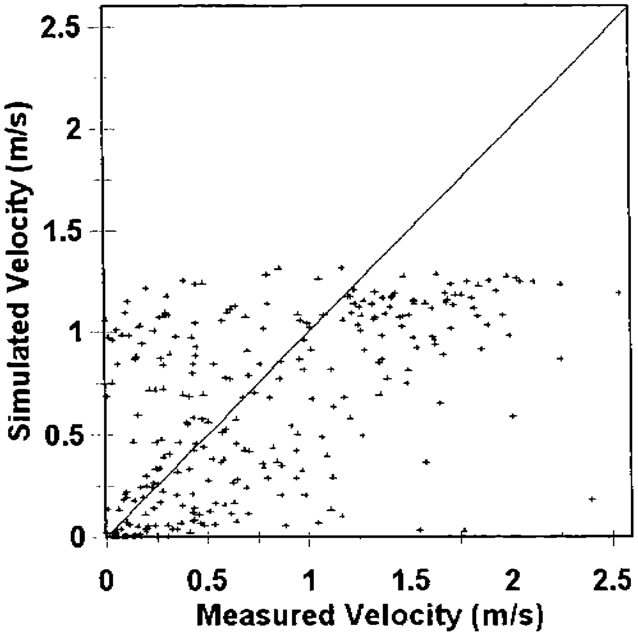


Site 52 Deep Beds H, Q = 13109 cfs



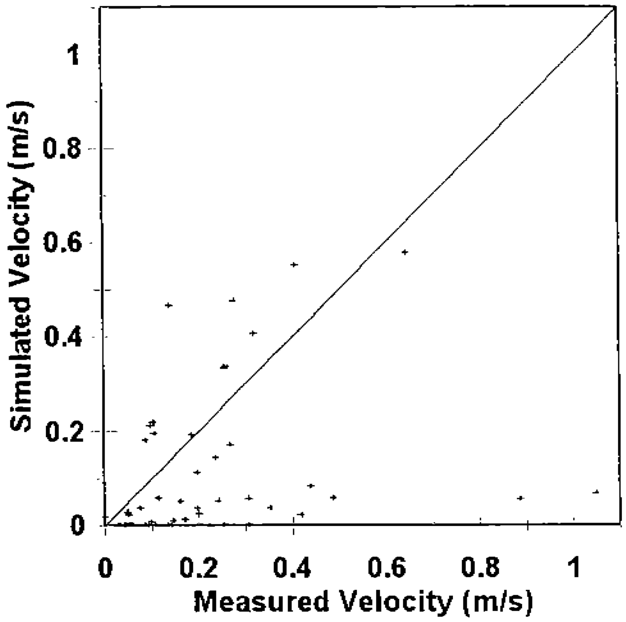
Site 52

All Validation Velocities

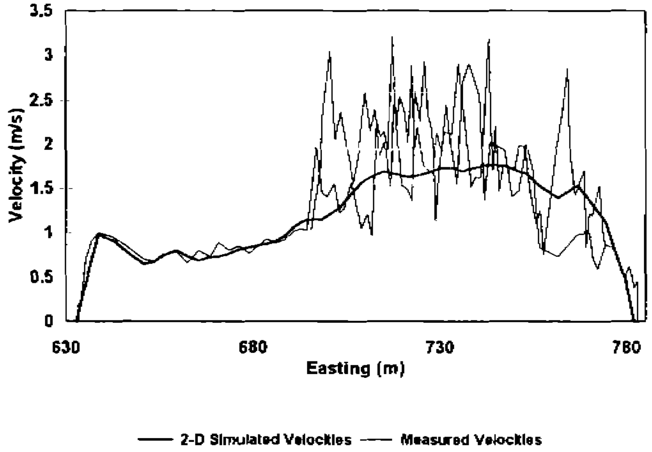


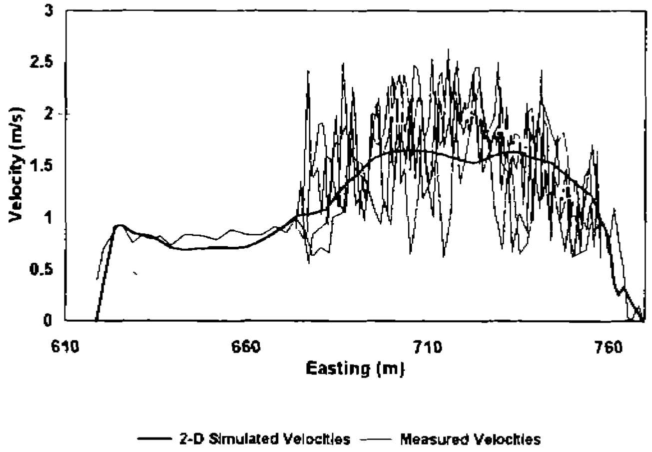
Site 52

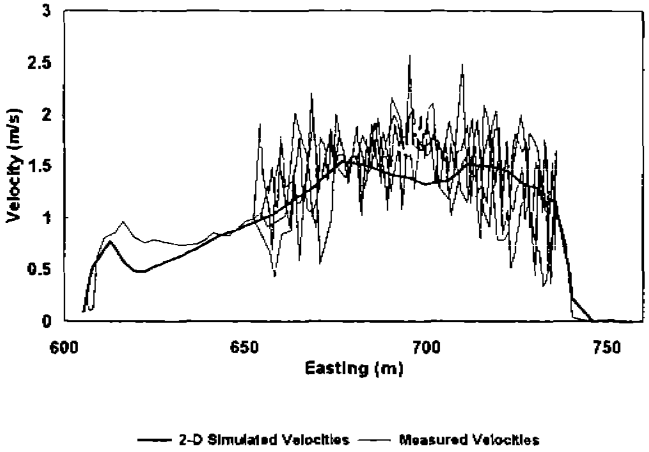
Between Transect Non-ADCP Velocities

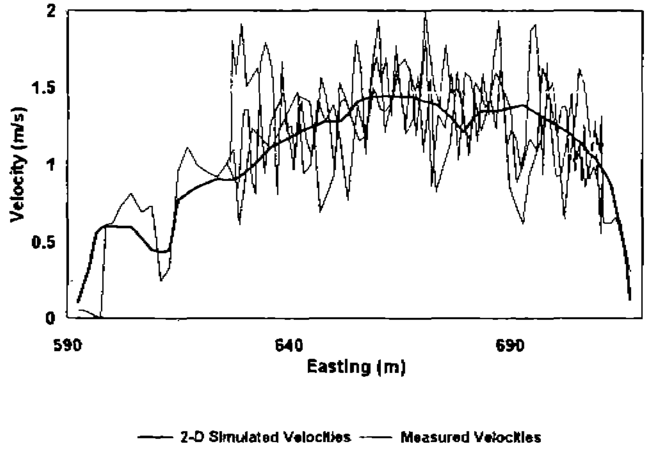


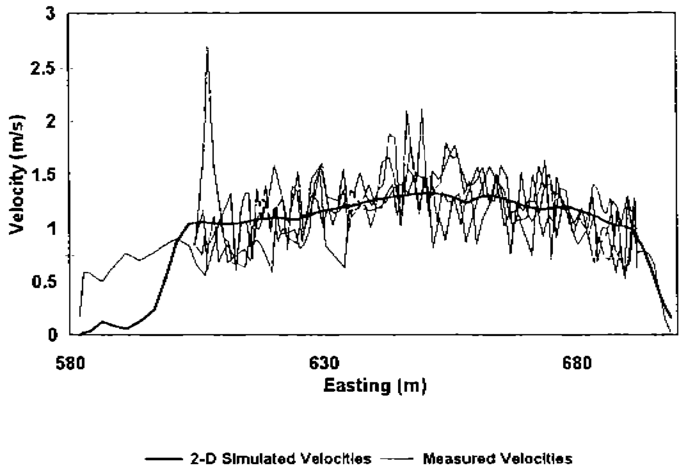
Hawes Study Site

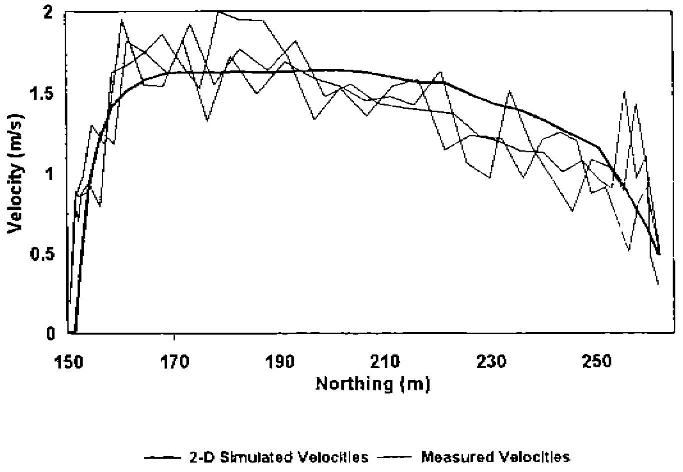

Hawes Study Site XS2, Q = 8293 cfs

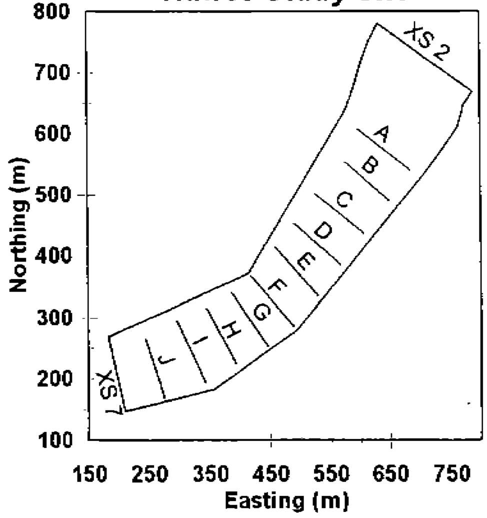

Hawes Study Site XS3, Q = 8320 cfs

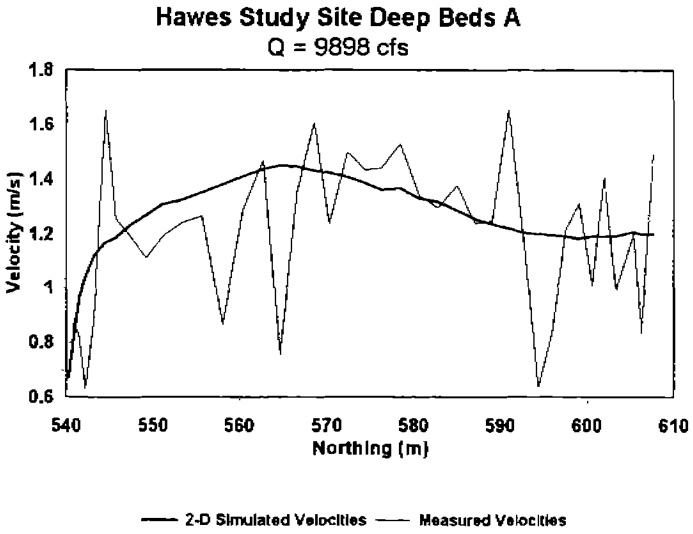

Hawes Study Site XS4, Q = 8320 cfs

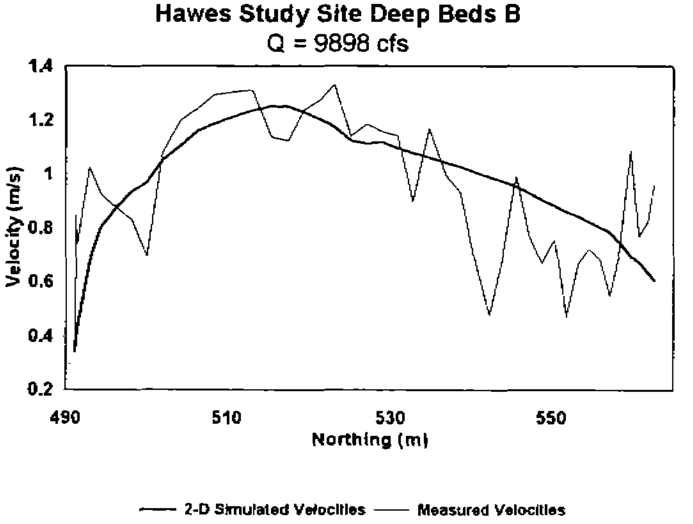

Hawes Study Site XS5, Q = 8320 cfs

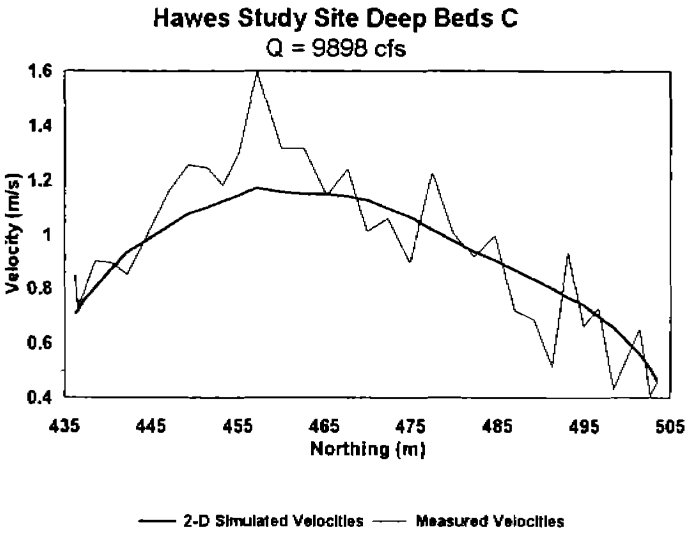

Hawes Study Site XS6, Q = 8320 cfs

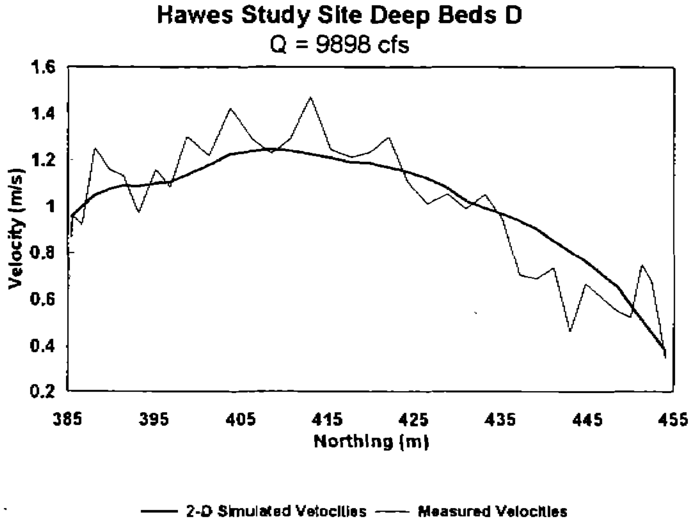

Hawes Study Site XS7, Q = 8320 cfs


Hawes Study Site

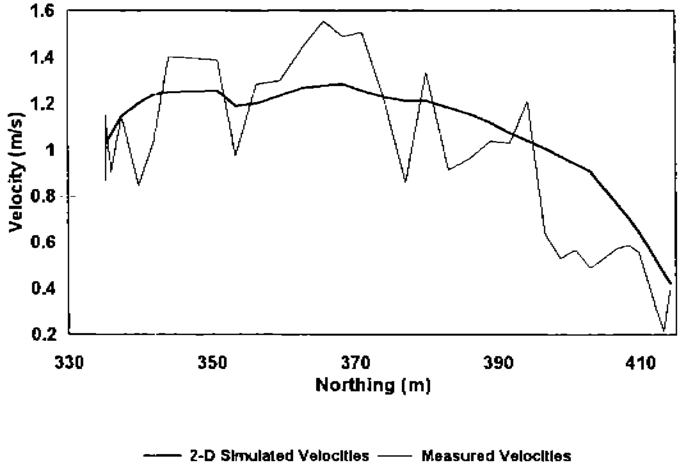

Hawes Study Site Deep Beds A
Q = 9898 cfs
Velocity (m/s)
1.8
1.6
1.4
1.2
1
0.8
0.6
540
550
560
570
580
590
600
610
Northing (m)
2-D Simulated Velocities
Measured Velocities


Hawes Study Site Deep Beds B
Q = 9898 cfs
Velocity (m/s)
1.4
1.2
1
0.8
0.6
0.4
0.2
490
510
530
550
Northing (m)
2-D Simulated Velocities
Measured Velocities

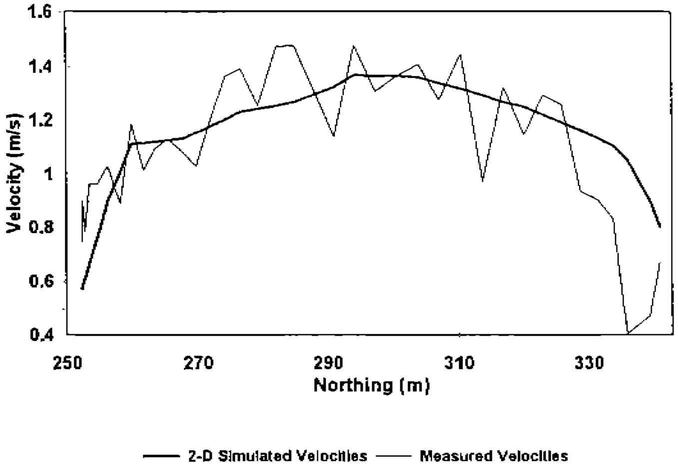

Hawes Study Site Deep Beds C
Q = 9898 cfs
Velocity (m/s)
1.6
1.4
1.2
1
0.8
0.6
0.4
435
445
455
465
475
485
495
505
Northing (m)
2-D Simulated Velocities
Measured Velocities


Hawes Study Site Deep Beds D
Q = 9898 cfs
Velocity (m/s)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
385
395
405
415
425
435
445
455
Northing (m)
2-D Simulated Velocities
Measured Velocities

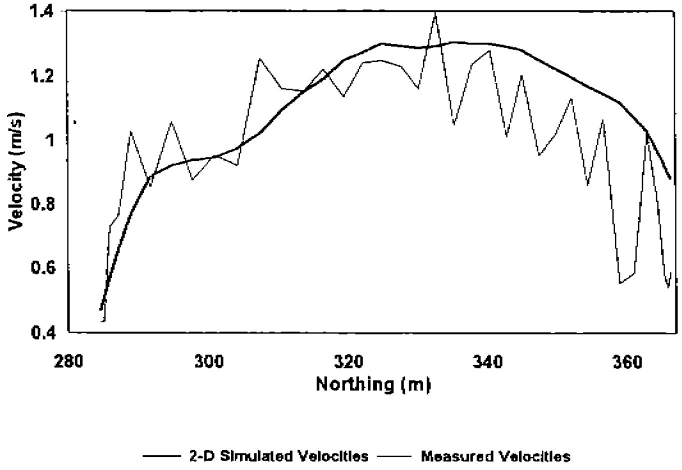
Hawes Study Site Deep Beds E
Q = 9898 cfs



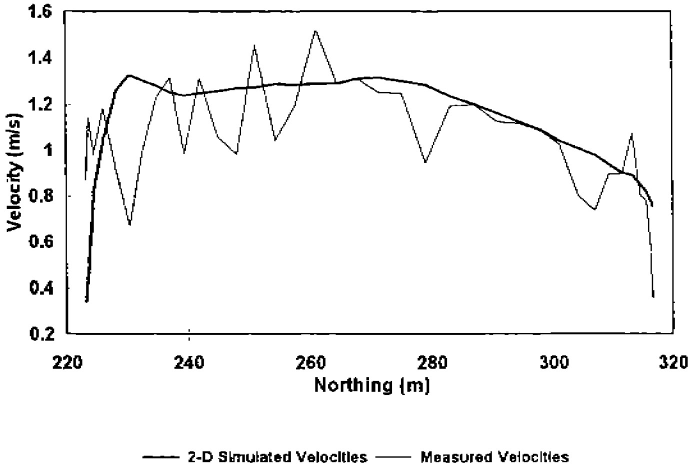
Hawes Study Site Deep Beds G
Q = 9898 cfs



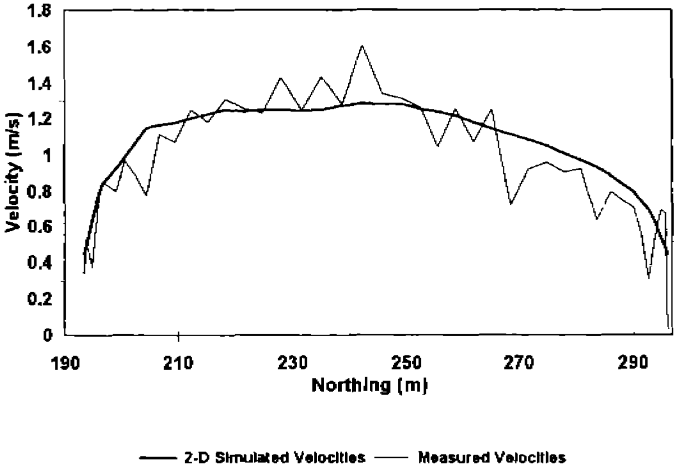
Hawes Study Site Deep Beds F
Q = 9898 cfs



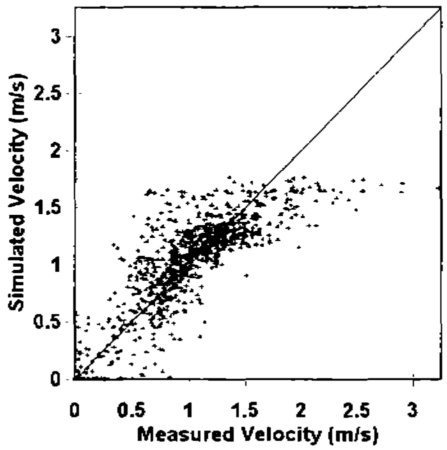
Hawes Study Site Deep Beds H
Q = 9898 cfs



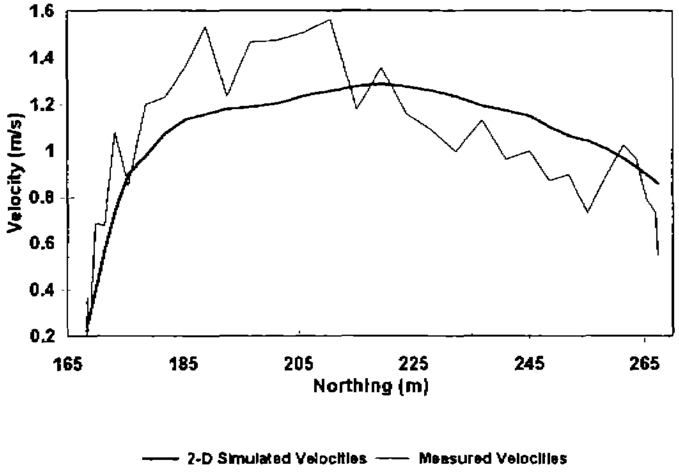
Hawes Study Site Deep Beds I
Q = 9898 cfs



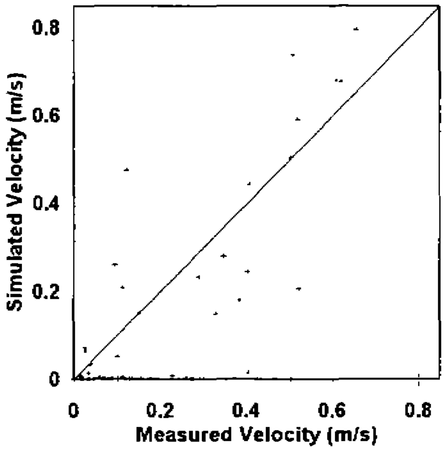
Hawes Study Site
All Validation Velocities



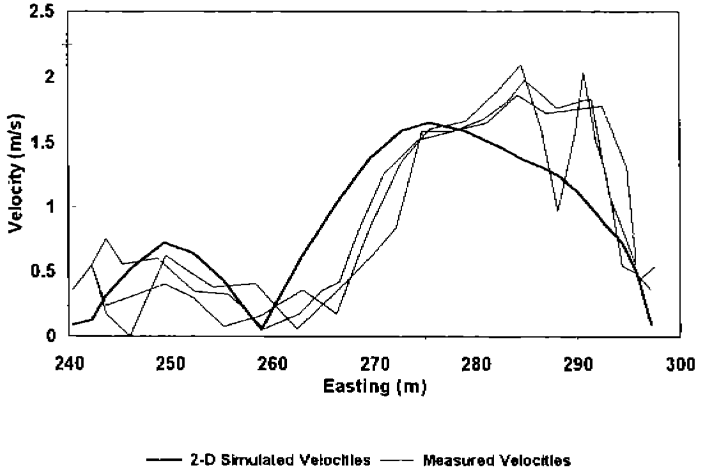
Hawes Study Site Deep Beds J
Q = 9898 cfs

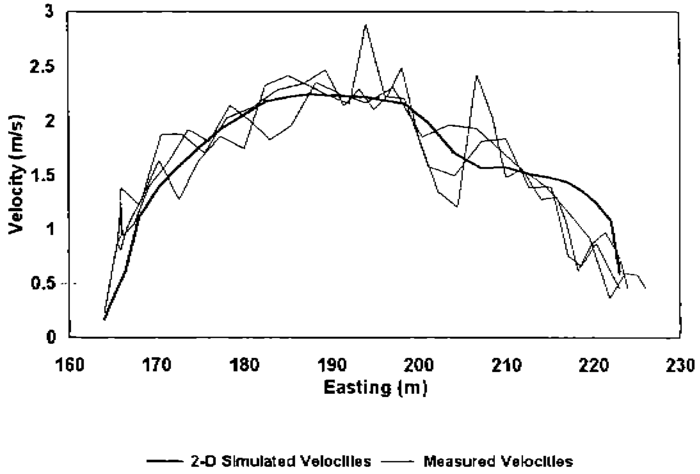


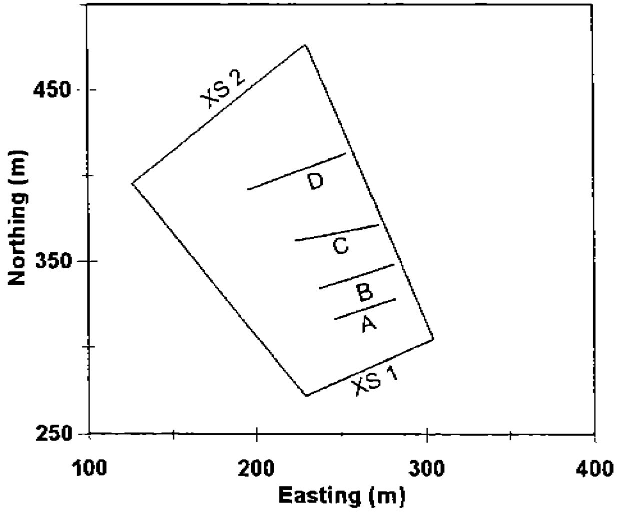
Hawes Study Site
Between Transect Non-ADCP Velocities

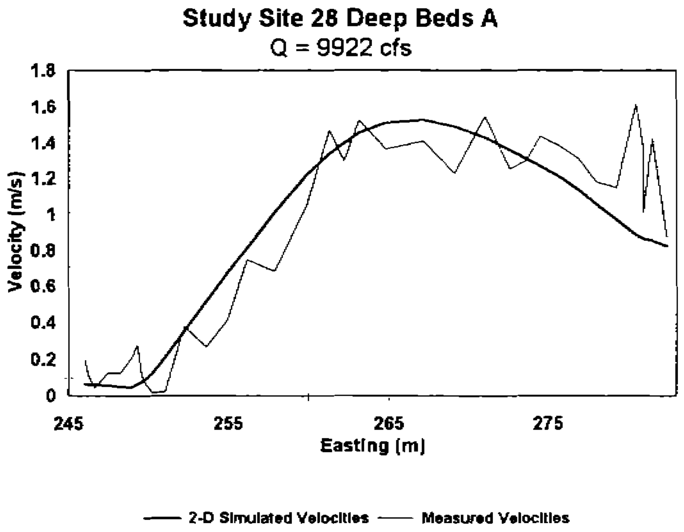


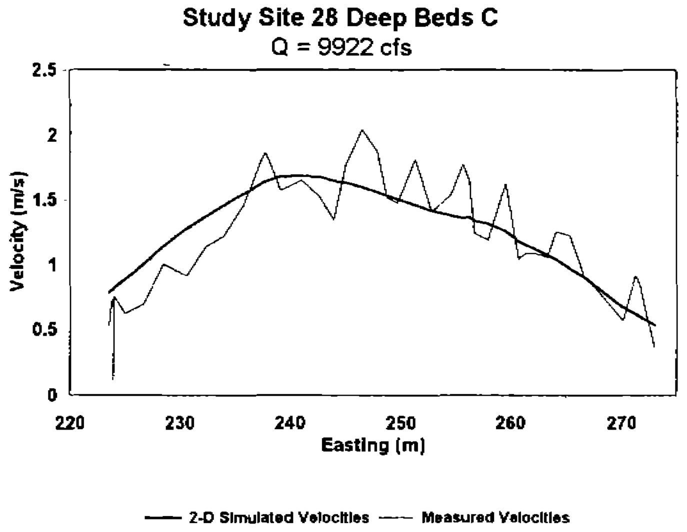
Study Site 28

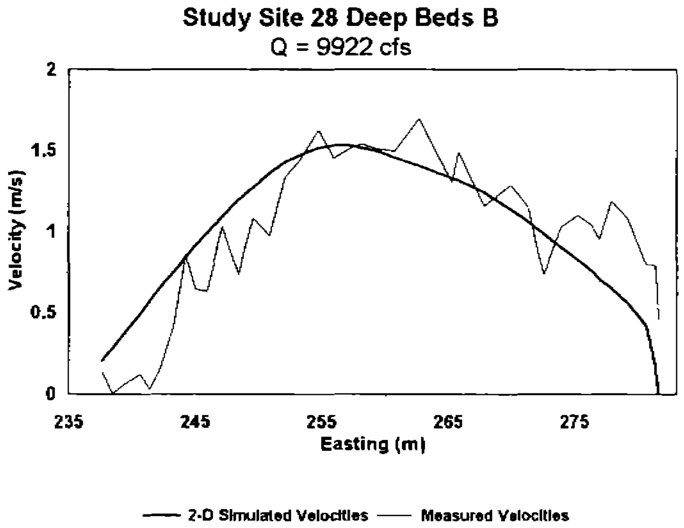

Study Site 28 XS1, Q = 15079 cfs

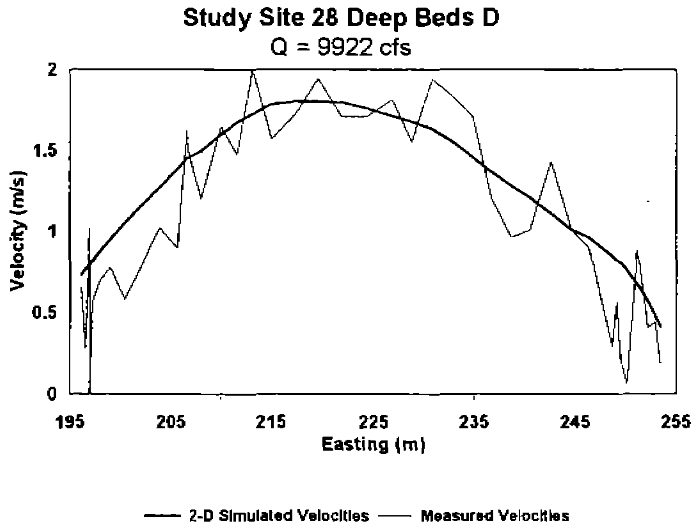

Study Site 28 XS2, Q = 15079 cfs


Study Site 28

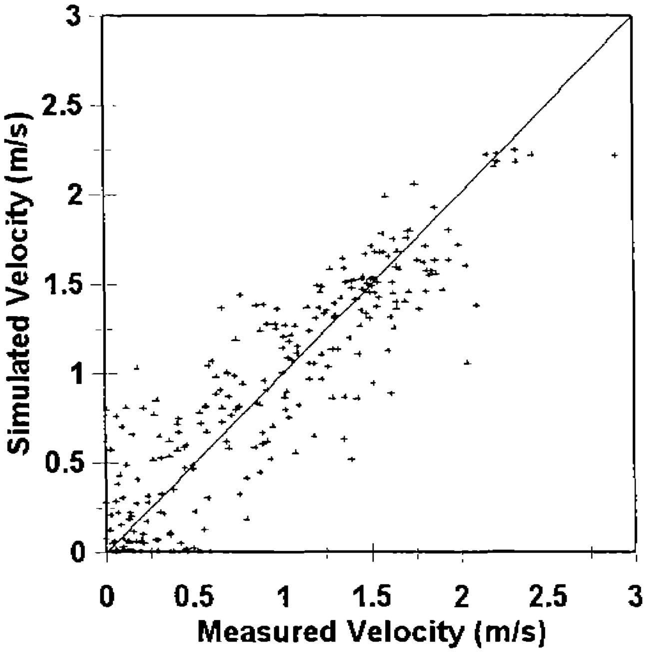

Study Site 28 Deep Beds A
Q = 9922 cfs


Study Site 28 Deep Beds C
Q = 9922 cfs

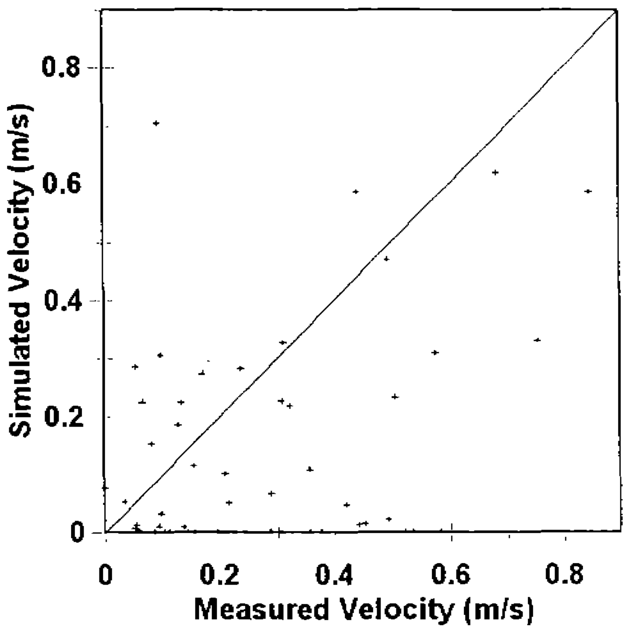

Study Site 28 Deep Beds B
Q = 9922 cfs


Study Site 28 Deep Beds D
Q = 9922 cfs

Study Site 28
All Validation Velocities

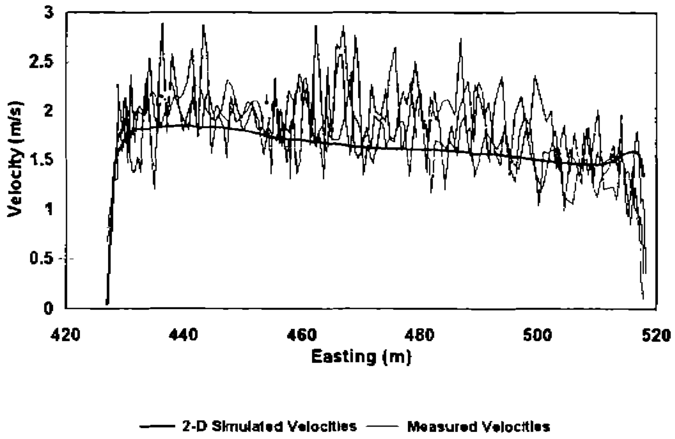


Study Site 28
Between Transect Non-ADCP Velocities

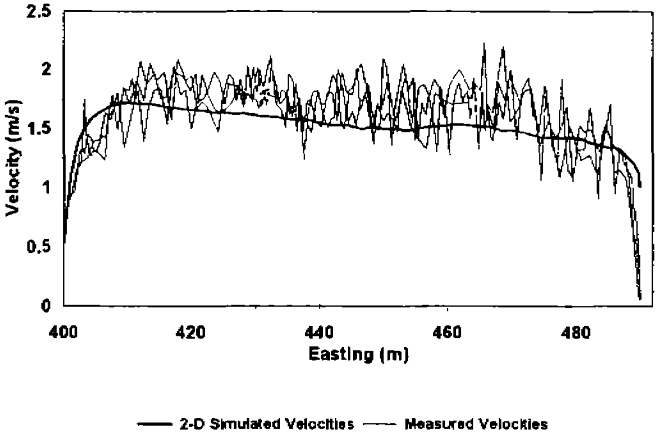


Powerline Study Site

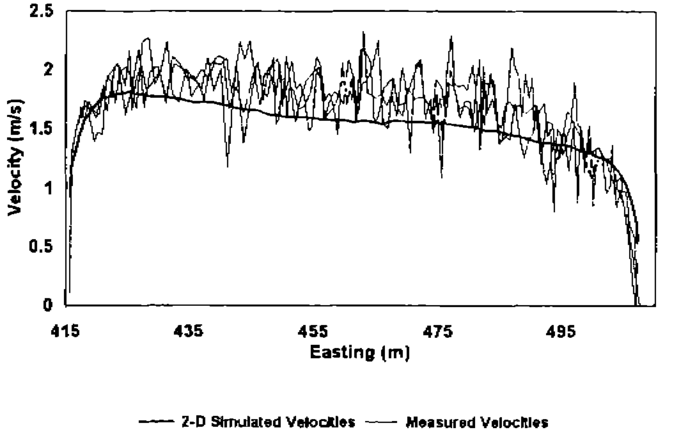
Powerline Study Site XS2
Q = 15097 cfs



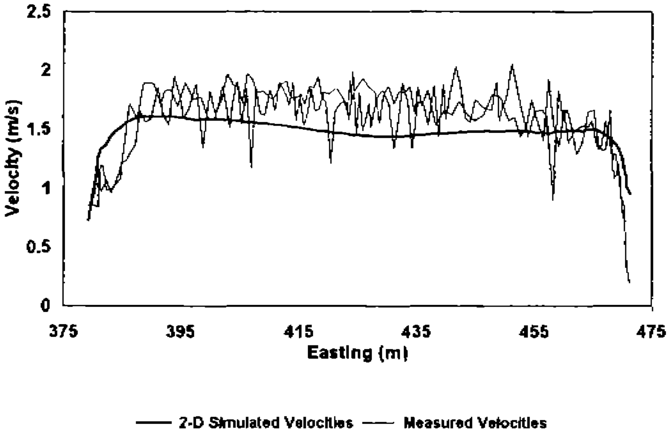
Powerline Study Site XS4
Q = 14628 cfs

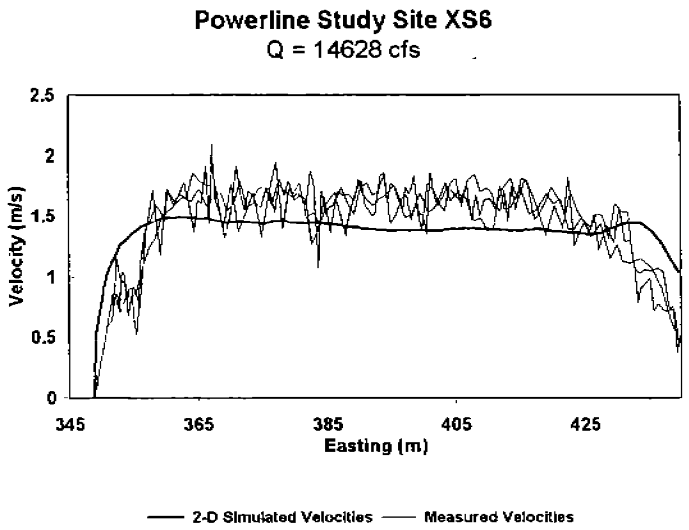


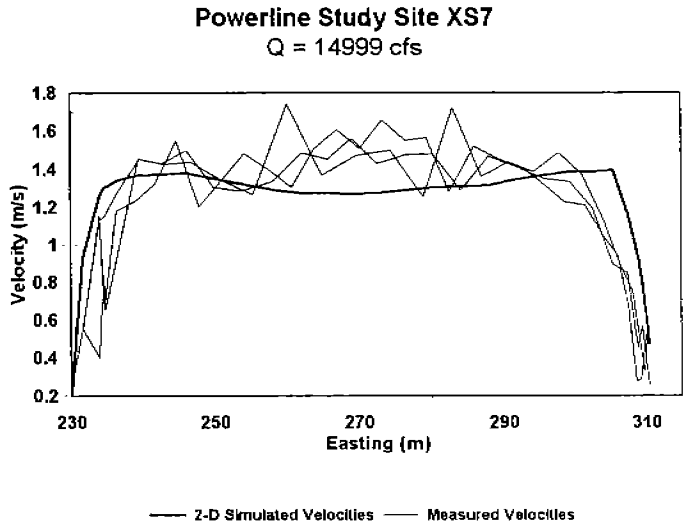
Powerline Study Site XS3
Q = 14628 cfs

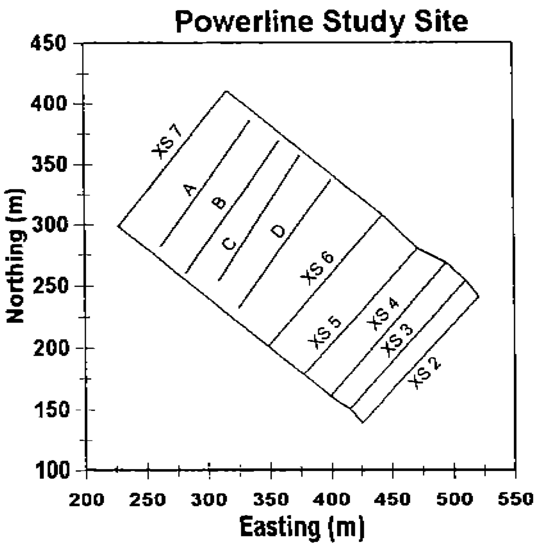


Powerline Study Site XS5
Q = 14628 cfs

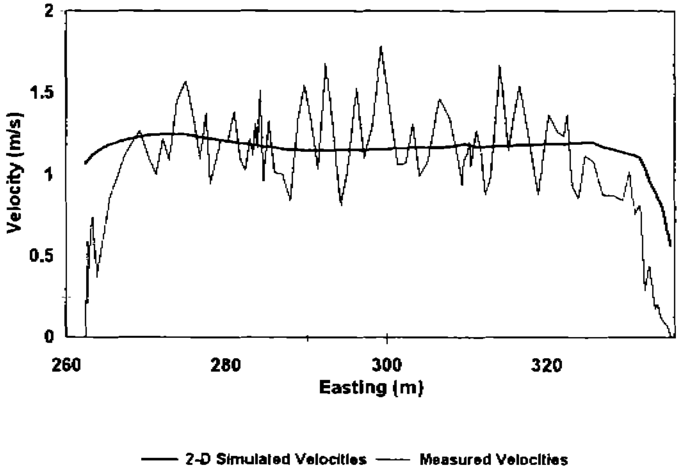



Powerline Study Site XS6
Q = 14628 cfs

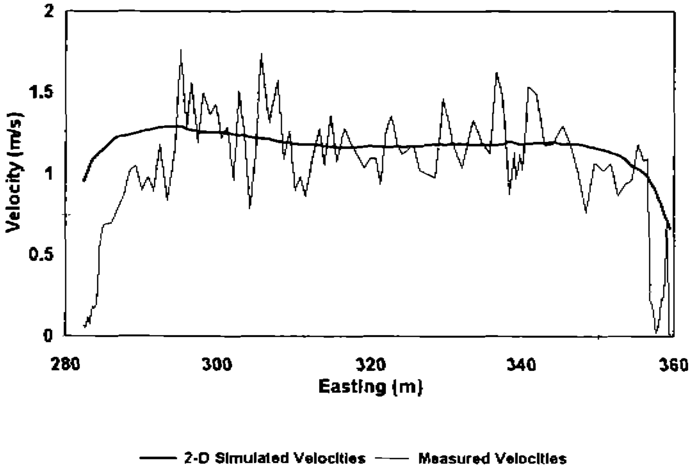

Powerline Study Site XS7
Q = 14999 cfs


Powerline Study Site

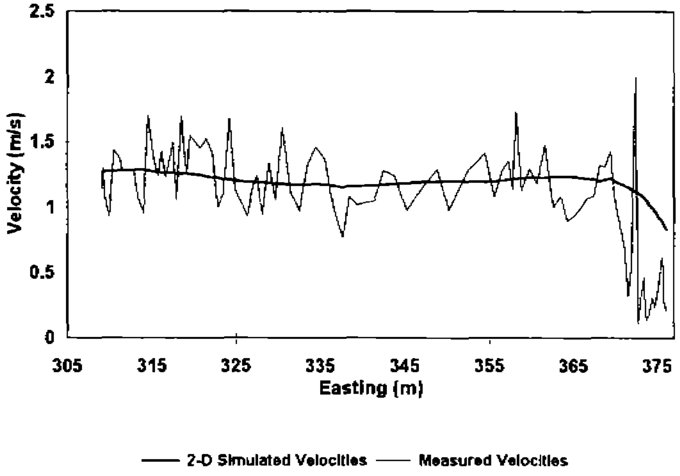
Powerline Study Site Deep Beds A
Q = 11135 cfs



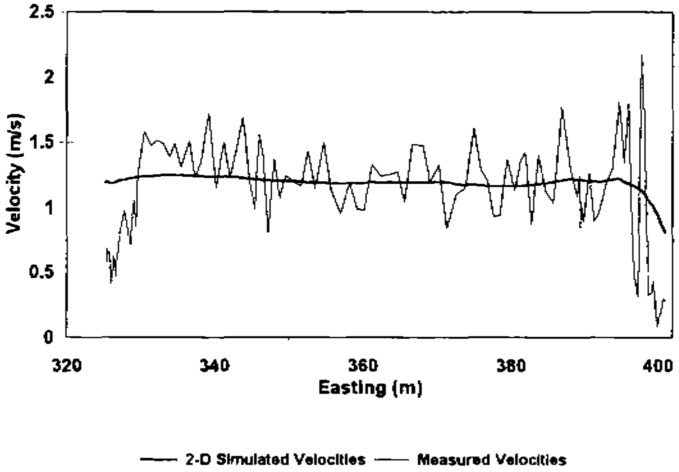
Powerline Study Site Deep Beds B
Q = 11135 cfs



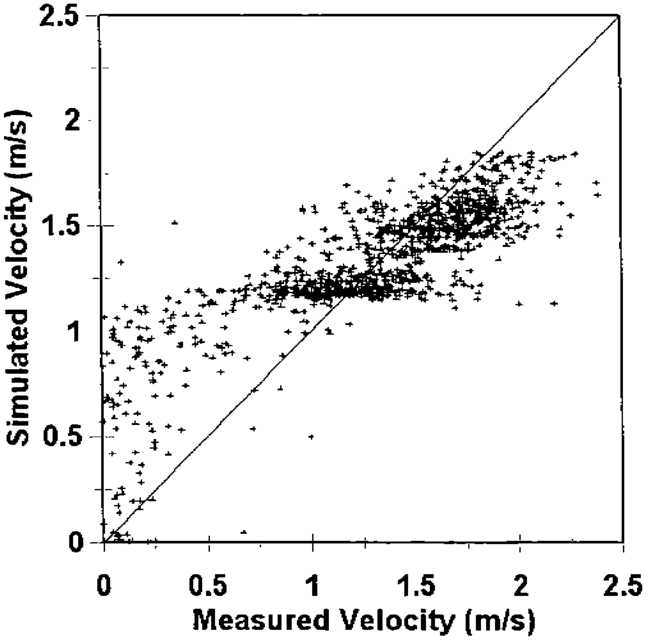
Powerline Study Site Deep Beds C
Q = 11135 cfs



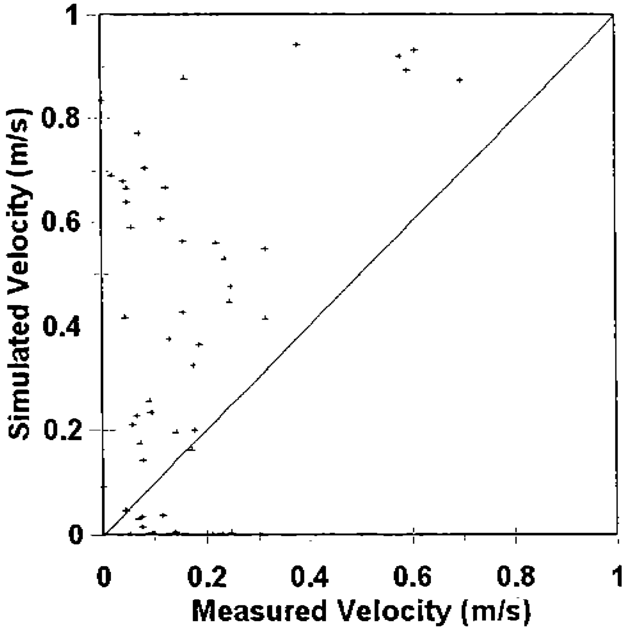
Powerline Study Site Deep Beds D
Q = 11135 cfs



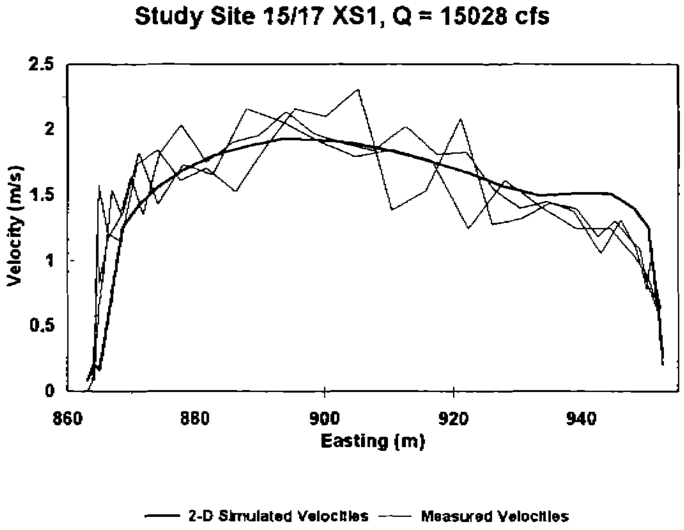
Powerline Study Site
All Validation Velocities

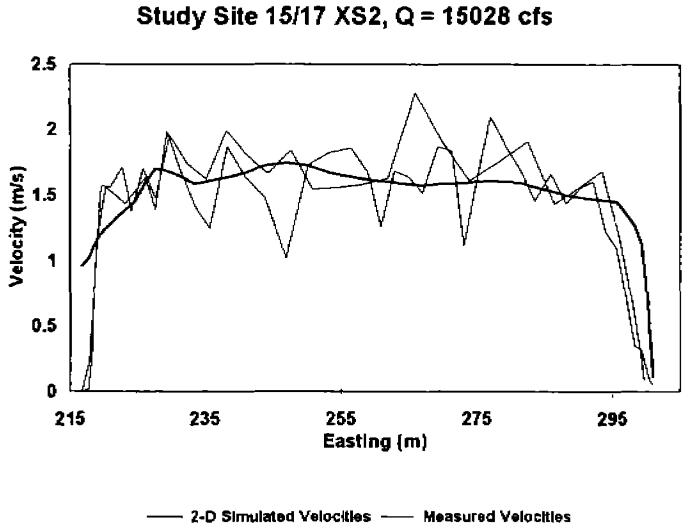


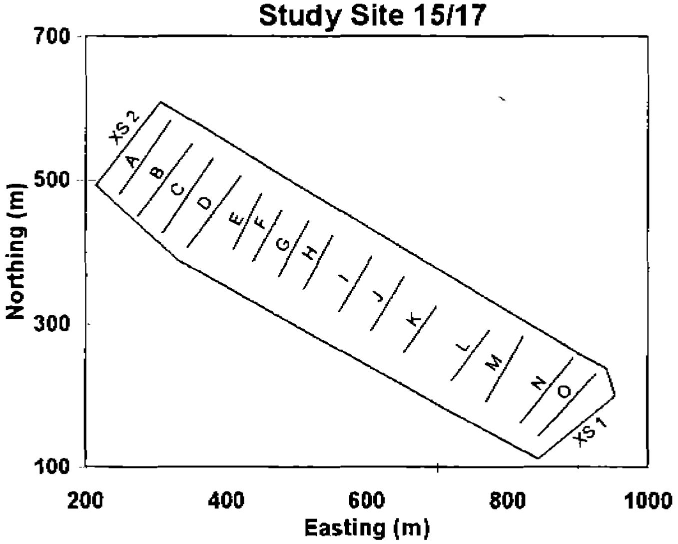
Powerline Study Site
Between Transect Non-ADCP Velocities

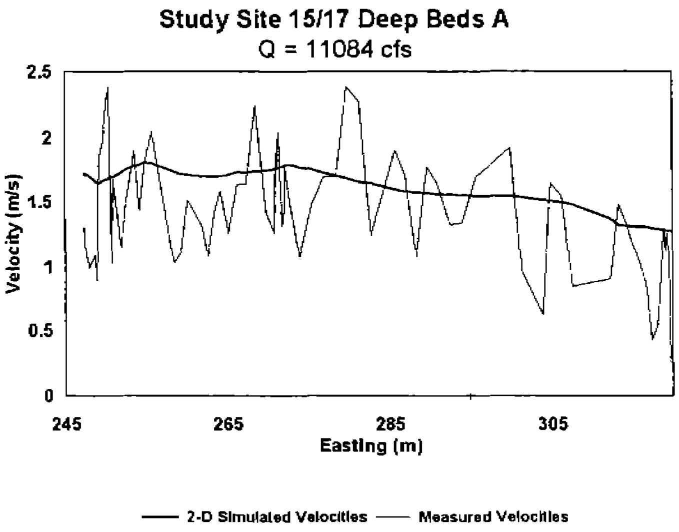


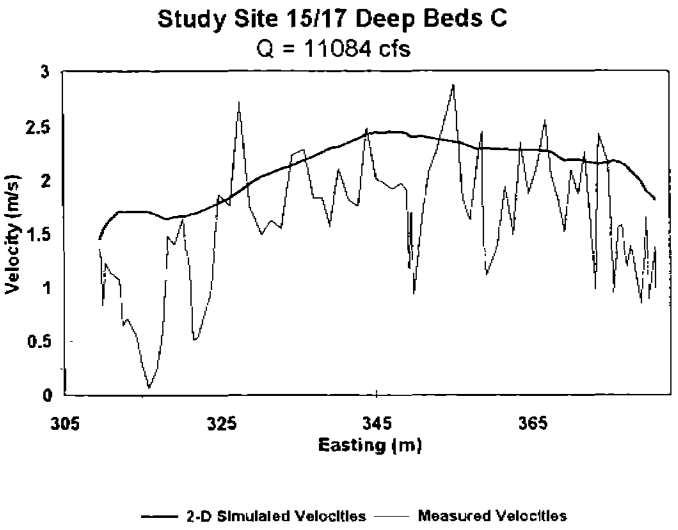
Study Site 15/17

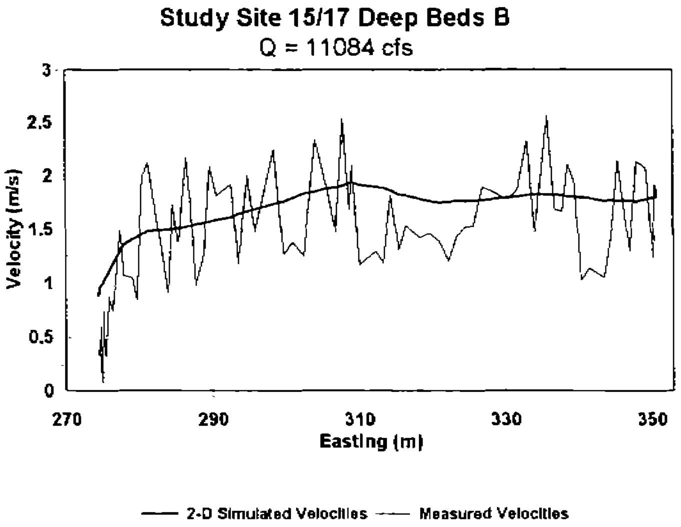


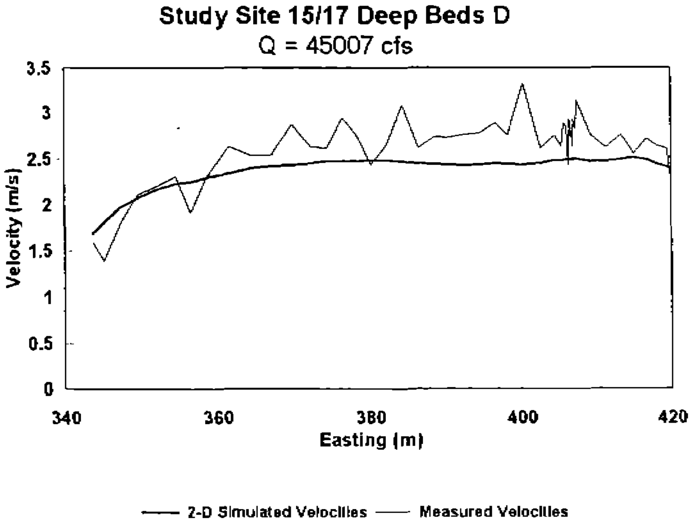


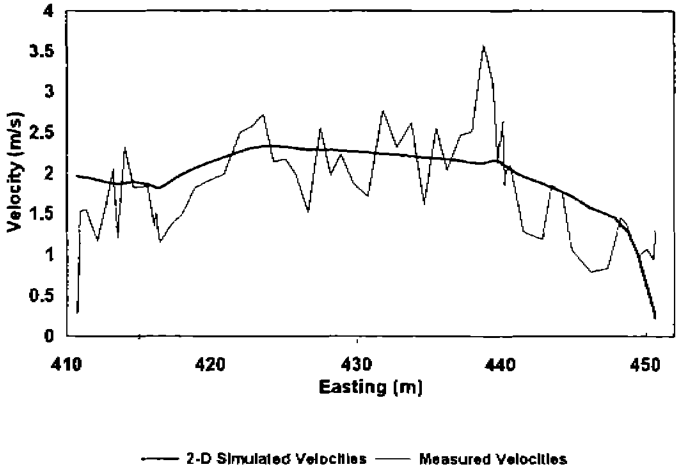


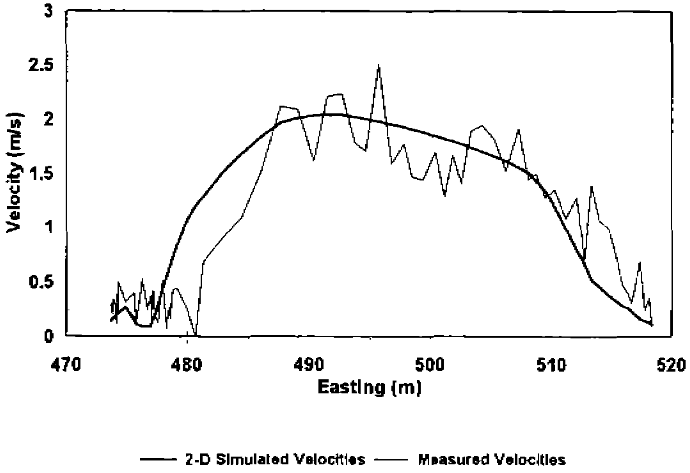

Study Site 15/17 Deep Beds A
Q = 11084 cfs

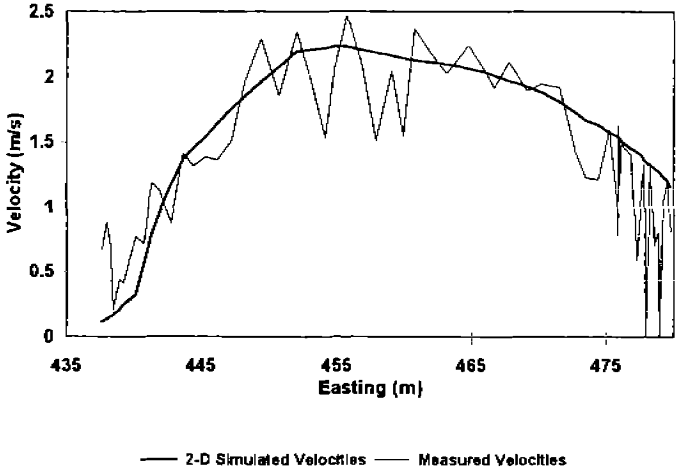

Study Site 15/17 Deep Beds C
Q = 11084 cfs

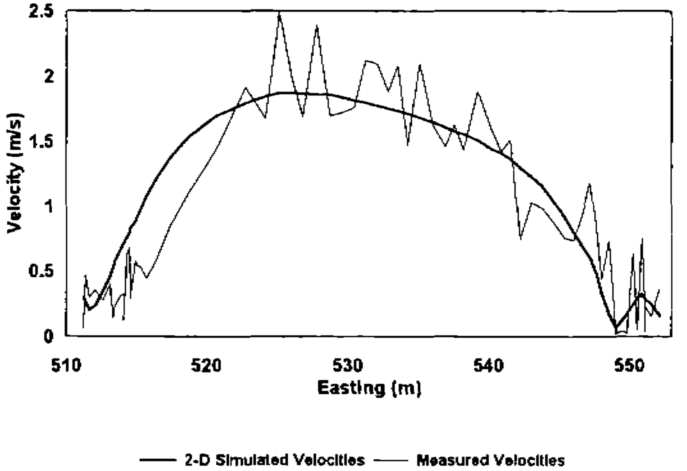

Study Site 15/17 Deep Beds B
Q = 11084 cfs

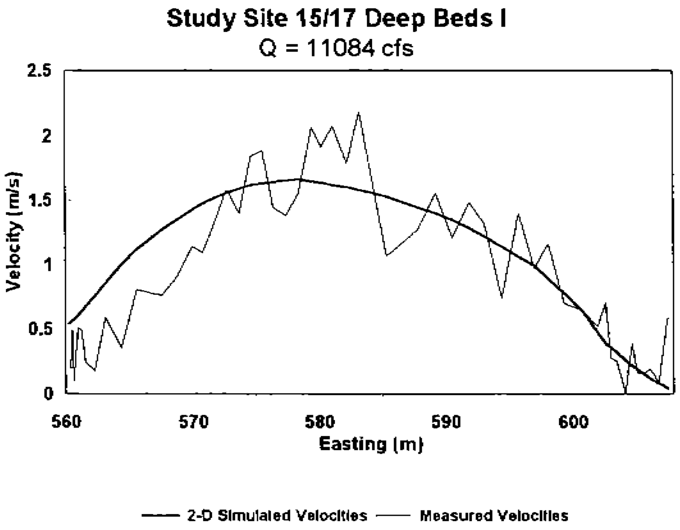

Study Site 15/17 Deep Beds D
Q = 45007 cfs

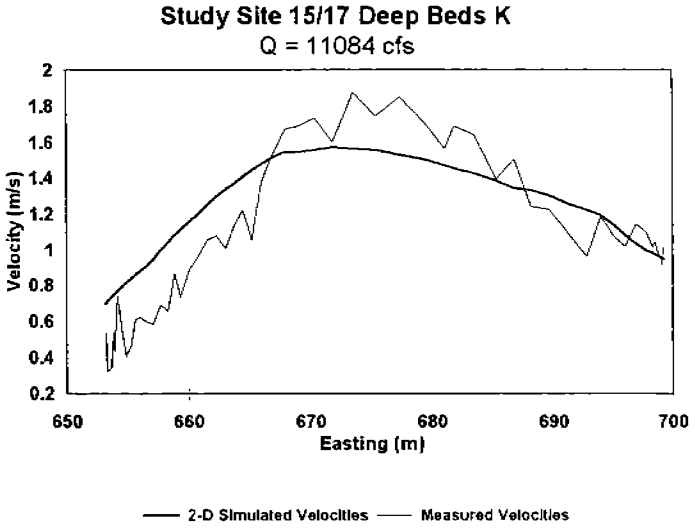

Study Site 15/17 Deep Beds E
Q = 11084 cfs

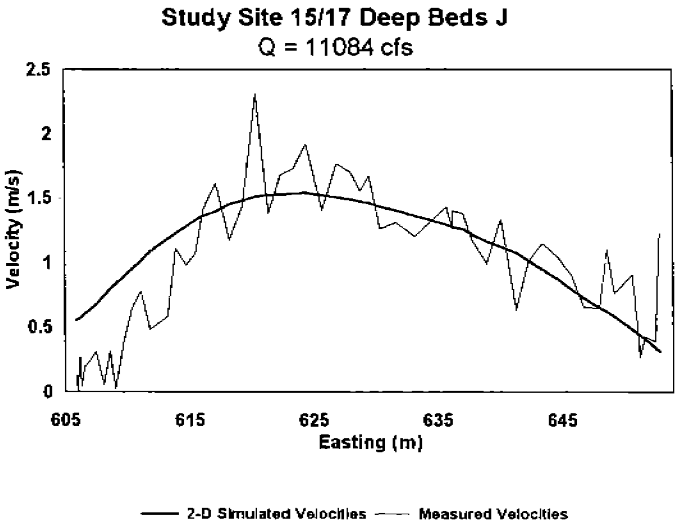

Study Site 15/17 Deep Beds G
Q = 11084 cfs

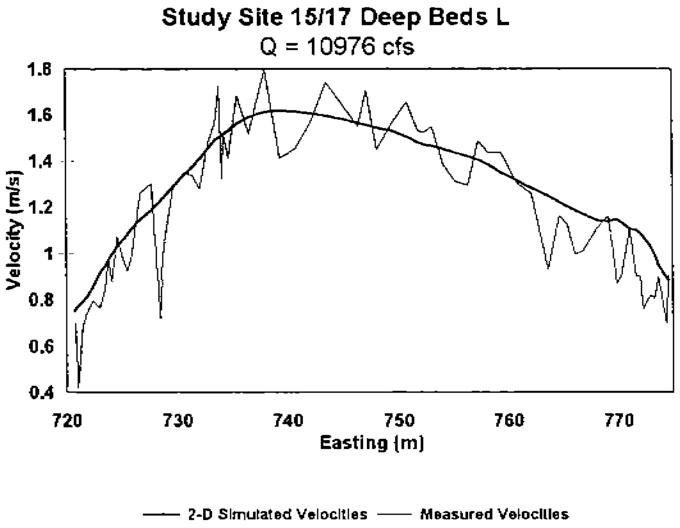

Study Site 15/17 Deep Beds F
Q = 11084 cfs

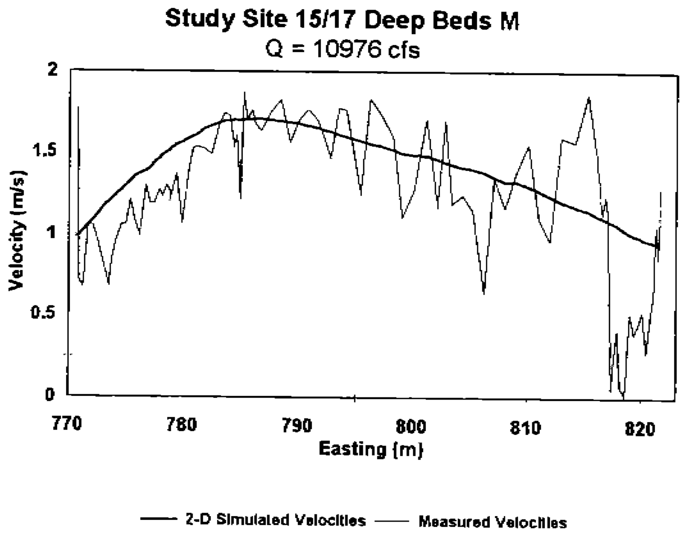

Study Site 15/17 Deep Beds H
Q = 11084 cfs

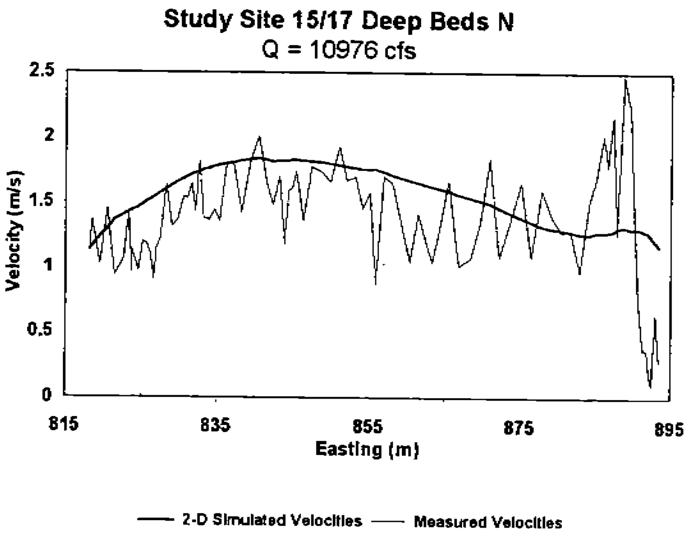

Study Site 15/17 Deep Beds I
Q = 11084 cfs

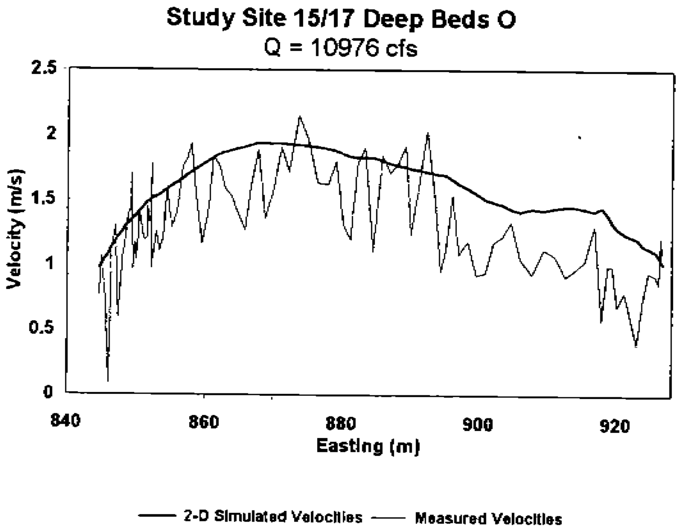

Study Site 15/17 Deep Beds K
Q = 11084 cfs


Study Site 15/17 Deep Beds J
Q = 11084 cfs

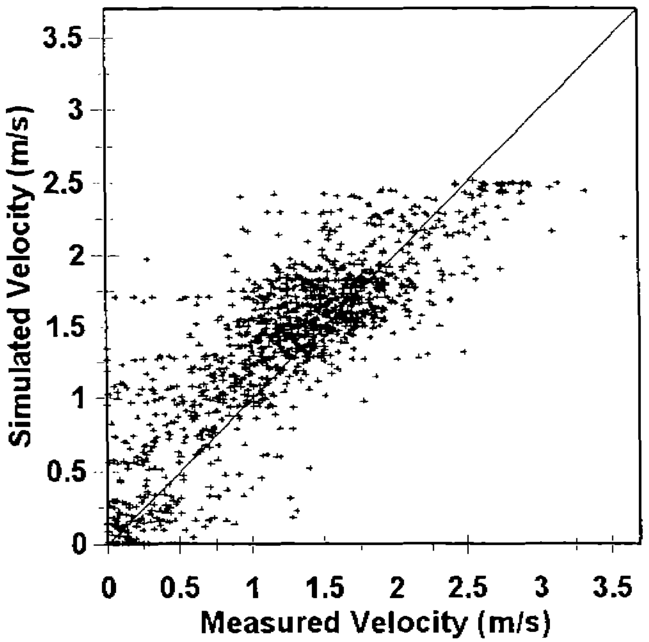

Study Site 15/17 Deep Beds L
Q = 10976 cfs


Study Site 15/17 Deep Beds M
Q = 10976 cfs
Velocity (m/s)
2
1.5
1
0.5
0
770
780
790
800
810
820
Easting (m)
2-D Simulated Velocities
Measured Velocities

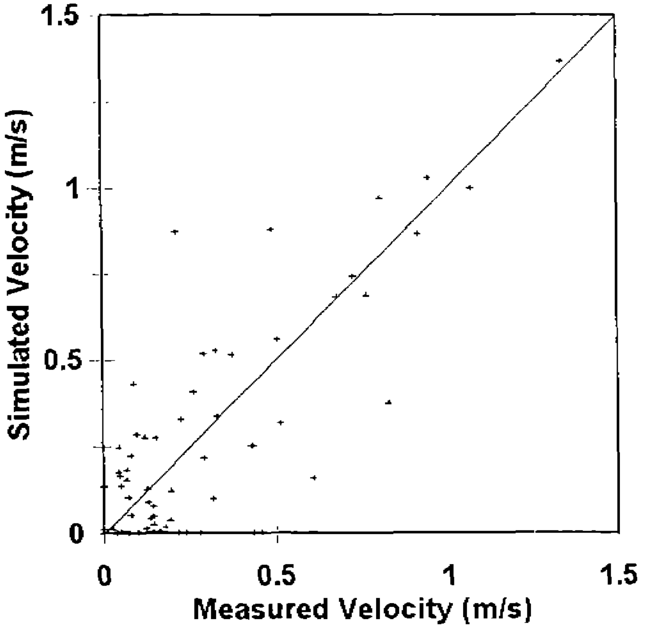

Study Site 15/17 Deep Beds N
Q = 10976 cfs
Velocity (m/s)
2.5
2
1.5
1
0.5
0
815
835
855
875
895
Easting (m)
2-D Simulated Velocities
Measured Velocities


Study Site 15/17 Deep Beds O
Q = 10976 cfs
Velocity (m/s)
2.5
2
1.5
1
0.5
0
840
860
880
900
920
Easting (m)
2-D Simulated Velocities
Measured Velocities

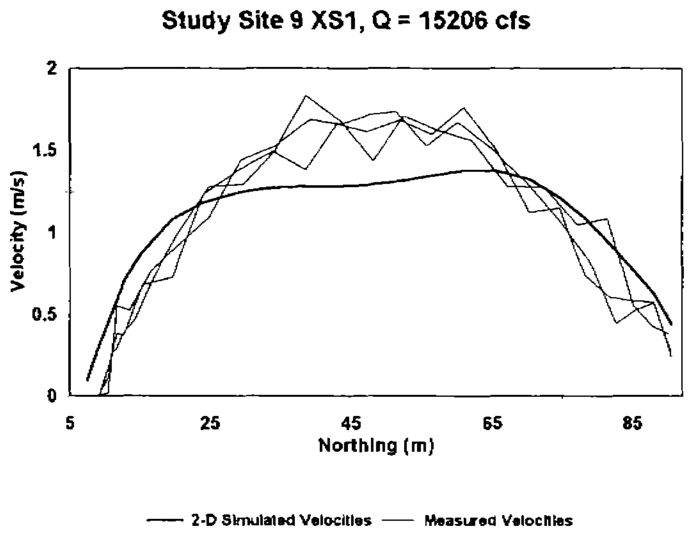
Study Site 15/17
All Validation Velocities

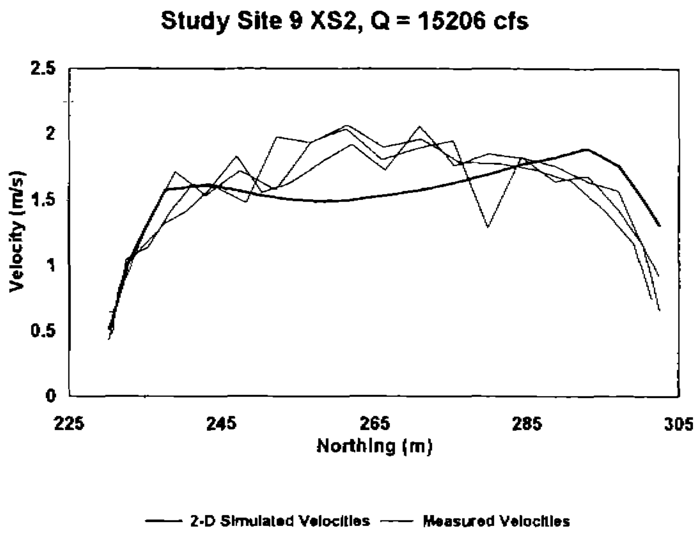


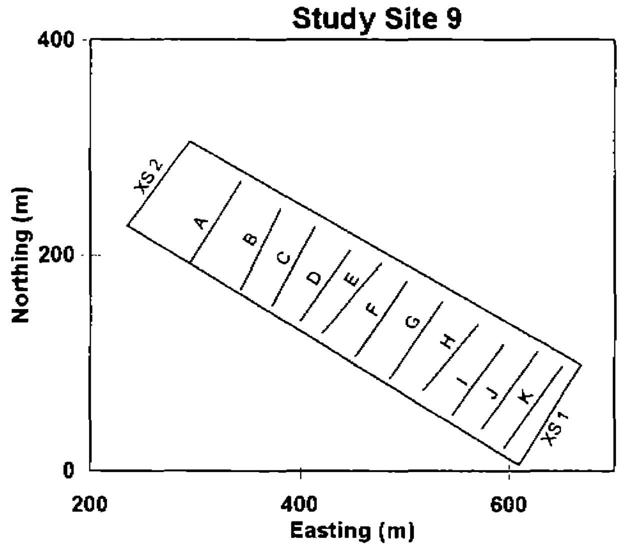
Study Site 15/17
Between Transect Non-ADCP Velocities

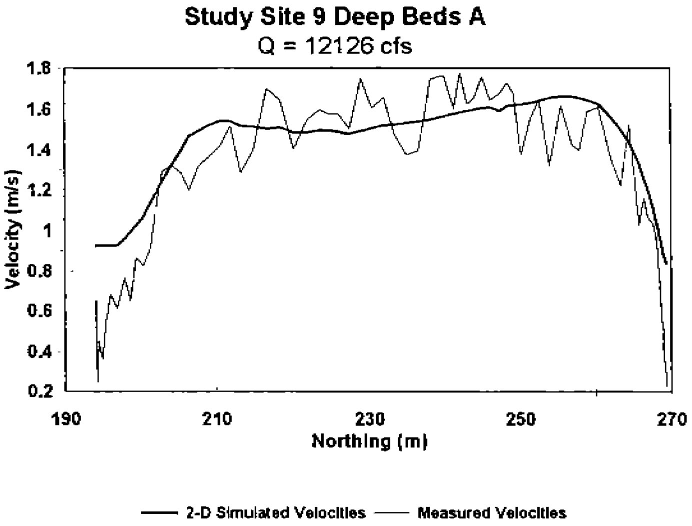


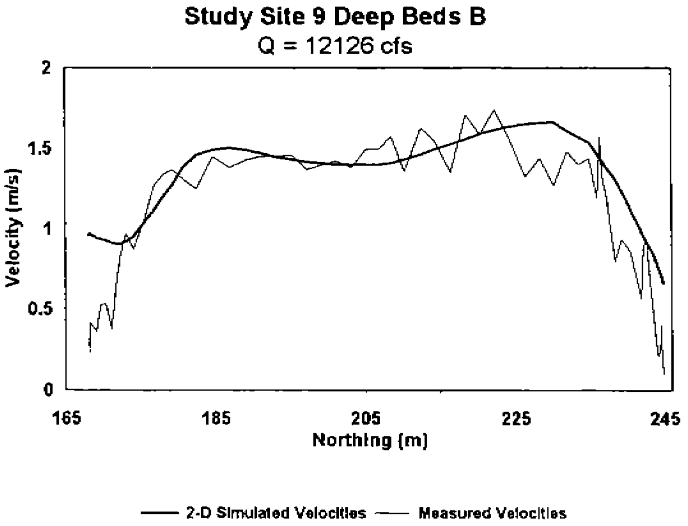
Study Site 9

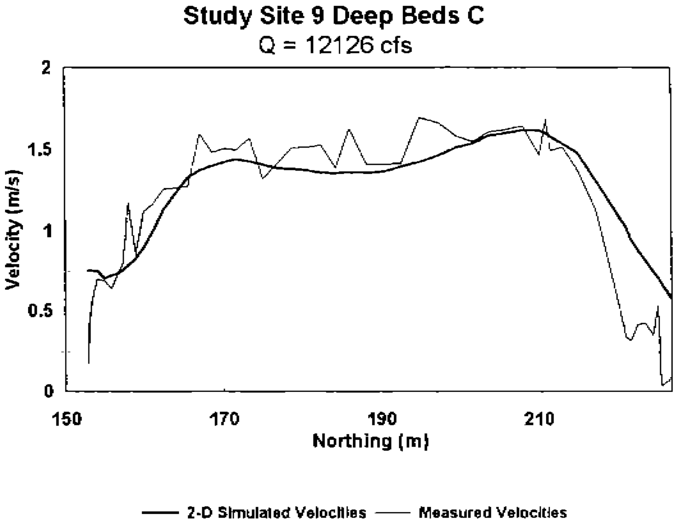

Study Site 9 XS1, Q = 15206 cfs

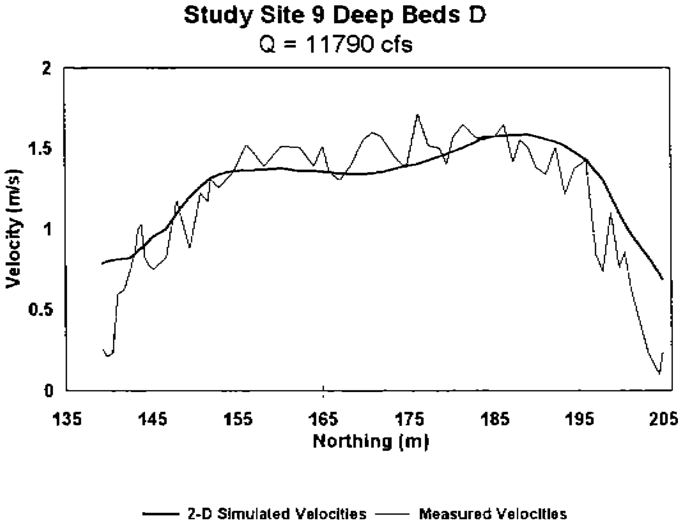

Study Site 9 XS2, Q = 15206 cfs


Study Site 9

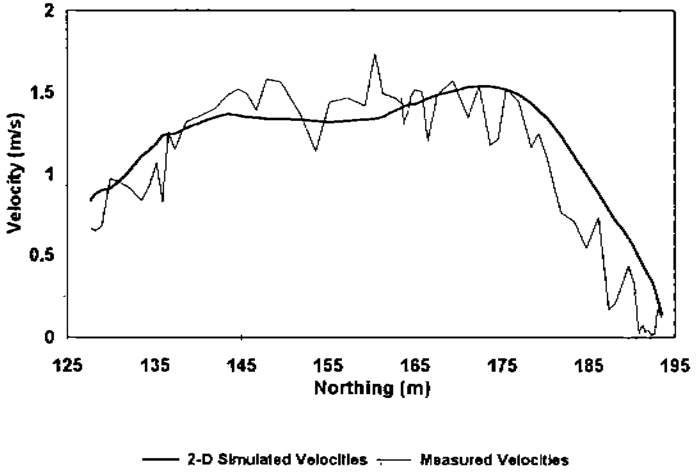

Study Site 9 Deep Beds A
Q = 12126 cfs


Study Site 9 Deep Beds B
Q = 12126 cfs

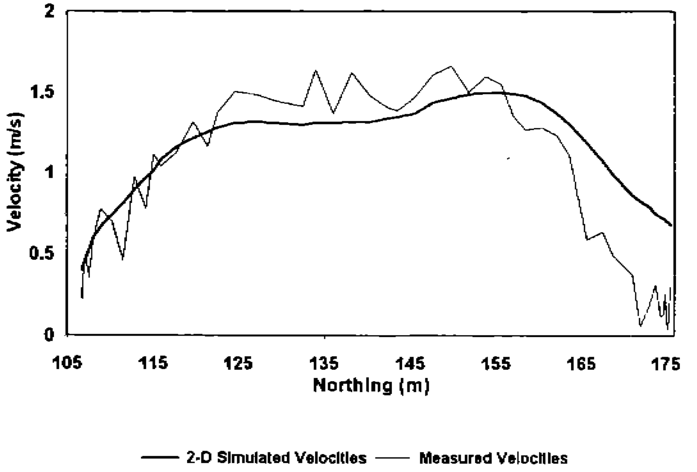

Study Site 9 Deep Beds C
Q = 12126 cfs


Study Site 9 Deep Beds D
Q = 11790 cfs

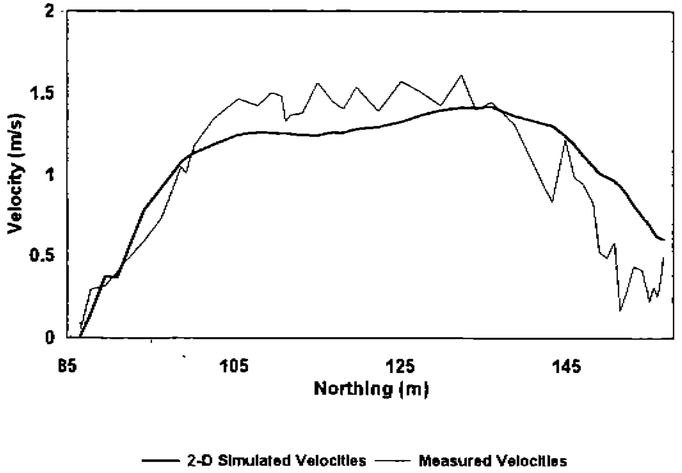
Study Site 9 Deep Beds E
Q = 11790 cfs



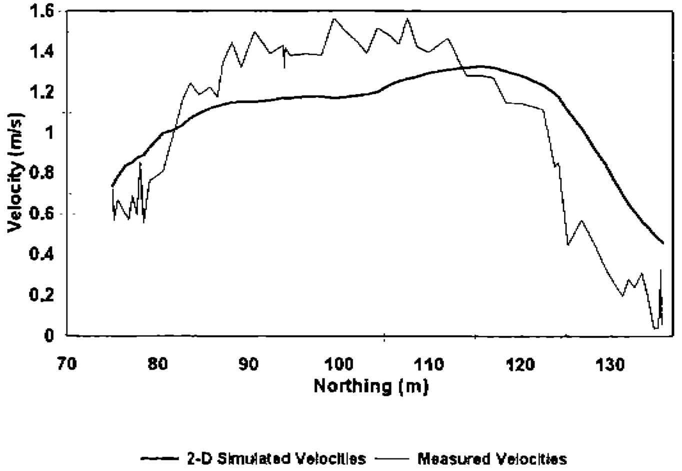
Study Site 9 Deep Beds F
Q = 11790 cfs

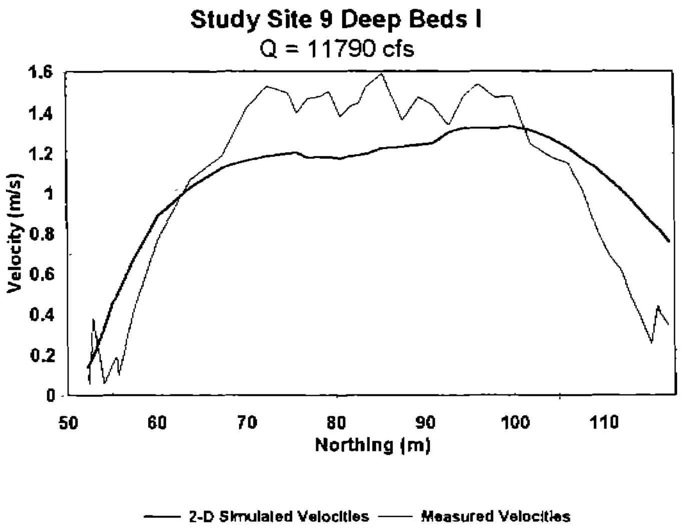


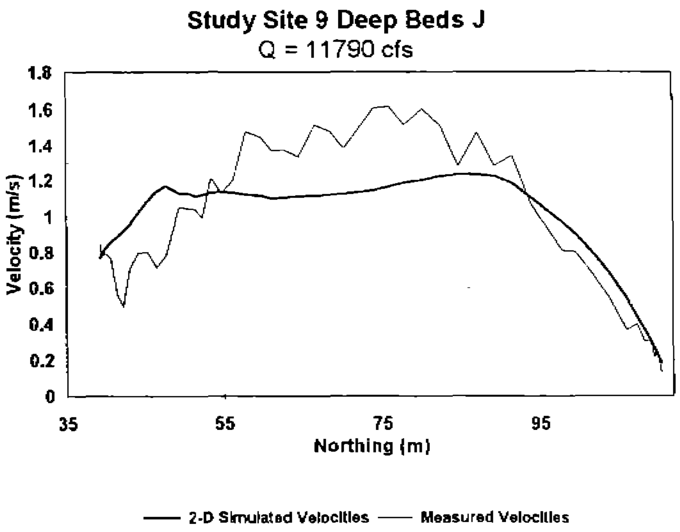
Study Site 9 Deep Beds G
Q = 11790 cfs

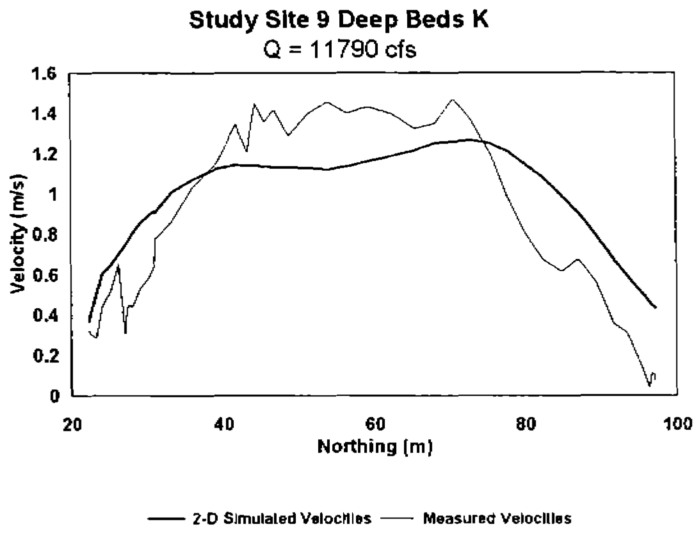


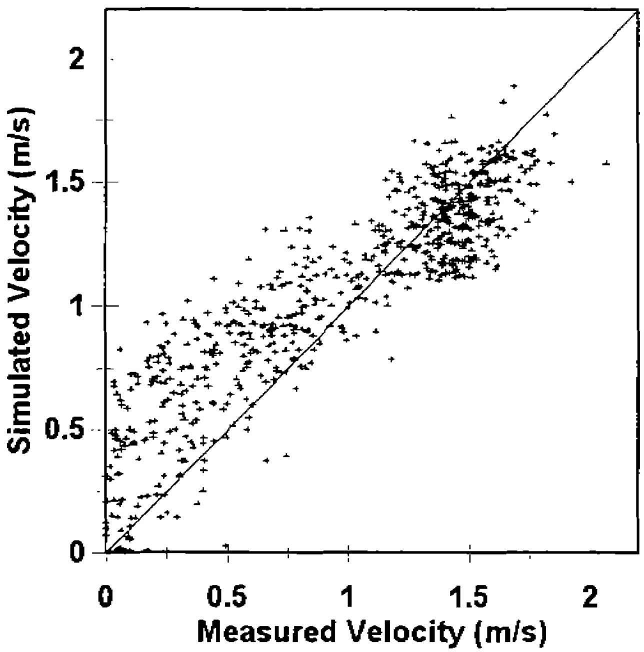
Study Site 9 Deep Beds H
Q = 11790 cfs



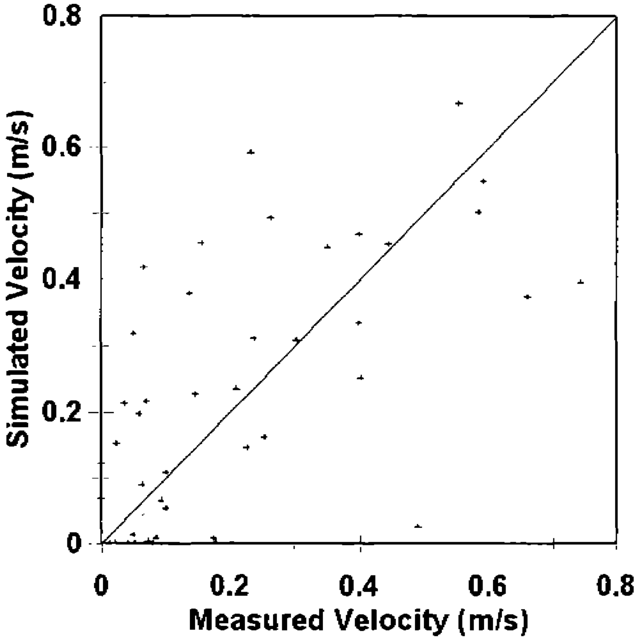

Study Site 9 Deep Beds I
Q = 11790 cfs


Study Site 9 Deep Beds J
Q = 11790 cfs


Study Site 9 Deep Beds K
Q = 11790 cfs



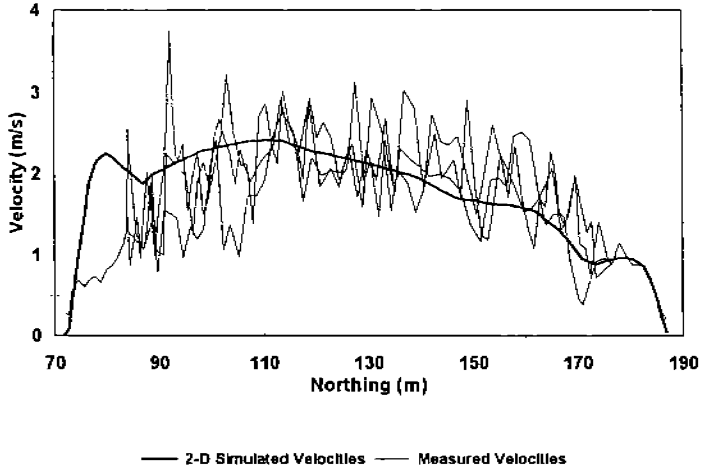
Study Site 9
All Validation Velocities



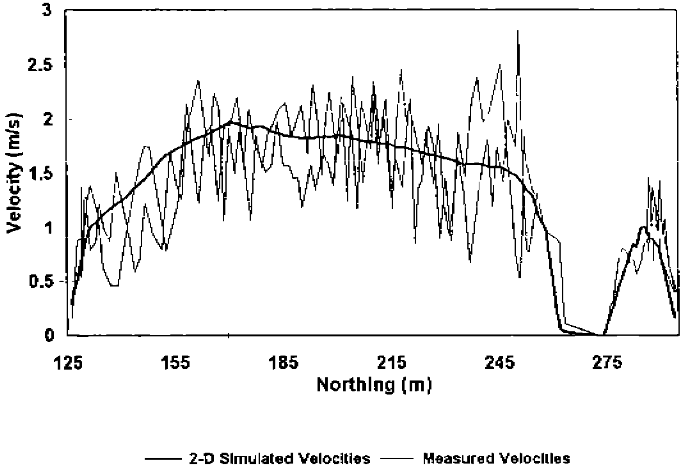
Study Site 9
Between Transect Non-ADCP Velocities

Price Study Site

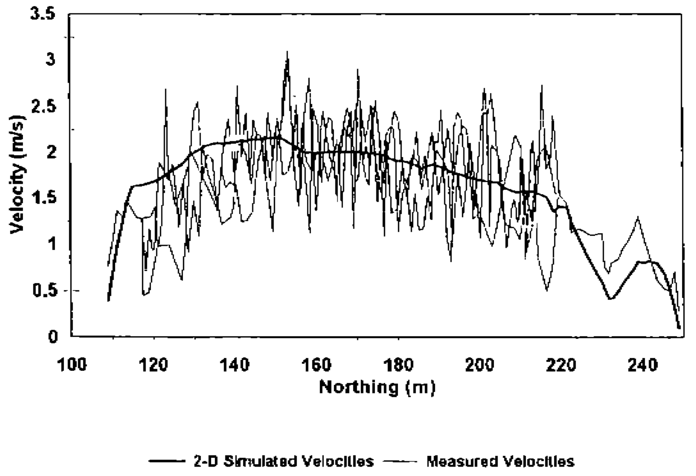
Price Study Site XS2, Q = 14371 cfs



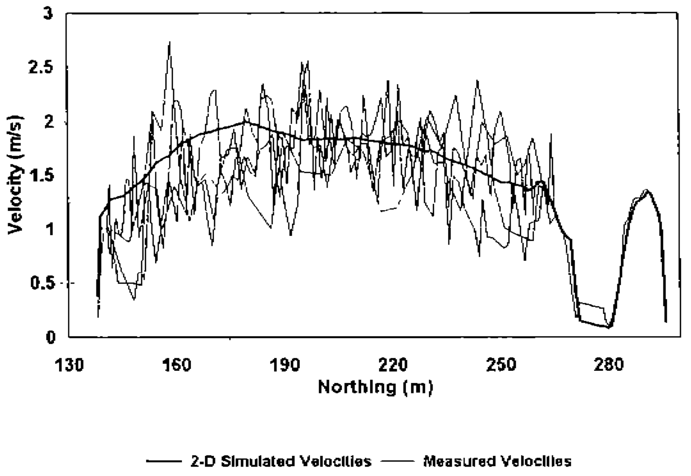
Price Study Site XS4, Q = 14389 cfs

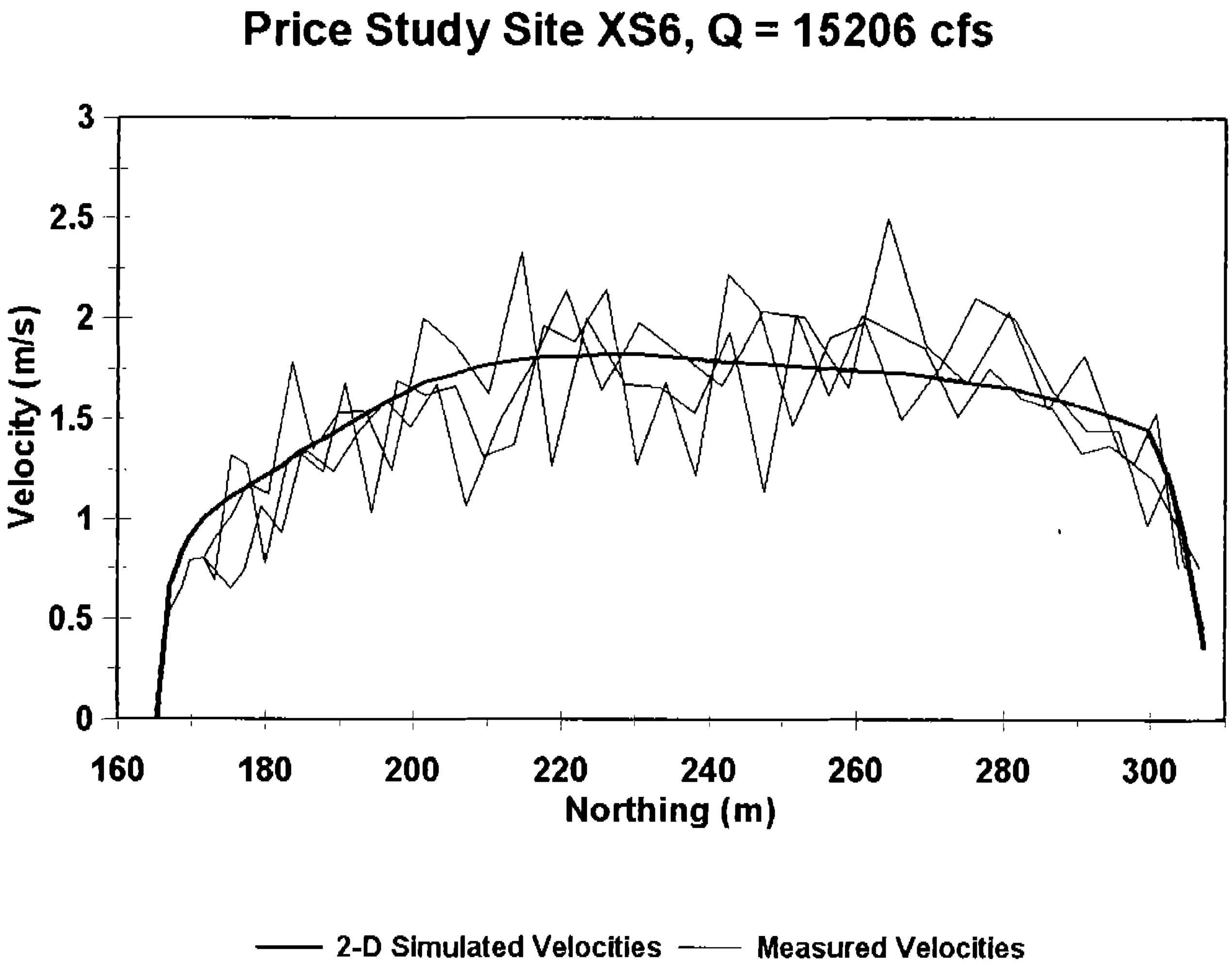


Price Study Site XS3, Q = 14389 cfs



Price Study Site XS5, Q = 14389 cfs




Price Study Site XS6, Q = 15206 cfs
Velocity (m/s)
3
2.5
2
1.5
1
0.5
0
160
180
200
220
240
260
280
300
Northing (m)
2-D Simulated Velocities
Measured Velocities

APPENDIX G
SIMULATION STATISTICS

Salt Creek Site Boards In

Flow (cfs)	Net Q	Sol Δ	Max F
3250	0.1%	< .000001	0.60
3500	0.1%	< .000001	0.50
3750	0.1%	< .000001	0.61
4000	0.1%	< .000001	0.49
4250	0.1%	< .000001	0.71
4500	0.03%	< .000001	1.72
4750	0.03%	< .000001	1.65
5000	0.05%	< .000001	0.45
5250	0.05%	< .000001	0.50
5500	0.1%	< .000001	0.55
6000	0.03%	< .000001	0.81
6500	0.02%	< .000001	0.89
7000	0.01%	< .000001	0.98
7500	0.1%	< .000001	1.07
8000	0.0004%	< .000001	1.07
9000	0.001%	< .000001	0.50
10000	0.01%	< .000001	2.01
11000	0.01%	< .000001	0.86
12000	0.01%	< .000001	0.79
13000	0.001%	< .000001	0.66
14000	0.001%	< .000001	0.76
15000	0.04%	< .000001	1.32
17000	0.04%	< .000001	1.64
19000	0.03%	< .000001	1.42
21000	0.01%	< .000001	1.31
23000	0.003%	< .000001	2.50
25000	0.001%	< .000001	3.55
27000	0.0003%	< .000001	1.24
29000	0.01%	< .000001	1.45
31000	0.003%	< .000001	1.19

Salt Creek Site Boards Out

Flow (cfs)	Net Q	Sol Δ	Max F
3250	0.01%	< .000001	1.007
3500	0.7%	< .000001	0.84
3750	0.1%	< .000001	0.65
4000	0.1%	< .000001	0.92
4250	0.1%	< .000001	0.57
4500	0.1%	< .000001	0.57
4750	0.1%	< .000001	0.84
5000	0.1%	< .000001	0.65
5250	0.05%	< .000001	0.66
5500	0.03%	< .000001	0.68
6000	0.01%	< .000001	1.08
6500	0.2%	< .000001	0.95
7000	0.001%	< .000001	0.73
7500	0.001%	< .000001	0.45
8000	0.003%	< .000001	0.48
9000	0.003%	< .000001	1.32
10000	0.01%	< .000001	0.72
11000	0.01%	< .000001	0.77
12000	0.02%	< .000001	0.95
13000	0.03%	< .000001	1.19
14000	0.03%	< .000001	1.04
15000	0.03%	< .000001	1.04
17000	0.01%	< .000001	1.26
19000	0.01%	< .000001	0.93
21000	0.02%	< .000001	1.18
23000	0.01%	< .000001	1.60
25000	0.003%	< .000001	6.46
27000	0.0003%	< .000001	2.80
29000	0.01%	< .000001	4.78
31000	0.0002%	< .000001	2.81

Upper Lake Redding Site Boards Out

Flow (cfs)	Net Q	Sol Δ	Max F
3250	0.2%	< .000001	0.29
3500	0.3%	< .000001	0.29
3750	0.2%	< .000001	0.29
4000	0.2%	.000007	0.29
4250	0.2%	< .000001	0.29
4500	0.2%	< .000001	0.29
4750	0.1%	< .000001	0.31
5000	0.1%	.000004	0.32
5250	0.1%	< .000001	0.32
5500	0.02%	.000001	0.31
6000	0.05%	< .000001	0.30
6500	0.1%	< .000001	0.30
7000	0.1%	.000003	0.34
7500	0.1%	.000005	0.34
8000	0.1%	.000001	0.35
9000	0.03%	< .000001	0.37
10000	0.001%	.000003	0.35
11000	0.03%	< .000001	0.43
12000	0.1%	< .000001	0.67
13000	0.1%	< .000001	0.54
14000	0.1%	< .000001	0.46
15000	0.1%	< .000001	0.45
17000	0.1%	< .000001	0.44
19000	0.1%	< .000001	0.51
21000	0.1%	< .000001	0.46
23000	0.03%	< .000001	0.59
25000	0.02%	< .000001	1.45
27000	0.05%	.000008	0.77
29000	0.1%	< .000001	0.53
31000	0.1%	< .000001	1.54

Upper Lake Redding Site Boards In

Flow (cfs)	Net Q	Sol Δ	Max F
3250	0.002%	.000002	0.20
3500	0.01%	< .000001	0.20
3750	0.02%	< .000001	0.20
4000	0.04%	< .000001	0.20
4250	0.05%	< .000001	0.20
4500	0.1%	< .000001	0.20
4750	0.1%	< .000001	0.21
5000	0.1%	< .000001	0.23
5250	0.1%	< .000001	0.23
5500	0.1%	< .000001	0.21
6000	0.1%	< .000001	0.20
6500	0.1%	< .000001	0.20
7000	0.1%	< .000001	0.20
7500	0.1%	< .000001	0.20
8000	0.1%	< .000001	0.23
9000	0.1%	< .000001	0.23
10000	0.1%	< .000001	0.23
11000	0.1%	< .000001	0.47
12000	0.1%	< .000001	0.30
13000	0.1%	< .000001	1.00
14000	0.1%	< .000001	0.28
15000	0.1%	< .000001	0.31
17000	0.1%	< .000001	0.46
19000	0.2%	< .000001	0.28
21000	0.2%	< .000001	0.38
23000	0.1%	< .000001	0.42
25000	0.1%	< .000001	0.35
27000	0.1%	< .000001	0.32
29000	0.05%	< .000001	0.30
31000	0.01%	< .000001	0.31

Lower Lake Redding Site Boards Out

Flow (cfs)	**Net Q**	**Sol Δ**	**Max F**
3250	0.4%	.000006	0.44
3500	0.4%	.000006	0.46
3750	0.04%	.000006	0.47
4000	0.04%	.000006	047
4250	0.03%	.000007	0.46
4500	0.04%	.000007	0.47
4750	0.04%	.000008	0.47
5000	0.05%	.000009	0.47
5250	0.05%	.000001	0.48
5500	0.1%	.000001	0.50
6000	0.1%	.000001	0.52
6500	0.1%	.000001	0.54
7000	0.1%	.000002	0.58
7500	0.1%	.000002	0.61
8000	0.1%	.000002	0.63
9000	0.0004%	.000008	2.41
10000	0.004%	.000002	2.71
11000	0.04%	.000008	2.17
12000	0.1%	.000006	1.69
13000	0.1%	.000009	1.51
14000	0.2%	.000004	1.21
15000	0.03%	.000004	1.11
17000	0.01%	.000004	0.96
19000	0.01%	.000003	0.73
21000	0.02%	.000002	0.72
23000	0.01%	.000001	0.71
25000	0.01%	< .000001	0.70
27000	0.02%	< .000001	0.68
29000	0.02%	.000005	0.67
31000	0.003%	< .000001	0.73

Lower Lake Redding Site Boards In

Flow (cfs)	Net Q	Sol Δ	Max F
3250	0.01%	< .000001	0.63
3500	0.2%	.000001	1.21
3750	0.2%	< .000001	0.94
4000	0.2%	< .000001	0.79
4250	0.2%	< .000001	0.69
4500	0.2%	< .000001	0.63
4750	0.2%	< .000001	0.58
5000	0.2%	< .000001	0.54
5250	0.2%	< .000001	0.51
5500	0.2%	< .000001	0.49
6000	0.2%	< .000001	0.45
6500	0.1%	< .000001	0.43
7000	0.1%	< .000001	0.41
7500	0.04%	.000004	0.90
8000	0.04%	< .000001	1.05
9000	0.05%	< .000001	0.65
10000	0.05%	< .000001	0.55
11000	0.04%	< .000001	0.45
12000	0.02%	< .000001	1.59
13000	0.02%	< .000001	0.89
14000	0.02%	< .000001	0.71
15000	0.02%	< .000001	0.64
17000	0.01%	< .000001	1.27
19000	0.01%	< .000001	1.00
21000	0.02%	.000001	1.00
23000	0.02%	.000004	1.00
25000	0.04%	< .000001	3.39
27000	0.1%	< .000001	1.95
29000	0.1%	.000001	3.12
31000	0.2%	< .000001	1.19

Posse Grounds Site

Flow (cfs)	Net Q	Sol Δ	Max F
3250	0.7%	.000008	2.10
3500	0.7%	.000001	2.09
3750	0.4%	.000008	1.82
4000	0.7%	.000007	1.98
4250	0.5%	.000004	2.57
4500	0.04%	.000006	2.47
4750	0.1%	.000003	2.51
5000	0.02%	.000004	2.36
5250	0.1%	.000002	2.71
5500	0.04%	.000002	2.30
6000	0.3%	.000002	2.26
6500	0.1%	.000002	1.82
7000	0.1%	.000003	2.44
7500	0.3%	.000003	2.49
8000	0.02%	.000003	2.15
9000	0.002%	.000008	2.15
10000	0.01%	.000009	2.93
11000	0.01%	.000003	2.38
12000	0.01%	< .000001	3.23
13000	0.02%	.000005	3.11
14000	0.04%	< .000001	3.26
15000	0.04%	< .000001	2.03
17000	0.1%	< .000001	1.18
19000	0.1%	< .000001	1.50
21000	0.1%	.000005	0.89
23000	0.1%	.000007	1.41
25000	0.1%	< .000001	1.34
27000	0.1%	< .000001	1.64
29000	0.1%	< .000001	1.19
31000	0.03%	< .000001	1.31

Site 130

Flow (cfs)	Net Q	Sol Δ	Max F
3250	0.04%	<.000001	0.35
3500	0.04%	<.000001	0.34
3750	0.03%	<.000001	0.34
4000	0.01%	.000008	0.35
4250	0.05%	.000005	0.37
4500	0.1%	<.000001	0.25
4750	0.1%	<.000001	0.27
5000	0.1%	<.000001	0.27
5250	0.2%	<.000001	0.28
5500	0.1%	.000004	0.29
6000	0.1%	<.000001	0.31
6500	0.1%	<.000001	0.38
7000	0.1%	<.000001	0.41
7500	0.1%	<.000001	0.42
8000	0.1%	<.000001	0.43
9000	0.1%	.000002	0.44
10000	0.1%	.000002	0.45
11000	0.2%	<.000001	0.48
12000	0.2%	.000001	0.50
13000	0.2%	<.000001	0.51
14000	0.2%	<.000001	0.53
15000	0.1%	.000004	0.55
17000	0.2%	.000006	2.16
19000	0.2%	.000004	1.86
21000	0.6%	<.000001	1.00
23000	0.1%	.000002	0.98
25000	0.04%	.000001	1.00
27000	0.03%	<.000001	1.00
29000	0.2%	<.000001	0.75
31000	0.2%	.000009	0.79

Site 112

Flow (cfs)	Net Q	Sol Δ	Max F
3250	1.9%	.000008	3.31
3500	1.3%	.000004	3.19
3750	1.3%	.000005	1.81
4000	1.4%	.000004	1.46
4250	1.7%	.000007	1.20
4500	1.7%	.000005	1.05
4750	1.7%	.000007	1.00
5000	1.6%	.000006	1.00
5250	1.4%	.000007	1.00
5500	1.3%	.000008	1.00
6000	0.9%	.000009	1.00
6500	0.6%	.000009	1.00
7000	0.4%	.000002	0.88
7500	0.5%	.000002	0.98
8000	0.5%	.000002	0.76
9000	0.5%	.000001	0.76
10000	0.5%	.000001	0.92
11000	0.3%	.000002	1.08
12000	0.3%	.000002	0.96
13000	0.3%	.000002	0.85
14000	0.2%	.000838	0.91
15000	0.1%	.000003	8.12
17000	0.2%	.000009	1.35
19000	0.3%	.000002	0.90
21000	0.3%	.000008	0.93
23000	0.3%	< .000001	0.86
25000	0.3%	< .000001	0.80
27000	0.2%	< .000001	0.79
29000	0.1%	< .000001	0.91
31000	0.1%	< .000001	1.03

Site 96

Flow (cfs)	Net Q	Sol Δ	Max F
3250	4.9%	< 000001	0.60
3500	2.0%	<.000001	0.73
3750	0.1%	.000002	0.79
4000	0.7%	<.000001	0.79
4250	0.3%	<.000001	0.79
4500	0.3%	<.000001	0.77
4750	0.4%	<.000001	0.81
5000	0.1%	<.000001	0.80
5250	0.5%	.000009	0.84
5500	0.9%	<.000001	0.83
6000	0.6%	<.000001	0.79
6500	0.5%	.000001	0.90
7000	0.3%	.000001	0.88
7500	0.2%	<.000001	0.83
8000	0.1%	.000001	0.77
9000	0.5%	<.000001	0.72
10000	0.7%	<.000001	0.72
11000	0.6%	<.000001	0.72
12000	0.5%	<.000001	0.70
13000	0.2%	<.000001	0.89
14000	0.01%	.000002	0.90
15000	0.1%	<.000001	0.97
17000	0.1%	<.000001	1.01
19000	0.1%	<.000001	0.91
21000	0.1%	<.000001	0.88
23000	0.1%	<.000001	0.86
25000	0.1%	<.000001	0.79
27000	0.05%	<.000001	0.86
29000	0.03%	<.000001	0.83
31000	0.002%	<.000001	0.78

Site 81

Flow (cfs)	Net Q	Sol Δ	Max F
3250	0.1%	<.000001	0.31
3500	0.1%	<.000001	0.26
3750	0.03%	<.000001	0.27
4000	0.002%	<.000001	0.28
4250	0.01%	<.000001	0.29
4500	0.04%	<.000001	0.29
4750	0.04%	<.000001	0.29
5000	0.01%	<.000001	0.30
5250	0.05%	<.000001	0.29
5500	0.1%	<.000001	0.30
6000	0.1%	<.000001	0.31
6500	0.2%	<.000001	0.32
7000	0.1%	<.000001	0.33
7500	0.1%	<.000001	0.35
8000	0.1%	<.000001	0.36
9000	0.1%	<.000001	0.40
10000	0.1%	<.000001	0.51
11000	0.1%	<.000001	0.62
12000	0.1%	<.000001	0.54
13000	0.1%	<.000001	0.61
14000	0.1%	<.000001	0.66
15000	0.1%	<.000001	0.68
17000	0.04%	<.000001	0.69
19000	0.01%	<.000001	0.75
21000	0.02%	<.000001	0.70
23000	0.03%	<.000001	0.84
25000	0.03%	<.000001	0.94
27000	0.02%	<.000001	0.92
29000	0.02%	<.000001	0.87
31000	0.01%	<.000001	0.85

Site 80

Flow (cfs)	Net Q	Sol Δ	Max F
3750	0.2%	.000003	0.20
4000	0.05%	<.000001	0.20
4250	3.2%	<.000001	0.35
4500	0.3%	<.000001	0.20
4750	0.3%	<.000001	0.20
5000	0.3%	<.000001	0.20
5250	0.5%	<.000001	0.20
5500	0.6%	<.000001	0.20
6000	0.5%	<.000001	0.20
6500	0.6%	<.000001	0.20
7000	0.6%	<.000001	0.20
7500	0.5%	<.000001	0.20
8000	0.5%	<.000001	0.20
9000	0.3%	<.000001	0.20
10000	0.03%	<.000001	0.20
11000	0.3%	<.000001	0.20
12000	0.3%	<.000001	0.23
13000	0.3%	<.000001	0.26
14000	0.1%	<.000001	0.29
15000	0.03%	<.000001	1.47
17000	0.1%	<.000001	1.58
19000	0.1%	<.000001	1.53
21000	0.2%	<.000001	1.78
23000	0.2%	<.000001	1.86
25000	0.2%	<.000001	1.52
27000	0.2%	<.000001	1.04
29000	0.3%	<.000001	0.94
31000	0.3%	<.000001	0.92

Site 61/63

Flow (cfs)	Net Q	Sol Δ	Max F
3250	0.2%	<.000001	2.26
3500	0.1%	.000004	1.88
3750	0.1%	.000003	1.79
4000	0.04%	<.000001	1.69
4250	0.001%	.000002	2.28
4500	0.03%	.000006	2.06
4750	0.03%	.000002	1.93
5000	0.03%	.000001	1.74
5250	0.03%	.000005	1.59
5500	0.02%	.000003	1.45
6000	0.02%	.000002	1.75
6500	0.02%	.000002	1.62
7000	0.002%	.000001	1.50
7500	0.02%	<.000001	1.60
8000	0.04%	<.000001	1.68
9000	0.1%	<.000001	4.75
10000	0.2%	<.000001	2.73
11000	0.2%	.000004	2.00
12000	0.2%	.000001	2.09
13000	0.1%	.000003	1.47
14000	0.1%	.000001	1.40
15000	0.01%	.000007	1.45
17000	0.02%	.000001	1.55
19000	0.02%	.000001	2.01
21000	0.04%	.000002	2.08
23000	0.1%	<.000001	2.12
25000	0.1%	.000008	2.35
27000	0.04%	<.000001	2.02
29000	0.03%	.000001	2.54
31000	0.02%	.000001	2.87

Site 52

Flow (cfs)	Net Q	Sol Δ	Max F
3250	0.04%	.000003	0.11
3500	0.05%	.000003	0.11
3750	0.1%	.000006	0.12
4000	0.1%	.000004	0.12
4250	0.1%	.000003	0.13
4500	0.0003%	.000006	0.13
4750	0.1%	.000006	0.13
5000	0.1%	.000009	0.14
5250	0.1%	.000005	0.18
5500	0.1%	.000005	0.17
6000	0.1%	.000007	0.15
6500	0.01%	.000008	0.16
7000	0.01%	.000001	0.17
7500	0.03%	.000002	0.17
8000	0.0004%	.000002	0.18
9000	0.03%	.000003	0.18
10000	0.004%	.000006	0.22
11000	0.002%	.000003	1.40
12000	0.01%	.000002	0.88
13000	0.003%	.000008	0.60
14000	0.01%	.000001	0.53
15000	0.005%	.000001	1.00
17000	0.01%	.000007	1.77
19000	0.01%	.000009	1.00
21000	0.1%	.000007	1.00
23000	0.01%	.000002	1.18
25000	0.01%	.000003	1.22
27000	0.01%	.000002	1.13
29000	0.01%	.000003	0.69
31000	0.01%	.000001	0.48

Above Hawes Hole Site

Flow (cfs)	Net Q	Sol A	Max F
3250	0.02%	<.000001	2.79
3500	0.05%	.000002	1.96
3750	0.1%	.000002	1.46
4000	0.1%	.000004	1.23
4250	0.05%	.000003	1.03
4500	0.1%	<.000001	0.89
4750	0.1%	<.000001	0.82
5000	0.1%	<.000001	0.82
5250	0.1%	<.000001	0.75
5500	0.1%	<.000001	0.68
6000	0.1%	<.000001	0.66
6500	0.1%	.000008	0.66
7000	0.1%	.000007	0.67
7500	0.1%	<.000001	0.68
8000	0.1%	<.000001	0.67
9000	0.1%	<.000001	4.45
10000	0.1%	<.000001	2.23
11000	0.1%	.000001	1.66
12000	0.1%	.000002	1.41
13000	0.05%	<.000001	2.55
14000	0.001%	<.000001	1.65
15000	0.01%	<.000001	1.47
17000	0.03%	<.000001	1.27
19000	0.01%	.000001	0.99
21000	0.002%	.000003	0.90
23000	0.05%	.000008	1.06
25000	0.03%	<.000001	1.78
27000	0.1%	<.000001	0.77
29000	0.1%	.000002	1.86
31000	0.1%	.000007	0.97

Site 28

Flow (cfs)	Net Q	Sol Δ	Max F
3250	0.2%	<.000001	0.23
3500	0.2%	<.000001	0.36
3750	0.3%	<.000001	0.57
4000	0.3%	<.000001	0.46
4250	0.3%	<.000001	0.48
4500	0.3%	<.000001	0.48
4750	0.3%	<.000001	0.47
5000	0.3%	<.000001	0.46
5250	0.3%	<.000001	0.45
5500	0.3%	<.000001	7.42
6000	0.2%	<.000001	0.47
6500	0.2%	<.000001	0.41
7000	0.3%	<.000001	0.40
7500	0.3%	<.000001	0.39
8000	0.2%	<.000001	0.39
9000	0.2%	<.000001	0.37
10000	0.9%	.000001	0.41
11000	0.7%	.000003	0.45
12000	0.1%	<.000001	0.41
13000	0.1%	<.000001	1.41
14000	0.1%	<.000001	1.93
15000	0.1%	<.000001	1.32
17000	0.1%	.000001	0.79
19000	0.1%	.000009	0.71
21000	0.2%	.000002	0.82
23000	0.2%	<.000001	0.74
25000	0.02%	<.000001	0.69
27000	0.1%	<.000001	0.62
29000	0.1%	<.000001	0.88
31000	0.1%	.000005	0.76

Powerline Riffle Site

Flow (cfs)	Net Q	Sol Δ	Max F
3250	0.8%	.000002	0.50
3500	0.9%	<.000001	0.50
3750	0.9%	<.000001	0.50
4000	0.99%	<.000001	0.50
4250	1.0%	<.000001	0.49
4500	1.1%	<.000001	0.49
4750	1.1%	<.000001	0.51
5000	1.1%	<.000001	0.50
5250	1.2%	<.000001	0.56
5500	1.2%	<.000001	0.57
6000	1.1%	<.000001	0.58
6500	1.1%	<.000001	0.57
7000	1.1%	<.000001	0.56
7500	1.0%	<.000001	0.56
8000	0.9%	.000001	0.56
9000	0.8%	<.000001	0.54
10000	0.6%	<.000001	0.52
11000	0.4%	<.000001	0.54
12000	0.2%	<.000001	0.54
13000	0.1%	<.000001	0.52
14000	0.01%	<.000001	0.58
15000	0.1%	<.000001	0.95
17000	0.2%	<.000001	0.99
19000	0.1%	<.000001	1.17
21000	0.01%	<.000001	2.82
23000	0.01%	<.000001	2.87
25000	0.03%	<.000001	1.50
27000	0.02%	<.000001	1.77
29000	0.03%	.000007	1.54
31000	0.1%	<.000001	1.24

Site 15/17

Flow (cfs)	Net Q	Sol Δ	Max F
3250	0.4%	.000002	1.20
3500	0.4%	<.000001	1.18
3750	0.4%	.000008	1.31
4000	0.4%	<.000001	1.19
4250	0.3%	.000002	1.09
4500	0.3%	.000002	1.07
4750	0.3%	.000002	1.05
5000	0.3%	.000002	1.02
5250	0.2%	.000002	0.99
5500	0.2%	.000003	0.95
6000	0.1%	.000002	0.94
6500	0.1%	.000002	0.96
7000	0.1%	.000002	0.97
7500	0.1%	.000002	0.97
8000	0.1%	.000003	0.97
9000	0.01%	.000003	0.93
10000	0.05%	<.000001	0.84
11000	0.1%	<.000001	0.80
12000	0.02%	<.000001	0.81
13000	0.1%	.000001	0.81
14000	0.2%	.000009	0.95
15000	0.2%	.000001	1.01
17000	0.3%	.000006	0.97
19000	0.3%	.000002	0.83
21000	0.3%	.000004	1.46
23000	0.4%	.000003	1.58
25000	0.4%	<.000001	1.34
27000	0.4%	.000002	1.28
29000	0.5%	<.000001	0.97
31000	0.4%	<.000001	0.94

Site 9

Flow (cfs)	Net Q	Sol Δ	Max F
3250	0.4%	.000002	0.26
3500	0.4%	.000002	0.25
3750	0.5%	.000002	0.25
4000	0.5%	.000002	0.26
4250	0.5%	.000002	0.26
4500	0.5%	.000002	0.26
4750	0.6%	.000002	0.27
5000	0.6%	.000002	0.27
5250	0.6%	.000002	0.27
5500	0.6%	.000003	0.28
6000	0.6%	.000002	0.28
6500	0.7%	.000002	0.30
7000	0.7%	.000002	0.30
7500	0.6%	.000002	0.31
8000	0.6%	.000003	0.32
9000	0.6%	.000003	0.33
10000	0.6%	.000003	0.35
11000	0.4%	.000008	0.35
12000	0.3%	.000002	0.37
13000	0.2%	.000002	0.38
14000	0.1%	.000002	0.37
15000	0.1%	.000003	0.42
17000	0.02%	.000002	0.76
19000	0.1%	.000002	0.65
21000	0.2%	.000001	1.53
23000	0.8%	.000008	0.61
25000	0.3%	<.000001	0.78
27000	0.3%	<.000001	0.53
29000	0.3%	.000003	0.53
31000	0.2%	.000002	0.53

Price Riffle Site

Flow (cfs)	Net Q	Sol Δ	Max F
3250	0.1%	.000009	1.06
3500	0.03%	.000005	1.03
3750	0.05%	.000007	0.996
4000	0.01%	.000006	0.98
4250	0.02%	.000006	1.00
4500	0.004%	.000006	1.02
4750	0.04%	.000006	1.15
5000	0.1%	.000006	1.18
5250	0.1%	.000005	1.16
5500	0.1%	.000004	1.23
6000	0.2%	.000003	1.31
6500	0.2%	.000004	1.85
7000	1.4%	.000002	1.05
7500	0.2%	<.000001	1.27
8000	0.2%	.000003	1.29
9000	0.1%	.000001	1.49
10000	0.1%	.000006	1.39
11000	0.1%	.000001	1.97
12000	0.003%	.000002	1.91
13000	0.1%	.000001	1.74
14000	0.1%	.000005	1.43
15000	0.1%	<.000001	1.24
17000	0.1%	<.000001	1.00
19000	0.01%	<.000001	1.00
21000	0.1%	.000006	1.26
23000	0.03%	.000001	1.01
25000	0.03%	<.000001	0.88
27000	0.02%	<.000001	0.84
29000	0.02%	<.000001	0.85
31000	0.1%	<.000001	0.84

APPENDIX H
HABITAT SUITABILITY CRITERIA

Fall-run Fry Rearing

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Cover	SI Value	Adjacent Velocity (ft/s)	SI Value
0	0.86	0	0.00	0	0.00	0	0.56
0.10	0.96	0.1	0.00	0.1	0.24	1.83	1.00
0.20	1.00	0.2	0.82	1	0.24	100	1.00
0.25	1.00	0.7	0.94	2	0.24		
0.40	0.95	1.3	1.00	3	0.24		
0.60	0.77	1.8	1.00	3.7	1.00		
0.90	0.40	2.5	0.93	4	1.00		
1.10	0.22	3.0	0.85	4.7	1.00		
1.30	0.13	5.0	0.37	5	1.00		
1.60	0.06	6.0	0.19	5.7	1.00		
2.54	0.02	7.0	0.10	7	0.24		
2.55	0.00	8.0	0.05	8	1.00		
100	0.00	10.0	0.02	9	0.24		
		13.0	0.02	9.7	0.24		
		15.0	0.04	10	0.24		
		16.5	0.04	100	0.00		
		18.6	0.01				
		18.7	0.00				
		100	0.00				

Fall-run Juvenile Rearing

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Cover	SI Value	Adjacent Velocity (ft/s)	SI Value
0	0.47	0	0.00	0	0.00	0	0.09
0.20	0.85	0.3	0.00	0.1	0.24	4.14	1.00
0.30	0.96	0.4	0.41	1	0.24	100	1.00
0.40	1.00	1.6	0.90	2	0.24		
0.50	0.98	2.0	0.98	3	0.24		
0.60	0.91	2.2	1.00	3.7	1.00		
1.10	0.35	2.5	1.00	4	1.00		
1.30	0.21	3.0	0.94	4.7	1.00		
1.50	0.13	3.5	0.84	5	1.00		
1.70	0.09	5.5	0.32	5.7	1.00		
2.10	0.06	6.5	0.17	7	0.24		
2.60	0.08	8.0	0.07	8	1.00		
2.75	0.10	9.5	0.04	9	0.24		
3.93	0.00	10.5	0.03	9.7	0.24		
100	0.00	13.5	0.03	10	0.24		
		17.5	0.07	100	0.00		
		19.0	0.07				
		20.0	0.06				
		22.0	0.02				
		23.7	0.01				
		23.8	0.00				
		100	0.00				

Late-fall-run Fry Rearing

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Cover	SI Value	Adjacent Velocity (ft/s)	SI Value
0	1.00	0	0.00	0	0.00	0	0.69
0.20	0.98	0.1	0.00	0.1	0.21	2.96	1.00
0.30	0.95	0.2	0.84	1	0.21	100	1.00
0.60	0.79	0.6	0.96	2	0.39		
1.20	0.30	1.0	1.00	3	0.39		
1.40	0.18	1.2	1.00	3.7	1.00		
1.60	0.10	1.6	0.96	4	0.39		
1.80	0.05	2.0	0.87	4.7	1.00		
2.20	0.01	2.5	0.48	5	1.00		
2.40	0.01	3.0	0.25	5.7	1.00		
2.61	0.00	3.5	0.10	7	0.39		
100	0.00	4.0	0.04	8	1.00		
		4.5	0.01	9	0.21		
		17.3	0.00	9.7	0.21		
		100	0.00	10	0.39		
				100	0.00		

Late-fall-run Juvenile Rearing

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Cover	SI Value	Adjacent Velocity (ft/s)	SI Value
0	0.47	0	0.00	0	0.00	0	0.09
0.20	0.85	0.3	0.00	0.1	0.21	4.14	1.00
0.30	0.96	0.4	0.41	1	0.21	100	1.00
0.40	1.00	1.6	0.90	2	0.39		
0.50	0.98	2.0	0.98	3	0.39		
0.60	0.91	2.2	1.00	3.7	1.00		
1.10	0.35	2.5	1.00	4	0.39		
1.30	0.21	3.0	0.94	4.7	1.00		
1.50	0.13	3.5	0.84	5	1.00		
1.70	0.09	5.5	0.32	5.7	1.00		
2.10	0.06	6.5	0.17	7	0.39		
2.60	0.08	8.0	0.07	8	1.00		
2.75	0.10	9.5	0.04	9	0.21		
3.93	0.00	10.5	0.03	9.7	0.21		
100	0.00	13.5	0.03	10	0.39		
		17.5	0.07	100	0.00		
		19.0	0.07				
		20.0	0.06				
		22.0	0.02				
		23.7	0.01				
		23.8	0.00				
		100	0.00				

Winter-run Fry Rearing

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Cover	SI Value	Adjacent Velocity (ft/s)	SI Value
0	1.00	0	0.00	0	0.00	0	0.54
0.10	0.99	0.1	0.00	0.1	0.07	2.25	1.00
0.30	0.92	0.2	0.71	1	0.07	100	1.00
0.50	0.79	0.5	0.89	2	1.00		
1.10	0.27	0.9	1.00	3	1.00		
1.30	0.15	1.1	1.00	3.7	1.00		
1.50	0.08	1.4	0.95	4	1.00		
1.70	0.04	1.6	0.89	4.7	1.00		
2.00	0.01	3.0	0.24	5	1.00		
2.20	0.01	3.5	0.12	5.7	1.00		
2.58	0.00	4.0	0.06	7	1.00		
100	0.00	5.0	0.02	8	1.00		
		7.0	0.02	9	0.07		
		9.0	0.08	9.7	0.07		
		9.5	0.08	10	1.00		
		10.2	0.05	100	0.00		
		10.3	0.00				
		100	0.00				

Winter-run Juvenile Rearing

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Cover	SI Value	Adjacent Velocity (ft/s)	SI Value
0	0.47	0	0.00	0	0.00	0	0.09
0.20	0.85	0.3	0.00	0.1	0.07	4.14	1.00
0.30	0.96	0.4	0.41	1	0.07	100	1.00
0.40	1.00	1.6	0.90	2	1.00		
0.50	0.98	2.0	0.98	3	1.00		
0.60	0.91	2.2	1.00	3.7	1.00		
1.10	0.35	2.5	1.00	4	1.00		
1.30	0.21	3.0	0.94	4.7	1.00		
1.50	0.13	3.5	0.84	5	1.00		
1.70	0.09	5.5	0.32	5.7	1.00		
2.10	0.06	6.5	0.17	7	1.00		
2.60	0.08	8.0	0.07	8	1.00		
2.75	0.10	9.5	0.04	9	0.07		
3.93	0.00	10.5	0.03	9.7	0.07		
100	0.00	13.5	0.03	10	1.00		
		17.5	0.07	100	0.00		
		19.0	0.07				
		20.0	0.06				
		22.0	0.02				
		23.7	0.01				
		23.8	0.00				
		100	0.00				

APPENDIX I
SITE HABITAT MODELING RESULTS

Salt Creek Study Site Boards In WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	1,898	388	2,249	529	3,671	1,096
3,500	1,986	403	2,368	554	3,816	1,164
3,750	2,046	423	2,445	585	3,951	1,238
4,000	2,120	449	2,500	623	4,025	1,325
4,250	2,167	467	2,521	649	4,045	1,386
4,500	2,204	488	2,517	679	4,042	1,448
4,750	2,287	505	2,571	705	4,027	1,509
5,000	2,507	521	2,892	728	4,376	1,563
5,250	2,820	550	3,274	766	4,771	1,637
5,500	2,947	590	3,403	815	4,932	1,724
6,000	2,678	743	2,313	973	3,249	1,903
6,500	2,578	717	2,182	917	2,962	1,725
7,000	2,562	710	2,259	888	3,012	1,603
7,500	3,162	736	3,093	892	3,748	1,522
8,000	2,825	783	2,704	1,045	3,772	2,099
9,000	2,815	793	2,358	1,041	3,399	2,038
10,000	2,773	792	2,175	1,021	3,049	1,944
11,000	2,673	776	2,112	982	2,915	1,812
12,000	2,564	719	2,169	903	2,932	1,644
13,000	3,027	742	3,026	900	3,734	1,534
14,000	2,939	718	2,846	878	3,572	1,520
15,000	3,291	1,096	2,798	1,226	3,281	1,754
17,000	3,196	1,099	2,758	1,229	3,233	1,754
19,000	2,952	1,040	2,649	1,172	3,152	1,703
21,000	2,720	951	2,499	1,083	3,000	1,617
23,000	3,233	866	3,140	993	3,665	1,508
25,000	3,214	869	3,105	994	3,630	1,497
27,000	1,848	848	1,037	916	1,051	1,191
29,000	2,761	1,059	2,124	1,159	2,248	1,565
31,000	2,025	927	1,287	1,001	1,308	1,299

Salt Creek Study Site Boards Out WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	1,794	330	2,156	437	3,552	871
3,500	1,799	377	2,137	515	3,525	1,071
3,750	1,889	391	2,275	538	3,713	1,134
4,000	1,972	410	2,366	568	3,821	1,208
4,250	2,024	428	2,429	596	3,927	1,271
4,500	2,080	447	2,472	624	3,988	1,337
4,750	2,131	467	2,500	652	4,011	1,399
5,000	2,159	488	2,491	681	4,005	1,458
5,250	2,204	504	2,508	703	3,991	1,509
5,500	2,350	518	2,694	725	4,146	1,561
6,000	2,586	730	2,174	930	2,957	1,738
6,500	2,944	648	3,352	887	4,885	1,849
7,000	2,974	677	3,312	925	4,860	1,922
7,500	2,978	710	3,221	963	4,692	1,979
8,000	2,941	735	3,077	992	4,430	2,025
9,000	2,815	787	2,738	1,051	3,817	2,116
10,000	2,766	808	2,377	1,060	3,396	2,074
11,000	2,661	807	2,122	1,041	3,028	1,982
12,000	2,652	803	2,106	1,018	2,925	1,884
13,000	2,549	748	2,125	940	2,895	1,713
14,000	2,480	702	2,203	878	2,974	1,584
15,000	2,450	665	2,269	829	3,103	1,487
17,000	3,104	785	3,022	942	3,741	1,574
19,000	3,383	1,081	3,039	1,220	3,549	1,782
21,000	3,367	1,083	3,072	1,225	3,598	1,799
23,000	2,779	1,000	2,534	1,136	3,016	1,686
25,000	2,513	822	2,334	955	2,974	1,494
27,000	3,100	973	2,739	1,089	3,041	1,558
29,000	3,234	924	3,063	1,046	3,542	1,541
31,000	3,044	939	2,769	1,047	3,105	1,483

Upper Lake Redding Study Site Boards In WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	5,532	3,005	1,916	2,670	1,120	1,103
3,500	4,817	2,613	1,897	2,328	1,139	994
3,750	4,294	2,287	1,918	2,044	1,162	902
4,000	3,895	2,025	1,930	1,815	1,207	828
4,250	3,570	1,797	1,973	1,616	1,253	761
4,500	3,257	1,591	1,962	1,434	1,279	696
4,750	3,056	1,436	1,974	1,298	1,299	649
5,000	2,877	1,315	1,950	1,192	1,290	615
5,250	2,716	1,204	1,936	1,095	1,309	584
5,500	2,605	1,120	1,925	1,023	1,314	563
6,000	2,545	1,019	2,059	939	1,483	559
6,500	2,493	932	2,145	868	1,609	561
7,000	2,393	864	2,084	811	1,594	554
7,500	2,342	825	2,026	779	1,568	556
8,000	2,336	804	1,983	762	1,533	558
9,000	2,265	820	1,778	786	1,409	616
10,000	2,248	800	1,803	771	1,441	626
11,000	2,357	824	1,914	802	1,550	687
12,000	2,447	858	2,021	838	1,671	733
13,000	2,498	894	2,109	877	1,734	785
14,000	2,320	917	1,964	901	1,605	815
15,000	2,022	827	1,806	810	1,468	725
17,000	2,098	704	2,144	693	1,862	631
19,000	2,561	792	2,629	784	2,314	737
21,000	2,797	914	2,402	907	2,103	866
23,000	2,714	1,003	1,799	999	1,587	967
25,000	2,626	897	1,826	896	1,592	882
27,000	2,691	903	1,945	901	1,739	883
29,000	2,539	975	1,703	972	1,463	950
31,000	1,807	958	961	952	839	923

Upper Lake Redding Study Site Boards Out WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	4,152	3,087	2,502	2,726	873	1,037
3,500	3,761	2,928	2,178	2,586	813	985
3,750	3,431	2,810	1,943	2,483	782	950
4,000	3,104	2,731	1,753	2,414	751	929
4,250	2,784	2,648	1,569	2,341	705	904
4,500	2,550	2,571	1,452	2,273	676	881
4,750	2,419	2,511	1,440	2,221	705	864
5,000	2,255	2,499	1,405	2,211	709	860
5,250	2,174	2,449	1,393	2,167	719	851
5,500	2,067	2,421	1,378	2,143	716	845
6,000	1,837	2,355	1,334	2,087	719	833
6,500	1,682	2,258	1,318	2,003	724	812
7,000	1,526	2,163	1,279	1,922	702	794
7,500	1,374	2,045	1,211	1,821	674	771
8,000	1,291	1,893	1,163	1,687	639	722
9,000	1,274	1,514	1,192	1,354	747	603
10,000	1,271	1,130	1,245	1,018	865	490
11,000	1,348	878	1,315	801	979	440
12,000	1,473	712	1,457	659	1,144	406
13,000	1,634	624	1,630	590	1,319	425
14,000	1,707	581	1,708	561	1,429	463
15,000	1,770	564	1,789	551	1,564	484
17,000	1,945	607	1,902	600	1,688	561
19,000	1,899	691	1,672	688	1,511	660
21,000	1,879	649	1,579	655	1,446	667
23,000	1,936	721	1,550	726	1,395	738
25,000	1,992	716	1,653	725	1,491	751
27,000	2,018	729	1,711	738	1,549	765
29,000	1,933	748	1,638	753	1,483	766
31,000	1,641	667	1,418	673	1,242	695

Lower Lake Redding Study Site Boards In WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	14,549	3,030	11,599	2,679	3,714	1,043
3,500	14,600	3,158	11,212	2,795	3,653	1,108
3,750	14,591	3,256	10,864	2,882	3,618	1,148
4,000	14,555	3,356	10,485	2,972	3,554	1,188
4,250	14,479	3,459	10,055	3,063	3,454	1,230
4,500	14,358	3,560	9,577	3,154	3,325	1,272
4,750	14,211	3,655	9,109	3,239	3,194	1,314
5,000	14,035	6,141	8,641	3,316	3,072	1,353
5,250	13,831	3,816	8,151	3,385	2,947	1,391
5,500	13,633	3,877	7,665	3,441	2,850	1,422
6,000	13,069	3,961	6,600	3,517	2,615	1,468
6,500	12,422	3,988	5,647	3,547	2,364	1,512
7,000	11,700	3,969	4,831	3,533	2,096	1,531
7,500	10,957	3,889	4,195	3,461	1,936	1,502
8,000	10,251	3,772	3,722	3,357	1,885	1,465
9,000	8,698	3,426	2,958	3,050	1,701	1,354
10,000	7,243	2,993	2,526	2,667	1,681	1,223
11,000	6,065	2,568	2,320	2,299	1,728	1,131
12,000	5,155	2,181	2,289	1,965	1,811	1,060
13,000	4,579	1,858	2,481	1,687	2,143	1,016
14,000	4,344	1,612	2,861	1,480	2,614	1,023
15,000	4,206	1,439	3,181	1,336	2,973	1,037
17,000	3,821	1,194	3,337	1,148	3,272	1,064
19,000	3,455	1,069	2,921	1,058	2,837	1,086
21,000	3,114	981	2,129	989	2,122	1,077
23,000	2,743	916	1,336	932	1,434	1,040
25,000	2,166	766	773	890	907	890
27,000	1,722	540	640	556	753	658
29,000	1,577	454	750	462	837	531
31,000	1,783	447	1,196	448	1,254	497

Lower Lake Redding Study Site Boards Out WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	3,112	1,679	2,381	1,469	594	491
3,500	2,893	1,560	2,238	1,365	569	456
3,750	2,631	1,440	2,043	1,260	526	421
4,000	2,409	1,328	1,886	1,163	492	390
4,250	2,218	1,224	1,745	1,072	468	360
4,500	2,066	1,137	1,630	996	453	335
4,750	1,949	1,080	1,527	946	435	319
5,000	1,886	1,030	1,502	903	429	305
5,250	1,818	980	1,497	858	432	292
5,500	1,698	931	1,446	816	425	280
6,000	1,437	862	1,277	756	398	263
6,500	1,339	829	1,229	728	398	255
7,000	1,307	790	1,233	695	416	249
7,500	1,280	749	1,222	359	407	239
8,000	1,279	712	1,228	626	408	223
9,000	1,276	580	1,290	511	435	186
10,000	1,292	533	1,232	471	440	180
11,000	1,163	450	1,112	399	381	159
12,000	1,287	423	1,223	374	415	147
13,000	1,322	420	1,309	373	468	151
14,000	1,664	416	1,756	372	721	165
15,000	2,342	464	2,508	418	1,000	197
17,000	4,102	631	4,426	566	1,521	261
19,000	5,674	926	6,178	833	1,953	393
21,000	6,905	1,197	7,611	1,075	2,280	495
23,000	9,580	1,860	9,546	1,657	2,716	700
25,000	7,853	2,481	7,881	2,198	2,276	868
27,000	5,237	2,129	5,083	1,885	1,686	774
29,000	3,741	1,699	3,168	1,506	1,332	649
31,000	3,079	1,549	2,302	1,375	1,112	627

Posse Grounds Study Site WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	4,593	915	5,128	809	1,747	323
3,500	5,179	987	5,569	874	1,909	359
3,750	5,023	1,029	5,261	911	1,918	376
4,000	4,302	1,034	4,475	915	1,861	417
4,250	4,379	1,088	4,475	975	1,959	469
4,500	4,238	1,055	4,264	945	1,855	451
4,750	4,459	1,130	4,304	1,000	1,824	432
5,000	4,167	1,165	4,065	1,030	1,885	440
5,250	3,975	1,169	3,973	1,033	2,023	454
5,500	3,892	1,245	3,858	1,096	2,064	520
6,000	3,880	1,343	3,762	1,187	2,017	627
6,500	3,723	1,252	3,706	1,116	2,029	558
7,000	3,579	1,264	3,660	1,136	2,246	607
7,500	3,309	1,219	3,452	1,110	2,269	663
8,000	3,310	1,205	3,417	1,103	2,249	706
9,000	3,258	1,153	3,120	1,061	2,096	735
10,000	3,401	1,169	2,997	1,087	2,053	841
11,000	2,431	973	2,182	898	1,568	729
12,000	2,411	752	2,470	693	1,999	606
13,000	2,133	644	2,285	602	2,000	581
14,000	2,067	613	2,245	575	2,009	583
15,000	2,147	601	2,271	570	2,045	617
17,000	2,175	641	2,062	615	1,825	707
19,000	2,086	689	1,496	669	1,418	742
21,000	1,771	695	1,057	681	1,028	763
23,000	1,351	476	1,069	473	998	504
25,000	1,589	351	1,703	356	1,629	396
27,000	2,279	494	2,532	505	2,439	577
29,000	2,334	610	2,595	623	2,545	703
31,000	2,388	608	2,692	624	2,508	723

Study Site 130 WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	4,340	889	3,366	854	2,523	775
3,500	4,357	928	3,364	891	2,515	803
3,750	4,349	963	3,340	923	2,508	829
4,000	4,403	992	3,420	950	2,597	848
4,250	4,309	1,013	3,334	969	2,549	866
4,500	4,161	1,015	3,219	971	2,504	873
4,750	4,048	1,011	3,122	968	2,456	880
5,000	3,932	1,007	3,000	966	2,385	885
5,250	3,855	1,007	2,913	965	2,327	889
5,500	3,758	973	2,853	935	2,279	865
6,000	3,535	964	2,619	927	2,151	885
6,500	3,360	928	2,448	895	2,045	879
7,000	3,190	902	2,240	872	1,915	878
7,500	3,044	879	2,084	850	1,817	874
8,000	2,920	855	1,960	828	1,723	867
9,000	2,722	822	1,760	798	1,544	865
10,000	2,579	802	1,604	779	1,443	861
11,000	2,420	769	1,500	750	1,412	845
12,000	2,280	717	1,424	703	1,402	815
13,000	2,284	691	1,521	675	1,501	781
14,000	2,276	682	1,606	667	1,669	773
15,000	2,605	669	2,244	661	2,374	783
17,000	3,389	716	3,557	729	4,054	974
19,000	3,835	849	3,948	887	4,582	1,310
21,000	3,867	848	3,793	897	4,521	1,388
23,000	3,729	764	3,724	818	4,466	1,328
25,000	3,798	839	3,441	903	4,037	1,452
27,000	3,550	838	2,748	897	3,322	1,454
29,000	3,510	863	2,359	919	2,969	1,490
31,000	3,312	861	1,885	895	2,326	1,450

Study Site 112 WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	5,280	2,264	4,467	2,017	1,263	846
3,500	5,248	2,186	4,448	1,951	1,292	837
3,750	5,301	2,139	4,572	1,917	1,379	859
4,000	5,308	2,134	4,631	1,916	1,448	873
4,250	5,536	2,110	4,977	1,877	1,653	776
4,500	5,526	2,055	5,015	1,828	1,821	753
4,750	5,520	1,965	5,074	1,751	2,067	742
5,000	5,585	1,884	5,174	1,686	2,206	745
5,250	5,648	1,869	5,217	1,674	2,274	743
5,500	5,648	1,849	5,155	1,655	2,298	734
6,000	5,761	1,861	5,013	1,670	2,384	761
6,500	5,775	1,972	4,798	1,778	2,368	846
7,000	5,834	1,772	4,769	1,604	2,411	793
7,500	5,727	1,787	4,531	1,617	2,284	802
8,000	5,721	1,801	4,405	1,635	2,338	838
9,000	5,582	1,743	4,041	1,598	2,221	891
10,000	5,482	1,644	3,917	1,513	2,236	873
11,000	5,392	1,598	3,758	1,481	2,291	906
12,000	5,713	1,470	4,385	1,376	2,898	905
13,000	5,825	1,538	4,628	1,452	3,201	1,022
14,000	5,940	1,433	5,036	1,355	3,701	962
15,000	5,891	1,291	5,212	1,230	3,941	918
17,000	5,712	1,423	4,944	1,390	3,797	1,199
19,000	4,754	1,194	3,952	1,166	2,885	1,003
21,000	6,474	1,380	5,978	1,359	4,150	1,230
23,000	6,400	1,640	5,856	1,616	4,129	1,472
25,000	6,311	1,501	5,761	1,479	4,221	1,341
27,000	5,987	1,794	5,290	1,778	4,214	1,669
29,000	4,680	1,578	4,181	1,599	3,902	1,654
31,000	4,128	1,527	3,658	1,561	3,619	1,665

Study Site 96 WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	4,093	540	3,689	451	1,455	211
3,500	3,945	920	3,477	767	1,425	366
3,750	3,197	918	3,060	757	1,299	389
4,000	2,767	825	2,775	675	1,183	375
4,250	2,569	769	2,558	629	1,085	357
4,500	2,353	730	2,321	599	999	342
4,750	2,248	702	2,207	579	972	325
5,000	2,121	673	2,056	559	937	310
5,250	2,024	669	1,945	559	905	309
5,500	1,893	680	1,802	569	884	310
6,000	1,634	709	1,570	594	789	310
6,500	1,515	745	1,450	621	745	319
7,000	1,433	750	1,374	618	722	328
7,500	1,328	737	1,247	598	699	345
8,000	1,166	693	1,097	553	657	352
9,000	819	510	802	415	494	281
10,000	765	420	677	344	518	276
11,000	725	409	590	347	473	304
12,000	561	344	443	285	355	211
13,000	500	318	412	269	339	201
14,000	450	281	442	240	354	140
15,000	541	272	530	237	494	139
17,000	632	249	603	220	758	199
19,000	629	228	541	194	648	228
21,000	540	206	501	173	552	204
23,000	472	175	493	161	559	181
25,000	486	154	509	151	749	208
27,000	582	183	619	174	917	295
29,000	641	210	688	195	994	323
31,000	648	247	699	225	984	379

Study Site 81 WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	11,346	5,135	10,608	4,623	3,663	2,179
3,500	10,526	4,859	9,828	4,375	3,374	2,066
3,750	9,890	4,627	9,137	4,167	3,135	1,971
4,000	9,367	4,418	8,545	3,983	2,921	1,901
4,250	8,907	4,258	7,951	3,847	2,718	1,878
4,500	8,543	4,167	7,538	3,777	2,538	1,900
4,750	7,997	3,958	7,132	3,581	2,320	1,765
5,000	7,439	3,744	6,659	3,357	2,110	1,519
5,250	7,008	3,579	6,297	3,202	2,035	1,412
5,500	6,634	3,422	6,079	3,060	2,204	1,345
6,000	5,905	3,017	5,848	2,702	2,493	1,210
6,500	5,782	2,777	5,864	2,494	2,605	1,146
7,000	5,588	2,633	5,722	2,367	2,664	1,100
7,500	5,419	2,515	5,564	2,263	2,660	1,060
8,000	5,267	2,412	5,426	2,174	2,676	1,039
9,000	5,133	2,247	5,292	2,036	2,739	1,023
10,000	4,941	2,122	5,029	1,934	2,730	1,023
11,000	4,808	2,040	4,887	1,866	2,935	1,016
12,000	4,526	1,862	4,674	1,718	3,122	1,009
13,000	4,102	1,693	4,359	1,578	3,100	1,001
14,000	3,944	1,569	4,221	1,473	3,161	983
15,000	4,044	1,480	4,425	1,401	3,485	986
17,000	4,202	1,315	4,764	1,291	4,299	1,115
19,000	4,300	1,238	4,725	1,240	3,991	1,176
21,000	4,517	1,226	4,925	1,221	4,007	1,133
23,000	4,299	1,104	4,736	1,093	3,989	985
25,000	4,355	1,034	4,887	1,038	4,328	999
27,000	4,637	1,152	5,179	1,171	4,884	1,189
29,000	4,502	1,132	5,061	1,162	5,035	1,234
31,000	4,658	1,198	5,288	1,223	5,415	1,277

Study Site 80 WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	0	0	0	0	0	0
3,500	0	0	0	0	0	0
3,750	8,093	574	9,077	514	3,116	225
4,000	8,550	649	9,289	580	3,252	256
4,250	9,700	1,134	9,415	1,008	3,336	414
4,500	9,683	878	9,752	784	3,411	343
4,750	10,019	960	9,804	858	3,454	375
5,000	10,508	1,170	9,766	1,045	3,572	453
5,250	10,842	1,369	9,598	1,222	3,579	531
5,500	11,142	1,556	9,479	1,390	3,573	609
6,000	11,723	1,995	9,173	1,783	3,543	788
6,500	11,996	2,481	8,626	2,219	3,455	991
7,000	12,091	2,862	8,204	2,561	3,416	1,154
7,500	11,777	3,161	7,580	2,831	3,274	1,292
8,000	11,083	3,323	6,914	2,979	3,145	1,381
9,000	9,358	3,175	5,917	2,861	3,009	1,415
10,000	7,764	2,790	5,050	2,523	2,791	1,359
11,000	6,262	2,330	4,245	2,108	2,508	1,268
12,000	5,010	1,998	3,461	1,805	2,218	1,185
13,000	3,944	1,714	2,834	1,547	2,022	1,086
14,000	3,076	1,474	2,324	1,329	1,864	1,001
15,000	2,567	1,308	2,066	1,180	1,836	950
17,000	2,316	1,164	2,107	1,050	1,954	899
19,000	2,647	938	2,781	857	2,543	784
21,000	3,396	962	3,652	894	3,308	895
23,000	3,797	993	4,157	941	3,795	1,011
25,000	3,926	1,032	4,333	994	3,955	1,116
27,000	4,037	1,097	4,400	1,061	3,894	1,189
29,000	4,302	1,176	4,589	1,142	3,989	1,308
31,000	4,328	1,210	4,648	1,179	4,004	1,347

Study Site 61/63 WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	29,291	9,310	29,722	8,305	10,868	3,611
3,500	29,774	9,375	30,391	8,367	11,361	3,661
3,750	31,860	9,496	32,387	8,486	11,964	3,770
4,000	33,208	9,684	33,782	8,662	12,440	3,888
4,250	32,705	10,039	33,398	8,981	12,472	4,038
4,500	31,992	10,273	32,699	9,191	12,417	4,144
4,750	30,441	10,279	31,209	9,198	11,927	4,154
5,000	28,674	10,193	29,449	9,122	11,326	4,126
5,250	26,989	10,015	27,711	8,964	10,978	4,064
5,500	25,342	9,844	25,950	8,819	10,601	4,040
6,000	22,605	9,558	23,044	8,591	9,802	4,082
6,500	20,826	9,220	20,844	8,303	9,112	4,019
7,000	19,994	9,055	19,642	8,172	8,873	4,047
7,500	18,832	8,885	18,270	8,038	8,334	4,076
8,000	18,114	8,669	17,492	7,848	8,022	4,013
9,000	17,428	8,330	16,818	7,539	7,990	3,878
10,000	17,099	7,831	16,667	7,100	8,311	3,740
11,000	17,380	7,294	16,936	6,625	9,132	3,547
12,000	17,530	6,942	17,032	6,328	9,930	3,491
13,000	18,460	6,836	18,216	6,262	11,281	3,615
14,000	19,397	6,719	19,395	6,178	12,704	3,711
15,000	19,557	6,721	19,143	6,211	13,099	3,922
17,000	21,009	6,965	18,892	6,485	13,403	4,372
19,000	23,887	7,064	19,264	6,633	14,061	4,741
21,000	25,143	7,567	19,013	7,158	14,077	5,337
23,000	24,904	7,804	18,180	7,388	13,449	5,515
25,000	25,000	7,820	17,997	7,450	13,677	5,786
27,000	26,072	7,513	20,082	7,212	15,994	5,869
29,000	25,914	7,379	20,385	7,113	16,551	5,971
31,000	25,649	7,539	19,785	7,339	16,319	6,459

Study Site 52 WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	3,486	790	1,790	763	925	602
3,500	3,374	843	1,696	811	896	634
3,750	3,255	823	1,618	790	871	608
4,000	3,151	798	1,573	763	872	578
4,250	3,088	778	1,574	740	910	547
4,500	3,009	769	1,554	728	921	528
4,750	2,998	755	1,547	718	941	542
5,000	2,939	746	1,547	707	961	534
5,250	2,892	735	1,544	695	986	527
5,500	2,817	717	1,547	673	1,008	514
6,000	2,693	697	1,550	643	1,037	492
6,500	2,586	677	1,507	619	1,039	465
7,000	2,488	643	1,471	585	1,009	439
7,500	2,359	639	1,405	579	977	429
8,000	2,302	620	1,357	559	961	412
9,000	2,242	603	1,401	544	1,031	416
10,000	2,109	578	1,301	524	989	403
11,000	2,046	560	1,294	513	1,019	409
12,000	2,122	554	1,398	513	1,139	425
13,000	2,070	547	1,381	506	1,118	405
14,000	1,910	535	1,364	495	1,143	406
15,000	1,990	546	1,425	511	1,168	448
17,000	1,979	543	1,568	508	1,198	446
19,000	1,960	519	1,568	487	1,195	417
21,000	1,789	510	1,404	487	1,102	433
23,000	1,701	506	1,351	486	1,056	423
25,000	1,595	504	1,071	493	987	463
27,000	1,598	525	1,129	520	1,076	511
29,000	1,687	518	1,391	518	1,368	531
31,000	1,784	517	1,410	515	1,373	517

Above Hawes Hole Study Site WUA (ft²)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	27,114	10,283	25,093	9,453	13,314	6,233
3,500	25,360	9,707	23,764	8,941	12,863	5,931
3,750	24,152	9,168	22,969	8,451	12,831	5,613
4,000	22,775	8,736	23,165	8,063	12,663	5,392
4,250	21,457	8,412	20,585	7,779	12,499	5,260
4,500	20,218	8,104	19,482	7,506	12,338	5,131
4,750	19,095	7,873	18,478	7,300	12,132	5,025
5,000	18,073	7,698	17,411	7,140	11,798	4,943
5,250	17,134	7,531	16,398	6,986	11,440	4,862
5,500	16,308	7,327	15,503	6,801	11,062	4,776
6,000	15,070	6,923	14,053	6,437	10,510	4,608
6,500	14,460	6,669	13,105	6,218	10,308	4,562
7,000	13,536	6,434	12,082	5,997	9,849	4,447
7,500	12,164	6,106	10,867	5,706	9,285	4,334
8,000	10,943	5,653	10,013	5,315	8,794	4,225
9,000	11,208	4,960	10,415	4,698	8,150	3,975
10,000	12,120	4,598	11,499	4,326	8,927	3,609
11,000	12,497	4,447	12,189	4,196	9,543	3,604
12,000	13,081	4,350	13,097	4,145	10,109	3,704
13,000	13,458	4,179	13,872	3,930	10,818	3,344
14,000	14,268	4,173	14,948	3,932	12,353	3,465
15,000	14,360	4,135	15,548	3,908	13,555	3,650
17,000	14,887	4,235	15,883	3,980	14,702	3,972
19,000	14,056	4,460	13,884	4,262	13,844	4,713
21,000	13,525	4,102	13,315	3,960	13,250	4,552
23,000	14,306	3,895	14,354	3,807	14,670	4,677
25,000	14,995	4,185	14,893	4,145	15,272	5,254
27,000	14,919	4,276	16,354	4,220	15,307	5,279
29,000	16,389	4,065	18,933	4,078	17,076	5,052
31,000	20,560	4,773	23,259	4,867	20,728	5,783

Study Site 28 WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	3,437	887	2,012	834	1,510	779
3,500	3,284	854	1,932	802	1,439	760
3,750	3,178	825	1,912	772	1,427	742
4,000	3,073	802	1,852	749	1,407	729
4,250	3,006	786	1,834	732	1,440	724
4,500	2,970	775	1,841	722	1,507	721
4,750	2,916	772	1,801	719	1,517	725
5,000	2,861	772	1,766	718	1,515	728
5,250	2,811	766	1,747	712	1,507	721
5,500	2,780	767	1,736	714	1,531	722
6,000	2,741	746	1,821	698	1,572	725
6,500	2,760	705	1,941	661	1,615	699
7,000	2,705	683	1,923	642	1,634	682
7,500	2,682	682	1,948	642	1,683	685
8,000	2,597	685	1,881	647	1,652	691
9,000	2,432	686	1,754	658	1,609	732
10,000	2,214	801	1,475	750	1,284	811
11,000	1,802	711	1,299	672	1,224	740
12,000	2,237	582	1,970	567	1,751	637
13,000	2,351	590	2,210	577	2,331	675
14,000	2,354	580	2,294	583	2,427	750
15,000	2,304	576	2,273	585	2,444	788
17,000	2,280	569	2,182	580	2,151	836
19,000	2,198	592	1,804	601	1,726	810
21,000	2,063	610	1,399	608	1,332	769
23,000	1,797	558	1,091	561	1,092	721
25,000	1,790	534	1,177	552	1,196	749
27,000	1,587	505	1,213	534	1,413	755
29,000	2,336	463	2,377	479	2,435	703
31,000	2,444	516	2,547	524	2,595	740

Powerline Riffle Study Site WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	5,851	3,797	5,144	3,466	3,680	1,890
3,500	5,369	3,761	4,638	3,446	3,517	1,941
3,750	4,846	3,724	4,127	3,408	3,160	1,904
4,000	4,383	3,699	3,754	3,382	3,030	1,875
4,250	3,966	3,699	3,449	3,383	2,901	1,876
4,500	3,650	3,704	3,252	3,383	2,810	1,861
4,750	3,291	3,682	3,096	3,362	2,735	1,838
5,000	3,013	3,642	2,962	3,325	2,715	1,814
5,250	2,834	3,593	2,873	3,282	2,716	1,801
5,500	2,749	3,519	2,823	3,220	2,725	1,794
6,000	2,647	3,276	2,737	3,017	2,722	1,773
6,500	2,573	2,946	2,638	2,732	2,669	1,696
7,000	2,514	2,601	2,503	2,430	2,577	1,591
7,500	2,461	2,254	2,372	2,124	2,474	1,480
8,000	2,494	1,954	2,332	1,864	2,456	1,403
9,000	2,519	1,458	2,221	1,435	2,381	1,283
10,000	2,495	1,146	1,995	1,169	2,199	1,229
11,000	2,460	992	1,779	1,036	2,038	1,193
12,000	2,264	868	1,527	918	1,791	1,109
13,000	2,081	773	1,304	825	1,545	1,027
14,000	1,805	659	1,037	701	1,145	859
15,000	2,113	602	1,572	641	1,822	790
17,000	2,446	709	1,953	767	2,580	994
19,000	2,446	780	2,023	841	2,380	1,087
21,000	1,627	510	1,495	572	1,942	818
23,000	1,779	496	1,876	563	2,420	833
25,000	1,879	572	1,883	640	2,540	914
27,000	1,939	570	2,038	645	2,859	946
29,000	2,074	547	2,369	637	3,397	1,002
31,000	2,235	537	2,560	630	3,639	1,005

Study Site 15/17 WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	17,981	6,786	14,289	5,921	5,350	2,231
3,500	17,164	6,517	13,750	5,686	5,284	2,178
3,750	16,507	6,304	13,387	5,500	5,445	2,194
4,000	15,866	6,071	12,820	5,277	5,322	2,094
4,250	15,432	5,902	12,559	5,129	5,836	2,101
4,500	15,127	5,721	12,495	4,990	6,107	2,172
4,750	14,873	5,482	12,487	4,784	6,145	2,156
5,000	14,501	5,285	12,295	4,625	6,290	2,162
5,250	14,290	5,091	12,175	4,473	6,543	2,187
5,500	14,024	4,954	11,894	4,358	6,431	2,169
6,000	13,578	4,681	11,721	4,169	6,809	2,194
6,500	13,127	4,309	11,415	3,867	6,652	2,176
7,000	12,693	4,094	11,072	3,673	6,692	2,119
7,500	12,660	3,859	11,264	3,482	7,653	2,133
8,000	12,334	3,704	11,201	3,378	8,193	2,280
9,000	11,313	3,231	10,705	2,961	8,602	2,179
10,000	10,757	3,157	10,127	2,937	7,671	2,452
11,000	10,559	2,845	10,572	2,629	8,737	2,194
12,000	10,195	2,862	10,591	2,701	8,500	2,407
13,000	10,307	2,740	10,649	2,649	8,000	2,387
14,000	10,753	2,877	11,096	2,747	8,288	2,619
15,000	10,229	2,764	10,789	2,679	8,136	2,642
17,000	10,055	2,825	9,778	2,783	8,315	2,894
19,000	10,381	3,093	9,094	3,056	8,315	3,445
21,000	10,294	3,024	8,330	2,945	7,886	3,325
23,000	10,077	2,748	8,428	2,760	8,779	3,267
25,000	10,832	2,885	10,021	2,931	10,131	3,534
27,000	11,870	2,856	12,008	2,957	12,802	3,777
29,000	12,602	3,264	13,327	3,425	14,679	4,627
31,000	11,810	3,337	12,066	3,538	12,984	4,642

Study Site 9 WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	11,299	3,921	7,895	3,758	4,807	3,015
3,500	10,724	3,746	7,687	3,593	4,599	2,890
3,750	10,314	3,577	7,550	3,427	4,504	2,741
4,000	10,017	3,424	7,447	3,275	4,454	2,590
4,250	9,670	3,301	7,201	3,152	4,322	2,469
4,500	9,427	3,204	7,045	3,055	4,221	2,367
4,750	9,271	3,127	6,981	2,975	4,147	2,281
5,000	9,170	3,077	6,917	2,924	4,123	2,228
5,250	9,080	3,022	6,924	2,870	4,148	2,180
5,500	8,924	2,965	6,779	2,815	4,100	2,133
6,000	8,683	2,771	6,554	2,622	4,109	1,949
6,500	8,350	2,622	6,407	2,481	4,025	1,840
7,000	8,476	2,558	6,615	2,424	4,229	1,816
7,500	8,642	2,577	6,911	2,448	4,474	1,860
8,000	8,329	2,538	6,698	2,419	4,405	1,873
9,000	7,894	2,401	6,780	2,290	4,451	1,791
10,000	7,196	2,171	6,384	2,081	4,260	1,690
11,000	6,948	1,978	6,295	1,900	4,096	1,600
12,000	6,558	1,843	5,951	1,774	3,766	1,491
13,000	6,397	1,741	5,678	1,672	3,543	1,405
14,000	6,351	1,687	5,110	1,622	3,235	1,354
15,000	6,381	1,737	4,666	1,663	2,988	1,393
17,000	6,162	1,756	3,856	1,657	2,573	1,361
19,000	5,482	1,657	3,385	1,544	2,285	1,243
21,000	5,390	1,537	3,910	1,462	2,724	1,168
23,000	5,394	1,550	4,493	1,488	2,974	1,251
25,000	6,233	1,756	5,790	1,681	3,637	1,421
27,000	5,943	1,620	5,844	1,544	3,593	1,232
29,000	6,178	1,722	6,051	1,638	3,695	1,282
31,000	7,070	1,816	7,564	1,724	4,639	1,306

Price Riffle Study Site WUA (ft^2)

	Fall-run		Late-fall-run		Winter-run	
Flow (cfs)	Fry	Juvenile	Fry	Juvenile	Fry	Juvenile
3,250	4,647	2,577	5,073	2,269	1,480	827
3,500	4,701	2,467	5,087	2,172	1,498	793
3,750	4,812	2,358	5,160	2,076	1,501	759
4,000	4,956	2,243	5,313	1,975	1,564	723
4,250	5,159	2,116	5,711	1,862	1,729	682
4,500	5,179	2,033	5,784	1,789	1,799	661
4,750	5,378	1,984	5,974	1,745	1,910	654
5,000	5,337	1,904	5,978	1,674	1,970	632
5,250	5,290	1,801	5,945	1,582	2,077	601
5,500	5,619	1,761	6,264	1,545	2,364	595
6,000	5,748	1,741	6,344	1,529	2,584	608
6,500	6,109	1,783	6,668	1,575	3,067	684
7,000	5,956	1,740	6,650	1,541	3,299	702
7,500	5,739	1,650	6,459	1,464	3,360	713
8,000	5,748	1,643	6,358	1,449	3,376	731
9,000	6,050	1,635	6,357	1,417	3,855	765
10,000	6,248	1,619	6,791	1,383	4,604	836
11,000	6,088	1,705	6,522	1,460	4,910	981
12,000	5,972	1,788	6,297	1,525	4,947	1,061
13,000	6,226	1,871	6,461	1,602	5,348	1,162
14,000	6,215	1,945	6,290	1,682	5,390	1,331
15,000	5,498	1,823	5,330	1,567	4,850	1,303
17,000	5,028	1,679	4,481	1,411	4,322	1,382
19,000	5,245	1,681	4,386	1,385	4,325	1,521
21,000	4,572	1,552	3,849	1,306	4,061	1,568
23,000	4,336	1,413	3,686	1,195	3,822	1,469
25,000	3,894	1,257	3,131	1,060	3,390	1,350
27,000	4,340	1,364	3,553	1,161	3,598	1,463
29,000	3,828	1,180	3,455	1,038	3,413	1,290
31,000	4,144	1,353	3,564	1,212	3,488	1,409

APPENDIX J
SEGMENT HABITAT MODELING RESULTS

Fall-run Fry WUA (ft^2)

Flow (cfs)	Reach 6 Boards In	Reach 6 Boards Out	Reach 5	Reach 4
3,250	160,423	72,315	1,488,562	310,195
3,500	157,967	68,628	1,461,855	291,390
3,750	155,792	66,279	1,491,153	272,722
4,000	154,351	64,113	1,478,401	255,740
4,250	152,667	61,732	1,447,835	240,606
4,500	150,577	60,177	1,400,085	229,759
4,750	149,651	59,378	1,340,046	218,257
5,000	150,723	58,427	1,276,515	207,650
5,250	153,088	58,166	1,219,383	200,231
5,500	152,994	58,927	1,162,671	197,849
6,000	144,742	59,343	1,076,094	192,651
6,500	138,490	63,157	1,027,073	189,601
7,000	132,705	62,489	987,535	185,033
7,500	136,316	61,493	920,058	182,726
8,000	126,379	60,438	878,705	181,538
9,000	115,137	58,432	854,996	178,408
10,000	104,426	57,788	861,683	172,710
11,000	95,446	55,774	860,183	169,555
12,000	88,085	57,211	883,521	160,310
13,000	91,375	56,823	905,810	155,386
14,000	87,409	58,566	935,357	148,975
15,000	90,042	63,138	951,758	152,684
17,000	86,402	86,067	974,404	159,754
19,000	82,893	100,785	962,999	158,956
21,000	78,424	108,899	1,029,185	126,325
23,000	83,106	118,770	1,026,002	126,082
25,000	78,347	103,218	1,052,079	127,585
27,000	55,137	94,227	1,080,166	130,969
29,000	66,993	85,474	1,072,383	137,566
31,000	53,124	76,377	1,090,278	144,365

Late-fall-run Fry WUA (ft^2)

Flow (cfs)	Reach 6 Boards In	Reach 6 Boards Out	Reach 5	Reach 4
3,250	124,556	63,213	1,432,767	261,560
3,500	123,575	60,075	1,414,343	244,172
3,750	122,458	59,449	1,453,482	227,618
4,000	120,749	58,648	1,448,174	214,582
4,250	118,364	57,559	1,417,933	204,543
4,500	114,954	56,739	1,374,481	198,716
4,750	112,628	56,387	1,319,663	194,643
5,000	114,089	55,876	1,257,237	189,552
5,250	116,395	56,023	1,196,392	185,557
5,500	114,915	58,376	1,133,768	184,202
6,000	91,992	49,141	1,032,322	180,206
6,500	83,979	66,433	959,582	177,325
7,000	79,180	65,639	910,641	171,677
7,500	87,010	63,799	844,090	168,780
8,000	77,656	61,399	805,312	165,903
9,000	66,034	56,894	779,547	159,838
10,000	60,459	51,378	800,489	149,453
11,000	58,733	47,119	806,031	143,826
12,000	59,996	48,462	848,498	135,216
13,000	74,698	50,343	885,857	129,855
14,000	73,769	55,029	936,552	122,394
15,000	74,339	61,671	964,000	131,427
17,000	76,754	86,812	948,224	133,579
19,000	75,058	97,781	854,180	128,553
21,000	66,050	107,577	905,142	104,020
23,000	66,757	112,617	899,763	114,814
25,000	62,515	98,770	918,752	116,594
27,000	31,216	85,971	1,011,176	128,449
29,000	46,912	77,267	1,038,966	146,676
31,000	33,104	65,619	1,024,118	154,386

Winter-run Fry WUA (ft^2)

Flow (cfs)	Reach 6 Boards In	Reach 6 Boards Out	Reach 5	Reach 4
3,250	87,154	62,510	562,621	157,210
3,500	89,025	61,587	565,676	151,626
3,750	90,946	63,932	587,342	140,543
4,000	91,876	65,147	595,624	136,639
4,250	91,753	66,305	599,940	133,666
4,500	90,978	66,949	599,860	131,654
4,750	89,976	67,333	593,713	129,931
5,000	94,333	67,231	578,626	129,552
5,250	99,521	67,097	567,184	130,038
5,500	101,296	69,373	555,131	131,060
6,000	75,354	51,326	533,007	131,184
6,500	70,058	80,331	516,278	130,976
7,000	68,881	79,961	507,348	129,475
7,500	78,685	77,212	480,768	132,303
8,000	78,493	73,080	465,233	134,116
9,000	70,909	64,677	443,239	136,903
10,000	65,698	59,050	478,507	128,653
11,000	64,633	53,784	517,041	130,403
12,000	66,160	53,414	577,882	122,539
13,000	80,855	54,344	627,183	116,067
14,000	80,919	57,910	706,159	105,802
15,000	78,212	62,543	762,018	123,778
17,000	81,821	76,423	780,461	144,539
19,000	80,226	75,480	706,836	134,788
21,000	71,811	78,090	724,657	115,771
23,000	74,101	72,051	730,934	132,843
25,000	69,986	68,940	761,857	137,455
27,000	31,016	66,240	850,217	156,988
29,000	47,975	70,944	909,606	183,712
31,000	33,113	61,476	917,701	189,362

Fall-run Juvenile WUA (ft^2)

Flow (cfs)	Reach 6 Boards In	Reach 6 Boards Out	Reach 5	Reach 4
3,250	44,002	34,312	525,086	168,836
3,500	42,837	33,295	516,053	165,755
3,750	41,929	31,988	506,828	162,893
4,000	41,505	31,055	500,017	160,267
4,250	41,158	30,136	500,224	158,505
4,500	40,977	29,379	494,892	157,196
4,750	40,999	28,944	484,521	155,165
5,000	57,616	28,847	472,800	152,573
5,250	41,430	28,440	462,554	149,420
5,500	41,965	28,164	453,031	146,180
6,000	44,262	30,478	437,516	136,817
6,500	43,552	28,475	429,452	125,023
7,000	42,930	28,098	415,378	112,951
7,500	42,549	27,628	403,861	100,694
8,000	42,327	26,865	389,700	90,525
9,000	40,195	24,550	366,604	73,118
10,000	37,076	22,332	343,932	62,690
11,000	34,063	20,292	326,096	56,789
12,000	30,739	19,089	307,575	52,852
13,000	29,083	17,735	303,378	49,050
14,000	27,158	16,760	295,111	46,214
15,000	31,129	16,440	287,064	43,946
17,000	28,782	19,641	295,610	46,566
19,000	27,553	26,595	292,924	49,951
21,000	26,312	28,248	294,145	39,799
23,000	25,107	31,969	297,394	37,214
25,000	23,509	33,532	300,465	38,989
27,000	21,667	33,464	306,678	37,972
29,000	24,657	29,884	294,400	37,488
31,000	22,530	28,611	311,954	37,773

Late-fall-run Juvenile WUA (ft^2)

Flow (cfs)	Reach 6 Boards In	Reach 6 Boards Out	Reach 5	Reach 4
3,250	41,773	32,405	473,650	153,022
3,500	40,971	32,051	465,747	150,648
3,750	40,389	31,081	458,037	147,887
4,000	40,261	30,465	452,442	145,370
4,250	40,136	29,827	452,547	143,761
4,500	40,145	29,342	448,229	142,521
4,750	40,341	29,126	439,214	140,637
5,000	40,604	29,193	428,767	138,314
5,250	41,088	28,980	419,607	135,572
5,500	41,789	28,881	411,171	132,808
6,000	44,216	31,218	397,833	125,003
6,500	43,162	29,897	391,379	114,857
7,000	42,295	29,770	379,513	104,210
7,500	41,689	27,450	369,939	93,465
8,000	43,165	28,940	357,967	84,674
9,000	41,136	27,123	337,271	69,533
10,000	38,119	25,045	316,547	60,586
11,000	35,184	23,014	301,242	55,280
12,000	31,910	21,683	286,347	51,753
13,000	30,177	20,102	282,764	48,301
14,000	28,562	18,985	276,321	44,930
15,000	32,293	18,506	271,036	42,790
17,000	30,354	21,517	282,896	46,150
19,000	29,406	28,026	282,744	49,388
21,000	28,315	29,576	286,178	39,448
23,000	27,104	32,653	290,711	37,785
25,000	26,223	33,637	295,729	39,906
27,000	22,789	33,578	303,106	39,340
29,000	26,206	30,420	293,470	39,867
31,000	23,620	29,067	312,861	40,386

Winter-run Juvenile WUA (ft^2)

Flow (cfs)	Reach 6 Boards In	Reach 6 Boards Out	Reach 5	Reach 4
3,250	30,012	22,447	231,314	80,455
3,500	30,839	24,914	229,338	81,336
3,750	31,705	25,426	228,916	79,619
4,000	32,859	26,195	229,221	77,980
4,250	33,671	26,789	228,786	77,429
4,500	34,514	27,485	229,045	76,659
4,750	35,453	28,213	226,453	75,669
5,000	36,338	28,971	222,136	74,611
5,250	37,532	29,599	218,408	73,749
5,500	38,926	30,265	215,916	73,212
6,000	41,917	32,732	213,928	71,834
6,500	39,561	34,238	214,618	69,215
7,000	37,812	35,186	213,375	65,480
7,500	36,401	35,840	213,238	61,929
8,000	44,828	36,137	211,882	60,027
9,000	43,488	36,563	202,957	56,574
10,000	41,241	35,236	192,392	56,143
11,000	38,968	33,415	189,399	54,351
12,000	36,216	31,665	191,418	52,520
13,000	34,564	29,232	191,542	49,763
14,000	34,576	27,607	194,747	46,077
15,000	37,671	26,497	203,902	44,429
17,000	37,324	28,682	233,753	52,528
19,000	37,315	33,291	253,550	58,129
21,000	36,706	34,294	260,475	48,842
23,000	35,401	34,413	268,330	49,266
25,000	33,698	32,749	279,798	52,275
27,000	27,513	33,153	292,539	53,362
29,000	32,662	32,045	293,412	57,225
31,000	28,267	30,599	320,361	57,197