J Haas

WATER QUALITY CONTROL BOARD

# NOSSAMAN, GUTHNER, KNOX & ELLIOTT, LLP

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## MEMORANDUM

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| **TO:** | Jeremy Haas<br>San Diego Regional Water Quality Control Board |
| **cc** | Andrew Henderson, Esq.<br>Kristine Thalman<br>Bryan Starr<br>Melissa A. Poole |
| **FROM:** | Mary Lynn K. Coffee |
| **DATE:** | August 22, 2007 |
| **RE:** | Comments of BIA/SC, BIA0C and BILD on Revised Tentative Order R9-2007<br>- |
| **By:** | Overnight Express Mail |

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Enclosed are hard copies of the comment letter prepared on behalf of the industry associations listed above regarding Revised Tentative Order R9-2007, and Attachments A and B to that letter. The enclosed comment letter was submitted to you electronically by 5:00 p.m. PST this evening. In preparing these documents for shipment overnight, we discovered that certain cross references were omitted, and certain references and citations were mistaken. Therefore, this package also includes 'red-line' of our comment letter indicating the errors in our electronic submission. While these errors are purely administrative and do not change the substance or content of the comments submitted, we hope that their correction will aid you in more easily following and understanding the comment package, and we apologize for the typographical mistakes. Thanks very much.

MLC

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REFER TO FILE #
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August 22, 2007

**Submitted via Email; Original Sent Via California Overnight Express**
Mr. Jeremy Haas
California Regional Water Quality Control Board, San Diego Region
9174 Sky Park Court, Suite 100
San Diego, CA 92123

**Re: Public Comments Regarding Revised Tentative Order No. R9-2007-0002, NPDES No. CAS01087420 Waste Discharge Requirements for Discharges or Urban Runoff from the Municipal Separate Storm Sewer Systems (MS4s) Draining the Watersheds of the County of Orange, the Incorporated Cities of Orange County, and the Orange County Flood Control District Within the San Diego Region (July 6, 2007)**

Dear Mr. Haas:

The Building Industry Association of Southern California ("BIA/SC")[1], the Building Industry Association of Orange County ("BIAOC")[2] and the Building Industry Legal Defense Foundation ("BILD")[3], through their undersigned counsel, respectfully submit these comments to:

- The California Regional Water Quality Control Board, San Diego Region ("Regional Board") regarding Revised Tentative Order No. R9-2007-0002, NPDES No. CAS01087420, Waste Discharge Requirements for Discharges or Urban Runoff from the Municipal Separate Storm Sewer Systems (MS4s) Draining the Watersheds of the County of Orange, the Incorporated Cities of Orange County, and the Orange County Flood Control District Within the San Diego Region, dated July 6, 2007 (the "2nd Tentative Order"); and

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[1] BIA/SC is a is a nonprofit trade organization representing more than 2,400 member companies that collectively employ more than 200,000 people. BIASC's mission is to promote and protect the building industry to ensure its members' success in providing homes for all Southern Californians.

[2] BIAOC is the local chapter of the BIASC.

[3] BILD is a non-profit mutual benefit corporation and a wholly-controlled affiliate of BIA/SC, whose purposes is to defend the legal rights of current and prospective home and property owners and to maintain a favorable business climate for the construction industry in Southern California.

- The related Response to Comments Section X of the Fact Sheet/Technical Report for Tentative Order R9-2007-0002, also dated July 6, 2007 (the "Response to Comments").

We appreciate the opportunity to review and comment on the 2nd Tentative Order and Response to Comments. BIA/SC, BIAOC and BILD applaud the Regional Board's goal for the 2nd Tentative Order – which is clean water to protect the beneficial uses identified for South Orange County in the Water Quality Control Plan for the San Diego Basin (9) ("Basin Plan"). As stakeholders, BIA/SC, BILD andBIAOC are committed to working with the Regional Board and Copermittees to achieve this goal.

In addition to this comment letter, we are submitting concurrently herewith as Attachment A and also in electronic form, a red-line version of selected excerpts form the 2nd Tentative Order. The red-lined text focuses only on specific sections of the 2nd Tentative Order, which we comment on in this letter and believe require substantial further revision. The red-lined text focuses primarily on those addressing proposed requirements for regional and subregional Best Management Practices ("BMPs"), hydromodification control, including low impact development strategies and site design BMPs, and construction BMPs, include Active Treatment Systems ("ATS"). The red-lining submitted is not intended to dictate to the Regional Board exactly how to "wordsmith" further edits to the 2nd Tentative Draft. Instead, the red-lining is intended to supplement the comments in this letter by providing a more comprehensive understanding by the Regional Board and Regional Board staff regarding the substance of the comments and concerns set forth in this letter.

In making these comments and preparing the supplemental comments of the redline, we have reviewed, rely upon, and incorporate herein by reference the technical information, technical studies and reports, and comments prepared and submitted by the Construction Industry Coalition for Water Quality ("CICWQ") in their letter on the 2nd Tentative Draft dated August 22, 2007, enclosing the technical memorandum entitled "Geosyntec Comments Regarding Revised Tentative Order No. R9-2007-0002, NPDES No. CAS01087420 Waste Discharge Requirements for Discharges or Urban Runoff from the Municipal Separate Storm Sewer Systems (MS4s) Draining the Watersheds of the County of Orange, the Incorporated Cities of Orange County, and the Orange County Flood Control District Within the San Diego Region (July 6, 2007)," dated August 22, 2007 ("CICWQ Comments").

Notwithstanding our support for the underlying goals of the 2nd Tentative Order, BIA/SC, BIAOC and BILD respectfully urge the Regional Board to require additional revisions to the 2nd Tentative Order prior to its adoption, because, among other reasons:

1) The Regional Board has failed to address and provide a considered and meaningful response to many of the critical comments and concerns of the regulated community that were lodged in response to the Regional Board's Tentative Order No. R9-2007-0002, NPDES No. CAS01087420, Waste Discharge Requirements for Discharges or Urban Runoff from the Municipal Separate Storm Sewer Systems (MS4s)

Draining the Watersheds of the County of Orange, the Incorporated Cities of Orange County, and the Orange County Flood Control District Within the San Diego Region, dated February 9, 2007 (the "1st Tentative Order");

2) The 2nd Tentative Order contains requirements that would discourage, and in some cases render infeasible or impossible, the implementation of programs and strategies that provide significant water quality benefit; and

3) The 2nd Tentative Order contains numerous technically and legally inappropriate requirements that should be substantially altered prior to adoption of a final order, including the requirements dealing with regional and subregional BMPs, hydromodification control, LID strategies and construction BMPs, including ATS.

## I. <u>The Regional Board Has Failed to Address and Respond Adequately to Previously Submitted Comments and Concerns</u>.

Based on our review of the Response to Comments, we believe we are compelled to restate and reinforce several crucial comments that were previously submitted by BIAOC and BILD in response to the 1st Tentative Order (the "BIA April Comments"). Without withdrawing or minimizing any of the prior BIA April Comments, we selectively emphasize the following key comments, which were not dealt with adequately in the Response to Comments and the 2nd Tentative Order, and which are equally applicable to and underpin many of these comments now submitted.

- *Failure to consider balancing factors*. As stated in the BIA April Comments (at pp. 22-29), we disagree with the Regional Board's assertion that it is not required to engage in balancing factors under Cal. Water Code §§ 13241 and 13263 when adopting the requirements of MS4 permits. The plain language of §§ 13241 and 13263 require that, unless if violates a federal *mandate,* whenever a Regional Board considers and imposes waste discharge requirements ("WDRs") and permit conditions, it must consider all of the factors prescribed in section 13241, including costs of compliance with those WDRs and permit conditions and, perhaps most importantly, the characteristics of the hydrographic unit under consideration and quality of water that is available to the individual water bodies within the unit. *City of Burbank v. State Water Resources Control Board*, 26 Cal. Rptr. 3d 304, 35 Cal. 4th 613, 625 (2005). In the Response to Comments, the Regional Board has failed to respond to this point, instead focusing on whether such requirements "go beyond" federal law, and hence whether such requirements constitute an unfunded mandate in violation of the California Constitution. While that argument may be somewhat related to the point made in the BIA April Comments, it is not the same. Instead of asking whether the Regional Board's determination of Maximum Extent Practicable ("MEP") "goes beyond" federal law, the Regional Board should recognize that determining MEP as required by federal law does not present a federal *mandate* to the Board that conflicts with the Board's appropriate exercise of discretion under Porter-

Cologne (including §§ 13241 and 13263) in crafting pollution control measures for MS4 permits. Instead, pursuant to the terms of the federal delegation of the NPDES permitting program to the State of California,[4] Porter-Cologne (including §§ 13241 and 13263) provides state law direction to the Regional Boards to guide their exercise of discretion in carrying out federal law by determining waste discharge requirements that constitute MEP. The federal Clean Water Act provides EPA and State Administrators with broad discretion in determining permit requirements appropriate to control stormwater discharges to the MEP, particularly because stormwater compliance with water quality standards is to be achieved through an iterative process. Nothing in federal law prevents Regional Boards from considering Cal. Water Code § 13241 factors in determining permit requirements necessary to *meet* the MEP standard, and the Regional Boards would not be violating a federal mandate to comply with State law in doing so. *City of Burbank v. State Water Resources Control Board*, 35 Cal. 4th 613, 629 (2005)("The states are free to manage their own water quality programs so long as the do not compromise the federal clean water standards). In fact, the delegation to the States was based on the very fact that Porter-Cologne provided an appropriate state law framework for implementation of federal Clean Water Act requirements.[5] The Regional Board's failure to recognize this important distinction has it headed toward a glaring legal error.

- *Unfunded state mandates*. The Regional Board has the legal authority under State law to impose mandates that "exceed" or are "more explicit" than the mandates or specific requirements of federal law. *Building Industry Association of San Diego County v. State Water Resources Control Board*, 124 Cal.App.4th 866 (2004); *City of Burbank v. State Water Resources Control Board*, 35 Cal.4th 613 (2005). However, when the Regional Board elects to use its discretion to impose mandates that do not comport with the federal Clean Water Act, including the MEP standard, it is electing to impose a state mandate within the meaning of California Constitution, Art. XIII B, Section 6. The California Supreme Court explained that the purpose of Art. XIII B, section 6 is "to preclude the state from shifting financial responsibility for carrying out

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[4] 54 Fed.Reg. 40664 (Oct. 3, 1989); *WaterKeepers Northern California v. State Water Resources Control Bd.*, 102 Cal. App. 4th 1448, 1452 (2002); Cal. Water Code § 13370 *et seq.*; *see* also NPDES Memorandum of Agreement Between US Environmental Protection Agency and the California State Water Resources Control Board (1989)(Regional Boards shall regulate all discharges subject to NPDES permits subject to federal and State law regulations and policy. MOA § I.C.3.a.)..

[5] EPA expressly embraced the Porter-Cologne legislative scheme and statutory framework as adequate to protect the waters of the United States under the Clean Water Act. 54 Fed.Reg. 40664 (Oct. 3, 1989); *WaterKeepers Northern California v. State Water Resources Control Bd.*, 102 Cal. App. 4th 1448, 1452 (2002); Cal. Water Code § 13370 *et seq;* See generally NPDES Memorandum of Agreement Between US Environmental Protection Agency and the California State Water Resources Control Board, approved September 25, 1989, amended.

governmental functions to local agencies, which are 'ill-equipped' to assume increased financial responsibilities because of the taxing and spending limitations that articles XIII A and XIII B impose." *Department of Finance v. Commission on State Mandates* (2003) 30 Cal.4th 727, 735 quoting *County of San Diego v. State of California* (1997) 15 Cal.4th 68, 81. In *County of Los Angeles v. Commission on State Mandates* (2007) 150 Cal. App. 4th 898, the court rejected the Regional Board's argument that all NPDES permit conditions are necessarily mandated under federal law and stated: "We are not convinced that the obligations imposed by a permit issued by a Regional Water Board necessarily constitute federal mandates under all circumstances. As explained in that case, the existence of a federal, as contrasted with a state, mandate is not easily ascertainable." Clearly, the Regional Board may impose such state mandates under Porter-Cologne; however, once imposed, the California Constitution requires that they must be funded by the State. Since portions of the 2nd. Tentative Order "are more explicit" than and "exceed" a proper determination of standards required to implement the federal CWA, including MEP, as discussed above, implementation of these provisions must be funded by the State. Specifically, the hydromodification control provisions in the 2nd Tentative Order continue to constitute state mandates. Under federal and state law, hydromodification constitutes non-point source pollution.[6] The hydromodification related requirements of the 2nd Tentative Order regulate this non-point source of pollution, which is reserved to state and local control in the Clean Water Act. This conclusion is consistent with EPA's position that it does not regulate "flow" as a pollutant and the State Board's classification of hydromodification as a nonpoint source.[7] As such, the Regional Board may, and in light of the nature of adverse impacts probably should regulate the non-point source pollution resulting from hydromodification. However, it does so by imposition of state mandates under Porter-Cologne, creating issues with respect to state unfunded mandates and CEQA. See section 9 of Attachment A..

- *Improper interpretation of MEP standard.* We concur with the proposition that the MEP standard is a flexible, technology-based standard. However, the law does direct and reasonably constrain the Regional Board's exercise of discretion and flexibility. The Regional Board must, as discussed above, take into account and rationally reconcile the balancing factors set forth in Cal. Water Code §§ 13241 and 13263. In addition, the Regional Board must take into account the policy and guidance documents prepared by State Water Resources Control Board ("State

[6] See *National Wildlife Federation v. Gorsuch*, 693 F.2d, 156 (D.C. Cir. 1982) (Deferring to EPA determination that hydromodification is not properly addressed through NPDES permits because of the absence of a discharge of a pollutant. See also *Missouri ex rel. Ashcroft v. Department of Army*, 672 F. 2d 1297 (8th Cir. 1982) (hydromodification did not cause discharge so as to trigger NPDES permit requirement). California Non-Point Source Program Plan (NPS Program Plan), Volume II: California Management Measures for Polluted Runoff at §§ 5.0-5.1 (January 2000); Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program, at Section VI (May 2004). *See* Cal. Water Code § 79114(b)

[7] 65 Fed. Reg.43586, 43619 (July 13, 2000); State *Water Resource Control Board Nonpoint Source Program Strategy and Implementation Plan* 1998-2013.

Board") relevant to setting MEP in developing standards.[8] *See* pp. 29-34 of the BIA April Comments. It is not clear from the record, due to failure to consider and conduct appropriate balancing for any of the proposed control measures, the failure to identify and provide in a circumscribed fashion the body of technical evidence relied upon in establishing specific control measures, and the failure to provide reasonably specific findings regarding the comparative environmental suitability, technical suitability and cost-effectiveness of particular control measures, whether the measures are appropriately tailored for stormwater quality control under state or federal law. For example, it cannot be ascertained whether the specific control measures addressed in the CICWQ Comments are a reasonable exercise of discretion and technically and factually appropriate, taking into account federal law and/or appropriate state law and State Board guidance.

- *Procedural issues*. We appreciate the clarification provided by the Regional Board in the Response to Comments regarding the nature of the proceedings being utilized by the Regional Board to consider and adopt the Tentative Order. *See* pp. 11-13 of Response to Comments. Because the Regional Board considers this action to be an administrative adjudication, however, we would expect full compliance with Cal. Gov. Code §11425.10 *et seq.* (Administrative Adjudication Bill of Rights), which requires, among other things, that a copy of the procedures to be followed be given to the individuals at whom the adjudication is directed. Cal. Gov. Code §11425.10(a)(2).

- *Application of Tentative Order requirements to projects with pre-existing approvals*. Although some aspects of the 1st Tentative Order were slightly revised to better accommodate existing land use approvals, the 2nd Tentative Order still does not take into account the infeasibility (both technical and legal) of imposing new planning requirements on projects that are already approved. *See* p. 23 of 2nd Tentative Order. The Response to Comments similarly fails to address our previous comments about the infeasibility of incorporating site design BMPs into projects that have obtained final approval, and instead concludes that "construction activities should comply with water quality regulations in place at the time of construction." *See* p. 40 of Response to Comments and pp. 64-66 of the BIA April Comments. The obvious concern about imposing new site design requirements on projects that have reached a certain stage in the approval process is that the new requirements, such as hydromodification control provisions, will necessarily require substantial site re-design if imposed at the back end of a project – after approvals have been granted. As was explained in our earlier

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8 "To achieve the MEP standard, municipalities must employ" [and therefore MS4 Permits should be designed to require,] "whatever Best Management Practices (BMPs) are technically feasible (i.e., are likely to be effective) and are not cost prohibitive. The major emphasis is on technical feasibility. Reducing pollutants to the MEP means [devising an MS4 Permit to require] choosing effective BMPs and rejecting applicable BMPs only where other effective BMPs will serve the same purpose, or BMPs would not be technically feasible, or the cost would be prohibitive." State Water Resources Control Board Memorandum, entitled "*Definition of Maximum Extent Practicable*," prepared by Elizabeth Jennings, Senior Staff Counsel, February 11, 1993; parenthetical added.

comments, there are legal impediments to imposing "new" requirements on projects after approvals have been granted.[9]

- *Improper regulation of discharges into the MS4. See* pp. 29-34 of the BIA April Comments. Removal of "into" language is justified based on SWRCB Order WQ-20001-15, which determined that the Regional Board may encourage the control of discharges into the MS4 but there is not authority to create penalties for Copermittees due to the improper discharges of others into the MS4. Certain provisions of the 2nd Tentative Order, including Section A.1 continue to create a violation as a result of such discharges. This language should be removed or revised to reflect Copermittees responsibility to adopt means, measures and controls to address discharges into MS4 systems that may cause pollution (i.e., illicit discharges) when discharged, but should not create permit violations for discharges which are beyond the control of the Copermittees. *See* section 3 of Attachment A.

- *Failure to consider regional and site-specific conditions.* As a general matter, the 2nd Tentative Order does not sufficiently allow for the consideration of site-specific, and in some cases regional, physical, hydrological and receiving water conditions and circumstances relevant to the control of stormwater quality and hydromodification. This concern is explained in more detail on pp. 37-45 of the BIA April Comments. These comments were not adequately addressed in the Response to Comments and the revisions reflected in the 2nd Tentative Order. The failure to appreciate these comments is particularly troubling with respect t hydromodification control requirements, including site design BMP requirements and LID strategies, and ATS mandates. As currently proposed, these requirements of the 2nd Tentative Order do not allow sufficient flexibility for the adequate consideration of site-specific conditions and circumstances, such as soil type, terrain, infiltration capacity and proper scale, etc. See section 2, section 6 fn 2, and Section 7 of Attachment A. Contrary to the suggestion in the Response to Comments, we do not believe the Regional Board had entirely ignored site-specific conditions in development of the 1st Tentative Order. *See* p. 23 of Response to Comments. Instead, we believe that the controlling law, and specifically Water Code section 13241, indicates that the MS4 permit should provide reasonable flexibility (and greater flexibility than provided by the 2nd Tentative Order) for the Copermittees and regulated community to consider and respond to site-specific conditions and circumstances, particularly in implementing hydromodification controls, site design BMPs, and ATS systems. With some relatively minimal, but

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[9] Local agencies have limited land use authority to condition projects that have already completed CEQA review and received all discretionary permits and approvals. By definition, issuance of ministerial permits do not involve discretionary action, and, while local agencies can enforce all conditions or approval and mitigation measures specified for a project prior to issuance of ministerial permits, they cannot impose new conditions to ministerial permits. 14 C.C.R. § 15041; Cal. Pub. Res. Code § 21166. Further, common law and statutory vested rights can impact the ability of any local agency to impose additional requirements on certain projects. *See* Cal. Gov. Code § 65864 *et seq.* (development agreements); Cal. Gov. Code § 66498.1 *et seq.* (subdivision map act); *Avco Community Developers, Inc. v. South Coast Reg'l Comm'n*, 17 Cal.3d 785, 791 (1976) (common law vesting rights).

important changes to the proposed language of 2nd Tentative Order, sufficient flexibility can be provided, which will improve water quality control and better comply with applicable law. *See* Section 5 of Attachment A and CICWQ Comments.

- *Collaboration between Copermittees and other groups*. The 2nd Tentative Order, like its precursor, does not sufficiently encourage cooperation of Copermittees with one another and other groups in a manner that can benefit water quality. Agreements with HOAs, COAs and similar entities may improve water quality; and such collaboration may allow the Copermittees to expand their water quality reach, which allows for greater water quality benefits. *See* pp. 67-68 of the BIA April Comments. The Response to Comments states that the 2nd Tentative Order would not preclude collaboration with HOAs and other groups. *See* p. 62 of Response to Comments. To better assure that such collaboration is encouraged, the 2nd Tentative Order should be further revised as provided in to more specifically permit and encourage collaboration on BMP implementation and programs that will benefit water quality.

- *Failure to consider and integrate into the 2nd Tentative Order existing programs that address water quality issues*. The 2nd Tentative Order should recognize, approve, and comport with existing, highly-evolved and indeed *award-winning* water quality and natural resource conservation, management and protection programs such as the Special Area Management Plan ("SAMP"), Habitat Conservation Plan ("HCP"), Southern Subregion Natural Community Conservation Plan ("NCCP") and other large-scale aquatic and uplands resource programs that have been carried out in Orange County. The 2nd Tentative Order fails to adequately consider and take into account these programs, and presents new water quality and hydromodification control requirements that conflict with those developed under the water quality and natural resource management conservation and protection programs pursuant to extensive watershed and subwatershed specific hydrological, biological, geomorphic and habitat resource studies. Because of this failure, the 2nd Tentative Order, as proposed, would negate the careful work that has gone into developing these programs, and prevent and in some cases preclude their proper implementation. *See* pp. 70-71 of the BIA April Comments. Notably, the prospective inability of the 2nd Tentative Order's requirements to operate in harmony with these existing local programs exemplifies the more general failure to recognize the importance of site-specific and sub-regional conditions and circumstances. These local programs properly take into account many, variable site-specific and sub-regional natural conditions and circumstances, which is consistent with the balancing factors set forth in Water Code section 13241. The 2nd Tentative Order does not.

- *Legal Authority Requirements*. We remain concerned that the Tentative Order does not accurately reflect the BMP based and adaptive management approach to regulation of storm water quality, including the applicable compliance standard with respect to the control of the discharge of pollutants from the MS4 as set forth in 33 USC § 1342(p)(3)(B). *See* Section 4 of Attachment A.

## II. The 2nd Tentative Order Will Discourage, and in Some Situations, Prohibit Programs and Strategies that Provide Significant Water Quality Benefits.

Although some changes were made to the provisions now in the 2nd Tentative Order and related findings that deal with regional or shared BMPs, these changes do not adequately address the concerns previously expressed in the BIA April Comments regarding the implementation of regional and sub-regional BMPs. *See* the BIA April Comments at pp. 35-38. In fact, the language in the 2nd Tentative Order will make it more difficult, and in some cases impossible, to implement such BMPs – even those proven to be very effective water quality measures.

As was explained in the more detail in the CICWQ technical memorandum previously submitted commenting on the 1st Tentative Order (the "April Technical Comments"), several regional shared or end-of-pipe BMPs implemented in Orange County, including those associated with the San Joaquin Marsh, the Natural Treatment System, and the Aliso Creek and Salt Creek water quality improvement projects, are extremely effective and useful components of the Copermittees' to enhance, improve and restore surface water quality and control non-point source pollution. *See* Geosyntec Consultants Memorandum entitled "Comments on Draft South Orange County MS4 Permit, Tentative Order No. R9-2007-0002, NPDES No. CAS0108740" (April 4, 2007), pp. 7-8, submitted by the CICWQ; County of Orange Report of Waste Discharge. In addition, the efficacy of shared or regional BMPs has been recognized by State Board and United States Environmental Protection Agency ("EPA").[10] These types of programs and projects enjoy support by various environmental groups as important tools to protect, and improve water quality, but the 2nd Tentative Order creates significant and newly proposed hurdles to their implementation that are not consistent with applicable law or good policy.[11] In light of the acceptance by both the regulated community, environmental groups, the State Board and EPA of the value of surface water quality restoration and enhancement programs and related BMPs, it is inappropriate and exceedingly poor policy for the Regional Board to discourage and effectively prevent these programs, as the 2nd Tentative Order would do.

Specifically, the 2nd Tentative Order would add new requirements for implementation of regional or subregional BMPs or "FETDs" (Facilities that Extract, Treat and Discharge, as they

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[10] *See* generally State Water Resources Control Board- California Coastal Commission ("SWRCB-CCC"), *Nonpoint Source Program Strategy and Implementation Plan, 1998-2013 (PROSIP)*, SWRCB-CCC, Non Point Source-Coastal Zone Act Reauthorization Act (NPS-CZARA) Program, Fact Sheet 6. *See generally,* EPA NPS-CZARA guidance: http://www.epa.gov/owow/nps; http://www.epa.gov/OWOW/wetlands/facts/fact25.html; and http://www.epa.gov/owow/wetlands.

[11] *See*, e.g., http://www.naturaltreatmentsystem.org/pdf/NTSnewsletter.pdf ("Irvine Ranch Water District has done a marvelous job of helping with the problem of water quality in Upper Newport Bay. Nutrients are a major problem because they cause algae to grow and that doesn't leave enough oxygen for the fish. IRWD is doing a lot of work upstream to remove nutrients. IRWD has a major project that we strongly support to build 31 more sites where nature is going to be allowed to do its job of filtering nutrients out of the water" -- Jack Keating, Newport Bay Naturalists and Friends and "The Natural Treatment System being developed by the Irvine Ranch Water District will have a tremendous impact on the water quality in the Bay. The process will remove unwanted sediment, nutrients and other contaminants from the urban runoff. If left untreated, these pollutants would undoubtedly end up in the Bay" --Garry Brown, Executive Director, Orange County Coastkeeper).

are defined in the 2nd Tentative Order) that are implemented pursuant to South Orange County surface water enhancement and restoration projects. The 2nd Tentative Order would mandate that, over time, despite issuance of multiple State and federal agency approvals for South Orange County surface water enhancement and improvement projects, each facility associated with those improvement projects must obtain individual Waste Discharge Requirements ("WDRs"), produce effluent that complies with each and every receiving water quality standard, and comply with new and substantial additional monitoring requirements in excess of those mandated by the approved improvement program in order to be implemented. See, *e.g.*, 2nd Tentative Order §§ E.7, E.9, and B.5. These requirements will make it much more difficult – if not prohibitive in terms of compliance risks and conditions – to implement enhancement, restoration and improvement program related shared and regional BMPs.

The successful and effective shared and regional BMPs that are already implemented in the watershed, including those mentioned above, have demonstrated that regional and subregional BMPs are an important tool in the compliance "toolbox" to address non-point source pollution, and improve and enhance the biological and chemical integrity of surface waters for purpose of meeting water quality standards and Total Maximum Daily Loads ("TMDLs"). As a policy and legal matter, these types of treatment BMPs should be allowed, encouraged and permitted under the MS4 stormwater permitting program. Direct permitting under the MS4 Permit would eliminate the individual permitting hurdle created for these programs by the 2nd Tentative Order.

In addition, the 2nd Tentative Order creates an unworkably and legally unjustified standard for permitting of these types of water quality improvement program BMPs. The fundamental problem with the 2nd Tentative Order vis-à-vis FETDs is that it would require any and all effluent issuing from every FETD to comply with all water quality standards, even where the surface water that serves as the 'influent' (natural receiving water) to the FETD does not meet all water quality standards and the respective FETD is designed to *improve* area water quality by removing *some* amount of naturally-occurring and/or otherwise uncaptured pollutants or contaminants. By requiring "perfection" of the effluent leaving FETDs, the 2nd Tentative Order effectively makes insistence on perfection the enemy of reasonable improvement.

Not only is such a stance unwise from a policy standpoint, it is also legally infirm. First, many FETDs are put in place pursuant to water quality enhancement and improvement programs designed to help remediate naturally-occurring pollutants, such as indicator bacteria, and to supplement other required controls for difficult to manage non-point source contaminants.. It is obviously good and appropriate for agencies and jurisdictions to collaborate to improve surface water quality, particularly in the beaches and creeks of South Orange County, for purposes of environmental restoration and protection of health and safety, by minimizing these types of contaminants through FETDs. Consistent with the goals of the federal Clean Water Act, Copermittees should be encouraged, and the MS4 permit should facilitate programs to enhance and restore the biological, physical and chemical integrity of receiving waters. 33 U.S.C. §1251. Similarly, under Porter-Cologne, the primary purpose of the statewide program for water quality is to protect quality of waters from degradation. Cal. Water Code §13000. Where waters fall short of water quality standards, both federal and State program encourage enhancement and restoration, particularly if there are controllable water quality factors that, if addressed, can improve water quality and beneficial use. Cal. Water Code § 13241(c) (basin plans must address "water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area"). See, *e.g.*, Cal. Water Code Chap. 4, §§ 10537 *et. seq.*; Cal. Water Code Chap. 6, Watershed Protection Program, §§79070 *et. seq.*

Of course, to assure that these programs will improve water quality and not unintentionally degrade it, permitting of the BMPs used in conjunction with them is appropriate, and monitoring is important. However, the policy set forth in the 2nd Tentative Order concerning FETDs (i.e., that all FETDs must be (rather than may, in the discretion of the Regional Board be) individually permitted and that discharges from FETDs must meet all stated objectives regardless of initial receiving water quality) is untenable for legal and factual reasons.

First, California law concerning the natural right of upstream property owners to discharge storm water from their respective properties should be considered.[12] By force of gravity, storm water discharges, particularly those from existing development will ultimately enter water courses and MS4 systems. These flows from natural and existing urban areas will benefit from treatment by FETDs, since compliance with applicable stormwater quality controls have not effectively eliminated receiving water quality standard exceedences. FETDs can supplement stormwater quality control measures, particularly those applicable to existing and new development, to better achieve desired water quality.

Because up-gradient property owners enjoy a property right to discharge naturally occurring storm water from their properties, the proposed permit obligations at issue here should be reconsidered in light of that fact that such stormwater naturally flows into the MS4 systems. Importantly, such stormwater flows are often naturally "contaminated" from the moment they hit the ground due to both natural and anthropogenic pollutants. For example, "indicator bacteria" is considered a pollutant by the Regional Board, but it exists naturally in storm water. *See* Attachment B[13]. Similarly, natural loads of many constituents exceed the Regional Board's

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[12] Since 1873, it has been the settled law of California that higher-ground property owners have the right to discharge natural storm water from their properties. As the California Supreme Court confirmed in Ogburn v. Conner, 46 Cal. 346 (1873):

> "The principle seems to be established and indisputable that when two parcels of land belonging to different owners lie adjacent to each other, and one parcel lies lower than the other, the lower one owes a servitude to the upper to receive the water which naturally runs from it, provided the industry of man has not been used to create the servitude; or in other words, more familiar to students of the common law, the owner of the upper parcel of land has a natural easement in the lower parcel to the extent of the natural flow of water from the upper parcel to and upon the lower." Id. at 352, quoting Butler v. Peck, 16 Ohio St. 334, 342 (1865).

[13] List et al. 2005 examined nearly 20 years of bacteria water quality data from Orange County watersheds and found that exceedances of criteria were found from both natural watersheds with little human influence and urbanized watersheds and that strong evidence was present to conclude that the predominant source of indicator bacteria is natural and not anthropogenic.

stated objectives for storm water quality. *See* Attachment B[14]. In addition, stormwater has been shown to be contaminated by constituents that are deposited on land by aerial deposition, which has no bounds. *See* Attachment B[15]. In light of the fact that stormwater flows contain pollutants even when compliance with stormwater quality requirements is largely achieved, the 2nd Tentative Order should be revised to encourage programs designed to improve the quality of storm receiving waters through the thoughtful use of FETDs – consistent with their rights and duties to protect the environment and act in furtherance of the public health and safety.

Second, the federal Clean Water Act encourages enhancement and restoration programs, and California law provides that these programs should be implemented if they improve water quality—it does not require that improvement program measures must be capable of treating non-compliant receiving waters to the point that they will meet all water quality before they can be implemented. Watershed management, water quality improvement, and non-point source pollution control projects, like those associated with FETDs, must instead meet the following standards:

- they must describe the baseline water quality of the water body impacted;
- define water quality and beneficial use goals;
- and improve water quality or reduce pollutants.

*See* Cal. Water Code §§10532, 79114(a); 79114(f)(2); and 79114(f)(4).

Plainly, the proposed, heavy-handed conditioning of FETDs would frustrate and conflict with the water quality statutes that the Regional Board is tasked with administering. The Regional Board's interpretations of those statutes, even assuming they are not "clearly erroneous," are "significant factors" that support revision of the 2nd Revised Tentative Order. *Nipper v. California Auto. Assigned Risk Plan*, 19 Cal.3d 35, 45 (1977).

As a consequence, the Regional Board would be acting without rational basis and contrary to the law if it were to insist that every FETD must treat naturally-variable storm water to the fixed objectives and standards that it currently employs. Further, while permitting of these programs is important, they should be permitted through the MS4 permit, as opposed to requiring individual permitting . Therefore, as a legal and policy matter, we request that the language of the 2nd Tentative Order be revised as set forth in Attachment A, section 1 to encourage, rather

14 Stein and Yoon, 2007 found that natural areas, including those located in Orange County, are a substantial source of total suspended solids (TSS) during wet weather events, with some streams exhibiting TSS concentrations exceeding 100,000 mg $L^{-1}$ and very high total sediment yields (<4,000 kg $ha^{-1}$).

15 Sabin and Schiff (2007) and Sabin et al. (2005) indicate: 1) that dry atmospheric deposition represents a significant fraction of the total pollutant load in southern California waterbodies, and 2) that atmospheric deposition represents a significant source of metal loads in streams draining urbanized watersheds in southern California (57-100% of total pollutant load). Dry deposition, principally metals such as Cd, Cr, Cu, Pb, and Zn, can be a major source of stream water pollution following rainfall events.

than discourage water quality enhancement, improvement and non-point source pollution control programs that provide significant water quality benefit.

## III. <u>The Tentative Order Continues to Contain Legally and Technically Inappropriate Requirements.</u>

### A. Requirement to Infiltrate Dry Weather Flows.

The 2nd Tentative Order requires that all dry weather flows containing significant pollutant loads be diverted from infiltration devices. *See* page 22, section D.1.c(6)(b). Such a requirement is inappropriate because infiltration of pretreated dry weather flows is an important management method to prevent dry weather flow impacts to receiving waters, including hydromodification impacts. Although per the discussion in the Fact Sheet, which accompanied the 1st Tentative Order, discharge of dry weather flows would be allowed to infiltrate in certain types of vegetated BMPs, it is likely that infiltration basins will be a primary component of hydromodification control systems. Thus, the requirement to "divert" dry weather flows from these basins will likely pose a problem and create significantly inconsistent requirements. To improve hydromodification control, permittees must have the flexibility to design appropriate hydromodification control BMPs.

In addition, as a practical matter as written in the 2nd Tentative Order, it is difficult to interpret the term "dry weather flows containing significant pollutant loads" in any meaningful way. Vague provisions deny the regulated community of due process because they do not provide the regulated community with adequate notice of what is required to comply and, conversely, fail to provide adequate notice as to what may constitute a violation.[16] As such, we recommend that the 2nd Tentative Order be revised in accordance with the principles set forth in the technical comments submitted concurrently herewith by CICWQ. *See* CICWQ Comments, pp. 1-2; *see* also section 5 of Attachment A.

### B. Hydromodification Control Requirements.

As noted in our previous comments, we have significant concerns with the hydromodification control requirements as proposed in the 2nd Tentative Order. As written, the 2nd Tentative Order does not include sufficient waivers for projects that will not increase the potential for hydromodification or that discharge to a receiving waters that are not susceptible to hydromodification. For these types of new and redevelopment projects, there is no nexus to condition projects that do not have the potential to cause downstream hydromodification impacts

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16 It is a basic concept of law that "Notice is fundamental to due process." 7 Witkin § 638 (10th ed. 2006). The lack of an adequate definition constitutes improper notice to the regulated community in violation of due process. Cal. Const. Art. I, §§ 7, 15; Cal. Gov. Code § 11340 et *seq.* A "standard that has no content is no standard at all and is unreasonable." *Wheeler* v. *State Bd. of Forestry* 144 Cal.App.3d 522, 527-528 (1983). Thus, in order to provide the regulated community with sufficient notice of what is required to comply and what will constitute a violation so as to satisfy basic due process standards, the 2d Tentative Order should be revised to provide further clarification regarding a number of terms and conditions.

to implement expensive, unnecessary hydromodification controls. As such, we recommend that the Regional Board consider the types of waivers set forth and further explained in the CICWQ Comments.

First, with respect to waivers from hydromodification control requirements, the 2nd Tentative Order provides that conditional waivers may be allowed in situations where receiving waters are severely degraded or significantly hardened, however, such waivers must contain requirements for in-stream measures designed to improve the beneficial uses adversely affected by hydromodification, and these measures must be implemented within the same watershed as the project. *See* p. 36, section D.1.h(3)(c)(ii)(b). There are significant technical issues associated with these requirements, and from a policy perspective they are not appropriate. Projects should be encouraged to implement control measures that will address water quality impacts caused by the project development, rather than to implement in-stream measures in significantly hardened channels that, by definition, are not affected by hydromodification.. As a practical matter, implementation of these types of measures will be expensive, but will provide little benefit.

Second, the changes in the 2nd Tentative Order with respect to waivers for lack of discharge-caused hydrology changes are a step in the right direction but still are legally and technically problematic. From a legal perspective if a development does not increase the amount of existing imperviousness or discharge into a waterbody susceptible to hydromodification impacts, there is no constitutionally sufficient nexus to impose hydromodification control requirements.[17] Nor is there sufficient nexus to impost in stream restoration requirements to obtain a waiver avoiding the already constitutionally infirm hydromodification control requirements. From a technical perspective, requiring hydromodification controls for projects without impacts imposes costly and unnecessary measures on projects that are not likely adversely affect beneficial use. Therefore, we request that the Regional Board consider revising the Tentative Order to include hydromodification control waivers in accordance with these principles as further explained in the CICWQ comments.

### C. Construction Requirements Equate to Grading Limits and Mandate Advanced Treatment Systems.

#### 1. Advanced Treatment Systems.

The 2nd Tentative Order requires implementation of Advanced Treatment Systems ("ATS") for sediment in situations identified by the Copermittees to pose an "exceptional threat

[17] *Dolan v. City of Tigard* 512 U.S. 374 (1994). In *Dolan*, the U.S. Supreme Court held that a dedication requirement was invalid because it was not proportional to the project's impacts. In that case, the court reasoned that although the project at issue would create some additional impacts (increased storm water runoff and traffic) the conditions imposed were not necessary to address the project's impacts. The court stated that the agency imposing the condition must make "some sort of individualized determination" that the conditions were related both in nature and extent to project impacts. *Id.* at 391.

BMP approach to the control of high risk construction sites as outlined in the CICWQ comments. See section 8 of Attachment A.

**2. Grading Limits.**

With respect to BMP implementation at construction sites, the 2nd Tentative Order requires the Copermittees to limit the maximum amount of disturbed area prior to implementation of either temporary or permanent erosion control measures. *See* 2nd Tentative Order page 41, section D.2.d(1)(vi). This amounts to incorporation of grading limits into the 2nd Tentative Order. Legally, such proposed grading limits are not a proper interpretation of the MEP standard, as discussed above, and are likely to result in arbitrary, unworkable implementation standards.

As an alternative approach to unworkable, unjustified grading limits, we propose a "pro-active" approach to managing construction sediment and erosion.[19] Pollution prevention is the cornerstone of a construction storm water program that will enhance water quality. To achieve this goal, the 2nd Tentative Order should be revised to focus on minimizing pollutants in construction site discharges through (i) enhanced pollution prevention planning, (ii) more diligent inspection by the Copermittee and site contractor, and (iii) stricter requirements for the design and maintenance of Best Management Practices ("BMPs"). See section 8 of Attachment A.

With regard to soil and sediment, the primary pollutants of concern at construction sites, these objectives may be met through a comprehensive system of BMPs that include measures from four categories: runoff controls; erosion controls, sediment controls, and non-storm water management controls. Based on the collective experience of the construction industry observing construction sites throughout California, the majority of sites can be well protected with good SWPPP design, more diligent and proper application and maintenance of BMPs, as well as use of a hierarchy of complementary BMPs. This proactive approach is one that contractors can successfully implement, if given appropriate permit driven guidelines. Moreover, this approach is consistent with the Clean Water Act and supported by EPA.[20]

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19 We characterize our recommended approach as "pro-active" because it has as its principal aim pollution prevention, rather than "after the fact" pollution treatment and/or control. We believe the proactive approach, based on proven effluent control measures and explicit implementation guidelines is not only consistent with "performance based permitting," but is the best way to achieve it.

20 The relevant statutes, EPA regulations and case law all provide that NPDES permits may rely on BMPs as opposed to prescriptive measures, such a numeric limits. 40 C.F.R. § 122.44(k)(2); 33 U.S.C. § 1342(p)(3)(A); 33 U.S.C. § 1311(b)(1)(C); 40 C.F.R. § 122.44(k)(2); *Citizens Coal Council v. United States EPA*, 447 F.3d 879, 896 n.18 (6th Cir. 2006) (EPA has a "longstanding interpretation of the CWA as allowing BMPs to take the place of numeric effluent limitations [in permits issued under] 40 C.F.R. §122.44(k).") EPA continues to utilize BMPs as both BAT and BCT for construction sites, expressly finding that numeric effluent limits for construction sites are cost prohibitive with little demonstrative results. *See* Effluent Limitation Guidelines and New Source Performance Standards for the Construction and Development Category, 67 Fed. Reg. 42644, 42658 (proposed June 24, 2002) (to be codified at 40 C.F.R. pt. 122 and 450) ("EPA did not consider numeric pollutant controls a viable option" for construction storm water discharges).

This "pro-active" BMP approach is explained in more detail in the CICWQ Comments submitted concurrently herewith. *See* CICWC Comments, pp. 3-4.

**D. LID Provisions Should be Amended to Properly Take Into Account Proper Scale of LID Strategies.**

We are pleased that the Response to Comments supports the consideration of proper scale in the implementation of LID strategies. *See* pp. 43-44 of Response to Comments. LID strategies can be most effectively implemented when scale is considered. As noted in the previously submitted Technical Comments, in many instances, applying the proposed BMP site requirements at a project level may lead to poor project design when compared to applying these requirements at a broader sub-watershed or watershed scale. *See* pp. 9-11 of April Technical Comments. Thus, we request that the 2nd Tentative Order be amended to include language to the effect the proper scale will be taken into account when determining appropriate implementation, and ultimately compliance, with the LID site design BMP requirements. Again, for illustrative purposes, we are concurrently presenting red-lined language that better indicates what we believe the policy should be, as specifically set forth in sections 2 and 5 of Attachment A.

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This comment letter and Attachment (red-line of the 2nd Tentative Order), Attachment B, and the CICWQ Comments set forth proposed terms, conditions, and requirements of the 2nd Tentative Order that are inappropriate legally, scientifically, or as a matter of good water quality policy. These materials also indicate support for alternative terms, conditions and requirements that will achieve the Regional Board's laudable water quality goals in an appropriate and effective manner. BILD and BIAOC, thus, respectfully request that the Regional Board consider this information carefully and revise the 2nd Tentative Order before adopting it.

Thank you for the opportunity to provide comments on the 2nd Tentative Order. We respectfully request that this letter and accompanying information be placed into the record. We look forward to working with the Regional Board to effect necessary revisions to the 2nd Tentative Order. We would be more than happy to discuss any of these issues further with the Regional Board and/or Regional Board staff.

Sincerely,

Mary Lynn K Coffee

Mary Lynn Coffee
of NOSSAMAN, GUTHNER, KNOX & ELLIOTT, LLP

MLC

# Attachment A

## Section 1

**Section E. 7. – 9.**

7. Urban runoff treatment and/or mitigation must occur as set forth in this Order prior to the discharge of urban runoff into a receiving waters. ~~Treatment BMPs must not be constructed in waters of the U.S. or State unless the urban runoff flows are sufficiently pretreated to protect the values and functions of the water body. Federal regulations at 40 CFR 131.10(a) state that in no case shall a state adopt waste transport or waste assimilation as a designated use for any waters of the U.S. Authorizing the construction of an urban runoff treatment facility within a water of the U.S., or using the water body itself as a treatment system or for conveyance to a treatment system, would be tantamount to accepting waste assimilation as an appropriate use for that water body. Furthermore, the construction, operation, and maintenance of a pollution control facility in a water body can negatively impact the physical, chemical, and biological integrity, as well as the beneficial uses, of the water body. Without federal authorization (e.g., pursuant to Clean Water Act Section 404), waters of the U.S. may not be converted into, or used as, waste treatment or conveyance facilities. Similarly waste discharge requirements pursuant to California Water Code Section 13260 are required for the conversion or use of waters of the State as waste treatment or conveyance facilities. Diversion from waters of the U.S./State to treatment facilities and subsequent return to waters of the U.S. is allowable, provided that the effluent complies with applicable NPDES requirements.~~

~~8. The issuance of waste discharge requirements and an NPDES permit for the discharge of urban runoff from MS4s to waters of the U.S. is exempt from the requirement for preparation of environmental documents under the California Environmental Quality Act (CEQA) (Public Resources Code, Division 13, Chapter 3, section 21000 et seq.) in accordance with the CWC section 13389.~~

9. Copermittees have implemented and have proposed to continue implementing facilities that extract water from waters of the U.S. that do not meet water quality standards, subject such extracted water to treatment, then discharge the treated water back to waters of the U.S. Without sufficient treatment processes, facilities that extract, treat, and discharge (FETDs) to waters of the U.S. may discharge effluent that does not support all designated beneficial uses, and therefore, these processes must be permitted. ~~Use of t~~Theis MS4- NPDES Permit will serve to regulate discharges from FETDs but the Regional Board does not waive its discretion to require ~~is an interim approach until~~ individual or general NPDES requirements for such discharges ~~are developed. At that time, the FETD discharges will be expected to meet all applicable water quality standards.~~ At this time, monitoring of FETDs is necessary to characterize their effectiveness, and ensure that facilities do not

**Comment [MAP1]:** See section II of comment letter for detailed discussion of standards applicable an d appropriate for these types of programs.

**Comment [MAP2]:** Cal Water Code § 13389 was part of Porter-Cologne adopted to accomplish the delegation of administration of the Clean Water Act, including the issuance of NPDES permits, to California. It does not exempt from CEQA other permits and or requirements imposed by the Regional Board under Porter-Cologne. Cal. Water Code § 13372. Cal. Water Code § 13372 provides that the provisions of Chapter 5.5 of Porter-Cologne "apply only to actions required under the Federal Water Pollution Control Act and acts amendatory thereof or supplementary thereto." Section 13389 is part of Chapter 5.5 of Porter-Cologne. The court in *Committee for a Progressive Gilroy v. State Water Resources Control Board*, 192 Cal.App.3d 847 (1987) held that orders restoring water waste discharge levels to originally approved levels for a wastewater treatment plant were not exempt from compliance with CEQA by section 13389 because that section applies only to actions required under the Clean Water Act. Orders of the Regional and State Boards regarding wastewater discharge issued under the authority of the Porter-Cologne Water Quality Control Act were not required by the Clean Water Act and thus not exempt from CEQA review. In its discussion of Cal. Water Code Section 13389 a California appellate court stated. "Chapter 5.5 of the Porter-Cologne Act was enacted to allow the State of California to administer the National Pollutant Discharge Elimination System (NPDES). permits program. This chapter was patterned after the Federal Water Pollution Control Act, which created the NPDES permit system. Section 1371 of that act excludes the issuance of NPDES permits from the requirements of the National Environmental Policy Act after which CEQA was patterned. It is fairly apparent that the exemption for the promulgation of waste discharge requirements from CEQA contained in Water Code section 13389 was meant to parallel the exemption for the issuance of NPDES permits from the requirements of NEPA found in section 1371 of the federal act." *Pacific Water Conditioning Ass'n., Inc. v. City Council*, 73 Cal.App.3d 546, 557 (1977). Thus, the purpose of section 13389 was to exempt from CEQA permits issued by the State under the Clean Water Act not WDRs that are adopted under Porter-Cologne.

add or concentrate pollutants, create conditions of erosion, or unreasonably affect the quality of receiving waters.

**Section B.5.**

5. Facilities that Extract, Treat, and Discharge (FETDs). Each Permittee that extracts water from waters of the U.S., submits the water to treatment processes, then discharges the treated effluent to waters of the U.S. must implement the following:

a. The effluent discharged to waters of the U.S. must ~~not contain pollutants added by the treatment process or pollutants in greater concentration than the influent~~ improve, restore or enhance water quality, and reduce pollution;

b. The discharge must not degrade beneficial uses; and

~~b. The discharge must not cause or contribute to a condition of erosion;~~

~~c. The discharge must not cause or contribute to a condition of pollution or nuisance;~~

~~d. Submit verification to the Regional Board of compliance with Clean Water Act Section 404 at least 30 days prior to discharging effluent to waters of the U.S.; and~~

c. Conduct monitoring in accordance with Receiving Waters and Urban Runoff Monitoring and Reporting Program No. R9-2007-0002, Attachment E to this Order.

**Comment [MAP3]:** Consistent with the goals of the federal Clean Water Act to enhance and restore the chemical, physical and biological integrity of receiving waters, where waters fail to meet water quality standards, discharges must not degrade and should enhance beneficial uses. 33 USC § 1251. Similarly, under Porter-Cologne, the primary purpose of the statewide program for water quality is to protect the quality of receiving waters, including their beneficial uses, from degradation. Cal. Water Code§ 13000 et *seq.* In addition, watershed management plans and nonpoint source pollution control projects, such as FETDs, must descirbe the baseline water quality of hte waterbody impacted and define water quality and beneficial use goals, improve water quality or reduce pollutants. Cal. Water Code §§ 79114(a)(; (f)(2); (f)(4); 10534. These types of projects sare not.a nd shoudl not be reuired to meet all applicable water quality standards.

**Comment [MAP4]:** This standard is necessary to reflect that these projects are enhancement projects adopted pursuant to state law and consistent with federal law. See above for further explantion.

# Attachment A

## Section 2

**D.1.d.(4).**

(4) Site Design BMP Requirements

(a) Each Copermittee must require each Priority Development Project to implement site design BMPs to the MEP, which will collectively minimize directly connected impervious areas, limit loss of existing infiltration capacity, and protect areas that provide important water quality benefits necessary to maintain riparian and aquatic biota, and/or are particularly susceptible to erosion and sediment loss.

**Comment [MAP5]:** This language is necessary to accurately reflect the compliance standard for MS4 dischargers as set forth in 33 USC 1342(p)(3)(B).

(b) In determining the degree to which LID strategies must be, or have been implemented, it is appropriate for Copermittees to consider the scale of development, other site design BMPs employed, and volume and flow controls achieved by other BMPs implemented for a project area, including without limitation, regional, subregional and site-specific treatment control, hydromodification and LID measures and BMPs.

**Comment [MAP6]:** In many instances, applying BMP site requirements at a project level may lead to poor project design when compared to applying these requirements at a broader sub-watershed or watershed scale. *See* pp. 9-11 of April Technical Comments. Thus, we request that the 2nd Tentative Order be amended to include clear and specific language to the effect the proper scale will be taken into account when determining appropriate implementation, and ultimately compliance, with the LID site design BMP requirements.

# Attachment A

## Section 3

**Section A.1.**

Discharges ~~into and~~ from the municipal storm sewer systems (MS4s) is a manner causing, or threatening to cause, a condition of pollution, contamination, or nusiance (as defined in CWC section 13050), in waters of the state are prohibited.

**Comment [MAP7]:** Removal of "into" language is justified based on SWRCB Order WQ-20001-15, which determined that the Regional Board may encourage the control of discharges into the MS4 but there is not authority to create penalties for Copermittees due to the improper discharges of others into the MS4. This provision creates a violation as a result of such discharges. This language should be removed or revised to reflect Copermittees responsibility to adopt means, measures and controls to *control discharges into MS4 system that* may cause pollution (i.e., illicit discharges) but should not create a per se permit violation for discharges which are beyond the control of the Copermittees.

# Attachment A

## Section 4

**Section B.1.**

Each Copermittee must ~~prohibit all types of~~ adopt means, measures and controls to prevent non-storm water discharges into its MS4 unless such discharges are either authorized by a separate individual or general National Pollutant Discharge Elimination System (NPDES) permit or waste discharge requirements; or not prohibited in accordance with sections B.2. and B.3. below.

**Comment [MAP8]:** This language is required to reflect the BMP based and adaptive management approach to stormwater quality control pursuant to the Clean Water Act.

**Section C.1.**

a. Control to the maximum extent practicable the contribution of pollutants in discharges of runoff associated with industrial and construction activity to its MS4 and control the quality of runoff associated with industrial and construction activity to its MS4 and control the quality of runoff from industrial and construction sites. This requirement applies both to industrial and construction sites which have coverage under the statewide general industrial or construction storm water permits, as well as to those sites which do not. Grading ordinances must be ~~upgraded~~ updated and enforced as necessary to comply with this Order;

**Comment [MAP9]:** This language is necessary to accurately reflect the compliance standard for MS4 dischargers as set forth in 33 USC 1342(p)(3)(B).

b. Prohibit all identified illicit discharges not otherwise allowed pursuant to section B.2 including but not limited to:

(1) Sewage;
(2) Discharges of wash water resulting from the hosing or cleaning of gas stations, auto repair garages, or other types of automotive services facilities;
(3) Discharges resulting from the cleaning, repair, or maintenance of any type of equipment, machinery, or facility including motor vehicles, cement-related equipment, and port-a-potty servicing, etc.;
(4) Discharges of wash water from mobile operations such as mobile automobile washing, steam cleaning, power washing, and carpet cleaning, etc.;
(5) Discharges of wash water from the cleaning or hosing of impervious surfaces in municipal, industrial, commercial, and residential areas including parking lots, streets, sidewalks, driveways, patios, plazas, work yards and outdoor eating or drinking areas, etc.;
(6) Discharges of runoff from material storage areas containing chemicals, fuels, grease, oil, or other hazardous materials;
(7) Discharges of pool or fountain water containing chlorine, biocides, toxic amounts of salt, or other chemicals; discharges of pool or fountain filter backwash water;
(8) Discharges of sediment, pet waste, vegetation clippings, or other landscape or construction-related wastes; and
(9) Discharges of food-related wastes (e.g., grease, fish processing,

and restaurant kitchen mat and trash bin wash water, etc.).

c. Prohibit and eliminate illicit connections to the MS4;

d. Control to the maximum extent practicable the discharge of spills, dumping, or disposal of materials other than storm water to its MS4;

**Comment [MAP10]:** This language is necessary to accurately reflect the compliance standard for MS4 dischargers as set forth in 33 USC 1342(p)(3)(B).

e. Require compliance with conditions in Copermittee ordinances, permits, contracts or orders (i.e., hold dischargers to its MS4 accountable for their contributions of pollutants and flows);

f. Utilize legally available enforcement mechanisms to require compliance with Copermittee storm water ordinances, permits, contracts, or orders;

**Comment [MAP11]:** This language is necessary to accurately reflect the compliance standard for MS4 dischargers as set forth in 33 USC 1342(p)(3)(B): Copermittees are only required to utilize enforcement mechanisms to the extant that such mechanisms are legally available.

g. Control to the maximum extent practicable the contribution of pollutants from one portion of the shared MS4 to another portion of the MS4 through interagency agreements among Copermittees. Control of the contribution of pollutants from one portion of the shared MS4 to another portion of the MS4 through interagency agreements with other owners of the MS4 such as Caltrans, the Department of Defense, or Native American Tribes is encouraged;

**Comment [MAP12]:** This language is necessary to accurately reflect the compliance standard for MS4 dischargers as set forth in 33 USC 1342(p)(3)(B).

h. Carry out all inspections, surveillance, and monitoring necessary to determine compliance and noncompliance with local ordinances and permits and with this Order, including the prohibition on illicit discharges to the MS4. This means the Copermittee must have authority to enter, monitor, inspect, take measurements, review and copy records, and require regular reports from industrial facilities discharging into its MS4, including construction sites;

i. Require the use of BMPs to prevent or reduce the discharge of pollutants into MS4s to the MEP; and

j. Require documentation on the effectiveness of BMPs implemented to reduce the discharge of pollutants to the MS4 to the MEP.

Attachment A

Section 5

**Section D.1.a. – c.**

**1. DEVELOPMENT PLANNING COMPONENT**

Each Copermittee must implement a program which meets the requirements of this section and (1) reduces Development Project discharges of pollutants from the MS4 to the MEP, (2) prevents Development Project discharges from the MS4 from causing or contributing to a violation of water quality standards, (3) prevents illicit discharges into the MS4; and (4) manages increases in runoff discharge rates and durations from Development Projects that are likely to cause increased erosion of stream beds and banks, silt pollutant generation, or other impacts to beneficial uses ~~and stream habitat~~ due to increased erosive force.

**Comment [MAP13]:** Regional Boards may regulate point and nonpoint source pollutants that adversely effect beneficial uses or water quality but do not have independent jurisdiction over stream habitat absent a nexus to beneficial use and water quality.

a. **GENERAL PLAN**

Each Copermittee must revise as needed its General Plan or *equivalent plan (e.g., Comprehensive, Master, or Community Plan)* for the purpose of providing effective water quality and watershed protection principles and policies that ~~direct land-use decisions and~~ require implementation of consistent water quality protection measures for Development Projects.

**Comment [MAP14]:** Local jurisdictions retain the authority to determine appropriate land use and planning decisions -- not the Regional Board. Cal. Const. art. XI, section 7. "Under the police power granted by the Constitution, counties and cities have plenary authority to govern…" *Candid Enterprises, Inc. v. Grossmont Union High School Dist.* 39 Cal.3d 878, 885 (1985). Thus, the local jurisdictions, not the Regional Board, have plenary authority over local land use decisions. "[L]and use planning in essence chooses particular uses for the land; while environmental regulation, at its core, does not mandate particular uses of the land but requires only that, however the land is used, damage to the environment is kept within prescribed limits." *California Coastal Com'n. v. Granite Rock Co.* 480 U.S. 572 (1987).

b. **ENVIRONMENTAL REVIEW PROCESS**

Each Copermittee must revise as needed its current environmental review processes to accurately evaluate water quality impacts and cumulative impacts and identify appropriate measures to avoid, minimize and mitigate those impacts for all Development Projects.

c. **APPROVAL PROCESS CRITERIA AND REQUIREMENTS FOR ALL DEVELOPMENT PROJECTS**

For all proposed Development Projects, each Copermittee during the planning process, and prior to project approval and issuance of local permits, must prescribe the necessary requirements so that Development Project discharges of pollutants from the MS4 will be reduced to the MEP, will not cause or contribute to a violation of water quality standards, and will comply with Copermittee's ordinances, permits, plans, and requirements, and with this Order.

The requirements must include, but not be limited to, implementation by the project proponent or municipality of the following:

(1) Source control BMPs that reduce storm water pollutants of concern in urban runoff, including prevention of illicit discharges into the MS4; minimization of irrigation runoff; storm drain system stenciling or signage; properly designed outdoor material storage areas; properly designed outdoor work areas; and properly designed trash storage areas. Source control BMP selection should take into account relevant site-specific conditions, including but not limited to, soils characteristics, groundwater conditions and infiltration characteristics;

(2) Site design BMPs where feasible which maximize infiltration, provide retention, slow runoff, minimize impervious footprint, direct runoff from impervious areas into landscaping and other pervious surfaces, and construct impervious surfaces to minimum widths necessary. In determining the degree to which LID strategies should be implemented, Copermittees should consider the relationship of the project to planning scale (e.g., specific plan, subdivision map, tract map or lot), the site design BMPs implemented at relevant scales and volume and flow reduction controls achieved by other BMPs, including site specific and regional and subregional treatment BMPs. Site design BMPs should take into account relevant site-specific conditions, including but not limited to, soils characteristics, groundwater conditions and infiltration characteristics and flood control, hydrology and channel stability goals and constraints;

(3) Buffer zones for natural water bodies, where feasible and taking into account the planning scale at which the project is proposed and the value of the drainages that may be present on site. Where buffer zones are infeasible or inappropriate in light of resource values, require project proponent to implement other buffers such as trees, access restrictions, etc;

(4) Measures necessary so that grading or other construction activities meet the provisions specified in section D.2 of this Order; and

(5) Submittal of proof of a mechanism under which ongoing long-term maintenance of all structural post-construction BMPs will be conducted.

(6) Infiltration and Groundwater Protection

To protect groundwater quality, each Copermittee must

**Comment [MAP15]:** To the extent that source control BMPs involve runoff volume reductions and hydromodification control via percolation, site-specific conditions are a critical consideration to assess technical feasibility. Controlling law, and specifically Water Code section 13241, indicates that the 2nd Tentative Order should provide reasonable flexibility for the Copermittees and regulated community to consider and respond to site-specific conditions and circumstances.

**Comment [MAP16]:** Scale is a critical factor in determining technically appropriate BMPs; applying site design BMP requirements at a project level may lead to poor project design when compared to applying these requirements at a broader sub-watershed or watershed scale. *See* pp. 9-11 of April Technical Comments.

**Comment [MAP17]:** Controlling law, and specifically Water Code section 13241, indicates that the Tentative Order should provide reasonable flexibility for the Copermittees and regulated community to consider and respond to site-specific conditions and circumstances, particularly with respect to site design BMP requirements, including incorporation of LID strategies.

**Comment [MAP18]:** Copermittees should be encouraged to prioritize mitigation to achieve the greatest return in terms of water quality benefit and resource value. *See* prior comment regarding scale.

apply restrictions to the use of treatment control BMPs that are designed to primarily function as centralized infiltration devices (such as large infiltration trenches and infiltration basins). Such restrictions must be designed so that the use of such infiltration treatment control BMPs must not cause or contribute to an exceedance of groundwater quality objectives. At a minimum, each treatment control BMP designed to primarily function as a centralized infiltration device must meet the restrictions below, unless it is demonstrated that a restriction is not necessary to protect groundwater quality. The Copermittees may collectively or individually develop alternative restrictions on the use of treatment control BMPs which are designed to primarily function as centralized infiltration devices. Alternative restrictions developed by the Copermittees can partially or wholly replace the restrictions listed below. The restrictions are not intended to be applied to small infiltration systems dispersed throughout a development project.

(a) Urban runoff must undergo pretreatment such as sedimentation or filtration prior to infiltration;

(b) All dry weather flows shall undergo pretreatment such as filtration in vegetated pretreatment BMPs, to reduce ~~containing~~ significant pollutant loads prior to ~~must be diverted from~~ infiltration ~~devices~~;

**Comment [MAP19]:** See CICWQ Comments, comment 1.

(c) Pollution prevention and source control BMPs must be implemented at a level appropriate to protect groundwater quality at sites where infiltration treatment control BMPs are to be used;

(d) Infiltration treatment control BMPs must be adequately maintained so that they remove pollutants to the MEP;

(e) The vertical distance from the base of any infiltration treatment control BMP to the seasonal high groundwater mark must be at least 10 feet, except as provided in this subsection. Where groundwater basins do not support beneficial uses, this vertical distance criteria may be reduced, provided groundwater quality is maintained. If infiltration soils have a high absorptive capacity, as required by subsection (f) of this provision, a minimum depth of at least 3 feet is allowed. Additionally, infiltration of runoff that is treated, prior to infiltration, in a treatment control BMP that addresses the pollutants of concern in groundwater in accordance with other provisions of this Order is allowed with a minimum of 3 feet separation to groundwater;

(f) The soil through which infiltration is to occur must have physical and chemical characteristics (such as appropriate cation exchange capacity, organic content, clay content, and infiltration rate) which are adequate for proper infiltration durations and treatment of urban runoff for the protection of groundwater beneficial uses except that infiltration of treated urban runoff is allowed for hydromodification purposes in soils as set forth in subsection (e) above;

(g) Infiltration treatment control BMPs must not be used for areas of industrial or light industrial activity; areas subject to high vehicular traffic (25,000 or greater average daily traffic on main roadway or 15,000 or more average daily traffic on any intersecting roadway); automotive repair shops; car washes; fleet storage areas (bus, truck, etc.); nurseries;[1] and other high threat to water quality land uses and activities as designated by each Permittee. Areas of mixed land uses that include a low percentage of high threat to water quality land uses and activities may use infiltration treatment control BMPs, provided sufficient pre-treatment is provided. Also, runoff from these areas that is treated, prior to infiltration, in a treatment control BMP that addresses pollutants of concern in groundwater and is implemented in accordance with this Order may be infiltrated for hydromodification control purposes; and

(h) Infiltration treatment control BMPs must be located a minimum of 100 feet horizontally from any water supply wells used for domestic consumption.

**Comment [MAP20]:** Technical data shows that fewer feet of separation is protective of groundwater when conditions of this section are met, giving greater flexibility to implement some of the best performing treatment control BMPs. See April Technical Comments, p. 12.

**Comment [MAP21]:** This language is necessary to allow flexibility to comply with LID and hydromodification control measures as contained in this Tentative Order. See April Technical Comments, p. 12.

**Comment [MAP22]:** See previous comment.

**Comment [MAP23]:** Requiring a minimum of 100 feet horizontal separation from groundwater wells is only needed for wells with certain uses. Limitations in BMPs needed to comply hydromodification control and treatment control requirements should not be more protective than necessary to protect the relevant uses. See April Technical Comments, p. 13.

[1] Except with regard to treated nursery runoff or clean storm water runoff.

# Attachment A

## Section 6

**Section D.1.d.(6)**

(6) Treatment Control BMP Requirements[2]

Each Copermittee must require each Priority Development Project to implement treatment control BMPs to the MEP which meet the following requirements:

Comment [MAP24]: This language is necessary to accurately reflect the compliance standard for MS4 dischargers as set forth in 33 USC 1342(p)(3)(B).

(a) All treatment control BMPs for a single Priority Development Project must collectively be sized to comply with the following numeric sizing criteria:

(i) Volume-based treatment control BMPs must be designed to mitigate (infiltrate, filter, or treat) the volume of runoff produced from a 24-hour 85th percentile storm event, as determined from the County of Orange's 85th Percentile Precipitation Isopluvial Map[3]; or

(ii) Flow-based treatment control BMPs must be designed to mitigate (infiltrate, filter, or treat) either: a) the maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of a storm event; or b) the maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity (for each hour of a storm event), as determined from the local historical rainfall record, multiplied by a factor of two.

(b) Treatment control BMPs for all Priority Development Projects must mitigate ~~(infiltrate, filter, or treat)~~ (treat through infiltration, settling, filtration or other unit processes) the required volume or flow of runoff from all developed portions of the project, including landscaped areas.

Comment [MAP25]: Note: this was not our edit. This was provided in 2nd Tentative Order.

(c) All treatment control BMPs must be located so as to

[2] Low-Impact Development (LID) and other site design BMPs that are correctly designed to effectively infiltrate, filter, or treat runoff can be considered treatment control BMPs. Similarly, flow volume reductions achieved by treatment control BMPs should be considered in addressing LID site design BMPs, and compliance with hydromodification control.

[3] The isopluvial map is available from the County of Orange. The map can also be found as Figure A-1 Exhibit 7.II in the Model WQMP (September 2003), page 105 of 157 at http://www.ocwatersheds.com/StormWater/PDFs/2003_DAMP/2003_DAMP_Section_7_New_Development _Significant_Redevelopment.pdf.

infiltrate, filter, or treat runoff prior to its discharge to any waters of the U.S. Multiple Priority Development Projects may use shared treatment control BMPs as long as construction of any shared treatment control BMP is completed prior to the use or occupation of any Priority Development Project from which the treatment control BMP will receive runoff.

(d) All treatment control BMPs for Priority Development Projects must, at a minimum:

(i) Be ranked with high or medium pollutant removal efficiency for the project's most significant pollutants of concern, as the pollutant removal efficiencies are identified in the Copermittees' Model SUSMP or in the Copermittees' local SUSMPs as they are updated. Treatment control BMPs with a low removal efficiency ranking must only be approved by a Copermittee when a feasibility analysis has been conducted which exhibits that implementation of treatment control BMPs with high or medium removal efficiency rankings are infeasible for a Priority Development Project or portion of a Priority Development Project.

(ii) Be correctly sized and designed so as to remove pollutants to the MEP.

(e) Target removal of pollutants of concern from urban runoff.

(f) Be implemented close to pollutant sources (where shared BMPs are not proposed), and prior to discharging into waters of the U.S.

(g) Not be constructed within a waters of the U.S. or waters of the State unless in accordance with the requirements for FETDs as set forth in this Order.

(h) Include proof of a mechanism under which ongoing long-term maintenance will be conducted to ensure pollutants are reduced to the MEP for the life of the project. The mechanisms may be provided by the project proponent or Copermittee.

(i) Be designed and implemented with measures to avoid the creation of nuisance or pollution associated with vectors, such as mosquitoes, rodents, and flies.

**Comment [MAP26]:** Note: this was not our edit. This was provided in 2nd Tentative Order.

# Attachment A

## Section 7

**Section D.1.d.(8)**

(8) Low Impact Development (LID) Site Design BMP, Hydromodification Control and Treatment Control BMP Substitution Program

**Comment [MAP27]:** These changes are necessary to allow flexibility for small projects and infill projects to comply with this Order. Not allowing for such flexibility could discourage smart growth.

The Copermittees may develop a LID site design BMP, hydromodification control and treatment control BMP substitution program for incorporation into local SUSMPs, ~~which would allow a Priority Development Project to substitute implementation of a high level of site design BMPs for implementation of some or all treatment control BMPs. At a minimum~~, the program must meet the requirements below:

(a) Prior to implementation, the program must clearly exhibit that it will achieve equal or better runoff quality from each ~~Priority Development Project~~project which participates in the program;

(b) ~~For each Priority Development Project participating, the program must require all applicable source control BMPs listed in section D.1.d.(5) to be implemented;~~

~~(c)~~ For each ~~Priority Development P~~project participating, the program must require that runoff originating from exposed impervious parking areas, work areas, storage areas, staging areas, trash areas, and other similar areas where pollutants are generated and/or collected, must be routed through pervious areas prior to entering the MS4;

(d) ~~For each Priority Development Project participating, the program must require that all site design BMPs listed in section D.1.d.(4) be implemented;~~

~~(e) The program must only apply to Priority Development Projects and Priority Development Project categories with a relatively low potential to generate high levels of pollutants. The program must not apply to automotive repair shops or streets, roads, highways, or freeways that have high levels of average daily traffic;~~

~~(f)~~ The program must develop and utilize specific design criteria for each site design and treatment control

BMP to be utilized by the program;

(g) The program must include mechanisms to verify that each Priority Development Projectproject participating in the program is inwill achieve compliance with all applicable *SUSMP* requirements by implementation of the substitute BMPs; and

(h) The program must develop and implement a review process which verifies that each LID site design and/or treatment control BMP to be implemented meets the designated design criteria. The review process must also verify that each Priority Development Projectproject participating in the program is in compliance with all applicable SUSMP requirements.

The Copermittees may allow the substitution of the following types of control measures and BMPssite design and/or treatment control BMPs for onsite and/or site specific BMPs and control measures required byin this Order. This does not limit the Copermittees from allowing other BMP substitutions programs in accordance with the provisions of this Order.

(a) Copermittees may allow the implementation of subregional or regional LID, hydromodification control, and/or treatment control measures and BMPs, provided that the regional or subregional measures and BMPs provide the level of pollutant and flow control mandated by this Order, and discharge to the same receiving water as would have been the case if on-site and/or site specific controls had been incorporated into the SUSMP.

(b) For Redevelopment projects, the Copermittees may allow the hydromodification control and treatment control requirements of this Order for all or a portion of the project area to be met by controlling a substitute area that drains to the same receiving water so long as the substitute area has equivalent flow and pollutant characteristics to the project area.

(c) In SUSMPs for Redevelopment projects, the Copermittees may allow the payment of fees toward installation, implementation , maintenance and operation of approved subregional and regional hydromodification, control and/or treatment control BMPs, provided that the subregional or regional measures and BMPs, are reasonably likely to be funded and implemented in a period of time sufficient to mitigate post-construction adverse water quality impacts, provide the level of pollutant and flow control mandated by this Order, and discharge to the same receiving water as would have been the case if on-site and/or site specific controls had been incorporated into the SUSMP.

**Comment [MAP28]:** This standard for funding and implementation of mitigation measures is derived from CEQA case law, and constitutes the standard to determine when mitigation measures are sufficiently certain to constitute actual mitigation of impacts.

# Attachment A

## Section 8

**Section D.2.d.(1)**

(1) Designate BMPs: Each Copermittee must designate a minimum set of BMPs and other measures to be implemented at all construction sites. The designated minimum set of BMPs must include:

(a) General Site Management:

(i) Pollution prevention, where appropriate;
(ii) Development and implementation of a site-specific storm water management plan;
(iii) Minimization of areas that are cleared and graded during the wet season to only the portion of the site that is necessary for construction and capable of control through effective implementation of erosion and sediment controls;
(iv) Minimization of exposure time of disturbed soil areas;
(v) Minimization of grading during the wet season and correlation of grading with seasonal dry weather periods to the extent feasible;
(vi) ~~Limitation of grading to a maximum disturbed area as determined by each Copermittee before either temporary or permanent erosion controls are implemented to prevent storm water pollution. The Copermittee has the option of temporarily increasing the size of disturbed soil areas by a set amount beyond the maximum, if the individual site is in compliance with applicable storm water regulations and the site has adequate control practices implemented to prevent storm water pollution;~~
~~(vii)~~ *Temporary stabilization and reseeding of disturbed soil areas as rapidly as feasible;*
(viii) Wind erosion controls;
(ix) Tracking controls;
(x) Non-stormwater management measures to prevent illicit discharges and control stormwater pollution sources;
(xi) Waste management measures;
(xii) Preservation of natural hydrologic features

**Comment [MAP29]:** Legally, such proposed grading limits are not a proper interpretation of the MEP standard, as discussed in our accompanying comment letter and previously submitted comments, and are likely to result in arbitrary, unworkable implementation standards. As an alternative approach to unworkable, unjustified grading limits, we propose a "pro-active" approach to managing construction sediment and erosion. To achieve this goal, the 2d Tentative Order should be revised to focus on minimizing pollutants in construction site discharges through (i) enhanced pollution prevention planning, (ii) more diligent inspection by the Copermittee and site contractor, and (iii) stricter requirements for the design and maintenance of Best Management Practices ("BMPs"). With regard to soil and sediment, the primary pollutants of concern at construction sites, these objectives may be met through a comprehensive system of BMPs that include measures from four categories: runoff controls; erosion controls, sediment controls, and non-storm water management controls. Based on the collective experience of the construction industry observing construction sites throughout California, the majority of sites can be well protected with good SWPPP design, more diligent and proper application and maintenance of BMPs, as well as use of a hierarchy of complementary BMPs. This proactive approach is one that contractors can successfully implement, if given appropriate permit driven guidelines. Moreover, this approach is consistent with the Clean Water Act and supported by EPA. This "pro-active" BMP approach is explained in more detail in the CICWQ Comments submitted concurrently herewith.

where feasible;

(xiii) Preservation of riparian buffers and corridors where feasible;

(xiv) Evaluation and maintenance of all BMPs, until removed; and

(xv) Retention, reduction, and proper management of all pollutant discharges on site to the MEP standard.

(b) Erosion and Sediment Controls:

(i) Erosion prevention. Erosion prevention is to be used as the most important measure for keeping sediment on site during construction;

(ii) Sediment controls. Sediment controls are to be used as a supplement to erosion prevention for keeping sediment on-site during construction;

(iii) Slope stabilization must be used on all active slopes during rain events regardless of the season, and on all inactive slopes during the *rainy season and during rain events in the dry* season; and

(iv) Permanent revegetation or landscaping as early as feasible.

(c) Designate enhanced BMPs for 303(d) impairments and ESAs: Each Copermittee must implement, or require implementation of, enhanced sediment and erosion control BMPs~~measures~~ to address the exceptional threat to water quality posed by all construction sites tributary to CWA section 303(d) water body segments impaired for sediment or turbidity. Each Copermittee must also implement, or require implementation of, enhanced, site-specific measures for construction sites within or adjacent to or discharging directly to coastal lagoons, the ocean, or other receiving waters within environmentally sensitive areas (as defined in section Attachment C of this Order).

(i) ~~Advanced Sediment Treatment:~~ Each Copermittee must require implementation of ~~advanced treatment~~enhanced BMPs for erosion and sediment at construction sites (or portions thereof) that are determined by the Copermittee to be an exceptional threat to water quality. In evaluating the threat to water

**Comment [MAP30]:** Note: this was not our edit. This was provided in 2d Tentative Order.

**Comment [MAP31]:** As discussed more thoroughly in the CICWQ Comments (see. pp. 3-4) there are significant technical issues outstanding with respect to the implementation of ATS for construction sites, including toxicity concerns, deprivation of alluvial systems of natural sediment loads, nature and characteristics of receiving water, and the feasibility of incorporating these systems at small sites. These issues must be addressed before ATS is mandated for construction sites. It is inappropriate, both legally and technically, to require implementation of this type of treatment technology as part of the MS4 program without sufficient scientific information regarding its proper operation and maintenance, and the potential adverse effects on water quality associated with its implementation. See CICWQ Comments, p. 3 and Attachment A for further discussion of enhanced BMP approach and concerns associated with implementation of ATS.

quality, the following factors must be considered by the Copermittee:

[a] Soil erosion potential or soil type;
[b] The site's slopes;
[c] Project size and type;
[d] Sensitivity of receiving water bodies;
[e] Proximity to receiving water bodies;
[f] Non-storm water discharges;
[g] Ineffectiveness of other BMPs; and
[h] Any other relevant factors.

(d) Implement BMPs: Each Copermittee must implement, or require the implementation of, the designated minimum BMPs and any additional measures necessary to comply with this Order at each construction site within its jurisdiction year round. However, BMP implementation requirements can vary based on wet and dry seasons. Dry season BMP implementation must plan for and address unseasonal rain events that may occur during the dry season.

# Attachment A

## Section 9

**Section E.8.**

8. To the extent required under federal law. ~~T~~the issuance of waste discharge requirements and an NPDES permit for the discharge of urban runoff from MS4s to waters of the U.S. is exempt from the requirement for preparation of environmental documents under the California Environmental Quality Act (CEQA) (Public Resources Code, Division 13, Chapter 3, section 21000 et seq.) in accordance with the CWC section 13389.

**Comment [MAP32]:** Cal Water Code § 13389 was part of Porter-Cologne adopted to accomplish the delegation of administration of the Clean Water Act, including the issuance of NPDES permits, to California. It does not exempt from CEQA other permits and/or requirements imposed by the Regional Board under Porter-Cologne. Cal. Water Code § 13372. Cal. Water Code § 13372 provides that the provisions of Chapter 5.5 of Porter-Cologne "apply only to actions required under the Federal Water Pollution Control Act and acts amendatory thereof or supplementary thereto." Section 13389 is part of Chapter 5.5 of Porter-Cologne. The court in *Committee for a Progressive Gilroy v. State Water Resources Control Board*, 192 Cal.App.3d 847 (1987) held that orders restoring water waste discharge levels to originally approved levels for a wastewater treatment plant were not exempt from compliance with CEQA by section 13389 because that section applies only to actions required under the Clean Water Act. Orders of the Regional and State Boards regarding wastewater discharge issued under the authority of the Porter-Cologne Water Quality Control Act were not required by the Clean Water Act and thus not exempt from CEQA review. In its discussion of Cal. Water Code Section 13389 a California appellate court stated, "Chapter 5.5 of the Porter-Cologne Act was enacted to allow the State of California to administer the National Pollutant Discharge Elimination System (NPDES). permits program. This chapter was patterned after the Federal Water Pollution Control Act, which created the NPDES permit system. Section 1371 of that act excludes the issuance of NPDES permits from the requirements of the National Environmental Policy Act after which CEQA was patterned. It is fairly apparent that the exemption for the promulgation of waste discharge requirements from CEQA contained in Water Code section 13389 was meant to parallel the exemption for the issuance of NPDES permits from the requirements of NEPA found in section 1371 of the federal act." *Pacific Water Conditioning Ass'n., Inc. v. City Council*, 73 Cal.App.3d 546, 557 (1977). Thus, the purpose of section 13389 was to exempt from CEQA permits issued by the State under the Clean Water Act  not WDRs that are adopted under Porter-Cologne.

# Attachment B

# ASSESSMENT OF WATER QUALITY CONCENTRATIONS AND LOADS FROM NATURAL LANDSCAPES

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Technical Report 500

# EXECUTIVE SUMMARY

More than 100 waterbodies in southern California have been designated as impaired for their beneficial uses under Section 303(d) of the Clean Water Act for a range of constituents. Despite the number of impaired waterbodies, currently there is no basis for differentiating water quality problems from natural variability. Without knowing the range of natural background levels, it is difficult to discern whether high levels of naturally occurring constituents indicate a pollution problem. Furthermore, lack of information on background concentrations, load, and flux complicates determination of appropriate management targets when remediating impaired waterbodies. To fully evaluate the effect of anthropogenic activities, it is important to describe water quality in streams draining natural environments and to understand the factors that control these "natural loadings". The overall goal of this study is to evaluate the water quality contributions and properties of stream reaches in natural catchments throughout southern California. Specific questions addressed by this study are:

- What are the ranges of concentrations, loads, and fluxes of various metals, nutrients, solids, algae, and bacteria associated with storm and non-stormwater runoff from natural areas?
- How do the ranges of constituent concentrations and loads associated with natural areas compare with those associated with urban (developed) areas and existing water quality standards?
- How do the environmental characteristics of catchments influence constituent concentrations and loads from natural landscapes?

These questions were addressed by measuring surface water quality at 22 natural open-space sites spread across southern California's coastal watersheds (Figure ES-1). Sites were selected to represent a range of conditions and were located across six counties and twelve different watersheds: Arroyo Sequit, Los Angeles River, San Gabriel River, Malibu Creek, San Mateo Creek, San Juan Creek, Santa Ana River, San Luis Rey River, Santa Clara River, Ventura River, and Calleguas Creek watersheds. Data were collected from each of the selected sampling sites during both dry weather and wet weather conditions. Three dry season sampling events were conducted; spring 2005, fall 2005, and spring 2006. A total of 30 storm sampling-events were conducted during two wet seasons between December 2004 and April 2006, with each site being sampled during two to three storms. At each survey location the flow and physical and biological parameters of the site, such as percent canopy cover, were documented. Water samples were collected and analyzed for pH, total dissolved solids (TDS), total suspended solids (TSS), hardness, total and dissolved organic carbon (TOC, DOC), nitrate, nitrite, ammonia, total Kjeldahl nitrogen (TKN), total phosphorus (TP) orthophosphate (OP), total metals (arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium, and zinc), and bacteria (total coliform, *E. coli*, and *enterococcus*). During dry weather, algal samples were also collected for chlorophyll a and algal percent cover analysis.

Four basic analyses were used to characterize water quality from natural areas. First, the means, variances, and ranges of concentrations, loads, and fluxes were calculated to provide an estimate of expected baseline water quality. Second, water quality statistics from natural sites were compared with previous data collected by SCCWRP from watercourses draining developed areas of the greater Los Angeles basin to determine if significant differences existed between natural and developed areas (Stein and Tiefenthaler 2005, Stein *et al.* 2007, Ackerman *et al.* 2003). Third, wet and dry weather mean concentrations were compared with relevant water quality standards to evaluate how measured data compares to established management targets. Fourth, concentrations and loads from natural sites were analyzed to determine the factors that most influenced variability among sites.

The results of this study yielded the following conclusions:

- Concentrations and loads in natural areas are typically between one to two orders of magnitude lower than in developed watersheds.
- Wet-weather TSS concentration from natural catchments was similar to that from developed catchments.
- Differences between natural and developed areas are greater in dry weather than in wet weather (Figures ES-2 and ES-3).
- Dry weather loading can be a substantial portion of total annual load in natural areas.
- Peak concentration and load occur later in the storm in natural areas than in developed areas.
- Natural catchments do not appear to exhibit a stormwater first flush phenomenon.
- Concentrations of metals from natural areas were below the California Toxic Rules standards.
- The ratio of particulate to dissolved metals varies over the course of the storm.
- Wet-weather bacteria concentrations for *E. coli*, *enterococcus*, and total coliform exceeded freshwater standards in 40 to 50% of the samples.
- Concentrations of several nutrients were higher than the proposed USEPA nutrient guidelines for Ecoregion III, 6.
- Catchment geology was the most influential factor on variability in water quality from natural areas.
- Catchments underlain by sedimentary rock generally produce higher constituent concentrations than those underlain by igneous rock.
- Other environmental factors such as catchment size, flow-related factors, rainfall, slope, and canopy cover as well as land cover did not significantly affect the variability of water quality in natural areas.
- This study produced regionally applicable flux estimates for natural catchments encompassing storm and non-storm conditions (Table ES-1).

The flux estimates generated from this study should be applicable for estimates of the contribution of natural areas to overall watershed load throughout the southern California region. Because the sampling sites are representative of the major geologic and natural land cover settings of the region, they can be used to estimate regional or watershed specific loading from natural areas. The concentration provided by this study can also be used to help calibrate watershed models that account for rainfall runoff rates and antecedent dry conditions. Such models can be used to simulate water quality loading under a range of antecedent and rainfall conditions, thereby providing managers with additional tools for evaluation of background water quality conditions.

**Table ES-1. Estimated total annual fluxes of metals (kg/year km$^2$), nutrients (kg/year km$^2$), and solids (mt/year km$^2$) in natural catchments. No data available (-).**

| Annual Flux (kg/year km$^2$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Arsenic | Cadmium | Chromium | Copper | Iron | Lead | Nickel | Selenium | Zinc |
| Arroyo Seco | 0.31 | 0.06 | 0.58 | 0.36 | 189.50 | 0.19 | 0.20 | 0.13 | 1.11 |
| Piru Creek | 0.22 | 0.01 | 0.54 | 0.39 | 474.10 | 0.11 | 0.38 | 0.09 | 0.96 |
| Sespe Creek | 0.06 | 0.03 | 0.43 | 0.44 | 573.30 | 0.12 | 0.46 | 0.14 | 1.14 |
| Santiago Creek [a] | 0.16 | 0.05 | 0.13 | 0.21 | 65.70 | 0.05 | 0.22 | 0.54 | 0.67 |
| Tenaja Creek [a] | 0.03 | 0.01 | 0.07 | 0.05 | 77.10 | 0.03 | 0.03 | 0.02 | 0.29 |

| Annual Flux (kg/year km$^2$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Ammonia | Total Nitrogen | Dissolved Organic Carbon | Total Organic Carbon | Ortho-phosphate | Total Phosphoru s | Total Dissolved Solids | Total Suspended Solids |
| Arroyo Seco | 3 | 230 | 860 | 890 | 8 | 5 | 63 | 9 |
| Piru Creek | 3 | 190 | 620 | 1320 | 6 | - | - | 315 |
| Sespe Creek | 8 | 290 | 650 | 950 | 7 | - | 87 | 4059 |
| Santiago Creek [a] | 7 | 450 | 1710 | 1770 | 11 | 28 | 193 | 5 |
| Tenaja Creek [a] | 1 | 40 | 200 | 180 | 2 | 6 | 12 | 4 |

[a] Total fluxes are only for the eight months of the study from December 2005 through August 2006 during which the stream was flowing. No stream flow was present after August 2006 until the start of the next storm season.

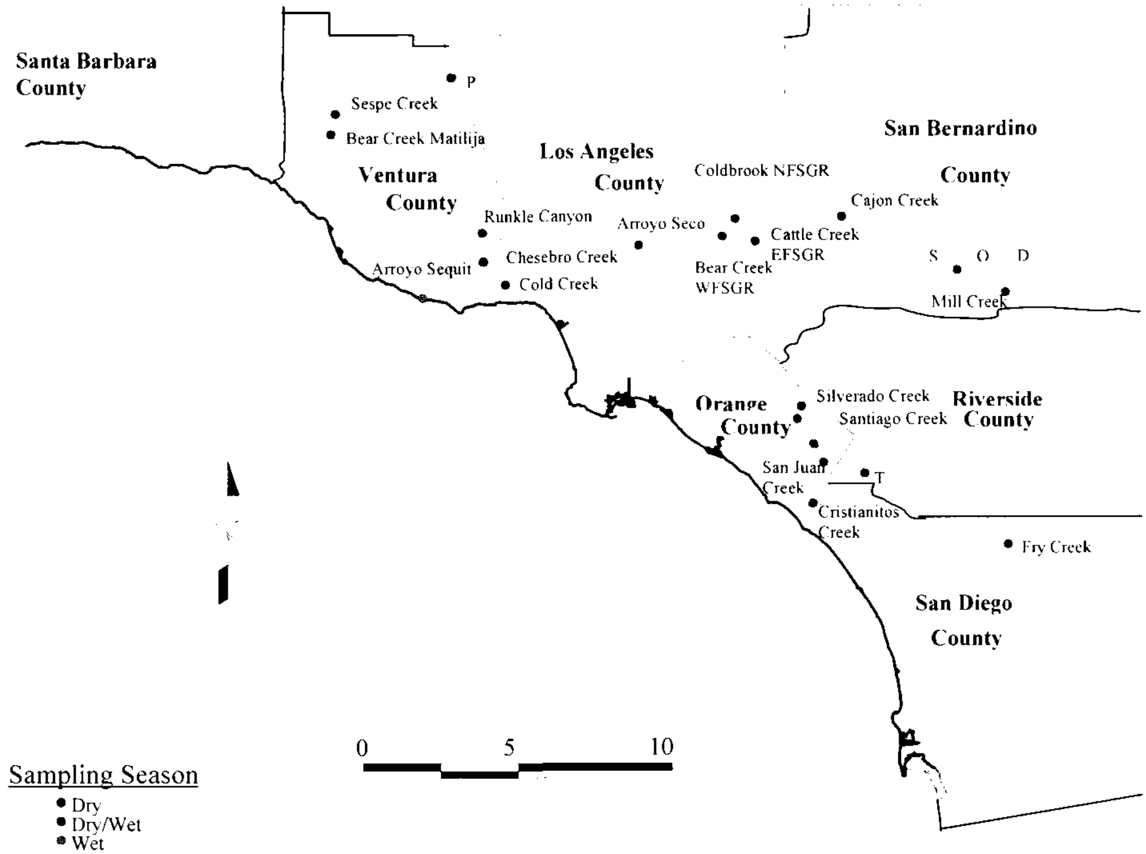


**Figure ES-1. Study sites: red dots indicate sites sampled during dry weather only; blue dots indicate sites sampled in both dry and wet weather; and green dots indicate sites sampled during wet weather only.**

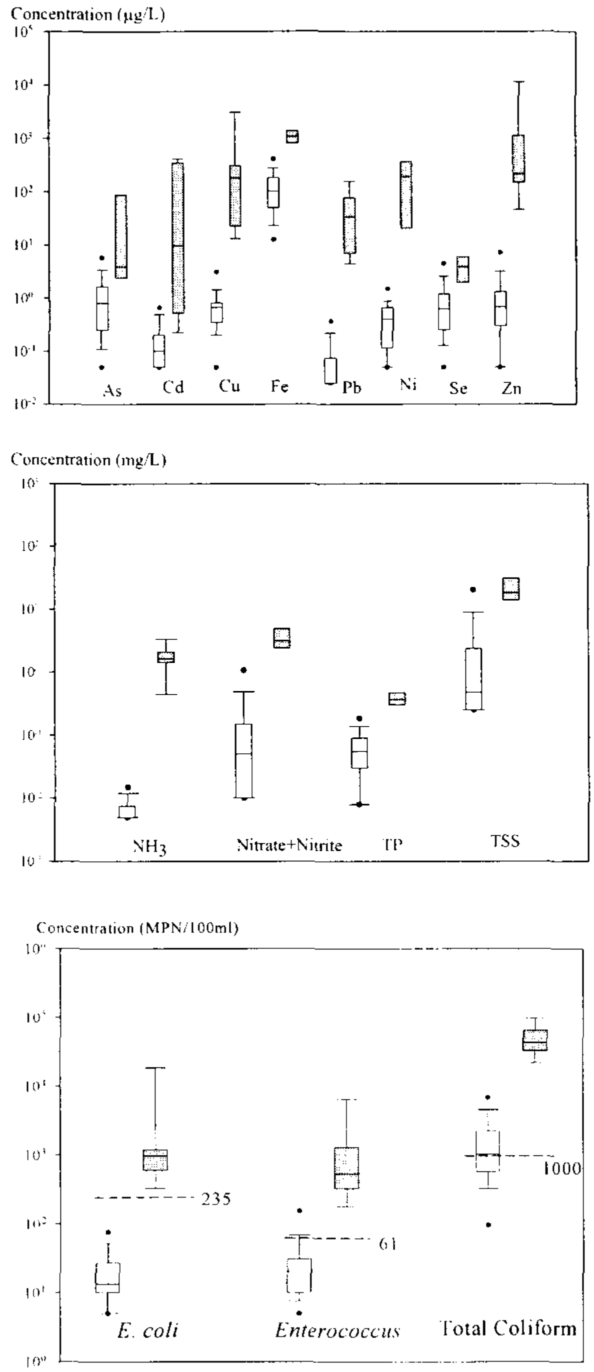


**Figure ES-2. Comparison of dry weather concentrations of metals, nutrients, TSS, and bacteria between natural and developed catchments. White boxes represent natural catchments, while gray boxes represent developed catchments. Solid lines within boxes indicate the median of all values in the category. Boxes indicate 25th and 75th percentiles, and error bars indicate 10th and 90th percentiles. Solid dots indicate 5th and 95th percentiles. The Y axis is in log scale. Dotted lines indicate Department of Health and Safety draft guidelines for freshwater recreation.**

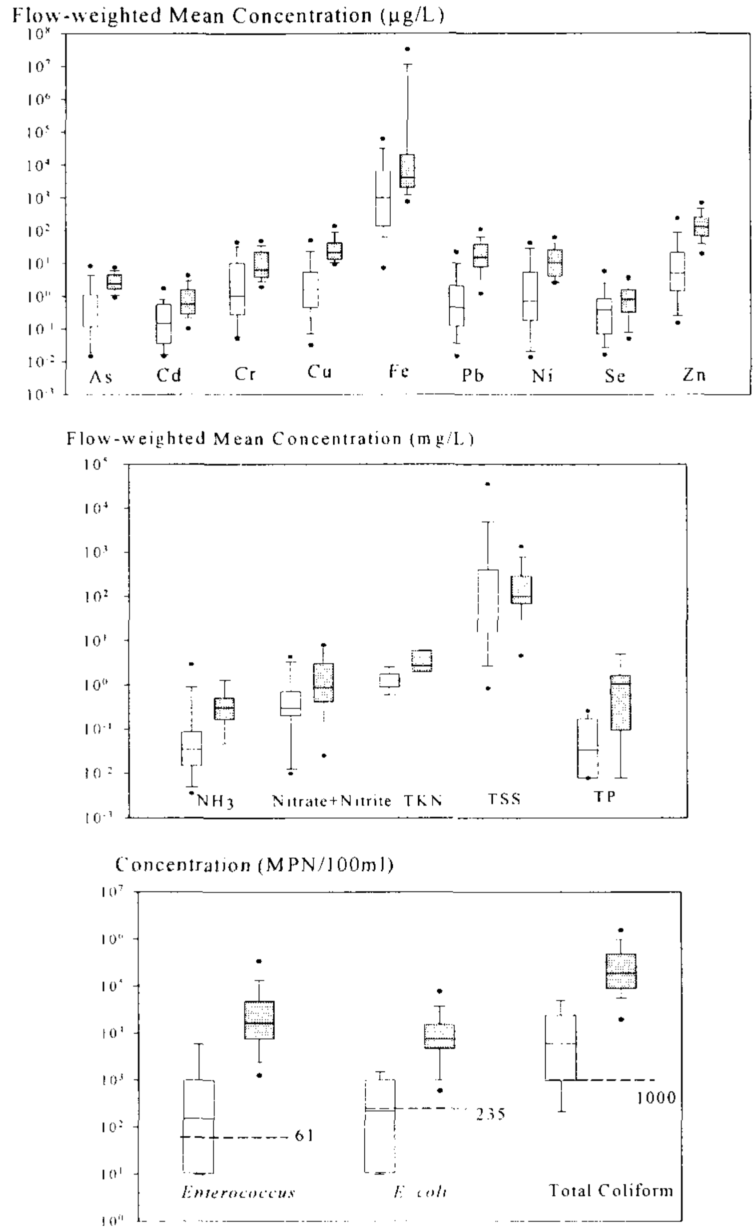


**Figure ES-3. Comparison of wet weather concentrations of metals, nutrients, TSS, and bacteria between natural and developed catchments. White boxes represent natural catchments, while gray boxes represent developed catchments. Solid lines within boxes indicate the median of all values in the category. Boxes indicate 25th and 75th percentiles, and error bars indicate 10th and 90th percentiles. Solid dots indicate 5th and 95th percentiles. The Y axis is in log scale. Dotted lines indicate Department of Health and Safety draft guidelines for freshwater recreation.**

# ACKNOWLEDGEMENTS

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# INTRODUCTION

## Background

More than 100 stream reaches in southern California's coastal watersheds are currently designated as impaired for water quality with respect to their designated beneficial uses. Consequently, they have been added to the US Environmental Protection Agency (USEPA) 303(d) list for a range of constituents including nutrients, algae, bacteria, and metals. In the Los Angeles Region of the Water Quality Control Board (LARWQCB) alone, Section 303(d) listings will result in the development of more than a dozen Total Maximum Daily Loads (TMDLs) in the Los Angeles, San Gabriel, Malibu, Ballona, and Santa Clara watersheds over the next several years. For most of the designated reaches, TMDLs will be developed and National Pollutant Discharge Elimination System (NPDES) permits will be issued that contain requirements intended to ensure that water quality standards are met and beneficial uses are protected. One of the important steps in TMDL development is to identify all sources of the constituent(s) of concern in order to accurately quantify loads and set appropriate standards and allocations.

One of the challenges in developing TMDLs and estimating loads from coastal watersheds is accounting for the natural contribution from undeveloped catchments. This natural contribution can be affected by natural land cover and the underlying geology in a watershed can directly affect constituent concentrations. Trace metals, which are a source of impairment in many watersheds, occur naturally in the environment (Turekian and Wedepohl 1961, Trefry and Metz 1985, Horowitz and Elrick 1987). In southern California, the metavolcanics that make up the transverse ranges are known to leach certain metals as they weather. This was documented by Schiff and Tiefenthaler (2000), who used an iron normalizing technique to assess the magnitude of anthropogenic enrichment of trace metals in suspended sediments of stormwater runoff in the Santa Ana Watershed and found that nearly all of the nickel and chromium emissions – and approximately two-thirds of the copper, lead, and zinc emission -- were of natural origin. Land cover/vegetation type can also affect total loadings in a watershed. Studies have also shown that land cover type may significantly impact water quality (Detenbeck *et al.* 1996, Johnes *et al.* 1996, Johnson *et al.* 1997, Gergel *et al.* 1999, Richards *et al.* 1996, Larsen *et al.* 1988). For example, grasslands (both native and non-native) have been shown to contribute relatively high loadings of nitrogen following rainfall events (Johnes et. al 1996). These loadings contribute to total nitrate and nitrite concentrations and may play a role in algal levels in streams and estuaries. Large portions of the total mass of metals in water are associated with sediments, including clay/silt particles and particulate organic carbon, which are influenced by land cover (Johnson *et al.* 1997, Gergel *et al.* 1999, Richards *et al.* 1996). Bacteria levels in water are also affected by other natural and anthropogenic conditions. Wildlife, including birds and mammals, may be sources of bacteria to natural streams. Grant *et al.* (2001) studied enterococci bacteria in a costal saltwater marsh and found that bacteria generated in the marsh had greater effect on coastal water quality than dry season urban runoff. The presumed sources of these bacteria were birds that used the tidal salt marsh as habitat. Ahn *et al.* (2005) also investigated sources of bacteria in urban stormwater in southern California and concluded that natural sources could be significant contributors to total bacteria levels. However, no studies have been found that attempt to quantify background (or reference) levels of bacteria, and little to no information is available on this issue.

To compensate for the lack of adequate information on natural sources of metals, nutrients, and bacteria, many TMDLs are written with load allocations based on data from other parts of the country or, worse yet, anecdotal data from previous time periods. As a result, these TMDLs may be developed with inefficient or overly stringent load allocations in order to meet numeric targets. The need for information on loading from undeveloped areas is amplified by the desire for many managers to use background concentrations or conditions as part of the numeric target for their TMDL. For example, the TMDL for bacteria for Santa Monica Bay beaches used a watershed that was comprised of entirely open land use as a benchmark for success. Urbanized watersheds were required to generate no more bacterial exceedence days than the open, benchmark watershed. Unfortunately, little is known about the bacterial dynamics or wet and dry weather contributions from the open land uses, making the efficacy of this requirement difficult to assess.

## Goals of the study

The overall goal of this project is to evaluate the contributions and properties of stream reaches in undeveloped catchments throughout southern California in order to assist environmental managers establish load allocations and appropriate numeric targets. Specific questions that will be addressed are:

- What are the ranges of concentrations, loads and flux rates of various trace metals, nutrients, and solids associated with storm and non-stormwater runoff from natural areas?
- How do the ranges of constituent concentrations and loads associated with natural areas compare with those associated with urban (developed) areas and existing water quality standards?
- How do environmental characteristics of catchments influence constituent concentrations and loads from natural landscape?

This project begins to fill the existing gap in the understanding of loadings to streams from natural landscapes by characterizing the natural condition of flow, suspended solids, organic carbon, nutrients, metals, and bacteria, and relate these to watershed properties such as geology, soils, and vegetative cover. The results of this project provide valuable information for development of water quality standards, TMDL allocations, and regional nutrient criteria. Furthermore, this project will produce tools that managers and decision makers can use to better predict the impact of future land use on water quality and more accurately evaluate the effectiveness of management strategies.

# STUDY DESIGN

The overall goal of this study was to characterize wet and dry weather water quality at a set of sites that is representative of existing natural conditions in southern California. This goal was accomplished in four phases. First, existing data was compiled and organized. Second, southern California watersheds were characterized in terms of geology and land cover and selected appropriate sites that represent the range of natural conditions found throughout the region. Third, both dry and wet weather sampling was conducted. Fourth, assessment tools including estimates of dry and wet weather ambient concentrations, flux rates, and expectations of beneficial use conditions were developed. The main phases of the study design are summarized below.

## Compilation of existing data sources

The goal of Phase 1 was to compile and summarize existing data from natural sites to help inform the sampling design for subsequent phases of the project. The study's *a priori* hypothesis, based on existing literature, was that geology and land cover would be key features influencing variation in water quality from natural areas. In order to test this hypothesis, preliminary analysis of the existing data on water quality in natural areas of southern California was conducted using data from USEPA's Environmental Monitoring and Assessment Program (EMAP) and the State of California's Surface Water Ambient Monitoring Program (SWAMP). These data were used to investigate the effect of geology and land cover on natural loadings of selenium and zinc. The analysis of variance (ANOVA) showed the levels of selenium were significantly different in different land cover groups. The levels of selenium were also significantly different in different geology types. These results suggested that geology and land cover might influence the levels of several nutrients and metals in surface water. It also demonstrated that the effects of geology and land cover on surface water quality were appropriate factors for further investigation. The detailed results of the preliminary investigation are included in Appendix I. It is important to note that the existing data were too limited to adequately quantify regional background concentrations or to discern other factors that may influence these concentrations. However, they were useful in guiding development of the study design for this project.

## Watershed characterization

The goal of Phase 2 was to characterize southern California watersheds in terms of their general features, geology, and land cover. Southern California's coastal watersheds occur in a variety of geologic and topographic settings, have a variety of soil types, and contain a variety of natural vegetation communities. These factors are known to influence natural loadings (Lakin and Byers 1941, Dunne and Leopold 1978, Ohlendorf *et al.* 1986, Larsen 1988, Ohlendorf *et al.* 1988, Ledin *et al.* 1989, Tracy *et al.* 1990, Tidball *et al.* 1991, Detenbeck *et al.* 1993, Presser *et al.* 1994, Hounslow 1995, Johnes *et al.* 1996, Richards *et al.* 1996, Johnson *et al.* 1997b, Gergel *et al.* 1999, Hibbs and Lee 2000). In addition, wildlife, including birds and mammals, may be sources of bacteria to natural streams. This phase characterized the major watersheds in terms of their physical and biological characteristics. The watershed and site characterizations were catalogued in GIS for use in later portions of the project to facilitate information transfer to other efforts that may use this data. Geologic and land cover type for the coastal watersheds in southern California were determined by plotting watershed boundaries over digitalized geology (California Division of Mines and Geology,1962) and land cover maps (National Oceanographic Administration (NOAA) Coastal Change Analysis Program (CCAP) 1999). The results of the analysis for this phase are provided in Appendix II.

## Selection of sampling sites

The goal of Phase 3 was to select sampling sites that would represent the range of natural conditions throughout southern California. Using the watershed characterization and the list of data gaps produced under Phases 1 and 2, a series of potential sampling sites (i.e., stream reaches) were selected. Sites were selected that covered the range of factors that were assumed to affect variability in loadings from natural systems.

### *General framework for site selection*

Review of existing data suggested that surficial geology and dominant land cover likely influenced water quality loading from minimally developed catchments. Consequently, this study's sampling design involved stratified sampling based on these two independent variables. The overall sampling framework for the project is shown in Table 1.

Geologic forms consist of a certain lithologic type or combination of types, including igneous, sedimentary, or metamorphic, which may be consolidated or divided into different classes (American Geological Institute 1984). Land cover types consist of forest, shrub, and grassland, which may also be consolidated and divided into different classes (National Oceanographic and Atmospheric Administration 2003). Due to resource constraints, priority was given to sites in areas representing the largest proportion of natural areas in the study region: sedimentary rocks-shrub group, igneous rocks-shrub group, sedimentary rocks-forest group, and igneous rocks-shrub group. This prioritization of geology/land use combinations encompassed the majority of natural area in the coastal watersheds of southern California.

### *Criteria for site selection*

A series of criteria was developed to provide objective guidelines to classify catchments in various conditions and select appropriate natural sites for inclusion in the study. These criteria were established through literature survey and meetings with the project's technical advisory committee and stakeholders, after consulting various agencies involved in water quality management. The result was a consensus list of criteria that would ensure that sampling would capture natural conditions without influence from any land-based anthropogenic input[1] and be representative of the range of natural conditions that exist in southern California.

- Catchments draining to the sites should be natural and as close to pristine condition as possible. Contributing drainage area should be at least 95% undeveloped.
- Field reconnaissance should reveal no evidence of anthropogenic effects such as septic tanks, isolated residence, excessive wildlife or human use, or evidence of excessive channel erosion.
- Sites should be regionally distributed across southern California. To meet this criterion, sampling sites should be distributed across the six major southern California counties and include as many of the major watersheds draining to the Southern California Bight as possible.
- Sites should be representative of major geologic settings/land cover types and be relatively homogenous. For this study, sites screened with these general criteria were grouped in terms of representative geology and land cover for southern California (Table 1). The goal was to select a minimum of four to five sites representing each of the priority treatments in the sampling framework (i.e., locations with an "A" prioritization in Table 1).

[1] Aerial deposition of anthropogenic emissions may affect the surface water quality at the selected sampling sites. Due to the regional nature of this source, no attempt was made to exclude or control for effects of dry or wet aerial deposition.

- Sites should have either year-round or prolonged dry weather flow that allows sampling during both storm and non-storm conditions. A stream with prolonged dry weather flow can be defined as one that still flows one to two months after the end of the last storm, even if it dries up later in the season.
- *Sites should be targeted toward 3rd -order watersheds in which streams have large enough* catchments to reliably generate flow during both storm and non-storm conditions. This position in the watershed also allows selection of sites for which catchments are small enough to have homogenous contributing drainage areas. Sites at this position in the watershed are representative of the watershed position of many of the less pristine waterbodies to which data from this study will be compared.
- Sites should not be within catchments that have burned during the previous three years. According to a study on the impact of wildfire in the Santa Monica Mountains (Gamradt and Kats 1997), erosion following the 1993 wildfire produced major changes in stream morphology and composition. These fire-induced landslides and siltation eliminated pools and runs, and altered habitats. Thus, streams that were impacted by wildfires were excluded from this study[2].
- The stream reach being sampled should be ratable for flow to allow computation of mass loadings of water quality constituents.
- Sites should be located in an area where sampling can be conducted safely.
- Field crews should be able to access the sampling location after hours and on weekends.
- Property owners and other responsible parties must provide permission for site access and sampling.

### *Selected sampling sites*

Candidate sites were selected based on a review of existing data from the SWAMP, EMAP, United States Geological Services (USGS) Hydrologic Benchmark Network, USGS National Water Quality Assessment, Heal The Bay, Malibu Creek Watershed Monitoring Program, Santa Barbara Coastal Long Term Ecological Research Project (SBC-LTER), and conversations with US Forest Service Resource staff officers, Counties of Ventura, Los Angeles, Orange, San Bernardino, San Diego, various stormwater agencies and the technical advisory committee for this project.

Forty-five candidate sites were identified using the criteria describe above. Following detailed office and field investigation, a total of 22 sites were selected for inclusion in the study. The sites were are located across six counties and twelve different watersheds: Arroyo Sequit, Los Angeles River, San Gabriel River, Malibu Creek, San Mateo Creek, San Juan Creek, Santa Ana River, San Luis Rey River, Santa Clara River, Ventura River, and Calleguas Creek, as shown in Figure 1 and listed in Table 2. Detailed information on each site is provided in Appendix III.

## Dry and wet weather sampling

The goal of Phase 4 was to collect samples at selected sampling sites over the course of two years during both dry weather and wet weather conditions. These data were used to estimate the dry and wet weather metal concentrations, flux rates, and loads associated with natural areas.

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[2] Wildfires occur regularly in southern California and are natural elements of native habitats. In this study, however, the impact of wildfire was not investigated and only natural sites with no history of wildfire over the past 3 years were included in order to limit the number of variables that affected water quality.

### *Site characterization*

Each catchment was characterized for its environmental settings: 1) land cover type (forest/shrub), 2) geology type (sediment/igneous), 3) catchment size, 4) average slope, 5) elevation, 6) latitude, and 7) percent canopy cover. Geologic and land cover type for the coastal watersheds in southern California were determined by plotting catchment boundaries over a digitized geology map (Strand 1962, Rogers 1965, 1967, Jennings and Strand 1969) and land cover map (NOAA CCAP 2003). The rest of catchment characteristics were assessed using ArcView GIS 3.2a (ESRI, Redlands, CA). Percent canopy cover was defined as a percent vegetation cover over the study reach based on field measurements using a spherical forest densitometer (Wildco, Buffalo, NY).

### *Dry weather sampling*

Three dry weather sampling events were conducted: spring 2005, fall 2005, and spring 2006 (Table 3). Dry weather sampling was initiated following at least 30 consecutive days with no measurable rain to minimize effects of residual stormwater return flow. Water samples were collected as composite grab samples, with equivalent volumes collected from three different points across the stream (approximately 10, 50, and 90% distance across). A replicate water sample was collected in the same way 10 minutes after completion of the initial water sampling. Collected water samples were immediately placed on ice for subsequent analyses. At each sampling location and during each round of sample collection, temperature, pH, and dissolved oxygen (DO) were measured in the field using Orion 125 and Orion 810 field probes (Thermo Electron Corporation, Waltham, MA). Canopy cover was assessed using a spherical densitometer (Wildco, Buffalo, NY). Measurements were taken in triplicate at each transect. Stream discharge was measured as the product of the channel cross-sectional area and the flow velocity. Channel cross sectional area was measured in the field. At each sampling event, velocity was measured using a Marsh-McBirney Model 2000 flow meter (Frederick, MD). The flow meter measured velocity using the Faraday law of electromagnetic induction. The velocity was measured at three points along each transect, and the values from three transects were integrated to estimate overall flow at each site. To estimate biomass of algae, percent cover of algae was assessed visually at each site using the defined algal protocol (Appendix IV) as modified from the EPA Rapid Bioassessment Protocol (Barbour *et al.* 1999). Percent algal cover was estimated separately for benthic algae, algae attached to rocks or vascular plants, and free floating algae. Algae were sampled for chlorophyll-a analysis along each transect with a periphyton sampler modeled on the sampler described by Davies & Gee (1993). Algal samples were immediately frozen on dry ice for subsequent analyses. Details of the method of algal sampling and percent cover assessment are described in Appendix IV.

### *Wet weather sampling*

A total of 30 site-events were sampled during two wet seasons between December 2004 and April 2006, with each site being sampled during two to three storms (Table 4). A site was considered eligible for sampling if it had not received measurable rainfall for three consecutive days and flow was no more than 20% above baseflow. When rain was forecast, field crews were deployed and sampling was initiated when flows exceeded base flow by approximately 10 to 20%. Streams were sampled manually when safety and access restrictions permitted. In other cases, an automatic sampling method was used.

Stream discharge and rainfall were measured during each sampling event. Rainfall was measured using a standard tipping bucket that recorded in 0.025 cm increments. Stream discharge was measured as the product of the channel cross-sectional area and the flow velocity. Channel cross sectional area was measured in the field prior to the onset of rain. Velocity was measured using an acoustic Doppler velocity (AV) meter. The AV meter was mounted to the invert of the stream channel, and velocity, stage, and instantaneous flow data were transmitted to a data logger/controller upon query commands found in the data logger software.

### *Manual sampling (pollutograph)*

Manual sampling was used at streams where safety and access concerns permitted. Between 10 and 12 discrete grab samples were collected per storm at approximately 30 to 60 minutes intervals for each site-event, based on optimal sampling frequencies in southern California described by Leecaster *et al.* (2002). Samples were collected more frequently when flow rates were high or rapidly changing, and less frequently during lower flow periods. Samples were collected using peristaltic pumps with Teflon® tubing and stainless steel intakes fixed at the bottom of the channel pointed in the upstream direction in areas of undisturbed flow. After collection, the samples were stored in pre-cleaned glass bottles on ice with Teflon-lined caps until they were shipped to the laboratory for analysis. Streams were sampled until flow measurements indicated that flow had subsided to at least 50% of the peak flow. For prolonged events, water quality sampling was terminated after 24 hours. Even after the end of sampling periods, flow measurements often continued to reflect the prolonged descending tail of the hydrograph for several days.

### *Automatic sampling*

When site accessibility and/or safety prohibited manual sampling, automatic samplers were used. Samplers were installed ahead of the storm event and streams were auto-sampled to collect four composite samples representing different portions of the storm hydrograph. The automatic sampler collected "microsamples" at set intervals during each portion of the storm. Samples were collected every five minutes for the first bottle. The interval between each microsample was increased for each subsequent bottle to allow a greater portion of the storm to be sampled. Samples for the second, third, and fourth bottles were taken at ten-, twenty-, and forty-minute intervals, respectively. Ultimately, each sample bottle consisted of a composite of 18 microsamples representing one portion of the storm. Intervals were determined based on expected duration of storm. If a storm was expected to last for several days, longer intervals were set. If a storm was expected to last for a short period of time, shorter intervals were set. In most cases, the four sample bottles were analyzed individually. In some cases two bottles were composited if analysis of the storm hydrograph revealed that they captured similar portions of the storm event. All sample tubing was triple purged with ambient and de-ionized water between samples. After collection, the samples were stored in pre-cleaned glass bottles on ice with Teflon®-lined caps until they were shipped to the laboratory for analysis.

## *Laboratory analysis*

Water samples were analyzed for pH, hardness, conductivity, total recoverable metals, nutrients, DOC/TOC, TDS/TSS, and bacteria and algal samples were analyzed for chlorophyll a following protocols approved by the USEPA (1983) and standard methods approved by the American Public Health Association (Greenberg *et al.* 2000). Metals were prepared by digestion, followed by analysis using inductively coupled plasma-mass spectrometry (ICP-MS) to obtain total recoverable concentrations of arsenic, cadmium, copper, chromium, iron, lead, nickel, selenium, and zinc. In addition, samples of winter 2006 were analyzed for both dissolved and particulate concentrations for each metal. Total dissolved solids (TDS) were analyzed using a flow injection analyzer (Lachat Instruments model Quik Chem 8000). Total suspended solids (TSS) were analyzed by filtering a 10- to 100-ml aliquot of stormwater through a tarred 1.2 mm (micron) Whatman GF/C filter. The filters plus solids were dried at 60°C for 24 hours, cooled, and weighed. Nitrate and nitrite were analyzed using cadmium reduction method and ammonia was analyzed using distillation and automated phenate. Total Kjeldahl nitrogen (TKN) was analyzed using digesting/distilling and semi-automated digester. Total organic carbon (TOC) and dissolved organic carbon (DOC) were determined via high temperature catalytic combustion using a Shimadzu 5000 TOC Analyzer. Orthophosphate was analyzed using a titration method. Total phosphorus was persulfate-digested. Every analysis included QA/QC checkup with certified reference materials, duplicate analyses, matrix spike/ matrix spike duplicates, calibration standards traceable to the National Institute of Standards, and method blanks. Table 5 shows the list of analytes, along with minimum detection limits (MDLs) and applicable units for each analyte.

## *Data analysis*

### Dry weather

Three analyses were used to characterize dry weather water quality from natural areas. First the means, variances, and ranges of concentrations, loads, and fluxes were calculated to provide an estimate of expected natural (background) water quality. Loads were calculated as the product of flow and concentration for each sample (Equation 1):

$$\text{Load} = \sum F_i \cdot C_i \qquad (1)$$

where $F_i$ was the mean flow at sampling site $i$, and $C_i$ was the concentration at site $i$ for individual constituents.

A mass loading was expressed as load/day instead of an event based load. Flux was calculated as the ratio of the mass loading per contributing catchment area. All data were analyzed to determine if they were normally distributed. For constituents that were not normally distributed, results were recorded as geometric means and upper and lower ends of 95% confidence intervals[3]. If the data were normally distributed, results were recorded as arithmetic means ± the 95% confidence interval.

Second, factors that impact variability in water quality of natural catchments were investigated. To explain variability in water quality among the natural catchments, relationships between environmental characteristics of the catchments and water quality constituent concentrations and fluxes were investigated using multivariate analyses. In this study, an ordination method, redundancy analysis (RDA) was used. RDA is a canonical extension of principal component analysis (PCA) and a form of direct gradient analysis that describes variation between two multivariate data sets (Rao 1964, ter Braak and Verdonschot 1995); and a matrix of predictor variables (e.g., environmental variables, explanatory variables, or independent variables) is used to quantify variation in a matrix of response variables (e.g., water quality variables, response variables, or dependent variables). For this study, RDAs were performed using the program CANOCO 4.54 (ter Braak and Smilauer 1997). Water quality variables used in the RDA were concentrations of all constituents. Environmental variables were geologic types (igneous rock vs. sedimentary rock), land cover types (forest vs. shrub), latitude of site, catchment area ($km^2$), elevation of site (km), slope of catchment, mean flow ($m^3$/sec), and percent canopy cover. Dummy values were assigned for the categorical variables; such as geology and land cover types. For example, a sampling site within a catchment dominated by igneous rock was assigned the value of one for igneous rock and a value of zero for sedimentary rock.

Prior to conducting the RDA, variables were log transformed to improve normality. Each set of variables was centered and standardized to normalize the units of measurement so that the coefficients would be comparable to one another. The environmental variables were standardized to zero mean and unit variance. Interaction terms were not considered.

The importance of the environmental variables was determined by stepwise selection. In each step the extra fit was determined for each variable, i.e., the increase in regression sum of squares over all constituents when adding a variable to the regression model. The variable with the largest extra fit was

[3] The confidence interval represents values for the population parameter for which the difference between the parameter and the observed estimate is not statistically significant at the 5% level.

then included, and the process was repeated until no variables remained that could significantly improve the fit of the model. The statistical significance of the effect of including a variable was determined by means of a Monte Carlo permutation test. The number of permutations to be carried out was limited to 199 because the power of the test increases with the number of permutations, but only slightly so beyond 199 permutations (Lepš and Šmilauer 2003).

The results of the multivariate analysis were visualized by means of biplots that represent optimally the joint effect of the environmental variables on water quality variables in a single plane (ter Braak 1990). In addition, the entire water quality data set was grouped based on the most influential environmental variables. Subsequent analyses, such as analysis of variance, ANOVA (Sokal and Rohlf 1995), were carried out to examine the significance of differences among the groups with a significance level of $p < 0.05$.

Lastly, concentrations and fluxes in natural catchments were compared with data previously collected from developed catchments to determine if significant differences existed between the two groups. Data for developed catchments were obtained from Southern California Coastal Water Research Project (SCCWRP) dry weather studies of metals, nutrients, and TSS in Ballona Creek, Coyote Creek, Los Angeles River, San Gabriel River, San Jose Creek, and Walnut Creek, California (Ackerman and Schiff 2003, Stein and Tiefenthaler 2005, Stein and Ackerman 2007). The data from the SCCWRP dry weather studies were collected at the developed sites and processed in the same manner as the data from the natural sites. More information on selected developed sites is provided in Appendix V. Differences between natural and developed catchments were investigated by comparing median values using ANOVA, (Sokal and Rohlf 1995) with a significance of $p < 0.05$. Eight metals (arsenic, cadmium, copper, iron, lead, nickel, selenium, and zinc), three nutrients (ammonia, nitrate+nitrite, and total phosphorus), , three bacterial indicators, and TSS were examined. Mean concentration and flux data were log-transformed and compared. If data failed in normality test, a one-way ANOVA on ranks (Kruskall 1952, Kruskall and Wallis 1952) was performed to examine differences between the groups. The Kruskal-Wallis test is most commonly used when one attribute variable and one measurement variable exist, and the measurement variable does not meet the assumptions of an ANOVA: normality and homoscedasticity. It is the non-parametric analogue of a single-classification ANOVA. To determine how variability observed in natural catchments related to variability observed in developed catchments, the respective coefficient of variation (%CV) [4] for the two data sets was compared. The %CV accounts for differences in sample size and in the magnitude of means and provides a relative measure of variability. Results were back-transformed for presentation in summary tables to allow easier comparison with other studies. In all cases non-detects were assigned values of ½ minimum detection limits.

*Wet weather*

Three analyses were used to characterize wet-weather water quality from natural areas. First the means, variances, and ranges of concentrations, loads, and fluxes were calculated to provide an estimate of expected baseline water quality. Event flow-weighted mean (FWM) concentrations, mass loadings, and flux rates were calculated for each site. Using only those samples for a single storm, the event FWM was calculated according to Equation 2:

[4] % CV = 100 x (standard deviation/mean)

$$FWM = \frac{\sum_{i=1}^{n} C_i \bullet F_i}{\sum_{i=1}^{n} F_i} \quad (2)$$

where: *FWM* was the flow-weighted mean for a particular storm; *Ci* was the individual runoff sample concentration of $i^{th}$ sample; *Fi* was the instantaneous flow at the time of $i^{th}$ sample; and n was the number of samples per event.

Event mass loadings were calculated as the product of the FWM and the storm volume during the sampling period. Flux estimates facilitated loading comparisons among catchments of varying sizes. Flux was calculated as the ratio of the mass loading per storm and contributing catchment area. All data were analyzed to determine if they were normally distributed. For those constituents that were not normally distributed, results were recorded as geometric means and upper/lower 95% confidence intervals. If the data were normally distributed, results were recorded as arithmetic means ± the 95% confidence interval.

Second, factors that impact variability in water quality from the natural catchments were investigated. To explain variability in water quality among different natural catchments, relationships between environmental characteristics of the catchments and concentrations were investigated using multivariate analyses. Variability within a storm event was also examined in terms of first flush. Variability of constituent levels within a storm event and between seasons was examined. First, flows and concentrations within storm events were evaluated by examining the time-concentration series relative to the hydrograph using a pollutograph. A first flush in concentration from individual storm events, defined as a peak in concentration preceding the peak in flow, is often observed in small urban watersheds (Characklis and Wiesner 1997, Sansalone and Buchberger 1997, Buffleben *et al.* 2002, Stein *et al.* 2006). This observation was quantified using cumulative discharge plots for which cumulative mass emission was plotted against cumulative discharge volume during a single storm event (Bertrand-Krajewski *et al.* 1998). When these curves are close to unity, mass emission is a function of flow discharge. A strong first flush was defined as ≥75% of the mass being discharged in the first 25% of runoff volume. A moderate first flush was defined as ≥30% and ≤75% of the mass being discharged in the first 25% of runoff volume. No first flush was assumed when ≤30% of the mass was discharged in the first 25% of runoff volume. Second, changes in proportions of metals between particulate phase and dissolved phase over the course of storm were examined and compared with concentrations of TSS, TDS, and flow. The Pearson correlation analysis was conducted to test correlation of the ratios with flow. Lastly, ANOVA was conducted in order to test if constituent concentrations differed significantly among different seasons. The %CV for each constituent was compared among different seasons in order to estimate the degree of seasonal variability.

Relationships between catchment characteristics and constituent concentration were investigated using RDA. Water quality variables used in the RDA were flow-weighted concentrations (FWMC) of all measured water quality constituents. Environmental variables used were geologic setting (igneous vs. sedimentary), land cover type (forest vs. shrub), latitude, catchment area ($km^2$), elevation of sampling location (km), slope of drainage area, total rainfall of storm event (cm), baseline flow ($m^3$/sec), mean flow ($m^3$/sec), peak flow of storm event ($m^3$/sec), total volume of stormwater runoff ($m^3$), and percent canopy cover (%). The RDA and subsequent analyses, such as ANOVA, were conducted in a similar manner to those of the dry weather data.

Concentrations and loads in natural catchments were compared with data previously collected from developed catchments to determine if significant differences existed between natural and developed areas. Stormwater data from developed catchments in the greater Los Angeles area were obtained from a previous SCCWRP study (Stein *et al.* 2007) and the Ventura County Watershed Protection District. The developed catchments included Los Angeles River, San Jose Creek, Ballona Creek, Coyote Creek, Walnut Creek, San Gabriel River, Pueblo Creek, and Calleguas Creek. Details of selected developed sites are provided in Appendix IV. Differences between natural and developed catchments were investigated using a one-way ANOVA (Sokal and Rohlf 1995) with a significance level of $p < 0.05$. Means for flow-weighted concentration and flux per each sampling event were estimated. Flow-weighted mean concentration and flux data were log-transformed prior to comparison. If data failed in the equal variance test, a Kruskal-Wallis ANOVA on ranks was performed to examine difference between the groups. To determine how the variability observed in natural catchments related to that observed in developed catchments, respective %CV of the two data sets were compared.

In addition to chemistry data, catchment hydrology was compared to that of developed watersheds. For each storm, the mean flow, peak flow, and total runoff volume was calculated relative to the total rainfall for that storm. Storm flow patterns relative to rainfall and catchment size were compared between developed and undeveloped watersheds to assess differences in hydrologic response using linear and log-linear regression analysis.

## Estimation of annual loadings from natural landscapes

Annual loadings of metals, nutrients, and solids from natural streams in southern California were estimated, and storm-originated load and non-storm-originated load estimates were compared. Year-round flow data that were necessary to estimate annual loads were not available at all natural sites. Thus, 5 out of 22 natural sites were selected to represent the diversity in the catchment size, geologic setting, land cover type, and flow conditions in southern California (Figure 19). The study sites included three perennial streams (Arroyo Seco, Sespe Creek, and Piru Creek) and two intermittent streams (Santiago Creek and Tenaja Creek) with catchment sizes ranging from 17 to 318 $km^2$, respectively (Table 6). The USGS daily flow data were available for the perennial sites. For the intermittent sites, water pressure sensors to monitor flow were installed.

### *Flow data from USGS gauging stations*

For the three gauged systems, daily average flows for the 1994-2004 water years were downloaded from the USGS website (http://waterdata.usgs.gov/ca/nwis/sw). This ten-year period contains dry, wet, and moderate years, and is, therefore, representative of the expected range of rainfall conditions. Flow data was unavailable for the 2004 water year for Piru Creek and the 1998 and 2001 water years for Sespe Creek. Flow data for the 2005 and 2006 water years were not available due to incomplete data quality check by USGS.

### *Flow monitoring using water level loggers*

At the two ungauged intermittent streams, pressure transducers to measure water surface elevation (i.e., water level) were installed. Water level was monitored every 15 minutes during the 8-month study period from December 2005 through July 2006 using Hobo® model U20-001-01 water level logger (Onset Computer, Bourne, MA). Two water level loggers were deployed at each site. One was installed above the water level to measure atmospheric pressure and the other was installed under water level to measure combined pressure of atmospheric and water pressures. The water pressure was computed by subtracting the atmospheric pressure from the combined pressure. Water level was estimated based on the temperature that was logged with the pressure. Water level data were converted to flow data using flow-rating curves that were obtained from previous sampling events conducted during the dry and wet seasons of 2004 through 2006. Separate rating curves for dry and wet weather flows were obtained. A rating curve with the highest correlation coefficient among possible linear or non-linear regressions was selected to convert a water level into flow for each site.

### Storm flow *separation from non*-storm flow

Storm flow was separated from non-storm flow based on rainfall data for the sites monitored with the Hobo water level loggers. For the USGS gauged sites long-term rainfall data were not available, thus, storm flow was separated from non-storms flow using the following steps: First, $\Delta X_i$, the difference of flow between two data points was computed according to Equation 3:

$$X_i - X_{i-1} = \Delta X_i \qquad (3)$$

where $X_i$ was flow at time $i$.

Second, the beginning of each storm event was defined for a time when $\Delta X_i$ changed from zero or a negative value to a positive value with $\Delta X_i$ that is more than 60% of $X_i$. The 60% criterion was set to exclude the increase of flow due to the natural fluctuation of base flow (Hatje *et al.* 2001). Third, a peak flow point was identified as a time just before $\Delta X_i$ turned negative. Next, the end of each storm event was defined as $T_i$ after the peak flow occurred, when the $\Delta X_i$ was negative and the flow reduced to 50% of peak flow. If $\Delta X_i$ became zero or positive before it dropped to the 50% of peak flow, a time of the last negative $\Delta X_i$ was assigned as the end of the storm event. Storm flows and non-storm flows were summed separately for each water year.

### *Estimation of loads and fluxes*

Annual load for each water quality constituent was estimated according to Equation 4:

$$W = \sum_j Cm \bullet Qj \bullet K \qquad (4)$$

where $W$ was the load (mt or kg); $Cm$ was the FWM for storm flow or mean concentration for non-storm flow (mg/L or µg/L); $Q_j$ was the total discharge volume of flow ($Q_{\text{storm flow}}$ = mean daily storm flow days with storm flow/year; $Q_{\textit{non}\text{-storm flow}}$ was the mean daily non-storm flow days with non-storm flow/year); and $K$ was the unit conversion factor of $10^6$.

Loadings were calculated separately for storm vs. non-storm discharge volume. Loading estimates were based on the product of the mean concentration determined by this study and mean volume over the period of record. Implicit in this approach is the assumption that the concentration values determined during the two years of this study are representative of typical concentrations in natural areas. The total annual load for each water year was obtained by summing the storm load and non-storm load. In order to account for differences in catchment size, an annual flux for each site was computed as load divided by the size of drainage area.

**Table 1. Sampling framework.** **Highest priority (A) and Lowest priority (C).**

| **Land Cover** | **Dominant Geology** | | |
|---|---|---|---|
| | Sedimentary Rocks | Metamorphic Rocks | Igneous Rocks |
| Forest | A | C | A |
| Shrub | A | C | A |
| Grassland | B | C | B |

**Table 2. Study site locations, characteristics, and sampling conditions.**

| | | Sampling Conditions | | | | |
|---|---|---|---|---|---|---|
| Arroyo Seco | LA River | Dry/Wet | Igneous | Forest | 34.2124 | -118.1780 |
| Bear Creek WFSGR | San Gabriel | Dry/Wet | Igneous | Forest | 34.2408 | -117.8840 |
| Cattle Creek EFSGR | San Gabriel | Dry/Wet | Igneous | Shrub | 34.2283 | -117.7670 |
| Coldbrook NFSGR | San Gabriel | Dry/Wet | Igneous | Forest | 34.2922 | -117.8390 |
| Chesebro Creek | Malibu Creek | Dry/Wet | Sedimentary | Forest | 34.1557 | -118.7260 |
| Cold Creek | Malibu Creek | Dry | Sedimentary | Shrub | 34.0902 | -118.6470 |
| Cristianitos Creek | San Mateo | Dry/Wet | Sedimentary | Shrub | 33.4621 | -117.5610 |
| San Juan Creek | San Juan | Dry | Sedimentary | Shrub | 33.5819 | -117.5240 |
| Santiago Creek | Santa Ana | Dry/Wet | Sedimentary | Shrub | 33.7086 | -117.6150 |
| Bell Creek | San Juan | Dry/Wet | Sedimentary | Shrub | 33.6347 | -117.5570 |
| Silverado Creek | Santa Ana | Dry/Wet | Sedimentary | Shrub | 33.7461 | -117.6010 |
| Seven Oaks Dam | Santa Ana | Dry/Wet | Igneous | Shrub | 34.1477 | -117.0600 |
| Cajon Creek | Santa Ana | Dry | Igneous | Shrub | 34.3023 | -117.4640 |
| Mill Creek | Santa Ana | Dry/Wet | Igneous | Shrub | 34.0822 | -116.8890 |
| Fry Creek | San Luis Rey | Dry/Wet | Igneous | Forest | 33.3445 | -116.8830 |
| Piru Creek | Santa Clara River | Dry/Wet | Sedimentary | Shrub | 34.6911 | -118.8510 |
| Sespe Creek | Santa Clara River | Dry/Wet | Sedimentary | Shrub | 34.5782 | -119.2580 |
| Bear Creek Matilija | Ventura River | Dry/Wet | Sedimentary | Forest | 34.5184 | -119.2710 |
| Runkle Canyon | Calleguas | Dry/Wet | Sedimentary | Shrub | 34.2408 | -118.7310 |
| Tenaja Creek | San Mateo | Dry/Wet | Igneous | Shrub | 33.5508 | -117.3833 |
| Arroyo Sequit | Arroyo Sequit | Wet | Sedimentary | Shrub | 34.0458 | -118.9347 |

**Table 3. Dry weather sampling events: Shaded boxes indicate sampling events occurred at the site; unshaded boxes indicate no sampling due to lack of flow during the season.**

| Site Name | Spring 2005 | Fall 2005 | Spring 2006 |
|---|---|---|---|
| Arroyo Seco | | | |
| Bear Creek WFSGR | | | |
| Cattle Creek EFSGR | | | |
| Coldbrook NFSGR | | | |
| Chesebro Creek | | - | - |
| Cold Creek | | | |
| Cristianitos Creek | | - | - |
| San Juan Creek | | | |
| Santiago Creek | | | |
| Bell Creek | | | |
| Silverado Creek | | | |
| Santa Ana River at Seven Oaks Dam | | | |
| Cajon Creek | | | |
| Mill Creek | | | |
| Fry Creek | | - | |
| Piru Creek | | | |
| Sespe Creek | | | |
| Bear Creek Matilija | | | |
| Tenaja Creek | | - | |

Table 4. Wet-weather sampling events. Shaded boxes indicate sampling events occurred at the site; unshaded boxes indicate no sampling due to lack of flow during the season. Automatic sampling (Auto); Manual grab sampling (Pol). Numbers in parenthesis indicate the number of composite samples collected.

| Site Name | 7-Dec-04 | 28-Dec-04 | 7-Jan-05 | 11-Feb-05 | 17-Mar-05 | 29-Apr-05 | 2-Jan-06 | 28-Feb-06 | 11-Mar-06 | 28-Mar-06 | 4-Apr-06 |
|---|---|---|---|---|---|---|---|---|---|---|---|
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**Table 5. Comparison of minimum detection limits (MDLs) for constituents analyzed.**

| | | |
|---|---|---|
| pH | 0.1 pH unit | SM4500H+B |
| Conductance | 0.1 micromhos | SM2510B |
| DO | 0.01 mg/L | SM4500OG |
| Temperature | 0.01 °C | SM2550B |
| Hardness | 1.0 mg/L | SM2340A EDTA titration |
| **Nutrients** | | |
| $NH_3$ | 0.01 mg/L | SM 4500-NH3F |
| TKN | 0.14 mg/L | EPA 351.2 |
| Nitrate+Nitrite | 0.02 mg/L | SM 4500-NO3/-NO2 |
| TP/OP | 0.016 mg/L | SM 4500-P C |
| TSS | 0.5 mg/L | SM 2540-D |
| TDS | 0.1 mg/L | SM 2540-C |
| TOC | 0.5 mg/L | EPA 451.1 |
| DOC | 0.5 mg/L | EPA 451.1 |
| **Metals** | | |
| Arsenic | 0.1 µg/L | EPA 200.8 |
| Cadmium | 0.1 µg/L | EPA 200.8 |
| Chromium | 0.1 µg/L | EPA 200.8 |
| Copper | 0.1 µg/L | EPA 200.8 |
| Iron | 1.0 µg/L | EPA 200.8 |
| Lead | 0.05 µg/L | EPA 200.8 |
| Nickel | 0.1 µg/L | EPA 200.8 |
| Selenium | 0.1 µg/L | EPA 200.8 |
| Zinc | 0.1 µg/L | EPA 200.8 |
| **Bacteria** | | |
| Total Coliform | 10 MPN/100 ml | Idexx Quantitray |
| *E. coli* | 10 MPN/100 ml | Idexx Quantitray |
| *Enterococcus* | 10 MPN/100 ml | Idexx Quantitray |
| **Algae** | | |
| Chlorophyll a | 0.005 mg/L | EPA 446.0 |

Dissolved oxygen (DO); ammonia ($NH_3$); total dissolved solids (TDS); total suspended solids (TSS); total organic carbon (TOC); dissolved organic carbon (DOC); total Kjeldahl nitrogen (TKN); total phosphorus (TP); and orthophosphate (OP).

**Table 6. Study site characteristics, including catchment size.**

| | Stream Type | | | | Geologic Type | Land Cover Type | |
|---|---|---|---|---|---|---|---|
| Santiago Creek | Intermittent | 17.02 | Orange | Santa Ana | Sedimentary | Shrub | Hobo water level logger |
| Arroyo Seco | Perennial | 41.50 | Los Angeles | Los Angeles River | Igneous | Forest | USGS11098000* |
| Tenaja Creek | Intermittent | 42.47 | Riverside | San Mateo | Igneous | Shrub | Hobo water level logger |
| Sespe Creek | Perennial | 128.46 | Ventura | Santa Clara River | Sedimentary | Shrub | USGS 11111500* |
| Piru Creek | Perennial | 318.65 | Ventura | Santa Clara River | Sedimentary | Shrub | USGS 11109375* |

*USGS gauging station numbers.

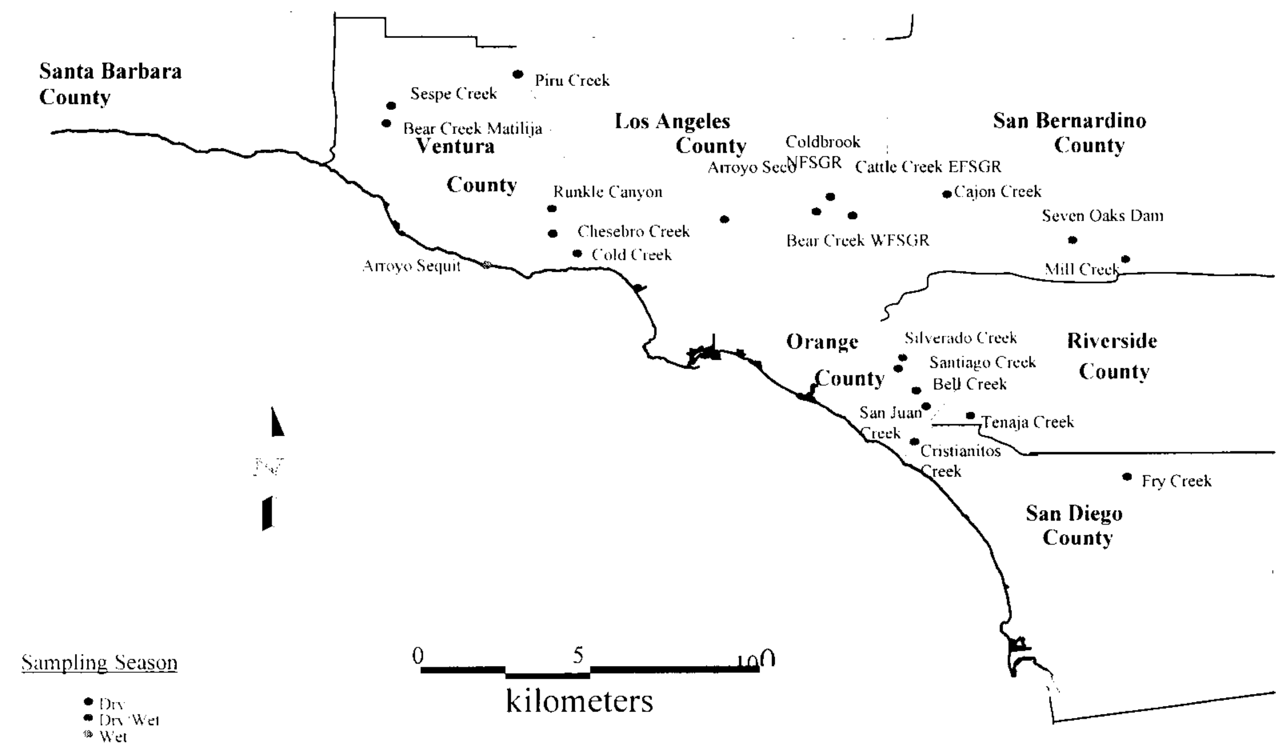


**Figure 1. Study sites: red dots indicate sites sampled during dry weather only; blue dots indicate sites sampled in both dry and wet weather; and green dots indicate sites sampled during wet weather only.**

# DRY WEATHER

## Background

Over the last decade, efforts to manage water quality have concentrated mainly on stormwater, which is perceived to be the largest source of pollutant loading (Driscoll *et al.* 1990, Lau *et al.* 1994, Wong *et al.* 1997, Noble *et al.* 2000, Schiff 2000, Ackerman and Schiff 2003). However, dry weather pollutant loadings may also constitute a significant impact to water quality in terms of both concentration and load (McPherson *et al.* 2002, McPherson *et al.* 2005, Stein and Tiefenthaler 2005). For instance, in six urban watersheds in the Los Angeles region, dry weather loading accounted for 20 to 50% of the total annual load of metals depending on the year's rainfall (Stein and Ackerman 2007); Table 7). In southern California, which is characterized by a dry Mediterranean climate with limited annual precipitation, the majority of rainfall occurs in the winter, with an average of only 37 rainfall days per year (Ackerman and Weisberg 2003, Nezlin and Stein 2005). Thus, dry weather flow can constitute a significant portion of total annual flow, particularly during dry years. Although concentrations of pollutants in dry weather flow might be relatively low (Mizell and French 1995, Duke *et al.* 1999), dry weather flow can be a chronic source of pollution and may impose threats to aquatic life because of its consistent contribution (Bay and Greenstein 1996, Stein and Tiefenthaler 2005, Stein and Ackerman 2007, Ackerman *et al.* 2003). This section provides dry weather concentration and flux estimates for natural areas.

## Flow and field measurements

Seven of the nineteen streams sampled were intermittent, while the rest were perennial; intermittent streams included Chesebro Creek, Cristianitos Creek, San Juan Creek, Santiago Creek, Bell Creek, Fry Creek, and Tenaja Creek. Mean flow ranged from 0 to 0.72 $m^3$/sec with a mean of 0.33 $m^3$/sec. Dissolved oxygen was 6.14 ±3.4 mg/L (mean ± standard deviation), total hardness was 225.9 ±182.29 mg/L, pH was 8.0 ±0.4, water temperature was 16.77 ±3.04 °C, and percent canopy cover was 87 ±11 %.

Flow at natural sites varied at multiple time scales. Flow in intermittent streams decreased consistently after the last storm of the season to zero over a period of months. Review of monthly average flow data from USGS (USGS National Water Information System: Web Interface, http://waterdata.usgs.gov/ca/nwis) showed that base flow in perennial streams varied over one order of magnitude, with the highest flows occurring in May and the lowest occurring in September.

## Concentrations, loads, and fluxes ranges

Nutrients, except TOC and total phosphorus (TP), were neither normally nor log-normally distributed. Metals were mostly log-normally distributed. Bacteria were log-normally distributed. Thus, statistical summaries of all constituents were performed based on the assumption of the lognormal distribution. In all cases, concentrations, loads, and fluxes observed from the natural sites exhibited a great deal of variability, as indicated by large 95% confidence intervals (CI; Table 8). For example, the geometric mean of total dissolved solids was 274.4 mg/L and the 95% CI ranged from 183.0 mg/L to 411.5 mg/L.

No significant difference among sampling events in spring 2005, fall 2005, and spring 2006 was observed for most of constituents. The exceptions were concentrations of DOC, TOC, cadmium (Cd), and orthophosphate (OP), which showed significant differences among sampling events.

Mean concentration of DOC in fall 2005 was more than two times greater than that in spring 2005 and spring 2006. However, no consistent or systematic differences where one sampling event had higher concentrations for all four constituents were observed. Mean flows of sampling sites were significantly lower in fall 2005 than spring 2005 and spring 2006. Concentrations. Loads, and fluxes for each study site are shown in Appendix VII.

## Algal levels at natural catchments

Algal abundance varied among seasons and years. Algae were observed at most of sampling sites in spring and fall 2005 except Mill Creek where the flow was too fast to safely access the stream for sampling. In contrast, algae were seldom observed during sampling events in fall 2006. In spring, stream algae were dominated by the green filamentous algae *Cladophora* spp. In addition, *Nostoc* spp., which have gelatinous bodies and grow attached to hard substrates, were observed, but constituted a minor component of the total algal community. Observations during the fall of 2005 suggest a shift in the community type as flows decreased, with *Nostoc* spp. becoming the dominant algae, and *Cladophora* spp. being rarely observed. This trend, however, was not repeated in 2006. *Nostoc* spp. was rarely observed during sampling events in 2006. Mean chlorophyll-a concentrations were 439 $mg/m^2$ for benthic algae, 0.48 $mg/m^2$ for attached algae, and 0.034 $mg/m^2$ for free floating algae (Table 8). The total chlorophyll-a concentration was 440 $mg/m^2$. The geometric mean of percent cover for each algae type were 23.6% for benthic algae, 6.4% for attached algae, and 2.6% for free floating algae (Table 8).

## Effect of environmental characteristics on dry weather water quality in natural catchments

Geologic type (sedimentary rock and igneous rock) and slope were the main sources of variance in the dry weather water quality data. The stepwise selection in RDA resulted in these variables significantly increasing the overall model fitness (Table 9). The remaining six variables did not appreciably increase the fitness of the model and were excluded in subsequent RDAs. Excluding less significant environmental variables increased the percent of variance explained by the model to 45.4%, compared to 20.3% for the model that included all nine variables (Table 10).

The predominant source of variability was geology. The first axis of the RDA model explained 66.4% of variance in the data set and was primarily determined by the two geology variables (Tables 10 and 11). Among the variables retained in the RDA model, slope contributed least to variation along the first axis and most along the second axis (Table 11). This indicates that geologic setting is a more important factor in defining dry weather water quality of natural catchments than the other environmental factors tested here.

Correlations between water quality and environmental variables are explained in the biplot (Figure 2). Copper, selenium, zinc, nickel, iron, TDS, TOC, and TKN were positively correlated with sedimentary rock. Nitrate+nitrite was negatively correlated with sedimentary rock and positively correlated with igneous rock. Arsenic was positively correlated with slope. Other constituents exhibited no strong correlation with any of the environmental variables.

Concentrations of several constituents exhibited significant differences between the different geology groups. Results of the ANOVA indicate that copper, iron, nickel, selenium, OP, and TDS concentrations were significantly higher in natural catchments underlain by sedimentary rock than those underlain by igneous rock ($p < 0.05$). Other constituents did not exhibit any significant differences between the geologic groups.

## Comparison with developed catchments

Concentrations and fluxes differed significantly between the natural and developed catchments for all constituents ($p < 0.005$; Figure 3a, 4a, 5, 6, and 7). Metal concentrations at the natural catchments were two to three orders of magnitude lower than concentrations observed in the developed catchments (Figure 3a). For example, the geometric mean for copper was 0.56 µg/L in the natural catchments and 132.40 µg/L in the developed catchments. Concentrations of ammonia, TP, nitrate+nitrite, and TSS in the natural catchments were two to three orders magnitude lower than concentrations in the developed catchments; for example, the geometric mean concentration of ammonia was 6.05 mg/L in the developed areas and 0.061 mg/L in the natural areas. Similarly, the geometric mean flux of ammonia was 896g/ $km^2$ day in the developed areas and 3g/$km^2$ day in the natural areas (Figure 4a). Bacteria concentrations were approximately two orders of magnitude lower at natural sites than in the developed Ballona Creek watershed (Figure 7). These differences were statistically significant ($p = < 0.001$) for all three bacteria indicators.

Concentrations of metals, nutrients, and solids at the natural catchments were separated for igneous and sedimentary geology types; concentrations at each geology type were then compared with concentrations at the developed catchments. Concentrations at natural sites underlain by sedimentary and igneous rock were both significantly lower than concentrations at the developed catchments (Figure 3b and 4b).

In all cases, the variability observed in the natural areas was substantially higher than that observed in developed areas (Table 12). The %CVs of copper, lead, and zinc in the natural areas were more than two orders of magnitude greater than those in the developed areas. The greater %CVs in the natural catchments resulted from the larger geometric standard deviations compared with the geometric mean values.

## Discussion

Dry weather concentrations of metals, nutrients, solids, and bacteria from natural catchments in the southern California Costal region were lower than those from developed catchments. Furthermore, dry weather concentrations documented in this study were one to three orders of magnitude lower than concentrations for reference sites in existing ambient monitoring programs such as EMAP and SWAMP (Table 13). These differences likely results from the fact that EMAP and SWAMP use a broad definition of "natural" and assign sites probabilistically based on general catchment land use. In some cases, there may be low levels of rural residential, ranching, or agricultural (e.g., orchards) land uses upstream of the sampling sites, even though the reference sites are far from major urban developments and meets the general definition of "natural" (NOAA CCAP 2003). Conversely, in this study sites were rigorously selected to exclude any potential effects of non-natural land use or land cover.

Dry weather concentrations were consistently lower than established water quality management targets. Mean concentrations of metals were below the chronic standards of the California Toxic Rules for inland surface waters (freshwater aquatic life protection standards; Table 14a). There are currently no established nutrient standards available for comparison to data collected from the natural catchments. However, in December 2000, USEPA proposed standards for TKN.

nitrate+nitrite, total nitrogen (TN), and TP, respectively, for Ecoregion III, 6, which includes southern California (USEPA 2000; Table 14b). Although these proposed standards have not been approved, they provide a reasonable basis of comparison to levels of potential environmental concern. The geometric means of all nutrients were below or similar to the proposed USEPA regional nutrient criteria. The USEPA criteria were developed for the entire year and do not separate dry weather condition from wet weather condition. When comparing geometric means from this study with the proposed USEPA nutrient criteria, it is important to realize that the USEPA criteria are averaged on the 25$^{th}$ percentiles of concentrations from four seasons that include wet and dry weather. As shown in this study, levels of nutrients can vary considerably between dry and wet weather. Therefore, it is important to consider storm and non-storm conditions separately in future criteria development.

Median bacteria levels at the natural sites were lower than the Department of Health and Safety (DHS) draft guideline for freshwater recreation for *E. coli* and enterococci but higher for total coliforms (Figure 7). Instances of exceedance of the standards were not correlated with the runoff volume or with catchment size ($p > 0.05$).

There are no established water quality criteria for algae. Thus, the algal levels in this study were compared with literature values typically associated with eutrophic conditions. The mean algal biomass of 147 mg/m$^2$ at the natural sites was slightly lower than the algal nuisance threshold of 150 mg/m$^2$ stated in USEPA's Nutrient Criteria Technical Guidance Manual for Rivers and Streams (2000), but was higher than the 84 mg/m$^2$ suggested as a 50th percentile concentration of chlorophyll-a for eutrophic streams by Biggs and Thomsen (1995). Similarly, the total percent cover of three algal types of 32.6% was higher than the 30% cover suggested as a 50th percentile condition for eutrophic streams by Biggs and Thomsen (1995). However, algal biomass was substantially lower than values at developed sites reported by Welch *et al.* (1988) and Dodds *et al.* (1998).

Neither chlorophyll-a concentration nor algal percent cover was significantly correlated with any nutrient concentrations. The lack of correlation may be due to the narrow range of low values observed for both algae and nutrients at the natural sites. Alternatively, algal levels may be more related to levels of organic nutrients or to physical factors, such as flow or canopy cover, as suggested by Biggs and Thomsen (1995). In addition, the results of this study with respect to algal types and biomass are limited by the number of sampling events conducted during the dry weather. More frequent and continuous sampling/survey throughout the year is necessary to assess more representative changes in algal community and biomass. The lack of correlation between algal biomass and nutrients may also be partly due to this limitation.

The contribution of atmospheric deposition was not accounted for in this study. Therefore, concentration and flux data presented here include contributions from both natural loading and atmospheric deposition to the catchment and subsequent washoff. Prior studies show that rates of atmospheric nitrogen deposition can be quite high in xeric regions, such as those that include the majority of coastal catchments in southern California (Clark *et al.* 2000). Smith *et al.* (2003) showed that estimates of annual loading of TN and TP could be 16 to 30% lower when corrected for atmospheric deposition rates. In addition, mountainous areas within the South Coast air basin, within the greater Los Angeles area, receive the highest nitrogen deposition rates in the country (Fenn and Kiefer 1999, Fenn *et al.* 2003). In addition, Bytnerowicz and Fenn found thatdry deposition[5] of nitrogen over large areas of California was of greater magnitude than wet

[5] The removal of atmospheric particles that, in the absence of water in the atmosphere (i.e.,, rain), settle to the ground as particulate matter.

deposition[6] due to the arid climate (Bytnerowicz and Fenn 1996). Finally, Fenn *et al.* found that the contribution of atmospheric deposition could be even higher in late summer when fog occurs with unusually high atmospheric $NO_3^-$ and $NH_4^+$ (Fenn *et al.* 2002). These findings imply that the dry weather concentrations of nutrients derived solely from natural sources may be even lower than values presented in this study.

This study showed that concentrations of metals, nutrients, and solids from natural catchments are highly variable. This may result from numerous factors, such as temporal and spatial variability and methods of data analysis. One factor that may influence data variability is treatment of non-detects (NDs). In this study, the percent of NDs for a given constituent ranged from 1.8% for TSS to 59.6% for TP (Table 15). Samples that are ND can be assigned a value ranging from zero to the MDL. In this study, zero was not considered because zero values do not allow calculation of geometric statistics. To be conservative, samples were assigned a value of one-half the MDL to ND samples used in this study. Use of the MDL instead of one-half MDL for ND samples would have resulted in less than a 2% increase in median concentration for most constituents. The exceptions were ammonia, nitrate+nitrite, OP, and TSS, which would have increased by 12, 18, 30, and 8%, respectively.

Environmental settings such as geology and land cover have been shown to affect water quality in natural catchments (Lakin and Byers 1941, Dunne and Leopold 1978, Ohlendorf *et al.* 1986, Larsen 1988, Ledin *et al.* 1989, Tracy *et al.* 1990, Tidball *et al.* 1991, Detenbeck *et al.* 1993, Presser *et al.* 1994, Hounslow 1995, Johnes *et al.* 1996, Richards *et al.* 1996, Johnson *et al.* 1997a, Gergel *et al.* 1999, Hibbs and Lee 2000). In this study, geology was the primary factor in determining dry weather water quality in natural catchments. Levels of TDS and other constituents were generally higher in streams draining sedimentary catchments than those draining igneous catchments. This difference can be explained by the higher erodibility of sedimentary rock resulting in the increased release of sediment and associated constituents into the water. Differences in constituent concentrations based on geologic setting were most pronounced for compounds that are typically associated with particles, such as copper, zinc, and nickel. Less difference was observed for compounds typically found primarily in the dissolved phase, such as arsenic and selenium.

Constituent concentrations also varied as a function of catchment slope. The likely mechanism for this effect is an increase in erosion and washoff associated with steeper watersheds (Naslas *et al.* 1994). Overall, the effect of both slope and geology was less pronounced for dry weather conditions than for wet weather conditions, most likely due to a lower amount of overland (surface) runoff.

Land cover did not have a significant effect on dry weather water quality in this study. However, other studies have documented the importance of land cover on water quality (Nolan and Hitt 2003, Willett *et al.* 2004). Binkley *et al.* (2004) reported phosphorus levels in hardwood-forested streams that were more than two orders of magnitude higher than the concentrations found in this study. In our study, forested catchments did not show significantly higher levels for any phosphorus-related constituents than shrub catchments. This highlights the importance of considering regional differences. The soils of hardwood forests typically include well-developed O-horizons and are subject to relatively long periods of saturation. These factors contribute to leaching of nutrients from decaying organic matter in the O-horizon to the streams draining the catchments. In contrast, forested areas in southern California are characterized by young sandy soils with little to no O-horizon and generally low organic matter. These soils are not

[6] The removal of atmospheric particles to the earth's surface by rain or snow (SRA 2003).

substantially different than those found in scrub-shrub areas; hence, differences in nutrient loading were not expected.

Table 7. Means of dry weather and wet-weather concentrations for metals (total recoverable), nutrients, and solids. Data not available ('- ').

| Constituent | Arroyo Seco | | Piru Creek | | Santiago Creek | | Sespe Creek | | Tenaja Creek | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet | |
| Arsenic | 2.17 | 0.89 | 2.01 | 0.47 | 0.49 | 0.22 | 0.46 | 0.36 | 1.38 | 0.73 | µg/L |
| Cadmium | 0.28 | 0.37 | 0.08 | 0.04 | 0.08 | 0.11 | 0.26 | 0.20 | 0.08 | 0.34 | µg/L |
| Chromium | 0.12 | 6.97 | 0.23 | 8.94 | 0.22 | 0.25 | 0.08 | 5.40 | 0.31 | 2.82 | µg/L |
| Copper | 0.58 | 3.63 | 0.73 | 5.51 | 0.42 | 0.38 | 0.95 | 4.83 | 0.13 | 2.33 | µg/L |
| Iron | 37.86 | 2264.78 | 154.69 | 7962.21 | 131.83 | 121.22 | 108.86 | 7253.36 | 200.50 | 3322.19 | µg/L |
| Lead | 0.03 | 2.26 | 0.07 | 1.85 | 0.03 | 0.11 | 0.03 | 1.54 | 0.12 | 1.44 | µg/L |
| Nickel | 0.16 | 2.20 | 0.53 | 5.76 | 0.80 | 0.27 | 0.73 | 5.36 | 0.62 | 1.21 | µg/L |
| Selenium | 0.77 | 0.52 | 0.66 | 0.53 | 0.97 | 1.04 | 1.45 | 0.69 | 0.72 | 0.50 | µg/L |
| Zinc | 0.70 | 12.64 | 0.32 | 16.11 | 0.75 | 1.46 | 0.37 | 14.35 | 0.94 | 12.50 | µg/L |
| Ammonia | 0.01 | 0.03 | 0.01 | 0.03 | 0.00 | 0.02 | 0.01 | 0.09 | 0.01 | 0.06 | mg/L |
| *Total Nitrogen* | 0.43 | 2.23 | 0.54 | 2.35 | 0.41 | 1.01 | 0.55 | 3.32 | 0.24 | 1.56 | mg/L |
| Dissolved Organic Carbon | 2.82 | 6.75 | 3.07 | 5.80 | 3.13 | 3.28 | 3.50 | 5.53 | 5.23 | 6.24 | mg/L |
| Total Organic Carbon | 3.18 | 6.53 | 9.97 | 6.71 | 3.65 | 3.22 | 6.92 | 6.66 | 4.43 | 6.01 | mg/L |
| Total Phosphorus | 0.04 | 0.01 | - | - | 0.05 | 0.06 | - | - | 0.18 | 0.18 | mg/L |
| Orthophosphate | 0.02 | 0.08 | 0.03 | 0.06 | 0.04 | 0.01 | 0.05 | 0.06 | 0.00 | 0.11 | mg/L |
| Total Dissolved Solids | 269.83 | 401.52 | - | - | 439.72 | 334.96 | 869.67 | 417.54 | 399.50 | 349.11 | mg/L |
| Total Suspended Solids | 0.29 | 107.03 | 2.55 | 5454.92 | 0.96 | 13.97 | 0.38 | 51969.43 | 2.38 | 184.15 | mg/L |

**Table 8. Dry weather geometric means (Geomean), along with upper and lower limits of 95% confidence interval (CI) for concentrations, mass load, and flux.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| Arsenic | 0.66 | 0.94 | 0.47 | 7.90 | 13.72 | 4.55 | 0.33 | 0.51 | 0.21 |
| Cadmium | 0.11 | 0.15 | 0.09 | 1.34 | 2.20 | 0.81 | 0.06 | 0.10 | 0.03 |
| Chromium | 0.17 | 0.22 | 0.13 | 2.03 | 3.22 | 1.28 | 0.08 | 0.14 | 0.05 |
| Copper | 0.56 | 0.72 | 0.43 | 6.64 | 10.59 | 4.16 | 0.28 | 0.43 | 0.18 |
| Iron | 83.90 | 109.83 | 64.10 | 997.79 | 1628.97 | 611.18 | 41.37 | 69.19 | 24.73 |
| Lead | 0.05 | 0.06 | 0.03 | 0.55 | 0.89 | 0.34 | 0.02 | 0.04 | 0.01 |
| Nickel | 0.30 | 0.41 | 0.22 | 3.56 | 6.03 | 2.10 | 0.15 | 0.24 | 0.09 |
| Selenium | 0.58 | 0.84 | 0.41 | 6.95 | 11.84 | 4.08 | 0.29 | 0.49 | 0.17 |
| Zinc | 0.56 | 0.82 | 0.39 | 6.70 | 10.52 | 4.27 | 0.28 | 0.50 | 0.16 |
| | | | | | | | | | |
| | | | | | | | | | |
| Ammonia | 0.01 | 0.01 | 0.01 | 0.07 | 0.11 | 0.05 | 0.003 | 0.005 | 0.002 |
| Nitrate+Nitrite | 0.05 | 0.08 | 0.03 | 0.58 | 1.08 | 0.31 | 0.02 | 0.05 | 0.01 |
| Total Kjeldahl Nitrogen | 0.28 | 0.31 | 0.25 | 3.29 | 5.07 | 2.14 | 0.14 | 0.22 | 0.09 |
| Dissolved Organic Carbon | 2.68 | 3.39 | 2.12 | 31.87 | 49.86 | 20.37 | 1.32 | 2.17 | 0.80 |
| Total Organic Carbon | 2.85 | 3.37 | 2.41 | 33.88 | 51.18 | 22.43 | 1.40 | 2.18 | 0.91 |
| Orthophosphate | 0.02 | 0.02 | 0.01 | 0.20 | 0.33 | 0.13 | 0.008 | 0.014 | 0.005 |
| Total Phosphorus | 0.05 | 0.06 | 0.04 | 0.57 | 0.89 | 0.36 | 0.02 | 0.04 | 0.01 |
| | | | | | | | | | |
| | | | | | | | | | |
| Total Dissolved Solids | 274.43 | 411.49 | 183.02 | 3132.46 | 5804.84 | 1690.37 | 137.86 | 250.53 | 75.87 |
| Total Suspended Solids | 0.85 | 1.27 | 0.57 | 10.12 | 17.80 | 5.76 | 0.42 | 0.78 | 0.23 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Algae*** | **Percent Cover (%)** | | | **Chlorophyll-a (mg/m²)** | | |
| | | | | | Mean | Min | Max | Mean | Min | Max |
| *E. coli* | 15.83 | 20.11 | 12.46 | Benthic | 23.60 | 0.00 | 100.00 | 439.20 | 0.00 | 6946.20 |
| *Enterococcus* | 19.84 | 25.49 | 15.45 | Attached | 6.40 | 0.00 | 38.10 | 0.48 | 0.00 | 2.30 |
| Total Coliform | 1047.83 | 1429.96 | 767.82 | Free floating | 2.60 | 0.00 | 37.20 | 0.03 | 0.00 | 0.21 |

* Algal data were normally distributed and arithmetic means, minimums and maximums were computed.

**Table 9. Dry weather results of stepwise selection of environmental variables using redundancy analysis (RDA)[a].**

| Environmental Variables | Extra Fit | Cumulative Fit | Significance (p value) |
|---|---|---|---|
| Igneous Rock | 0.073 | 0.073 | 0.005 |
| Sedimentary Rock | 0.073 | 0.146 | 0.005 |
| Slope | 0.040 | 0.186 | 0.04 |
| Mean Flow | 0.039 | 0.225 | >0.05 |
| Elevation | 0.034 | 0.259 | >0.05 |
| Catchment Size | 0.032 | 0.291 | >0.05 |
| Canopy Cover | 0.032 | 0.323 | >0.05 |
| Latitude | 0.025 | 0.348 | >0.05 |
| Forest | 0.023 | 0.371 | >0.05 |
| Shrub | 0.023 | 0.395 | >0.05 |

[a] Variables are given in the order of inclusion. The extra and cumulative fits are given as percentages relative to the total sum of squares over all water quality variables (comparable to the percentage explained variance in univariate regression). Number of observations: 1006. Total number of water quality variables: 18. Significance was determined by Monte Carlo permutation using 199 random permutations.

**Table 10. Statistical summary of RDA for dry weather water quality.**

| | | Axes 1 | Axes 2 | Axes 3 | Axes 4 |
|---|---|---|---|---|---|
| Eigenvalues | | 0.075 | 0.038 | 0.22 | 0.11 |
| Water Quality Environment Correlations | | 0.65 | 0.65 | 0.00 | 0.00 |
| Cumulative Percentage variance | Water Quality Data | 7.50 | 11.00 | 33.00 | 45.00 |
| Cumulative Percentage variance | Water Quality-Environment Relation | 66.00 | 100.00 | 0.00 | 0.00 |

**Table 11. Canonical coefficients of environmental variables with the first two axes of RDA for dry weather concentrations of metals, nutrients, and solids.**

| Environmental Variables | Water Quality Constituent Axes 1 | Water Quality Constituent Axes 2 |
|---|---|---|
| Sedimentary Rock | -0.63 | -0.15 |
| Igneous Rock | 0.63 | 0.15 |
| Slope | 0.16 | 0.64 |

Table 12. Comparison of percent coefficient of variation (%CV) between natural sites and developed sites for metals, nutrients, and solids in the dry weather condition. Data were not available ('-').

| Metal | Natural | | | Developed | | |
|---|---|---|---|---|---|---|
| | Sample Size | Concentration %CV | Flux %CV | Sample Size | Concentration %CV | Flux %CV |
| Arsenic | 51 | 530 | 1500 | 4 | 81 | 950 |
| Cadmium | 51 | 2300 | 13000 | 4 | 980 | 14000 |
| Chromium | 51 | 1400 | 7600 | 8 | 41.30 | 200 |
| Copper | 51 | 460 | 1800 | 11 | 4.40 | 72 |
| Iron | 51 | 3.20 | 16 | 8 | 0.14 | 1.20 |
| Lead | 51 | 6100 | 28000 | 10 | 15.10 | 200 |
| Nickel | 50 | 1000 | 4300 | 8 | 5.00 | 29 |
| Selenium | 51 | 650 | 2400 | 8 | 52 | 380 |
| Zinc | 51 | 710 | 3000 | 11 | 1.7 | 23 |
| Ammonia | 51 | 24000 | 190000 | 10 | 320 | 720 |
| Nitrate+Nitrite | 51 | 8500 | 37000 | 8 | 97 | 550 |
| Total Kjeldahl Nitrogen | 50 | 540 | 3900 | 0 | - | - |
| Dissolved Organic Carbon | 51 | 88 | 460 | 0 | - | - |
| Total Organic Carbon | 51 | 65 | 350 | 0 | - | - |
| Orthophosphate | 51 | 25000 | 91000 | 0 | - | - |
| Total Phosphorus | 49 | 5100 | 25000 | 8 | 350 | 3400 |
| Total Dissolved Solids | 51 | 1.60 | 6.30 | 0 | NA | NA |
| Total Suspended Solids | 50 | 500 | 2300 | 8 | 11 | 53 |
| *E coli* | 52 | 29 | - | 12 | 0.28 | - |
| *Enterococcus* | 52 | 20 | - | 12 | 0.45 | - |
| Total Coliform | 52 | 0.50 | - | 12 | 0.0036 | - |

**Table 13. Comparison of dry weather geometric means of concentration of the natural catchments with geometric means from reference sites of the existing ambient monitoring programs (EMAP and SWAMP).**

| | | |
|---|---|---|
| Selenium (µg/L) | 13.70 | 0.58 |
| Zinc (µg/L) | 5.25 | 0.56 |
| Ammonia (mg/L) | 1.47 | 0.01 |
| Dissolved Organic Carbon (mg/L) | 1.67 | 2.68 |
| Total Phosphorus (mg/L) | 1.99 | 0.05 |
| Total Nitrogen (mg/L) | 301 | 0.32 |
| Total Suspended Solids (mg/L) | 495 | 0.85 |

**Table 14a. Water quality standards for metals. Standards are from the California Toxics Rule (CTR) – Inland surface waters for freshwater aquatic life protection. Standards for hardness-dependent metals shown here are those at 100 mg/L. Four-day criteria are used for the comparison of the dry weather water quality.**

| | | |
|---|---|---|
| Arsenic | 150 | Independent |
| Cadmium | 2.20 | |
| Chromium (III) | 180 | |
| Copper | 9.00 | Dependent |
| Nickel | 52 | |
| Lead | 2.50 | |
| Selenium | 5.00 | Independent |
| Zinc | 120 | Dependent |

**Table 14b. Comparison of EPA proposed nutrient criteria for rivers and streams for Ecoregion III, 6 (central and southern California) with dry weather geometric means.**

| | | **Natural Catchments in Dry Weather Geometric Mean** |
|---|---|---|
| Total Kjeldahl Nitrogen (mg/L) | 0.36 | 0.28 |
| Nitrate+Nitrite (mg/L) | 0.16 | 0.05 |
| Total Nitrogen (mg/L) | 0.52 | 0.33 |
| Total Phosphorus (mg/L) | 0.03 | 0.05 |

**Table 15. Percent non-detects (%ND) of the dry weather data. Constituents not shown did not have NDs.**

| | | | |
|---|---|---|---|
| Arsenic | 21 | 163 | 12.9 |
| Cadmium | 74 | 165 | 44.8 |
| Chromium | 45 | 164 | 27.4 |
| Copper | 18 | 164 | 11.0 |
| Lead | 5 | 163 | 3.1 |
| Nickel | 92 | 164 | 56.1 |
| Selenium | 31 | 165 | 18.8 |
| Zinc | 36 | 169 | 21.3 |
| Ammonia | 35 | 165 | 21.2 |
| Dissolved Organic Carbon | 67 | 115 | 58.3 |
| Nitrate | 4 | 104 | 3.8 |
| Nitrite | 24 | 120 | 20.0 |
| Orthophosphate | 64 | 119 | 53.8 |
| Total Kjeldahl Nitrogen | 32 | 108 | 29.6 |
| Total Phosphorus | 62 | 104 | 59.6 |
| Total Dissolved Solids | 21 | 108 | 19.4 |
| Total Suspended Solids | 2 | 109 | 1.8 |

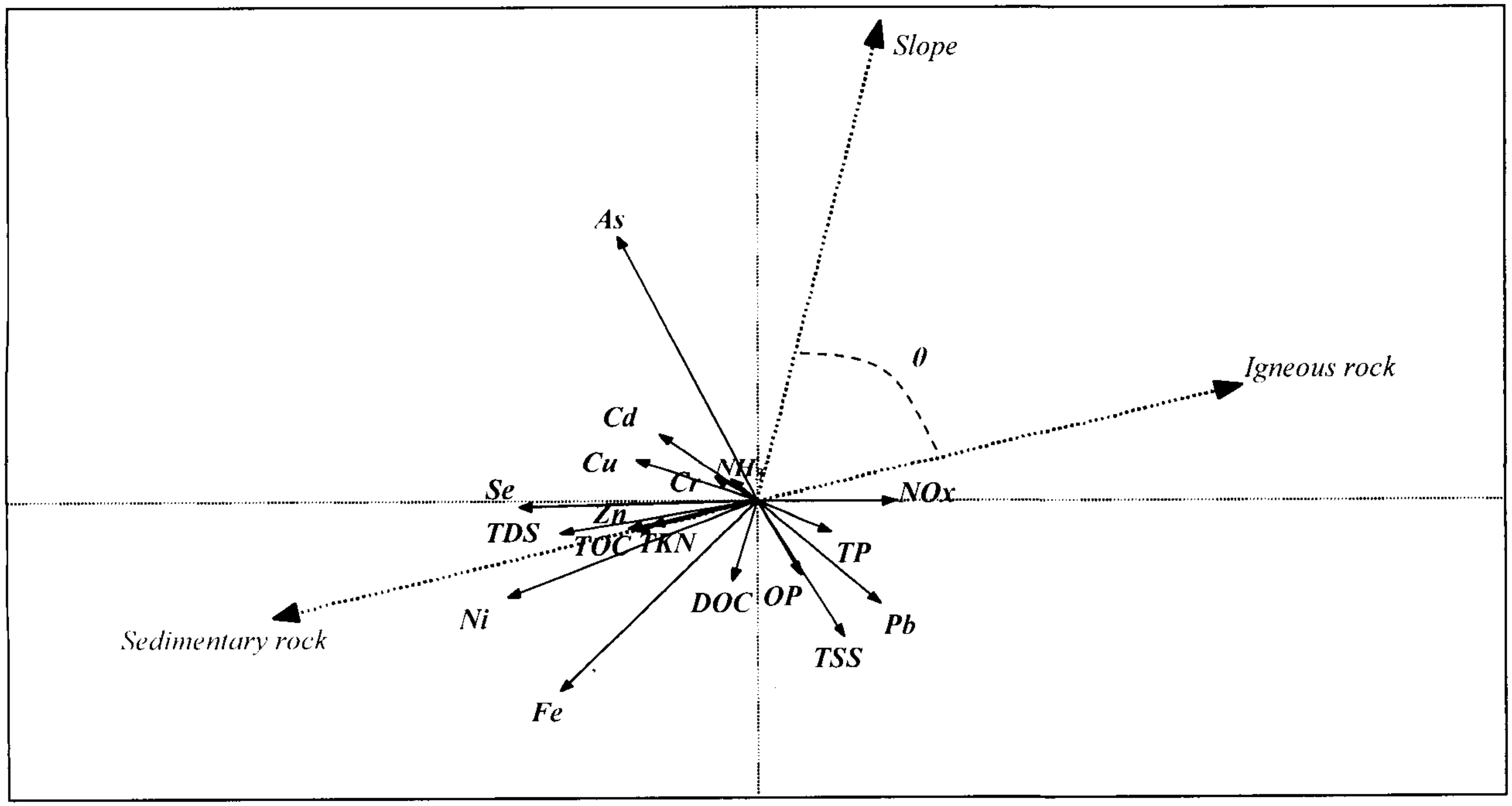


Figure 2. Correlation biplots showing relations between dry weather concentrations of metals, nutrients, and solids (solid arrows) and environmental variables (dotted arrows). Eigen values: 0.151 and 0.0280 for the first (horizontal) and second (vertical). cos $\theta \approx$ correlation coefficient between two variables (arrows). Longer arrows indicate which factor is more important in generating variability (Ter Braak, 1995). Total dissolved solids (TDS); total suspended solids (TSS); total organic carbon (TOC); dissolved organic carbon (DOC); total Kjeldahl nitrogen (TKN); total phosphorus (TP); orthophosphate (OP); and Nitrate+Nitrite (NOx ).

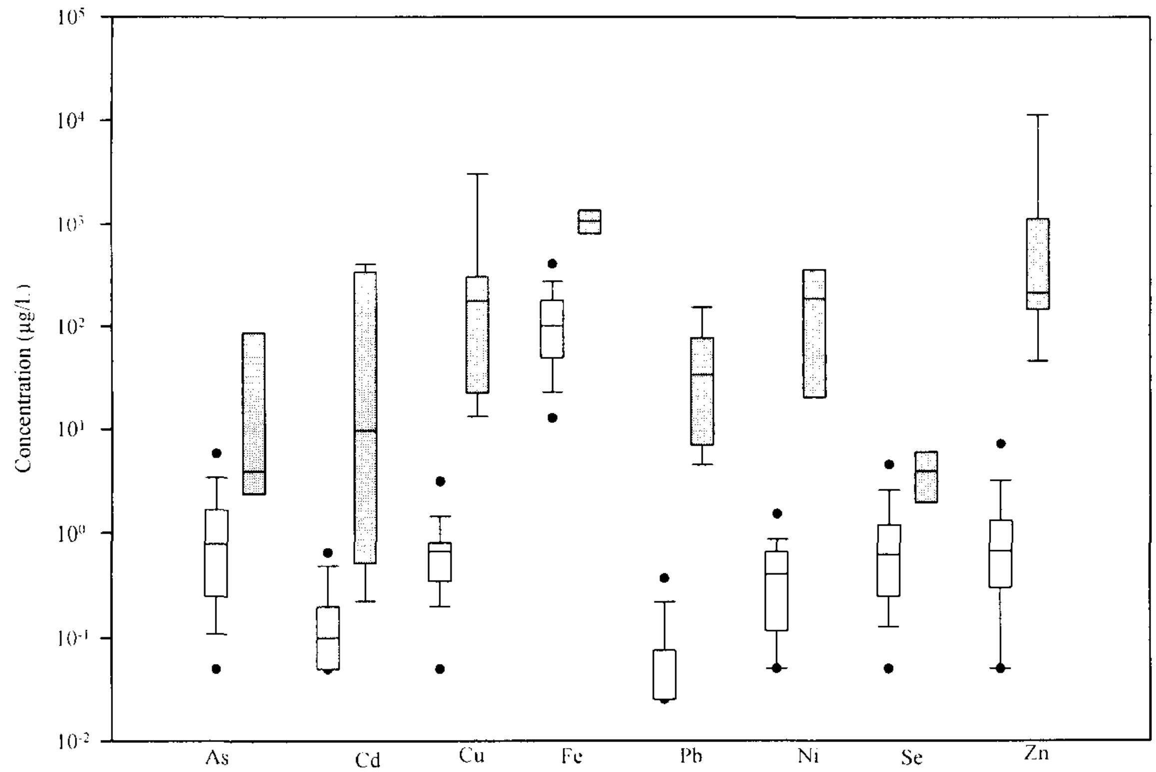


Figure 3a. Comparison of dry weather concentrations of metals between natural and developed catchments. White boxes represent natural sites, and gray boxes represent developed sites. Solid lines indicate the median of all values in the category. Boxes indicate 25th and 75th percentiles, and error bars indicate 10th and 90th percentiles. Solid dots represent 5th and 95th percentiles.. The Y axis is in log scale.

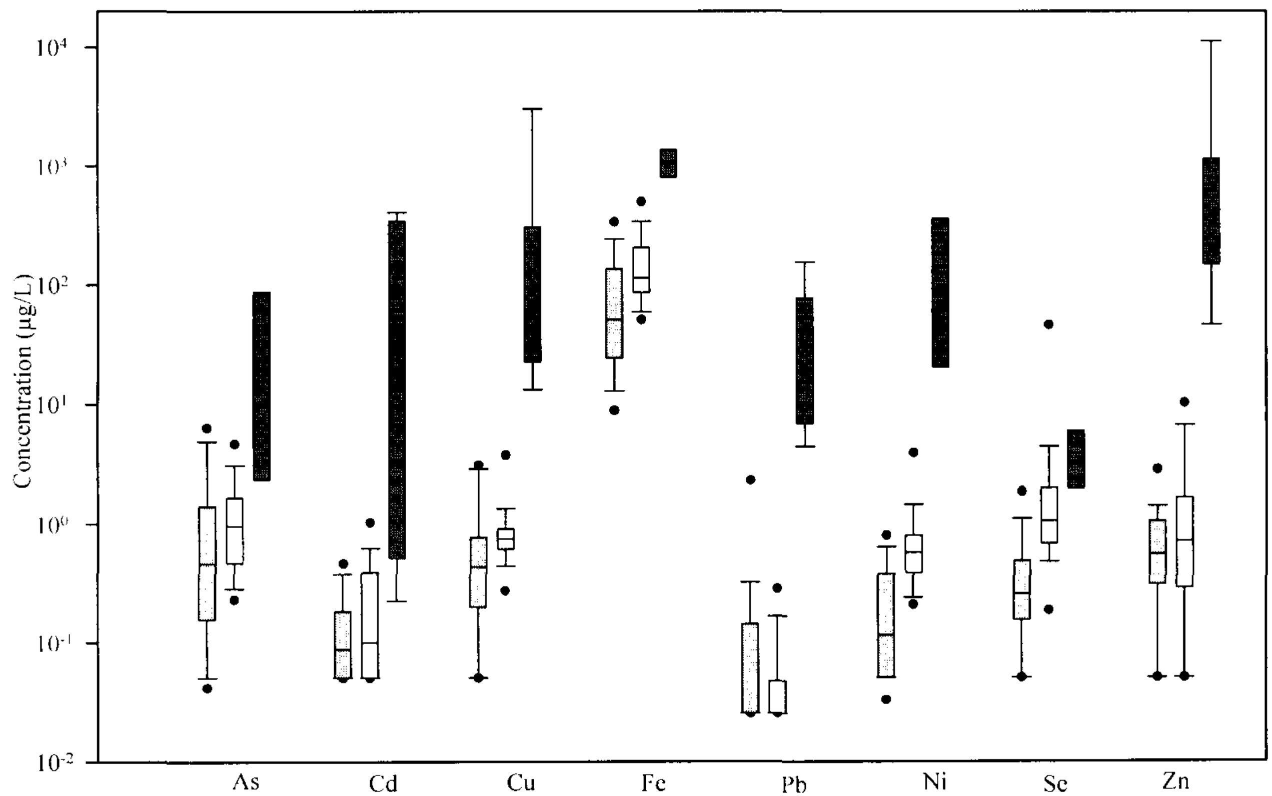


Figure 3b. Comparison of dry weather concentrations of metals between natural and developed catchments. Light gray boxes represent natural sites underlain by igneous rock; white boxes represent natural sites underlain by sedimentary rock; and dark gray boxes represent developed sites. Solid lines indicate the median of all values in the category. Boxes indicate 25th and 75th percentiles, and error bars indicate 10th and 90th percentiles. Solid dots represent 5th and 95th percentiles. The Y axis is in log scale.

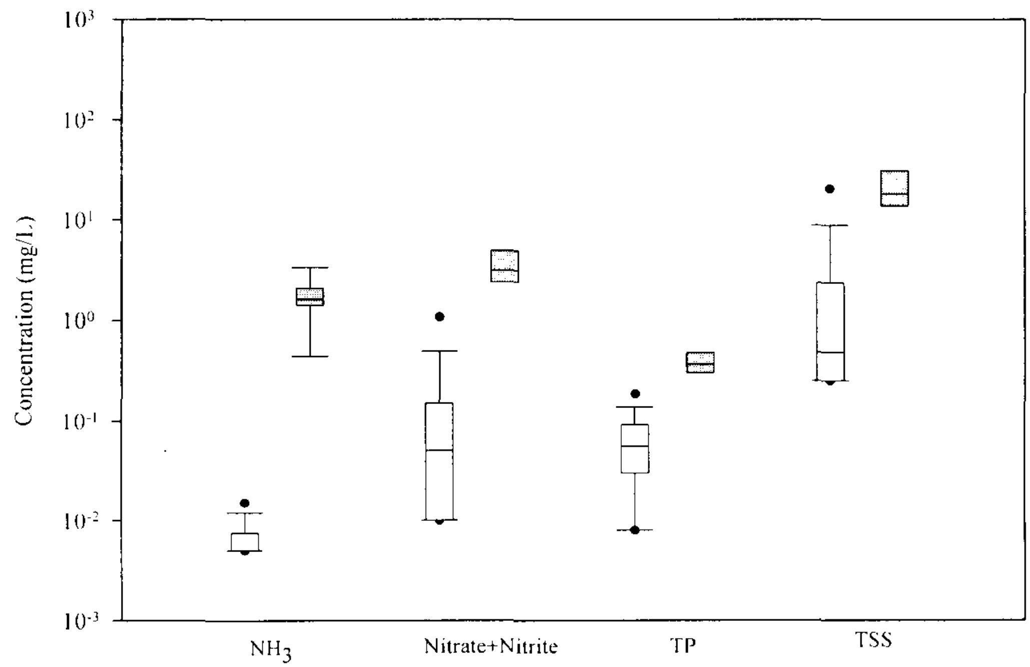


**Figure 4a.** **Comparison of dry weather concentrations of ammonia ($NH_3$), nitrate+nitrite, total phosphorus (TP), and total suspended solids (TSS) between natural and developed catchments. White boxes represent natural sites, and gray boxes represent developed sites. The Y axis is in log scale.**

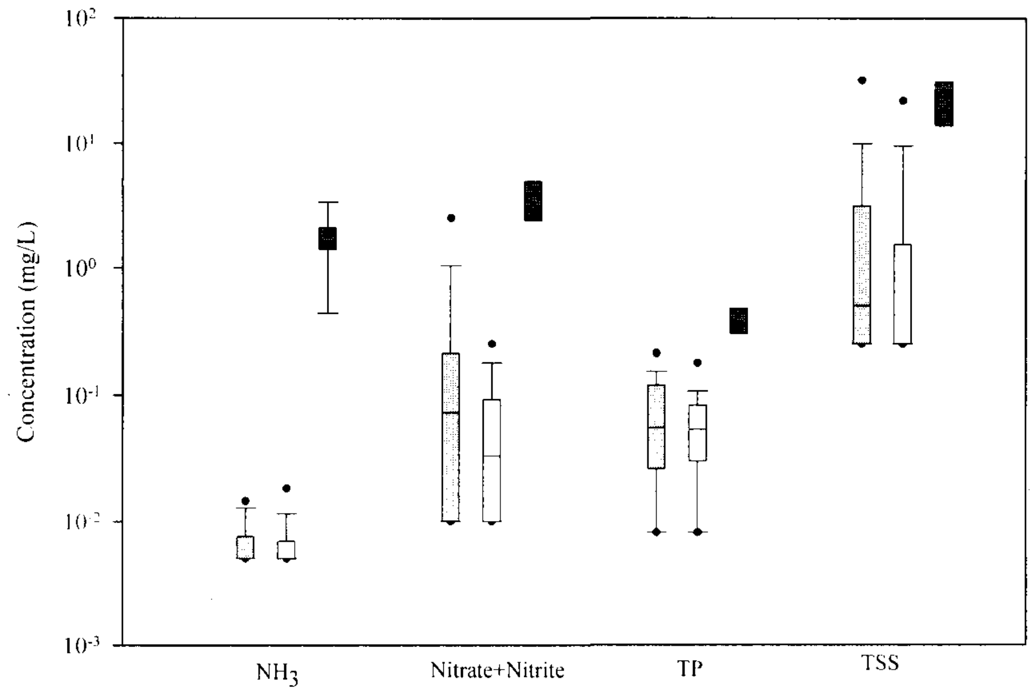


Figure 4b. Comparison of dry weather concentrations of ammonia ($NH_3$), nitrate+nitrite, total phosphorus (TP), and total suspended solids (TSS) between natural and developed catchments. Light gray boxes represent natural sites underlain by igneous rock, white boxes represent natural sites underlain by sedimentary rock, and dark gray boxes represent developed sites. The Y axis is in log scale.

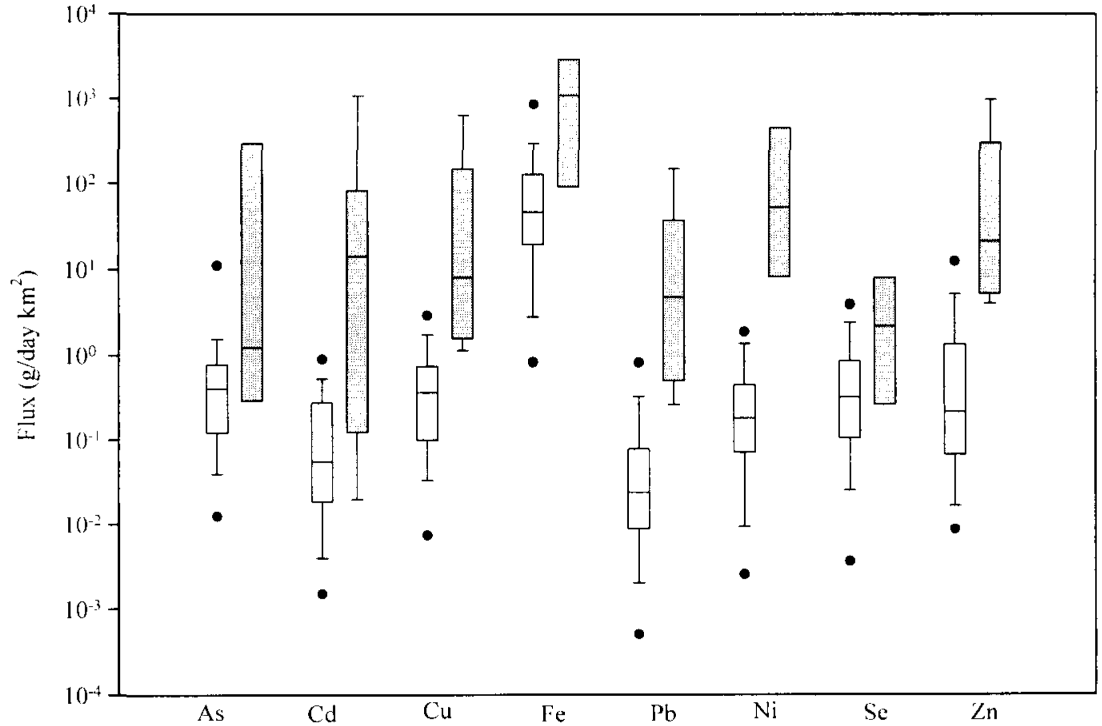


**Figure 5. Comparison of dry weather fluxes of metals between natural and developed catchments. White boxes represent natural sites, while gray boxes represent developed sites. The Y axis is in log scale.**

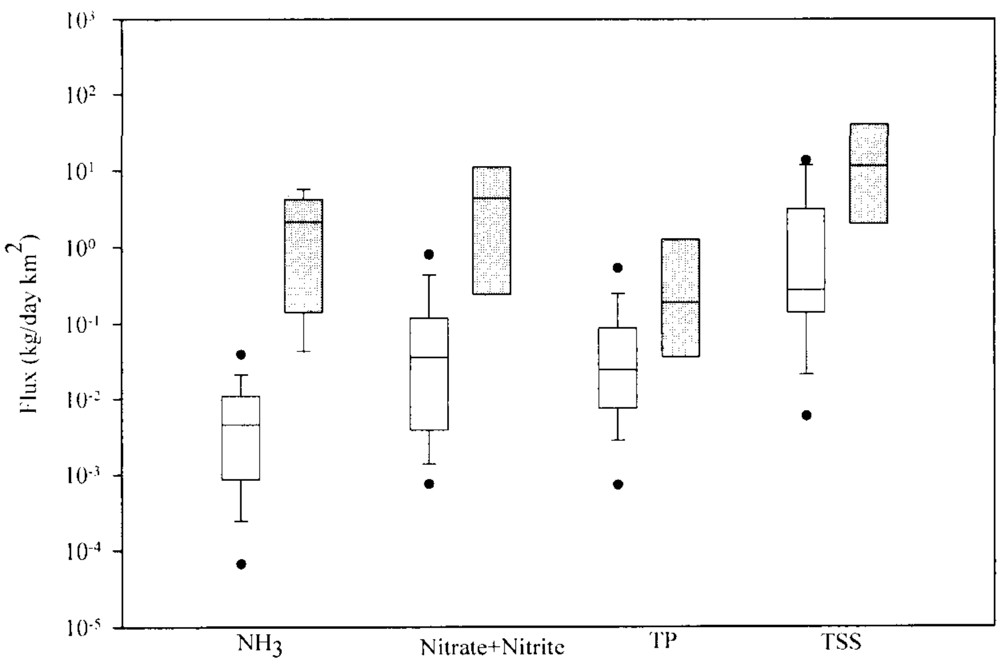


**Figure 6.** Comparison of dry weather fluxes of ammonia ($NH_3$), nitrate+nitrite, total phosphorus (TP), and total suspended solids (TSS) between natural and developed catchments. White boxes represent natural sites, while gray boxes represent developed sites. The Y axis is in log scale.

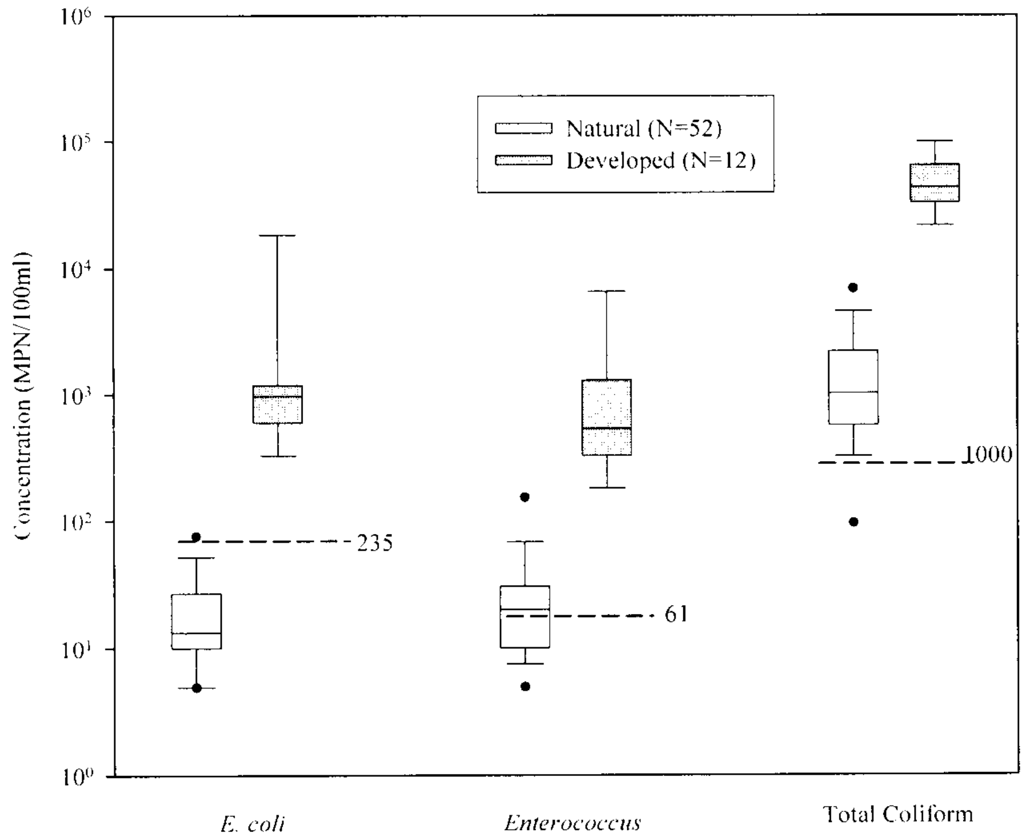


Figure 7. Comparison of dry weather bacteria concentrations between undeveloped and developed catchments. Blue boxes represent natural catchments, and yellow boxes represent developed catchments. The Y axis is in log scale. N is the number of samples per catchment type. Dotted lines are Department of Health and Safety draft guideline for freshwater recreation.

# WET WEATHER

## Background

Stormwater runoff has been recognized as a major source of pollution to many of the nations waterways (Characklis and Wiesner 1997, Davis *et al.* 2001). In southern California, pollutants associated with stormwater have been shown to result in significant ecological effects in local receiving waters of the Southern California Bight (Bay and Greenstein 1996, Noble *et al.* 2000, Schiff 2000). Consequently, much effort and resources have been devoted to the evaluation and management of stormwater (USEPA 1995, Wong *et al.* 1997, Ackerman and Schiff 2003, Ahn *et al.* 2005). One of the challenges associated with stormwater management is accounting for the impact of biogenic inputs, or the natural contribution from undeveloped areas (natural loadings) on overall water quality.

Unlike man-made compounds, such as Polychlorinated Biphenyls (PCBs), many constituents found in stormwater, such as metals, nutrients, and solids, can originate from natural, as well as anthropogenic, sources (Turekian and Wedepohl 1961, Dickert 1966, Trefry and Metz 1985, Horowitz and Elrick 1987, Seiler *et al.* 1999). Therefore, high levels of these constituents may not directly indicate a water quality problem, and it may be difficult to differentiate anthropogenic effects and natural variability in the system.

Existing ambient monitoring programs typically include a few reference streams in relatively undeveloped areas, but mainly focus on dry weather water quality and devote little, if any, resources for characterizing reference conditions for stormwater runoff. To compensate for the lack of data on natural stormwater loadings, water quality standards, such as TMDLs, are often written using load allocations based on data from other parts of the country or, with anecdotal data from previous time periods. As a result, these standards may be ineffective or overly stringent. Quantification of stormwater loads from natural areas in southern California (presented in this section) would help remedy this situation.

## Rainfall and flow

Annual rainfall during the study period (2004 to2006) was compared to the average annual rainfall from 1872 to 2006 (Figure 8; Los Angeles County Department of Public Works (LADPW) rain gage station #716 at Ducommun St., Los Angeles, CA - http://ladpw.org/wrd/Precip/index.cfm). Rainfall for the 2004-2005 storm season was significantly above the long-term average annual rainfall of 40 cm. In contrast, annual rainfall during 2006 was approximately two-thirds of the average. Therefore the two study years represented an unusually wet year and a below-average rainfall year.

Event rainfall over the study period ranged from 0.81 to 17.20 cm. Mean storm flow was 1.39 $\pm$2.31 $m^3$/sec and flow varied from 1.51 x $10^{-2}$ to 9.76 $m^3$/sec. Peak flows ranged from 6.88 x $10^{-2}$ to 53.72 $m^3$/sec with the mean of 4.82 $\pm$11.42 $m^3$/sec.

The mean total rainfall per storm event among the study catchments varied between the two years of sampling. During 2004-2005, mean rainfall was 7.3 cm/storm event, while in 2005-2006 it was 4.6 cm/storm event. The higher magnitude, frequency and duration of rainfall translated to average mean flows during 2004 being approximately four times larger than in 2005. Mean peak flow was 1.3 $\pm$1.6 $m^3$/sec in 2004-2005 vs. 8.1$\pm$ 15.3($m^3$/sec) in 2005-2006.

## Ranges of concentrations, loads, fluxes for metals, nutrients, and solids

Geometric means ranged from 0.3 to 5 µg/L for metals except iron (962 µg/L) and from 0.04 to 6 mg/L for nutrients. Geometric means of TDS and TSS were 98 and 251 mg/L, respectively, and those of bacteria ranged from 123 to 4467 MPN/100ml. Concentrations, loads and fluxes for each constituent are summarized as geometric means and upper and lower 95% CI in Table 16. In all cases, concentrations and loads observed from the natural catchments exhibited a great deal of variability, as indicated by large 95% CI; concentrations, loads, and fluxes generally varied over one order of magnitude. Concentrations. Loads, and fluxes for each study site are shown in Appendix VIII.

## Temporal variability in concentration and load

No first flush was observed in stormwater runoff from the natural catchments as indicated by the cumulative mass loading plots. In all cases less than 30% of total mass was discharged during the first 25% of the storm runoff volume. For example, the mass loading for Piru Creek was roughly proportional to the percent volume discharged in Piru Creek (Figure 9). From a concentration perspective, concentrations varied over the course of the storm; however, peak concentrations for metals, nutrients, and solids occurred after the peak flow, unlike the pattern typically observed in developed catchments, where peak concentrations occur during the rising limb of the hydrograph. An example of the pollutograph for Piru Creek shows that the peak concentration of copper occurred on the decreasing limb of the hydrograph (Figure 10), and the pollutograph was more spread out in natural areas than typically observed in developed watersheds.

No significant differences in constituent concentrations, loads, or fluxes were observed between early-season storms and late-season storms. In addition, there was no significant correlation between cumulative annual rainfall, concentration, load, or flux for any of the constituents sampled. No significant correlations were observed between FWMCs or fluxes and event rainfall.

Levels of constituents varied between among storm seasons. The range of variability in data was larger during the wetter 2004 storm season than during the drier 2005 storm season. Variability among different storm events in 2004 was significantly larger than variability in 2005, for all constituents except TDS (Appendix VI - Table 1). For example, the %CV for TSS in 2004 was approximately three times larger than that in 2005: 1,154 and 393, respectively. Geometric means for all constituents except DOC and TP were higher in 2004 than those in 2005 (Appendix VI – Table 2).

## Particulate vs. dissolved concentrations of metals in storm runoff

Ratios of particulate to dissolved metals concentrations changed over the course of storms. Particulate metals increased with increased flow, and were significantly associated with an increase in the concentration for TSS ($p < 0.05$). Figure 11 shows an example of this pattern from a storm event at Bear Creek. The concentration of TSS sharply increased with the increase in rainfall and flow, while the concentration of TDS dropped, primarily due to dilution by increased runoff. Once the flow dropped, the concentration of TSS also dropped, but the concentration of TDS did not return to the pre-storm levels for approximately two days (Figure 11). The pattern of TSS concentration was synchronized with the increase in particulate metals and inversely related to TDS concentrations. Although this pattern was consistent among all metals, the ratio of particulate to dissolved concentration varied by metal. Arsenic (As) and selenium (Se) exist primarily in a dissolved phase throughout storms, indicated by the fact that all samples were below the 1:1 reference line of equal distribution between the two phases (Figure 11). At peak flow, the ratio of particulate over dissolved metals for As and Se increased by approximately two orders of magnitude coincident with an increase in TSS. Copper (Cu), lead (Pb), and zinc (Zn) existed primarily in the dissolved phase during baseflow conditions. However, during peak flow particulate metals increased by three orders of magnitude and the majority of metals in storm runoff occur in the particulate phase. Increased particulate metal concentrations persisted long after flow subsided; the ratio of particulate to dissolved metals did not return back to the pre-storm levels for two days following peak flow.

## Environmental factors that influence variability in constituent concentrations

The influence of environmental variables on water quality data was examined in a two-step process. First, RDA was used to identify the variables that accounted for the majority of variance in the data set as a whole. Second, the entire water quality data set was grouped based on the environmental variables identified by the RDA model. The data were log-transformed and the significance of differences between the groups was analyzed using ANOVA.

Geologic setting (sedimentary vs. igneous) and elevation were the main determinants of variance in the wet-weather water quality data. According to the RDA stepwise selection, geology and elevation showed higher extra fit than the other eleven variables tested and significantly increased the fitness of the model (Table 17). Because sedimentary geologic setting, igneous geologic setting, and elevation were the only variables that significantly contributed to the fitness of the RDA model ($p < 0.05$), subsequent RDA analysis was conducted using only these three environmental variables, thereby maximizing the ability of the model to resolve differences between environmental classes.

The RDA model with three environmental variables explains 66.6% of variance in water quality data (Table 18). In contrast, the model that included all fourteen environmental variables explained only 44.3% of variance. The first axis of the RDA model was determined by the two geologica setting variables. This axis had a canonical coefficient of $\pm 0.5167$ and explained 84.5% of total model variance relating water quality to environmental variables; the second axis of the RDA model was determined by elevation, had a canonical coefficient of 0.3777, and explained 15.5% of total model variance (Tables 19 and 20).

Most metals, TSS, and a few nutrients were correlated with geology variables as shown in the biplot (Figure 12). Total suspended solids and metals (except arsenic) were positively correlated with sedimentary rock. Dissolved organic carbon and TOC were negatively correlated with sedimentary rock and positively correlated with igneous rock. Total Kjeldahl nitrogen was strongly positive-correlated with elevation. Arsenic, OP and TDS were negatively correlated with elevation. Other constituents exhibited no strong correlation with any of the environmental variables. The correlations suggested by the RDA results were reconfirmed by regression analysis.

Concentrations of several constituents exhibited significant differences between the two geologic types. Results of the ANOVA indicate that Cu, Ni, Se, Zn, $NH_3$, and TSS. concentrations were significantly higher in runoff from natural catchments underlain by sedimentary rock than those underlain by igneous rock ($p < 0.05$). Other constituents did not exhibit any significant differences between the geologic types.

## Comparison with developed catchments

Hydrologic responses of natural catchments were different from those of developed catchments. The ratios of peak flow to catchment size increased less sharply in response to the increase of rainfall in natural catchments than in response to increased rainfall in developed catchments (Figure 13a.). Ratios of mean flow and total runoff volume to catchment size also increased less sharply in response to increase of rainfall in natural catchments than in response to increased rainfall in developed catchments. This difference between natural catchments and developed catchments was likely due to difference in the amount of impervious surface in the catchments. In addition, storms at the natural sites were bigger than storms at the developed sites in terms of total rainfall of a storm event. Most storms at the natural sties were distributed above the average total rainfall per storm event at Los Angeles DPW station #716 at Ducommun St., Los Angeles, CA, between 1997 and 2003 (Figure 13b). This is primarily because most of natural sites are located at upper portions of the watershed, while most of developed sites are located at lower portions of the watershed. The natural sites in mountainous areas of higher altitude are more likely to have more frequent and higher precipitation than the developed sites.

Flow-weighted mean concentrations (FWMCs) from the natural catchments were significantly different ($p < 0.05$) from those of developed catchments in southern California for all constituents examined except TSS. Comparisons were conducted for a total of nine metals (As, Cd, Cr, Cu, Fe, Pb, Ni, Se, and Zn), four nutrients ($NH_3$, TKN, TP, and nitrate+nitrite), and TSS. Among them, Cd, Se, $NH_3$, TKN, and TSS passed both normality and equivariance tests and were analyzed using ANOVA. Constituents that failed the normality test were examined using one-way ANOVA on ranks. Metal concentrations at the natural catchments were approximately one to two orders of magnitude lower than concentrations observed in the developed areas (Figures 14a and 14b). Concentrations of $NH_3$, nitrate+nitrite, and TKN for the natural catchments were about one order of magnitude lower than those for the developed catchments; conversely, TSS concentrations showed no significant difference between geologic setting (Figures 15a and 15b). Comparison of fluxes (i.e., mass loading per unit area) between the natural and the developed catchments showed that fluxes for As, Cu, Fe, Pb, Ni, Zn were one order of magnitude lower in natural catchments (Figure 16); $NH_3$ concentrations were also one order of magnitude lower for natural catchments than for developed catchments (Figure 17).

Wet weather bacteria levels in the Los Angeles River were higher than those from natural sites, although the differences were not as great as during dry weather (Figure 7). Stormwater bacteria levels at the natural catchments were approximately two to three orders of magnitude lower than those at developed sites in Los Angeles River watershed (Figure 18). Kruskal-Wallis ANOVA on ranks showed that differences between wet weather bacteria levels were significant. It should be noted that bacteria monitoring in the Los Angles River included fecal coliforms instead of *E. coli*, precluding a direct comparison with the natural sites. However, based on an assumption that *E. coli* levels typically equal 80% of fecal coliforms, median *E. coli* levels in the Los Angeles River were almost 20 times higher than those observed at the natural sites.

In all cases, the variability observed in the natural catchments was substantially larger than that observed in the developed catchments both in terms of FWMCs and fluxes based on %CV (Table 20). For example, in the developed catchments, the geometric mean of FWMCs for Fe was 9,729 µg/L and the geometric standard deviation was 18. Comparatively, the geometric mean for iron was 962 µg/L and the geometric standard deviation was 11 in the natural catchments. Greater %CVs in the natural catchments resulted from the larger geometric standard deviation compared with the geometric value.

## Discussion

Constituent concentrations from natural areas were generally one order of magnitude lower than those from the developed catchments, with the exception of TSS. Both FWMC and flux of TSS in the natural catchments were similar to those in the developed catchments, indicating that natural areas may be a substantial source of TSS to downstream areas. Previous studies on developed catchments have reported a strong correlation between particle-bound pollutant load and TSS, particularly for metals (Characklis and Wiesner 1997, Stenstrom *et al.* 1997). However, as shown in this study, high TSS from natural catchments does not automatically correspond to high pollutant load. There are several potential reasons for this discrepancy. First, natural areas may intrinsically produce less pollutant washoff (i.e., less source material). Second, the particle size distribution, and hence the affinity between pollutants and particles, may differ between natural and developed areas. Third, pollutant partitioning to various particle size fractions may be different between natural and developed sites. The results of this study strongly suggest the first reason (i.e., less source material) contributes to lower loads. However, differences in the nature of the particle sizes and the associated pollutant partitioning remain to be investigated. This information would provide additional insight into the contribution of natural areas to downstream transport and deposition patterns.

Metal concentrations were compared with the California Toxics Rules (CTR) acute toxicity standards for inland surface waters (freshwater aquatic life protection standards; Table 21a). Concentrations were consistently below the CTR standards for all metals except for a few isolated exceedances for copper. When compared to the CTR criteria, total copper concentrations from individual samples exceeded the standard in 15 out of a total of 133 samples analyzed, while none of the FWMC values exceeded CTR standards (Figure 19a). However, when dissolved concentrations of copper[7] were compared with the CTR standard, only one out of 133 values exceeded CTR standard (Figure 19b).

The CTR criteria are based on dissolved concentrations; hence the CTR provides a simple matrix for the conversion of total to dissolved concentrations. However, as shown in this study, the ratio of particulate to dissolved metal concentrations varies over the course of a storm. Therefore, it is difficult to infer toxicity from an instantaneous sample. Bioavailability, and thus toxicity, will be affected by numerous factors, including partitioning between particulate and dissolved phases, pH, conductivity and concentration of DOC (Paulson and Amy 1993). Therefore, estimates of metal toxicity should be based on direct measure of dissolved concentrations.

There are no established nutrient standards available for comparison to data collected from the natural catchments in this study. However, in December 2000, USEPA proposed guidelines of 0.363 mg/L, 0.155 mg/L, 0.518 mg/L, and 0.030 mg/L for TKN, nitrate+nitrite, TN, and TP, respectively for Ecoregion III, 6, which includes southern California (USEPA 2000; Table 21b). The geometric means of flow-weighted concentrations of TKN and TP in the natural catchments were similar or below the proposed standards; however, the geometric means of nitrate+nitrite and TN were above the proposed levels. Higher levels of nitrate+nitrite, which lead to high TN (TN = TKN+ nitrate+nitrite) in the natural areas, suggest that wet weather natural background levels for nutrients in southern California may exceed currently proposed USEPA guidelines. This may be because the USEPA guidelines are not specific for the wet weather only, but based on the lower quartile of all existing nutrient data, including data from both wet and dry conditions. Thus, the USEPA guidelines for wet weather may underestimate actual natural background nutrient levels.

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[7] Dissolved concentrations of metals were analyzed separately from particulate concentrations only for stormwater samples collected in the winter of 2005/2006.

In addition to exceeding the proposed USEPA guideline, wet-weather TN level measured in this study were close to levels considered eutrophic by Dodds *et al.* (Dodds *et al.* 1998). Dodds *et al.* classified 100 temperate streams in the United States and defined eutrophic condition as the upper one-third of observed nutrient levels. This discrepancy implies that natural streams in southern California may be substantial sources of nitrogen to downstream waterbodies that have the potential to contribute to nitrogen levels with associated algal growth in receiving waters.

Several factors could have influenced the estimates of natural concentrations and fluxes provided by this study. First, the treatment of NDs, which occur fairly frequently given the inherently low concentrations of constituents in natural catchments can significantly impact concentration estimates (Table 22). However, the assignment of a value of one-half of the detection limit to NDs are not expected to change the findings of this study. This can be illustrated by examining the nutrient data, which had a higher incidence of NDs than metals due to higher MDLs (Table 5). In this study's data, 53% of the total phosphorous samples were ND. If a value equal to the detection limit (instead of one-half of the detection limit) had been assigned to these samples, the overall geometric mean concentration would have increased by only 0.05%, primarily due to the large fluctuation of concentrations over the course of each storm event. Because several high concentrations during a storm event greatly influence the FWMC, the value assigned to a few samples at lower concentrations does not substantially affect the mean. Concentrations of TP in the natural catchments typically exhibited a change of five to six orders of magnitude during a storm event. If the NDs occurred during low flow, the change of the NDs was not likely to affect the FWMCs.

The role of aerial deposition, which was not accounted for in this study, is another factor that could have influenced the this study's estimates. If aerial deposition had been considered, the natural background levels estimated by this study would have been even lower. Atmospheric deposition can be a significant factor that affects loadings in natural areas. For example, in Midwestern and Northeastern streams, atmospheric deposition of nitrogen can account for nearly all downstream nitrogen loads (Smith *et al.* 1987, Puckett 1995). Studies show that rates of atmospheric nitrogen deposition were high in the xeric wet region, which includes a majority of coastal catchments in southern California (Clark *et al.* 2000). The study by Smith *et al.* (2003) reported that loadings of TN and TP could be 16 to 30% lower when corrected with atmospheric deposition rate. This suggests that the nutrient levels in the natural catchments could be lower than values presented in this study. Sabin *et al.* (2005) showed that atmospheric deposition potentially accounted for as much as 57 to 100% of the total trace metal stormwater loads to a small impervious urban catchment in Los Angeles, CA. Mountainous areas within the South Coast air basin, which include portions of four counties in the Los Angeles area, received the highest nitrogen deposition in the country (Fenn and Kiefer 1999, Fenn *et al.* 2003). This suggests potential strong contribution of atmospheric deposition to metals and nutrients in the natural catchments of southern California. Consequently, the contribution of atmospheric deposition should be investigated to assess more accurate natural contribution to loadings.

Geology and elevation were the two factors that controlled most variability in among natural catchments. In this study, land cover did not significantly impact water quality. This result differs from previous studies which have reported that land use and land cover types have a significant impact on water quality (Larsen 1988, Detenbeck *et al.* 1993, Johnes *et al.* 1996, Richards *et al.* 1996, Johnson *et al.* 1997a, Gergel *et al.* 1999). Previous studies have focused on the influence of natural vs. developed land cover on surface water quality or on the effect of different types of developed land use/land cover. The influence of different types of natural land cover on water quality has not been extensively examined prior to this study. Our ANOVA results showed that levels of constituents were not significantly different between two different land cover groups (forest and shrub). This suggests that any differences that might occur due to different types of natural land cover are subtle, and not a key deterministic factor in water quality, unlike the relatively dramatic differences between natural vs. developed land cover previously investigated. However, Miller *et al.*' study (2005) addressed the importance of land cover on natural water quality, indicating that the ecosystem in mature forested Sierra catchments could be a significant source for nutrients. The concentrations of ammonia, nitrate, and phosphate were high in surface runoff from forested systems: as high as 87.2 mg/L, 95.4 mg/L, 24.4 mg/L for ammonia, nitrate, and phosphate, respectively. These values are even greater (one-order of magnitude) than maximum values for developed land uses observed in southern California coastal catchments (Ackerman and Schiff 2003). Values from Miller *et al.* were one to two orders of magnitude higher than the upper ends of 95% CI values for nutrients presented in this study. Miller *et al.* suggested that nutrients that were driven from mature organic horizons (O-horizons[8]) might have had little contact with mineral soil or root zone where strong retention and/or uptake of these ions would be expected. The major difference in nutrient levels between the Sierran catchments and the natural catchments examined in this study may be due to difference in abundance of O-horizon. The coastal catchments in southern California are characterized by young soils with poorly-developed O-horizons and substantially lower standing biomass than the Sierran catchments (Griffin and Critchfield 1972 (reprinted with supplement, 1976)). The Lake Tahoe region and the southern California mountainous areas are located in California, but they are categorized as different ecoregions[9] and the nutrient levels vary by up to two orders of magnitudes. This highlights the importance of identifying region-specific background water quality and potentially significant impact of land cover on water quality.

Other environmental factors, such as catchment size, flow-related factors, rainfall, slope, and canopy cover, as well as land cover, did not significantly affect the variability of water quality. This suggests that the findings of this study may be extrapolated as natural background water quality to the southern California's coastal region. For example, natural catchments in this study were relatively small because few large undeveloped watersheds exist in the coastal region of southern California. In general, concentrations would be expected to vary with increasing catchment size due to loss processes that reduce constituent mass as it travels downstream through stream channels (Alexander *et al.* 2000, Peterson *et al.* 2001). However, no significant difference of natural background concentrations among catchments with different size was observed in this study. This allows extrapolation of this study's findings to natural background water quality for other larger or smaller developed watersheds.

Temporal patterns (within and between storm variability) were different in natural catchments than those observed in developed catchments. No first flush was observed in natural catchments, even for small catchments where first flush is most commonly observed in developed areas. The

[8] O-horizon: At the top of the profile is the O horizon. The O horizon is primarily composed of organic matter. Fresh litter is found at the surface, while at depth all signs of vegetation structure has been destroyed by decomposition. The decomposed organic matter, or humus, enriches the soil with nutrients (nitrogen, potassium, etc.), aids soil structure (acts to bind particles), and enhances soil moisture retention.

[9] Ecoregions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources. They are designed to serve as a spatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem components. By recognizing the spatial differences in the capacities and potentials of ecosystems, ecoregions stratify the environment by its probable response to disturbance. These general purpose regions are critical for structuring and implementing ecosystem management strategies across federal agencies, state agencies, and nongovernmental organizations that are responsible for different types of resources within the same geographical areas (http://www.epa.gov/wed/pages/ecoregions.htm).

observation of first flush occurs because pollutants deposited onto exposed areas can be dislodged and entrained by the rainfall-runoff process. In developed areas, the stormwater that initially runs off an area will be more polluted than the stormwater that runs off later, after the rainfall has 'cleansed' the catchment. The first flush can occur up to several hours prior than the peak flow during a storm (Hoffman *et al.* 1984, Smith *et al.* 2000, Stein *et al.* 2006). The existence of first flush should not be assumed in all cases. Intensive monitoring of stormwater runoff from some (usually larger) catchments has failed to observe this phenomenon, mainly due to the complex commingling of flows from different areas within a large catchment (New South Wales Environment Protection Authority 2005). The lack of first flush in the natural catchments may be explained by the fact that first flush is generally seen only where the supply of pollutants is limited (New South Wales Environment Protection Authority 2005). For example, in natural catchments, sediment, as well as and associated bound pollutants, generated from soil erosion will not exhibit a first flush because the supply of soil particles is practically unlimited. As long as rainfall continues and generates storm runoff, there is a continuous input of the sediments (TSS and TDS). Thus, there is also almost no limitation of TSS-correlated constituents, especially metals, during storms, as indicated by the spread observed in the pollutograph of natural areas. This may partially explain the comparability of TSS FWMC for natural and developed areas. Differences in pollutant delivery timing for natural areas compared to developed areas may provide some ability to segregate downstream loads that are anthropogenic in origin and most prevalent in the early part of storms, from those that are natural in origin and most prevalent later in the storm. This should be investigated further through additional empirical and modeling analysis.

**Table 16. Wet weather geometric means (Geomean), upper and lower ends of 95% confidence interval (CI) for flow-weighted mean concentrations (FWMC), mass loads (mass load per storm event), and fluxes (mass load per unit area); loads and fluxes are per storm event.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Geomean | | | | | |
| Arsenic | 0.39 | 0.71 | 0.21 | 17.40 | 44.63 | 6.78 | 0.87 | 1.91 | 0.40 |
| Cadmium | 0.14 | 0.24 | 0.08 | 6.26 | 15.46 | 2.53 | 0.31 | 0.73 | 0.14 |
| Chromium | 1.40 | 3.09 | 0.63 | 62.59 | 188.88 | 20.74 | 3.13 | 7.98 | 1.23 |
| Copper | 1.54 | 3.17 | 0.75 | 68.84 | 201.07 | 23.57 | 3.45 | 8.68 | 1.37 |
| Iron | 962 | 2313 | 400 | 43100 | 139746 | 13293 | 2158 | 6160 | 756 |
| Lead | 0.51 | 1.06 | 0.24 | 22.80 | 64.84 | 8.02 | 1.14 | 2.94 | 0.44 |
| Nickel | 1.03 | 2.46 | 0.43 | 46.24 | 152.10 | 14.06 | 2.32 | 6.36 | 0.84 |
| Selenium | 0.33 | 0.60 | 0.18 | 14.93 | 41.22 | 5.41 | 0.75 | 1.85 | 0.30 |
| Zinc | 5.32 | 11.16 | 2.54 | 238.44 | 680.97 | 83.49 | 11.94 | 31.52 | 4.52 |
| | | | | | | | | | |
| | | | | Geomean | | | | | |
| Ammonia | 0.04 | 0.08 | 0.02 | 1.91 | 4.68 | 0.78 | 0.10 | 0.21 | 0.04 |
| Dissolved Organic Carbon | 6.26 | 9.54 | 4.11 | 338.67 | 915.76 | 125.25 | 11.83 | 30.35 | 4.61 |
| Nitrate+Nitrite | 0.34 | 0.58 | 0.19 | 15.01 | 36.20 | 6.22 | 0.75 | 1.54 | 0.37 |
| Orthophosphate | 0.04 | 0.06 | 0.02 | 1.91 | 4.35 | 0.84 | 0.10 | 0.20 | 0.05 |
| Total Kjeldahl nitrogen | 1.21 | 1.55 | 0.95 | 70.74 | 255.66 | 19.58 | 2.63 | 7.18 | 0.96 |
| Total Organic Carbon | 6.28 | 9.91 | 3.98 | 339.54 | 935.81 | 123.20 | 11.86 | 31.31 | 4.49 |
| Total Phosphorus | 0.12 | 0.21 | 0.07 | 1.12 | 4.54 | 0.28 | 0.09 | 0.55 | 0.02 |
| | | | | | | | | | |
| | | | | Geomean | | | | | |
| Total Dissolved Solids | 251 | 338 | 187 | 11200 | 25300 | 4990 | 637 | 1260 | 320 |
| Total Suspended Solids | 98.12 | 280.84 | 34.28 | 5069.70 | 20983.90 | 1224.84 | 257.25 | 854.39 | 77.46 |
| | | | | | | | | | |
| | | | | | | | | | |
| *E. coli* | 125 | 399 | 39.70 | | | | | | |
| *Enterococcus* | 140 | 511 | 38.80 | | | | | | |
| Total coliform | 4460 | 13100 | 1510 | | | | | | |

**Table 17. Wet weather results of stepwise selection of environmental variables using redundancy analysis (RDA)[a].**

| Environmental Variable | Extra Fit | Cumulative Fit | Significance (p value) |
|---|---|---|---|
| Sedimentary Rock | 0.119 | 0.119 | 0.025 |
| Igneous Rock | 0.119 | 0.239 | 0.025 |
| Elevation | 0.094 | 0.333 | 0.105 |
| Peak Flow | 0.055 | 0.388 | 0.390 |
| Mean Flow | 0.047 | 0.435 | 0.200 |
| Catchment Size | 0.044 | 0.479 | 0.890 |
| Canopy Cover | 0.044 | 0.522 | 0.080 |
| Total Runoff Volume | 0.040 | 0.562 | 0.305 |
| Latitude | 0.039 | 0.601 | 0.190 |
| Baseline Flow | 0.031 | 0.632 | 0.905 |
| Total Rainfall | 0.027 | 0.660 | 0.220 |
| Shrub | 0.023 | 0.683 | 0.445 |
| Forest | 0.023 | 0.706 | 0.445 |
| Slope | 0.017 | 0.723 | 0.165 |

[a]Variables are given in the order of inclusion. The extra and cumulative fits are given as %ages relative to the total sum of squares over all water quality variables (comparable to the % explained variance in univariate regression). Number of observations: 472; total number of water quality variables: 18. Significance was determined by Monte Carlo permutation using 199 random permutations.

**Table 21a. Water quality standards for metals using the California Toxics Rule (CTR) – Inland surface waters for freshwater aquatic life protection. Standards for hardness dependency based on the hardness of 100 mg/L.**

| | | |
|---|---|---|
| Arsenic | 340 | Independent |
| Cadmium | 4.52 | |
| Chromium | 550 | Dependent |
| Copper | 14.00 | |
| Nickel | 469.17 | Dependent |
| Lead | 81.65 | |
| Selenium | 19.34 | Independent |
| Zinc | 119.82 | Dependent |

**Table 21b. Comparison of USEPA proposed nutrient criteria for rivers and streams for Ecoregion III, 6 (Central and southern California) with wet weather geometric means.**

| | | **Natural Catchments in Wet Weather Geometric Mean (mg/L)** |
|---|---|---|
| Total Kjeldahl Nitrogen | 0.36 | 0.34 |
| Nitrate+Nitrite | 0.16 | 1.21 |
| Total Nitrogen | 0.52 | 1.55 |
| Total Phosphorus | 0.03 | 0.03 |

**Table 22. Percent non-detects (%ND) for wet weather data. Constituents not shown did not have NDs.**

| | | | |
|---|---|---|---|
| Arsenic | 62 | 355 | 17.5 |
| Cadmium | 96 | 355 | 27.0 |
| Chromium | 11 | 355 | 3.1 |
| Copper | 9 | 254 | 3.5 |
| Lead | 76 | 355 | 21.4 |
| Nickel | 21 | 355 | 5.9 |
| Selenium | 56 | 355 | 15.8 |
| Ammonia | 73 | 216 | 33.8 |
| Nitrate | 44 | 220 | 20.0 |
| Nitrite | 93 | 218 | 42.7 |
| Orthophosphate | 41 | 210 | 19.5 |
| Total Phosphorus | 112 | 212 | 52.8 |
| Total Suspended Solids | 34 | 213 | 16.0 |

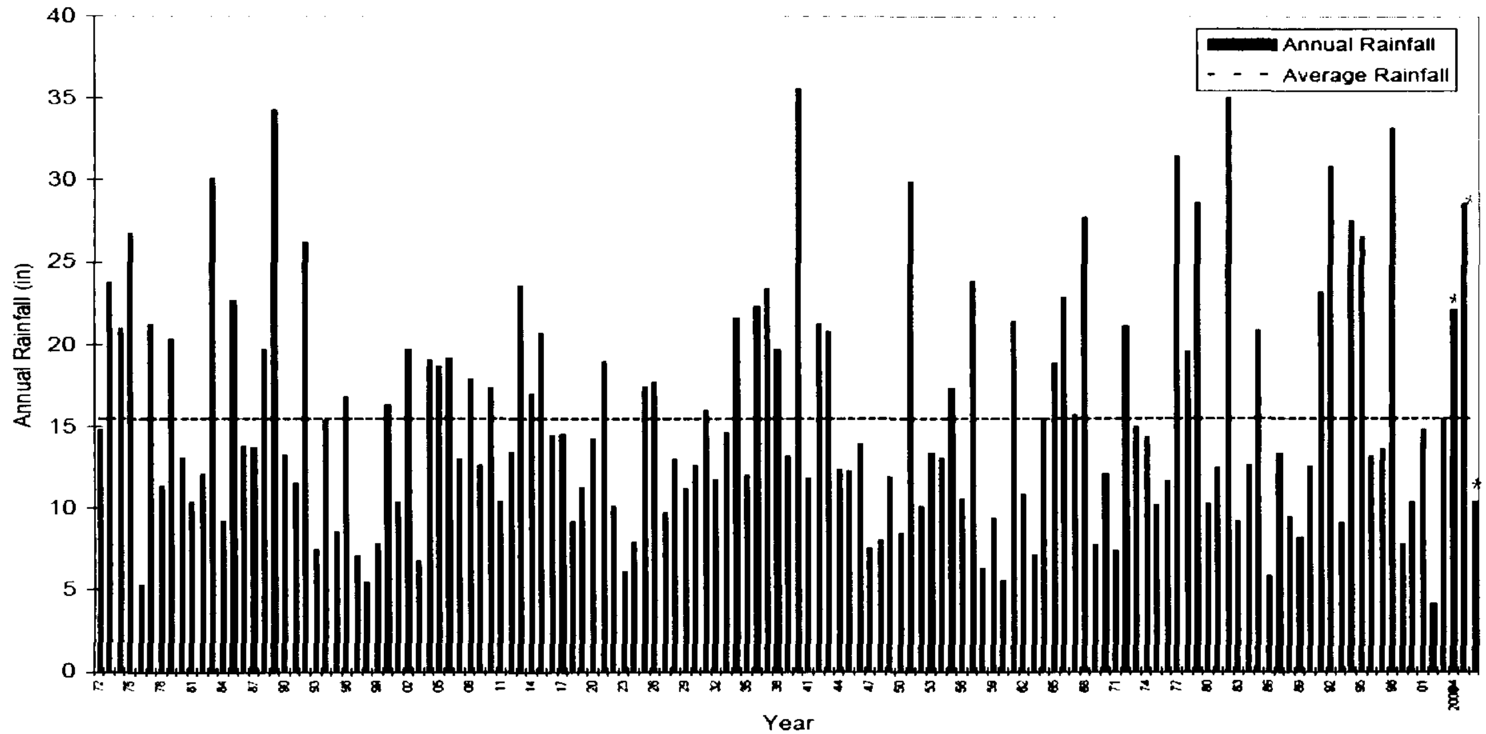



Figure. 8. Comparison of annual rainfall (wet season) at LADPW station #716, Ducommun St., Los Angeles in 2004, 2005, and 2006 with the average rainfall over 135 years. Red dotted line indicates the average annual rainfall of 135 years. * indicates the period of this study from 2004 through 2006.

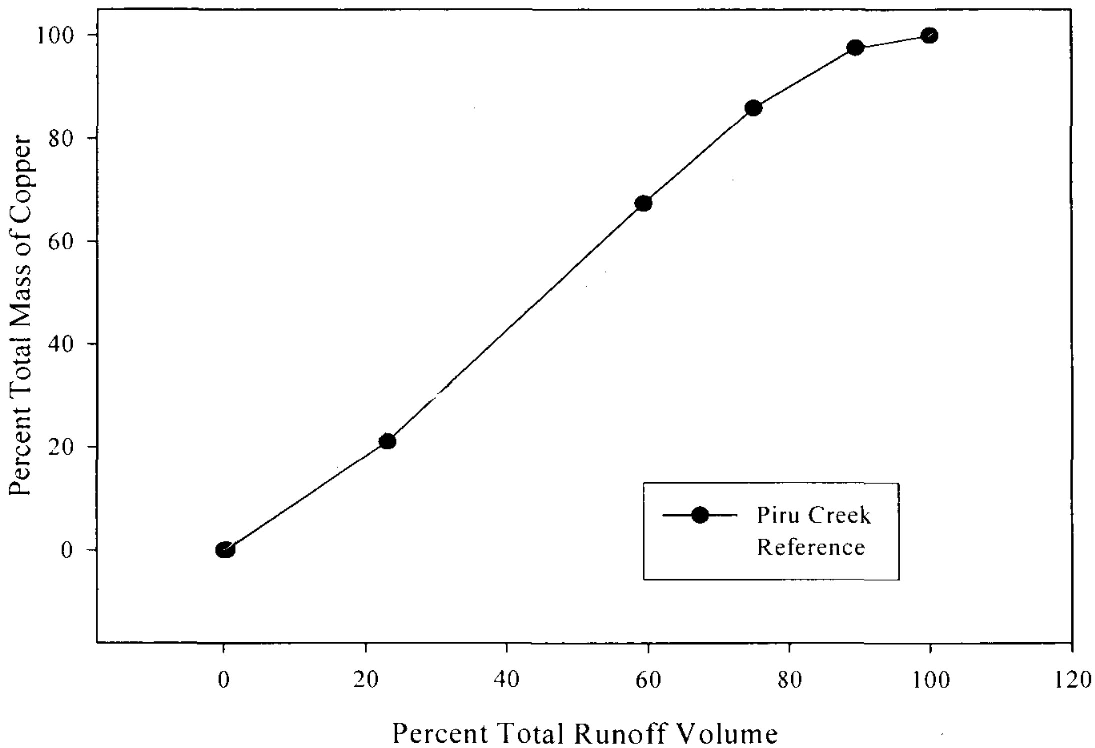



**Figure 9. Cumulative copper mass loads for a storm (February 27 through March 1, 2006) at Piru Creek. Reference line indicates a 1:1 relationship between volume and mass loading. Portions of the curve above the line indicate proportionately higher mass loading per unit volume.**

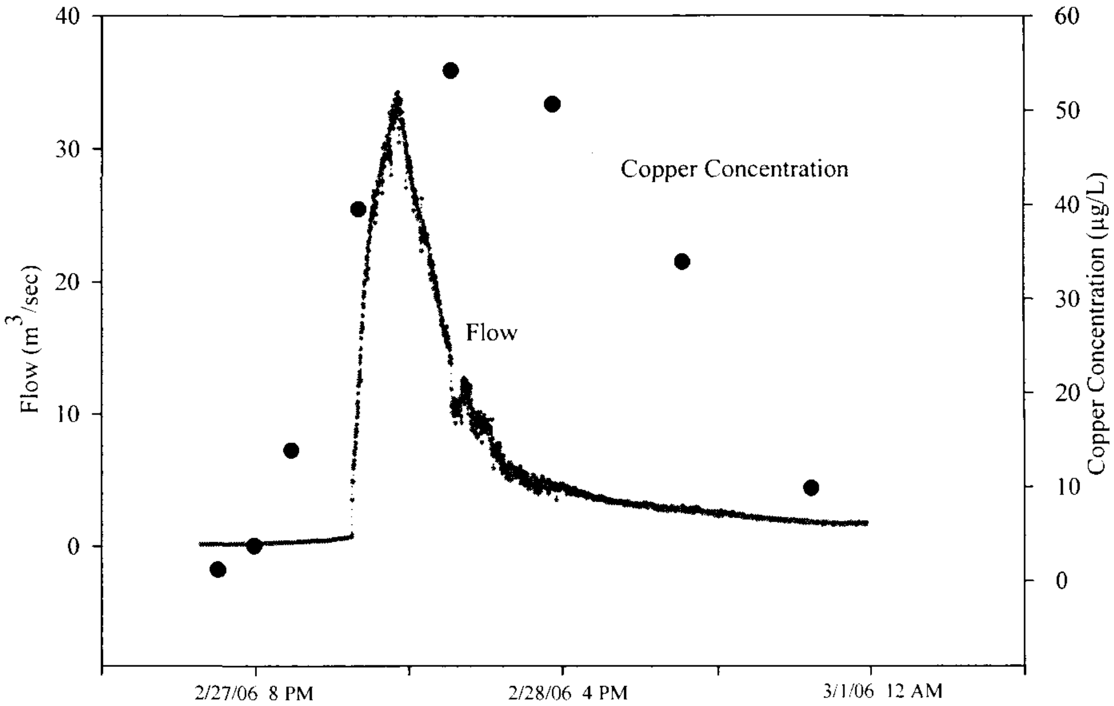



**Figure 10. Variation in total copper concentrations with time for storm event in Piru Creek from February 27 through March 1, 2006.**

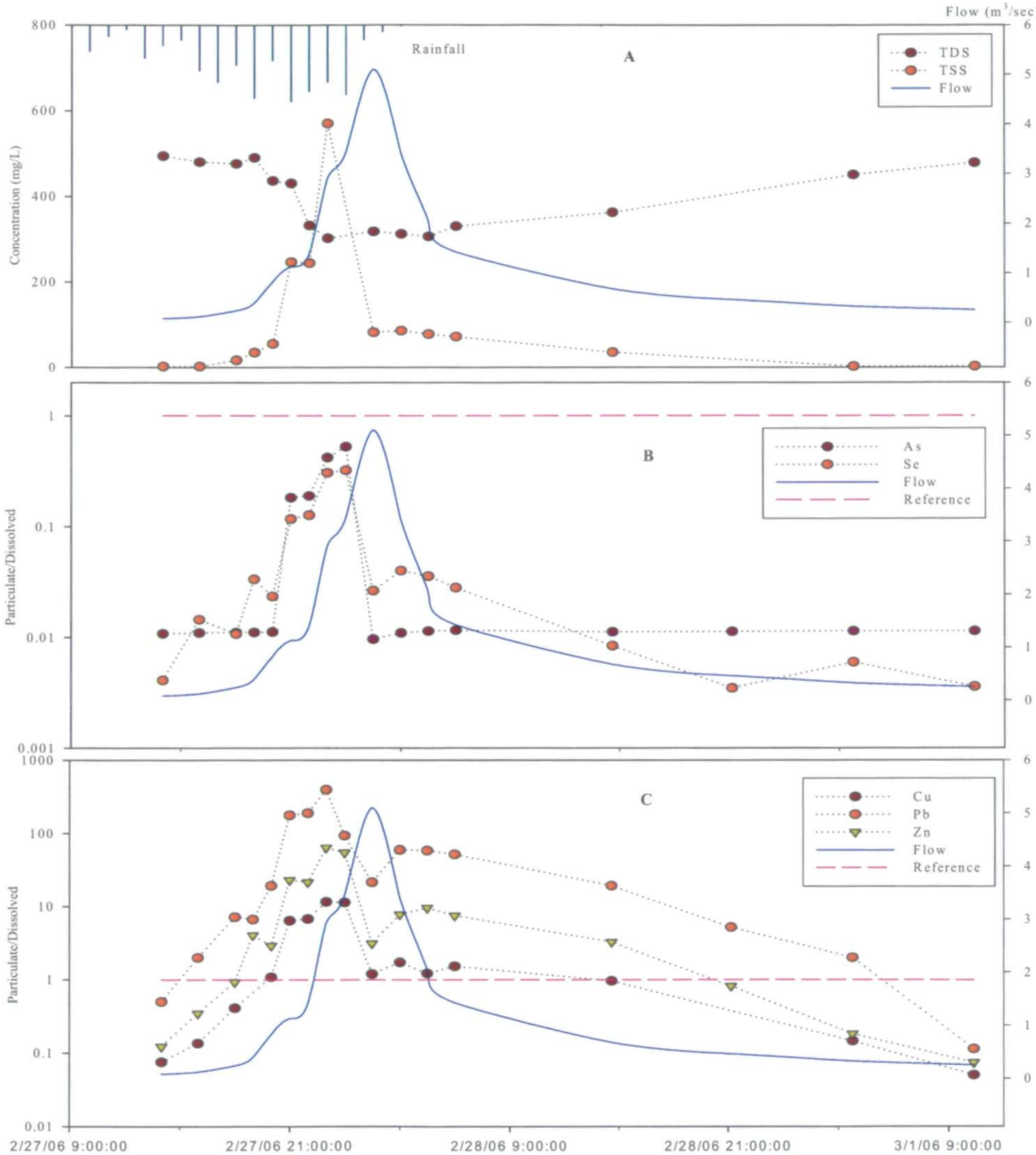



**Figure 11. Change in the ratio of particulate metals over dissolved metals over the course of a storm event at Bear Creek, a tributary to North Fork Matilija, CA.**

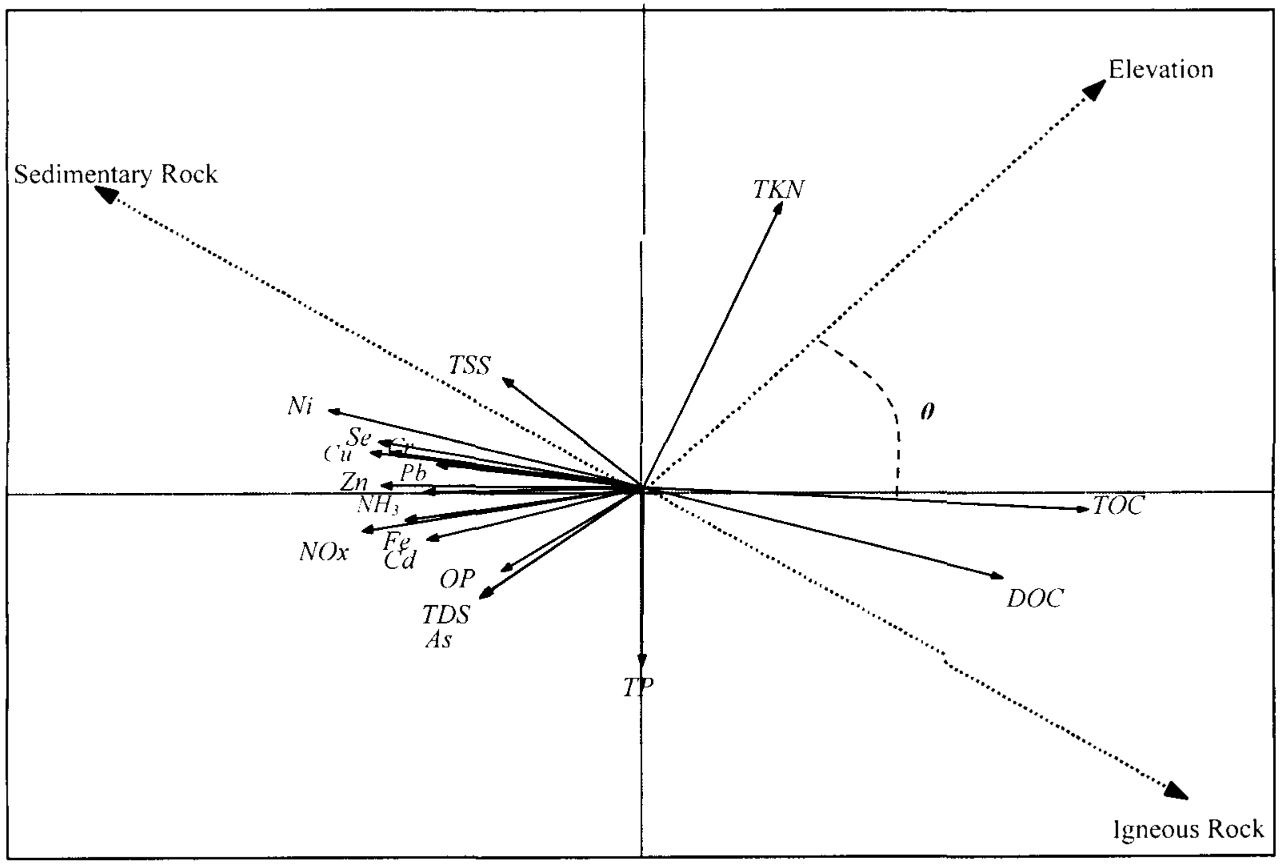



Figure 12. Correlation biplots showing the relations between wet weather concentrations of metals, nutrients, and solids (solid arrows) and environmental variables (dotted arrows). Eigenvalues: 0.151 and 0.0280 for the first (horizontal) and second (vertical) axes. *cos θ* ≈ correlation coefficient between two variables (arrows). Longer arrow indicates which factor is more important in generating variability. total dissolved solids (TDS); total suspended solids (TSS); total organic carbon (TOC); dissolved organic carbon (DOC; total Kjeldahl nitrogen (TKN); total phosphorus (TP); orthophosphate (OP); and Nitrate+Nitrite (NOx).

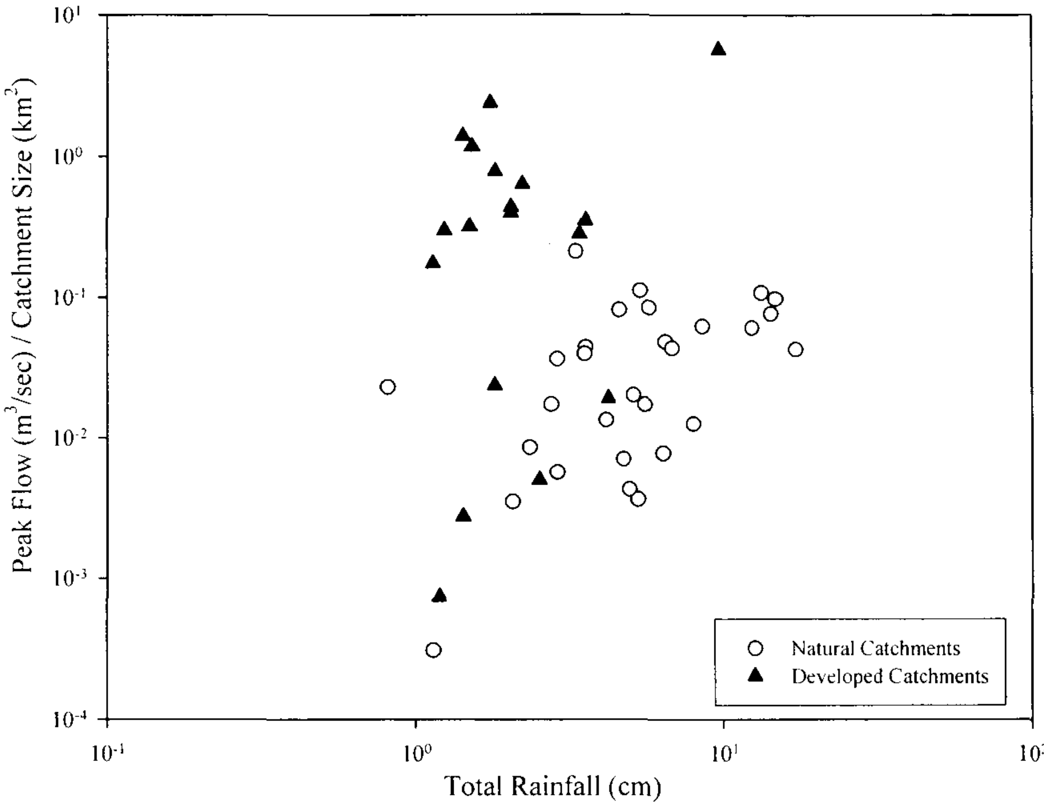



**Figure 13a. Comparison of peak flow over catchment size vs. rainfall between natural catchments and developed catchments; X and Y axes are in log scale.**

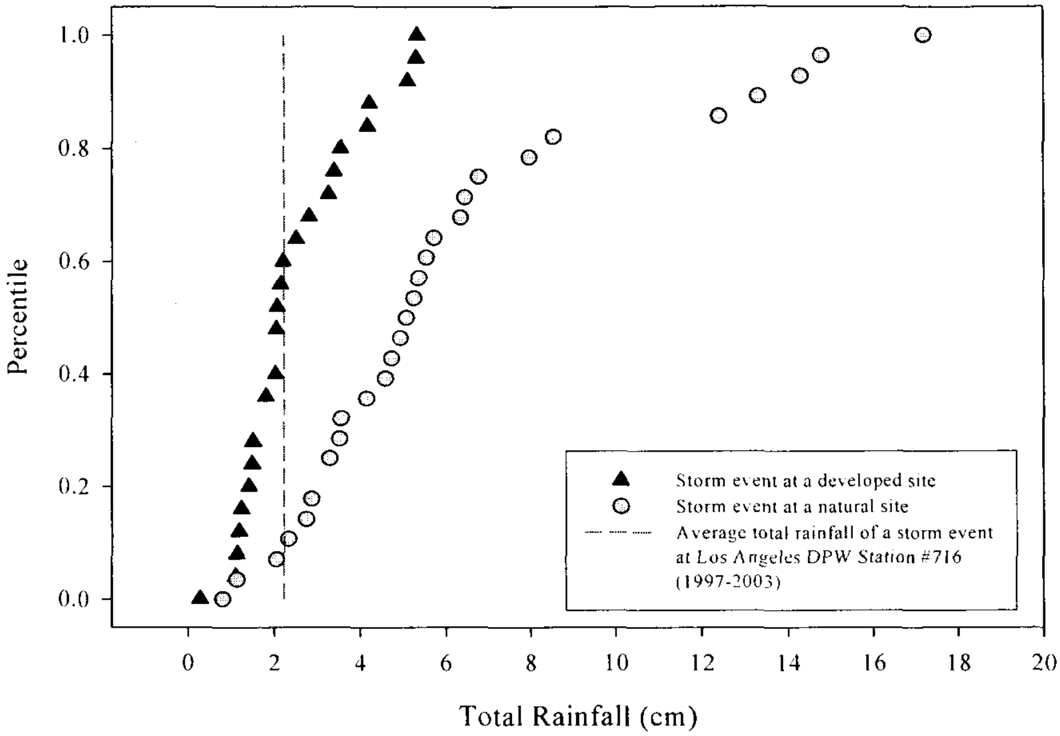



**Figure 13b. Distribution of storm events in terms of total rainfall per storm event.**

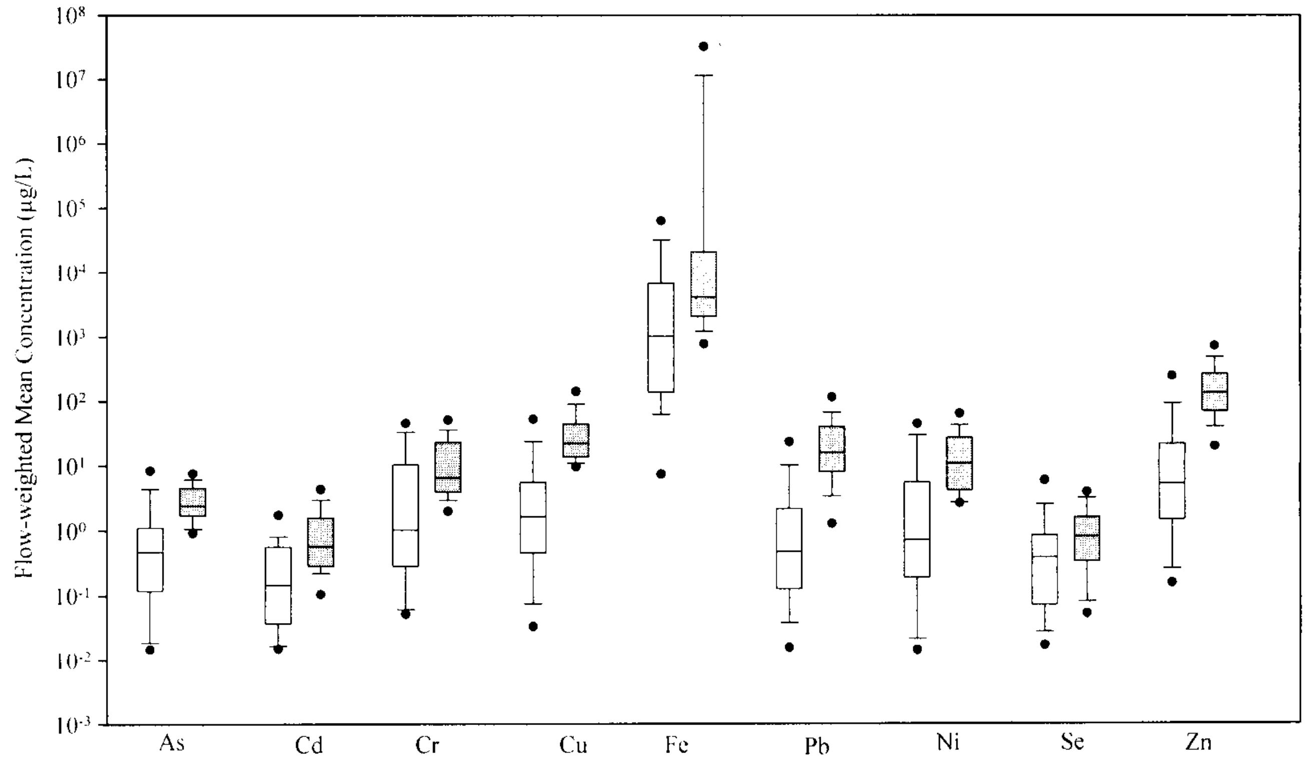



**Figure 14a.** Comparison of wet weather flow-weighted concentrations of metals between natural and developed catchments. White boxes represent natural catchments, and gray boxes represent developed catchments. Solid lines indicate the median of all values in the category. Boxes indicate 25th and 75th percentiles, and error bars indicate 10th and 90th percentiles. Solid dots represent 5th and 95th percentiles. The Y axis is in log scale.

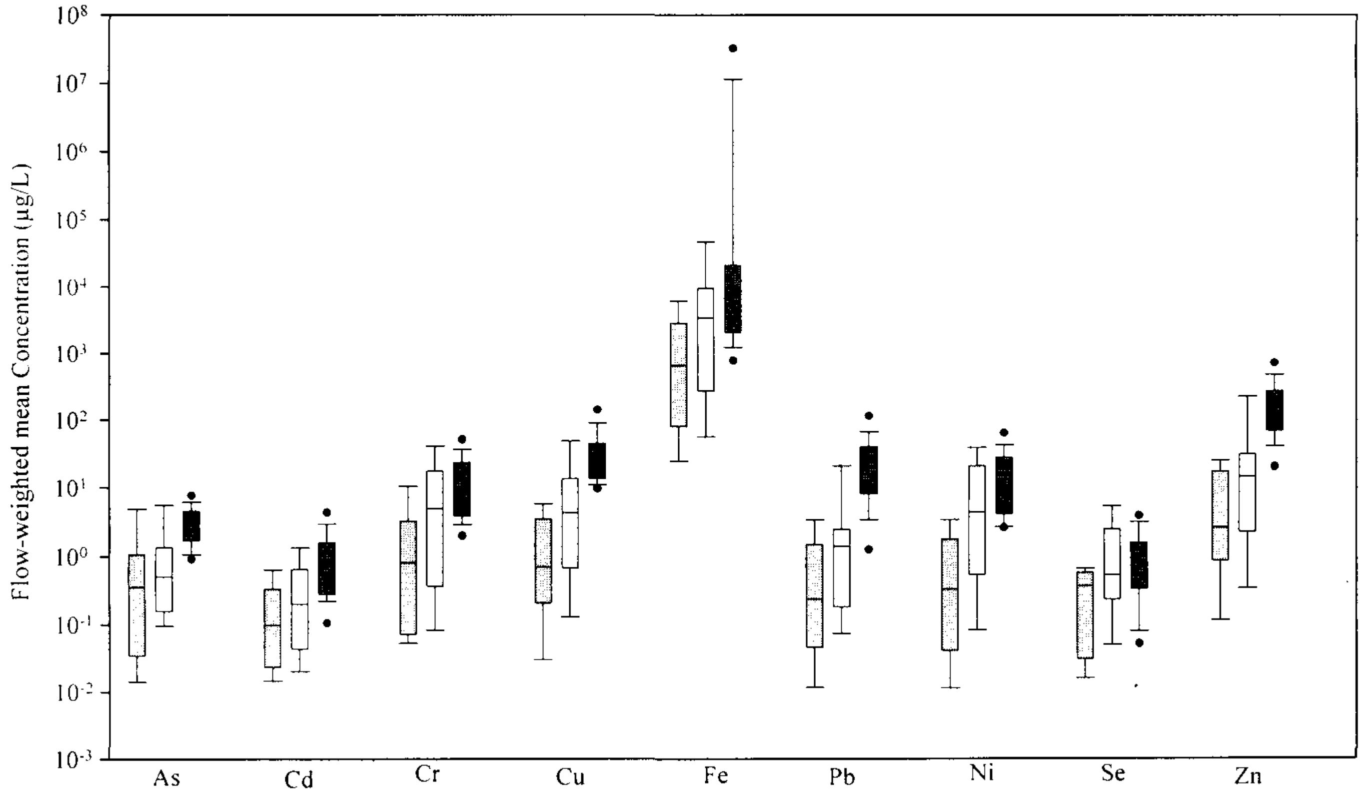



**Figure 14b.** Comparison of wet weather flow-weighted concentrations of metals between natural and developed catchments. Light gray boxes represent natural sites underlain by igneous rock, white boxes represent natural sites underlain by sedimentary rock, and dark gray boxes represent developed sites. Solid lines indicate the median of all values in the category. Boxes indicate 25th and 75th percentiles, and error bars indicate 10th and 90th percentiles. Solid dots represent 5th and 95th percentiles. The Y axis is in log scale.

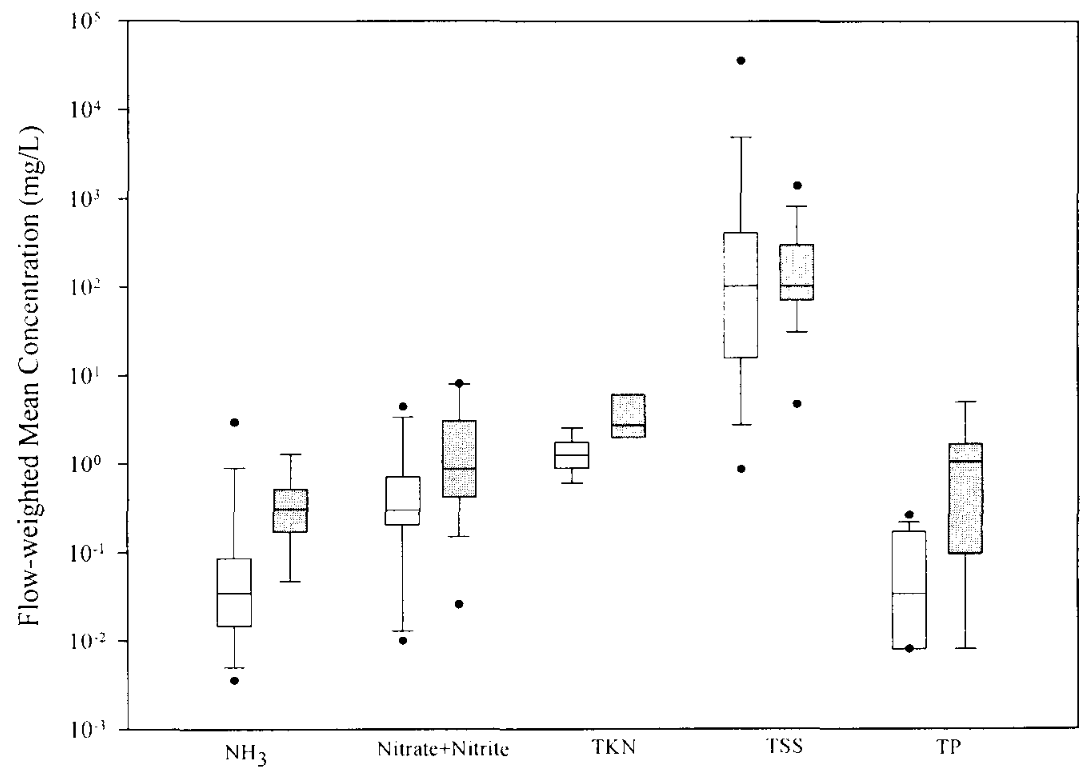



**Figure 15a.** ***Comparison of wet weather flow-weighted concentrations of ammonia ($NH_3$), nitrate+nitrite, total Kjeldahl nitrogen (TKN), total suspended solids (TSS), and total phosphorous (TP) between natural and developed catchments. White boxes represent natural catchments, and gray boxes represent developed catchments. The Y axis is in log scale.***

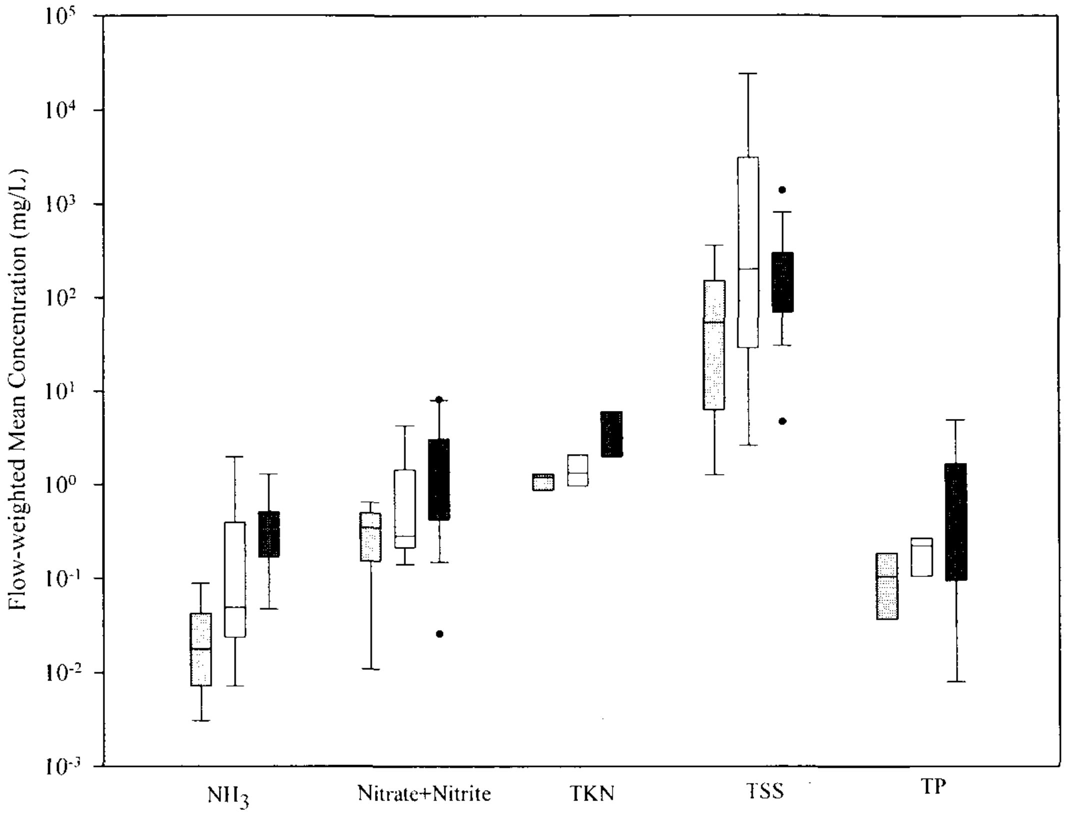



**Figure 15b.** Comparison of wet weather flow-weighted concentrations of ammonia ($NH_3$), nitrate+nitrite, total Kjeldahl nitrogen (TKN), total suspended solids (TSS), and total phosphorous (TP) between natural and developed catchments. Light gray boxes represent natural sites underlain by igneous rock, white boxes represent natural sites underlain by sedimentary rock, and dark gray boxes represent developed sites. Y axis is in log scale.

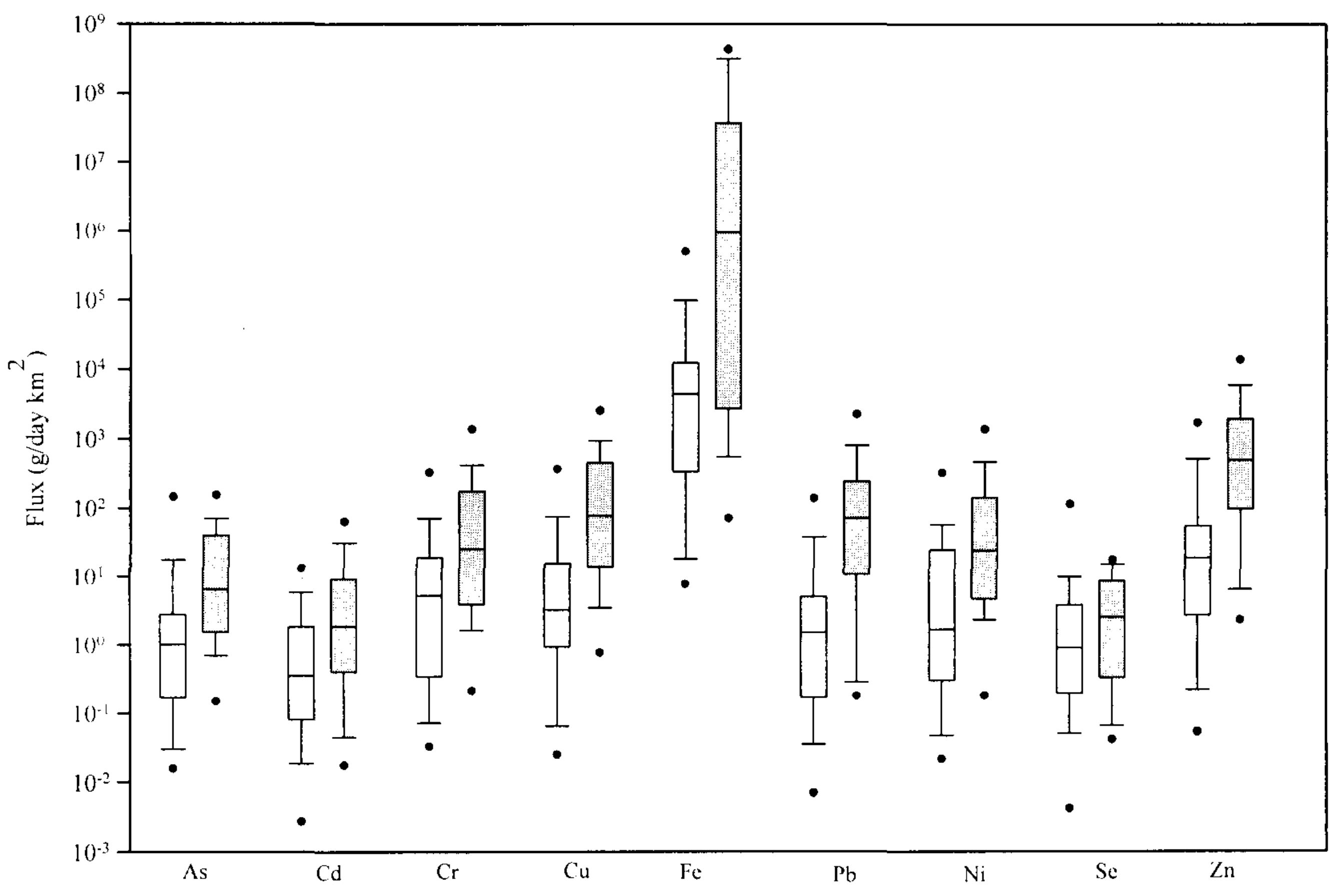



**Figure 16.** Comparison of wet weather fluxes of metals between natural and developed catchments. White boxes represent natural catchments, and gray boxes represent developed catchments. Y axis is in log scale

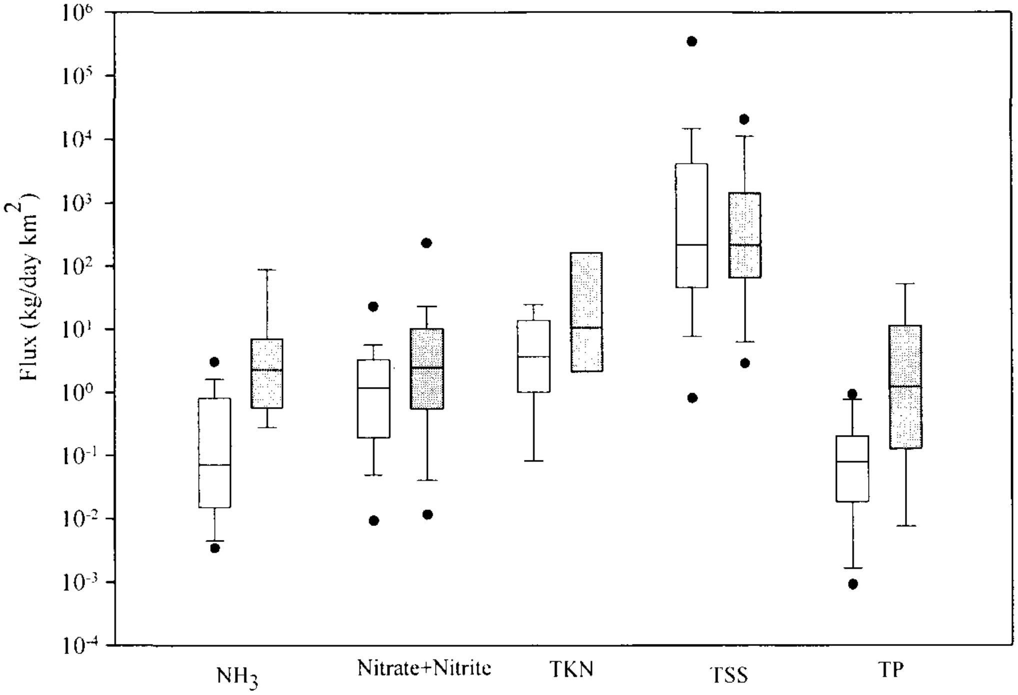



**Figure 17. Comparison of wetweather fluxes of ammonia ($NH_3$), nitrate+nitrite, total Kjeldahl nitrogen (TKN), total phosphorus (TP), and total suspended solids (TSS) between natural and developed catchments. White boxes represent natural catchments, while gray boxes represent developed catchments. All fluxes are expressed in kg/day $km^2$. Y axis is in log scale.**

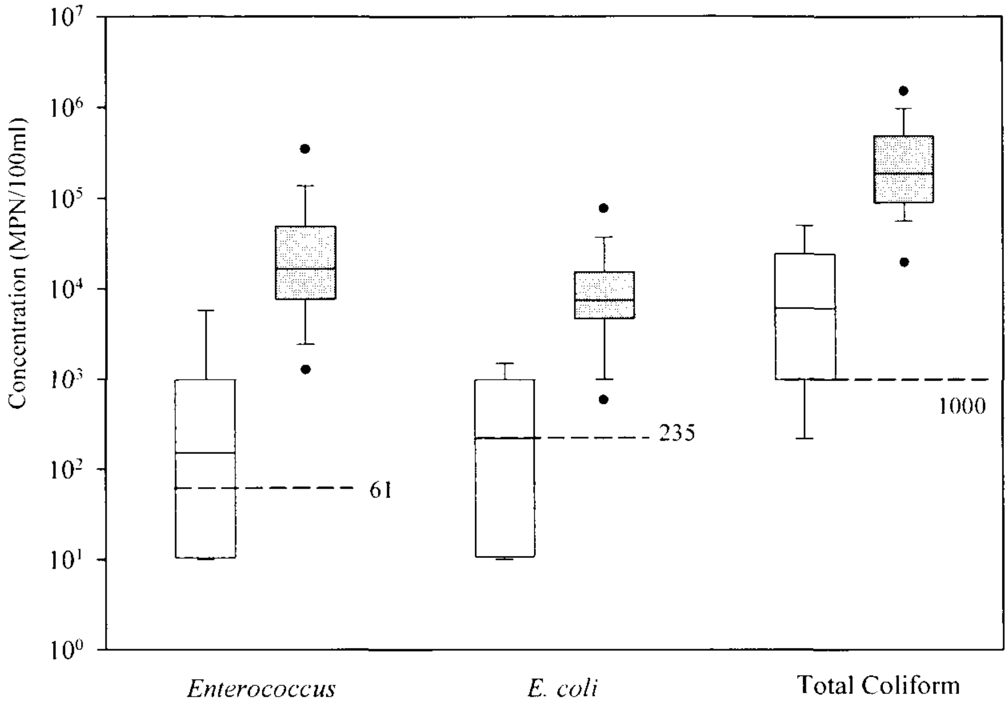



**Figure 18. Comparison of wet weather flow-weighted concentrations of bacteria between natural and developed catchments. White boxes represent natural catchments, and gray boxes represent developed catchments. .Y axis is in log scale. Dotted lines represent Department of Health and Safety draft guideline for freshwater recreation.**

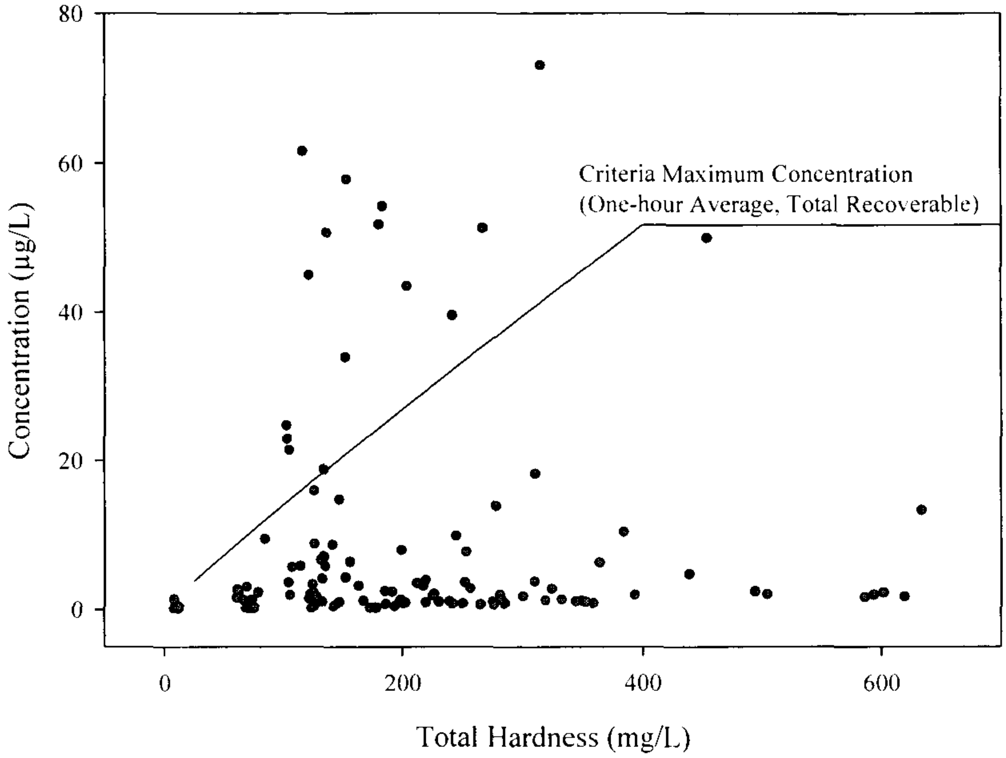



**Figure 19a. Copper concentrations at natural catchments compared with the hardness-adjusted standard under the California Toxics Rule (CTR). The stormwater concentrations are compared with the acute standard.**

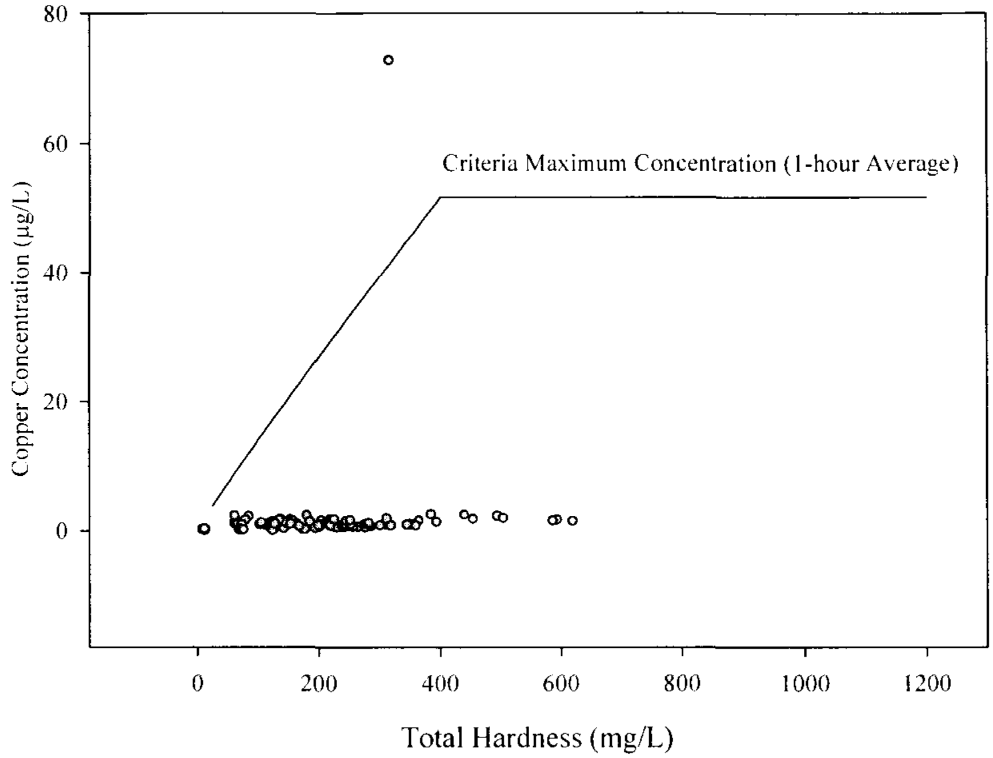



**Figure 19b. Wet weather dissolved copper concentrations at natural catchments compared with the hardness-adjusted standard under the California Toxics Rule (CTR). The stormwater concentrations are compared with the acute standard.**

# ESTIMATION OF ANNUAL LOADS

## Background

Constituent concentration ranges from natural areas that were documented in prior sections of this discussion provide valuable understanding of natural background water quality in southern California's costal watersheds (Figure 20). However, estimates of watershed loadings are required for many regulatory and management programs. For example, a number of water quality regulations (e.g., TMDLs) are based on daily or annual pollutant loads, rather than on concentration. Furthermore, evaluation of the overall contribution from natural areas to total watershed loading requires estimates of annual loadings based on measured concentrations from natural areas combined with long-term flow data.

Annual loading estimates should account for constituent contributions during both wet (storm) and dry (non-storm) periods. Unfortunately, existing ambient water quality monitoring studies often collect concentration data from natural areas only during dry weather. Seldom are there sufficient flow and water chemistry data available for both wet and dry seasons to fully estimate annual loading. Lack of distinct wet and dry weather data is particularly problematic in areas with semi-arid climates, such as southern California. Previous studies indicate that constituent concentrations from natural areas during wet and dry weather conditions might be within the same order of magnitude. However, non-storm flow can constitute a significant portion of the total annual flow, especially during years with low rainfall. Consequently, dry weather loading has the potential to be a substantial component of the total annual constituent load. In southern California's developed watersheds, dry weather metal load has been shown to constitute minor to appreciable portions of the total annual load (McPherson *et al.* 2002, Stein *et al.* 2003, Stein and Tiefenthaler 2005). For example, McPherson *et al.* (2002) reported that dry weather load contributed 8 to 42% of the total annual trace metal load in the Ballona Creek watershed near Los Angeles, CA. Past studies of the relative contributions of dry vs. wet weather load have focused solely on developed/urban watersheds (Duke *et al.* 1999, McPherson *et al.* 2002, McPherson *et al.* 2005). These prior studies lack information on wet and dry weather concentrations and sufficient flow data to fully estimate loading from natural areas. This section provides estimates of annual load from natural areas during both wet and dry weather conditions.

## Flow

Three of the six streams studied were perennial (flowed all year): Arroyo Seco, Sespe Creek, and Piru Creek. The remaining streams were intermittent (flowing until mid-July or mid-August 2006 before drying up). Rating curves used for the conversion of water level into flows at the water level logged sites are shown in Figures 21a and 21b. The average storm flow in the perennial streams was 10.27 $m^3$/sec, which was two orders of magnitude greater than the average non-storm flow at the perennial streams (Table 23).

The relative volume discharged during the storm vs. non-storm periods varied based perennial or intermittent stream type. The annual discharge volume of non-storm flow was larger than the annual discharge volume of storm flow over the ten-year period at the perennially flowing Arroyo Seco and Piru Creek. The storm and non-storm volumes were similar at Sespe Creek except for the 1995 water year (Figure 22). The annual storm discharge at the intermittent streams (Santiago Creek and Tenaja Creek) was more than double the annual non-storm discharge due to the discontinuity of flow from late summer through fall. For example, the annual storm discharge volume at Santiago Creek was $6.5 \times 10^6$ $m^3$ and the annual non-storm discharge volume was $2.5 \times 10^6$ $m^3$.

Percent differences between storm and non-storm discharge volumes at perennial streams were greater in years with less overall discharge, which were dry years (1999 to2004; Figure 22). This implies that the contribution of the non-storm flow to annual discharge volume becomes more important in dry years.

## Ranges of annual fluxes and the contribution of non-storm flow to the fluxes

Annual fluxes for metals (except Fe) ranged from tens to hundreds of grams per year $km^2$. Nutrient fluxes varied largely among constituents and streams. Ammonia ranged from one to eight kilograms per year·$km^2$, OP and TP ranged from kilograms to tens of kilograms per year $km^2$, and other nutrients ranged from ten to thousands of kilograms per year·$km^2$. For example ammonia was found to be 3 kilograms per year $km^2$ at Arroyo Seco, and total organic carbon was found to be 1,320 kilograms per year $km^2$. Total suspended solids ranged from 4.2 to 4,059 metric ton per year $km^2$. The median, minimum, and maximum values for each constituent are summarized in Table 24.

Storm flow contributed the majority of annual fluxes for constituents except As, nutrients, TOC, and TDS (Figure 23). Total suspended solids were almost entirely derived from storm runoff. However, between 40 and 60% of As, Cd, and Se were derived from non-storm flow.

## Loading in perennial vs. intermittent streams

In the intermittent streams, storm flow was a major source of most metals, all nutrients, and solids (Tables 25 and 26). More than 97% of the TSS load was contributed by storm flow. In perennial streams, even though the annual non-storm discharge accounted for more than one-half of the total annual discharge, a greater portion of the annual load was contributed by high constituent concentrations in the storm flow (Table 25s and 26). Non-storm flow contributed more to annual metal loads at perennial streams than at the intermittent streams. For example, the non-storm flow contributed 51 to 78% for Cd at the perennial streams, while the non-storm flow contributed 10 to 21% for Cd at the intermittent streams.

Annual flux was generally lower at the intermittent streams than at the perennial streams (Table 27). This mainly resulted from differences in the total annual discharge volume. In addition, the annual fluxes at Santiago Creek and Tenaja Creek were derived from the annual loads of only eight months, December 2005 through July 2006, because the streams dried up in July 2006. Yet, the annual fluxes at the perennial streams -- Arroyo Seco, Piru Creek, and Sespe Creek -- were derived from the annual loads of the entire 12 months, December 2005 through December 2006.

## Discussion

Annual flux rates were significantly lower in natural catchments than in developed catchments in southern California (Table 27). This difference can be illustrated by comparing this study's results to data from Ballona Creek, which is located in southern California and includes a significant portion of the City of Los Angeles, California. Approximately 85% of the 330 $km^2$ catchment is charactarized by urban land uses (Wong *et al.* 1997). Annual fluxes of Cr, Cu, Pb, Ni, Zn, and TSS for Ballona Creek were based on the load values presented in studies by McPherson *et al.* (2005) and Tiefenthaler *et al.* (in review). Annual fluxes of Cr, Cu, Pb, Ni, and Zn were one to two orders of magnitude higher at Ballona Creek than at natural streams. In contrast, fluxes of TSS was two to three orders of magnitude higher at Piru Creek and Sespe Creek than that at Ballona Creek. This is expected due to storm-induced erosion of soil from open areas in the natural catchments. Unlike urban catchments with larger impervious area and concrete-bottom channels, the five natural catchments are mainly open lands that can contribute large volumes of sediment (and hence TSS). In addition, in-channel erosion of natural streams, which can be a substantial source of TSS (Trimble 1997, Pons 2003) does not occur in concrete lined channels, such as Ballona Creek.

In the overall context, natural catchments contribute proportionately less of the total annual load to the receiving waters than would be expected based solely on catchment area. For example, approximately 2,300 kg of Cu, 1,150 kg of Pb, 11,550 kg of Zn are discharged from the Los Angeles River watershed annually (Tiefenthaler *et al.* in review). Arroyo Seco, a natural subwatershed of the Los Angeles River, occupies approximately 2% of the Los Angeles River catchment area, but contributes less than 1% of the total annual load of Cu, Pb, and Zn. This contribution drops to less than 0.6% for the dry weather load.

Watershed geology has been shown to be a major factor that influences constituent concentrations (and hence loads) from natural catchments. This difference is illustrated by patterns of TSS flux. Flux of TSS from Sespe and Piru Creeks were two to three orders of magnitude larger than those at other streams. The dominant geologic type of both Piru Creek and Sespe Creek is a sedimentary rock, which can be more easily eroded and can discharge more suspended solids into the water than igneous rock. The flux of TSS at Arroyo Seco, which is underlain by igneous rock, was only 8 mt/year $km^2$, less than 0.2% of the flux at Sespe Creek. In addition to the effect of geologic type, the magnitude of storm flow at Sespe and Piru Creeks were five times larger than that at Arroyo Seco.

The combined effect of geology and hydrology may also explain the higher nutrient fluxes observed in the natural streams in this study compared to nation-wide averages reported from a study by Clark *et al.* (2000). Clark reported total annual loading of nutrients from 85 natural stream basins across the United States, with a median annual basin flux of ammonia, total nitrogen, orthophosphate, and total phosphorus of 8.1, 86, 2.8, and 8.5kg/$km^2$, respectively (Table 27). At four of the five sites from this study, nutrient flux was three to four time greater than the basin median value reported by Clark *et al.* The higher phosphorus loadings at the natural streams may have resulted from mineral weathering of phosphorus-enriched sediments. For example, the TP loadings at Santiago Creek, where the dominant geologic type is a marine sedimentary rock, were three times higher than the values recorded in the Clark *et al.* (2000) stream basin study.

The contribution of dry weather load was proportionately smaller in natural areas than in developed watersheds. According to McPherson *et al.*, dry season loads in the urbanized Ballona Creek watershed accounted for 54, 19, 33, and 44% of Cr, Cu, Pb, and Ni loadings, respectively (McPherson *et al.* 2002). In contrast, dry season loads in the natural streams accounted for 8, 16, 4, and 21% of total annual Cr, Cu, Pb, and Ni loadings, respectively. Considering the relatively smaller contribution of the dry weather flow to the total annual discharge volume in Ballona Creek, which ranged from 9 to 25%, the proportional contribution of dry weather loadings in Ballona Creek was considerably higher than that in the natural streams, where more than half of the total volume discharged was derived from the non-storm flow. This difference likely results from the fact that dry weather flow (and loading) in Ballona Creek in comprised almost entirely of urban runoff that continually washes pollutants off of developed surfaces. In contrast, dry weather flow in natural streams is a combination of ground water discharge, and residual interflow, neither one of which typically has high constituent concentrations.

Estimated differences between storm and non-storm flux at natural areas could be influenced by two factors. First, the estimation of storm loading is directly dependent on the method used to separate storm flow from non-storm flow. The storm flow separation is in turn directly dependent on how to treat the prolonged tail part of storm hydrographs in the natural streams, which may persist for days or weeks after the cessation of rain. For this study, the end of a storm was defined as the point in time where flow was 50% that of the peak flow. The degree to which the choice of the 50% criterion influences general conclusions about the annual loadings was examined by estimating storm loadings using a cutoff of 25% of the peak flow. Using this cutoff, the mean total annual days with storm flow increased from 12, 19, and 20 days to 16, 37, and 43 days at Sespe Creek, Piru Creek, and Arroyo Seco, respectively. The change in the number of storm-days is more dramatic in wet years such as 1994 and 1998 due to their prolonged high flow during the spring and the summer. For instance, the application of the 25% criterion increased the storm flow days for the water year of 1998 at Arroyo Seco more than 100% from 46 to 104 days. This increase of the storm flow days translated to an increase of the total annual discharge volume of storm flow by 46, 25, and 9% at Arroyo Seco, Piru Creek, and Sespe Creek, respectively. In terms of changes in loading, storm flow loads of TN increased from 43 to 54 mt/year and TSS from 100,453 to 124,948 mt/year in Piru Creek. Constituents that were mainly contributed by the non-storm flow decreased due to the decrease of the total discharge volume of the non-storm flow. The non-storm load of TP at Arroyo Seco decreased from 40 kg/year to 27 kg/year with the 25% criterion.

Second, distribution of constituents between the dissolved and particulate phase may also influence differences in loadings between storm flow and non-storm flow. More than 60% of the annual load for cadmium and selenium were derived from the non-storm flow at the perennial streams. The higher occurrence of these metals in the non-storm flow may be correlated with the distribution of the metals between a dissolved phase and a particulate phase. Arsenic, cadmium, and selenium exist mainly in the dissolved phase in storm flow (Figure 24). A considerable number of samples show more than 100 times higher dissolved concentrations than particulate concentrations for these metals. This indicates that loading of arsenic, cadmium, and selenium depends less on levels of total suspended solids, and can occur at relatively high levels in non-storm flow. Other metals exist either mainly in particulate phase or in both phases in storm flows. Thus, the level of total suspended solids directly affects the levels of these particle-bound metals and partially determines the contribution of the non-storm flow to the total annual loadings. For example, lead and zinc were found mostly in particulate phase in the storm flow, which contributed 85 to 98% of the annual load. The contribution of storm flow to zinc load mirrors the high level of total suspended solids. In addition, higher particle-bound constituents are more easily mobilized during storms; therefore, a high proportion of particulate-bound metals occur during storms.

In this study, the distribution of metals between dissolved and particulate phases in non-storm flow was not measured. However, metals in urban non-storm flow occur predominantly in the dissolved phase, partially due to low total suspended solids concentrations (McPherson *et al.* 2002, Stein and Ackerman 2007). Preliminary data collected in the San Gabriel Watershed (Bernstein *et al.* in prep) suggests that this pattern is also true in natural streams. Therefore, it is reasonable to assume that the distribution of metals loading between storm and non-storm conditions in natural systems is largely a function of the particle dynamics of each particular metal. The particle dynamics and associated constituent loading should be a focus of future investigation.

**Table 23. Means of storm and non-storm flows ( $m^3$/sec) in intermittent and perennial streams.**

| | | | |
|---|---|---|---|
| Intermittent | Santiago Creek | 0.19 | 0.92 |
| | Tenaja Creek | 0.03 | 1.81 |
| | Mean | 0.11 | 1.37 |
| Perennial | Arroyo Seco | 0.16 | 2.04 |
| | Piru Creek | 1.00 | 10.73 |
| | Sespe Creek | 0.26 | 9.81 |
| | Mean | 0.63 | 10.27 |

**Table 24. Ranges of annual fluxes for metals, nutrients, and solids in natural streams.**

| | Unit | | | |
|---|---|---|---|---|
| Arsenic | g/year $km^2$ | 160 | 30 | 310 |
| Cadmium | | 30 | 10 | 60 |
| Chromium | | 430 | 70 | 580 |
| Copper | | 360 | 50 | 440 |
| Iron | | 190000 | 65000 | 570000 |
| Lead | | 110 | 30 | 190 |
| Nickel | | 220 | 30 | 460 |
| Selenium | | 130 | 20 | 540 |
| Zinc | | 160 | 30 | 310 |
| Ammonia | kg/year $km^2$ | 3.0 | 1.0 | 8.0 |
| Total Nitrogen | | 230 | 40 | 450 |
| Dissolved Organic Carbon | | 650 | 200 | 1700 |
| Total Organic Carbon | | 950 | 180 | 1800 |
| Orthophosphate | | 7.0 | 2.0 | 11 |
| Total Phosphorus | | 6.0 | 5.0 | 28 |
| Total Dissolved Solids | mt/year $km^2$ | 74.7 | 12 | 190 |
| Total Suspended Solids | | 8.7 | 4.2 | 4100 |

Table 25. Annual load estimation of metals and the contribution of the dry weather loads in the annual loads.

| Stream Type | Site Name | Contribution Type | Arsenic | Cadmium | Chromium | Copper | Iron | Lead | Nickel | Selenium | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Perennial | Arroyo Seco | Annual Storm Load (kg) | 3.05 | 1.28 | 23.90 | 12.40 | 7780.00 | 7.75 | 7.56 | 1.78 | 43.40 |
| | | Annual Non-storm Load (kg) | 10.10 | 1.33 | 0.54 | 2.71 | 176.00 | 0.12 | 0.72 | 3.61 | 3.27 |
| | | Total Annual Load (kg) | 13.10 | 2.60 | 24.40 | 15.10 | 7950.00 | 7.87 | 8.28 | 5.38 | 46.60 |
| | | % Non-storm Load | 76.80 | 50.90 | 2.20 | 17.80 | 2.20 | 1.50 | 8.70 | 67.00 | 7.00 |
| | Piru Creek | Annual Storm Load (kg) | 8.72 | 0.65 | 164.00 | 101.00 | 146000.00 | 34.10 | 106.00 | 9.72 | 296.00 |
| | | Annual Non-storm Load (kg) | 60.10 | 2.24 | 6.91 | 21.90 | 4610.00 | 2.18 | 15.90 | 19.70 | 9.67 |
| | | Total Annual Load (kg) | 68.80 | 2.89 | 171.00 | 123.00 | 151000.00 | 36.30 | 121.00 | 29.40 | 306.00 |
| | | % Non-storm Load | 87.30 | 77.50 | 4.00 | 17.80 | 3.10 | 6.00 | 13.10 | 67.00 | 3.20 |
| | Sespe Creek | Annual Storm Load (kg) | 3.58 | 2.01 | 54.00 | 48.20 | 72500.00 | 15.30 | 53.50 | 6.91 | 143.00 |
| | | Annual Non-storm Load (kg) | 3.68 | 2.08 | 0.60 | 7.54 | 865.00 | 0.20 | 5.78 | 11.50 | 2.91 |
| | | Total Annual Load (kg) | 7.26 | 4.09 | 54.50 | 55.80 | 73300.00 | 15.50 | 59.30 | 18.40 | 146.00 |
| | | % Non-storm Load | 50.70 | 50.90 | 1.10 | 13.50 | 1.20 | 1.30 | 9.70 | 62.50 | 2.00 |
| Intermittent | Tenaja Creek | Annual Storm Load (kg) | 0.87 | 0.40 | 3.35 | 2.77 | 3950.00 | 1.71 | 1.44 | 0.60 | 14.80 |
| | | Annual Non-storm Load (kg) | 0.80 | 0.04 | 0.18 | 0.07 | 116.00 | 0.07 | 0.36 | 0.41 | 0.54 |
| | | Total Annual Load (kg) | 1.66 | 0.44 | 3.53 | 2.84 | 4070.00 | 1.78 | 1.80 | 1.01 | 15.40 |
| | | % Non-storm Load | 47.90 | 9.80 | 5.00 | 2.50 | 2.80 | 3.90 | 19.80 | 40.90 | 3.50 |
| | Santiago Creek | Annual Storm Load (kg) | 1.44 | 0.71 | 1.62 | 2.50 | 792.00 | 0.73 | 1.74 | 6.77 | 9.53 |
| | | Annual Non-storm Load (kg) | 1.24 | 0.19 | 0.56 | 1.06 | 334.00 | 0.06 | 2.03 | 2.47 | 1.89 |
| | | Total Annual Load (kg) | 2.68 | 0.90 | 2.18 | 3.56 | 1120.00 | 0.79 | 3.77 | 9.23 | 11.40 |
| | | % Non-storm Load | 46.40 | 21.00 | 25.80 | 29.80 | 29.70 | 8.00 | 53.90 | 26.70 | 16.60 |

Table 26. Annual load estimation of nutrients and solids and the contribution of the non-storm flow loads in the annual loads.

| Stream Type | Site Name | Contribution Type | Ammonia | Total Nitrogen | Dissolved Organic Carbon | Total Organic Carbon | Orthophosphate | Total Phosphorus | Total Dissolved Solids | Total Suspended Solids |
|---|---|---|---|---|---|---|---|---|---|---|
| Perennial | Arroyo Seco | Annual Storm Load (mt) | 0.09 | 7.66 | 23.18 | 22.45 | 0.27 | 0.03 | 1379.00 | 368.00 |
| | | Annual Non-storm Load (mt) | 0.03 | 2.03 | 13.14 | 14.83 | 0.08 | 0.20 | 1257.00 | 1.00 |
| | | Total Annual Load (mt) | 0.12 | 9.69 | 36.32 | 37.28 | 0.35 | 0.22 | 2636.91 | 369.00 |
| | | % Non-storm Load | 22.90 | 20.90 | 36.20 | 39.80 | 22.30 | 87.70 | 47.70 | 0.40 |
| | Piru Creek | Annual Storm Load (mt) | 0.48 | 43.25 | 106.86 | 124.00 | 1.03 | - | - | 100452 |
| | | Annual Non-storm Load (mt) | 0.32 | 16.12 | 91.57 | 298.00 | 0.96 | - | - | 76.00 |
| | | Total Annual Load (mt) | 0.80 | 59.37 | 198.43 | 421.19 | 1.99 | - | - | 100529 |
| | | % Non-storm Load | 40.40 | 27.20 | 46.10 | 70.70 | 48.40 | - | - | 0.10 |
| | Sespe Creek | Annual Storm Load (mt) | 0.95 | 33.21 | 55.24 | 66.61 | 0.55 | - | 4174.00 | 519565 |
| | | Annual Non-storm Load (mt) | 0.07 | 4.34 | 27.80 | 54.94 | 0.38 | - | 6907.00 | 3.00 |
| | | Total Annual lLoad (mt) | 1.01 | 37.55 | 83.04 | 121.54 | 0.93 | - | 11081.69 | 519568 |
| | | % Non-storm Load | 6.50 | 11.60 | 33.50 | 45.20 | 41.00 | - | 62.30 | 0.00 |
| Intermittent | Tenaja Creek | Annual Storm Load (mt) | 0.07 | 1.86 | 7.43 | 7.16 | 0.13 | 0.22 | 416.00 | 219.00 |
| | | Annual Non-storm Load (mt) | 0.00 | 0.14 | 3.01 | 2.55 | 0.00 | 0.10 | 230.00 | 1.00 |
| | | Total Annual Load (mt) | 0.07 | 1.99 | 10.44 | 9.71 | 0.13 | 0.32 | 646.00 | 221.00 |
| | | % Non-storm Load | 4.20 | 6.90 | 28.90 | 26.30 | 1.70 | 31.70 | 35.70 | 0.60 |
| | Santiago Creek | Annual Storm Load (mt) | 0.11 | 6.60 | 21.41 | 21.02 | 0.09 | 0.37 | 2189.00 | 91.00 |
| | | Annual Non-storm Load (mt) | 0.01 | 1.03 | 7.94 | 9.24 | 0.09 | 0.11 | 1114.00 | 2.00 |
| | | Total Annual Load (mt) | 0.12 | 7.63 | 29.34 | 30.26 | 0.18 | 0.49 | 3302.00 | 94.00 |
| | | % Non-storm Load | 10.20 | 13.50 | 27.00 | 30.50 | 51.80 | 23.60 | 33.70 | 2.60 |

Table 27. Total annual fluxes of metals (kg/year km$^2$), nutrients (kg/year km$^2$), and solids (mt/year km$^2$) in natural streams in natural areas in comparison with fluxes of another urban stream (Ballona Creek) and other natural streams (numerous perennial streams across the nation). No data available ('-'). Stream type: intermittent (I) and perennial (P).

| Stream Type | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| P | Arroyo Seco | 0.31 | 0.06 | 0.58 | 0.36 | 189.50 | 0.19 | 0.20 | 0.13 | 1.11 |
| P | Piru Creek | 0.22 | 0.01 | 0.54 | 0.39 | 474.10 | 0.11 | 0.38 | 0.09 | 0.96 |
| P | Sespe Creek | 0.06 | 0.03 | 0.43 | 0.44 | 573.30 | 0.12 | 0.46 | 0.14 | 1.14 |
| I | Santiago Creek [a] | 0.16 | 0.05 | 0.13 | 0.21 | 65.70 | 0.05 | 0.22 | 0.54 | 0.67 |
| I | Tenaja Creek [a] | 0.03 | 0.01 | 0.07 | 0.05 | 77.10 | 0.03 | 0.03 | 0.02 | 0.29 |
| | Developed Stream | - | - | 1.20[b] | 4.00[b] | - | 1.40[b] | 1.10[b] | - | 16.70 [c] |

| Stream Type | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| P | Arroyo Seco | 3 | 230 | 860 | 890 | 8 | 5 | 62.78 | 8.79 |
| P | Piru Creek | 3 | 190 | 620 | 1320 | 6 | - | - | 315.14 |
| P | Sespe Creek | 8 | 290 | 650 | 950 | 7 | - | 86.58 | 4059.12 |
| I | Santiago Creek [a] | 7 | 450 | 1710 | 1770 | 11 | 28 | 192.67 | 5.47 |
| I | Tenaja Creek [a] | 1 | 40 | 200 | 180 | 2 | 6 | 12.24 | 4.18 |
| | Developed Stream | - | - | - | - | - | - | - | 15.30[b] |
| | Natural Streams [d] | 8.10 | 86 | - | - | 2.80 | 8.50 | - | - |

[a] Total fluxes are only for the eight months of the study from December 2005 through August 2006.
[b] McPherson *et al.* 2005
[c] Tiefenthaler *et al.* in review
[d] Clark *et al* 2000

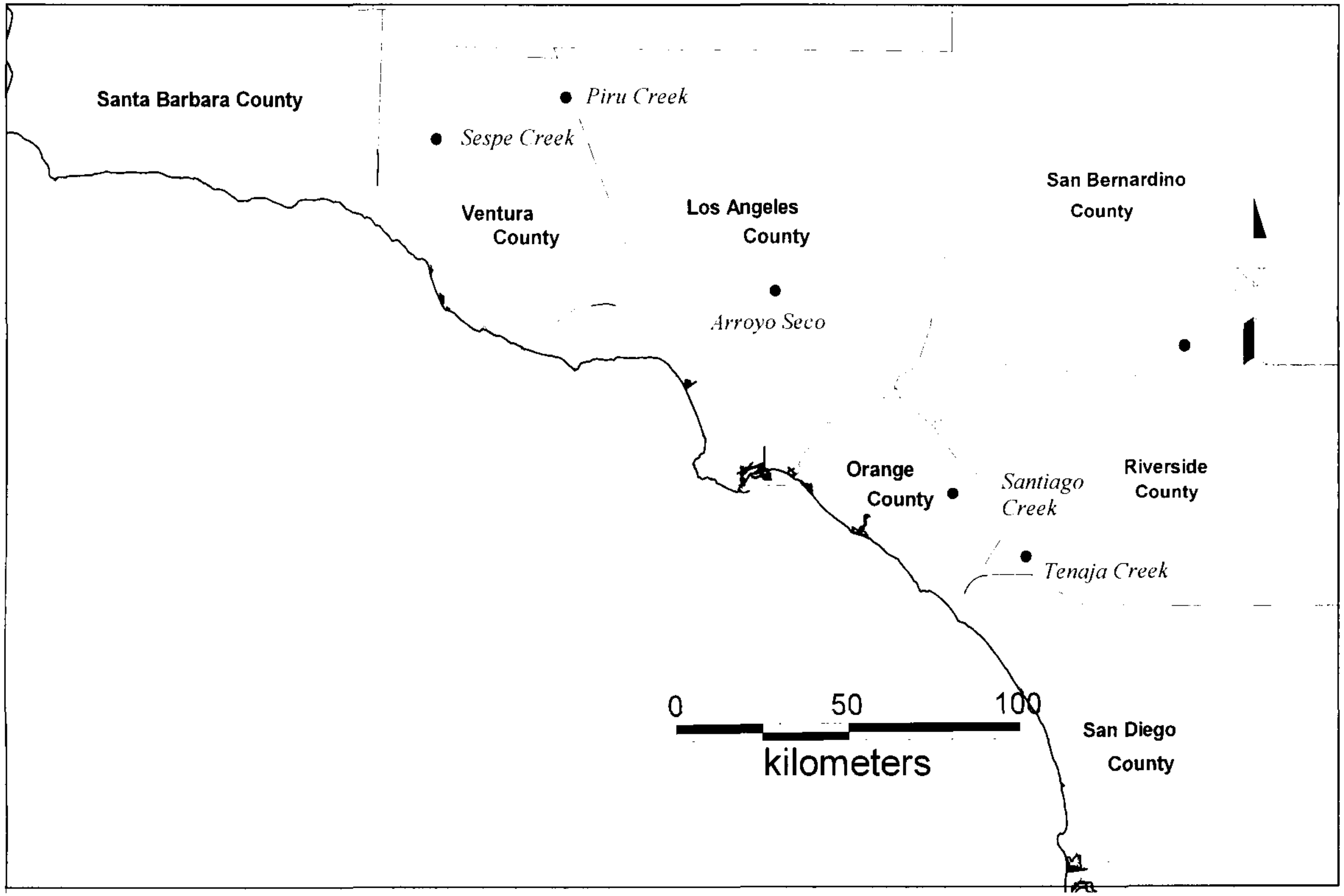
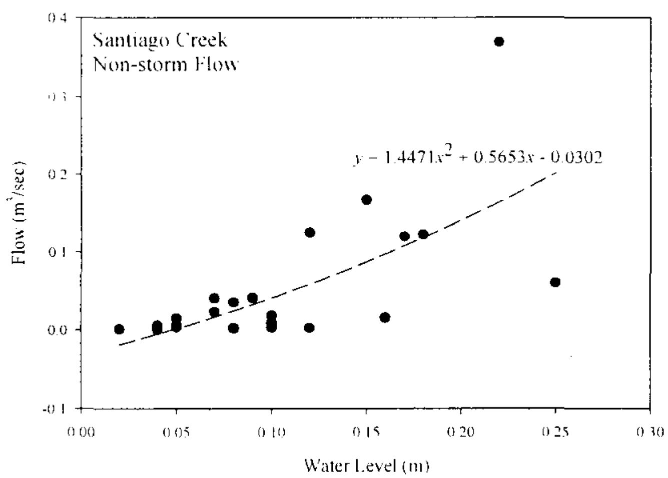



Figure 20. Map of study sites for the estimation of annual loads.



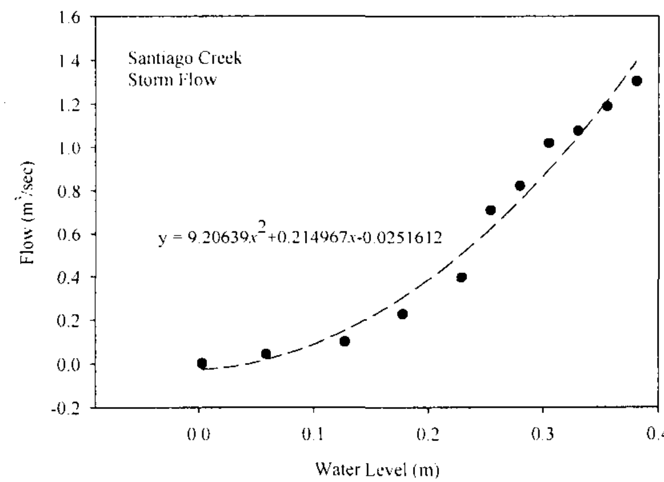




**Figure 21a. Rating curves at Santiago Creek for non-storm and storm flows. $r^2$ Values are 0.43 and 0.97 for non-storm and storm flows, respectively.**

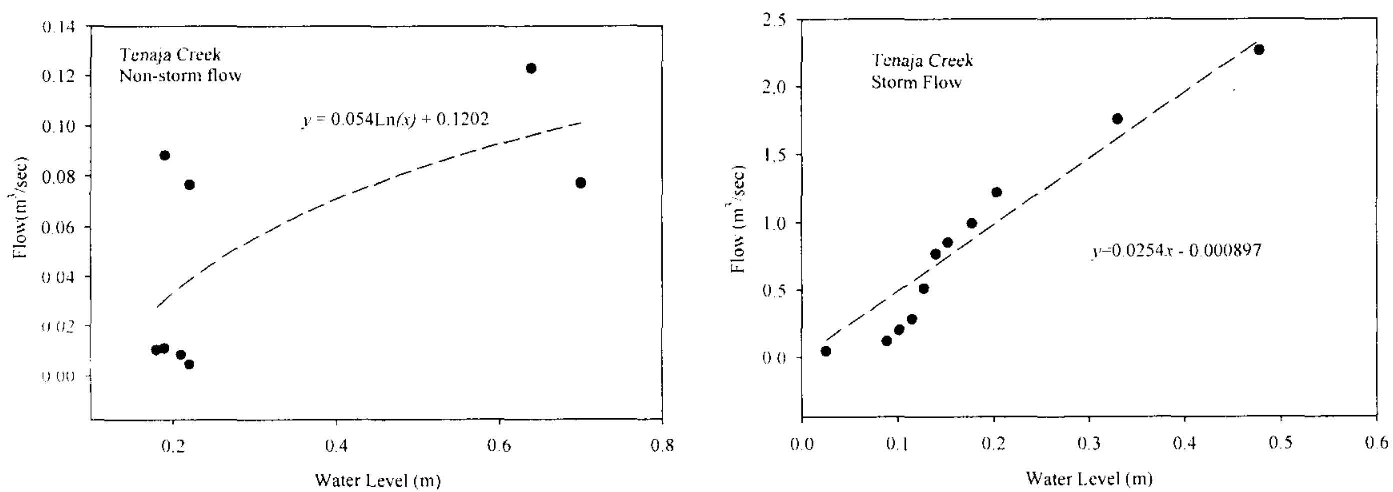



**Figure 21b. Rating curves at Tenaja Creek for non-storm flow and storm flows. $r^2$ Values are 0.43 and 0.97 for non-storm and storm flows, respectively.**

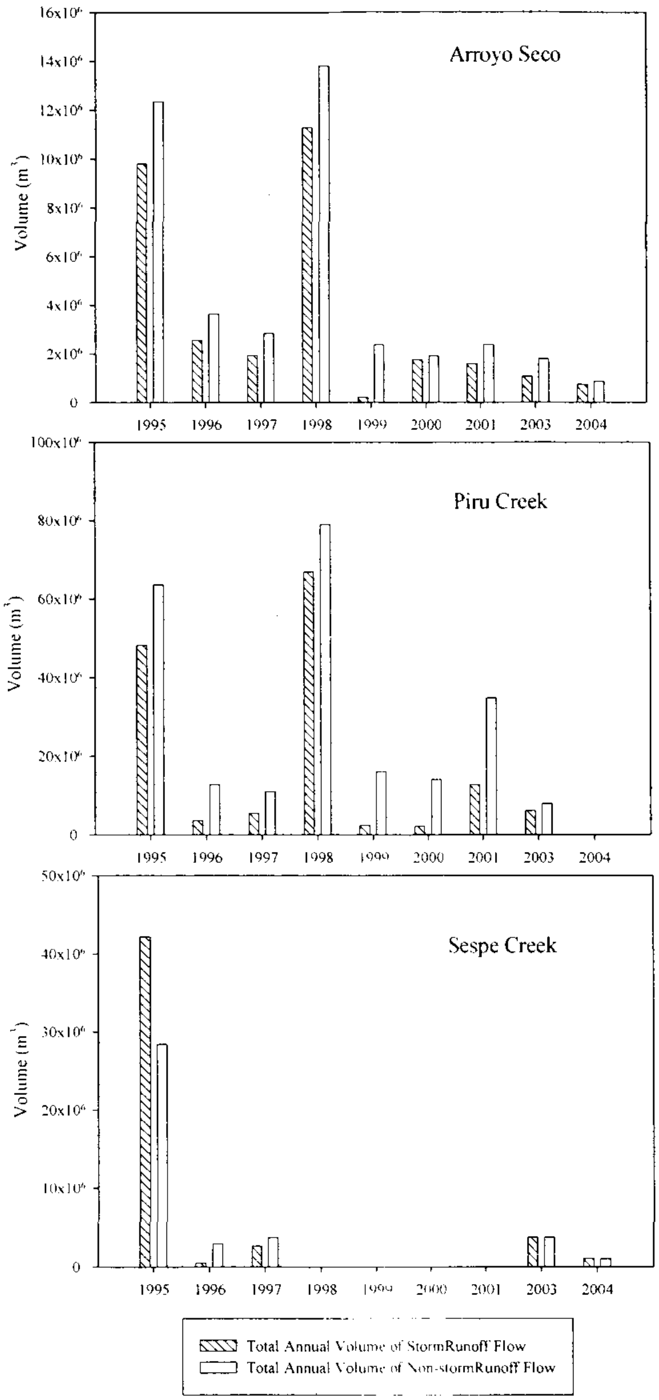



**Figure 22. Comparison of annual storm flow and non-storm flow volumes. The flow data for the 2004 water year for Piru Creek and for the 1998 to2001 water years for Sespe Creek are not available. The flow data of the water year 2002 for Arroyo, Piru, and Sespe Creeks were not included in the analysis due to the insufficient quality of the data set.**

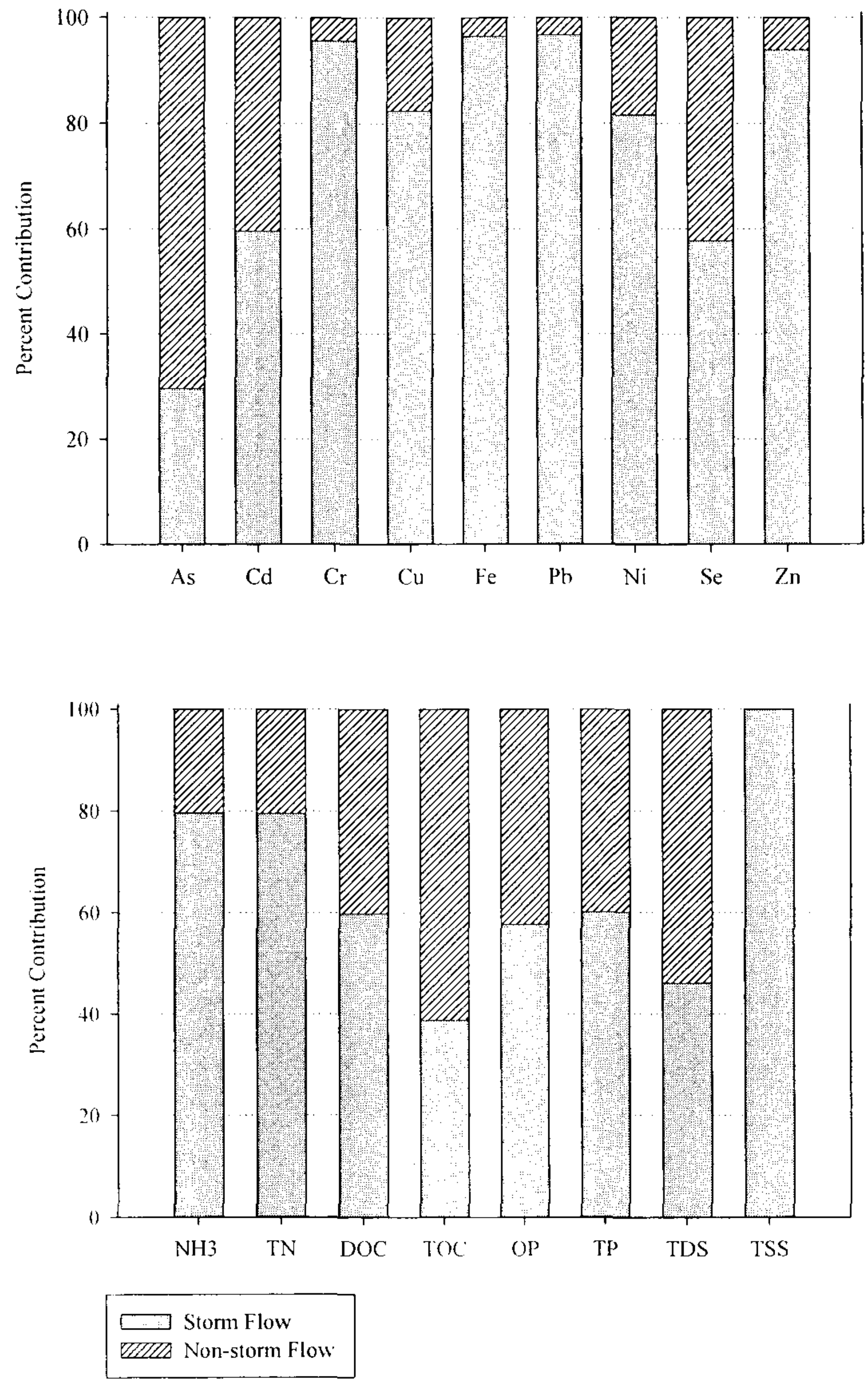



**Figure 23.** Percent contribution of storm flow and non-storm flow to total annual fluxes of metals, nutrients, and solids; ammonia ($NH_3$,); total nitrogen (TN); dissolved organic carbon (DOC); total organic carbon (TOC); orthophosphate (OP); total phosphorus (TP); total dissolved solids (TDS); and total suspended solids (TSS).

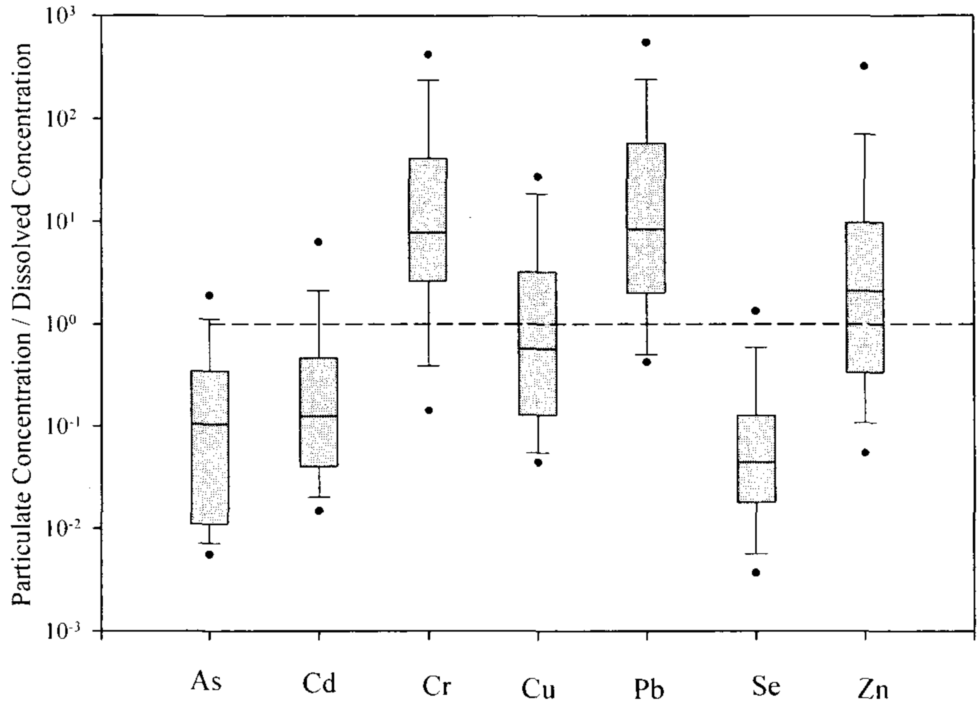



**Figure 24. Ratios of particulate concentrations over dissolved concentrations for metals in storm flow. The dissolved and particulate concentrations were analyzed with samples of storm, which were collected in the winter of 2006. The dotted line references a 1:1 ratio; Solid lines indicate the median of all values in the category. Boxes indicate 25$^{th}$ and 75$^{th}$ percentiles, and error bars indicate 10$^{th}$ and 90$^{th}$ percentiles. Solid dots represent 5$^{th}$ and 95$^{th}$ percentiles. The Y axis is in log scale.**

# CONCLUSIONS

This study yielded the following conclusions about water quality in streams draining natural catchments.

*1. Concentrations in natural areas are typically between one to two orders of magnitude lower than in developed watersheds.* Dry and wet weather concentrations, loads, and fluxes from natural catchments ranged widely; however, the levels were significantly lower than both those from developed catchments and existing water quality standards.

*2. Wet-weather TSS in the natural catchments was similar to those in the developed catchments.* This implies that natural areas may be a substantial source of TSS to downstream areas. The level of TSS presented this study, however, should not be extended to interpretations or policy concerning overall sediment transport, sediment budget or adsorbed pollutants in the watersheds. In this study, the levels of TSS were measured in order to estimate suspended sediments in water column, which carries adsorbed metals and other water quality pollutants (Pitt *et al.* 1995). Using only TSS for sediment load, however, under-estimates the heavier soil particle fraction such as sand-size materials is especially critical in surface waters originating in areas where the dominant geology is sedimentary; USGS has declined to use it since 2000 because a documented persistent bias in the TSS results against sand-sized materials (Gray *et al.* 2000).

*3. Both the storm and non-storm flux from the natural watersheds were significantly low compared with those from the developed watersheds.* Therefore, control of natural sources would likely provide little overall load reduction for downstream receiving waters.

*4. Differences between natural and developed areas during the dry season are much greater than during the wet season.* Differences between natural and developed areas suggest that management of non-storm loading in developed watersheds has the potential to provide substantial water quality benefit.

*5. Dry weather loading can be a substantial portion of total annual load in natural areas.* Non-storm flow accounts for more than half of the annual discharge in the natural streams. Similarly, a considerable portion of annual load resulted from non-storm flow. In particular, annual loads of arsenic, cadmium, selenium, total organic carbon, orthophosphate, and total dissolved solids were largely contributed by non-storm flow. For chromium, iron, lead, nickel, zinc, ammonia, and total suspended solids the dominant portion of annual load was from storm flow.

*6. Concentrations of metals were below the California Toxic Rules standards.* Concentrations in natural areas were below CTR standards during both storm and non-storm conditions.

*7. Wet-weather concentrations of E. coli, enterococcus, and total coliform and dry weather concentration for total coliform exceeded DHS freshwater standards in 40 to 50% of the samples.* These results are based on relatively small sample size for bacteria analysis and are being investigated further by a subsequent study that involves more frequent sampling of bacteria from natural areas.

*8. Concentrations of several nutrients were higher than the USEPA proposed nutrient guidelines for Ecoregion III, 6.* It is important to note that the ultimate approach for nutrient weighted mean concentrations of this study provide relevant background water quality concentrations for the southern California region.

In this study, the geology types were divided into two groups: sedimentary rocks and igneous rocks. There is, however, possible variation within the groups, which may influence concentrations of constituents in water. To estimate more representative background water quality for a specific watershed of interest, more comprehensive classification of geology at a regional scale is necessary. Metamorphic type may have different influence on water quality due to its different physical characteristics even though the chemical composition of the metamorphic rocks may be similar to either sedimentary or igneous rocks.

This study quantified contributions from natural areas, but did not identify sources of natural loadings. Potential sources include; vegetation, soils, atmospheric deposition, and groundwater recharge. Measurement of constituent concentrations in subsurface flow and/or at groundwater discharge locations would help provide insight into these sources. Measurement of wet and dry deposition at natural areas would provide insight into the contribution of aerial deposition to natural loadings. Sabin *et al.* (2005) reported that dry deposition of trace metals to the land surface within developed watersheds was potentially a very large contributor to watershed loadings based on comparisons to load estimates from stormwater runoff. However, this has not been fully investigated for natural areas, where rates of interception by vegetation and infiltration are expected to be much higher.

Analysis of particle size distribution and associated binding of pollutants to various size particles would provide insight into the differences between natural and developed watersheds. Because many pollutants are bound to particulates in stormwater, understanding the proportional distribution among various particle size fractions would allow more precise modeling and isolation of the contribution of natural sources to downstream concentration and load. This would facilitate investigation of management strategies that target anthropogenic portions of pollutant load.

Wildfire is a potential constituent source that can significantly contribute to natural loadings. Fires occur regularly in southern California and are natural elements of native habitats. Post-fire water quality in natural areas can differ from the previous-fire water quality. In this study the impact of wildfire was not investigated (only natural sites with no history of wildfire over the past three years were included in the study). Thus, the results of this can be used for the comparison with post-fire water quality data in order to investigate the impact of wildfire on natural loadings. These studies would provide valuable information for development of freshwater water quality criteria by better characterizing appropriate background conditions.

Finally, the findings of this study indicate that a subset of natural sites be incorporated into ongoing monitoring programs in order to build a more extensive data set on background water quality under a range of conditions.

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# APPENDICES

**Appendix I:** Review of pre-existing water quality monitoring data
ftp://ftp.sccwrp.org/pub/download/PDFs/500_NL_APPENDIX_I.pdf

**Appendix II:** Characterization of coastal watersheds in southern California by geology and land use types
ftp://ftp.sccwrp.org/pub/download/PDFs/500_NL_APPENDIX_II.pdf

**Appendix III:** Description of study sites
ftp://ftp.sccwrp.org/pub/download/PDFs/500_NL_APPENDIX_III.pdf

**Appendix IV:** Algal sampling protocol
ftp://ftp.sccwrp.org/pub/download/PDFs/500_NL_APPENDIX_IV.pdf

**Appendix V:** Description of developed sites for the comparison with natural sites
ftp://ftp.sccwrp.org/pub/download/PDFs/500_NL_APPENDIX_V.pdf

**Appendix VI:** Seasonal patterns in water quality data
ftp://ftp.sccwrp.org/pub/download/PDFs/500_NL_APPENDIX_VI.pdf

**Appendix VII:** Dry weather concentrations, loads, and fluxes for each study site
ftp://ftp.sccwrp.org/pub/download/PDFs/500_NL_APPENDIX_VII.pdf

**Appendix VIII:** Wet weather concentrations, loads, and fluxes for each study site
ftp://ftp.sccwrp.org/pub/download/PDFs/500_NL_APPENDIX_VIII.pdf

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# Contribution of trace metals from atmospheric deposition to stormwater runoff in a small impervious urban catchment

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**Abstract**

The contribution of atmospheric deposition to emissions of trace metals in stormwater runoff was investigated by quantifying wet and dry deposition fluxes and stormwater discharges within a small, highly impervious urban catchment in Los Angeles. At the beginning of the dry season in spring 2003, dry deposition measurements of chromium, copper, lead, nickel, and zinc were made monthly for 1 year. Stormwater runoff and wet deposition samples also were collected, and loading estimates of total annual deposition (wet + dry) were compared with annual stormwater loads. Wet deposition contributed 1–10% of the total deposition inside the catchment, indicating the dominance of dry deposition in semi-arid regions such as Los Angeles. Based on the ratio of total deposition to stormwater, atmospheric deposition potentially accounted for as much as 57–100% of the total trace metal loads in stormwater within the study area. Despite potential bias attributable to processes that were not quantified in this study (e.g., resuspension out of the catchment or sequestration within the catchment), these results demonstrate atmospheric deposition represents an important source of trace metals in stormwater to waterbodies near urban centers.


*Keywords:* Urban; Atmospheric deposition; Stormwater; Los Angeles; Trace metal

## 1. Introduction

Urban stormwater runoff can be highly contaminated with heavy metals and other toxic compounds, representing a significant non-point source of pollution to waterbodies within and adjacent to urban centers (Sansalone and Buchberger, 1997; Smullen et al., 1999; Buffleben et al., 2002). In Southern California, mass emissions from urban stormwater runoff can be higher than from point sources (e.g., wastewater treatment plants and industrial discharges) (Schiff et al., 2000). Furthermore, urban stormwater runoff can be toxic to aquatic organisms, and trace metals may be one of the constituents responsible for this toxicity (Marsalek et al., 1999; Schiff et al., 2002; Greenstein et al., 2004).

While future water quality improvements in urban areas may depend on contaminant reduction from stormwater, many of the trace metal sources to urban stormwater have not been well characterized. In semi-arid regions such as Southern California, pollutants may build-up on impervious surfaces during the extended dry season, and subsequently wash-off into nearby waterbodies once the wet season begins. Atmospheric deposition may be especially important as a source of pollutants to stormwater in these regions because significant quantities of trace metals and other pollutants are emitted

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into the atmosphere daily (SCAQMD, 2003), and the ultimate fate of the trace metals in particular is unknown.

Yet despite this potential, there are relatively few studies specifically targeting the pollutant contribution of atmospheric deposition to urban stormwater runoff in Los Angeles. The majority of atmospheric deposition research has focused on areas such as the Great Lakes and Chesapeake Bay regions (Lin et al., 1993; Baker et al., 1997; Paode et al., 1998). These areas have different atmospheric emissions and climatic parameters, and greater precipitation than Southern California, which may increase the importance of wet vs. dry deposition. Studies specific to urban atmospheric deposition have been limited even though urban areas have been shown to have higher deposition rates for a number of pollutants, including trace metals (Galloway et al., 1982; Yi et al., 2001). The present research was designed to quantify the contribution of atmospheric deposition of trace metals to stormwater loadings in a small urban catchment in Los Angeles.

## 2. Methods

Los Angeles has a semi-arid climate, with an average annual rainfall of 33 cm. Typically, the bulk of this precipitation occurs from December to March. Starting with the beginning of the dry season in May 2003 and continuing for 1 year, dry deposition and atmospheric concentrations of chromium, copper, nickel, lead and zinc were measured for 48 h once a month, on days without rain within a defined catchment in Los Angeles. Concentrations of trace metals in rain and stormwater within the catchment were measured from December 2003 to March 2004. The data were used to estimate the contribution of atmospheric deposition to stormwater loadings within the catchment. The site was selected to minimize sources of trace metals to stormwater within the catchment other than urban background atmospheric deposition.

### 2.1. Site description

The catchment was located in the San Fernando Valley of Los Angeles, California, within the grounds of a water reclamation plant. This site was suitable for this study as (1) the land surface was relatively flat; (2) the plant was surrounded by an earthen berm, preventing surface runoff from surrounding areas from entering the catchment; (3) sources of metals inside the plant were limited because of restricted access and lack of major industrial activities within the plant. Virtually all of the surface flow from the catchment was routed through a single catch basin, which was the site of runoff collection. The estimated drainage area to the catch basin was 5 ha based upon facility storm drain plans, discussions with the Plant Engineer, visual inspection, and on site measurements. The drainage area consisted primarily of impervious surfaces including asphalt roads, concrete sidewalks, and concrete structures with monolithic poured foam roofs. Unpaved dirt and vegetated areas covered <20% of the drainage area. A runoff coefficient of 1.0 was assumed because pervious areas were not subject to substantial infiltration. Evaluation of this assumption led to minimal bias and any overestimation of the runoff volume would result in conservative estimates of stormwater discharges. Traffic inside the plant was limited to ~50 vehicles per day, and streets were cleaned weekly.

### 2.2. Instrumentation

Dry deposition measurements were made using a modification of surrogate surfaces used by Paode et al. (1998) and Lin et al. (1993). Surrogate surfaces for this study were comprised of a circular PVC deposition plate, 33 cm in diameter, with a sharp edge (< 10° angle), covered with a Mylar® sheet coated with Apezion L grease. The grease was liquefied by heating and then painted onto the Mylar® film to obtain a thin, uniform 10 μm layer. During sampling, the plate was mounted onto a tripod at a height of 2 m. Atmospheric concentrations of trace metals on total suspended particulate (TSP) were collected using a filter-based sampling system attached to a vacuum pump. The open-faced inlet was loaded with a 37 mm, 2.0 μm pore Teflon® filter, and sampling was done at a flow rate of 10 l/min. The open-faced inlet was expected to reduce large particle losses to the walls and inlets typical of conventional impactor samplers. Wind speed and direction, temperature, and relative humidity were measured using a portable meteorological station (PortLog, Rain Wise, Inc., Bar Harbor, Maine).

Event-based wet deposition samples were collected using an automated rainwater collector developed by the National Atmospheric Deposition Program (NADP, 1997). The cover opened during periods of precipitation and closed when precipitation ended, eliminating evaporation from the sampler and preventing contamination of the sample. A pre-cleaned container was used for each event.

Flow-weighted composite stormwater samples were collected during each storm in 500 ml plastic bottles using an ISCO 6700 automated stormwater sampler, which also logged flow to determine runoff quantity.

### 2.3. Sample preparation and analysis

For the deposition plates, Mylar® sheets were cut into 30 cm diameter circles, wiped with methanol and soaked in 10% nitric acid followed by methanol for 5 min each, then rinsed with distilled water, and allowed to air dry.

Each sheet was coated with a thin layer of grease, mounted on a deposition plate, and stored in clean, airtight containers for transport to the field. After sampling, the Mylar® sheets were removed, folded (greased side inward), and placed inside a clean glass jar. In the laboratory, Mylar® sheets were cut into 10 smaller pieces and rinsed three successive times with 15 ml of *n*-hexane. The rinses were combined into a 50 ml centrifuge tube. The Mylar pieces were then rinsed with 5% optima grade nitric acid and the acid and hexane rinses were combined. The hexane was evaporated in a 50 °C water bath and the sample was acid-digested at 65 °C under sonication for a minimum of 24 h.

Prior to sampling, a clean Teflon® filter was loaded into the TSP sample holder, and the sample holder was stored in a clean plastic bag for transport to the field. After sampling, the filter was stored in a clean petri dish prior to analysis. In the laboratory, Teflon® filters were placed into clean 15 ml plastic centrifuge tubes and 10 ml of 5% optima grade nitric acid was added and the tubes capped tightly. The samples were acid-digested at 65 °C under sonication for a minimum of 24 h.

For wet deposition and stormwater analyses, collection vessels were cleaned with soap and water, soaked in 10% nitric acid and rinsed with distilled water. All stormwater samples from a given storm were acidified to pH 2 with ultra-pure nitric acid and stored at 4 °C. A representative composite from each storm was digested by acidification to pH <2 using $HNO_3$ for a minimum of 16 h.

All acid-digested samples were transferred to a centrifuge tube and analyzed for metals per EPA Method 200.8 using inductively coupled plasma-mass spectroscopy. Method detection limits ranged from 0.5 to 1.0 ng. A five-point external calibration curve, laboratory blank, matrix spike, and matrix spike duplicate were measured with each batch of 15 or less samples to ensure quality. Matrix spike recoveries were within 99–107% for all metals. Matrix spike duplicates were within 10% of the original spike for all metals (relative percent difference or RPD). All laboratory blanks were non-detectable. Field blanks (greased Mylar® sheets mounted on a deposition plate, Teflon® filters loaded into a TSP sampling cartridge, stormwater sample bottles filled with distilled water) were prepared, taken to the field, and analyzed along with the samples. All field blanks contained detectable levels of trace metals, and all samples were corrected for their respective field blank. Field blank corrections were typically <20% of the sample mass for copper, lead and zinc, but up to 100% of sample mass for chromium and nickel. Field duplicates indicated the precision of the deposition plates for each of the five metals, on average, was 31% (chromium), 25% (copper), 24% (lead), 87% (nickel) and 47% (zinc) RPD. This was an acceptable level of precision for field duplicates because differences of less than a factor of two between fluxes measured during different sampling events were not considered significant.

### 2.4. Mass loading calculations

Annual dry deposition mass loadings were calculated for each metal by multiplying the mean daily flux from each sampling event by the number of dry days between that sampling event and the next. These loadings were then summed to obtain the total annual load inside the catchment. It was assumed that no dry deposition occurred during periods of rain. Any errors introduced by this assumption would be small because of the limited number of days with precipitation that occurred during the year.

The annual event mean concentration (EMC) was calculated for both rainwater and stormwater using Eq. (1):

$$C_m = \frac{\sum_{i=1}^{n}(C_i V_i)}{\sum_{i=1}^{n} V_i}, \quad (1)$$

where $C_m$ is the annual EMC for population $j$; $C_i$ the concentration during storm event $i$; $V_i$ the weighting factor—total volume sampled for event $i$; $n$ the number of storm events sampled.

For wet deposition, the total mass loading for each metal was then calculated by multiplying the rainwater annual EMC by the area of the catchment and the total volume of rainfall during the year, which was obtained from published precipitation data from the Sepulveda Dam Rain Gauge (NOAA, 2003, 2004), located less than 1.5 km from the catchment.

The individual wet deposition flux for each storm was calculated by multiplying the rainwater EMC by the catchment area and the volume of rainfall from a single storm. The mean storm flux provided a better comparison to the mean daily dry deposition flux because it more closely approximated a daily wet deposition value than the annual flux.

The mass loadings of trace metals in stormwater were calculated by multiplying the stormwater annual EMC (Eq. (1)) by the total volume of runoff during the storm season. To obtain stormwater volumes, standard hydrologic equations were used based on water level, slope, and roughness of the storm drain pipe from which samples were collected. Water level was measured using a bubbler. Pipe slope and roughness were provided by the facility manager. Flow estimates were calibrated using the relationship between rainfall, measured runoff volumes, and catchment area (Fig. 1) to account for uncertainties in the inputs and assumptions used in the flow calculations (e.g. estimated slope, assumption of uniform flow, etc.). The relationship between rainfall

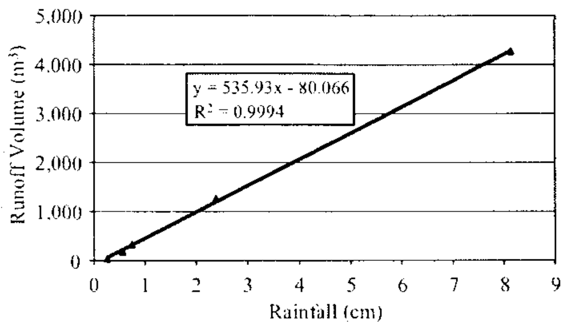


Fig. 1. Linear regression of rainfall vs. runoff measured in an urban Los Angeles catchment.

and runoff was significant ($R^2 > 0.99$) and this regression was used to estimate runoff volume for storms that were not sampled, providing a good approximation of the total runoff volume inside the catchment for the entire year. From the $y$-intercept of the regression equation, when rainfall was <0.15 cm, runoff volume was zero. This was supported by observations at the site.

## 3. Results

### 3.1. Dry atmospheric deposition fluxes and atmospheric concentrations

The TSP detection frequency was 100% for all trace metals except chromium, which was 92%. Atmospheric concentrations of trace metals on TSP were relatively stable over time (Fig. 2a). The ranges of chromium, copper, lead, and zinc concentrations were all within factors of two during the year-long survey, while nickel concentrations were the most variable, but still within a factor of four.

Deposition plate detection frequencies were 100% for all metals except nickel, which was only detected in ~50% of the samples. With the exception of a single event, discussed below, dry deposition fluxes were normally distributed and not highly variable over time during the course of this study (Fig. 2b). Dry deposition fluxes of all metals ranged within factors of 2–5 from their mean values. For all five metals, deposition fluxes were not significantly correlated with meteorological parameters including mean daily wind speed, temperature and relative humidity, maximum 10-min wind speed, and antecedent rainfall days ($p > 0.05$).

Forest fires in nearby mountains and offshore (i.e. Santa Ana) wind conditions occurred during a single sampling event in October. The highest fluxes for all metals were measured during this unique event. While the sample size limited the application of statistical tests of significance, it is interesting to note the fluxes measured during these unusual conditions of forest fires were factors of four (chromium and copper), six (zinc), eight (lead), and 13 (nickel) times greater than the mean fluxes for all other sampling events.

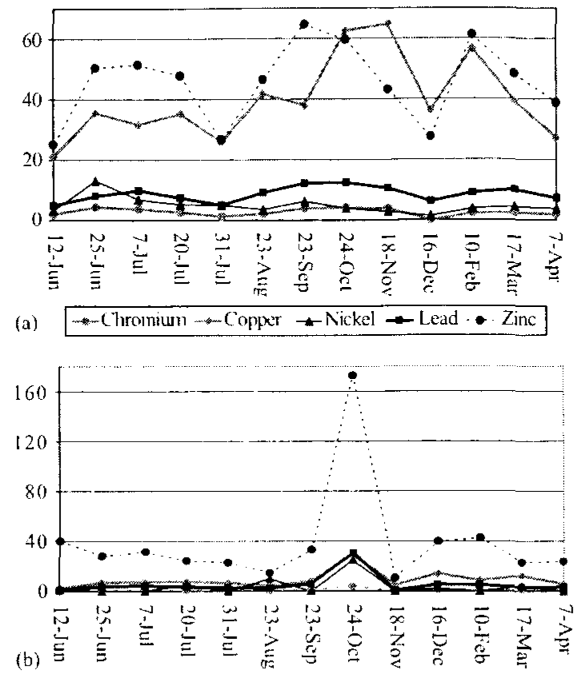


Fig. 2. Time series of (a) dry deposition flux in μg/m²/day (MDL = 0.01) and (b) atmospheric concentration in ng/m³ (MDL = 0.03) based on sampling times/air volumes collected.

### 3.2. Storm events

There were 21 rainfall events inside the catchment during the period from October 2003 through April 2004 (Fig. 3). The total amount of rainfall from these events was 20 cm, with ~75% of the total rainfall for the season produced by only three storms. Samples of rainwater were collected from seven events, comprising ~70% of the total rainfall for the season. Ten rainfall events had sufficient volume to generate runoff within the catchment. Stormwater runoff samples were collected from six of these events, comprising ~50% of the total stormwater runoff inside the catchment during the season.

Detection frequencies in rainwater were low for most metals (Table 1). The highest concentrations for all metals were from the December 14, 2003 storm. The rainwater annual EMCs for each of the five metals were an order of magnitude lower than the rainwater concentrations from the December 14th storm. The relative proportions of metals in rainwater and on atmospheric TSP at the site were similar; indicating particle scavenging from the atmosphere was the likely source of these metals in precipitation (Fig. 4).

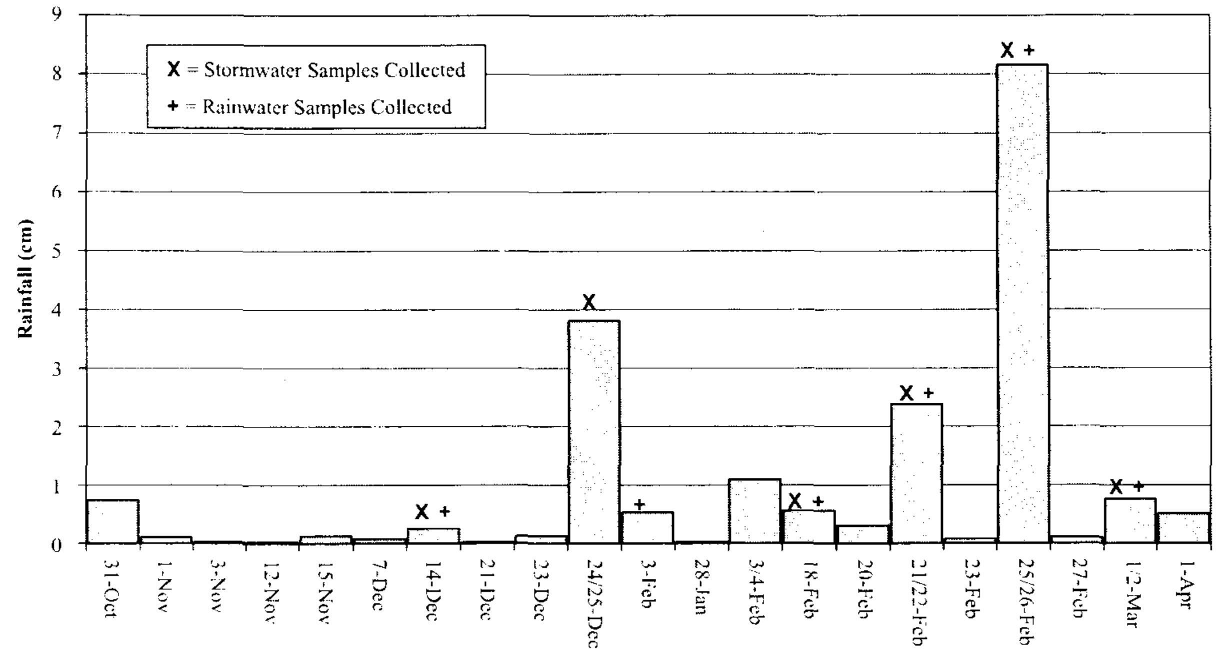


Fig. 3. Rainfall in the catchment during the 2003–2004 storm season. Cumulative rainfall over the sample period was 19.7 cm.

Table 1
Concentrations of metals in precipitation and stormwater inside the catchment

| | Detection frequency (%) | Range (μg/l) | Annual event mean concentration ± standard error (μg/l) |
|---|---|---|---|
| *Precipitation* | | | |
| Chromium | 14 | b.d.–2.2 | $0.09 \pm 0.06$ |
| Copper | 86 | b.d.–14 | $1.0 \pm 0.6$ |
| Lead | 29 | b.d.–5.0 | $0.15 \pm .09$ |
| Nickel | 71 | b.d.–3.2 | $0.19 \pm 0.12$ |
| Zinc | 43 | b.d.–210 | $7.8 \pm 4.9$ |
| *Stormwater* | | | |
| Chromium | 100 | 2.1–20 | $3.1 \pm 1.6$ |
| Copper | 100 | 5.9–37 | $27 \pm 24$ |
| Lead | 100 | 1.2–16 | $12 \pm 10$ |
| Nickel | 100 | 2.1–8.5 | $6.6 \pm 5.2$ |
| Zinc | 100 | 32–320 | $160 \pm 130$ |

Method detection limit was <0.1 μg/l for all metals. b.d. = below detection.

Chromium, copper, nickel, lead, and zinc were detected in 100% of the stormwater runoff samples (Table 1). The highest concentrations of chromium and zinc were observed during the first sampled storm of the season (December 14, 2003), while the highest concentrations of copper, lead, and nickel were observed during the largest storm of the season (February 25, 2004). No relationship was evident between stormwater concentrations and parameters such as storm intensity, mean or peak flow rates, or antecedent rainfall days using regression models ($p > 0.05$). Thus, the annual EMCs were used to estimate the loads of trace metals in stormwater runoff within the catchment.

### 3.3. *Wet vs. dry deposition flux compared to stormwater loading estimates*

Based on the total annual flux, dry deposition fluxes were substantially greater than wet deposition fluxes (Table 2). Wet deposition comprised 1–10% of the total annual deposition (wet + dry) inside the catchment. For all five metals, the mean wet deposition fluxes per storm (which typically lasted $\leqslant 1$ day) were the same order of magnitude as the daily dry deposition fluxes (Table 2); the differences between individual storm wet fluxes and daily dry fluxes ranged from a factor of 1–4 for all metals. Only zinc had a higher mean wet deposition flux per storm compared with the daily dry deposition flux.

For each metal, the estimated mass of cumulative wet and dry atmospheric deposition to the catchment was similar to the estimated mass of trace metals discharged from the catchment through stormwater runoff (Table 3). Annual wet and dry deposition mass ranged from 57% (for zinc) to approximately 100% (for nickel and lead) of the annual stormwater load. Annual dry deposition had the greatest potential for influencing stormwater mass emissions. Between 52% (for zinc) and approximately 100% (for nickel and lead) could be attributed to dry deposition alone. Moreover, rainwater concentrations were typically more than an order of magnitude lower than concentrations in stormwater runoff (Table 1).

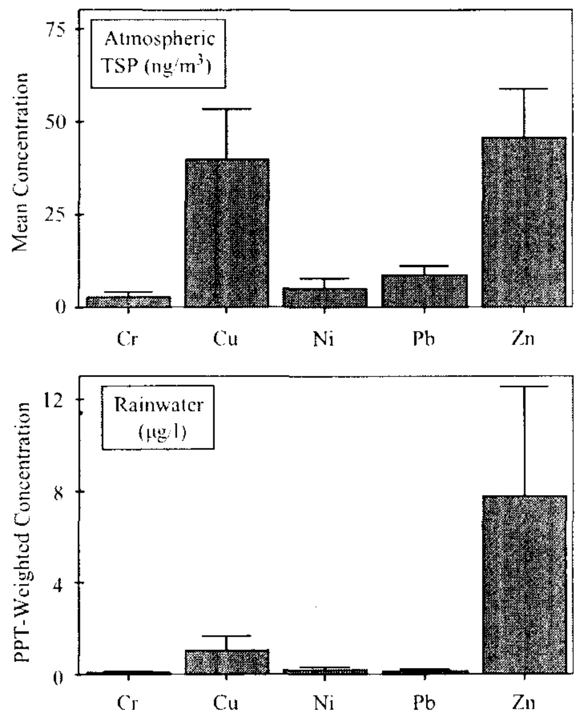


Fig. 4. Mean trace metal concentrations on atmospheric TSP and in precipitation measured in the catchment. Error bars represent the standard error of the mean.

## 4. Discussion

### 4.1. *Deposition fluxes*

Atmospheric deposition of trace metals in semi-arid urban areas has unique characteristics not observed in previous studies (Table 4). The magnitude of the total deposition fluxes measured in urban Los Angeles in the present study was significantly higher than the fluxes measured at non-urban sites. This demonstrates the importance of anthropogenic sources in urban areas to higher deposition rates. Also, annual wet deposition fluxes were significantly lower than dry deposition fluxes, indicating the dominance of dry deposition in arid regions compared with other areas of the country. For example, wet deposition comprised only 1–10% of the total deposition flux in the present study, while measurements near Chesapeake Bay, where annual rainfall is typically three times that of Los Angeles, indicated wet deposition accounted for 20–50% of the total flux (Baker et al., 1997). Thus, dry deposition appears to be the dominant mechanism for transfer of atmospheric pollutants to watershed surfaces because of the low rainfall quantity in semi-arid regions like Los Angeles.

Table 2
Comparison between wet and dry deposition fluxes[a]

| Metal | Wet deposition fluxes | | Dry deposition fluxes | |
|---|---|---|---|---|
| | Annual flux[b] (μg/m$^2$/yr) | Average flux per storm (μg/m$^2$ storm) | Annual flux[c] (μg/m$^2$/yr) | Average daily flux (μg/m$^2$/day) |
| Chromium | 18 (0–45) | 0.84 (0.07–1.6) | 440 (250–620) | 1.3 (0.7–1.8) |
| Copper | 200 (0–520) | 9.6 (0.9–18) | 3211 (1800–4600) | 9.4 (5.3–14) |
| Lead | 29 (0–74) | 1.4 (0.1–2.6) | 2000 (390–3600) | 5.8 (1.1–10) |
| Nickel | 38 (0–96) | 1.8 (0.2–3.4) | 1300 (0–2700) | 3.7 (0–8.0) |
| Zinc | 1500 (0–3900) | 73 (6–140) | 13,000 (4900–22,000) | 39 (14–64) |

[a]Ranges in parentheses.
[b]October 2003–April 2004 storm season.
[c]May 2000–April 2004 dry days.

Table 3
Comparison of metal loadings from atmospheric deposition and stormwater runoff from May 2003–April 2004 (g/year)

| | Chromium | Copper | Nickel | Lead | Zinc |
|---|---|---|---|---|---|
| Wet deposition | 1 | 10 | 2 | 1 | 77 |
| Dry deposition | 22 | 160 | 63 | 99 | 670 |
| Stormwater runoff | 32 | 230 | 59 | 93 | 1300 |
| Wet deposition/stormwater | 0.03 | 0.04 | 0.03 | 0.01 | 0.06 |
| Dry deposition/stormwater | 0.69 | 0.70 | 1.07 | 1.06 | 0.52 |
| Total deposition(wet + dry)/stormwater | 0.72 | 0.74 | 1.10 | 1.08 | 0.57 |

Table 4
Comparison of measured air concentrations and fluxes of trace metals

| | | Year | Chromium | Copper | Lead | Nickel | Zinc |
|---|---|---|---|---|---|---|---|
| Air concentration ($ng/m^3/year$) | | | | | | | |
| This Study | | 2003–2004 | 2.8 | 40 | 9 | 4.9 | 46 |
| Los Angeles[a] | | 2002–2003 | 4.9 | 52 | 14 | 9.2 | 84 |
| Los Angeles[b] | | 1998–1999 | 4.9 | 39 | 25 | 8.7 | 106 |
| Total deposition flux: wet + dry ($mg/m^2/year$) | | | | | | | |
| This study | | 2003–2004 | 0.46 | 3.4 | 2.0 | 1.3 | 14.5 |
| Lake michigan[c] | | 1993–1994 | 0.20 | 1.9 | 1.6 | 0.6 | 6.0 |
| Lake superior[c] | | | 0.21 | 3.1 | 1.5 | 0.8 | 8.8 |
| Lake erie (urban influenced)[c] | | | 1.06 | 4.2 | 1.8 | 0.7 | 16.5 |
| Chesapeake bay | Wye | 1990–1992 | 0.35 | 0.60 | 1.2 | 0.93 | 3.7 |
| Atmsopheric deposition | Elms | | 0.25 | 0.67 | 1.1 | 0.71 | 3.5 |
| Study (non-urban)[d] | Haven Beach | | 0.20 | 0.85 | 1.2 | 1.1 | 7.1 |

[a]Stolzenbach et al. (2004).
[b]SCAQMD (2000).
[c]Sweet et al. (1998).
[d]Baker et al. (1997).

Temporal variability of dry deposition fluxes was low, in agreement with the findings of Sabin et al. (2004) for urban Los Angeles. The exception was the sampling event during Santa Ana winds and forest fires, which produced high fluxes for all metals, suggesting these anomalous conditions contributed to high fluxes. Other seasonal or meteorological variables were not correlated with fluxes due, in part, to the limited range of meteorological data resulting from the mild climate in Southern California. These results suggest daily, chronic conditions are primarily responsible for the majority of the dry deposition mass of trace metals in Southern California, as demonstrated by computer modeling developed by Lu et al. (2003).

While direct measurements of trace metal deposition fluxes have not been made extensively in Southern California, other data for Los Angeles indicate atmospheric TSP concentrations of trace metals at the study site were approximately half the concentrations measured at other urban sites in Los Angeles (Table 4). This result was not unexpected, since the site in the present study was located in a relatively suburban area of the city, and predominantly upwind of significant point and mobile sources. Because dry deposition is directly proportional to atmospheric concentrations near the surface (Hicks et al., 1984), higher deposition fluxes, and subsequently higher loadings from deposition, would be expected in heavily urbanized areas which have higher atmospheric concentrations.

### 4.2. Contribution to stormwater loading

The data from the present study indicate atmospheric deposition is an important contributor to stormwater runoff in urban catchments. Assuming the total quantity deposited onto the catchment was available for removal in stormwater runoff, atmospheric deposition potentially accounted for as much as 57–100% of the total trace metal loads in annual stormwater discharges. The finding that atmospheric deposition and stormwater loadings were approximately the same order of magnitude is in agreement with previous studies in this region (Lu et al., 2003; Sabin et al., 2004), and further demonstrates atmospheric deposition should not be ignored when assessing sources of trace metal pollution to contaminated waterbodies near urban centers.

There are several limitations to these findings. First, not all of the trace metal loads estimated from the average daily deposition measurements may be effectively available for immediate washoff. Some fraction of the deposited material may be removed from surfaces by means other than stormwater runoff due to processes we have not quantified, including resuspension out of the catchment or sequestration within the catchment through uptake by vegetation, accretion, adsorption, and other means (James and Shivalingaiah, 1985; Novotny et al., 1985). Second, material remaining on the surface may not be completely washed off during storm events (Vaze and Chiew, 2002). The amount of material mobilized during surface flows depends on a number of factors, such as surface type (e.g., impervious vs. natural surfaces), street cleaning practices, and rainfall intensity and duration (Novotny et al., 1985; Vaze and Chiew, 2002). This material may then be available for removal at a later time, and thus some portion of the runoff load may be due to materials that were deposited earlier than the period of measurement.

## 5. Conclusions

This research demonstrates: (1) atmospheric deposition potentially accounted for 57–100% of the trace metal loads in annual stormwater discharges in this highly impervious catchment; and (2) dry deposition appears to be the dominant mechanism for transfer of atmospheric pollutants to surfaces in semi-arid Los Angeles. Because atmospheric deposition is potentially a large fraction of runoff load, further research into the processes of resuspension and sequestration of deposited materials, and washoff in stormwater runoff is warranted.

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# METAL DRY DEPOSITION RATES ALONG A COASTAL TRANSECT IN SOUTHERN CALIFORNIA

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March 2007

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Established 1969

Lisa Sabin
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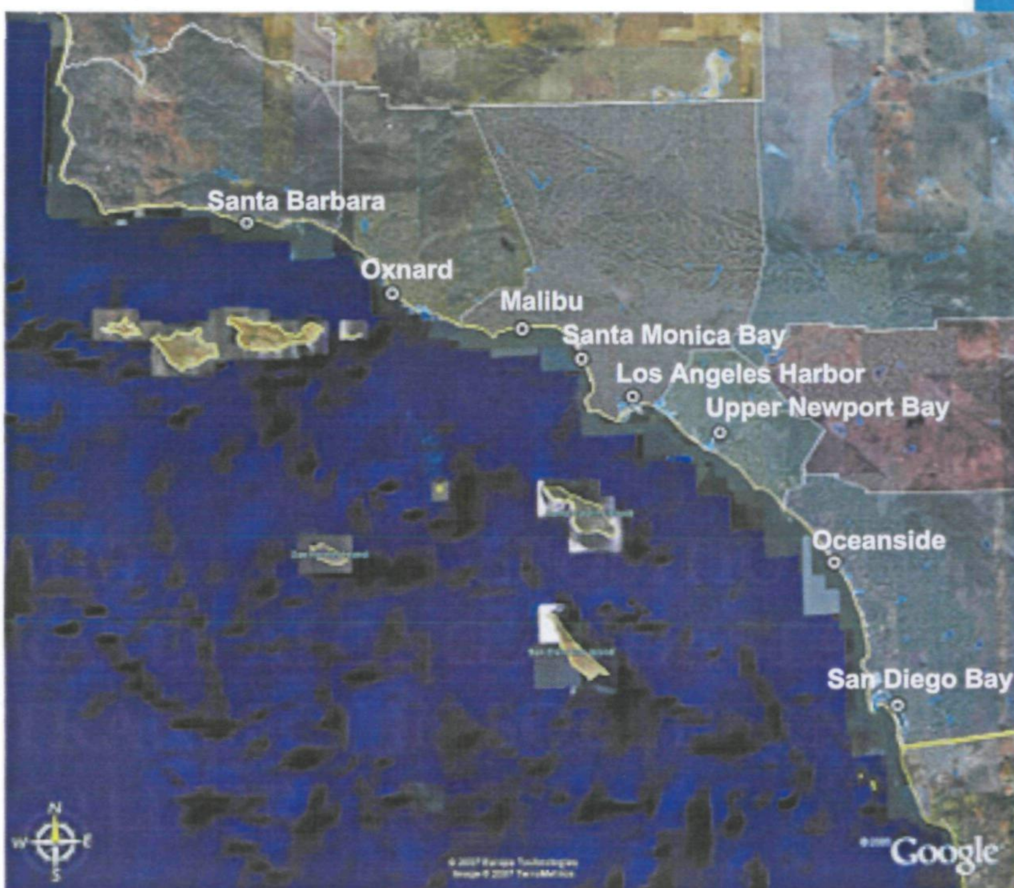


Southern California Coastal Water Research Project

# METAL DRY DEPOSITION RATES ALONG A COASTAL TRANSECT IN SOUTHERN CALIFORNIA

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Technical Report 509

# ABSTRACT

While recent studies indicate atmospheric deposition is a significant source of metals to the Santa Monica Bay and coastal river systems of the Los Angeles area, the spatial extent of the atmospheric source along the entire southern California coast has not been measured in thirty years. This study provides measurements of dry atmospheric deposition of chromium, copper, lead, nickel and zinc at eight sites located along the coast between Santa Barbara and San Diego, and compares these data to historic measurements from the 1970's. Median dry deposition fluxes across sites ranged between 0.23 to 3.6 (chromium), 0.21 to 5.4 (nickel), 0.52 to 14 (lead), 0.89 to 29 (copper), and 4.8 to 160 (zinc) $\mu g/m^2/day$. Differences in metal dry deposition flux rates observed between sites were dominated by proximity to urban areas and/or other nearby sources, with the highest metal fluxes observed near the Los Angeles Harbor and San Diego Bay sites. Compared with data from the 1970's, lead fluxes were typically one to two orders of magnitude lower in the present study (2006), indicating atmospheric sources of these metals have decreased over the past three decades. Chromium fluxes were also lower in 2006 compared with the 1970's, although to a lesser extent than for lead. In contrast, copper and zinc fluxes were typically within the same order of magnitude between the two time periods, with some higher measurements observed in 2006 compared with the 1970's. This result indicates atmospheric sources of copper and zinc have increased over the past three decades in southern California. Differences in sampling conditions (e.g., Santa Ana winds) and measurement techniques may also explain, in part, the differences observed in metal flux rates for these time periods. ; However, these limitations were most important for those metals with the smallest difference in flux rates measured in the 1970's vs. 2006 (e.g., chromium).

## ACKNOWLEDGEMENTS

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# INTRODUCTION

Atmospheric deposition represents a significant fraction of the total pollutant load to many contaminated waterbodies, relative to other sources (Duce *et al.* 1991, Lin *et al.* 1993, Scudlark *et al.* 1994, Wu *et al.* 1994, Baker *et al.* 1997, Scudlark and Church 1997). In southern California, the atmosphere has been shown to be a significant contributor to metal pollution in the Santa Monica Bay and coastal river systems of Los Angeles, primarily through deposition onto the land surface during dry periods, and subsequent removal by stormwater runoff during rain events (Lu *et al.* 2003; Sabin *et al.* 2005, 2006a).

Dry deposition flux rates of metals vary primarily as a function of both sources (e.g., proximity to urban areas, or other nearby sources) and meteorological conditions (e.g., wind speeds). In Los Angeles, the highest metal deposition rates have been observed within 100 m of a large freeway, a major source of particle-bound pollutant metals, while urban background deposition rates have been observed within approximately 450 m of the freeway (Sabin *et al.* 2006b). In addition, substantially lower flux rates (compared with urban background rates in Los Angeles) have been observed at a non-urban coastal site upwind of Los Angeles (Sabin *et al.* 2006a).

No measurements of the dry deposition gradient of metals along the entire Southern California coast have been made in thirty years. During the mid-1970's, atmospheric deposition studies, conducted at a number of sites along the coast between Santa Barbara and San Diego, provided data on the extent of the urban influence during that time. These historical data demonstrated coastal Los Angeles was a hotspot for dry deposition of a number of constituents (e.g., DDT, PCB, metals), compared with areas along the coast to the north and south of greater Los Angeles (Young *et al.* 1976, Young and Jan 1977). However, during the past thirty years, there have been changes in atmospheric pollution sources, including decreases for some pollutants (e.g., lead) and increases for others (e.g., copper and zinc). There has also been considerable population growth along the coast, including an expansion of urban areas of Los Angeles and San Diego, as well as increased urbanization of areas that were predominantly non-urban/agricultural in the 1970's. Thus, substantial differences would be expected between dry deposition flux rates along the southern California coast measured during the 1970's and those measured in 2006, and it is likely that the direction of the change may vary depending on the metal and the location.

The goal of this study was to gain a better understanding of the dry deposition rates of metals, the spatial extent of the urban footprint along the coast of Southern California, and how these have changed over the past thirty years. To accomplish this goal, the following objectives were defined: (1) measure the dry deposition flux gradient of five pollutant metals (chromium, copper, lead, nickel and zinc) along a north-south coastal transect of southern California; and (2) compare these measurements with historic metal dry deposition flux rates from the 1970's.

# METHODS

## General Approach

Measurements of metal dry deposition fluxes were made weekly on a north-south transect along the coast of southern California between Santa Barbara and San Diego over a four month period during Summer and Fall 2006 (Table 1). Each site was sampled at least ten times. All samples were collected for 48 hours during periods with no measurable precipitation.

### *Sampling sites*

There were a total of eight sampling sites along the Southern California coast, including sites at Santa Barbara, Oxnard, Malibu, Santa Monica Bay, Los Angeles Harbor, Upper Newport Bay, Oceanside and San Diego Bay (Figure 1). All sites were located within approximately 1 km of the coast with the exception of Upper Newport Bay (located approximately 8 km inland) and Los Angeles Harbor (located approximately 3 km inland). Sampling was conducted on a weekly to biweekly basis between June 2006 and October 2006 at all sites except Los Angeles Harbor, where sampling was conducted between August 2006 and November 2006.

Specific site selection criteria incorporated the recommendations of the National Atmospheric Deposition Program (NADP 2001). These criteria included: locations generally representative of the region, with minimal impact of local point or area sources; areas a minimum distance of 100 m from major line sources; and all objects or structures located a distance of at least twice their height from the sampling equipment. These recommendations were followed to the extent possible in populated urban areas.

## Instrumentation

Dry deposition flux measurements were made using a 33-cm diameter circular polyvinyl chloride (PVC) plate with a sharp leading edge (<10 degree angle), covered with a Mylar® sheet coated with uniform 10-μm layer of Apiezon L grease. This instrument passively collects particles on a PVC plate as they fall from the air. The deposition plate was mounted on a tripod at a height of approximately 2 m. This surrogate surface has been used successfully in a number of recent studies of atmospheric deposition in Los Angeles (Sabin *et al.* 2005, Lim *et al.* 2006).

Measurements of meteorological conditions were not collected at the sites during sampling events; however, data from nearby weather stations were accessed through the National Climatic Data Center (NCDC http://www.ncdc.noaa.gov/oa/ncdc.html). These data provided 24-hour average wind speed, wind direction, and precipitation amounts for each sampling date. However, the 24-hour meteorological data were for the time period from midnight to midnight each day, while sampling times generally started in the morning around 11:00 AM and finished 48 hours later. Thus the meteorological data did not correspond exactly to the time of the dry deposition measurements, but provided a general description of the wind conditions at the time of sampling.

## Sample Preparation and Chemical Analysis

Prior to sampling, Mylar was cut into 33-cm diameter circles and cleaned by wiping with methanol-soaked wipes, then immersed in 10% nitric acid followed by methanol for 10 minutes each. The Mylar sheets were then rinsed with distilled water and allowed to air dry. Dry Mylar sheets were coated with a thin layer of Apiezon L grease, which was liquefied by heating and then painted onto the Mylar film to obtain a thin, uniform 10-μm layer. The Mylar sheets were then mounted onto the deposition plates one day prior to sampling, and the deposition plates were stored in airtight plastic containers for transport to the field.

After sampling, the Mylar sheets were removed from the deposition plates in the field, folded (greased side inward), and placed inside a clean glass jar. In the lab, each Mylar sheet was divided into ten smaller pieces. The smaller pieces were then returned to respective original sample jars, rinsed three successive times with 15 ml of n-hexane to dissolve the Apiezon grease, then rinsed with 5% Optima Grade nitric acid. The acid and hexane rinses were subsequently combined, the hexane was evaporated in a 50°C water bath, and the remaining acidified sample was then heated to 65°C under sonication for a minimum of 24 hours.

All acid-digested samples were analyzed for 26 metals per EPA Method 200.8 using inductively coupled plasma-mass spectroscopy (ICP-MS). Results reported here are for chromium, copper, lead, nickel and zinc, which are the primary metals associated with water quality issues in Southern California. Method detection limits were 0.05 ng for lead, 0.1 ng for chromium, nickel and zinc, and 0.4 ng for copper. These limits correspond to minimum detectable deposition fluxes of 0.004 $\mu g/m^2$/day for lead, 0.009 $\mu g/m^2$/day for chromium, nickel and zinc, and 0.003 $\mu g/m^2$/day for copper. Laboratory blanks, analyzed with each batch of 15 samples, were consistently nondetectable. Matrix spike recoveries ranged from 93 to 107% for all five metals. Duplicate matrix spikes indicated the precision of the laboratory analysis method, with relative percent differences (RPD) of 1% or less for all five metals.

Each week of sampling, a blank deposition plate was prepared along with the sample deposition plates and taken into the field in an airtight plastic container. These field blanks were analyzed along with the samples collected each week. Field blanks contained detectable levels of metals, and all samples were corrected for their respective field blank. To assess the precision of the deposition plates, duplicate deposition plate samples were collected during approximately 10% of sample events. These field duplicates indicated the average RPD's between collocated deposition plates were 33% (chromium), 10% (copper), 25% (nickel), 23% (lead), and 18% (zinc).

## Data Analysis

Metal dry deposition fluxes were first compared among sites along the north-south transect. Because the data were not normally distributed, the non-parametric Kruskal-Wallis One Way Analysis of Variance on Ranks (ANOVA on ranks) and the Dunn's Method for pairwise multiple comparisons were used to test for significant differences in flux rates between sites. Differences between sites were also evaluated by comparing the medians and ranges of flux rates between sites.

Median dry deposition fluxes of metals at each site were next compared with historical data, estimated from figures published by Young and Jan (1977) from data collected at similar sites along the coast in 1975. A different surrogate surface was used by Young and Jan (1977); however, few data exist on metal dry deposition flux rates from that period. The site locations in the Young and Jan (1977) study were located on a north-south transect along the southern California coast; most of these sites were located near the sites used in the present study, allowing a unique opportunity to compare dry deposition flux rates in southern California across a thirty year time span. Each of the sites in the Young and Jan (1977) study were matched to a site with approximately the same geographic location for the purpose of the present study using corresponding site identification numbers. For the Young and Jan (1977) data, site identification numbers were: Site 1 - Carpenteria, Site 2 - Port Hueneme, Site 3 - Zuma Beach, Site 4 - Santa Monica, Site 5 - Long Beach, Site 6 - Newport Beach, Site 7 - San Clemente Beach, and Site 8 - Encinitas. For the data from the present study, site identification numbers were: Site 1 - Santa Barbara, Site 2 - Oxnard, Site 3 - Malibu (Malibu Lagoon State Beach), Site 4 - Santa Monica Bay (Hyperion Treatment Facility), Site 5 - Los Angeles Harbor, Site 6 - Upper Newport Bay, Site 7 - Oceanside, and

Site 8 - San Diego Bay. In the present study, site 8 (San Diego Bay) is located substantially to the south and in an area with an expected higher impact from nearby urban areas as well as the activities in the bay than the 1975 site 8 (Encinitas). The data from Young and Jan (1977) were measured under desert wind (Santa Ana) conditions. No data for nickel fluxes were available from the Young and Jan (1977) study.

# RESULTS

## Meteorological Conditions

Average wind direction was typically from the west or southwest on most sampling days. A few days had average wind directions from the east or southeast, but these did not dominate any given sampling event. Average 24-hour wind speeds were highest near the Santa Monica Bay site (6.0 to 10 m/s), followed by the San Diego Bay site (4.8 to 8.0 m/s). Oceanside had the lowest 24-hour average wind speeds (2.0 to 5.1 m/s). All other sites had similar 24-h average wind speed ranging between 3 and 7 m/s. There were no obvious relationships observed between wind speeds and direction and deposition flux rates. In addition, from the data available, none of the sampling events were dominated by strong Santa Ana wind conditions. However, because samples were collected over a three-day period for a single sample, there were a small number of sample events for which Santa Ana winds were a factor on at least one of the sampling days.

## Dry Deposition Flux Rates

Median fluxes in $\mu g/m^2/day$ across sites ranged between 0.23 and 3.6 (chromium), 0.21 and 5.4 (nickel), 0.52 and 14 (lead), 0.89 and 29 (copper), and 4.8 and 160 (zinc; Figure 2). For all metals, flux rates were significantly different between sites (ANOVA on ranks, $p < 0.001$). The highest median fluxes were observed at the Los Angeles Harbor site for chromium, lead, nickel, and zinc. For copper, the highest median flux was observed at the San Diego Bay site, although the median flux at the Los Angeles Harbor was within the same order of magnitude. Typically, the median fluxes for all metals at the Los Angeles Harbor site were one to two orders of magnitude higher than the median fluxes at the other sites (with the exception of copper, as noted previously). The lowest median fluxes for all metals were observed at the Oxnard site. For copper, lead and zinc, all other sites had median fluxes that were at least one order of magnitude higher than the median flux at the Oxnard site.

Within-site dry deposition flux rates for all metals were within a factor of nine; most within-site dry deposition flux rates were within a factor of five or less for the Malibu, Santa Monica Bay, Los Angeles Harbor, Upper Newport Bay, and Oceanside sites (Figure 2). The greater variability observed at the Santa Barbara and Oxnard sites was due to a single high flux measurement during one sampling event for chromium, copper, and zinc. In these cases, the highest flux values were an order of magnitude higher than the next highest flux value at the site. At the San Diego Bay site, variability was within a factor of nine for chromium and lead, but was higher (up to two orders of magnitude higher) for copper, nickel and zinc.

### *Comparisons with historical data*

Chromium fluxes ranged from 1 to 16 $\mu g/m^2/day$ in 1975, compared with median fluxes of 0.22 to 3.6 $\mu g/m^2/day$ in 2006 (Figure 3). Chromium fluxes were higher at all sites in 1975 compared with 2006. Oxnard (Site 2) had the highest flux in 1975 that was two orders of magnitude greater than the median flux measured at this site in 2006. The largest single chromium flux measured in 2006 of 4.3 $\mu g/m^2/day$, measured at the Los Angeles Harbor (Site 5), was an order of magnitude lower than the largest flux measured in 1975 (Figure 3).

Copper fluxes were similar between the two time periods, ranging from 1 to 38 $\mu g/m^2/day$ in 1975, compared with median fluxes of 0.89 to 30 $\mu g/m^2/day$ in 2006 (Figure 3). Copper fluxes were generally higher in 1975, although the differences between fluxes measured in 1975 and those measured in 2006 were typically within the same order of magnitude. Exceptions were Oxnard (Site 2), Santa Monica Bay (Site 4) and Oceanside (Site 7), with 2006 fluxes higher by one to two orders of magnitude than those measured in 1975; and the San Diego Bay (Site 8), higher by one order of magnitude in 2006 than in 1975. The single highest copper measurement in 2006 (53 μg/m$^2$/day), measured at the San Diego site, was higher than the highest 1975 measurement, but within the same order of magnitude.

Lead fluxes ranged from 20 to 330 μg/m$^2$/day in 1975 compared with median fluxes of 0.5 to 14 μg/m$^2$/day in 2006 (Figure 3). For all sites, lead fluxes were one to two orders of magnitude lower in 2006 than those measured in 1975. During the 2006 study, only one site (Site 5 - Los Angeles Harbor) had lead fluxes greater than 3 μg/m$^2$/day, while all sites during the 1975 study had lead fluxes at least one order of magnitude higher than this. The four southern sites (from Los Angeles Harbor to Encinitas) in 1975 had lead fluxes greater than 100 μg/m$^2$/day. The single highest lead flux in 2006 (23 μg/m$^2$/day), measured at the Los Angeles Harbor site, was approximately the same as the lowest flux measured in 1975.

Zinc fluxes in 1975 ranged from 20 to 100 μg/m$^2$/day compared with median fluxes of 4.8 to 160 μg/m$^2$/day in 2006 (Figure 3). At most sites, zinc fluxes were higher in 1975, however, differences were typically within the same order of magnitude. An exception was Los Angeles Harbor (Site 5), in which the zinc flux in 2006 was an order of magnitude higher than in 1975. Zinc fluxes at San Diego Bay (Site 8) were also higher in 2006 than in 1975, although the difference was less than one order of magnitude.

# DISCUSSION

In southern California, variability in metal dry deposition flux rates along the coast was directly linked to proximity to urban areas. Dry deposition hotspots were observed near Los Angeles Harbor and San Diego Bay, both highly urbanized areas. Areas to the north and south of Los Angeles, and to the north of San Diego, had reduced metal flux rates by comparison. The Los Angeles Harbor site was located downwind of the harbor within a highly urbanized area, representing a mix of influences from harbor activities and nearby urban sources. The San Diego Bay site was located downwind of the harbor within an industrialized portion of the bay. Sites at Santa Barbara, Oxnard, Malibu, Hyperion and Oceanside were all located within 1 km of the coast where urbanization was less dense. Therefore, not only were these sites affected by influences associated with localized urban air, but also by cleaner offshore air masses upwind of the southern California coast during the typical southwest wind conditions that dominated the sampling period.

The median dry deposition fluxes for all metals measured at the Los Angeles Harbor site were comparable to measurements in other studies in Los Angeles and Chicago (Table 2). Except for copper, dry deposition flux rates for all sites in the present study were typically one order of magnitude lower than those measured near the Great Lakes at sites other than Chicago, possibly because under the sampling conditions in the present study, coastal sites were predominantly upwind of major sources or located in less dense urban areas. In the case of copper, both Los Angeles Harbor and San Diego Bay had similar flux rates compared with Chicago and other sites near the Great Lakes.

Within-site variability of flux rates differed according to metal and site, but was typically less than one order of magnitude in most cases. This study was designed to reduce variability within a site by concentrating the sampling during the summer months (June-September) to avoid periods of rainfall and unusual meteorological conditions (e.g., Santa Ana winds, which are more prominent during the fall). These conditions were avoided because they result in substantially reduced (in the case of rainfall) and increased (in the case of Santa Ana winds) deposition flux rates compared with the more typical chronic conditions that dominate throughout the majority of the year in southern California (Lu *et al.* 2003, Sabin *et al.* 2006). In cases for which within-site variability was greater than one order of magnitude, a single high measurement value was typically the cause. For example, the final sampling event at the Santa Barbara site had the highest dry deposition flux rates observed at this site for all metals (except lead) by one order of magnitude. During this event, the wind condition on one of the sampling days was somewhat different from previous sampling events at this site. The higher wind speeds and potential urban influence due to a change in the dominant wind direction may explain the higher deposition flux rates for all metals observed during this event compared with other events at this site. However, a more in-depth analysis of the influence of meteorological variables on dry deposition flux rates was not possible because of the limited meteorological data available for each sample event.

Differences observed between the dry deposition flux rates of metals measured in the 1970's by Young and Jan (1977) and the present study can be primarily attributed to three factors. First, sources of metals have changed across southern California since the 1970's, and the magnitude and direction (increase or decrease) of these changes varied depending on the metal. That lead fluxes were one to two orders of magnitude higher at all sites in 1975 indicates atmospheric sources of lead were lower in 2006. This was not surprising since atmospheric sources of lead have been dramatically reduced since the 1970's because of the removal of lead from automobile fuel in California in 1992 (ARB 1992). Today, the major source of atmospheric lead in California is due to resuspension of lead from historic emissions that have accumulated over many years in road dust and soil particles of urban areas (Lankey *et al.* 1998). Each year, some portion of the lead in road dust and soils is removed through stormwater runoff, thereby gradually reducing the quantity available for the next resuspension and deposition cycle.

In contrast with lead, zinc fluxes were higher in 2006 at the urban-influenced Los Angeles Harbor site than 1975 measurements, indicating atmospheric sources of zinc have increased since the 1970's. This is likely given that automobiles are a large source of airborne zinc in urban areas (Watson *et al.* 2000, Councell *et al.* 2004) and the number of vehicle miles traveled in the Los Angeles region nearly doubled in the past two decades (Crane and Ong 2004). A similar result for copper, with higher flux rates in 2006 observed at the Los Angeles Harbor and San Diego Bay sites, may also be explained by increased urban sources; in the case of the San Diego Bay site, increased activities at the naval ship yard may be a significant source of higher flux rates. However, as previously discussed, it is important to note the San Diego Bay site was not well matched geographically to the 1975 Encinitas site, the southern-most site during the 1975 study. Thus, the higher copper fluxes for the San Diego Bay site in the 2006 study may also be due, at least in part, to the difference in site location and proximity to nearby sources.

The second major reason for the differences observed between the 1975 data and the present study is the differences in the wind conditions during the two studies. The data in 1975 were all collected under desert wind conditions (Santa Ana winds). These conditions are known to increase dry deposition flux rates. Both model estimates and measurement data in Los Angeles have found metal dry deposition flux rates may increase during Santa Ana wind conditions by as much as factors of two to eight, depending on the metal (Lu *et al.* 2003, Sabin *et al.* 2005). This difference in wind conditions during sampling provides further evidence of the increase in zinc sources since the 1970's, because if sources were the same, lower zinc fluxes would be expected in the current study under the non-Santa Ana wind conditions. Santa Ana wind conditions may also explain, in part, the lower chromium flux rates in the present study relative to the 1970's because the major source of chromium has remained the same over the last three decades. The effect of Santa Ana wind conditions was less important for lead because the magnitude of the difference in flux rates between time periods was larger than the effect of wind condition alone.

The third reason for differences between the 1975 data and the present study, and an important limitation of this comparison, is the differences in the sampling methods and analysis techniques. There have been improvements in dry deposition measurement techniques since the 1970's (Lim *et al.* 2006). In particular, the deposition plates used in the present study have been compared favorable with the more traditional method of calculating deposition rates, which involved making air concentration measurements and using an assumed deposition velocity to calculate dry deposition flux rates (Lim *et al.* 2006). However, no method comparison has been done for the surrogate surfaces used by Young and Jan (1977) and the deposition plates used in the present study. This factor is most important for those metals (e.g., chromium) with the smallest difference between fluxes measured in the 1970's and those of the current study.

**Table 1. Inventory of samples collected at each site by sampling week.**

| | Site | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sampling Week | Santa Barbara | Oxnard | Malibu | Santa Monica Bay | Los Angeles Harbor | Upper Newport Bay | Oceanside | San Diego Bay |
| 27-Jun-06 | | | | | | | | 2 |
| 05-Jul-06 | 1 | 1 | 1 | 2 | | | | |
| 11-Jul-06 | | | | | | 1 | 1 | 2 |
| 18-Jul-06 | 1 | 1 | 1 | 1 | | 1 | 1 | 1 |
| 26-Jul-06 | 1 | 1 | 1 | 1 | | | | |
| 02-Aug-06 | | | | | | 1 | 1 | |
| 08-Aug-06 | 1 | 1 | 1 | 1 | | 1 | 1 | 1 |
| 16-Aug-06 | | | | | 1 | 1 | 1 | 1 |
| 22-Aug-06 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 30-Aug-06 | 1 | 1 | 1 | 1 | | | | |
| 06-Sep-06 | | | | | 1 | 2 | 1 | 1 |
| 12-Sep-06 | 1 | 1 | 1 | 1 | | | | |
| 19-Sep-06 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 26-Sep-06 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 03-Oct-06 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 17-Oct-06 | 1 | | | | 2 | | | |
| 23-Oct-06 | | | | | 3 | | | |
| 01-Nov-06 | | | | | 1 | | | |
| Number of Samples Collected at Each Site | 10 | 10 | 10 | 11 | 12 | 11 | 10 | 12 |

**Table 2. Comparison of metal dry deposition flux rates ($\mu g/m^2/day$).**

| | Chromium | Copper | Lead | Zinc |
|---|---|---|---|---|
| Lim et al., 2006 | | | | |
| Urban Sites in Los Angeles and Orange County, CA USA | | | | |
| Los Angeles River -1 | 6 | 21 | 15 | 130 |
| Los Angeles River -2 | 2.3 | 30 | 31 | 160 |
| Los Angeles River -3 | 9 | 16 | 32 | 110 |
| Ballona Creek | 2.7 | 18 | 20 | 77 |
| Dominguez Channel | 3.3 | 12 | 11 | 74 |
| Santa Ana River | 4.3 | 30 | 10 | 180 |
| Yi et al., 2001 | | | | |
| Chicago, IL USA | 5.7 | 63 | 38 | 120 |
| South Haven, MI USA | 0.7 | 31 | 23 | 51 |
| Sleeping Bear Dunes, MI USA | 1.6 | 79 | 35 | 68 |
| This Study | | | | |
| Santa Barbara | 0.34 | 2.0 | 1.3 | 14 |
| Oxnard | 0.23 | 0.89 | 0.52 | 4.8 |
| Malibu | 0.29 | 1.9 | 1.0 | 12 |
| Hyperion | 0.39 | 3.9 | 1.0 | 16 |
| Los Angeles Harbor | 3.6 | 22 | 14 | 160 |
| Newport | 0.64 | 5.1 | 1.8 | 22 |
| Oceanside | 0.48 | 4.2 | 1.4 | 40 |
| San Diego Bay | 0.99 | 29 | 3.3 | 63 |

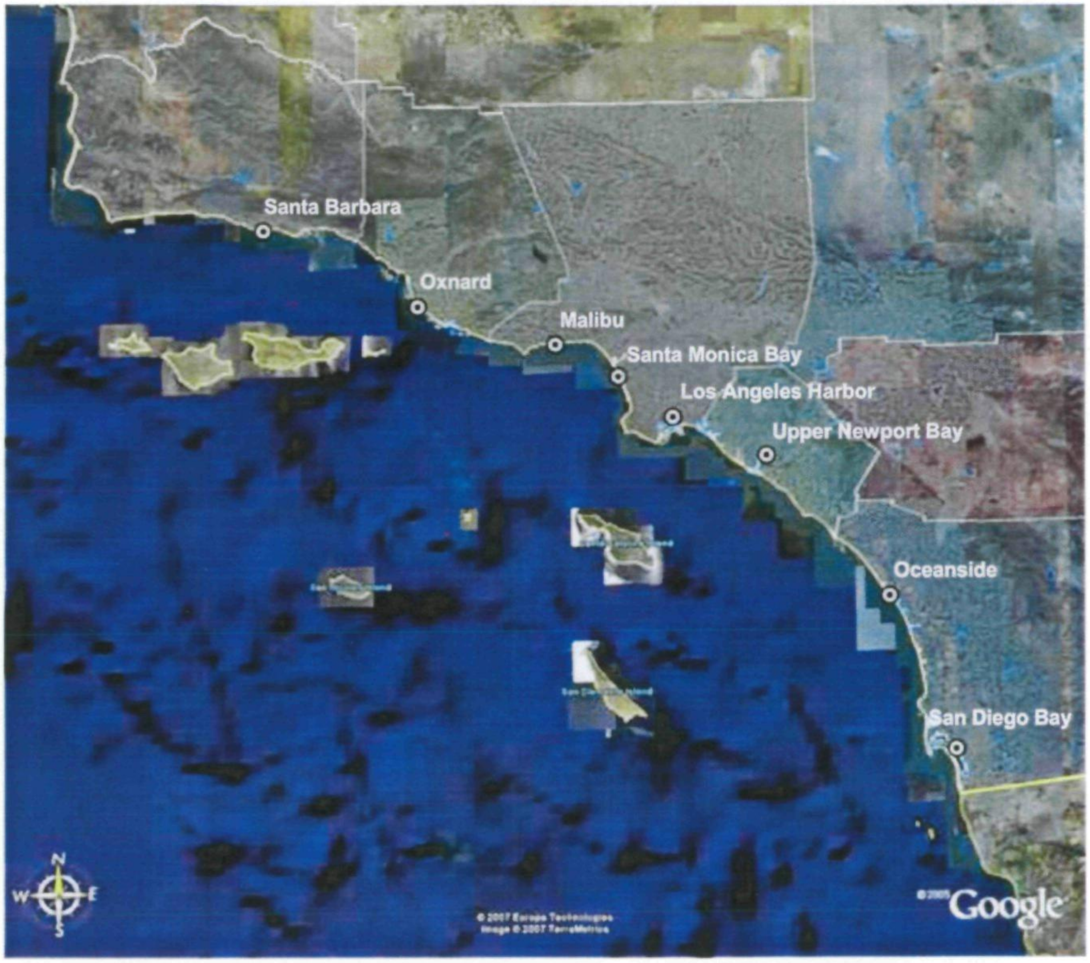


**Figure 1. Eight sampling sites along the Southern California coast.**

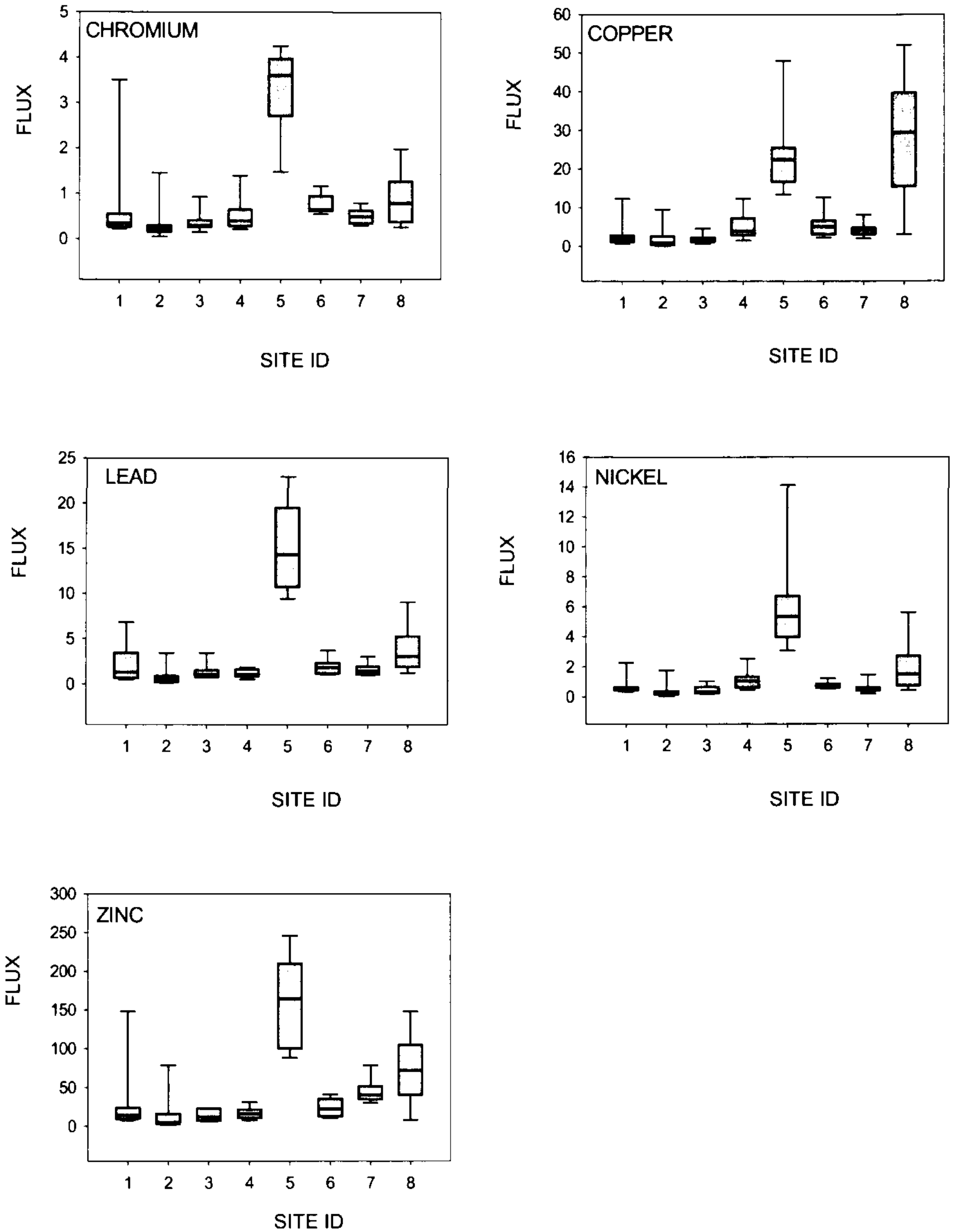


**Figure 2. Metal dry deposition flux (µg/m$^2$/day) at eight sites on a north-south transect along the southern California coast. Box plots represent medians and interquartile ranges. Error bars indicate the 10$^{th}$ and 90$^{th}$ percentiles.**

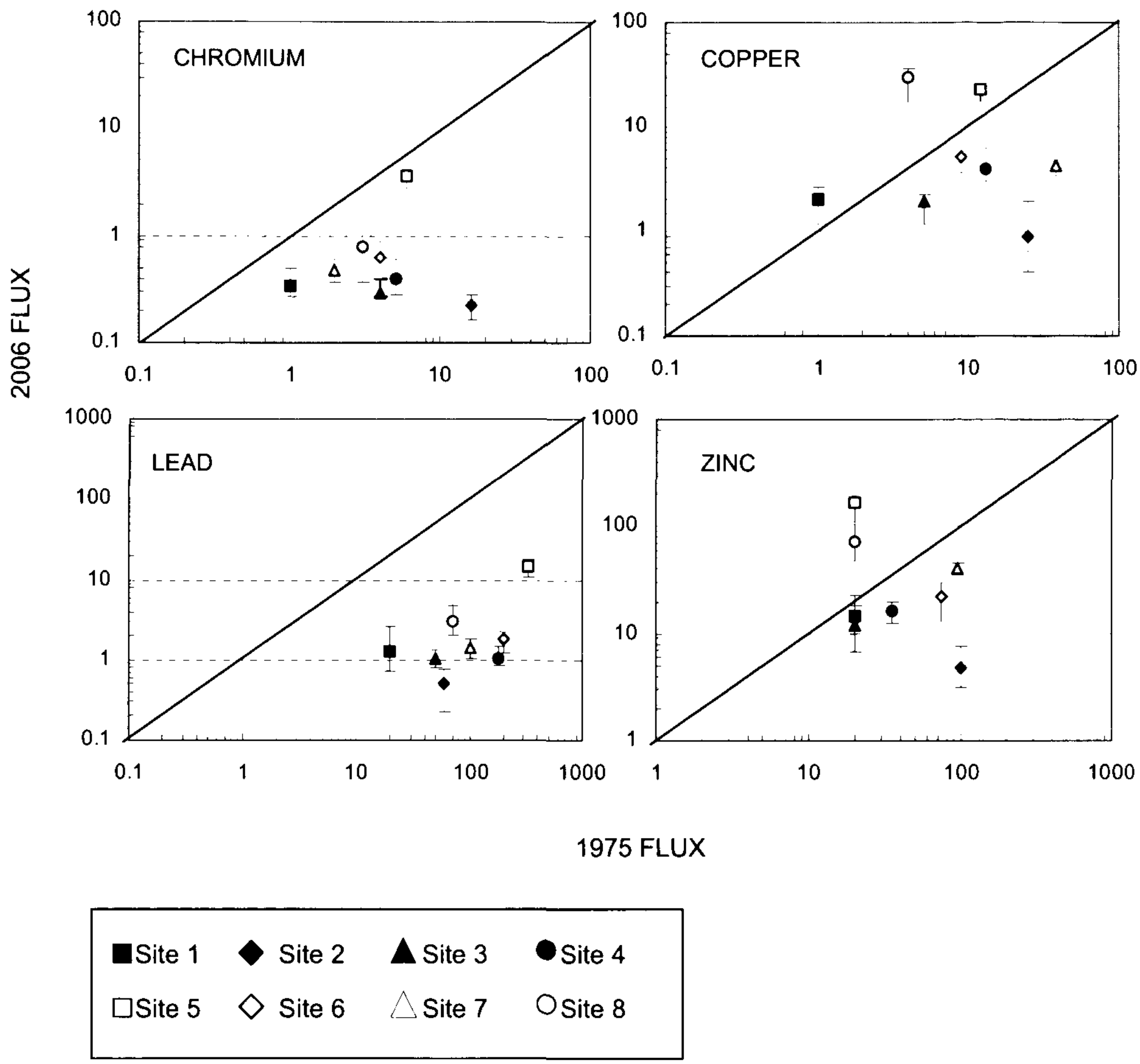


**Figure 3. Comparison of 1975 and 2006 metal dry deposition flux rates (μg/m²/day). Error bars indicate the 25th and 75th percentiles for the 2006 data.**

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FLOW/SCIENCE®

August 22, 2007

Mr. Jeremy Haas
California Regional Water Quality Control Board, San Diego Region
9174 Sky Park Court, Suite 100
San Diego, CA 92123

Re: Public Comments Regarding Revised Tentative Order No. R9-2007-0002, NPDES No. CAS01087420
Waste Discharge Requirements for Discharges or Urban Runoff from the Municipal Separate Storm Sewer Systems (MS4s) Draining the Watersheds of the County of Orange, the Incorporated Cities of Orange County, and the Orange County Flood Control District Within the San Diego Region (July 6, 2007)

Dear Mr. Haas,

Please find attached a copy of a report entitled "Review of Bacteria Data from Southern California Watersheds," prepared by Flow Science Incorporated in April 2005. This report describes a study that was conducted to evaluate concentrations of indicator bacteria in wet and dry weather flows from both developed and undeveloped watersheds in southern California. The study was conducted to determine if runoff would meet water quality criteria, and to assess the differences, if any, in concentrations of indicator bacteria in runoff from developed and undeveloped watersheds.

The primary dataset reviewed in the report consists of indicator bacteria concentrations measured in flows from several coastal watersheds located in southern Orange County; these data were collected by Orange County and span a time period of 1986-2004. These data demonstrate that criteria for indicator bacteria are frequently exceeded by fresh water creek and river flows, and that exceedances occur even for flows from largely natural, undeveloped watersheds with little human influence. These data showed exceedances from both developed and undeveloped watersheds during both dry and wet weather periods. Data from the Orange County watersheds showed that the level of development within these watersheds had little if any effect on the concentrations of indicator bacteria in receiving waters.

We are providing this report to you with the expectation that these data will be taken into account in the development of the above-referenced permit. Please contact us if you have any questions.

Sincerely,

Susan C. Paulsen

Susan C. Paulsen, Ph.D., P.E.
Vice President and Senior Scientist

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# REVIEW OF BACTERIA DATA FROM SOUTHERN CALIFORNIA WATERSHEDS

Reviewed By

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## SUMMARY

Available data from Southern California watersheds demonstrate that both existing and EPA-recommended bacteria water quality criteria are routinely exceeded in fresh water creek and river flows, often by one or more orders of magnitude. Exceedances of criteria occur even for flows from largely natural, undeveloped watersheds with little human influence. Even in urbanized watersheds, there is strong evidence that the predominant source of indicator bacteria may be natural (not anthropogenic) – including, for example, bacteria from wildlife, birds, and regrowth within the environment, including sediments. Both measurement data and numerous literature sources have shown that both wet and dry weather bacteria concentrations frequently exceed objectives in creeks and rivers, and that bacteria concentrations rise dramatically during wet-weather periods.

Data from Orange County coastal watersheds indicate that although bacteria in storm water runoff may be elevated within urban storm drain systems, the level of development within these watersheds has little if any effect on the concentrations of indicator bacteria in the receiving waters. These results are consistent with data from other watersheds within Orange County and in other parts of Southern California. No clear trend is evident in bacteria concentrations over time, with concentrations remaining relatively steady, even in areas where land use characteristics have changed over time. Both the concentrations of bacteria in runoff and the impacts of elevated bacteria concentrations on downstream water quality appear to vary by site and with the size of the contributing stream, and thus are likely a function of the dominant sources of bacteria, local hydrologic conditions and climate, and other site-specific factors.

## INTRODUCTION

Flow Science has conducted a study of available data and information on the concentrations of indicator bacteria in storm water and dry weather runoff. The goals of this study were to evaluate variations in the concentrations of bacteria during both wet and dry conditions, variations in bacteria levels with the level of development in a watershed or drainage area, changes in bacteria levels over time or with changes in development or land use areas, and the sources of bacteria in runoff and in receiving waters.

In conducting the analysis, Flow Science utilized water quality criteria and thresholds to evaluate available data. These thresholds were obtained from the Water Quality Control Plan (Basin Plan) for the Santa Ana Region, which contains fecal coliform water quality objectives for inland surface waters that apply to the beneficial uses of water contact recreation (REC-1)[1] and non-water contact recreation (REC-2)[2], from proposed EPA water quality criteria, and from Title 17 "beach posting" thresholds. These thresholds are discussed in greater detail below.

Flow Science evaluated data on bacteria concentrations in Southern California. Data were available for watersheds along the Newport Coast, for inland watersheds, and from Los Angeles County. In addition, Flow Science reviewed literature and studies conducted by others.

## BACKGROUND: BACTERIA WATER QUALITY STANDARDS

The Basin Plan bacteria objectives currently contained in the Santa Ana Basin Plan were originally developed by the National Technical Advisory Committee (NTAC) to the Federal Water Pollution Control Administration in 1968.[3] These recommendations were based upon prospective

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[1] See Basin Plan at p. 4-6: "REC-1 Fecal coliform: log mean less than 200 organisms/100 mL based on five or more samples/30 day period, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period."

[2] See Basin Plan at p. 4-6: "REC-2 Fecal coliform: average less than 2000 organisms/100 mL and not more than 10% of samples exceed 4000 organisms/100 mL for any 30-day period."

[3] See *Water Quality Criteria, a Report of the National Technical Advisory Committee to the Secretary of the Interior*, Federal Water Pollution Control Administration: Washington, D.C., April 1, 1968, at p. 8 and p. 12:

"Surface waters should be suitable for use in "secondary contact" recreation – activities not involving significant risks of ingestion – without reference to official designation of recreation as a water use. For this purpose, in addition to aesthetic criteria, surface waters should be maintained in a condition to minimize potential health hazards by utilizing fecal coliform criteria. In the absence of local epidemiological experience, the Subcommittee recommends an average not exceeding 2,000 fecal coliforms per 100 ml and a maximum of 4,000 per 100 ml, except in specified mixing zones adjacent to outfalls."

epidemiological studies conducted by the United States Public Health Service in 1948, 1949, and 1950. These studies found an "epidemiologically detectable health effect" at levels of 2300 to 2400 coliforms per 100 ml at bathing beaches on Lake Michigan (at Chicago) and in the Ohio River. Later work conducted in the mid-1960s showed that approximately 18% of the coliforms present in the mid-1960s at the Ohio location belonged to the fecal coliform subgroup. The recreational contact water quality criteria suggested by the committee were based upon the fraction of coliforms present as fecal coliforms and a factor of safety of two.

The fecal coliform standards recommended in 1968 were adopted by many states and municipalities and remain in use in many locations (including in the Santa Ana Region). Several studies conducted since 1968 have questioned these criteria and recommended use of alternatives.[4] As early as 1972, a Committee formed by the National Academy of Science-National Academy of Engineers noted the deficiencies in the study design and data used to establish the recreational fecal coliform criteria, and stated that it could not recommend a recreational water quality criterion because of a paucity of valid epidemiological data (Committee on Water Quality Criteria, 1972).

In response to these concerns, EPA in 1972 initiated studies at marine and freshwater bathing beaches that were designed to correct the deficiencies in the earlier studies and analyses. These studies were conducted at sites contaminated either with pollution from multiple point sources (usually treated effluents that had been disinfected) or by effluents discharged from single point sources. The studies examined three bacterial indicators of fecal pollution (*E. coli*, enterococci, and fecal coliforms) and found that fecal coliform densities showed "little or no correlation" to gastrointestinal illness rates in swimmers. In contrast, a good correlation was found between swimming-associated gastrointestinal symptoms and either *E. coli* or enterococci in swimming waters (Dufour, 1984). Based on these studies, EPA in 1986 proposed section 304(a) criteria for full body contact recreation based upon *E. coli* and/or enterococci but noted that "it is not until their adoption as part of the State water quality standards that the criteria become regulatory" (USEPA, 1986).

EPA's current recommendations for bacteria water quality objectives (USEPA, 2003) include the use of *E. coli* and/or enterococci as the basis for water quality criteria to protect fresh recreational waters and the use of enterococci as the basis for marine water quality criteria. The EPA recommends that the use of fecal coliform be discontinued for both freshwater and marine

---

"Fecal coliforms should be used as the indicator organism for evaluating the microbiological suitability of recreation waters. As determined by multiple-tube fermentation or membrane filter procedures and based on a minimum of not less than five samples taken over not more than a 30-day period, the fecal coliform content of primary contact recreation waters shall not exceed a log mean of 200/100 ml, nor shall more than 10 percent of total samples during any 30-day period exceed 400/100 ml."

[4] For a summary of these studies, see the discussion provided on pages 1-3 of the *Ambient Water Quality Criteria for Bacteria — 1986*, USEPA 440/5-84-001, January 1986.

waters. EPA's recommendations recognize that bacteria concentrations are quite variable and are best characterized in terms of a probability distribution. Because bacteria concentrations tend to follow log-normal distributions, EPA's current recommendations specify that compliance should be based upon geometric means computed with data collected over a long-term (e.g., 30 days, or seasonally) and "upper percentile values," clarifying that compliance should not be determined using "single sample maximum" values. Upper percentile values are calculated bacteria densities that are intended to correspond to a known geometric mean-based risk level, and are intended to be used to interpret any single measurement. EPA recommends that states acquire enough sample data to calculate site-specific upper percentile values to characterize water quality for waters where exposure is greatest (e.g., bathing beaches). EPA's recommended water quality criteria for freshwater and marine waters are presented in Tables 1 and 2.

**Table 1. Water quality criteria for bacteria recommended by EPA for fresh recreational waters**

| Risk level[a] [% of swimmers] | Geometric mean density [per 100 ml] | Upper Percentile Value Allowable Density [per 100 ml] | | | |
|---|---|---|---|---|---|
| | | 75th percentile | 82nd percentile | 90th percentile | 95th percentile |
| Enterococci criteria | | | | | |
| 0.8 | 33 | 62 | 79 | 107 | 151 |
| 0.9 | 42 | 79 | 100 | 137 | 193 |
| 1.0 | 54 | 101 | 128 | 175 | 247 |
| *E. coli* criteria | | | | | |
| 0.8 | 126 | 236 | 299 | 409 | 576 |
| 0.9 | 161 | 301 | 382 | 523 | 736 |
| 1.0 | 206 | 385 | 489 | 668 | 940 |

a) The risk level corresponds to the anticipated excess illness rate. For example, a risk level of 0.8% is believed to correspond to an illness rate of 8 gastrointestinal illnesses per 1,000 swimmers in excess of background illness rates.

**Table 2. Water quality criteria for enterococci recommended by EPA for marine recreational waters**

| Risk level[a] [% of swimmers] | Geometric mean density [per 100 ml] | Upper Percentile Value Allowable Density [per 100 ml] | | | |
|---|---|---|---|---|---|
| | | 75th percentile | 82nd percentile | 90th percentile | 95th percentile |
| 0.8 | 4 | 13 | 20 | 35 | 63 |
| 0.9 | 5 | 16 | 24 | 42 | 76 |
| 1.0 | 6 | 19 | 29 | 50 | 91 |
| 1.1 | 8 | 23 | 35 | 61 | 110 |
| 1.2 | 9 | 28 | 42 | 73 | 133 |
| 1.3 | 11 | 34 | 51 | 89 | 161 |
| 1.4 | 14 | 41 | 62 | 107 | 195 |
| 1.5 | 17 | 49 | 75 | 130 | 235 |
| 1.6 | 20 | 60 | 91 | 157 | 284 |
| 1.7 | 24 | 72 | 109 | 189 | 344 |
| 1.8 | 29 | 87 | 132 | 229 | 415 |
| 1.9 | 35 | 105 | 160 | 276 | 502 |

a) The risk level corresponds to the anticipated excess illness rate. For example, a risk level of 0.8% is believed to correspond to an illness rate of 8 gastrointestinal illnesses per 1,000 swimmers in excess of background illness rates.

The Santa Ana Region currently continues to utilize fecal coliform bacteria to assess water quality applicable to recreational beneficial uses. However, the Santa Ana Regional Board is currently conducting a triennial review of its Basin Plan, and is including an evaluation of recreational beneficial use designations and water quality objectives as part of the Basin Plan update process. We currently anticipate that the Santa Ana Regional Board will likely update fresh water bacteria water quality objectives; updated objectives may be consistent with the recommendations contained in EPA's November 2003 Implementation Guidance (see Tables 1 and 2).

## ADDITIONAL GUIDELINES FOR BACTERIA

Although not enforceable as water quality objectives, Orange County beaches and bays are "posted" and access may be restricted when exceedances of certain bacteria levels are observed. The "posting" levels are described in Title 17 of the California Code of Regulations, Section 7958 (Bacteriological Standards):

The minimum protective bacteriological standards for waters adjacent to public beaches and public water-contact sports areas shall be as follows:

(1) Based on a single sample, the density of bacteria in water from each sampling station at a public beach or public water contact sports area shall not exceed:

(A) 1,000 total coliform bacteria per 100 milliliters, if the ratio of fecal/total coliform

bacteria exceeds 0.1; or
(B) 10,000 total coliform bacteria per 100 milliliters; or
(C) 400 fecal coliform bacteria per 100 milliliters; or
(D) 104 enterococcus bacteria per 100 milliliters.

(2) Based on the mean of the logarithms of the results of at least five weekly samples during any 30-day sampling period, the density of bacteria in water from any sampling station at a public beach or public water contact sports area, shall not exceed:
(A) 1,000 total coliform bacteria per 100 milliliters; or
(B) 200 fecal coliform bacteria per 100 milliliters; or
(C) 35 enterococcus bacteria per 100 milliliters.

## COMPARISON LEVELS USED IN THIS REPORT

Flow Science used the following numeric values in analyzing available bacteria data:

Fecal Coliform (from existing Santa Ana Basin Plan water quality standards and Title 17 beach "posting" requirements):
- Single Sample: 400 MPN (or CFU)/100mL[5].
- Geometric Mean: 200 MPN (or CFU)/100mL.

Enterococci (from EPA-recommended criteria):
- Single Sample: 247 MPN (or CFU)/100mL.
- Geometric Mean: 54 MPN (or CFU)/100mL.

Total Coliform (from Title 17 beach "posting" requirements):
- Single Sample: 10,000 MPN (or CFU)/100mL.
- Geometric mean: 1,000 MPN (or CFU)/100mL.

Enterococci criteria used by Flow Science in this report correspond to a proposed 1.0% acceptable risk level, 95$^{th}$ percentile, while fecal and total coliform criteria correspond to beach posting levels. Of course, the beach "posting" requirements apply at the beach, not in upstream freshwater flows, but the numeric values provide a useful threshold value against which data can be compared.

[5] Basin Plan specifies no more than 10% of single samples to exceed this value

## MONITORING DATA AND RESULTS

Flow Science examined data on bacteria concentrations from a variety of sources in the Santa Ana Region, including streams in coastal watersheds, the Santa Ana River, and inland streams. Data sources included:

- Bacteria concentrations in stream flows from Orange County coastal watersheds
- Bacteria concentrations in freshwater bodies in the Santa Ana region
- Bacteria concentration in runoff samples collected by the Los Angeles County Department of Public Works

Data from each of these sources are examined in greater detail below.

### Review of Data from Orange County Coastal Watersheds

Flow Science has reviewed data from Orange County samples collected between 1986 through 2004.[6] Figures for Orange County coastal watersheds are shown in Appendix A; watersheds and data collection locations are shown in Figures A1-2. Figures A3, A4, and A5 present long-term geometric mean concentrations, calculated as the geometric mean concentration of all available samples (including both wet and dry weather samples) for the period of record, of enterococci, fecal coliforms, and total coliforms, respectively. As shown in Figure A3, long-term geometric mean concentrations of enterococci exceed EPA's proposed freshwater enterococci water quality criteria in all the coastal creeks for which data were available. Similarly, long-term geometric mean concentrations of fecal coliform in most Newport Coast creeks exceed existing Santa Ana Basin Plan REC-1 fecal coliform water quality criteria. Figures A6, A7, and A8 present long-term geometric mean concentrations of enterococci, fecal coliform, and total coliforms plotted against the percent of development within each watershed. There is no apparent correlation for any of the three indicator bacteria presented in these figures with amount of the watershed that has been developed. Note that Figures A6 through A8 utilize the current (2005) level of development for each watershed.[7]

[6] Data were obtained from http://www.ocbeachinfo.com/downloads/data/index.htm on February 11 and March 22, 2005. For enterococci, data were available from March 30, 1999, through December 21, 2004. For fecal coliform and total coliform, data were available from January 7, 1986, through December 21, 2004. No data were available for *E. coli*.

[7] The area of watershed that was developed was initially established by PBS&J in 1999 (PBS&J, 1999). These values have been subsequently updated based on information from 2005. Two watersheds experienced significant development between 1999 and 2005: the Crystal Cove Creek watershed increased from ~5% to ~70% developed, and the Muddy Creek watershed increased from ~1% to ~60% developed. The level of development within the other coastal watersheds remained approximately constant.

To facilitate analysis, individual samples were segregated as follows: wet-weather[8], summer dry-weather[9], and winter dry-weather.[10] As shown in Figure A9, wet weather samples exceed single sample threshold values most frequently, regardless of which indicator bacteria are sampled (72%, 61%, and 39% of wet-weather enterococci, fecal coliform, and total coliform samples, respectively, exceed single sample thresholds). Summer dry weather samples exceed thresholds less frequently than wet-weather samples, and winter-dry weather samples exceed thresholds least frequently. The single sample thresholds used to calculate the percent of samples in exceedance are 247, 400, and 10,000 MPN/100mL for enterococci, fecal coliform, and total coliform, respectively.

Figures A10 through A53 present the following information for each site: a) a time-series scatter plot of single sample concentrations of enterococci, fecal coliform, and total coliform for the wet and dry weather data, b) wet and dry weather cumulative distribution functions for each bacteria, and c) the percentage of individual samples that exceed corresponding thresholds in each month. From this analysis, the following conclusions may be reached:

1. Lowest geometric mean concentrations of each of the three bacteria (enterococci, fecal coliform, and total coliform) occurred at the Pelican Hill Waterfall station (watershed 95% developed, primarily golf course), and highest geometric mean concentrations of each bacteria occurred at the Emerald Bay Drain station (watershed 3% developed). In the Muddy Creek watershed, which experienced substantial development between 1999 and 2005 (see footnote 7), enterococci concentrations appear to have decreased as the watershed became more developed. Trends were less evident for fecal and total coliform levels. Similar patterns emerged in data from the Crystal Cove Creek watershed, the other watershed that experienced significant development between 1999 and 2005. Enterococci and fecal coliform concentrations appear to have decreased, while any trends in the total coliform record are unclear. These results indicate that bacteria concentrations in creeks may decline as the level of development increases, and bacteria concentrations in runoff from developed watersheds may be lower than runoff from creeks in less developed coastal areas.

2. No relationship was found between the percentage of the watershed developed and the long-term geometric mean bacteria concentrations (see Figures A6, A7 and A8).

3. The time series plots indicate that concentrations of indicator bacteria are not increasing over time. By visual inspection, bacteria concentrations may be

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[8] "Wet-weather" samples are those samples that were collected within two days of a rainfall event greater than or equal to 0.1 inches as measured by the Newport Beach Harbor Station.

[9] "Summer dry-weather" samples are defined as samples collected from April-November, but not within two days of rainfall greater than or equal to 0.1 inches as measured by the Newport Beach Harbor Station.

[10] "Winter dry-weather" samples are defined as samples collected from December-March, but not within two days of rainfall greater than or equal to 0.1 inches as measured by the Newport Beach Harbor Station.

decreasing over the data record in five catchments (Pelican Point Creek, Muddy Creek, Emerald Bay Drain, El Morro Creek upstream station, and Crystal Cove Creek). At the remaining six stations, no apparent long-term trend in bacteria concentration is observed. Very little if any correlation is evident between long-term trends and percentage of watershed developed, as the apparent slight decrease in bacteria concentrations was observed in watersheds that range from 1-95% developed.

4. Although Figure A9 shows that taken as a whole, wet-weather samples have higher concentrations than dry-weather samples, data from some locations show the opposite trend. At Pelican Point Creek (95% developed), dry weather concentrations for enterococci and fecal coliform are higher than wet weather concentrations. At the Emerald Bay Drain (3% developed), fecal and total coliform dry weather concentrations are significantly greater than wet weather concentrations. At El Morro Creek (1% developed), Broadway Creek (25% developed), and Crystal Cove Creek upstream station (70% developed) there is no significant difference (by visual inspection of Figures A34-36, A50-52, and A38-40, respectively) between wet and dry weather bacteria concentration distributions.

5. The general observation that winter dry-weather samples on average contain fewer bacteria than summer dry-weather samples is evident in many of the scatter plots. Figures A10, A34, A38, A42, and A46 (presenting data from Pelican Point Creek, El Morro Creek, Crystal Cove Creek upstream, Crystal Cove Creek, and Buck Gully) illustrate this behavior most clearly.

These results are consistent with the results from an earlier study (PBS&J, 1999) in which long-term geometric mean concentrations of bacteriological data from November 1996-October 1999 were evaluated.

**Bacteria Concentrations in Inland Waters in the Santa Ana Region**

As part of the activities conducted by the Stormwater Quality Standards Task Force, CDM has compiled bacteriological data from several agencies within the Santa Ana Region (CDM, 2005). The CDM study included data collected and compiled by Orange County, the Regional Water Quality Control Board (Region 8), the Santa Ana Watershed Project Authority, the County of San Bernardino, the County of Riverside, the United States Environmental Protection Agency (EPA), the United States Geological Survey, and Orange County Coastkeeper. Select figures produced by CDM in this study are shown in Appendix B. CDM performed an overview analysis of all bacteria data collected, and reached the following broad-based and general conclusions:

1. Concentrations of indicator bacteria in samples collected from inland water bodies very frequently exceed existing Basin Plan fecal coliform water quality objectives and EPA-proposed *E. coli* criteria.

2. Bacteria concentrations in samples obtained from upstream, largely undisturbed areas are typically lower than those in samples from downstream areas affected by urbanized land uses. Concentrations in upstream samples are more frequently below water quality objectives and proposed criteria than downstream samples.

3. Winter dry-weather samples are more likely to meet objectives than summer dry-weather samples, consistent with results from the Orange County coastal watersheds.

CDM also conducted a detailed analysis of six sites[11] for which long-term data records were available. These six sites exhibited varying degrees of urbanization and channel modification. A map showing the locations of these six sites is shown in Appendix B as Figure B1. Detailed results from these stations are reproduced in Appendix B as Figures B2 through B13. Land use distributions for the areas tributary to the study sites are shown in Table 3.

**Table 3. Approximate land use distributions in the watersheds of CDM's six detailed study sites**

| Site | % Vacant | % Residential | % Commercial | % Industrial | % Other |
|---|---|---|---|---|---|
| Chino Cr.[a] | 3.2 | 61.3 | 16.7 | 9.7 | 9.1 |
| Santa Ana Delhi Channel | 0.9 | 52.4 | 26.0 | 9.2 | 11.5 |
| Temescal Cr. | 67.3 | 16.2 | 2.4 | 3.4 | 10.7 |
| Santa Ana R. at Imperial Highway[b] | - | - | - | - | - |
| Santa Ana R. at MWD Crossing[c] | - | - | - | - | - |
| Icehouse Canyon Creek | 100 | 0 | 0 | 0 | 0 |

a) Chino Creek land use data are for portion of watershed downstream of San Antonio Dam.
b) CDM concluded that any potential relationship between land use and bacteria concentrations in this reach of the Santa Ana River is likely masked by the interception of flows by Prado Dam; consequently, no data land use data were available in the CDM report for this site.
c) CDM did not include land use statistics for this station in its report. The report states that land use is "diverse...a combination of commercial, residential, industrial, and agricultural lands. The upper part of the watershed includes natural undeveloped lands...Residential land is dispersed throughout the contributing area."

11 The six sites examined by CDM include: Chino Creek at Schaeffer Avenue, the Santa Ana Delhi Channel, Temescal Creek at Lincoln Avenue, the Santa Ana River at Imperial Highway, the Santa Ana River at the Metropolitan Water District crossing, and Icehouse Canyon Creek in the Angeles National Forest.

By examining these sites in detail, CDM found the following:

1. In streams where flow rate data are available, high bacteria counts are in many cases but not always associated with high flow events (presumably caused by rainfall). Bacteria concentrations in samples collected from Chino Creek at Schaeffer Avenue (Figure B2) and the Santa Ana Delhi Channel (Figure B3) are frequently elevated and do not exhibit any apparent correlation with flow rate in the channel. In Temescal Creek (Figure B4) and the Santa Ana River at the MWD crossing (Figure B5), the data are widely scattered and patterns are difficult to detect. In the Santa Ana River at Imperial Highway (Figures B6-7), data show that bacteria levels are elevated during high flow events and the levels remain elevated for 1-2 days after the high flow has receded.

2. Bacteria concentrations appear to be decreasing over time at three locations (Chino Creek at Schaeffer Ave. (data record 2002-2004), Santa Ana River at MWD Crossing (data record 1984-2004), and Santa Ana River at Imperial Highway (data record 1981-2004)). At the other three locations, no long-term trends are apparent.

3. All sites except Icehouse Canyon Creek have regularly exceeded current or proposed water quality objectives. As mentioned previously, concentrations at the two Santa Ana River sites have shown a decreasing trend, and since 1998 most samples have been at or below objective levels. Icehouse Canyon Creek, at elevation 5,100 feet in the Angeles National Forest, has only one sample (of 40 total samples; a fecal coliform measurement of 9,400 MPN/100mL) in the data record that does not comply with existing or anticipated water quality objectives, indicating that runoff from remote, undeveloped, forested catchments at higher elevations may have significantly lower bacteria levels than runoff from lower elevation watersheds, including undeveloped watersheds at lower elevations. Figures B8-13 show, for each of the six sites, the percent of months in which single sample thresholds are exceeded when samples are classified as summer dry, winter dry, or wet-weather.

**Los Angeles County Monitoring Data**

Los Angeles County has prepared an Integrated Receiving Water Impacts Report (Los Angeles County, 2001), which includes bacteria concentrations measured in runoff collected downstream of catchments that exhibited primarily single land use types. Los Angeles County data for indicator bacteria for several major land use types are shown in Table 4 (adapted from Table 4-12 of the L.A. County report).

**Table 4. Bacteria concentration means, medians and coefficients of variation (C.V.) from Los Angeles County Land Use Sites**

| | Total Coliform | | | Fecal Coliform | | | Enterococcus | | |
|---|---|---|---|---|---|---|---|---|---|
| **Land Use Type** | **Mean** | **Median** | **CV[a]** | **Mean** | **Median** | **CV[a]** | **Mean** | **Median** | **CV[a]** |
| **Commercial** | 1,140,000 | 1,250,000 | 0.71 | 528,750 | 90,000 | 1.35 | 86,250 | 40,000 | 1.18 |
| **Vacant** | 9,187 | 2,200 | 1.25 | 1,397 | 500 | 2.60 | 679 | 500 | 0.98 |
| **High density S.F. residential** | 1,366,667 | 1,600,000 | 0.30 | 933,333 | 900,000 | 0.70 | 610,000 | 140,000 | 1.41 |
| **Transportation** | 692,500 | 600,000 | 0.82 | 328,750 | 205,000 | 1.22 | 32,000 | 32,000 | 0.65 |
| **Light industry** | 454,000 | 160,000 | 1.42 | 338,220 | 30,000 | 2.09 | 98,200 | 130,000 | 0.73 |

a) "CV" refers to "Coefficient of Variation", calculated by dividing the standard deviation by the mean.

The data shown in Table 4 demonstrate that significantly lower bacteria concentrations were observed in runoff from vacant land areas than in other land use types. These data were collected by Los Angeles County in Sawpit Creek, downstream of Monrovia Creek, in the City of Monrovia; this catchment is in the San Gabriel Mountains in a very steep, sparsely vegetated area far from the ocean. Low concentrations of indicator bacteria from the Sawpit Creek watershed are consistent with low concentrations in samples collected from Icehouse Canyon Creek, both mountainous, high elevation watersheds. These results differ from observations from the Orange County coastal watersheds, which indicate no relationship between percentage development in a watershed and bacteria concentrations. The differences are most likely due to differences in catchment characteristics, local climate, the numbers and types of wildlife present, or to other factors. In any case, both the mean and median concentrations observed for each Los Angeles County land use type exceeded applicable water quality thresholds.

Los Angeles County also measured bacteria concentrations in several "mass emission" stations. These stations were sited to capture runoff from major Los Angeles County watersheds that generally have heterogeneous land use, with the objective of estimating pollutant loads to the ocean and of identifying long-term trends in pollutant concentrations, where possible. The mass emission stations include Malibu Creek (watershed 6% impervious; measurement station near Malibu Canyon Road), Ballona Creek (watershed 45% impervious; measurement station between Sawtelle Boulevard and Sepulveda Boulevard in Los Angeles), the Los Angeles River (watershed 35% impervious; measurement station between Willow Street and Wardlow Road in Long Beach), and the San Gabriel River (watershed 30% impervious; measurement station below the San Gabriel River Parkway in Pico Rivera).

In addition to the land use data reported in Table 4, Los Angeles County reached a number of conclusions using data collected at these mass emission stations. The following conclusions are cited directly from the Los Angeles County report (2001):

- The Malibu Creek station appears to have consistently lower [bacteria] counts than other mass emission stations.

- Every wet weather mass emission bacteria sample taken exceeded the public health criteria for indicator bacteria. All of the dry weather bacteria samples taken for the low flow diversion projects exceeded the public health criteria. Most of the dry weather mass emission bacteria samples taken exceeded the public health criteria. Wet weather flows contained bacteria densities at much higher levels (three to four orders of magnitude) than dry weather flows.

- Except for 1996-97, densities observed during the first storm of each rainy season were not necessarily higher than during consecutive storm events, suggesting that there was no consistent "first-flush" effect in these watersheds. Peak densities were observed at different times each year. In 1995-96, the peak density at all four mass emission stations and one land use station coincided with the peak storm of the season.

- Except for somewhat lower [bacteria] densities at Malibu Creek, there was no seasonal or regional consistency in cell densities. There was a very wide range of densities for all stations.

Consistent with data from Orange County coastal watersheds, the Los Angeles County data show that samples collected during wet-weather exhibit significantly higher bacteria concentrations than samples collected during dry weather.

## ADDITIONAL DATA ON SOURCES AND CONCENTRATIONS OF BACTERIA IN RUNOFF

Numerous additional studies and data reports have shown a correlation between elevated bacteria concentrations and rainfall events in Southern California. This correlation is evident in data collected from a variety of environments. For example, elevated concentrations of indicator bacteria have been observed during wet weather conditions at Huntington Beach (Boehm et al.,2002; Kim et al., 2004; Reeves et al., 2004), and northern Orange County and Santa Cruz County (Dwight et al., 2004).

Several studies also indicate that runoff from undeveloped watersheds contains bacteria concentrations that exceed relevant water quality standards. For example, storm water runoff from the head of the Rose Creek watershed in the San Diego Region contains levels of indicator bacteria well in excess of water quality objectives, even though this area is non-urban, contains no sewer lines or lift stations, and is restricted from public access (Schiff and Kinney, 2001). Moore (2001) found that concentrations of indicator bacteria in San Juan Creek sampling stations reflecting rural land uses exceeded water quality criteria, and that rainfall events resulted in higher bacteria concentrations at both rural and urban sites than dry weather. (Moore (2001) also found that storm drains can be major sources of dry weather bacteria pollution.)

The level or type of development is not necessarily indicative of bacteria levels in runoff, or of the presence of human-derived bacteria. In Mission Bay, a highly urbanized watershed, extensive efforts have been made to eliminate human sources of bacteria by repairing the sanitary sewer system and diverting dry weather flows to a local waste water treatment plant. Source tracking studies suggest that human sources contribute a minor fraction of the total fecal inputs to the Bay, and yet violations of water quality standards continue to occur (see Colford et al., 2005, and references therein). Pednekar et al. (2005) also found that changes in land use associated with the development of agricultural lands[12] within watersheds tributary to Newport Bay did not have a significant impact on bacteria loads, stating "The storm loading rate of coliform...appears to be unaffected by the dramatic shift away from agricultural land-use."

A number of studies have indicated that runoff from urban areas may not be the sole or even the primary source of elevated bacteria concentrations in receiving waters, but that such elevated levels may be caused by non-human sources, such as terrestrial wildlife and birds or even local sediments. Studies conducted at Huntington Beach have indicated that there may be many sources of indicator bacteria to the surf zone, including urban runoff, flow from adjacent wetlands, birds, and sediments (Grant et al., 2001). A recent study by Noblet et al. (2004) indicates that birds may be the source of high concentrations of indicator bacteria at the mouth of the Santa Ana River and in the nearby surf zone, and suggested that local sediments may be the source of fecal steroids, indicating the presence of fecal-associated material in the sediments. Another study by the Los Angeles Regional Water Quality Control Board (2004) erected a bird exclusion structure on Cabrillo Beach, and found that bacteria levels below the structure were reduced up to 60% compared to levels measured outside the structure, while exceedances of water quality standards were reduced by 65% below the structure. The Los Angeles Regional Board also reported that "high bacterial densities may be largely from the beach itself."

Other studies have provided additional evidence that the bacteria found in creeks may result from natural, not urban, sources. Orange County recently studied the efficacy of several best management practices (BMPs) for reducing bacteria concentrations in Aliso Creek, Orange County, California. Results of this study have been summarized by GeoSyntec (2005) (attached as Appendix C). The BMPs that were evaluated include 1) a multimedia filtration and UV sterilization system, and 2) wetland ponds. The study, which was conducted during dry weather, found that both BMPs greatly reduced concentrations of indicator bacteria[13], but that bacteria levels rebounded within a short distance downstream of the BMPs. In the case of the filtration/sterilization, the geometric mean concentration of fecal coliform increased from 317 cfu/100mL at the outlet of the BMP to

[12] Tributary creeks to Newport Bay studied by Pednekar et al. include the San Diego Creek (SDC) and the Santa Ana Delhi Channel (SAD). The SDC watershed remained between 52-60% developed over the study period. Agricultural land-use decreased from 34% to 2%, while commercial land-use increased from 1% to 10%, industrial land-use from 2% to 20%, and residential land-use from 11% to 25%. The SAD watershed remained between 88-92% developed over the study period. Agricultural and residential land-use decreased while commercial land-use increased from 3% to 15% and industrial land-use increased from 19% to 33%.

[13] In comparing influent and effluent, multimedia filtration/UV sterilization resulted in a 99.6% reduction in fecal coliform concentration; wetland ponds achieved a 90-99% reduction in fecal coliform concentrations.

2575 cfu/100mL in a natural channel at a distance of 35 feet downstream of the BMP. In the case of the wetland ponds, effluent was routed through a pipe approximately 200 feet long to the monitoring station, which recorded concentrations approximately two times greater than what could be accounted for based on mass-balance calculations. However, uncertainty in flow measurements, data variability, and the fact that ~37% of the flow is not intercepted by the wetlands indicate that regrowth is not the only possible explanation for the unexpectedly high bacteria concentrations at the pipe outlet.

The link between bacteria concentrations in rivers and streams and downstream water quality, including surf zone water quality, has been examined by a number of authors in addition to those cited above. PBS&J (1999) found that even though Newport coastal creek waters contained high concentrations of indicator bacteria, it did not appear that these waters had a significant impact on bacteria concentrations in the surf zone. Ahn et al. (2005) found that while storm water runoff from the Santa Ana River may lead to "very poor" surf zone water quality, the impact on the surf zone was generally confined to <5 km around the river outlet. Pednekar et al. (2005) studied bacteria concentrations in Newport Bay, California, and found that approximately 70% of the variability in the coliform record could be attributed to rainfall, implying that storm water runoff from the surrounding watershed is a primary source of coliform in Newport Bay. A difference in scale may account for the different conclusions reached by different studies – the Ahn et al. and Pednekar et al. studies found significant impacts on surf zone water quality by examining large creeks and rivers, while PBS&J's conclusion that creek water quality does not significantly affect surf zone water quality is based on a study of small to medium sized creeks – and clearly highlights the need for site-specific evaluations of bacterial water quality.

Presumably, the source of bacteria affects its pathogenicity and risk to human health, but data on human health risks from non-human source bacteria are scarce. Some studies (see, e.g., Schroeder et al., 2002) call into question whether the presence or concentration of indicator bacteria in urban runoff has any relationship with the possible presence of human pathogens. Schroeder et al. sampled paved and grass areas of parks, roofs, residential lawns, ponds, storm drains and similar surfaces to characterize the microbial community that may be present in urban water. Each sample was tested for indicator organisms (coliforms, fecal coliforms, *E. coli*, and enterococci), viruses (adenovirus, enterovirus, hepatitis A virus, and rotavirus), bacteria (enterohemorrhagic Escherichia coli, enterotoxigenic Escherichia coli, Shigella, Salmonella, and Staphylococcus aureus), and protozoa (Giardia lamblia and Cryptosporidium parvum). The study states found that although pathogens can be found in urban drainage, "there does not appear to be a relationship between the presence of pathogens and the concentration or presence of indicator organisms." Of particular note, a recent epidemiological study of health risks due to swimming in Mission Bay (Colford et al., 2005), where concentrations of indicator bacteria are believed to be predominantly from non-human sources, concluded that the risks of swimming-related illness were uncorrelated with exceedances of state water quality thresholds or with levels of indicator bacteria.

In conclusion, the available data from Southern California indicate that bacteria concentrations are often elevated in runoff from both urban and undeveloped watersheds, particularly during wet weather conditions. The level of development appears to have little effect on bacteria concentrations in storm flows. There is no clear trend in bacteria concentrations over time, with concentrations remaining relatively steady, even in areas where land use characteristics have changed over time. Available data also indicate that multiple sources may contribute to high concentrations of indicator bacteria, including natural sources such as wildlife, birds, and sediments. Regrowth within the environment also occurs, resulting in elevated bacteria concentrations even downstream of the point where relatively bacteria-free flows enter natural channels or man-made conveyances. Finally, the impact of high bacteria concentrations on downstream water quality appears to vary by location and conditions.

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# APPENDIX A

## DATA FROM ORANGE COUNTY COASTAL CREEKS

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**Figure A 1: Location of coastal catchments and surf zone areas along the Newport Coast.**

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**Figure A 2: Additional detail on the catchment areas (information collated from the PBS&J report, 1999 and updated 2005).**

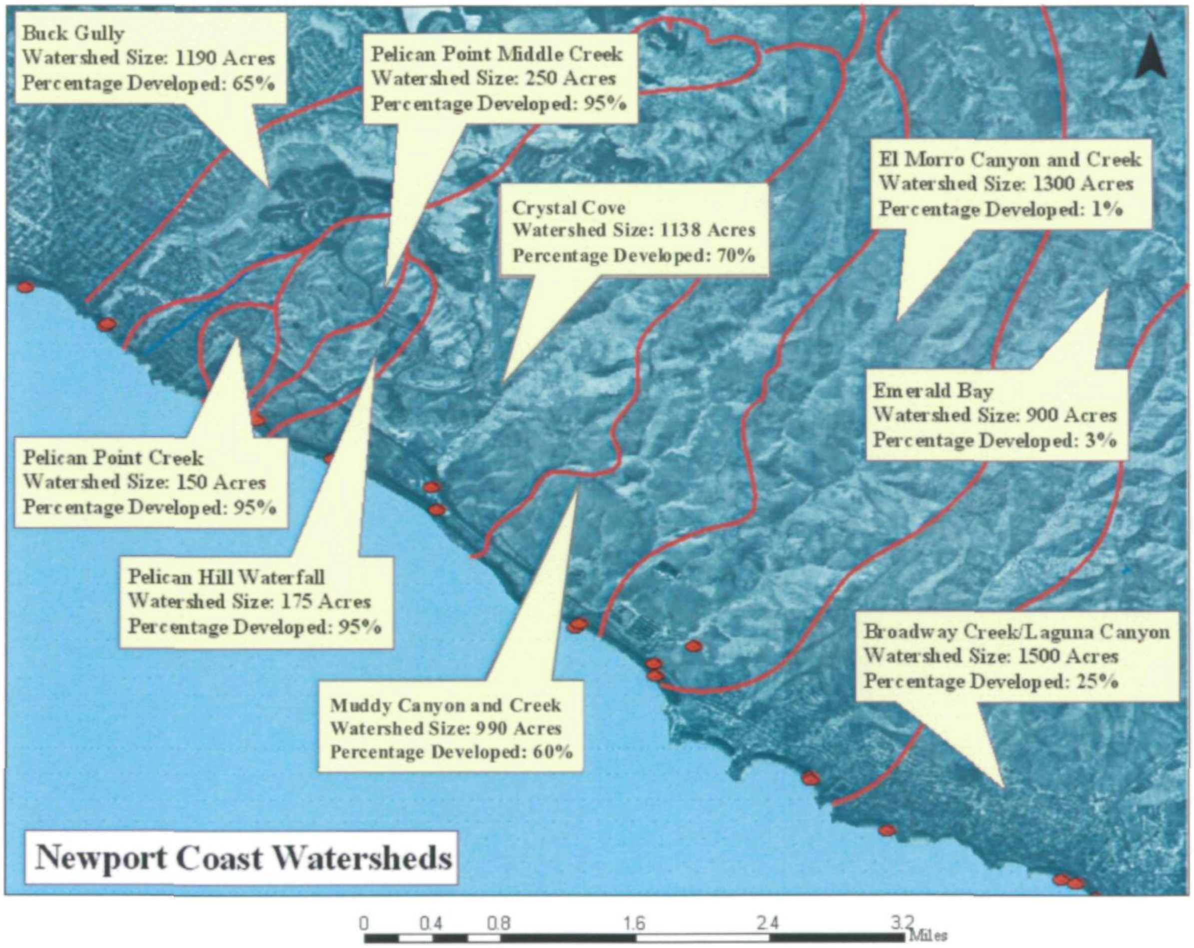

**Figure A 3: Long-term geometric mean concentration for enterococci (data from 3/30/99 to 12/21/04). Dashed line represents EPA's suggested 30-day geometric mean water quality criterion for enterococci corresponding to a 1.0% risk level.**

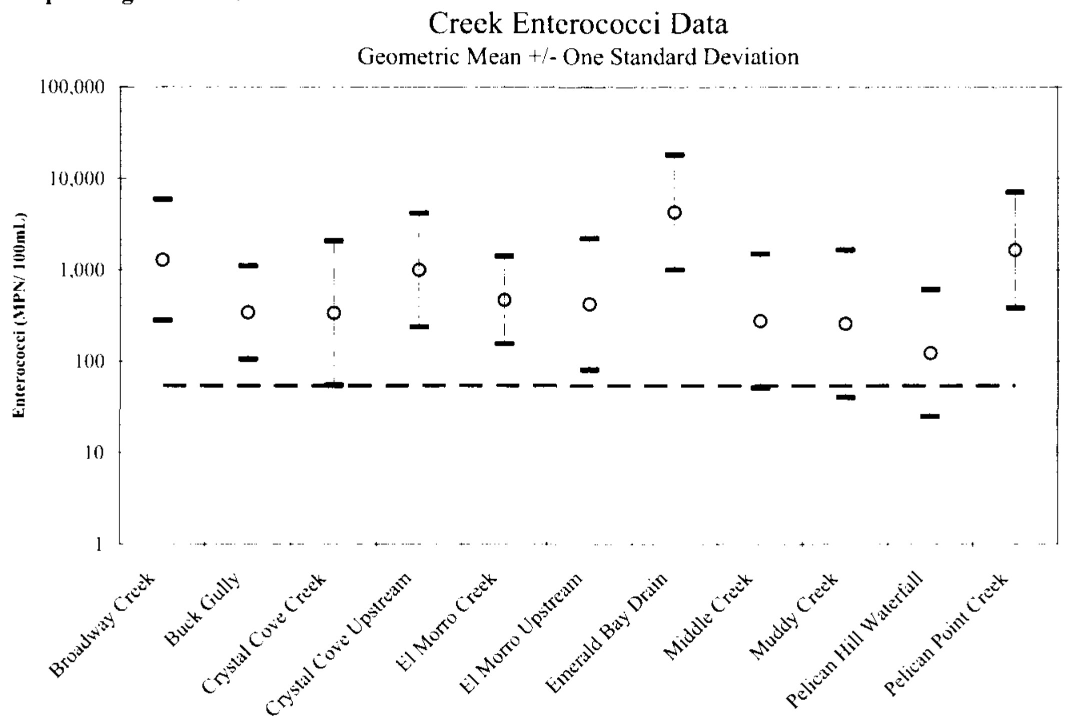


**Figure A 4: Long-term geometric mean fecal coliform concentrations (data from 1/7/86 to 12/21/04). Dashed line corresponds to the current Santa Ana Basin Plan water quality criterion for 30-day log mean (geometric mean) fecal coliform concentrations.**

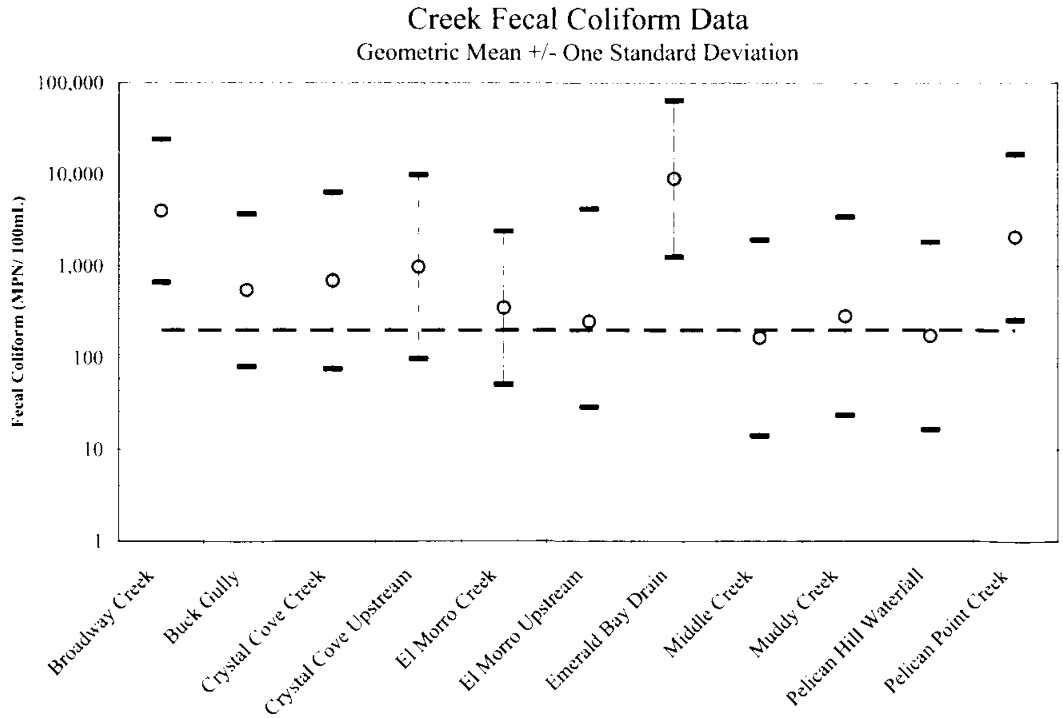

**Figure A 5: Long-term geometric mean concentrations for total coliform (data from 1/7/86 to 12/21/04)**

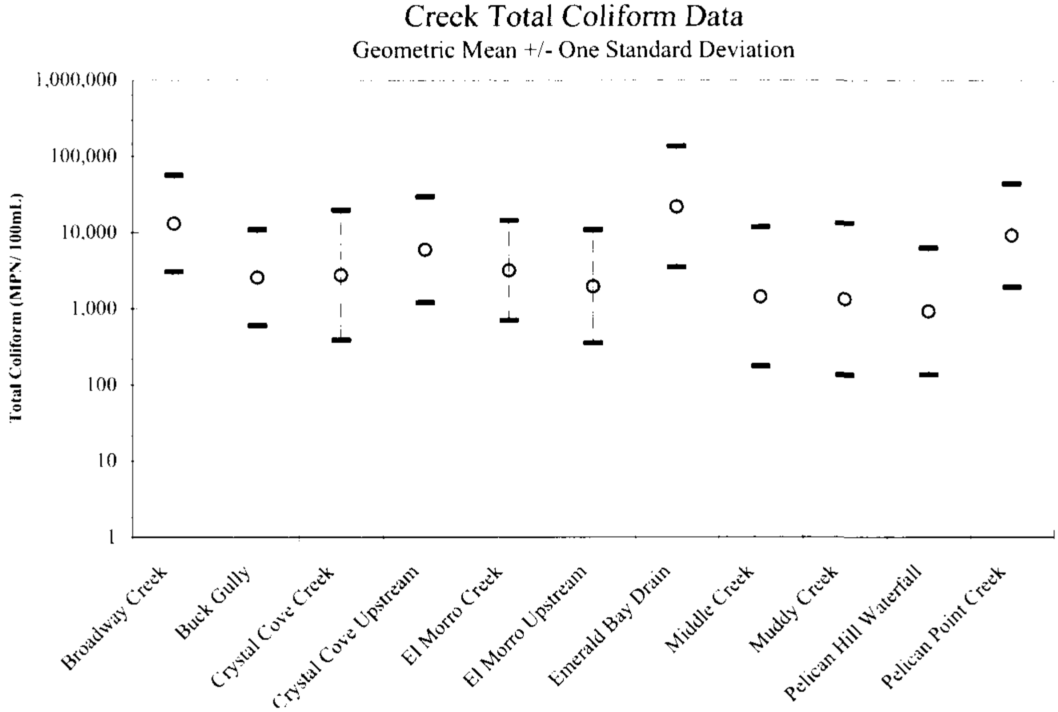


**Figure A 6: Relationship between % developed and the long-term geometric mean enterococci concentration (data from 3/30/99 to 12/21/04). Dashed line represents EPA's suggested 30-day geometric mean water quality criterion for enterococci corresponding to a 1.0% risk level.**

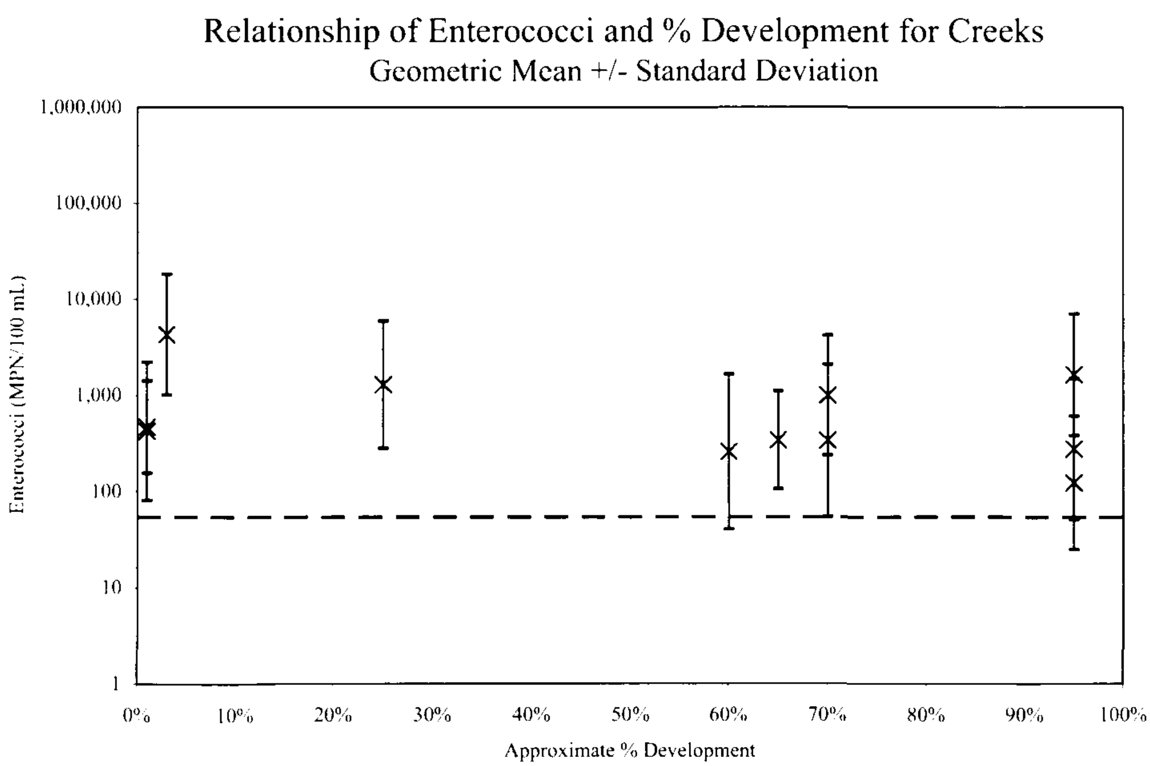

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**Figure A 7: Relationship between % developed and the long-term geometric mean fecal coliform concentration (data from 1/7/86 to 12/21/04). Dashed line corresponds to the current Santa Ana Basin Plan water quality criterion for 30-day log mean (geometric mean) fecal coliform concentrations.**

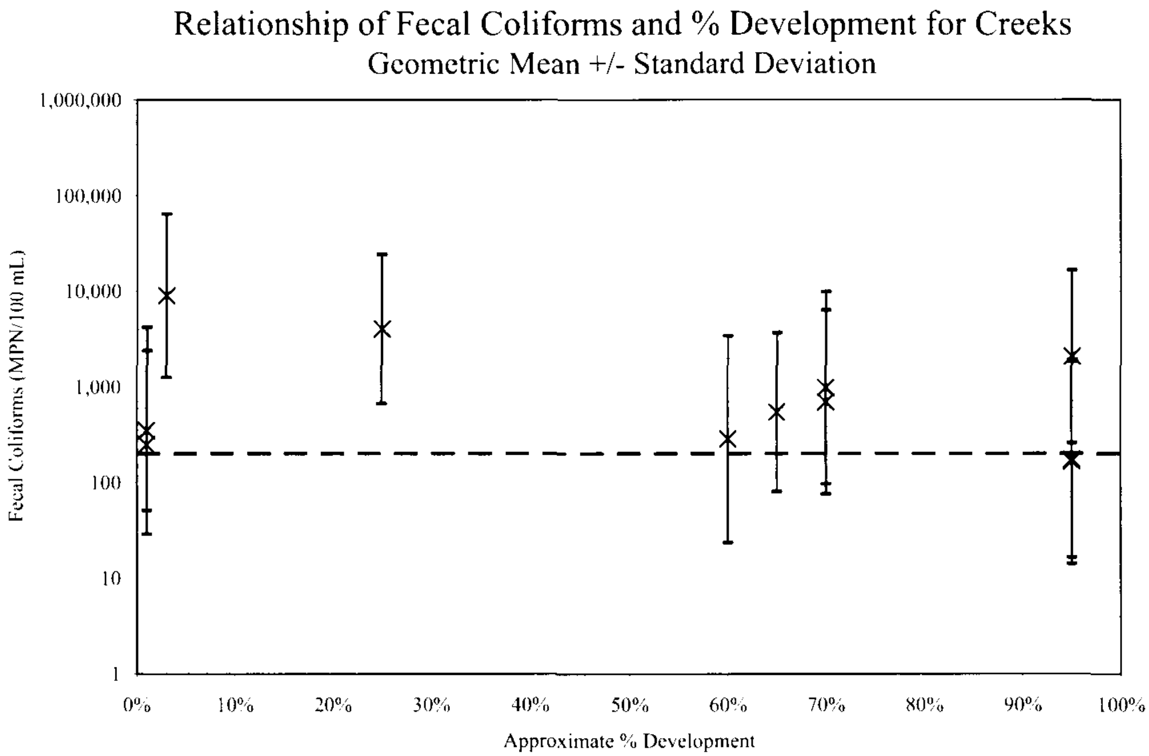

**Figure A 8: Relationship between % developed and the long-term geometric mean total coliform concentration (data from 1/7/86 to 12/21/04).**

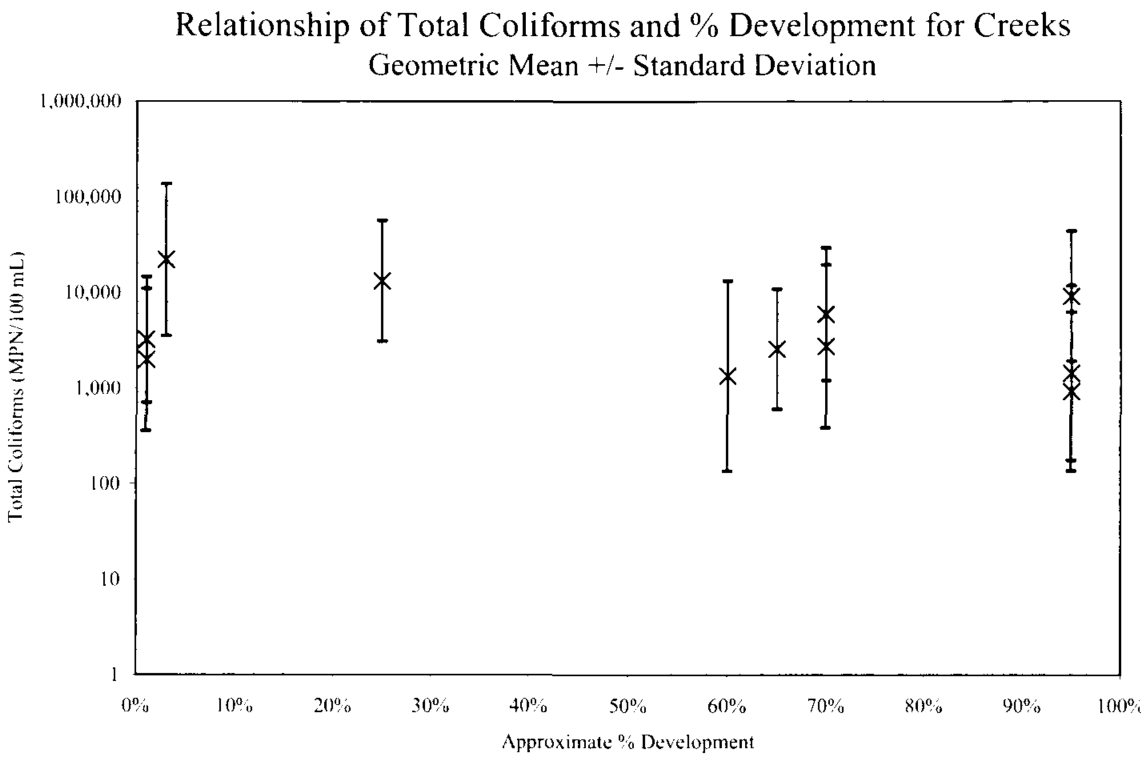

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**Figure A 9: Percent of samples in exceedance of thresholds by weather type (data from 1/7/86 to 12/21/04 for total and fecal coliform and from 3/30/1999 to 12/21/04 for enterococci). "Wet" data are those within two days of rainfall totaling 0.1" or greater at Newport Harbor. "Summer Dry" samples were collected from April-November, but not within two days of 0.1" or more of rain. "Winter Dry" samples were collected from December-March, but not within two days of 0.1" or more of rain. Threshold values against which data were compared are 247, 400, and 10,000 MPN/100mL, for enterococci, fecal coliform, and total coliform, respectively.**

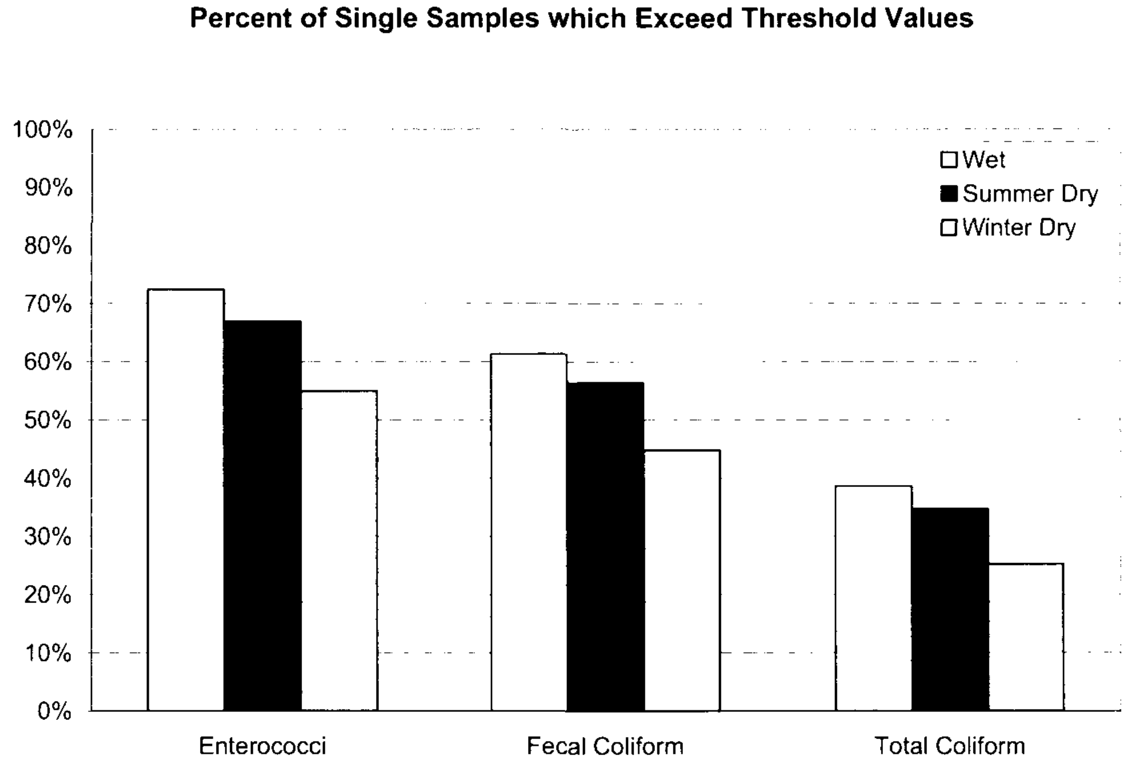
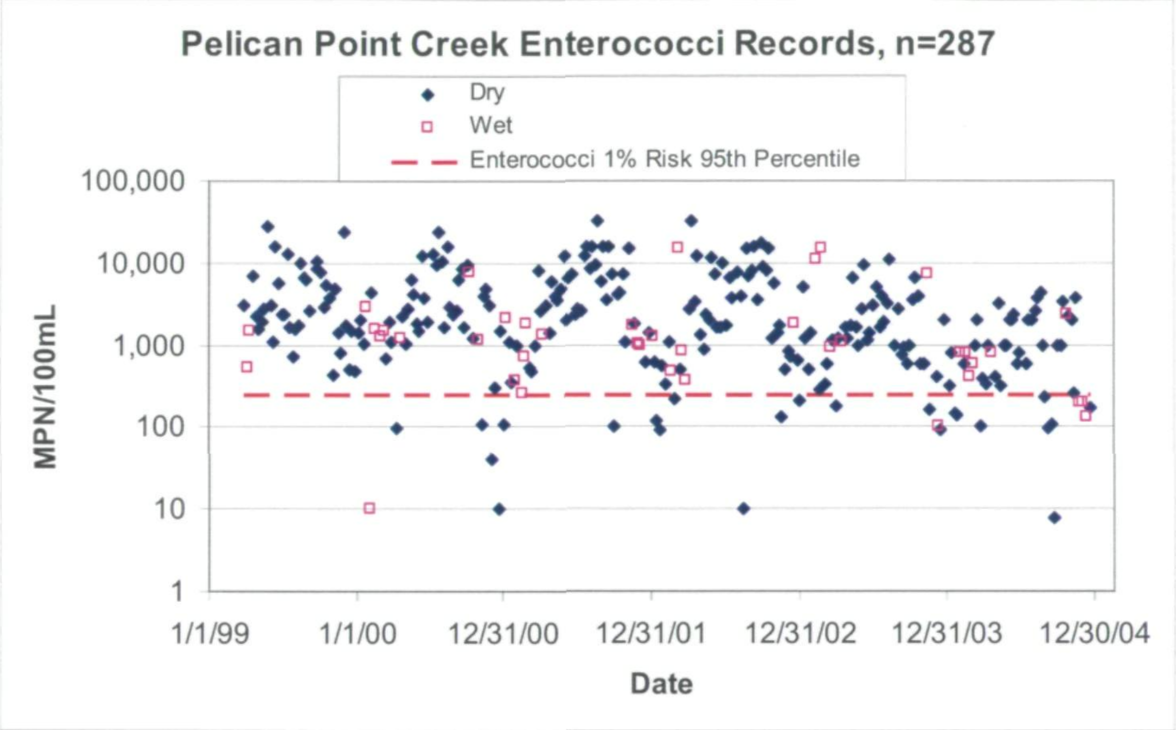


Figure A 10: Pelican Point Creek enterococci data and corresponding cumulative frequency distribution



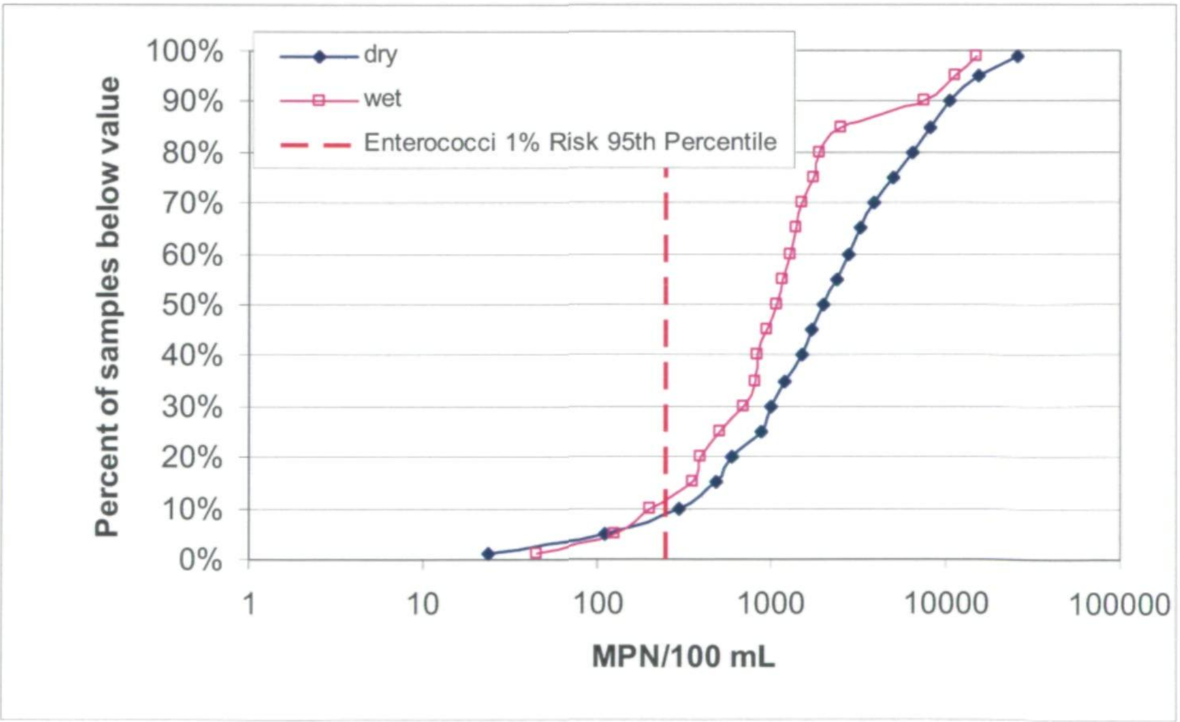
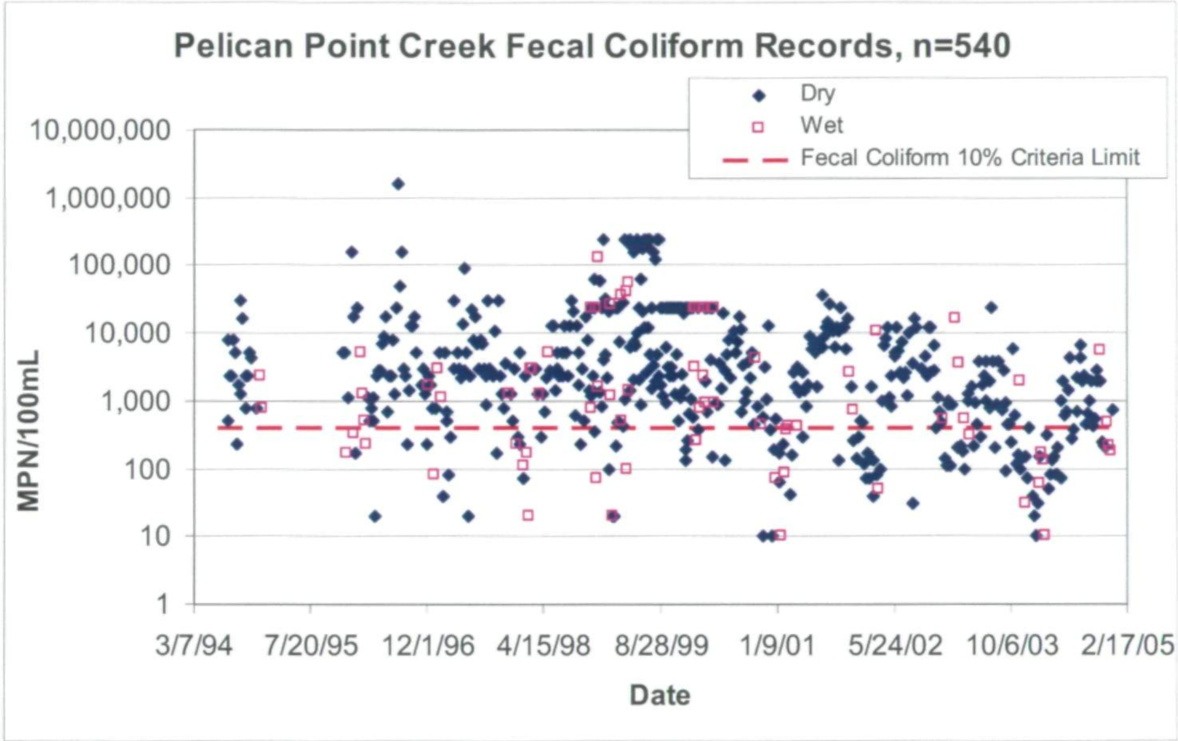



**Figure A 11: Pelican Point Creek fecal coliform data and corresponding cumulative frequency distribution**



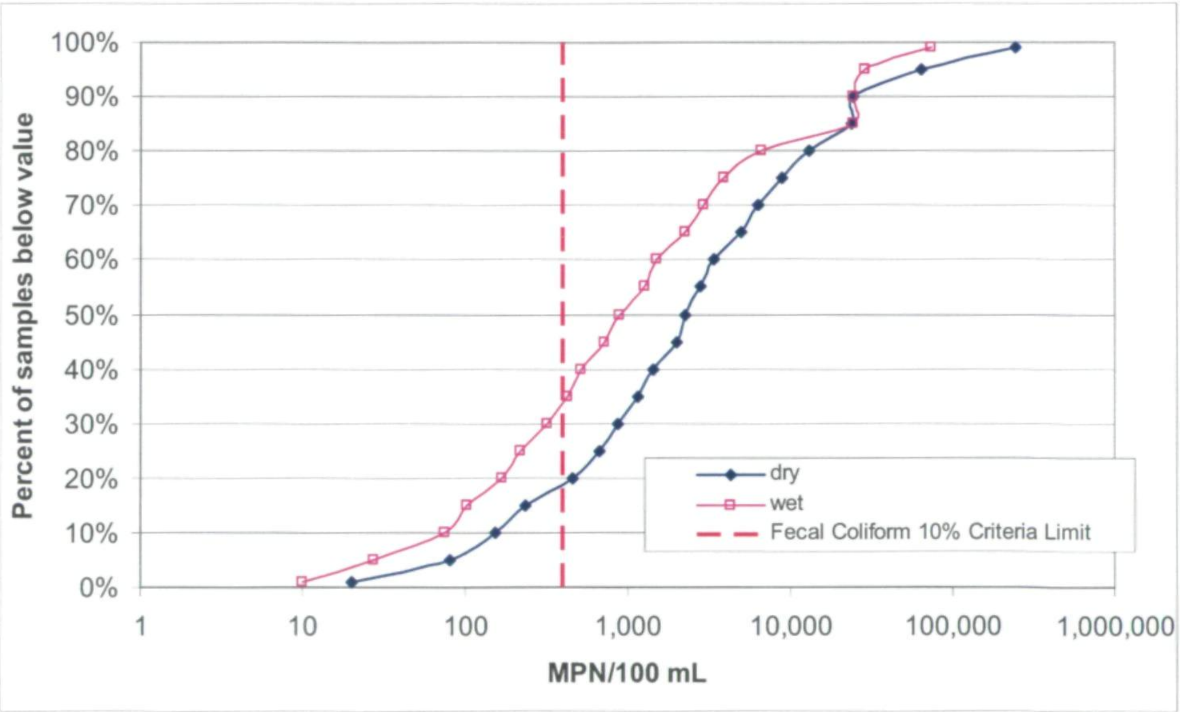



Figure A 12: Pelican Point Creek total coliform data and corresponding cumulative frequency distribution

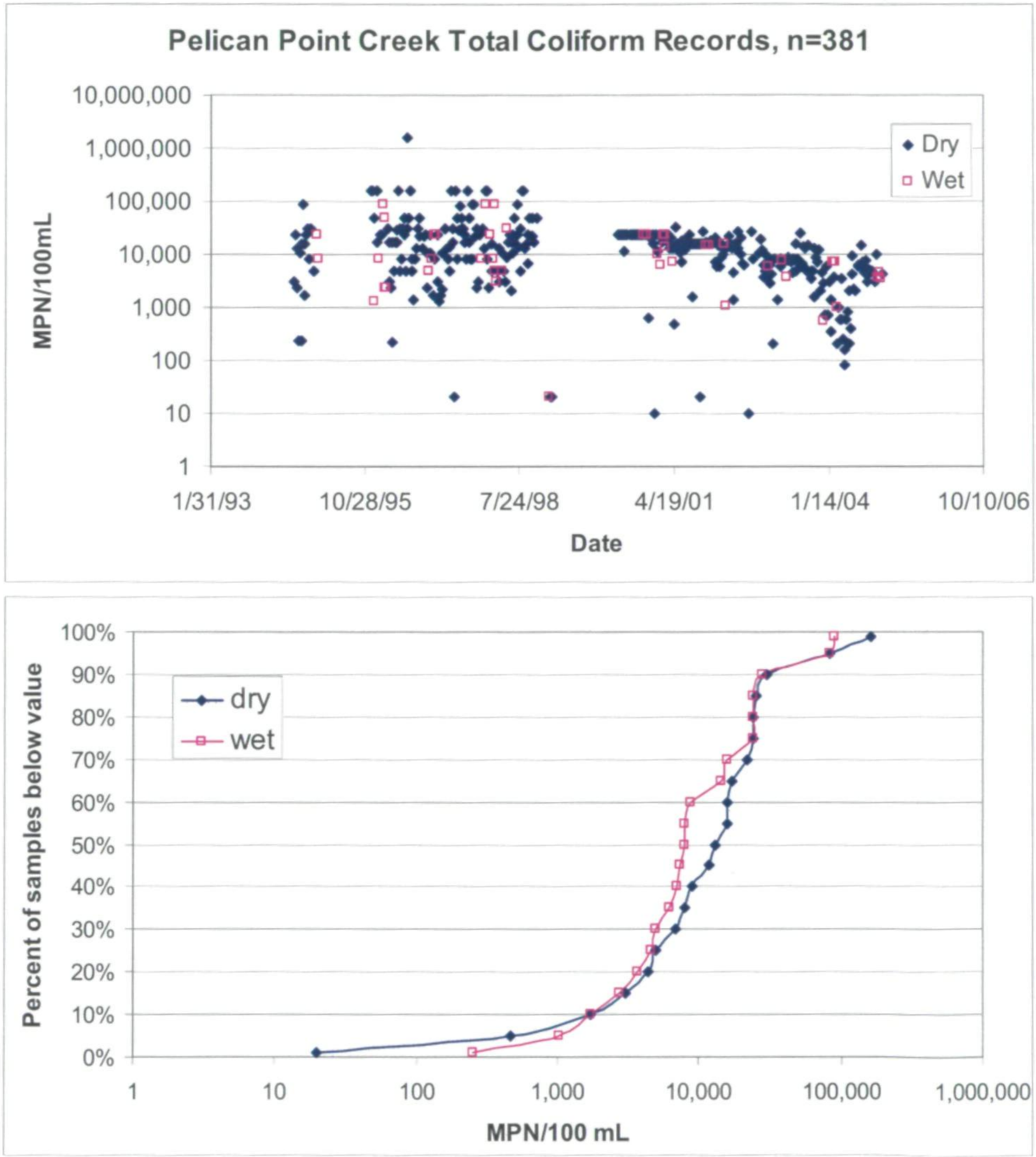


Figure A 13: Percentage of samples from Pelican Point Creek which exceed thresholds, by month

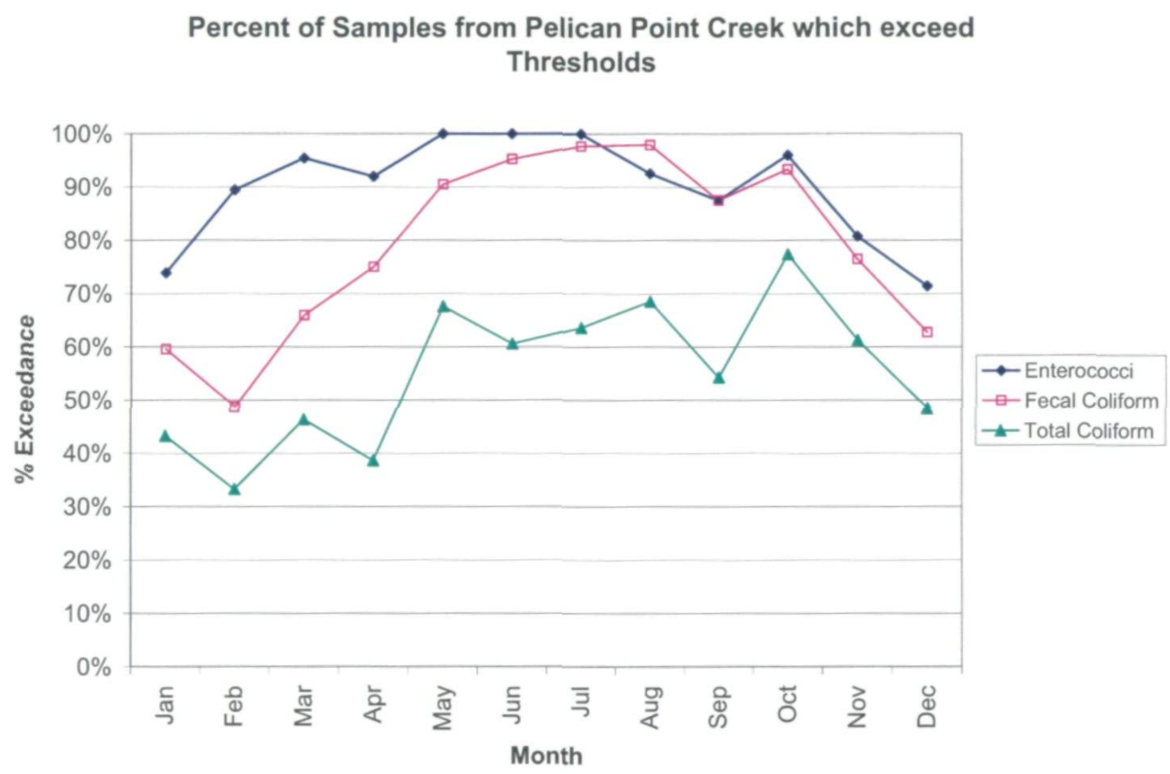
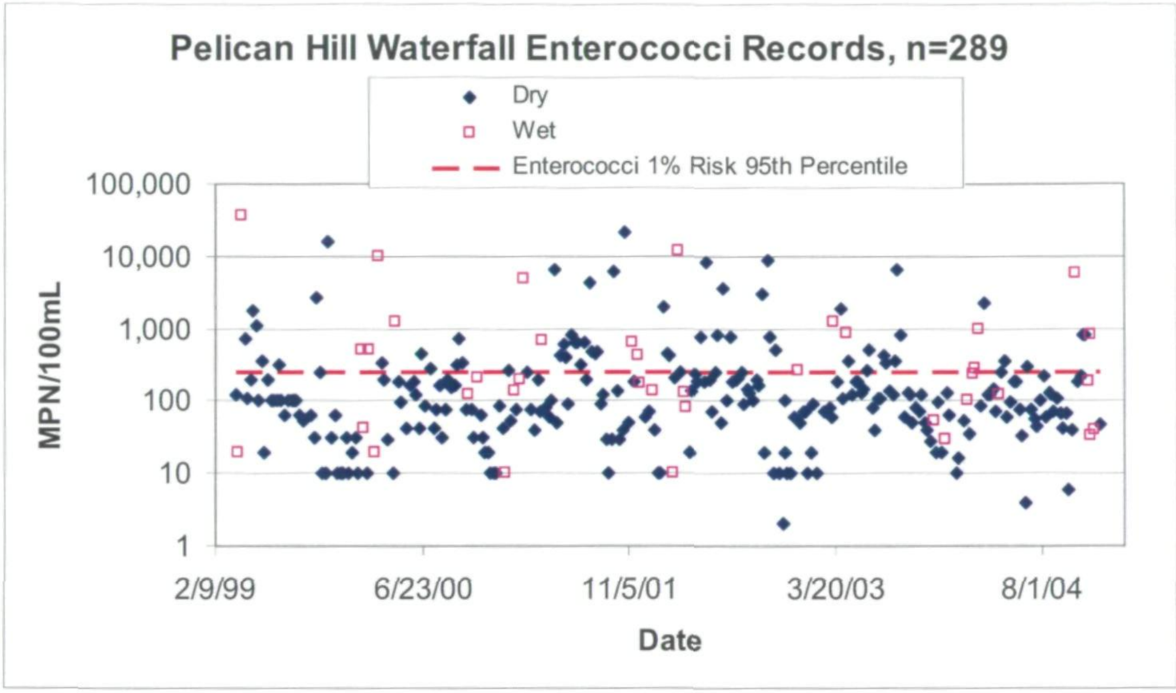


**Figure A 14: Pelican Hill Waterfall enterococci data and corresponding cumulative frequency distribution**



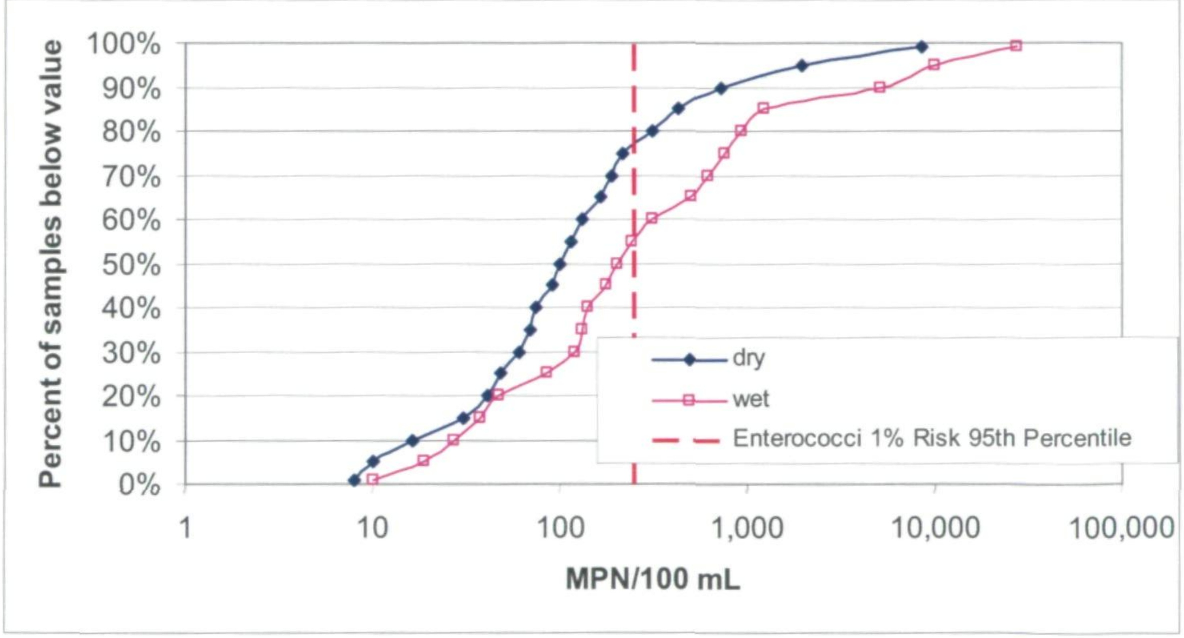
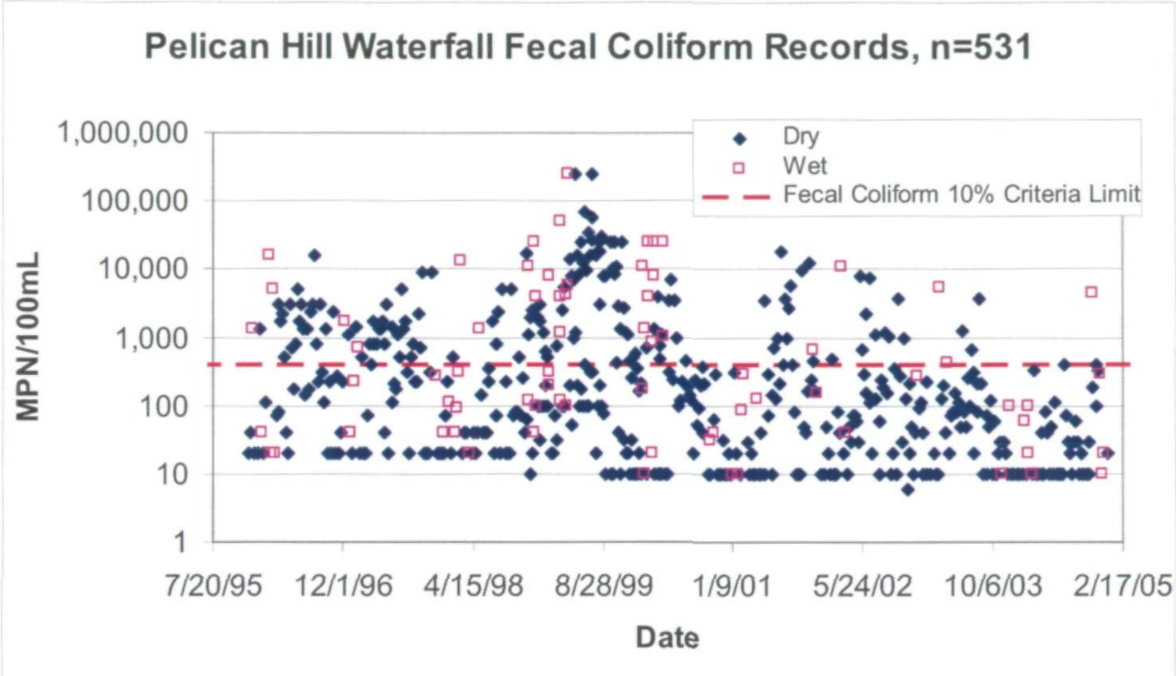



Figure A 15: Pelican Hill Waterfall fecal coliform data and corresponding cumulative frequency distribution



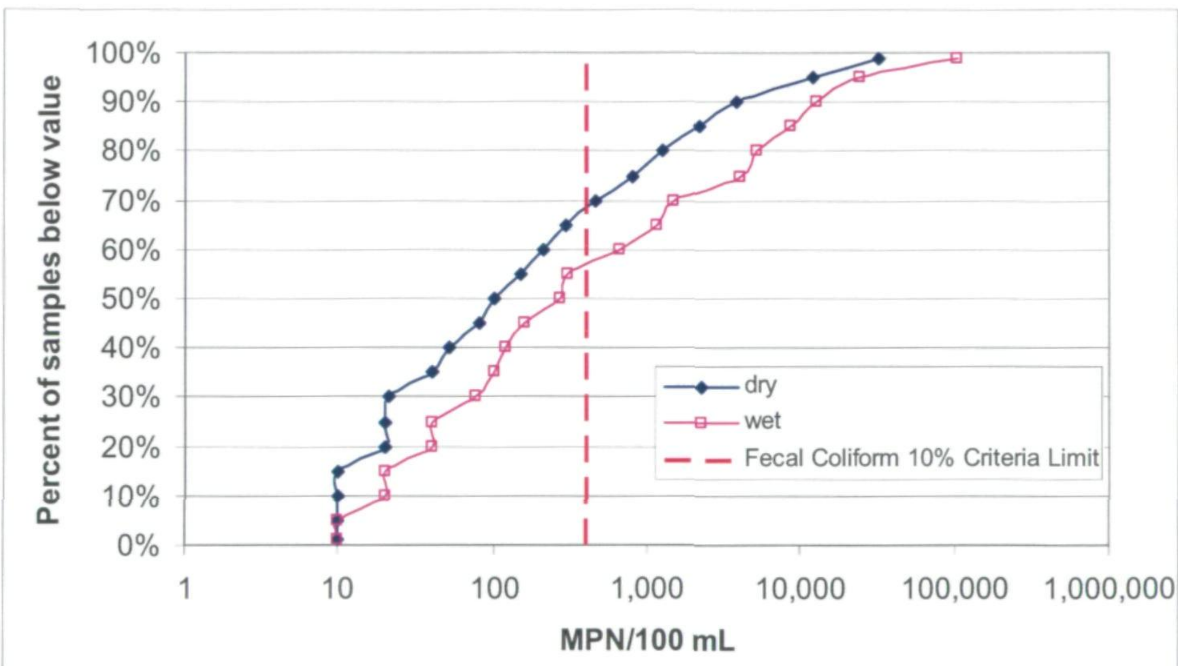
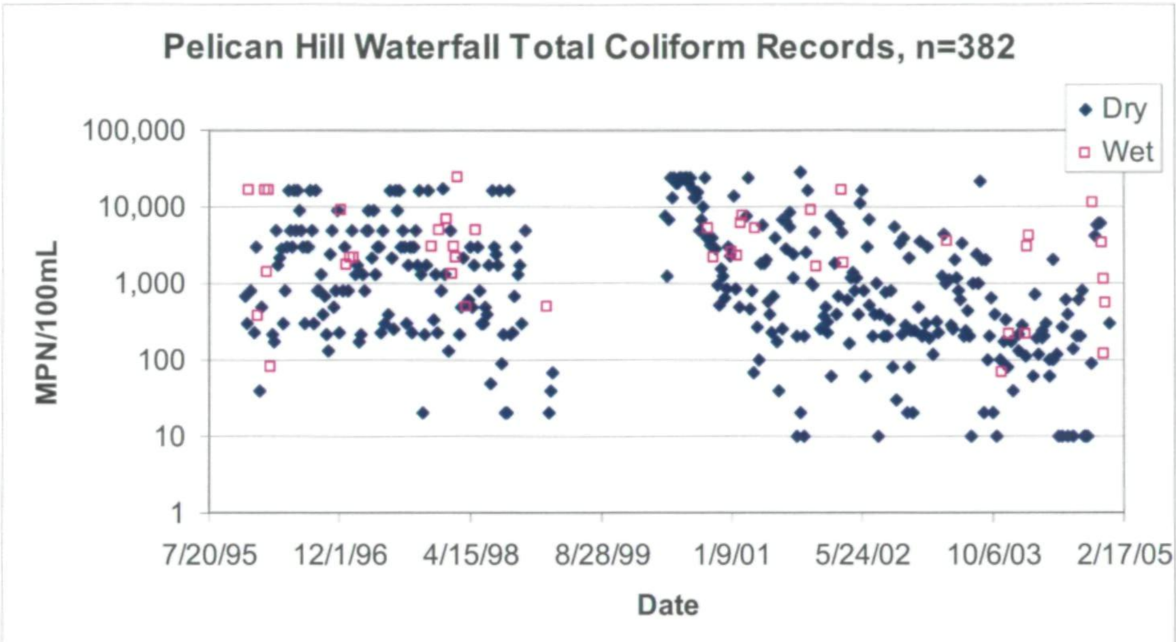



Figure A 16: Pelican Hill Waterfall total coliform data and corresponding cumulative frequency distribution



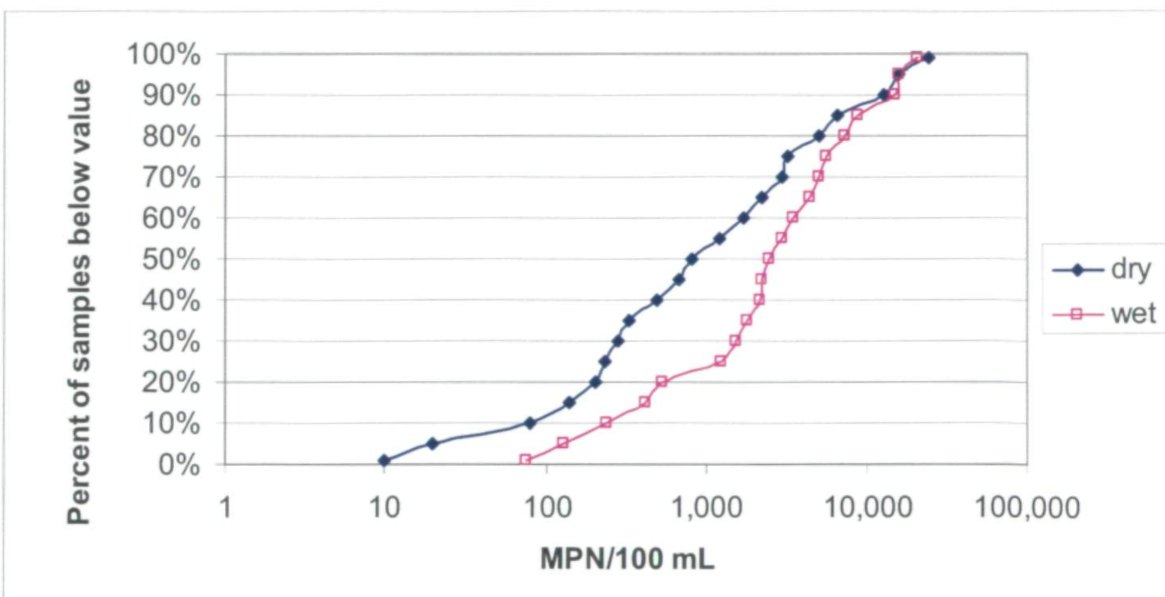



Figure A 17: Percentage of samples from Pelican Hill Waterfall which exceed thresholds, by month

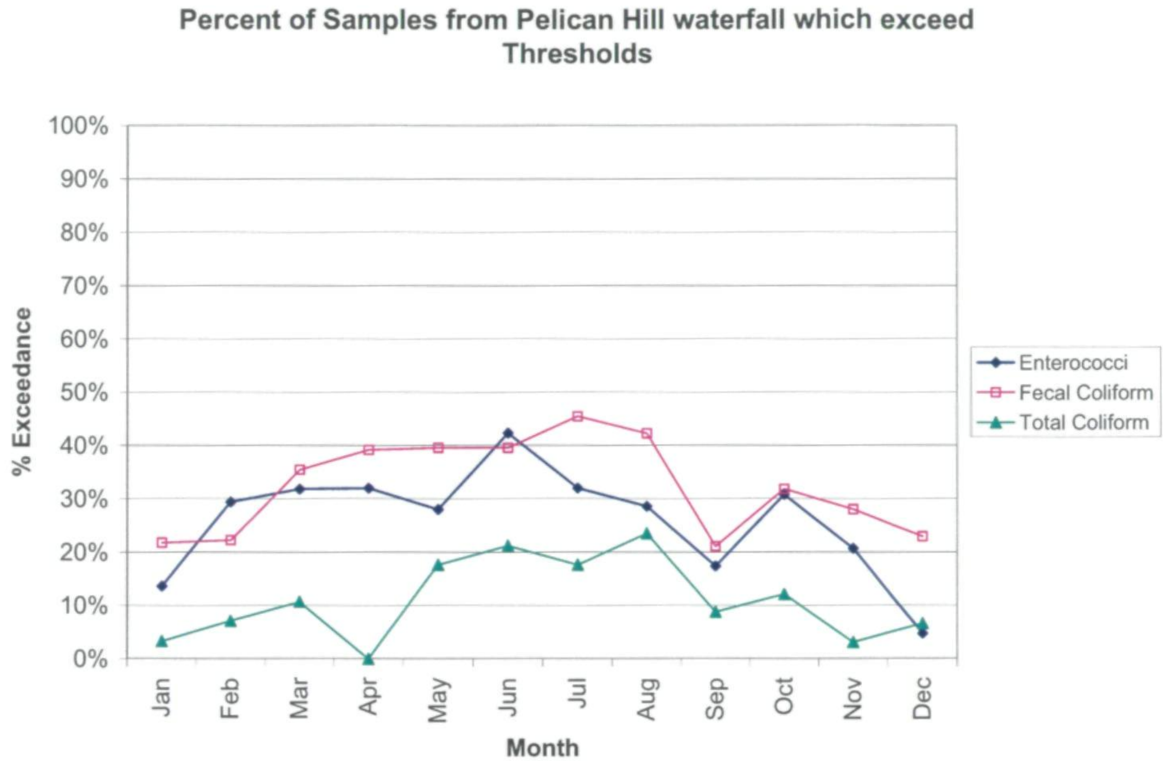
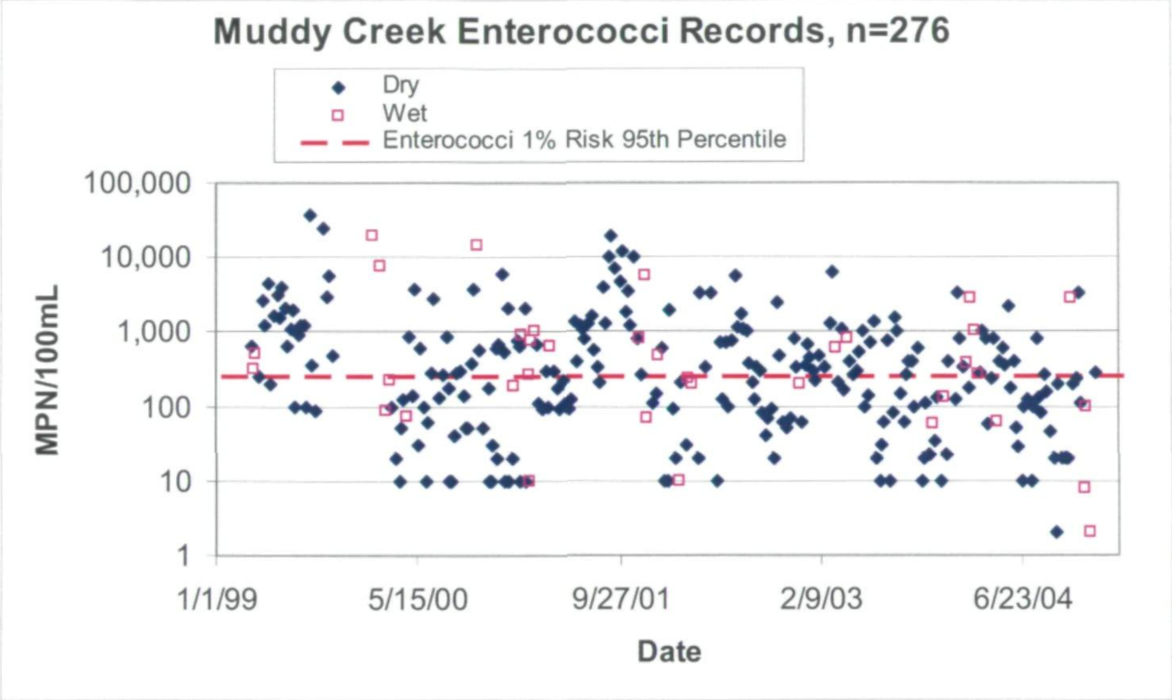


Figure A 18: Muddy Creek enterococci data and corresponding cumulative frequency distribution



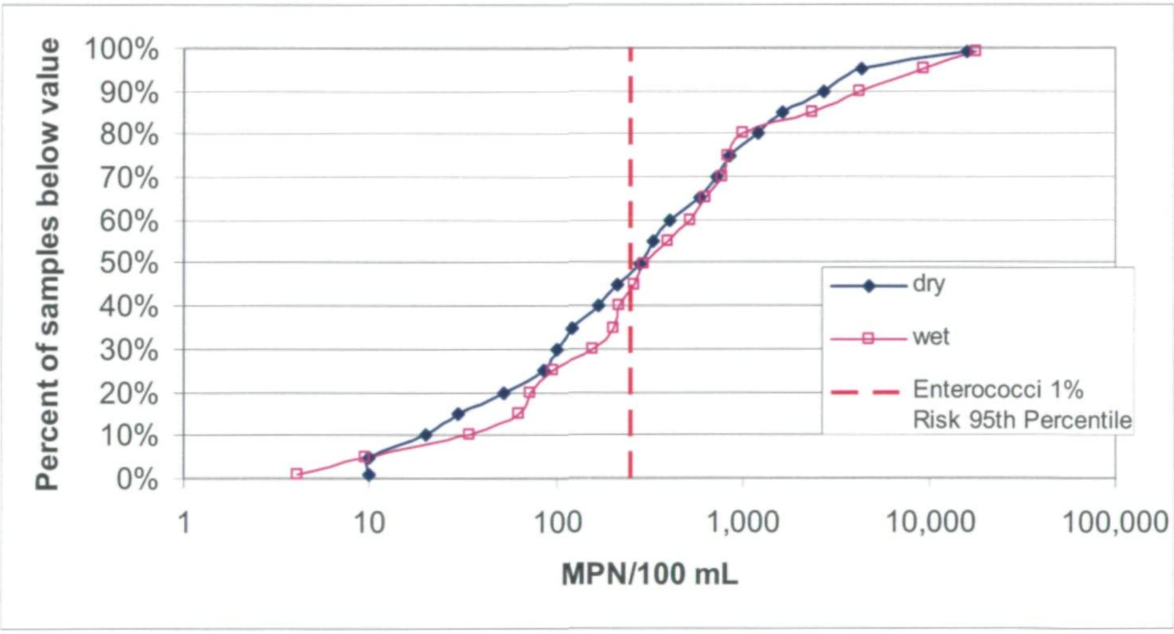
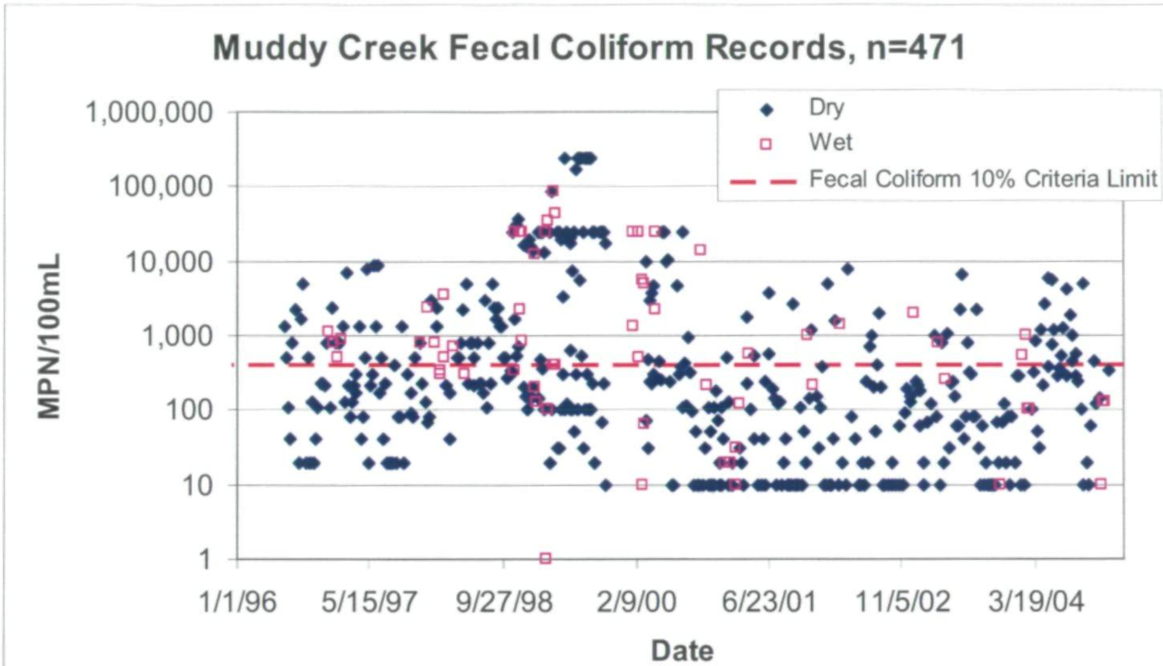



**Figure A 19: Muddy Creek fecal coliform data and corresponding cumulative frequency distribution**



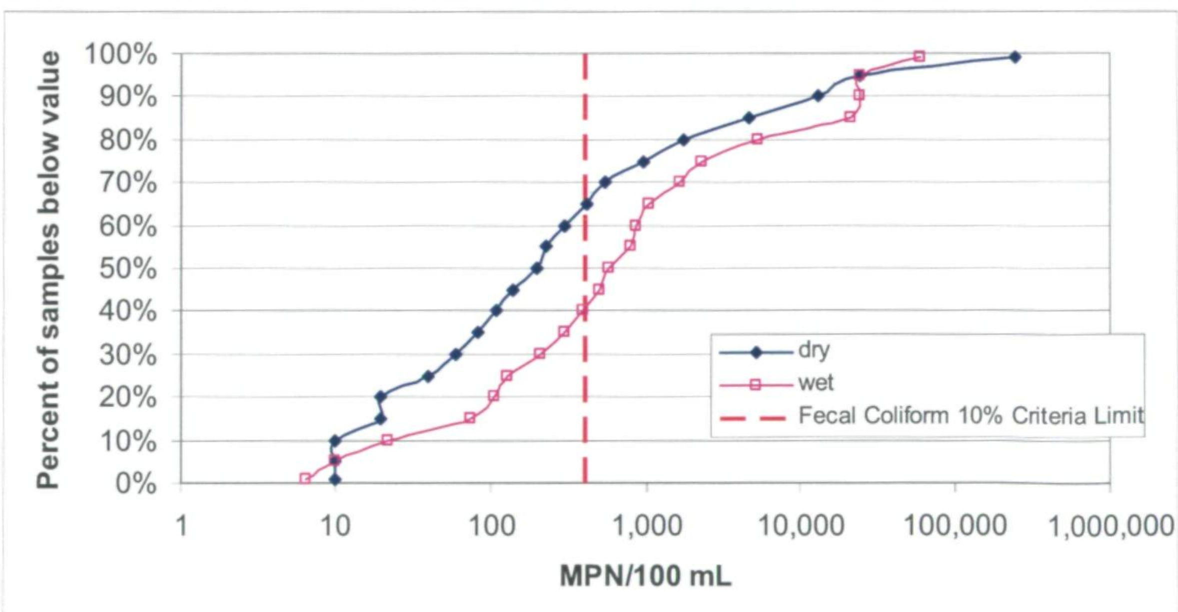
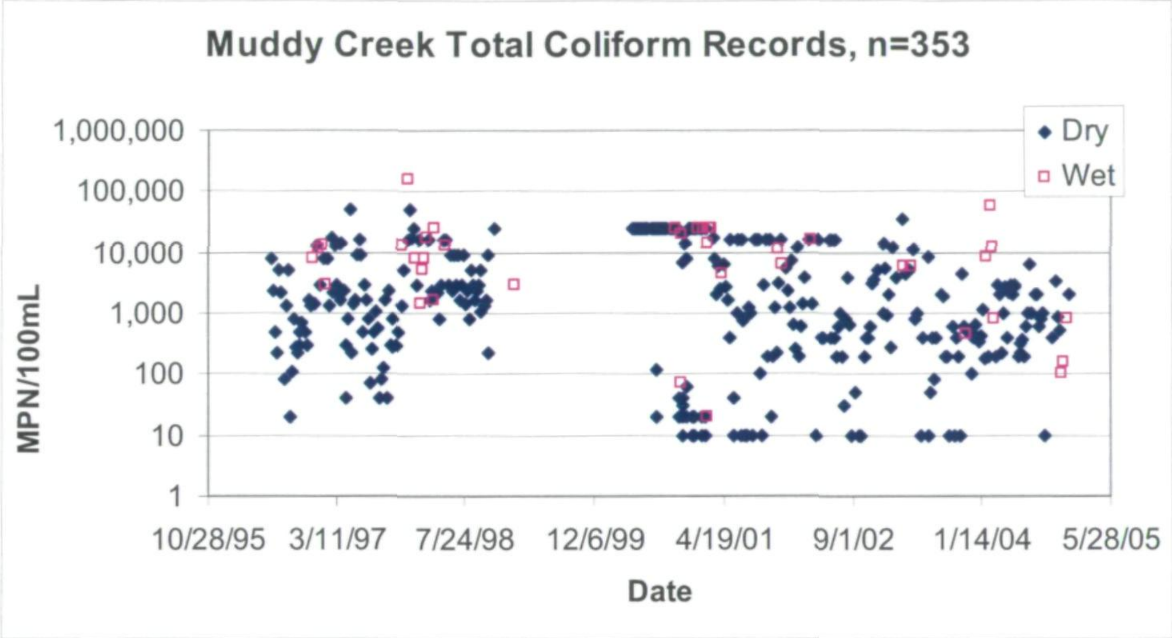



Figure A 20: Muddy Creek total coliform data and corresponding cumulative frequency distribution



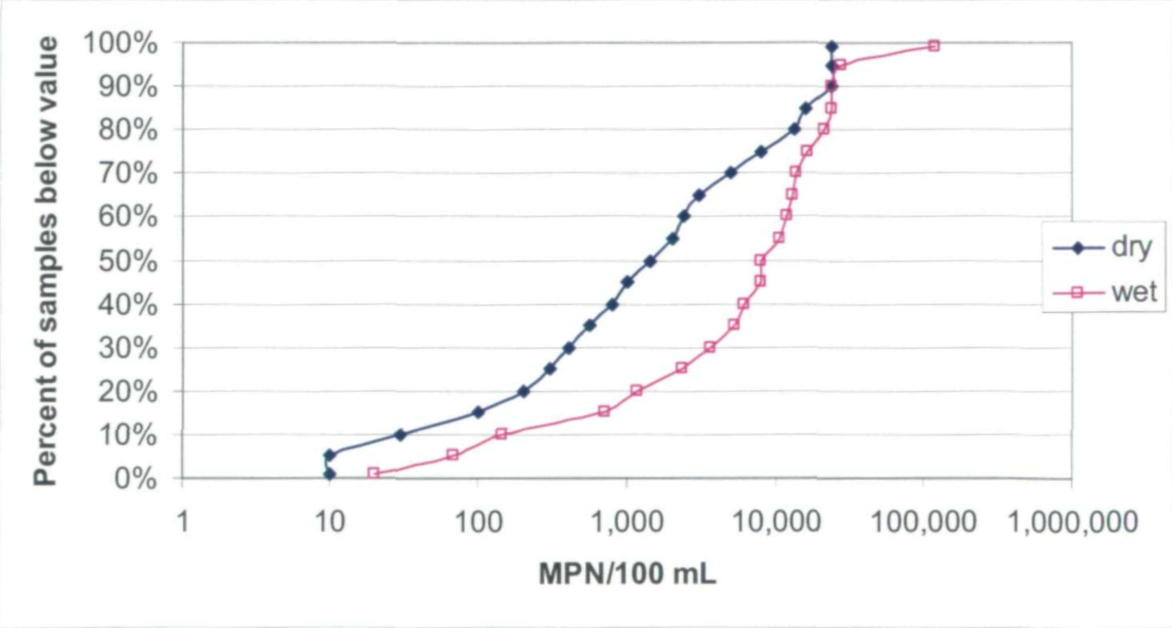



Figure A 21: Percentage of samples from Muddy Creek which exceed thresholds, by month

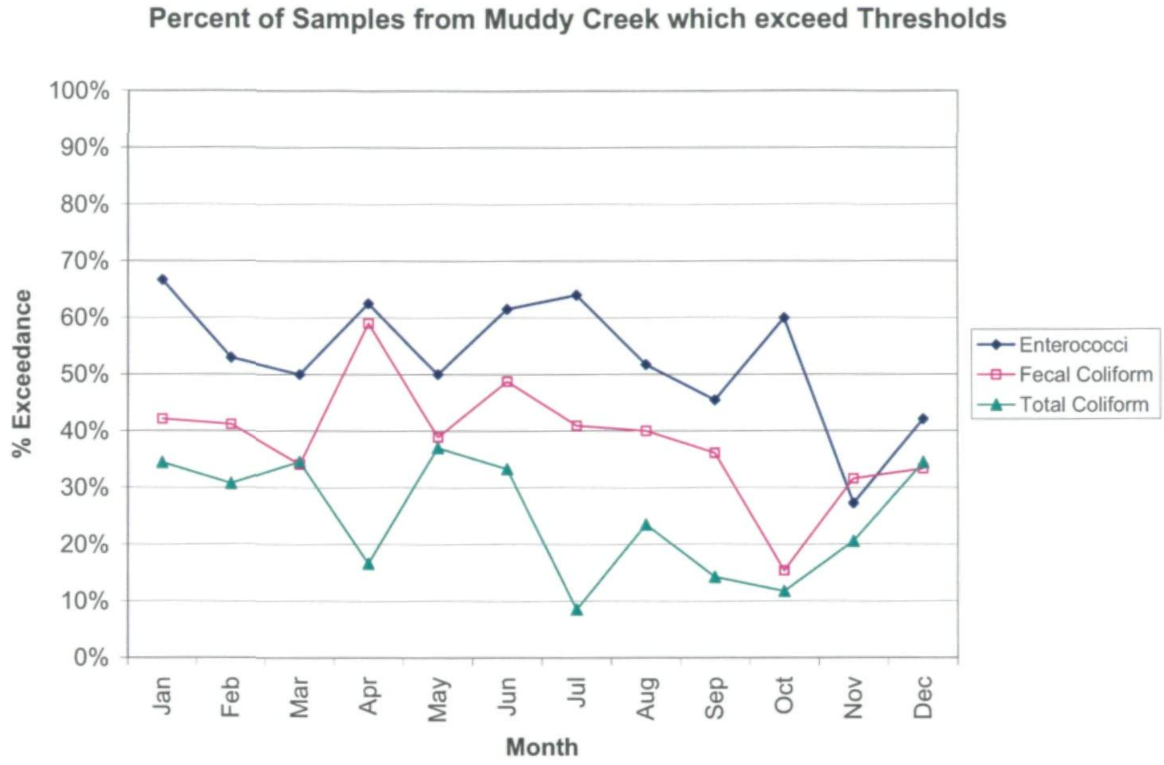
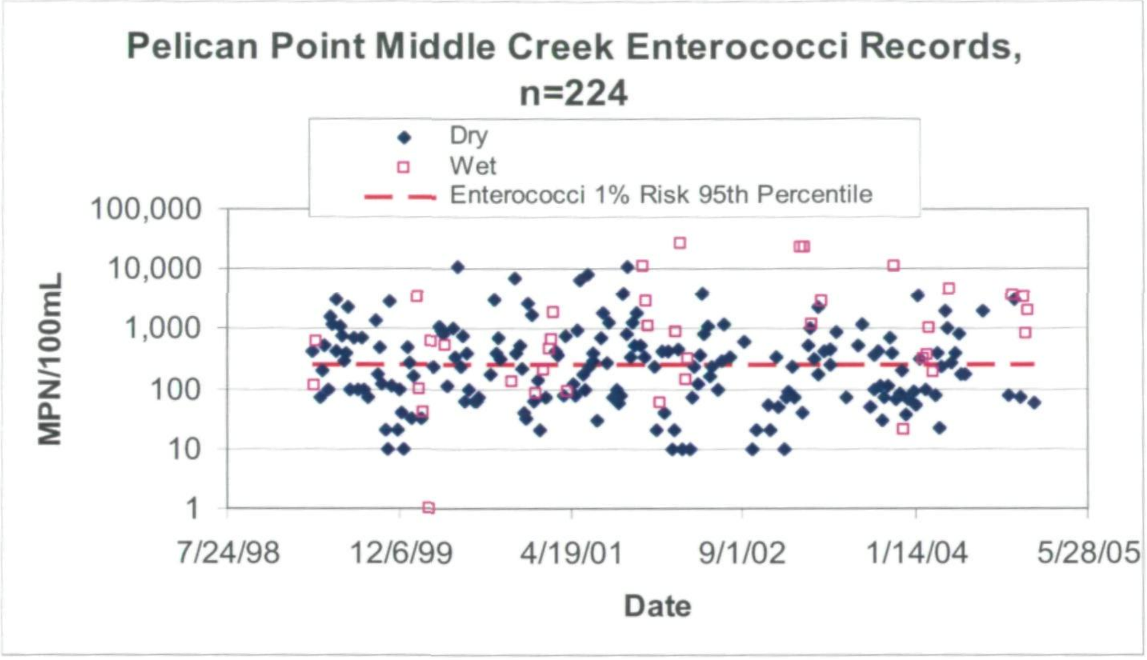


**Figure A 22: Pelican Point Middle Creek enterococci data and corresponding cumulative frequency distribution**



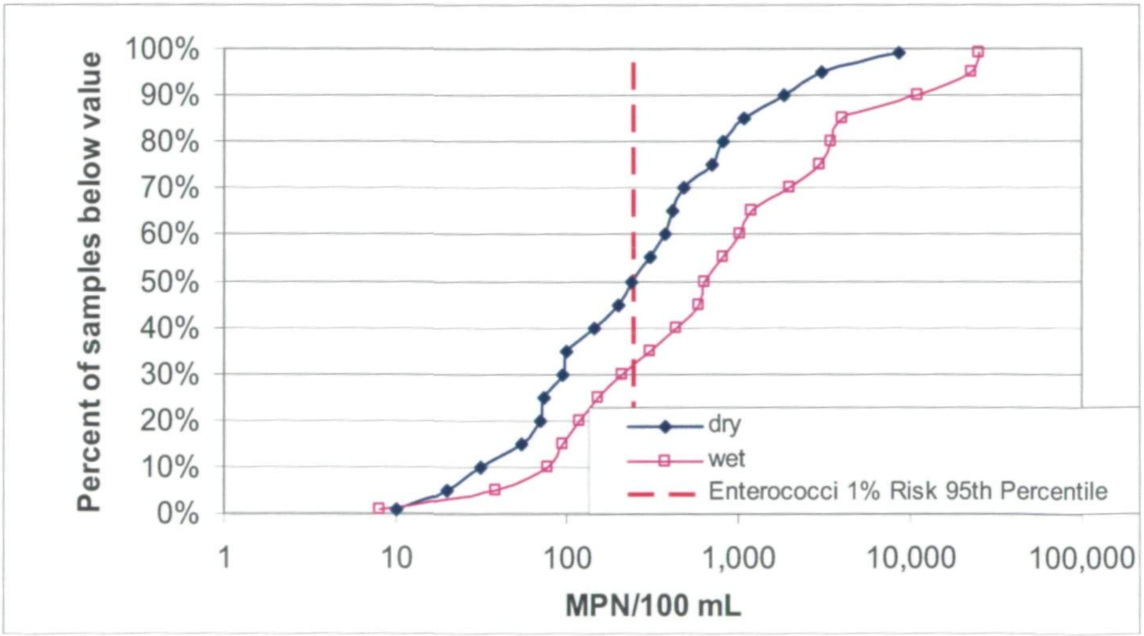



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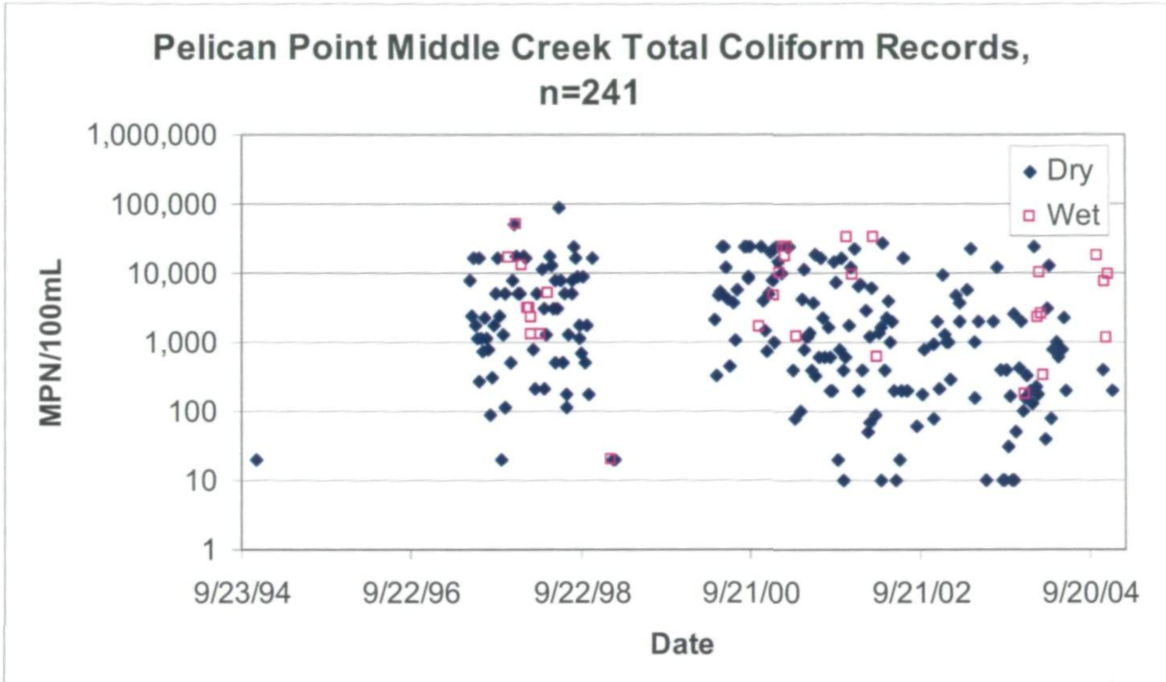
**Figure A 23: Pelican Point Middle Creek fecal coliform data and corresponding cumulative frequency distribution**

**Figure A 24: Pelican Point Middle Creek total coliform data and corresponding cumulative frequency distribution**



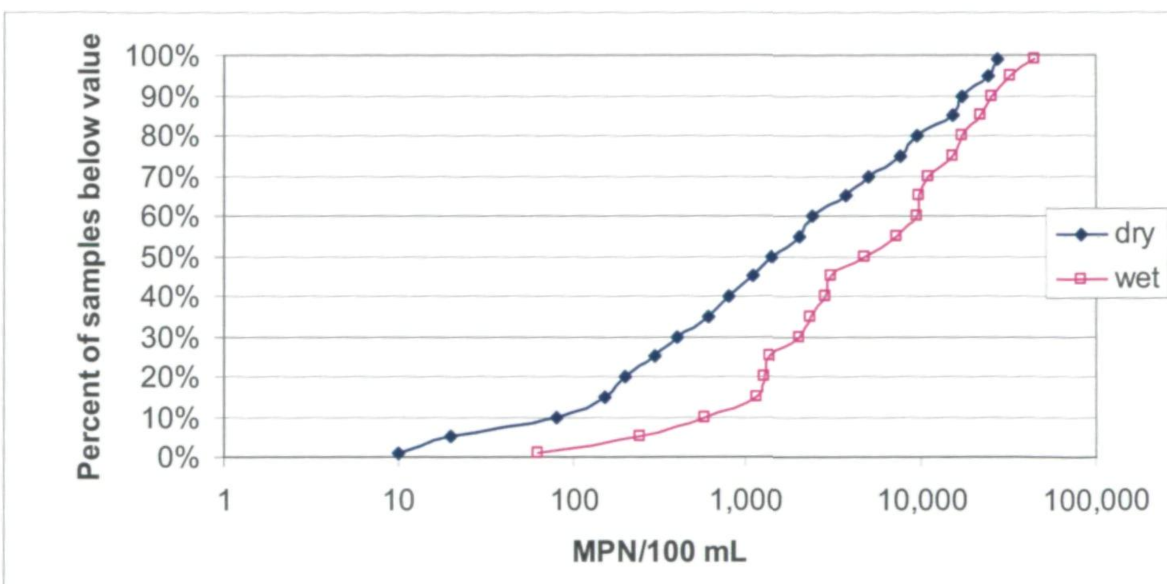



Figure A 25: Percentage of samples from Pelican Point Middle Creek which exceed thresholds, by month

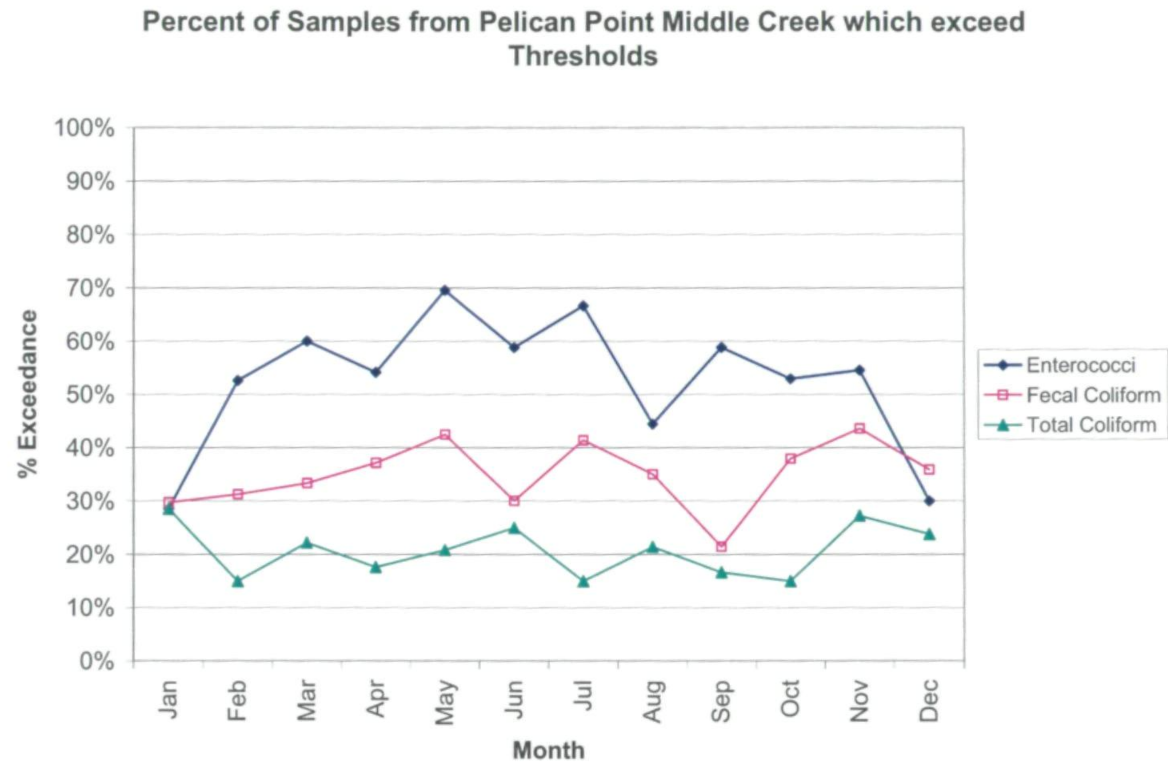


**Figure A 26: Emerald Bay Drain enterococci data and corresponding cumulative frequency distribution**

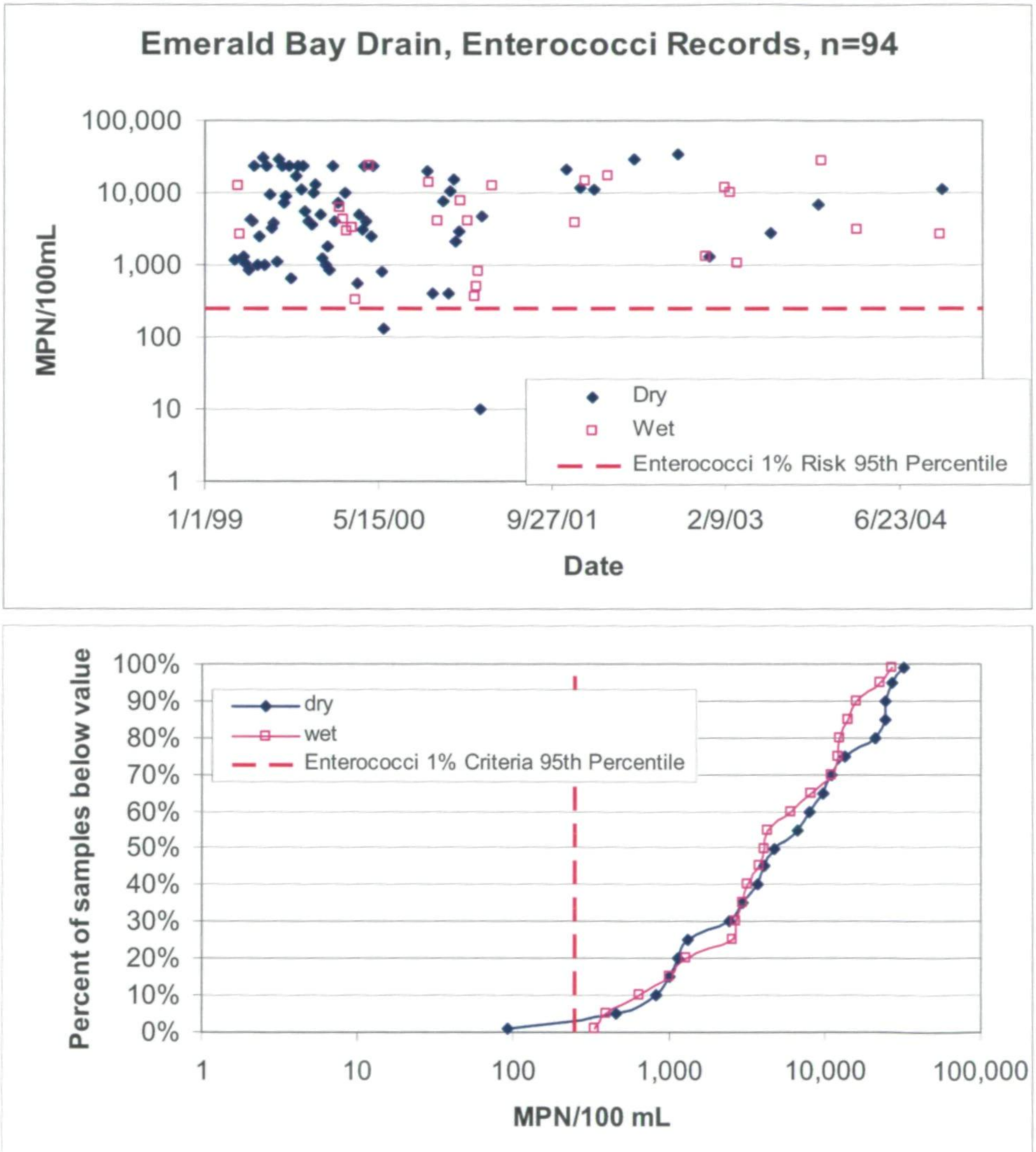
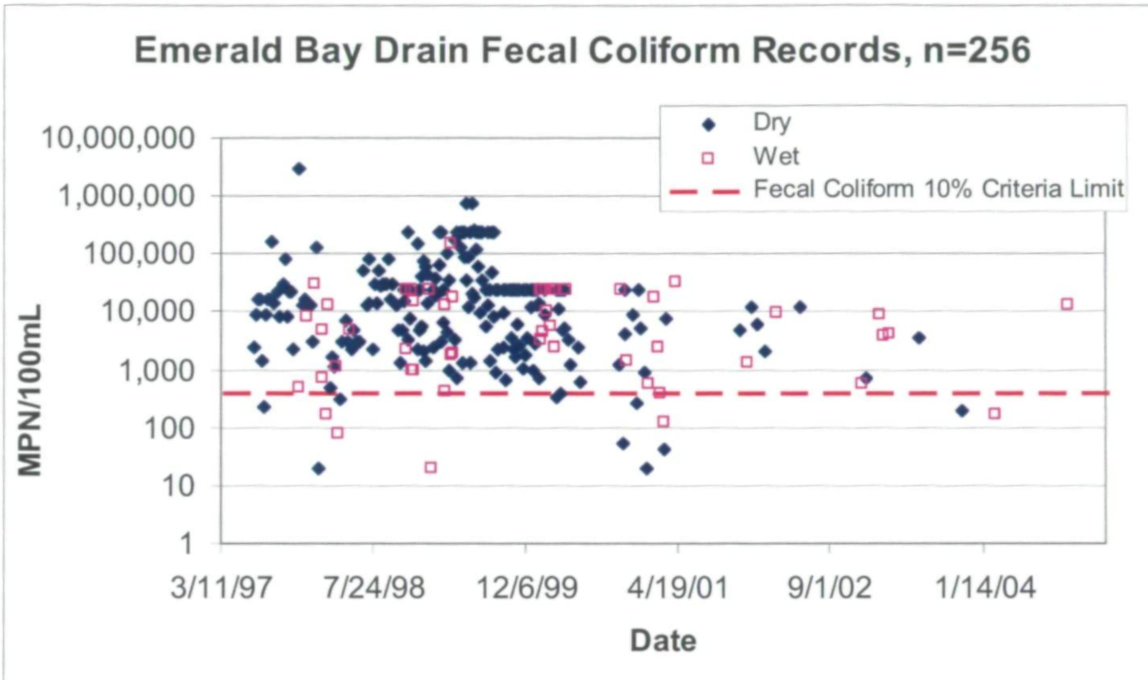


**Figure A 27: Emerald Bay Drain fecal coliform data and corresponding cumulative frequency distribution**



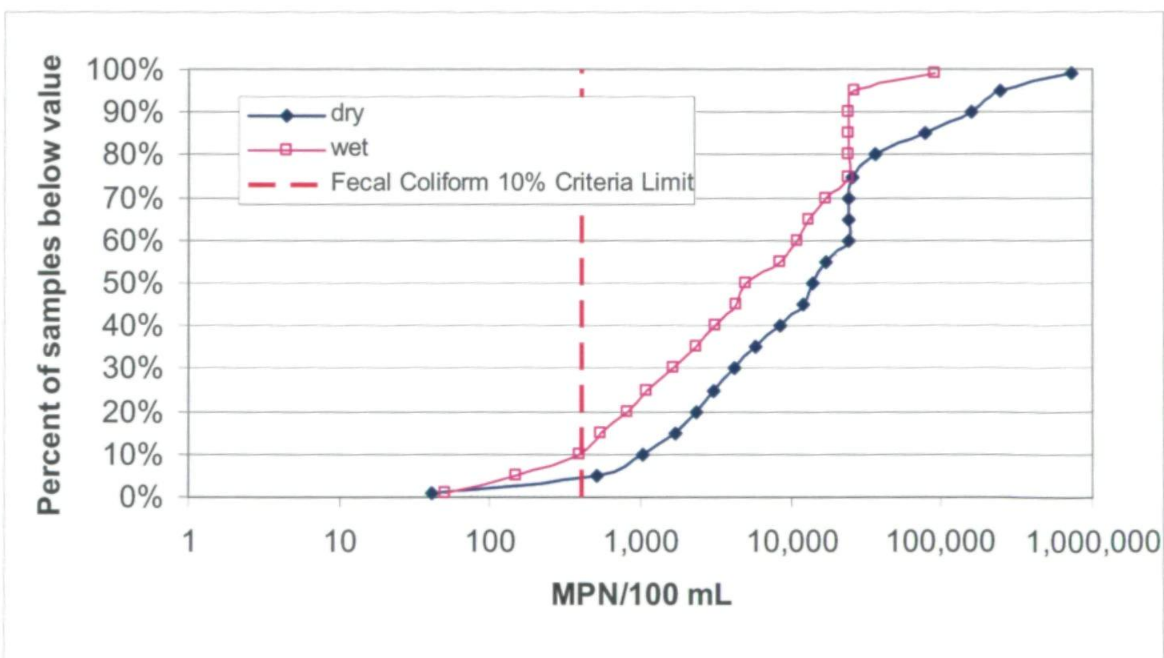
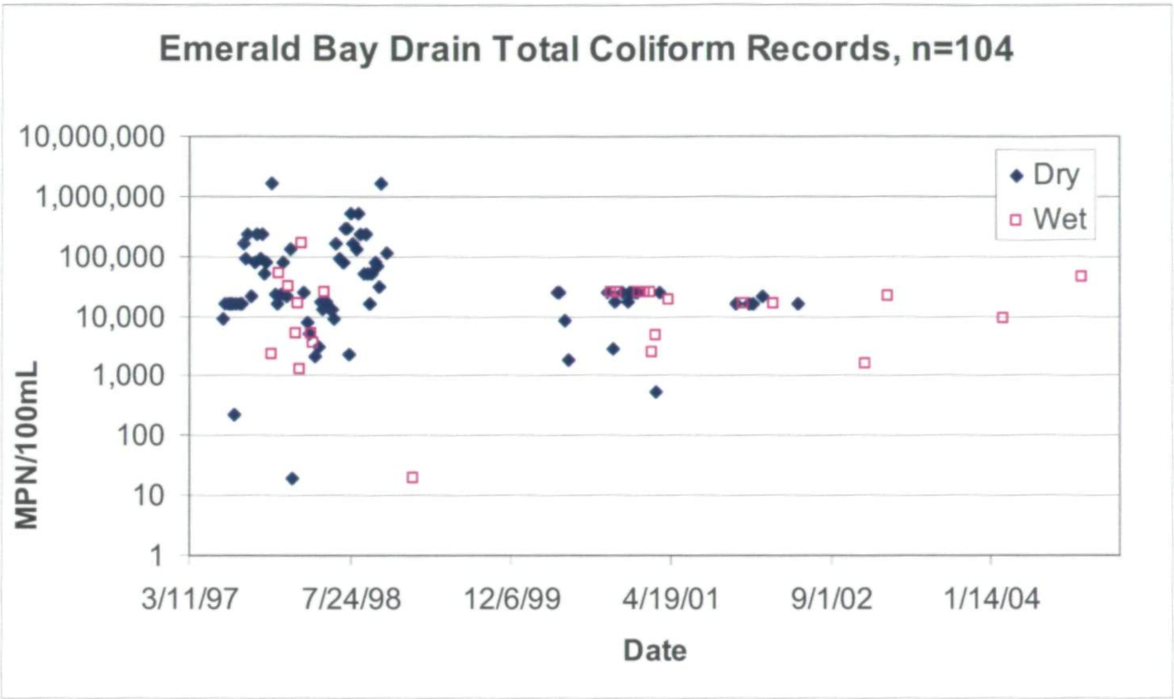



**Figure A 28: Emerald Bay Drain total coliform data and corresponding cumulative frequency distribution**



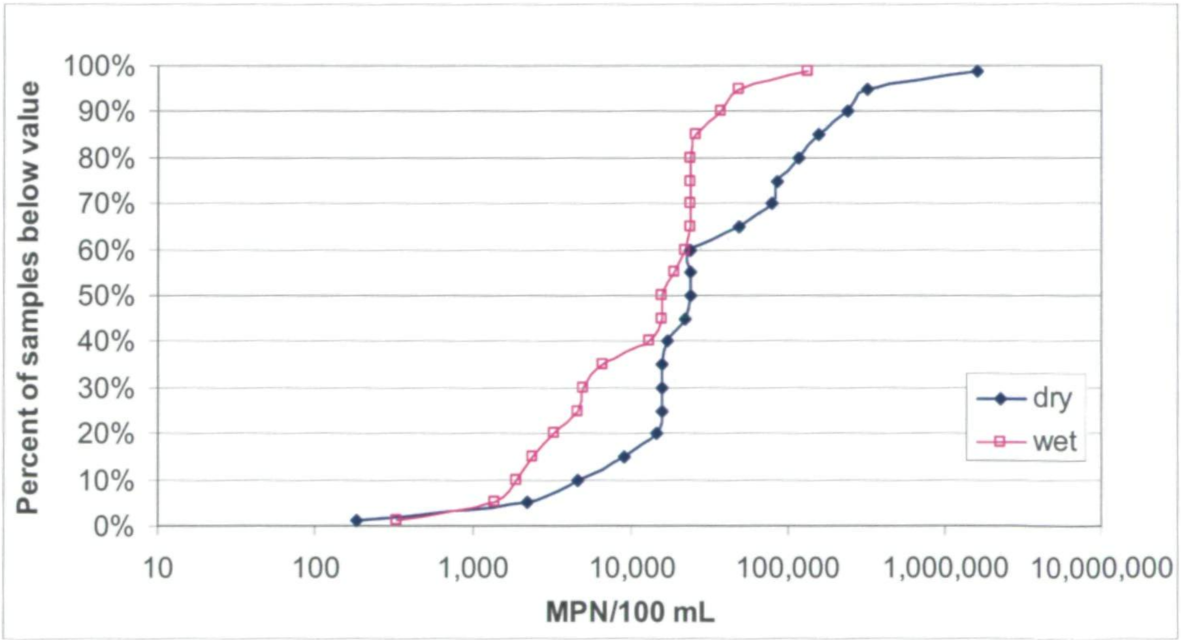



Figure A 29: Percentage of samples from the Emerald Bay Drain which exceed thresholds, by month

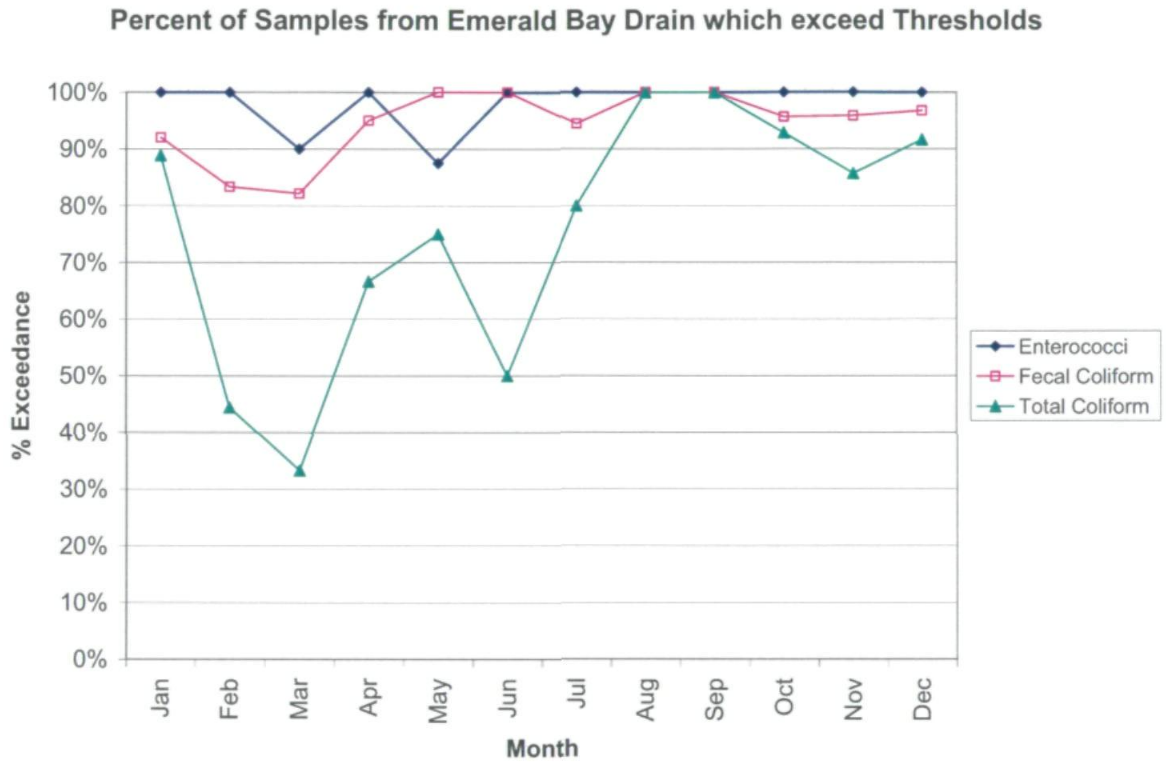
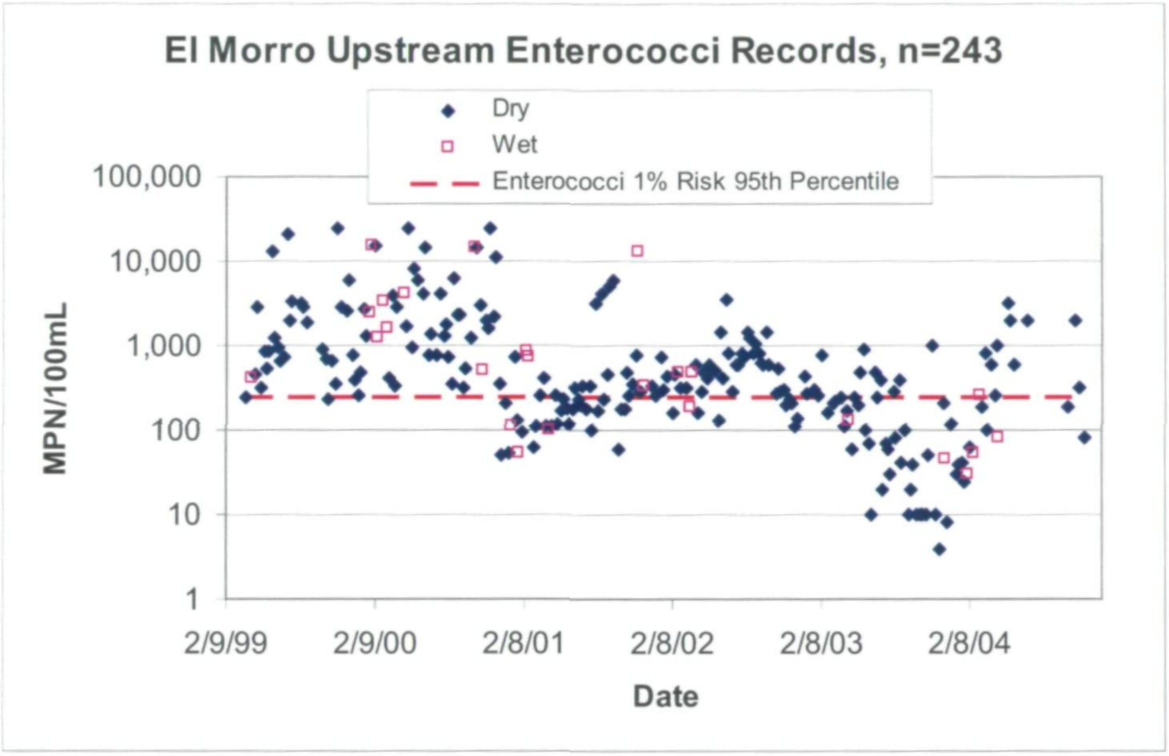


Figure A 30: El Morro Creek Upstream enterococci data and corresponding cumulative frequency distribution



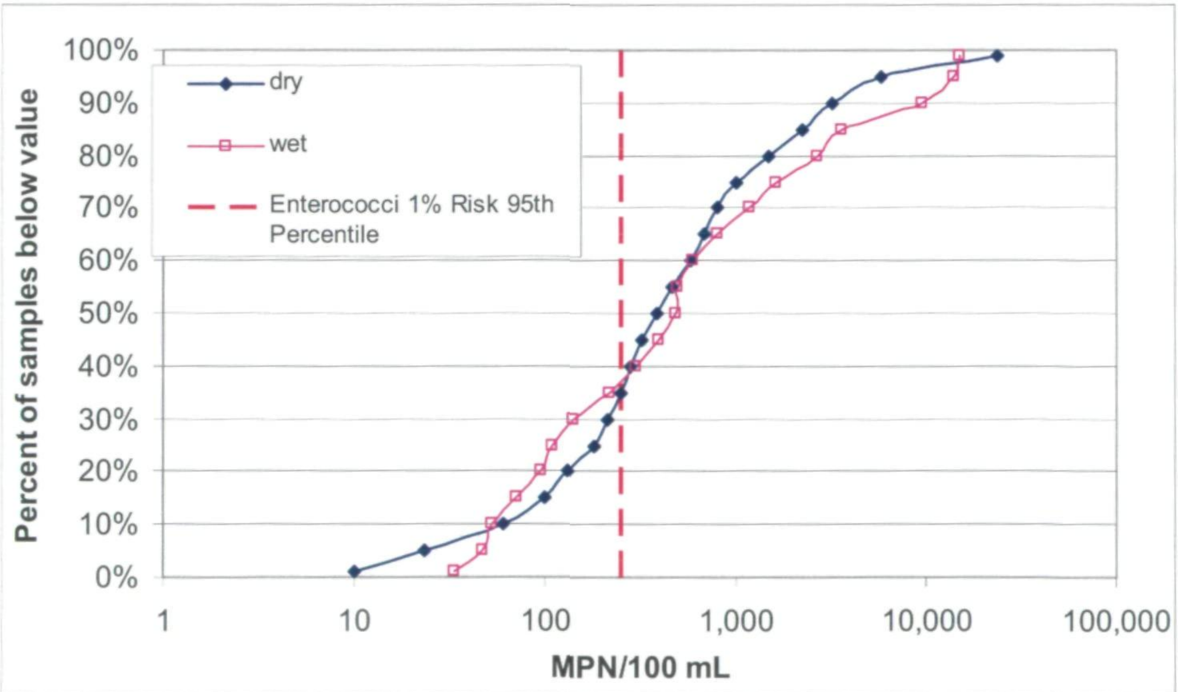



**Figure A 31: El Morro Creek Upstream fecal coliform data and corresponding cumulative frequency distribution**

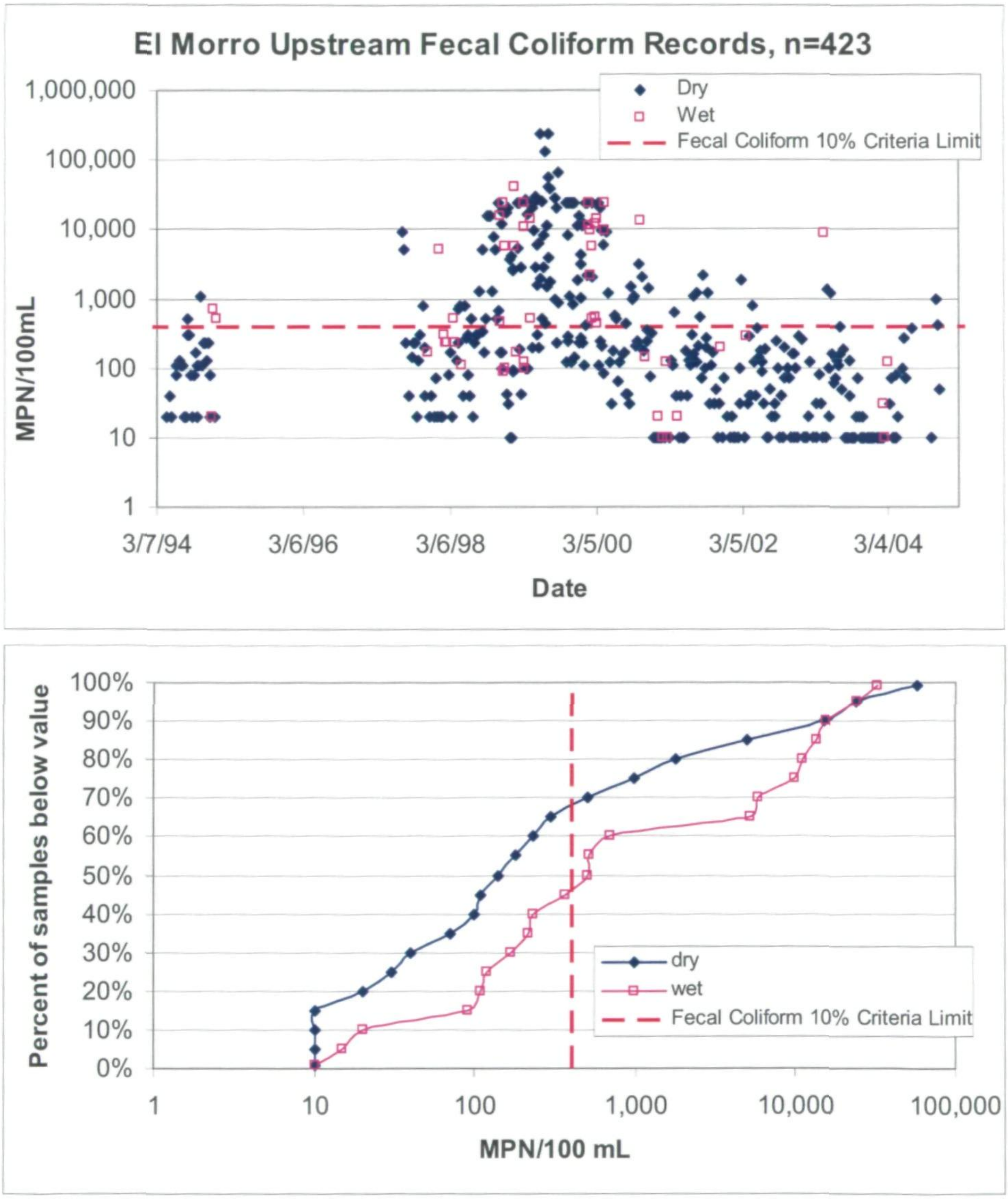
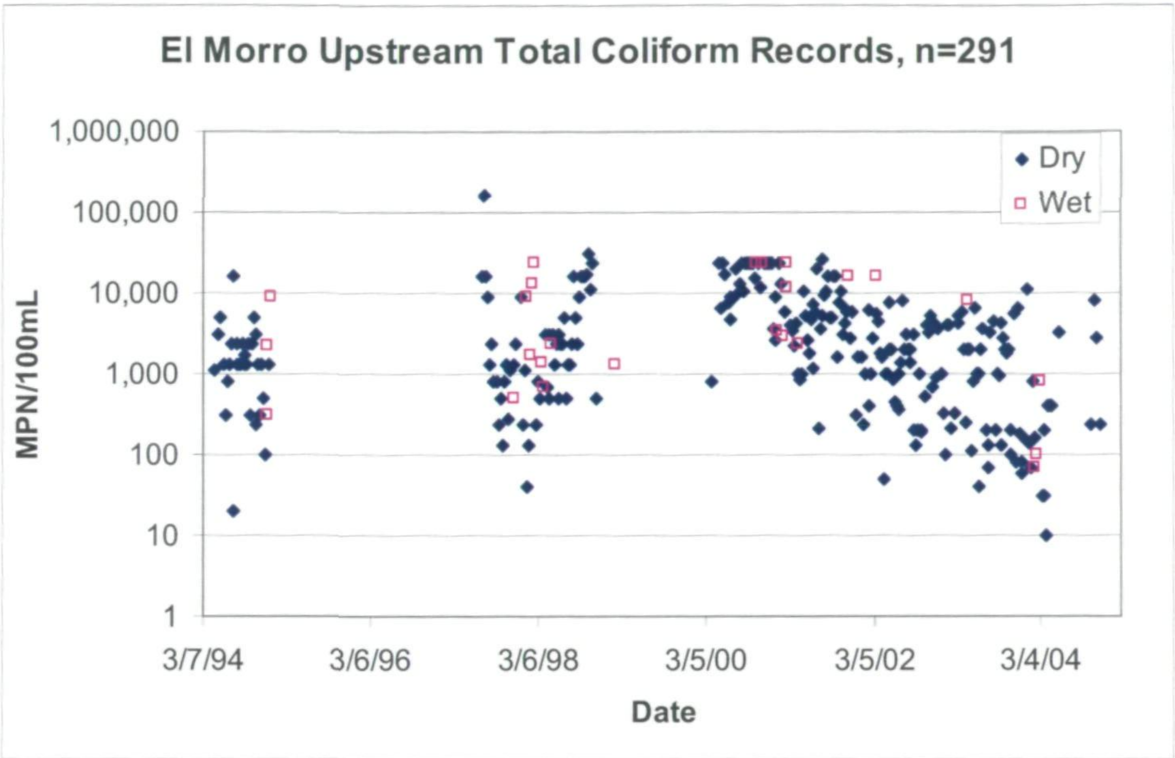


**Figure A 32: El Morro Creek Upstream total coliform data and corresponding cumulative frequency distribution**



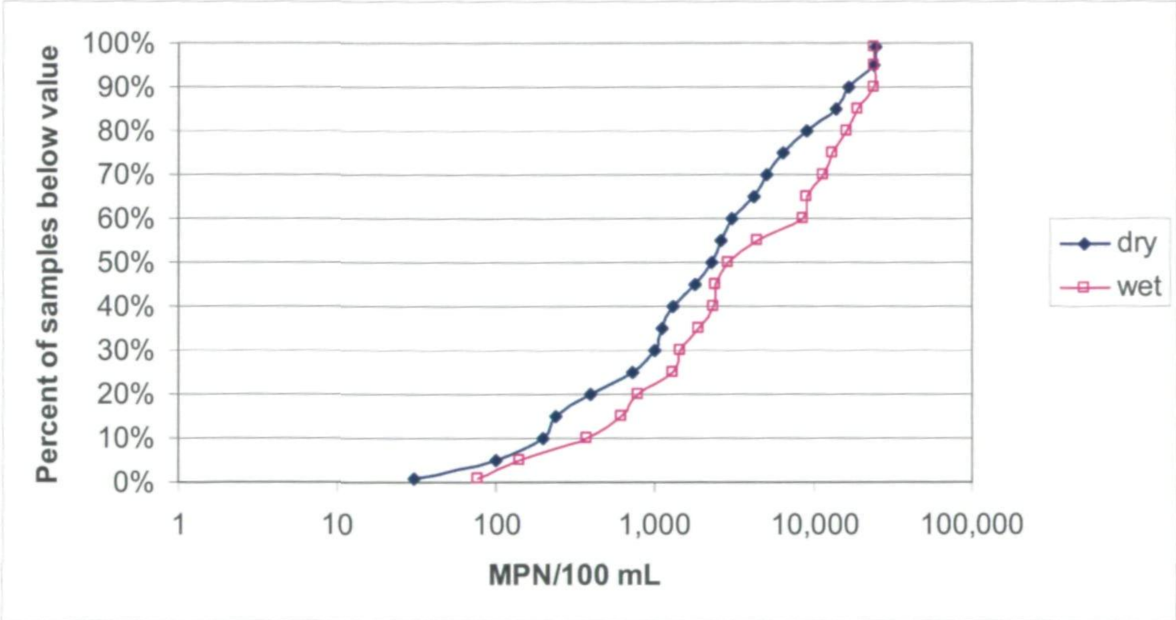



Figure A 33: Percentage of samples from El Morro Creek Upstream which exceed thresholds, by month

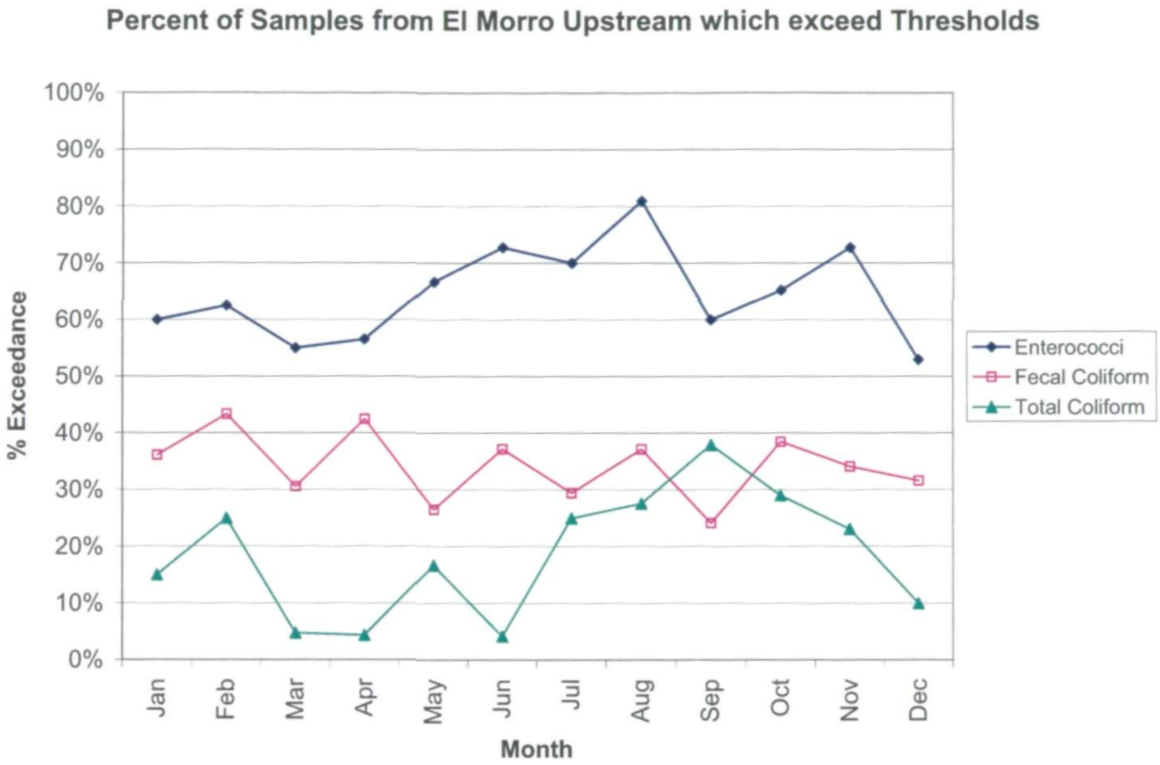


**Figure A 34: El Morro Creek enterococci data and corresponding cumulative frequency distribution**

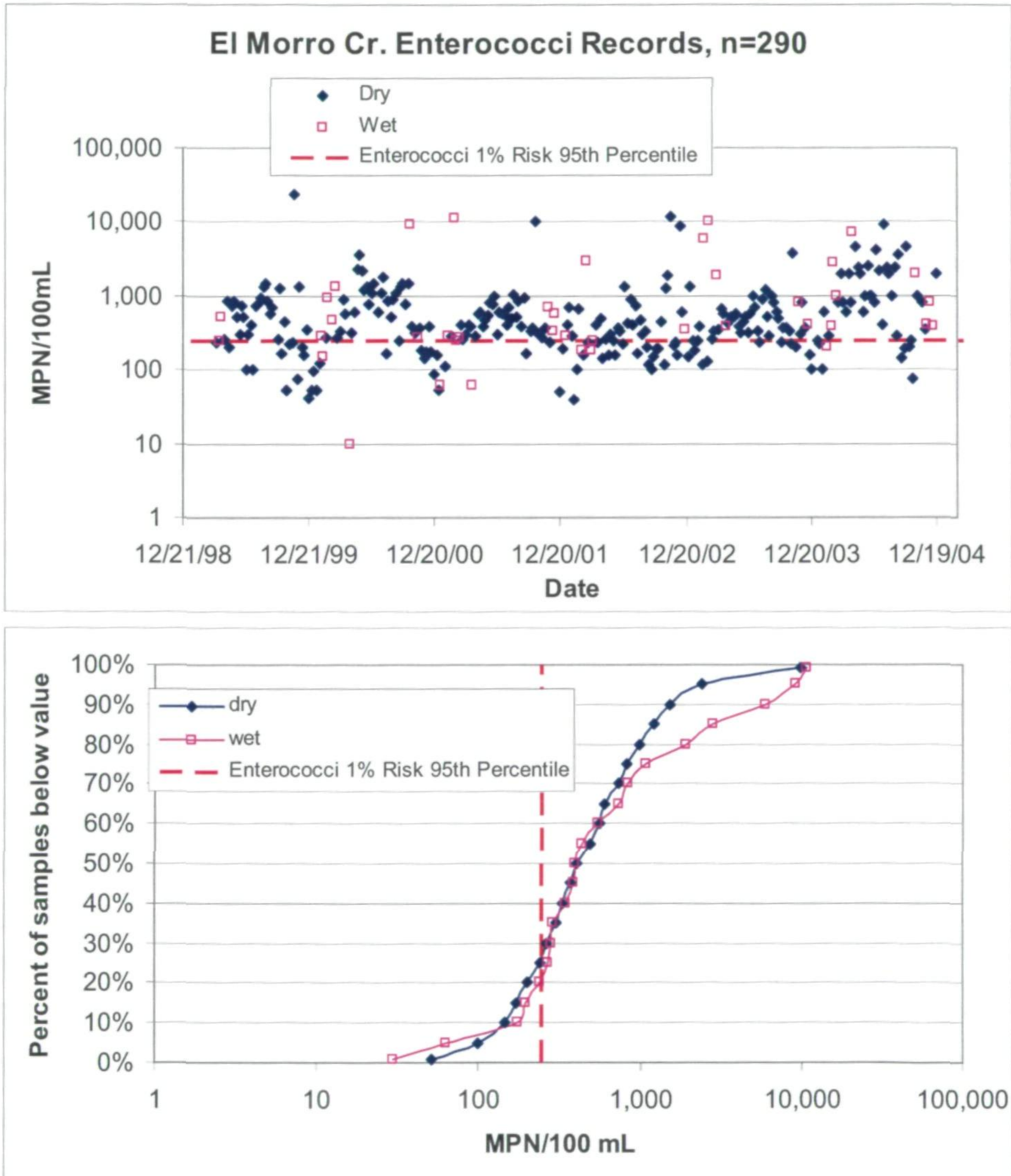
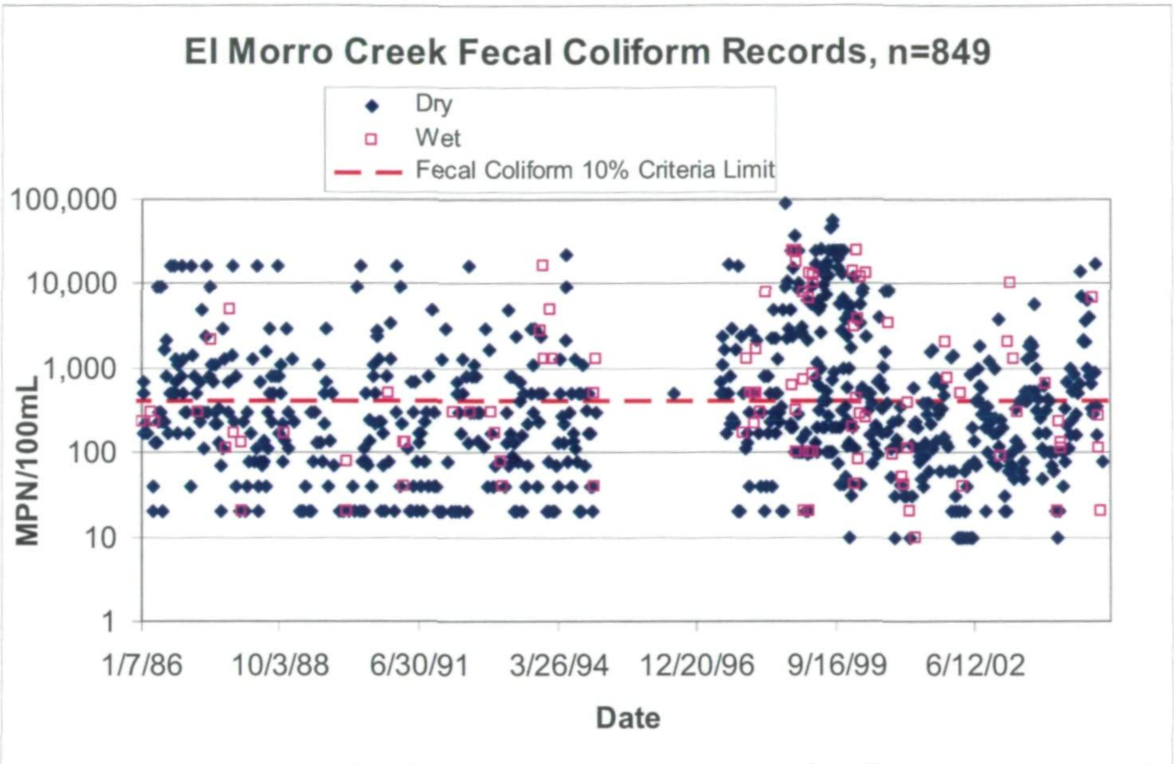


Figure A 35: El Morro Creek fecal coliform data and corresponding cumulative frequency distribution



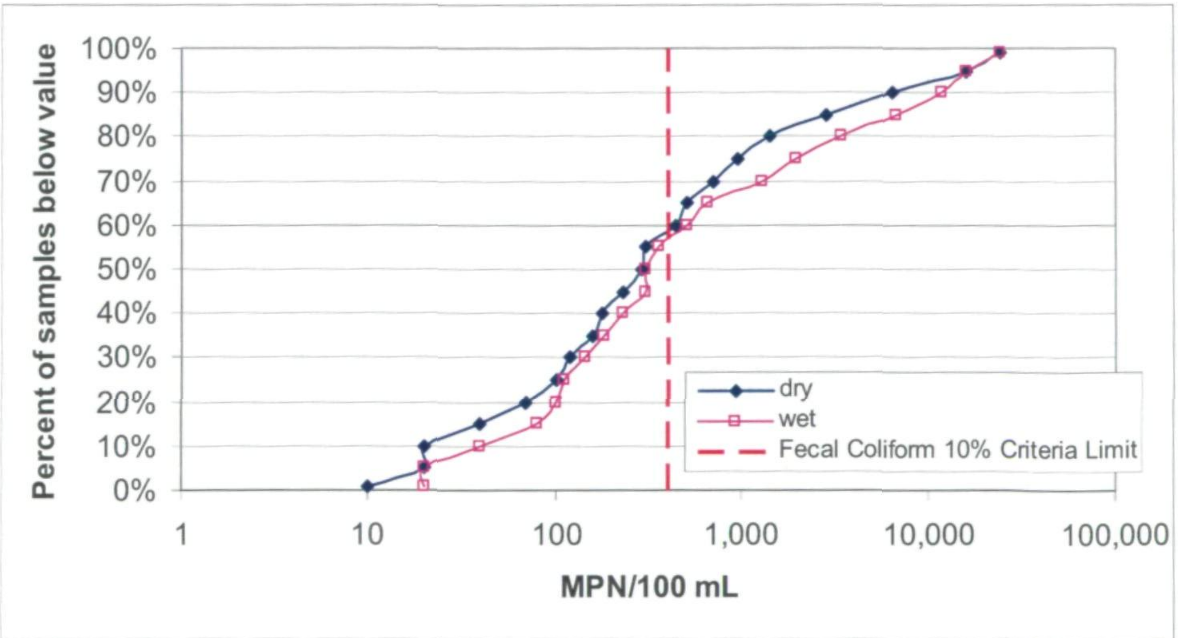



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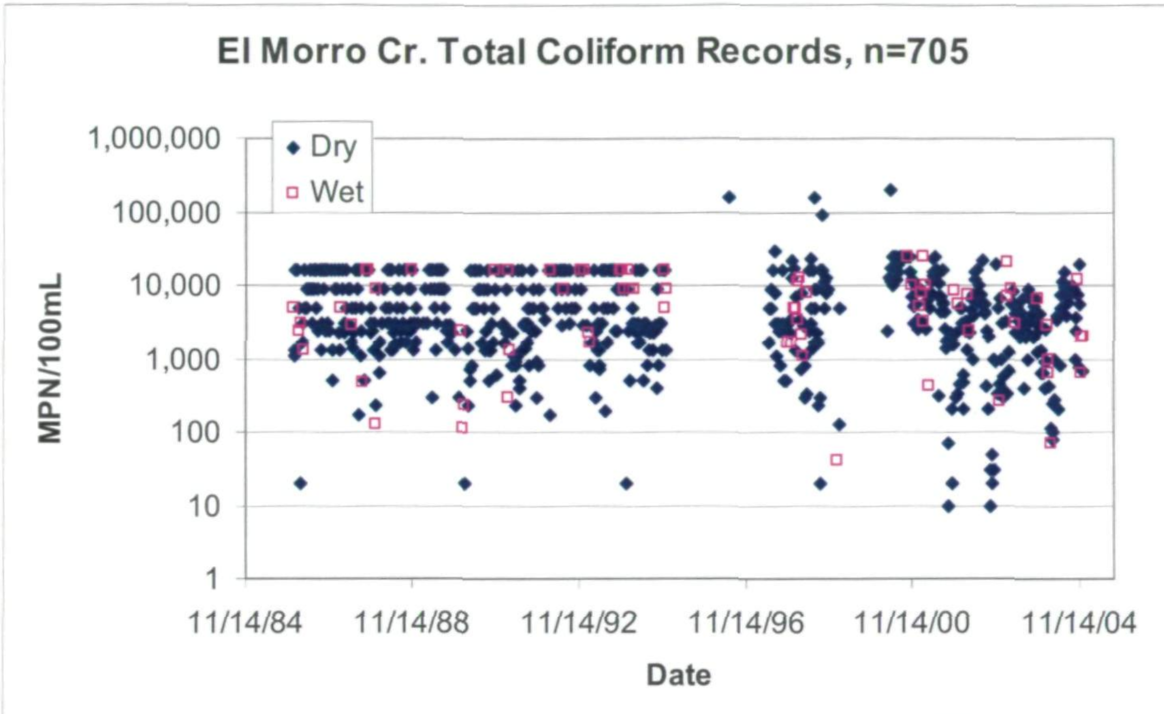
**Figure A 36: El Morro Creek total coliform data and corresponding cumulative frequency distribution**



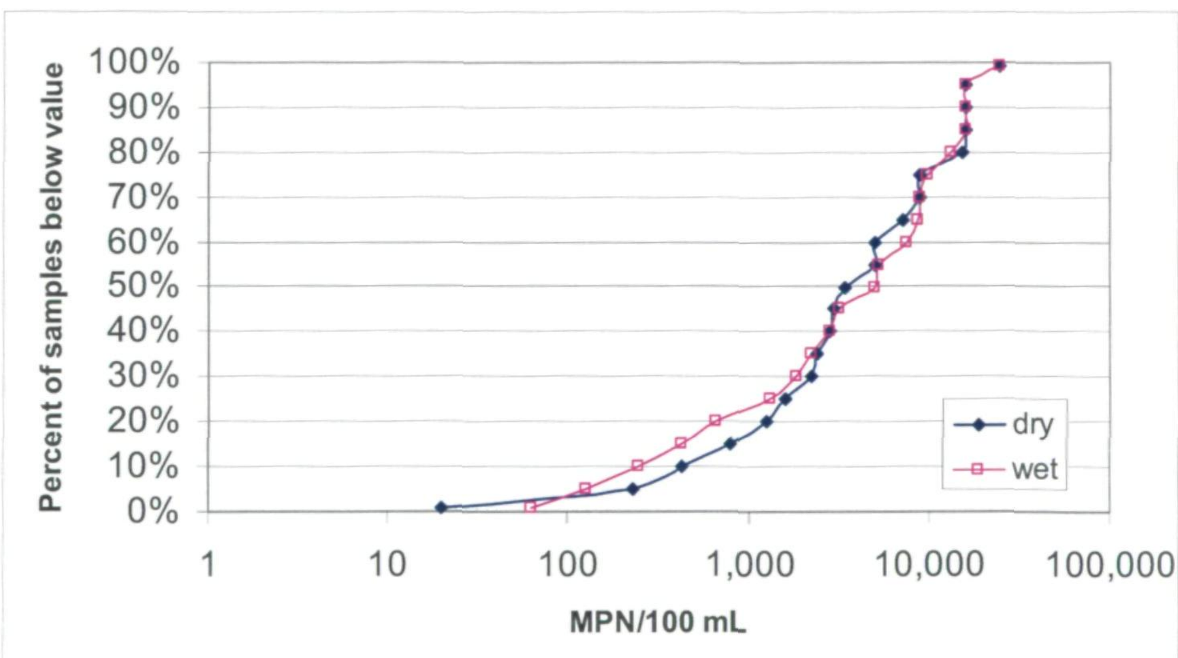



**Figure A 37: Percentage of samples from El Morro Creek which exceed thresholds, by month**

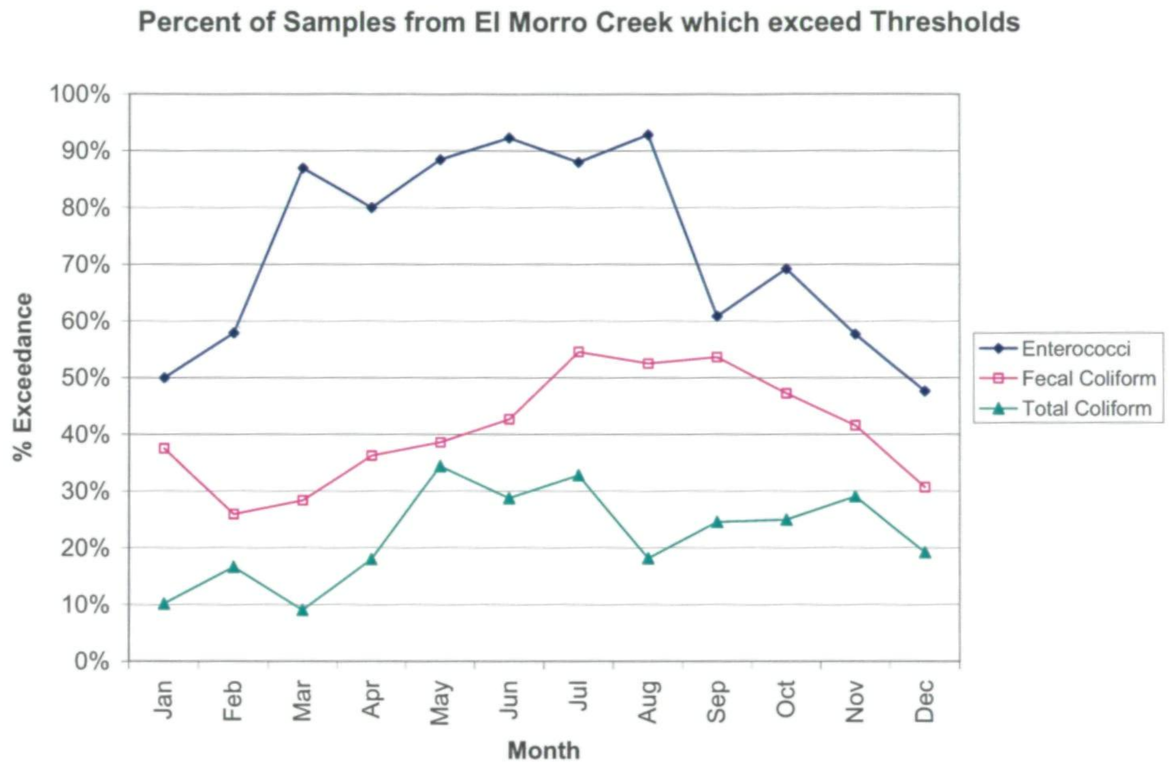
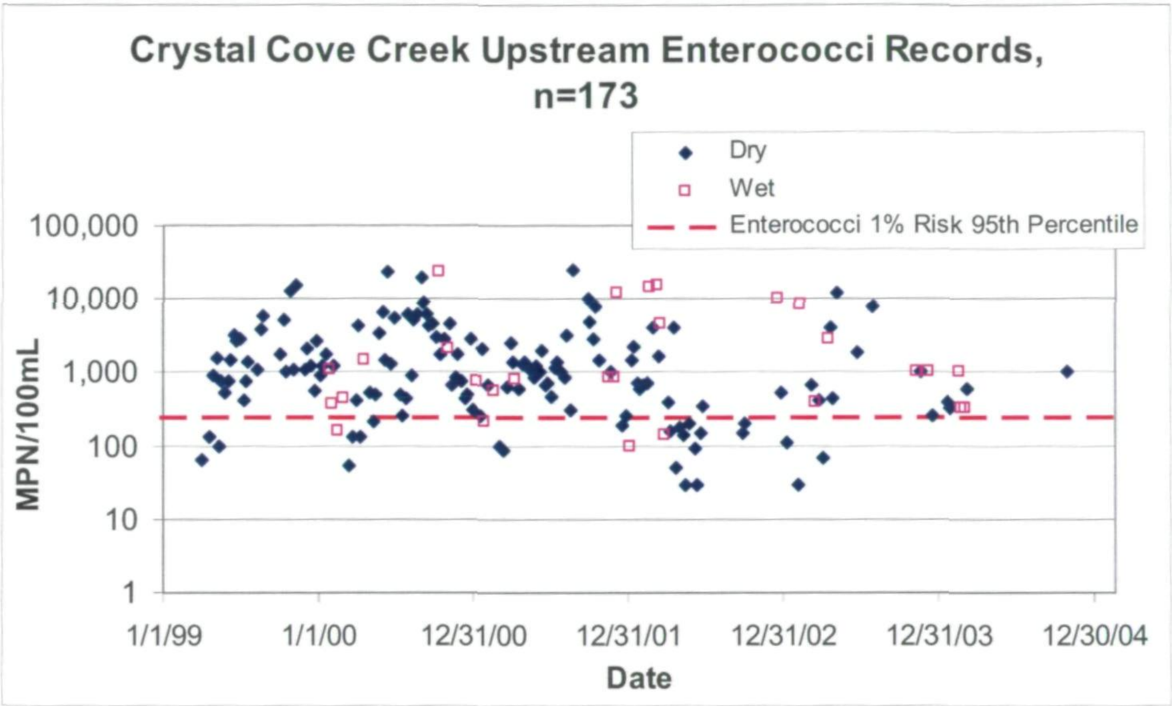


**Figure A 38: Crystal Cove Creek Upstream enterococci data and corresponding cumulative frequency distribution**



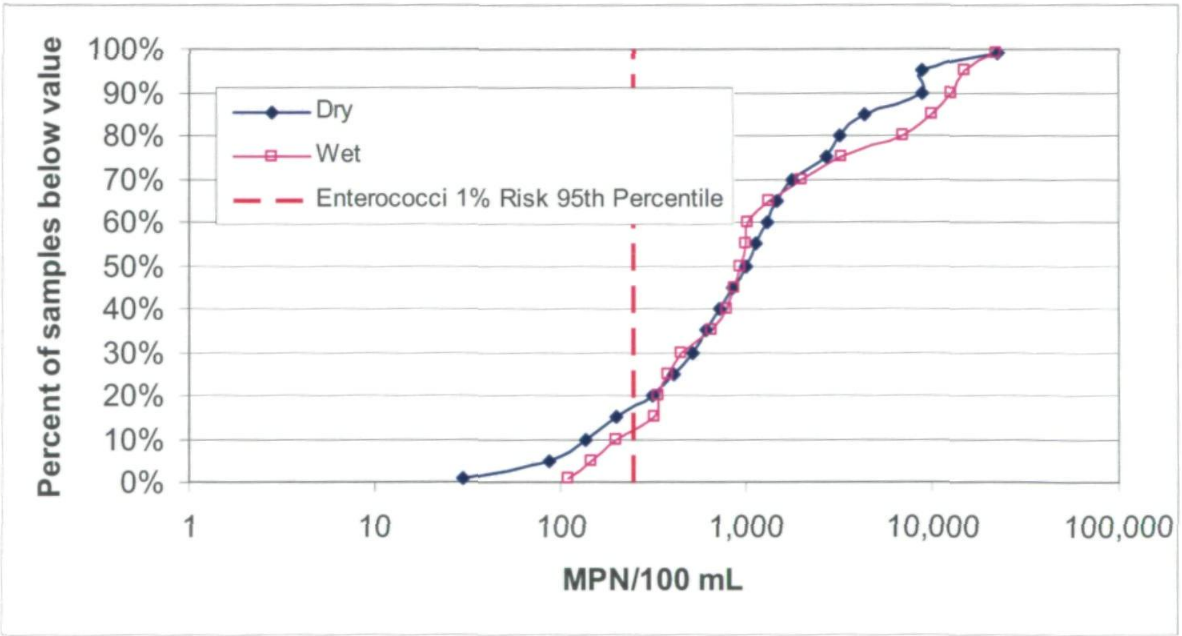



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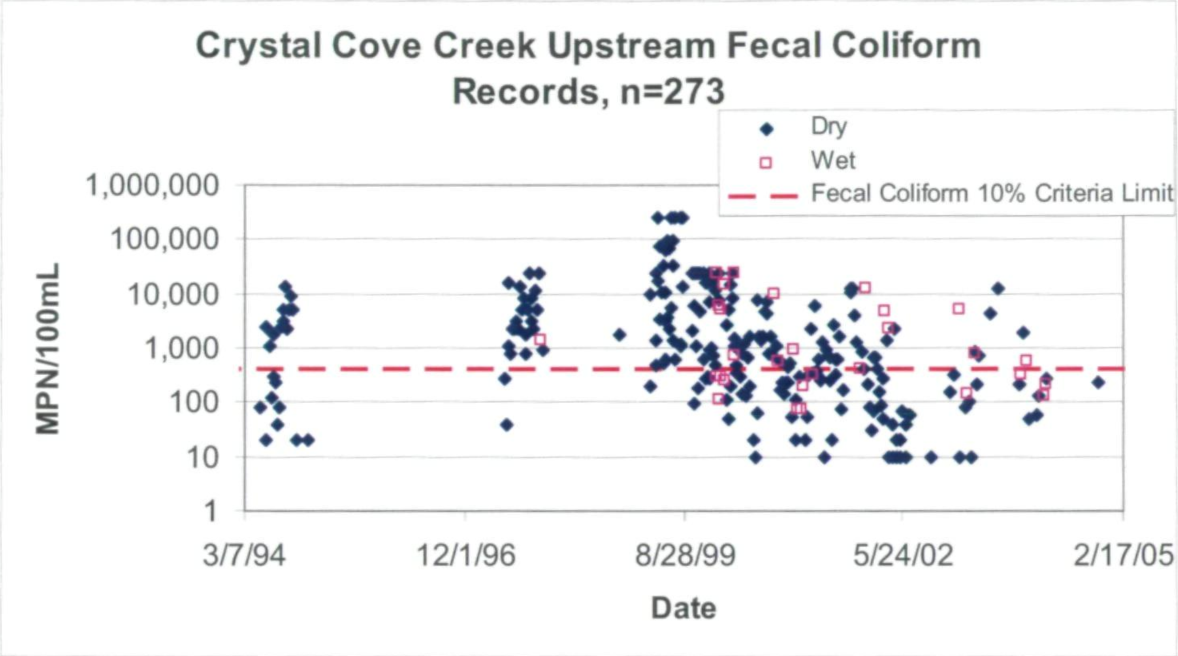
**Figure A 39: Crystal Cove Creek Upstream fecal coliform data and corresponding cumulative frequency distribution**



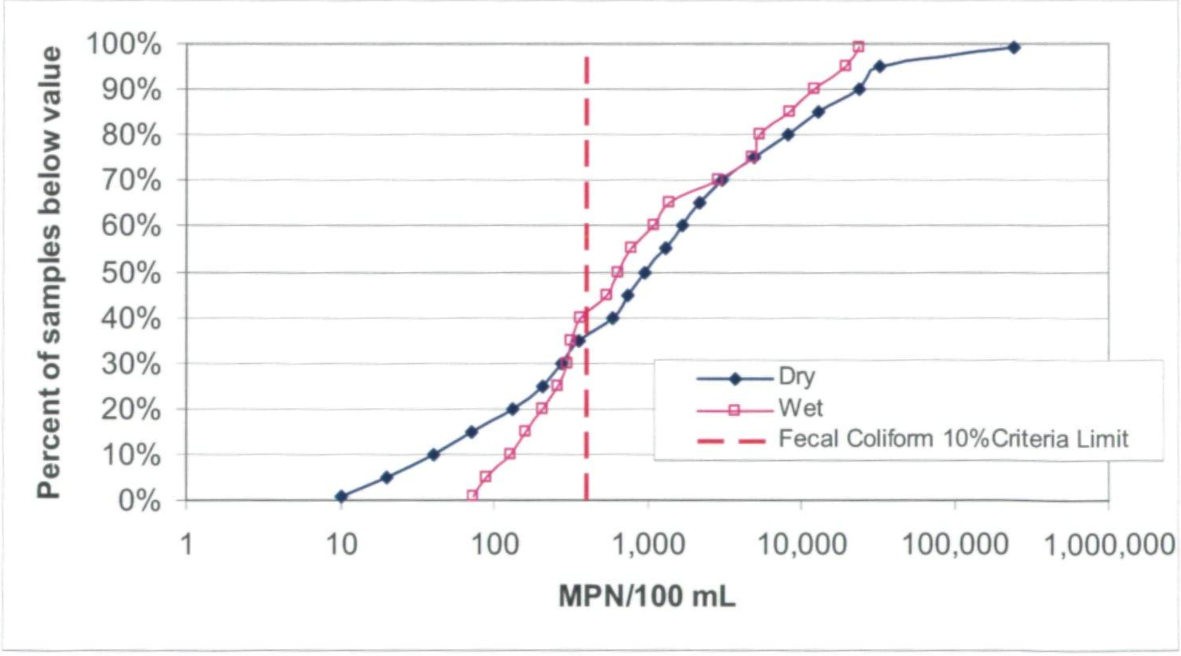
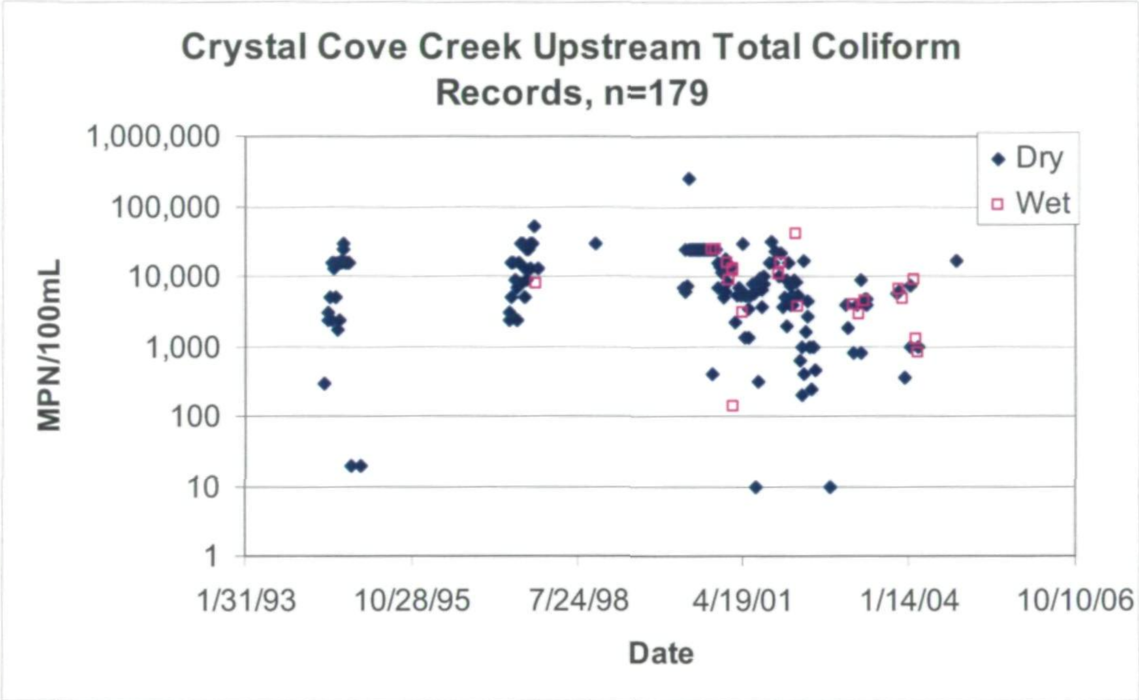



Figure A 40: Crystal Cove Creek Upstream total coliform data and corresponding cumulative frequency distribution



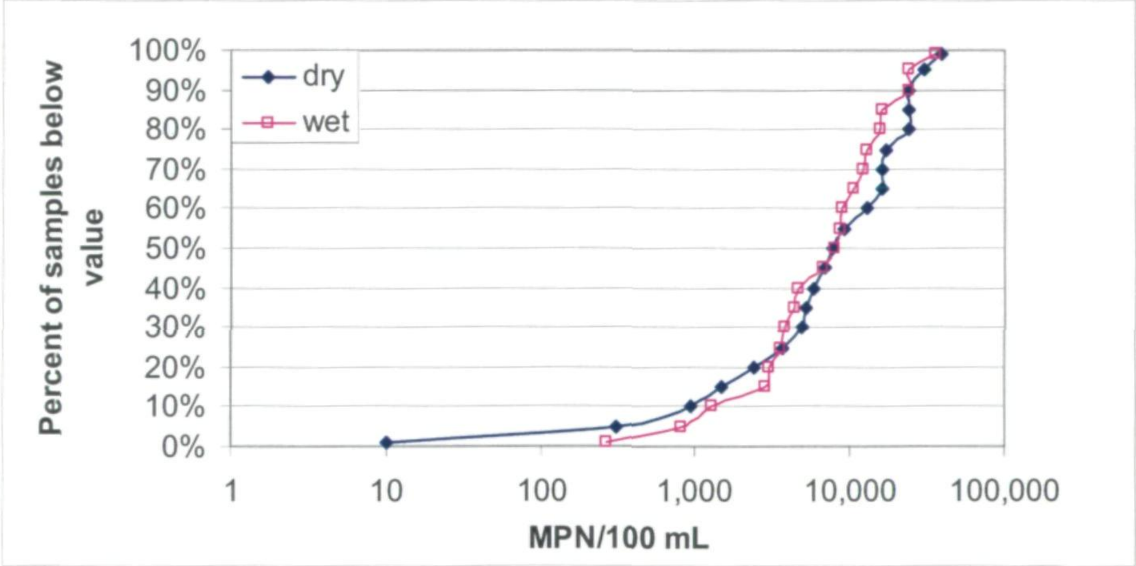



Figure A 41: Percentage of samples from Crystal Cove Creek Upstream which exceed thresholds, by month

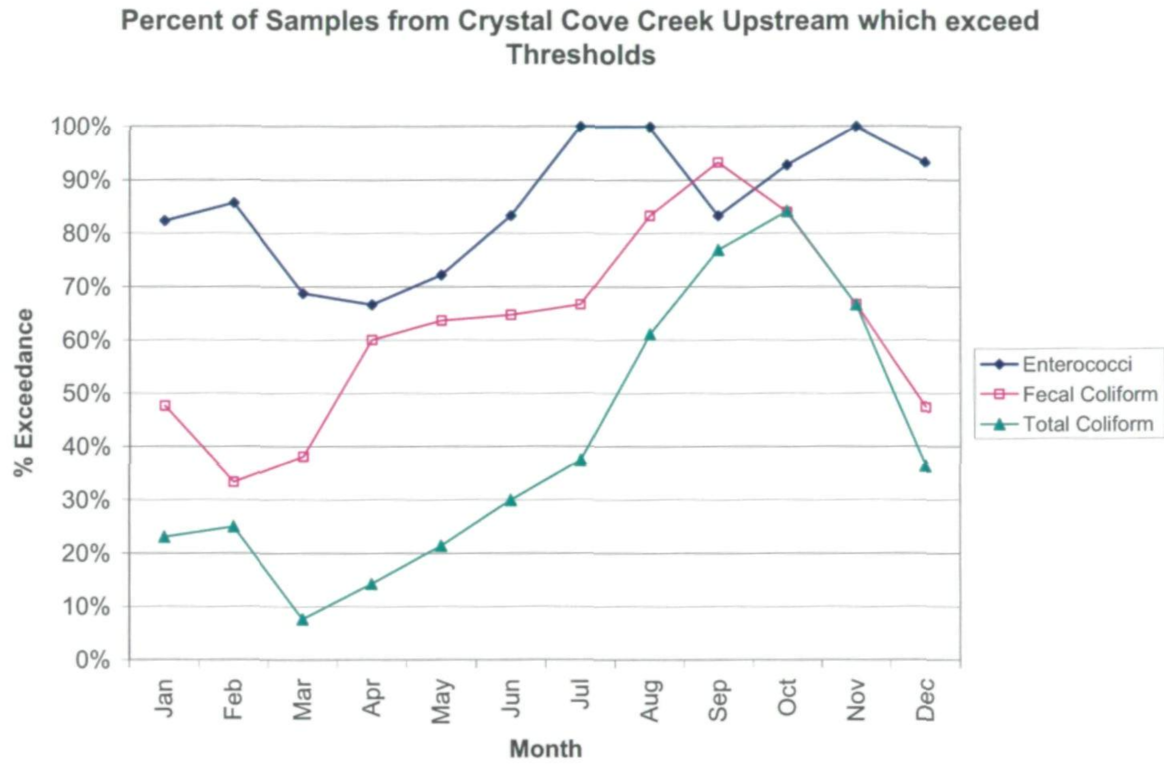
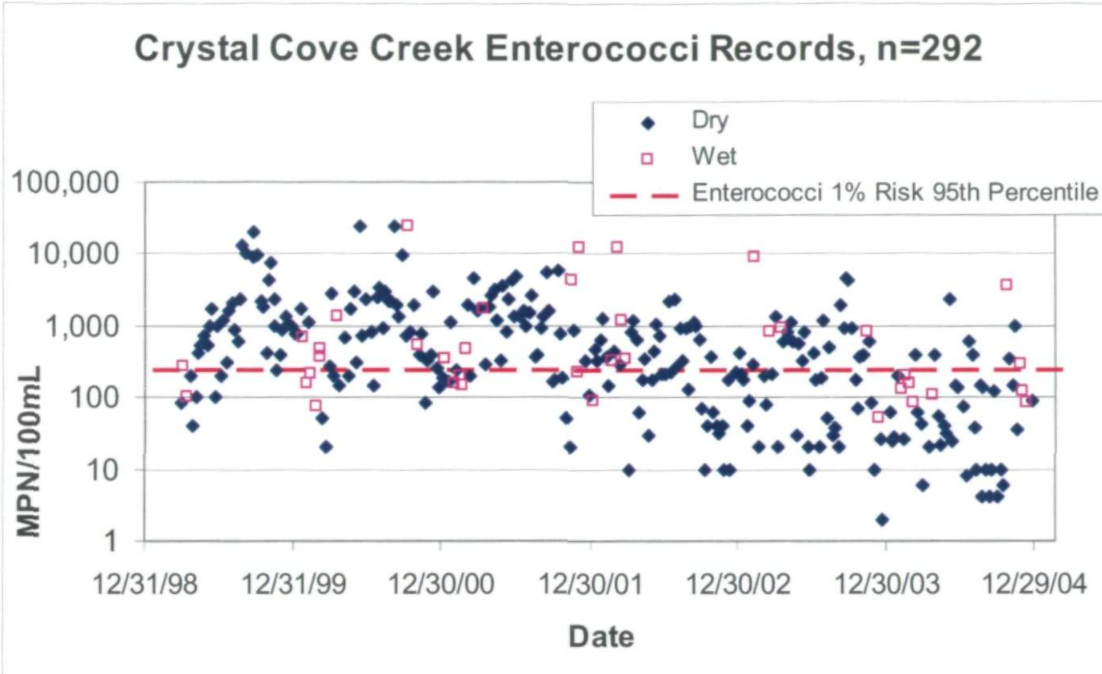


**Figure A 42: Crystal Cove Creek enterococci data and corresponding cumulative frequency distribution**



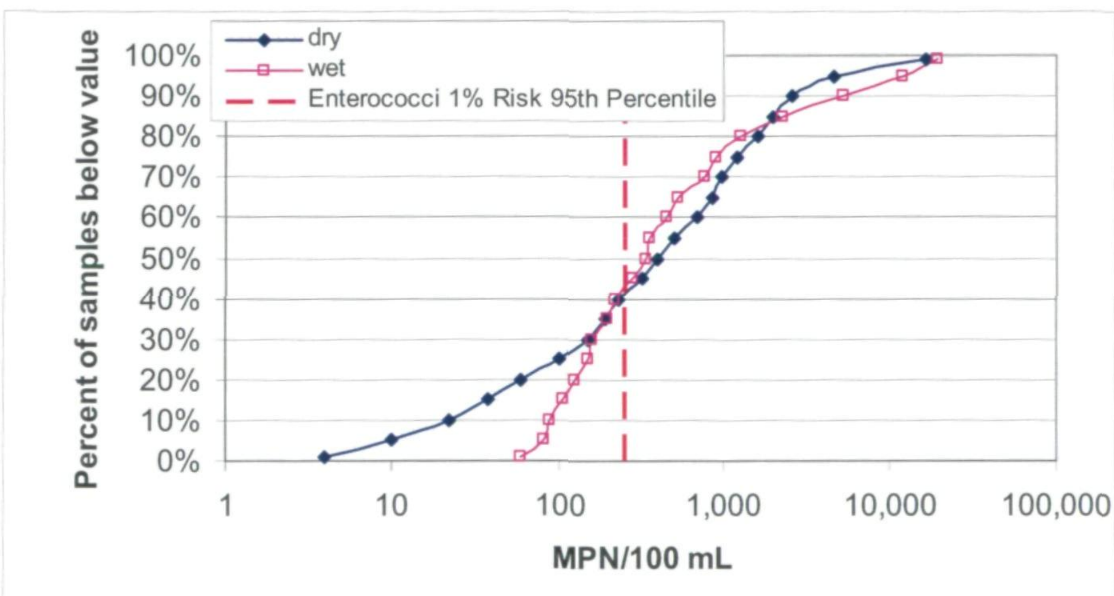
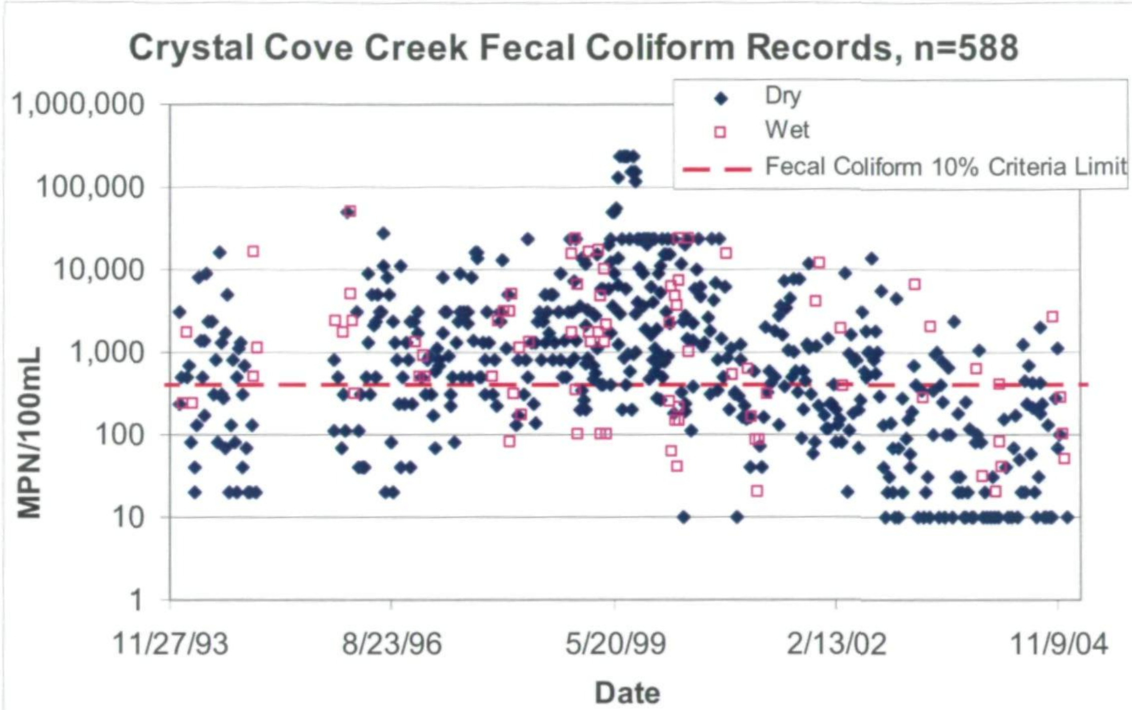



Figure A 43: Crystal Cove Creek fecal coliform data and corresponding cumulative frequency distribution



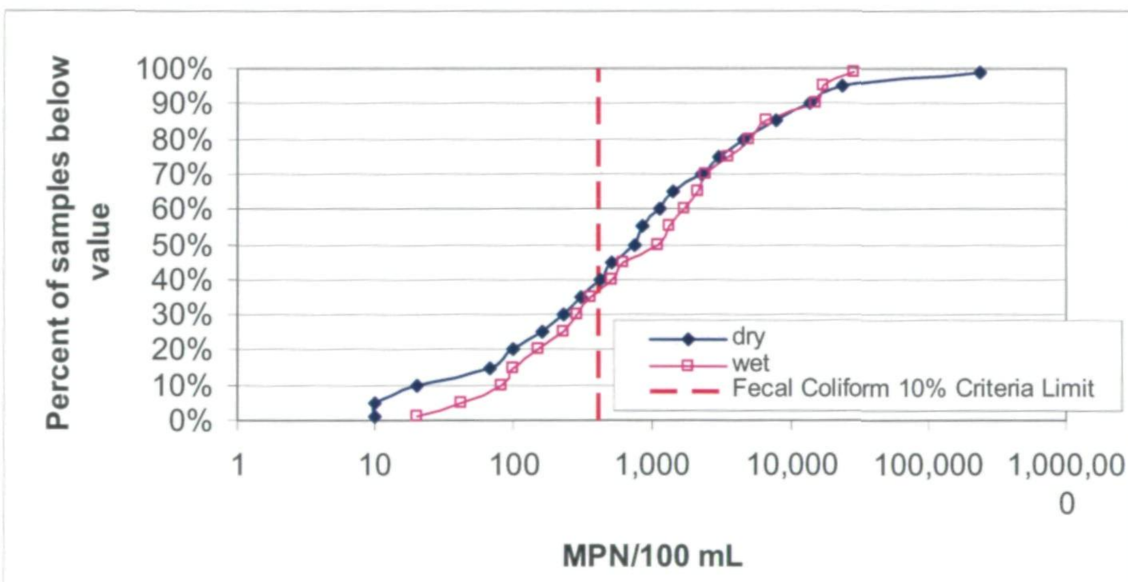



Figure A 44: Crystal Cove Creek total coliform data and corresponding cumulative frequency distribution

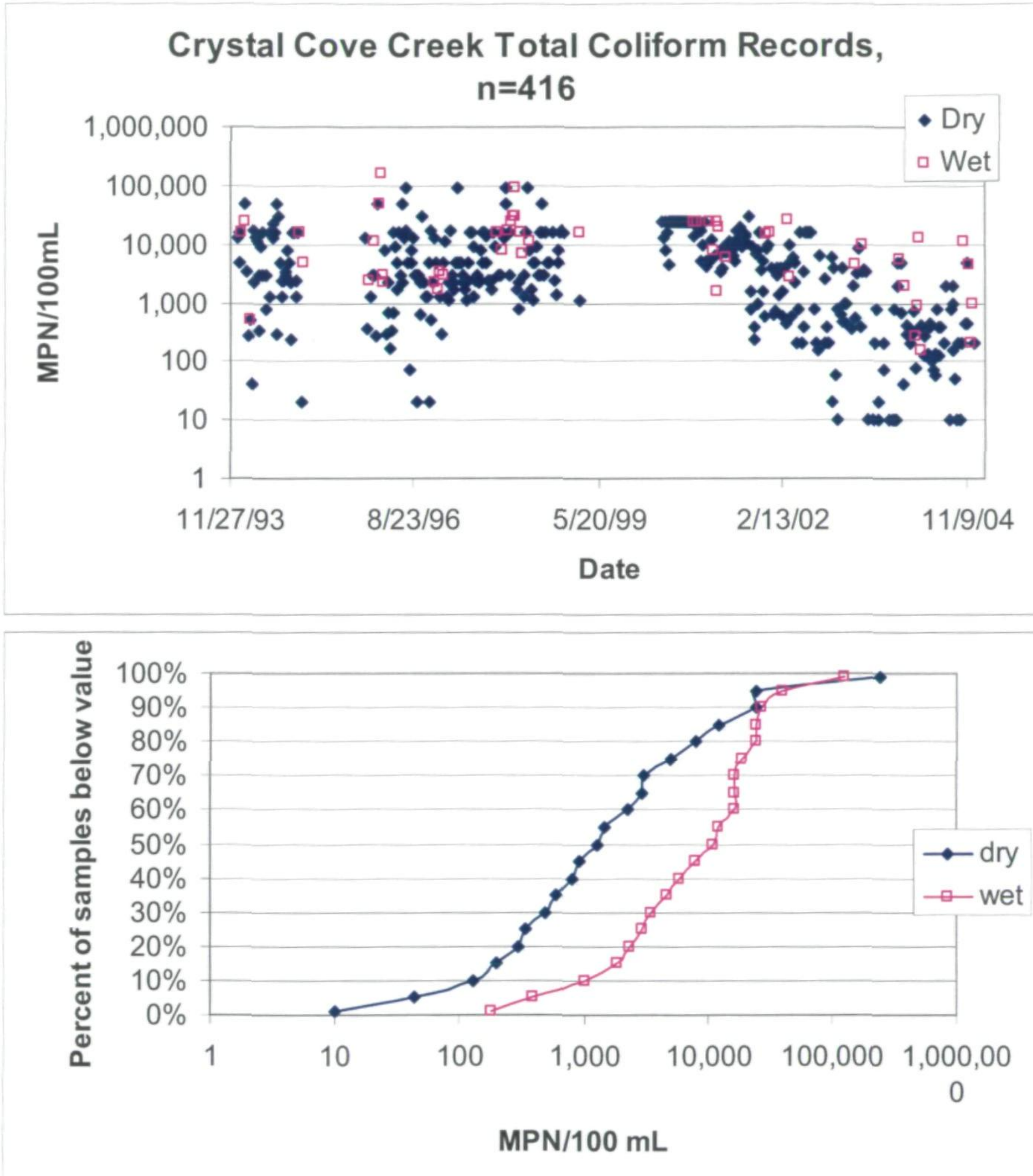


Figure A 45: Percentage of samples from Crystal Cove Creek which exceed thresholds, by month

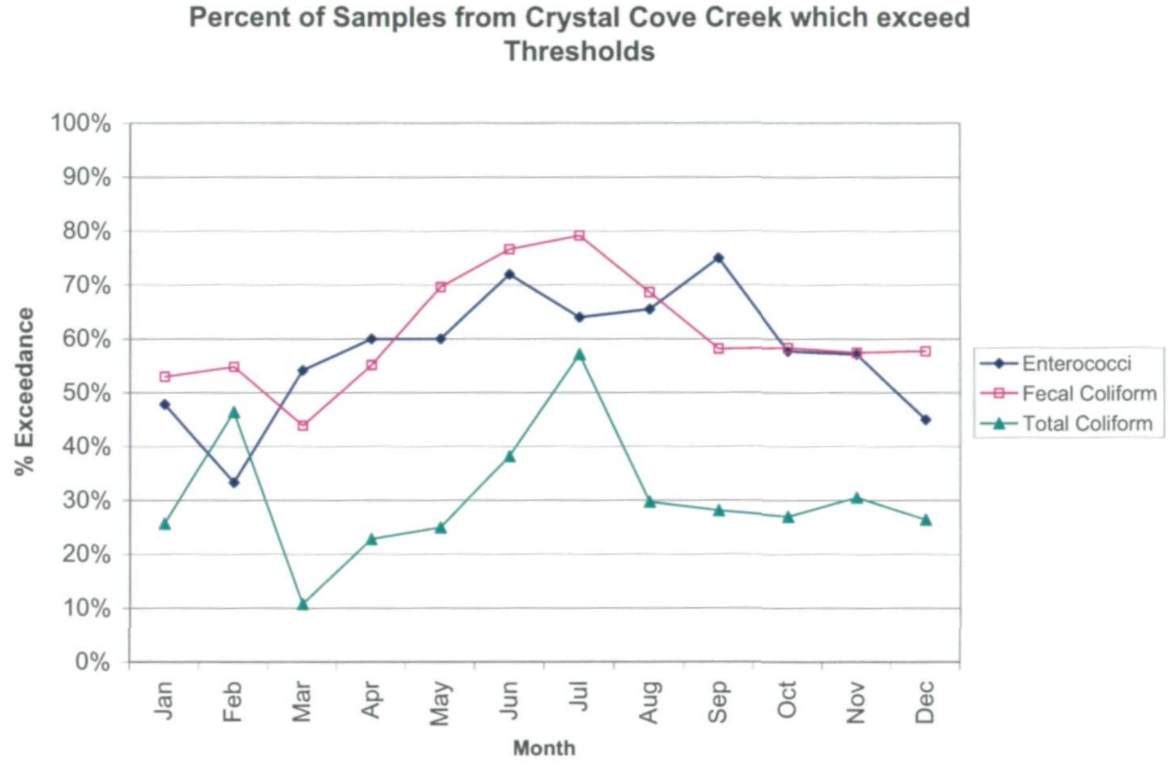
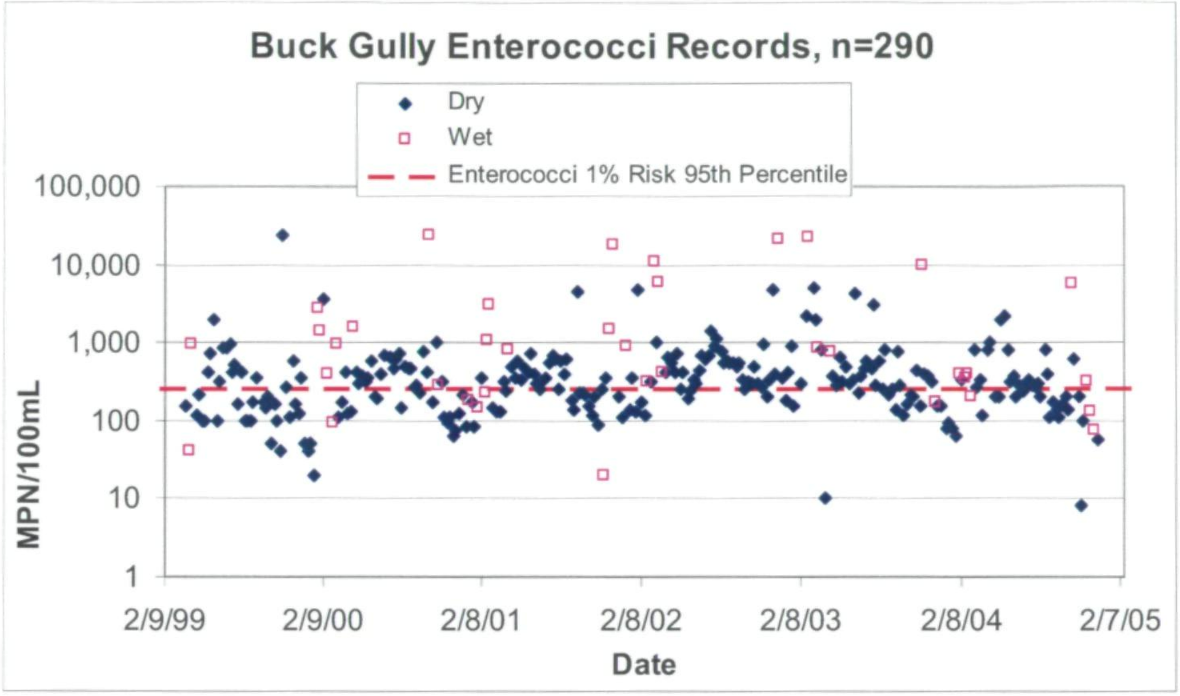


**Figure A 46: Buck Gully enterococci data and corresponding cumulative frequency distribution**



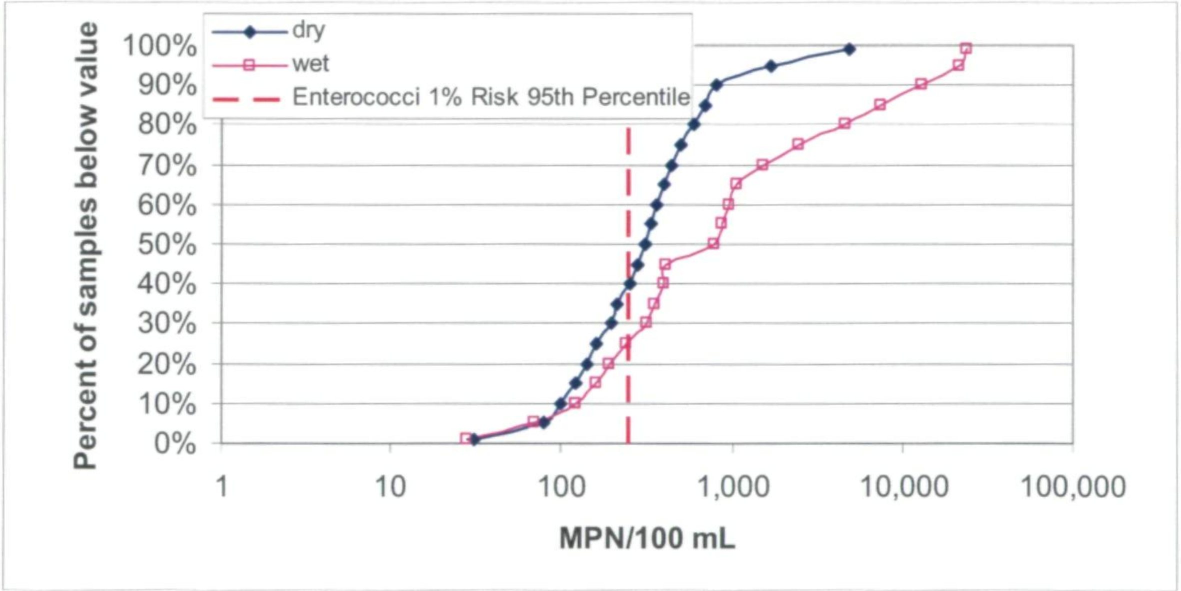
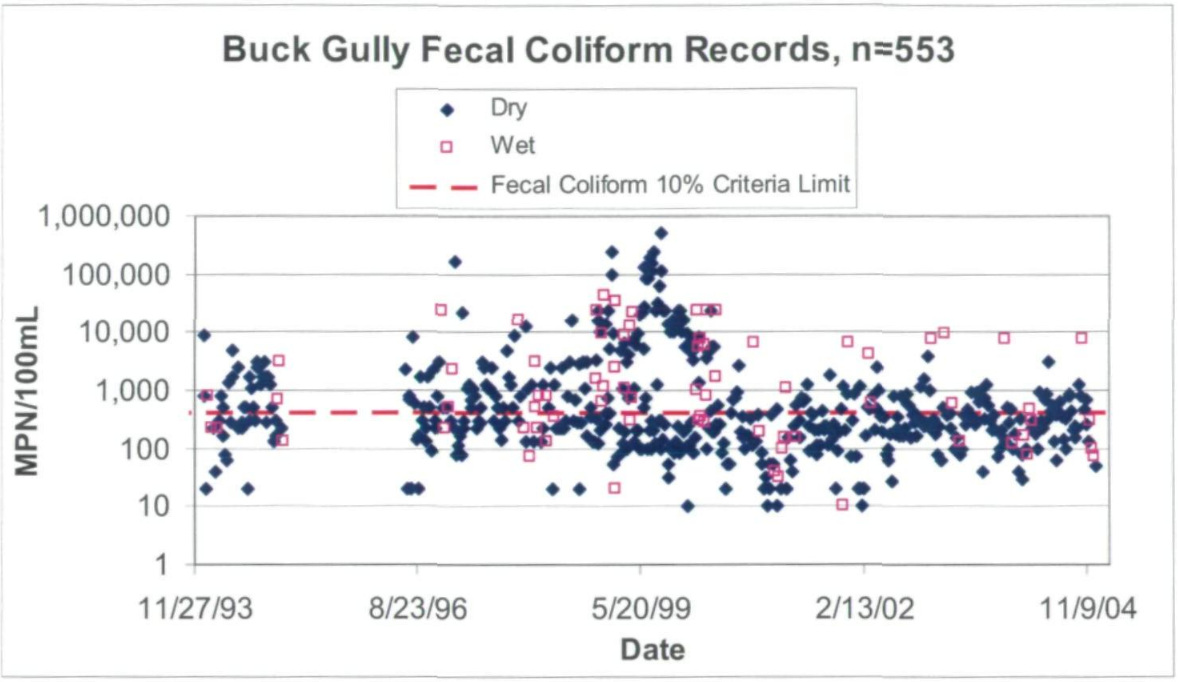



Figure A 47: Buck Gully fecal coliform data and corresponding cumulative frequency distribution



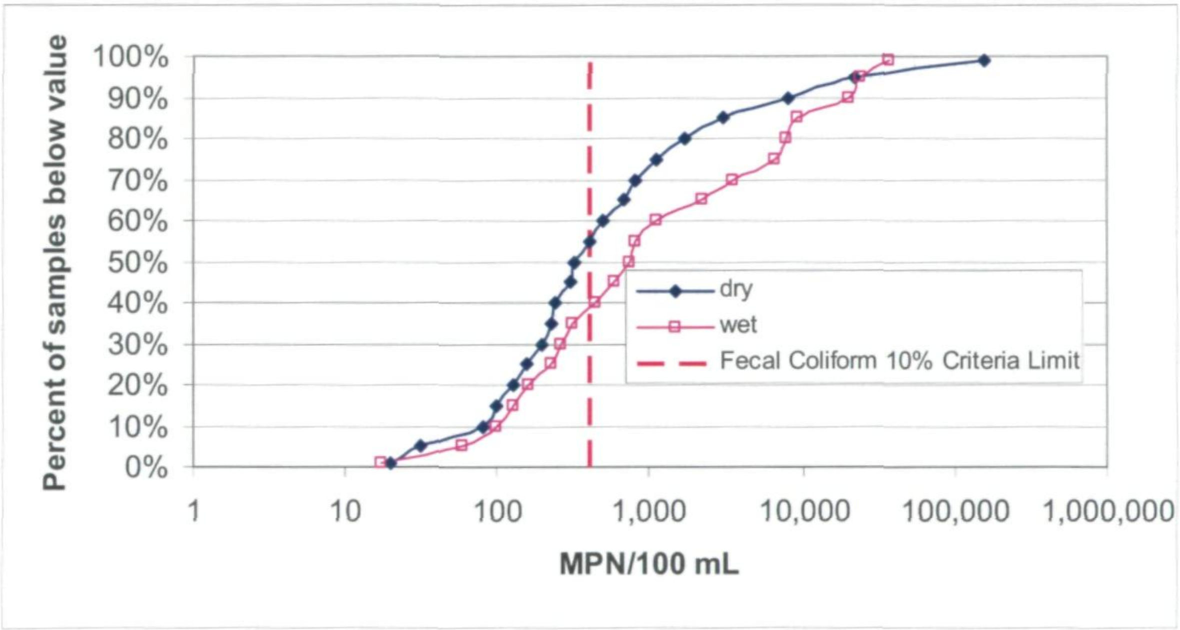
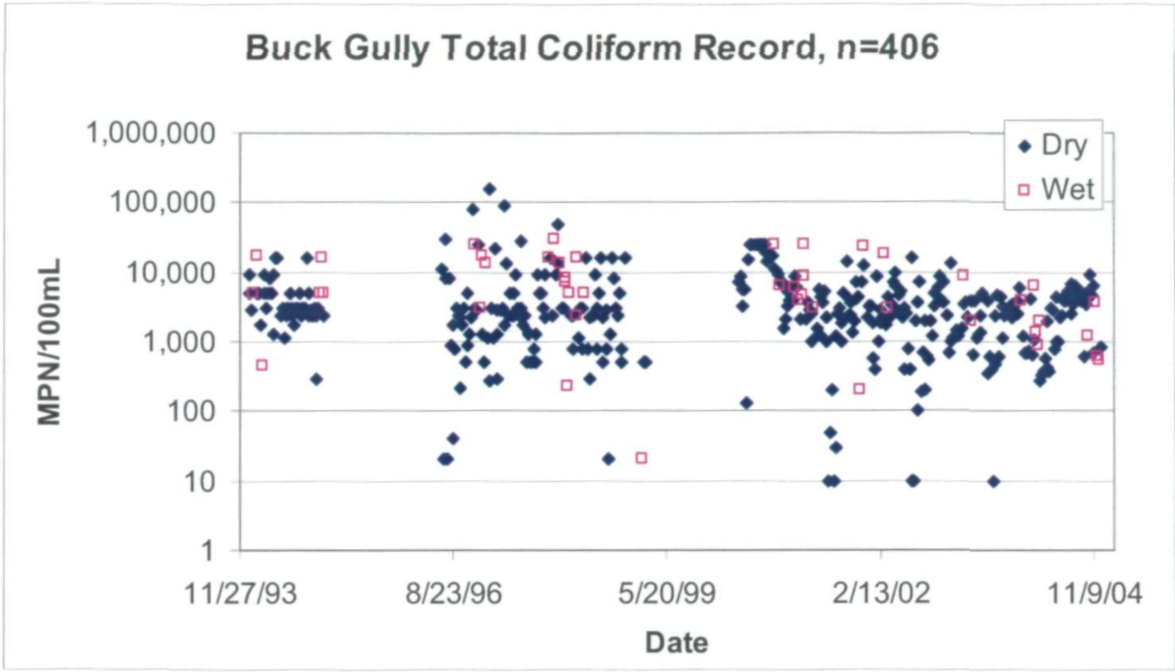



**Figure A 48: Buck Gully total coliform data and corresponding cumulative frequency distribution**



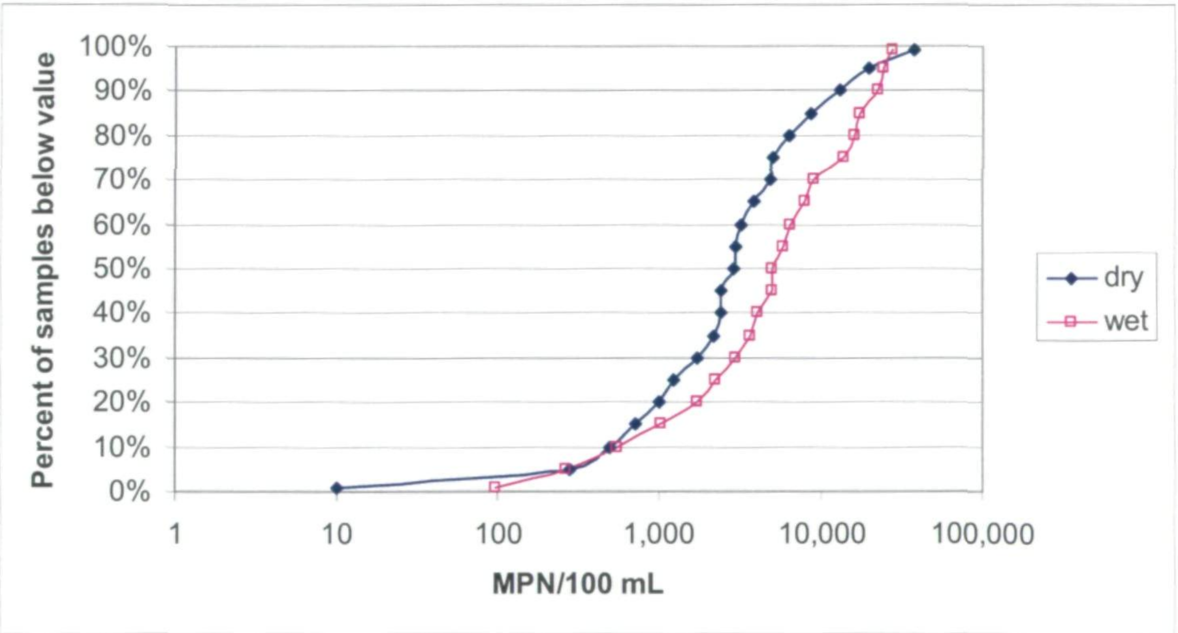



Figure A 49: Percentage of samples from Buck Gully which exceed thresholds, by month

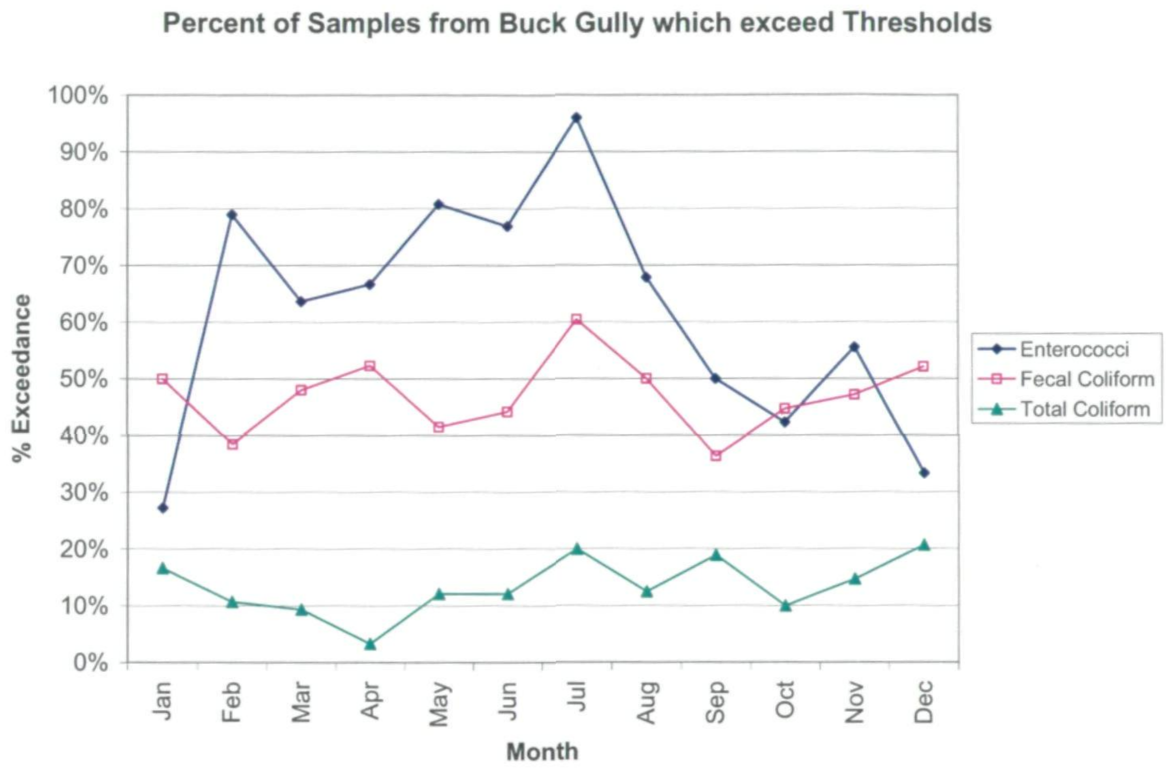


**Figure A 50: Broadway Creek enterococci data and corresponding cumulative frequency distribution**

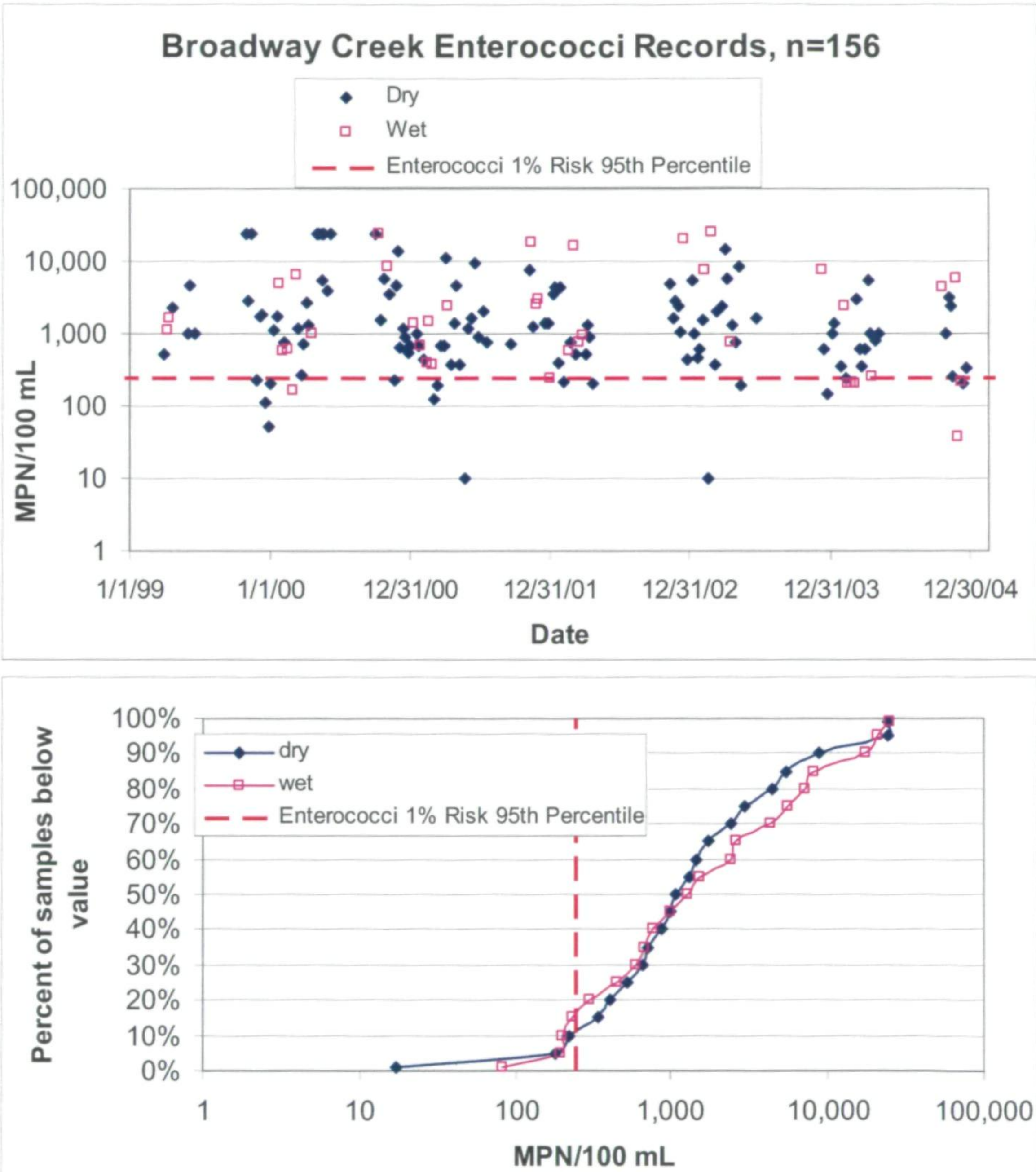


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**Figure A 51: Broadway Creek fecal coliform data and corresponding cumulative frequency distribution**

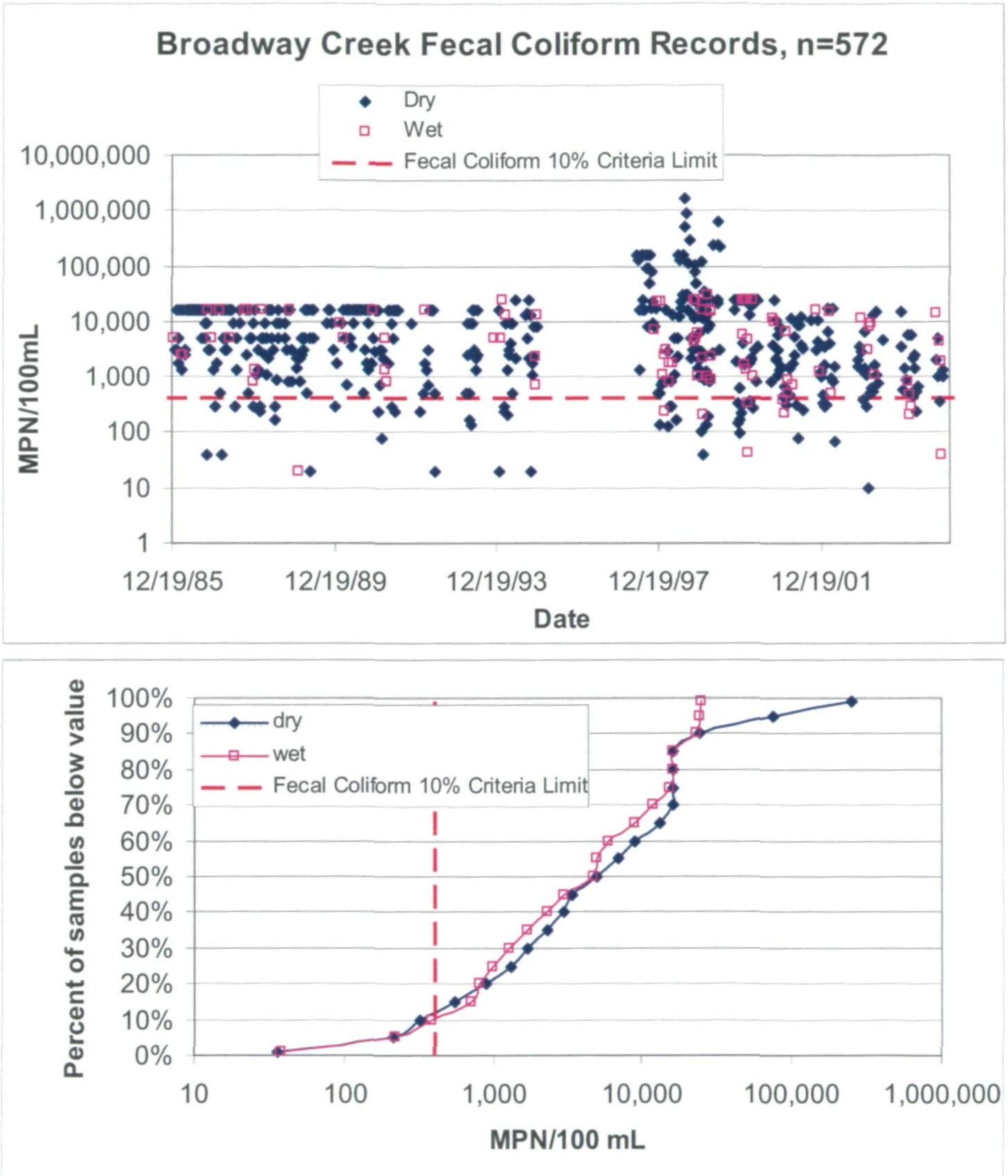
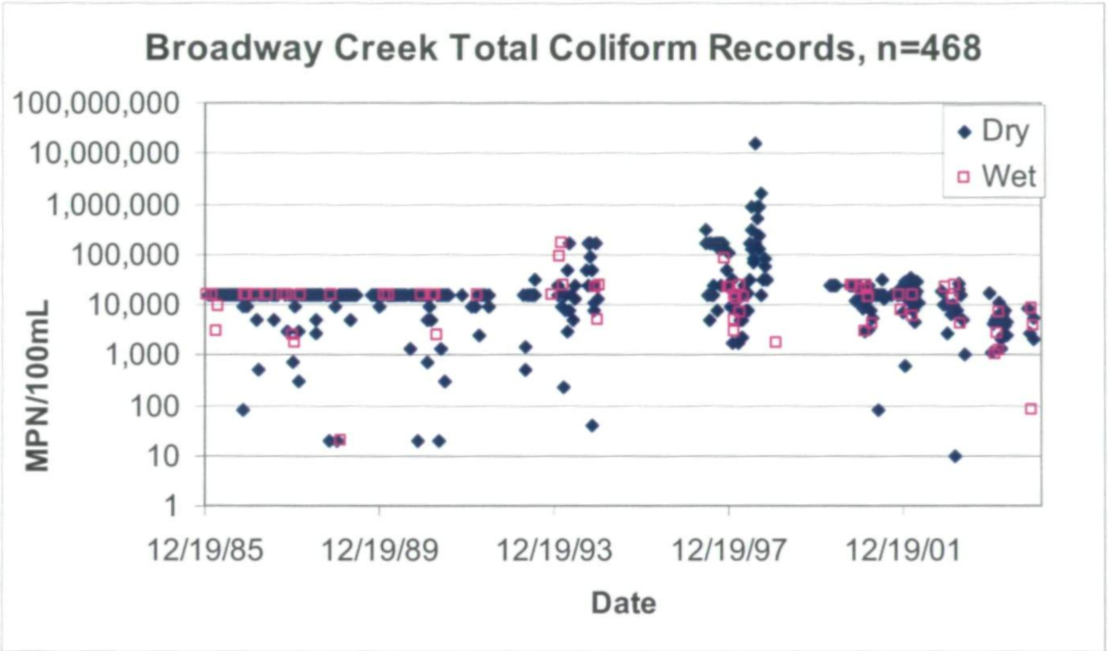


Figure A 52: Broadway Creek total coliform data and corresponding cumulative frequency distribution



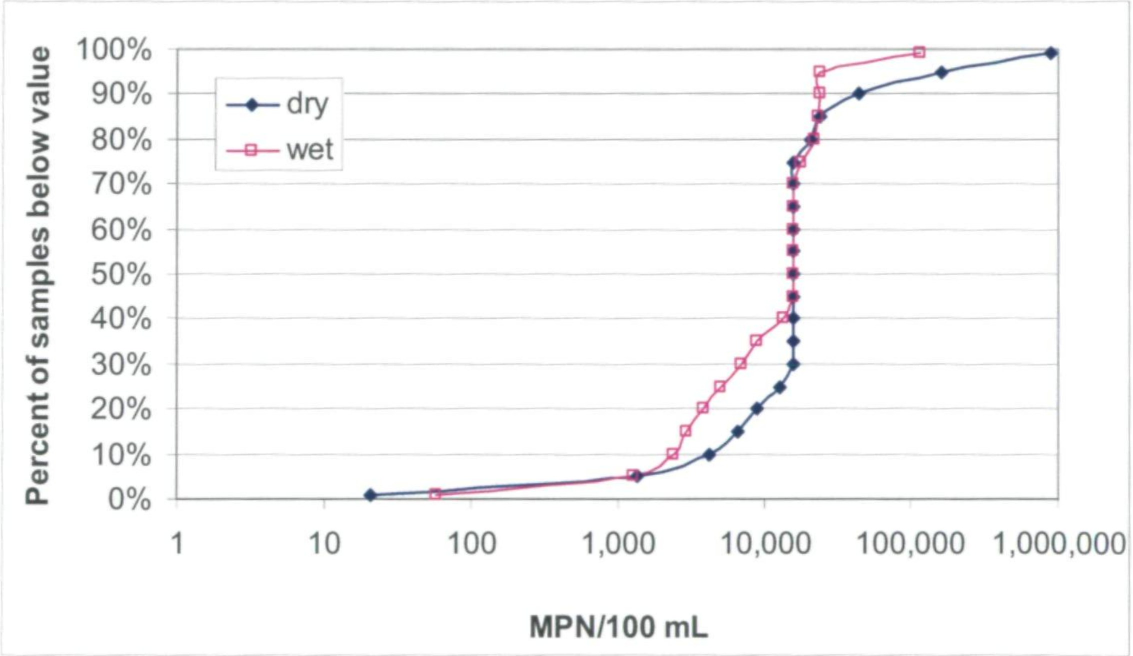
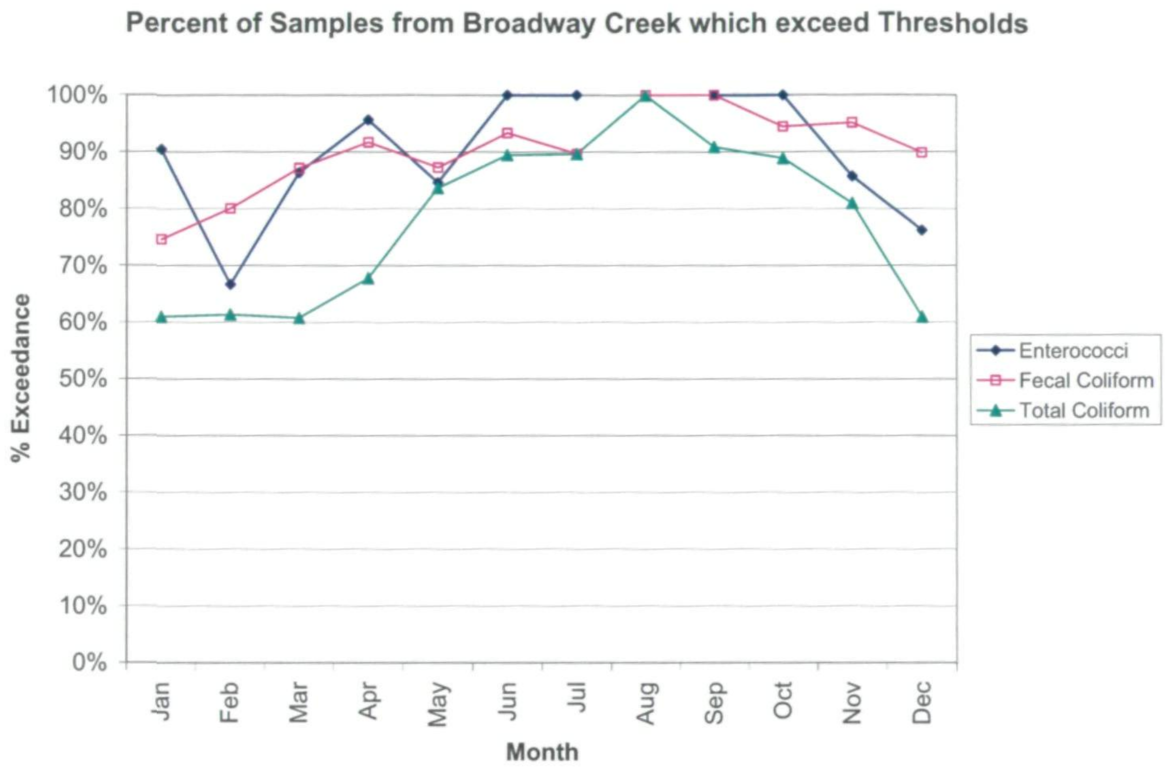



Figure A 53: Percentage of samples from Broadway Creek which exceed thresholds, by month



APPENDIX B

DATA FROM SANTA ANA REGION

FIGURES REPRODUCED FROM CDM 2005

**Figure B 1: Santa Ana Watershed and sites selected by CDM for detailed bacteriological analysis (CDM 2005 Figure 19)**

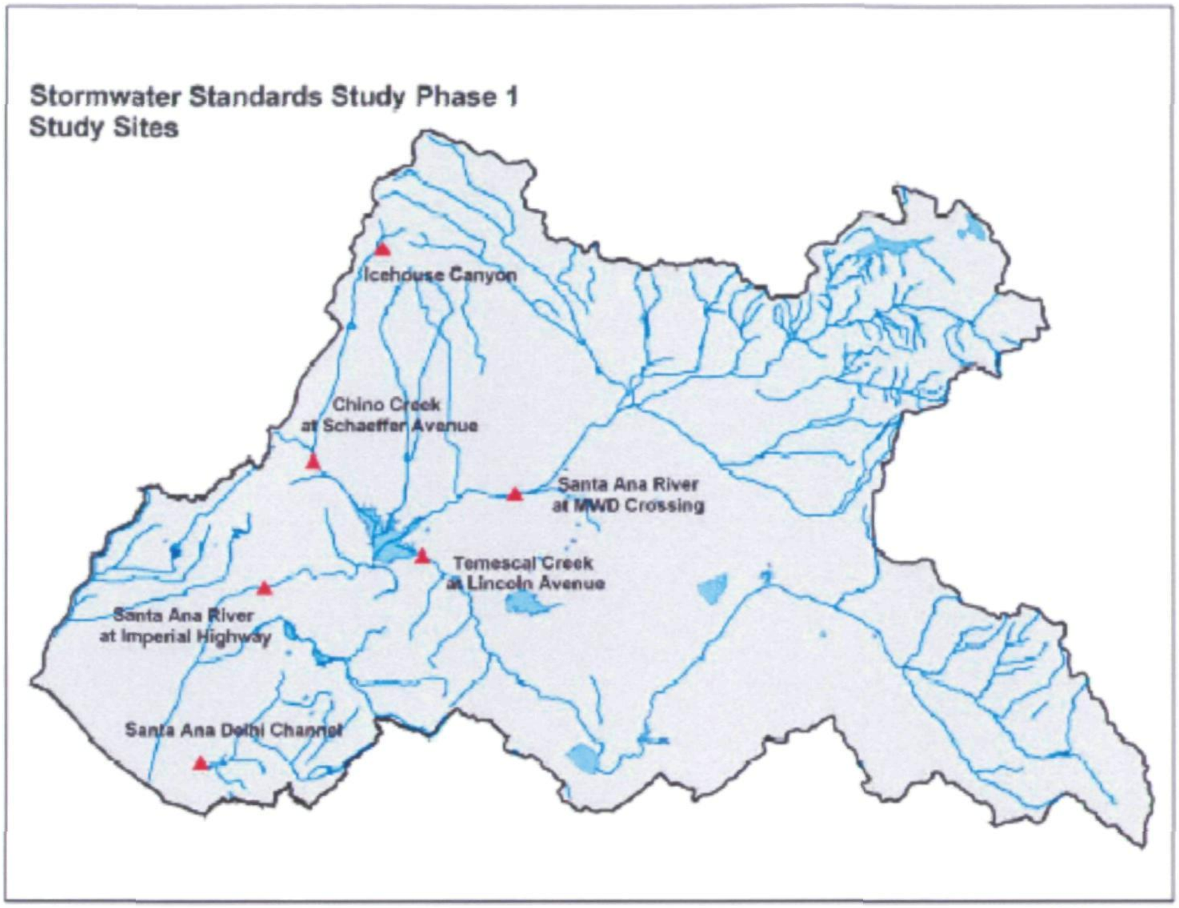



Figure 19
Study Sites Selected for Detailed Analysis

Figure B 2: Flow rate and bacteria concentration, Chino Creek (CDM 2005 Figure 35)

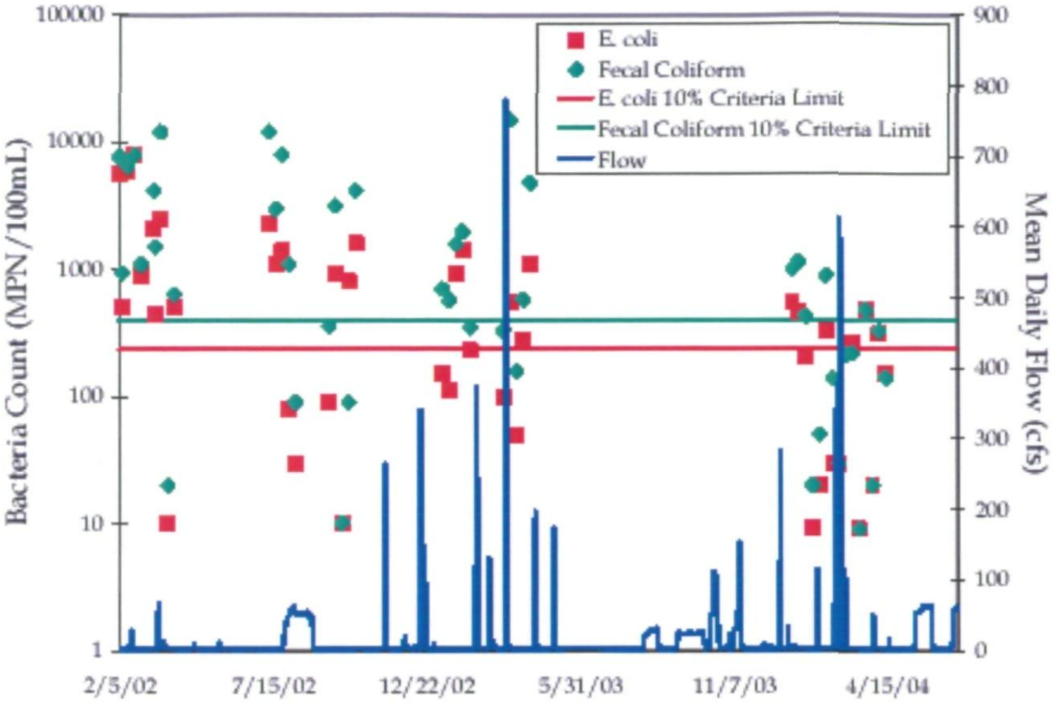



Figure 35
Time Series of Bacteria Counts and Flow at the Chino Creek at Schaeffer Avenue Study Site

**Figure B 3: Flow rate and bacteria concentration, Santa Ana Delhi Channel (CDM 2005 Figure 53)**

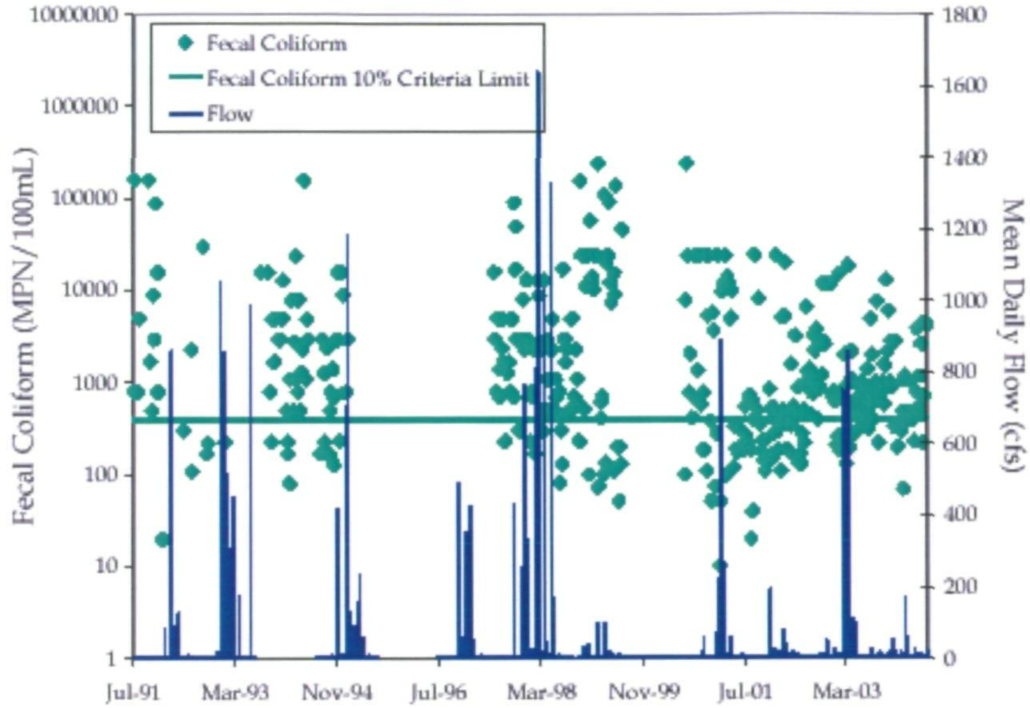



**Figure 53**
**Time Series of Bacteria Concentrations and Flow in the Santa Ana Delhi Channel - Backbay**

Figure B 4: Flow rate and bacteria concentration, Temescal Creek (CDM 2005 Figure 72)

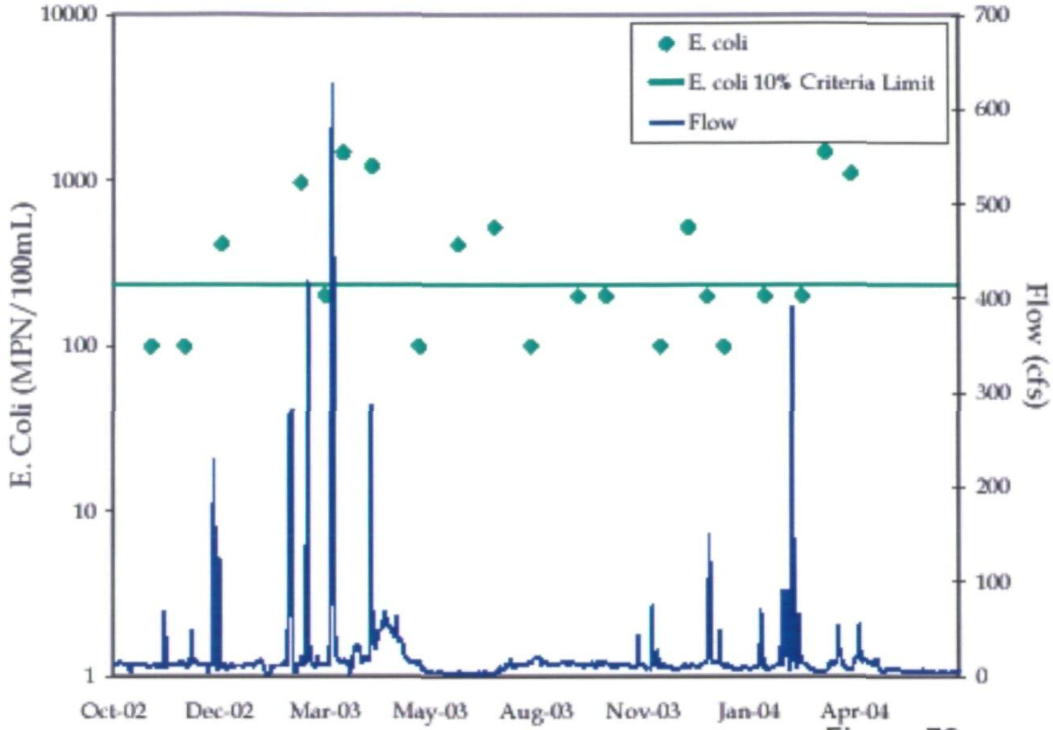



Figure 72
Time Series of Bacteria Concentrations and Flow in Temescal Creek from October 2002 to April 2004

**Figure B 5: Flow rate and bacteria concentration, Santa Ana River at MWD Crossing (CDM 2005 Figures 98 and 99)**

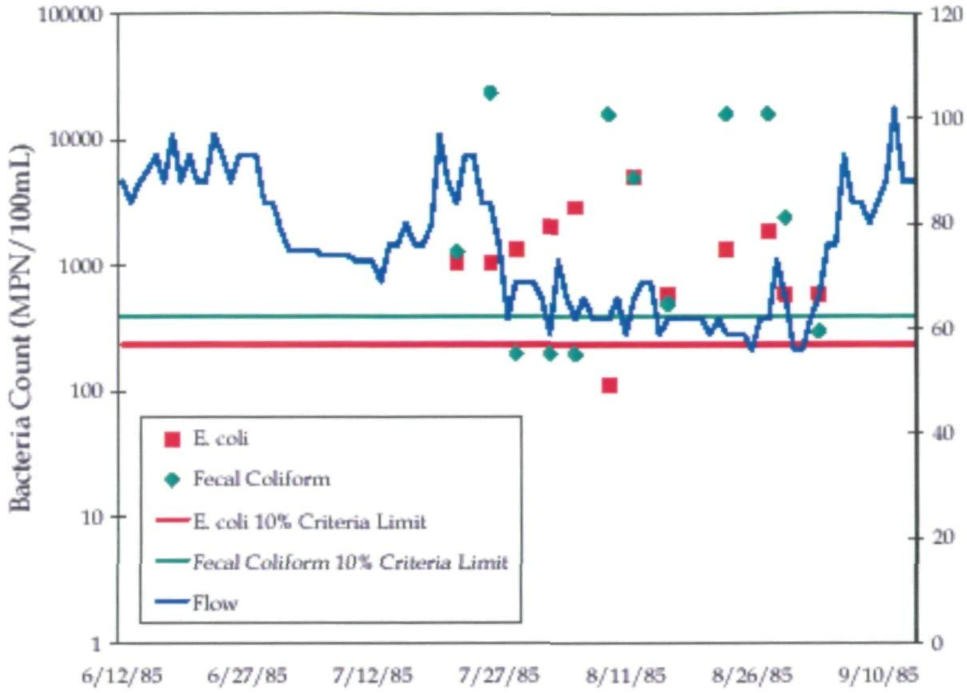



**Figure 98**
**Time Series of Bacteria Concentrations and Flow in the Santa Ana River at the MWD Crossing Study Site**

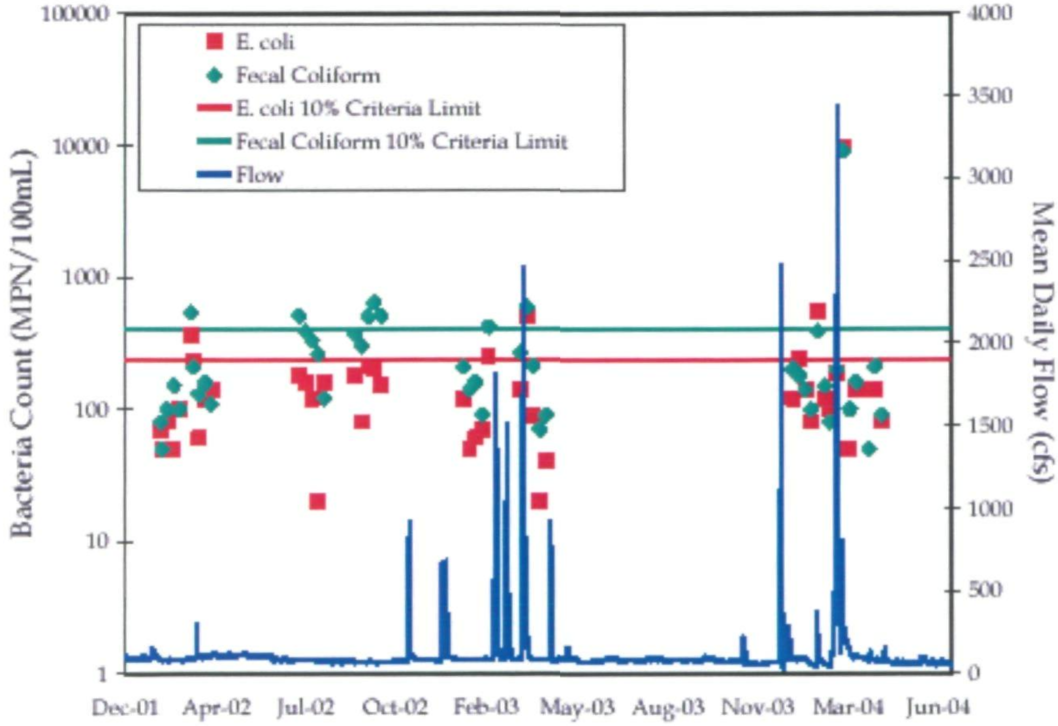



**Figure 99**
**Time Series of Bacteria Concentrations and Flow in the Santa Ana River at the MWD Crossing Study Site**

**Figure B 6: Flow rate and bacteria concentration, Santa Ana River at Imperial Highway (CDM 2005 Figure 83)**

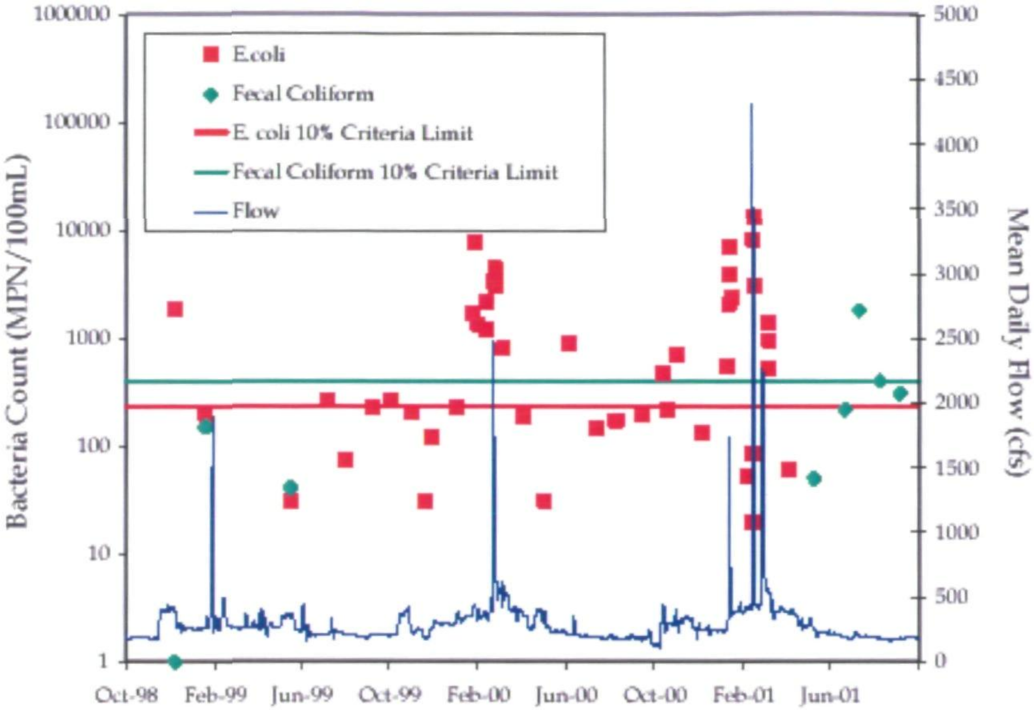



**Figure 83**
**Time Series of Bacteria Concentrations and Flow in the Santa Ana River at the Imperial Highway Study Site**

Figure B 9: Percent of months exceeding objectives (CDM 2005 Figure 110)

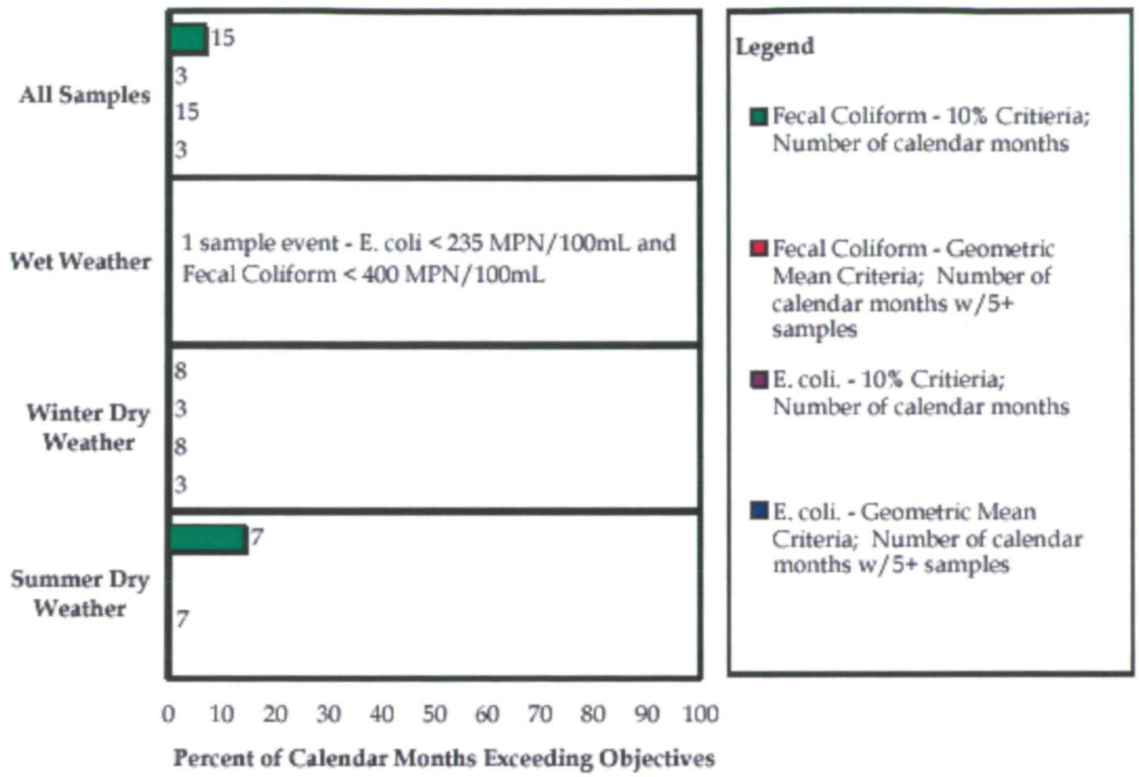



Figure 110
Comparison with Existing and Potential Bacteria Water Quality Objectives
Icehouse Canyon Creek

Figure B 10: Percent of months exceeding objectives (CDM 2005 Figure 88)

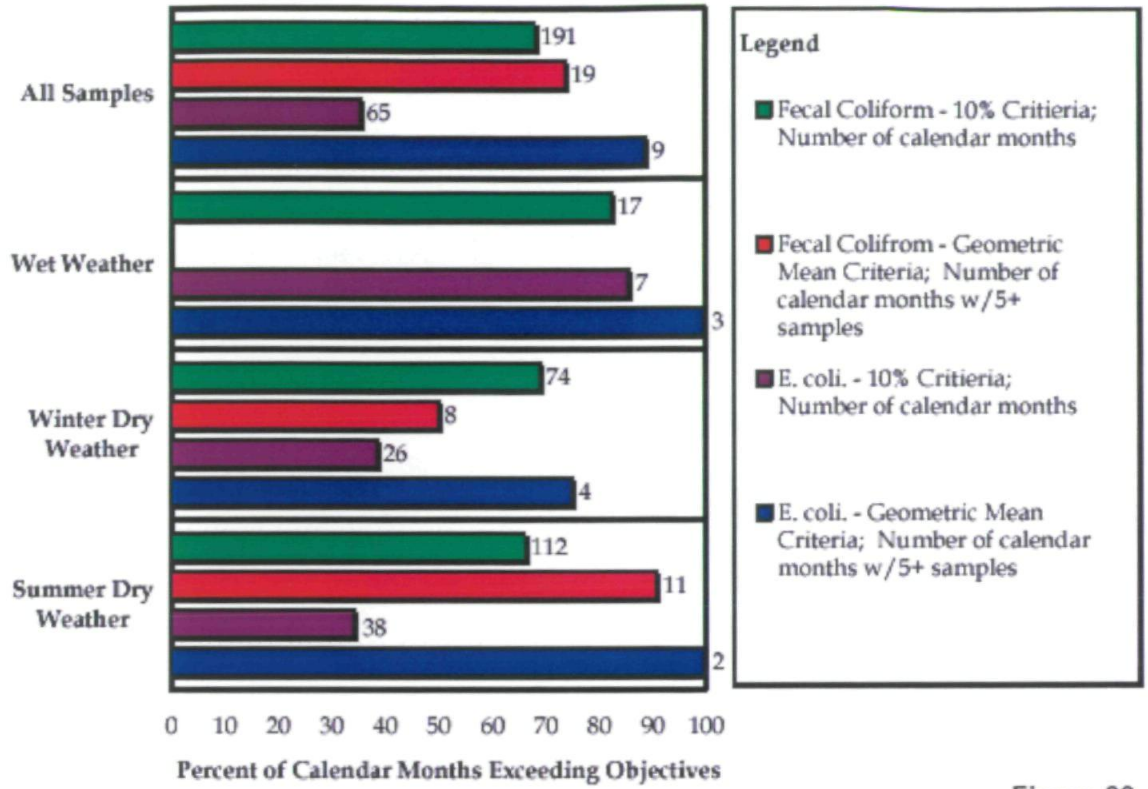



Figure 88
Comparison with Existing and Potential Bacteria Water Quality Objectives
Santa Ana River at Imperial Highway

Figure B 11: Percent of months exceeding objectives (CDM 2005 Figure 74)

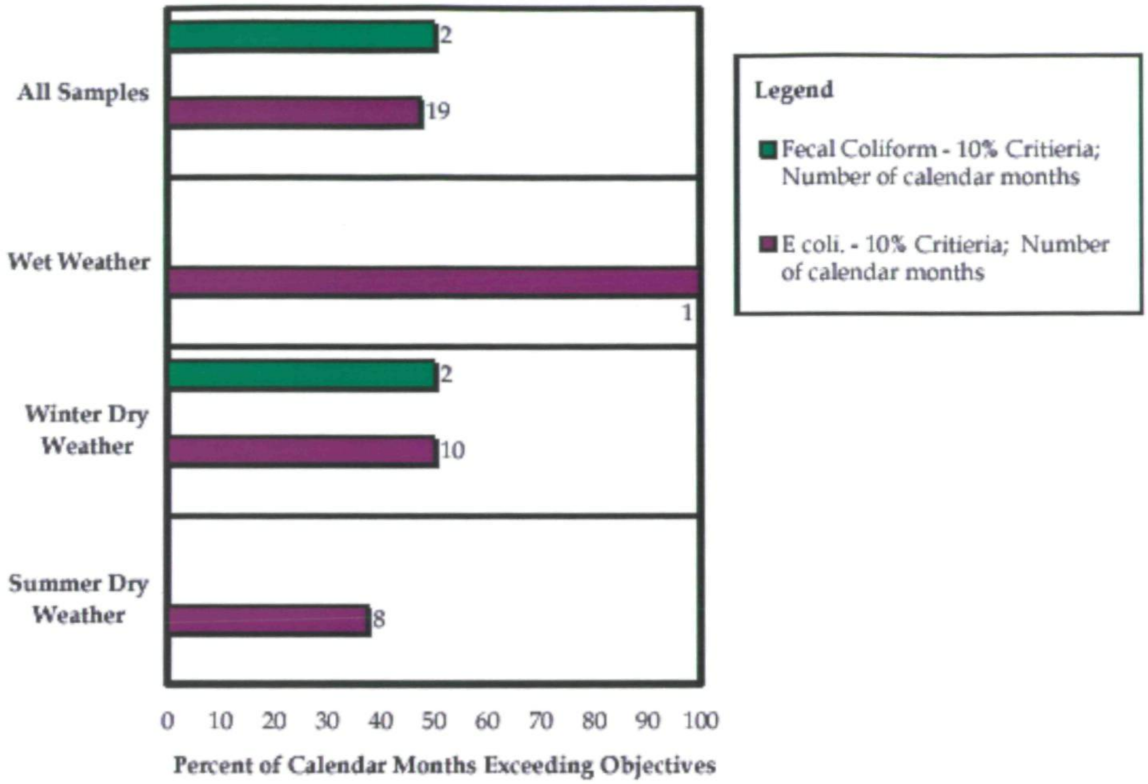



Figure 74
Comparison with Existing and Potential Bacteria Water Quality Objectives
Temescal Creek Near Lincoln Avenue

Figure B 12: Percent of months exceeding objectives (CDM 2005 Figure 38)

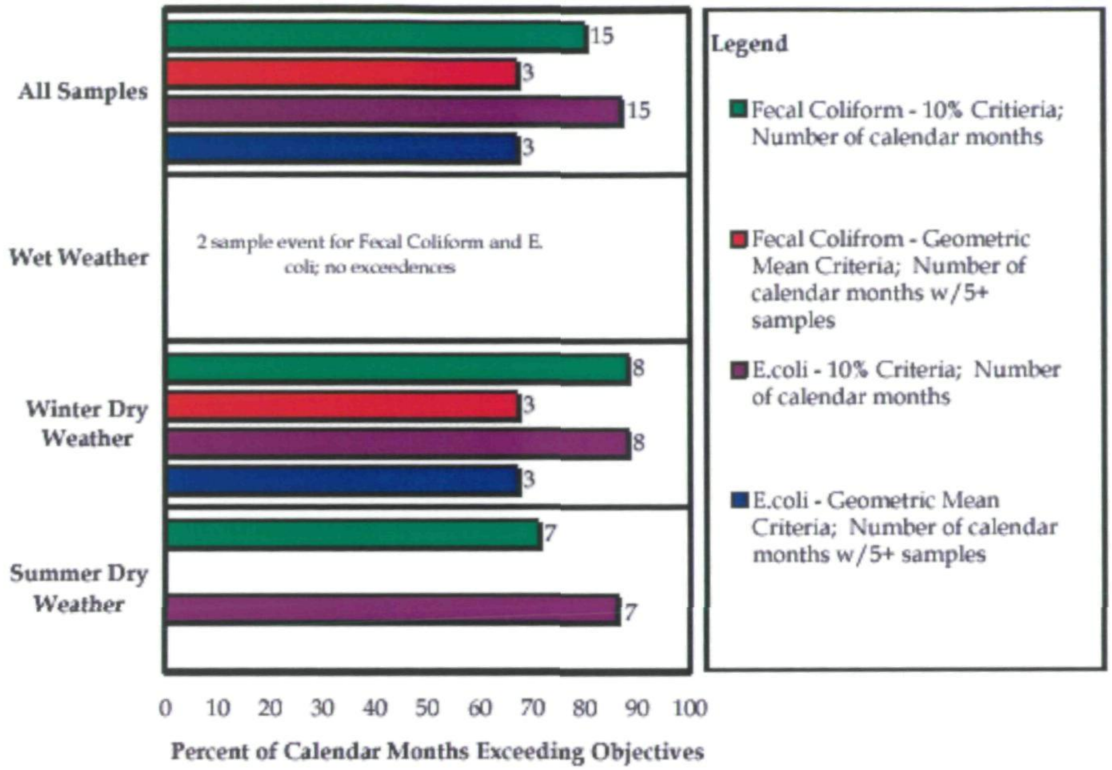



Figure 38
Comparison with Existing and Potential Bacteria Water Quality Objectives
Chino Creek At Schaeffer Ave.

Figure B 13: Percent of months exceeding objectives (CDM 2005 Figure 57)

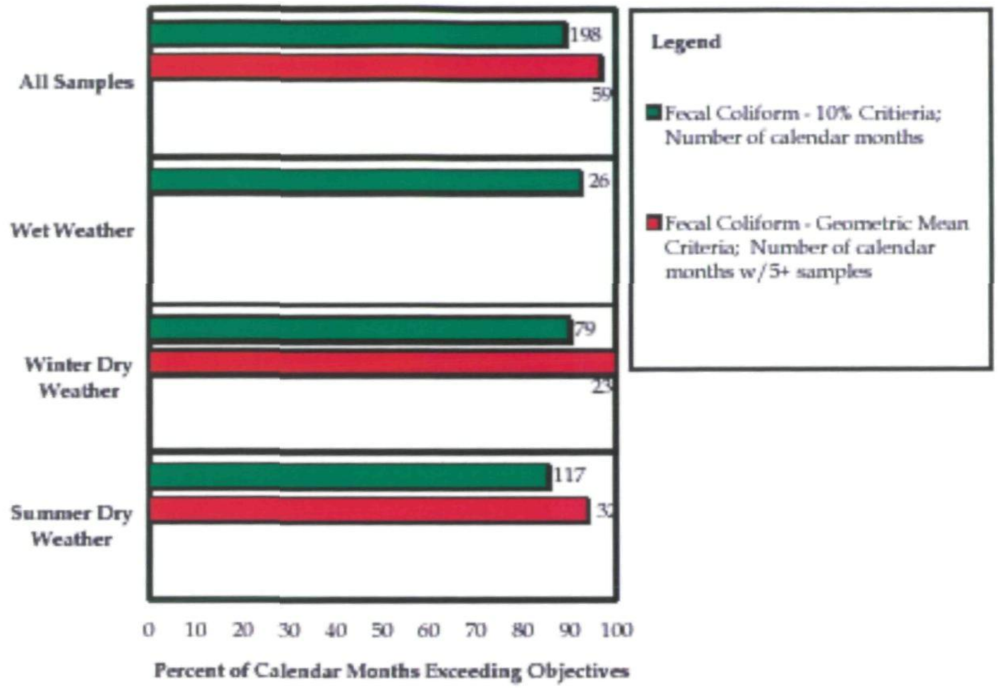



Figure 57
Comparison with Existing and Potential Bacteria Water Quality Objectives
Santa Ana Delhi Channel near Irvine Ave.

# APPENDIX C

## DATA FROM ALISO CREEK

GEOSYNTEC CONSULTANTS

838 SW First Avenue, Suite 530
Portland, Oregon 97204

(503) 222-9518
(503) 242-1416 Fax

# MEMORANDUM

TO: SUSAN PAULSEN, FLOW SCIENCE

FROM: BRUCE WILLIAMSON, LISA AUSTIN, GEOSYNTEC CONSULTANTS

SUBJECT: ALISO CREEK BMP EFFECTIVENESS ANALYSIS

DATE: APRIL 13, 2005

CC: PETER MANGARELLA, GEOSYNTEC CONSULTANTS

## Introduction

This purpose of this technical memorandum is to assess the efficacy of Best Management Practices (BMPs) installed in parts of Aliso Creek, Orange County, California (Figure 1) on the removal of pathogen indicators. Pathogen indicator data collected by Orange County Resources and Development Management Department in this watershed and on these BMPs has received increasing attention when project design features are evaluated by regulatory authorities. Therefore, it is important that we have a good understanding of these findings and their uncertainties.

The two BMPs assessed in this memo are:

1. Dry weather flows are passed through multimedia filtration/UV sterilization using a proprietary treatment unit 'Clear Creek Systems'. This treats low flow runoff from a two square mile catchment with mixed urban land use. The storm drain facility and catchment are designated as J01P28 in the watershed map and plans (Figure 1, 2B).

2. Wetland ponds to intercept watershed runoff and treat dry weather flow and first flush. These treat low flow and first flush runoff from a two square mile residential catchment. The storm drain facility and catchment are designated as J03P02 in the watershed map and plans (Figure 1, 2A).

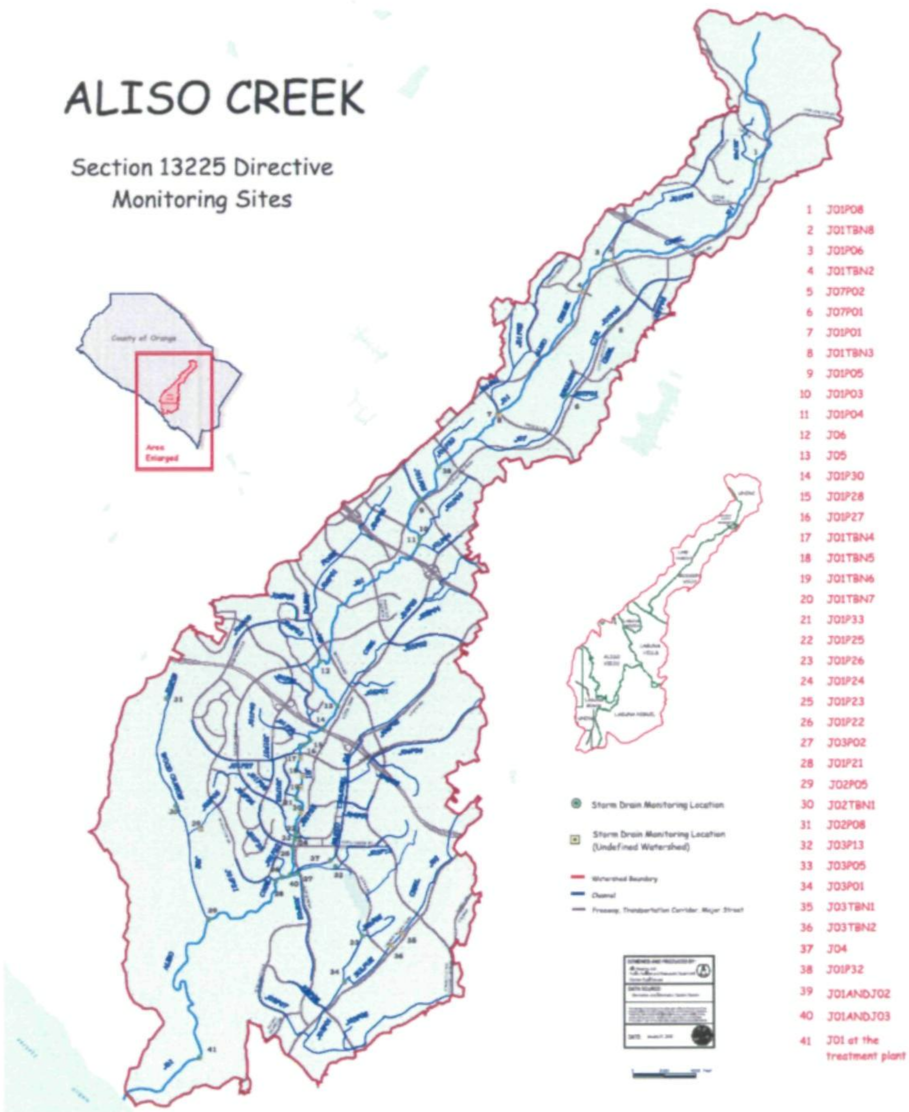
All monitoring of the BMPs and their receiving waters took place during dry weather. Consequently, low flows were mostly sampled, but during the wet season a proportion of these were probably elevated flows during storm recessions.

The data were collected by the County of Orange and its city partners and is available in reports listed at http://www.ocwatersheds.com/watersheds/Aliso_reports_studies.asp, and also in Evaluation Reports by the County of Orange.[1,2]

[1] County of Orange Resources and Development Management Department, Watershed and Coastal Resources Division. 'Aliso Creek Clean Beaches Initiative. Final Report for Agreement 01-227-550-0' submitted to Regional

Note that the Aliso Creek watershed Quarterly Progress Reports (QPR) refer to other BMPs installed in stormwater drains of urban watersheds at a number of locations in the Aliso Creek watershed. These include grassy swales for treating park runoff to Sulfur Creek in Laguna Niguel and a wetland biofilter in another branch of Sulfur Creek in Laguna Hills The status of the these BMPs is unclear, and no monitoring data for these BMPs were located in the QPR.

**Figure 1**

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and State Boards in January 2005 and 'Wetland Capture and Treatment Final Report for Agreement No. 01-122-259-0' submitted to Regional and State Boards in March 2004.

[2] "Wetland Capture and Treatment Final Report for Agreement No. 01-122-259-0" submitted to Regional and State Boards in March 2004.

**Figure 2A:** Location of J03P02

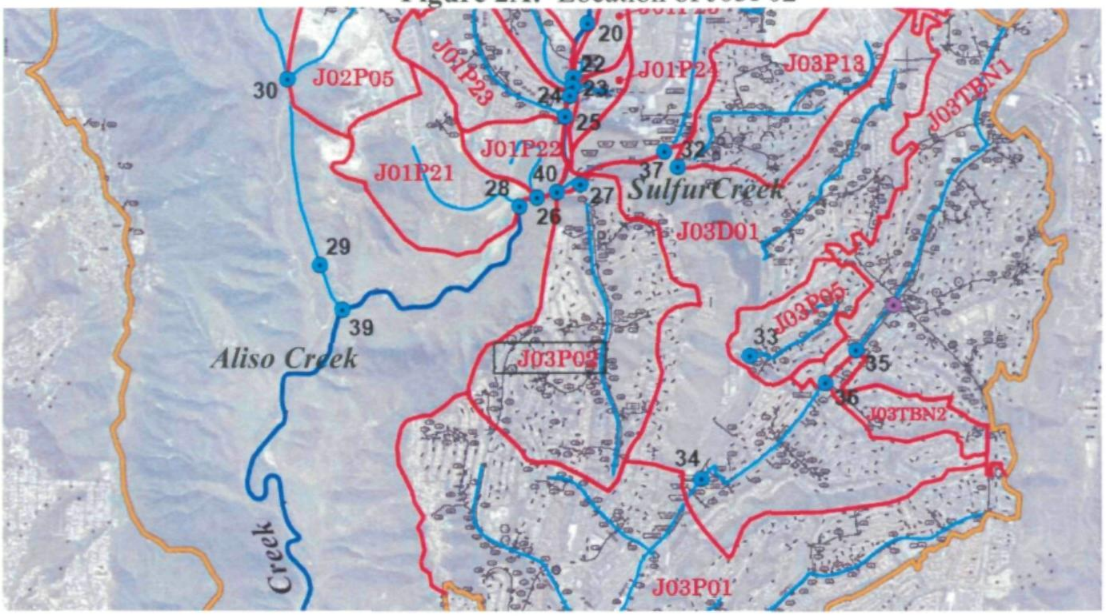
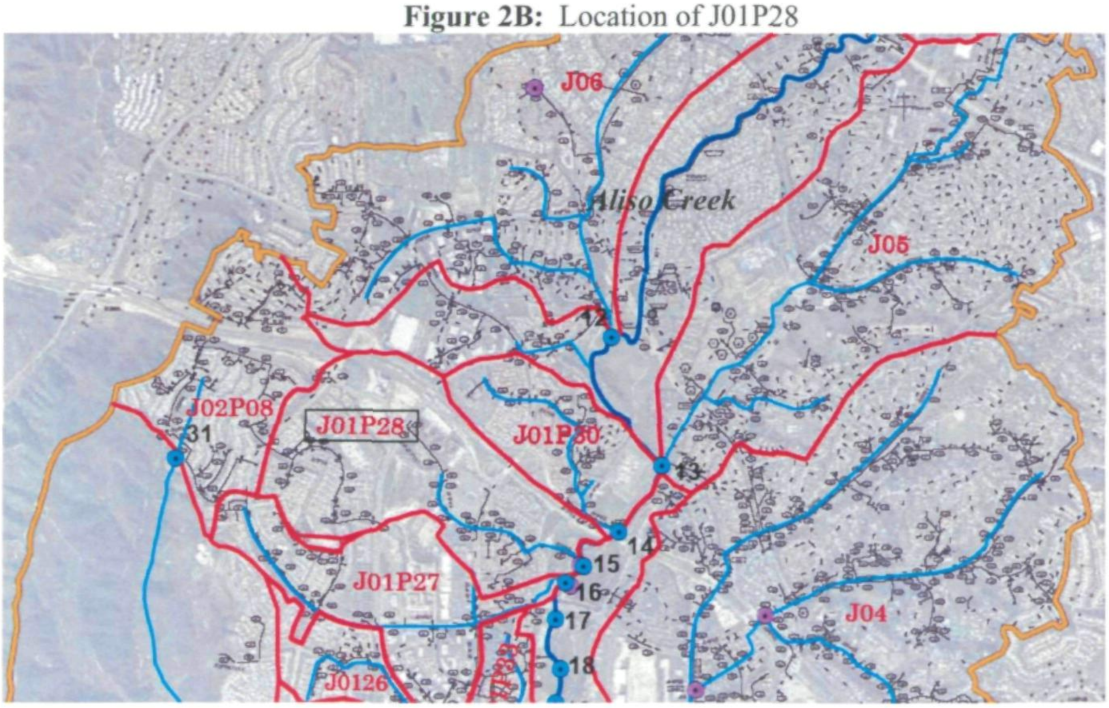



**Figure 2B:** Location of J01P28



# Site Description

### Aliso Creek Watershed

Aliso Creek watershed encompasses 30.4 square miles and includes portions of the cities of Aliso Viejo, Dana Point, Laguna Niguel, Laguna Woods, Laguna Beach, and Lake Forest. Its main tributary, Aliso Creek, originates in the Santa Ana Mountains inside the boundaries of the Cleveland National Forest. Smaller tributaries include Wood Canyon, Sulphur Creek, the Aliso Hills Channel, and English Channel (Figure 1).

Aliso Creek is the subject of a Directive issued by the San Diego Regional Water Quality Control Board (RWQCB) in 2001 for an investigation of urban runoff in the Aliso Creek watershed. The Directive found that the Permittees may be discharging waste with high bacteria levels from municipal storm drain outfalls into Aliso Creek and its tributaries. The Directive required the Permittees to begin a comprehensive monitoring program and undertake investigations within the storm drain system to identify the causes of the problem and the control actions needed to correct the problem. This has resulted in a comprehensive study involving weekly sampling of approximately 35 storm drains and their respective receiving waters, and numerous other initiatives in identifying sources and source control.

Part of the creek (J03P02) is subject to a Cleanup and Abatement Order (CAO) issued by the RWQCB in 1999. This was the result of a survey which showed that pathogen indicators (PI) in the drain were much higher than in Aliso Creek. Experience gained from the more comprehensive monitoring carried out since that time has shown that J03P02 is in the low to middle of the range of PI concentrations compared to the rest of the Aliso Creek watershed.

### Sand Filtration/UV Sterilization

The J01P28 Interim Water Quality Improvement Package Plant BMP was executed in response to the San Diego RWQCB 13225 Directive to clean up Aliso Creek.

This treatment unit is located near the outlet of the J01P28 subcatchment (Figure 2). This subcatchment is a tributary to the main stem of Aliso Creek. The storm drain conveys runoff water from a fully developed area of approximately two square miles in the city of Aliso Viejo. Land uses in the catchment include residential, commercial, light industry, and parks. The BMP was installed in July 2003.

The CCS treatment system includes three multi media filters, two organo clay filters and two ultraviolet light disinfection chambers. The package plant treatment system has three main phases:

- Sediment and debris removal
- Oils, pesticides, and trace metals removal
- Disinfection

The larger debris and trash removal is performed at the inlet strainer that is located in an energy dissipation basin within the storm drain. Sediment removal is performed in the basin and in the multimedia filter. Oils, pesticides and trace metals are removed via adsorption onto the organo-clay media while the ultraviolet light chamber removes bacteria and viruses.

The package plant treatment system filters and disinfects approximately 100,000 gallons per day of urban dry weather runoff. The design capacity is 250,000 gallons per day. By October 2004, a total of 1.4 million gallons had been treated.

Monitoring results from the years 2001 through June 2003 were combined to form the "before" dataset, while results from August 2003 through December 2004 constituted the "after" dataset.

Once discharged from the unit, the water flows through a ponded area approximately 20 feet long, 6 feet wide and 1.5 feet deep, then 30 feet through a natural ditch to Aliso Creek. A monitoring site is located in the natural ditch 15 feet from Aliso Creek.

### Wetlands

Wetlands have been installed near the outlet of subcatchment J03P28, which is a tributary to Sulfur Creek, itself a tributary to Aliso Creek (Figure 2A). The wetlands are positioned at the bottom of the catchment and designed to capture 100% of the low flows before they discharge to Aliso Creek. The catchment (538 acres) is entirely residential (1600 households, new to 30 years old). A number of structural BMPs have been implemented from 2000 to the present day.

1. From May 2000 to March 2001, dry weather flows were diverted to the AWMA Regional Sewage Treatment Plant.

2. From March 2001 to April 2003 (actually it is not clear when unit stopped operating), dry weather flows in the drain were treated by a mobile Clear Creek Systems filtration/UV treatment unit. The flow was diverted to the treatment plant (e.g., 15% of total flow in the July-September 2002 quarter) when the filter clogged or the UV malfunctioned.

3. The three wetlands were constructed progressively starting in about March 2001 and were completely online from April 2003[2].

J0302 has been subject to detailed studies because of the CAO. These include visual (video) inspection of sewer and storm drain pipes, field reconnaissance, resident surveys, flow monitoring, a wide range of upwatershed sampling and the identification the sources of the pathogenic indicator bacteria. Samples were examined for human enteroviruses, antibiotic resistance, and genotypes of E. coli. The researchers concluded that the primary sources of PI in J03P02 are not likely to be human, and are likely to be due to cows (soil fertilizer amendments), birds, rabbits, and some unidentified other animals. In the Aliso Creek QPRs, the Co-Permittees indicate that the following sources probably contribute to fecal coliform (FC) in J03P02:

- Organic soil amendments
- Turfgrass areas

- Wildlife
- Domestic pets
- Accumulated organic debris in the surface and subsurface storm drain system
- Street sweeping debris

The wetlands – called East, West and North, were positioned to capture 100% of catchment runoff during dry weather and first flush. Design features are summarized in Table 1. The hydrological network is outlined in Figure 3.

Wetland inflow is taken by intercepting flows in the stormwater pipes, including the 60-inch main pipe. After passing through the wetlands, some of the treated stormwater is routed back though the 60-inch pipe to an open channel just before its confluence with Sulfur Creek. Effluent from the West Wetland is discharged directly to this open channel, and does not pass through the pipe. Another untreated, unmonitored inflow also discharges to this point (Figure 2).

**Table 1:** Wetland design features (reference see footnote 2).

| Wetland | Total Catchment Area (acres) | Planned intercepted area (acres) | Wetland Area (acres) | Depth (ft) |
|---|---|---|---|---|
| East | 374 | 37 | 0.3 | 1 |
| West | 342 | 312 | 0.69 | 0.5 |
| North | 122 | 122 | 0.3 | 1 |

### Sampling Procedures

All sampling was conducted during "dry weather," which is defined as no rain on the day of sampling. Sampling was conducted under strict protocols (see Aliso Creek 8th Quarterly Progress Report). Quality Assurance/Quality Control (QA/QC) sampling procedures were implemented that should have prevented contamination during sampling and significant changes to the sample during transport to the laboratory.

**Directive Monitoring:** Each location has three monitoring sites: two of these are on the main stem, 25 feet upstream and downstream of the storm drain discharge, the other is on the storm drain itself, approximately 15 feet above its confluence with the stream. These three sites were monitored weekly, so that at least five samples were collected each month, at random intervals. Some of these monitoring sites are shown in Figure 1.

**BMP Monitoring:** In addition to the directive sampling program, the influent and effluent to the BMPs were monitored.

**Figure 2.** Source: Wetland Capture and Treatment Final Report (2004)[2]. Note: untreated Surface Flow from North Wetland should probably be 0.0304 cfs.

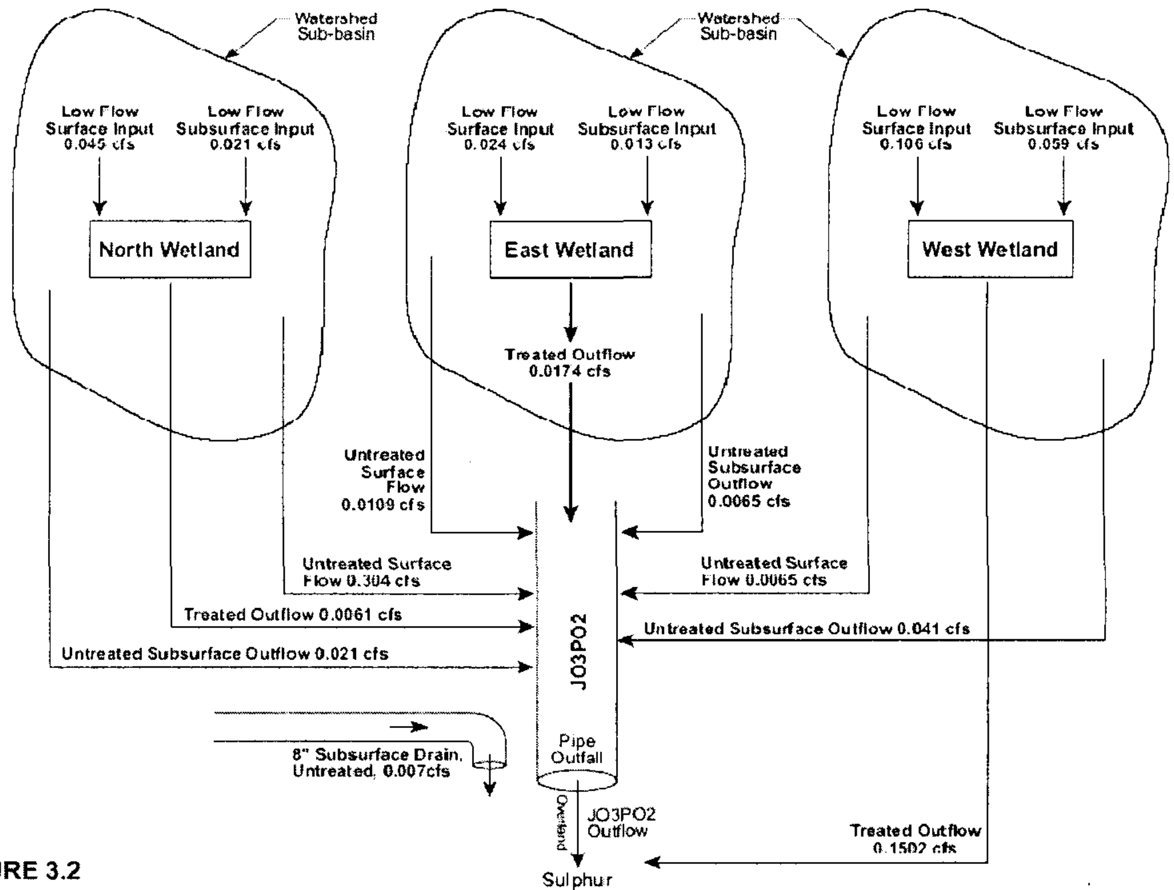



**FIGURE 3.2**
WetCAT Flow Distribution, Summer 2003

**CH2MHILL**

## Summary of Monitoring Results

### *J01P28 - Multimedia Filtration/UV Digestion*

**Influent/effluent.** Comparison of the influent and effluent concentrations demonstrates a 99.6% reduction in fecal coliform levels. The geometric mean decreases from 77,414 CFU/100mL to 317 CFU/100mL.

**Stream and drain monitoring.** A statistical analysis of the levels in the receiving water (the "directive" dataset) is summarized in Table 2 and as box plots in Figure 3-4. These refer to all data collected before BMP installation. The County monitoring reports summarize data for quarterly monitoring periods. In the QPR, quarterly monitoring data are compared between years to reduce variance from seasonality, and constitute a more powerful assessment of the data. However, for our purposes here, the lumped data is sufficient to demonstrate their findings.

**Table 2:** Comparison of geometric means (cfu/100 ml) before and after multimedia filtration/UV sterilization. The BMP is installed about 35 feet upstream of the storm drain monitoring site.

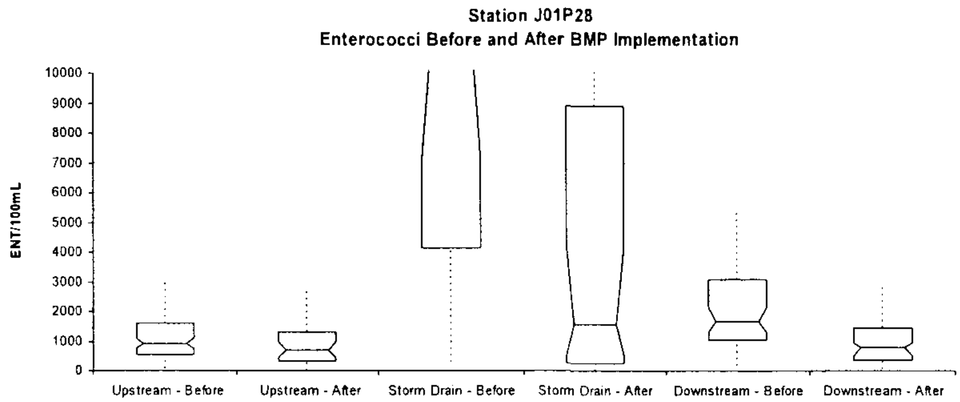
| **Locations** | **TC** | | **FC** | | **ENT** | |
|---|---|---|---|---|---|---|
| | before | after | before | after | before | after |
| u/s | 5353 | 2851 | 775 | 773 | 990 | 662 |
| storm drain | 52267 | 15232* | 14633 | 5827* | 9171 | 1401* |
| d/s | 17248 | 5142* | 2722 | 1696* | 1791 | 839* |

* = significant change (1-way ANOVA, $\alpha<0.05$)

**Regrowth.** Comparison of effluent and the 'directive' storm drain monitoring site, show a large increase in FC levels in the approximately 35 feet between the unit discharge and the storm drain monitoring site. No other discharges were found, which suggest that rapid re-growth has taken place in the water column, or re-infection has occurred from sloughing or resuspension of bacteria from immersed channel-side vegetation, organic debris and/or sediments. The geometric mean increases in this short distance from 317 cfu/100mL to 2,575 cfu/100mL.

Further work is planned by the County on the re-growth issue. Permits have been requested to perform clean up work on the habitat and the storm drain outlet basin.

Figure 4 (continued)




## *J03P02 – Wetland BMPs*

**Influent/effluent.** All monitoring took place during dry weather. Flows were measured, but only once per month and not for each sampling occasion. Most sampling took place at lows flows. The flow was typically 0.25 cfs with a range of 0.13-0.56 cfs.

Wetland monitoring in the three wetlands showed 90 to 99 percent reduction in FC levels from 2001 to present day (e.g. see Table 3). (Note that the three wetlands were installed and monitored progressively – results from 2001 were from one wetland only). Overall, 90 percent of treated effluent samples met the REC-1 objectives for FC. Although enterococci (ENT) levels dropped by 60 to 99 percent in wetlands, wetland effluent did not meet the steady state objective of 33 cfu/100ml during the period of monitoring (2001-2004). Few individual wetland samples met the single-sample objective.

**Table 3:** East Wetland fecal coliform (cfu/100mL) removal March 2001 – August 2002.

| Parameter | Inflow | Outflow | Removal |
|---|---|---|---|
| Median | 5000 | 50 | 99% |
| Mean | 14900 | 150 | 99% |
| Geometric mean | 2,800 | 35 | 99% |

Overall there has been a progressive decline in FC and ENT since the wetlands have progressively come on line.

As well as the wetland monitoring, the effluent from the mobile UV sterilization unit was monitored when it was installed (between March 2001 to April 2003). The influent was not monitored directly. A cursory scan of the results suggests that the treatment unit effluent quality met REC-1 requirements on most months, but failed at times, which was attributed to the sand filter clogging.

**Stream and drain monitoring.** No "before BMP implementation" could be found because the 'directive' monitoring period encompassed either diversion to the sewage treatment plant, UV sterilization and/or wetland treatment. (However, some data is available somewhere, because it led to the CAO).

The dry weather discharge from the storm drain had little or no effect on the FC levels in Sulfur Creek. The flow from J03P02 is about 10 percent of the flow in Sulfur Creek.

The bacterial quality of the J03P02 storm drain discharge has steadily improved over the monitoring period. However, the improvement is quite complex, as described in the following section.

**Re-growth.** There is evidence that re-growth occurs between the wetlands and the storm drain monitoring sites. The concentrations in the open channel at the end of the pipe are about twice what is expected based on mass flow considerations.

However, there are some ambiguities in the various Quarterly Reports about the nature of the connection between the catchments, wetlands, and the J03P02 monitoring site[3]. This has been resolved in the detailed report on the BMP project for J03P02[2]. Measurements show that a high proportion of the flow is not intercepted (about 37 percent). Figure 2 also shows that the largest wetland ('West') bypasses and discharges downstream from the pipe.

Therefore, the apparent re-growth phenomenon could be wholly or partly due to the "recontamination" by the un-intercepted flows from the catchment. The project investigated this by carrying out a mass balance calculation. Unfortunately the report does not give any details on the calculations, but states that concentrations at the end of the pipe after discharge are about twice what is expected based on these mass flow considerations.

GeoSyntec confirmed that there was about this order of magnitude difference between observed and calculated mass flows using flows given in Figure 2 and using appropriate median FC numbers for the summer 2003 monitoring period. However, the proposition of re-growth, while plausible, is uncertain because:

- There is a significant input of untreated surface and subsurface flows into and at the end of the J03P02 pipe
- Most flows were estimated and not measured
- Many of the FC and ENT concentrations used in the mass flow calculations were not measured and assumed values were taken from the monthly monitoring data.
- There is a high degree of variability in monitored FC and ENT

The rates of this apparent re-growth appear to be seasonal and variable. As described above, usually observed levels at the J03P02 monitoring site are higher than the combined flows from the wetland. Fecal coliform and enterococci increase by about 100 percent in-pipe during spring, summer, and fall. However, this apparent re-growth does not occur during winter months and

[3] Most comments imply a 200 foot pipe, but 14th QPR refer to pipe outlet and 200 feet overland distance.

sometimes die-off can be observed. For example, the winter FC levels in 2004 were 1/8th of those predicted from the combined treated and untreated contributions, while ENT levels are about the same as predicted levels. The report suggests that die-off and re-growth (or re-contamination) of ENT and FC may be temperature and salinity dependent.

The overall findings of the BMP study to this particular watershed is that as the BMPs came on line, there was a steady improvement in the quality of the J03P02 discharge to Sulfur Creek during some seasons[4]. Results from monitoring the drain downstream of the BMPs show:

- Spring (Apr-Jun) geomeans for FC fell from 2001-2003. The 2004 geomean was similar to that for 2003.
- Summer (Jul-Sep) geomeans for FC have not fallen with statistical significance
- Winter (Jan-Mar) geomeans for FC fell from 2002 – 2004.

## Discussion and Conclusions

Filtration coupled with UV sterilization reduced indicator bacteria to below the REC-1 standard. This was demonstrated at both sites. However, the benefits are compromised by what appears to be re-growth. At J01P28, the re-growth/re-inoculation occurred in a natural steam reach consisting of a pool and run, which was shaded with riparian vegetation dangling in the stream. It occurred within only 35 feet of the discharge point from the treatment unit.

Wetlands reduced fecal coliform (FC) levels by 90 to 99 percent to below the REC-1 guideline for 90 percent of the samples. They also reduced enterococci (ENT) levels by 60 to 99 percent, but the effluent from the three wetlands always exceeded the steady-state ENT objective, and usually exceeded the single sample objective. As with J01P28, the benefits of wetland treatment were compromised by the low-flow capture rate and what appears to be re-growth or re-contamination after discharge from the BMPs. Concentrations of FC and ENT increase between the wetland effluent and the J03P02 monitoring site 15 feet from its confluence with Sulfur Creek. The summary report proposed that most of the re-growth/re-inoculation occurred within a 200-foot pipe carrying wetland effluent to the confluence with Sulfur Creek.[2]

The study report proposed that re-growth was plausible because there was opportunity and time for re-growth to occur. The combined effluent from the East and North wetland is conveyed to Sulfur Creek through the pipe, which has a transit time during low flow of 15 minutes. As stated in the Wetland Capture and Treatment Final Report 2004[2] "Given ..... the microbiologists 'rule of thumb' that bacterial populations can double every 15 minutes under ideal conditions, rapid in-pipe propagation of FC and ENT in the dark pipe may be the main factor, or may be combined with recontamination from bioslimes or muck deposits" (Clean-Up & Abatement Order 99-211 17th QPR). Another possible reason is that the structures which divert low flow from the stormwater pipes to the wetland also trap and retain organic debris, which may act as substrates

[4] This is somewhat surprising given that the drain water was treated by multimedia filtration UV disinfection or diverted to the sewer system while the wetlands were constructed.

for re-growth. However, re-contamination by unmonitored inflows may also be partly or wholly responsible for the observed increase between the BMPs and the confluence.

The results suggest that the benefits of BMPs may be compromised by re-growth, which occurred in both the natural channel and pipe downstream of the monitored BMPs. The various investigators have concluded that treatment systems would need to be positioned at the bottom of the watershed directly before discharge to the receiving water body – mainly to prevent regrowth during warm weather conditions.[1] Another important general conclusion in the study (see City of Laguna 6th QPR Aliso Creek 13225 Directive) states 'that "primary" bacteria concentrations (from direct deposits of bird droppings, for example) in runoff can be magnified by the "secondary" propagation of bacteria populations within the environment, so that *controlling propagation* may ultimately become as important as *source reduction* in reducing overall outfall concentrations. The research results also suggest that the presumption of a statistically valid relationship between certain concentrations of fecal coliform and an acceptable vs. unacceptable magnitude of public health risk (which is the basis for the REC-1 and REC-2 objectives) may be seriously flawed.'

The proposition that re-growth occurs after treatment has wide ranging implications for stormwater management. Given the uncertainties outlined above as to whether re-growth occurs after wetland treatment, the County study results should be confirmed by more detailed studies and sampling, such as:

- more frequent sampling of concentrations taking into account time of travel
- stormwater runoff monitoring (not just dry weather flows)
- measurement of flows where possible.

It is unknown whether the re-growth phenomenon apparent at the Aliso Creek sites would result in much higher concentrations over longer distances, but such an experiment cannot be conducted at the County-selected sites.

Finally, it is re-emphasized that monitoring was only conducted during dry weather conditions – mostly low flow and do not reflect storm runoff conditions, except for possibly occasionally during the storm regression phase. The impact of storm runoff on the treatment efficacy of the BMPs tested at Aliso Creek is unknown. Likewise, it is unknown what impact high flow may be on the mechanisms that lead to re-growth or re-inoculation; such flows may deliver organic debris and sediments and also slough off slimes and accumulations of organic detritus.

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REFER TO FILE #
020532 - 0004

August 22, 2007

**Errata Version Correcting Typographical Errors**

**Submitted via Email; Original Sent Via California Overnight Express**
Mr. Jeremy Haas
California Regional Water Quality Control Board, San Diego Region
9174 Sky Park Court, Suite 100
San Diego, CA 92123

**Re: Public Comments Regarding Revised Tentative Order No. R9-2007-0002, NPDES No. CAS01087420 Waste Discharge Requirements for Discharges or Urban Runoff from the Municipal Separate Storm Sewer Systems (MS4s) Draining the Watersheds of the County of Orange, the Incorporated Cities of Orange County, and the Orange County Flood Control District Within the San Diego Region (July 6, 2007)**

Dear Mr. Haas:

The Building Industry Association of Southern California ("BIA/SC")[1], the Building Industry Association of Orange County ("BIAOC")[2] and the Building Industry Legal Defense Foundation ("BILD")[3], through their undersigned counsel, respectfully submit these comments to:

- The California Regional Water Quality Control Board, San Diego Region ("Regional Board") regarding Revised Tentative Order No. R9-2007-0002, NPDES No. CAS01087420, Waste Discharge Requirements for Discharges or Urban Runoff from the Municipal Separate Storm Sewer Systems (MS4s) Draining the Watersheds of the County of Orange, the Incorporated Cities of Orange County, and the Orange

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[1] BIA/SC is a is a nonprofit trade organization representing more than 2,400 member companies that collectively employ more than 200,000 people. BIASC's mission is to promote and protect the building industry to ensure its members' success in providing homes for all Southern Californians.

[2] BIAOC is the local chapter of the BIASC.

[3] BILD is a non-profit mutual benefit corporation and a wholly-controlled affiliate of BIA/SC, whose purposes is to defend the legal rights of current and prospective home and property owners and to maintain a favorable business climate for the construction industry in Southern California.

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County Flood Control District Within the San Diego Region, dated July 6, 2007 (the "2nd Tentative Order"); and

- The related Response to Comments Section X of the Fact Sheet/Technical Report for Tentative Order R9-2007-0002, also dated July 6, 2007 (the "Response to Comments").

We appreciate the opportunity to review and comment on the 2nd Tentative Order and Response to Comments. BIA/SC, BIAOC and BILD applaud the Regional Board's goal for the 2nd Tentative Order – which is clean water to protect the beneficial uses identified for South Orange County in the Water Quality Control Plan for the San Diego Basin (9) ("Basin Plan"). As stakeholders, BIA/SC, BILD a^nd^BIAOC are committed to working with the Regional Board and Copermittees to achieve this goal.

In addition to this comment letter, we are submitting concurrently herewith as Attachment A and also in electronic form, a red-line version of selected excerpts form the 2nd Tentative Order. The red-lined text focuses only on specific sections of the 2nd Tentative Order, which we comment on in this letter and believe require substantial further revision. The red-lined text focuses primarily on those addressing proposed requirements for regional and subregional Best Management Practices ("BMPs"), hydromodification control, including low impact development strategies and site design BMPs, and construction BMPs, include Active Treatment Systems ("ATS"). The red-lining submitted is not intended to dictate to the Regional Board exactly how to "wordsmith" further edits to the 2nd Tentative Draft. Instead, the red-lining is intended to supplement the comments in this letter by providing a more comprehensive understanding by the Regional Board and Regional Board staff regarding the substance of the comments and concerns set forth in this letter.

In making these comments and preparing the supplemental comments of the redline, we have reviewed, rely upon, and incorporate herein by reference the technical information, technical studies and reports, and comments prepared and submitted by the Construction Industry Coalition for Water Quality ("CICWQ") in their letter on the 2nd Tentative Draft dated August 22, 2007, enclosing the technical memorandum entitled "Geosyntec Comments Regarding Revised Tentative Order No. R9-2007-0002, NPDES No. CAS01087420 Waste Discharge Requirements for Discharges or Urban Runoff from the Municipal Separate Storm Sewer Systems (MS4s) Draining the Watersheds of the County of Orange, the Incorporated Cities of Orange County, and the Orange County Flood Control District Within the San Diego Region (July 6, 2007)," dated August 22, 2007 ("CICWQ Comments").

Notwithstanding our support for the underlying goals of the 2nd Tentative Order, BIA/SC, BIAOC and BILD respectfully urge the Regional Board to require additional revisions to the 2nd Tentative Order prior to its adoption, because, among other reasons:

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1) The Regional Board has failed to address and provide a considered and meaningful response to many of the critical comments and concerns of the regulated community that were lodged in response to the Regional Board's Tentative Order No. R9-2007-0002, NPDES No. CAS01087420, Waste Discharge Requirements for Discharges or Urban Runoff from the Municipal Separate Storm Sewer Systems (MS4s) Draining the Watersheds of the County of Orange, the Incorporated Cities of Orange County, and the Orange County Flood Control District Within the San Diego Region, dated February 9, 2007 (the "1st Tentative Order");

2) The 2nd Tentative Order contains requirements that would discourage, and in some cases render infeasible or impossible, the implementation of programs and strategies that provide significant water quality benefit; and

3) The 2nd Tentative Order contains numerous technically and legally inappropriate requirements that should be substantially altered prior to adoption of a final order, including the requirements dealing with regional and subregional BMPs, hydromodification control, LID strategies and construction BMPs, including ATS.

## I. The Regional Board Has Failed to Address and Respond Adequately to Previously Submitted Comments and Concerns.

Based on our review of the Response to Comments, we believe we are compelled to restate and reinforce several crucial comments that were previously submitted by BIAOC and BILD in response to the 1st Tentative Order (the "BIA April Comments"). Without withdrawing or minimizing any of the prior BIA April Comments, we selectively emphasize the following key comments, which were not dealt with adequately in the Response to Comments and the 2nd Tentative Order, and which are equally applicable to and underpin many of these comments now submitted.

- *Failure to consider balancing factors.* As stated in the BIA April Comments (at pp. 22-29), we disagree with the Regional Board's assertion that it is not required to engage in balancing factors under Cal. Water Code §§ 13241 and 13263 when adopting the requirements of MS4 permits. The plain language of §§ 13241 and 13263 require that, unless if violates a federal *mandate,* whenever a Regional Board considers and imposes waste discharge requirements ("WDRs") and permit conditions, it must consider all of the factors prescribed in section 13241, including costs of compliance with those WDRs and permit conditions and, perhaps most importantly, the characteristics of the hydrographic unit under consideration and quality of water that is available to the individual water bodies within the unit. *City of Burbank v. State Water Resources Control Board,* 26 Cal. Rptr. 3d 304, 35 Cal. 4th 613, 625 (2005). In the Response to Comments, the Regional Board has failed to respond to this point, instead focusing on whether such requirements "go beyond" federal law, and hence whether such requirements constitute an unfunded mandate in

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violation of the California Constitution. While that argument may be somewhat related to the point made in the BIA April Comments, it is not the same. Instead of asking whether the Regional Board's determination of Maximum Extent Practicable ("MEP") "goes beyond" federal law, the Regional Board should recognize that determining MEP as required by federal law does not present a federal *mandate* to the Board that conflicts with the Board's appropriate exercise of discretion under Porter-Cologne (including §§ 13241 and 13263) in crafting pollution control measures for MS4 permits. Instead, pursuant to the terms of the federal delegation of the NPDES permitting program to the State of California,[4] Porter-Cologne (including §§ 13241 and 13263) provides state law direction to the Regional Boards to guide their exercise of discretion in carrying out federal law by determining waste discharge requirements that constitute MEP. The federal Clean Water Act provides EPA and State Administrators with broad discretion in determining permit requirements appropriate to control stormwater discharges to the MEP, particularly because stormwater compliance with water quality standards is to be achieved through an iterative process. Nothing in federal law prevents Regional Boards from considering Cal. Water Code § 13241 factors in determining permit requirements necessary to *meet* the MEP standard, and the Regional Boards would not be violating a federal mandate to comply with State law in doing so. *City of Burbank v. State Water Resources Control Board,* 35 Cal. $4^{th}$ 613, 629 (2005)("The states are free to manage their own water quality programs so long as the do not compromise the federal clean water standards). In fact, the delegation to the States was based on the very fact that Porter-Cologne provided an appropriate state law framework for implementation of federal Clean Water Act requirements.[5] The Regional Board's failure to recognize this important distinction has it headed toward a glaring legal error.

- *Unfunded state mandates.* The Regional Board has the legal authority under State law to impose mandates that "exceed" or are "more explicit" than the mandates or specific requirements of federal law. *Building Industry Association of San Diego County v. State Water Resources Control Board,* 124 Cal.App.4th 866 (2004); *City of*

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[4] ~~**Delegation MOU citations**~~54 Fed.Reg. 40664 (Oct. 3, 1989); *WaterKeepers Northern California v. State Water Resources Control Bd.*, 102 Cal. App. 4th 1448, 1452 (2002); Cal. Water Code § 13370 *et seq.*; *see* also NPDES Memorandum of Agreement Between US Environmental Protection Agency and the California State Water Resources Control Board (1989)(Regional Boards shall regulate all discharges subject to NPDES permits subject to federal and State law regulations and policy. MOA § I.C.3.a.)..

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[5] EPA expressly embraced the Porter-Cologne legislative scheme and statutory framework as adequate to protect the waters of the United States under the Clean Water Act. 54 Fed.Reg. 40664 (Oct. 3, 1989); *WaterKeepers Northern California v. State Water Resources Control Bd.*, 102 Cal. App. 4th 1448, 1452 (2002); Cal. Water Code § 13370 *et seq;* See generally NPDES Memorandum of Agreement Between US Environmental Protection Agency and the California State Water Resources Control Board, approved September 25, 1989, amended.

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*Burbank v. State Water Resources Control Board*, 35 Cal.4th 613 (2005). However, when the Regional Board elects to use its discretion to impose mandates that do not comport with the federal Clean Water Act, including the MEP standard, it is electing to impose a state mandate within the meaning of California Constitution, Art. XIII B, Section 6. The California Supreme Court explained that the purpose of Art. XIII B, section 6 is "to preclude the state from shifting financial responsibility for carrying out governmental functions to local agencies, which are 'ill-equipped' to assume increased financial responsibilities because of the taxing and spending limitations that articles XIII A and XIII B impose." *Department of Finance v. Commission on State Mandates* (2003) 30 Cal.4th 727, 735 quoting *County of San Diego v. State of California* (1997) 15 Cal.4th 68, 81. In *County of Los Angeles v. Commission on State Mandates* (2007) 150 Cal. App. 4th 898, the court rejected the Regional Board's argument that all NPDES permit conditions are necessarily mandated under federal law and stated: "We are not convinced that the obligations imposed by a permit issued by a Regional Water Board necessarily constitute federal mandates under all circumstances. As explained in that case, the existence of a federal, as contrasted with a state, mandate is not easily ascertainable." Clearly, the Regional Board may impose such state mandates under Porter-Cologne; however, once imposed, the California Constitution requires that they must be funded by the State. Since portions of the 2nd. Tentative Order "are more explicit" than and "exceed" a proper determination of standards required to implement the federal CWA, including MEP, as discussed above, implementation of these provisions must be funded by the State. Specifically, the hydromodification control provisions in the 2nd Tentative Order continue to constitute state mandates. Under federal and state law, hydromodification constitutes non-point source pollution.[6] The hydromodification related requirements of the 2nd Tentative Order regulate this non-point source of pollution, which is reserved to state and local control in the Clean Water Act. This conclusion is consistent with EPA's position that it does not regulate "flow" as a pollutant and the State Board's classification of hydromodification as a nonpoint source.[7] As such, the Regional Board may, and in light of the nature of adverse impacts probably should regulate the non-point source pollution resulting from hydromodification. However, it does so by imposition of state mandates under Porter-Cologne, creating issues with respect to state unfunded mandates and CEQA. See section 9 of Attachment A..

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[6] See *National Wildlife Federation v. Gorsuch*, 693 F.2d, 156 (D.C. Cir. 1982) (Deferring to EPA determination that hydromodification is not properly addressed through NPDES permits because of the absence of a discharge of a pollutant. See also *Missouri ex rel. Ashcroft v. Department of Army*, 672 F. 2d 1297 (8th Cir. 1982) (hydromodification did not cause discharge so as to trigger NPDES permit requirement). California Non-Point Source Program Plan (NPS Program Plan), Volume II: California Management Measures for Polluted Runoff at §§ 5.0-5.1 (January 2000); Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program, at Section VI (May 2004). *See* Cal. Water Code § 79114(b)

[7] 65 Fed. Reg.43586, 43619 (July 13, 2000); State *Water Resource Control Board Nonpoint Source Program Strategy and Implementation Plan* 1998-2013.

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- *Improper interpretation of MEP standard.* We concur with the proposition that the MEP standard is a flexible, technology-based standard. However, the law does direct and reasonably constrain the Regional Board's exercise of discretion and flexibility. The Regional Board must, as discussed above, take into account and rationally reconcile the balancing factors set forth in Cal. Water Code §§ 13241 and 13263. In addition, the Regional Board must take into account the policy and guidance documents prepared by State Water Resources Control Board ("State Board") relevant to setting MEP in developing standards.[8] *See* pp. 29-34 of the BIA April Comments. It is not clear from the record, due to failure to consider and conduct appropriate balancing for any of the proposed control measures, the failure to identify and provide in a circumscribed fashion the body of technical evidence relied upon in establishing specific control measures, and the failure to provide reasonably specific findings regarding the comparative environmental suitability, technical suitability and cost-effectiveness of particular control measures, whether the measures are appropriately tailored for stormwater quality control under state or federal law. For example, it cannot be ascertained whether the specific control measures addressed in the CICWQ Comments are a reasonable exercise of discretion and technically and factually appropriate, taking into account federal law and/or appropriate state law and State Board guidance.

- *Procedural issues.* We appreciate the clarification provided by the Regional Board in the Response to Comments regarding the nature of the proceedings being utilized by the Regional Board to consider and adopt the Tentative Order. *See* pp. 11-13 of Response to Comments. Because the Regional Board considers this action to be an administrative adjudication, however, we would expect full compliance with Cal. Gov. Code §11425.10 *et seq.* (Administrative Adjudication Bill of Rights), which requires, among other things, that a copy of the procedures to be followed be given to the individuals at whom the adjudication is directed. Cal. Gov. Code §11425.10(a)(2).

- *Application of Tentative Order requirements to projects with pre-existing approvals.* Although some aspects of the 1st Tentative Order were slightly revised to better accommodate existing land use approvals, the 2nd Tentative Order still does not take into account the infeasibility (both technical and legal) of imposing new planning requirements on projects that are already approved. *See* p. 23 of 2nd Tentative Order. The Response to Comments similarly fails to address our previous comments about the infeasibility of incorporating site design BMPs into projects that have obtained

[8] "To achieve the MEP standard, municipalities must employ" [and therefore MS4 Permits should be designed to require,] "whatever Best Management Practices (BMPs) are technically feasible (i.e., are likely to be effective) and are not cost prohibitive. The major emphasis is on technical feasibility. Reducing pollutants to the MEP means [devising an MS4 Permit to require] choosing effective BMPs and rejecting applicable BMPs only where other effective BMPs will serve the same purpose, or BMPs would not be technically feasible, or the cost would be prohibitive." State Water Resources Control Board Memorandum, entitled "*Definition of Maximum Extent Practicable*," prepared by Elizabeth Jennings, Senior Staff Counsel, February 11, 1993; parenthetical added.

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final approval, and instead concludes that "construction activities should comply with water quality regulations in place at the time of construction." *See* p. 40 of Response to Comments and pp. 64-66 of the BIA April Comments. The obvious concern about imposing new site design requirements on projects that have reached a certain stage in the approval process is that the new requirements, such as hydromodification control provisions, will necessarily require substantial site re-design if imposed at the back end of a project – after approvals have been granted. As was explained in our earlier comments, there are legal impediments to imposing "new" requirements on projects after approvals have been granted.[9]

- *Improper regulation of discharges into the MS4.* *See* pp. 29-34 of the BIA April Comments. Removal of "into" language is justified based on SWRCB Order WQ-20001-15, which determined that the Regional Board may encourage the control of discharges into the MS4 but there is not authority to create penalties for Copermittees due to the improper discharges of others into the MS4. Certain provisions of the 2nd Tentative Order, including Section A.1 continue to create a violation as a result of such discharges. This language should be removed or revised to reflect Copermittees responsibility to adopt means, measures and controls to address discharges into MS4 systems that may cause pollution (i.e., illicit discharges) when discharged, but should not create permit violations for discharges which are beyond the control of the Copermittees. *See* section 3 of Attachment A.

- *Failure to consider regional and site-specific conditions.* As a general matter, the 2nd Tentative Order does not sufficiently allow for the consideration of site-specific, and in some cases regional, physical, hydrological and receiving water conditions and circumstances relevant to the control of stormwater quality and hydromodification. This concern is explained in more detail on pp. 37-45 of the BIA April Comments. These comments were not adequately addressed in the Response to Comments and the revisions reflected in the 2nd Tentative Order. The failure to appreciate these comments is particularly troubling with respect t hydromodification control requirements, including site design BMP requirements and LID strategies, and ATS mandates. As currently proposed, these requirements of the 2nd Tentative Order do not allow sufficient flexibility for the adequate consideration of site-specific conditions and circumstances, such as soil type, terrain, infiltration capacity and proper scale, etc. See section 2, section 6 fn 2, and Section 7 of Attachment A. Contrary to the

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[9] Local agencies have limited land use authority to condition projects that have already completed CEQA review and received all discretionary permits and approvals. By definition, issuance of ministerial permits do not involve discretionary action, and, while local agencies can enforce all conditions or approval and mitigation measures specified for a project prior to issuance of ministerial permits, they cannot impose new conditions to ministerial permits. 14 C.C.R. § 15041; Cal. Pub. Res. Code § 21166. Further, common law and statutory vested rights can impact the ability of any local agency to impose additional requirements on certain projects. *See* Cal. Gov. Code § 65864 *et seq.* (development agreements); Cal. Gov. Code § 66498.1 *et seq.* (subdivision map act); *Avco Community Developers, Inc. v. South Coast Reg'l Comm'n*, 17 Cal.3d 785, 791 (1976) (common law vesting rights).

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suggestion in the Response to Comments, we do not believe the Regional Board had entirely ignored site-specific conditions in development of the 1st Tentative Order. *See* p. 23 of Response to Comments. Instead, we believe that the controlling law, and specifically Water Code section 13241, indicates that the MS4 permit should provide reasonable flexibility (and greater flexibility than provided by the 2nd Tentative Order) for the Copermittees and regulated community to consider and respond to site-specific conditions and circumstances, particularly in implementing hydromodification controls, site design BMPs, and ATS systems. With some relatively minimal, but important changes to the proposed language of 2nd Tentative Order, sufficient flexibility can be provided, which will improve water quality control and better comply with applicable law. *See* Section 5 of Attachment A and CICWQ Comments.

- *Collaboration between Copermittees and other groups.* The 2nd Tentative Order, like its precursor, does not sufficiently encourage cooperation of Copermittees with one another and other groups in a manner that can benefit water quality. Agreements with HOAs, COAs and similar entities may improve water quality; and such collaboration may allow the Copermittees to expand their water quality reach, which allows for greater water quality benefits. *See* pp. 67-68 of the BIA April Comments. The Response to Comments states that the 2nd Tentative Order would not preclude collaboration with HOAs and other groups. *See* p. 62 of Response to Comments. To better assure that such collaboration is encouraged, the 2nd Tentative Order should be further revised as provided in to more specifically permit and encourage collaboration on BMP implementation and programs that will benefit water quality.

- *Failure to consider and integrate into the 2nd Tentative Order existing programs that address water quality issues.* The 2nd Tentative Order should recognize, approve, and comport with existing, highly-evolved and indeed *award-winning* water quality and natural resource conservation, management and protection programs such as the Special Area Management Plan ("SAMP"), Habitat Conservation Plan ("HCP"), Southern Subregion Natural Community Conservation Plan ("NCCP") and other large-scale aquatic and uplands resource programs that have been carried out in Orange County. The 2nd Tentative Order fails to adequately consider and take into account these programs, and presents new water quality and hydromodification control requirements that conflict with those developed under the water quality and natural resource management conservation and protection programs pursuant to extensive watershed and subwatershed specific hydrological, biological, geomorphic and habitat resource studies. Because of this failure, the 2nd Tentative Order, as proposed, would negate the careful work that has gone into developing these programs, and prevent and in some cases preclude their proper implementation. *See* pp. 70-71 of the BIA April Comments. Notably, the prospective inability of the 2nd Tentative Order's requirements to operate in harmony with these existing local programs exemplifies the more general failure to recognize the importance of site-specific and sub-regional conditions and circumstances. These local programs properly take into account many,

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variable site-specific and sub-regional natural conditions and circumstances, which is consistent with the balancing factors set forth in Water Code section 13241. The 2nd Tentative Order does not.

- *Legal Authority Requirements*. We remain concerned that the Tentative Order does not accurately reflect the BMP based and adaptive management approach to regulation of storm water quality, including the applicable compliance standard with respect to the control of the discharge of pollutants from the MS4 as set forth in 33 USC § 1342(p)(3)(B). *See* Section 4 of Attachment A.

## II. The 2nd Tentative Order Will Discourage, and in Some Situations, Prohibit Programs and Strategies that Provide Significant Water Quality Benefits.

Although some changes were made to the provisions now in the 2nd Tentative Order and related findings that deal with regional or shared BMPs, these changes do not adequately address the concerns previously expressed in the BIA April Comments regarding the implementation of regional and sub-regional BMPs. *See* the BIA April Comments at pp. 35-38. In fact, the language in the 2nd Tentative Order will make it more difficult, and in some cases impossible, to implement such BMPs – even those proven to be very effective water quality measures.

As was explained in the more detail in the CICWQ technical memorandum previously submitted commenting on the 1st Tentative Order (the "April Technical Comments"), several regional shared or end-of-pipe BMPs implemented in Orange County, including those associated with the San Joaquin Marsh, the Natural Treatment System, and the Aliso Creek and Salt Creek water quality improvement projects, are extremely effective and useful components of the Copermittees' to enhance, improve and restore surface water quality and control non-point source pollution. *See* Geosyntec Consultants Memorandum entitled "Comments on Draft South Orange County MS4 Permit, Tentative Order No. R9-2007-0002, NPDES No. CAS0108740" (April 4, 2007), pp. 7-8, submitted by the CICWQ; County of Orange Report of Waste Discharge. In addition, the efficacy of shared or regional BMPs has been recognized by State Board and United States Environmental Protection Agency ("EPA").[10] These types of programs and projects enjoy support by various environmental groups as important tools to protect, and improve water quality, but the 2nd Tentative Order creates significant and newly proposed hurdles to their implementation that are not consistent with applicable law or good policy.[11] In

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10 *See* generally State Water Resources Control Board- California Coastal Commission ("SWRCB-CCC"), *Nonpoint Source Program Strategy and Implementation Plan, 1998-2013 (PROSIP)*, SWRCB-CCC, Non Point Source-Coastal Zone Act Reauthorization Act (NPS-CZARA) Program, Fact Sheet 6. *See generally*, EPA NPS-CZARA guidance: http://www.epa.gov/owow/nps; http://www.epa.gov/OWOW/wetlands/facts/fact25.html; and http://www.epa.gov/owow/wetlands.

11 *See*, e.g., http://www.naturaltreatmentsystem.org/pdf/NTSnewsletter.pdf ("Irvine Ranch Water District has done a marvelous job of helping with the problem of water quality in Upper Newport Bay. Nutrients are a major problem because they cause algae to grow and that doesn't leave enough oxygen for the fish. IRWD is doing a lot of work upstream to remove nutrients. IRWD has a major project that we strongly support to build 31 more sites where

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light of the acceptance by both the regulated community, environmental groups, the State Board and EPA of the value of surface water quality restoration and enhancement programs and related BMPs, it is inappropriate and exceedingly poor policy for the Regional Board to discourage and effectively prevent these programs, as the 2nd Tentative Order would do.

Specifically, the 2nd Tentative Order would add new requirements for implementation of regional or subregional BMPs or "FETDs" (Facilities that Extract, Treat and Discharge, as they are defined in the 2nd Tentative Order) that are implemented pursuant to South Orange County surface water enhancement and restoration projects. The 2nd Tentative Order would mandate that, over time, despite issuance of multiple State and federal agency approvals for South Orange County surface water enhancement and improvement projects, each facility associated with those improvement projects must obtain individual Waste Discharge Requirements ("WDRs"), produce effluent that complies with each and every receiving water quality standard, and comply with new and substantial additional monitoring requirements in excess of those mandated by the approved improvement program in order to be implemented. See, *e.g.,* 2nd Tentative Order §§ E.7, E.9, and B.5. These requirements will make it much more difficult – if not prohibitive in terms of compliance risks and conditions – to implement enhancement, restoration and improvement program related shared and regional BMPs.

The successful and effective shared and regional BMPs that are already implemented in the watershed, including those mentioned above, have demonstrated that regional and subregional BMPs are an important tool in the compliance "toolbox" to address non-point source pollution, and improve and enhance the biological and chemical integrity of surface waters for purpose of meeting water quality standards and Total Maximum Daily Loads ("TMDLs"). As a policy and legal matter, these types of treatment BMPs should be allowed, encouraged and permitted under the MS4 stormwater permitting program. Direct permitting under the MS4 Permit would eliminate the individual permitting hurdle created for these programs by the 2nd Tentative Order.

In addition, the 2nd Tentative Order creates an unworkably and legally unjustified standard for permitting of these types of water quality improvement program BMPs. The fundamental problem with the 2nd Tentative Order vis-à-vis FETDs is that it would require any and all effluent issuing from every FETD to comply with all water quality standards, even where the surface water that serves as the 'influent' (natural receiving water) to the FETD does not meet all water quality standards and the respective FETD is designed to *improve* area water quality by removing *some* amount of naturally-occurring and/or otherwise uncaptured pollutants or contaminants. By requiring "perfection" of the effluent leaving FETDs, the 2nd Tentative Order effectively makes insistence on perfection the enemy of reasonable improvement.

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nature is going to be allowed to do its job of filtering nutrients out of the water" -- Jack Keating, Newport Bay Naturalists and Friends and "The Natural Treatment System being developed by the Irvine Ranch Water District will have a tremendous impact on the water quality in the Bay. The process will remove unwanted sediment, nutrients and other contaminants from the urban runoff. If left untreated, these pollutants would undoubtedly end up in the Bay" --Garry Brown, Executive Director, Orange County Coastkeeper).

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Not only is such a stance unwise from a policy standpoint, it is also legally infirm. First, many FETDs are put in place pursuant to water quality enhancement and improvement programs designed to help remediate naturally-occurring pollutants, such as indicator bacteria, and to supplement other required controls for difficult to manage non-point source contaminants.. It is obviously good and appropriate for agencies and jurisdictions to collaborate to improve surface water quality, particularly in the beaches and creeks of South Orange County, for purposes of environmental restoration and protection of health and safety, by minimizing these types of contaminants through FETDs. Consistent with the goals of the federal Clean Water Act, Copermittees should be encouraged, and the MS4 permit should facilitate programs to enhance and restore the biological, physical and chemical integrity of receiving waters. 33 U.S.C. §1251. Similarly, under Porter-Cologne, the primary purpose of the statewide program for water quality is to protect quality of waters from degradation. Cal. Water Code §13000. Where waters fall short of water quality standards, both federal and State program encourage enhancement and restoration, particularly if there are controllable water quality factors that, if addressed, can improve water quality and beneficial use. Cal. Water Code § 13241(c) (basin plans must address "water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area"). See, *e.g.*, Cal. Water Code Chap. 4, §§ 10537 *et. seq.*; Cal. Water Code Chap. 6, Watershed Protection Program, §§79070 *et. seq.*

Of course, to assure that these programs will improve water quality and not unintentionally degrade it, permitting of the BMPs used in conjunction with them is appropriate, and monitoring is important. However, the policy set forth in the 2nd Tentative Order concerning FETDs (i.e., that all FETDs must be (rather than may, in the discretion of the Regional Board be) individually permitted and that discharges from FETDs must meet all stated objectives regardless of initial receiving water quality) is untenable for legal and factual reasons.

First, California law concerning the natural right of upstream property owners to discharge storm water from their respective properties should be considered.[12] By force of gravity, storm water discharges, particularly those from existing development will ultimately enter water courses and MS4 systems. These flows from natural and existing urban areas will benefit from treatment by FETDs, since compliance with applicable stormwater quality controls have not effectively eliminated receiving water quality standard exceedences. FETDs can

[12] Since 1873, it has been the settled law of California that higher-ground property owners have the right to discharge natural storm water from their properties. As the California Supreme Court confirmed in Ogburn v. Conner, 46 Cal. 346 (1873):

> "The principle seems to be established and indisputable that when two parcels of land belonging to different owners lie adjacent to each other, and one parcel lies lower than the other, the lower one owes a servitude to the upper to receive the water which naturally runs from it, provided the industry of man has not been used to create the servitude; or in other words, more familiar to students of the common law, the owner of the upper parcel of land has a natural easement in the lower parcel to the extent of the natural flow of water from the upper parcel to and upon the lower." Id. at 352, quoting Butler v. Peck, 16 Ohio St. 334, 342 (1865).

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supplement stormwater quality control measures, particularly those applicable to existing and new development, to better achieve desired water quality.

Because up-gradient property owners enjoy a property right to discharge naturally occurring storm water from their properties, the proposed permit obligations at issue here should be reconsidered in light of that fact that such stormwater naturally flows into the MS4 systems. Importantly, such stormwater flows are often naturally "contaminated" from the moment they hit the ground due to both natural and anthropogenic pollutants. For example, "indicator bacteria" is considered a pollutant by the Regional Board, but it exists naturally in storm water. *See* Attachment B[13]. Similarly, natural loads of many constituents exceed the Regional Board's stated objectives for storm water quality. *See* Attachment B[14]. In addition, stormwater has been shown to be contaminated by constituents that are deposited on land by aerial deposition, which has no bounds. *See* Attachment B[15]. In light of the fact that stormwater flows contain pollutants even when compliance with stormwater quality requirements is largely achieved, the 2nd Tentative Order should be revised to encourage programs designed to improve the quality of storm receiving waters through the thoughtful use of FETDs – consistent with their rights and duties to protect the environment and act in furtherance of the public health and safety.

Second, the federal Clean Water Act encourages enhancement and restoration programs, and California law provides that these programs should be implemented if they improve water quality—it does not require that improvement program measures must be capable of treating non-compliant receiving waters to the point that they will meet all water quality before they can be implemented. Watershed management, water quality improvement, and non-point source pollution control projects, like those associated with FETDs, must instead meet the following standards:

- they must describe the baseline water quality of the water body impacted;
- define water quality and beneficial use goals;
- and improve water quality or reduce pollutants.

13 List et al. 2005 examined nearly 20 years of bacteria water quality data from Orange County watersheds and found that exceedances of criteria were found from both natural watersheds with little human influence and urbanized watersheds and that strong evidence was present to conclude that the predominant source of indicator bacteria is natural and not anthropogenic.

14 Stein and Yoon, 2007 found that natural areas, including those located in Orange County, are a substantial source of total suspended solids (TSS) during wet weather events, with some streams exhibiting TSS concentrations exceeding 100,000 mg $L^{-1}$ and very high total sediment yields (<4,000 kg $ha^{-1}$).

15 Sabin and Schiff (2007) and Sabin et al. (2005) indicate: 1) that dry atmospheric deposition represents a significant fraction of the total pollutant load in southern California waterbodies, and 2) that atmospheric deposition represents a significant source of metal loads in streams draining urbanized watersheds in southern California (57-100% of total pollutant load). Dry deposition, principally metals such as Cd, Cr, Cu, Pb, and Zn, can be a major source of stream water pollution following rainfall events.

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*See* Cal. Water Code §§10532, 79114(a); 79114(f)(2); and 79114(f)(4).

Plainly, the proposed, heavy-handed conditioning of FETDs would frustrate and conflict with the water quality statutes that the Regional Board is tasked with administering. The Regional Board's interpretations of those statutes, even assuming they are not "clearly erroneous," are "significant factors" that support revision of the 2nd Revised Tentative Order. *Nipper v. California Auto. Assigned Risk Plan*, 19 Cal.3d 35, 45 (1977).

As a consequence, the Regional Board would be acting without rational basis and contrary to the law if it were to insist that every FETD must treat naturally-variable storm water to the fixed objectives and standards that it currently employs. Further, while permitting of these programs is important, they should be permitted through the MS4 permit, as opposed to requiring individual permitting . Therefore, as a legal and policy matter, we request that the language of the 2nd Tentative Order be revised as set forth in Attachment A, section 1 to encourage, rather than discourage water quality enhancement, improvement and non-point source pollution control programs that provide significant water quality benefit.

## III. The Tentative Order Continues to Contain Legally and Technically Inappropriate Requirements.

### A. Requirement to Infiltrate Dry Weather Flows.

The 2nd Tentative Order requires that all dry weather flows containing significant pollutant loads be diverted from infiltration devices. *See* page 22, section D.1.c(6)(b). Such a requirement is inappropriate because infiltration of pretreated dry weather flows is an important management method to prevent dry weather flow impacts to receiving waters, including hydromodification impacts. Although per the discussion in the Fact Sheet, which accompanied the 1st Tentative Order, discharge of dry weather flows would be allowed to infiltrate in certain types of vegetated BMPs, it is likely that infiltration basins will be a primary component of hydromodification control systems. Thus, the requirement to "divert" dry weather flows from these basins will likely pose a problem and create significantly inconsistent requirements. To improve hydromodification control, permittees must have the flexibility to design appropriate hydromodification control BMPs.

In addition, as a practical matter as written in the 2nd Tentative Order, it is difficult to interpret the term "dry weather flows containing significant pollutant loads" in any meaningful way. Vague provisions deny the regulated community of due process because they do not provide the regulated community with adequate notice of what is required to comply and, conversely, fail to provide adequate notice as to what may constitute a violation.[16] As such, we

[16] It is a basic concept of law that "Notice is fundamental to due process." 7 Witkin § 638 (10th ed. 2006). The lack of an adequate definition constitutes improper notice to the regulated community in violation of due process. Cal. Const. Art. I, §§ 7, 15; Cal. Gov. Code § 11340 et *seq*. A "standard that has no content is no standard at all and is unreasonable." *Wheeler* v. *State Bd. of Forestry* 144 Cal.App.3d 522, 527-528 (1983). Thus, in order to provide the

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recommend that the 2nd Tentative Order be revised in accordance with the principles set forth in the technical comments submitted concurrently herewith by CICWQ. *See* CICWQ Comments, pp. 1-2; *see* also section 5 of Attachment A.

**B. Hydromodification Control Requirements.**

As noted in our previous comments, we have significant concerns with the hydromodification control requirements as proposed in the 2nd Tentative Order. As written, the 2nd Tentative Order does not include sufficient waivers for projects that will not increase the potential for hydromodification or that discharge to a receiving waters that are not susceptible to hydromodification. For these types of new and redevelopment projects, there is no nexus to condition projects that do not have the potential to cause downstream hydromodification impacts to implement expensive, unnecessary hydromodification controls. As such, we recommend that the Regional Board consider the types of waivers set forth and further explained in the CICWQ Comments~~ and section 2 of Attachment A~~.

First, with respect to waivers from hydromodification control requirements, the 2nd Tentative Order provides that conditional waivers may be allowed in situations where receiving waters are severely degraded or significantly hardened, however, such waivers must contain requirements for in-stream measures designed to improve the beneficial uses adversely affected by hydromodification, and these measures must be implemented within the same watershed as the project. *See* p. 36, section D.1.h(3)(c)(ii)(b). There are significant technical issues associated with these requirements, and from a policy perspective they are not appropriate. Projects should be encouraged to implement control measures that will address water quality impacts caused by the project development, rather than to implement in-stream measures in significantly hardened channels that, by definition, are not affected by hydromodification.. As a practical matter, implementation of these types of measures will be expensive, but will provide little benefit.

Second, the changes in the 2nd Tentative Order with respect to waivers for lack of discharge-caused hydrology changes are a step in the right direction but still are legally and technically problematic. From a legal perspective if a development does not increase the amount of existing imperviousness or discharge into a waterbody susceptible to hydromodification impacts, there is no constitutionally sufficient nexus to impose hydromodification control requirements.[17] Nor is there sufficient nexus to impost in stream restoration requirements to

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regulated community with sufficient notice of what is required to comply and what will constitute a violation so as to satisfy basic due process standards, the 2d Tentative Order should be revised to provide further clarification regarding a number of terms and conditions.

[17] *Dolan v. City of Tigard* 512 U.S. 374 (1994). In *Dolan*, the U.S. Supreme Court held that a dedication requirement was invalid because it was not proportional to the project's impacts. In that case, the court reasoned that although the project at issue would create some additional impacts (increased storm water runoff and traffic) the conditions imposed were not necessary to address the project's impacts. The court stated that the agency imposing the

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obtain a waiver avoiding the already constitutionally infirm hydromodification control requirements. From a technical perspective, requiring hydromodification controls for projects without impacts imposes costly and unnecessary measures on projects that are not likely adversely affect beneficial use. Therefore, we request that the Regional Board consider revising the Tentative Order to include hydromodification control waivers in accordance with these principles as further explained in the CICWQ comments~~ and section 5 of Attachment A~~.

**C. Construction Requirements Equate to Grading Limits and Mandate Advanced Treatment Systems.**

**1. Advanced Treatment Systems.**

The 2nd Tentative Order requires implementation of Advanced Treatment Systems ("ATS") for sediment in situations identified by the Copermittees to pose an "exceptional threat to water quality." *See* page 42, section D.2.d(1)(c). Although the provision leaves it up to the Copermittees to determine when ATS will be required at construction sites based on a number of factors, the 2nd Tentative Order nonetheless mandates its implementation without first considering the significant technical, environmental legal and policy issues associated with ATS. These concerns are spelled out in great detail in our previously submitted comments. *See* p. 57 of BIA April Comments. We will not repeat these comments here in their entirety but respectfully encourage the Regional Board to take a serious look at the technical, legal and policy issues associated with the implementation of ATS, including those identified by the Blue Ribbon Panel, which was tasked by the State Board tasked with examining the issues associated with incorporating numeric effluent limits into various types of storm water permits.[18]

As discussed more thoroughly in the CICWQ ~~comments~~ Comments (see. pp. 3-4) there are significant technical issues outstanding with respect to the implementation of ATS for construction sites, including adverse water quality and biological impacts due to toxicity of ATS discharge, adverse hydromodification and biological impacts due to ATS discharges that deprive alluvial systems of natural and ecologically beneficial sediment loads, infeasibility of operation on construction sites, and unclear and unavailable cost information. The "targeted outcome" to which any ATS should aim (difficult it is to safely hit any target) is the natural background level of sediment in southern California streams, which target is naturally variable, event-specific and unpredictable as evidenced by the results presented by Stein and Yoon (2007). *See* Attachment B. This work clearly shows that not only does nature violate CTR criteria for constituents such

condition must make "some sort of individualized determination" that the conditions were related both in nature and extent to project impacts. *Id.* at 391.

18 The findings and recommendations of the Blue Ribbon Report set forth at least 5 prerequisite studies and conditions that need to precede imposition of ATS to control construction site runoff, including consideration of issues associated with toxicity associated with active treatment systems, issues associated with long-term use of chemicals and consideration of runoff flow and peak volume. Blue Ribbon Panel Report entitled "*The Feasibility of Numeric Effluent Limits Applicable to Discharges of Storm water Associated with Municipal, Industrial and Construction Activities*" (June 2006), pp. 16-17.

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as copper, but natural background loads of sediment (both instantaneous concentrations and total loads) are highly variable and can result in TSS values in certain watersheds more than 100,000 $mgL^{-1}$. Thus, the mandate to use ATS to achieve certain theoretical clarify of stormwater discharges without reference to or flexibility to account for natural runoff and receiving water conditions fails to comply with 33 U.S.C. § 1342(p)(3) and related regulations governing promulgation of technology-based control measures) and Porter-Cologne, including §§ 13241(c) and 13263. These issues must be addressed before Permittees are required to adopt ordinances mandating ATS for any subset of construction sites.

Not only is this approach to implementation of ATS in the Tentative Order technically inappropriate in light of the available scientific evidence, and contrary to the recommendations of the Blue Ribbon Panel, but it is also completely out of step with the position taken by the State Board with respect to the Construction General Permit ("CGP"). Therefore, we request that the Regional Board remove the requirement to mandate ATS from the 2nd Tentative Order entirely, until sufficient, reliable information is known with respect to the implications, both legal and technical, of implementing such treatment technology. We support a proactive and enhanced

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With regard to soil and sediment, the primary pollutants of concern at construction sites, these objectives may be met through a comprehensive system of BMPs that include measures from four categories: runoff controls; erosion controls, sediment controls, and non-storm water management controls. Based on the collective experience of the construction industry observing construction sites throughout California, the majority of sites can be well protected with good SWPPP design, more diligent and proper application and maintenance of BMPs, as well as use of a hierarchy of complementary BMPs. This proactive approach is one that contractors can successfully implement, if given appropriate permit driven guidelines. Moreover, this approach is consistent with the Clean Water Act and supported by EPA.[20]

This "pro-active" BMP approach is explained in more detail in the CICWQ Comments submitted concurrently herewith. *See* CICWC Comments, pp. 3-4.

**D. LID Provisions Should be Amended to Properly Take Into Account Proper Scale of LID Strategies.**

We are pleased that the Response to Comments supports the consideration of proper scale in the implementation of LID strategies. *See* pp. 43-44 of Response to Comments. LID strategies can be most effectively implemented when scale is considered. As noted in the previously submitted Technical Comments, in many instances, applying the proposed BMP site requirements at a project level may lead to poor project design when compared to applying these requirements at a broader sub-watershed or watershed scale. *See* pp. 9-11 of April Technical Comments. Thus, we request that the 2nd Tentative Order be amended to include language to the effect the proper scale will be taken into account when determining appropriate implementation, and ultimately compliance, with the LID site design BMP requirements. Again, for illustrative purposes, we are concurrently presenting red-lined language that better indicates what we believe the policy should be, as specifically set forth in sections 2 and 5 of Attachment A.

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This comment letter and Attachment (red-line of the 2nd Tentative Order), Attachment B, and the CICWQ Comments set forth proposed terms, conditions, and requirements of the 2nd Tentative Order that are inappropriate legally, scientifically, or as a matter of good water quality policy. These materials also indicate support for alternative terms, conditions and requirements

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[20] The relevant statutes, EPA regulations and case law all provide that NPDES permits may rely on BMPs as opposed to prescriptive measures, such a numeric limits. 40 C.F.R. § 122.44(k)(2); 33 U.S.C. § 1342(p)(3)(A); 33 U.S.C. § 1311(b)(1)(C); 40 C.F.R. § 122.44(k)(2); *Citizens Coal Council v. United States EPA*, 447 F.3d 879, 896 n.18 (6th Cir. 2006) (EPA has a "longstanding interpretation of the CWA as allowing BMPs to take the place of numeric effluent limitations [in permits issued under] 40 C.F.R. §122.44(k).") EPA continues to utilize BMPs as both BAT and BCT for construction sites, expressly finding that numeric effluent limits for construction sites are cost prohibitive with little demonstrative results. *See* Effluent Limitation Guidelines and New Source Performance Standards for the Construction and Development Category, 67 Fed. Reg. 42644, 42658 (proposed June 24, 2002) (to be codified at 40 C.F.R. pt. 122 and 450) ("EPA did not consider numeric pollutant controls a viable option" for construction storm water discharges).

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that will achieve the Regional Board's laudable water quality goals in an appropriate and effective manner. BILD and BIAOC, thus, respectfully request that the Regional Board consider this information carefully and revise the 2nd Tentative Order before adopting it.

Thank you for the opportunity to provide comments on the 2nd Tentative Order. We respectfully request that this letter and accompanying information be placed into the record. We look forward to working with the Regional Board to effect necessary revisions to the 2nd Tentative Order. We would be more than happy to discuss any of these issues further with the Regional Board and/or Regional Board staff.

Sincerely,

Mary Lynn Coffee
of NOSSAMAN, GUTHNER, KNOX & ELLIOTT, LLP

MLC