EPA Region VIII

Mixing Zones and Dilution Policy

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U.S. Environmental Protection Agency
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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII
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DENVER, COLORADO 80202-2466

DEC 29 1994

Subject: Transmittal of Mixing Zones & Dilution Policy

Dear Colleague,

I am pleased to enclose for your information and use a document titled ***EPA Region VIII Mixing Zones and Dilution Policy***. You may recall that two previous drafts of this policy (dated August 13, 1993 and January 14, 1994) were distributed for comment. The enclosed final policy responds to the comments received on the two drafts (see Appendix B) and incorporates a number of changes that both alter and clarify the policy.

The overall objectives of the policy are to help States and Indian Tribes upgrade current methods for deriving water quality-based permit limits, improve the technical defensibility of NPDES permits, and reduce risks associated with mixing zone and dilution practices. The basis for the policy is the Region's belief that the current approach of presumptively providing the entire low flow for dilution often results in effluent plumes (with elevated pollutant concentrations) extending far downstream of the discharge. This current approach does not adequately control effluent plume size or quality and may pose considerable risk to sensitive downstream uses.

Implementation of this policy will be a high priority for EPA during upcoming state and tribal water quality standards triennial reviews. However, the Region recognizes that there are other important tasks facing States and Tribes (e.g., antidegradation procedures, wetland standards, biological criteria). The Region plans to work with each State and Tribe individually to implement this policy in a timely manner along with all other priority water quality standards initiatives. When completed, state and tribal implementation of the policy will consist of the following: (1) adoption of necessary revisions to the state or tribal mixing zone policy; (2) development of a detailed mixing zone and dilution implementation procedure; and (3) clear resolution of each of the issues discussed in Chapter 2 of the policy.

In the past several years, Region VIII States have taken huge strides by adopting numeric, chemical-specific criteria for toxic pollutants. Likewise, a number of Indian Tribes will soon be establishing such criteria for reservation waters. It is my hope that this policy will be useful in establishing improved procedures for the critical task of translating these water quality criteria into effluent limitations for point source discharges.

Sincerely,

Max H Dodson

Max H. Dodson, Director
Water Management Division

Enclosure

FORWARD

The Clean Water Act provides a clear mandate to the U.S. Environmental Protection Agency (EPA), States and Indian Tribes to develop and implement water quality standards for surface waters. Within the last five years, all States located within EPA Region VIII have significantly increased the number of specific substances that are the subject of numeric water quality criteria. These efforts promise to greatly improve the level of water quality protection afforded to surface waters. Although establishing appropriate water quality criteria is a difficult and ongoing task that must respond to the latest scientific information, equally important is the process of translating ambient criteria into technically-defensible total maximum daily loads and water quality-based permit limits under the National Pollutant Discharge Elimination System. Such standards implementation efforts must also be subjected to periodic evaluation so that the procedures followed are consistent with the latest and best available methods.

This document provides technical guidance and EPA Region VIII policy regarding one particular aspect of water quality standards implementation: establishment of mixing zone and dilution requirements. It was issued in support of EPA regulations. This document does not establish or affect legal rights or obligations. It does not establish a binding norm and is not finally determinative of the issues addressed. Agency decisions in any particular case will be made by applying both federal and state/tribal requirements on the basis of specific facts when permits are issued or water quality standards or other regulations are promulgated.

This document may be revised in the future. Comments from users are welcome. Send comments to the U.S. EPA Region VIII, Water Management Division, 999 18th Street, Suite 500, Denver, CO 80202-2466.

> This issue of the EPA Region VIII Mixing Zones and Dilution Policy has been updated to reflect some changes in Chapter 4 and Appendix A. In particular, changes have been made in EPA Region VIII's mixing zone model STREAMIX I based on comments received over the last year. Accordingly, the description and mathematical derivation for STREAMIX I found in the Policy has been updated. The changes incorporated in the STREAMIX I (version 2) code include changes to the calculation of extreme (e.g. maximum) concentrations within the mixing zone. This change will have very little effect, however, in situations where the effluent flow (Q_{eff}) is much smaller than the receiving water flow (Q_{up}).

EPA Region VIII

Mixing Zones and Dilution Policy

TABLE OF CONTENTS

EPA Region VIII
Mixing Zones and Dilution Policy

EXECUTIVE SUMMARY

Under EPA Clean Water Act (CWA) regulations, States and Indian Tribes may designate a ***mixing zone*** or provide a ***dilution allowance*** when setting water quality-based permit limits for point source discharges, provided that an appropriate authorizing policy is included in the state or tribal water quality standards. In either case, relief is provided to the permittee by allowing the discharge to mix with the receiving waterbody before attainment with water quality criteria is required. Within a mixing zone, for example, certain water quality criteria otherwise applicable to the waterbody may be exceeded. Where a discharge mixes with the receiving waterbody very rapidly, a mixing zone analysis need not be completed, and a dilution allowance based on the ***critical low flow*** of the receiving water may be provided.

States and Indian Tribes may designate a mixing zone or provide a dilution allowance when setting water quality-based permit limits.

Although most EPA Region VIII States have a mixing zone policy included in their water quality standards regulation, a true mixing zone approach is generally not followed in developing water quality-based permit limits. Instead, EPA Region VIII States typically follow a simplified mass balance approach that effectively provides the entire critical low flow as a dilution allowance in calculating the permit limit, regardless of the rate of mixing. Some States have recently adapted this practice by applying chronic as well as acute critical low flows to accommodate the two-tiered water quality standards scheme of chronic and acute standards.

Providing such dilution allowances, without considering how quickly the discharge actually mixes with the receiving waterbody, can result in discharge-receiving water mixtures that are considerably in excess of criteria far downstream of the discharge. High pollutant concentrations in such ***effluent plumes*** represent a threat to designated and existing uses (e.g., drinking water intakes, recreational areas, and aquatic life spawning and nursery areas). For discharges with average physical characteristics and a typical outlet structure design, EPA Region VIII believes that such effluent plumes normally are present, as such discharges simply do not mix rapidly with receiving waters. Where there are multiple discharges to a waterbody, overlapping effluent plumes pose especially significant ecological and human health risks. However, properly implementing a mixing zone approach controls the size and quality of effluent plumes, consistent with state or tribal water quality standards requirements, and reduces risks to aquatic life and human health.

This policy statement on mixing zones and dilution is intended to help EPA Region VIII States and Tribes upgrade current methods for deriving water quality-based permit limits, improve the technical defensibility of NPDES permits, and limit the environmental risks posed by effluent plumes. Chapter 2 identifies the specific mixing zone and dilution implementation issues that most concern EPA Region VIII. For these issues, States and Tribes will need to consider the range of technically-defensible approaches and then select and document the approach that will be used in deriving water quality-based permit limits. This will entail:

- establishing methods to determine if a discharge mixes completely or incompletely;
- developing criteria to limit the size of mixing zones;
- selecting methods to derive effluent limits to achieve mixing zone size restrictions;
- adopting minimum in-zone quality requirements for mixing zones;
- implementing the "no acute lethality" requirement for mixing zones;
- identifying dilution allowances to be granted where complete mixing occurs;
- specifying situations where a mixing zone or dilution allowance may be denied;
- explaining any differences in implementation of chemical-specific and whole effluent toxicity requirements; and
- affirming state/tribal authority to re-evaluate mixing zone and dilution decisions based on new information.

The remainder of the policy statement provides guidance and recommendations on implementation of these key issues. Chapter 3 provides a model mixing zone-dilution policy that includes recommended policy language on each of the key issues. Chapter 4 provides a specific model implementation procedure that is consistent with, and could be used to implement, the model policy statement in Chapter 3. Note that on each of the key implementation issues, the Region's model approach represents one option in a range of acceptable options. Chapter 5 includes discussion of particular case examples that examine how use of the Region's model implementation procedure would affect existing permit limits. Finally, the appendices provide additional guidance and background information on the basis for the Region's recommended policies and procedures, including Regional responses to the major comments and questions that were received on various drafts of this policy statement.

Implementation of this policy statement will be a high priority for EPA in working with States and Tribes during upcoming water quality standards triennial reviews.

Implementation of this policy statement will be a high priority for EPA in working with States and Tribes during upcoming water quality standards triennial reviews. However, the Region recognizes that most States face a variety of high-priority needs with regard to revising water quality standards and establishing implementation procedures. These priorities include, for example, establishing antidegradation implementation procedures, developing water quality standards for wetlands, updating chemical-specific numeric criteria for toxic pollutants, developing biological criteria, and ensuring water quality protection for threatened and endangered species. Accordingly, the Region plans to continue to work with each State and Tribe individually to develop and adopt all needed water quality standards revisions in a timely manner and in an appropriate sequence. Because States and Tribes have varying needs, implementation of this policy may not occur at the same time throughout the Region. Thus, because not all States and Tribes will be implementing this policy immediately, where a State or Tribe has not established a procedure, or has not documented a clear approach to a particular issue, the model implementation procedure in Chapter 4 of this policy statement will be considered in the interim as the Region's preferred method of making mixing zone and dilution decisions. This policy may therefore influence individual NPDES permits issued by the Region or certain State-issued NPDES permits. The model policy and procedure will also be a likely starting point for the Region in developing federal replacement requirements, should disapproval of state or tribal water quality standards become necessary.

CHAPTER 1. INTRODUCTION

A **mixing zone** is an area surrounding or downstream of a point source discharge where the effluent plume is progressively diluted by the receiving water and certain numerical criteria otherwise applicable to the segment may be exceeded. A mixing zone analysis is typically incorporated into the derivation of total maximum daily loads (TMDLs) and water quality-based National Pollutant Discharge Elimination System (NPDES) permit limits where point source discharges mix in an **incomplete** manner with receiving waters. The mixing zone analysis is developed to ensure compliance with mixing zone requirements (such as size and in-zone quality requirements) that are included in the applicable state or tribal standards. A mixing zone provides relief to the permittee in that compliance with certain criteria is not required within the zone. However, a mixing zone is granted on a parameter-by-parameter basis, and for some parameters or criteria, compliance may be required at the end-of-pipe. Where a discharge mixes with the receiving water in a **rapid and complete** manner, a mixing zone analysis is not needed and a **dilution allowance** based on critical low-flow conditions may be incorporated into the derivation of TMDLs and NPDES permits.

A mixing zone analysis is developed to ensure compliance with mixing zone requirements that are included in the applicable state or tribal standards.

COMMON MIXING ZONE AND DILUTION PRACTICES

Situation	**Approach**
• Slow or "Incomplete" Mixing	Mixing zone analysis is required to determine the allowable dilution.
• Rapid and "Complete" Mixing	Dilution up to critical low flow may be allowed.
• No Dilution Available (Low Flow = Zero)	Achieve criteria at end-of-pipe.

State/tribal mixing zone-dilution **policies** should establish, in language readily understood by the public, the situations in which a mixing zone or dilution allowance may be authorized. To facilitate implementation, such policies should also define the situations in which a mixing zone or dilution allowance may be limited or denied. State/tribal mixing zone-dilution implementation **procedures** should establish the specific methods, guidelines, and approaches that will be followed in implementing the state/tribal mixing zone-dilution policy. The procedures should be explained with a sufficient level of detail to ensure consistency when used to derive point source discharge permit limits. Mixing zone-dilution procedures should clearly identify the issues and decisions that are left to the discretion and best professional judgment of the permit writer. However, to the extent appropriate, the procedure should specify a particular approach to promote consistency.

Unfortunately, it is not possible to establish a wholly deterministic procedure (i.e., a "black box") with which to make all mixing zone-dilution decisions. Nor is it advisable to make all mixing zone-dilution decisions based on a simplistic approach which overlooks the mixing characteristics and waterbody uses (e.g., fish spawning, drinking water supply) particular to the site. To appropriately address site-specific environmental concerns and the mixing characteristics of individual discharges, mixing zone-dilution decisions should be made on a case-by-case basis using the best factual information available at the time of the decision. However, as a practical matter, sufficient information and resources are not always available to fully characterize mixing and localized waterbody uses. Accordingly, mixing zone-dilution policies, and particularly the procedures used to implement such policies, should clearly set forth the considerations, guidelines, and default assumptions that will be utilized in making such case-by-case decisions.

Mixing zone and dilution decisions should be made on a case-by-case basis using the best information available at the time of the decision.

Under EPA's water quality standards regulation, States and Indian Tribes may adopt policies authorizing the use of mixing zones in setting TMDLs and water quality-based permit limits (see 40 CFR 131.13). Pursuant to federal regulation, the decision regarding whether to allow mixing zones is made by the individual States/Tribes (i.e., States/Tribes may elect to allow or to prohibit mixing zones for purposes of water quality based permit limits). Where a State/Tribe elects to allow mixing zones, the State/Tribe must include an authorizing policy in their water quality standards regulation. Such mixing zone policies are subject to EPA review and approval. States and Tribes must also establish procedures to be followed in implementing their mixing zone policies. Such mixing zone procedures also are subject to EPA review and approval and should be incorporated into the narrative toxics criterion implementation procedure required by the Federal water quality standards regulation (see 40 CFR 131.11(a)(2)). State/tribal decisions regarding mixing zones for individual discharges are subject to EPA review through the NPDES permits process.

To assist States and Tribes in establishing appropriate mixing zone and dilution policies and procedures, EPA-Headquarters has periodically issued technical guidance on this topic. National EPA guidance can be found in the ***Technical Support Document for Water Quality Based Toxics Control*** (1991), the ***Water Quality Standards Handbook*** (1983 and 1993), and ***Quality Criteria for Water*** ("the Red Book", 1976). Other sources of information and guidance include ***Water Quality Criteria 1972*** ("the Blue Book", National Academy of Sciences).

Purpose and Objectives

A primary purpose of this policy statement is to assist the States and Indian Tribes in EPA Region VIII to establish technically-defensible (and thus approvable) mixing zone and dilution policies and implementation practices. The policy statement identifies the particular mixing zone and dilution issues that will most directly influence EPA Region VIII approval decisions (see Chapter 2). The policy statement also includes a model policy and procedure that States and Tribes can adopt as their own, with or without modification (see Chapters 3 and 4). The model policy and procedure are included as separate items because, although both are required elements of state/tribal water quality programs, incorporating the entire text of the mixing zone-dilution procedure into the state/tribal water quality standards regulation is optional. States/Tribes may, instead, include such detailed procedures in their standards by reference in order to allow for periodic updates and improvements to such procedures without going through a rulemaking action (i.e., where allowed under state/tribal rulemaking requirements). Where such procedures are adopted by reference, they must be included in any triennial review package submitted to EPA Region VIII for review and approval.

A primary purpose of this policy statement is to assist States and Tribes to establish technically-defensible mixing zone and dilution practices.

The Region's intent is that this policy will result in two basic types of improvements to existing mixing zone and dilution practices. First, it is the Region's intent to reduce the environmental risks posed by mixing zones. This objective is embodied in the recommended policy of requiring all point source discharges to comply with acute aquatic life criteria at the end-of-pipe. Such an approach would result in rapid and Region-wide reduction in the risks posed by mixing zones. Second, it is the Region's intent to eliminate unacceptable environmental risks in specific cases. This goal resulted, for example, in the recommended policy of requiring end-of-pipe compliance with applicable criteria where site-specific factors support such an approach (e.g., where, in a specific case, there is a drinking water intake a short distance downstream of a discharge). Thus, the Region's policy is intended to promote more judicious use of mixing zone authority generally and to encourage elimination of existing mixing zones where there is sufficient evidence that such mixing zones pose unacceptable environmental risks.

As noted above, state and tribal implementation of this policy statement will serve the additional purpose of satisfying, in part, the requirement in Section 131.11 of the Federal water quality standards regulation for a narrative toxics criterion implementation procedure. The recommended components of such implementation procedures have been discussed in prior guidance issued by the Region (see January 17, 1990 Regional letter sent to each state Water Division Director, ***Compliance with the Toxics Requirements of Section 303(c)(2)(B) of the Clean Water Act and the Water Quality Standards Regulation (40 CFR 131.11)***, copies available from the Region) and Chapter Two of the recent update to the ***Technical Support Document for Water Quality Based Toxics Control (TSD)*** (see pp. 31-32).

The specific objectives of this policy statement on mixing zones and dilution are to:

(1) **Supplement existing EPA policy and guidance in this area.** Although extensive EPA guidance has been issued in the past, that guidance has typically described a range of acceptable approaches without clearly delineating a recommended approach. This policy statement is intended to fill that gap.

(2) **Identify the particular mixing zone and dilution issues that will most directly influence EPA approval/disapproval decisions.** In order to minimize the potential for EPA disapproval of water quality standards, this policy provides advance notice of the particular issues for which States and Tribes will need to document a clear approach in order for EPA Region VIII to consider the federal requirements satisfied.

(3) **Establish a common framework to promote consistency among Region VIII States and Tribes on mixing zone-dilution issues.** Although the Region intends to allow each State and Tribe the flexibility to customize their approach to mixing zones and dilution, this policy statement is also intended to promote consistency on key issues and to ensure that certain minimum elements are addressed by all States and Tribes.

(4) **Promote implementation of policies and procedures that will appropriately minimize the size and impacts of mixing zones in surface waters.** Although EPA regulations allow the use of mixing zones, it is important to remember that mixing zones are basically allocated impact zones. As such, mixing zones should be carefully limited or eliminated to ensure protection of aquatic life and human health.

CHAPTER 2. MIXING ZONE AND DILUTION ISSUES

> ***States and Tribes may deviate from the Region's recommended approach as long as each of the issues is clearly resolved and the approach selected is technically defensible.***

To assist States and Indian Tribes in establishing mixing zone and dilution practices that are approvable under CWA Section 303(c) and EPA's water quality standards regulation (40 CFR 131), this chapter of the policy statement identifies and discusses the particular issues that States and Tribes will need to address and clearly resolve in their mixing zone and dilution policies and implementation procedures. For each of the issues, there is a range of approaches that may be used. The particular approach that is recommended by the Region is discussed briefly below and incorporated into the model policy and implementation procedure presented in Chapters 3 and 4, respectively. However, States and Tribes may deviate from the Region's recommended approach as long as each of the issues is clearly resolved and the approach selected is documented and technically defensible.

Implementation of this policy statement will be a high priority for EPA in working with States and Tribes during upcoming water quality standards triennial reviews. However, the Region recognizes that most States face a variety of high-priority needs with regard to revising water quality standards and establishing implementation procedures. These priorities include, for example, establishing antidegradation implementation procedures, developing water quality standards for wetlands, updating chemical-specific numeric criteria for toxic pollutants, developing biological criteria, and ensuring water quality protection for threatened and endangered species. Accordingly, the Region plans to continue to work with each State and Tribe individually to develop and adopt all needed water quality standards revisions in a timely manner and in an appropriate sequence. Because States and Tribes have varying needs, implementation of this policy may not occur at the same time throughout the Region. Thus, because not all States and Tribes will be implementing this policy immediately, where a State or Tribe has not established a procedure, or has not documented a clear approach to a particular issue, the model implementation procedure in Chapter 4 of this policy statement will be considered in the interim as the Region's preferred method of making mixing zone and dilution decisions. This policy may therefore influence individual NPDES permits issued by the Region or certain State-issued NPDES permits. The model policy and procedure will also be a likely starting point for the Region in developing federal replacement requirements, should disapproval of state or tribal water quality standards become necessary.

In some cases, state or tribal implementation of this policy statement may involve adding considerable detail to previously adopted state or tribal water quality standards. In keeping with past practice (e.g., antidegradation policies and procedures), EPA will approve adoption of detailed implementation procedures or guidance which are not formally part of the State or Tribe's water quality standard regulation as long as the results of such procedures are legally enforceable under state or tribal law. Thus, one way to implement this policy statement would be to develop a separate mixing zones-dilution implementation procedure that is included in the water quality standards by reference.

The mixing zone and dilution issues for which a clear state or tribal approach will need to be documented include the following:

Issue # 1: With regard to complete mix/incomplete mix decisions, the policy/implementation method must satisfy the following minimum requirements:

(a) **The policy and procedure must require, prior to concluding that a discharge mixes in a near instantaneous and complete fashion, that a sound factual basis be documented in the NPDES permit.**

(b) **Specific guidelines to be used in making such complete mix/incomplete mix decisions must be established.**

(c) **A method or process must be described by which a permittee may demonstrate that near instantaneous and complete mixing is achieved at critical conditions. At a minimum, the policy and procedure must establish an operational definition of "near instantaneous and complete mixing" and require a permittee to coordinate with the State/Tribe and EPA on the development and execution of a rate of mixing study plan.**

Discussion: One of the primary problems with the existing approach followed by Region VIII States is that the entire low flow is assumed to dilute the effluent, regardless of the local rate of ambient mixing. Where the rate of ambient mixing is slow (i.e., incomplete mixing is occurring), assuming the entire low flow as dilution is likely to result in a lengthy downstream effluent plume with water quality characteristics that are considerably in excess of applicable criteria and toxicity objectives. Such effluent plumes can pose considerable risks to human health and aquatic life and should be limited consistent with a state or tribal mixing zone policy. Because ambient mixing is often slow, EPA Region VIII believes that the current approach does not adequately address the potential risks of effluent plumes or adequately control the size of mixing zones. To address this problem, the Region will expect States and Tribes to establish a procedure for making complete mix/incomplete mix determinations. Once this initial determination is made, States and Tribes will be expected to apply a defensible mixing zone (in the case of incomplete mixing) or dilution approach (in the case of complete mixing), as appropriate. The Regional model approach to this issue calls for determining complete or incomplete mixing based on best professional judgment (BPJ). The procedure assumes near instantaneous and complete mix where: (1) there is an effluent diffuser that covers the entire stream or river width at low flow, or (2) the mean daily flow of the discharge exceeds the chronic low flow of receiving water. The permittee may also show "near instantaneous and complete mixing"[1] consistent with a study plan developed in consultation with the State and EPA. Otherwise, incomplete mixing is assumed and a mixing zone approach is implemented. The Region intends to allow States and Indian Tribes the flexibility to use this recommended approach or to follow alternative approaches. For example, States and Tribes may elect to use different guidelines for determining when near instantaneous and complete mixing exists, or use a different operational definition of "near instantaneous and complete mixing" for purposes of field mixing studies. However, in issuing and reviewing NPDES permits, the Region will not support any assumptions of complete mixing unless a reasonable, factual basis has been documented in the permit.

One of the primary problems with the existing approach followed by Region VIII States is that the entire low flow is assumed to dilute the effluent, regardless of the local rate of ambient mixing.

Issue # 2: **Where mixing is incomplete, the policy/procedure must explain how mixing zones will be sized for aquatic life and human health protection. At a minimum, absolute maximum size restrictions (e.g., by waterbody type) and factors to be considered in establishing site-specific mixing zone dimensions must be established.**

Discussion: In developing a mixing zone approach, it is important to set absolute maximum size restrictions. Such maximum size restrictions promote consistency and facilitate development of water quality-based permits. The Region's recommended approach calls for the size and shape of mixing zones, where allowed, to be determined case-by-case. However, the following maximum size restrictions are specified. For streams and rivers, mixing zones must not exceed one-half of the cross-sectional area or a length 10 times the stream width at critical low flow, whichever is more limiting. For lakes, mixing zones must not exceed 5% of the lake surface area or 200 feet in radius, whichever is more limiting. Site-specific factors that may be the basis for down-sizing individual mixing zones include

[1] "Near instantaneous and complete mixing" is defined in the model procedure as no more than a 10% difference in bank-to-bank concentrations within a longitudinal distance not greater than 2 stream/river widths. In addition, the phrases "near instantaneous and complete mixing" and "complete mixing" are used interchangeably in this policy statement.

existing bioaccumulation problems in fish tissue or sediment, biologically-important areas, low acute to chronic ratio, potential human exposure from drinking water or recreation, attraction of aquatic life to the effluent plume, toxicity/persistence of the substance, zone of passage for migrating fish (including access to tributaries), and cumulative effects of multiple discharges and multiple mixing zones. EPA Region VIII intends to allow States and Indian Tribes the flexibility to follow the Region's model approach, to incorporate reasonable modifications, or to pursue other protective alternatives. For example, States and Tribes may elect to use somewhat smaller or somewhat larger maximum size restrictions or to include more specific guidelines for adjusting mixing zone size and shape in specific cases. However, the Region will carefully review approaches that deviate from the recommended size limits in its review of adopted state and tribal mixing zone policies and procedures.

Maximum size restrictions ensure consistency statewide and facilitate development of water quality-based permits.

Issue # 3: The policy/procedure must describe methods by which effluent limits will be derived to achieve mixing zone size and shape requirements (such as particular mathematical models).

Discussion: Once a State or Tribe has established the allowable size of a mixing zone in a particular case, methods are needed to derive permit limits that will achieve the size restrictions. These methods should be fairly specific, but flexible enough to address both data-rich and data-poor situations. The Region's recommended approach is to use one of three progressively more sophisticated methods. The ***default method*** may be used where data necessary to implement a more sophisticated approach are lacking or where a conservative approach is warranted based on site-specific environmental concerns. For streams, the default method requires that no more than 10% of the critical low flow be provided as dilution. For lakes, the default method requires that no more than 4:1 dilution be allowed (20% effluent). The default method is very easy to implement, but because it is not based on the ambient mixing rate, the resulting dilution allowance is conservative (i.e., it is based on worst-case mixing assumptions). The ***modeling method*** may also be used to ensure that mixing zone size restrictions are achieved. Several different modeling methods, ranging from simple (ambient diffusion only) to more data-intensive (discharge-induced and ambient diffusion) are recommended. Because the modeling method is driven by site data, it yields more dilution where mixing is relatively rapid and less dilution where mixing is relatively

Several different modeling methods are recommended, ranging from simple to more data-intensive.

slow. In addition, the modeling method generally yields more dilution than the default method. The ***field study method*** requires use of field data quantifying the actual ambient mixing rate. As such, the field study method yields the most accurate estimate of the dilution that will achieve mixing zone size restrictions, but it also requires the most site data. EPA Region VIII intends to allow States and Indian Tribes the flexibility to follow the Region's recommended protocol or to develop their own (technically-defensible) methods. States and Tribes may elect to rely exclusively on a single method, or use a combination of methods (such as those in the EPA model procedure). Regardless of the method(s) selected by the State or Tribe, EPA will require the implementation document to include a level of detail that is sufficient to ensure reasonable consistency when used to derive water quality-based permit limits.

Issue # 4: Minimum in-zone quality requirements must be clearly established for all mixing zones including, at a minimum, the narrative "free from" criteria (i.e., including a prohibition of acute lethality to aquatic life).

Discussion: EPA policy is that state and tribal mixing zone policies must include minimum in-zone quality requirements that apply within mixing zones. Such in-zone quality requirements can serve to provide protection, for example, to organisms residing within or passing through the mixing zone. The Region recommends that States and Tribes address this issue by clarifying that their narrative "free from" water quality criteria apply within mixing zones. Such narrative criteria typically require that surface waters shall be "free from substances that settle to form objectionable deposits, float as debris, scum, oil, or other matter, produce objectionable color, odor, taste, or turbidity, are acutely toxic, and produce undesirable or nuisance aquatic life." Regardless of the exact language that is adopted by a State or Tribe, a minimum narrative requirement that must apply within mixing zones is that mixing zones must not result in lethality to aquatic life caused by passage through the mixing zone by migrating fish, or by less mobile forms drifting through a plume. States and Tribes may also specify that mixing zones may not result in toxicity to sessile organisms that reside within mixing zones. See comment # 11 in Appendix B for additional discussion.

Issue # 5: Where mixing is incomplete, the policy/procedure must clearly explain how chemical-specific acute criteria are to be implemented to comply with the "no acute lethality" requirement that applies within mixing zones. The policy/procedure must also require compliance with acute whole effluent toxicity limitations at the end-of-pipe, without an allowance for dilution (i.e., where such acute WET limits are included in a permit).

Discussion: In developing water quality-based permit limits, a difficult issue is setting daily maximum (acute) permit limits for individual substances that will achieve the no acute lethality requirement that applies within mixing zones. This issue is difficult because a discharge at concentrations in excess of acute criteria may be lethal to organisms occupying or passing through the mixing zone (i.e., depending upon the duration and magnitude of the exposure). The Region's recommendation for acute chemical-specific criteria is to require compliance with such criteria at the end-of-pipe, without an allowance for dilution. The Region believes that this approach is the best means of ensuring that the no acute lethality requirement that applies within mixing zones will be achieved. However, the Region is aware that other approaches are currently in use that allow a small area for mixing (often referred to as a zone of initial dilution) where chemical-specific acute criteria need not be achieved. Because these approaches are described in EPA guidance and used by some States, the Region will approve use of such methods if the method is clearly described and appropriately protective (see Regional guidance on this topic in Appendix D). For acute whole effluent toxicity limitations, the Region will continue to require end-of-pipe compliance, with no allowance for dilution (i.e., except where mixing is found to be near instantaneous and complete). See comments 8, 13, and 17 in Appendix B.

In incomplete mix situations, acute whole effluent toxicity limitations must be achieved at the end-of-pipe, without an allowance for dilution.

Issue # 6: **Guidelines must be included regarding the amount of dilution to be provided where near instantaneous and complete mixing is determined to occur (i.e., "critical" low flows for human health as well as aquatic life criteria) and factors (e.g., drinking water intakes, presence of biologically-important areas, etc.) that may be the basis for site-specific reduction of the dilution allowance.**

Discussion: In cases where complete mixing is occurring, it is important to describe how the dilution allowance will be established. Establishing a clear approach to this issue ensures consistency and provides a basis to address site-specific environmental concerns. To best define dilution allowances for implementing water quality standards, the Region feels that it is most appropriate to define both ambient critical flows and effluent critical flows. In particular, a distinction should be made between the ambient and effluent flows to be used for standards of longer duration (e.g. chronic aquatic life standards) and those to be used for shorter duration standards (e.g. acute aquatic life standards). Under the model procedure, the flows shown below are applied as a maximum dilution allowance. However, dilution may be further limited in individual cases to a portion of the critical low flow based on site-specific environmental concerns. The Region believes that the duration and frequency of the flows used should match the duration and frequency criteria provisions found in the state or tribal water quality standards. In other words, the duration (e.g., 1 hour, 4 day, 30 day) and excursion frequency (e.g., 3 years) associated with each standard, whether it is for aquatic life uses, recreational uses, drinking water, agricultural uses, wildlife protection or other uses, should match the duration and frequency of the ambient dilutions flows used to implement those standards. In addition, the Region is recommending the use of the "biologically-based" method for calculating critical ambient flows. The Region has found that there are significant advantages statistically and functionally to this distribution-free method, including a thorough analysis of historical data and the ability to determine seasonal/monthly flows without exceeding frequency provisions in state standards. The biologically-based method contrasts with the more traditional "extreme" methods that utilize much less data and return less accurate results. (See Appendix E.) Although the Region recommends the flows shown below, the Region intends to allow States and Tribes the flexibility to determine the critical low flows that are appropriate. States and Tribes may also want to establish more specific guidelines for restricting dilution allowances in individual cases (e.g., States and Tribes may want to further restrict dilution allowances for human health criteria where a discharge is within 2 miles of a drinking water intake). The critical flows[1] recommended by the Region are as follows:

<u>Stream Flows</u>	
Aquatic life, chronic	4-day, 3-year flow (biologically based)
Aquatic life, acute	1-day, 3-year flow (biologically-based)
Human health (carcinogens)	harmonic mean flow
Human health (non-carcinogens)	4-day, 3-year flow (biologically-based) or 1-day, 3-year flow (biologically-based)
<u>Effluent Flows</u>	
Aquatic life, chronic	Mean daily flow
Aquatic life, acute	Maximum daily flow
Human Health (all)	Mean daily flow

[1] These flows are recommended by EPA Region VIII. The actual duration (e.g. 4 day) and frequency (e.g. 3-year) of the flows used should match the duration and frequency provisions of the aquatic life, human health, and other standards found in state water quality standards. For human health non-carcinogens, Region VIII is making a distinction between parameters that typically have an effect after prolonged exposures (e.g. copper) and those that have more of an immediate effect (e.g. nitrite). For simplicity, Region VIII is recommending use of the chronic aquatic life flow for the longer-acting parameters and the acute aquatic life flow for the shorter-acting parameters. For information on how to calculate these flows, see ***EPA's Stream Design Flow for Steady-State Modeling; Technical Guidance Manual for Performing Wasteload Allocation; Book 6; Design Conditions*** (1986).

Issue # 7: The policy/procedure must identify situations in which a mixing zone or an allowance for dilution will/may be denied (at a minimum, such situations include absence of available dilution at critical low flow conditions).

> ***The Clean Water Act does not grant dischargers the right to discharge at concentrations that exceed applicable water quality criteria.***

Discussion: One problem sometimes encountered in implementing water quality controls is that dischargers may believe they are automatically ***entitled*** to a dilution allowance or a mixing zone. In fact, the Clean Water Act provides no express entitlement even to discharge, let alone to discharge at concentrations that exceed applicable water quality criteria. Although discharges may be (and usually are) permitted under the NPDES program, the Clean Water Act requires that such permits include effluent limits that will fully protect designated and existing uses. In some cases, protecting uses may require that a discharge not be granted a dilution allowance or mixing zone. Thus, it is important that mixing zone implementation documents clearly communicate to dischargers the situations in which a mixing zone or a dilution allowance may be denied. For example, the Region's model approach calls for prohibiting dilution or a mixing zone for any discharge to a wetland (see question # 5 in Appendix B for additional discussion). In addition, any of the factors for limiting or denying a mixing zone (e.g., presence of drinking water intakes or biologically-important areas) may also be the basis for limiting or denying an allowance for dilution. Finally, a mixing zone or dilution allowance may not be provided where the critical low flow is zero (at a minimum, States and Tribes will be expected to implement this requirement). States and Indian Tribes may follow this model approach or develop their own approach, which may be more or less comprehensive than the Region's model. For example, States and Indian Tribes may adopt additional guidelines for special situations (e.g., South Dakota has prohibited mixing zones for all lake discharges).

Issue # 8: The policy and procedure must address development of both chemical-specific and whole effluent toxicity (WET) limits.

Discussion: It is important for State and Tribal mixing zone policies and procedures to clearly address development of both toxicity and chemical-specific permit limits. Such clarity facilitates permit issuance and avoids possible misunderstanding and potential disputes. Although in general the dilution and mixing zone approach is likely to be the same in each case, any differences should be explicit. For example, in incomplete mix situations, where a State or Tribe elects to provide a limited zone of initial dilution for acute chemical-specific criteria, the policy and procedure should: (1) include clear implementation guidelines, and (2) clearly state that acute WET limits will be applied at the end-of-pipe, without an allowance for dilution (as discussed above under Issue # 5). In general, State and Tribal mixing zone-dilution policies and procedures will be expected to cover both chemical-specific and whole effluent toxicity limits and to clearly explain any policy or procedural differences for the two types of permit limits.

Issue # 9: The mixing zone policy must clearly establish state/tribal authority to revisit and adjust mixing zone analyses or dilution allowances as better information on the rate of mixing and/or the impacts of the discharge becomes available.

Discussion: This issue may be addressed by inclusion of a simple provision in the state or tribal mixing zone policy. For example, the Region's model policy includes the following: "All mixing zone-dilution assumptions are subject to review and revision as information on the nature and impacts of the discharge becomes available (e.g., chemical and/or biological monitoring at the mixing zone boundary). At a minimum, mixing zone and dilution decisions are subject to review and revision along with all other aspects of the discharge permit upon expiration of the permit."

CHAPTER 3. MODEL POLICY[1]

PURPOSE

(a) This policy addresses how mixing and dilution of point source discharges with receiving waters will be addressed in developing chemical-specific and whole effluent toxicity discharge limitations for point source discharges. Depending upon site-specific mixing patterns and environmental concerns, some pollutants/criteria may be allowed a mixing zone or dilution while others may not. In all cases, mixing zone and dilution allowances shall be limited as necessary to protect the integrity of the receiving water ecosystem and designated waterbody uses.

MIXING ZONES

(b) Where dilution is available at critical conditions and the discharge does not mix at a near instantaneous and complete rate with the receiving water (incomplete mixing), an appropriate mixing zone may be designated. However, mixing zones may be denied on a parameter-by-parameter basis where practicable (e.g., many ambient criteria can be achieved at the end-of-pipe without a mixing zone allowance). Where a mixing zone is allowed, its size and shape will be determined on a case-by-case basis. Mixing zones for streams and rivers shall not exceed one-half of the cross-sectional area or a length 10 times the stream width at critical low flow, whichever is more limiting. Mixing zones in lakes shall not exceed 5% of lake surface area or 200 feet in radius, whichever is more limiting. These limits are intended to establish the maximum allowable size of mixing zones; however, individual mixing zones may be further limited or denied in consideration of designated and existing uses or presence of the following concerns in the area affected by the discharge:

(i) bioaccumulation in fish tissues or wildlife,
(ii) biologically important areas such as fish spawning/nursery areas,
(iii) low acute to chronic ratio,
(iv) potential human exposure to pollutants resulting from drinking water or recreational activities,
(v) attraction of aquatic life to the effluent plume,
(vi) toxicity/persistence of the substance discharged,
(vii) zone of passage for migrating fish or other species (including access to tributaries), and
(viii) cumulative effects of multiple discharges and mixing zones.

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[1] This model policy is included as an example of the type of mixing zone-dilution policy that would satisfy federal requirements.

(c) Within the mixing zone designated for a particular substance, certain numeric water quality criteria for that substance may not apply. However, all mixing zones shall be free from substances that:

(i) settle to form objectionable deposits,
(ii) float as debris, scum, oil, or other matter,
(iii) produce objectionable color, odor, taste, or turbidity,
(iv) are acutely toxic[1], and
(v) produce undesirable or nuisance aquatic life.

(d) In incomplete mix situations, discharge limitations to implement acute aquatic life (chemical-specific) criteria and narrative (no acute toxicity) criteria shall be based on achieving such acute criteria at the end-of-pipe (i.e., without an allowance for dilution). This approach is intended to implement the narrative requirement prohibiting acutely toxic conditions in the mixing zone. In implementing this requirement, the objective shall be to avoid acute toxicity to migrating fish, organisms that are attracted to the effluent plume, less mobile organisms drifting through the mixing zone, and sessile organisms that reside within the mixing zone. For chemical-specific acute criteria, a limited exception to this rule is provided under paragraph (e) of this policy (regarding certain minor POTWs).

DILUTION ALLOWANCES

(e) Where the discharge is to a river or stream, dilution is available at critical conditions, and available information is sufficient to reasonably conclude that there is near instantaneous and complete mixing of the discharge with the receiving water (complete mixing), an appropriate dilution allowance may be provided in calculating chemical-specific and WET discharge limitations. The basis for concluding that such near instantaneous and complete mixing is occurring shall be documented in the rationale for the NPDES permit. The dilution allowance for continuous dischargers shall be based on the critical low flow (or some portion of the low flow). The requirements and environmental concerns identified in paragraphs (b) and (c) above

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[1] Although EPA recommends that state and tribal narrative "free from" toxicity criteria apply to acute and chronic toxicity to humans, animals and plants (see suggested language on page 3-24 of the ***Water Quality Standards Handbook***), within mixing zones EPA recommends a narrative requirement prohibiting acutely toxic conditions. The Region acknowledges that there are a variety of methods that can be used to implement this requirement; the one recommended by the Region is described in paragraph (d) above.

may be considered in deciding the portion of the critical low flow to provide as dilution. The following critical low flows[1] shall be used for streams and effluents:

Stream Flows	
Aquatic life, chronic	4-day, 3-year flow (biologically based)
Aquatic life, acute	1-day, 3-year flow (biologically-based)
Human health (carcinogens)	harmonic mean flow
Human health (non-carcinogens)	4-day, 3-year flow (biologically-based) or 1-day, 3-year flow (biologically-based)
Effluent Flows	
Aquatic life, chronic	Mean daily flow
Aquatic life, acute	Maximum daily flow
Human Health (all)	Mean daily flow

For chemical-specific and chronic WET limits, an appropriate dilution allowance may also be provided for certain minor POTWs where allowing such dilution will pose insignificant environmental risks (i.e., regardless of whether mixing is complete or incomplete). However, for acute WET limits, an allowance for dilution is authorized only where dilution is available and mixing is complete.

For controlled discharges, such as lagoon facilities that discharge during high ambient flows, the stream flow to be used in the mixing zone analysis should be the lowest flow expected to occur during the period of discharge.

(f) Where a discharger has installed a diffuser in the receiving water, all or a portion of the critical low stream flow may be provided as a dilution allowance. The determination shall depend on the diffuser design and on the requirements and potential environmental concerns identified in paragraphs (b) and (c) above. Where a

[1] These flows are recommended by EPA Region VIII. The actual duration (e.g. 4 day) and frequency (e.g. 3-year) of the flows used should match the duration and frequency provisions of the aquatic life, human health, and other standards found in state water quality standards. For human health non-carcinogens, Region VIII is making a distinction between parameters that typically have an effect after prolonged exposures (e.g. copper) and those that have more of an immediate effect (e.g. nitrate). For simplicity, Region VIII is recommending use of the chronic aquatic life flow for the longer-acting parameters and the acute aquatic life flow for the shorter-acting parameters. For information on how to calculate these flows, see ***EPA's Stream Design Flow for Steady-State Modeling; Technical Guidance Manual for Performing Wasteload Allocation; Book 6; Design Conditions*** (1986).

diffuser is installed across the entire river/stream width (at critical low flow), it will generally be presumed that near instantaneous and complete mixing is achieved, and that providing the entire critical low flow as dilution is appropriate.

OTHER CONSIDERATIONS

(g) Where dilution flow is not available at critical conditions (i.e., the waterbody is dry), the discharge limits will be based on achieving applicable water quality criteria (i.e., narrative and numeric, chronic and acute) at the end-of-pipe, and neither a mixing zone or an allowance for dilution will be provided.

(h) Discharge limitations for point sources to a wetland will be based on achieving all applicable water quality criteria (i.e., narrative and numeric, chronic and acute) at the end-of-pipe.

(i) All mixing zone-dilution assumptions are subject to review and revision as information on the nature and impacts of the discharge becomes available (e.g., chemical or biological monitoring at the mixing zone boundary). At a minimum, mixing zone and dilution decisions are subject to review and revision along with all other aspects of the discharge permit upon expiration of the permit.

(j) For certain pollutants (e.g., ammonia, dissolved oxygen, metals) that may exhibit increased toxicity or other effect on water quality after dilution and complete mixing with receiving waters is achieved, the wasteload allocation shall address such toxicity or other effect on water quality as necessary to fully protect designated and existing uses (i.e., the point of compliance may be something other than the mixing zone boundary or the point where complete mixing is achieved).

CHAPTER 4. MODEL IMPLEMENTATION PROCEDURE[1]

This procedure describes how dilution and mixing of point source discharges with receiving waters will be addressed in developing discharge limitations for point source discharges. For purposes of this procedure, a mixing zone is defined as a designated area or volume of water surrounding or downstream of a point source discharge in which the discharge is progressively diluted by the receiving water and numerical water quality criteria may not apply. Where justified based on site-specific considerations, such a mixing zone may be designated in the context of an individual permit decision. Discharges may also be provided an allowance for dilution where it is determined that the discharge mixes with the receiving water in a near instantaneous and complete fashion. Such mixing zones and allowances for dilution will be granted on a parameter-by-parameter and criterion-by-criterion basis as necessary to fully protect existing and designated uses.

The procedure to be followed is composed of six individual elements, or steps. The relationship of the six steps and an overview of the mixing zone-dilution procedure is illustrated in Figure 1. Please note that Figure 1 is a simplification of this procedure and is not intended to be used or interpreted without the accompanying explanatory text. Each of the six individual steps is described below.

Step 1 - No Dilution Available During Critical Conditions

Where dilution flow is not available at critical low flow conditions, discharge limitations will be based on achieving applicable narrative and numeric water quality criteria at the end-of-pipe.

Step 2 - Dilution Categorically Prohibited for Wetland Discharges

Permit limitations for discharges to a wetland shall be based on achieving all applicable water quality criteria (i.e., narrative and numeric, chronic and acute) at the end-of-pipe[2].

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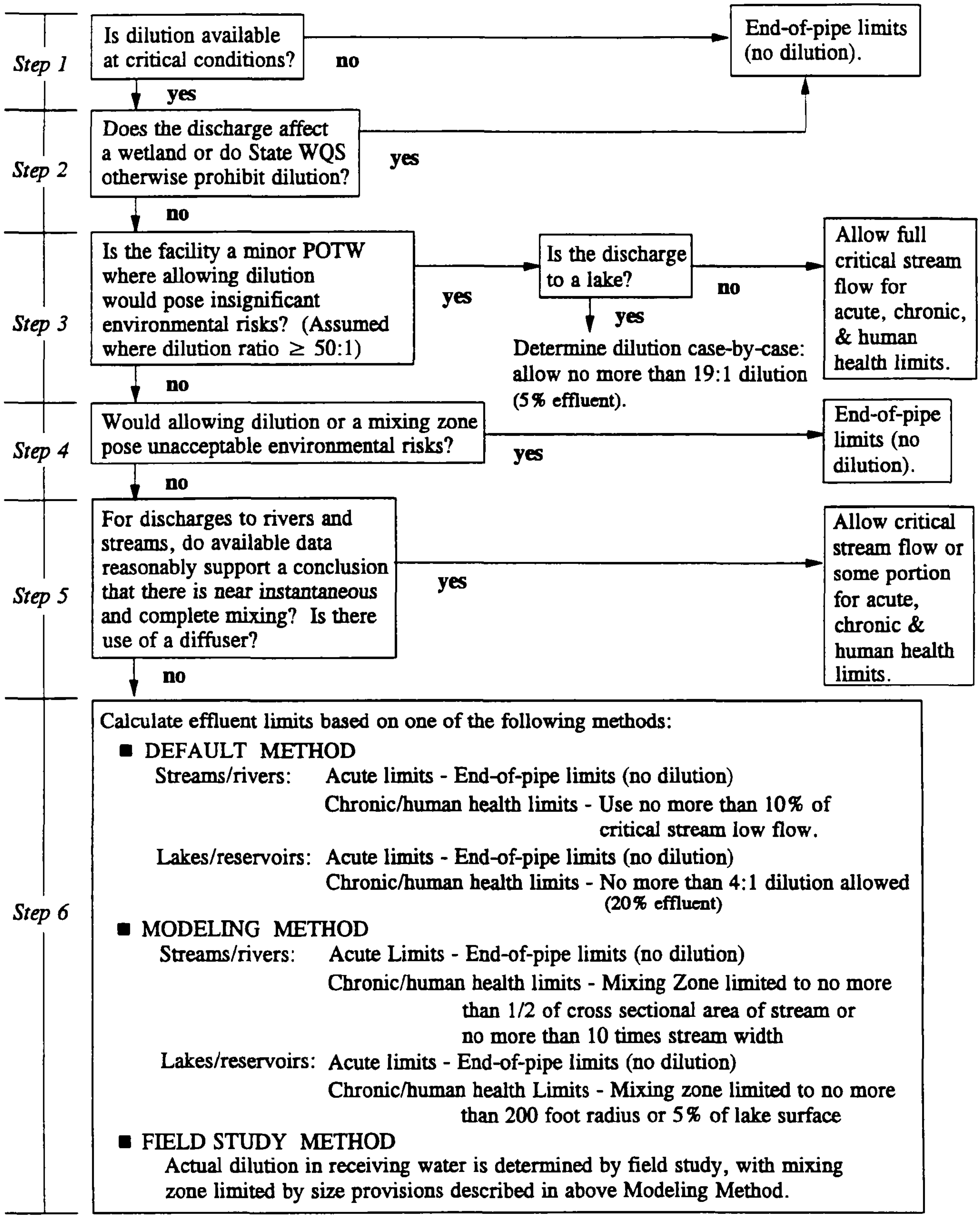
1 This model procedure is included as an example of the type of mixing zones-dilution implementation procedure that would satisfy federal requirements.

2 States and Tribes may also categorically prohibit dilution, for example, for discharges of certain substances or classes of substances or for discharges to certain types of waterbodies.

Figure 1

EPA Region VIII Model Mixing Zone/Dilution Procedure *



*** This procedure is applied to both chemical-specific and WET limits. In the case of complex discharges, the dilution or mixing zone may vary parameter-by-parameter.**

Step 3 - Procedure for Certain Minor POTWs

This step establishes the dilution procedure that is to be followed for certain minor POTWs where it is determined by the permit writer that applying the procedure, based on available information, poses insignificant environmental risks. POTWs that are classified as minor dischargers and discharge to a lake or discharge to a river/stream segment at a dilution ratio greater than or equal to 50:1 shall be presumed to qualify for this procedure. Minor POTWs with dilution ratios less than 50:1 may also qualify for this procedure, at the discretion of the permit writer, where the permittee is able to adequately demonstrate that applying this procedure poses insignificant environmental risks. For purposes of this procedure, the river/stream dilution ratio is defined as the chronic low flow of the segment upstream of the POTW discharge divided by the mean daily flow of the POTW. (An exception to this applies to controlled discharge discharges, such as lagoon facilities that discharge during high flows. In such cases, the river/stream dilution ratio is defined as the lowest upstream flow expected during the period of discharge divided by the mean daily flow of the discharge.)

In any case where the permit writer determines that applying this procedure could pose unacceptable environmental risks, the minor POTW will not qualify for this procedure. Factors that are to be considered in evaluating potential environmental risks are the same as those described below in Step 4.

For minor POTWs that qualify for this procedure and discharge to lakes, the allowance for dilution for chemical-specific and chronic WET limits will be determined on a case-by-case basis (dilution for acute WET limits shall not be provided under this procedure). As a general guideline, dilution up to 19:1 (5% effluent) may be provided. However, this allowance may be adjusted downward (made more stringent) on a case-by-case basis depending upon lake size during critical conditions, lake flushing potential, designated and existing uses of the lake, uses of the lake portion affected by the discharge, and the factors described in Step 4.

For minor POTWs that qualify for this procedure and discharge to a river/stream segment, dilution up to the full chronic aquatic life, acute aquatic life and human health critical flows may be provided as dilution (dilution for acute WET limits shall not be provided under this procedure). This maximum allowance may be adjusted downward (made more stringent) based on factors described in Step 4.

Step 4 - Site-Specific Risk Considerations

Where allowing a mixing zone or a dilution allowance would pose unacceptable environmental risks, the discharge limitations will be based on achieving applicable narrative and numeric water quality criteria at the end-of-pipe. The existence of environmental risks may also be the basis for a site-specific mixing zone size restriction or dilution allowance. Such risk determinations will be made on a case-by-case and parameter-by-parameter basis. In general, this procedure does not establish any bright line tests with which to make such risk determinations. Rather, such decisions are to be made in consideration of the designated and existing uses and all relevant site-specific environmental concerns, including the following:

- **Bioaccumulation in fish tissues or wildlife.** Both potential and existing bioaccumulation concerns should be evaluated. As a general guideline, discharge of pollutants with bioconcentration factors (BCF) greater than 300 indicates a potential risk of downstream bioaccumulation.

- **Biologically important areas such as fish spawning areas or shallow water nursery areas.** Information on either the existence of spawning areas within the proposed zone of influence or a "shore hugging" effluent plume in an aquatic life segment could support a conclusion that allowing dilution or a mixing zone would pose significant risk to a biologically important area. Presence of a threatened or endangered species downstream should also be considered in light of the duration and magnitude of potential exposure of the species (i.e., to the effluent plume) and the sensitivity of the particular species.

- **Low acute to chronic ratio.** For substances with low acute to chronic ratios, indicating that acute effects may occur at concentrations "close" to those that have been demonstrated to result in chronic effects, restricting or denying a mixing zone or dilution allowance may be appropriate in order to avoid acutely-toxic concentrations within the mixing zone.

- **Potential human exposure to pollutants resulting from drinking water or recreational activities.** Existence of a drinking water intake or a recreational area within or near the proposed zone of influence would strongly suggest that an allowance for dilution or a mixing zone is not appropriate (i.e., particularly where human health exposure concerns are limiting for the substance in question).

- **Attraction of aquatic life to the effluent plume.** Where available data support a conclusion that fish or other aquatic life are attracted to the effluent plume, resulting in adverse effects such as acute or chronic toxicity, it may well be appropriate to set discharge limitations based on achieving applicable narrative and numeric water quality criteria at the end-of-pipe (i.e., for the substances believed to be causing the toxic effects).

- **Toxicity/persistence of the substance discharged.** It may also be appropriate to deny dilution or a mixing zone for particularly toxic or persistent substances. This factor should be given added weight where the discharge is to a closed aquatic system where the substance is expected to remain biologically available and a watershed-based solution such as total maximum daily load implementation is unlikely in the near-term.

- **Zone of passage for migrating fish or other species (including access to tributaries).** Where available data suggest that allowing dilution or a mixing zone would inhibit migration of fish or other species, it may be appropriate to set discharge limitations based on achieving applicable narrative and numeric water quality criteria at the end-of-pipe. This factor includes consideration of whether the effluent plume will block migration into tributary segments.

- **Cumulative effects of multiple discharges and mixing zones.** In some cases, existence of overlapping effluent plumes may necessitate limiting or denying dilution or mixing zones for the discharging facilities. Any allowances for dilution should be restricted as necessary to protect the integrity of the receiving water ecosystem and designated waterbody uses. Although such concerns may be more appropriately addressed in a watershed-based control program (such as a TMDL), it may be appropriate to limit or deny dilution for all discharges to a watershed as an interim measure until a long-term solution can be developed and implemented.

Step 5 - Complete Mix Procedure

For point source discharges to rivers/streams where available data are adequate to support a conclusion that there is near instantaneous and complete mixing of the discharge with the receiving water (complete mixing) the full critical low flow (or a portion thereof) may be provided as dilution for chemical-specific and WET limitations. Such determinations of complete mixing will be made on a case-by-case basis using best professional judgment. Presence of an effluent diffuser that covers the entire stream/river width (at critical low flow) will generally be assumed to provide complete mixing. Further, where the mean daily flow of the discharge exceeds the chronic low stream flow of the receiving water, complete mixing will generally be assumed. Conversely, where the mean daily flow of the discharge is less than or equal to the chronic low flow of the receiving water, it will generally be assumed that complete mixing does not occur unless otherwise demonstrated by the permittee. Demonstrations of complete mixing by the permittee should be consistent with a study plan that is developed in cooperation with the State/Tribe and EPA Region VIII. Refer to EPA's *Technical Support Document for Water Quality Based Toxics Control*, 1991, for a list of appropriate mixing study references. For purposes of such studies, "near instantaneous and complete mixing" is operationally defined as no more than a 10%

difference in bank-to-bank concentrations within a longitudinal distance not greater than 2 stream/river widths. For controlled discharges, such as lagoon facilities that discharge only during high flow, the test of "near and instantaneous and complete mixing" will be made using the expected rate of effluent discharge and the lowest upstream flow expected to occur during the period of discharge.

The following critical low flows[1] shall be applied for streams and effluents:

Stream Flows	
Aquatic life, chronic	**4-day, 3-year flow (biologically based)**
Aquatic life, acute	**1-day, 3-year flow (biologically-based)**
Human health (carcinogens)	**harmonic mean flow**
Human health (non-carcinogens)	**4-day, 3-year flow (biologically-based) or 1-day, 3-year flow (biologically-based)**
Effluent Flows	
Aquatic life, chronic	**Mean daily flow**
Aquatic life, acute	**Maximum daily flow**
Human Health (all)	**Mean daily flow**

Where complete mixing can be concluded, and environmental concerns identified in Step 4 do not justify denying dilution but are nevertheless significant, some portion of the critical low flows identified above may be provided as dilution. Such decisions will take site-specific environmental concerns into account as necessary to ensure adequate protection of designated and existing uses.

Step 6 - Incomplete Mix Procedure

This step addresses point source discharges that exhibit incomplete mixing. Because the mixing zone policy requires compliance with narrative and numeric acute criteria at the

1 These flows are recommended by EPA Region VIII. The actual duration (e.g. 4 day) and frequency (e.g. 3-year) of the flows used should match the duration and frequency provisions of the aquatic life, human health, and other standards found in state water quality standards. For human health non-carcinogens, Region VIII is making a distinction between parameters that typically have an effect after prolonged exposures (e.g. copper) and those that have more of an immediate effect (e.g. nitrate). For simplicity, Region VIII is recommending use of the chronic aquatic life flow for the longer-acting parameters and the acute aquatic life flow for the shorter-acting parameters. For information on how to calculate these flows, see ***EPA's Stream Design Flow for Steady-State Modeling; Technical Guidance Manual for Performing Wasteload Allocation; Book 6; Design Conditions*** (1986).

end-of-pipe in incomplete mix situations, this step focusses on chronic aquatic life (chemical-specific and WET) and human health limits. The following provides guidelines for determining the amount of dilution available for dischargers that exhibit incomplete mixing. There are three methods described below, each with different levels of information needed to perform a mixing zone analysis.

- **Default Method**

This method addresses situations in which necessary information to implement the modeling method (e.g. channel slope, depths, widths, velocities, etc.) are not readily available. This method may also be utilized where there are concerns about the potential environmental impacts of allowing a mixing zone (i.e., there is information to suggest that environmental impacts may result from allowing a mixing zone but the information is not sufficiently conclusive to completely deny dilution as provided under step 4). In these situations, the default method provides a conservative (i.e., minimal) dilution allowance. A conservative allowance for dilution is appropriate in such cases in order to ensure adequate protection for designated and existing uses and to ensure that chronic aquatic life and human health criteria are attained at the edge of the mixing zone. Following this method may incidentally create an incentive for the discharger to generate the site-specific information necessary to use the modeling method described below. An exception to this method will be made where available data (though limited) support a preliminary conclusion that dilution should not be allowed. In such cases, effluent limits may be based on achieving criteria at the end-of-pipe, consistent with step 4. In addition, there may be some parameters where no mixing zone is necessary because achieving compliance with criteria at the end-of-pipe is practicable.

In general, this method will be employed where either of the following two tests are satisfied:

(1) Environmental Impacts Test

This test is satisfied where either:

(a) available data on potential environmental impacts of allowing a mixing zone support a conclusion that a full (maximum) mixing zone should not be allowed (e.g., there is a downstream concern regarding bioaccumulation or toxicity of a particular substance), or

(b) available data on the receiving water and downstream uses are inadequate to determine the appropriate (regulatory) mixing zone dimensions (width, length) necessary to fully protect designated and existing uses (e.g., it is not clear where the physical extent of downstream fish spawning or human recreational areas begin and end).

(2) Modeling Input Data Test

This test is satisfied where needed data to proceed with the modeling method (e.g. channel slope, depths, widths, velocities, etc.) are not readily available.

Stream/River Dischargers: For discharges to streams or rivers where either of the two tests described above are satisfied, dilution will be established on a case-by-case basis. As a general guideline, dilution calculations which use up to 10% of the critical low flow for chronic aquatic life limits (numeric and WET) or human health limits may be used in developing effluent limitations. However, this allowance may be adjusted downward on a case-by-case basis depending upon relevant site-specific information, designated and existing uses of the segment, and especially the uses of the segment portion affected by the discharge. No dilution may be provided for acute aquatic life limits (i.e., either chemical-specific or WET). In addition, where available data suggest that an allowance for dilution may pose unacceptable environmental risk, it may be appropriate to deny an allowance for dilution for chronic aquatic life or human health limits until sufficient data are available to support a decision.

Lake/Reservoir Dischargers: For dischargers to lakes or reservoirs where either of the two tests described above are satisfied, dilution will be established on a case-by-case basis. As a general guideline, dilution up to 4:1 (20% effluent) may be provided for chronic aquatic life analyses (numeric and WET) or human health analyses. However, this allowance may be adjusted downward on a case-by-case basis depending upon discharge flow, lake size, lake flushing potential, designated and existing uses of the lake, and uses of the lake portion affected by the discharge. No dilution may be provided for acute aquatic life limits. In addition, where available data suggest that an allowance for dilution may pose unacceptable environmental risk, it may be appropriate to deny an allowance for dilution until sufficient data are available to support a decision.

■ **Modeling Method**

Stream/River Dischargers: For parameters where a mixing zone is allowed (e.g., based on a finding that compliance at the end-of-pipe is not practicable), the chronic aquatic life (numeric and WET) and human health mixing zone should not exceed one-half the cross-sectional area or a length 10 times the stream width, whichever is more restrictive. These restrictions apply to the stream or river at critical low flow and the effluent discharge at critical flow (see flows described in Step 5). Individual mixing zones may be further limited or denied due to site-specific considerations (as described under Step 4). It may be necessary only to limit mixing zone size for particular parameters or for particular criteria (i.e., aquatic life or human health). For human health water quality parameters that have an effect over a short period of exposure (e.g. NO_3), it may be more appropriate to require compliance with applicable criteria at the end-of-pipe.

A calculation must first be performed to see if the discharge mixes within the one-half area before or after the length limit (10 times the stream width). (See Example 4.1) All calculations are at the critical stream and effluent design flows (see flows described under Step 5). This calculation as well as other mixing zone calculations can be performed using the simplified equations below or using more complex models (e.g. CORMIX, PLUMES, etc.) In addition, EPA Region VIII has developed a spreadsheet model (STREAMIX I) for mixing in rivers and streams based on the equations presented below. Please see Appendix A for a discussion of STREAMIX I and field validation examples.

Appendix A provides methods to determine both the average concentration in a mixing zone as well as the maximum, or extreme, concentration in the mixing zone. In doing a site specific analysis on mixing zones, it may become important to estimate concentrations immediately along the shoreline rather than estimate concentrations that are lateral averages within the mixing zone. In the course of calculating mixing zone concentrations to determine discharge effluent limits, Region VIII recommends using as a first course of action the average mixing zone concentrations. In that light, the following discussion on methods for calculating mixing zone concentrations are based on the average values rather than extreme values.

The equations below are for surface discharges (not submerged) to stream or rivers. This approach can be adapted to address both bank discharges as well as surface dischargers anywhere along the lateral width of the stream. In addition, the equations below provide a conservative estimate of mixing because mixing due to momentum of the discharge is not considered; only mixing due to ambient diffusion is considered. When a discharge has a significant amount of momentum laterally across the stream, the actual time and distance to achieve one-half mixing will most likely be shorter than indicated by the equations below. Using more complex models or performing field tests is recommended if mixing characteristics due to discharge-induced momentum as well as other factors are significant.

An approximation for plume width (w_{mix}) at distance X downstream from a discharge at the bank of a river or stream can be made by using the following equation:

$$w_{mix} = \sqrt{2\pi D_y X/u} \tag{1}$$

Solving for X, the equation is changed to:

$$X = \frac{(w_{mix})^2 u}{2\pi D_y} \tag{2}$$

The distance for one-half width mixing for a <u>bank discharge</u> is then estimated by the following equation:

$$X_{1/2} = \frac{(W/2)^2 u}{2\pi D_y} \tag{3}$$

For a discharge near the <u>center of flow</u> in the river or stream, the following equation can be used for one-half width mixing:

$$X_{1/2} = \frac{(W/2)^2 u}{8\pi D_y} \tag{4}$$

where

$X_{1/2}$ = distance downstream to achieve one-half width mixing (ft)
u = velocity of stream at critical low flow downstream of discharge (ft/sec)
W = width of the river at critical low flow downstream of discharge (ft)
D_y = lateral dispersion coefficient for critical low flow downstream of discharge (ft^2/sec)

where

$$D_y = cdu^* \tag{5}$$

c = channel irregularity factor (unitless)
c = 0.1 for straight, rectangular streams
c = 0.3 for channelized streams or irrigation canals
c = 0.6 for natural channels with moderate meandering
c = 1.0 for streams with significant meandering
c > 1.0 for streams with sharp 90° and greater bends
d = water depth at critical low flow downstream of discharge (ft)
u^* = shear velocity (ft/sec)

where

$$u^* = \sqrt{gds} \tag{6}$$

g = acceleration due to gravity (32.2 ft/sec^2)
s = slope of the channel downstream of discharge (ft/ft)

Example 4.1: Calculation of distance to achieve one-half width mixing. An industry has a surface bank discharge into a stream which, at critical low flow, has a depth of 1 foot and a width of 62 feet. The velocity of the stream at chronic low flow (4-day, 3-year flow) below the discharge is 1.5 feet per second. The average slope of the stream is 0.0008 feet/feet. The stream below the discharge exhibits moderate meandering. Ignoring any momentum from the discharge itself, what is the distance below the discharge where the effluent plume will extend to one half the stream width?

Solution: The distance to achieve one-half width mixing is given by the equation $X_{1/2} = (W/2)^2u/2\pi D_y$. The shear velocity is calculated as $u^* = (gds)^{1/2} = (32.2 \text{ ft/sec}^2 \times 1 \text{ ft} \times 0.0008)^{1/2} = 0.16$ ft/sec. The dispersion coefficient is given as $D_y = cdu^* = 0.6 \times 1 \text{ ft} \times 0.16 \text{ ft/sec} = 0.096 \text{ ft}^2\text{/sec}$. The distance to achieve one-half width mixing is estimated by:

$X_{1/2} = ((62 \text{ ft}/2)^2 \times 1.5 \text{ ft/sec})/(2 \times \pi \times 0.096 \text{ ft}^2\text{/sec}) =$ **2400 feet**.

• If Distance to Attain One-Half Width Mixing ($X_{1/2}$) < 10 Stream Widths

If the downstream distance to attain one-half width mixing is less than 10 times the stream width, then the chronic/human health analysis uses one-half of the critical low flow of the stream (chronic aquatic life or human health) as dilution. The normal mass balance equation can be used to determine effluent limits in this situation:

$$C_{eff} = \frac{C_{mix}(Q_{eff} + 0.5Q_{up}) - (0.5Q_{up}C_{up})}{Q_{eff}} \qquad (7)$$

where

C_{eff} = effluent concentration (mg/l or μg/l)

Q_{eff} = effluent flow (ft^3/sec)

C_{up} = upstream concentration (mg/l or μg/l)

Q_{up} = upstream low flow at critical conditions (ft^3/sec)

C_{mix} = average concentration in the mixing zone plume (chronic or human health criterion) (mg/l or μg/l)

<u>WET Limits</u>

For chronic aquatic life WET limitations, the dilution for testing would be calculated using only one-half of the upstream critical low flow (e.g. effluent dilution = $Q_{eff}/(Q_{eff} + Q_{up}/2)$.

• If Distance to Attain One-Half Width Mixing ($X_{1/2}$) > 10 Stream Widths

If the downstream distance to attain one-half width mixing is greater than 10 times the stream width, then the effluent limit is given as:

$$C_{eff} = \frac{C_{mix}(Q_{eff} + \theta\, Q_{up}) - (\theta\, Q_{up} C_{up})}{Q_{eff}} \qquad \textbf{(8)}$$

where

C_{eff} = effluent concentration (mg/l or μg/l)

Q_{eff} = effluent flow (ft^3/sec)

C_{up} = upstream concentration (mg/l or μg/l)

Q_{up} = upstream low flow at critical conditions (ft^3/sec)

C_{mix} = average concentration in the mixing zone plume (chronic or human health criterion) (mg/l or μg/l)

and

θ = percentage of upstream flow mixing with effluent flow

For bank dischargers:

$$\theta = \frac{\left(\frac{\sqrt{(2\pi D_y X/u)}}{W}\right)(Q_{up} + Q_{eff}) - Q_{eff}}{Q_{up}} \qquad \textbf{(9)}$$

For center dischargers:

$$\theta = \frac{\left(\frac{\sqrt{(8\pi D_y X/u)}}{W}\right)(Q_{up} + Q_{eff}) - Q_{eff}}{Q_{up}} \tag{10}$$

D_y = lateral dispersion coefficient for critical low flow (ft^2/sec) (See page 31 for equation used to calculate D_y)

X = distance downstream from discharge = 10 times the stream width (ft)

W = stream width at critical stream flow downstream of discharge (ft)

u = stream velocity at critical stream flow downstream of discharge (ft/sec)

An Example of how these equations may be applied is presented in Example 4.2. Further discussion of the equations presented above is given in Appendix A. In addition, Appendix A presents the derivation and validation of Region VIII's spreadsheet model (STREAMIX I).

WET Limits

For chronic aquatic life WET limitations, the dilution for testing would be calculated using only the fraction of the upstream critical low flow that has mixed with the effluent flow. This fraction of upstream flow used in the dilution is defined by θ as defined in equation (9) and (10) (e.g. effluent dilution = $Q_{eff}/(Q_{eff} + \theta Q_{up})$.

Lake Dischargers: The chronic aquatic life/human health mixing zone should not exceed 5% of the lake surface area or 200 foot radius, whichever is more restrictive. Individual mixing zones may be further limited or denied due to site specific considerations. It may be necessary only to limit mixing zone size for particular parameters or for particular criteria (i.e., aquatic life or human health). For human

Example 4.2: Calculation of effluent limits for discharge. A municipal facility has a surface bank discharge into a river which has a depth of 1 foot and a width of 80 feet. The velocity of the river at chronic low flow (4-day, 3-year flow) below the discharge is 1.4 feet per second. The lateral dispersion coefficient (D_y) at critical flow has been calculated as 0.32 ft^2/sec for the river below the discharge. The municipal discharge has a mean daily flow of 17 cfs and a maximum daily flow of 25 cfs. The receiving water has a 4-day, 3-year low flow above the discharge of 90 cfs and a 1-day, 3-year low flow of 74 cfs. The particular pollutant of concern is aluminum which has ambient criteria of 87 μg/l (4-day chronic) and 750 μg/l (1-hour acute). No aluminum has been detected in the upstream waters. It has been determined that a mixing zone would be allowed in this situation. Determine the effluent limits for the facility based on the appropriate mixing zone procedures.

Solution: Since the facility does not mix instantaneously with the receiving water, the daily maximum effluent limitation would be the acute criteria of 750 μg/l aluminum independent of what procedure is used to determine the chronic effluent limitation. To determine how much of the receiving water can be used in dilution calculations for the chronic limitation, the distance downstream to the point of half-width mixing must be computed. Substituting the values into the equation for distance to half-width mixing, we obtain $X_{1/2} = (W/2)^2u/2\pi D_y = ((80/2)^2 \times 1.4)/(2 \times \pi \times 0.32) = 1114$ feet. The distance downstream to achieve half-width mixing is greater than 10 times the width (1114 feet > 800 feet), therefore the amount of flow from the receiving water used in the dilution calculations will be less than half of the river flow. Rather, the fraction of flow which mixes with the effluent at the downstream point 10 times the width (800 feet) is used in the chronic dilution calculation. This fraction is given with equation 9 on page 32 of the Policy text. Substituting into the equation, we obtain $\theta = \{[(2 \times \pi \times 0.32\ ft^2/sec \times 800\ ft/1.4\ ft/sec)^{1/2}/80]\ (17\ cfs + 90\ cfs) - 17\}/90 = \underline{0.31}$. The chronic limits (4-day average) for the discharger would be based on the mass balance equation using 31% of the upstream chronic low flow for dilution:

$$C_{eff} = [C_{mix}(Q_{eff} + \theta Q_{up}) - (\theta Q_{up}C_{up})]/Q_{eff}$$

$$= [87\ \mu g/l(17\ ft^3/sec + (31\%)90\ ft^3/sec) - ((31\%)90\ ft^3/sec \times 0\ \mu g/l)]/17\ ft^3/sec$$

$$= \underline{\mathbf{230\ \mu g/l}}\ \text{(chronic limit)}$$

Since this is a 4-day chronic limit, it should be converted into a 30 day limit by using the appropriate conversion procedures (see EPA's Technical Support Document for Water Quality-based Controls for methods of conversion).

health water quality parameters that have an effect over a short period of exposure (e.g. NO_3), it may be more appropriate to require compliance with applicable criteria at the end-of-pipe.

Once a distance from the point of discharge to the edge of the mixing zone is determined, the amount of dilution available and the required effluent limit is determined by computer modeling or the simple relationship:

$$C_{eff} = 0.3(z/d)(C_{mix}) \quad \textbf{(11)}$$

where

C_{eff} = effluent concentration (mg/l or μg/l)

z = distance from discharge (ft)

C_{mix} = average concentration in the mixing zone plume (chronic water quality criterion) (mg/l or μg/l)

d = pipe diameter (ft)

This relationship is derived from the equation given in EPA's Technical Support Document for Water Quality-based Toxics Control; March 1991; page 75. More complex models are discussed in further detail in this text.

■ Field Study Method: Field studies which document the actual mixing characteristics in the receiving water can be used to determine in-situ dilution. The mixing zone size limitations described above in the Modeling Method section still apply in this situation. In addition, prior to conducting field mixing studies, it should be determined that compliance with criteria at the end-of-pipe is not practicable.

CHAPTER 5. CASE EXAMPLES

This chapter provides some case examples to demonstrate the potential effect of application of the Region VIII mixing zone policy on NPDES permit effluent limits. The simplified procedures as described in the previous chapter (**4. Model Mixing Zone-Dilution Implementation Procedure**) were followed. The rationale for each example is documented using the mixing zone flow chart found in Figure 1, also found in Chapter 4, as a template.

When the "Modeling Method" approach was used in the examples to calculate revised effluent limits, the equations and mixing zone size limitations found in Section IV were used.

The case examples are based on actual NPDES dischargers in Region VIII. The results pertaining to effluent limits found in the case examples are not intended to be conclusive. Assumptions pertaining to discharge and receiving water characteristics were made in some instances to complete the example. The case examples nonetheless serve to illustrate how the mixing zone procedures could affect limitations in NPDES permits.

The results pertaining to effluent limits found in the case examples are not intended to be conclusive. Assumptions pertaining to discharge and receiving water characteristics were made in some instances to complete the example.

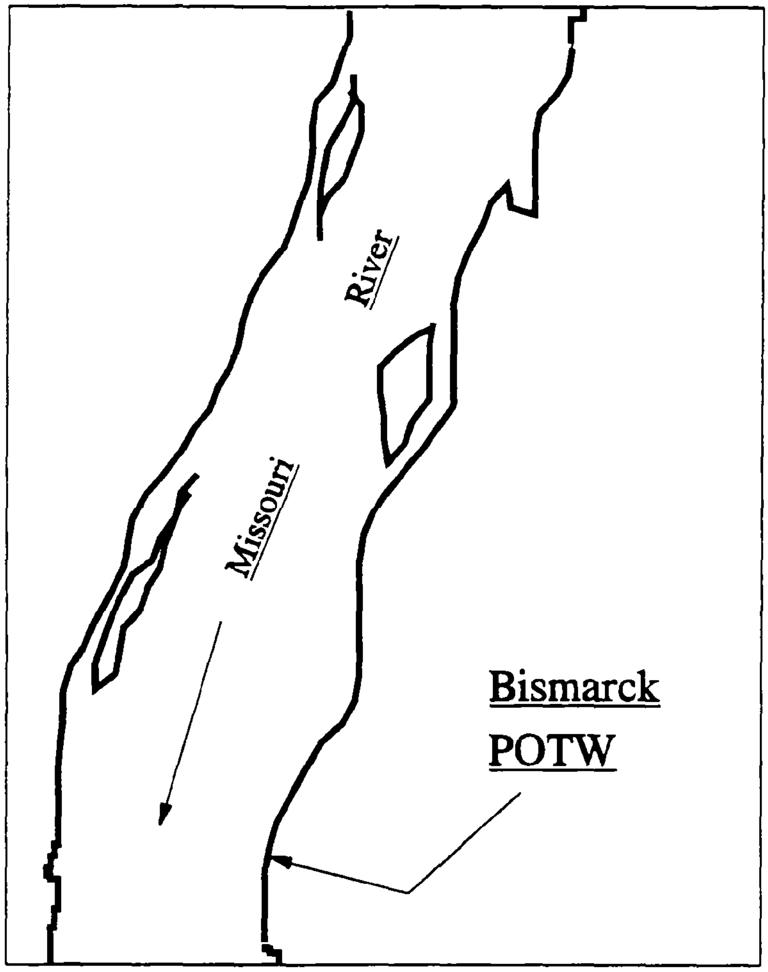
DEFAULT METHOD EXAMPLES

Bismarck, ND; Yankton, SD These are two examples where the default method was used. The default method is intended primarily for those situations where necessary information to perform modeling (e.g. channel slope, depths, widths, velocities, etc.) are not readily available. In addition, the default method can be used, such as in these examples, for pollutants where achieving the acute numeric criteria at the end-of-pipe (without an allowance for dilution) will always be more limiting than the (mixing zone-based) chronic effluent limitations (i.e., regardless of what mixing zone method is selected). The default method may also be appropriate where there are concerns about the potential environmental impacts of allowing a mixing zone and a conservative amount of dilution is desired.

MODELING METHOD EXAMPLES

Tremonton, UT; Silverthorne/Dillon, CO, Green River, WY, Steamboat Springs, CO
In these examples, enough information was available to perform simplified modeling using the equations and approaches described in Chapter 4. The first calculation to be made is to determine whether or not the mixing plume extends to the half stream width prior to a distance 10 times the stream width downstream from the discharge. In the case of Tremonton, Silverthorne/Dillon, and Steamboat Springs the 1/2 stream width was reached prior to the 10 X width. In the case of Green River, the 10 X width longitudinal limit was reached prior to the 1/2 width limit. The daily maximum limit for Green River is based on meeting acute standards at the end-of-pipe. This limit (1 mg/l-N) is low because of the high pH (9.0 s.u.) exhibited in the effluent. Take note that for parameters which have criteria that vary with pH, temperature, or hardness, the most critical point in the stream may be further downstream beyond the mixing zone (far field) where more ambient mixing occurs. In these far field analyses, it may be seen that factors such as pH, temperature, or hardness are not as favorable as within the mixing zone. Consider the example of un-ionized ammonia toxicity which is particularly sensitive to pH conditions. The pH regime downstream from the mixing zone may be higher than the pH within the mixing zone, possibly making the point downstream where complete mix occurs more limiting to effluent limits.

Case Example: Bismarck, ND



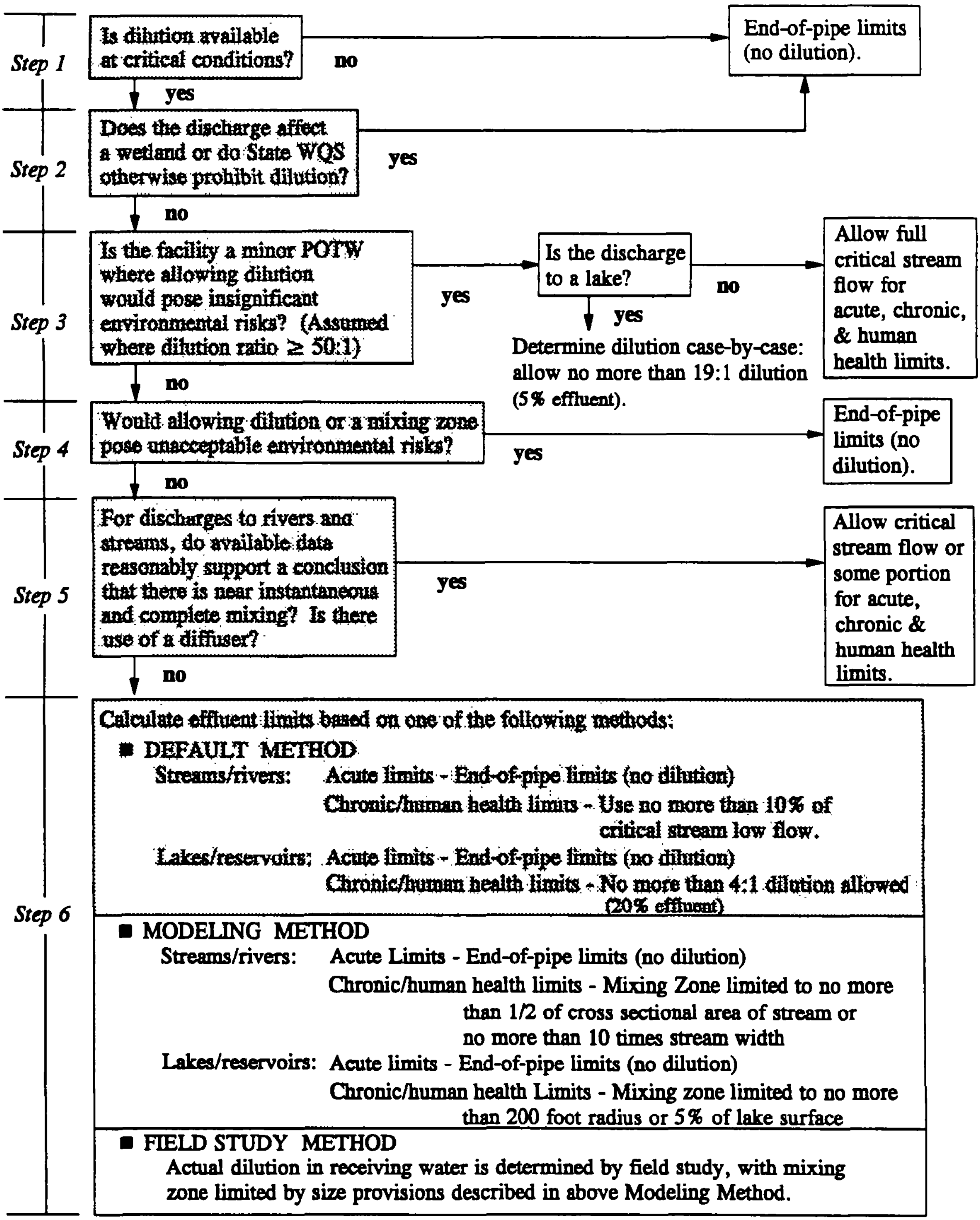
Pollutant:	Chlorine
Receiving Water:	acute low flow (1 day, 3 year) = 10,000 cfs
Discharge:	9.3 cfs
Current Effluent Limit:	4.5 mg/l TRC
Mixing Zone-based Effluent Limit:	0.019 mg/l TRC (daily maximum)

The mixing zone-based limit is based on meeting the acute chlorine criteria (0.019 mg/l) at the end of the pipe (no dilution allowed). Using the default method, the chronic limit would be based on using 10% of the upstream flow for dilution. The resultant chronic limit would be greater than the acute limit, making the acute limit the more restrictive of the two.

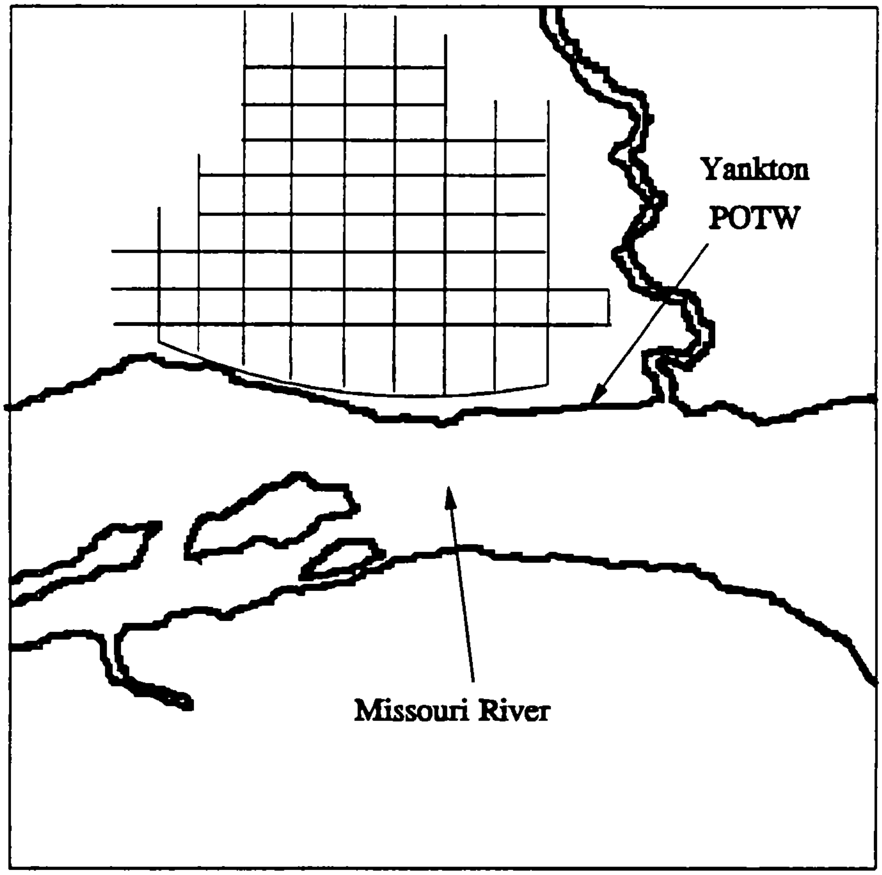
Mixing Zone Flow Chart

Bismarck Case Example

(Shaded boxes indicate decision path for example.)



Case Example: Yankton, SD



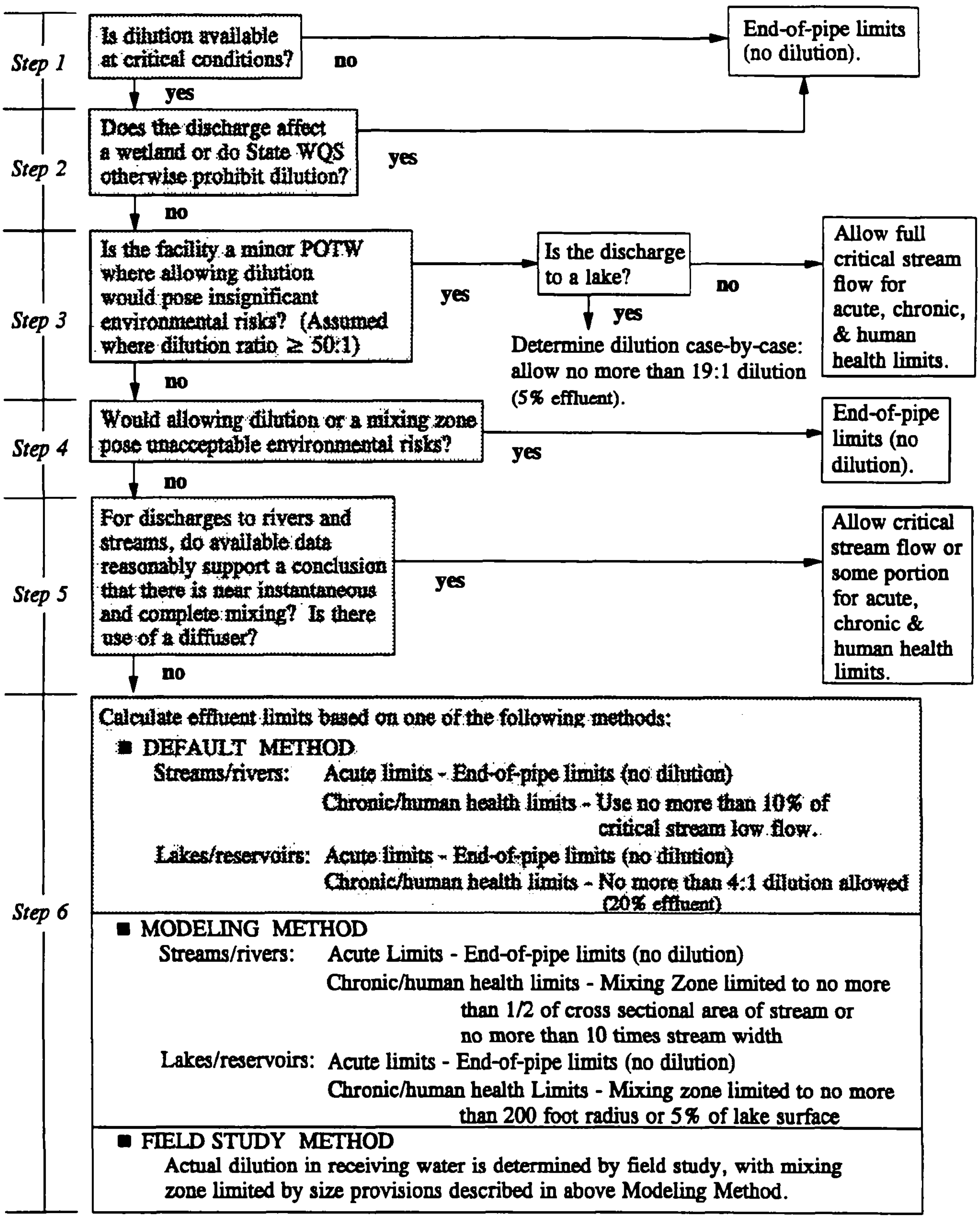
Pollutants:	Ammonia and Chlorine
Receiving Water:	approx. 9000 cfs low flow
Discharge:	2.5 cfs
Current Effluent Limits:	no ammonia limits; 1.0 mg/l TRC (summer)
Mixing Zone-based Effluent Limits:	3.7 mg/l-N ammonia; 0.02 mg/l TRC (both daily maximum limits)

The mixing zone-based limits are based on meeting acute standards at the end-of-pipe (no dilution allowed). The acute standard for TRC is 0.02 mg/l and the chronic ammonia standard is 0.04 mg/l-N un-ionized ammonia. At an effluent pH of 7.7 s.u. and a temperature of 20° C, the 0.04 mg/l-N is equivalent to 2.11 mg/l-N total ammonia. In South Dakota, the acute standard is determined by multiplying the chronic standard by 1.75. The acute standard (as well as the acute effluent limit) is 1.75 x 2.11 = 3.7 mg/l-N total ammonia. In calculating the chronic limits using the default dilution of 10% of the upstream flow, it is shown that the chronic limits are greater than the acute limits, making the acute limits more restrictive.

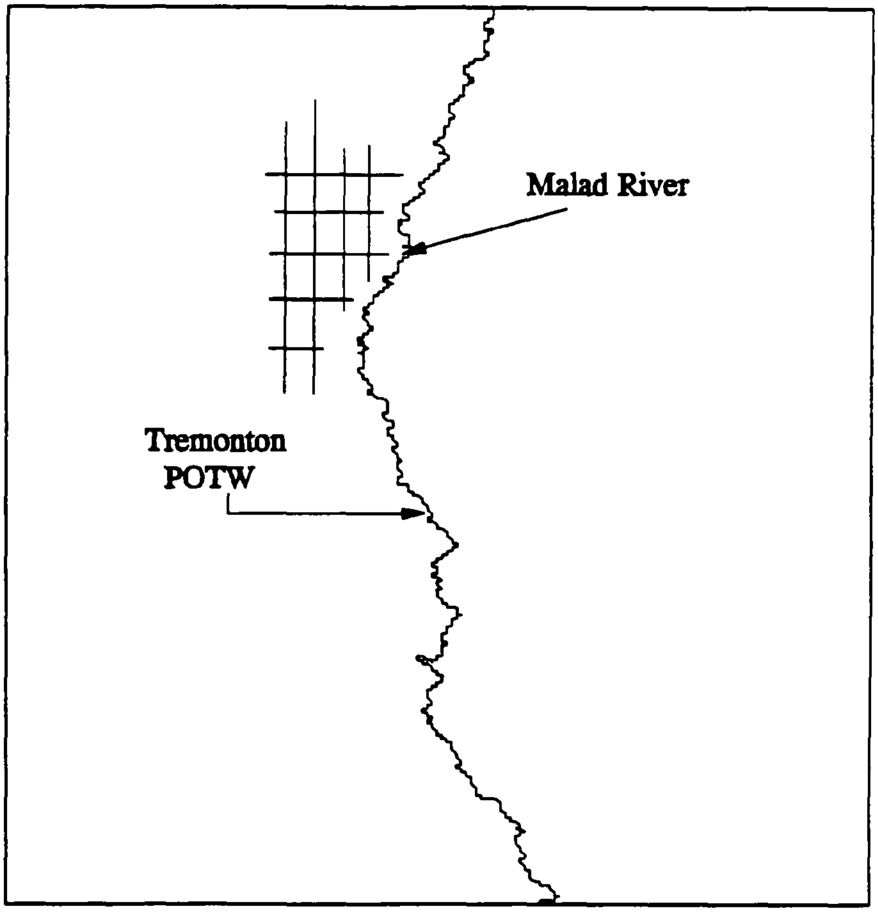
Mixing Zone Flow Chart

Yankton Case Example

(Shaded boxes indicate decision path for example.)



Case Example: Tremonton, UT



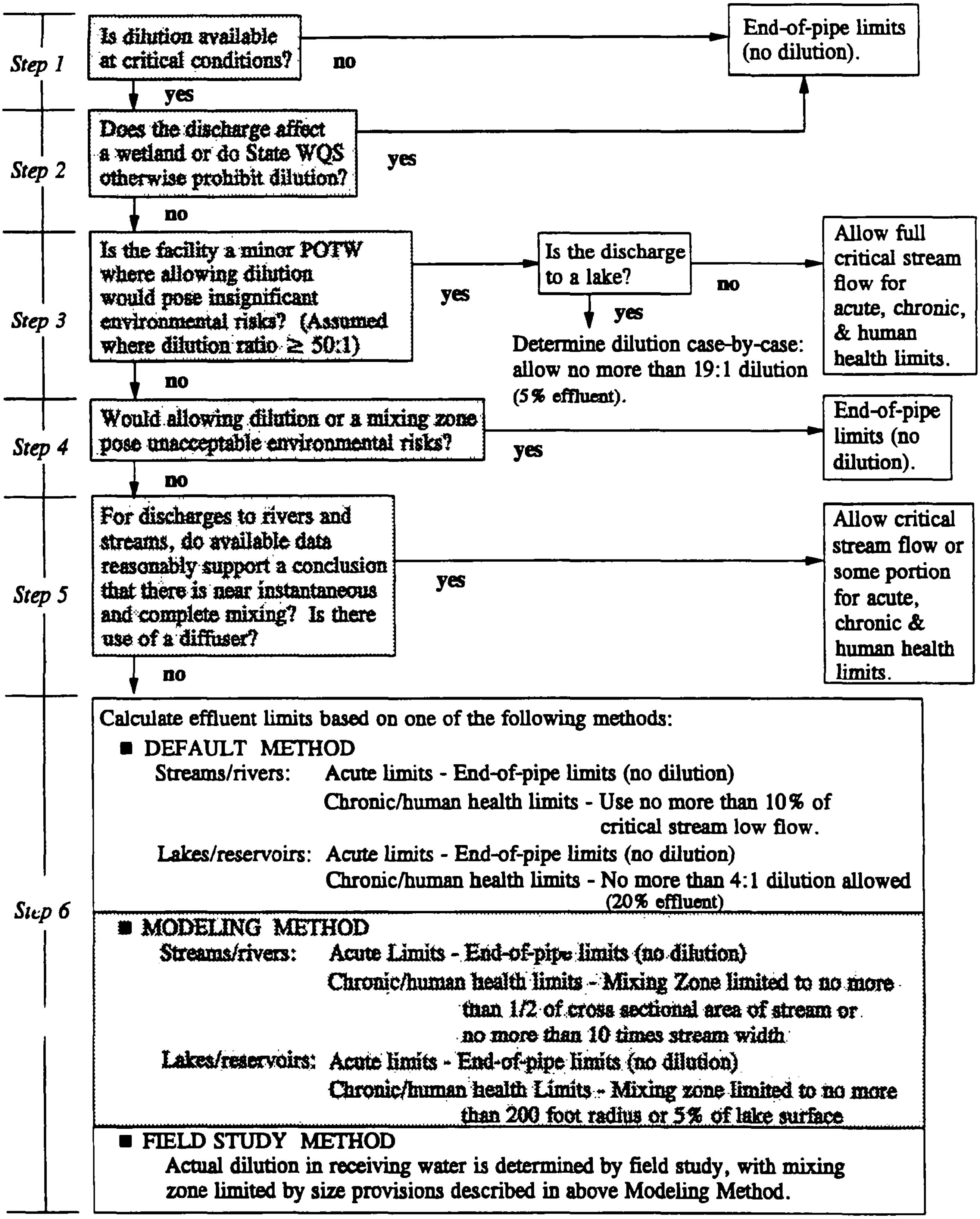
Pollutant:	Ammonia
Receiving Water:	30 cfs (7Q10 June-Sept)
Discharge:	2.32 cfs
Current Effluent Limit:	14 mg/l-N 30 day; 25 mg/l-N daily max.
Mixing Zone-based Effluent Limit:	7.6 mg/l-N 30 day; 11 mg/l-N daily max.
Model assumptions:	stream slope = 0.0003; width = 11 ft;
c = 0.8; depth = 2.9 ft;	velocity = 1 ft/sec; Dy = 0.388 ft^2/sec
Background quality:	0.1 mg/l-N ammonia

The mixing zone analysis shows that the effluent plume reaches the 1/2 width limit prior to the longitudinal limit of 10 X width. Thus, the mixing zone-based effluent limits are calculated using 1/2 the upstream critical low flow for the chronic (30 day) limit and and using the end-of-pipe requirement for the the acute (daily max.) limit. The in-stream chronic standard is 1.1 mg/l-N total ammonia. The effluent conditions were assumed to be 7.6 pH and 20° C. At these conditions, the acute standard is 11 mg/l-N total ammonia.

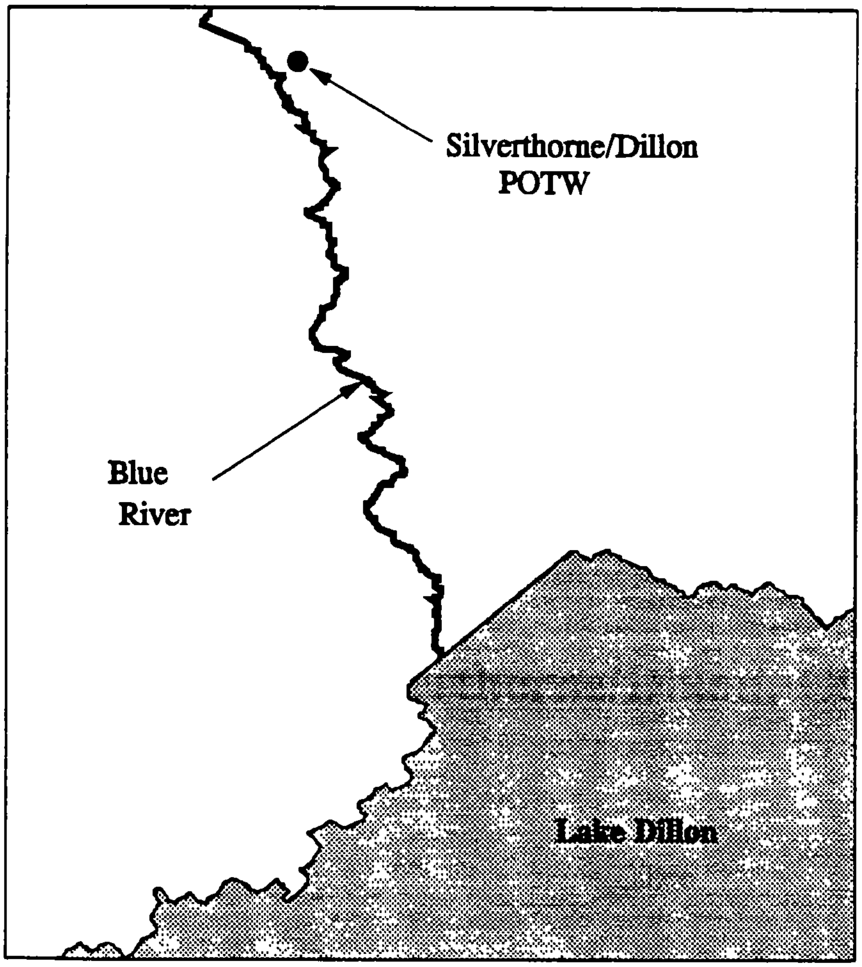
Mixing Zone Flow Chart

Tremonton Case Example

(Shaded boxes indicate decision path for example.)



Case Example: Silverthorne/Dillon, CO

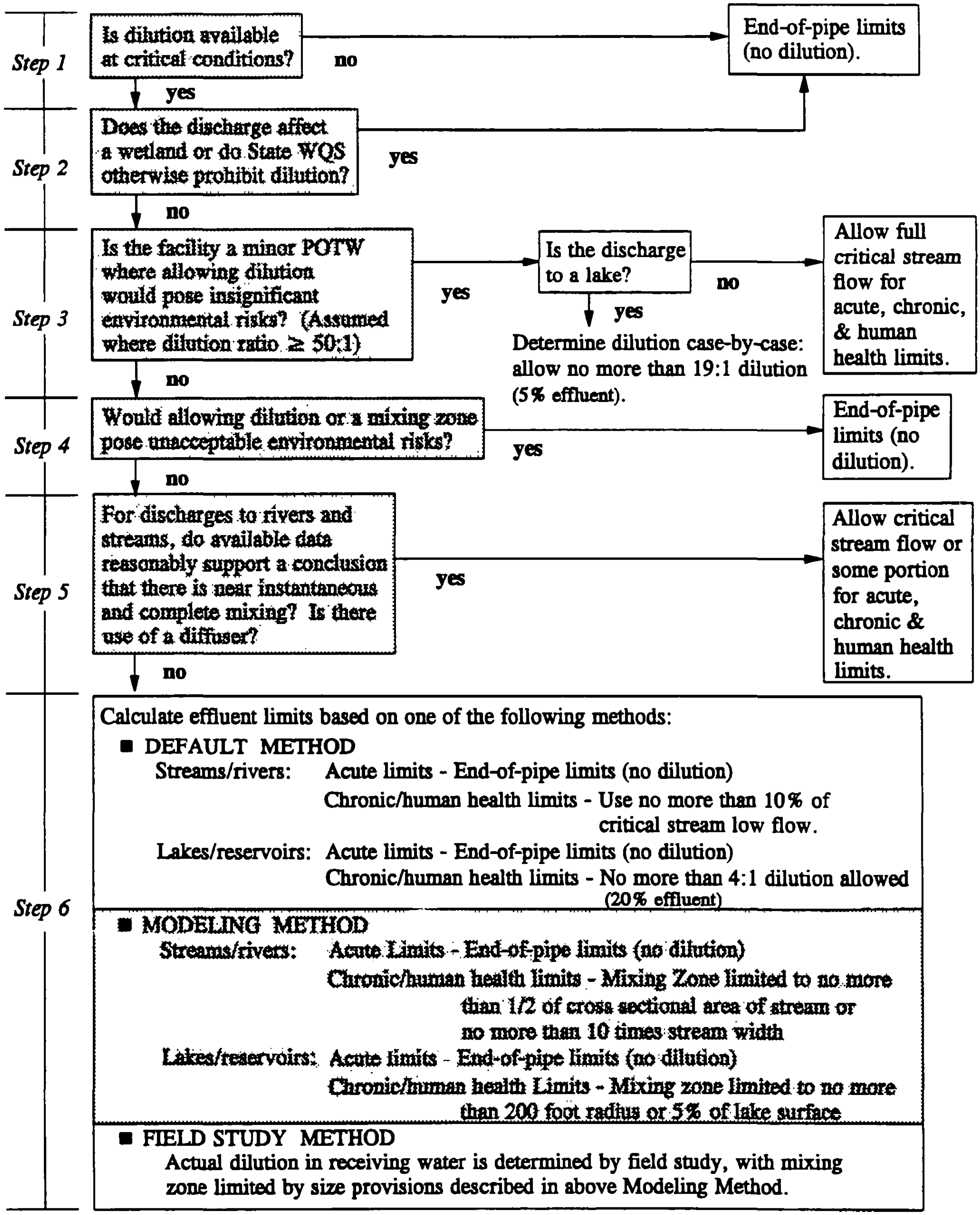


Pollutant:	Ammonia
Receiving Water:	24 cfs (30E3 October)
Discharge:	4.2 cfs
Current Effluent Limit:	8.8 mg/l-N 30 day; no acute limit
Mixing Zone-based Effluent Limit:	3.1 mg/l-N 30 day; 22 mg/l-N daily max.
Model assumptions:	stream slope = 0.013; width = 20 ft;
c = 0.6; depth = 1 ft;	velocity = 1.4 ft/sec; Dy = 0.388 ft^2/sec
Background quality:	0 mg/l-N

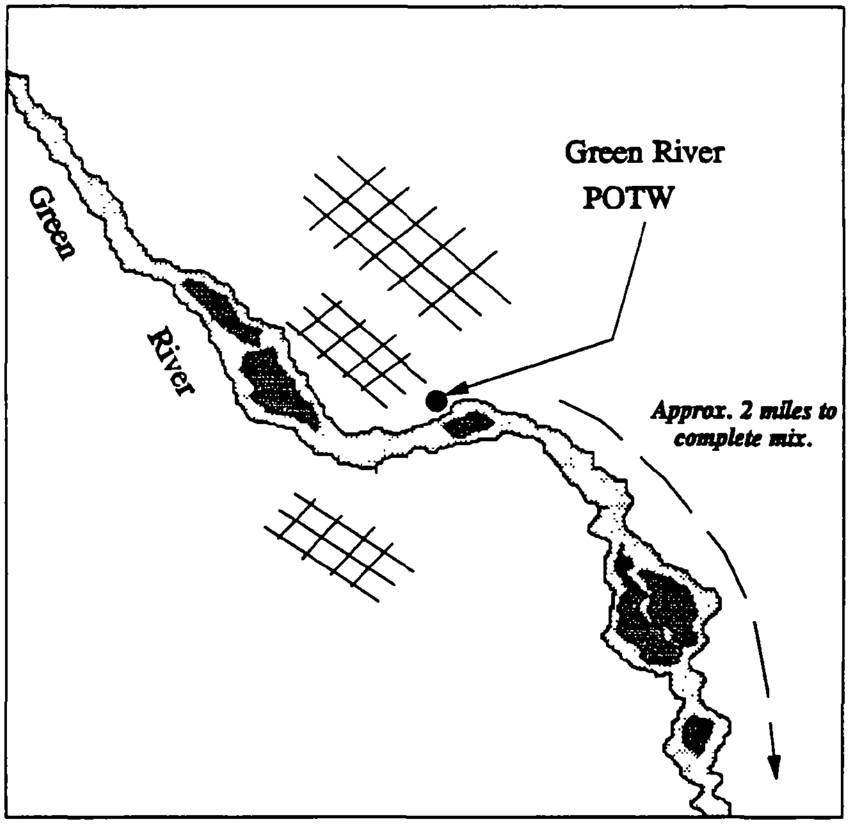
The mixing zone analysis shows that the effluent plume reaches the 1/2 width limit prior to the longitudinal limit of 10 X width. Thus, the mixing zone-based effluent limits are based on using 1/2 the upstream critical low flow for the chronic (30 day) limit and using the end-of-pipe requirement for the acute (daily max.) limit. The in-stream chronic standard is 0.8 mg/l-N total ammonia. The effluent conditions were assumed to be 6.7 pH and 16° C temp. At these conditions, the acute standard is 22 mg/l-N total ammonia.

Mixing Zone Flow Chart
Silverthorne/Dillon Case Example

(Shaded boxes indicate decision path for example.)



Case Example: Green River, WY



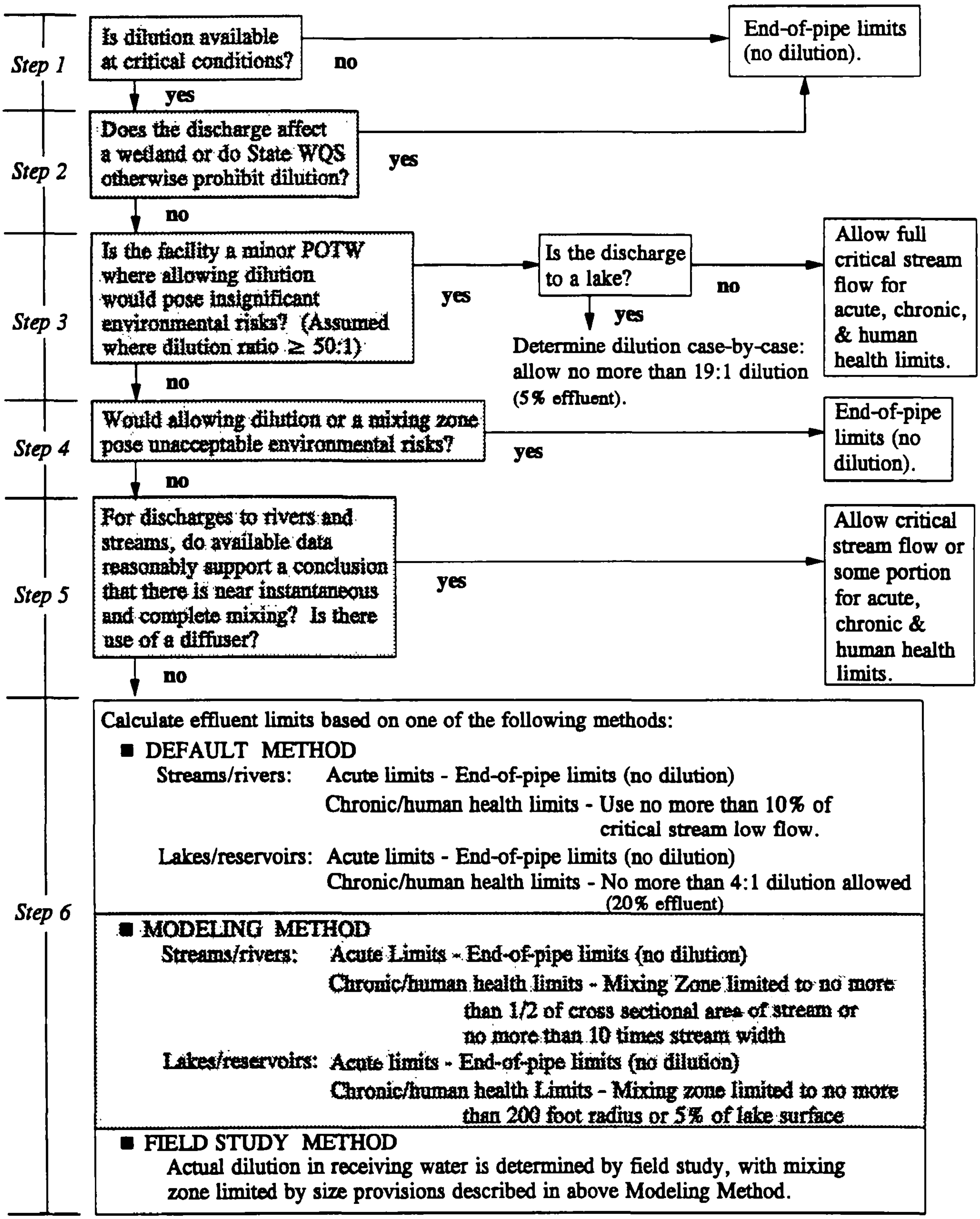
Pollutant:	Ammonia
Receiving Water:	236 cfs (7Q10 winter)
Discharge:	2.3 cfs
Current Effluent Limit:	no limits
Mixing Zone-based Effluent Limit:	15 mg/l-N 30 day; 1 mg/l-N daily max.
Model assumptions:	stream slope = 0.0021; width = 115; c = 0.6; depth = 1.6 ft; velocity = 1.3 ft/sec; Dy = 0.316 ft^2/sec
Background quality:	0.0 mg/l-N ammonia

The mixing analysis in the Green River indicates that the mixing plume reaches the longitudinal limit of 10 X width before reaching the 1/2 width limit. At this distance from the discharge (1150 feet), only 36% of the Green River flow has mixed with the effluent and the plume width is 42 ft. The chronic limit (30 day) was based on the 36% dilution. The in-stream conditions were assumed to be pH 8.5 s.u. and 5° C. At these conditions, the chronic standard is 0.39 mg/l-N of total ammonia. The acute limit (daily max.) was based on end-of-pipe requirements. Effluent conditions were pH 9.0 s.u. and 16° C. At these conditions, the acute standards is < 1 mg/l-N total ammonia.

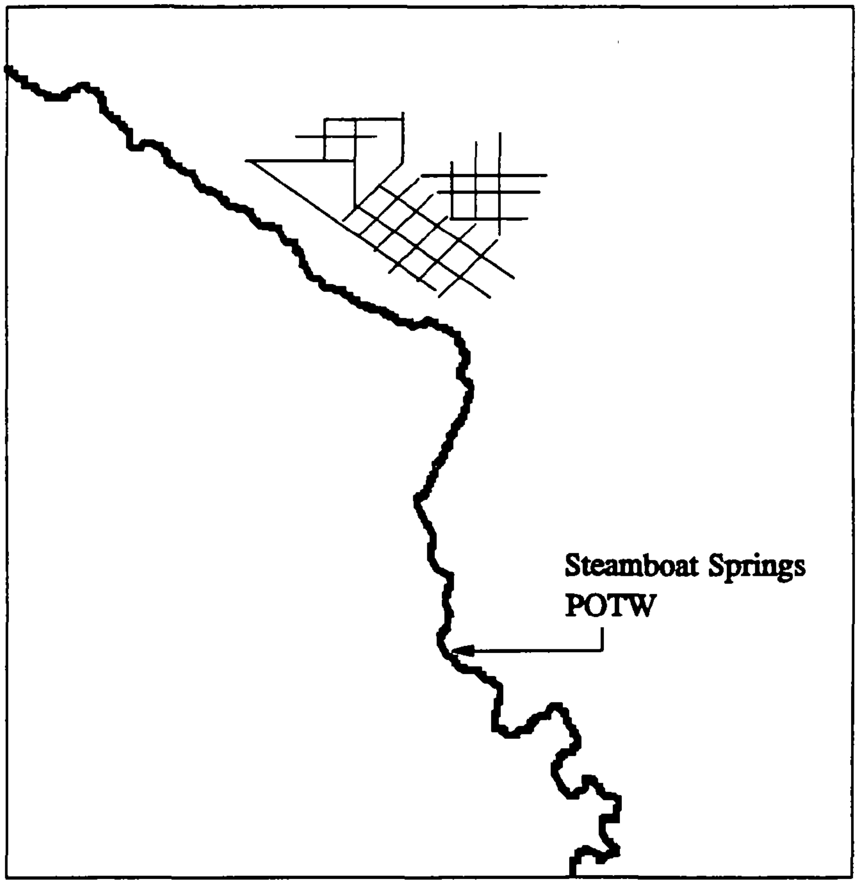
Mixing Zone Flow Chart

Green River Case Example

(Shaded boxes indicate decision path for example.)



Case Example: Steamboat Springs, CO



Pollutant:	Copper
Receiving Water:	56 cfs (30E3)
Discharge:	5.2 cfs
Current Effluent Limit:	no current limit for copper; normal full-mix limit would be 141 μg/l Cu
Mixing Zone-based Effluent Limit:	78 μg/l (30 day); 18 μg/l (daily max.)
Model assumptions:	stream slope = 0.011; width = 30 ft;

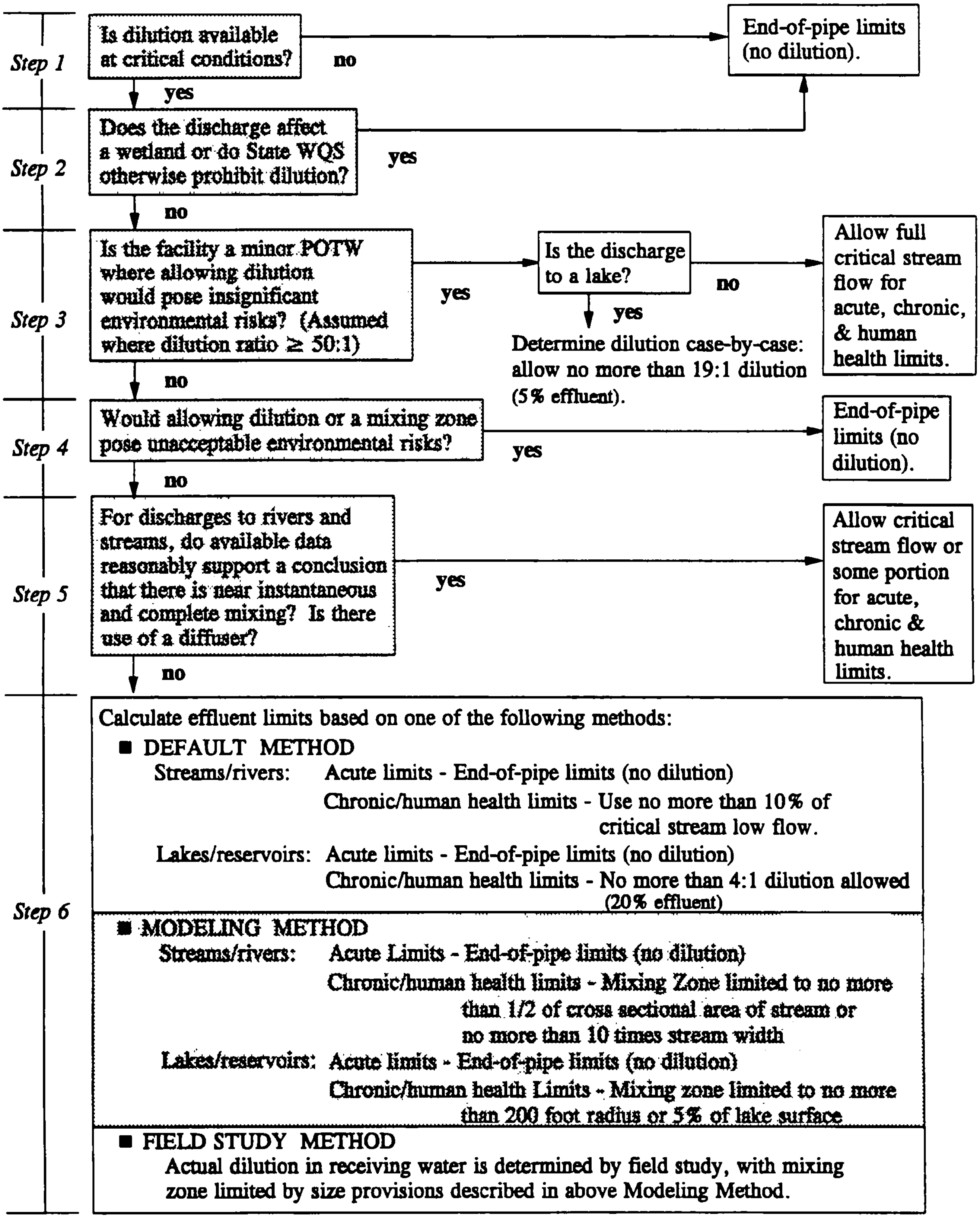
c = 0.7; depth = 1.5 ft; velocity = 1.3 ft/sec; Dy = 0.244 ft^2/sec

Background quality:	0 μg/l Cu

The mixing zone analysis shows that the effluent plume reaches the 1/2 width limit prior to the longitudinal limit of 10 X width. Thus, the mixing zone-based effluent limits are based on using 1/2 the upstream critical low flow for the chronic (30 day) limit and using the end-of-pipe requirement for the acute (daily max.) limit. The in-stream chronic standard is 12 μg/l copper and an acute standard of 18 μg/l copper. The daily maximum limit provides the greatest limitation for the discharger because it is less than the 30 day limit.

Mixing Zone Flow Chart
Steamboat Springs Case Example

(Shaded boxes indicate decision path for example.)



APPENDIX A - REGION VIII SIMPLIFIED MIXING ZONE MODEL

There are several equations that are presented in the EPA Region VIII Mixing Zones and Dilution Policy to aid in the calculation of mixing zone plume size and pollutant concentration within the mixing zone. The following describes the derivation and validation of the equations as well as the model that Region VIII recommends for use in performing mixing zone analyses if more complex models are not used. The Region VIII approach is based on utilization of simplified mathematical relationships found in the literature.

The Region VIII model (STREAMIX I, version 2) can be used to estimate both average and extreme pollutant concentrations within the mixing zone as well as the width of the mixing zone plume for surface dischargers (not submerged) into a river or stream. Upstream pollutant concentrations are taken into account in the model. The discharge can be situated at the bank of the receiving water or at any point laterally across the waterbody. The model is two dimensional with assumptions of vertically uniform concentration, constant depth, and constant velocity. There is also an assumption that mixing occurs through ambient diffusion with no contribution from discharge momentum. In addition, the model calculates in-mixing zone concentrations for instances where the upstream water has a higher concentration than the effluent.

Figure A-1 provides a schematic of a discharge into a river. The basic mass balance equation can be used to describe the pollutant concentration in the mixing zone:

$$C_{mix}(\theta Q_{up} + Q_{eff}) = Q_{eff}C_{eff} + \theta Q_{up}C_{up} \qquad \text{(A-1)}$$

where

C_{mix} = concentration of pollutant in the mixing zone at various distances downstream of the discharge (mg/l)

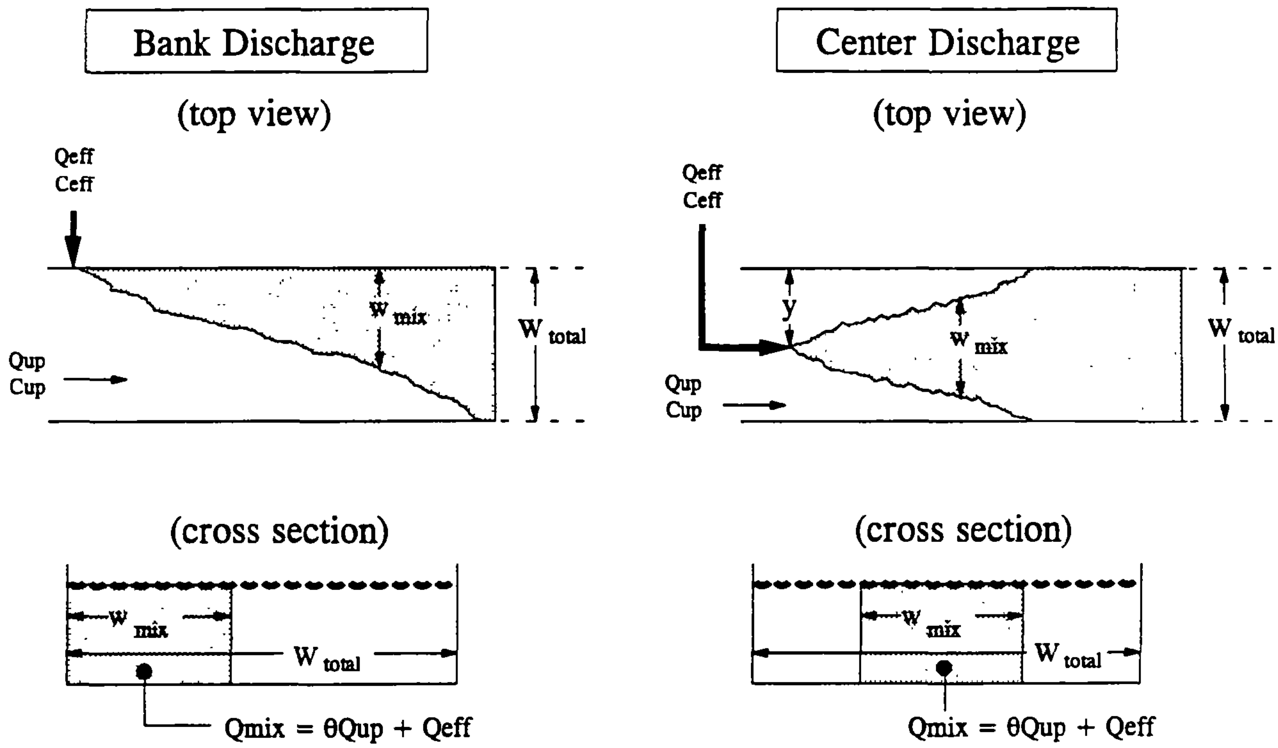
Q_{up} = upstream low flow at critical conditions (ft^3/sec)

C_{up} = upstream concentration (mg/l)

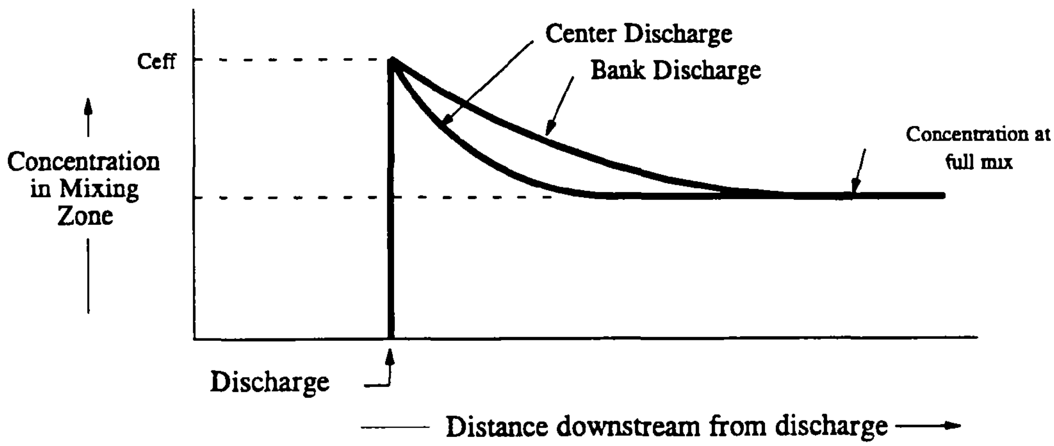
C_{eff} = effluent concentration (mg/l)

Q_{eff} = effluent flow (ft^3/sec)

Figure A-1
Schematic of Mixing Zones in Rivers



$$Cmix = (QeffCeff + \theta QupCup)/(\theta Qup + Qeff)$$



Cmix = mixing zone concentration
Ceff = effluent concentration
Qeff = effluent flow
Cup = upstream concentration
Qup = upstream flow

w_{mix} = width of mixing zone
W_{total} = total width of river
θ = fraction of upstream flow mixed with effluent flow
y = distance of discharge from stream bank

θ = percentage of upstream flow mixing with effluent flow at distance X from the discharge (unitless)

An equation that describes the ratio of flow in the mixing zone plume (Q_{mix}) and the total combined flow of the upstream waters and the effluent discharge (Q_{total}) can be shown to equal the ratio of the width of the mixing zone plume and the total width of the stream (assuming a rectangular cross section):

$$\frac{Q_{mix}}{Q_{total}} = \frac{(Q_{eff} + \theta Q_{up})}{(Q_{eff} + Q_{up})} = \frac{w_{mix}\, du}{W_{total}\, du} = \frac{w_{mix}}{W_{total}} \qquad \text{(A-2)}$$

where

w_{mix} = width of the mixing zone plume (ft)
W_{total} = width of the total stream (ft)
d = depth of the stream (ft)
u = velocity of the stream (ft/sec)

Solving for θ,

$$\theta = \frac{\left(\frac{w_{mix}}{W_{total}}\right)(Q_{up} + Q_{eff}) - Q_{eff}}{Q_{up}} \qquad \text{(A-3)}$$

From the literature (Fischer, et al; 1979), an equation that describes the width of a mixing plume (w_{mix}) associated with a centerline discharge in the middle of a river can be approximated by the equation $4(2D_yX/u)^{1/2}$ where D_y is the lateral dispersion coefficient and X is the longitudinal distance downstream from the point of discharge. The Region VIII model recommends the following similar formulation:

$$w_{mix} = \sqrt{8 \pi D_y \frac{X}{u}} \qquad \text{(A-4)}$$

for centerline discharges and

$$w_{mix} = \sqrt{2\pi D_y \frac{X}{u}} \tag{A-5}$$

for bank discharges. Region VIII recommends these equations based on validation runs with actual data. These two equations for mixing plume width can be combined into one formulation which is a function of the distance off the nearest bank:

$$w_{mix} = \sqrt{(2\frac{y}{W} + 1)^2\, 2\pi D_y \frac{X}{u}} \tag{A-6}$$

where

w_{mix} = width of mixing zone plume (ft)

W = width of stream downstream of discharger (ft)

y = the lateral distance from the stream bank to the discharge at some point in the river where y is less than or equal to 1/2 the entire stream width (ft)

X = distance downstream of discharge (ft)

u = velocity of stream downstream of discharge (ft/sec)

D_y = lateral dispersion coefficient (ft^2/sec)

where

$$D_y = cdu^* \tag{A-7}$$

c = channel irregularity factor (unitless)

c = 0.1 for straight, rectangular streams
c = 0.3 for channelized streams or irrigation canals
c = 0.6 for natural channels with moderate meandering
c = 1.0 for streams with significant meandering
c > 1.0 for streams with sharp 90° and greater bends

d = water depth at critical low flow downstream of discharge (ft)
u^* = shear velocity (ft/sec)

where

$$u^* = \sqrt{gds} \tag{A-8}$$

g = acceleration due to gravity (32.2 ft/sec^2)
d = water depth at critical low flow downstream of discharge (ft)
s = slope of the channel downstream of discharge (ft/ft)

The value for the mixing zone plume (w_{mix}) should be restricted such that $(w_{mix})_{max} = W_{total}$.

Rearranging the mass balance equation (A-1) to solve for C_{mix}, the equation becomes:

$$C_{mix} = \frac{Q_{eff}C_{eff} + \theta Q_{up} C_{up}}{(\theta Q_{up} + Q_{eff})} \tag{A-9}$$

To determine the laterally-averaged mixing zone concentration, we can substitute θ as given in equation (A-3) into this equation, we obtain:

$$(C_{mix})_{average} = \frac{C_{eff}Q_{eff} + \dfrac{[\frac{w_{mix}}{W}(Q_{up} + Q_{eff}) - Q_{eff}]}{Q_{up}}(Q_{up}C_{up})}{\dfrac{[\frac{w_{mix}}{W}(Q_{up} + Q_{eff}) - Q_{eff}]}{Q_{up}}(Q_{up}) + Q_{eff}} \tag{A-10}$$

This equation is used in the STREAMIX I model to represent the laterally averaged concentration in the mixing plume at distance X downstream from the discharge ($C_{average}$). This further reduces to:

$$(C_{mix})_{average} = \frac{C_{eff}Q_{eff} + [\frac{w_{mix}}{W}(Q_{up} + Q_{eff}) - Q_{eff}](C_{up})}{\frac{w_{mix}}{W}(Q_{up} + Q_{eff})} \quad \text{(A-11)}$$

With a zero concentration of the pollutant in the upstream water ($C_{up} = 0$), the equation reduces to:

$$(C_{mix})_{average} = \frac{C_{eff}Q_{eff}W}{w_{mix}(Q_{up} + Q_{eff})} \quad \text{(A-12)}$$

or, substituting the formulation for w_{mix} from equation (A-6) into this equation, we define $(C_{mix})_{average}$ as a function of distance downstream of the discharge:

$$(C_{mix})_{average} = \frac{C_{eff}Q_{eff}W}{\sqrt{(2\frac{y}{W} + 1)^2\, 2\pi D_y \frac{X}{u}}\,(Q_{up} + Q_{eff})} \quad \text{(A-13)}$$

For approximating the <u>extreme</u> concentration within the mixing plume ($(C_{mix})_{maximum}$ for instances where $C_{eff} > C_{upstream}$ or $(C_{mix})_{minimum}$ for instance where $C_{eff} < C_{upstream}$), the same formulation used to derive the average lateral concentration is used, except a slightly different expression is used for w_{mix}. We will define this new w_{mix} formulation w_{mix}'. Instead of equation (A-6), w_{mix}' will be defined as:

$$w_{mix}^{/} = \sqrt{(2\frac{y}{W} + 1)^2 \pi D_y \frac{X}{u}} \qquad \text{(A-14)}$$

The equation for w_{mix}' is used only to mathematically approximate the extreme concentration and has no physical meaning. The full equation used in STREAMIX I to represent the extreme concentration is then given as:

$$(C_{mix})_{extreme} = \frac{C_{eff}Q_{eff} + [\frac{w_{mix}^{/}}{W}(Q_{up} + Q_{eff}) - Q_{eff}](C_{up})}{\frac{w_{mix}^{/}}{W}(Q_{up} + Q_{eff})} \qquad \text{(A-15)}$$

which is the same as equation (A-11) but with the w_{mix}' formulation. Assuming the upstream concentration is zero (C_{up} = 0) and the discharge is from the stream bank, the equation becomes:

$$(C_{mix})_{extreme} = \frac{C_{eff}Q_{eff}W}{\sqrt{\pi D_y \frac{X}{u}}(Q_{up} + Q_{eff})} \qquad \text{(A-16)}$$

This equation is the same equation presented in both the Technical Support Document for Water Quality-based Toxics Control (US Environmental Protection Agency; 1991) and in Fischer, *et al* (1979). In the Technical Support Document, the Q_s is the same as (Q_{up} + Q_{eff}). In both the Technical Support Document and in Fischer, *et al* (1979), the formulation given in equation (A-16) describes the maximum concentration within the mixing zone associated with a bank discharge.

In summary, Region VIII recommends the following mathematical relationships for use in approximating plume width and mixing zone concentrations

- PLUME WIDTH:

$$w_{mix} = \sqrt{(2\frac{y}{W} + 1)^2\, 2\pi\, D_y\, \frac{X}{u}} \quad \text{(A-17)}$$

- CONCENTRATION IN MIXING ZONE:

$$C_{mix} = \frac{Q_{eff}C_{eff} + \theta Q_{up}C_{up}}{(\theta Q_{up} + Q_{eff})} \quad \text{(A-18)}$$

where

$$\theta = \frac{(\frac{w_{mix}}{W_{total}})(Q_{up} + Q_{eff}) - Q_{eff}}{Q_{up}} \quad \text{(A-19)}$$

For average concentration $(C_{mix})_{average}$:

$$w_{mix} = \sqrt{(2\frac{y}{W} + 1)^2\, 2\pi\, D_y\, \frac{X}{u}} \quad \text{(A-20)}$$

For extreme concentration $(C_{mix})_{extreme}$:

$$w'_{mix} = \sqrt{(2\frac{y}{W} + 1)^2\, \pi\, D_y\, \frac{X}{u}} \quad \text{(A-21)}$$

The equations summarized above provide the basis for STREAMIX I. STREAMIX I is for a single discharge with an effluent solute concentration either greater than or less than the solute concentration of the upstream river water. The model is two dimensional with assumptions of uniform concentration gradient in the vertical, constant depth, and constant velocity. The lateral diffusion coefficient can be changed from river segment to segment to accommodate different channel configurations. In addition, an optional first order decay term is included which can be used to influence both the maximum and average mixing zone concentrations.

Since STREAMIX I calculates both the extreme and average pollutant concentrations within the mixing zone, certain terms are defined in Figure A-2 to help describe the nomenclature used in STREAMIX I. The "extreme" concentration in the mixing zone can represent either a maximum concentration in the cross section of the river (for the instance where the upstream water has a lower concentration than the effluent discharge) or a minimum concentration (for the instance where the upstream water has a higher concentration than the effluent discharge).

To validate STREAMIX I, comparisons were made between the modeled output and data from several field mixing zone studies. Figures A-3 through A-7 provide the results of these comparisons. In all cases, plume widths as well as average and shoreline/centerline extreme concentrations were modeled. Where information on specific lateral diffusion coefficients were given, the channel irregularity factor was adjusted to render the actual value reported value for the coefficient. Coefficients were otherwise estimated. For additional validation, STREAMIX I was used to calculate plume concentrations for a hypothetical mixing problem given in Fischer, *et al.* Figure A-8 gives the result of that comparison.

The input parameters needed to run the STREAMIX I spreadsheet model include:

. effluent flow (ft^3/sec)
. effluent concentration (mg/l or μg/l) — *The value of effluent concentrations can be either a known or unknown value for the model. As an unknown, iterative runs are performed using the ambient criteria as the target concentration within the mixing zone.*

. upstream flow and concentration (mg/l or μg/l)
. stream slope (ft/ft)
. stream depth at critical low flow downstream from discharge (ft)
. stream width at critical low flow downstream from discharge (ft)
. stream velocity at critical low flow downstream from discharge (ft/sec)
1st order decay coefficient for pollutant (1/day) (optional; use only if needed)

Also, a general understanding of the stream or river shape is needed to estimate the channel irregularity factor (see discussion above associated with equation A-7).

Figure A-2
Cross Sections of Mixing Zones in River

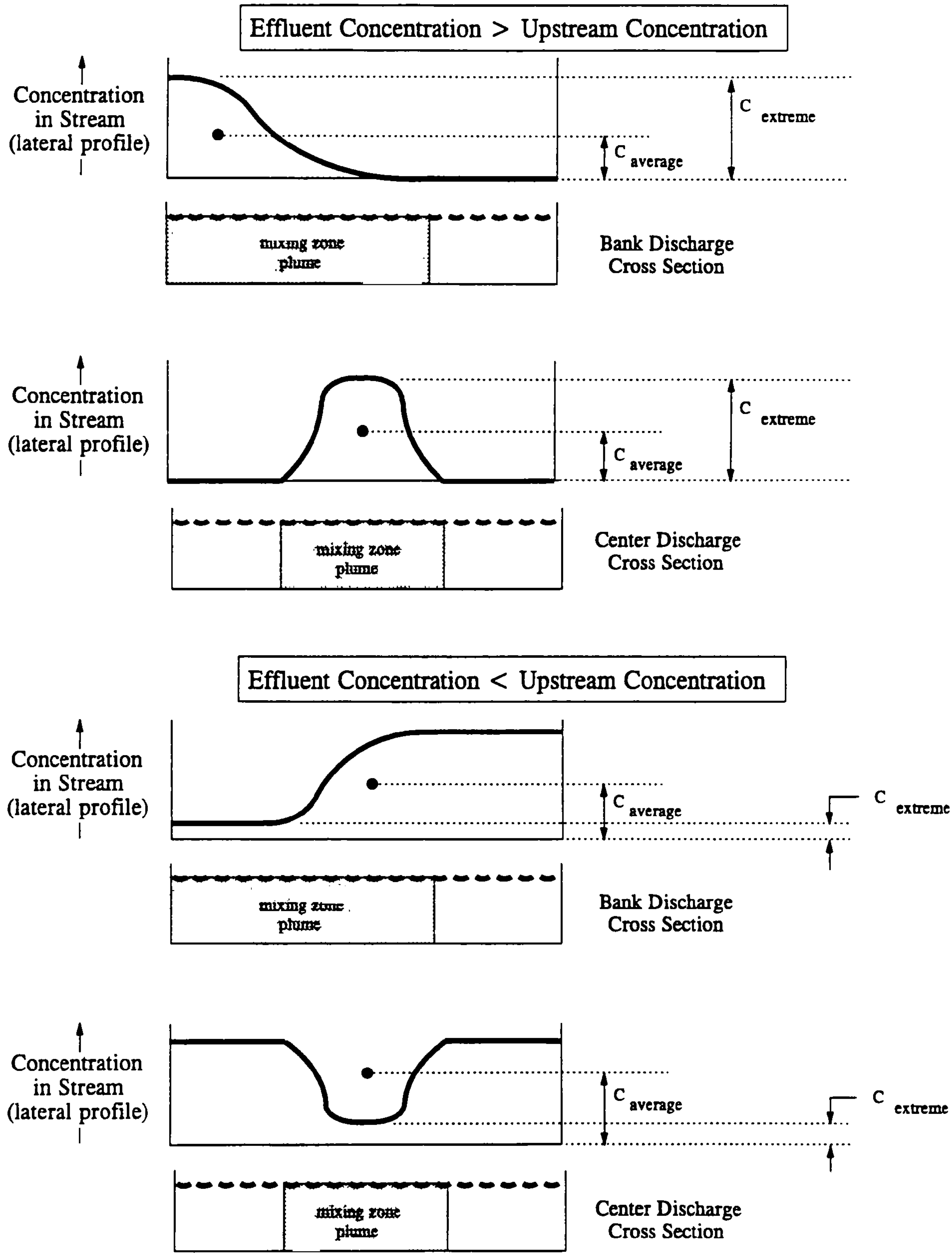
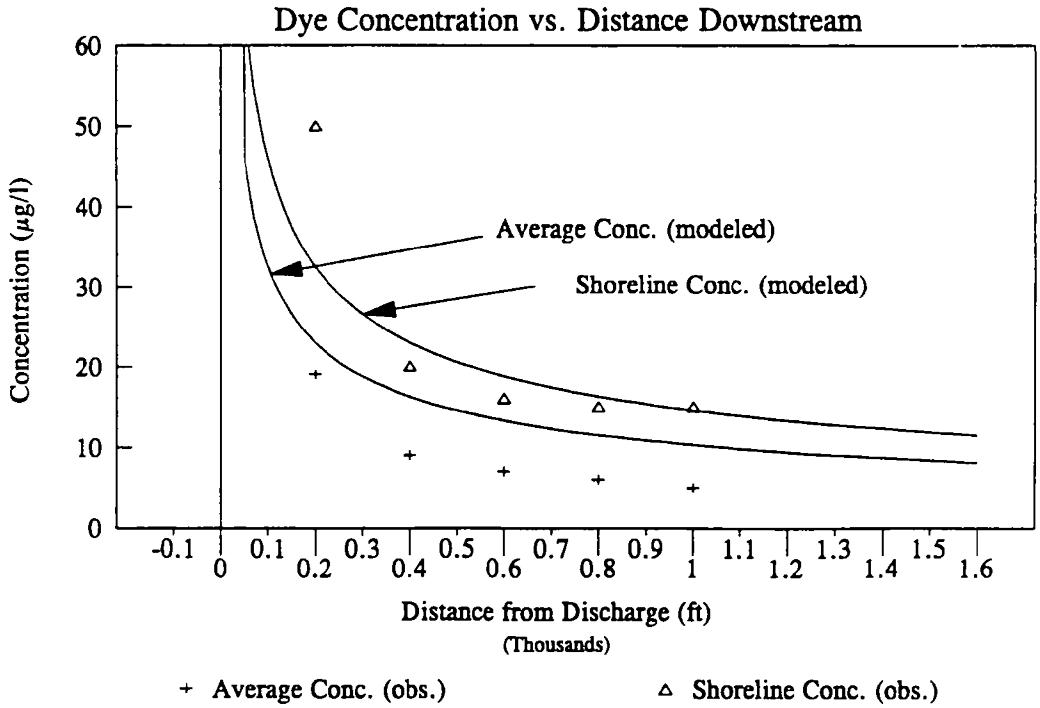


Figure A-3
Validation of STREAMIX Model

Atrisco Feeder Canal (NM)

(Fischer, 1967)

(Centerline Discharge)



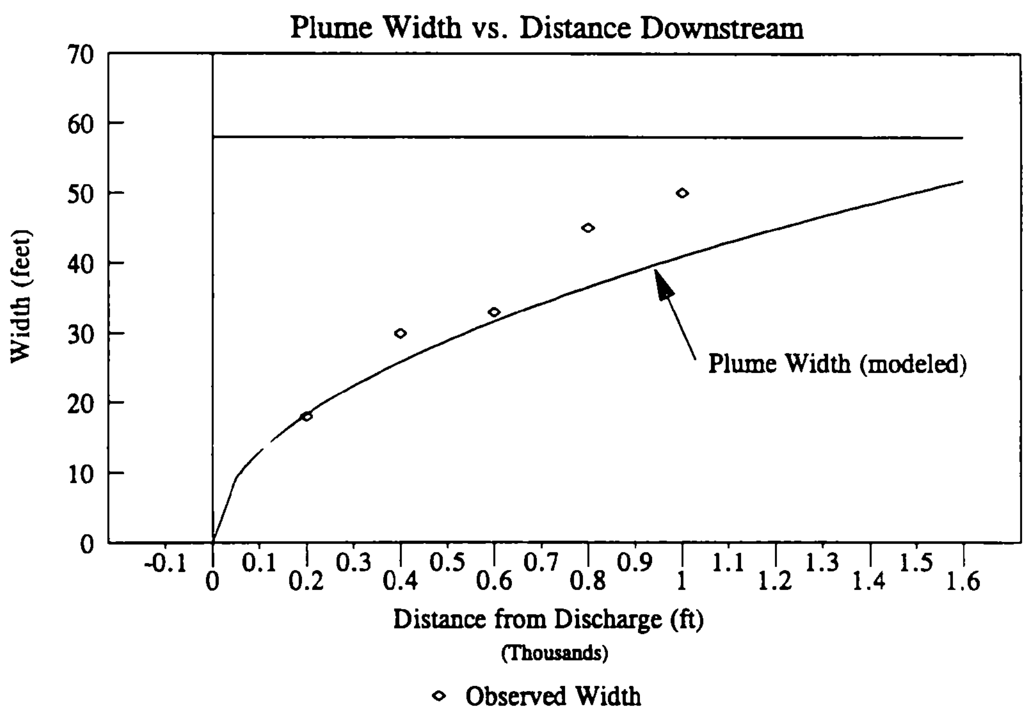
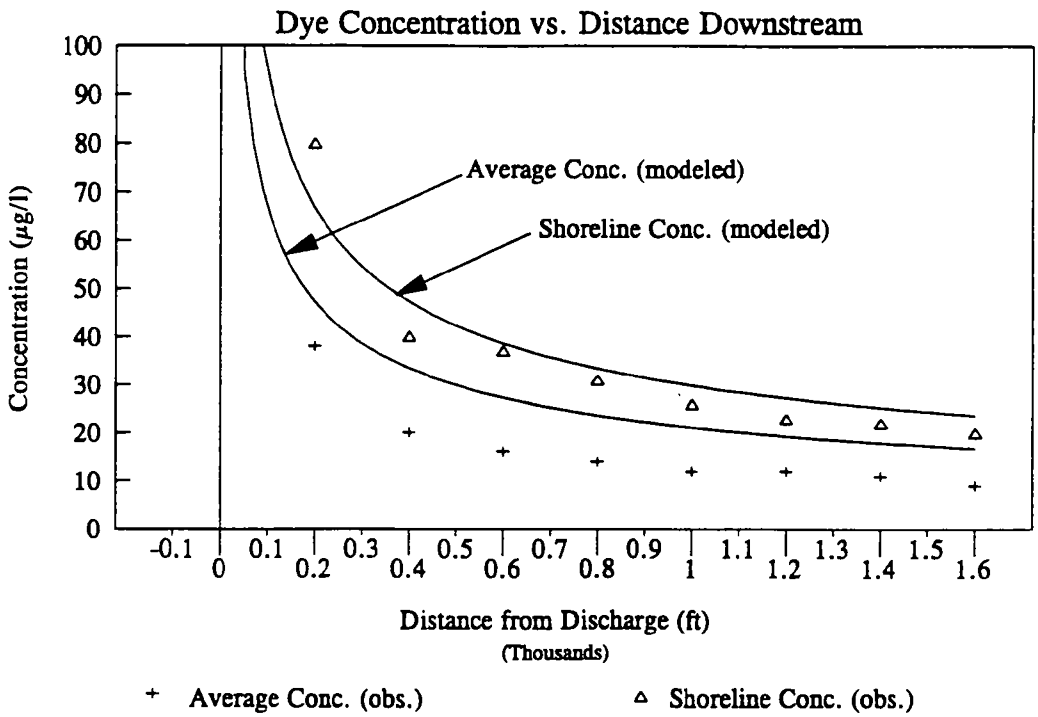


Figure A-4
Validation of STREAMIX Model

Atrisco Feeder Canal (NM)
(Fischer, 1967)
(Bank Discharge)



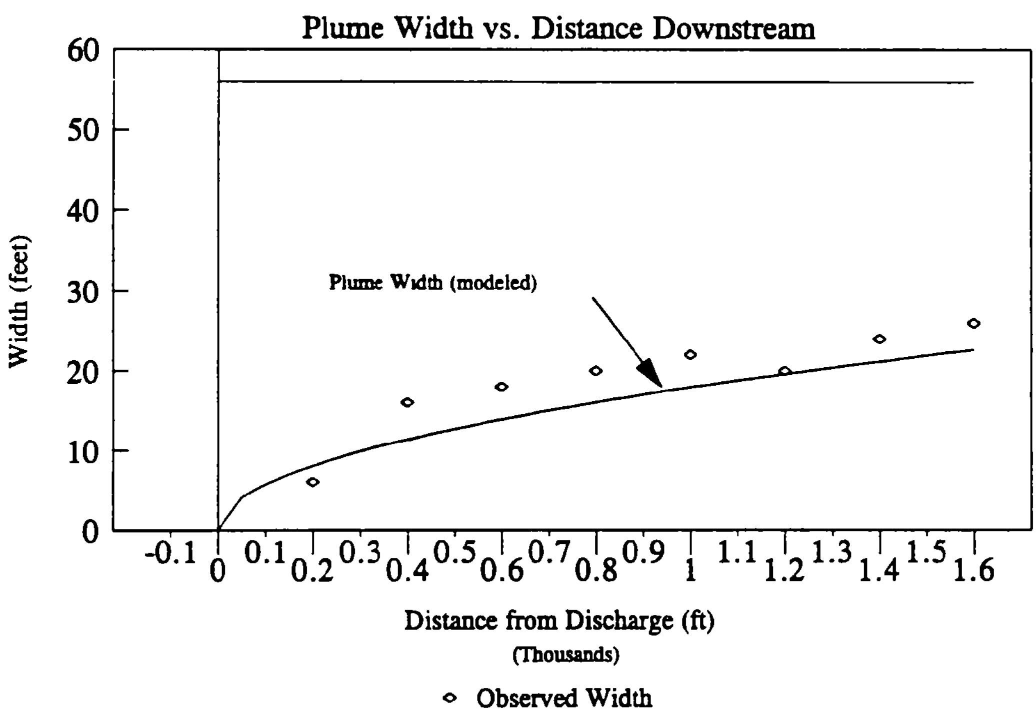
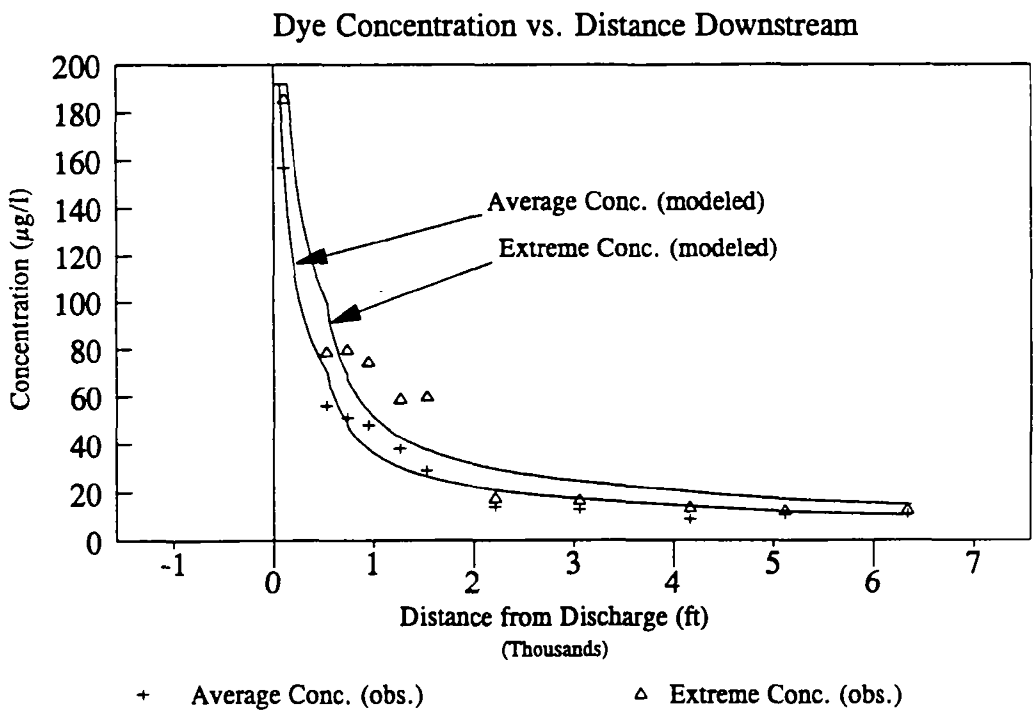


Figure A-5
Validation of STREAMIX Model

Arkansas River (CO)

(USGS, 1980)

(Bank Discharge)



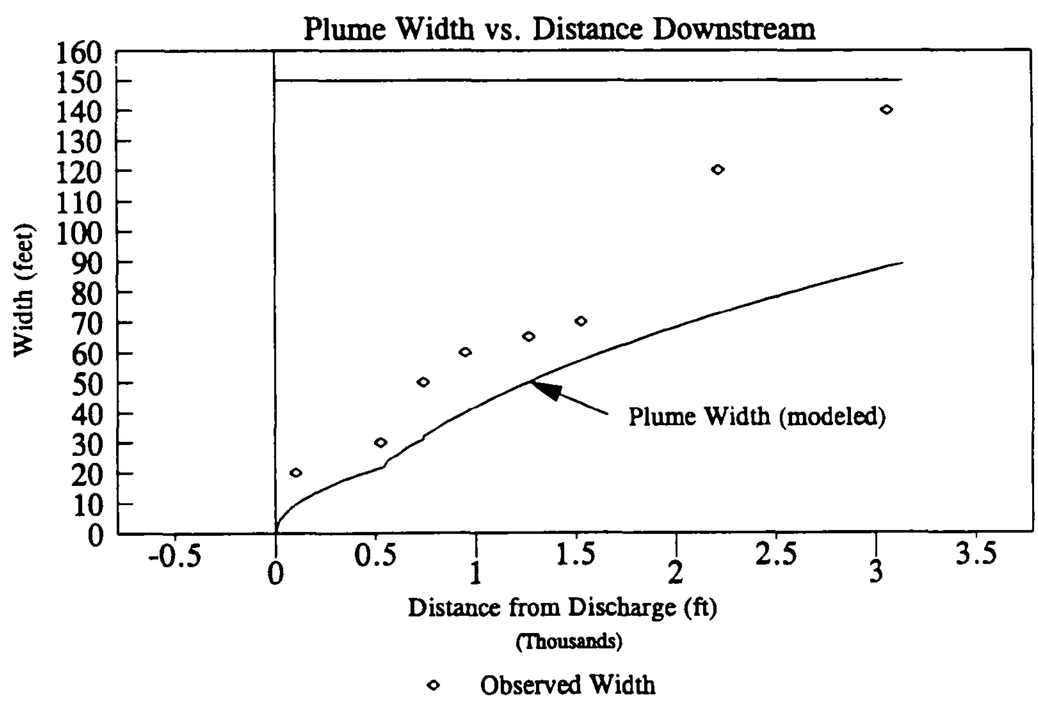
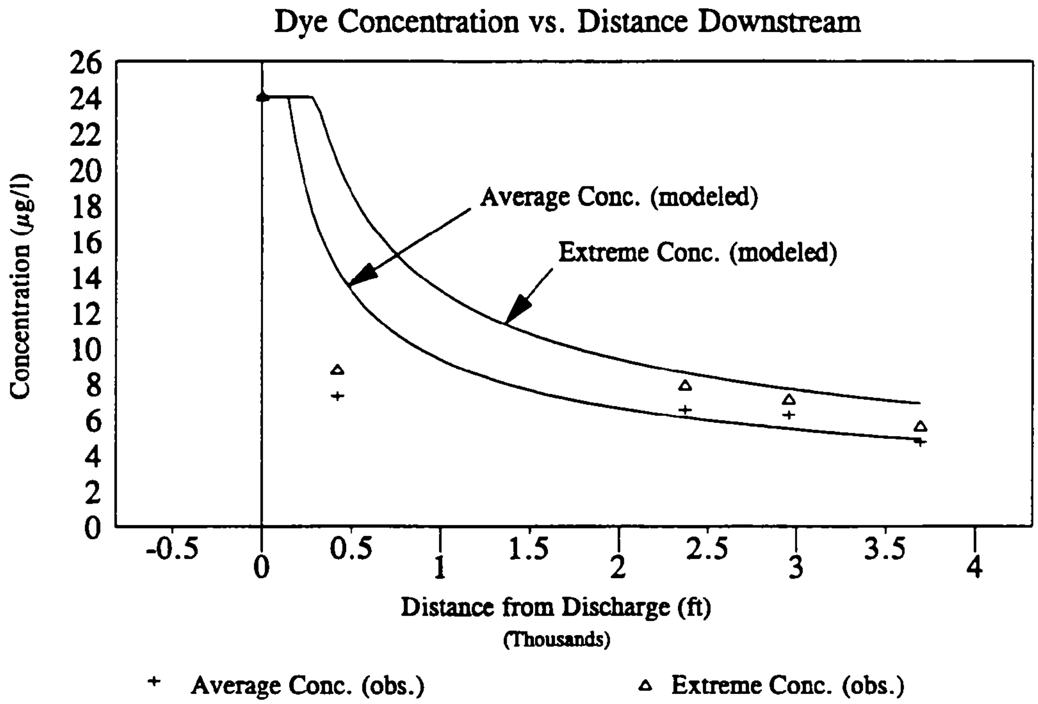


Figure A-6
Validation of STREAMIX Model

South Platte River (CO)

(USGS, 1985)

(Bank Discharge)



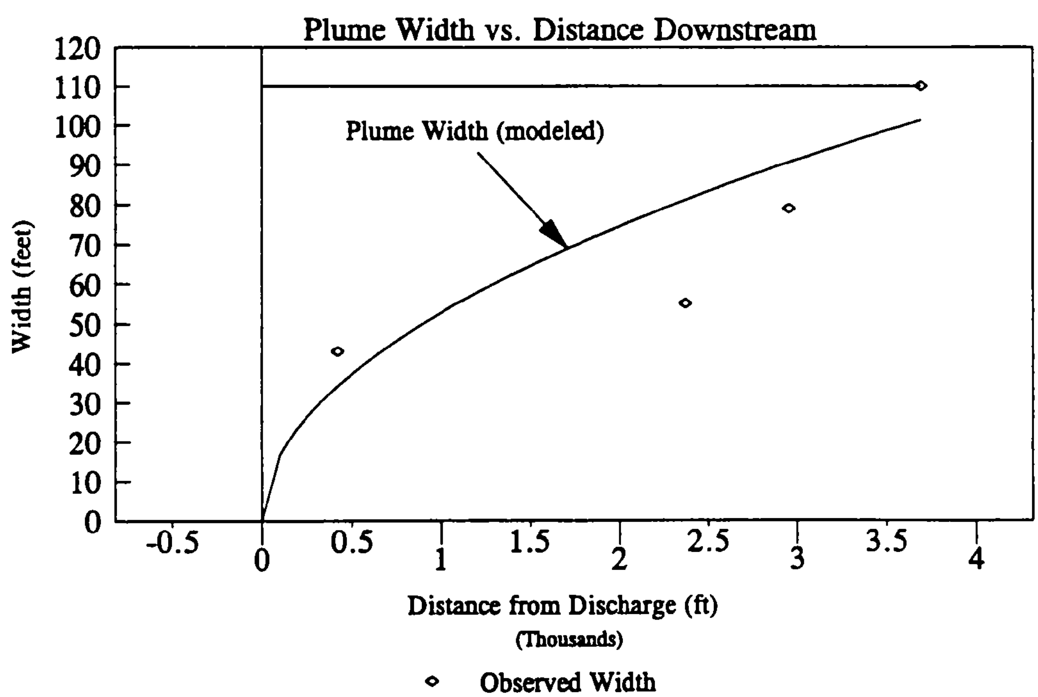
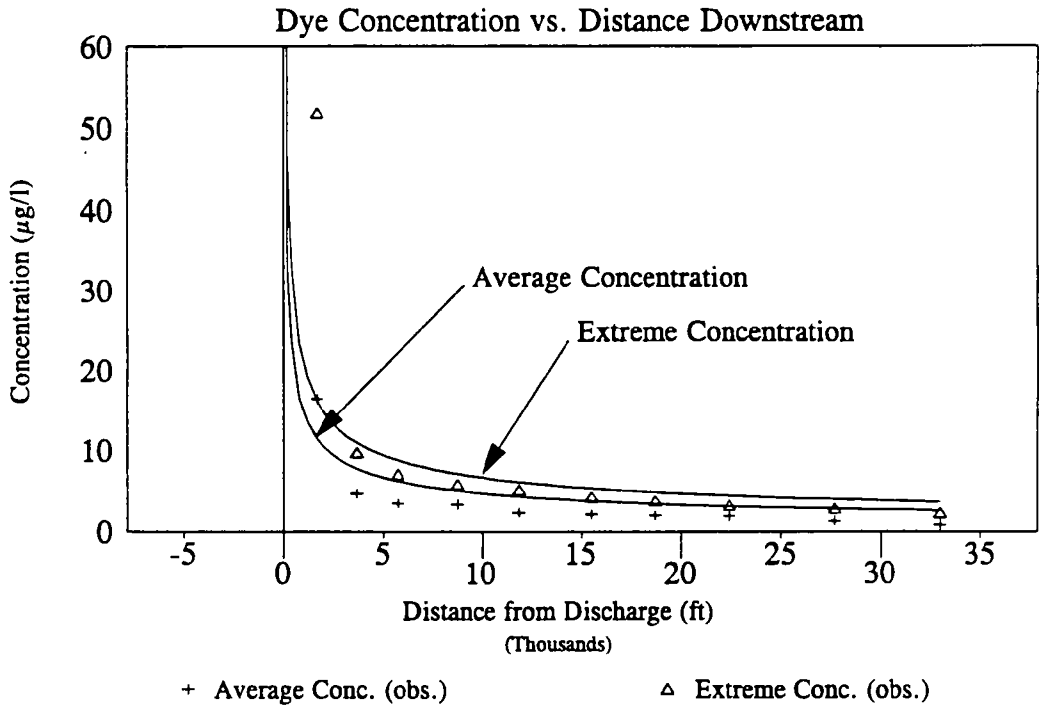


Figure A-7
Validation of STREAMIX Model
Missouri River
(Yotsukura, 1970)
(Centerline Discharge)



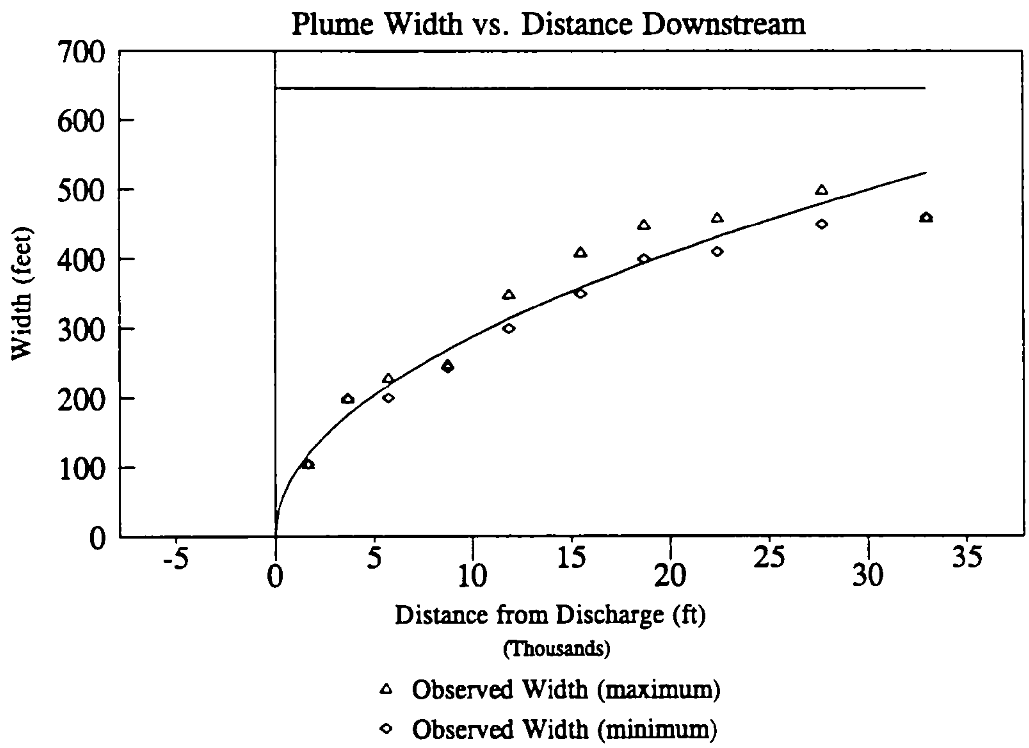
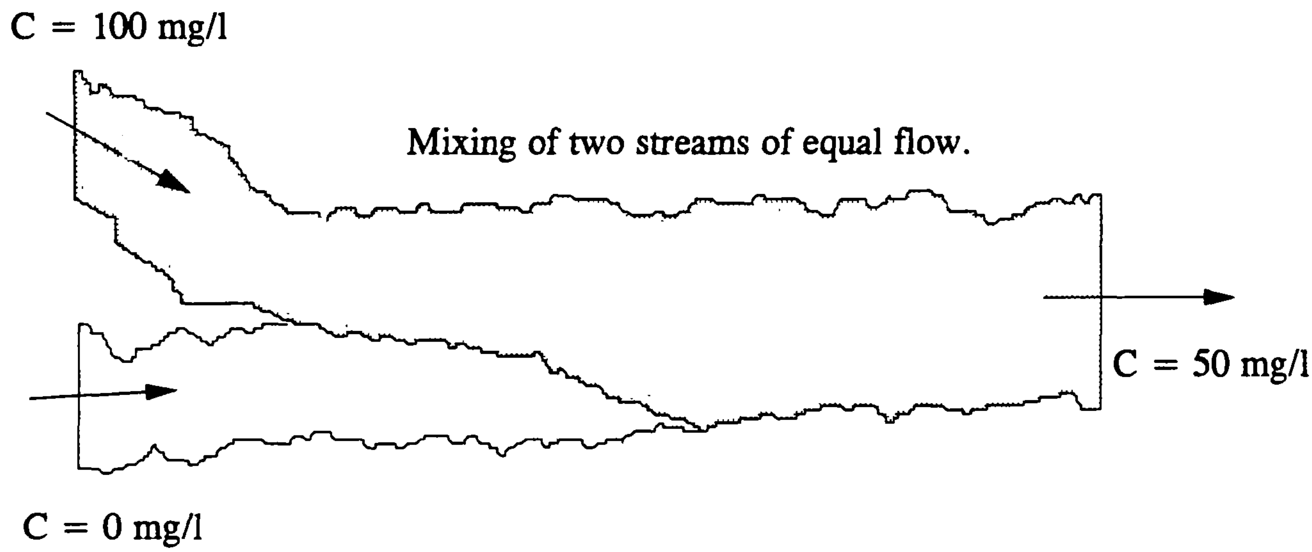
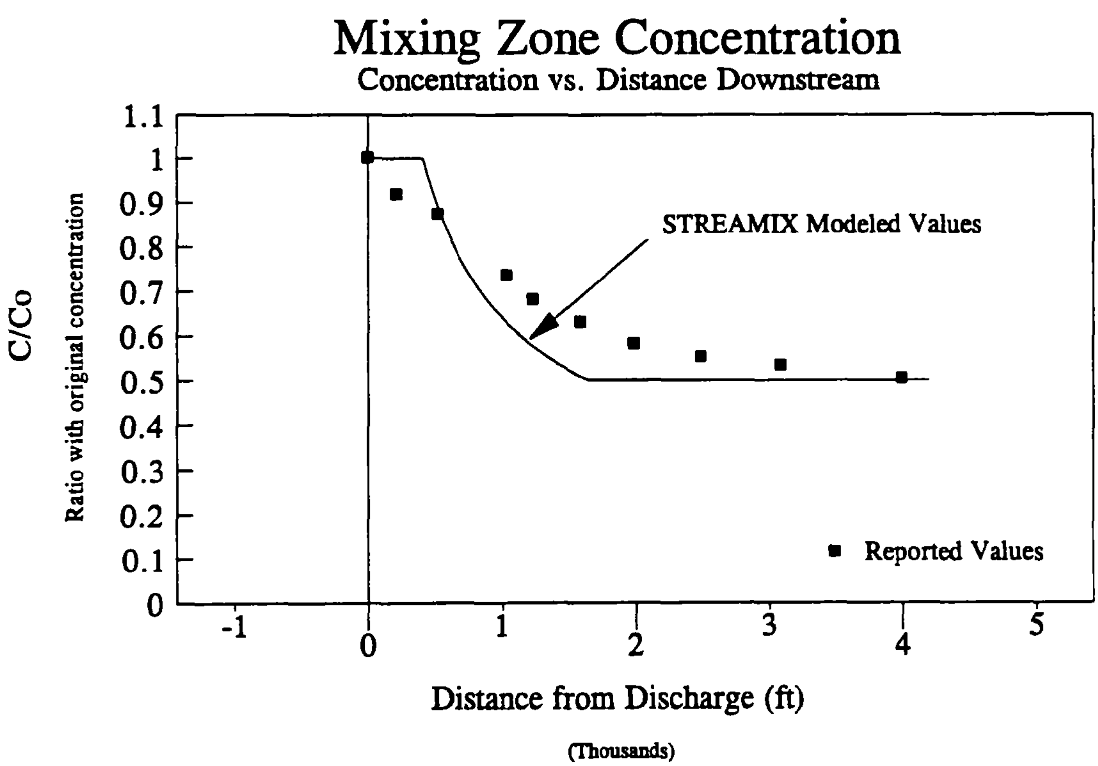


Figure A-8
Validation of STREAMIX Model

Sample Mixing Zone Problem
(Fischer, et al, 1979)





For a copy of STREAMIX I, direct requests to:

US EPA; Region VIII
Monitoring and Standards Section
Water Management Division
999 18th Street; Suite 500
Denver, Colorado 80202-2466
Attention: Bruce Zander

References for Appendix A

Fischer, H.B. (1967). "Transverse Mixing in a Sand-Bed Channel"; USGS Professional Paper 575-D, Pages D267-D272.

Fischer, H.B., List, E.J., Koh, R.C.Y., Imberger, J. and Brooks, N. (1979). Mixing in Inland and Coastal Waters; Academic Press, Inc., NY

United States Geological Service (1980). Selected Hydrologic Data, Arkansas River Basin, Pueblo and Southeastern Fremont Counties, Colorado 1975-1980; USGS Open-File Report 80-1185.

United States Geological Service (1985). Selected Hydrologic Data for the South Platte River Through Denver, Colorado; USGS Open-File Report 84-703.

Yotsukura, N., Fischer, H.B., Sayre, W. (1970). "Mixing Characteristics of the Missouri River Between Sioux City, Iowa, and Plattsmouth, Nebraska"; USGS Water-Supply Paper 1899-G.

APPENDIX B - EPA REGION VIII RESPONSES TO MAJOR COMMENTS AND QUESTIONS

Comments on First Draft Issued August 13, 1993

1. A number of commenters asserted that the policy statement does not establish a sound technical basis for changing existing dilution approaches in EPA Region VIII States, and that documented proof that existing approaches are causing an environmental problem is lacking.

Response: The Region acknowledges that there is a lack of information on impacts to biota and human health resulting from the generous dilution allowances currently incorporated into water quality-based NPDES permits in the Region. The Region agrees that it would be useful to characterize the ecological and human health risks of current dilution practices. However, the Region also believes that, except in effluent-dominated situations, most point sources do not mix rapidly with receiving waters. Where ambient mixing is incomplete, generous dilution allowances result in effluent plumes with concentrations and toxicity considerably in excess of ambient water quality objectives (i.e., regardless of stream flow and assuming effluent quality is at or near permitted levels). Such plumes are of concern because:

1) chemical-specific and toxicity objectives are not achieved in the plume,

2) effluent plumes can extend far downstream before complete mixing and criteria are achieved,

3) effluent plumes are often located along the shore in shallow waters that are critical nursery areas for aquatic organisms,

4) aquatic life can be attracted to effluent because of its temperature, and

5) studies have demonstrated correlation of criteria exceedences with in-stream impacts to biota, particularly for toxicity (see TSD, 1991).

The Region believes that the current Region-wide approach of presumptively providing the entire low flow as dilution ignores these site-specific mixing and dilution issues. The Region is particularly concerned that, in incomplete mix situations, the same generous dilution is always assumed regardless of the actual rate of mixing. The Regional position is that exceedence of criteria in ambient waters is a serious matter, that mixing zones should be kept small, and that mixing zone size limitations should be implemented in a realistic manner.

Thus, the Region's basis for changing existing practice (in addition to the legal and consistency issues discussed below) is the need to consider site-specific information such as the rate of mixing in determining the level of dilution that is appropriate. Quite frankly, the Region sees little or no technical merit in the mixing zone-dilution approach currently in use, and believes that a more realistic approach should be employed to improve this aspect of the water quality-based permitting process. The Region's recommended approach allows considerable flexibility to take relevant site information into account, and use of the recommended approach will improve the technical basis for water quality-based limits in Region VIII.

2. Several commenters were concerned that the economic impacts of implementation of the policy statement could be tremendous and have not been evaluated by the Region; a related concern was that the proposed policy requiring compliance with acute criteria at the end-of-pipe in incomplete mix situations will be costly for dischargers. Specific concerns were expressed regarding small municipalities that have controlled-discharge lagoon wastewater treatment facilities.

Response: The Region recognizes that implementing the Region's policy statement will require an investment of state/tribal resources, and in some cases will result in more stringent effluent limits. However, the Region emphasizes that the dilution allowances currently provided are considerably more generous than those which are routinely applied in other Regions, including other western Regions (see Appendix C). The Region believes that if the costs of implementing a more protective approach were "tremendous," the problem would be apparent in these other Regions.

In addition, the costs of implementing the Region's policy statement will depend upon the specifics of the particular approach developed by the State or Tribe. The Region emphasizes that its policy statement includes more recommendations than it does hard and fast requirements. Although the Region generally will expect States and Tribes to do a better job of making mixing zone and dilution decisions, the Region is not requiring any specific approach. The policy statement does identify key issues that States and Tribes will need to address and resolve; however, there is flexibility on these key issues to modify the Region's recommended approach.

One example is the issue of determining when a discharge mixes with the receiving water in a "near instantaneous and complete" manner. Where such "complete mixing" occurs (such as when a diffuser has been installed), there will probably be little or no change to existing permit limits for stream/river discharges as a result of the Region's policy statement, because the full low flow will continue to be provided as dilution. The Region notes that, as long as a reasonable technical basis is evident, States and Tribes may establish their own definitions, guidelines, or procedures for identifying when "complete mixing" is occurring.

As a second example, although recommended low flows are included in the policy, the final choice of appropriate low flows is another matter which has been left to the discretion of each State and Tribe. In the case of low flows to implement human health criteria for carcinogens, the Region has recommended use of the harmonic mean flow. For sixty streams where the harmonic mean and 7Q10 flows were compared, EPA's TSD reports that the harmonic mean was at least double the 7Q10 at all sixty sites. Thus, for carcinogens, the Region notes that implementation of the recommended approach would likely result in less-stringent treatment requirements.

A third example is the issue of mixing zone size restrictions. Although the policy statement includes recommended maximum size restrictions, the policy also provides States and Tribes with discretion to establish maximum size allowances somewhat smaller or somewhat larger than the Regional recommendation. Although there are limits on what the Region can accept, the survey of State mixing zone size restrictions in Appendix C shows that there are a variety of different approaches to restricting mixing zone size.

Other notable issues where States and Tribes have flexibility include the approach to wetland discharges (see comment # 5), the approach for small POTWs (see comment # 7), and the choice of particular modeling or other methods for deriving effluent limits to achieve mixing zone size restrictions.

With respect to the comments regarding implementation of acute chemical-specific criteria in incomplete mix situations, the Region has changed its position on this issue. Although the Region continues to recommend compliance with such criteria at the end-of-pipe, the policy statement has been changed to allow each State and Tribe the flexibility to determine whether or not to allow a limited mixing zone (i.e., a zone of initial dilution) on a case-by-case basis. Further, Appendix D of the policy statement now contains Regional guidance on how such an approach for acute chemical-specific criteria could be implemented.

Regarding small municipalities with controlled-discharge lagoon facilities, the Region notes that step 3 of the Region's model procedure includes provisions allowing certain small POTWs to qualify for more generous dilution allowances (see page 22). The Region anticipates that some lagoon facilities would satisfy the requirements for coverage under step 3. The Region also intends to allow States and Tribes the flexibility to develop their own provisions establishing conditions under which small facilities may qualify for less-restrictive dilution requirements; various formulations of such provisions may be appropriate, provided that they are based on an evaluation of environmental risk, rather than treatment costs (see comment # 7 below).

In sum, although there will be some costs of implementing the Region's policy statement, the Region believes these costs will not be "tremendous" and will depend upon how a host of specific policy issues are addressed by the individual States and Tribes.

3. One commenter asserted that since federal regulations at 40 CFR 131.13 state that development of mixing zone policies is discretionary, there is no clear regulatory mandate for the Region's policy statement.

Response: The Region disagrees with this assessment and believes that its policy statement has a strong legal basis. Although it is true that EPA's water quality standards regulation provides for state/tribal discretion on mixing zone policies, the discretion concerns whether to adopt such policies or alternatively to require criteria compliance at the end-of-pipe. Where a State or Tribe elects to allow mixing zones, the water quality standards regulation clearly establishes Agency authority to review and approve/disapprove the adopted mixing zone policy. The Region's policy statement is intended to assist States and Tribes to establish mixing zone approaches that are fully approvable.

EPA's water quality standards regulation in no way authorizes dilution approaches that automatically and presumptively provide the entire low flow as dilution. To the contrary, EPA's position has always been that where mixing is incomplete, mixing zone size should be carefully limited in each individual case, and that the approach should take the site-specific uses, mixing rate, and discharge location into account (see Red Book-1976, WQS Handbook-1983, TSD-1991). In incomplete mix situations, the Region does not consider the existing approach of Region VIII States to be a true "mixing zone approach;" such an approach requires, at a minimum, some consideration of the rate of mixing and an effort to achieve mixing zone size restrictions based on that rate of mixing. Rather, the Region considers the existing approach of its States to be an approach that automatically and presumptively provides generous dilution regardless of site-specific mixing or environmental risk factors. The result is considerable uncertainty regarding effluent plume size, quality, and effects. As such, the Region is not convinced that the existing practice of Region VIII States is authorized by the EPA water quality standards regulation.

In a number of cases, the Region also has some doubt regarding whether existing practice is consistent with State mixing zone authority as defined by the State water quality standards. Such State mixing zone policies typically authorize mixing zones, but only if such mixing zones will, for example, "provide a zone of passage," "be as small as practicable," and/or "not intersect spawning or nursery areas, migratory routes, or municipal water intakes." EPA Region VIII believes that current approaches do not implement, or even consider, such State requirements and that a strong argument can be made in any case that current approaches exceed the mixing zone authority provided under EPA's water quality standards regulation.

4. A comment was received that since the Region VIII policy statement is not a federal law, State approaches will vary from Region to Region and will not be consistent throughout the United States.

Response: The Region believes that consistency on mixing zone and dilution approaches is already a serious problem, but that implementation of the Regional policy statement will improve national consistency on this issue. The Region's evaluation of current approaches nationally indicates that the existing practice in Region VIII is less protective, less technically-sound, and less reflective of site-specific circumstances than what is done elsewhere, particularly in incomplete mix situations. Even among States in neighboring Regions, Region VIII has found that Arizona, Arkansas, California, Missouri, and Nebraska, for example, routinely apply mixing zone practices that are more protective, and more consistent with state and federal requirements, than those in Region VIII. Because many States currently use approaches more technically and legally defensible than those in use by Region VIII States, the Region believes that implementation of the recommended approach would actually improve national consistency on this issue.

5. On the subject of mixing zones and dilution for discharges to wetlands, a commenter pointed out that in some instances, sewage treatment plants were intentionally constructed near wetlands to provide additional treatment prior to the wastewater reaching a relatively pristine receiving stream. The commenter suggested that these discharges may not have an overall detrimental effect on the wetland environment, and often benefit wetlands during periods of drought. This commenter was concerned that implementation of the proposed policy could result in dischargers bypassing wetlands and increasing nutrient loads to receiving streams.

Response: Regarding discharges to wetlands, the Region notes that the issue of the water quality standards and particularly the numeric criteria applicable to wetlands will probably have a more significant effect on permit limits than will the approach to mixing zones and dilution. In many wetlands, there is little or no surface water flow that could be the basis for a dilution allowance. Further, where there is surface water flow in a wetland, the amount of dilution that could be provided to a discharge may not be significant where the flow is small compared to the discharge or where there is a slow rate of mixing of the effluent with the receiving waters. As a result, even where a State or Tribe decided to allow mixing zones for wetlands, any potential permit relief for a discharger would be small because the available dilution will typically be small. The more important threshold issue for discharges to wetlands will be the application of water quality standards in protecting wetlands (e.g., selection of criteria appropriate to protecting wetland uses could potentially have a much more significant effect than any decision about whether or not to allow a mixing zone). The Region also emphasizes that its mixing zones and dilution policy statement allows for State and Tribal flexibility on this question. Although the Regional recommendation is to require compliance with applicable criteria at the end-of-pipe for wetland discharges, States and Tribes are free to implement other defensible approaches. Wetlands are surface waters of the United States subject to the same water quality standards requirements as any other waterbody (e.g., criteria must be sufficient to protect uses, etc.), and under federal regulations, surface waters (including wetlands) may not be used for waste assimilation. The Region's recommendation for wetland discharges is based on its belief that, given the sluggish flows, low mixing potential, and important values and functions of wetlands, a requirement for wetland discharges to achieve applicable criteria at end-of-pipe is appropriate. The Region generally tends to discount the validity of providing a "mixing zone" in a wetland because of the lack of mixing in wetlands. The Region recognizes that implementation of its recommended approach may create an incentive for dischargers to route effluent directly to streams where greater mixing rates, greater dilution, and less-restrictive effluent limits may be available. The Region notes that this incentive is not exclusive to wetland discharges, but may occur wherever the available dilution at an existing discharge location is less than at an alternative location.

6. Several commenters expressed the belief that the Region is rushing States to comply with its mixing zone policy, and that moving ahead with the document is premature and unnecessary, given the pending reauthorization of the Clean Water Act.

Response: The Region emphasizes that improvements to State mixing zone implementation procedures has been a Regional priority for more than three years (as evidenced, for example, by the Region's State-EPA Agreement (SEA) guidance). On the subject of potential Clean Water Act (CWA) revisions, the Region acknowledges that revisions concerning mixing zones are possible, and that if such revisions are adopted, changes to the federal water quality standards regulations would be likely. However, the Region has no basis to anticipate new requirements that would fundamentally change EPA's approach to mixing zones. Any changes to the CWA and the federal water quality standards regulation are likely to simply support and formalize EPA's position on mixing zones over the last twenty years. The Region believes that EPA's approach to mixing zones has been remarkably constant over the years, and that this policy statement is not a departure from EPA's long-standing philosophy, but rather an identification of priority issues and a clarification of one acceptable means of addressing those issues. Because this Region VIII policy statement is consistent with previous EPA guidance, and would only bring current Region VIII practices reasonably into line with that guidance, the Region sees no reason to wait for CWA revisions. To the contrary, as discussed above, the Region believes there are strong technical, equity, and legal reasons for improving existing State policies and implementation procedures on mixing zones and dilution.

7. A comment was received that mixing zone/dilution requirements for small POTWs should be consistent with those for all other dischargers. This commenter suggested

that requirements should be based on the type of pollutant, the critical low flow conditions and cumulative effects of all dischargers (point and nonpoint).

Response: The Region emphasizes that the policy statement allows flexibility on this issue. The Region continues to recommend that less-stringent requirements (e.g., dilution equal to the full low flow) should generally be provided to small POTWs discharging to large waterbodies where the environmental risk of allowing such dilution is small. This provision is included based primarily upon practical considerations, weighing potential risks against both state/tribal resources and potential costs to small communities. However, States and Tribes may elect to apply the same mixing zone-dilution requirements to all facilities consistently. In addition, States and Tribes may elect to develop their own risk-based approaches for identifying facilities that merit less stringent requirements. As the commenter suggests, such approaches should consider the type of pollutant, the amount of available dilution, and potential cumulative effects. In addition, the Region believes that such approaches should consider existing pollutant accumulation in fish tissues or sediments and other site-specific environmental risks. The Region cautions, however, that EPA approval of any less-stringent state or tribal approach for small POTWs will require a showing that the approach applies only in situations where the environmental risks are small. Although treatment costs play a role in the water quality standards process (e.g., as a basis for issuing a variance), it is not appropriate to apply less-stringent mixing zone or dilution requirements based solely on cost considerations. State or tribal approaches to this issue that are not founded on an evaluation of environmental risks will not be approved by the Region.

8. One commenter supported the Region's proposed policy to meet acute chemical-specific criteria at the end-of-pipe at all times regardless of the presence of a mixing zone, but suggested that chronic and acute WET limits should be based on critical effluent and low flow stream conditions.

Response: The Region believes that in incomplete mix situations, compliance with acute chemical-specific and acute WET limits should be required at the end-of-pipe without an allowance for dilution. However, the Regional policy has been modified to provide additional state/tribal flexibility to decide whether to allow limited dilution for acute chemical-specific criteria (i.e., a zone of initial dilution). For acute whole-effluent toxicity limits, the Region will continue to require compliance at the end-of-pipe without an allowance for dilution. The basis for the decision on acute chemical-specific criteria is that some (but not all) States in other Regions are allowing a zone of initial dilution. In addition, EPA guidance (TSD, 1991) supports a range of approaches, including the zone of initial dilution approach and the Region's recommended approach of requiring end-of-pipe compliance. The basis for the decision on acute WET limitations is that such limits are based on an LC50, with typically two species tested, while acute chemical-specific criteria are designed to achieve a much higher level of protection, based on a much larger species database. Thus, the Region believes that acute WET limits are a somewhat less rigorous measure of potential acute effects, and that dilution for acute WET limits is not justified in any case because of the importance of avoiding acutely toxic exposures to organisms in receiving waters.

9. One commenter was concerned that mixing zone monitoring procedures weren't included in the policy statement and probably should be addressed in State/Tribal mixing zone policies before being approved by EPA.

Response: The Region believes that any monitoring of mixing zones should be required of the permittee, and that it is a good idea to include a permittee monitoring provision in state/tribal mixing zone policies or implementation procedures. Such a provision would serve to provide notice to permittees and a basis for including monitoring requirements in NPDES permits. For example, it may be necessary in some cases to require ambient monitoring in the NPDES permit to confirm that mixing zone size limitations are being achieved. At a minimum, the Region recommends that mixing policies or implementation procedures include a provision addressing how a permittee may evaluate whether near complete mixing exists. Such a provision would be useful in situations where a permittee chooses to determine the local mixing rate as a basis for requesting revised effluent limitations.

Comments on Second Draft Issued January 14, 1994

10. Several commenters urged that greater flexibility be given to States to establish mixing zone provisions that consider site-specific conditions and factors.

Response: The Region believes that more than adequate flexibility is provided by the policy and that changes to the policy to address this comment are not necessary. The Region believes that these commenters may have misunderstood the purpose of the Region's model policy and procedure included in Chapters 3 and 4, respectively. The model policy and procedure are intended to provide a recommended ***example*** of the type of policy and procedure that States and Tribes may adopt. However, States and Tribes are not required to follow the approaches contained within the Region's models. Although States and Tribes are expected to resolve all key issues, there is a range of approaches that may be used on each issue. The Region believes that this approach provides more than adequate flexibility to States and Tribes to consider site-specific conditions and factors in developing mixing zone and dilution provisions. The Region also notes that the purpose of step 4 in the model procedure is to promote consideration of site-specific environmental risks in determining the mixing zone or dilution allowance that is appropriate.

11. Comments were received that the policy seems to be geared towards protecting organisms which "reside" within or pass through the mixing zone, and that the purpose of a mixing zone is to provide an "allocated impact zone," that does not expose organisms swimming or drifting through the mixing zone to acute toxicity. These commenters expressed concern that the term "reside" broadens the protection of organisms to include unintended organisms, such as sessile plants, and urged Region VIII to remove any ambiguities relating to the term "reside" prior to finalization.

Response: The Region intends to provide States and Tribes with the flexibility to determine, as a matter of policy, whether or not to protect organisms that reside within the mixing zone. Issue #4 discussed within Chapter 2 of the policy explains that States and Tribes will need to establish minimum in-zone quality requirements that apply within mixing zones. In discussing issue # 4, protection of sessile organisms is identified as an example of the type of protection that can be provided by such requirements. However, although States and Tribes may establish a policy of protecting sessile organisms residing within mixing zones, it is not the intent of EPA to require such protection. In establishing minimum quality requirements, the Region does recommend that States and Tribes clearly resolve whether or not protection of sessile organisms is required. At a minimum, the Region will expect that state and tribal policies will provide for mixing zones that will not result in lethality to aquatic life caused by passage through the mixing zone by migrating fish, or by less mobile forms drifting through the plume.

12. Comments were received that Region VIII, in establishing generic mixing zone dimensions, ignores the need to configure mixing zones on the basis of site-specific factors and <u>actual</u> risk of exposure. These commenters also asserted that the Region's recommended mixing zone size limitations are not appropriate for ephemeral streams located in arid regions.

Response: Although the Region intends to provide States and Tribes with flexibility to address the size restriction issue, we continue to recommend that States and Tribes establish maximum mixing zone size restrictions. An important consideration on this issue is that specifying maximum size limits simplifies implementation by avoiding the need to conduct detailed and resource-intensive studies in each case. The Region notes that a large number of States, including those in arid Regions, now specify maximum allowable mixing zone dimensions. In several cases, States in arid Regions have specified maximum mixing zone size limitations that are more restrictive than those recommended by EPA Region VIII. However, where States or Tribes are interested in developing an approach to limiting mixing zone size based on site-specific factors, we would consider all proposals and work with the State or Tribe. We also note that the recommended approach provides for much greater consideration of site-specific factors than does the current dilution approach now applied within the Region. The Region is confused by the ephemeral streams comment since in most cases discharges to ephemeral streams will not be eligible for a mixing zone because of a lack of flow at the critical condition.

13. Several commenters questioned EPA Region VIII's draft recommendation to require compliance with chemical-specific acute aquatic life criteria at the end-of-pipe. These commenters asserted that it is sufficient to demonstrate (consistent with EPA TSD methods) that lethality to organisms, either swimming or drifting through the mixing zone, will not occur.

Response: The Region intends to provide States and Tribes with the flexibility to determine how best to ensure that no acute lethality occurs within mixing zones. The TSD method referenced would be acceptable to the Region. For States and Tribes that elect to provide for zones of initial dilution (i.e., zones where acute criteria may be exceeded), the Region would also accept and prefers the method specified in Appendix D of this policy. In general, however, the Region continues to recommend that a zone of initial dilution approach not be followed and that chemical-specific acute aquatic life criteria be implemented at the end-of-pipe as the most efficient and effective way of ensuring compliance with the "no acute lethality" requirement.

14. Comments were received questioning EPA's recommended one-hour averaging period for acute aquatic life criteria, particularly for metals. These commenters recommended that EPA Region VIII should ensure that the draft policy is consistent with any recommendations coming out of the Aquatic Life Criteria Guidelines Committee findings.

Response: EPA Region VIII is monitoring the progress of the Aquatic Life Criteria Guidelines Committee and is aware that changes to the Agency's recommended § 304(a) criteria may be issued at some point in the future. When and if such changes are finalized, the Region will make appropriate revisions to this policy. The Region also notes that, regardless of the averaging period specified by the criterion, a mixing zone or zone of initial dilution is an area where the criterion magnitude may be continuously exceeded. Since most State criteria (per EPA guidance) specify that exceedences may occur only once every three years, and State standards generally require that mixing zones be kept as small as practicable, the Region believes that there are strong reasons for keeping mixing zones and zones of initial dilution small. This is one reason why the Region continues to prefer that acute criteria be applied at the end-of-pipe, without a zone of initial dilution.

15. Comments were received asserting that the Region's draft policy presumes that an exceedence of the acute criteria is indicative of actual acute in-stream toxicity. This commenter recommended that the Regional policy integrate WET testing results into the

mixing zone decision; where WET testing results show no actual acute toxicity, extending mixing zones should be authorized.

Response: The presumption incorporated into the policy is that exceedence of the acute criteria is predictive of acute toxicity and therefore that exceedence of the acute criteria should be avoided. The Region also continues to believe, as advocated in EPA's TSD and the Agency's policy of independent application, that both whole effluent toxicity and chemical-specific methods should be fully implemented. This means that a finding of "no toxicity" based on a WET test is not adequate grounds for suspending application of chemical-specific requirements. Because they are areas where criteria are exceeded, mixing zones should be kept small, regardless of the outcome of WET tests.

16. Several commenters asserted that the Region's approach should consider the actual toxicological mode of action for the pollutant of concern (e.g., the selenium standard is a bioaccumulation concern based on long exposures, not rapidly induced acute toxicity).

Response: Although this issue could be considered a mixing zone issue, the Region believes that it is more appropriately considered when establishing criteria. It is our understanding that this issue is being addressed by the Aquatic Life Criteria Guidelines Committee. Developing guidance to address this concern is beyond the scope and intent of this Regional policy statement.

17. Comments were received that the Region should account for dilution when establishing acute WET limitations.

Response: As explained in the response to a similar comment on the first draft of this policy (see comment # 8, above), the Region believes that in incomplete mix situations, compliance with acute chemical-specific and acute WET limits should be required at the end-of-pipe without an allowance for dilution. The Region has decided to allow States and Tribes the flexibility to consider dilution in establishing chemical-specific, but not WET, daily maximum or "acute" permit limits. For acute WET limits, the Region will continue to require compliance at the end-of-pipe without an allowance for dilution. The basis for this requirement is the need, based on State requirements and long-standing EPA policy, to avoid acute lethality within mixing zones. Because the endpoint for acute WET tests is 50% lethality of test species, an allowance for dilution would result in a portion of the mixing zone where greater than 50% lethality of aquatic organisms could potentially occur. The likelihood for lethality within the mixing zone is increased due to the fact that only two species are generally used in conducting WET tests. Thus, the Region believes that implementation of acute WET limits at 100% effluent provides reasonable but not certain assurance that acutely lethal conditions will be avoided in mixing zones; and that providing a dilution allowance would create an unacceptable source of additional uncertainty.

18. A comment was received inquiring about the use of diffusers including their effectiveness and any operation and maintenance problems.

Response: In response to this comment, the Region conducted a survey of industries and municipal facilities nationwide that utilize diffusers. The methods and results of that survey are described in a report that is available from the Region. Generally, the survey indicated that the facilities contacted have been extremely satisfied with the performance of the diffusers, with 75% of facilities reporting no minor or major operational problems since installation. State officials expressed satisfaction with the enhanced mixing, as verified through dye dilution tests.

19. One commenter noted that under step 3 of the model procedure, a small POTW with a high dilution ratio may be allowed the full critical low flow as a dilution allowance. For a pollutant such as chlorine, and assuming the dilution ratio is greater than 50:1, that could lead to water quality-based effluent limits for total residual chlorine of 1 mg/l or more. What is the rationale for concluding that such POTW discharges will not result in toxicity in the receiving water, when the ambient acute criterion for chlorine is 19 ug/l?

Response: Step 3 of the model procedure does allow special considerations for small POTWs with high dilution ratios (e.g., an allowance of the full critical flow as a dilution allowance). For minor POTWs with dilution ratios greater than or equal to 50:1, the procedure *presumes* that such special considerations are appropriate. Minor POTWs with dilution ratios less than 50:1 may also qualify at the discretion of the permit writer. However, the procedure does not *require* the permit writer to follow this approach for every parameter. The procedure specifies that "in any case where the permit writer determines that applying this procedure could pose unacceptable environmental risks, the minor POTW will not qualify for this procedure." The intent is to allow the permit writer the discretion to override, on a parameter-by-parameter basis, the presumption that is built into the model procedure for minor POTWs with greater than or equal to 50:1 dilution. Using the example of a discharge of chlorine at 1 mg/l or more, a permit writer would have the flexibility to determine that such a discharge poses an unacceptable risk of acute lethality to aquatic life in the vicinity of the discharge. Such a determination would make sense in cases where aquatic life is known to be attracted to the effluent plume. Permit writers also have discretion to establish technology-based requirements where it is determined that limitations more stringent than required by water quality standards are reasonably achievable. Finally, any new or expanded discharge could be subjected to antidegradation requirements, which may result in an analysis of alternatives and a similar finding that a more restrictive permit limit is a reasonably achievable alternative.

APPENDIX C. STATE, TRIBAL, AND EPA MIXING ZONE AND DILUTION POLICIES AND IMPLEMENTATION METHODS

Introduction

This appendix presents information on current mixing zone and dilution policies and implementation methods of various States, Indian Tribes, and EPA Regional Offices. The information was submitted by the water quality standards coordinators and water quality permit specialists in EPA's Regional offices in response to a written request from EPA Region VIII dated August 26, 1993. The Region VIII request for information included specific questions on how States, Indian Tribes, or EPA Regions currently address a number of mixing zone and dilution issues when developing water quality-based permits. The purpose of the survey was to allow a comparison of current State, Tribal, and Regional approaches to each other and to the methods included in EPA's various guidance documents. A main objective was to characterize the range of implementation approaches nationally on key mixing zone and dilution topics.

The survey requested information on current approaches on a number of mixing zone and dilution issues, including any information regarding:

- methods for determining whether a discharge exhibits ***complete or incomplete mixing***,
- ***dilution flows*** typically provided in complete mix situations,
- whether any incomplete mix, ***mixing zone-based permits*** have been issued, and if so, how such permits were developed,
- situations where dilution or mixing zones are or may be ***denied***,
- policies specifically for ***wetland discharges***,
- policies specifically for ***small facilities***,
- the ***legal basis*** for providing mixing zones and dilution, and
- regulatory mixing zone ***size limitations***.

Results

Seven responses were received from EPA Regions III (Philadelphia), IV (Atlanta), V (Chicago), VI (Dallas), VII (Kansas City), IX (San Francisco), and X (Seattle). Including the six States in EPA Region VIII, the survey included 48 of the 60 jurisdictions currently administering a CWA § 303(c) water quality standards program. A summary of the responses for each survey question is presented below. Included in the summary for each question is an overview of both the current approach employed in EPA Region VIII and the "model" or recommended approach proposed by the Region. In general, the survey responses show that there is a range of approaches in use nationally, and that the approaches recommended for use by EPA Region VIII are identical, or very similar, to those already in use elsewhere.

Question 1(a). What guidelines, rules-of-thumb, initial presumptions, or other thresholds, if any, are used by your States/by the Region to determine whether a discharge exhibits complete or incomplete mixing?

Current Approach Used in EPA Region VIII: This issue is typically not addressed in Region VIII when developing water quality-based permit limits (i.e., the decision regarding the appropriate dilution allowance does not take the local rate of mixing into account).

"Model" Approach Proposed by the Region: The model procedure calls for determining complete or incomplete mixing based on best professional judgment (BPJ). The procedure presumes complete mix where there is an effluent diffuser that covers the entire stream/river width at low flow or when the mean daily flow of discharge exceeds the chronic low flow of receiving water (i.e., where effluent flow > stream flow). In other cases, the permittee may show complete mixing consistent with a study plan developed in consultation with the State and EPA. "Complete mixing" is defined as no more than a 10% difference in bank-to-bank concentrations within a longitudinal distance not greater than 2 stream/river widths.

Overview of Survey Responses: The survey responses indicate that most Regions and States do not have formal guidelines or "rules of thumb" to define where complete mix or incomplete mix is occurring. In Region III, if the effluent constitutes 50% or more of instream flow, it is assumed that the stream is effluent-dominated and that complete mixing occurs. The other Regions typically indicated that either "complete mix is generally presumed" (Regions V and VI) or "incomplete mix is generally presumed" (Regions VII and IX), and that the initial presumption can be overridden based on site-specific analysis. It is important to note that some States that were reported as "assuming complete mix" also provide dilution allowances which are less, and sometimes significantly less, than the critical low flow (see Question 1(b)). Thus, many times where "complete mixing" is assumed, a dilution allowance is ultimately provided that is consistent with, or more stringent than, what would result from an "incomplete mix" approach. One example of a narrative approach to this issue was reported for Illinois. In Illinois, for purposes of determining whether a zone of initial dilution (ZID) should be allowed when implementing acute aquatic life criteria, immediate dispersion is defined as: "an effluent's merging with receiving waters without delay in time after its discharge and within close proximity of the end of the discharge pipe, so as to minimize the length of exposure time of aquatic life to undiluted effluent."

Question 1(b). What human health and aquatic life dilution flows are typically used by your States/by the Region where complete mixing is occurring?

Current Approach Used in EPA Region VIII: As discussed above, water quality-based permits in Region VIII are typically not affected by whether the discharge exhibits complete mixing or incomplete mixing. Rather, in nearly all permits the following dilution flows are provided:

	Aquatic Life	Human Health
Colorado	Chronic (30 day) - 30E3	30 day standards - 30E3
	Acute (1 day) - 1E3	1 day standards - 1E3
Montana	7Q10	7Q10
North Dakota	7Q10	7Q10
South Dakota	7Q25 or 7Q5[1]	7Q25 or 7Q5[1]
Utah	7Q10	7Q10
Wyoming	7Q10	7Q10

"Model" Approach Proposed by the Region: The flows shown below are used as a maximum allowance under the model procedure. However, dilution may be limited to a portion of the critical low flow based on site-specific environmental concerns. The procedure specifies that the actual duration (e.g., 4 day) and frequency (e.g., 3-year) of the flows used should match the duration and frequency provisions found in state water quality standards.

Region VIII Recommended Critical Low Flows:

Aquatic life, chronic	4-day, 3-year flow (biologically based)
Aquatic life, acute	1-day, 3-year flow (biologically based)
Human health (carcinogens)	harmonic mean flow
Human health (non-carcinogens)	4-day, 3-year flow (biologically based) or 1-day, 3-year flow (biologically based)

[1] 7Q25 is provided for segments classified coldwater permanent, coldwater marginal or warmwater permanent. 7Q5 is provided for segments classified warmwater semipermanent or warmwater marginal.

Overview of Survey Responses: The survey indicated a wide range of different dilution flows in complete mix situations. By contrast, Region IX indicated that: (1) this question is not relevant because complete mix assumptions are not made in Region IX, (2) their focus has been on implementing mixing zone size requirements, and (3) complete mixing has not typically been achieved even at the edge of the mixing zone. Responses from other Regions indicated that, where complete mix is assumed, dilution may be based on all or a portion (e.g., 1/6, 1/4, 1/3, 1/2) of the following flows: 1 cfs, 1Q10, 7Q10, 7Q2, 30Q10, 1Q20, 3Q20, or the biological flow for aquatic life, and the annual average, long-term average, harmonic mean, 30Q5, 30Q2, or the 7Q10 flow for human health. In some States, acute aquatic life criteria are required to be met at the end-of-pipe without an allowance for dilution (e.g., Florida), even in complete mix situations. In other States, acute criteria are implemented assuming full low flow as dilution (e.g., Georgia, where the 7Q10 is provided). See examples in Table 1. The differences between the low flow statistics listed in Table 1 will vary. For example, the TSD reports that, for sixty streams selected at random, the harmonic mean flow was at least 2 times the 7Q10 flow at all sixty sites, and was at least 3.5 times the 7Q10 flow at forty sites. The TSD also reports that for smaller rivers (i.e., low flow of 50 cfs), the 30Q5 flow averaged 1.1 times the 7Q10 flow; while for larger rivers, (i.e., low flow of 600 cfs) the 30Q5 flow averaged 1.4 times the 7Q10 flow.

Question 2(a). Have your States or has the Region issued <u>mixing zone-based</u> permits following an assumption of incomplete mixing (please give any notable examples or some indication of frequency)?

Current Approach Used in EPA Region VIII: No, with very few exceptions. Permits generally are provided the full critical flow as dilution, with no mixing zone analysis or requirements considered. Exceptions include a very small number of permits in Colorado and Utah where a mixing zone-based permit limit was developed.

"Model" Approach Proposed by the Region: Under the Region's model procedure, mixing zone-based permit limits would be developed wherever incomplete mixing is occurring. As discussed under Question 1(a), incomplete mixing would generally be presumed unless: (1) the low flow is zero, (2) there is an effluent diffuser that covers the entire stream/river width at low flow, (3) the mean daily flow of discharge exceeds the chronic low flow of receiving water, or (4) the permittee demonstrates complete mixing consistent with a study plan developed in consultation with the State and EPA.

TABLE 1
EXAMPLE REGION/STATE DILUTION FLOWS ALLOWED IN COMPLETE MIX SITUATIONS

REGION/ STATE	AQUATIC LIFE	HUMAN HEALTH	NOTES
Region 3	Acute: 1Q10 Chronic: 7Q10	Carcinogens: harmonic Mean Non-Carcinogens: 30Q5	
Alabama	Acute: 1Q10 Chronic: 7Q10	Carcinogens: annual average Non-Carcinogens: 7Q10	
Florida	Acute: end-of-pipe Chronic: not specified	harmonic mean	a
Georgia	7Q10	annual average	
Kentucky	7Q10	Carcinogens: harmonic mean Non-carcinogens: 7Q10	
Tennessee	3Q20 1Q20 for regulated streams	30Q2	
Illinois	1/4 7Q10	1/4 harmonic mean	
Indiana	1/2 7Q10	1/2 7Q10	
Ohio	Acute: 7Q10 Chronic: 30Q10	harmonic mean	b
Wisconsin	1/4 7Q10 (c)	1/4 annual average	
Arkansas	Acute: 1/8 7Q10 (d) Chronic: 1/4 7Q10 (d)	harmonic mean or long-term average	
Oklahoma	1/4 7Q2 or 1 cfs	long-term average	
Texas	Acute: 1/4 7Q2 Chronic: 7Q2	harmonic mean	
Region 7	mostly 7Q10	mostly 7Q10	
Region 9	N/A	N/A	
Idaho	Acute: 1Q10 Chronic: 7Q10	harmonic mean	

Table 1 Notes:

a For aquatic life, Florida is proposing 7Q10 for chemical-specific criteria, 1Q10 for chronic WET.

b Ohio allows a varying portion of the low flow that is inversely related to stream flow (the more flow in the stream, the less is assumed to mix completely with the discharge) up to the entire low flow.

c One quarter of the biological flow is used for aquatic life if that flow is available.

d These restrictions are for toxics; for non-toxics, the 7Q10 flow is applied.

Overview of Survey Responses: Although some States were reported as providing the full low flow regardless of the local mixing rate (e.g., New Mexico, Georgia), true "mixing zone" based permits are routinely developed in Regions III, VII, IX, and X (for estuarine discharges). In addition, in a number of other States (including all States in Region V) the amount of dilution provided is similar to, or more stringent than, what would result from application of a mixing zone approach. Some examples include:

- Region III: Pennsylvania, West Virginia, Delaware, and Virginia implement a mixing zone-based approach wherever incomplete mixing is occurring. The procedure involves assessing each discharge to determine complete/incomplete mixing, and then developing the wasteload allocations using their procedures (the incomplete mix procedures all involve some sort of mixing zone approach). For example, Pennsylvania has been modeling mixing zones using concepts similar to those proposed by Region VIII for some time. The District of Columbia and Maryland are starting to implement this approach.

- Region IV: In Florida, approximately 10 permits have been developed using a mixing zone-based approach.

- Region VI: In Arkansas, for toxics, water quality-based permits are developed assuming a mixing zone equal to one quarter of the 7Q10 flow. In Oklahoma, for aquatic life, water quality based permits are developed assuming complete mixing with 25% of the 7Q2 low flow, or 1 cfs, whichever is greater. For the three Indian Tribes administering water quality standards programs, no mixing zone or dilution is provided.

- Region VII: All medium-large river discharges have mixing zone-based permits, with very few exceptions. For example, in Nebraska, the State models the critical low flow to be awarded for dilution based on restricting the plume to the appropriate length.

- Region IX: The focus has been on compliance with standards at the edge of the mixing zone. Generally, complete mixing has not been found to occur.

- Region X: In Idaho, complete mix is generally assumed, with 25% of the low flow provided as dilution. In Alaska, the Region is assessing marine mixing using near and far-field models. Most major permits to marine and estuarine receiving waters have mixing zone analyses based on modeling. Mixing zone is set at specified radius from the discharge, not to exceed 10% of the width of a waterbody or 10% of the area (whichever is less). For river discharges, a complete mix assumption is the norm, but careful assessment of mixing may occur on a case-by-case basis.

Question 2(b). What method is used by the Region/by your States to quantify the level of dilution provided in incomplete mix situations (e.g., modeling, a set % of critical low flow, field study)?

Current Approach Used in EPA Region VIII: In one of the very few examples of a "mixing zone" approach, a field study was conducted. The purpose of the study was primarily to determine the point downstream where complete mixing was achieved. That point was chosen as the end of the mixing zone and the point of compliance. In another case involving a lake discharge, however, a modeling method was used to achieve chronic criteria within a 200 foot radial distance of the discharge.

"Model" Approach Proposed by the Region: Any of three progressively more sophisticated methods may be utilized under the model procedure. The ***default method*** is to be used where data necessary to implement a more sophisticated approach are lacking or where a conservative approach is warranted based on site-specific environmental concerns. For streams, the default method requires that no more than 10% of the critical low flow be provided as dilution. For lakes, the default method requires that no more than 4:1 dilution be allowed (20% effluent). The ***modeling method*** is used to ensure that regulatory mixing zone size restrictions are achieved at low flow. Several different modeling methods, ranging from simple (ambient diffusion only) to more complex (discharge-induced and ambient diffusion) are recommended. The ***field study method*** requires use of field data quantifying the actual ambient mixing rate to implement regulatory mixing zone size restrictions.

Overview of Survey Responses: Generally either a set percentage of the low flow or a mixing zone model (such as CORMIX or PLUME) is used to implement mixing zone size and shape requirements. Occasionally, a field study is conducted to characterize the actual pattern and rate of mixing. In Region IX States, monitoring requirements are included in the permit to verify that standards are achieved outside the mixing zone. Examples include the following:

- Region III: The Region and the States have used the Cornell Mixing Zone Model (CORMIX), a % of the low flow, exposure analysis, and a few dye studies to implement mixing zone requirements.

- Region IV: In Florida, for 3 paper mills and 5 POTWs, dye studies were completed. In Kentucky, 1/3 of the 7Q10 flow is used to implement chronic mixing zone requirements; for acute, the State routinely uses the models UMERGE AND UDKHDEN to implement ZID requirements for small discharges to large rivers (such as the Ohio).

- Region VII: Generally, a set % of the low flow is provided as dilution to implement mixing zone requirements (e.g., 1/4 low flow). In some cases, site-specific mixing dynamics are characterized with modeling (e.g., in Nebraska).

- Region IX: In marine waters, the PLUME model or equivalent is used to determine a dilution ratio based on momentum and density differences under critical conditions. The dilution ratio is then used with numeric standards (chronic values) to determine effluent limits. In fresh waters, a set percentage of the low flow (often a court decreed minimum flow) is used to implement mixing zone requirements. Field studies/ambient water quality monitoring are normally a requirement for marine and fresh waters to verify compliance with mixing zone requirements.

- Region X: In Idaho, a set % of the low flow is used (25%). In Alaska, the models UMERGE, UPLUME, CDIFF, RDIFF, WASP4, etc. are used by the Region for marine discharges, sometimes with dye study for confirmation.

Question 2(c). What mixing zone or dilution, if any, is provided by the Region/by your States for acute aquatic life criteria where incomplete mixing is occurring?

Current Approach Used in EPA Region VIII: Generally, an incomplete mixing assumption is not made and the critical low flow is provided as dilution. In one of the few instances where a mixing zone approach was implemented, the 1985 TSD method of requiring compliance with acute chemical-specific criteria within a short distance of the outfall[1] was used. For acute whole effluent toxicity limitations, compliance is generally required at the end-of-pipe without an allowance for dilution, with very few exceptions.

"Model" Approach Proposed by the Region: Under the model procedure, to avoid acutely lethal concentrations within mixing zones, acute chemical-specific aquatic life criteria and acute whole effluent toxicity limits must be achieved at the end-of-pipe without an allowance for dilution[2].

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[1] This method requires compliance with acute criteria within the most restrictive of the following: (1) 10% of the distance from the outfall to the edge of the mixing zone, (2) a distance of 50 times the discharge length scale in any spatial direction, or (3) a distance of 5 times the local water depth in any horizontal direction from the discharge outlet.

[2] Although not recommended by the Region, States and Tribes may designate a small portion of the chronic mixing zone within which acute <u>chemical-specific</u> criteria must be achieved (i.e., a zone of initial dilution).

Overview of Survey Responses: Generally, States are using a variety of methods to implement acute criteria in incomplete mix situations. A number of States require compliance with acute criteria or the FAV (twice the CMC) at the end-of-pipe. Other States provide a set percentage of the chronic mixing zone or critical low flow as a zone of initial dilution (ZID). As discussed above under Question 1(b), a number of States routinely "assume complete mixing" and thus avoid this issue. Finally, some States provide fixed ZID size limitations in their water quality standards. Examples include:

- Region III: The Region recommends any of the methods for preventing lethality to passing organisms outlined in the TSD. In Pennsylvania, the State uses the 15 minute travel time guideline described in the TSD. In Virginia, half of the 1Q10 flow is provided as dilution for acute criteria or compliance with the FAV is required at the end-of-pipe for stream dominated situations.

- Region IV: In Florida, compliance with acute criteria is required at the end-of-pipe. In Kentucky, the State is proposing that no new ZIDs be allowed in High Quality waters, lakes, and reservoirs; for all other waters, a new ZID will only be allowed if a submerged multi-port outfall structure is present, and ZID size will be restricted based on the 3 TSD recommendations (square root of port cross-sectional area, etc.)

- Region V: Compliance with the FAV is typically required at the end-of-pipe.

- Region VI: In Arkansas, for toxics, the acute dilution allowance is assumed to be 1/8 of the 7Q10 flow. In Texas, for streams and rivers, the standards limit ZID size to 60 feet downstream and 20 feet upstream from a discharge point; however, the dilution allowance for acute criteria is generally one quarter of the 7Q2 low flow. For lakes and reservoirs, the standards limit ZID size to a radius of 25 feet from the point of discharge. New Mexico requires compliance with acute criteria at the end-of-pipe, without an allowance for dilution.

- Region VII: In Nebraska, for coldwater Class A and B and Warmwater Class B streams, acute mixing zones must be $\leq$ 125 feet in length or < 5% of chronic mixing zone length, whichever is most restrictive. For warmwater Class A streams, ZIDs must be $\leq$ 250 feet or < 5% of chronic mixing zone length, whichever is less. Also, all acute mixing zones must be $\leq$ 1/2 stream width. In Missouri, for Class C streams with 7Q10 < 0.1 cfs, no ZID is allowed; for all other streams and for lakes, the ZID equals 10% of the mixing zone.

- Region IX: Normally, acute aquatic life criteria are met at the end-of-pipe. Exceptions have been granted for some thermal discharges and for some deep ocean water discharges having very high initial dilution.

- Region X: In Idaho, 25% of 1Q10 flow is provided. In Alaska, for marine discharges, compliance with acute criteria is required at the end-of-pipe.

Question 3. Does your Region/do your States have policies or cases where dilution or mixing zones are prohibited either in general or for particular pollutants or types of waterbodies (i.e., for a reason other than a zero critical flow)?

Current Approach Used in EPA Region VIII: In South Dakota, lake discharges are not allowed a zone of mixing. In some of the other States, there is policy language that could be used as a basis for denying a mixing zone in specific cases. For example, the Colorado water quality standards state that "the ecological and human health effects of some pollutants may be so adverse that a mixing zone for such pollutants will not be allowed."

"Model" Approach Proposed by the Region: The model procedure requires all discharges to wetlands to achieve compliance with water quality criteria at the end-of-pipe, without an allowance for dilution. Also, a mixing zone or dilution allowance may be denied or limited where allowing such dilution would pose unacceptable environmental risks. Such risk determinations are to be made on a case-by-case basis in consideration of relevant site-specific concerns, including bioaccumulation in fish tissue or sediment, biologically-important areas, potential human exposure from drinking water or recreation, attraction of aquatic life to the effluent plume, toxicity/persistence of the substance, zone of passage for migrating fish (including access to tributaries), and cumulative effects of multiple discharges and multiple mixing zones.

Overview of Survey Responses: The responses indicate that mixing zones may be prohibited based on a variety of factors, including presence of: drinking water intakes, critical habitat, recreational areas, ceremonial use areas, shore fishing areas, or tributaries. Mixing zones may also be denied for particular substances such as bioaccumulative or persistent toxics, or for particular types of waterbodies such as lakes or reservoirs. Examples include:

- Region III: Mixing zones are not appropriate where: (1) the mixing zone would infringe on critical habitat areas such as spawning areas, areas with sensitive biota, drinking water supplies, or public recreation areas, (2) the discharge plume attaches to the stream bottom, or (3) the discharge contains bioaccumulative pollutants defined as substances with a BCF of 100 or greater. In Virginia, for discharges to lakes, the acute and chronic wasteload allocation should be set equal to the acute and chronic standard, respectively.

- Region IV: In Alabama, industrial facilities not discharging below the surface are not provided a mixing zone. In Kentucky, the State is proposing that no new mixing zone or ZID be allowed for existing priority pollutant discharges to lakes and reservoirs.

- Region V: The Great Lakes Water Quality Guidance proposes to eliminate mixing zones for certain bioaccumulative and persistent pollutants. In general, Region V States restrict mixing zones in close proximity to bathing beaches, drinking water intakes, shore fishing areas, and the mouths of tributaries.

- Region VI: In Arkansas, mixing zones are not allowed for bacteria, oil, grease, and pH. Mixing zones shall also not include any domestic water supply intake. For the Pueblos of Isleta, Sandia, and San Juan, mixing zones are prohibited to allow for recreational and/or ceremonial use of all reservation waters.

- Region VII: In Nebraska, for public water supply criteria, mixing zones cannot extend to within a 2 mile zone of influence from any public drinking water supply intake.

- Region IX: In Guam, mixing zones are prohibited in high quality waters (M-1 marine and S-1 inland).

- Region X: Under the current Alaska water quality standards, mixing zones are not currently allowed for carcinogens, mutagens, teratogens, and pollutants that bioaccumulate without a finding from the State that the effects within such a zone would be insignificant.

Question 4. Does your Region/do your States have policies or cases with regard to dilution or mixing zones for discharges to wetlands?

Current Approach Used in EPA Region VIII: Colorado recently clarified the water quality standards applicable to wetlands, and that effort resulted in development of a draft implementation document that described the mixing zone approach to be followed for wetland discharges. This draft guidance calls for the size and shape of the mixing zone within a wetland to be determined by the Division considering factors contained within the State water quality standards. Generally, the guidance calls for viewing a discharge to a wetland in a manner similar to a discharge to a standing water body.

"Model" Approach Proposed by the Region: The model procedure requires all discharges to wetlands to achieve compliance with water quality criteria at the end-of-pipe, without an allowance for dilution.

Overview of Survey Responses: Overall, the responses indicate few mixing zone-dilution policies specific to wetland discharges. Those that exist generally require compliance with criteria at the end-of-pipe. Examples include:

- Region III: In Virginia, for discharges to marshes or swamps, the acute and chronic wasteload allocation should be set equal to the acute and chronic standard, respectively.

- Region IV: In Florida, the water quality standards require that "substances in concentrations which are chronically toxic to humans, animals, or plants, or provide adverse physiological or behavioral response in humans or animals, shall not be present" in a wetland. EPA implements this requirement by not giving credit for dilution when calculating WET limits for discharges to wetlands.

- Region V: Generally, mixing is not allowed if a discharge is to a wetland.

- Region VI: In Louisiana, discharges to freshwater lakes, ponds, and wetlands must achieve criteria within a 100 foot mixing zone and a 25 foot ZID.

- Region VII: In Iowa, for all pollutants, no mixing zone or ZID is allowed for waters designated as lakes or wetlands.

Question 5. Does your Region/do your States have policies or cases where less-restrictive mixing zone-dilution requirements are applied to small facilities (e.g., de minimis discharges, exemptions for certain types of discharges, etc.)?

Current Approach Used in EPA Region VIII: The full critical low flow is provided as dilution in virtually all permits, regardless of mixing rate, facility size, stream size, or other site-specific information.

"Model" Approach Proposed by the Region: For certain minor POTWs, the model procedure would allow the full critical low flow as dilution, as long as allowing such dilution poses insignificant environmental risks.

Overview of Survey Responses: No mixing zone or dilution policies specific to small facilities were reported in the survey responses.

Question 6. In each of your States what written authority, if any, is the basis for providing a mixing zone or dilution for water quality-based permits (e.g., mixing zone policy, low-flow policy, other)?

Current Approach Used in EPA Region VIII: EPA Region VIII States generally have some type of mixing zone or low flow policy, or both, in their adopted water quality standards. In some cases, however, these policies are fairly general and lacking in specific requirements, particularly size limitations.

"Model" Approach Proposed by the Region: The Region's model policy statement would provide detailed and specific authority to establish a mixing zone or make an allowance for dilution when implementing aquatic life and human health criteria. The policy covers chemical-specific and whole effluent toxicity discharge limitations and allows for a site-specific approach based on local mixing rates and environmental concerns. Maximum size restrictions for mixing zones in incomplete mix situations are specified, as are critical low flows that represent the maximum allowable dilution in complete mix situations.

Overview of Survey Responses: The responses indicated that all States have written authority to provide mixing zones or dilution in their water quality standards. A number of States have additional detail in a guidance, policy, or implementation document.

Question 7. What mixing zone size limitations, if any, are included in the water quality standards in your States (e.g., width, length for streams/rivers, diameter for lakes, etc.)?

Current Approach Used in EPA Region VIII: In general, although Region VIII States have a mixing zone and/or low flow policy in their water quality standards, State standards lack specific limitations on mixing zone size. However, at a minimum, narrative requirements for mixing zones are described. As mentioned above, these mixing zone requirements do not normally influence actual permitting decisions.

Colorado: Specific size limitations are not included. The State standards do include several narrative provisions potentially affecting mixing zone size: "where necessary to protect aquatic life, there shall be a zone of passage...", "mixing zones shall not overlap so as to cause harmful effects in adjacent waters or to interfere with zones of passage," and "biological communities shall not be interfered with to a degree which is damaging to the ecosystem..."

Montana: Specific size limitations are not included, but the mixing zone policy requires the extent of the mixing zone to be minimized to the extent practicable, and that a mixing zone not affect existing or reasonably anticipated uses outside the mixing zone.

North Dakota: Mixing zone size is limited to no more than 25% of the cross-sectional area or volume of flow and no more than 50% of the width. Mixing zones must also be as small as possible and shall not intersect spawning or nursery areas, migratory routes, or municipal water intakes.

South Dakota: Size limitations are not included. The State standards do specify, however, that discharges to flowing waters must meet the applicable criteria at the edge of its zone of mixing. For lakes, no zone of mixing is permitted.

Utah: Specific size limitations are not included. Narrative mixing zone requirements in State standards include: "the zone shall small in extent and must not form a barrier to migrating aquat life."

Wyoming: Size limitations are not included. The State mixing zone polic does require, however, a zone of passage around the mixing zone which "shall not contain pollutant concentrations that exceed the chronic aquatic life values."

"Model" Approach Proposed by the Region: The model procedure specifies that the size and shape of mixing zones, where allowed, should be determined case-by-case. The following maximum size restrictions apply. For streams and rivers, mixing zones should n exceed one-half of the cross-sectional area or a length 10 times the stream width at critical low flow, whichever is more limiting. For lakes, mixing zones should not exceed 5% of tl lake surface area or 200 feet in radius, whichever is more limiting.

Overview of Survey Responses: In general, State approaches to limit mixing zone size for streams specify a given fraction (e.g., 1/4, 1/3, 1/2, etc.) of the stream width, cross-sectional area, or flow (i.e., at the critical low flow condition) beyond which the mixing zc may not extend. Note that States with apparently identical width restrictions (e.g., 1/4 cro sectional area) may in fact have different requirements in practice if their critical low flow assumptions are different. Some States supplement the width restriction with a length restriction. A few States provide only a length restriction. For lakes, the typical approach to limit the radial extent of the mixing zone from the point of discharge; however, other approaches are in use. See Table 1 for specific examples.

TABLE 2
EXAMPLE MIXING ZONE SIZE RESTRICTIONS

REGION/ STATE	WIDTH (STREAMS)	LENGTH (STREAMS)	RESTRICTION FOR LAKES	NOTES
Region 3	< 2/3 width			a
Florida	< 3/4 width (b)	< 800 meters	< 125,600 m^2	c
Kentucky	< 1/3 width < 1/2 area		< 1/10 width (b,d)	
Illinois	< 1/4 area/flow		< 26 acres	
Indiana	< 1/4 area/flow < 1/2 width		no discharges	
Ohio	< 1/2 width < 1/5 width at mouth (e) < 1/3 area	< 5 x width		f
Louisiana	< 1/3 low flow (g)		< 100 ft. radius (h)	
Oklahoma	< 1/4 7Q2 (i)	< 13 x width		
Texas		< 300' (dwnstrm) < 100' (upstrm)	< 100 ft. radius	
Missouri	< 1/4 width, area < 1/4 low flow	< 1/4 mile	< 1/4 width or 100 feet radius	f,j
Nebraska		< 2,500 feet		k
Arizona	< 1/2 area	< 500 meters	(l)	
California		< 250 feet	< 25 ft. radius (m)	
Guam	< 1/4 area	< 5 x width		
Idaho	< 1/4 flow, width, or 300 m + diffuser length		< 10% area	

Table 2 Notes:

a	Regional recommendation based on the Red Book.
b	Proposed language.
c	In addition, all mixing zones shall not exceed 10 % of total waterbody length or 10 % of total waterbody area.
d	Would be applied from point of discharge in any spatial direction.
e	The mouth is defined as that area of the stream from the confluence upstream for a distance five times the width of the stream at the confluence.
f	For non-thermal discharges.
g	For streams with 7Q10 flow > 100 cfs; where flow ≤ 100 cfs, the full 7Q10 flow is provided as dilution; for Mississippi and Atchafalaya Rivers other restrictions apply.
h	For discharges to freshwater lakes, ponds, and wetlands.
i	At a minimum, 1 cfs is provided as dilution.
j	For streams with 7Q10 > 20 cfs; for smaller and Class C streams, other restrictions apply.
k	For coldwater Class A and B and warmwater Class B streams; for Warmwater Class A streams, mixing zones shall be less than 5,000 feet.
l	Adjacent mixing zones in lakes shall be no closer than the greatest horizontal dimension of any of the individual mixing zones.
m	In addition, the sum of all lake mixing zones shall not exceed 5 % of lake volume.

APPENDIX D - ALTERNATIVE PROCEDURES FOR CHEMICAL-SPECIFIC ACUTE CRITERIA IN INCOMPLETELY-MIXED SITUATIONS

Background

A common narrative provision found in state water quality standards is the prohibition of acute lethality within a mixing zone[1]. However, applying this "no acute lethality" mixing zone provision can be somewhat problematic in that a decision to allow an acute mixing zone (zone of initial dilution) will typically lead to pollutant concentrations in the immediate vicinity of the discharge that are in excess of the acute chemical-specific criterion. Depending upon the magnitude of exceedence and an organism's duration of exposure, allowing such zones of initial dilution could well result in conditions that are acutely lethal to aquatic life. Not surprisingly, implementation of the "no acute lethality" requirement (i.e., when setting acute chemical-specific as well as WET permit limits) has been addressed in different ways across the country (see summary to Question 2(c) in Appendix C). EPA has acknowledged the difficulties of addressing the issue by presenting four options to avoid acute lethality within a mixing zone in its ***Technical Support Document for Water Quality-based Toxics Control*** (see Section 4.3.3 on page 71).

For both chemical-specific and WET limits, Region VIII recommends the TSD option of meeting acute standards (and toxicity objectives) at the end-of-the-pipe with no consideration for dilution. The Region believes that this is the simplest and most reliable method of avoiding acute lethality within the mixing zone. This recommendation is based, in large part, on the fact that discharges (especially in the winter) tend to attract aquatic life; this phenomenon results in an actual period of exposure to the effluent plume that precludes a simple "swim through" exposure time assumption. In contrast, the Region acknowledges that allowing ZIDs is a fairly common existing practice which is recognized in the TSD, and that certain "incomplete mix" discharges can nevertheless exhibit fairly rapid mixing with the receiving water (especially where there is high discharge momentum). With this in mind, the Region provides the following guidance which allows a zone of initial dilution under certain conditions:

[1] Note that this Region VIII policy statement establishes such a provision as a minimally-required element of state and tribal mixing zone policies (see Issue # 4 in Chapter 2).

Policy

For acute chemical-specific standards in incomplete mix situations, although achieving such standards at the end-of-pipe is recommended by the Region, EPA will also approve mixing zone policies that allow a zone of initial dilution on a case-by-case basis where:

- there is evidence of rapid mixing between the discharge and receiving water based on factors such as a high exit velocity of the discharge (e.g., > 10 feet per second), and

- the rationale for the discharge permit includes an evaluation of risks (such as those described in Step 4 of the Region's model procedure) and a finding that allowing a zone of initial dilution poses no unacceptable risks.

Where both of the above two conditions are met in a particular case, it is recommended that the zone of initial dilution (ZID) for achieving acute standards be limited as follows:

Lakes: The ZID volume may not exceed 10% of the volume of the chronic mixing zone. This may be implemented by allowing a ZID radial distance equal to 10% of the chronic mixing zone radial distance, or through other appropriate methods (e.g., if the chronic mixing zone is 200 feet in radius, then the allowable acute ZID may not be more than 20 feet in radius).

Rivers and Streams: The ZID volume must be small. This may be implemented by applying the more stringent of the following two restrictions:

1) ZID volume or flow may not exceed 10% of the chronic mixing zone volume or flow (e.g., if the chronic mixing zone allows a dilution flow rate of 18 cfs, then the allowable acute ZID would be no more than a flow rate of 1.8 cfs); or

2) ZID length may not exceed a maximum downstream length of 100 feet.

For acute whole effluent toxicity objectives, EPA Region VIII will continue to require that such objectives be achieved at the end-of-pipe without an allowance for dilution (see Issue # 5 in Chapter 2 and Question # 8 in Appendix B for additional discussion).

APPENDIX E - RECOMMENDED CRITICAL LOW FLOWS

Background

There are numerous methods discussed in the scientific literature on how low flows can be calculated for a stream or river. The two fundamental approaches to performing such a calculation are the extreme methods (e.g., log Pearson Type III analysis) and the empirical methods (e.g., EPA's biologically-based method). In addition to deciding what method is most appropriate for their waters, both States and Tribes must address the issue of what is the appropriate return interval (frequency) and averaging period (duration) for the chronic and acute numeric criteria they have adopted.

Region VIII has made recommendations pertaining to critical low flows in their Mixing Zone and Dilution Policy Document while at the same time acknowledging the need to tailor decisions concerning critical low flows. The following describes some of the rationale for those recommendations.

Recommendations Related to Critical Low Flow

METHOD OF CALCULATING FLOWS: Region VIII believes calculation of critical low flows is best performed by using the method developed by EPA. This method is referred to as the "biologically-based" method, but is actually a non-parametric method for analyzing a flow record. This method could be used on <u>any</u> combination of an X day, Y year low flow. For example, it can be used to calculate a 7Q10, a 7Q25, a 30Q3, as well as a 4 day, 3 year low flow. The following observations are made when comparing the biologically-based method and the more traditional, extreme methods:

- The extreme methods typically rely on the existence of a numeric distribution (the ability to fit a line through a certain plot of flow data). Because data typically does not fit the distribution exactly (especially at the very low flows), there can be considerable error associated with this "force-fitting" of the data to a distribution. The EPA biologically-based method, on the other hand, does not require the flow data to follow any numeric distribution. An empirical analysis is simply performed to determine what X-day flow has occurred on the average every Y-years.

- The extreme methods typically use only one data point for every year of record. In contrast, the EPA biologically-based method utilizes all the data and performs an analysis of all flows and their long term trends through time. For example, for a 12 year data set, many of the extreme methods would make a determination using only 12 data points. In contrast, the biologically-based method would use over

4000 data points for that same period to determine critical low flows. A greater number of data points makes the biologically-based method more statistically robust.

- The extreme methods only account for one low flow excursion value per year even if there were multiple low flow excursions of the same magnitude within the year. The biologically-based method considers all the low flow excursions for the full period of record. Because of this, flows calculated using the biologically-based method are typically lower than the same X-day Y-year flow calculated using an extreme method.

An analysis was performed on daily flow data from several stream stations to determine the actual frequency of a 7Q10 low flow calculated using the log Pearson III extreme method. It was seen that 7Q10's calculated using the extreme method reoccur much more frequency than once every 10 years. Typically, 7Q10's calculated through this method reoccur every 3 years or more frequently. The results of this analysis as well as a comparison between different critical low flows are given in Table E-1.

TABLE E.1 COMPARISON OF VARIOUS CRITICAL LOW FLOWS

Stream Station (USGS Gauge Number)	7Q10 Flow Extreme Method log Pearson III (cfs)	Actual Recurrence Interval for 7Q10 (years)	7Q10 Flow Biologically-based Method (cfs)	4 Day, 3 Year Flow Biologically-based Method (cfs)	Harmonic Mean Flow (cfs)
Shoshone R. (WY) 06285100	124	2.5	73	79	557
Waphpeton R. (ND) 05051500	16.7	1.8	2.0	7.8	131
Virgin R. (UT) 09408150	38	2.5	32	34	116
Wind R. (WY) 06235500	67	1.8	54	56	246
Green R. (CO) 09217000	32	2.7	27	31	85

DURATION/FREQUENCY: Some of the fundamental aspects of numeric water quality standards for surface waters are the duration (e.g., 4 day averaging period) and frequency (e.g., exceedence allowed every 3 years). States and Tribes are encouraged to take these aspects into consideration when defining "critical" low flows--those flows that are used in establishing acceptable loads to achieve water quality standards. Region VIII recommends that the duration and frequency provisions found in the standards reflect the duration and frequency of critical design flow. For example, if a particular aquatic life criteria has a 4 day, 3 year duration and frequency, the 4 day, 3 year low flow is recommended for use in implementing that standard. It is important to note that a State or Tribe should use different critical low flows for each of their chronic standards and acute standards, matching the appropriate durations and frequencies of these criteria.

EPA has developed a PC-based program that can be used to analyze daily flow records using either the log Pearson III extreme method or the EPA biologically-based method. This computer program (DFLOW) can calculate any combination of X-day and Y-year for the period of record. In addition, the program can be used to calculate the harmonic mean for use with certain human health criteria.

The following are two references available from EPA to further provide details on flow analysis as well as describe the basis of the DFLOW model:

US EPA (1986). Technical Guidance Manual for Performing Waste Load Allocation; Book VI; Design Conditions: Chapter 1, Stream Design Flow for Steady-State Modeling; Office of Water.
US EPA (1990). DFLOW User's Manual; Dr. L. Rossman, ORD/RREL.