Regulatory Mixing Zone Internal Management Directive

Part Two: Reviewing Mixing Zone Studies

June 2013

DEQ
State of Oregon
Department of
Environmental
Quality

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By: Sonja Biorn-Hansen
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Questions or comments on this IMD can be directed to:
Sonja Biorn-Hansen, DEQ Surface Water Management Section, or Steve Schnurbusch, Western Region, Salem Office.

Alternative formats (Braille, large type) of this document can be made available.
Contact DEQ’s Office of Communications & Outreach, Portland, at (503) 229-5696, or toll-free in Oregon at 1-800-452-4011, ext. 5696.

Disclaimer

This internal management directive (IMD) represents the department's current process for allocating regulatory mixing zones and reviewing mixing zone studies. The recommendations in this IMD should not be construed as a requirement of rule or statute. The IMD outlines general guidelines; it is not meant to limit how the department conducts regulatory mixing zone analyses, which are performed on a case-by-case basis. The department anticipates revising this document as needed to address additional issues or clarify direction to staff.

Document Development

Prepared By: Sonja Biorn-Hansen May 2012

Reviewed By Steve Schnurbusch and Ranei Nomura Spring 2012

Approved By: ______________________ Date: __________

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1. Introduction

Overview

Purpose

The purpose of this internal management directive (IMD) is to assist department staff in allocating regulatory mixing zones (RMZs) in National Pollutant Discharge Elimination System (NPDES) individual permits for intermittent and continuous wastewater discharges. The effective implementation date for this IMD is July 1, 2008. All completed applications received after this date must be processed pursuant to the guidelines contained in the IMD.

The IMD is in two parts to address the following issues:

<u>Part 1: Allocating Regulatory Mixing Zones</u>

- Details the necessary steps for sizing and allocating an RMZ in accordance with state and federal regulations.
- Clarifies what documentation is needed in both the permit and permit evaluation report (fact sheet) to support allocation of an RMZ.

<u>Part 2: Reviewing Mixing Zone Studies</u>

- Provides for staff consistency when requesting and reviewing mixing zone study information.
- Clarifies for staff and permit applicants what information should be provided in a mixing zone study prior to permit development.

Role of the Permit Writer

The primary role of the permit writer is to ensure that a mixing zone study has the minimum information necessary to proceed with allocating a new mixing zone or reviewing an existing one. However, not every permit writer will have the necessary experience or knowledge to make this determination. It may also be difficult for the permit writer to interpret the information in the study. In these situations, consultation with DEQ modeling and laboratory staff will be necessary.

Organization

Part 2 of this IMD is organized into the following sections:

1. Introduction
2. Mixing and Modeling Basics
3. Expected Effort and Mixing Zone Study Checklist
4. Mixing Zone Study Components

What is a Mixing Zone Study?

Pursuant to Oregon Administrative Rule (OAR) 340-041-0053(2)(e) and (f), the department may request information to properly define an RMZ or evaluate an existing RMZ. The applicant provides this information to the department as a "mixing zone study." The following are considered essential components of a study:

- **Environmental mapping** Section 4.1
  A map and characterization of the specific habitats, critical resource areas, and other beneficial uses of the receiving water.

- **Outfall and RMZ characteristics** Section 4.2
  A description of the existing or proposed RMZ, including a description of existing or proposed outfalls.

- **Ambient receiving water conditions** Section 4.3

- **Discharge characteristics** Section 4.4

- **Mixing zone modeling analysis** Section 4.5
  Information on the type of model used, why it was selected over other models, and results of the modeling exercise. Results of the modeling exercise will predict available dilution in the receiving water.

In gathering the above information, the applicant should be made aware that the RMZ must be evaluated under critical conditions, with justification provided for the determination of when these conditions are expected to occur. The determination should take into account the fact that pollutant concentrations and uses of the receiving stream may vary with the season. Additionally, the size and travel time associated with the physical mixing zone may vary from season to season as effluent and instream flows and velocities vary.

Studies may range in level of effort and complexity depending on the nature of the discharge and sensitivity of the receiving water. The department's expectation for different situations is discussed further in Section 3: Expected Effort and Mixing Zone Study Checklist. A printable version of the checklist is contained in Appendix A.

2. Mixing and Modeling Basics

2.1 Physical Mixing Characteristics

Factors Controlling Mixing

Mixing processes are largely controlled by two factors:

- **Discharge characteristics**
  Discharge velocity, flow rate, diffuser and port dimensions and configurations (e.g., port or pipe diameter, number of discharge ports, diffuser and port orientation angles, elevation of port or pipe off the bottom), temperature, and density.

- **Ambient receiving water conditions**
  Ambient velocity, flow rate, lateral cross sections and depth, density profile, and bottom roughness.

Near and Far-Field Mixing Processes

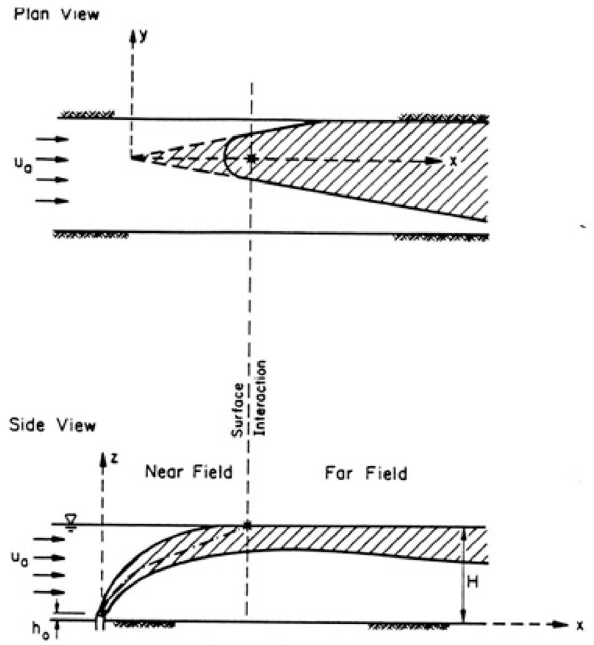
The physical mixing process can be conceptualized in two distinct regions: near-field and far-field (see Figure 2-1):

- **Near-field**
  The near-field region is defined where initial jet momentum, buoyancy flux, and outfall characteristics control the mixing process. Designers of diffusers and outfalls try to maximize initial mixing and dilution in this near-field region. When the discharge flow encounters a boundary condition (see Influence of Boundary Interactions on Mixing later in this section) such as a surface, bottom, or internal ambient density stratification layer, the near-field region ends and the transition to the far-field begins.

- **Far-field**
  The far-field region is the area where ambient processes dominate the mixing process. Once the discharge interacts with a vertical boundary (e.g., the water surface), the mixing processes are primarily a function of the ambient conditions characterized by the longitudinal dispersion of the discharge plume by ambient velocity. The discharge in the far-field loses its “memory” of its initial conditions and mixing is now mainly a function of the ambient conditions.

To summarize, the near-field region is typically the region that is controlled by initial discharge characteristics (e.g., flow rate, port diameter) and buoyancy. The far-field region is the region that is controlled by ambient conditions (e.g., ambient velocity and density field, cross sectional area).

Figure 2-1. Example of Near and Far-Field Regions (CORMIX manual)



Influence of Boundary Interactions on Mixing

There are several types of boundary interactions:

- Bottom boundaries – The discharge plume hits the bottom of the receiving water [Figure 2-2(c)]. These are more likely to occur when the outfall is near the bottom. Attachments of the discharge plume may also occur in what are known as “wake” or “Coanda” attachments. A wake attachment occurs when the crossflow of the receiving water bends the plume over [Figure 2-2(a)]. A Coanda attachment occurs when entrainment demand of the effluent jet itself forces the plume over; this is due to low pressure effects as the jet periphery is close to the water bottom [Figure 2-2(b)].

- Stratification boundaries – The discharge plume hits an intermediate boundary layer due to density stratification of the ambient water body. These typically occur in estuaries, oceans, or reservoirs. [Figure 2-2(d)]

- Surface water boundaries – The discharge plume hits the surface. This interaction will occur in most discharge situations. [Figure 2-2(e)]

- Bank attachments – The discharge plume hugs the bank. Bank attachments are more like to occur when the outfall is near the bank. [Figure 2-2(f)]

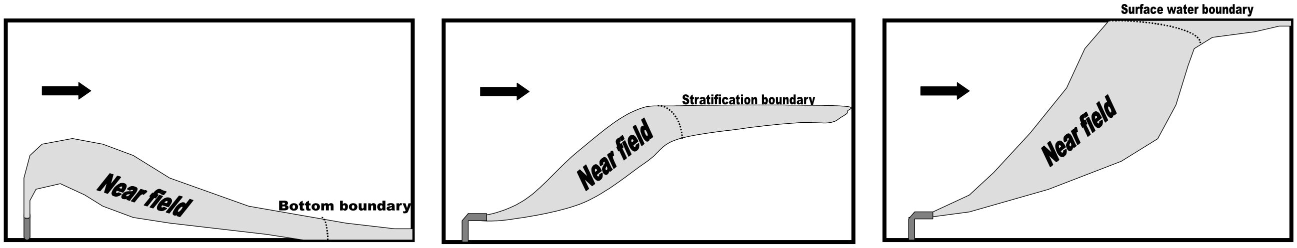
Boundaries inhibit mixing; therefore each boundary interaction needs to be modeled.

Figure 2-1: Boundary Examples

a) Wake Attachment
(side view)

b) Coanda Attachment
(side view)

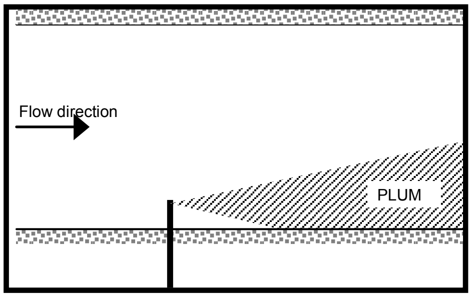
Figures from Fischer, H.B. et al. "Mixing Inland and
Coastal Waters," Academic Press, 1979.)



c) Bottom Boundary
(side view)

d) Stratification Boundary
(side view)

e) Surface Boundary
(side view)

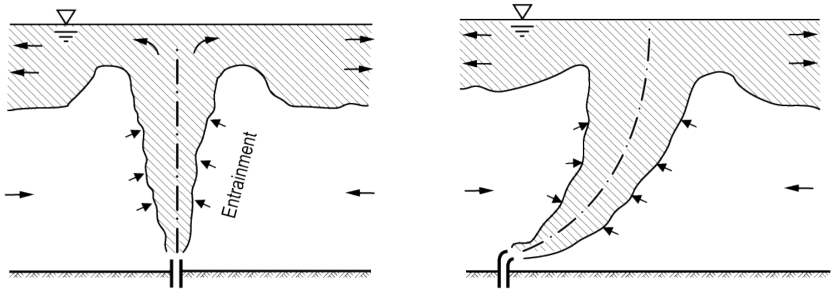


f) Bank Attachment
(top or plan view)

Re-Entrainment of Discharge

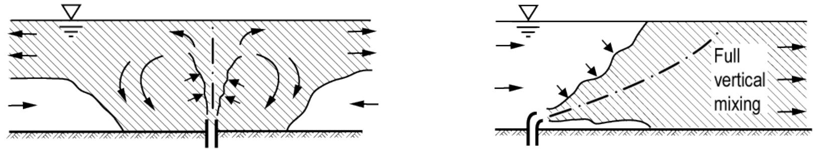
In shallow environments, discharges can become re-entrained in the near-field region due to instabilities associated with surface and bottom interactions and localized recirculation cells that extend over the entire water depth [see Figure 2-3(b), below]. Because re-entrainment can cause a build up of pollutant concentrations and reduce the amount of dilution actually occurring in the receiving water, it is important to know whether re-entrainment is occurring. See Figure 2-3 below for more examples of near-field stability and instabilities.

Figure 2-3. Near-field Stability and Instability (CORMIX manual)



a) Deep Water, High Buoyancy,
Vertical: Near Field

c) Deep Water, High Buoyancy,
Near-Horizontal: Stable Near-Field



b) Shallow Water, Low Buoyancy,
Vertical: Unstable near-Field
with Local Mixing and
Restratification

d) Shallow Water, Low Buoyancy,
Near Horizontal: Unstable
Near-Field with Full Vertical Mixing

2.2 Mixing Zone Models

Available Models

The department prefers EPA-supported models (e.g., PLUMES, CORMIX), but the permit writer may consider other models if adequate documentation on model selection is provided as discussed in Section 4.5: What type of information is needed? For more information on EPA-supported models visit EPA's Center for Exposure Assessment Modeling located on-line at http://www.epa.gov/ceampubl/swater/index.htm or EPA Water Quality Models at http://www.epa.gov/ost/wqm/.

Steady-State vs. Dynamic Models

The mixing zone models typically used by DEQ are considered "steady-state" models meaning they make predictions based on steady conditions that are fixed (e.g., flow rates, pollutant concentrations). A dynamic model is a model that takes changing conditions into account. For example, a dynamic model may be needed in estuaries where there are hourly tidal fluctuations.

When Steady-State Mixing Zone Models May Not Be Appropriate

Mixing zone models are not always able to adequately simulate discharge conditions. Many models are not appropriate when discharge is to:

- Shallow streams of non-uniform flow where the stream substrate (e.g., rocks, boulders, logs) impedes water flow. In this case, a simple field study using a conductivity meter may be sufficient. It needs to be performed during conditions that approximate critical conditions.

- Tidally-influenced waterbodies, which are highly dynamic and may cause re-entrainment of the effluent plume as tides change.

A dynamic model may be needed in a highly dynamic system like an estuary. These models have the ability to simulate unsteady flow in two and three dimensions, but they are typically complex and require a large amount of data, including field measurements for calibration and validation of the model. Field dye studies for the entire tidal cycle coupled with steady-state modeling may also be feasible. Note that several scenarios may need to be modeled over the tidal cycle. See Appendix C: Critical Flow Conditions for more information on tidal influences.

Model Sensitivity

It is important to evaluate model sensitivity when performing any type of modeling because slight changes in some input parameters can provide significantly different model results. For example, mixing zone model predictions are typically sensitive to changes in stream velocity. Therefore, it is important to obtain an accurate instream velocity data set to maximize the confidence in the model predictions.

Model sensitivity should be determined prior to collecting the necessary data to run the model. A sensitivity analysis will indicate where accurate field measurements need to be obtained to reduce uncertainty in the model results. When analyzing for sensitivity, the key is to change only one input variable at a time. If more than one input variable is changed at the same time, it is impossible to determine which variable caused the change in output results. See Section 4.5: Was the appropriate model used? for more detail on how to check model sensitivity.

3. Expected Effort and Mixing Zone Study Checklist

3.1 Level of Effort For Different Types of Discharges

Overview

The complexity of a mixing zone study will depend on the nature of the discharge and sensitivity of the receiving water. To determine the minimum information needed in a study, the department has classified discharges into three "effort levels" discussed further in this Section:

- Level 1 – Simple
- Level 2 – Moderate
- Level 3 – Complex

Section 4.5 describes the level of modeling associated with each level of field study.

These different effort levels have been developed based on the department's experience with existing mixing zone studies. These are general guidelines to be used when determining the appropriate effort level. The permit writer should communicate with the permit holder to ensure the appropriate effort level has been chosen.

Note: It may be acceptable to proceed with conservative assumptions if the minimum information requested for these effort levels is not available or will take too long to collect. For example, conservative estimates of instream critical flow condition may be used if actual flow data is incomplete and the critical flow condition for the year has recently passed. In some cases, the permit applicant may also accept more conservative assumptions to prevent delays in permit issuance.

Level 1: Simple

Level 1 represents the simplest approach and is appropriate for evaluating a discharge with a low level of risk to ecological resources and public health. To be specific, this level is appropriate for a discharge for which **both** of the following are true:

1) The discharge has **no** reasonable potential to exceed acute criteria at the end of pipe and the available dilution in the receiving water is greater than 20 times 25% of critical flow (see section 4.2 of Part 1 of the RMZ IMD for definitions). If the potential to exceed acute criteria in this situation is only due to chlorine and ammonia, the discharge may still be considered in the context of a **Level 1** effort because these pollutants rapidly change to less toxic forms and do not bioaccumulate.

2) The discharge is not classified as "major" (see item #5 on p. 10).

The comparison of dilution against "25% critical flow" is directly related to the temperature water quality standard and temperature mixing zone requirements. The temperature water quality standard in OAR 340-041-0028(12)(b)(A) uses 25% of flow to evaluate discharges for temperature concerns prior to TMDL or other cumulative effects analysis:

> "…no single discharge may cause temperature to the water body to increase more than 0.3 °C (0.5 °F) above applicable criteria after mixing with either 25% of stream flow or the temperature mixing zone, whichever is more restrictive."

The use of a dilution factor of 20 or more to characterize a Level 1 effort represents the department's judgment and experience with existing mixing zone studies. The department believes that the availability of dilution at this level, or greater, lessens concerns over temperature increases and a Level 1 effort is appropriate.

Level 2: Moderate

Level 2 represents the next tier of complexity and is generally appropriate for the following situations:

1) A discharge with the reasonable potential to exceed acute criteria at the end of pipe, but the available dilution in the receiving water is greater than 20 times 25% of critical flow. If potential to exceed acute criteria in this situation is only due to chlorine and ammonia and the discharge is not classified as "major," a **Level 1** effort may still be considered because these pollutants rapidly change to less toxic forms and do not bioaccumulate.
2) A discharge that meets the acute criteria at end of pipe, but available dilution in the receiving water is less than 20 times 25% of critical flow.

Level 3: Complex

Level 3 is the most complex approach and is generally appropriate for either of the following:

1) A discharge with the reasonable potential for major environmental impact (see step #2 in flow chart presented in **Figure 3-1**).
2) A discharge with the reasonable potential for exceeding acute criteria at the end of pipe and available dilution in the receiving water is less than 20 times 25% of critical flow. If potential to exceed acute criteria in this situation is only due to chlorine and ammonia, a **Level 2** effort may still be considered because these pollutants rapidly change to less toxic forms and do not bioaccumulate.

Examples

See Appendix B: Examples of Mixing Zone Study Effort Levels for examples of different mixing zone study effort levels.

Decision Flow Chart to Dedermine Level of Effort

A flow chart that may be used to determine the level of effort expected from the applicant when doing a mixing zone study is provided in Figure 3-1. This flow chart assumes that critical questions pertaining to the department's antidegradation policy and statewide narrative criteria (OAR 340-041-0004 and 0007, respectively) have been addressed..

The major decision steps include the following:

1) **Is dilution available at critical flow?**
   Discharges to waterbodies with no available dilution are required to meet applicable water quality criteria at the end-of-pipe. In some circumstances, an intake credit, a variance, site specific criteria or a use attainability analysis may be considered (see the department's *Use Attainability*

Analysis IMD and *Variance IMD* for more information). Note, however, that these alternatives may be resource intensive and are not available in all circumstances.

2) **Is there potential to impact ecologically sensitive areas?**
In some situations, a discharge may have the potential to impact ecologically sensitive areas because the RMZ encroaches on frequently used public beaches, a drinking water intake, or spawning or unique habitat for threatened and endangered species. In these situations, a Level 3 effort is needed.

3) **Are acute criteria met at end of pipe?**
A review of discharge characterization data must be performed to determine whether the discharge will meet acute criteria at the end of pipe. This data should be included in the permit application. If the data does not exist or is insufficient to complete the reasonable potential and mixing zone analysis, the permit writer must request the necessary information before proceeding.

If ammonia and chlorine are the only acute criteria with the reasonable potential to be exceeded at end-of-pipe, Level 1 or 2 mixing zone studies may still be considered because these pollutants do not bioaccumulate and quickly change to less toxic forms.

This review must be conducted using the most current version of the department's *Reasonable Potential Analysis and Limits Workbook* in Excel format available on the DEQ website at:
http://www.deq.state.or.us/wq/pubs/imds/rpaIMD.pdf
Using the workbook will allow for a statistical comparison of the maximum expected concentration against the acute criteria. A simple comparison of discharge characterization data against the criteria is not sufficient.

4) **Is dilution with 25% of critical flow greater than 20?**
Using the applicable low flow critical condition, a determination must be made as to whether or not 25% of this low flow rate would yield a dilution factor greater than 20 when considering the discharge flow rate (in other words, dilution with the entire stream flow must be greater than or equal to 80).

$(.25Q_s + Q_e) / Q_e > 20$?   *Where:* Q_s = *stream 7Q10 flow (cfs)*
Q_e = *discharge flow (cfs)*

The applicable low flow rate for most sources discharging to flowing systems is the 7Q10 flow (see Table 4-2: Receiving Water Flow Statistics to Use in Mixing Zone Analysis and Table 4.3: Effluent Flow statistics to Use in Mixing Zone Analysis of this part of the RMZ IMD) for additional information on critical flow conditions). For sources that discharge below dams or other impoundments, a minimum release rate may be a more appropriate statistic to represent low flow conditions.

5) **Is the facility classified as "major"?**
The classification of a facility as major or minor is determined when the facility first applies for a permit, and is reviewed at each permit renewal. The process by which the determination is made is described below for informational purposes.

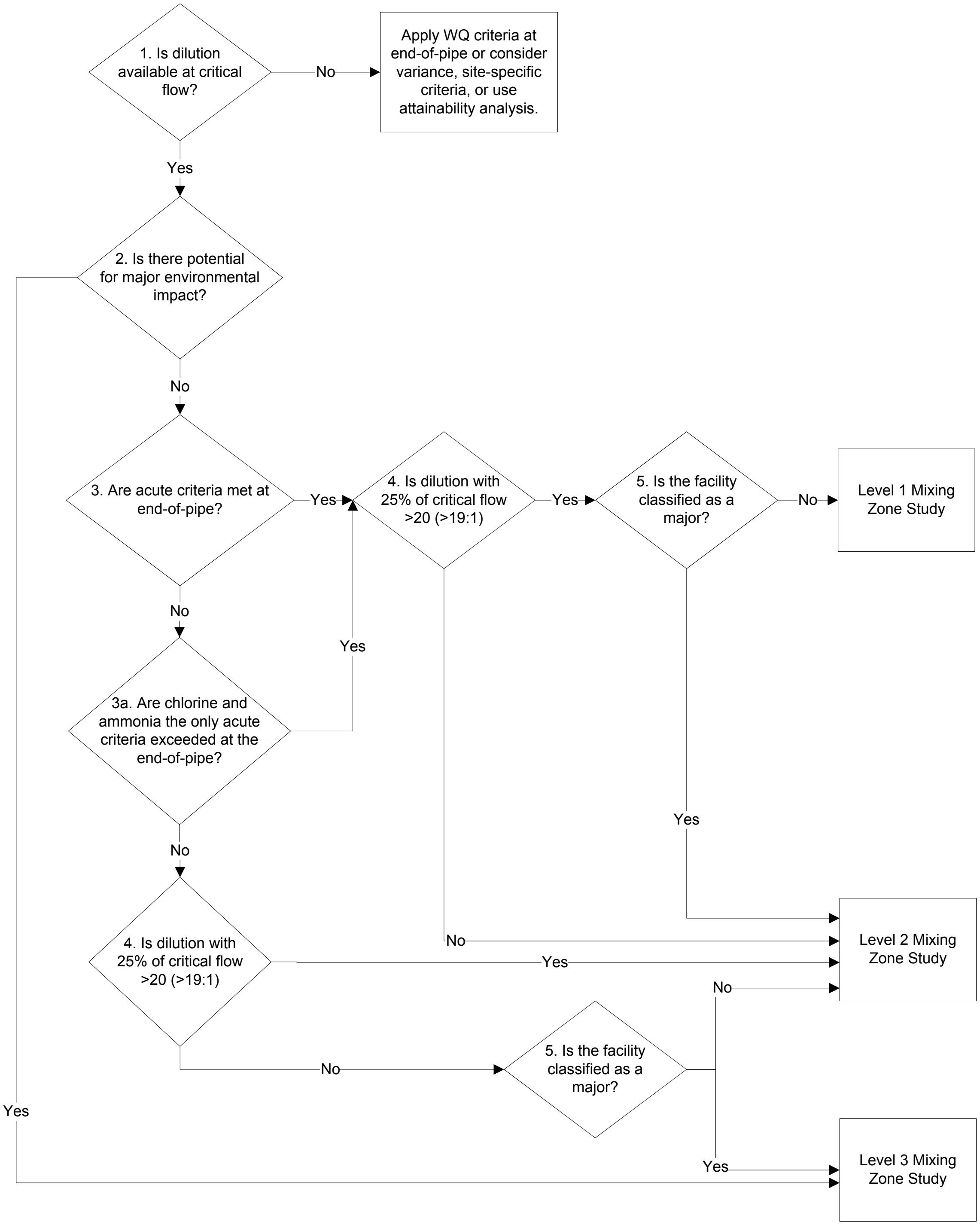
For industrial facilities, EPA's *NPDES Permit Rating Work Sheet* (available at http://www.epa.gov/npdes/pubs/owm0116.pdf) must be completed to determine if a facility is a "major" discharger. (This is part of the NPDES permit issuance process regardless of whether an RMZ is being considered.) This scoring system considers the toxic pollutant potential of the discharge, discharge flow, receiving stream flow, presence of conventional pollutants (e.g., biochemical oxygen demand, total suspended solids, ammonia), public health impact, water quality factors (e.g., receiving stream is water quality limited, wasteload allocation assigned, discharge shows toxicity), and proximity to coastal waters.

For domestic facilities, a facility may be classified as a "major" discharger for EPA purposes if any one of the following is true:

- Design flow is 1 million gallons per day (MGD) or greater;
- Service population is 10,000 or greater; or
- Discharge causes significant water quality impacts.

The permittee, with departmental support may petition the EPA to re-classify a domestic facility with a design flow at 1 MGD or greater as "minor" if actual average dry weather flows are significantly below 1 MGD and not expected to rise.

Figure 3-1: Decision Flow Chart for Determining Level of Effort



3.2 Permit Writer's Quick Review Checklist

How to Use the Checklist

Prior to performing an in-depth review of a mixing zone study, the permit writer must use the most current version of the checklist in **Table 3-1** to determine if the necessary information has been provided by the applicant. **The completed checklist must be incorporated into the permit evaluation report (fact sheet).**

Missing Information?

Normally, a permit application is reviewed for completeness to ensure that necessary data has been included. If items in the checklist have not been provided, the permit writer should contact the applicant to request the missing information. The permit writer may determine that the information is not necessary after talking with the applicant. The permit writer must document these decisions on the checklist or by memo to the permit file. With manager approval, the permit writer may decide to assist the applicant in collecting some of this information.

Enough Detail?

See Section 4: Mixing Zone Study Components for information on the level of detail needed for each item in the checklist.

Table 3-1. Mixing Zone Study Information Checklist (see Appendix A for a printable copy)

<table>
<tr><td colspan="5">Oregon DEQ Mixing Zone Study Checklist
(to be submitted to DEQ with Report on Mixing Zone Study) (v. 2.0, May 2012)</td></tr>
<tr><td colspan="4">Legal Name:
Common Name:
Facility ID#:
Application #:</td><td>Date Submitted:
Conducted by:</td></tr>
<tr><td colspan="3">Study Level <i>(to be filled out by DEQ)</i>:
☐ Level 1 - Simple
☐ Level 2 - Moderate
☐ Level 3 – Complex
(See Part 2 of RMZ, Section 3.1, p.8)</td><td>Information:
X = required
E = estimate is acceptable
M = measurement (field or engineering plans)
D = desirable</td><td>Check if Complete
(or note deficiencies)
<i>To be filled out by DEQ.</i></td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>1. Environmental Mapping (RMZ IMD Part 2, Section 4.1, p. 19)</td><td></td></tr>
<tr><td>X</td><td>X</td><td>X</td><td>A. Attach plan view map showing outfall and a segment of river that extends at least 1/2 mile upstream and downstream of outfall. Map should indicate the following features downstream of outfall unless otherwise noted. By checking whether the specific feature is present or not, the permittee is certifying they have researched the information resources listed in Section 4.1 (Environmental Mapping) of the RMZ IMD.
<table>
<tr><th>Feature</th><th>Present</th><th>Not present</th></tr>
<tr><td>Known commercial or recreational shellfish areas</td><td></td><td></td></tr>
<tr><td>Fish spawning/rearing habitat</td><td></td><td></td></tr>
<tr><td>Cold water refugia for fish</td><td></td><td></td></tr>
<tr><td>Areas identified as having species (fish or non-fish) that may be sensitive to impact of discharge*</td><td></td><td></td></tr>
<tr><td>Physical structures expected to attract fish (e.g., piers, large woody debris, outfalls)</td><td></td><td></td></tr>
<tr><td>Public access areas such as boat ramps, docks or public beaches</td><td></td><td></td></tr>
<tr><td>Drinking water intakes within the vicinity of the outfall and ½ mile downstream (to be identified by DEQ. Link to internal webpage is http://deq05/wqoutfalls/EOPbasics.aspx</td><td colspan="2">To be determined by DEQ</td></tr>
<tr><td>Other NPDES discharges upstream and downstream within ½ mile of outfall (to be identified by DEQ. Link to internal webpage is http://deq05/wqoutfalls/EOPbasics.aspx)</td><td colspan="2">To be determined by DEQ</td></tr>
</table>
*If such species are found to be present, report should include a description of such species.
Page number(s) ___________</td><td></td></tr>
<tr><td>X</td><td>X</td><td>X</td><td>B. Are there threatened and endangered species in the RMZ? ☐ Yes ☐ No
If yes, report should include a description of threatened and endangered species present, habitat, and migration pathways as well as source(s) of information.
Page number(s) ___________</td><td></td></tr>
</table>

Oregon DEQ Mixing Zone Study Checklist
(to be submitted to DEQ with Report on Mixing Zone Study) (v. 2.0, May 2012)

<table>
<tr><td></td><td></td><td>**D**</td><td>C. Other information as appropriate.
<table>
<tr><th>Type of Information
(check all that apply)</th><th>Page Number(s)</th></tr>
<tr><td>☐ Detailed salmonid use</td><td></td></tr>
<tr><td>☐ Bioassessment.</td><td></td></tr>
<tr><td>☐ Fish migration study</td><td></td></tr>
<tr><td>☐ Thermal imagery</td><td></td></tr>
<tr><td>☐ Map or measurements of channel width/depth</td><td></td></tr>
<tr><td>☐ Published information supporting environmental mapping</td><td></td></tr>
<tr><td>☐ Other. Describe:</td><td></td></tr>
</table></td><td></td></tr>
<tr><td></td><td></td><td></td><td>**2. Outfall Location and Mixing Description (**RMZ IMD Part 2, Section 4.2, p.24)</td><td></td></tr>
<tr><td>**E**</td><td>**M**</td><td>**M**</td><td>A. Outfall Measurements:
<table>
<tr><th>Measurement</th><th>Page Number(s)</th></tr>
<tr><td>Distance from bank (ft):</td><td></td></tr>
<tr><td>Height above bottom (ft):</td><td></td></tr>
</table></td><td></td></tr>
<tr><td>**E**</td><td>**M**</td><td>**M**</td><td>B. If present, diffuser and port dimensions, orientation angle and configuration (include drawings, if available)
☐ N/A
☐ Description on page number(s) __________
☐ Drawing on page number(s): __________</td><td></td></tr>
<tr><td>**X**</td><td>**M**</td><td>**M**</td><td>C. Outfall Location:
Latitude:_________________________

Longitude:_______________________
This information may be available on the following internal webpage:
http://deq05/wqoutfalls/EOPbasics.aspx</td><td></td></tr>
<tr><td>**E**</td><td>**E**</td><td>**E**</td><td>D. River mile of outfall:_______________
This information may be available on the following internal webpage:
http://deq05/wqoutfalls/EOPbasics.aspx</td><td></td></tr>
<tr><td>**D**</td><td>**D**</td><td>**D**</td><td>E. Photographs of the outfall vicinity
☐ N/A
☐ See attached on page number(s): __________</td><td></td></tr>
<tr><td>**X**</td><td>**X**</td><td>**X**</td><td>F. Description and plan view of current RMZ and ZID as described in permit:
☐ See attached on page number(s): __________</td><td></td></tr>
</table>

<table>
<tr><th></th><th></th><th></th><th>Part 3. Ambient Receiving Water Conditions (RMZ IMD Part 2, Section 4.3, p.26)</th><th></th></tr>
<tr><td>E</td><td>E</td><td>E</td><td>A. Parameter:
Dates of Critical Period:
<i>(Note:may vary with parameter. See Section 4.3, p.26)</i>
☐ See attached on page number(s) __________
___
Justification for Critical Period:
☐ See attached on page number(s) __________
___
For Riverine Systems:
Flow statistics and dilutions corresponding to critical period:
<table>
<tr><th>Flow Statistic</th><th>Stream Flow (cfs)</th><th>Velocity (ft/sec)*</th><th>Dilution at edge of ZID</th><th>Dilution at edge of RMZ</th><th>Page Number(s)</th></tr>
<tr><td>1Q10</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>7Q10</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>30Q5</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Harmonic Mean</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
*For systems where velocity can be approximated by a single value. If velocity profile is needed, go to next section B.

Describe source (USGS, other) and extent of flow data on which critical flow statistics are based.
☐ N/A
☐ See attached on page number(s) __________

For Marine/Estuarine Systems:
Refer to Table 4-2 on p. 30 for appropriate statistics and describe in an attachment.
☐ N/A
☐ See attached on page number(s) __________</td><td></td></tr>
<tr><td>E</td><td>E/M</td><td>E/M</td><td>B. Velocity profile* for each critical flow condition
☐ N/A
☐ See attached on page number(s) __________
*for systems that where velocity cannot be approximated by a single value.</td><td></td></tr>
<tr><td>E</td><td>E/M</td><td>M</td><td>C. Cross sectional area (width and depth) for each critical flow.
☐ See attached on page number(s) __________</td><td></td></tr>
<tr><td>E</td><td>E/M</td><td>M</td><td>D. Temperature and salinity profiles
☐ N/A (no stratification)
☐ See attached on page number(s) __________</td><td></td></tr>
<tr><td>E</td><td>E</td><td>E</td><td>E. Manning's roughness coefficient:
Page number __________</td><td></td></tr>
</table>

			Part 4. Discharge Characteristics (RMZ IMD Part 2, Section 4.4, Table 4-3, p. 31)	
E	**X**	**X**	A. Discharge flow rates for critical flow scenarios:	

	☐ **Domestic**	☐ **Industrial**
Aquatic Life: Acute	☐ For plants operating at <85% DWDF[1] during the critical period: Use maximum daily average flow for the past 3 years during the period when the critical receiving water flow is most likely to occur. ☐ For plants operating at 85-100% of DWDF: Use DWDF x PF[2]	☐ Use maximum daily average flow for the past 3 years during the period when the critical receiving water flow is most likely to occur. ☐ If flows are expected to increase over the life of the permit, estimate highest daily maximum flow.
	Applicable Effluent Flow :	Page No.:
Aquatic Life: Chronic	☐ For plants operating at 85-100% of DWDF during the critical period: Use DWDF. ☐ For plants operating at <85% DWDF: Use highest monthly average flow for the past 3 years during the critical period or during the period when the critical condition is likely to occur.	☐ Use highest monthly average flow for the past 3 years during the period when the critical receiving water flow is most likely to occur. ☐ If flow is expected to increase, estimate highest monthly average maximum flow.
	Applicable Effluent Flow :	Page No.:
Human Health	☐ Carcinogens: Use the annual average design flow as specified in the engineering report or permit application, or use the annual average flow based on DMR analysis. ☐ Non-carcinogens: ☐ For plants operating at 85-100% of design capacity: Use the dry weather design flow. ☐ For plants operating at <85% of design flow: Use highest monthly average flow for the past 3 years during the period when the critical receiving water flow is most likely to occur.	☐ Carcinogens: Use the annual average flow based on the permit application or DMR analysis. ☐ Non-carcinogens: Use highest monthly average flow for the past 3 years during the period when the critical receiving water flow is most likely to occur. If flows are expected to increase over the life of the permit, estimate highest average monthly flow.
	Applicable Effluent Flow :	Page No.:

Notes:

[1] DWDF - Dry Weather Design Flow

[2] PF – Peaking Factor

	E/M	**M**	B. Discharge chemistry data:	

Check if N/A	Parameter	Value	Page Number(s)
	Temperature (F)		
	Conductivity (µmhos)		
	Salinity (ppt)		

			Part 5. Mixing Zone Modeling* (RMZ IMD Part 2, Section 4.5, p. 32)	
	D	**M**	A. Field mixing measurements (e.g., dye studies) ☐ N/A ☐ See attached on page number(s) __________	
X	**X**	**X**	B. Model selection and application discussion ☐ N/A ☐ See attached on page number(s) __________	
X	**X**	**X**	C. Description of mixing and plume dynamics (near-field and far-field) ☐ N/A ☐ See attached on page number(s) __________	
X	**X**	**X**	D. Sensitivity analysis ☐ N/A ☐ See attached on page number(s) __________	
X	**X**	**X**	E. Model results table (see Table 4-4 on page 34 of Section 4.5 of Part 2 of the RMZ IMD for an example) ☐ N/A ☐ See attached on page number(s) __________	

*Note: In some cases (e.g., shallow streams with non-uniform flow and tidally-influence waterbodies), modeling is not appropriate. See RMZ IMD Part 2, Section 2.2, p. 6.

DEQ Reviewer Comments

Name of DEQ Reviewer:

Date:

1. Describe deficiencies, if any.

2. Which if any need to be addressed before the permit can be issued?

3. Which if any may be addressed through permit conditions?

The checklist and reviewer comments should be attached to the permit evaluation report.

4. Mixing Zone Study Components

Introduction

As discussed earlier, the essential mixing zone study components include:

- Environmental mapping
- Outfall and RMZ description
- Ambient receiving water conditions
- Discharge characteristics
- Mixing zone modeling analysis

While the level of detail and type of information may vary for each of these components, this Section provides a general idea of what should be expected for each component.

4.1 Environmental Mapping

Overview

"Environmental mapping" is done to identify the areas in and around the RMZ that may be sensitive to the impact of the discharge. It involves characterizing and mapping specific habitats, critical resources areas, and other beneficial uses within the segment of the water body receiving the discharge.

Beneficial uses fall into the following categories:

- Designated beneficial uses. These are described in the Oregon Administrative Rules.
- All uses actually attained on or after November 28, 1975.
- All current uses.

Beneficial uses include the use of the receiving water by species such as fish and amphibians.

A complete environmental mapping exercise will result in the identification of all beneficial uses associated with the receiving water body around the point of discharge. Where possible, existing uses that have been impaired or extirpated should also be identified.

The information gained through environmental mapping is used to evaluate the potential environmental impact of the discharge and make decisions about the allowable size and placement of an RMZ.

While this information can be provided as a narrative, physically mapping key pieces of information provides for a reference that is easy to visualize and understand. This section details the information necessary for a complete environmental map and specifies when a physical map is preferred. Further information that may be necessary for very complex Level 3 situations is also discussed.

Available Resources

The following websites provide information that can be used to help identify the various species that may be making use of the receiving water body around the point of discharge

The Oregon Explorer website contains natural resource data compiled by state and federal agencies, local governments, university scientists, and citizens.

http://www.oregonexplorer.info/

The Oregon Biodiversity Center also includes information from a wide variety of sources. http://orbic.pdx.edu/data-request.html

The following websites provide habitat information for fish populations in Oregon:

- Oregon DEQ Fish Use Maps http://www.deq.state.or.us/wq/rules/div041tblsfigs.htm)
- Oregon department of Fish and Wildlife (ODFW) Timing Guidelines (http://www.dfw.state.or.us/lands/inwater/)

Note: The second of the above two sites contains "In-water work" guidelines. These guidelines identify where threatened aquatic species are located, and the time periods of their migration, rearing and spawning.

- ODFW Fish Distribution/Habitat maps (http://nrimp.dfw.state.or.us/OregonPlan/default.aspx?p=130)

Spawning/rearing/migration in each stream segment, organized by major salmonid species and/or by sub-basin.

- ODFW maps (http://nrimp.dfw.state.or.us/OregonPlan/)

Oregon Plan core areas: the most productive areas for salmonids in the Oregon Coast and southern Oregon.

- ODFW Data Resources (http://nrimp.dfw.state.or.us/nrimp/default.aspx)

Index and links for available data from ODFW.

- Threatened and endangered fish species (http://www.dfw.state.or.us/threatened_endangered/t_e.html)

State and federal listed species.

- ODFW fact sheet (http://www.dfw.state.or.us/ODFWhtml/InfoCntrFish/PDFs/BKG_Coastal.pdf) Information on Oregon's coastal salmon and trout.

Other useful websites:

- Outfall Location Data (use to identify Public Water Supplies with drinking water intakes downstream of outfalls)
- Oregon DEQ Beneficial Use Tables by Basin (http://www.deq.state.or.us/wq/rules/div041tblsfigs.htm#t1)
- Oregon DEQ Facility Profiler (http://deq12.deq.state.or.us/fp20/)
- Oregon DEQ Laboratory Data (http://www.deq.state.or.us/lab/lasar.htm) DEQ air and water quality monitoring data
- Storet Data (http://www.storet.org/website/cdamap/viewer.htm)

Data contained in the Pacific Northwest Water Quality Data Exchange and U.S. Geological Survey National Water Information System (NWIS) in and around Oregon connected with GIS.

- Oregon DEQ Source Water Assessment Maps (http://www.deq.state.or.us/wq/dwp/results.htm)

Maps of the groundwater and surface water drinking water source areas and potential contaminant sources identified within those drinking water source areas available as GIS data layers.

- http://www.oregonexplorer.info/ (I'm not sure how to characterize)

Levels 1, 2, & 3

For all effort levels, the following information is needed. The permit writer will develop this information and request that the permittee perform it as part of the mixing zone analysis.

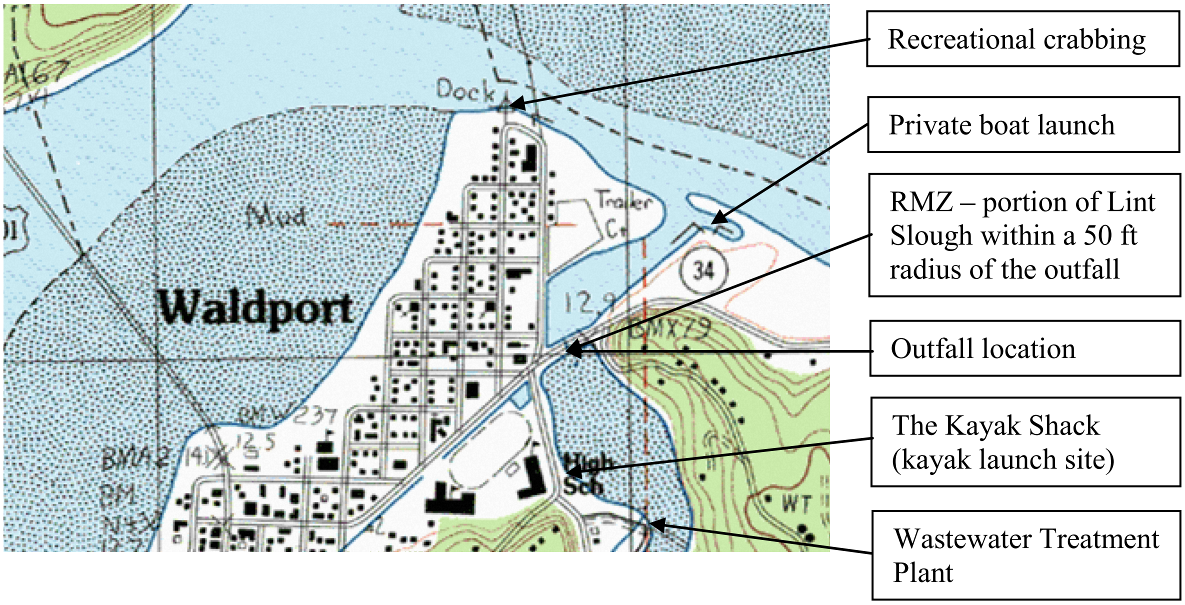
1) Plan view map delineating the following areas within or near the mixing zone:
2)
    - Known commercial or recreational shellfish harvesting areas.
    - Fish spawning/rearing habitat.
    - Cold water refugia for fish (e.g., cold water tributaries).
    - Physical structures expected to attract fish (e.g., piers, outfalls, large woody debris).
    - Public access areas such as boat ramps, docks or public beaches.
    - Drinking water intakes within the vicinity of the outfall and within ½ mile downstream of the outfall.
    - Other NPDES discharges upstream and downstream within ½ mile.

2) If applicable, description of threatened and endangered (T&E) species presence, habitat, and migration pathways.

Example

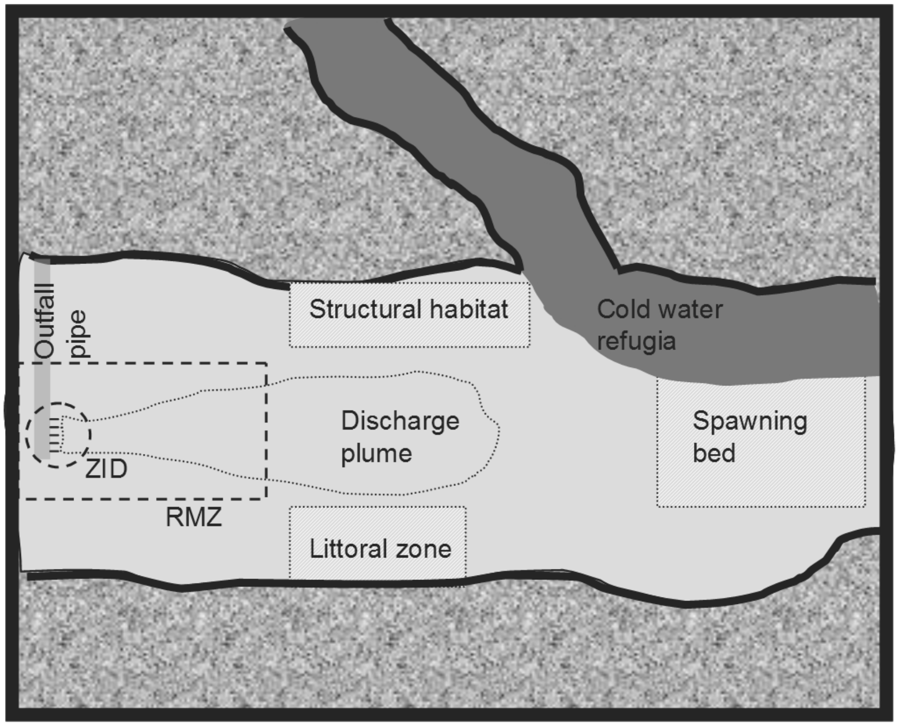
See **Figures 4-1 & 4-2** for mapping examples. Note: Narrative descriptions are also acceptable.

Figure 4-1. Level 1 Environmental Map Example



There are no active redds (fish eggs) in the RMZ and no critical habitat in the vicinity in need of additional protection. There is no commercial or recreational shell fishing in Lint Slough. There are no other NPDES discharges or drinking water intakes within ½ mile of the outfall. There are no public beaches; however, the Slough is used for recreational kayaking.

Figure 4-2. Level 3 Environmental Map Example



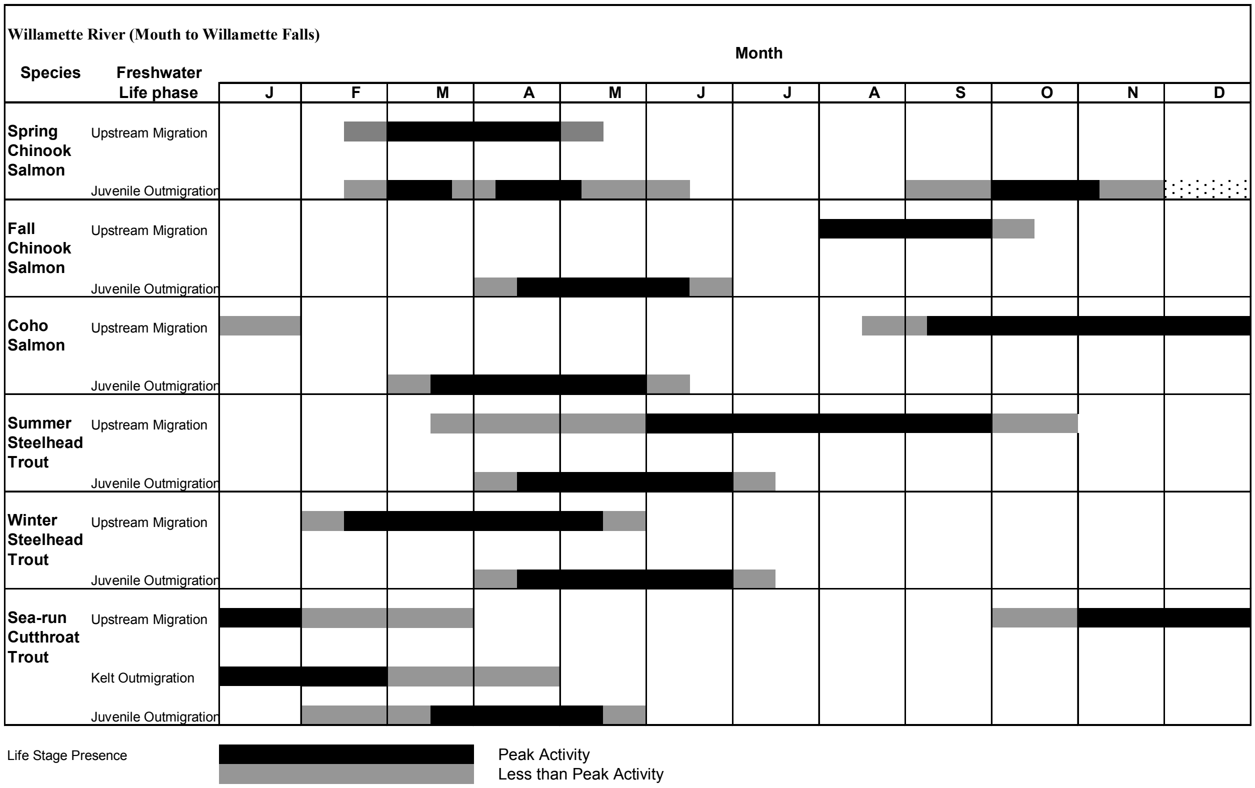
Additional Information: Level 3

The following are examples of additional information that may be necessary for a Level 3 mixing zone study. Since gathering this additional information may be expensive and assessment of this data may be inconclusive, the permit writer should discuss whether the information is needed with his or her manager, other experienced DEQ staff, experts outside of the agency, and the permit applicant.

- Detailed salmonid T&E use (e.g., spawning, holding, rearing, migratory pathways).
- Measure of biologic integrity (e.g., rapid bioassessments, benthic surveys).
- Fish migrations studies (see Figure 4-3: Detailed T&E Salmnid Use in the Lower Willamette River).
- Thermal imagery [e.g., Forward Looking Infrared (FLIR) camera technology].
- Maps illustrating channel width and depth and receiving water depth in the vicinity of the outfall.
- Published literature or agency reports in support of the environmental mapping.

Additional information may be found in Table 5-2 of Part 1 of the RMZ IMD, entitled “RMZ-related bioassessment techniques”.

Figure 4-3. Detailed T&E Salmonid Use in the Lower Willamette River



4.2 Outfall and RMZ Characterization

Overview

This section describes how to characterize an existing outfall and RMZ necessary for a mixing zone evaluation done as part of a permit renewal. If a new outfall is being proposed for an existing source or the permit application is for a new source, all available design engineering information, ambient receiving water body and proposed effluent characterization at time of application must be provided.

All Levels

The minimum characterization required for all levels includes the following:

1) A plan view of the discharge that includes the locations of the RMZ and, if defined, ZID boundaries, including the narrative descriptions in the permit of the RMZ and ZID. (Not applicable for new outfalls or new permit applications.)

2) Outfall distance from bank and outfall height above bottom.
   a. **Level 1**: Estimate
   b. **Level 2 & 3**: Measurement in field or from engineering plans and diagram (see Figure 4-4).

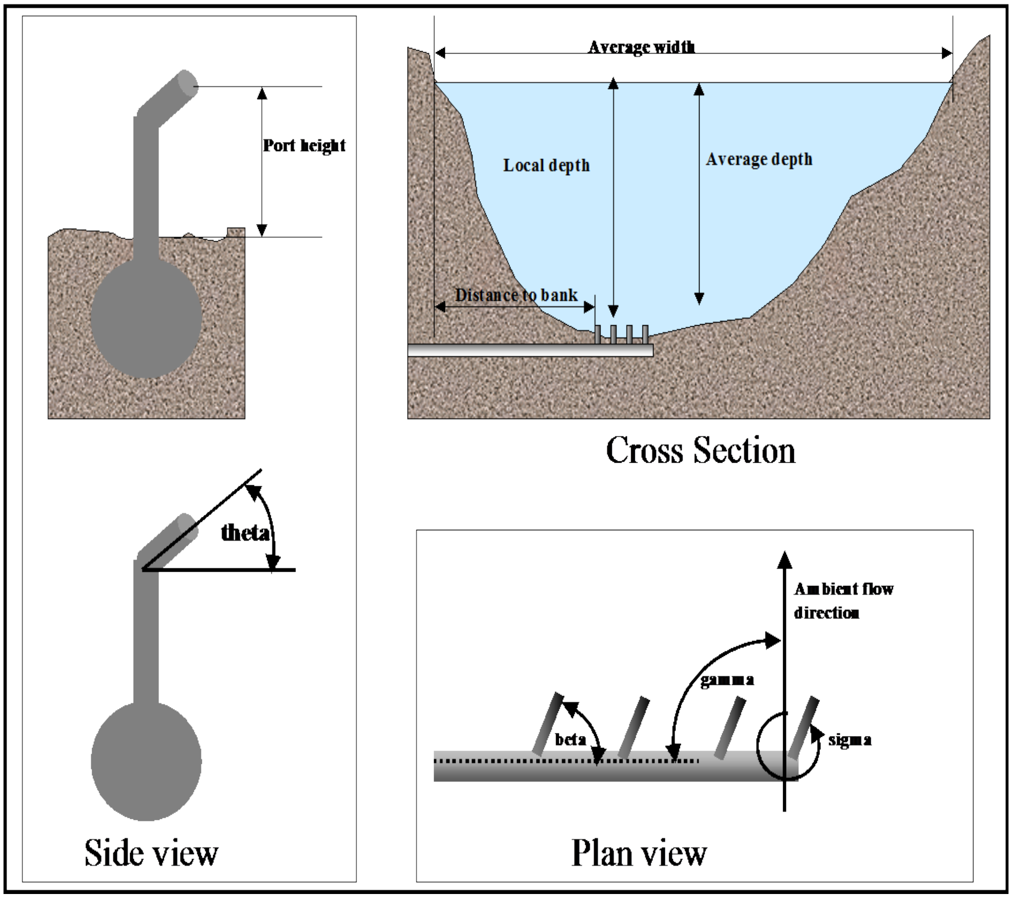
3) If present, the following diffuser and port dimensions and configurations are required:
   a. Diffuser length
   b. Number of ports (note and describe blocked or non-functioning ports)
   c. Orientation angles
      i. THETA – vertical angle of discharge between the port centerline and a horizontal plane (-45° and 90°).
      ii. SIGMA – horizontal angle of discharge measured counterclockwise from the ambient current direction (x-axis) to the plan projection of the port centerlines (0° to 360°).
      iii. BETA – relative orientation angle measured either clockwise or counterclockwise from the average plan projection of the port centerlines to the nearest diffuser axis (0° to 90°).
      iv. GAMMA – average alignment angle of the diffuser pipe measured counterclockwise from the ambient current direction (x-axis) to the diffuser axis (0° to 180°)

   Depending upon level the aforementioned information shall be in the following form:
   a. **Level 1**: Estimate
   b. **Level 2 & 3**: Measurement in field or from engineering plans and diagram (see Figure 4-4).

4) The latitude and longitude and river mile location of the outfall. The permit writer can assist the applicant in determining river mile.

5) **Optional, but desirable:** Photographs of the area of discharge (upstream and downstream). Photographs provide valuable information particularly to those who have not visited the outfall site and are a good tool for historical reference.

Figure 4-4. Levels 2 and 3 Plan Example for Discharge Placement



4.3 Ambient Receiving Water Conditions

Overview

Specific information about ambient receiving water conditions is critical when modeling mixing because these conditions greatly influence the mixing process. These conditions include:

- Critical flow statistics
- Receiving water body cross-sectional profile (width and depth)
- Velocity profile
- Density, temperature, and salinity profile (for stratified systems)
- Manning’s roughness coefficient

Unfortunately, ambient information is not always readily available and may take additional time and resources to collect. To ensure that the proper information is submitted, the next sections describe available resources, level of effort necessary to characterize ambient conditions, and applicable ambient conditions in more detail.

Resources for Flow Data

For data on historical stream flow, the permit writer should be using the following:

- USGS Real-Time Stream Flow Data
  http://waterdata.usgs.gov/or/nwis/rt
- National Water Information System (NWIS) Data (includes surface water, groundwater, and water quality data)
  http://waterdata.usgs.gov/or/nwis/
- Oregon Water Resources Department Historical Stream Flow Data
  http://www.wrd.state.or.us/OWRD/SW/streamflow.shtml

To calculate critical low stream flows, the department primarily uses the EPA-supported DFLOW 3 tool at http://www.epa.gov/waterscience/dflow/, but other tools are acceptable provided they are discussed in advance with the department.

Characterizing Critical and "Off-Design" Conditions

Ambient conditions vary depending on the time of year. To protect receiving waters, the department considers critical flow statistics (described in the next section) as well as "off-design" conditions when allocating an RMZ. "Off-design" conditions are discharge and stream conditions that are not typically associated with low flow conditions, but may be important when evaluating a discharge. For example, peak discharge flow or wet weather conditions could be critical off-design conditions. Late fall conditions where instream temperatures have cooled but stream flow is still low, or winter conditions when discharge temperature is high but receiving stream temperature is low may also need to be considered.

Effort Level for Riverine Environments

Level 1	Level 2	Level 3
Estimates of ambient velocity based on assumptions regarding flow, depth, cross-sectional area, slope, and friction factors acceptable if local velocity data is not available.	Measurements of ambient velocity during critical and off-design conditions at a location representative of the average water column velocity are desirable, but estimates are acceptable. Detailed cross-sectional profile (width and depth) data is needed if local velocities are estimated based on calculations.	Direct measurements of ambient velocity, salinity (if applicable), and temperature at different depths during critical conditions for consideration of density stratification on mixing dynamics are necessary. Estimates for off-design conditions, if necessary, are acceptable.

Effort Level for Tidally-Affected Waterbodies, Estuaries, Bays, and Oceans

Level 1	Level 2	Level 3
Measurements of ambient velocity during critical and off-design conditions are desirable. On a case-by-case basis, estimates of local velocities, salinities, and thermal gradient in lieu of measurements depending on expected plume behavior may be acceptable.	Direct measurements of ambient velocity during critical conditions representative of water column velocity within the mixing zone are necessary. Estimates for off-design conditions, if necessary, are acceptable.	Same as Level 2

Statistics for Critical Flow Conditions

Mixing zones must be modeled under reasonable “critical” flow conditions to ensure that impacts to receiving waters are assessed under worst case conditions. The critical period will typically be late summer when stream flows are low and temperatures are high, but there are exceptions. The critical period may also vary with the parameter in question. Justification should be provided for the critical period defined for each parameter.

For riverine systems, critical flow condition statistics vary depending on the potential impact as follows:

- A short, very infrequent flow condition for acute toxicity (1Q10) and slightly longer period for chronic toxicity (7Q10) are used by the department. Note that in some cases these critical conditions do not differ significantly and it may be acceptable to use the 7Q10.
- Longer term human health impacts are evaluated on a longer term flow statistic (30Q5 for non-carcinogenic criteria and harmonic mean flow for carcinogenic criteria).

For information on flow statistics for both riverine and tidally-affected waterbodies, see Table 4-2. This table summarizes the minimum required ambient flow statistics for riverine systems recommended by EPA’s *Technical Support Document for Water Quality-based Toxics Control, March 1991* (or *TSD*) and tidally-affected systems as recommended by Washington Department of Ecology’s *Water Quality Program Permit Writer’s Manual, July 2005*.

Receiving Waterbody Cross-Sectional Profile

The cross section of the receiving water may vertically and laterally constrain plume spreading. In such cases, it is important to confirm that the mixing model used does not assume an infinite receiving water body since such a model will not be able to model boundary interactions. The cross sectional profile within the RMZ and ZID need to be described and diagrammed.

Ambient Velocity Profile

Ambient velocity greatly influences plume dynamics and plume shape. Sometimes assuming an average velocity over the entire depth is adequate for modeling purposes, but if there are significant changes in velocity with respect to depth, a velocity profile is necessary.

The velocity profile is developed by measuring the velocity at multiple points in both the vertical and horizontal direction at a particular location (or transect) along the stream. If there are significant changes in river bathymetry within the mixing zone, velocity profiles should be developed at representative locations.

A velocity profile (or ambient velocity) is needed for each flow statistic for which modeling is to be performed.

If the receiving stream is tidally influenced, the velocity dynamics need to be described over the tidal cycle.

Temperature and Salinity Profile

Salinity and temperature profiles of a water body affect its density, which will influence the plume dynamics of a discharge due to buoyant forces. Waterbodies that are stratified either due to salinity or temperature must be described and diagrammed because stratification greatly affects how an effluent plume will mix with the receiving water. Stratification typically occurs in deep waterbodies (i.e., lakes and reservoirs) and tidally-influenced areas (i.e., oceans and estuaries).

In tidal systems, salinity and temperature profiles over the full tidal cycle are necessary if they are likely to occur. Note that in some cases a river may be influenced by the tide, but not have stratification issues due to salinity or temperature profiles (e.g., lower Willamette River to the Oregon City falls). Maximum and minimum stratification conditions must also be characterized because these are typically worst case conditions.

Manning’s Roughness Coefficient

Manning’s roughness coefficient (*n*) is a measure of the friction at the stream bottom. The channel morphology should be described and Manning’s *n* estimated based on this description.

Table 4-1. Estimate of Manning’s n

Description	*n*
Bare earth, straight	0.020 - 0.030
Bare earth, winding	0.040 - 0.05
Mountain streams, gravel, cobbles	0.040 - 0.050
Mountain streams, gravel, cobbles, and boulders	0.050 - 0.70
Grass lined, weeds	0.050 - 0.06
Heavy brush, timber	0.10 - 0.12
Major rivers	0.030 - 0.035
Sluggish with pools	0.040 - 0.050

Table 4-2. Receiving Water Flow Statistics to Use in Mixing Zone Analysis

Water Quality Criteria	Streamflow Statistics[1] for Rivers	Ambient Statistics for Marine/Estuarine Waters[2]
Aquatic Life: Acute	• 1Q10 • associated velocity	Critical velocity = 10th and 90th percentile current velocities derived from a cumulative frequency distribution analysis. The current velocity frequency distribution analysis should be conducted, at minimum, over one neap and spring tide cycle[3]. Critical ambient density profile = density profile that results in the lowest mixing. Critical diffuser depth = depth at MLLW[4]. For estuaries, the diffuser depth is defined for low-water slack and low river flow conditions.
Aquatic Life: Chronic	• 7Q10 • associated velocity	Critical velocity = 50th percentile current velocity derived from a cumulative frequency distribution analysis. The current velocity frequency distribution analysis should be conducted, at a minimum, over one tidal cycle. Critical ambient density profile = density profile that results in the lowest mixing. Critical diffuser depth = depth at MLLW.
Human Health	• Carcinogens: Harmonic mean[5] • Non-carcinogens: 30Q5[6] • associated velocities	Note: Statistics for marine/estuarine waters are the same for both carcinogens and non-carcinogens. Use the median velocity taken over one tidal cycle or from as many tidal cycles as are available in the period of record. Critical ambient density profile = density profile that results in average mixing. For marine waters, critical diffuser depth = depth at MLLW. For estuaries, the diffuser depth is defined as the smaller of the median water depth at either the ebb tide or the flood tide during the critical receiving water period.

[1] Technical Support Document for Water Quality-based Toxics Control, U.S. EPA, March 1991.

[2] Table VI -3, "Applicable criteria/design conditions for determining the acute and chronic dilution factors for aquatic life" and Table VII-1 "Design conditions for water quality-based permitting of human health criteria" from Water Quality Program Permit Writer's Manual, Washington Department of Ecology, November 2010.

[3] Spring tides occur around full and new moons. Neap tides occur around the first and last quarters of the lunar cycle. The greatest range of tidal elevation is seen during spring tides and the smallest range of tidal elevations occurs during neap tides.

[4] MLLW stands for Mean Lower Low Water and it is equal to the average height of the lower of the two daily low tides. For more explanation, see oregon.gov/DSL/SSNERR/images/explain_**tides**.ppt

[5] Use the harmonic mean flow for the representative period of record. The representative period is the period that best represents flows as they now exist. For instance, if a dam was constructed that modified flows, use data from the time after the dam was constructed to determine the critical flow.

[6] If the 30Q5 is not available, use the 7Q10 as an estimate of the 7Q10.

4.4 Discharge Characteristics

Overview

Flow, temperature, and density are the major discharge characteristics that influence mixing. This section discusses the specific information needed for each of these characteristics so mixing conditions may be properly assessed.

Discharge Flow Statistics

Discharge flow statistics should be developed to coincide with the critical period. This will typically be late summer when stream flows are low and temperatures are high, but there are exceptions. As mentioned in Section 4.3, the critical period may vary with the parameter in question. The permit writer may use different discharge flow rates depending on the timing of environmental factors (e.g., salmonid migration, shellfish harvesting). Table 4-3: Effluent Flow Statistics to Use in Mixing Zone Analyses shown below, provides more information on effluent flow statistics that are needed.

Table 4-3. Effluent Flow Statistics to Use in Mixing Zone Analyses (for both riverine and marine/estuarine systems)

Water Quality Criteria	Effluent Flow[1]	
	Domestic	Industrial
Aquatic Life: Acute	For plants operating at <85% DWDF[2] during the critical period: Use maximum daily average flow for the past 3 years during the period when the critical receiving water flow is most likely to occur. For plants operating at 85-100% of DWDF: Use DWDF x PF[3]	Use maximum daily average flow for the past 3 years during the period when the critical receiving water flow is most likely to occur. If flows are expected to increase over the life of the permit, estimate highest daily maximum flow.
Aquatic Life: Chronic	For plants operating at 85-100% of DWDF during the critical period: Use DWDF. For plants operating at <85% DWDF: Use highest monthly average flow for the past 3 years during the critical period or during the period when the critical condition is likely to occur.	Use highest monthly average flow for the past 3 years during the period when the critical receiving water flow is most likely to occur. If flow is expected to increase, estimate highest monthly average maximum flow.
Human Health	Carcinogens: Use the annual average design flow as specified in the engineering report or permit application, or use the annual average flow based on DMR analysis. Non-carcinogens: For plants operating at 85-100% of design capacity: Use the dry weather design flow. For plants operating at <85% of design flow: Use highest monthly average flow for the past 3 years during the period when the critical receiving water flow is most likely to occur.	Carcinogens: Use the annual average flow based on the permit application or DMR analysis. Non-carcinogens: Use highest monthly average flow for the past 3 years during the period when the critical receiving water flow is most likely to occur. If flows are expected to increase over the life of the permit, estimate highest average monthly flow.

Notes:

[1] Table VI -3, "Applicable criteria/design conditions for determining the acute and chronic dilution factors for aquatic life" and Table VII-1 "Design conditions for water quality-based permitting of human health criteria" from Water Quality Program Permit Writer's Manual, Washington Department of Ecology, November 2010.
[2] DWDF - Dry Weather Design Flow
[3] PF – Peaking Factor

Temperature and Density

Temperatures and conductivity and/or salinity to determine densities of the discharge for the critical time periods are needed. Temperature values should be determined as follows:

Water Quality Criteria	Effluent Temperature
Acute	90th % of daily maximums during critical period
Chronic	Average daily temperature during critical period
Human health	Annual average

4.5 Mixing Zone Modeling Analysis

Overview

Several numerical models are available for simulating mixing. Because different models perform better under specific conditions, models should be selected that best match the conditions being simulated. This section details what information is needed to determine if the correct model was used and whether the modeling results are acceptable.

Expected Level of Effort When Modeling

As explained in Section 3.1, the level of effort expected for different types of discharges varies depending on whether the discharge is classified as simple (Level 1), moderate (Level 2) or complex (Level 3). Generally, the following is expected for each level:

- ***Level 1***
  Modeling using design conditions and available data without field sampling or further calibration of the model is acceptable. In some instances, ambient-induced mixing equations may be used to predict dilutions at the edge of the ZID and RMZ as discussed in EPA's *TSD*, Section 4.4.5, p. 77).

- ***Level 2***
  Modeling with design conditions and available data is acceptable, but some field sampling to gather model input data is expected. Sensitivity analysis should be conducted to determine model sensitivity to various input parameters.

- ***Level 3***
  Field data is necessary to calibrate or validate the model. Characterization of field dilution data should be based on a department-approved tracer study performed during critical conditions or is translatable to critical conditions. Field studies during off-design conditions may also be necessary if these time periods are important. See "Characterizing Critical and 'Off-Design'

Conditions" in Section 4.3 for more information on types of conditions that may need to be considered.

Note: Mixing zone models are not always able to adequately simulate discharge conditions. Many models are not appropriate when discharge is to shallow streams of non-uniform flow or to tidally influenced waterbodies. See "When steady-state mixing zone models may not be appropriate" at the end of section 2.1.

What Type of Information is Needed?

Generally, modeling for each critical flow condition is needed. However, in some cases the critical conditions do not differ significantly (e.g., 1Q10 vs. 7Q10 in large streams) and it is acceptable to model fewer conditions. The following information is needed for each condition modeled to assess the modeling analysis:

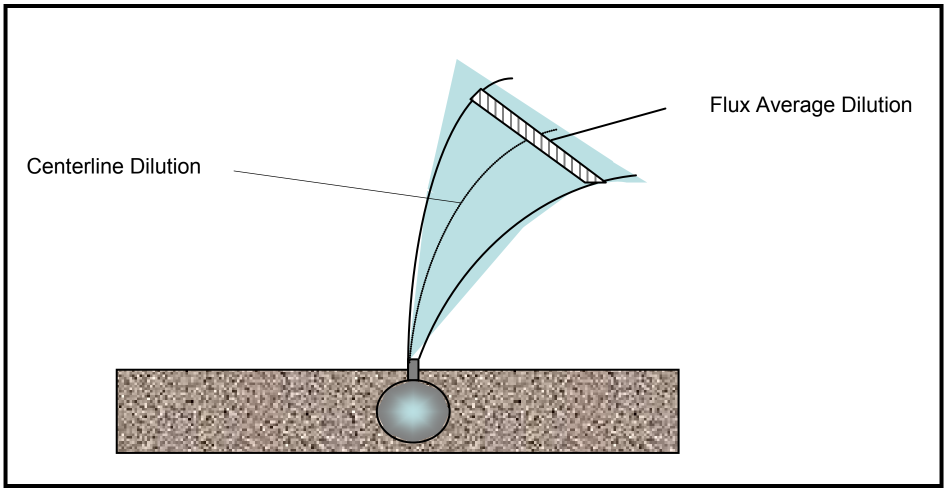
1) Version number of model(s) used and the reason for selecting the model(s). If more than one model was used or if a different one was used for the far-field analysis versus the near-field analysis, an explanation should be provided.

2) A description of the model input parameters used.

3) Description of the physical mixing occurring within the near-field and far-field, including:
    a. When the plume interacts with the surface or other boundary conditions. (Levels 1 and 2)
    b. Near-field dynamic attachments (e.g., if the plume attaches to the stream bottom). (Levels 2 and 3)
    c. Occurrence of near-field instabilities associated with surface and bottom interaction and localized recirculation cells extending over the entire water depth (Levels 2 and 3)
    d. Where the plume loses its initial momentum and where the far-field process begins. (Levels 2 and 3)
    e. Stratification of the plume. (Levels 2 and 3)
    f. Shape of the plume in three dimensions. (Levels 2 and 3)
    g. Whether there are any buoyant upstream intrusions. (Levels 2 and 3)

4) Predicted "minimum centerline" dilution at the edge of the ZID defined in permit and "average flux" dilution at edge of the RMZ defined in the permit. These are described further below and in Figure 4-5. For a new discharge where the ZID and RMZ have yet to be allocated, predicted dilutions based on estimated ZID and RMZ sizes are acceptable if the estimates were developed based on *RMZ IMD Part 1*.
    - Centerline Dilution: This is the minimum dilution that occurs at the centerline of the plume and where the effluent is most concentrated. Centerline dilution is applied to acute criteria at the edge of the ZID.
    - Flux Average Dilution: This is the average dilution across the entire cross-section of the plume. Flux average dilution is applied to chronic criteria and human health criteria at the edge of the RMZ.

Figure 4-5. Centerline and Flux Average dilution



5) The following information is needed regarding model results:
   a. A list of the modeling scenarios performed with the critical conditions and flow statistic provided for each.

6) For each modeling scenario, a summary table displaying the modeling results including all input parameters needed to run the model(s) and results achieved for each modeling scenario. Include model sensitivity results. See the following example in Table 4-4. Note: the example only provides basic inputs. Other critical inputs, such as port angle and orientation, may be needed.

Table 4-4. Modeling Results Summary Example for Riverine Systems

Model Run Description	Flow Statistic	Ambient Conditions					Discharge Conditions			Outfall Characteristics		Dilutions Predicted by Model	
		Velocity (ft/s)	Depth (ft)	Width (ft)	Flow (cfs)	Temp (° F)	Flow (mgd)	Port Velocity (ft/s)	Temp (° F)	# Ports	Port Diam. (inches)	ZID	MZ
Existing Condition: outfall w/single port	30Q10												
	7Q10												
	1Q10												
	Harmonic Mean Flow												
Proposed Scenarios 1, 2, 3 etc.: (describe)	30Q10												
	7Q10												
	1Q10												
	Harmonic Mean Flow												

Was the Appropriate Model Used?

To determine if results from the modeling are sufficient to proceed with permit development, the permit writer must:

1. **Become familiar with the assumptions and limits of various models.**
   See discussion entitled xx in Section 2.1 for more information.

2. **Review the information provided by the applicant to:**
   a. *Classify the type of discharge and then determine which models are applicable.*
   There are three classifications:
      i. Submerged single port diffuser,
      ii. Submerged multi-port diffuser, and
      iii. Surface discharge.

   b. *Determine the possibility of boundary interaction.*
   See Section 2-1: Influence of Boundary Interactions, for a discussion of boundaries. Since not all mixing zone models are designed to model the various boundary conditions, it is important to understand what boundary interactions could exist and use a model to simulate these boundary conditions.

   c. *Determine whether there are instabilities in the near-field, such as surface or bottom interactions or localized recirculation areas which may cause buildup of discharge concentrations by obstructing discharge flow.*
   See Section 2-1: Re-entrainment of Discharge for a discussion of instabilities.

   A series of equations can be used to determine whether a discharge is stable (no re-entrainment likely to occur) based on the discharge and receiving water characteristics. Typically, the department will use the CORMIX model to determine stability for each simulation. CORMIX is readily available to staff and designed to account for stability internally within its programming. If a discharge is determined to be unstable, a model that can simulate unstable conditions must be used. In general, standard jet-integral models cannot be used for unstable conditions because of entrainment issues.

3. **Ask the following:**
   a. *Is the model EPA-supported or have a proven scientific track record?*
   If no, supporting document for the model should be provided otherwise it should not be accepted.

   b. *Does the applicant's reason for selecting the model make sense?*
   If it does not, then it should not be accepted without further explanation from the applicant.

   c. *Does the applicant adequately address the sensitivity of the model?*
   See Section 2-2: Model Sensitivity, for background information. Prior to collecting field data or more data, the model should have been run using available data or assumptions to determine its sensitive parameters. If this step was not performed, then the model must be analyzed for sensitivity by the applicant or permit writer before proceeding with permit development.
   Follow these steps:
      i. Run the model by entering the maximum, minimum, and a few intermediate values for each parameter likely to be sensitive. Parameters most likely to be sensitive include

discharge flow rate and temperature and ambient velocity and temperature. Models can also be sensitive to the location and type of stratification in stratified waterbodies.

ii. Change only one input variable at a time otherwise it is impossible to determine which input variable caused the changes in output results.

iii. If there is no plan to collect additional data to confirm modeling results, the most conservative dilution results must be used.

d. *For permit renewals, are the modeling results consistent with what is known about the existing RMZ?*

The applicant or permit writer must do a quick check of the predicted dilution factors from the chosen mixing zone model to determine if they are reasonable. Follow these steps:

i. Calculate the percentage of stream mixing with discharge using the dilution factor from the model and the following basic mass balance equation.

% of stream mixing with discharge = ((D-1) x Qe)/Qs
Where: *D = predicted dilution factor (From the model output)*
Q_e *= discharge flow (cfs)*
Q_s *= stream flow (cfs)*

ii. Compare this percentage with what is actually known about the discharge. See the following for an example of the different conclusions reached for one flow scenario when existing information differs.

An example mass balance exercise follows.

Flow Scenario:
Model predicted dilution factor at edge of mixing zone (DF) = 45
Discharge flow (Q_e) = 1.80 mgd x 1.547 = 2.78 cfs
Stream 7Q10 flow (Q_s) = 170 cfs
⇨ *% of stream mixing with discharge = ((DF x Q_e)/Q_s) x 100*
= [(45 x 2.78)/170] x 100 = **73.5%**

Existing Information	Conclusion
Example 1: Dye study indicates discharge stays on one side of stream and does not mix with majority (>50%) of stream.	Model is over predicting dilution. Model must be refined or a different model used.
Existing Information	**Conclusion**
Example 2: No knowledge of discharge mixing characteristics or field studies.	Discharge may cause migration blockage because it mixes with a significant portion of stream. Additional field data may be needed or discharge characteristics (e.g., outfall configuration, discharge volume and rate, discharge chemistry) may need to be changed.

Permit development may proceed when the permit writer is satisfied that the modeling results are sufficient. If further assistance is needed in evaluating the modeling results, the permit writer may consult with the modeling specialist in the region or headquarters.

References

Jirka, Gerhard H., Robert L. Doneker, Steven W. Hinton. 1996. User's Manual for CORMIX: A Hydrodynamic Mixing Model and Decision Support System for Pollutant Discharges into Surface Waters. U.S. EPA, Office of Science and Technology, Washington, DC.

U.S. EPA. 1990. NPDES Non-Municipal Rating System – Permit Rating Worksheet. http://www.epa.gov/npdes/pubs/owm0116.pdf

U.S. EPA. 1991. Technical Support Document for Water Quality-based Toxics Control. EPA/505/2-2-90-001.

Washington Department of Ecology. 2005. Water Quality Program Permit Writer's Manual. Publication #92-109.

Appendix A: Mixing Zone Study Checklist

Oregon DEQ Mixing Zone Study Checklist

(to be submitted to DEQ with Report on Mixing Zone Study) (v. 2.0, May 2012)

<table>
<tr><td colspan="4">Legal Name:
Common Name:
Facility ID#:
Application #:</td><td colspan="2">Date Submitted:
Conducted by:</td></tr>
<tr><td colspan="3">Study Level <i>(to be filled out by DEQ)</i>:
☐ Level 1 - Simple
☐ Level 2 - Moderate
☐ Level 3 – Complex
(See Part 2 of RMZ, Section 3.1, p.8)</td><td colspan="2">Information:
X = required
E = estimate is acceptable
M = measurement (field or engineering plans)
D = desirable</td><td>Check if Complete
(or note deficiencies)
<i>To be filled out by DEQ.</i></td></tr>
<tr><td>1</td><td>2</td><td>3</td><td colspan="2">1. Environmental Mapping (RMZ IMD Part 2, Section 4.1, p. 19)</td><td></td></tr>
<tr><td>X</td><td>X</td><td>X</td><td colspan="2">A. Attach plan view map showing outfall and a segment of river that extends at least 1/2 mile upstream and downstream of outfall. Map should indicate the following features downstream of outfall unless otherwise noted. By checking whether the specific feature is present or not, the permittee is certifying they have researched the information resources listed in Section 4.1 (Environmental Mapping) of the RMZ IMD.
<table>
<tr><th>Feature</th><th>Present</th><th>Not present</th></tr>
<tr><td>Known commercial or recreational shellfish areas</td><td></td><td></td></tr>
<tr><td>Fish spawning/rearing habitat</td><td></td><td></td></tr>
<tr><td>Cold water refugia for fish</td><td></td><td></td></tr>
<tr><td>Areas identified as having species (fish or non-fish) that may be sensitive to impact of discharge*</td><td></td><td></td></tr>
<tr><td>Physical structures expected to attract fish (e.g., piers, large woody debris, outfalls)</td><td></td><td></td></tr>
<tr><td>Public access areas such as boat ramps, docks or public beaches</td><td></td><td></td></tr>
<tr><td>Drinking water intakes within the vicinity of the outfall and ½ mile downstream (to be identified by DEQ. Link to internal webpage is http://deq05/wqoutfalls/EOPbasics.aspx</td><td colspan="2">To be determined by DEQ</td></tr>
<tr><td>Other NPDES discharges upstream and downstream within ½ mile of outfall (to be identified by DEQ. Link to internal webpage is http://deq05/wqoutfalls/EOPbasics.aspx)</td><td colspan="2">To be determined by DEQ</td></tr>
</table>
*If such species are found to be present, report should include a description of such species.
Page number(s) __________</td><td></td></tr>
<tr><td>X</td><td>X</td><td>X</td><td colspan="2">B. Are there threatened and endangered species in the RMZ? ☐ Yes ☐ No
If yes, report should include a description of threatened and endangered species present, habitat, and migration pathways as well as source(s) of information.
Page number(s) __________</td><td></td></tr>
</table>

Oregon DEQ Mixing Zone Study Checklist
(to be submitted to DEQ with Report on Mixing Zone Study) (v. 2.0, May 2012)

<table>
<tr><td></td><td></td><td>D</td><td>C. Other information as appropriate.
<table>
<tr><th>Type of Information
(check all that apply)</th><th>Page Number(s)</th></tr>
<tr><td>☐ Detailed salmonid use</td><td></td></tr>
<tr><td>☐ Bioassessment.</td><td></td></tr>
<tr><td>☐ Fish migration study</td><td></td></tr>
<tr><td>☐ Thermal imagery</td><td></td></tr>
<tr><td>☐ Map or measurements of channel width/depth</td><td></td></tr>
<tr><td>☐ Published information supporting environmental mapping</td><td></td></tr>
<tr><td>☐ Other. Describe:</td><td></td></tr>
</table></td><td></td></tr>
<tr><td></td><td></td><td></td><td>2. Outfall Location and Mixing Description (RMZ IMD Part 2, Section 4.2, p.24)</td><td></td></tr>
<tr><td>E</td><td>M</td><td>M</td><td>A. Outfall Measurements:
<table>
<tr><th>Measurement</th><th>Page Number(s)</th></tr>
<tr><td>Distance from bank (ft):</td><td></td></tr>
<tr><td>Height above bottom (ft):</td><td></td></tr>
</table></td><td></td></tr>
<tr><td>E</td><td>M</td><td>M</td><td>B. If present, diffuser and port dimensions, orientation angle and configuration (include drawings, if available)
☐ N/A
☐ Description on page number(s) __________
☐ Drawing on page number(s): __________</td><td></td></tr>
<tr><td>X</td><td>M</td><td>M</td><td>C. Outfall Location:
Latitude:_________________________

Longitude:_______________________
<i>This information may be available on the following internal webpage:</i>
http://deq05/wqoutfalls/EOPbasics.aspx</td><td></td></tr>
<tr><td>E</td><td>E</td><td>E</td><td>D. River mile of outfall:_______________
<i>This information may be available on the following internal webpage:</i>
http://deq05/wqoutfalls/EOPbasics.aspx</td><td></td></tr>
<tr><td>D</td><td>D</td><td>D</td><td>E. Photographs of the outfall vicinity
☐ N/A
☐ See attached on page number(s): __________</td><td></td></tr>
<tr><td>X</td><td>X</td><td>X</td><td>F. Description and plan view of current RMZ and ZID as described in permit:
☐ See attached on page number(s): __________</td><td></td></tr>
</table>

<table>
<tr><th></th><th></th><th></th><th>Part 3. Ambient Receiving Water Conditions (RMZ IMD Part 2, Section 4.3, p.26)</th><th></th></tr>
<tr><td>E</td><td>E</td><td>E</td><td>A. Parameter:
Dates of Critical Period:
<i>(Note:may vary with parameter. See Section 4.3, p.26)</i>
☐ See attached on page number(s) __________
____
Justification for Critical Period:
☐ See attached on page number(s) __________
____

For Riverine Systems:
Flow statistics and dilutions corresponding to critical period:
<table>
<tr><th>Flow Statistic</th><th>Stream Flow (cfs)</th><th>Velocity (ft/sec)*</th><th>Dilution at edge of ZID</th><th>Dilution at edge of RMZ</th><th>Page Number(s)</th></tr>
<tr><td>1Q10</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>7Q10</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>30Q5</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Harmonic Mean</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
*For systems where velocity can be approximated by a single value. If velocity profile is needed, go to next section B.

Describe source (USGS, other) and extent of flow data on which critical flow statistics are based.
☐ N/A
☐ See attached on page number(s) __________

For Marine/Estuarine Systems:
Refer to Table 4-2 on p. 30 for appropriate statistics and describe in an attachment.
☐ N/A
☐ See attached on page number(s) __________</td><td></td></tr>
<tr><td>E</td><td>E/M</td><td>E/M</td><td>B. Velocity profile* for each critical flow condition
☐ N/A
☐ See attached on page number(s) __________
*for systems that where velocity cannot be approximated by a single value.</td><td></td></tr>
<tr><td>E</td><td>E/M</td><td>M</td><td>C. Cross sectional area (width and depth) for each critical flow.
☐ See attached on page number(s) __________</td><td></td></tr>
<tr><td>E</td><td>E/M</td><td>M</td><td>D. Temperature and salinity profiles
☐ N/A (no stratification)
☐ See attached on page number(s) __________</td><td></td></tr>
<tr><td>E</td><td>E</td><td>E</td><td>E. Manning's roughness coefficient:
Page number __________</td><td></td></tr>
</table>

<table>
<tr><td></td><td></td><td></td><td>Part 4. Discharge Characteristics (RMZ IMD Part 2, Section 4.4, Table 4-3, p. 31)</td><td></td></tr>
<tr><td>E</td><td>X</td><td>X</td><td>C. Discharge flow rates for critical flow scenarios:
<table>
<tr><td></td><td>☐ Domestic</td><td>☐ Industrial</td></tr>
<tr><td rowspan="2">Aquatic Life: Acute</td><td>☐ For plants operating at <85% DWDF[1] during the critical period: Use maximum daily average flow for the past 3 years during the period when the critical receiving water flow is most likely to occur.
☐ For plants operating at 85-100% of DWDF: Use DWDF x PF[2]</td><td>☐ Use maximum daily average flow for the past 3 years during the period when the critical receiving water flow is most likely to occur.
☐ If flows are expected to increase over the life of the permit, estimate highest daily maximum flow.</td></tr>
<tr><td>Applicable Effluent Flow :</td><td>Page No.:</td></tr>
<tr><td rowspan="2">Aquatic Life: Chronic</td><td>☐ For plants operating at 85-100% of DWDF during the critical period: Use DWDF.
☐ For plants operating at <85% DWDF: Use highest monthly average flow for the past 3 years during the critical period or during the period when the critical condition is likely to occur.</td><td>☐ Use highest monthly average flow for the past 3 years during the period when the critical receiving water flow is most likely to occur.
☐ If flow is expected to increase, estimate highest monthly average maximum flow.</td></tr>
<tr><td>Applicable Effluent Flow :</td><td>Page No.:</td></tr>
<tr><td rowspan="2">Human Health</td><td>☐ Carcinogens: Use the annual average design flow as specified in the engineering report or permit application, or use the annual average flow based on DMR analysis.
☐ Non-carcinogens:
☐ For plants operating at 85-100% of design capacity: Use the dry weather design flow.
☐ For plants operating at <85% of design flow: Use highest monthly average flow for the past 3 years during the period when the critical receiving water flow is most likely to occur.</td><td>☐ Carcinogens: Use the annual average flow based on the permit application or DMR analysis.
☐ Non-carcinogens: Use highest monthly average flow for the past 3 years during the period when the critical receiving water flow is most likely to occur. If flows are expected to increase over the life of the permit, estimate highest average monthly flow.</td></tr>
<tr><td>Applicable Effluent Flow :</td><td>Page No.:</td></tr>
</table>
Notes:
[1] DWDF - Dry Weather Design Flow
[2] PF – Peaking Factor</td><td></td></tr>
</table>

	E/M	**M**	D. Discharge chemistry data:	

Check if N/A	Parameter	Value	Page Number(s)
	Temperature (F)		
	Conductivity (µmhos)		
	Salinity (ppt)		

			Part 5. Mixing Zone Modeling* (RMZ IMD Part 2, Section 4.5, p. 32)	
	D	**M**	A. Field mixing measurements (e.g., dye studies) ☐ N/A ☐ See attached on page number(s) ___________	
X	**X**	**X**	B. Model selection and application discussion ☐ N/A ☐ See attached on page number(s) ___________	
X	**X**	**X**	C. Description of mixing and plume dynamics (near-field and far-field) ☐ N/A ☐ See attached on page number(s) ___________	
X	**X**	**X**	D. Sensitivity analysis ☐ N/A ☐ See attached on page number(s) ___________	
X	**X**	**X**	E. Model results table (see Table 4-4 on page 34 of Section 4.5 of Part 2 of the RMZ IMD for an example) ☐ N/A ☐ See attached on page number(s) ___________	

*Note: In some cases (e.g., shallow streams with non-uniform flow and tidally-influence waterbodies), modeling is not appropriate. See RMZ IMD Part 2, Section 2.2, p. 6.

DEQ Reviewer Comments

Name of DEQ Reviewer:

Date:

4. Describe deficiencies, if any.

5. Which if any need to be addressed before the permit can be issued?

6. Which if any may be addressed through permit conditions?

The checklist and reviewer comments should be attached to the permit evaluation report.

Appendix B: Examples of Mixing Zone Study Effort Levels

*Note: the names of the permittee, city and receiving waters have been replaced with generic terminology.

Level 1: Simple

ABC Packaging:

The permittee discharges non-contact cooling water to the Mythical River through four outfalls at about River Mile 105.7. The NPDES permit defines the regulatory mixing zone (RMZ) at each outfall as the portion of the Mythical River from the discharge to 150 feet downstream of the point of discharge. All four discharge locations are submerged single port outfalls. A mixing zone study was conducted in 2001. The study consisted of using CORMIX, an EPA-approved model, to predict dilution at the edge of the RMZ. The mixing zone dilutions at the four outfalls ranged from 19:1 to 40:1 and the dilution at the edge of the zone of immediate dilution (ZID) ranged from 4:1 to 8:1.

ACME, Inc.

The permittee discharges non-contact to the Mythical Slough at RM 6.0. The NPDES permit defines the RMZ as a rectangle 25 meters wide and 70 meters upstream and 70 meters downstream of the discharge. The discharge occurs through a side-bank outfall that is above the water surface. A mixing zone study was conducted in 2001. The study consisted of using CORMIX, an EPA-approved model, to predict dilution at the edge of the RMZ. The RMZ dilution was estimated to be 6.3:1. The permit does not define a ZID.

City of Mythical

The city discharges to the Mythical River at RM 190. The NPDES permit defines the RMZ as that portion of the Mythical River within a 100 foot radius of the point of discharge. The ZID may not exceed 10 percent of the defined RMZ in any direction from the point of discharge. The city discharge consists of a 48-inch reinforced concrete pipe that extends over 150 feet from the river bank into the Mythical River. The outfall pipe is one 39-inch angled port at the water surface. The field work for the mixing zone was conducted in September 1994. The mixing zone study approach employed the injection of rhodamine WT dye into the effluent at know concentrations. The RMZ dilution was estimated to be 16:1 and the dilution at the edge of the ZID was estimated to be 2:1.

Level 2: Moderate

Mythical Mills

Mythical Mills discharges process wastewater to the Mythical River at RM 2.7. The NPDES permit defines the RMZ as that portion of the Mythical River within a 90 meter radius from the point of discharge. The discharge is through a submerged single port outfall. A mixing zone study was conducted in 2001. As part of the mixing zone evaluation, velocity profile data was collected. The study used the field data as input for modeling. The modeling consisted of using CORMIX, an EPA-approved model, to predict dilution at the edge of the RMZ. The RMZ dilution was estimated to be 24:1 and the dilution at the edge of the ZID was estimated to be 5:1.

City of Hypothetical

The city discharges wastewater to the Mythical River at RM 38.6. The NPDES permit defines the RMZ as that portion of the Mythical River within 150 feet downstream of the point of discharge. The discharge is through a submerged single port outfall. A mixing zone study was conducted in 2002. The modeling consisted of using CORMIX to predict dilution at the edge of the RMZ. The mixing zone evaluation also consisted of several model runs to assess the sensitivity of dilution predictions to input assumptions. The RMZ dilution was estimated to be 23:1 and the dilution at the edge of the ZID was estimated to be 3:1.

City of Example

The city discharges to the Mythical River at RM 168.5. The NPDES permit defines the RMZ as that portion of the Mythical River within a 100 foot radius of the point of discharge. The outfall is a 54-inch diameter corrugated metal pipe. The end of the outfall is on a rock peninsula which extends approximately 15 feet into the Mythical River from the main shoreline. The outfall is an open ended pipe without a diffuser. The mixing zone was evaluated by measuring the dilution of dye injected at a constant rate into the effluent stream and with CORMIX. The field work for the mixing zone was conducted in August 1994. The RMZ dilution was estimated to be 15:1 and the dilution at the edge of the ZID was estimated to be 5:1.

Level 3: Complex

City of Utopia

The city discharges wastewater to the Mythical River at RM 2.3. The NPDES permit defines the RMZ as that portion of the Mythical River from the point of discharge to 100 feet downstream of the discharge. The discharge is through a submerged single port outfall. A mixing zone study was conducted in 2003. The mixing zone evaluation consisted of a field dye study followed by modeling using CORMIX. The CORMIX model was first calibrated to field conditions. Then the model was used to run several scenarios. The RMZ dilution was estimated to be 42:1 and the dilution at the edge of the ZID was estimated to be 7:1.

ABC Paper Company

The permittee discharges wastewater to the Mythical River at RM 27.7. The NPDES permit defines the RMZ as that portion of the Mythical River from the point of discharge to 20 meters downstream of the discharge. The discharge is through a submerged multi-port diffuser consisting of 11 diffuser ports. A mixing zone study was conducted in 2003. The mixing zone evaluation consisted of a field dye study followed by modeling. Both CORMIX and Visual Plumes were used to determine which model more closely represented field conditions. The mixing zone evaluation concluded that DKHW from the Visual Plumes modeling suite better represented field conditions than CORMIX. Once the model was selected, several model runs were conducted for a variety of scenarios. The RMZ dilution was estimated to be 53:1 and the dilution at the edge of the ZID was estimated to be 5:1.

Appendix C: Critical Flow Conditions

Overview

Critical design flow conditions must be used when conducting a mixing zone study for the purpose of allocating an RMZ. EPA recommends either the hydrologic method developed by the U.S. Geological Survey or a biologically-based method developed by EPA for calculations of critical flows.

Although water quality criteria within the RMZ may be exceeded under these critical flows, the water within the RMZ must at all times be free from substances settling to form objectionable deposits; floating debris, scum, oil, or other matter; produce objectionable color, odor, taste, or turbidity; cause acutely toxic conditions; or produce undesirable or nuisance aquatic life.

EPA's *Technical Support Document for Water Quality-based Toxics Control* (*TSD)* describes the critical design flows that should be used when performing mixing zone analyses for the various waterbodies. This discussion is summarized in the following sections. The waterbodies are grouped as follows: rivers and run-of-rivers reservoirs, lakes and reservoirs, estuaries and coastal bays, and oceans.

Rivers and Run-of-Rivers Reservoirs

EPA's *TSD* defines rivers and run-of-river reservoirs as waterbodies that have a persistent throughflow in the downstream direction and do not exhibit significant natural density stratification. Critical design periods for these waterbodies are discussed in greater detail in A*ppendix D* of the *TSD*. The *TSD* recommends the use of the hydrologically or biologically based design flows. The critical flows are as follows:

- Aquatic Life

Acute criteria (CMC):	1Q10 or 1B3
Chronic criterion (CCC):	7Q10 or 4B3

- Human Health

Non-carcinogens:	30Q5
Carcinogens:	Harmonic mean flow

1Q10 is the lowest one day flow with an average recurrence frequency of once in 10 years.

7Q10 is the lowest average 7 consecutive day low flow with an average recurrence frequency of once in 10 years.

30Q5 is the lowest average 30 consecutive day low flow with an average recurrence frequency of one in 5 years.

harmonic mean flow is a long term mean flow value calculated by dividing the number of daily flows analyzed by the sum of the reciprocals of those daily flows. The equation is:

$$\frac{n}{\sum 1/Q_{i-n}}$$

where n = number of daily flows
Q = flow

1B3 and 4B3 are biologically-based design flows determined using a method developed by EPA. This method directly incorporates the aquatic-life water quality criteria averaging periods and frequencies specified for the CMC and CCC (i.e. 1 day and 3 years for the CMC and 4 days and 3 years for the CCC).

Note: Regulated rivers may have a minimum flow in excess of these toxicological flows. In these cases, EPA recommends using the minimum flow.

Design Flow Software

EPA has two software programs that can calculate both types of design flows. Hydrologically-based design flows can be calculated using the programs DFLOW or FLOSTAT, and biologically-based design flows can be calculated using DFLOW. Both programs are available from EPA at http://www.epa.gov/waterscience/dflow/. The software package WQHYDRO (Aroner) also has the ability to calculate both types of design flows.

Lakes and Reservoirs

The critical time period should be determined based on seasonal variations in water level, density stratification, wind speed and direction, and seasonal solar radiation. In general, all four seasons should be analyzed to determine the most critical period.

Estuaries and Coastal Bays

EPA's *TSD* defines estuaries as having a main channel reversing flow and coastal bays as having significant two-dimensional flow in the horizontal directions. For both water bodies, the critical design conditions recommended by EPA are based on a combination of the tides and the river conditions.

Because plume dynamics within an estuarine environment are so complex, discharge dilution can not be calculated simply based on the receiving stream critical low flow and the effluent discharge rate. Effluent mixing within an estuary is complicated by density stratification, tidal variation, wind effects, riverine inputs, and complex circulation patterns. The complex nature of the above factors requires site specific, empirical data to determine the critical dilution factors.

The TSD makes separate recommendations for estuaries without stratification and with stratification. In estuaries without stratification, the critical dilution condition includes a combination of low-water slack at spring tide for the estuary and design low flow for riverine inflow. In estuaries with stratification, a site-specific analysis of a period of minimum stratification and a period of maximum stratification, both at low-water slack, should be made to evaluate which one results in the lowest dilution. In general, minimum stratification is associated with low river inflows and large tidal ranges (spring tide), whereas maximum stratification is associated with high river inflows and low tidal ranges (neap tide).

In addition to evaluation of the above critical design conditions, an off-design condition should be evaluated as well. The recommended off-design condition for both stratified and unstratified conditions is that of maximum velocity during a tidal cycle. The off-design condition will likely result in greater dilution but it may carry the plume further downstream. Evaluations of this condition are necessary to assure toxic conditions are not carried downstream into critical resource areas such as shellfish habitat.

For application of acute criteria, the 10th % velocity over one tidal cycle should be used for critical slack conditions and 90th % for the off-design condition. For chronic and human health criteria the 50th% velocity should be used.

Oceans

EPA's *TSD* refers to two documents that discuss critical design periods for ocean analyses (EPA, 1982 and Muellenhoff et al, 1985). The *TSD* provides a brief summary of these documents as they relate to mixing analysis for oceanic outfalls.

Like critical conditions for estuarine environments, oceanic critical periods must include analysis for periods of maximum and minimum stratification. The analysis must also include periods when oceanic conditions, weather conditions, or discharge conditions indicate that water quality standards are likely to be exceeded. The *TSD* suggests the 10th percentile value from the cumulative frequency of each parameter should be used in the analysis.

Appendix D: Revision History

Overview

Rev. 1 Initial publishing of document, December 2007
Rev. 1.1 Minor editorial changes, February 2008
Rev. 2.0 Changes to content, wording and formatting, May 2012.
Rev. 2.1 Minor change to content, May 2013.

Revisions

Rev. 1.1

- P. 29, Table 4-2, change of required effluent flow parameter for human health (non-carcinogen) from “annual average flow” to “average dry weather design flow”
- P. 29, Table 4-2, correct footnotes on human health flow systems to reflect “carcinogen” or “non-carcinogen”

Rev. 2.0

Section 1

- Language has been added to clarify that the RMZ must be evaluated under critical conditions, and that justification must be provided for the determination of when these conditions are expected to occur. This was done to comply with the terms of the settlement agreement which stipulates that “data relevant to the mixing zone includes information for all appropriate seasons (depending on pollutants and seasonal uses).”

- The document has been revised to reflect the fact that DEQ no longer has resources to conduct mixing zone studies.

Section 3

- Mixing zone study information checklist has been modified so that it serves to document the findings of the mixing zone study.

- The terms swimming holes, swimming areas and fishing holes have been replaced with the terms public beaches, docks and boat ramps because they are more identifiable and therefore less likely to be overlooked.

Section 4

- The section on environmental mapping was expanded to include discussion of the different categories of beneficial uses and to include resources for identifying beneficial uses other than fish.

- The discussion of critical conditions has been expanded to emphasize that mixing zones must be modeled under critical conditions and that justification must be provided for the decision as to what constitutes critical conditions for each parameter being evaluated. This change was made to comply with the terms of the settlement agreement which stipulates that “data relevant to the mixing zone includes information for all appropriate seasons (depending on pollutants and seasonal uses).”

- Mention of far-field analysis has been removed from the discussion of receiving waterbody cross-sectional profile because mixing analyses are by definition not far-field analyses.

- The discussion of ambient velocity profile has been expanded and more detail on how it may be determined has been added.

- Table 4-2 entitled “Required Statistics for Critical Condition and Effluent Flow” has been updated and broken into two separate tables, one entitled “Table 4-2: Receiving Water Flow Statistics to Use in Mixing Zone Analyses” and the other entitled “Table 4-3: Effluent Flow Statistics to Use in Mixing Zone Analyses (For Both Riverine and Marine/Estuarine Systems)”. In addition, “highest daily maximum flow” has been replaced with “maximum daily average flow”. This change was made in order to avoid the accidental use of the instantaneous maximum flow.

- “Table 4-4 Modeling Results Summary Example for A Given Set of Conditions” has been replaced with “Table 4-4: Modeling Results Summary Example for Riverine Systems”.

- Section 4.6 entitled “Additional water quality data” has been deleted because it is redundant with DEQ’s RPA IMD and does not pertain specifically to mixing zone analyses.

Rev. 2.1

Section 4.5

- From page 36:

% of stream mixing with discharge = ((D-1) x Qe)/Qs
Where: D = predicted dilution factor ~~= (Qe+Qs)/Qe~~ (From the model output)
Q_e *= discharge flow (cfs)*
Q_s *= stream flow (cfs)*

- From page 37:

  Existing Information

  Example 1: Dye study indicates discharge stays on one side of stream and does not mix with majority (>50%) of stream.