Regulatory Mixing Zone Internal Management Directive

Part 2: Reviewing Mixing Zone Studies

December 2007

DEQ
State of Oregon
Department of Environmental Quality

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.

Questions or comments on this IMD can be directed to:
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1. INTRODUCTION

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 IMD is in two parts to address the following issues:

Part 1: Allocating Regulatory Mixing Zones

- 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.

Part 2: Reviewing Mixing Zone Studies

- Provides for staff consistency when requesting and reviewing mixing zone study information.
- Clarifies for staff and permit applicants the information that 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:

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. Generally, the applicant provides this information to the department as a "mixing zone study;" however, the department may provide assistance as resources allow. The following are considered essential components of a study:

- **Environmental mapping** Section 4.1, p. 17
  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, p. 23
  A description of the existing or proposed RMZ, including a description of existing or proposed outfalls.

- **Ambient receiving water conditions** Section 4.3, p. 25

- **Discharge characteristics** Section 4.4, p. 30

- **Mixing zone modeling analysis** Section 4.5, p. 31
  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.

- **Additional water quality data** Section 4.6, p. 37
  Additional receiving water and discharge quality data will likely be needed to determine if the applicant's discharge will comply with water quality standards. This data is not necessary for input into a mixing zone model, but it may be necessary to confirm modeling results or develop permit effluent limitations. If the data is not provided in the permit application or more data is needed, the permit writer should request it as part of the overall mixing zone study. See the department's most recent version of the ***Reasonable Potential Analysis Internal Management Directive (RPA IMD)*** for more specific information on data needs.

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*, p. 9.

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

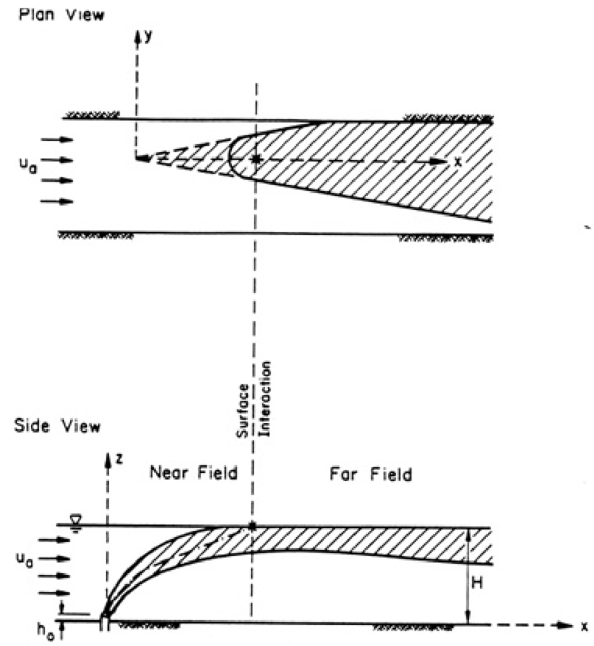
The physical mixing process can be conceptualized in two distinct regions: near-field and far-field (see Figure 2-1):

- **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*, p. 4) 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, 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), p. 5]. 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), p. 5]. 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), p. 5].

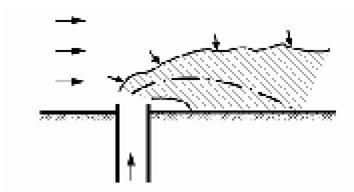
- Stratification boundaries – The discharge plume hits an intermediate boundary layer due to density stratification of the ambient water body. These typically occur in estuaries, oceans, or reservoirs. [Figure 2-2(d), p. 5]

- Surface water boundaries – The discharge plume hits the surface. This interaction will occur in most discharge situations. [Figure 2-2(e), p. 5]

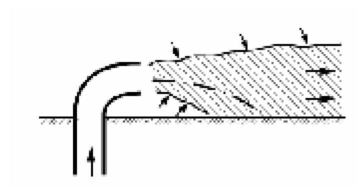
- Bank attachments – The discharge plume hugs the bank. Bank attachments are more like to occur when the outfall is near the bank. [Figure 2-2(f), p. 5]

Encountering a boundary will inhibit mixing because water is not available on all sides of the discharge plume to mix with. As a result, the boundary interaction would be a critical process that needs to be modeled.

Figure 2-2: Boundary Examples

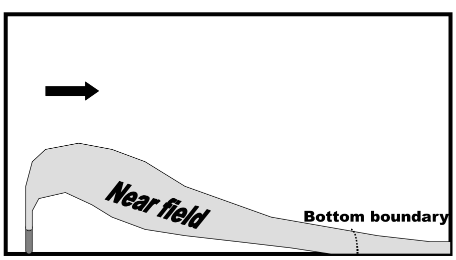


a) Wake Attachment
(side view)

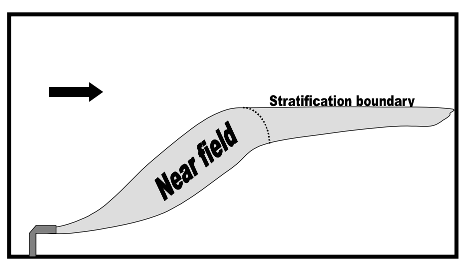


b) Coanda Attachment
(side view)

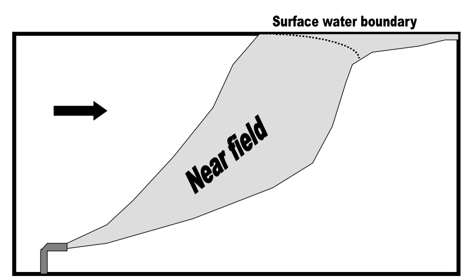
Figures from Fischer, H.B. et al. “Mixing Inland and Coastal Waters,” Academic Press, 1979.)



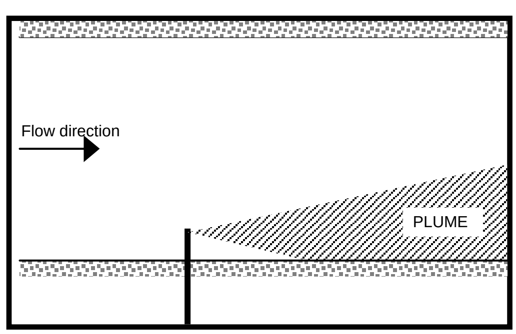
c) Bottom Boundary
(side view)



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)

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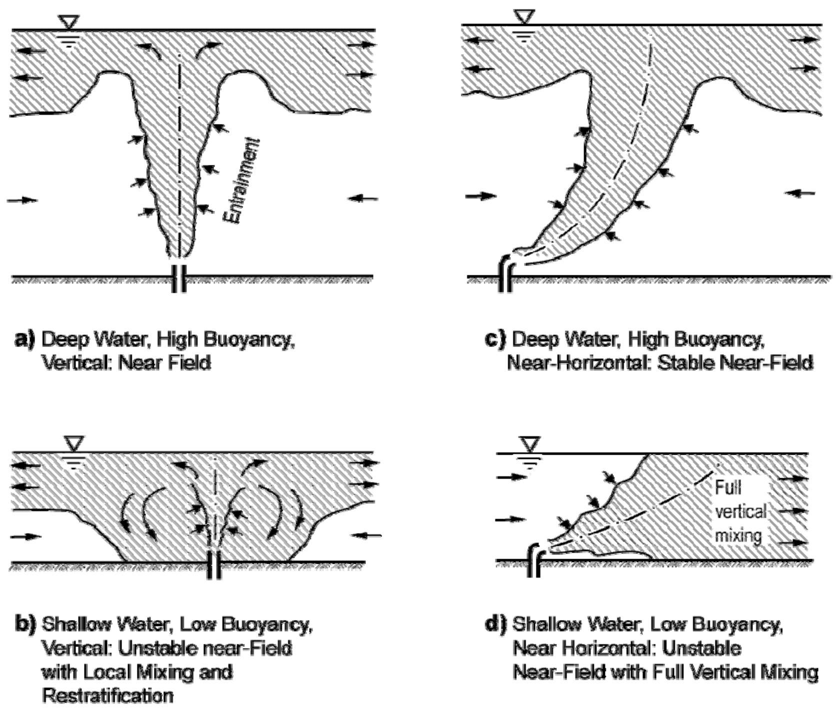

2.2 Mixing zone models

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 *What type of information is needed?*, p.31. 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.*
  For a shallow, wadeable stream, a simple field study using a conductivity meter may be appropriate if the conductivity of the discharge varies considerably from stream conductivity.

- *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

Model sensitivity is critical 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. This will allow accurate field measurements to be obtained for the sensitive parameters and 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?*, 3.c, p. 35 for more detail on how to check model sensitivity.

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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

These different effort levels were developed based on the department's experience with existing mixing zone studies

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 to evaluate a discharge with a low level of risk to ecological resources and public health. This level is generally appropriate for a discharge with **both** of the following characteristics:

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. 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 do not bioaccumulate and rapidly change to less toxic forms.

2) The discharge is not classified as "major" (see item #5 on p. 12).

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:

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 do not bioaccumulate and rapidly change to less toxic forms.

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 do not bioaccumulate and quickly change to less toxic forms.

Examples

See *Appendix B* for examples of different mixing zone study effort levels.

Decision flow chart to determine level of effort

A flow chart detailing the necessary decision steps in determining the level of effort to be expected from the applicant is provided in **Figure 3-1**, p. 13. 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 answered and the permit writer may proceed with permit development.

The major decision steps include the following:

1) **Is dilution available at critical flow?**
Discharges to waterbodies with no available dilution would be required to meet applicable water quality criteria at the end-of-pipe. As an alternative to applying water quality criteria at end-of-pipe, a variance, site specific criteria or a use attainability analysis could be considered [see the department's current version of the *Use Attainability Analysis IMD* for more information]. Note, however, that these alternatives are resource intensive.

2) **Is there potential for major environmental impact?**
In some situations, a discharge may have the potential to cause major environmental impact because it encroaches on frequently used public beaches, a drinking water intake, or spawning or unique habitat for threatened and endangered species. If there is potential for major environmental impact, 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 Permit Writers Corner of QNET. 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 (>19:1)?
Using the applicable low flow critical condition, a determination must be made of whether 25% of this low flow rate would yield a dilution factor greater than 20 when considering the discharge flow rate (or 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)*

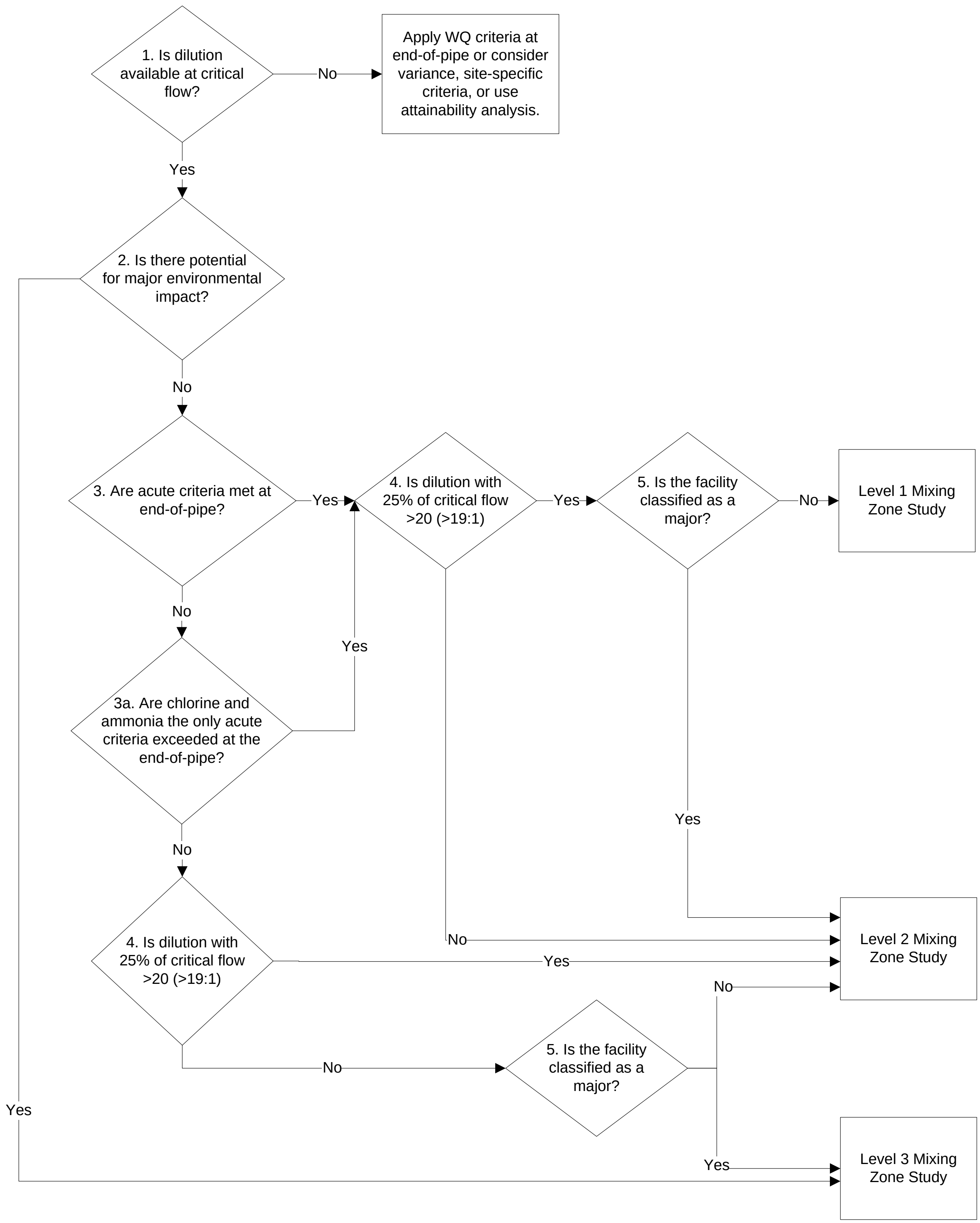
The applicable low flow rate for most sources discharging to flowing systems would be the 7Q10 flow (see *Section Table 4-2*: *Required Statistics for Critical Flow Condition and Effluent Flow*, p. 29, and Appendix C for additional information on critical flow conditions). For sources that discharge 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"?
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*, p. 17 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)

Oregon DEQ Mixing Zone Study Overview and Checklist				
Legal Name: **Common Name:** **Facility ID#:** **Application #:**			**Study Level:** ☐ **Level 1 - Simple** ☐ **Level 2 - Moderate** ☐ **Level 3 - Complex**	
Study Level: **X** = required **E** = estimate **M** = measurement (field or engineering plans) **D** = desirable			**Mixing Zone Study Information**	**Date Provided (or note NA)**
1	**2**	**3**	**Environmental Mapping** RMZ IMD Part 2, Section 4.1, p. 17	
X	**X**	**X**	Plan view map with the following: • Known commercial or recreational shellfish areas. • Fish spawning/rearing habitat. • Cold water refugia for fish. • Physical structures expected to attract fish (e.g., piers, irrigation intakes, outfalls). • Public access areas such as boat ramps or public beaches/swimming. • Drinking water intakes within the vicinity of the outfall and ½ mile downstream. • Other NPDES discharges upstream and downstream within ½ mile.	
X	**X**	**X**	Description of threatened and endangered species presence, habitat, and migration pathways.	
		D	Other (e.g., detailed salmonid use, bioassessments, fish migration studies, thermal imagery, maps illustrating channel width/depth, published literature supporting environmental mapping):	
			Outfall and Mixing Description RMZ IMD Part 2, Section 4.2, p. 23	
E	**M**	**M**	Outfall distance from bank and outfall height above bottom	
E	**M**	**M**	If present, diffuser and port dimensions and configuration (include drawings, if available)	
X	**M**	**M**	Latitude and longitude of outfall	
E	**E**	**E**	River mile of outfall	
D	**D**	**D**	Photographs of the outfall vicinity	
X	**X**	**X**	Description of present RMZ and ZID as described in permit	

Oregon DEQ Mixing Zone Study Overview and Checklist

Legal Name:
Common Name:
Facility ID#:
Application #:

Study Level:
☐ **Level 1 - Simple**
☐ **Level 2 - Moderate**
☐ **Level 3 - Complex**

Mixing Zone Study Information

Study Level: **X** = required; **E** = estimate; **M** = measurement (field or engineering plans); **D** = desirable

				Date Provided (or note NA)
			Ambient Receiving Water Conditions RMZ IMD Part 2, Section 4.3, p. 25	
E	**E**	**E**	Critical flow statistics	
E	**E/M**	**E/M**	Velocity profile for each critical flow condition (Level 1 may use 7Q10, 1Q10, and 30Q5 low flows, harmonic mean flow, or other critical flows to estimate velocity)	
E	**E/M**	**M**	Cross sectional area (width and depth) for each critical flow (near-field and far-field)	
E	**E/M**	**M**	Temperature and salinity profiles	
E	**E**	**E**	Manning's roughness coefficient	
			Discharge Characteristics RMZ IMD Part 2, Section 4.4, p. 30	
E	**X**	**X**	Flow rates	
	E/M	**M**	Temperature and conductivity and/or salinity	
			Mixing Zone Modeling RMZ IMD Part 2, Section 4.5, p. 31	
	D	**M**	Field mixing measurements (e.g., dye studies)	
X	**X**	**X**	Model selection and application discussion	
X	**X**	**X**	Description of mixing and plume dynamics (near-field and far-field)	
X	**X**	**X**	Sensitivity analysis	
X	**X**	**X**	Model results table	
Note: In some cases (e.g., shallow streams with non-uniform flow, tidally-influence waterbodies), modeling is not appropriate. See RMZ IMD Part 2, Section 2.2, When steady-state mixing zone models may not be appropriate, p. 7.				
			Additional Water Quality Data (if necessary) RMZ IMD Part 2, Section 4.6, p. 37	
			Discharge water quality data:	
			Ambient water quality data:	

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
- Additional water quality data

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 a method to characterize and map specific habitats, critical resources areas, and other beneficial uses within the segment of the water body receiving the discharge. This information will be 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 additional 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/)
  This site 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:

- 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.

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.

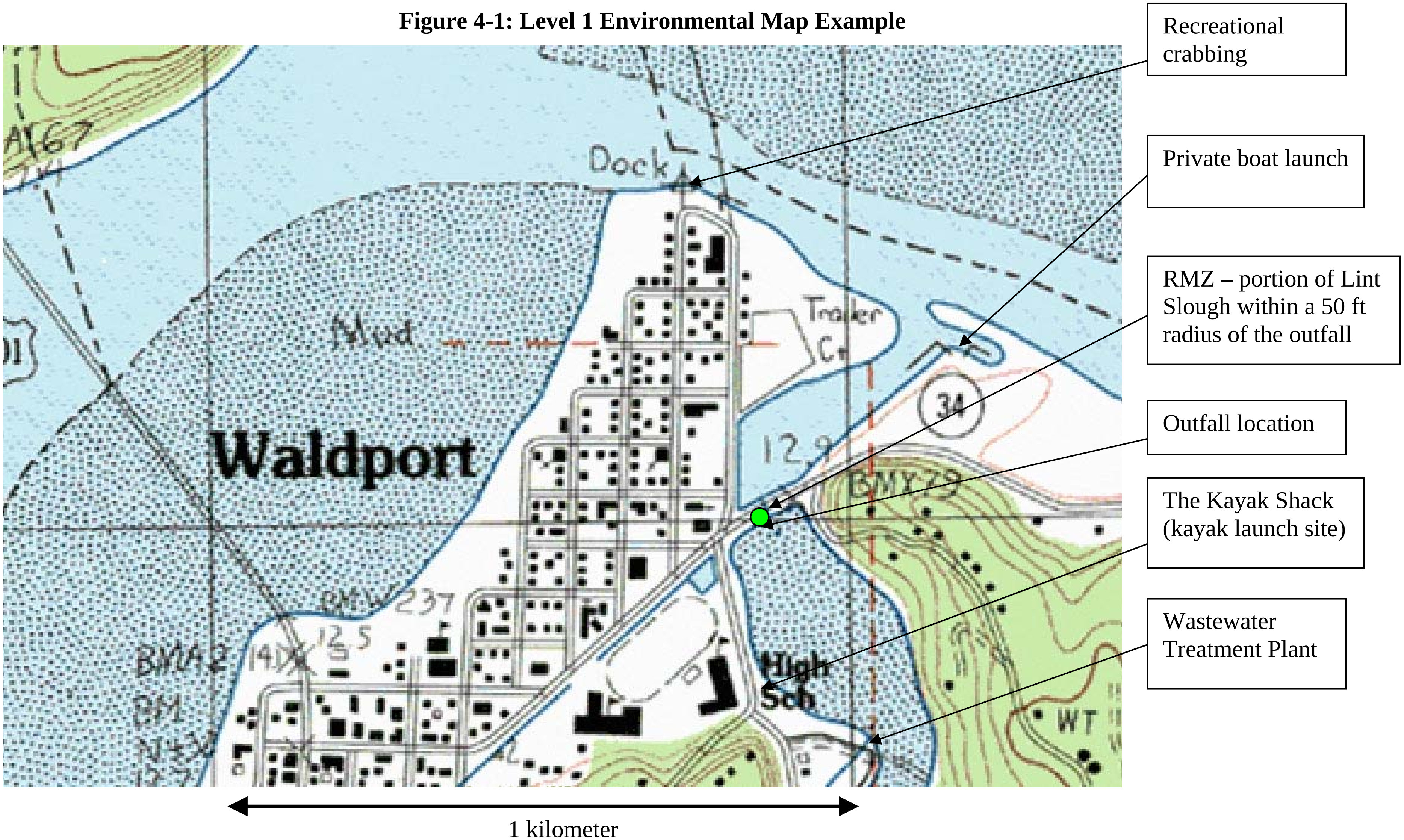
1) Plan view map delineating the following areas within or near the mixing zone:
   - Known commercial or recreational shellfish areas.
   - Fish spawning/rearing habitat.
   - Cold water refugia for fish (e.g., cold water tributaries).
   - Physical structures expected to attract fish (e.g., piers,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

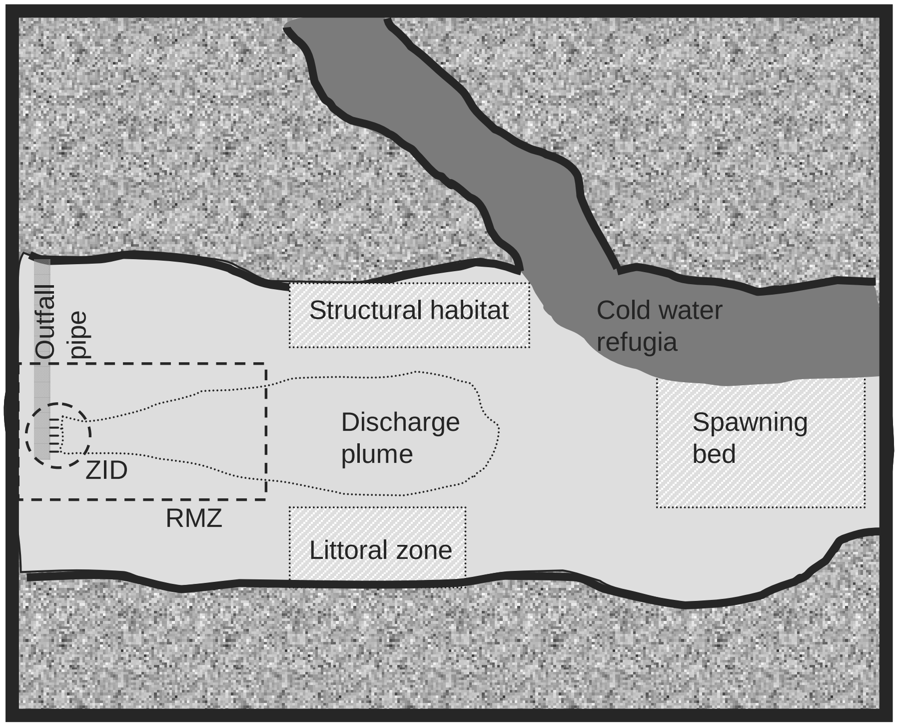
See **Figures 4-1 & 4-2** for mapping examples. Note: Narrative descriptions are also acceptable.

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

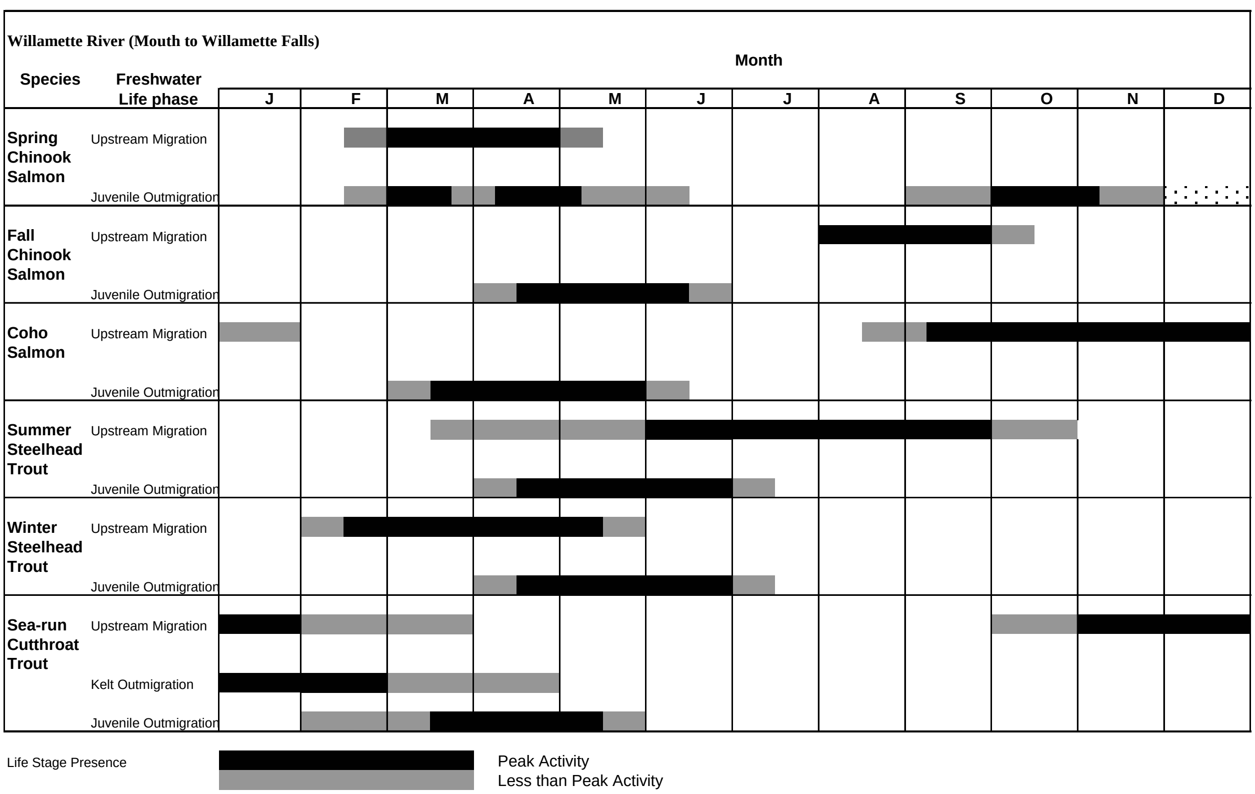


Additional information: Level 3

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 must 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 Salmonid Use in the Lower Willamette River*, p. 22).
- 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.

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



4.2 Outfall and RMZ characterization

Overview

This section describes what is needed for a complete characterization of an existing outfall and RMZ necessary for a mixing zone evaluation for the 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.
   - **Level 1**: Estimate
   - **Level 2 & 3**: Measurement in field or from engineering plans and diagram (see **Figure 4-4**, p. 5).

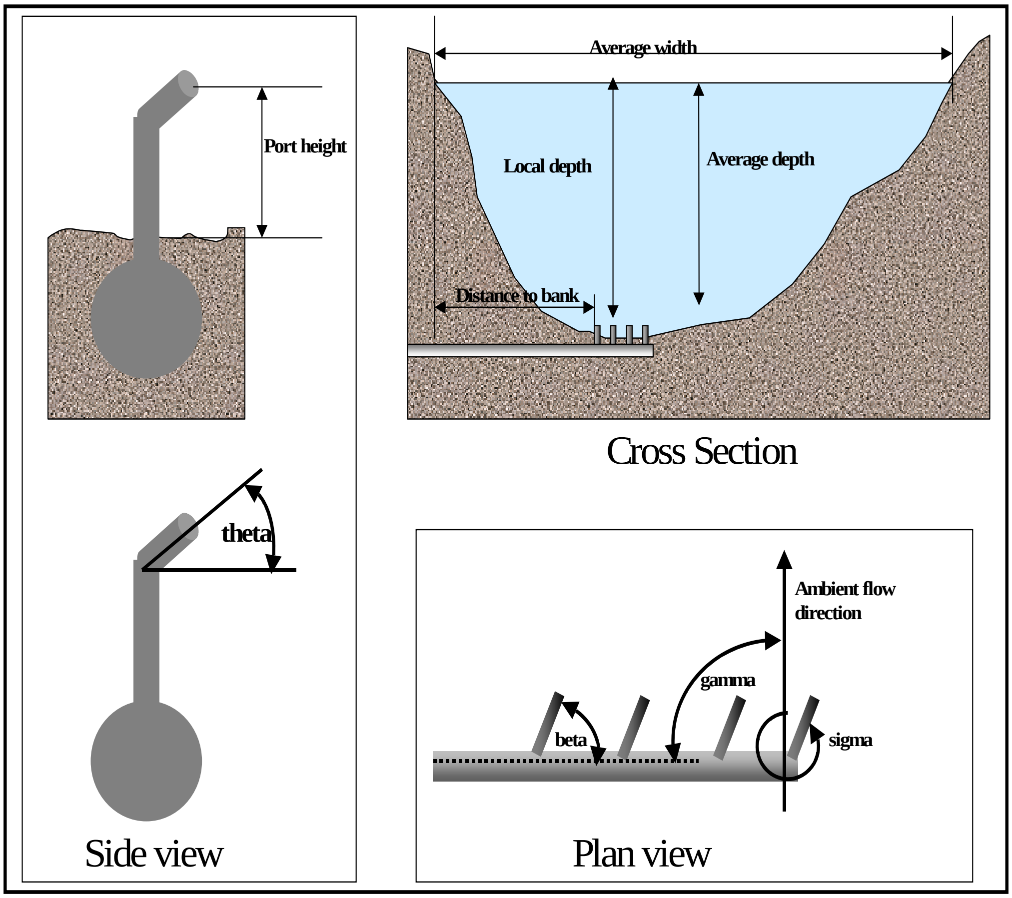
3) If present, the following diffuser and port dimensions and configurations are required:
   a. Diffuser length
   b. Number of ports (note and describe blocked or non-functioning ports)
   c. Orientation angles
      i. THETA – vertical angle of discharge between the port centerline and a horizontal 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:
   - **Level 1**: Estimate
   - **Level 2 & 3**: Measurement in field or from engineering plans and diagram (see **Figure 4-4**, p. 5).

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
- 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 StreamFlow 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 minimal and beneficial uses are protected because flow is a significant factor influencing dilution. 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 critical flow statistics for tidally-affected waterbodies, see **Table 4-2** *Required Statistics for Critical Flow Condition and Effluent Flow,* p. 29. 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*. Additional information is provided in Appendix C.

Receiving water body cross-sectional profile

The cross section of the receiving water may vertically and laterally constrain plume spreading. Some mixing models assume an infinite receiving water body and may not be appropriate depending on boundary interactions. The cross sectional profile within the RMZ and ZID need to be described and diagrammed. If far-field analysis is important, then cross-sectional areas further downstream also need to be included as well, especially if there are significant changes in downstream bathymetry (depth and width).

Ambient velocity profile

Ambient velocity greatly influences plume dynamics and plume shape. Hydro-dynamic mixing is very sensitive to stream velocity for most scenarios. Velocity measurements that correspond to the critical flows identified need to be described. If there are significant changes in velocity with respect to depth, a velocity profile is necessary. This is especially important for a near-field analysis. Usually, an average velocity over the entire depth is adequate. 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

Examples:

Columbia River near The Dalles: *n* = 0.030

Grande Ronde River at La Grande: *n* = 0.043

North Coast Basin: Main channels: *n* = 0.035 (Nehalem R, Necanicum R)

Tributaries: *n* = 0.050 (Rock Cr, Salmonberry R)

Willamette River: *n* = 0.035

Additional data

Additional data on the receiving water may be needed. See *Additional water quality data,* p. 37 for more information.

Table 4-2: Required Statistics for Critical Flow Condition and Effluent Flow

Discharge Type	Water Quality Criteria	CRITICAL FLOW PARAMETERS			EFFLUENT FLOW
		Flowing Systems[1]	Tidally-affected Waterbodies[2]		
			No stratification	Stratification	
DOMESTIC	Acute	• 1Q10 • associated velocity	Combination of low-water slack at spring tide and critical riverine low flow. Use 10th % velocity over one tidal cycle for critical case condition and 90th % velocity over one tidal cycle for off-design case.	Minimum and maximum stratification period. Typically minimum stratification occurs at low river flows and large tidal fluctuations (spring tide). Maximum stratification typically occurs at high river flows and small tidal fluctuations (neap tide). Use 10th % velocity over one tidal cycle for critical case condition and 90th % velocity over one tidal cycle for off-design case.	If operating between 85% and 100% of the design average dry weather flow (ADWF), use a peaking factor applied to the ADWF. The peaking factor is a ratio of daily maximum to monthly average flows. (If operating at less than 85% of dry weather design flow, use highest maximum daily flow for past three years during the critical period.)
	Chronic	• 7Q10 • associated velocity	Same as acute, except use 50th % velocity over one tidal cycle.[3]	Same as acute, except use 50th % velocity over one tidal cycle.[3]	Average daily dry weather design flow. (If operating at less than 85% of dry weather design flow, use highest monthly average plant effluent flow during critical flow condition for past five years.)
	Human Health	• 30Q5[4] • harmonic mean[5] • associated velocities	Combination of appropriate riverine design flow (30Q5 or harmonic mean) and average tidal condition. Use 50th % velocity over one tidal cycle.[3]	Combination of appropriate riverine design flow (30Q5 or harmonic mean) and average tidal condition. Use 50th % velocity over one tidal cycle.[3]	Non-carcinogen: Average dry weather design flow. Carcinogen: Average annual flow
INDUSTRIAL CONTINUOUS	Acute	• 1Q10 • associated velocity	Same as domestic discharge	Same as domestic discharge	Highest daily maximum flow during critical flow conditions over past three years. (If flow is expected to increase, estimate highest daily maximum flow.)
	Chronic	• 7Q10 • associated velocity	Same as domestic discharge	Same as domestic discharge	Highest monthly average flow during critical flow conditions over past three years. (If flow is expected to increase, estimate highest monthly average maximum flow.)
	Human Health	• 30Q5[4] • harmonic mean[5] • associated velocities	Same as domestic discharge	Same as domestic discharge	Non-carcinogen: Average dry weather design flow. Carcinogen: Average annual flow.
INDUSTRIAL NON-CONTINUOUS OR BATCH	Acute	• 1Q10 • associated velocity	Same as domestic discharge	Same as domestic discharge	Peak flow rate during discharge
	Chronic	• 7Q10 • associated velocity	Same as domestic discharge	Same as domestic discharge	Flow rate averaged over 24 hr period
	Human Health	• 30Q5[4] • harmonic mean[5] • associated velocities	Same as domestic discharge	Same as domestic discharge	Non-carcinogen: Average dry weather design flow. Carcinogen: Average annual flow

[1] Technical Support Document for Water Quality-based Toxics Control, U.S. EPA, March 1991.
[2] Water Quality Program Permit Writer's Manual, Washington Department of Ecology, July 2005.
[3] If data is unavailable to calculate 50th %, a sensitivity analysis should be run using a wide range of velocities, any of which could reasonably occur as the average velocity for any 4-day duration. The velocity which produces the lowest dilution should be used.
[4] 30Q5 is for non-carcinogens.
[5] Harmonic mean is for carcinogens.

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.

Flow statistics

Dry weather flow rates are used because the summer period is typically the most critical time for low dilution and higher instream concentrations of pollutants can occur. The permit writer may use different discharge flow rates depending on the timing of environmental factors (e.g., salmonid migration, shellfish harvesting). For example, to develop seasonal limits, appropriate seasonal discharge flows should be considered. **Table 4-2**: *Required Statistics for Critical Flow Condition and Effluent Flow*, p. 29, provide more information on effluent flow statistics that are needed.

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	90^{th} % of daily maximums during critical period
Chronic	Average daily temperature during critical period
Human health	Annual average

Additional data

Additional chemical data on the discharge may be needed. See *Additional water quality data*, p. 37, for more information.

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

Generally, the following is expected:

- ***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 basic input data should be expected.

- ***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*, p. 25 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*, p. 7.

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:

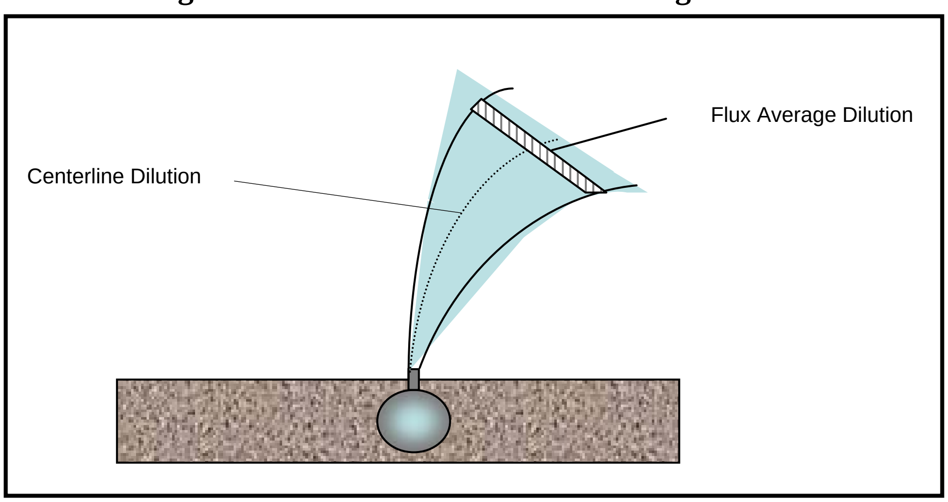
1) Version number of model(s) used and the reason for selecting the model(s). If more than one model was used or if a different one was used for the far-field analysis versus the near-field analysis, an explanation should be provided.

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



What type of information is needed? *continued*

5) 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 4-3 below. Note: the example only provides basic inputs, other critical inputs, such as port angle and orientation, may be needed.

Table 4-3 Modeling Results Summary Example

Model Run Description	Dilution			Ambient				Discharge				Outfall Characteristics	
	ZID	MZ	HH	Velocity (ft/s)	Depth (ft)	Width (ft)	Flow (cfs)	Temp (° F)	Flow (mgd)	Port Velocity (ft/s)	Temp (° F)	# Ports	Port Diameter (inches)
Existing Condition: outfall w/single port	5	27	na	2.5	20	100	5000	68	18	2.2	76	1	48
Proposed New Outfall w/ 12-Port Diffuser													
12-port diffuser	35	89	na	2.5	20	100	5000	68	18	3	76	12	12
12-port diffuser: Human Health	na	na	121	6	21	110	13000	62	22	3.6	72	12	12
Proposed New Outfall w/ 12-Port Diffuser: Off-Design Condition													
12-port diffuser: October	40	101	na	3.2	20	100	6440	66	18	3	75	12	12
Proposed New Outfall w/ 12-Port Diffuser: Sensitivity Runs													
12 port diffuser: ambient velocity sensitivity	31	86	na	2	20	125	5000	68	18	3	76	12	12
12 port diffuser: ambient velocity sensitivity	39	92	na	3	20	83	5000	68	18	3	76	12	12

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 *Mixing zone models*, p. 7 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 *Influence of boundary interactions on mixing*, p. 4 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 *Re-entrainment of discharge*, p. 6, 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 *Model sensitivity*, p. 7 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 = (Qe+Qs)/Qe*
   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.

Example: Mass Balance Exercise to Check Dilution Predictions

Flow Scenario:
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 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.

4.6 Additional water quality data

Overview

To develop permit limits, the permit writer will conduct a reasonable potential analysis (RPA) to determine whether the applicant's discharge has the reasonable potential to cause or contribute to a violation of water quality standards. While chemistry data for the discharge is submitted in standard permit application forms, additional data for both the discharge and receiving water may be needed for the RPA. An ideal time to supplement application data is with the mixing zone study since most studies require more information than required by the application forms. This section discusses potential additional data needs. See the most recent version of the *RPA IMD* for more specific information on application data needs.

Ambient receiving water quality data

The department has historical data on most of the major rivers, streams, and lakes in Oregon. In addition, other data is available through the U.S. Geological Survey, U.S. Forest Service, National Marine Fisheries Service, Oregon Department of Fish and Wildlife, and other government agencies. If there is insufficient ambient water quality, the department may develop a monitoring plan for the permit applicant to address the need for more data. Ambient data may need to be collected as part of a field mixing zone study or included as a monitoring requirement in future permits. The permit applicant and permit writer should discuss these data needs as early as possible in the permit development process.

Discharge data

For minor sources that don't commonly sample for the parameters listed in **Table 4-4**, a permit applicant should consider additional sampling and analysis of their discharge to meet application requirements. Data for all of these parameters may not be needed; however, the permit applicant and permit writer should discuss these data needs as early as possible in the permit development process. The applicant and permit writer should agree on common data sets, such as river or effluent flow, to ensure that all future calculations are compatible.

Table 4-4: Additional Water Quality Parameters for Discharge Characterization

Parameter	Applicability
Biochemical oxygen demand (BOD), carbonaceous BOD	Compliance with dissolved oxygen standard/far-field analysis
Total suspended solids (TSS)	Permit parameter
Turbidity	Compliance with turbidity standard
Dissolved oxygen	Compliance with dissolved oxygen standard/near field affects
Temperature	Compliance with temperature standard; affects ammonia toxicity; affects decay rates
pH	Permit parameter; affects metals partitioning; affects ammonia toxicity; compliance with pH standard at edge of ZID and RMZ
Ammonia	Compliance with ammonia criteria at edge if of ZID and RMZ; dissolved oxygen modeling/nutrient dynamics
Chlorine	Chlorine toxicity
Nitrogen and phosphorous components	Nutrient dynamics/affects on dissolved oxygen and pH/algal growth
Alkalinity	Compliance with pH standard at edge of ZID and RMZ
Hardness	Affects compliance of metals criteria at edge of ZID and RMZ
Conductivity, Total dissolved solids (TDS)	Conservative tracers
Metals	Compliance with metals criteria at edge of ZID and RMZ
Bioassays	Compliance with whole effluent toxicity requirement at edge of ZID and RMZ

5. REFERENCES

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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 Overview and Checklist

(v. 12-06-2006)

Legal Name:
Common Name:
Facility ID#:
Application #:

Study Level:
- ☐ **Level 1 - Simple**
- ☐ **Level 2 - Moderate**
- ☐ **Level 3 - Complex**

Mixing Zone Study Information

Study Level: **X** = required; **E** = estimate; **M** = measurement (field or engineering plans); **D** = desirable

1	2	3	Environmental Mapping — RMZ IMD Part 2, Section 4.1, p. 17	Date Provided (or note NA)
X	X	X	Plan view map with the following: • Known commercial or recreational shellfish areas. • Fish spawning/rearing habitat. • Cold water refugia for fish. • Physical structures expected to attract fish (e.g., piers, irrigation intakes, outfalls). • Public access areas such as boat ramps or public beaches/swimming. • Drinking water intakes within the vicinity of the outfall and ½ mile downstream. • Other NPDES discharges upstream and downstream within ½ mile.	
X	X	X	Description of threatened and endangered species presence, habitat, and migration pathways.	
		D	Other (e.g., detailed salmonid use, bioassessments, fish migration studies, thermal imagery, maps illustrating channel width/depth, published literature supporting environmental mapping):	
			Outfall and Mixing Description — RMZ IMD Part 2, Section 4.2, p. 23	
E	M	M	Outfall distance from bank and outfall height above bottom	
E	M	M	If present, diffuser and port dimensions and configuration (include drawings, if available)	
X	M	M	Latitude and longitude of outfall	
E	E	E	River mile of outfall	
D	D	D	Photographs of the outfall vicinity	
X	X	X	Description of present RMZ and ZID as described in permit	
			Ambient Receiving Water Conditions — RMZ IMD Part 2, Section 4.3, p. 25	
E	E	E	Critical flow statistics	
E	E/M	E/M	Velocity profile for each critical flow condition (Level 1 may use 7Q10, 1Q10, and 30Q5 low flows, harmonic mean flow, or other critical flows to estimate velocity)	
E	E/M	M	Cross sectional area (width and depth) for each critical flow (near-field and far-field)	
E	E/M	M	Temperature and salinity profiles	
E	E	E	Manning's roughness coefficient	
			Discharge Characteristics — RMZ IMD Part 2, Section 4.4, p. 30	
E	X	X	Flow rates	
	E/M	M	Temperature and conductivity and/or salinity	
			Mixing Zone Modeling — RMZ IMD Part 2, Section 4.5, p. 31	
	D	M	Field mixing measurements (e.g., dye studies)	
X	X	X	Model selection and application discussion	
X	X	X	Description of mixing and plume dynamics (near-field and far-field)	
X	X	X	Sensitivity analysis	
X	X	X	Model results table	
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, When steady-state mixing zone models may not be appropriate, p. 7.				
			Additional Water Quality Data (if necessary) — RMZ IMD Part 2, Section 4.6, p. 37	
			Discharge water quality data:	
			Ambient water quality data:	

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

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”