

MIXING ZONE EVALUATION



Photos courtesy of USDA NRCS

Prepared for:
State of Washington
Department of Ecology



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TETRA TECH

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1.0 INTRODUCTION

Mixing zones are specified areas around a wastewater discharge that are authorized under a state's National Pollutant Discharge Elimination System (NPDES) program as an area of effluent dilution, in which certain state water quality criteria may be exceeded. Typically, criteria can be exceeded in the mixing zone only if: (1) there is no acute toxicity (lethality) to organisms that might pass through the zone (i.e., the mixing zone can not be a barrier to migration or organism movement); (2) designated uses are not impaired; and (3) human health is not jeopardized in any way (EPA, 1991). Furthermore, water quality standards must be met outside the boundary of the mixing zone (e.g., at the downstream edge of a mixing zone in a lotic system), all designated uses outside or downstream of the mixing zone boundary must be protected, and the size of the mixing zone must be minimized. Depending on the effluent dilution available under low flow and the type(s) of pollutant of concern, states may allow acute and/or chronic mixing zones (i.e., zones established to address acute or chronic water quality standards, respectively), or no mixing zone at all (e.g., the Great Lakes Initiative prohibits mixing zones for bioaccumulative compounds such as mercury [EPA, 1995]).

State mixing zone policies often contain conflicts in that state standards are permitted to be exceeded (including, at times, standards for toxicity) within these zones, however beneficial uses must be protected and acute lethality is prohibited within these same areas. The limited size of mixing zones is a factor commonly thought to minimize any such impacts. However, actual monitoring of biological conditions within the regulatory mixing zone is rare. In fact, biomonitoring assessment guidance documents from some states expressly prohibit monitoring within mixing zones because these are areas in which state standards are not always met. As such, there is often no monitoring data available to ensure that the mixing zone restrictions set forth (e.g., EPA, 1991) are satisfied.

The State of Washington Department of Ecology (Ecology) has mixing zone regulations in their water quality standards (Chapter WAC 173-201A-100), which requires that a mixing zone “not have a reasonable potential to cause a loss of sensitive or important habitat, substantially interfere with the existing or characteristic uses of the waterbody, result in damage to the ecosystem, or adversely affect public health as determined by the department”. Furthermore, the regulations stipulate that the chronic mixing zone is a maximum of 300 feet downstream of a discharge, for streams and rivers, and that it is only as deep as the average water depth under critical low flow conditions, and no more than 25% of the stream width. The volume of the chronic mixing zone can be no more than 25% of stream flow under critical low flow conditions while the acute mixing zone is 10% of the chronic mixing zone volume.

Public and regulatory concerns regarding the conditions of communities within mixing zones have been increasing in recent years. As a result of this increased concern, Washington State is reevaluating existing guidance for monitoring conditions within mixing zones. This project constitutes a preliminary effort to determine the manner in which biological conditions within mixing zones are monitored in states throughout the U.S.

1.1 Objective of Project

Ecology is reviewing its mixing zone policies and guidance. The objective of this project was to inform this process by collecting available information on how other states evaluate the biological condition within mixing zones. Further, available data and reports from such studies were assembled so that the impacts of mixing zones on biological communities within those zones might be evaluated.

1.2 Project Organization

This project was organized according to three interrelated tasks:

Task 1: Contact EPA and States and Collect Data and Other Relevant Information

In this task available biological monitoring data from evaluations of mixing zones conducted throughout the U.S. were located and gathered. In addition to the actual monitoring data, we collected additional information, including supporting information on the methods used, study design (e.g., replication and site selection), thresholds for determining impairment (and whether a state has a set protocol for making such a determination), and other such information that may be useful in selecting appropriate biological methods for use in such mixing zone evaluations.

Task 2: Compile and Summarize Collected Data and Relevant Information

In this task, the monitoring information collected in Task 1 was compiled and summarized in an Access database. In summarizing these data it was critical to include the methods used in collecting the biological data. A key aspect of this task was to identify the criteria used (if any) to decide whether an authorized mixing zone is protective of the biological community.

Task 3: Compile Stratified List of Biological Assessment Methods

The goal of Task 3 was to use the gathered data and available scientific information to develop recommendations as to the biological monitoring required upon or prior to authorization of a mixing zone. As discussed below, these recommendations are presented in the form of recommendations for development of such guidance using Washington State's existing Biological Monitoring Program. These recommendations are based upon the results of Task 1 and 2 of this study, and upon the expertise of this project team and applicable scientific literature.

2.0 METHODS

In accomplishing Task 1, a telephone and/or e-mail survey of EPA regional and select state and local staff was conducted to determine 1) whether biological monitoring (not to be confused with whole effluent toxicity testing) was required or routinely conducted within regulatory mixing zones in a given state or EPA Region and 2) if example studies and methods used were available from such monitoring efforts. In accomplishing this, a list of EPA, state, and local contacts involved with aquatic biological monitoring programs was assembled (Appendix A). These people were then contacted by telephone or e-mail for information about mixing zone studies in their region, state, or locality.

Additionally, state guidance documents and applicable regulations were reviewed to determine what, if any, policies were in place for a given state regarding the monitoring of regulatory mixing zones. Such information was most often acquired via the internet and was typically referenced in mixing zone-specific or bioassessment guidance documents.

Once a mixing zone study was located and available for review, supporting documentation such as the NPDES permit and Fact Sheet were acquired from the permitting authority. Such documentation was necessary to determine the level of monitoring, as well as specific details regarding the regulatory mixing zone (e.g., type and size of discharge and pollutants for which a mixing zone were established). Combined with the information in the mixing zone study, information from the supporting documentation was used to complete the database compiled in Task 2.

Few mixing zone monitoring reports and associated data were available, therefore it was not possible to develop a stratified list of biological assessment methods. However, the results of Task 1 and 2 as well as the expertise of the project team were used to develop a series of recommendations on developing guidance for use in monitoring biological conditions within mixing zones.

3.0 RESULTS

3.1 Task 1

Tetra Tech contacted more than 50 representatives from EPA Regional, State, and local government agencies as well representatives from private industry (Appendix A). Information regarding state programs which monitor or require the monitoring of biological conditions within mixing zones both prior to and during discharge activities was solicited. Further, example reports and data sets were requested from those contacts that were aware of any such studies. Additionally, we were aware of some studies and were able to directly acquire such information from the state websites or contacts (e.g., Thompson Creek Mine in Idaho). Once mixing zone studies were identified, supporting information such as NPDES permits and Fact Sheets were acquired to assist in completion of the Task 2 database. Eighteen mixing zone studies were located for which both data and supporting information regarding the sampling methods used and discharger-specific information were available (Table 1).

Table 1. Summary of discharges for which the biological condition within permitted mixing zones has been monitored and the resulting data and supporting information were available for this study.

State	Discharge Name	Discharge Type
Alabama	Arkema Incorporated	Chemical Plant
Alaska	Red Dog Mine	Mining
Idaho	Thompson Creek Mine	Mining
Ohio	Jackson Pike Wastewater Treatment Plant	Municipal
Ohio	North Olmsted Wastewater Treatment Plant	Municipal
Ohio	Lancaster Wastewater Treatment Plant	Municipal
Ohio	Circleville Wastewater Treatment Works	Municipal
Ohio	Columbus Southerly WWTP	Municipal
Ohio	Medina County Sewer District (Liverpool) WWTP	Municipal
Ohio	North Royalton WWTP	Municipal
Ohio	Strongsville WWTP	Municipal
Oregon	Baker City	Mining
Oregon	Diamond-Odell	Mining
Oregon	Dufur	Mining
Oregon	North Powder	Mining
Pennsylvania	West Chester Taylor Run STP	Municipal

3.2 Task 2

The EPA Regional and state survey determined that most states neither mandate nor routinely conduct monitoring of biological conditions within mixing zones (Figure 1). Four states (Alabama, Hawaii, Ohio, and Oregon) either require or routinely conduct biological monitoring within mixing zones. Other states may conduct such studies on a site-specific basis or in response to specific concerns regarding a discharge (e.g., Thompson Creek Mine in Idaho), or

such information may have been generated by the discharger as part of the permitting process (e.g., Red Dog Mine in Alaska). In fact, biological monitoring protocols for many states require that all sampling be conducted outside any such mixing zones. The Oklahoma methods (OWRB 2001) for evaluating the attainment of beneficial uses in wadeable streams contains specific instructions to avoid mixing zones; “These SOPs are designed and intended to be used outside of the mixing zone of the receiving stream. **ALL ASSESSMENTS AND BIOLOGICAL COLLECTIONS SHOULD ONLY OCCUR AFTER AT LEAST 13 STREAM WIDTHS DOWNSTREAM OF THE POINT OF DISCHARGE.**” Language similar to this is common in assessment guidance documents reviewed in this evaluation and further illustrates that monitoring of biological condition within mixing zones is uncommon.

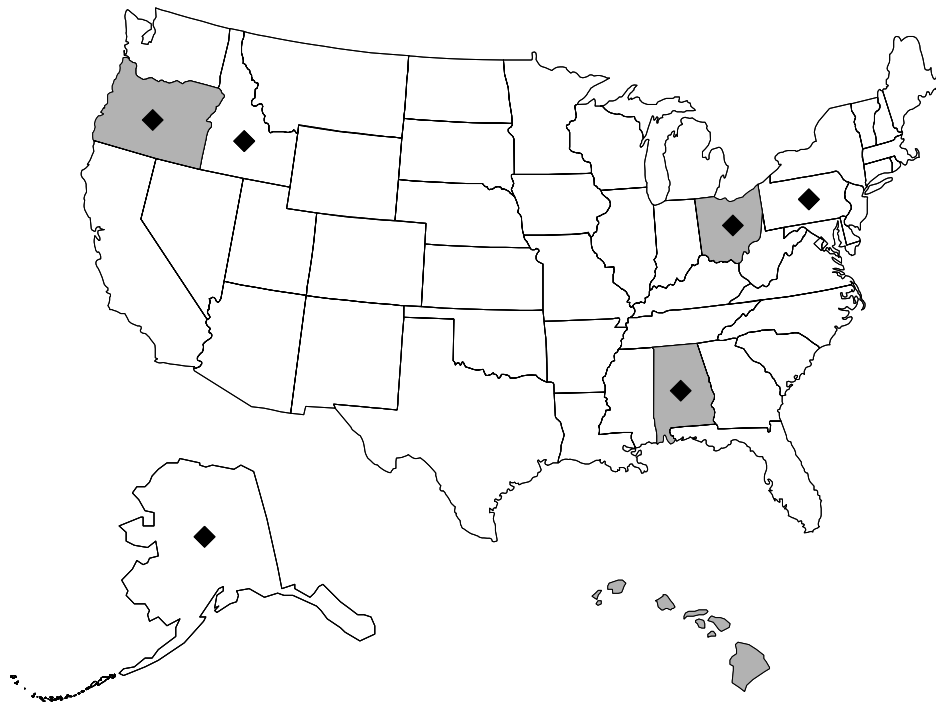


Figure 1. Summary of states which routinely monitor the biological conditions within mixing zones (shade) and those states from which example monitoring data and supporting information were available (diamonds).

3.2.1 Results by State

For states with large monitoring programs that routinely monitor conditions within mixing zones (Ohio and Oregon), a large amount of data exist. Standard methods are used in both Ohio and Oregon monitoring programs (ODEQ, 2003; OEPA, 1989). The data and/or supporting information from these states were not readily available and had to be requested from state personnel. Therefore, a limited number of studies were acquired and summarized within the time constraints of this project. The other studies acquired in this effort were the result of directed studies of a specific discharge and not the result of a state-wide monitoring program. The results of the surveys are detailed below for each of the states for which information was available or conducted.

Alabama

Sampling of benthic macroinvertebrates at specified distances (400 and 800 feet) from the discharge point of permitted discharges of greater than 1.0 MGD to coastal waters is required by the State of Alabama (Chapter 335-8-2-.12 of Alabama Department of Environmental Management Coastal Area Management Program Administrative Code). Such an evaluation appears to be required prior to initiation of discharge, upon applying to renew an existing permit, or after failure of accelerated whole effluent toxicity (WET) testing (accelerated testing is initiated following failure to meet established WET limits to determine whether observed toxicity is consistent).

A representative from Alabama Department of Environmental Management (ADEM) was able to provide us with the results of such a study conducted by the discharger's consultants in compliance with State of Alabama requirements (Payne Environmental Services, 2006). Replicate ponar grab samples were collected for analysis of benthic macroinvertebrate community downstream of the Arkema Chemicals, Inc. discharge to the Mobile River. The resulting report describes the results of the benthic macroinvertebrate communities at the sampling locations, but does not differentiate between conditions at the sampling sites or attempt to draw conclusions regarding potential impacts to benthic communities related to the discharge.

Alaska

Alaska does not have a program that requires the monitoring of biological conditions within mixing zones. As observed in other states, such studies are conducted on a case-by-case basis. One such study evaluated conditions within the mixing zone downstream of the Red Dog Mine in northwestern Alaska. Modified Rapid Bioassessment Protocols (Barbour et al., 1999) were used to evaluate the fish, benthic macroinvertebrate, and periphyton communities in the receiving streams. The resulting report (ADNR, 2005) presented the results of the sampling and community analyses, but did not evaluate difference among sites or draw conclusions regarding potential impacts to sampled communities.

Hawaii

Hawaii allows for mixing zones, but calls these areas “zones of mixing” and defines them as “limited areas around outfalls and other facilities to allow for the initial dilution of waste discharges. As per Section 11-54-9(c)(6)(A) of the Hawaii Administrative Rules (Department of Health), a discharge that is permitted a “zone of mixing” is required to “...perform appropriate effluent and receiving water sampling including monitoring of bottom biological communities and report the results of each sampling to the Director.” Based on discussions with State of Hawaii personnel we understand that all permitted discharges to which this requirement is applied are ocean discharges. Unfortunately, State personnel were unable to provide us with requested example studies and required that we file such a request via the Freedom of Information Act. Given the time constraints of this project, no such requests were filed.

Idaho

Idaho does not have an established protocol for use in monitoring the biological conditions within a mixing zone and no such monitoring is typically required. However, such monitoring

has been required and conducted on a site-specific basis. Such a mixing zone study was conducted for discharges below the Thompson Creek Mine near Salmon, Idaho (IDEQ 2000).

The Thompson Creek Mine discharges snowmelt runoff to Thompson Creek and a mixing zone has been established on this creek for multiple metals (e.g., arsenic, copper, lead, zinc) including mercury and selenium which are known to bioaccumulate. The extent of the mixing zone was determined through the use of CORMIX modeling and rhodamine dye. The fish, benthic macroinvertebrate, and periphyton communities were sampled using various quantitative techniques (e.g., Hess sampling and electrofishing) with replication to allow for statistical analyses of the results. Additionally, sediments as well as samples of periphyton, benthic macroinvertebrates, and fish tissues were required to be analyzed as part of a bioaccumulation analysis. No impacts to the biota were observed in this study.

Ohio

Ohio conducts routine monitoring of benthic macroinvertebrate and fish communities throughout the state. The monitored streams are organized by river basin and streams within a given basin are evaluated during the same period. The basins are selected for monitoring on a rotating basis. It appears that mixing zones downstream of permitted discharges are evaluated within the scope of the larger, routine monitoring efforts. As such, the biological conditions within mixing zones are routinely reported as part of basin-wide monitoring efforts (e.g., Ohio EPA, 1999). Mixing zone evaluations do not appear to be issued for each individual discharge, but rather as part of an evaluation report summarizing conditions within the entire basin. Further, these evaluations are considered and discussed in NPDES permits for dischargers (e.g., Jackson Pike Fact Sheet). Eight studies were located that were conducted in the mixing zones downstream of wastewater treatment plants in Ohio (Table 1).

The treatment plant discharges evaluated in these studies ranged in size from 1 MGD to greater than 100 MGD. Mixing zones were established for multiple compounds for all discharges and one of the nine permitted a mixing zone for bioaccumulative compounds. No consistent method was used to delineate the mixing zone and it was not apparent from the available information (e.g., NPDES permit, Fact Sheet) how the mixing zone was defined for most discharges. Both benthic macroinvertebrates and fish communities were sampled in the mixing zones using standard Ohio EPA methods (OEPA, 1989). Impairment was judged through the use of ecological indices (both the Index of Biotic Integrity [IBI] for fish and the Invertebrate Community Index [ICI]) as well as measures of EPT taxa, indicators of tolerant taxa, and individual fish health. All calculated scores were viewed in the context of Ohio's established biocriteria scores and scores indicative of non-attainment of designated uses have been clearly defined. All of the Ohio studies we reviewed appear to show evidence of impacts to the biological community related to the permitted discharge.

Oregon

Oregon's State Water Quality Strategy (ODEQ, 2005) involves sampling the biological communities within mixing zones to ensure compliance with applicable discharge permit limits. Such sampling is conducted in accordance with their standard operating procedures (ODEQ, 2003). We located data and supporting information from four such representative studies. As with Ohio, these studies appear to be conducted within the framework of larger stream

monitoring efforts and no specific mixing zone condition report is issued. Rather, the raw data and associated NPDES permits and Fact Sheets are available upon request from the state.

Each of the four mixing zone studies we reviewed involved a wastewater treatment plant with discharge flow ranging from 0.03 to 2.0 MGD. Typical constituents for which a mixing zone was allowed included ammonia, chlorine, and toxicity. Various models were used to define the mixing zones and in some cases, the extent of the mixing zone was estimated based upon design and 7Q10 flows. Only benthic macroinvertebrate communities were evaluated and IBI scores were calculated in determining potential impacts for each site. It is unknown whether the data gathered in these studies concluded that the biological communities were impacted.

Pennsylvania

The State of Pennsylvania does not require monitoring of biological conditions within mixing zones. However, it does appear that the Department of Environmental Protection (DEP) conducts such studies on an “as needed” basis. One available study evaluated the biological conditions in the mixing zone downstream of the Westchester Sewage Treatment Plant discharge to Taylor Run (PA DEP, 2006). This study sampled benthic macroinvertebrate communities at three sites in the stream (one upstream of the discharge and two downstream). It appears that at least one of these sites was within the regulatory mixing zone, however the study does not make this clear. The study evaluated measures of total taxa, total abundance and EPT taxa. EPT taxa is the total number of individuals from the Orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), which are generally considered to be the most sensitive aquatic insects. No replication or statistical analyses appear to have been conducted. This study concluded that the discharge was responsible for observed degraded biological community conditions, however this decision appears to be based largely on the judgment of the authors of the report and not on a rigorous analysis of the data.

3.3 Task 3

The objective of Task 3 was to use the gathered data and available scientific information to develop recommendations as to the biological monitoring required following (and possibly prior to) the authorization of a mixing zone. The limited information available on mixing zone evaluations conducted throughout the U.S. is insufficient with which to develop any conclusions as to what methods or study designs are more suitable than others for evaluating biological conditions within mixing zones. Recommendations and considerations for use in developing a program to monitor for potential impacts to the biota within mixing zones is included in the discussion section below.

4.0 DISCUSSION

Most states are not evaluating the condition of biological communities within mixing zones. There appears to be a conflict between the requirements that a mixing zone not prevent attainment of designated beneficial uses and the fact that a mixing zone is an area in which water quality criteria are allowed to be exceeded. It is generally assumed that the limited area provided for such mixing prevents any significant impacts to the biota in the larger area of the receiving water body. However, the lack of impacts are assumed and generally not confirmed through sampling (e.g., Oklahoma's biomonitoring protocols).

Not all states have explicit regulations regarding mixing zones. In fact, many states authorize mixing zones by policy and not regulation, and mixing zone characteristics are defined on a site-by-site basis within the NPDES permitting context. However, implicit in all state-authorized mixing zones is the stipulation that all designated uses within or beyond the mixing zone are met. In Tetra Tech's experience, many state agencies and EPA regions assume that so long as water quality standards are met at the edge of the mixing zone, and that the size of the mixing zone is minimized, effects on aquatic life uses (and other uses as well) will be negligible. However, based on our observations both in this study and in other professional interactions with states and dischargers, this assumption is rarely tested using direct biological measures within the mixing zone. In fact, Tetra Tech has observed some confusion on the part of some regulators and regulated parties alike with respect to allowable conditions in mixing zones. As a case in point, in a recently completed project conducted by Tetra Tech for the Water Environment Research Foundation examining relationships between whole effluent toxicity (WET) and instream biological condition (Diamond et al., 2002; 2007), there was considerable debate within the WERF project committee (EPA, state, municipality, consultant, and academic representatives) as to whether the study design should include biological samples within the chronic mixing zone because some felt that mixing zones were areas in which aquatic life impacts were allowed in water quality regulations.

Even in those states that monitor biological condition within mixing zones, the raw monitoring data are not readily available to the public (and possibly other regulators). In those states that do not conduct routine monitoring, but rather only on specific mixing zones on an as needed basis, the availability of those data are even more limited. Unless a mixing zone report was available online (e.g., the Red Dog Mine or Thompson Creek Mine), it was common for only a relatively few staff within an agency to have access to the requested information. Even then, the availability of such information appears to be often subject to the availability of hard copies of data in a regional office.

Even those states that have robust monitoring programs that include sampling within mixing zones typically do not identify regulatory mixing zones and evaluate those monitoring data separately (e.g., the data are not distinguished as originating from a mixing zone in the state database). Unless one has specific location information regarding each mixing zone and the associated sampling sites, it is difficult to locate appropriate monitoring data. Thus, any attempts to evaluate impacts in a given mixing zone are limited by not only data availability, but also data organization.

Many more mixing zone studies are probably conducted by the discharger than by a given state agency, but then either is not submitted to the state or the knowledge of the study is compartmentalized such that only a limited number of state employees are aware of or have access to that information. One example of this was encountered when discussing mixing zone evaluations with the personnel from The North Carolina Department of Natural Resources. Tetra Tech was advised that some dischargers (among them, Duke Energy) conducted such studies. Duke Energy representatives confirmed that such studies had been performed, but declined to provide details of either the methods used or the data gathered. Based on the experience of this project team, it is likely that such situations are fairly common.

The studies that we evaluated indicate that the data are rarely summarized and used in evaluating permit impacts on a large scale. Ohio and Oregon (and probably Hawaii) appear to conduct such monitoring on a wide scale. Ohio clearly uses collected data in evaluating permit conditions and the resulting data is discussed in NPDES permits and Fact Sheets. The remaining states either conduct no sampling within the mixing zone or only sample in response to concerns regarding a specific discharge. Wide scale or routine monitoring of biological conditions within mixing zones is rare.

While the small number of studies available for evaluation makes drawing broad conclusions difficult, it is clear that routine monitoring using defined methods with a pre-determined acceptable reference condition is necessary in evaluating potential impacts in mixing zones. Critical in this type of evaluation is a determination as to what specific community or communities (e.g., benthic macroinvertebrates and/or fish) are to be evaluated and defining the change in condition within the mixing zone relative to a reference site or reference condition that represents non-attainment of designated uses.

Bioaccumulation monitoring is sometimes required of discharges (e.g., Thompson Creek Mine) which have a mixing zone for bioaccumulative materials (e.g., mercury and selenium). However, such monitoring is not always required. Any future monitoring program should address whether tissue sampling for bioaccumulative materials is required when a mixing zone is permitted for such compounds.

4.1 Monitoring programs/methods

If Ecology's overall goal is to develop a mixing zone evaluation program suitable for use in monitoring biological conditions within mixing zones, then the results of this pilot study suggest that further analysis of programs from other states is unlikely to be of use. Because Washington has a robust biological monitoring program in place and a large amount of available data, it is advisable to work within the framework of the existing program to develop a mixing zone monitoring protocol. Washington has established methods to evaluate periphyton, benthic macroinvertebrate, and fish communities and a criterion to determine impairment (e.g., 25th percentile of reference population indicates impairment of a multimetric index). If applied correctly to develop a systematic mixing zone monitoring program, such a program would constitute a more rigorous monitoring program than that found in almost all other states (with the possible exception of Ohio and Oregon, which have similar, but not more advanced programs).

In developing a mixing zone evaluation program in Washington, the key focus should be the adaptation of the state's current Biological Monitoring Program (BMP) which is used to evaluate the condition of larger areas of streams (e.g., 5 miles). The same sampling methods and indicators could be used to evaluate specific sites within mixing zones relative to upstream or other similar sites. Such an adaptation of the existing program to meet these additional data needs would be efficient in that the same general sampling protocols and analysis methods would be used. However, the degree of rigor required to reliably identify differences among sites will be greater for a targeted mixing zone monitoring program than that required in meeting the current goals of Washington's BMP.

Future efforts should focus on evaluating methods and data analysis techniques already used in Washington State and an evaluation of necessary power (i.e., required replication) to determine the desired level of resolution in discriminating among impacted and reference sites. The study design and other Data Quality Objectives (DQOs) required to evaluate impacts related to a point-source discharge are much different from those used in a general assessment of stream quality. Particularly as the results of a mixing zone evaluation may become part of a compliance action or changes to an existing discharge permit, such a study should be designed to yield results that would be defensible, even within the context of a litigation challenge. As noted, the existing biomonitoring program should be the basis for any guidance for use in evaluating biological conditions within mixing zones. There are specific considerations in designing a monitoring program to evaluate potential impacts from a point-source discharge, which are summarized in Table 2.

Specific considerations to address in an effort to alter Ecology's current biological monitoring program for use in directed monitoring of conditions within mixing zones include an assessment of the replication necessary at each sampling site. The replication is directly related to the statistical power of a subsequent analysis and the final rigor of data generated in the monitoring program. The number and location of sampling locations are largely a factor of the type of system and physical size of the mixing zone. Also of consideration should be any potentially sensitive areas within the vicinity of the mixing zone. Smaller mixing zones may be adequately characterized with only one sampling location, while others may require several (stream size and other geomorphological descriptors are important considerations in determining the appropriate number of sampling locations). Washington's BMP currently uses the reference condition approach. If the system in which the mixing zone is established is already degraded, use of a reference site within the same system may be beneficial to determine whether the mixing zone further degrades the receiving water. The frequency of monitoring would most likely be tied to the NPDES permit cycle, however monitoring may be required more frequently depending on mixing zone size, pollutants, and site-specific concerns.

Additional considerations include how degradation is to be defined and how the data are to be analyzed and used. To meet the necessary rigor of a directed sampling program, hypothesis testing may be beneficial to determine differences among sites or a pre-determined level of acceptable deviation from an identified reference site or reference condition. Finally, it may be beneficial to determine how such monitoring data would be incorporated into permitting and other regulatory decisions.

Table 2. Considerations for development of a biological monitoring program designed to monitor for impacts to biological communities within regulatory mixing zones.

Replicate Sampling	Required to increase power of sampling and reduce variability to an acceptable level
Number of sampling locations	Larger mixing zones may require a stratified approach with a greater number of sampling sites
Location of sampling sites	Is the zone of initial dilution to be sampled or a site from elsewhere within the mixing zone
Reference Site or Reference Condition	If the biological impairment is not isolated to the mixing zone area, but is related to impacts other than the mixing zone, how will that be addressed in the study design (e.g., use of on-stream reference site or up and downstream sites)
Community to be sampled or metric to be calculated	The most appropriate community and/or metric for use in evaluating mixing zones may differ by water body type and not all may be required to be sampled
Bioaccumulation Monitoring	May be required for mixing zones established for bioaccumulative pollutants
Monitoring Frequency	Pre-set frequency of monitoring ensures all mixing zones are regularly monitored. May be necessary to monitor some (e.g., those in special resource waters) more frequently than others
Methods for Determining Difference	Simple comparison or hypothesis test
Data Evaluation	Determine how data are to be used in evaluating impacts within mixing zone (e.g., will discharger be required to evaluate causes of observed impact or will permit limits be altered in response to finding of impact within mixing zone)

Such a mixing zone monitoring program may also include a bioaccumulation monitoring component for mixing zones which have been established for bioaccumulative compounds such as mercury or selenium. It is unlikely that such monitoring would be required on a large-scale, but would be useful in monitoring upstream and downstream of a selected mixing zone to monitor for any potential bioaccumulation effects. A model for such a program might be California’s Mussel Watch program which analyzes concentrations of bioaccumulative materials in mussels living in the vicinity of permitted marine outfalls. While such a system could not be directly applied to freshwater systems, methods have been applied to freshwater in other studies (e.g., native periphyton, benthic macroinvertebrates, and fish in the case of the Thompson Creek Mine).

4.2 Next Steps

Washington has well developed guidance for how mixing zones should be defined, limited, and permitted (Ecology 92-109). A complimentary guidance document that could augment existing biological monitoring guidance (and also possibly be referenced by applicable regulations) could be developed that would detail the requirement for pre-discharge as well as post-discharge biological monitoring. Such guidance could be developed as an outgrowth and extension of the existing monitoring methods. Development of this guidance would address the considerations addressed above to allow for site-specific evaluation of conditions within mixing zones relative to appropriate reference sites. This would include an evaluation of power, physical extent of sampling (depending on extend of mixing zone), whether tissue sampling to evaluate bioaccumulation is necessary, and sampling methods to be used (will follow methods required in Washington’s BMP) with the goal of developing a stratified list of methods for use. This method list would be developed with goal of presenting guidance for monitoring that would depend on receiving water type (e.g., stream, non-wadeable river, or marine/estuarine), type of pollutants in mixing zone (e.g., bioaccumulative vs. non-bioaccumulative), and the size and extend of mixing zone (e.g., Figure 2).

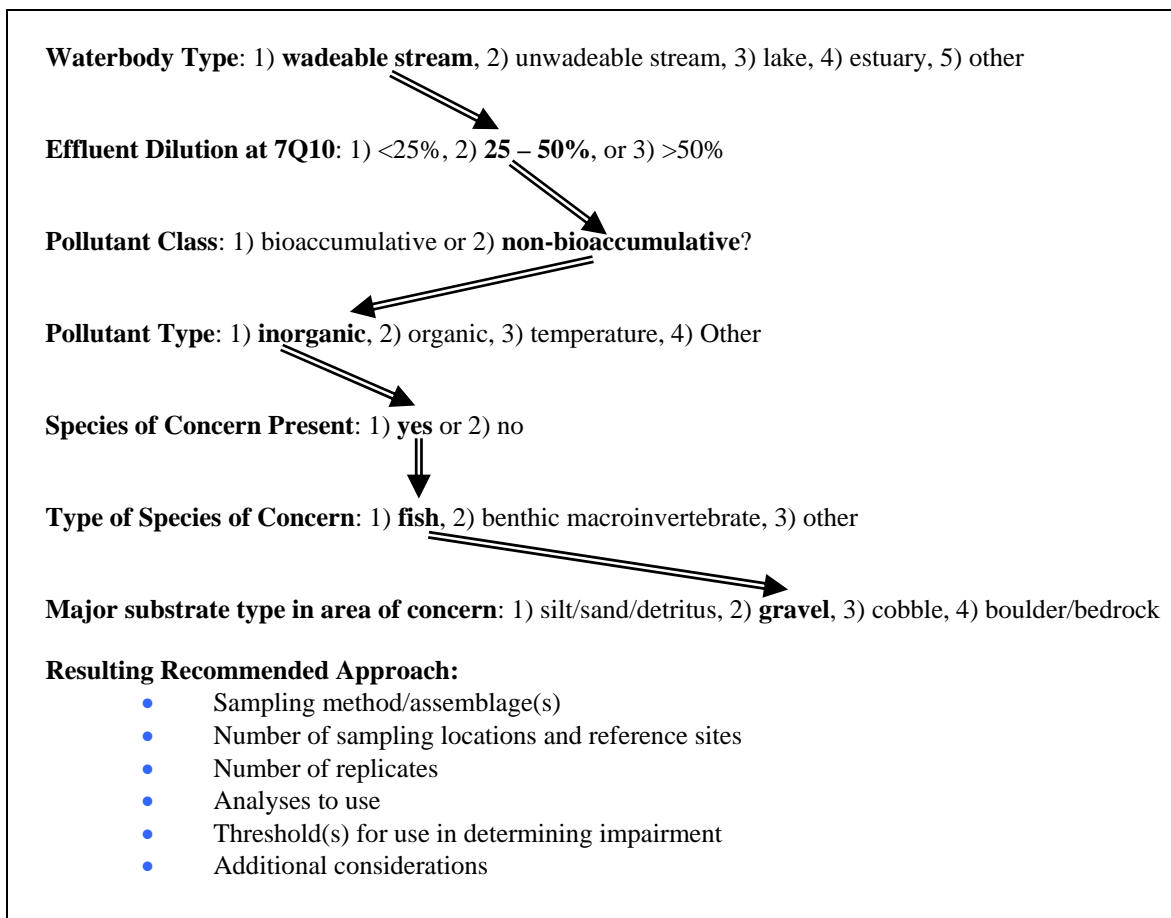


Figure 2. Flow chart of an example of a schematic that could be developed for use in identifying the most appropriate bioassessment method for use in a given mixing zone situation.

5.0 CONCLUSIONS

The biological conditions within mixing zones are rarely monitored. Only five states appear to have monitoring programs which either mandate or include the monitoring of biological conditions within mixing zones on a broad scale. In fact, the biomonitoring protocols for many states advise against or preclude the monitoring of biological conditions within mixing zones as these are areas in which applicable water quality standards may not be met. This illustrates an apparent inconsistency between regulations which generally require that the presence of a mixing zone may not preclude attainment of beneficial uses and the fact that water quality standards designed to protect beneficial uses are allowed to be exceeded within mixing zones. This conflict may have led to some of the confusion regarding expected conditions within mixing zones. This apparent conflict is dependent upon the conditions imposed by regulation or policy. Mixing zones, which are a very small area or small percentage of receiving water flow, are less likely to interfere with the beneficial uses of a water body than mixing zones which allow extensive areas or are defined by a point of complete mixing. The allowance of contiguous or overlapping mixing zones is also likely to compound the conflict between mixing zones and protection of beneficial uses.

Seventeen examples (containing both data, methods, and supporting documentation) of evaluations of biological conditions within mixing zones were located for this project. In only two states were a set of standard methods applied to such evaluations. Most often such studies are done on an as needed basis and using methods deemed appropriate by the organization conducting the study. It is likely that many more such evaluations have been conducted both by the regulatory community and by dischargers. However, most such reports are largely unavailable as the knowledge of such reports is compartmentalized within agencies or only available from dischargers that are unwilling to share such information. It appears that the availability of the results of such mixing zone studies are often limited. Further, it is unclear how frequently such data are available for use or considered during permit review processes.

The robust biological monitoring program in Washington State for ambient monitoring provides methodology and organization that could easily be used to develop a standardized protocol or guidance for monitoring of mixing zones. The development of such a program would necessitate the consideration of several factors required to modify a program designed to provide assessments of the conditions of larger areas to provide site-specific evaluations of conditions within mixing zones relative to appropriate reference areas.

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APPENDIX A

CONTACT INFORMATION

Table A-1. List of personnel which were contacted to solicit mixing zone reports and information.

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