Missouri Department of Natural Resources
Water Protection Program
Water Pollution Control Branch

2 Part II: Introduction to Water Quality Standards

2.1 Water Quality Standards

A **water quality standard (WQS)** defines the water quality goals for a waterbody. The WQS consists of 1) the beneficial use(s) of a waterbody, 2) the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and 3) the antidegradation rules and implementation procedures.

The federal water-quality standards regulation (40 CFR 131) describes state requirements and procedures for developing water quality standards. The Federal regulation also specifies procedures that the **Environmental Protection Agency (EPA)** must follow for reviewing and, where appropriate, promulgating water quality standards, if the state fails to promulgate. The state of Missouri develops and promulgates water quality standards to protect **waters of the state** in accordance with 40 CFR 131. The state follows a triennial (three-year) WQS review and revision process to ensure the WQS are current and reflective of the best science and data available. Missouri's Water Quality Standards can be found in the *Code of State Regulations* at 10 CSR 20-7.031.

2.2 Designation of Uses

To be consistent with the Clean Water Act (CWA), the state must provide water quality for the protection and propagation of fish, shellfish, and wildlife, and for recreation in and on the water (fishable/swimmable), where attainable [40 CFR 131.10(a)]. The Water Quality Standards regulations effectively establish a "rebuttable presumption" that the CWA Section 101(a)(2) uses are attainable and, therefore, must be assigned to a water body. The state must specify water uses to be achieved or maintained and set or designate those uses taking into account the use and value of the water body. The beneficial or designated uses for waters of the state are specified in the WQSs at 10 CSR 20-7.031(1)(C)1.-15. Categorically, these uses can be grouped into the following areas of protection: Aquatic Life, Recreation, Water Supply, Wildlife, and Aesthetics. As listed below, Missouri has adopted subcategories in its use classification system to further refine designated uses:

- Aquatic Life
  - Cold-water Fishery (CLD)
  - Cool-water Fishery (CLF)
  - General Warmwater Fishery (AQL - GWWF)
  - Limited Warmwater Fishery (AQL - LWWF)
- Recreation
  - Whole Body Contact Recreation (WBCR)
  - Secondary Contact Recreation (SCR)

- Water Supply
  - Drinking Water Supply (DWS)
  - Industrial (IND)
  - Irrigation (IRR)
- Wildlife
  - Livestock and Wildlife Watering (LWW)
- Aesthetics
  - Narrative Criteria [10 CSR 20-7.031(3)]

The beneficial uses of a waterbody are dependent upon actual use, the ability of the water to support the use now or in the future, and the likelihood of the water being used in a given manner. The use of water for the purpose of wastewater dilution or as a receiving water for a wastewater facility is not a beneficial use.

In additional to the beneficial or designated uses listed above, Missouri waters can also be designated as follows:

- Outstanding Resource Water [10 CSR 20-7.031(7-8)]
  - Outstanding National Resource Water (ONRW)
  - Outstanding State Resource Water (OSRW)
- Metropolitan No-Discharge Stream [10 CSR 20-7.031(6)]
- Losing Stream [10 CSR 20-7.031(1)(N)&(11)]

The designated uses of a water body are the formal, legally enforceable uses of the water as listed in 10 CSR 20-7.031, Tables G & H. An existing beneficial use or "existing use" are those uses actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards [10 CSR 20-7.031(H)]. Existing and attainable uses may or may not be reflected in the list of designated uses found in the WQS but must be protected. The following are common examples of existing and/or attainable uses that require protection.

Example 1: A private lake with obvious signs of whole-body contact recreational use (WBCR) receives effluent from a wastewater treatment facility 1.25 miles above the lake. While not a designated beneficial use, protection for whole body contact recreation is necessary and bacteria effluent limits are required during the recreational season.

Example 2: A water body located in an area of the state where habitat and conditions are favorable for a cold-water fishery, but this use has not been attained or maintained since the 1980s due to discharges and non-point source activities affecting water temperature. Because cold-water biota could be protected and propagate in the absence of the **anthropogenic** sources, a cold-water fishery (CLD) is an attainable use and the causes of the non-attainment must be remedied.

Existing and attainable uses can become designated uses through a structured scientific assessment known as a Use Attainability Analysis (UAA). Conversely, designated uses can be removed from a waterbody should the UAA process indicate the designated use is not attainable. This analysis includes the factors affecting the attainment of the use, which may include physical, chemical, biological, and economic factors as describe in Sec. 131.10(g). See the list of waterbodies that have undergone UAA on the department website at http://www.dnr.mo.gov/env/wpp/wqstandards/uaa/index.html. For the reviewer, the removal or addition of whole-body contact recreation is most important.

2.3 Waterbody Classification

All waters of the state have an assigned classification that identifies the hydrologic nature of the water body and the default characteristics and beneficial uses that may apply. The water body classification system used in Missouri is as follows:

- **Class L1** – Lakes used primarily for public drinking water supply [10 CSR 20-7.031(1)(F)1.]

- **Class L2** – Major reservoirs [10 CSR 20-7.031(1)(F)2.]

- **Class L3** – Other lakes that are waters of the state. These include both public and private lakes. For effluent regulation purposes, publicly owned L3 lakes are those for which a substantial portion of the surrounding lands are publicly owned or managed [10 CSR 20-7.031(1)(F)3.]

- **Class P** – Streams that maintain permanent flow even in drought periods [10 CSR 20-7.031(1)(F)4.]

- **Class P1** – Standing-water reaches of Class P streams [10 CSR 20-7.031(1)(F)5.]

- **Class C** – Streams that may cease flow in dry periods but maintain permanent pools which support aquatic life [10 CSR 20-7.031(1)(F)6.]

- **Class W** – Wetlands are waters of the state that meet the criteria in the *Corps of Engineers Wetlands Delineation Manual* (January 1987), and subsequent Federal revisions. Class W waters do not include wetlands that are artificially created on dry land and maintained for the treatment of mine drainage, stormwater control, drainage associated with road construction, or industrial, municipal or agricultural waste. Class W determination on any specific site shall be consistent with Federal law [10 CSR 20-7.031(1)(F)7.]

Beneficial or designated uses 10 CSR 20-7.031(1)(C)1.–11. of **classified waters** are identified in 10 CSR 20-7.031, Tables G and H. Beneficial or designated uses 10 CSR

20-7.031(1)(C)12.–15 of classified waters must be determined on a site-by-site basis and are therefore not listed in 10 CSR 20-7.031, Tables G and H.

Unclassified waters are those waters of the state that have not yet been classified using protocols established by the department. Prior to classification, all unclassified waters are protected for presumed beneficial uses of aquatic life protection, livestock and wildlife watering, and recreation (WBCR and SCR), wherever attainable. In addition to the aforementioned beneficial uses, unclassified waters have aesthetic protections under the WQS general criteria [10 CSR 20-7.031(3)].

2.4 Water Quality Criteria

Water quality criteria (WQC) are established to protect the beneficial or designated uses of a water body. WQC have elements of magnitude, duration, and frequency and can be either narrative or numeric in form. Narrative criteria are descriptive statements that describe the desired water quality goal for a water body. Numeric criteria are scientifically-derived ambient pollutant concentrations that have been developed by EPA or the state to protect human health and aquatic life.

2.4.1 Magnitude, Duration, and Frequency

To ensure protection of the beneficial or designated uses of a water body, water quality criteria contain three important components:

- Magnitude – The amount of a pollutant or water quality indicator that is allowable. Most criteria magnitudes are expressed in terms of concentration (e.g. milligrams per liter), although magnitudes for some pollutant parameters are expressed differently (e.g. pH and temperature). If the pollutant parameter is toxicity, magnitudes are often expressed in terms of toxic units and depend on the toxicity being tested (acute or chronic).
- Duration – The period (averaging period) over which the in-stream concentration is averaged for comparison with a criterion magnitude. Specifying the averaging period limits the duration of concentrations above the criteria. For example, most chronic criteria for the protection of aquatic life are expressed as a four (4)-day average concentration of a particular pollutant. The corresponding acute criteria for the protection of aquatic life are often expressed as one (1) hour concentrations. Other criteria have conditions or concentrations that are instantaneous in duration and are not to be exceeded or lower than more than a second (instant). Examples of “instantaneous criteria” with durations similar to those mentioned above include temperature and dissolved oxygen, respectively.
- Frequency – The number of allowable excursions or instances water body conditions can exceed or violate the combined magnitude and duration components of a criterion within a given period. For example, most chronic criteria for the protection

of aquatic life are stated as the four (4)-day average concentration not to be exceeded more often than once every three years, on average. The corresponding acute criteria for the protection of aquatic life are often expressed as the one (1) hour concentration not to be exceeded more often than once every three years, on average. Instantaneous criteria are "shall not exceed" criteria and should not occur in the water body.

The magnitude, duration, and frequency components of a water quality criterion collectively define the conditions required within a water body to maintain a given beneficial use. Conditions inconsistent with all three components of a water quality criterion are considered an exceedance of the criterion and a violation of the water quality standards in the water body. Pollutant reductions would then be required through point and nonpoint source controls to ensure compliance with the water quality standards.

2.4.2 Narrative Water Quality Criteria

Narrative criteria are descriptive statements that describe the desired water quality goal for a waterbody. Also known as "general" or "free from" criteria, narrative criteria are found at 10 CSR 20-7.031(3) of the water quality standards regulation. Narrative criteria are applicable to all waters of the state at all times including mixing zones. The narrative water quality criteria found in Missouri's Water Quality Standards regulation are:

- Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses; [10 CSR 20-7.031(3)(A)]

- Waters shall be free from oil, scum and floating debris in sufficient amounts to be unsightly or prevent full maintenance of beneficial uses; [10 CSR 20-7.031(3)(B)]

- Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses; [10 CSR 20-7.031(3)(C)]

- Waters shall be free from substances or conditions in sufficient amounts to result in toxicity to human, animal or aquatic life; [10 CSR 20-7.031(3)(D)]

- There shall be no significant human health hazard from incidental contact with the water; [10 CSR 20-7.031(3)(E)]

- There shall be no acute toxicity to livestock or wildlife watering; [10 CSR 20-7.031(3)(F)]

- Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community; [10 CSR 20-7.031(3)(G)]

- Waters shall be free from used tires, car bodies, appliances, demolition debris, used vehicles or equipment and solid waste as defined in Missouri's Solid Waste Law, section 260.200, RSMo, except as the use of such materials is specifically permitted pursuant to section 260.200.260.247; [10 CSR 20-7.031(3)(H)]

- Waters in mixing zones and unclassified waters which support aquatic life on an intermittent basis shall be subject to the following requirements [10 CSR 20-7.031(3)(I)]:
    1. The acute toxicity criteria of Tables A and B and the requirements of subsection (4)(B); and
    2. The following whole effluent toxicity conditions must be satisfied by the multiple dilution method (see Section 2.8. Whole Effluent Toxicity Testing below).

Through the effluent limit determination and derivation process, effluent limits for conventional, non-conventional, and toxic pollutants are developed so that the general criteria are met and beneficial uses in the water body are maintained. With the advent of antidegradation procedure, effluent limits are also developed to retain the assimilative capacity of a water body. Effluent limitations for Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS) are imposed at a level that ensures violations of the narrative criteria at 10 CSR 20-7.031(3)(A) and (C) do not occur. Oil and Grease effluent limitations are imposed for facilities where these pollutants are present so that the narrative criteria at 10 CSR 20-7.031(3)(B) are met. Water quality-based effluent limits for toxic pollutants are imposed upon a discharge so that toxics in toxic amounts are not present and the narrative criteria at 10 CSR 20-7.031(3)(D) and (F) are satisfied. Effluent limitations for bacteria are applied where secondary contact recreation exists and allows incidental contact with the water [10 CSR 20-7.031(3)(E)]. Toxicity testing is also required for many discharges so that the toxicity requirements outlined in 10 CSR 20-7.031(3)(I) are not violated (see Section 2.8., Whole Effluent Toxicity Testing).

2.4.3 Numeric Water Quality Criteria

Numeric water quality criteria are scientifically-derived ambient pollutant concentrations that have been developed by EPA or the state to be protective of human health or aquatic life. EPA develops numeric water quality criteria (numeric criteria) under the authority found in Section 304(a) of the CWA and issues the criteria as guidance to the states for use in developing or promulgating their own criteria. The state of Missouri's numeric water quality criteria are found at 10 CSR 20-7.031, Tables A & B of the water quality standards regulation. On these tables, numeric criteria are chronic unless noted as acute. Numeric criteria are classified as either **acute** or **chronic** depending upon the endpoint effect used during the toxicity studies upon which the criteria are based. The acute and chronic numeric criteria in the WQS were derived to be protective against acute and chronic toxicity effects, respectively, in the most sensitive species used in the toxicity testing.

2.4.3.1 Acute Criteria

An acute criterion is the maximum instantaneous or one (1) hour average concentration of a toxic substance or effluent that ensures adequate protection of sensitive species of aquatic organisms from acute toxicity resulting from exposure to toxic substances or effluent. Acute criteria will adequately protect the designated aquatic life use if not exceeded more than once every three (3) years. The terms "acute criteria" and "criteria maximum concentration" (CMC) are equivalent and may be used interchangeably in calculations, water quality reviews, and this document.

Acute criteria are employed in the water quality standards to effluent limit derivation process to protect aquatic life populations from acute toxicity. Acute toxicity is characterized by conditions producing adverse effects or lethality on aquatic life following short-term exposure. The acute criteria in Tables A and B of 10 CSR 20-7.031 are maximum concentrations that protect against acutely toxic conditions. Acute toxicity is also indicated by exceedance of whole-effluent toxicity (WET) test conditions of paragraph 10 CSR 20-7.031(3)(I)2. For substances not listed in Table A or B of 10 CSR 20-7.031, 0.3 of the median lethal concentration, or the no observed acute effect concentration for representative species, may be used to determine absence of acute toxicity.

The acute criteria found in Tables A and B of 10 CSR 20-7.031 must be met at all times in mixing zones and unclassified waters that support aquatic life on an intermittent basis [10 CSR 20-7.031(3)(I)1.] The acute toxicity criteria in Tables A and B of 10 CSR 20-7.031 are denoted as such by the word "acute" found next to the pollutant in the table. Instantaneous criteria that are protective against acutely toxic conditions are denoted as either maximum, maximum change or minimum for those parameters where an instantaneous criterion has been promulgated (e.g., temperature or dissolved oxygen).

2.4.3.2 Chronic Criteria

A chronic criterion is the four (4)-day average concentration of a toxic substance or effluent that ensures adequate protection of sensitive species of aquatic organisms from chronic toxicity resulting from exposure to toxic substances or effluent. One notable exception to the four (4)-day averaging period is the chronic criteria for total ammonia nitrogen that are thirty (30)-day average concentrations. Chronic criteria will adequately protect the designated aquatic life use if not exceeded more than once every three (3) years. The terms "chronic criteria" and "criteria continuous concentration" (CCC) are equivalent and may be used interchangeably in calculations, water quality reviews, and this document.

Chronic criteria are employed in the water quality standards to effluent limit derivation process to protect aquatic life populations from chronic toxicity. Chronic toxicity is characterized by conditions producing adverse effects on aquatic life or wildlife

following long-term exposure but having no readily observable effect over a short time period. Chronic numeric criteria in Tables A and B of 10 CSR 20-7.031 are maximum concentrations that protect against chronic toxicity; these values shall be considered four (4)-day averages excepting total ammonia nitrogen, which are thirty (30)-day averages. Chronic toxicity is also indicated by exceedance of WET test conditions of subsection 10 CSR 20-7.031(4)(P). For substances not listed in Table A or B of 10 CSR 20-7.031, commonly used endpoints such as the no-observed effect concentration or inhibition concentration of representative species may be used to demonstrate absence of toxicity.

The chronic criteria found in Tables A and B of 10 CSR 20-7.031 must be met at all times in classified waters excepting where a mixing zone is allowed [10 CSR 20-7.031(4)(A)4.A.]. Where mixing zones are allowed, chronic criteria must be met at the downstream edge of the mixing zone. All Table A and B criteria are chronic toxicity criteria, except those specifically denoted as acute or those that are protective of an instantaneous criterion (e.g. temperature or dissolved oxygen). The maximum chronic toxicity criteria in Tables A and B shall apply to waters designated for the indicated uses given in Tables G and H, and water contaminants shall not cause or contribute to concentrations in excess of these values.

2.5 Antidegradation Requirements

In accordance with Missouri's Water Quality Standard [10 CSR 20-7.031(2)] and federal antidegradation policy at Title 40 Code of Federal Regulation (CFR) Section 131.12 (a), the department developed a statewide antidegradation policy and corresponding procedures to implement the policy. Effective August 30, 2008, a wastewater treatment facility is required to comply with the AIP. The AIP is available at http://www.dnr.mo.gov/env/wpp/permits/antideg-implementation.htm. This procedure is applicable to new and expanded wastewater treatment facilities.

The department considers an expanded permitted discharge as an increase in dry-weather design flow or pollutant of concern load. New discharge is defined as the construction of a facility that does not currently possess a NPDES permit or the addition of a new pollutant of concern in a current NPDES permit. Also, an increase in pollutant loading (for example, a sewer extension without new pollutants of concern (POC)), could take place without an antidegradation review if the difference between the current actual facility flow and the dry-weather design flow can accommodate the new flow.

> Example 1: An existing wastewater treatment facility has a current design flow of 1.0 million gallons per day (MGD) and wishes to expand to 1.5 MGD. This expansion would require an Antidegradation Review.
>
> Example 2: An existing wastewater treatment facility has a current actual flow of 1.0 million gallons per day (MGD) and wishes to add additional sewer connections that

would increase the facility flow to 1.1 MGD. The dry-weather design flow is 1.5 MGD. This expansion would not require an Antidegradation Review.

A proposed discharge to a water body will be required to undergo a level of review that documents that the use of a water body's available assimilative capacity is justified. AIP requires new or expanded discharges either:

1) Demonstrate that the loading POC (see Part 3 for definitions and more details on POCs) is below allowed facility assimilative capacity and segment assimilative capacity, or
2) Demonstrate that loading of the POC will be maintained or decreased, or
3) Demonstrate or assume degradation with alternative analysis (See Tier 2 Review below).

If the discharge is degrading or assumed to be degrading, then, in order to complete the Administrative Record of Decision, the discharger must submit:

1) An alternative analysis that demonstrates the non-degrading and minimally degrading discharging options are either impracticable, non-cost efficient, or unaffordable, and
2) An evaluation of social and economic importance of the proposed degrading discharging activity for social and economic development of the community.

All **waters of the state** (except groundwater) are subject to the AIP. Dischargers must submit a determination of assigned tier(s) of protection to water quality for all **waters of the state** on a pollutant-by-pollutant basis. The applicant or the department can accomplish tier determinations if data is available using the approved procedure in Appendix 2 of the AIP. The discharger should consult AIP, Section 1.B. for the process of assigning Tier Protection Levels. Both Tier 1 and 2 Reviews are conducted on a pollutant-by-pollutant basis. Outstanding National and State Resource waters listed on Table D and E in the WQS at 10 CSR 20-7.031 automatically are assigned Tier 3 Reviews that are conducted on a waterbody-by-waterbody basis.

2.5.1 Tier 1 Reviews

2.5.1.1 Assigning Tier 1 Reviews

POCs that qualify for Tier 1 Reviews may be discharged in accordance with WQS without performing the alternative analysis or socio-economic importance demonstration; however, for a POC with Tier 1 designation, the discharger must provide existing (receiving) water quality data (EWQ), an appropriate water quality model, or department Section 303(d) listings. (Dischargers to water bodies having 305(b) listed POCs will need to ensure enough data is available and to determine present status of POC). Appendix 2 of the AIP demonstrates the statistical process (90% percentile value is significantly more than 95% of the WQS for POC) that applicants must use to designate POC as Tier 1

(below, at or near WQS), if POC is not department Section 303(d) or 305(b) listed for that waterbody.

2.5.1.2 Conducting Tier 1 Reviews

For Tier 1 POCs, beneficial uses must not be impacted by discharge. The discharger must demonstrate that the discharge will not violate the water quality criterion for that pollutant by preventing further degradation of existing water quality. The applicant can achieve this with two types of demonstrations: 1) For expanding discharges, maintaining loading or decreasing loading, thus reducing concentrations of POCs (see Appendix E of the *WQAR Instructional Guidance*), or 2) For new discharges (in some cases expanding discharges), developing a water quality-based effluent limit (see Part 3, Section 3.4). If the Tier 1 POC(s) has a total maximum daily load wasteload allocation, the new discharger will be required to obtain and demonstrate allocation from an existing discharger and the existing discharger will be required to demonstrate maintenance or reduction in loading.

2.5.2 Tier 2 Reviews

2.5.2.1 Assigning Tier 2 Reviews

For POCs with Tier 2 designation, applicant must provide basis for determination by providing EWQ or an appropriate water quality model. The applicant must consider the current EWQ value in the administrative record from previous sampling events (see AIP, Water Quality Assessment Procedures). Appendix 2 of the AIP demonstrates the statistical process (90% percentile value is significantly less than 95% of the WQS for POC) that applicants must use to designate POC as Tier 2 (better than WQS). By default, all waters of the state are assigned a Tier 2 Review. Applicant can demonstrate less than significant degradation by performing demonstration #1 or #2 in paragraph 2, Section 2.5 above. These demonstrations are sufficient to eliminate the requirement for a Tier 2 Review. Tier 2 Reviews are described below in Section 2.5.2.3.

2.5.2.2 Conducting Demonstrations of Insignificance

If degradation is insignificant (demonstration #1 and #2 in Section 2.5, paragraph 2 above), no Tier 2 Review is required; however, discharger must provide basis for insignificance determination. Insignificant demonstration can be conducted by demonstrating that loading for the expanded discharge will be maintained or reduced. This must be achieved through a reduction in permitted pollutant concentrations or pollutant discharge monitoring report (DMR) data concentrations. Degradation is considered minimal on a pollutant-by-pollutant basis if the proposed new or expanded loading is less than 10% of the facility assimilative capacity (FAC) (see AIP, Appendix 3 for examples). In some cases, cumulative degradation as discussed in the AIP may need to be evaluated for multiple discharges within a segment. When performing FAC or

insignificant demonstration calculations using the pollutant DMR data, applicant should use the 99th percentile of the DMR pollutant combined with the existing design flow. For the permitted pollutant discharge, applicant should use the maximum daily limit of the pollutant combined with the existing design flow. For more information, see Part 4, Section 4.3.4 for the effluent-limit determination process. For a list of activities that are considered not to result in significant degradation, see AIP, Section II. A.

An additional requirement of the demonstration of insignificance for POCs such as mercury, arsenic, chromium, copper, zinc, and lead, that bioaccumulate, is to assess the POC's potential for bioaccumulation. If the net load increase of these POCs is shown to decrease, no demonstration of potential bioaccumulation is needed. If the net increase is maintained or increased, a demonstration of insignificance using the facility assimilative capacity would be required or a demonstration of potential bioaccumulation is needed. A potential reference for this demonstration is:
http://www.epa.gov/waterscience/criteria/humanhealth/method/.

2.5.2.3 Conducting Tier 2 Review

For those discharge cases where less than significant degradation cannot be demonstrated, a Tier 2 Review must be completed. The applicant can assume significant degradation of one or all POCs and conduct a Tier 2 Review without collection of existing water quality. Recommendations for individual POCs that are assumed or determined to be Tier 2 are discussed in Part 3 Technology-Based Effluent Limits of this guidance.

A Tier 2 Review is an alternative analysis and a social and economic importance evaluation (See AIP, Section II.B. for more information on Tier 2 Reviews and conducting alternative analysis and SEI evaluations). Non-degrading to degrading alternatives are evaluated in terms of their practicability, economic efficiency, and affordability. Those alternatives that are deemed practicable by the applicant are evaluated in the economic efficiency analysis. Because the selection of the treatment that is less than 120% of the base alternative, depending on the discharge volume, a minimum of four (4) treatment alternatives is expected for evaluation. To assist with the estimation of capital costs of treatment, the department may use in its review the Pennsylvania's Department of Environmental Protection's Wastewater Construction Cost Database at the following link:
http://www.dep.state.pa.us/dep/DEPUTATE/Watermgt/wsm/WSM_TAO/InnovTech/CostDB.htm#Wastewater. We recommend the present worth framework for reporting cost information, although annualized cost information is acceptable as long as all cost comparison use the same framework. See page 26 of the AIP for explanation of the cost comparison procedures. See also EPA's *Interim Economic Guidance* at http://www.epa.gov/waterscience/standards/econworkbook/. The social and economic importance analysis should cover the treatment facility's design life. Over that design

life, the long-term benefit to the affect community should be identified and discussed. Relevant factors related to the importance of the discharge are then evaluated.

See Part 3, Section 3.4.5 for effluent-limit determination process.

2.5.3 Tier 3 Reviews

Tier 3 water bodies shall receive no degradation of water quality. Tier 3 reviews are assigned for Outstanding State Resource Waters (OSRW), Outstanding National Resource Water (ONRW) and for those situations when hydrologic connection to Tier 3 water bodies is established. For OSRWs, no degradation of water quality is allowed but new discharges will be permitted as long as water quality is not degraded. Essentially, new discharges to an OSRW will be required to use the total maximum daily load process. For ONRWs, no impact to water quality is allowed and no new discharges are allowed. If hydrologic connection via a losing stream to Tier 3 water bodies has been or is demonstrated, then the discharger must demonstrate that water quality in the Tier 3 segment will not be lowered.

Discharges in watersheds with significant losing segments should have a geohydrological evaluation by the MDNR's Division of Geology and Land Survey and be checked for available dye tracings information. A direct discharge to a Tier 2 losing segment or a Tier 2 segment within two miles of a Tier 2 Losing segment may impact a Tier 3 water body through groundwater. The process to ensure no degradation of the Tier 3 water can be accomplished by 1) the same process as the Tier 3 direct discharge (zero discharge into the Tier 2 stream), or 2) water quality modeling study to ensure that there is no modeled concentration in the Tier 3 water for the discharged pollutants. Because of the lack of models for losing streams to address the impacts adequately, this type of modeling exercise will have to be coordinated through the Water Quality Monitoring and Assessment Section prior to submittal of the water quality review assistance and antidegradation review request.

Temporary degradation of water receiving (usually less than one year) with Tier 3 protection may be allowed by the department on a case-by-case basis as explained in Section II.A of AIP document. Temporary degradation is for situations when a WWTF needs to make modifications due to unforeseen events. Temporary degradation reviews, which are essentially Tier 1 Reviews for the protection of beneficial uses, will be performed on a case-by-case basis by the NPDES Permits and Engineering Section with input from the Water Quality Monitoring and Assessment Section. The applicant must provided the information mentioned on Section II A. Page 23 of the AIP. Any request for evaluation of zero or temporary degradation will need to be submitted well in advance of anticipated permit issuance date (minimum of 12-18 months).

The following are examples of temporary degradation of water receiving with Tier 3 protection:

Example #1: An existing facility has problem with collection system inflow & infiltration or failure of equipment. The facility is exceeding its limits and increasing its load of the POC or POCs to the receiving water body. Facility owners must make repair; therefore, they request an antidegradation review for temporary degradation to the receiving water body. The applicant will provide information requested in the AIP on page 23 and a Tier 1 Review will be conducted for all POCs. A construction permit application would be submitted after the antidegradation review. A public notice of the antidegradation review will be required (see Page 35 of the AIP).

Example #2: Applicant requires in-stream modification to construct a temporary weir. The activity will result in temporary degradation of the stream. This activity will require a Section 401 Water Quality Certification and a Corps of Engineers 404 General Permit. The applicant will provide information requested in the AIP on page 23 and a Tier 1 Review will be conducted for all POCs. The Tier 1 Review as part of the 401 Certification would involve a presentation and discussion of the Best Management Practices (BMPs) to ensure that water quality standards are protected from the temporary degradation activity. A public notice of the Tier 1 Review will be required (see Page 35 of the AIP).

2.6 Regulatory Mixing Zones

Regulatory mixing zones are areas of limited size near a facility outfall where numeric water quality criteria (Note: Mixing does not apply to bacteria) may be exceeded. Although numeric water quality criteria may be exceeded, the narrative criteria found at 10 CSR 20-7.031(3) must be met at all times. State regulation requires that regulatory mixing zones do not overlap [10 CSR 20-7.031(4)(C)] and that zones of passage must be provided to avoid lethality to passing organisms [10 CSR 20-7.031(4)(E)]. To these ends, regulatory mixing zones are limited in size (volume, area, and length) so that designated beneficial uses and aquatic communities are not adversely impacted. While many hydrologic and biologic factors can prohibit or limit the sizing of regulatory mixing zones [10 CSR 20-7.031(4)(D)], the spatial characteristics and volume of flow used will normally be based upon stream characteristics during low flow conditions. Missouri's Water Quality Standards contain regulatory mixing zones for both chronic (mixing zone) and acute (zone of initial dilution) conditions. Figure 1 graphically illustrates an idealized relationship between a discharge outfall and its zone of initial dilution and mixing zone for a P stream.

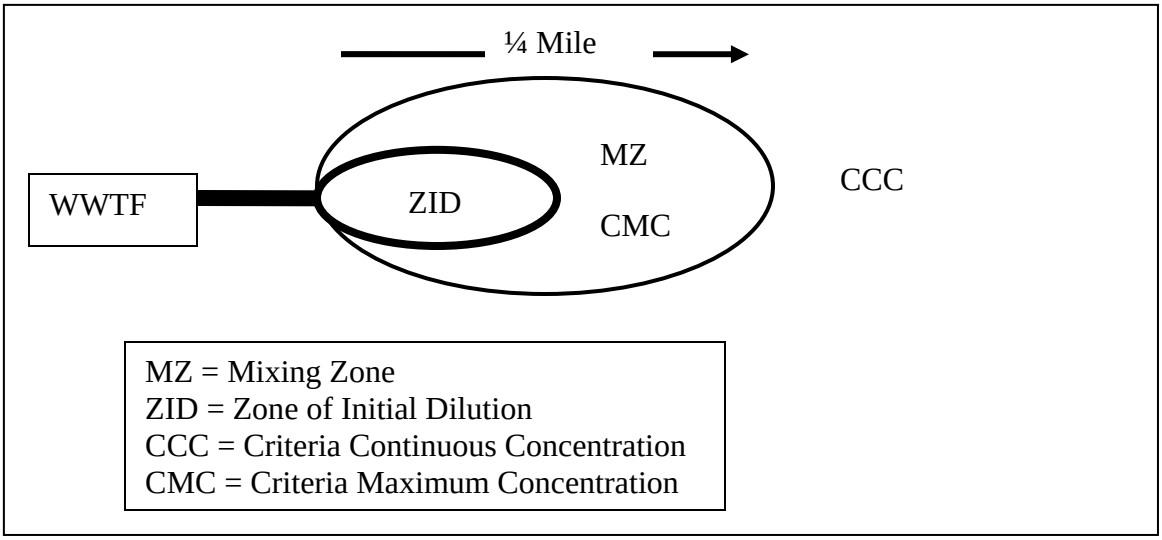

Figure 1. Regulatory Mixing Zone for a P Stream (1/4 Mile) showing area where CMC and CCC must be not be exceeded.

2.6.1 Low Flow Conditions

The low flow condition chosen for water quality review and effluent limit determination must ensure a reasonable worst-case scenario such that the desired frequency of compliance with applicable criteria is met. When determining critical design conditions, both hydrological and biological methods can be used to arrive at a reasonable stream design flow condition. Although the size of regulatory mixing zones under current practice is normally based upon hydrologic stream design flows, site-specific situations may arise where biologic stream design flows are the preferred condition. EPA recognizes the utility of both methods and provides discussion and recommendations usage in "Technical Guidance Manual for Performing Wasteload Allocation, Book VI: Design Conditions, Chapter 1."

2.6.1.1 Hydrologic Stream Design Flows

Hydrologic stream design flows rely on distribution statistics to determine what flow conditions are likely to occur in a stream at certain recurrence intervals. Average annual low flow values of "X" days in duration are determined from available data and fit to a numeric distribution (e.g. the log Pearson Type III frequency distribution) using one data point for every year of record. The resulting frequency distribution allows for the determination of annual low flow values of "X" days in duration at a recurrence interval of "Y" years. Hydrologic design flows are written as the X "Q" Y stream flow where "Q" is the symbol often used to denote volume of flow or discharge. For example, the 7Q10 stream design flow is the lowest average flow for seven (7) consecutive days that has a probable recurrence interval of once in ten (10) years. Commonly used hydrologic stream design flows and the criteria that are protected by those flows can be found in Table 1.

Stream Flow	Criteria Protected
1Q10	Aquatic Life Protection (AQL) – Acute *(ammonia only)
7Q10	AQL – Chronic, except ammonia nitrogen
30Q10	AQL – Chronic, ammonia nitrogen
30Q5	Human Health Protection, non-carcinogens
Harmonic Mean	Human Health Protection, carcinogens

Table 1: Common hydrologic stream design flows and criteria protected

- **1Q10** – the lowest average flow for one (1) day that has a probable recurrence interval of once in ten (10) years [10 CSR 20-7.031(1)(O)4.]. ***Note: Missouri water quality standards at 10 CSR 20-7.031(4)(F) indicate a preference for using the 7Q10 low flow for limit determinations based on acute criteria.**

- **7Q10** – the lowest average flow for seven (7) consecutive days that has a probable recurrence interval of once in ten (10) years [10 CSR 20-7.031(1)(O)1.]

- **30Q10** – the lowest average flow for thirty (30) consecutive days that has a probable recurrence interval of once in ten (10) years [10 CSR 20-7.031(1)(O)3.]

- **30Q5** – the lowest average flow for thirty (30) consecutive days that has a probable recurrence interval of once in five (5) years.

- **Harmonic Mean Flow** – low flow value derived using the number of daily flow measurements divided by the sum of the reciprocals of the flows (See EPA *Technical Support Document for Water Quality-based Toxics Control* (TSD) (505/2-90-001): http://www.epa.gov/npdes/pubs/owm0264.pdf)

Hydrologic stream design flows are statistically derived receiving water flows based on the selection and identification of an extreme value (e.g., 1Q10, 7Q10, 30Q10). The underlying assumption is that the hydrologic-stream design flow may occur a certain number of instances in a fixed number of years and one or more excursions below the design flow can and will occur. In this way, the hydrologic methods are independent of biological considerations and cannot easily replicate the durations and frequencies specified in aquatic life criteria. The critical low-flow value used must therefore be carefully chosen so that all applicable criteria are protected at an appropriate frequency.

2.6.1.2 Biologic Stream Design Flows

Once the department develops biological criteria, the biologic stream design flow (BSDF) may be used. In addition, these BSDFs are a better representation of the methodology used to develop current numeric criteria. BSDFs do not follow or fit a numeric distribution; rather these methods examine all of the available flow data for a period of

record and determine the actual frequency of biological exposure. In this way, biologic stream design flows can more accurately reflect the duration and frequency attributes of a water quality criterion. Biologic stream flows are written similarly to hydrologic stream flows in that they represent flows of "X" days in duration at a recurrence interval of "Y" years. The resulting biologic stream design flow is then written as X "B" Y stream flow where "B" is the symbol often used to denote the biological volume of flow or discharge. For example, the 4B3 stream design flow is the lowest average four (4) day flow that has a recurrence interval of three (3) years. Commonly used biologic stream design flows and the criteria that are protected by those flows can be found in Table 2.

Stream Flow	Criteria Protected
1B3	Aquatic Life Protection (AQL) – Acute
4B3	AQL – Chronic, except ammonia nitrogen
30B3	AQL – Chronic, ammonia nitrogen
4B3	Human Health Protection, non-carcinogens
Harmonic Mean	Human Health Protection, carcinogens

Table 2: Common biologic stream design flows and criteria protected

- **1B3** – the biologically-based 1-day average flow event that occurs (on average) once every 3 years.

- **4B3** – the biologically-based 4-day average flow event that occurs (on average) once every 3 years.

- **30B3** – the biologically-based 30-day average flow event that occurs (on average) once every 3 years.

- **Harmonic Mean Flow** – low flow value derived using the number of daily flow measurements divided by the sum of the reciprocals of the flows.

Biologic design flow methods directly use the durations and frequencies specified in aquatic life criteria (e.g., 1 day and 3 years (1B3) for CMC, 4 days and 3 years (4B3) for CCC) and as a result more accurately represent biological exposure to toxicity. While biologic design flows are the most compatible and protective option for effluent limit derivation purposes, the department has not historically used biologically-based methods opting instead for the more familiar hydrological-based methods. Use of biologically-based methods for wasteload allocation development will be on a case-by-case basis until their familiarity is more widespread. See *Technical Guidance Manual for Performing Wasteload Allocations, Book VI: Design Conditions – Chapter 1: Stream Design Flow for Steady-State Modeling.* EPA 440/4/86-014. 1986 for calculation methods.

2.6.1.3 Stream Low Flow Calculations

Stream low-flow conditions can be calculated through direct, relative, and default methods. A **direct determination** of stream low-flow conditions is the preferred approach and can be achieved through an analysis of daily stream flow data from the receiving water body. The analyses can be conducted using available software or spreadsheet calculations using low-flow frequency analyses (See Reference A for annotated methods). A **relative determination** of low-flow conditions can be achieved through a comparative analysis between a reference water body with similar hydrologic and physiographic characteristics and the subject water body. The reference water body would have information available for a direct determination of low-flow conditions and the subject waterbody would have low-flow conditions determined through a comparison of watershed areas (See **"**Evaluation of Drainage-Area Ratio Method Used to Estimate Streamflow for the Red River of the North Basin, North Dakota and Minnesota," USGS Scientific Investigations Report 2005-5017). A **default determination** of low-flow conditions can be achieved using default low-flow values obtained through an interpretation of water body classification from 10 CSR 20-7.031(1)(F). Default low-flow values are used in the absence of any other data or information from which to calculate low-flow conditions. The default low-flow values used by the department for water quality review and effluent-limit determination purposes can be found in Table 3.

Default Low-Flow Value			
Stream Class	***1Q10 (cfs)***	***7Q10 (cfs)***	***30Q10 (cfs)***
Unclassified	0.0	0.0	0.0
Class C	0.0	0.0	0.1
Class P and P1	0.1	0.1	1.0

Table 3: Default low-flow values by stream classification

Regulatory mixing zone size limits will normally be based on streams at the seven (7)-day Q_{10} low flow condition [10 CSR 20-7.031(4)(F)]. The 7Q10 low flow represents a reasonable worst-case scenario and is the critical hydrologic design condition for wastewater treatment facility design. To ensure appropriate protection and maintenance of beneficial uses during these critical low flow conditions, the WQS regulation ties the availability and size of regulatory mixing zones to the 7Q10 low flow of the receiving stream. Regulatory mixing zones based upon alternate low-flow values may be used provided they are protective of the averaging period and return frequency of the water quality criteria being considered (e.g. 1Q10 for CMC, 30Q10 for total ammonia nitrogen for CCC).

2.6.2 Mixing Zone (MZ)

A mixing zone (MZ) is an area of dilution of effluent in the receiving water beyond which chronic toxicity criteria must be met [10 CSR 20-7.031(1)(P)]. Within the mixing

zone numeric chronic criteria may be exceeded, but acute criteria, general criteria, and the whole effluent acute toxicity requirements of 10 CSR 20-7.031(3)(I) must be met at all times, except within the zone of initial dilution (if allowed). A MZ does not apply to bacteria. Dissolved oxygen may drop below the minimum in the MZ. The maximum size and extent of a mixing zone will depend on the 7Q10 low-flow of the receiving stream:

- *Streams with seven (7)-day Q_{10} low flows of less than 0.1 cfs* – not allowed [10 CSR 20-7.031(4)(A)4.B.(I)(a)].
- *Streams with seven (7)-day Q_{10} low flow of one-tenth to twenty (0.1 – 20) cfs* – one-quarter (1/4) of the stream width, cross-sectional area or volume of flow and length one-quarter (1/4) mile. If the discharger can document that rapid and complete mixing of the effluent occurs in the receiving stream, the mixing zone may be up to one-half (1/2) of the stream width, cross-sectional area or volume of flow [10 CSR 20-7.031(4)(A)4.B.(II)(a)]. The department has determined that rapid and complete mixing shall be defined as less than a five (5) percent difference in concentration across the receiving water body within close downstream proximity of the facility outfall.
- *Streams with seven (7)-day Q_{10} low flow of greater than twenty (20) cfs* – one-quarter (1/4) of stream width, cross-sectional area or volume of flow; length of one-quarter (1/4) mile [10 CSR 20-7.031(4)(A)4.B.(III)(a)].
- *Lakes* – not to exceed one-quarter (1/4) of the lake width at the discharge point or one hundred feet (100') from the discharge point, whichever is less [10 CSR 20-7.031(4)(A)4.B.(IV)(a)]. Discharges of wastewater into Class L1 lakes are prohibited by rule with only minor exceptions [10 CSR 20-7.015(3)(D)], therefore the mixing zone allowances specified above only apply to Class L2 and L3 lakes. See Reference B for methods of determining lake mixing zone.

2.6.3 Zone of Initial Dilution (ZID)

A zone of initial dilution (ZID) is small area of initial mixing below an effluent outfall beyond which acute toxicity criteria (CMC) must be met [10 CSR 20-7.031(1)(DD)]. Within the zone of initial dilution, numeric acute criteria may be exceeded but general criteria must be met at all times. The maximum size and extent of a zone of initial dilution will depend on the 7Q10 low-flow of the receiving stream:

- *Streams with seven (7)-day Q_{10} low flows of less than 0.1 cfs* – not allowed [10 CSR 20-7.031(4)(A)4.B.(I)(b)];
- *Streams with seven (7)-day Q_{10} low flow of one-tenth to twenty (0.1 – 20) cfs* – one-tenth (0.1) of the mixing zone width, cross-sectional area or volume of flow [10 CSR 20-7.031(4)(A)4.B.(II)(b)];
- *Streams with seven (7)-day Q_{10} low flow of greater than twenty (20) cfs* – one-tenth (0.1) of the mixing zone width, cross-sectional area or volume of flow and no more than ten (10) times the effluent design flow volume unless the use of diffusers or specific mixing zone studies can justify more dilution [10 CSR 20-7.031(4)(A)

4.B.(III)(b)]. Site-specific diffuser or mixing zone studies must be submitted to the department for review and approval prior to their use in establishing a volume of flow for the ZID. At no time, however, can the ZID volume of flow be greater than one-tenth (0.1) of the mixing zone width, cross-sectional area or volume of flow.

- *Lakes* – not allowed [10 CSR 20-7.031(4)(A)4.B.(IV)(b)].

Example: Table provides application of mixing zone regulations for a P Stream with an effluent design flow of 58.9 cfs and hydrologic stream flow.

Mixing Zone (MZ): One-quarter (1/4) of the stream volume of flow; length one-quarter (1/4) mile. [10 CSR 20-7.031(4)(A)4.B.(III)(a)].
Zone of Initial Dilution (ZID): One-tenth (0.1) of the mixing zone volume of flow, not to exceed 10 times the effluent design flow. [10 CSR 20-7.031(4)(A)4.B.(III)(b)].

	Flow (cfs)	MZ (cfs)	ZID (cfs)
7Q10	18,593	4648.3	464.8
1Q10	16,520	4130.0	413.0
30Q5	28,804	7201.0	589
30Q10	24,375	6093.8	589

2.7 Variances to Water Quality Standards

Variances to the WQS may be obtained via request to commission per RSMo 644.061. Clean Water Law establishes the requirement for a staff investigation of the variance request and recommendation to the Clean Water Commission within sixty days of receipt of a completed application. The commission can then make a preliminary decision on that recommendation. If the recommendation is to deny, the applicant has the right to a hearing. If the recommendation is to grant the variance, public notice is required prior to final commission approval.

No variance can be granted if the result would be an adverse effect on human health and upon fish, other aquatic life and wildlife. Applicability to the Water Quality and Antidegradation Review Process will depend on the variance request. More information on the variance process can be found in the MDNR Permit Manual.

2.8 Whole Effluent Toxicity (WET) Testing

To protect water quality, thus aquatic life and beneficial uses, from toxic substances that may be in wastewater, EPA's whole effluent approach involves the use of acute and chronic toxicity tests. The combined toxic effects of the discharge of pollutants may be evaluated using these testing methods. Whole effluent toxicity tests use standardized, surrogate freshwater or marine (depending upon the mixture of effluent and receiving

water (Test Dilution)) plants, invertebrates, and vertebrates. EPA publications list written protocols for toxicity testing with numerous freshwater species.

Missouri's water quality criteria have acute and chronic points of compliance. For unclassified water bodies and classified waters where a zone of initial dilution is not allowed, the point of compliance is at the outfall and only acute point of compliance applies. For classified waters with permanent flow, the chronic point of compliance is located at the edge of a mixing zone where receiving water must be suitable for long-term habitation even during low flow conditions. Short-term chronic and critical life stage (see Chronic Testing below) WET tests apply at the chronic point of compliance to assess suitability for complete life cycles of aquatic species. Inside of the mixing zone closer to the discharge is the acute point of compliance where there must be no lethality. WET tests only assessing short-term survival apply at the acute point of compliance.

2.8.1 Acute WET Tests

An acute toxicity test is defined as a test of 96-hours or less in duration in which lethality is the measured endpoint. In Missouri, the duration of the test may be assigned either 48 or 96 hours. In most cases, 48 hours is assigned. Currently, this is the only WET test that Missouri NPDES Permitees are required to perform. The test conditions for the test organism's *Ceriodaphnia dubia* and *Pimephales promelas* are summarized in each permit. For more information see: http://www.epa.gov/waterscience/methods/wet/disk2/

2.8.2 Chronic WET Tests

A chronic toxicity test is defined as a long-term test in which sublethal effects such as fertilization, growth, and reproduction are usually measured, in addition to lethality.
Chronic tests are full life-cycle tests or a shortened test of about 30 days that is known as an early life stage test. However, the duration of most of the EPA chronic toxicity tests have been shortened to 7 days by focusing on the most sensitive life-cycle stages. For this reason, the EPA chronic tests are called short-term chronic tests. Life cycle stages include: 1) Growth of larval fish (*Pimephales promelas)*, and 2) Mortality and the number of broods of daphnia (*Ceriodaphnia dubia*). For more information see: http://www.epa.gov/waterscience/methods/wet/disk3/

2.8.3 WET Test Frequency and Dilutions for Acute and Chronic Tests

The required WET test frequency can be established using the Table 4 and 5 below or defined by memorandum, *Revision of the Missouri Operating Permit Language for Whole Effluent Toxicity (WET) Tests , Uniform Application of Proposed Guidance and New WET Test Reporting Form*, dated August 05, 2005. Also, see the Permit Manual. Stormwater requires only acute testing except at the discretion of the permit writer. Chronic testing has some other situations requiring testing but "Majors" > 1 MGD require chronic testing.

Design Flow (gpd)	Acute WET Test Frequency	Chronic
< 22,500	Best Professional Judgement (BPJ)/None	NA
22,500 –999,999	Fourth Year of Permit Cycle	NA
> 1,000,000	Once/Year w/in Permit Cycle	Once/Year*

Table 4: WET Test Frequency for Publicly-Owned Treatment Works (POTWs). **Having less than 15:1 dilution in MZ or greater than 40% AEC. See department Permit Manual for more details*.

Design Flow (gpd)	Process Water		Storm Water
	Acute WET Frequency	Chronic WET Frequency	Acute WET Test Only
< 22,500	BPJ/ Not	BPJ/ None	None
22,500 – 99,999	Yearly	BPJ/Yearly	None
100,000 – 999,999	Twice/Year	Once/Year	Yearly/BPJ
> 1,000,000	Twice/Year	Twice/Year	Yearly

Table 5: WET Test Frequency for Industrial Facility Process/Storm Water.

The WET Test Allowable Effluent Concentration (AEC) is defined as the percent of effluent calculated to be present at the downstream edge of the zone of initial dilution. This compliance dilution must pass during multiple WET testing. As defined at 10 CSR 20-7.031(1)(DD), the zone of initial dilution is a small area of initial mixing below an effluent outfall beyond which acute toxicity criteria must be met. For unclassified waters and classified waters where a zone of initial dilution is not allowed, the AEC is 100 percent (%). For all other waters, the AEC can be calculated using the following formula:

AEC % = [outfall design flow csf / (ZID csf + outfall design flow cfs)] * 100.

Missouri's requires the multiple WET Test dilution method. Multiple dilution tests must be completed with: 100%, 50%, 25%, 12.5%, and 6.25% effluent, unless the AEC is less than 25% effluent, in which case dilutions will completed with four (4) times the AEC, two times the AEC, AEC, 1/2 AEC and 1/4 AEC. Two additional control tests are required: 1) 100% receiving stream water (if available), collected upstream of the outfall at a point beyond any influence of the effluent; and 2) a control that uses reconstituted water.

2.8.4 Whole Effluent Toxicity Criteria

EPA's recommended criteria for whole effluent toxicity are as follows: 1) To protect aquatic life against chronic effects, the ambient toxicity should not exceed 1.0 chronic toxic unit (TUc) to the most sensitive of at least three different test species. 2) For protection from acute effects, the ambient toxicity should not exceed 0.3 acute toxic units (TUa) to the most sensitive of at least three different test species. A TUa is equivalent to a LC_{50} dose. One TUa will kill one-half of the test organisms. A TUa set equal to one would allow acute toxicity; therefore, EPA chose 0.3 TUa as the criteria.

Missouri uses the narrative evaluation approach, i.e., failures of at least two multiple dilution tests constitute a violation of narrative requirement for aquatic life protection. For acute toxicity testing, the endpoint for pass/fail is a statistically significant mortality when compared to the upstream control water dilutions.

2.8.5 WET Testing Requirements

The memorandum, *Revision of the Missouri Operating Permit Language for Whole Effluent Toxicity (WET) Tests , Uniform Application of Proposed Guidance and New WET Test Reporting Form,* date August 05, 2005, provides the basis for WET Testing Requirements.

This memorandum is still applicable except the single dilution method is no longer performed. All NPDES permits are being revised to include this requirement. A more detailed list of WET Testing requirements can be found in a recently revised NPDES permit. The NPDES permit lists the testing schedule and follow-up requirement, test conditions, and the pass/fail procedures.

Below is a list and brief description of revisions made to Part 2:

Version	Date Completed	Description
Version 1.0	August 2, 2006	Portions of the original draft of Part II were written by John Hoke
Version 1.1	June 10, 2009	Revised Part II written by Todd Blanc. Updated to include antidegradation rule, WET Testing.

Missouri Department of Natural Resources
Water Protection Program
Water Pollution Control Branch

Reference A: Calculation of Hydrologically-based Design Flows, excerpt from EPA's "Technical Guidance Manual for Performing Wasteload Allocation, Book VI: Design Conditions, Chapter 1." http://www.epa.gov/waterscience/models/library/wlabook6chapter1.pdf

Design flows can be calculated as annual x-day average low flows whose return period is y years, i.e., the xQy low flow. These flows can be estimated from a historical flow record of n years using two different methods. The first is a distribution-free method that makes no assumption about the true probability distribution of annual low flows.

The expression for xQy is:

xQy = (1-e) X(ml) + eX(m2), where:

X(m) = the m-th lowest annual low flow of record
ml = [(n+1)/y]
m2 = [(n+l)/y] + 1
[z] = the largest integer less than or equal to z
e = (n+l)/y - [(n+l)/y]

This method is only appropriate when the desired return period is less than n/5 years.

The second method fits the historical low flow data to a specific probability density function and then computes from this function the flow whose probability of not being exceeded is 1/y. The log Pearson Type III distribution is a convenient function to use because it can accommodate a large variety of distributional shapes and has seen wide-spread use in stream flow frequency analysis. However, there is no physically based rationale for choosing one distribution over another. The xQy low flow based on the log Pearson Type III method is:

xQy = exp(u + K(g,y) s), where:

u = mean of the logarithms (base e) of the historical annual low flows,
s = standard deviation of the logarithms of the historical low flows,
g = skewness coefficient of the logarithms of the historical low flows,
K = frequency factor for skewness g and return period y.

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Water Protection Program
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Reference B: Example of Regulatory Mixing Zone Calculations and Determination for a Lake

Triangular Prism Method

Mixing Zone (MZ) Parameters:

According to the USGS 1:24,000K Quadrangle, the mainstem lake width near the *assumed* new facility outfall location is approximately 1833 feet (ft). Using "normal" water levels of 1833 ft wide and one-quarter of this width equals 458 ft. Therefore, because 100 feet is less than 458 ft, MZ = 100 feet [10 CSR 20-7.031(4)(A)5.B.(IV)(a)].

Mixing Zone Volume:

The flow volume approximates a triangular prism because of the slope of the lake bottom, where the formula is Volume = L*W*(D*0.5). Assuming that the width will be either side of the discharge (MZ) length (100 feet) to form the plume effect, the box dimensions are length (L) = 100 ft, width (W) = 100 ft, and depth (D) = 16 ft. Depth was obtained using mixing zone length projected 100 ft from shoreline to the intersecting contour on 7.5' USGS topographic map (shoreline contour=656 ft and lake depth contour at 100 ft from shore = 640 ft).

Volume = L*W*(D*(0.5)) = (100')*(100')*(8') = 80,000 ft^3.

The flow volume of 80,000 ft^3 is assumed as the daily mixing zone. Therefore;
(80,000 ft^3/day)*(1 day/86,400 sec) = 0.926 ft^3/sec.

NOTE: We recommend that site-specific morphometric data be used for a more accurate mixing zone determination.