Chapter 6

Water Quality-Based Effluent Limits

Permit writers must consider the impact of every proposed surface water discharge on the quality of the receiving water. Water quality goals for a water body are defined by State water quality standards. A permit writer may find, by analyzing the effect of a discharge on the receiving water, that technology-based permit limits are not sufficiently stringent to meet these water quality standards. In such cases, the CWA and EPA regulations require development of more stringent, water quality-based effluent limits (WQBEL) designed to ensure that water quality standards are met. In order to develop effective WQBELs, permit writers must be familiar with State water quality standards methods for predicting water quality impacts from discharges, and procedures for establishing WQBELs. This chapter provides basic information on these subjects. For more detailed information on water quality-based permitting, refer to the *Technical Support Document for Water Quality-Based Toxics Control* (TSD),[13] or equivalent State or regional procedures.

[13]USEPA (1991). *Technical Support Document for Water Quality-Based Toxics Control*. EPA-505/2-90-001. Office of Water Enforcement and Permits.

6.1 Overview of Water Quality Standards

WQBELs involve a site-specific evaluation of the discharge and its effect on the receiving water. A WQBEL is designed to protect the quality of the receiving water by ensuring that State water quality standards are met. To understand how to develop WQBELs, the permit writer must understand State water quality standards and the water quality goals they define.

Section 303(c) of the CWA requires every State to develop water quality standards applicable to all water bodies or segments of water bodies that lie within the State. Once standards are developed, EPA must approve or disapprove them. Water quality standards should (1) include provisions for restoring and maintaining the chemical, physical, and biological integrity of State waters, (2) provide, wherever attainable, water quality for the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water ("fishable/swimmable"), and (3) consider the use and value of State waters for public water supplies, propagation of fish and wildlife, recreation, agriculture and industrial purposes, and navigation. Currently, States are required to review their water quality standards at least once every three years and revise them as necessary. When writing a permit, the permit writer must use the most current State water quality standards. For more information regarding procedures for developing water quality standards, refer to EPA's Water Quality Standards Regulation at 40 CFR Part 131 and the *Water Quality Standards Handbook: Second Edition*.[14]

Under §510 of the CWA, States may develop water quality standards more stringent than required by the Water Quality Standards Regulation. Also, EPA reviews and approves or disapproves State-adopted water quality standards. EPA's review is to ensure that the State water quality standards meet the requirements of the CWA and the Water Quality Standards Regulation. EPA may promulgate a new or revised standard for a State where necessary to meet the requirements of the CWA.

[14]USEPA (1994). *Water Quality Standards Handbook: Second Edition*. EPA 823-B-94-005a. Office of Water.

6.1.1 Components of Water Quality Standards

Water quality standards are composed of three parts:

- Use classifications
- Numeric and/or narrative water quality criteria
- Antidegradation policy.

Each of these three components is described below.

Use Classification

The first part of a State's water quality standard is a classification system for water bodies based on the expected beneficial uses of those water bodies. The CWA describes various uses of waters that are considered desirable and should be protected. These uses include public water supply, recreation, and propagation of fish and wildlife. The States are free to designate more specific uses (e.g., cold water aquatic life, agricultural), or to designate uses not mentioned in the CWA, with the exception of waste transport and assimilation which is not an acceptable designated use (see 40 CFR §131.10(a)). Designated uses should support the "fishable/ swimmable" goal of Section 101(a)(2) of the CWA where such uses are attainable. A State must perform a use attainability analysis under 40 CFR §131.10(j) where it: (1) does not designate a "fishable/swimmable" use for a water; (2) wishes to remove a "fishable/swimmable" designated use; or (3) wishes to adopt subcategories of a designated "fishable/swimmable" use that would require less stringent criteria. The use attainability analysis is a structured scientific assessment of the factors affecting the attainment of a use. The analysis may include physical, chemical, biological, and economic factors as described in 40 CFR §131.10(g).

Water Quality Criteria

The second part of a State's water quality standard is the water quality criteria deemed necessary to support the designated uses of each water body. Section 303(a-c) of the CWA requires States to adopt criteria sufficient to protect designated uses for State waters. These criteria may be numeric or narrative. The CWA requires States to adopt numeric criteria for certain toxic pollutants where they are necessary to protect designated uses. EPA's Water Quality Standards Regulation encourages

States to adopt both numeric and narrative water quality criteria. See Section 6.1.2, Establishing Water Quality Criteria, of this manual for additional information on the development of numeric and narrative criteria.

Antidegradation Policy

The third part of a State's water quality standard is the State's antidegradation policy. Each State is required to adopt an antidegradation policy consistent with EPA's antidegradation regulations (40 CFR §131.12) and to identify the methods it will use for implementing the policy. Antidegradation policies provide three tiers of protection from degradation of water quality:

- **Tier 1—**Protects existing uses and provides the absolute floor of water quality for all waters of the United States. Existing instream water uses are those uses that were attained on or after November 28, 1975, the date of EPA's first Water Quality Standards Regulation, or uses for which existing water quality is suitable unless prevented by physical problems such as substrate or flow.
- **Tier 2—**Protects the level of water quality necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water in waters that are currently of higher quality than required to support these uses. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: (1) a finding that it is necessary to accommodate important economical or social development in the area where the waters are located; (2) full satisfaction of all intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing uses.
- **Tier 3—**Protects the quality of outstanding national resources, such as waters of national and State parks and wildlife refuges and waters of exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality (with the exception of some limited activities that result in temporary and short-term changes in water quality).

Additional information on water quality standards is available in the *Water Quality Standards Handbook: Second Edition*.[15]

6.1.2 Establishing Water Quality Criteria

Water quality criteria set ambient levels of individual pollutants or parameters, or describe conditions of a water body that, if met, will generally protect the designated use of the water. Water quality criteria are developed to protect aquatic life and human health, and, in some cases, wildlife from the deleterious effects of pollutants. Section 304(a) of the CWA directs EPA to publish water quality criteria guidance to assist States in developing water quality standards. EPA criteria or guidance consists of three components:

- **Magnitude—**The level of pollutant (or pollutant parameter), generally expressed as a concentration, that is allowable.
- **Duration—**The period of time (averaging period) over which the instream concentration is averaged for comparison with criteria concentrations.
- **Frequency—**How often criteria can be exceeded.

EPA's efforts on criteria development have been focused on the 65 pollutants listed in Section 307(a) of the CWA. Some of the 65 pollutants on the list are actually families or classes of organic compounds consisting of many individual chemicals. EPA translated this list into a new list of 129 priority toxic pollutants. Subsequently, two volatile chemicals and one water unstable chemical were removed from the list so that the present list contains 126 priority toxic pollutants. Criteria for the priority toxic pollutants that EPA has developed to date are contained in individual criteria documents and summarized in a document entitled *Quality Criteria for Water 1986,*[16] more commonly referred to as the *Gold Book*.

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[15]USEPA (1994). *Water Quality Standards Handbook: Second Edition*. EPA 823-B-94-005a. Office of Water.

[16]USEPA (1986). *Quality Criteria for Water, 1986*. EPA-440/5-86-001. Office of Water Regulations and Standards.

Numeric Criteria

Numeric water quality criteria are values expressed as levels, constituent concentrations, toxicity units (see discussion of whole effluent toxicity below), or numbers deemed necessary to protect designated uses. These criteria often form the basis for NPDES WQBELs. They also can be useful in assessing and managing nonpoint sources. In 1987, Congress increased the emphasis of the CWA on numeric criteria for toxic pollutants by enacting Section 303(c)(2)(B) of the act. This section requires States to adopt numeric criteria for the 126 priority toxic pollutants for which EPA has developed criteria guidance and where the discharge or presence of the pollutant could reasonably be expected to interfere with the designated uses of a water body. States may establish numeric criteria using EPA criteria guidance, modified to reflect site specific conditions, or other scientifically defensible methods.

EPA criteria for the protection of aquatic life address both short-term (acute) and long-term (chronic) effects on both freshwater and saltwater species. The following example shows the current EPA criteria for cadmium.

Example:

Aquatic Life

The procedures described in the *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* indicate that, except possibly where a locally important species is very sensitive, freshwater aquatic organisms and their uses should not be affected unacceptably if the 4-day average concentration (in ug/L) of cadmium does not exceed the numerical value given by $e^{(0.7852[1n(hardness)]-3.490)}$ more than once every 3 years on the average and if the one-hour average concentration (in ug/L) does not exceed the numerical value given by $e^{(1.128[1n(hardness)]-3.828)}$ more than once every 3 years on the average. For example, at hardnesses of 50, 100, and 200 mg/L as $CaCO_3$ the 4-day average concentrations of cadmium are 0.66, 1.1, and 2.0 ug/L, respectively, and the 1-hour average concentrations are 1.8, 3.9 and 8.6 ug/L. If brook trout, brown trout, and striped bass are as sensitive as some data indicate, they might not be protected by this criterion.

Human health criteria are designed to protect people from exposure resulting from consumption of water and fish or other aquatic life (e.g., mussels, crayfish). The following example contains EPA's human health criteria for cadmium.

Example:

Human Health

The ambient water quality criterion for cadmium is recommended to be identical to the existing drinking water standard which is 10 ug/L. Analysis of the toxic effects data resulted in a calculated level which is protective of human health against the ingestion of contaminated water and contaminated aquatic organisms. The calculated value is comparable to the present standard. For this reason a selective criterion based on exposure solely from consumption of 6.5 grams of aquatic organisms was not derived.

Narrative Criteria

All States have adopted narrative criteria to supplement numeric criteria for toxicants. Narrative criteria are statements that describe the desired water quality goal. Examples of narrative criteria are provided below. Narrative criteria can be the basis for limiting specific pollutants where the State has no numeric criteria for those pollutants or they can be used to limit toxicity where the toxicity cannot be traced to a specific pollutant. EPA's Water Quality Standards Regulation requires States to develop implementation procedures for narrative criteria that address all mechanisms to be used by the State to ensure that narrative criteria are attained.

Example:

Narrative criteria can be statements, requiring that discharges be "free from toxics in toxic amounts" or "free of objectionable color, odor, taste, and turbidity."

6.1.3 Future Directions for Water Quality Standards

The water quality standards program is constantly evolving. New scientific, regulatory, and policy developments affect the nature of the program. For example, three new areas where criteria are being developed include biological, sediment, and wildlife criteria.

- **Biological Criteria—**EPA is developing numerical values or narrative expressions that describe the reference biological integrity of aquatic communities inhabiting unimpaired waters of a designated aquatic life use. The biological communities in these waters represent the best attainable condition for the organisms. According to EPA policy, States should develop and implement biological criteria in their water quality standards.
- **Sediment Criteria—**Sediment contamination can result from the deposition of toxicants over long periods of time and is also responsible for water

quality impacts when these toxicants are released back into the water column. EPA has proposed sediment criteria for five organic chemicals (phenanthrene, fluoranthene, dieldrin, acenaphthene, and endrin) (59 *FR* 2652; 1/18/94). EPA also is developing sediment criteria for metals, and has begun development of implementation guidance for sediment criteria.

- **Wildlife Criteria—**EPA is undertaking an initiative to develop numeric wildlife criteria to establish ambient concentrations of certain chemicals to protect mammals and birds from adverse impacts due to consumption of food and/or water containing those chemicals.

6.2 Approaches to Implementing Water Quality Standards

The control of toxic discharges to waters of the United States in an important objective of the CWA. To effectively accomplish this objective, EPA recommends an integrated approach to implementing water quality standards and developing WQBELs. This integrated approach includes three elements: a chemical-specific approach, a whole effluent toxicity (WET) approach, and a biological criteria or bioassessment approach. Each of the three approaches is briefly described below. **Exhibit 6-1** summarizes the capabilities and limitations of each approach.

6.2.1 Chemical-Specific Approach

The chemical-specific approach uses the chemical-specific criteria for protection of aquatic life, human health, and wildlife adopted into a State's water quality standards. The criteria are used as the basis to analyze an effluent, decide which chemicals need controls, and derive permit limits that will control those chemicals to the extent necessary to achieve water quality standards in the receiving water. Chemical-specific WQBELs in NPDES permits involve a site-specific evaluation of the discharge and its effect upon the receiving water. This approach allows for the control of individual chemicals before a water quality impact has occurred or to assist in returning water quality to a level that will meet designated uses.

6.2.2 Whole Effluent Toxicity (WET) Approach

WET, the second approach to water quality-based toxics control, protects the receiving water quality from the aggregate toxic effect of a mixture of pollutants in the effluent. WET tests measure the degree of response of exposed aquatic test organisms to an effluent. The WET approach is useful for complex effluents where it

EXHIBIT 6-1
Components of an Integrated Approach to Water Quality-Based Toxics Control

Control Approach	Capabilities	Limitations
Chemical-Specific	– Human health protection – Complete toxicology – Straightforward treatability – Fate understood – Less expensive testing if only a few toxicants are present – Prevents impacts	– Does not consider all toxics present – Bioavailability not measured – Interactions of mixtures (e.g., additivity) unaccounted for – Complete testing can be expensive – Direct biological impairment not measured
Whole effluent toxicity	– Aggregate toxicity – Unknown toxicants addressed – Bioavailability measured – Accurate toxicology – Prevents impacts	– No direct human health protection – Incomplete toxicology (few species may be tested) – No direct treatment – No persistency or sediment coverage – Conditions in ambient may be different – Incomplete knowledge of causative toxicant
Bioassessments	– Measures actual receiving water effects – Historical trend analysis – Assesses quality above standards – Total effect of all sources, including unknown sources	– Critical flow effects not always assessed – Difficult to interpret impacts – Cause of impact not identified – No differentiation of sources – Impact has already occurred – No direct human health protection

may be infeasible to identify and regulate all toxic pollutants in the discharge or where chemical-specific pollutant limits are set, but synergistic effects are suspected to be problematic. The WET approach allows the permit writer to be protective of the narrative “no toxics in toxic amounts” criterion that is applicable to all waters of the United States and implement numeric criteria for toxicity (see the discussion below on acute and chronic toxicity).

There are two types of WET tests: acute and chronic. An acute toxicity test is usually conducted over a short time period (e.g., 48 hours) and the endpoint measured is mortality. The endpoint for an acute test is often expressed as an LC50 (i.e., the concentration of effluent that is lethal to 50 percent of the exposed test organisms). A chronic toxicity test is usually conducted over a longer period of time (e.g., 7 days) and the endpoint measured is mortality and sublethal effects, such as changes in reproduction and growth. The endpoint is often expressed as the no observed effect concentration (NOEC), the lowest observed effect concentration (LOEC), or the inhibition concentration (IC). The NOEC is the highest concentration of effluent at which no adverse effects are observed on the aquatic test organisms. The LOEC is the lowest concentration of effluent that causes observable adverse effects in exposed test organisms. The IC is an estimate of the effluent concentration that would cause a given percent reduction in a biological measurement of the test organisms.

To express criteria, facilitate modeling, and express permit limits, EPA recommends that toxicity be expressed in terms of “toxic units.” A toxic unit (TU) is merely the inverse of the sample fraction. Toxicity, expressed as percent sample, is divided into 100 to obtain toxic units.

Example:

If a chronic test result is a NOEC of 25 percent effluent, that result can be expressed as 100/25 or 4.0 chronic toxic units (4.0 TUc);

If an acute test result is a LC_{50} of 60 percent, that result can also be expressed as 100/60 or 1.7 acute toxic units (1.7 TUa).

It is important to distinguish acute toxic units (TUa) from chronic toxic units (TUc). The difference between TUa and TUc can be likened to the difference between miles and kilometers. Thus, to compare a TUa and a TUc, a conversion factor called an acute-to-chronic ratio (ACR), must be developed. The ACR is a conversion factor that changes TUa into equivalent TUc. If data are insufficient to calculate an ACR (i.e., less than 10 sets of WET data), EPA recommends a default value of ACR=10. Where sufficient data are available, the ACR should be calculated as the mean of the individual ACRs for each pair of acute and chronic WET test data. The following examples show: (1) how the ACR converts TUa into TUc; (2) how to calculate an ACR from existing data; and (3) how the ACR allows permit writers to compare TUa and TUc.

Acute to Chronic Ratio Formulas:

$$ACR = \frac{\text{Acute Endpoint}}{\text{Chronic Endpoint}} = \frac{LC_{50}}{NOEC}$$

- By definition:

$$TUa = \frac{100}{LC_{50}} \qquad TUc = \frac{100}{NOEC}$$

- Thus:

$$LC_{50} = \frac{100}{TUa} \qquad NOEC = \frac{100}{TUc}$$

- Substituting:

$$ACR = \frac{LC_{50}}{NOEC} = \frac{(100/TUa)}{(100/TUc)} = \frac{TUc}{TUa}$$

Example 1:

Given: LC_{50} = 28%
NOEC = 10%

$$ACR = \frac{LC_{50}}{NOEC} = \frac{28\%}{10\%} = 2.8$$

Example 2:

Given: TUc = 10.0
TUa = 3.6

$$ACR = \frac{TUc}{TUa} = \frac{10.0}{3.6} = 2.8$$

Example:

Toxicity data from POTW Discharge Monitoring Reports (C. dubia):

	LC_{50} (% Effluent)	**NOEC (% Effluent)**	**Acute to Chronic Ratio* (ACR)**
	62	10	6.2
	18	10	1.8
	68	25	2.7
	61	10	6.1
	63	25	2.5
	70	25	2.8
	17	5	3.4
	35	10	3.5
	35	10	3.5
	35	25	1.4
	47	10	4.7
Mean	**46**	**15**	**3.5**

* Calculated value.

Example:

Where:	Wasteload Allocation (WLA)	=	toxicity level in discharge that will meet state water quality criteria (calculated value)
	Acute WLA	=	1.5 TUa
	Chronic WLA	=	4.9 TUc

Because TUc and TUa are in different units, we can use the ACR to convert TUa to TUc assuming an ACR = 10 (default value).

TUa x ACR	=	TUa,c [where "TUa,c" = acute toxicity expressed in chronic toxicity units]
1.5 TUa x 10	=	15 TUa,c

4.9 TUc < 15 TUa,c: therefore the chronic WLA (4.9 TUc) is more stringent than the acute WLA (1.5 TUa); thus 4.9 TUc is used to develop the permit limit.

The ACR allows us to directly compare the chronic WLA of 4.9 TUc with the acute WLA of 1.5 TUa. Using the ACR of 10, we can express 1.5 TUa in chronic toxicity units as 15 TUa,c. We see that 4.9 TUc is less than 15 TUa,c, (the acute WLA expressed in chronic toxicity units). The more stringent value should be used for developing permit limits. Thus, the appropriate requirement that would meet both acute and chronic criteria for toxicity is 4.9 TUc.

6.2.3 Biological Criteria or Biological Assessment Approach

The biological criteria or biological assessment approach is the third approach to water quality-based toxics control. This approach is used to assess the overall biological integrity of an aquatic community. Biological criteria, or “biocriteria,” are numerical values or narrative statements that describe the reference biological integrity of aquatic communities inhabiting waters of a given designated aquatic life use. When incorporated into State water quality standards, biological criteria and aquatic life use designations serve as direct, legal endpoints for determining aquatic life use attainment. Once biocriteria are developed, the biological condition of a water body may be assessed through a biological assessment, or “bioassessment.” A bioassessment is an evaluation of the biological condition of a waterbody using biological surveys and other direct measurements of resident biota in surface waters. A biological survey, or “biosurvey,” consists of collecting, processing, and analyzing representative portions of a resident aquatic community to determine the community structure and function. The results of biosurveys may be compared to the reference water body to determine if the biocriteria for the designated use of the water body are being met. EPA issued guidance on this approach in *Biological Criteria: National Program Guidance for Surface Waters*.[17]

To be fully protective of water quality, EPA developed the concept of "independent application" to characterize the relationship of the three approaches to implementing water quality standards. Independent application says that the results of one approach should not be used to contradict or overrule the results of the others. Independent application recognizes that each approach has unique as well as overlapping attributes, sensitivities, and program applications; thus, no single approach for detecting impact should be considered uniformly superior to any other approach. For example, the inability to detect receiving water impacts using a biosurvey alone is insufficient evidence to waive or relax a permit limit established using either the chemical-specific or WET method.

6.3 Determining the Need for WQBELs

Once the applicable designated uses and water quality criteria for a water body are determined, the permit writer must ensure that dischargers do not cause exceedences of these criteria. If, after technology-based limits are applied, the permit writer projects that a point source discharger may exceed an applicable criterion, a WQBEL must be imposed. EPA regulations at 40 CFR §122.44(d) require that all effluents be characterized by the permitting authority to determine the need for WQBELs in the permit.

6.3.1 Defining "Reasonable Potential" to Exceed Applicable Criteria

In deciding whether or not WQBELs are needed to protect water quality, a permit writer must determine whether the discharge causes, has the reasonable potential to cause, or contributes to an excursion of numeric or narrative water quality criteria. EPA's regulation at 40 CFR §122.44(d)(1) establishes the basis for determining if there is an excursion of the numeric or narrative water quality criteria. At a minimum, the permit writer must make this determination at each permit reissuance and must develop WQBELs as necessary to control the discharge of pollutants.

[17] USEPA (1990). *Biological Criteria: National Program Guidance for Surface Waters*. EPA-440/5-91-004. Office of Science and Technology.

Reasonable Potential and Numeric Criteria

When conducting an effluent characterization to determine if WQBELs are needed based on chemical-specific numeric criteria in the water quality standards, the permit writer projects the receiving water concentration of pollutants contained in the effluent once that effluent enters the receiving water. If the projected concentration exceeds the applicable numeric water quality criterion for a specific pollutant, there is reasonable potential that the discharge may cause or contribute to an excursion above the applicable water quality standards and the permit writer must develop a WQBEL.

If a State has numeric criteria for WET, the permit writer projects the toxicity once the effluent enters the receiving water. The permit writer then compares the toxicity of the receiving water to the applicable State water quality criteria. If the projected toxicity exceeds the applicable numeric water quality criterion for WET, there is reasonable potential that the discharge may cause or contribute to an excursion above the applicable water quality standards and the permit writer must develop a WQBEL for WET.

Reasonable Potential and Narrative Criteria

If the permit writer determines that a discharge causes, has the reasonable potential to cause, or contributes to an in-stream excursion above a **narrative** criterion, the permit must contain effluent limits for WET unless the permit writer demonstrates that chemical-specific limits for the effluent are sufficient to attain and maintain applicable numeric and narrative water quality criteria.

The permit writer must investigate effluents for the presence of specific chemicals for which the State has not adopted numeric criteria, but which may be contributing to an excursion above a narrative criterion. In such cases, permit writers must establish limits using one of three options: (1) use EPA's national criteria, (2) develop their own criteria, or (3) control the pollutant through the use of an indicator.

General Considerations

When determining whether WQBELs are needed in a permit, the permit writer is required to consider, at a minimum: (1) existing controls on point and nonpoint sources of pollution; (2) the variability of the pollutant or pollutant parameter in the effluent; (3) the sensitivity of the species to toxicity testing; and (4) where appropriate, the dilution of the effluent in the receiving water (40 CFR §122.44(d)(ii)). The permit writer also must consider whether technology-based limits are sufficient to maintain State water quality standards. Finally, the permit writer should consider other available data and information pertaining to the discharger (e.g., compliance history, in-stream survey data, dilution, data from similar facilities) in addition to effluent monitoring data to assist in making an informed reasonable potential determination.

6.3.2 Determining Reasonable Potential With Effluent Monitoring Data

When characterizing an effluent for the need for a WQBEL, the permit writer should use any available effluent monitoring data as well as other information pertaining to the discharge (e.g., type of industry, compliance history, stream surveys) as the basis for a decision. The permit writer may already have effluent data available from previous monitoring, or he or she may decide to require the permittee to generate effluent monitoring data prior to permit issuance or as a condition of the issued permit. EPA recommends monitoring data be generated prior to permit limit development for the following reasons: (1) the presence or absence of a pollutant can be more clearly established or refuted; and (2) effluent variability can be more clearly defined. Data collection should begin far enough in advance of permit development to allow sufficient time for conducting toxicity tests and chemical analyses.

The permit writer can use the available effluent data and a water quality model to perform a reasonable potential analysis. The mass balance equation, presented in **Exhibit 6-2**, is a simple water quality model that can be used for this analysis. The permit writer would use the maximum observed effluent concentration, or a statistically projected worst-case value, to calculate a projected in-stream concentration, under critical stream conditions. The permit writer would then compare the projected receiving water concentration to the applicable water quality criteria to determine whether a water quality-based effluent limit is needed.

EXHIBIT 6-2
Basic Mass Balance Water Quality Equation

$$Q_d C_d + Q_s C_s = Q_r C_r$$

Q_d = waste discharge flow in million gallons per day (mgd) or cubic feet per second (cfs)
C_d = pollutant concentration in waste discharge in milligrams per liter (mg/l)
Q_s = background stream flow in mgd or cfs above point of discharge
C_s = background in-stream pollutant concentration in mg/l
Q_r = resultant in-stream flow, after discharge in mgd or cfs
C_r = resultant in-stream pollutant concentration in mg/l in the stream reach (after complete mixing occurs)

All toxic effects testing and exposure assessment parameters, for both effluent toxicity and individual chemicals, have some degree of uncertainty associated with them. The more limited the amount of data, the larger the uncertainty. To better characterize the effects of effluent variability and reduce uncertainty in the process of deciding whether to require an effluent limit EPA has developed a statistical approach to determining reasonable potential. This approach is described in detail in Chapter 3 of the *Technical Support Document for Water Quality-Based Toxics Control*[18] (hereafter referred to as the "TSD"). The statistical approach combines knowledge of effluent variability with the uncertainty due to a limited number of data to project an estimated maximum concentration for the effluent. This projected maximum concentration, after considering dilution, can then be compared to an appropriate water quality criterion to determine the need for an effluent limit.

Example:

Q_s = Available dilution from upstream river flow = 1.2 cfs
Q_d = Discharge flow = 0.31 cfs
C_s = Upstream river concentration = 0.8 mg/l
C_d = Statistically projected maximum discharge concentration = 2.0 mg/l
C_r = Receiving water concentration
Water Quality Criterion = 1.0 mg/l

$$C_r = \frac{Q_d\ C_d + Q_s\ C_s}{Q_r} = \frac{(0.31\,\text{cfs})\ (2.0\,\text{mg/l}) + (1.2\,\text{cfs})\ (0.8\,\text{mg/l})}{(1.2\,\text{cfs}) + (0.31\,\text{cfs})}$$

C_r = 1.05 mg/l

Discussion: Since the downstream concentration (C_r) exceeds the water quality criterion, there is a reasonable potential for water quality standards to be exceeded.

[18]USEPA (1991). *Technical Support Document for Water Quality-Based Toxics Control*. EPA-505/2-90-001. Office of Water Enforcement and Permits.

Example:

$$C_r = \frac{(C_d)\ (Q_d) + (C_s)\ (Q_s)}{Q_r}$$

C_r	=	Receiving water (downstream) concentration (in toxic units)	
C_s	=	Receiving water background concentration	= 0 TU
Q_s	=	Receiving water flow	= 23.6 cfs (for acute protection) 70.9 cfs (the 7Q10 for chronic protection)
Q_d	=	Discharge flow	= 7.06 cfs
C_d	=	Discharge TUa	= 2.49 TUa
		TUc	= 6.25 TUc
Q_r	=	Downstream flow	= $Q_d + Q_s$

Water quality criterion for acute protection = 0.3 TUa

Water quality criterion for chronic protection = 1.0 TUc

$$C_r = \frac{(2.49)\ (7.06) + (0)\ (23.6)}{(7.06 + 23.6)} = 0.57 \text{ TUa for acute toxicity}$$

$$C_r = \frac{(6.25)\ (7.06) + (0)\ (70.9)}{(7.06 + 70.9)} = 0.57 \text{ TUc for chronic toxicity}$$

Discussion: Since the downstream concentration (C_r) exceeds the water quality criterion for acute toxicity (0.3 TUa), there is reasonable potential for water quality standards for toxicity to be exceeded.

6.3.3 Determining Reasonable Potential Without Effluent Monitoring Data

If the permit writer so chooses, or if the circumstances dictate, he or she may decide to develop and impose a WQBEL without facility-specific effluent monitoring data. WQBELs can be set for a single parameter or WET based on the available dilution and the water quality criterion or State standard in the absence of facility-specific effluent monitoring data. In justifying a limit, the more information the permit writer can acquire to support the limit, the better will be the regulatory authority's position in defending the limit, if necessary. Types of information that the permit writer may find useful include: type of industry or POTW, existing data on toxic pollutants, history of compliance problems and toxic impact, and type of receiving water and designated use. The permit writer must provide adequate justification for the limit in the permit development rationale or in the permit fact sheet. The permit writer may well find that he or she would benefit from the collection of effluent monitoring data prior to establishing the limit. The TSD[19] provides guidance on collecting monitoring data for establishing WQBELs.

If the permit writer, after evaluating all available information on the effluent, in the absence of effluent monitoring data, is not able to decide whether the discharge causes, has the reasonable potential to cause, or contributes to an excursion above a numeric or narrative criterion for WET or for individual toxicants, the permit writer should require WET or chemical-specific testing to gather further data. In such cases, the permit writer can require the monitoring prior to permit issuance, if sufficient time exists, or may require the testing as a condition of the issued (or reissued) permit. The permit writer could then include a clause in the permit that would allow the permitting authority to reopen the permit and impose an effluent limit if the effluent testing establishes that there is reasonable potential that the discharge will cause or contribute to an excursion above a water quality criterion.

6.4 Exposure Assessment and Wasteload Allocation

Before calculating a WQBEL, the permit writer must first determine the point source's wasteload allocation (WLA). The WLA is the fraction of a total maximum daily load (TMDL) for the water body that is assigned to the point source. This section discusses the concepts of the TMDL and WLA, describes methods for assessing exposure to pollutants in the receiving water, and explains how WLAs for a point source are calculated.

6.4.1 Total Maximum Daily Loads

A TMDL is a determination of the amount of a pollutant, or property of a pollutant, from point, nonpoint, and natural background sources, including a margin of safety, that may be discharged to a water quality-limited water body. Any loading above this capacity risks violating water quality standards. TMDLs can be expressed in terms of chemical mass per unit of time, by toxicity, or by other appropriate measures. **Exhibit 6-3** provides a graphic illustration of allocations under a TMDL.

[19]USEPA (1991). *Technical Support Document for Water Quality-Based Toxics Control*. EPA-505/2-90-001. Office of Water Enforcement and Permits.

EXHIBIT 6-3
Components of a TMDL

Section 303(d) of the CWA established the TMDL process to provide for more stringent water quality-based controls when technology-based controls are inadequate to achieve State water quality standards. These statutory requirements were codified at 40 CFR §130.7. When implemented accordingly, the TMDL process can broaden the opportunity for public comment, expedite water quality-based NPDES permitting, and lead to technically sound and legally defensible decisions for attaining and maintaining water quality standards. Also, the TMDL process provides a mechanism for integrating point and nonpoint pollutant sources into one evaluation.

Based on the TMDL, point source WLAs and nonpoint source load allocations (LAs) are established so that predicted receiving water concentrations do not exceed water quality criteria. TMDLs, WLAs, and LAs are established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards, with seasonal variations and a margin of safety that account for any lack of knowledge concerning the relationship between point source and nonpoint source loadings and water quality.

In some cases, the waterbody segment under consideration may contain only one point source discharger. In this situation, States typically develop a simple TMDL that considers the point source and background contributions of a pollutant from other sources. For other waterbody segments, a TMDL may not be available at the time the permit must be issued, or a TMDL may not be required at all. In such cases, permitting authorities have historically developed a single WLA for a point source discharging to the waterbody segment. Both simple TMDLs and single WLAs commonly rely on mass balance and simplified water quality models which assume steady-state, or constant conditions for variables such as background pollutant concentrations and stream flow. EPA has encouraged States to develop TMDLs for more difficult water quality problems involving multiple point and nonpoint source pollutant loads. These types of TMDLs require complex water quality models capable of simulating rainfall events and analyzing cumulative chemical fate and transport. Simple, steady-state modeling and more complex, dynamic modeling are discussed in greater detail in Section 6.4.3 below.

EPA is supporting innovative approaches linked to developing and implementing TMDLs, such as watershed-based trading. Trading means that pollution sources can sell or barter their ability to reduce pollution with other sources that are unable to reduce their pollutant loads as economically. TMDLs provide a basis for successful trading because they can be adapted to incorporate trades, and because the data and analyses generated in TMDLs allow water quality managers to better understand and predict the effects of proposed trades. The success of trading will rely on reasonable assurance that a TMDL will be implemented.

Further guidance related to establishing TMDLs can be found in Chapter 4 of EPA's TSD[20] and in the *Guidance for Water Quality-Based Decisions: The TMDL Process*.[21]

6.4.2 Calculating Wasteload Allocations

Before calculating a WQBEL, the permit writer must first know the WLA for the point source involved. As discussed above, the WLA is the fraction of a receiving

[20]USEPA (1991). *Technical Support Document for Water Quality-Based Toxics Control*. EPA-505/2-90-001. Office of Water Enforcement and Permits.

[21]USEPA 1991, *Guidance for Water Quality-Based Decisions: The TMDL Process.* EPA-440/4-91-0001. Office of Water.

water's TMDL that is allocated to one of its existing or future point sources of pollution. The appropriate WLA is determined through an exposure assessment. Water quality models are the primary tools utilized by regulatory agencies in conducting an exposure assessment to determine a WLA. Models establish a quantitative relationship between a waste's load and its impact on water quality. Modeling is usually conducted by a specialized work group within the regulatory agency; however, it is important that the permit writer understand this process. The permit writer will use the end result of the model, a WLA, to derive a WQBEL.

6.4.3 Selecting a Water Quality Model

Determining which model is appropriate for a given discharge and receiving water is based upon whether or not there is rapid and complete mixing of the effluent with the receiving water. If the receiving water does not have rapid and complete mixing, a mixing zone assessment is recommended. If there is rapid and complete mixing near the discharge point, a complete mix assessment involving fate and transport models is recommended.

Mixing Zone Assessment

In incompletely mixed discharge receiving water situations, mixing zone modeling is appropriate. Mixing zones are areas where an effluent undergoes initial dilution and are extended to cover secondary mixing in the ambient water body. A mixing zone is an allocated impact zone in the receiving water where acute and chronic water quality criteria can be exceeded as long as toxic conditions are prevented and the designated use of the water is not impaired as a result of the mixing zone.

The CWA allows mixing zones at the discretion of the State. Individual State policy determines whether or not a mixing zone is allowed. EPA recommends that States make a definitive statement in their water quality standards on whether or not mixing zones are allowed and how they will be defined. EPA provides guidance on when to require a mixing zone and how to determine the boundaries and size of a mixing zone.

In general, there are two stages of mixing: discharge-induced and ambient induced. The first stage is controlled by discharge jet momentum and buoyancy of the effluent. This stage generally covers most of the mixing zone allowed by State water quality standards. Beyond the point of discharge-induced mixing, mixing is controlled by ambient turbulence. Both discharge-induced mixing and ambient-induced mixing models are available for mixing zone analyses. The *Water Quality Standards Handbook*[22] and Chapter 4 of the TSD[23] provide further guidance on mixing zones and how to conduct a mixing zone analysis.

Complete Mix Assessment

If the distance from the outfall to complete mixing is insignificant, then mixing zone modeling is not necessary. For completely mixed discharge receiving water situations, there are two major types of fate and transport water quality models: steady-state and dynamic. Model selection depends on the characteristics of the receiving water, the availability of effluent data, and the level of sophistication desired. The minimum data required for model input include receiving water flow, effluent flow, effluent concentrations, and background pollutant concentrations.

a. Steady-State Modeling

A steady-state model requires single, constant inputs for effluent flow, effluent concentration, background receiving water concentration, receiving water flow, and meteorological conditions (e.g., temperature). If only a few pollutant or effluent toxicity measurements are available or if a daily receiving water flow record is not available, steady-state assessments should be used. Steady-state models calculate WLAs at critical conditions that are usually combinations of worst-case assumptions of receiving water flow, effluent pollutant concentrations, and environmental effects. For example, a steady-state model for ammonia considers the maximum effluent discharge to occur on the day of the lowest river flow, highest upstream concentration, highest pH, and highest temperature. WLAs and permit limits derived from a steady-state model will be

[22]USEPA (1994). *Water Quality Standards Handbook: Second Edition*. EPA 823-B-94-005a. Office of Water.

[23]USEPA (1991). *Technical Support Document for Water Quality-Based Toxics Control*. EPA-505/2-90-001. Office of Water Enforcement and Permits.

protective of water quality standards at the critical conditions and for all environmental conditions less than critical.

Steady-state modeling involves the application of a mass balance equation that allows the analyst to equate the mass of pollutants upstream of a given point (generally at a pollutant discharge, tributary stream or lateral inflow) to the mass of pollutants downstream after complete mixing. The basic formula for the mass balance model was presented as Exhibit 6-2. This model assumes that pollutants are conservative and additive, and considers only dilution as a mitigating factor affecting the pollutant concentration in-stream. The formula can be modified to account for factors such as degradation or sorption of the pollutant (in addition to dilution) where appropriate and feasible. A number of steady-state toxicant fate and transport models that consider factors affecting in-stream pollutant concentrations other than dilution are available and are discussed in Chapter 4 of the TSD[24].

The simple mass balance equation can be rearranged as follows to determine the downstream effect of a particular discharge concentration:

$$Q_d C_d + Q_s C_s = Q_r C_r$$

$$C_r = \frac{Q_d C_d + Q_s C_s}{Q_r}$$

The equation can be further rearranged to determine the WLA necessary to achieve a given in-stream concentration (C_r), such as a water quality criterion:

$$C_d = \frac{C_r Q_r - C_s Q_s}{Q_d}$$

Example:

Assume a stream has a critical design flow of 1.2 cfs and a background zinc concentration of 0.80 mg/l. The State water quality criterion for zinc is 1.0 mg/l or less. The WLA for a discharge of zinc with a flow of 200,000 gpd is [Note: 200,000 gpd = 0.31 cfs]:

C_d = [(1.0)(0.31+1.2)−(0.8)(1.2)]/0.31 = (1.51−0.96)/0.31 = 0.55/0.31 = 1.77 mg/l

[24]USEPA (1991). *Technical Support Document for Water Quality-Based Toxics Control*. EPA-505/2-90-001. Office of Water Enforcement and Permits.

Most States have adopted both acute and chronic numeric criteria for at least some pollutants. As such, steady-state WLA models should be used to calculate the allowable effluent load that will meet criteria at the appropriate design up-stream flow for those criteria. Each State specifies the appropriate design up-stream flow at which its water quality criteria should be applied. EPA recommends a design upstream flow for acute aquatic life criteria at the 1Q10 (1-day low flow over a 10-year period) and for chronic aquatic life criteria at the 7Q10 (7-day low flow over a 10-year period). EPA also recommends that the receiving water harmonic mean flow be used as the design upstream flow for human health protection.

Once a permit writer has a WLA for each applicable criterion, those WLAs must be translated into long term average effluent concentrations and, subsequently, maximum daily and average monthly permit limits. This process is discussed in Section 6.5 - Permit Limit Derivation. Calculating WLAs and the associated long-term average effluent concentrations for each applicable criteria and using the most stringent long-term average effluent concentration to calculate permit limits will ensure that the permit limits are protective of all applicable criteria.

b. Dynamic Modeling

If adequate receiving water flow and effluent concentration data are available to estimate frequency distributions of effluent concentrations, one of the dynamic modeling techniques could be used to develop WLAs. In general, dynamic models account for the daily variations of and relationships between flow, effluent, and environmental conditions, and therefore, directly determine the actual probability that a water quality standard will be exceeded. The three dynamic modeling techniques recommended by EPA include: continuous simulation, Monte Carlo simulation, and lognormal probability modeling.

- **Continuous simulation** is a fate and transport modeling technique that uses time series input data to predict receiving water quality concentrations in the same chronological order as that of the input variables.
- **Monte Carlo simulation** is a modeling technique that involves random selection of sets of input data for use in repetitive model runs in order to predict the probability distributions of receiving water quality concentrations.
- **Lognormal probabilistic dilution** is a modeling technique that calculates the probability distribution of receiving water quality concentrations from the lognormal probability distributions of the input variables.

These methods calculate a probability distribution for receiving water concentrations rather than a single, worst-case concentration based on critical conditions. Thus, they determine the entire effluent concentration frequency distribution required to produce the desired frequency of criteria compliance.

Chapter 4 of the TSD[25] describes steady-state and dynamic models in detail and includes specific model recommendations for toxicity and individual toxic pollutants for each type of receiving water—rivers, lakes, and estuaries. In addition, EPA has issued detailed guidelines on the use of fate and transport models of individual toxicants. Specific references for these models may be found in the *Watershed Tools Directory - A Collection of Watershed Tools*, available through the Assessment and Watershed Protection Division of the Office of Wetlands, Oceans and Watersheds [available through the internet at http://www.epa.gov]. These manuals describe in detail the transport and transformation processes involved in water quality modeling.

6.5 Permit Limit Derivation

WLAs are the outputs of water quality models, and the requirements of a WLA must be translated into a permit limit. The goal of the permit writer is to derive permit limits that are enforceable, adequately account for effluent variability, consider available receiving water dilution, protect against acute and chronic impacts, account for compliance monitoring sampling frequency, and assure attainment of the WLA and water quality standards. To accomplish these objectives, EPA recommends that permitting authorities use the statistical permit limit derivation procedure discussed in Chapter 5 of the TSD[26] with outputs from either steady-state or dynamic water quality models. EPA believes this procedure will result in the most defensible, enforceable, and protective WQBELs for both specific chemicals and WET.

[25]USEPA (1991). *Technical Support Document for Water Quality-Based Toxics Control*. EPA-505/2-90-001. Office of Water Enforcement and Permits.

[26]ibid.

6.5.1 Expression of Permit Limits

The NPDES regulations at 40 CFR §122.45(d) require that all permit limits be expressed, unless impracticable, as both average monthly limits (AMLs) and maximum daily limits (MDLs) for all discharges other than POTWs, and as average weekly limits (AWLs) and AMLs for POTWs. The MDL is the highest allowable discharge measured during a calendar day or 24-hour period representing a calendar day. The AML is the highest allowable value for the average of daily discharges obtained over a calendar month. The AWL is the highest allowable value for the average of daily discharges obtained over a calendar week.

Technical Note

In lieu of an AWL for POTWs, EPA recommends establishing an MDL (or a maximum test result for chronic toxicity) for toxic pollutants and pollutant parameters in water quality permitting. This is appropriate for at least two reasons. First, the basis for the 7-day average for POTWs derives from the secondary treatment requirements. This basis is not related to the need for assuring achievement of water quality standards. Second, a 7-day average, which could comprise up to seven or more daily samples, could average out peak toxic concentrations and therefore the discharge's potential for causing acute toxic effects would be missed. A MDL, which is measured by a grab sample, would be toxicologically protective of potential acute toxicity impacts.

The objective is to establish permit limits that result in the effluent meeting the WLA under normal operating conditions virtually all the time. It is not possible to guarantee, through permit limits, that a WLA will never be exceeded. It is possible, however, using the recommended permit limit derivation procedures to account for extreme values and establish low probabilities of exceedance of the WLA in conformance with the duration and frequency requirements of the water quality standards.

Since effluents are variable, and permit limits are developed based on a low probability of exceedance, permit limits should take effluent variability into consideration and ensure that the requisite loading from the WLA is not exceeded under normal conditions. In effect, the limits must force treatment plant performance levels that, after considering acceptable effluent variability, will only have a low statistical probability of exceeding the WLA and will achieve the desired loadings.

6.5.2 Limits Derived from Steady-State Model Outputs

A permit limit derived from a steady-state model output depends on the type of WLA. WLAs based on protecting aquatic life will have two results: acute and chronic requirements because State water quality standards generally provide both acute and chronic protection for aquatic life. In contrast, WLAs based on protecting human health will have only a chronic requirement. In either case, these WLA outputs need to be translated into maximum daily limits and average monthly limits. The acute and chronic WLA can be achieved for either specific chemicals or WET by using the following methodology to derive permit limits:

- Calculate a treatment performance level (frequency distribution described by a long-term average or LTA and a coefficient of variation or CV) that will allow the effluent to meet the WLA requirements modeled (there will be a calculation for the acute WLA requirement and a calculation for the chronic WLA requirement)
- For WET only, convert the acute WLA into an equivalent chronic WLA by multiplying the acute WLA by an acute-to-chronic ratio (ACR) (e.g., 2.0 TUa $\times$ 10 = 20 TUc where ACR = TUc/TUa = 10)
- Derive permit limits directly from whichever performance level is more protective.

EPA has developed tables (see Tables 5-1 and 5-2 in Chapter 5 of the TSD[27]) that permit writers can use to quickly determine the values necessary to translate a WLA into a permit limit. In addition, some permit authorities have developed their own computer programs to compute WQBELs from the appropriate inputs.

Some State water quality criteria and the corresponding WLAs are reported as a single value from which to define an acceptable level of effluent quality. An example of such a requirement is “copper concentration must not exceed 0.75 milligrams per liter (mg/l) in stream.” Steady state analyses assume that the effluent is constant and that the WLA value will never be exceeded. This assumption presents a problem in deriving permit limits because permit limits need to consider effluent variability. Where there is only one water quality criterion and only one WLA, permit limits can be developed using the following procedure:

- Consider the single WLA to be the chronic WLA

[27] USEPA (1991). *Technical Support Document for Water Quality-Based Toxics Control*. EPA-505/2-90-001. Office of Water Enforcement and Permits.

- Calculate a treatment performance level (an LTA and CV) that will allow the effluent to meet the WLA requirement modeled
- Derive maximum daily and average monthly permit limits based on the calculated LTA and CV.

6.5.3 Limits Derived from Dynamic Model Outputs

The least ambiguous and most exact way that a WLA for specific chemicals or whole effluent toxicity can be specified is through the use of dynamic modeling from which the wasteload allocation is expressed as a required effluent performance in terms of the LTA and CV of the daily values. When a WLA is expressed as such, there is no confusion about assumptions used and the translation to permit limits. A permit writer can readily design permit limits to achieve the WLA objectives. Once the WLA and corresponding LTA and CV are determined, the permit limit derivation procedure found in Chapter 5 of the TSD[28] may be used to develop effluent limits both for specific chemicals and for whole effluent toxicity.

6.5.4 Special Considerations Permits Protecting Human Health

Developing permit limits for pollutants affecting human health is somewhat different from setting limits for other pollutants because the exposure period is generally longer than one month, and can be up to 70 years, and the average exposure rather than the maximum exposure is usually of concern. Because compliance with permit limits is normally determined on a daily or monthly basis, it is necessary to set human health permit limits that meet a given WLA for every month. If the procedures for aquatic life protection were used for developing permit limits for human health pollutants, both the MDL and AML would exceed the WLA necessary to meet the required criteria concentrations. In addition, the statistical derivation procedure is not applicable to exposure periods over 30 days. Therefore, the recommended approach for setting WQBELs for human health protection is to set the average monthly limit equal to the WLA and calculate the maximum daily limit based on effluent variability and the number of samples per month using the statistical procedures described in Chapter 5 of the TSD[29].

[28]USEPA (1991). *Technical Support Document for Water Quality-Based Toxics Control*. EPA-505/2-90-001. Office of Water Enforcement and Permits.

[29]ibid.