Utah Division of Water Quality

Wasteload Analysis Procedures for Utah Pollution Discharge Elimination System Permits

Version 2.0

January 4, 2021

DOCUMENT VERSIONS

Version	Date	Summary of Changes
1.0	May 2012	Original document issued.
2.0	January 2021	• Reorganized document to improve usability. • Added description of capabilities of Utah River Model (Section 6). • Added procedures for modeling eutrophication using QUAL2Kw (Section 7). • Added Glossary. • Added List of Acronyms. • Added References.

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GLOSSARY

ambient condition: water quality of the receiving water immediately upstream of the point of discharge

assimilative capacity: the difference between the numeric criteria and the concentration in the waterbody of interest where the concentration is less than the criterion. Assimilative capacity is the capacity of a water body to dilute and absorb pollutants and prevent harmful effects (e.g., damage to public health or physical, chemical, biological integrity of the water).

beneficial use: use of waterbody, including protection and propagation of aquatic wildlife, recreation, public water supply, and agricultural supply

designated use: beneficial use of waterbody as specified in UAC R317-2-13

existing use: those uses actually attained in a water body on or after November 28, 1975, whether or not they are included in the water quality standards (UAC R317-1-1)

IC_{25}: the effluent concentration of a toxin that results in a 25% reduction in a biological measurement of the test organism, including reproduction, growth, fertilization, or mortality. A point estimate that is interpolated from the actual effluent concentrations at which measured effects occurred during a chronic test.

LC_{50}: the median lethal concentration of a toxin that kills half the members of a tested population after a specified duration

parameter of concern: a pollutant in the discharge that exceeds or is anticipated to exceed the ambient concentration in the receiving water

reasonable potential analysis: analysis to determine whether effluent will cause, have reasonable potential to cause, or contribute to an excursion above any state water quality standard

waters of the State of Utah: all streams, lakes, ponds, marshes, water-courses, waterways, wells, springs, irrigation systems, drainage systems, and all other bodies or accumulations of water, surface and underground, natural or artificial, public or private, which are contained within, flow through, or border upon this state or any portion thereof, except that bodies of water confined to and retained within the limits of private property, and which do not develop into or constitute a nuisance, or a public health hazard, or a menace to fish and wildlife, shall not be considered to be "waters of the state" under this definition (Section 19-5-102)

waters of the United States: waterbodies subject to the provisions of the Clean Water Act. Specific waters included under this definition are based on federal agencies' interpretation of the statute, implementing regulations and relevant case law. Refer to EPA for latest guidance on determination of waters of the US.

wetlands: those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstance do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

whole effluent toxicity: the aggregate toxic effect of an effluent as measured directly by a toxicity test.

Zone of Initial Dilution (ZID): that part of a receiving water where it is permissible to exceed the magnitude of an acute numeric criterion.

ACRONYMS

ADR	antidegradation review
AFO	animal feeding operation
BMP	best management practice
BPT	best practicable technology
BU	Beneficial use
CAFO	concentrated animal feeding operation
CBOD	carbonaceous biochemical oxygen demand
CFR	Code of Federal Regulations
DEQ	Utah Department of Environmental Quality
DMR	discharge monitoring report
DWQ	Utah Division of Water Quality
ELS	early life stages
EPA	United States Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
NOI	Notice of Intent
NPDES	National Pollution Discharge Elimination System
NPV	net present value
OHWM	ordinary high water mark
POC	parameter of concern
POM	particulate organic matter
POTW	publicly owned treatment works such as water reclamation facilities
RP	reasonable potential
SEEI	social, economic and environmental importance
SOP	standard operating procedures
TBEL	technology based effluent limit
TDS	total dissolved solids
TOC	total organic carbon
TWF	toxic weighting factor
UAC	Utah Administrative Code
UPDES	Utah Pollution Discharge Elimination System
USACE	United States Army Corp of Engineers
WET	whole effluent toxicity
WLA	wasteload analysis
WQBEL	water quality based effluent limit

1.0 PURPOSE AND BACKGROUND

The purpose of this guidance is to document the Utah Division of Water Quality's (DWQ) standard practices and procedures for conducting wasteload analyses. A wasteload analysis (WLA) determines water quality based effluent limits (WQBEL) for Utah Pollution Discharge Elimination System (UPDES) discharge permits. A WQBEL is an effluent limitation for a pollutant that has been determined necessary to ensure that water quality standards in the receiving water will not be violated. The WQBEL may be more stringent than a technology based effluent limitation (TBEL), which is a minimum waste treatment requirement based on type of industry and treatment technology (also referred to as a "categorical limit"), and secondary treatment requirements (also referred to as "secondary standards"), which are the minimum effluent quality requirements for all discharges per Utah Administrative Code (UAC) R317-1-3.2.

Water quality standards are established to protect and enhance existing and designated beneficial uses of waterbodies, including recreational, aquatic life, drinking water and agricultural uses. To protect the beneficial uses of waterbodies, narrative standards have been adopted per UAC R317-2-7.2 that apply to all receiving waters. . In addition, numeric criteria have been adopted for many priority pollutants per UAC R317-2-14.

> ***UAC R317-2-7.2 Narrative Standards***
> *It shall be unlawful, and a violation of these regulations, for any person to discharge or place any waste or other substance in such a way as will be or may become offensive such as unnatural deposits, floating debris, oil, scum or other nuisances such as color, odor or taste; or cause conditions which produce undesirable aquatic life or which produce objectionable tastes in edible aquatic organisms; or result in concentrations or combinations of substances which produce undesirable physiological responses in desirable resident fish, or other desirable aquatic life, or undesirable human health effects, as determined by bioassay or other tests performed in accordance with standard procedures.*

WQBELs are intended to ensure that water quality standards are not violated in order to protect the beneficial uses of the receiving water. The discharger may be granted full use of the assimilative capacity in the receiving water when determining WQBELs. Restricting the use of the assimilative capacity in the receiving water is handled through other programs, including antidegradation, TBELs, and secondary treatment requirements.

The United States Environmental Protection Agency (EPA) has identified the following steps to assess the need for WQBELs and to then establish the limits as necessary based on the assessment:

Step 1. Identify applicable water quality standards.
Step 2. Characterize the effluent and receiving water.
Step 3. Determine the need for parameter-specific WQBELs.
Step 4. Calculate parameter-specific WQBELs.

2.0 RECEIVING WATER

2.1 WATERS OF THE STATE

The UPDES program requires a permit for the discharge of pollutants from any point source into waters of the State.

> ***UAC R317-8-1.5(59) "Waters of the State"***
> *means all streams, lakes, ponds, marshes, watercourses, waterways, wells, springs, irrigation systems, drainage systems, and all other bodies or accumulations of water, surface and underground, natural or artificial, public or private, which are contained within, flow through, or border upon this State or any portion thereof, except that bodies of water confined to and retained within the limits of private property, and which do not develop into or constitute a nuisance, or a public health hazard, or a menace to fish or wildlife, shall not be considered to be "waters of the State." The exception for confined bodies of water does not apply to any waters which meet the definition of "waters of the United States" under 40 CFR 122.2. Waters are considered to be confined to and retained within the limits of private property only if there is no discharge or seepage to either surface water or groundwater. Waters of the State includes "wetlands" as defined in the Federal Clean Water Act.*

2.2 BENEFICIAL USES

The beneficial uses of the receiving water and downstream waters must be established in order to determine the WQBELs for a discharge. The use designations are described in UAC R317-2-6, and include drinking water, recreational, aquatic life, and agricultural water uses.

UAC R317-2-13 designates the beneficial uses for waterbodies in Utah. A GIS data layer is available to assist with the determination of the designated beneficial uses of a particular waterbody. A web-based mapping tool is also available (Utah Beneficial Uses and Water Quality Assessment Map).

If a waterbody is not specifically designated, one of the following designations will apply:

- UAC R317-2-13.9 All irrigation canals and ditches statewide, except as otherwise designated: 2B, 3E, 4
- UAC R317-2-13.10 All drainage canals and ditches statewide, except as otherwise designated: 2B, 3E
- UAC R317-2-13.12 All lakes and any reservoirs greater than 10 acres not listed in 13.12 are assigned by default to the classification of the stream with which they are associated.
- UAC R317-2-13.13 All waters not specifically classified are presumptively classified: 2B, 3D

In addition to protecting designated beneficial uses, “existing uses” must be maintained and protected. Existing uses are defined as any beneficial uses actually attained in a water body on or after November

28, 1975 (UAC R317-1), or uses that would be supported by the water quality, whether or not they are included in the water quality standards. For instance, if a stream is currently designated a warm water fishery (beneficial use (BU) Class 3B or 3C), yet it supported the propagation and survival of a non-aberrant, stable trout fishery (BU Class 3A) at some point after November 28, 1975, the "existing use" criteria would be those for BU Class 3A (protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain). In cases where a designated use is not an existing use, a use attainability analysis (UAA) or other scientific assessment could be used to determine whether the designated use is not sustainable due to extenuating watershed characteristics, human impacts or economic factors.

2.3 PROTECTION OF DOWNSTREAM USES

Per UAC R317-2-8: *All actions to control waste discharges under these rules shall be modified as necessary to protect downstream designated uses*.

2.4 WATER QUALITY CRITERIA

In addition to narrative standards that apply to all waters of the State, numeric criteria have been adopted for many priority pollutants per UAC R317-2-14. Table 2.14.1 lists numeric criteria for domestic, recreation, and agricultural uses and Table 2.14.2 lists numeric criteria for aquatic life uses.

Ditches and canals that have the beneficial use 3E (severely habitat limited) do not have numeric criteria for aquatic life use protection and narrative standards are applied for the WLA.

3.0 POLLUTANTS OF CONCERN

This section provides guidance for determining which pollutants to consider in the WLA. WQBELs shall be established for those pollutants in the discharge that are present in quantities or concentrations which have the potential to cause or contribute, directly or indirectly, to a violation of any water quality standard.

An initial list of pollutants of concern is developed based on the permit application, previous permit limits, review of monitoring data and knowledge of the discharger and pretreatment program. The determination of which pollutants may cause or contribute to a water quality violation is made through a reasonable potential analysis (RP). The RP procedures are outlined in the guidance document *Reasonable Potential Analysis Guidance* (DWQ 2015).

The Wasteload Analyst verifies that all pollutants in the discharge that have the potential to contribute to a water quality violation are considered.

3.1 IMPAIRED WATERS AND TOTAL MAXIMUM DAILY LOADS (TMDL)

Whether the immediate receiving water and/or downstream receiving waters are listed on the 303(d) list as impaired for any constituents and/or covered under an approved or in-process TMDL will be verified.

The 303(d) list in the latest approved Integrated Report will be referenced in order to determine which receiving water segments are listed and for which constituents, if any. For impaired waters, it will be verified whether or not a TMDL has been approved to address the impairment. For approved TMDLs, the wasteload allocation for the pollutant(s) specified in the TMDL will be the basis for the effluent limits.

For new discharges or sources to impaired waters, per UAC R317-2.2 *PROHIBITIONS No permit may be issued by the Director:*

(7) To a new source or a new discharger, if the discharge from its construction or operation will cause or contribute to the violation of water quality standards. The owner or operator of a new source or new discharger proposing to discharge into a water segment which does not meet Utah water quality standards or is not expected to meet those standards even after the application of the effluent limitations required by the UPDES rules and for which the Director has performed a wasteload allocation for the pollutants to be discharged, must demonstrate, before the close of the public comment period, that:

(a) There are sufficient remaining wasteload allocations to allow for the discharge; and

(b) The existing dischargers into the segment are subject to schedules of compliance designed to bring the segment into compliance with Utah Water Quality Standards. (See R317-2.)

For new permits to impaired waters without an approved TMDL, this provision has been interpreted to mean that the permit limit must be set at or below the water quality criterion for the impaired parameter since there is no assimilative capacity to be allocated.

For renewals of permits issued prior to the impairment listing, the concentration limit in the permit applies until a TMDL is completed and approved.

4.0 MIXING ZONES

The following procedures will be used by staff of DWQ as guidance in implementation of the mixing zone policy, and specifically in developing effluent limits for UPDES discharge permits for point source discharges into waters of the State. A regulatory mixing zone is a limited portion of a body of water, contiguous to a discharge, where dilution is in progress but has not yet resulted in concentrations that meet water quality standards for all pollutants.

4.1 ALLOWANCE FOR MIXING ZONE

A limited mixing zone may be allowed as defined by rule.

> ***UAC R317-2-5 Mixing Zones***
> *A mixing zone is a limited portion of a body of water, contiguous to a discharge, where dilution is in progress but has not yet resulted in concentrations which will meet certain standards for all pollutants. At no time, however, shall concentrations within the mixing zone be allowed which are acutely lethal as determined by bioassay or other approved procedure. Mixing zones may be delineated for the purpose of guiding sample collection procedures and to determine permitted effluent limits. The size of the chronic mixing zone in rivers and streams shall not exceed 2500 feet and the size of an acute mixing zone shall not exceed 50% of stream width nor have a residency time of greater than 15 minutes. Streams with a flow equal to or less than twice the flow of a point source discharge may be considered to be totally mixed. The size of the chronic mixing zone in lakes and reservoirs shall not exceed 200 feet and the size of an acute mixing zone shall not exceed 35 feet. Domestic wastewater effluents discharged to mixing zones shall meet effluent requirements specified in R317-1-3.*
>
> *5.1 Individual Mixing Zones. Individual mixing zones may be further limited or disallowed in consideration of the following factors in the area affected by the discharge:*
>
> a) *Bioaccumulation in fish tissues or wildlife,*
> b) *Biologically important areas such as fish spawning/nursery areas or segments with occurrences of federally listed threatened or endangered species,*
> c) *Potential human exposure to pollutants resulting from drinking water or recreational activities,*
> d) *Attraction of aquatic life to the effluent plume, where toxicity to the aquatic life is occurring.*
> e) *Toxicity of the substance discharged,*
> f) *Zone of passage for migrating fish or other species (including access to tributaries), or*
> g) *Accumulative effects of multiple discharges and mixing zones.*

All mixing zone-dilution assumptions are subject to review and revision as new information on the nature and impacts of the discharge becomes available (e.g., chemical or biological monitoring at the mixing zone boundary). Where justified, such as where there is a downstream drinking water intake, DWQ may require the discharger to conduct in-stream monitoring to verify that mixing zone size restrictions are being achieved. Mixing zone and dilution decisions are subject to review and revision along with all other aspects of the discharge permit upon expiration of the permit.

UAC R317-2-5 does not specify mixing zones for discharges to wetlands. EPA Region 8 policy prohibits mixing zones for discharges to wetlands (EPA 1995). Unless specific hydrologic information is available to substantiate the amount of standing water present during critical conditions, wetlands are generally considered to be completely dry during critical conditions and no mixing zone is granted. Discharges to impounded wetlands with outlet control structures may be granted a mixing zone per the limitations for discharges to lakes and reservoirs.

4.2 COMPLETELY MIXED DISCHARGES

Completely mixed discharges will receive a dilution allowance up to the critical low flow where such dilution will protect designated uses. When the receiving water flow during critical condition is equal to or less than twice the discharge rate, the discharge is considered to be instantaneously and completely mixed. When the receiving water flow during critical condition is greater than twice the discharge rate, a mixing zone may be granted up to the maximum allowable mixing zone. A discharge with diffusers or other mechanical mixing device will be evaluated for instantaneous and complete mixing.

4.3 INCOMPLETELY MIXED DISCHARGES

Where a discharge is not instantaneously and completely mixed, an appropriate mixing zone may be designated for purposes of implementing chronic and acute aquatic life and human health criteria. As described in the policy, for streams, the size of the chronic mixing zone shall not exceed 2,500 feet and the size of an acute mixing zone shall not exceed 50% of stream width nor have a residency time of greater than 15 minutes. For lakes, the size of the chronic mixing zone would normally not exceed 200 feet in radius and the size of the acute mixing zone would normally not exceed 35 feet in radius. Individual mixing zones may be further expanded, limited or disallowed in consideration of the following factors in the area affected by the discharge:

a) bioaccumulation in fish tissues or wildlife,
b) biologically important areas such as fish spawning/nursery areas or segments with occurrences of federally listed threatened or endangered species,
c) potential human exposure to pollutants resulting from drinking water or recreational activities,
d) attraction of aquatic life to the effluent plume, where toxicity to the aquatic life is occurring.
e) toxicity of the substance discharged,
f) zone of passage for migrating fish or other species (including access to tributaries), or
g) cumulative effects of multiple discharges and mixing zones.

For application of the acute water quality criteria for individual substances, a plume model will be used to calculate the length of the plume to reach 50% of the stream width at the critical low flow. A second calculation will be performed to determine the length of the plume corresponding to a 15-minute travel time calculated using the average velocity at the critical low flow. The second calculation is performed to ensure that organisms drifting through the plume will not be in the zone of initial dilution for longer than 15 minutes, which should minimize the potential for drifting organisms to be exposed to a 1-hour average concentration that exceeds the acute criterion. The more stringent of these two methods will be used to establish the acceptable size of the zone of initial dilution. The portion of the low stream flow that mixes with the effluent within the zone of initial dilution will be utilized in mass balance calculations to determine permit limits applying the various acute criteria. The result will be at least a 50% zone of passage at all times for migrating fish.

4.4 DELINEATING THE MIXING ZONE

Two primary methods are employed to delineate the mixing zone for incompletely mixed discharges: field study and plume model. The appropriate method for delineating the mixing zone will be selected based on the significance of the discharge, the sensitivity of the receiving water, and resource constraints and priorities.

The beginning of the mixing zone is typically at the point of compliance where the discharge meets Waters of the State (Refer to Section 2.1).

4.4.1 FIELD STUDY

A field study that quantifies the actual rate and pattern of mixing at or near low flow conditions may be used to delineate the mixing zone. The field study typically involves introduction of a conservative tracer into the effluent, and subsequent observation and/or measurement of the tracer plume as it progresses downstream in the receiving water. A typical compound used in tracer studies is rhodamine, which is a fluorescent, non-toxic, uv-stable, water-soluble, biodegradable dye that can be accurately measured in extremely small concentrations, down to 0.1 parts per billion (ppb). If there is sufficient difference between the effluent and the receiving water, other naturally occurring constituents, such as temperature, specific conductivity, and chloride concentration, can be used to delineate the mixing zone.

4.4.2 MODELING STUDY

A modeling study that simulates the rate and pattern of mixing at low flow conditions is another appropriate method for delineating the mixing zone. The Wasteload Analyst will select the appropriate model based on the significance and complexity of the discharge and the receiving water, and resource constraints and priorities. The following models have been applied to estimate plume dimensions and dilution in Utah.

- Utah Stream Mix Spreadsheet (Version 1.0): Mixing model for rivers and streams developed by EPA Region 8. This model does not consider boundary effects of the streambank, and therefore may not be considered conservative.

- Utah Jet Spreadsheet: Mixing model for lakes and reservoirs developed by EPA Region 8. Estimates plume dimensions and mixing for pipe and open channel discharges to lakes. Simplified assumptions that do not account for the boundary effects of the lake bottom, shoreline and water surface, currents, and density stratification.
- RIVPLUME5: Mixing model for rivers and streams developed by Washington Department of Ecology. This model does consider boundary effects of the streambank.
- CORMIX: EPA supported mixing zone model and decision support system for environmental impact assessment of regulatory mixing zones resulting from continuous point source discharges (Jirka et al. 1997). Applicable to more complex discharges, including multiple pipes and diffusers, boundary interactions, and buoyant plumes. Appropriate for discharges to rivers and streams, and lakes and reservoirs including the Great Salt Lake. The CORMIX methodology contains systems to model single-port, multiport diffuser discharges and surface discharge sources. Effluents considered may be conservative, non-conservative, heated, brine discharges or contain suspended sediments.
- Visual Plumes: EPA supported suite of mixing zone models for simulating surface water jets and plumes. Visual Plumes includes the DKHW model based on UDKHDEN, the surface discharge model PDS, the three-dimensional UM3 modelbased on UM, and the NRFIELD model based on RSB.

5.0 WASTELOAD ALLOCATION

This section describes procedures for deriving water quality based effluent limits (WQBEL) for UPDES permits. These guidelines are intended to be generally applicable and consistently applied; however, they are subject to modification to ensure protection of water quality standards based on the unique circumstances of a specific discharge.

5.1 CHARACTERIZING THE RECEIVING WATERS

The concept behind characterizing critical conditions in the receiving water is that if an effluent is controlled such that it does not cause water quality criteria to be exceeded in the receiving water at the critical flow condition, then the effluent controls will be protective and that water quality criteria will be attained at all flows. The critical condition in the receiving water typically occurs during low flows or volume; however, the critical condition may occur during high flows or volume if wet weather sources predominate.

5.1.1 FLOW FOR RIVERS AND STREAMS

The WQBELs are determined for the critical condition in the receiving water, which for most constituents occurs during low flow conditions in late summer. The low flow statistic used for the WLA is the 7Q10 flow, defined as the 7-day average low flow with a recurrence interval of 10 years. Typically, a summer seasonal 7Q10 will be calculated. However, at the request of the discharger and based on flexibility in the operation of their treatment works, seasonal WQBELs may be determined. Typical seasons are shown below, but may be modified as appropriate:

Winter: January 1 – March 31
Spring: April 1 – June 30
Summer: July 1 – September 30
Fall: October 1 – December 31

For facilities that discharge intermittently and not during low-flow conditions (e.g., lagoons), the stream flow to be used in the mixing zone analysis will be the lowest flow expected to occur during the period of discharge.

The Wasteload Analyst will determine the flow records to use to calculate the 7Q10 statistic. Typically, more flow records improve the accuracy of the 7Q10 estimate. However, other considerations may warrant limiting the time period of the flow records analyzed such as significant changes to diversion works or other hydrologic modifications to the system.

The estimation of critical low flow conditions depends on the quantity of flow records available.

1. Long term continuous daily flow records available (> 3 years)
   The 7Q10 flow statistic can be calculated directly from the flow records per methods described by USGS and EPA (Kiang et al. 2018 and USEPA 2018). The SWToolbox computer software can be

used to calculate the 7Q10 flow statistic on an annual or seasonal basis. The routine is available in either a stand-alone program DFLOW (Version 3.1 or later) or within the BASINS platform (Version 4.0 or later). DFLOW can directly import USGS gage daily flow records. Flow gages from other sources will need to be reformatted in order to import into DFLOW.

2. Limited continuous daily flow records available (< 3 years)
The data set is insufficient to calculate the 7Q10 flow statistic. In this case, the lowest 7-day average flow in the period of record can be used to estimate the critical low flow.

3. Instantaneous flow measurements (> 20 measurements)
The data set is insufficient to calculate the 7Q10 flow statistic. In this case, the 20th percentile of the discrete flow measurements will be used to estimate the critical low flow.

4. Limited instantaneous flow measurements (< 20 measurements)
The data set is insufficient to calculate the 7Q10 flow statistic or 20th percentile of flows. The Wasteload Analyst will use professional judgement in estimating the critical low flow. The estimate may rely on instantaneous measurements made during low flow periods or statistical estimates of ungauged tributaries using USGS's Stream Stats program for Utah.

5.1.2 WATER SURFACE ELEVATION FOR LAKES, RESERVOIRS, AND WETLANDS

The WQBELs are determined for the critical condition in the receiving water. No statistic is specified for lakes and reservoirs; therefore, the Wasteload Analyst will use professional judgement to estimate critical conditions. For the purposes of delineating the mixing zone and determining dilution, the lake and reservoir water surface will be assumed to be at the ordinary high water mark (OHWM).

Unless specific hydrologic information is available to determine the water surface elevation during critical conditions, wetlands are generally considered to be completely dry and have no standing water during critical conditions. The water surface for impounded wetlands with outlet control structures will be assumed to be at the OHWM.

5.1.3 WATER QUALITY

Ambient water quality conditions in the receiving water will be determined for the WLA. Water quality data will be obtained from the sampling station immediately upstream of the discharge. The most recent 5 years of sampling records is typically used to estimate ambient water quality conditions. If insufficient data exists within the prior 5 years, then longer historical data is referenced. Half of the detection limit is typically assumed for non-detect samples. For constituents lacking sampling data, ambient concentrations will be assumed based on best professional judgement.

Which statistic to calculate for ambient condition depends on the nature of the constituent:

- Bioaccumulative Toxics: Calculate the 80th percentile of water quality samples.

- Conventional Pollutants and Non-Bioaccumulative Toxics: Calculate the arithmetic mean of water quality samples.
- Dissolved Oxygen (DO): Calculate the mean DO and estimate the diel range based on sonde data, if available.

If sufficient data are available (n > 20), water quality summary statistics may be calculated on a seasonal basis; otherwise, water quality parameters will be summarized on an annual basis.

5.2 CHARACTERIZING THE EFFLUENT

5.2.1 DISCHARGE RATE

The discharge rate used to determine WQBELs is dependent on the type of facility, per rule.

UAC R317-8-4.3(2) Production-Based Limitations

(a) In the case of POTWs, permit effluent limitations, standards, or prohibitions will be calculated based on design flow.

(b) Except in the case of POTWs, calculation of any permit limitations, standards, or prohibitions which are based on production, or other measure of operation, will be based not upon the designed production capacity but rather upon a reasonable measure of actual production of the facility. For new sources or new dischargers, actual production shall be estimated using projected production. The time period of the measure of production will correspond to the time period of the calculated permit limitations; for example, monthly production will be used to calculate average monthly discharge limitations. The Director may include a condition establishing alternate permit standards or prohibitions based upon anticipated increased (not to exceed maximum production capability) or decreased production levels.

(c) For the automotive manufacturing industry only, the Director may establish a condition under R317-8-4.3(2)(b)2 if the applicant satisfactorily demonstrates to the Director at the time the application is submitted that its actual production, as indicated in R317-8-4.3(2)(b)1, is substantially below maximum production capability and that there is a reasonable potential for an increase above actual production during the duration of the permit.

(d) If the Director establishes permit conditions under and R317-8-4.3(2)(c):

1. *The permit shall require the permittee to notify the Director at least two business days prior to a month in which the permittee expects to operate at a level higher than the lowest production level identified in the permit. The notice shall specify the anticipated level and the period during which the permittee expects to operate at the alternate level.*

If the notice covers more than one month, the notice shall specify the reasons for the anticipated production level increase. New notice of discharge at alternate levels is required to cover a period or production level not covered by prior notice or, if during two consecutive months otherwise covered by a notice, the production level at the permitted facility does not in fact meet the higher level designated in the notice.

2. *The permittee shall comply with the limitations, standards, or prohibitions that correspond to the lowest level of production specified in the permit, unless the permittee has notified the Director under R317-8-4.3(2)(d)1, in which case the permittee shall comply with the lower of the actual level of production during each month or the level specified in the notice.*

3. *The permittee shall submit with the DMR the level of production that actually occurred during each month and the limitations, standards, or prohibitions applicable to that level of production.*

The discharge rate used for the WLA is to be provided by the permittee to DWQ in the permit application. Generally, the maximum 30-day average flow will be used to meet chronic criteria and the maximum daily flow to meet acute criteria.

5.2.2 WATER QUALITY

In order to determine water quality standards for dissolved metals and ammonia, the following constituents will need to be characterized in the discharge effluent: total hardness, temperature and pH. These constituents will be calculated from DWQ monitoring data and/or Discharge Monitoring Report (DMR), or estimated based on treatment design performance. For new or upgraded facilities, effluent concentrations are estimated based on data provided by the applicant or projections provided by the Design Engineer.

Generally, average hardness will be used to determine dissolved metals criteria. Average temperature and pH will be used to determine chronic ammonia criteria, and either 80th percentile or maximum pH will be used to determine acute criteria, depending on the amount of data available.

5.3 MODEL SELECTION

Model selection for far field fate and transport of pollutants beyond the mixing zone will depend on the constituents of concern, the significance of the discharge, and the complexity of the receiving water. Refer to Figure 6-1 for guidance on model selection for typical wasteload applications.

5.3.1 RIVERS AND STREAMS

- Mass Balance Mix Spreadsheet
  For conservative constituents, calculates mixed concentration and effluent limits based on mass balance equation.

- Mass Balance Mix with Decay Spreadsheet
  For non-conservative constituents, calculates mixed concentration and effluent limits based on mass balance equation with first order decay.

- Utah River Model
  Used to evaluate ammonia and dissolved oxygen compliance for minor discharges. Jointly developed by Utah DWQ and EPA Region 8. Contains AMMTOX routine developed by University of Colorado to evaluate pH rebound and calculate ammonia limits (Lewis et al. 2002). Contains modified Streeter-Phelps routine that evaluates DO sag and calculates BOD and DO limits. Refer to Section 6.0 for guidance on how the model is applied.

- QUAL2Kw
  Applicable to discharges that have the potential to substantially alter nutrient dynamics, algal growth and dissolved oxygen concentration in the receiving water, such as major POTWs. Refer to Section 7.0 for guidance on how the model is applied.

5.3.2 LAKES AND RESERVOIRS

Typically, modeling of pollutants beyond the mixing zone boundary is not required for a WLA. However, in some instances, it may be necessary to evaluate the fate and transport of pollutants throughout the entire lake or reservoir. Two examples of widely applied models for TMDLs and water quality in lakes and reservoirs are described below. The Wasteload Analyst will use professional judgement in selecting the appropriate program.

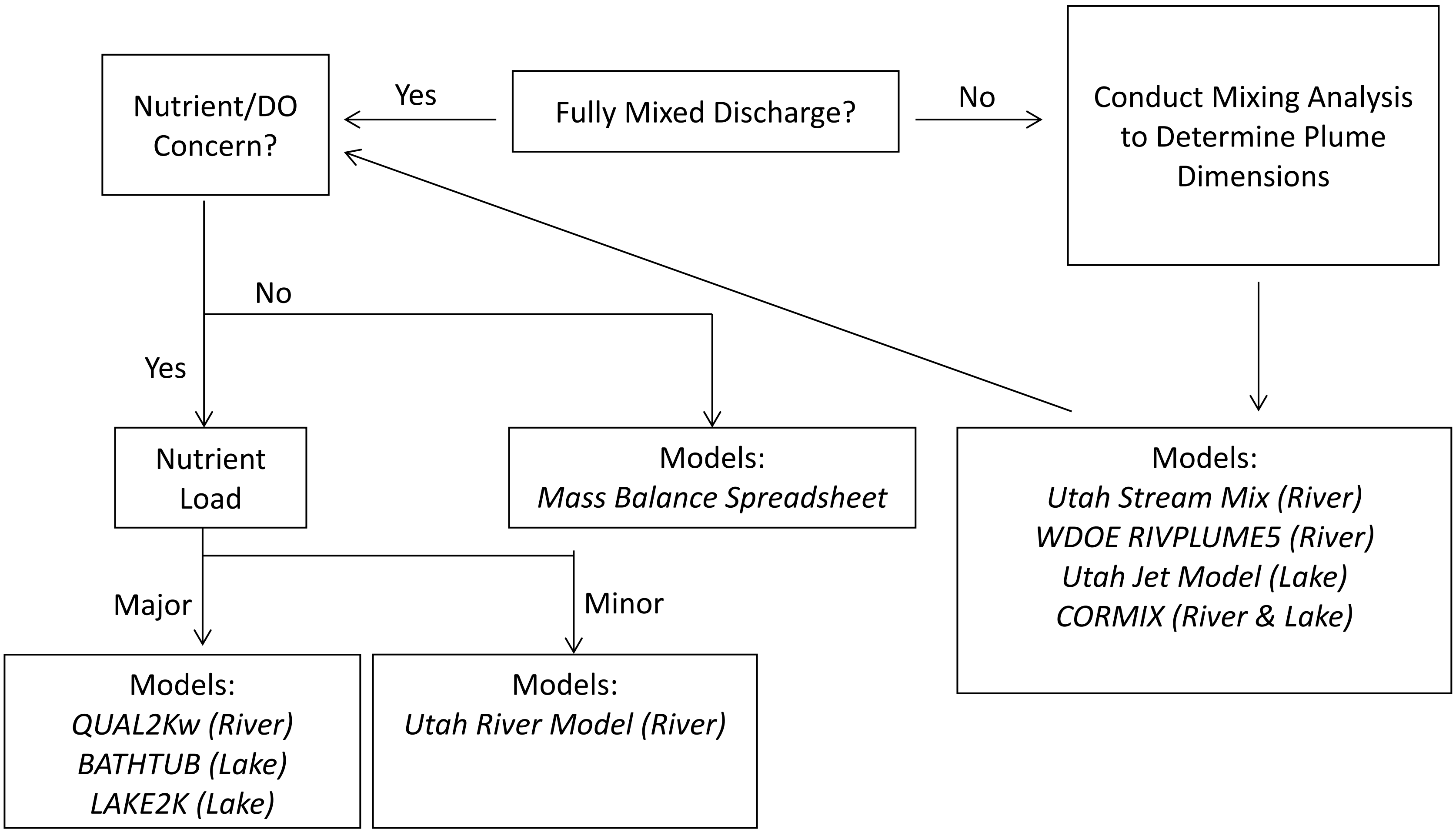
- BATHTUB
  Applicable to fully mixed lakes and reservoirs. Applies a series of empirical eutrophication models to morphologically complex lakes and reservoirs. The program performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network which accounts for advective and diffusive transport, and nutrient sedimentation. Eutrophication-related water quality conditions (total phosphorus, total nitrogen, chlorophyll-a, transparency, and hypolimnetic oxygen depletion) are predicted using empirical relationships derived from assessments of reservoir data.

- LAKE2K
  Applicable to vertically stratified lakes and reservoirs. One-dimensional vertical model that is designed to compute seasonal trends of water quality in stratified lakes.

- CE-QUAL-W2
  Applicable to vertically stratified lakes and reservoirs. A water quality and hydrodynamic model in 2-D (longitudinal-vertical) for rivers, estuaries, lakes, reservoirs and river basin systems. W2 models basic eutrophication processes such as temperature-nutrient-algae-dissolved oxygen-organic matter and sediment relationships.

- EFDC
  Applicable to incompletely mixed lakes and reservoirs in both the horizontal and vertical direction. A 3-D model that includes hydrodynamic, sediment-contaminant, and eutrophication components.

Figure 6-1: Model selection for wasteload analyses



5.4 DETERMINING EFFLUENT LIMITS

Water quality based effluent limits (WQBELs) are determined by calculating the flow and concentration of the pollutant in the discharge that will be protective of the water quality criteria in the receiving water.

5.4.1 INDIVIDUAL ALLOCATION

Typically, the wasteload allocation will be done on an individual point source basis, where the discharger is granted full assimilative capacity based on ambient conditions immediately upstream in the receiving waters.

5.4.2 WATERSHED ALLOCATION

In some instances where multiple point discharges to a receiving water occur, such as the Jordan River, a watershed approach to allocation will be taken. For a watershed allocation, the entire receiving water is modeled and the effect of upstream discharges on the conditions at each source will be considered. Depending on the fate and transport of the constituent, rather than granting full assimilative capacity at each discharge, the allocation may be proportional on a flow-weighted basis, i.e. each discharger receives the same concentration limit.

5.4.3 DISCHARGES TO GREAT SALT LAKE

Due to the lack of numeric criteria for aquatic life uses for the Great Salt Lake, special wasteload allocation procedures have been developed for direct discharges to the Great Salt Lake and discharges to canals or ditches that are tributary to the Great Salt Lake. These procedures are described in a separate document: *Interim Methods for Evaluating Use Support for Great Salt Lake, Utah Pollution Discharge Elimination System Permits Version 1.0* (DWQ, 2016).

5.4.4 DISCHARGES UNDER GENERAL PERMITS

Certain discharges to surface waters are authorized under one of the General Permits issued under DWQ's UPDES program. A WLA may be conducted to ensure protection of receiving waters under the General Permit. Since it is often unclear to which receiving waters, where within the watershed, and at what flow rate qualifying discharges will occur under the General Permit, the following assumptions are typically made for the WLA:

- The discharge is assumed to be to a 1C, 2B, 3A, 4 designated use receiving water, unless specifically restricted by the General Permit.
- The discharge rate is assumed to be the maximum rate allowed under the General Permit.
- The critical 7Q10 background flow in the receiving water is assumed to be zero or minimal.

WLAs are typically not conducted for General Permits related to stormwater discharges, as protection of the receiving waters is addressed through implementation of BMPs rather than effluent limitations for stormwater.

5.4.5 WHOLE EFFLUENT TOXICITY

Whole Effluent Toxicity (WET) refers to the aggregate toxic effect to aquatic organisms from all pollutants contained in a facility's effluent. It is one method to implement the Clean Water Act's prohibition of the discharge of toxic pollutants in toxic amounts. WET tests measure wastewater's effects on specific test organisms' ability to survive, grow and reproduce. WET test methods consist of exposing living aquatic organisms (plants, vertebrates and invertebrates) to various concentrations of a sample of wastewater, usually from a facility's effluent stream. WET tests are used by the UPDES to determine whether a facility's permit will need WET requirements.

The percent of effluent in the receiving water in a fully mixed condition, and acute and chronic dilution in an incompletely mixed condition are calculated in the WLA in order to generate WET limits. The LC_{50} (lethal concentration, 50%) percent effluent for acute toxicity and the IC_{25} (inhibition concentration, 25%) percent effluent for chronic toxicity, as determined by the WET test, needs to be below the WET limits, as determined by the WLA. The WET limit for LC_{50} is typically 100% effluent and does not need to be determined by the WLA. The UPDES Permit Writer will also use the IC_{25} percent effluent in the receiving water to inform the selection of dilution ratios in the required WET testing (i.e. typical dilutions would be 100, 50, 25, 12.5 and 6.25 percent effluent concentrations in the WET test); the selected dilution ratios should bracket the WET limits to maximize effectiveness of the WET test.

5.4.6 CONSERVATIVE CONSTITUENT

Conservative constituents do not degrade or decay in the natural environment. The following mass balance equation is used to determine WQBELs for conservative constituents:

$$C_bQ_b + C_oQ_o = C_s(Q_b + Q_o)$$

where:

C_b = background conservative constituent concentration, µg/l
Q_b = background flow within the mixing zone, cfs
Q_o = effluent flow, cfs
C_s = water quality criteria (acute or chronic, µg/l)
C_o = WQBEL conservative constituent concentration, µg/l

5.4.6.1 TOTAL DISSOLVED SOLIDS

For the purposes of the wasteload allocation, total dissolved solids (TDS) will be considered a conservative constituent, i.e. decay does not occur. With the exception of several site-specific standards noted in Footnote 4 of UAC R3117 Table 2.14.1, the TDS criterion is 1,200 mg/L for all Class 4 waters—waters protected for agricultural beneficial uses (UAC R317-2-14).

5.4.7 TOTAL SUSPENDED SOLIDS

Numeric criteria have been adopted for the maximum increase in turbidity in the receiving water due to the discharge (10 NTU maximum increase for 2A, 2B, 3A, and 3B waters and 15 NTU maximum increase for 3C and 3D waters). Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is an expression of the amount of light that is scattered by material in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid include clay, silt, finely divided inorganic and organic matter, algae, soluble colored organic compounds, and plankton and other microscopic organisms.

The secondary treatment requirements for total suspended solids (TSS) per UAC R317-1-3.2 are generally considered protective of the turbidity of the receiving water, and WQBELs for TSS are not determined.

5.4.8 TEMPERATURE

Two water quality criteria are applicable to thermal discharges to receiving waters with aquatic life beneficial uses 3A, 3B, and 3C (3D and 3E do not have numeric criteria for temperature): 1) maximum temperature, and 2) maximum temperature change (Table 6-1).

Table 5-1. Temperature criteria for aquatic life use protection (per UAC R317-2 Table 2.14.2)

Criteria	3A	3B	3C
Maximum Temperature (deg C)	20	27	27
Maximum Temperature Change (deg C)	2	4	4
The temperature standard shall be at background where it can be shown that natural or un-alterable conditions prevent its attainment. In such cases rulemaking will be undertaken to modify the standard accordingly.			

For the purposes of the wasteload, temperature is generally treated as a conservative constituent within the mixing zone unless specific circumstances warrant applying a heat balance of gains and losses.

The following mass balance equation is used to determine WQBELs for temperature:

$$T_b Q_b + T_o Q_o = T_s(Q_b + Q_o)$$

where:

T_b = Background temperature, deg C – seasonal or annual average
Q_b = Background flow in the mixing zone, cfs
Q_o = Effluent flow, cfs
T_s = Temperature criteria (deg C) – either max. temperature or T_b + max. temperature change, whichever is more restrictive
T_o = WQBEL temperature, deg C

In the case where the influent water is diverted from the receiving stream, the following mass balance equation is used to determine WQBELs for temperature:

$$T_b(Q_b - Q_o) + T_oQ_o = T_sQ_b$$

where:

T_b = Background temperature, deg C – seasonal or annual average
Q_b = Background flow above point of diversion, cfs
Q_o = Effluent flow, cfs
T_s = Temperature criteria (deg C) – either max. temperature or T_b + max. temperature change, whichever is more restrictive
T_o = WQBEL temperature, deg C

5.4.9 PH

The secondary treatment requirements for pH per UAC R317-1-3.2 (maintain pH within the range 6.5 to 9.0) are within the water quality criteria for waters with beneficial use(s) 1C, 2A, 2B, 3A, 3B, 3C, 3D, and 4 and are therefore considered generally protective. Discharges of nutrients that result in algal growth and elevated pH in the receiving water may make it necessary to determine WQBELs for pH.

5.4.10 DISSOLVED OXYGEN AND NUTRIENT DISCHARGES

Several water quality constituents commonly found in discharge effluent can potentially contribute to low dissolved oxygen conditions, including: organic content, typically estimated by carbonaceous biochemical oxygen demand (CBOD) or total organic carbon (TOC); nitrogen; phosphorus; dissolved oxygen; total suspended solids (TSS), and temperature. Both algae and microbial growth rates may increase with increasing nutrient concentrations, which in turn affects the DO dynamics within aquatic ecosystems. However, several chemical, physical and biological processes mediate these effects, such as light availability and temperature. Therefore, if DO concentrations in the receiving water are a concern (i.e., nutrient concentrations are high in the effluent, background DO conditions are near standards), then a model that considers the effects of nutrients and algal growth and decomposition will be employed. Refer to Sections 6.0 and 7.0 for a more detailed description of how the Utah River Model and QUAL2Kw are utilized to determine WQBELs for nutrient discharges to streams.

Per UAC R317-2-14, the dissolved oxygen water quality criteria for 3A and 3B waters depend on the presence or absence of fish early life stages (ELS) [Table 6-2]. Refer to Section 6.4.7 regarding determination of the timing of ELS presence and absence.

Pollution indicators have been adopted for BOD (5 mg/L for 3A, 3B, 3C, and 3D waters), nitrate (4 mg/L for 3A, 3B, and 3C waters), and total phosphorus (0.05 mg/L for 3A and 3B streams and 0.025 mg/L for 3A and 3B lakes). Generally, pollution indicators are not used to determine WQBELs.

Table 6-2. Dissolved oxygen criteria for aquatic life use protection (UAC R317-2 Table 2.14.2)

Minimum DO (mg/L)	3A		3B		3C	3D
	ELS Present	ELS Absent	ELS Present	ELS Absent		
Instantaneous	8.0	4.0	5.0	3.0	3.0	3.0
7-day Average	9.5	5.0	6.0	4.0	N/A	N/A
30-day Average	6.5		5.5		5.0	5.0

5.4.11 AMMONIA

Determining WQBELs for ammonia is complicated by two factors: control of toxicity by environmental variables and the non-conservative nature of ammonia in the receiving water.

The toxicity of ammonia in the receiving water depends on temperature and pH. Typically, the effluent will have a lower pH than the receiving water, and the mixed flow, as is characteristic of natural streams, will rise in pH to an equilibrium condition at some point downstream. This phenomenon results in increasing ammonia toxicity downstream of the point of discharge.

In the aquatic environment, ammonia undergoes transformations that changes the concentration downstream of the outfall. Ammonia is lost through nitrification (transformation of ammonia to nitrate) and uptake for plant growth, and is gained through mineralization (transformation of organic nitrogen to ammonia). In addition, tributaries and groundwater may provide additional dilution downstream.

Prediction of the controlling condition that is dependent on non-linear processes requires the use of a model that considers each of these factors. Either the AMMTOX model (Lewis et al. 2002) within the Utah River Model or the QUAL2Kw model is used to determine WQBELs for ammonia. Refer to Sections 6.0 and 7.0 for a more detailed description of how the Utah River Model and QUAL2Kw are utilized to determine WQBELs for ammonia discharges.

Per UAC R317-2-14, the water quality criteria for ammonia in the receiving water depends upon both temperature and pH. In addition, the chronic ammonia criterion for 3A to 3D waters depends on the presence or absence of fish early life stages (ELS). Footnote 9 in UAC R317-2 Table 2.14.2 presents the equations to use to determine the ammonia criteria and determination of ELS presence.

(9) The following equations are used to calculate Ammonia criteria concentrations:

(9a) The thirty-day average concentration of total ammonia nitrogen (in mg/l as N) does not exceed, more than once every three years on the average, the chronic criterion calculated using the following equations.

Fish Early Life Stages are Present:
$mg/L\ as\ N\ (Chronic) = ((0.0577/(1+10^{7.688-pH})) + (2.487/(1+10^{pH-7.688}))) * MIN\ (2.85,\ 1.45*10^{0.028*(25-T)})$

Fish Early Life Stages are Absent:
$mg/L\ as\ N\ (Chronic) = ((0.0577/(1+10^{7.688-pH})) + (2.487/(1+10^{pH-7.688}))) * 1.45*10^{0.028*(25-MAX(T,7))})$

(9b) The one-hour average concentration of total ammonia nitrogen (in mg/l as N) does not exceed, more than once every three years on the average the acute criterion calculated using the following equations.

Class 3A:
mg/L as N (Acute) = (0.275/(1+10$^{7.204-pH}$)) + (39.0/1+10$^{pH-7.204}$))

Class 3B, 3C, 3D:
mg/L as N (Acute) = 0.411/(1+10$^{7.204-pH}$)) + (58.4/(1+10$^{pH-7.204}$))

In addition, the highest four-day average within the 30-day period should not exceed 2.5 times the chronic criterion.

The "Fish Early Life Stages are Present" 30-day average total ammonia criterion will be applied by default unless it is determined by the Director, on a site-specific basis, that it is appropriate to apply the "Fish Early Life Stages are Absent" 30-day average criterion for all or some portion of the year. At a minimum, the "Fish Early Life Stages are Present" criterion will apply from the beginning of spawning through the end of the early life stages. Early life stages include the pre-hatch embryonic stage, the post-hatch free embryo or yolk-sac fry stage, and the larval stage for the species of fish expected to occur at the site. The Director will consult with the Division of Wildlife Resources in making such determinations. The Division will maintain information regarding the waterbodies and time periods where application of the "Early Life Stages are Absent" criterion is determined to be appropriate.

Rates for nitrification of ammonia to nitrate and uptake of ammonia for plant growth will be based on reasonable conditions derived from the scientific literature, unless empirical data are available for the site. For discharges with organic matter, mineralization rates of organic nitrogen to ammonia will be determined similarly.

5.4.12 TOTAL RESIDUAL CHLORINE

Total residual chlorine (TRC) is a non-conservative pollutant that experiences decay during transport to and within the receiving water. Therefore, calculation of the WQBEL requires two steps: 1) calculate the TRC effluent concentration required at the mixing zone boundary using a mass balance equation; 2) calculate the TRC WQBEL at the point of compliance using a decay model.

The following mass balance equation is used to solve for TRC concentration at the mixing zone boundary:

$$C_bQ_b + C_oQ_o = C_s(Q_b + Q_o)$$

where:

- C_b = Background TRC concentration, µg/l
- Q_b = Background flow in the mixing zone, cfs
- Q_o = Effluent flow, cfs
- C_s = TRC criteria (acute or chronic, µg/l)
- C_o = TRC concentration required at the mixing zone boundary, µg/l

The decay model uses a standard first order expression in which the time of travel in the stream reach is incorporated into the calculations. The model expression noted in the EPA's *Technical Guidance Manual for Performing Wasteload Allocations; Book 2, Chapter 3, Toxic Substances* June 1984, Appendix D, is used for TRC decay. The decay equation projects the amount of TRC loss from the point of compliance to the mixing zone boundary within the receiving water. The following TRC decay equation is used, solving for C_d.

$$C_o = C_d e^{(-kt)}$$

where:

C_d = WQBEL TRC concentration at point of compliance, µg/l
C_o = TRC concentration required at the mixing zone boundary, µg/l
k_{20} = Decay rate constant at 20 degrees Celsius, /day
t = Time of travel in mixing zone, day

The decay rate is temperature dependent and is adjusted based on the water temperature using the following equation:

$$k_T = k_{20}\theta^{T-20}$$

where:

Θ = Temperature correction coefficient

TRC decay rate will be selected based on literature values for each type of conveyance method (i.e. pipe, open channel). Alternatively, a field study may be performed to measure the decay rate in the system.

5.4.13 DISSOLVED METALS

The water quality criteria for certain dissolved metals (cadmium, chromium, copper, lead, nickel and zinc) in the receiving water depend upon total hardness (Table 6.3 and 6.4). Furthermore, the permit limits must be expressed in terms of total recoverable metals and the translator between dissolved and total recoverable fractions for certain metals (cadmium and lead) are also hardness dependent (Table 6.3 and 6.4). The equations in Table 6.3 and 6.4 calculate the water quality criteria for dissolved metals based on hardness dependence and convert the dissolved metals limit to the total recoverable metals limit through the use of a translator (conversion factor).

Development of metal effluent limits requires calculation of the total hardness of the mixed discharge. For wasteload purposes, hardness will be considered a conservative substance. The maximum hardness used in determining the water quality standard for dissolved metals shall be 400 mg/L as $CaCO_3$.

The effluent limits for metals in the UPDES permit are expressed as total recoverable metals; therefore, a translator must be applied to convert the dissolved metal fraction to a total hardness limit. Several methods have been developed to determine a site specific translator based on the characteristics of the effluent and the receiving water that may result in relaxed effluent limits. These studies are generally conducted by the applicant in consultation with DWQ.

Table 6-3. Hardness dependent dissolved metals criterion and translators for chronic condtions (UAC R317-2 Table 2.14.3a)

Metal	Dissolved Criterion	Translator from Total Recoverable to Dissolved Fraction*
Cadmium	$e^{(0.7977*ln(hardness)-3.909)}$	*1.101672 - ln(hardness) (0.041838)*
Chromium III	$e^{(0.8190(ln(hardness)) + 0.6848}$	0.86
Copper	$e^{(0.8545(ln(hardness)) -1.702)}$	0.96
Lead	$e^{(1.273(ln(hardness))-4.705)}$	*1.46203 - ln(hardness)(0.145712)*
Nickel	$e^{(0.8460(ln(hardness))+0.0584)}$	0.997
Zinc	$e^{(0.8473(ln(hardness))+0.884)}$	0.986
* Dissolved Concentration = Translator x Total Recoverable Concentration		

Table 6-3. Hardness dependent dissolved metals criterion and translators for acute conditions (UAC R317-2 Table 2.14.3b)

Metal	Dissolved Criterion	Translator from Total Recoverable to Dissolved Fraction*
Cadmium	$e^{(0.9789*ln(hardness)-3.866)}$	*1.136672 - ln(hardness)(0.041838)*
Chromium III	$e^{(0.8190(ln(hardness)) +3.7256)}$	0.316
Copper	$e^{(0.9422(ln(hardness))- 1.700)}$	0.96
Lead	$e^{(1.273(ln(hardness))-1.460)}$	*1.46203 - ln(hardness)(0.145712)*
Nickel	$e^{(0.8460(ln(hardness)) +2.255)}$	0.998
Silver	$e^{(1.72(ln(hardness))- 6.59)}$	0.85
Zinc	$e^{(0.8473(ln(hardness)) +0.884)}$	0.978
* Dissolved Concentration = Translator x Total Recoverable Concentration		

5.4.14 BACTERIA

The secondary treatment requirements for *E. coli* bacteria per UAC R317-1-3.2 (maximum 126 cfu/100 ml for 30-day geometric mean and maximum 158 cfu/100 ml for 7-day geometric mean) are equal to or less than the water quality criteria for waters with 1C, 2A and 2B beneficial use(s). Therefore, since secondary treatment requirements apply to all discharges that potentially contain bacteria, it is not necessary to determine WQBELs for *E. coli*.

5.5 DOWNSTREAM ANALYSIS

The wasteload allocation must ensure that downstream uses are protected.

UAC R317-2-8 Protection of Downstream Uses

All actions to control waste discharges under these rules shall be modified as necessary to protect downstream designated uses.

The downstream analysis includes the following considerations:

- Determination whether there are any beneficial uses downstream that are more restrictive than the immediate receiving water. If so, additional allocations may be required to ensure protection of the downstream waters.
- Estimation of the amount and quality of additional source water from tributaries and groundwater to the downstream waters, which provides additional dilution for the pollutants in the discharge.
- Consideration of the downstream effects of nutrients (nitrogen and phosphorus). Nutrients that cycle through the receiving water may cause downstream water quality problems (i.e. enhanced algal growth, low DO, high pH), particularly in low gradient streams and reservoirs with high residence time.
- Prediction of the fate and transport of pollutants that have the potential to bioaccumulate and/or biomagnify in the environment.

6.0 UTAH RIVER MODEL

The Utah River Model is applied to minor discharges that have the potential to result in toxic ammonia conditions and/or low dissolved oxygen conditions in the receiving stream. The Utah River Model is a Microsoft Excel spreadsheet that includes routines for delineating the mixing zone, calculating ammonia limits, evaluating compliance with dissolved oxygen criteria, and other miscellaneous tools. When performing a WLA using the Utah River Model, no calibration of model parameters is typically conducted and values for rates and kinetic coefficients are selected from the literature.

6.1 AMMTOX MODEL

The Ammonia Toxicity Model (AMMTOX) was developed at the University of Colorado to determine ammonia limits to meet temperature and pH dependent ammonia criteria in streams (Lewis et al. 2002). AMMTOX consists of two independent models, one that performs recurrence analysis on grab sample data for pH and temperature, and one that predicts concentrations of ammonia in a reach model framework. The AMMTOX routines have been incorporated into the Utah River Model.

6.2 STREAM DO MODEL

The Stream DO model implements the Modified Streeter-Phelps formula for evaluating DO sag in the receiving water and determining BOD and DO limits. The Modified Streeter-Phelps formula accounts for each of the primary oxygen sources and demands in the receiving water, including reaeration of DO, nitrification of ammonia, BOD decay, sediment oxygen demand (SOD) and algal growth, respiration and death.

6.3 STREAM MIX MODEL

The Stream Mix Model was developed jointly by EPA Region 8 and DWQ. The model is based on principles and formulations described in *Mixing in Coastal and Inland Waters* (Fischer et al. 1980).

6.4 MISCELLANEOUS TOOLS

Additional routines and tools in the Utah River Model include the following:

1. Mass balance mixing analysis.
2. Metals effluent limits calculator that considers hardness dependence of metals toxicity and metals translator from total recoverable to dissolved fraction.
3. WET effluent limits calculator.
4. Total residual chlorine effluent limits calculator that considers first order decay of TRC.
5. Temperature effluent limits calculator that considers heat loading.

7.0 QUAL2KW MODEL

The QUAL2Kw model is applied to discharges that have the potential to substantially alter nutrient dynamics, algal growth and dissolved oxygen concentration in the receiving stream or river, such as major POTWs.

QUAL2Kw is maintained and distributed by the State of Washington Department of Ecology. QUAL2Kw has the following capabilities (Pelletier and Chapra 2008):

- Version 6 - Non-steady, non-uniform flow using kinematic wave flow routing. Continuous simulation with time-varying boundary conditions for periods of up to one year. Also has the option to use repeating diel conditions similar to Version 5 but with either steady or non-steady flows.
- Version 5 - Steady flows with repeating diel boundary conditions. One dimensional. The channel is well-mixed vertically and laterally.
- Diel heat budget. The heat budget and temperature are simulated as a function of meteorology on a diel time scale.
- Diel water-quality kinetics. All water quality state variables are simulated on a diel time scale for biogeochemical processes.
- Heat and mass inputs. Point and non-point loads and abstractions are simulated.
- Phytoplankton and bottom algae in the water column, as well as sediment diagenesis, and heterotrophic metabolism in the hyporheic zone are simulated.
- Variable stoichiometry. Luxury uptake of nutrients by the bottom algae (periphyton) is simulated with variable stoichiometry of N and P.
- Automatic calibration. Includes a genetic algorithm to automatically calibrate the kinetic rate parameters.

The methods for data collection, model build, model calibration, and model application to WLAs are adapted from a joint research project undertaken by Utah State University and DWQ, documented in *Using QUAL2K Modeling to Support Nutrient Criteria Development and Wasteload Analyses in Utah* (Neilson et al. 2012).

7.1 DATA COLLECTION

Data meeting quality assurance and quality control requirements from DWQ, cooperating agencies and permittees will be considered for use in building and calibrating models. DWQ will conduct monitoring specifically for the purpose of QUAL2Kw model build and calibration. The permittee may provide voluntary support to data collection efforts. In some cases, due to limited resources, the model will need to rely upon existing monitoring data from DWQ or other agencies.

For data collection in support of QUAL2Kw model build and calibration, standard operating procedures (SOP) documented in *Field Data Collection for QUAL2Kw Model Build and Calibration Standard Operating Procedures* (UDWQ 2012) will be followed. The data collection procedures describe how to conduct a synoptic survey along the receiving water, which involves a combination of multi-parameter sonde deployment and sampling at multiple locations and over multiple days during steady-state flow conditions. The purpose of the synoptic survey is to characterize hydrologic and water quality conditions in the receiving water in order to populate the model and calibrate the rate parameters.

7.2 MODEL BUILD

This section reviews the data requirements and the data sources for QUAL2Kw. The model input will generally be based on direct field measurements or estimated from existing data sources. The model is typically built in Version 5 of QUAL2Kw and run in steady-state flow condition.

Table 7-1. QUAL2Kw model inputs

QUAL2Kw Sheet	Input Required	Source
Channel Properties		
Reach	Channel elevation, latitude, longitude	Google Earth
Reach	Channel slope, bottom width, bank side slope	Measured or Google Earth
Reach	Manning n roughness	Calibration parameter
Reach	Bottom algae coverage	Assumed 100% or field estimate
Reach	Bottom SOD coverage	Assumed 100% or field estimate
Reach	Prescribed SOD, CH4, NH4, and Inorg P flux	Measured or calibration inputs
Initial Conditions		
Initial Conditions	Constituent concentrations (See Table 7-2)	Typically not required input
Meteorology		
Air Temperature	Air temperature - hourly	Nearest station
Dew Point Temperature	Dew point temperature- hourly	Nearest station
Wind Speed	Wind speed- hourly	Nearest station
Solar	Solar radiation- hourly	Model calculated or nearest station
Cloud Cover	Cloud cover- hourly	Nearest station or not required with solar radiation input
Shade	Shading percent	Field estimate or Google Earth
Boundary Conditions		
Headwater	Mean flow rate	Measured (DWQ, USGS, or other)
Headwater	Constituent concentrations (See Table 7-2)	Sampling data
Point Sources	Mean flow rate	Measured (DWQ, USGS, or other)
Point Sources	Constituent concentrations (See Table 7-2)	Sampling data
Diffuse Sources	Mean flow rate	Estimated – literature values
Diffuse Sources	Constituent concentrations (See Table 7-2)	Estimated – literature values

Table 7-2. QUAL2Kw input constituents

Constituent	Units
Temperature	degree C
Conductivity	μmhos
Inorganic suspended solids	mgD/L
Dissolved oxygen	mgO_2/L
Carbonaceous biochemical oxygen demand	mgO_2/L
Organic nitrogen	μgN/L
Ammonia nitrogen	μgN/L
Nitrate nitrogen	μgN/L
Organic phosphorus	μgP/L
Inorganic phosphorus	μgP/L
Phytoplankton	μgA/L
Detritus	mgD/L
Alkalinity	$mgCaCO_3/L$
pH	SU

7.3 MODEL CALIBRATION

Model calibration is the process of parameterizing the rate coefficients in the model by minimizing the error between predicted results and observed data. Model calibration is very important, as it helps build confidence in applying the model to develop effluent limits. Specific guidance has been developed for applications that involve the use of QUAL2Kw as summarized in this section and described in detail in Neilson et al. 2012.

A QUAL2Kw calibration model template file has been developed to support data input, model population and model calibration. Specific instructions are provided in the QUAL2Kw model template file.

7.3.1 MODEL PARAMETERIZATION

This section outlines the typical procedures that are followed to calibrate the model. The calibration is divided into initial manual calibration procedures, followed by auto-calibration procedures. The objective is to parameterize the model as much as practicable utilizing observed data during the manual calibration, thereby reducing the number of parameters requiring auto-calibration. It may be necessary for the Wasteload Analyst to deviate somewhat from these typical procedures on a case-by-case basis.

1) Manual calibration procedures:*Flow balance*: Based on measured instream, point source and diversion flow rates, the steady-state flows are balanced in the model. It may be necessary to add or subtract groundwater in order to account for a large difference between predicted and observed flows. Specific conductivity is also used to account for unmeasured or unknown sources and improve the accuracy of the flow balance.

2) *Travel time and flow depth*: Manning's equation is typically used to simulate channel hydraulics, including flow velocity and depth. The Manning's roughness coefficient "n" is adjusted to minimize error between predicted and observed flow velocity (travel time) and flow depth. Travel time may be estimated using a hydraulic model such as HEC-RAS.
3) *Temperature*: The percent shading is adjusted to minimize error between predicted and observed minimum and maximum temperature. If incoming solar radiation is simulated rather than input from observed data, the light and heat coefficients are adjusted to minimize error between predicted and observed mean temperature.
4) *Inorganic suspended solids (ISS)*: The settling rate is adjusted to minimize error between predicted and observed ISS concentration.
5) *Reaeration rate*: Continuous diel DO measurements and whole stream metabolism methods are used to estimate reaeration rate. The reaeration formula that minimizes error with reaeration rate as estimated by whole stream metabolism methods is selected.
6) *Sediment oxygen demand (SOD)*: Direct measurements of SOD made by deploying chambers are preferred. In the absence of direct measurement, continuous diel DO observations and whole stream metabolism methods are used to estimate SOD.
7) *CBOD decay rate*: Direct measurements of the CBOD from the wastewater are preferred. In the absence of direct measurement, default values have been developed by DWQ.

Auto-calibration procedures:

8) *Fitness statistic*: Auto-calibration routines require a fitness statistic for model parameter optimization. A default fitness statistic has been developed that weights and combines error for multiple constituents, including DO, nitrogen, and phosphorus. The fitness statistic may be customized depending on data availability and quality for specific applications.
9) *Model parameters*: The model parameters to be optimized and range of acceptable values are specified for the auto-calibration routine. Default values for model parameters and acceptable ranges for auto-calibration have been developed.
10) *Genetic algorithm*: The auto-calibration utilizes a genetic algorithm that optimizes model parameterization through numerous model iterations. Typically, 100 populations are simulated each with 100 generations for a total of 10,000 simulations in the evolution. However, depending on model run time and time constraints, the auto-calibration routine may utilize less simulations.
11) *Auto-calibration*: The auto-calibration routine is run to determine the optimal set of model parameters.

7.3.2 MODEL PARAMETERIZATION WITH INSUFFICIENT DATA

In cases where insufficient data is available for model calibration, rate coefficients used in the modeling process will typically be taken from a calibrated model of a receiving water with similar physiographic characteristics.

7.3.2 MODEL VALIDATION

If available, an independent synoptic data set is used to validate the calibrated model performance. During model validation, none of the rate kinetics are adjusted, and the predicted and observed results are compared to evaluate model performance.

MODEL APPLICATION TO WLA

A QUAL2Kw model is populated in order to determine the wasteload allocation. The WLA model uses the channel characteristics and rate coefficients from the calibrated model. In cases where a synoptic survey has not been completed and a model of the receiving water has not been calibrated, the rate parameters will be taken from a calibrated model of a receiving water with similar hydrologic and water quality characteristics.

In order to simulate critical conditions in the waterbody, seasonal model inputs are generated for meteorology, as well as the hydrology and water quality of upstream and tributary point sources. The model is typically built in Version 5 of QUAL2Kw and run in steady-state flow condition.

7.4.1 MODEL INPUTS

The generation of critical flow and water quality conditions of the receiving water and tributary point sources for input to the QUAL2Kw model follows the general procedures for WLAs outlined in Section 5.

QUAL2Kw does allow for input of diel variation of water quality constituents. However, rarely is sufficient data available to adequately characterize diel variation, so only mean daily values are input into the model. In some cases, an estimate of diel range is applied to water temperature and/or dissolved oxygen.

The QUAL2Kw model also requires input of sub-daily meteorological data (air temperature, dew point temperature, wind speed, cloud cover). Long term (20 years) monthly and/or seasonal averages for air temperature, dew point, and wind speed for the nearest weather station is input into the model. Observed solar radiation data may be input or calculated by the model.

A QUAL2Kw WLA model template file has been developed to support data input and model application. Specific instructions are provided in the QUAL2Kw model template file.

7.4.2 DETERMINING EFFLUENT LIMITS

Several constituents in the wastewater affect the DO oxygen condition in the receiving water, including dissolved oxygen, carbonaceous biochemical oxygen demand, detritus, nitrogen and phosphorus. If it is determined that limits lower than secondary standards are necessary for any of these constituents in order to meet instream DO criteria, the Wasteload Analyst will consult with the facility regarding their capabilities and preferences for meeting the instream DO criteria. Consideration is given to the past performance and current capability of the facility, or for a new facility, the design engineer's projection of which constituents can be most cost effectively and reliably controlled.

8.0 EPA GUIDANCE AND TRAINING RESOURCES

NPDES Permit Writer's Manual: Chapter 6 Water Quality Based Effluent Limits. (2010) EPA 833-K-10-001.

Technical Support Document for Water Quality-Based Toxics Control. (1991) EPA 505/2-90-001. EPA

Water Quality Standards Academy

NPDES Permit Writer's Training Course

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