

Toxics Management Spreadsheet  
(TMS)  
PA Single Discharge Wasteload  
Allocation Program for Toxics  
User Manual

## Table of Contents

	<u>Page</u>
<b>1 Preface.....</b>	<b>1</b>
<b>2 Important Technical Issues And Procedures .....</b>	<b>2</b>
2.1 Design Stream Flows .....	2
2.2 Design Flow .....	3
2.3 Criteria Compliance Times .....	3
2.3.1 Acute Fish Criterion (AFC) .....	3
2.3.2 Chronic Fish Criterion (CFC) .....	3
2.3.3 Human Health Criteria (THH & CRL) .....	4
2.4 Complete Mix Times .....	4
2.5 Partial Mixing Factors.....	4
2.6 Background Pollutant Concentration.....	5
2.7 Hardness, pH and Dissolved Water Quality Criteria .....	5
2.8 Potable Water Withdrawals .....	6
2.9 Point of First Aquatic Life Use.....	6
2.10 Pollutant Fate .....	6
2.11 Factor of Safety.....	7
2.12 Water Quality Criteria.....	7
2.13 Water Quality Objective .....	7
2.14 Background Pollutant Variability .....	7
2.15 Effluent Variability .....	8
<b>3 Data Input Requirements.....</b>	<b>9</b>
<b>4 Determining Wasteload Allocations.....</b>	<b>11</b>
4.1 Background Concentration (cb).....	12
4.2 Water Quality Objective (cx).....	13
4.3 Design Stream Flow (qs) .....	14
4.3.1 Q7-10 Design Flow Condition.....	14
4.3.2 Harmonic Mean Design Flow.....	14
4.3.3 Special Conditions .....	15
4.4 Discharge Analysis Flow (qd) .....	15
4.5 Partial Mixing Factor (yc).....	15
4.5.1 Reach Slope (sl) .....	16
4.5.2 Reach Depth (d).....	16
4.5.3 Reach Width (w).....	19
4.5.4 Complete Mix Time (cmt) .....	23
4.5.5 Partial Mixing Factor (yc).....	23
4.5.6 Special Conditions .....	24
4.6 Instream Pollutant Fate Coefficient (k, Fate Coeff).....	25
4.7 Factor of Safety (FOS).....	25
4.8 Hardness & pH (Used for computing water quality criteria).....	25
<b>5 Determining Final Effluent Limitations .....</b>	<b>25</b>
5.1 Determining the Average Monthly Effluent Concentration for Aquatic Life Criteria .....	26
5.2 Determining the Average Monthly Limit for Human Health Criteria .....	27
5.3 Determining the “Governing” Water Quality-Based Effluent Limit (WQBEL) .....	27
5.4 Calculate the Maximum Daily Effluent Limit.....	28
5.4.1 Calculate Ratio of MaxDaily/Final Limit.....	28
5.4.2 Calculate Maximum Daily Limit.....	28

5.4.3	Calculate IMAX.....	28
5.4.4	Calculate Mass Based Limits.....	29
5.5	Recommended Effluent Limits.....	29
<b>Appendix A Derivation of Mixing Relationships.....</b>		<b>30</b>
<b>Appendix B INPUT DATA .....</b>		<b>34</b>

List of Figures

Figure 1: Determining Reach Depth.....	18
Figure 2 : Determining Reach Width.....	20

# 1 Preface

**The Toxics Management Spreadsheet (TMS)** uses a mass-balance water quality analysis model that includes consideration for mixing, first-order decay (fate coefficient) and other factors to determine recommended water quality-based effluent limits. The primary purpose of the model is to assist DEP permit engineers in determining appropriate NPDES permit limits for toxics and certain other substances. For each parameter evaluated, the program:

- Computes a Wasteload Allocation (WLA) on a single discharge basis (i.e., without the consideration of multiple source interactions) for each applicable criterion.
- Determines a recommended water quality-based effluent limitation (WQBEL) for each parameter.
- Performs a reasonable potential (RP) analysis by comparing the recommended WQBEL with the entered discharge concentration to determine if there is RP.
- Recommends average monthly, maximum daily and instantaneous maximum effluent limitations where RP exists and recommends monitoring requirements for parameters of concern based on practices outlined in Standard Operating Procedures (SOPs).

The TMS was designed using the latest version of Microsoft Excel® and is in macro-enabled binary file (XLSB) format. Macros must be enabled for the TMS to function. The TMS is not guaranteed to work with earlier versions of Excel®.

The TMS includes instructions for basic use of the TMS. This document gives detailed explanations of calculations performed by the TMS.

The TMS is a replacement for PENTOXSD, DEP's original mass-balance water quality toxics model, and the Toxics Screening Analysis (TSA), DEP's original spreadsheet used to determine RP. With some exceptions the calculations performed by the TMS are the same as those performed by PENTOXSD. Compared to PENTOXSD, the TMS contains the following major enhancements and modifications:

- Osmotic Pressure is treated as an acute criterion in the TMS. PENTOXSD treated Osmotic Pressure as a chronic criterion.
- The radio button must be selected to apply the Great Lakes criteria. In PENTOXSD this was applied automatically based on basin number. Additionally, when the Great Lakes criteria are applied in the TMS no dilution will be allowed for Bioaccumulative Chemicals of Concern (BCCs) and limits will be derived as the most stringent criterion.
- ORSANCO criteria are incorporated. When the ORSANCO Criteria radio button is selected the more stringent of ORSANCO criteria and statewide criteria will be applied. No dilution is allowed for BCC pollutants.
- Parameters will no longer be screened out when maximum analytical results are below the most stringent criterion (as was done in the TSA). For the TMS, WQBELs will be developed for all parameters for which a maximum discharge concentration is entered. Parameters will only be screened out as not needing limits or monitoring when a non-detect is reported at or below the Target Quantitation Limit (TQL).
- Only one reach (two nodes) can be entered in the TMS. Tributaries cannot be entered below the discharge.

- If the background concentration (stream conc) is greater than criteria the recommended effluent limit will be set to criteria. PENTOXSD would set the recommended effluent limit to the background concentration.
- The discharge concentration will not be recommended as an effluent limit if it is less than the effluent limit calculated by the TMS. PENTOXSD would recommend the less of the calculated limit and the entered discharge concentration.
- Limits below the most stringent criterion will not be recommended. In some cases, when AFC governed, PENTOXSD would recommend limits that were below criteria. In these cases, MDL will still be based on the calculated WQBEL (if less stringent than criteria).
- A PMF will be applied to the PWS criteria that are only applied at a PWS intake (25 Pa Code § 96.3(d)). PENTOXSD allowed for complete mix at the point of withdrawal.
- Special parameter monitoring requirements for TDS, bromide, chloride, sulfate and 1,4-dioxane requirements no longer apply and are not included in the TMS (starting 10/1/2020).

This document describes the technical methods contained in the TMS for performing WLA analyses and for determining recommended single discharge NPDES effluent limits. It contains a listing of the current input data (both required and optional) and describes how these data are used. It contains discussions of important technical considerations that are pertinent to the determination of effluent limits. The appendices contain additional information on some of the statistical and mathematical relationships described in the main body of the text.

## 2 Important Technical Issues and Procedures

The methods used by the TMS to determine recommended effluent limits are based on many technical issues and procedures. These are either required by regulation or are taken from the DEP *Toxics Management Strategy*, DEP ID: 361-0100-003, available on DEP's website at [www.depgreenport.state.pa.us/elibrary](http://www.depgreenport.state.pa.us/elibrary). These issues are discussed below.

### 2.1 Design Stream Flows

The TMS uses two different design stream flows to compute the WLAs. They are the Q7-10 (lowest 7-day average flow that occurs once every ten years) and Qh (harmonic mean flow). The Q7-10 stream flow is specified in 25 Pa. Code § 96.4(g), Table 1. This stream flow is used in the application of three of the four water quality criteria:

- Acute Fish Criteria (AFC), also referred to as Criteria Maximum Concentration
- Chronic Fish Criteria (CFC), also referred to as Criteria Continuous Concentration
- Threshold Human Health (THH)

The Qh flow is also specified by regulation in 25 Pa. Code § 96.4(g), Table 1. Refer to the *Implementation Guidance Design Conditions*, DEP ID: 391-2000-006, for more information on how to develop this flow. Qh flow is used to evaluate the non-threshold human health (carcinogen) criterion (CRL). In the absence of field data, the Qh flow is computed using a default equation that estimates this flow as a function of the Q7-10 flow.

## 2.2 Design Flow

The TMS requires a design flow of the discharge be entered which is used for the mass-balance calculation and the calculation of recommended mass-based effluent limits. The design flow that should be entered is typically the average annual design flow for the discharge, in million gallons per day (MGD).

## 2.3 Criteria Compliance Times

The TMS does not assume that all discharges completely mix with the stream. Therefore, it is necessary to define the mixing characteristics of the discharge. In doing so, the point of compliance with the water quality criteria must be established. This is accomplished by assigning different criteria compliance times (CCTs) for each criterion. These compliance times establish the locations where compliance with the water quality criteria is expected to occur. The following subsections provide an explanation of each.

### 2.3.1 Acute Fish Criterion (AFC)

The U.S. Environmental Protection Agency's (EPA's) *Technical Support Document for Water Quality-Based Toxics Control, March 1991, EPA/505/2-90-001* (TSD) suggests that compliance with acute fish criterion be at the end-of-pipe. Taken literally, this means a WLA equal to the criterion. EPA, however, will tolerate a small instream area where the criterion may be exceeded. Such an area allows for a WLA greater than the criterion. Therefore, DEP allows for an area of mixing downstream of the discharge for this criterion by establishing a maximum criteria compliance time of 15 minutes of travel time downstream of the discharge. The criteria compliance time (used to compute the mix factor) is then either this maximum criteria compliance time or the complete mix time, whichever occurs first.

### 2.3.2 Chronic Fish Criterion (CFC)

Chronic analyses frequently assume "complete mix." However, the actual application of complete mix can vary greatly from case to case. Sometimes less than 100 percent of the design stream flow will be assigned. Ambient mixing depends on several variables, such as stream width, depth, the location of the discharge outfall, stream velocity and stream slope. Application of the EPA ambient mixing equation suggests that mixing is:

- Relatively rapid for practically all stream flows of less than 50 cfs.
- Complete mixing will occur within 12 hours for stream flows between 50 to 250 cfs.
- Seldom complete for stream flows greater than 250 cfs.

These conclusions are based on ambient mixing. Other factors such as discharge diffusion, channel geometry and stream flow vs. discharge flow ratio can induce more rapid mixing.

Because of the uncertainties associated with mixing, DEP allows for an area of mixing downstream of the discharge for this criterion by establishing a maximum criteria compliance time of 12 hours travel time downstream of the discharge. The criteria compliance time (used to compute the mix factor) is then either this maximum criteria compliance time or the complete mix time, whichever occurs first.

### **2.3.3 Human Health Criteria (THH & CRL)**

DEP allows for an area of mixing downstream of the discharge for these criteria by establishing the maximum criteria compliance time of 12 hours travel time downstream of the current discharge or, for THH criteria, the estimated travel time downstream to the nearest potable water supply intake. The criteria compliance time (used to compute the mix factor) is then either this maximum criteria compliance time or the complete mix time, whichever occurs first.

The CCTs, discussed above, are used to compute the partial mix factor for each criterion. Before these partial mix factors can be determined, however, the complete mix time must be computed.

## **2.4 Complete Mix Times**

The TMS uses the EPA ambient mixing equation to estimate the time to complete mix. This equation can be found in the TSD section, *Ambient-Induced Mixing*. It has been adapted for use in Pennsylvania. An explanation of how this equation has been adapted for use in Pennsylvania can be found in Appendix A, Derivation of Mixing Relationships.

The adapted version of the EPA ambient mixing equation is used to compute the complete mix time. It is used when the user does not enter complete mix times and partial mix factors. The adapted version solves for complete mixing time, based on entered or estimated stream velocity, width and depth. Each of these variables may be computed or entered by the user. Once complete mix time is determined, it is used in conjunction with the CCT for each criterion, to compute the partial mix factor. This is discussed in the next section.

## **2.5 Partial Mixing Factors**

The Partial Mix Factor (PMF) is used to describe the fractional portion of the stream that mixes with the discharge at the CCT. A separate mix factor may be supplied directly by the user for each criterion or computed by dividing the criteria compliance time into the complete mix time. The partial mix factor is a value between 0 and 1. A value of 1 represents complete mixing between the stream and the discharge plume. A value of less than 1 means that there is incomplete mixing between the discharge and the stream at the criteria compliance time. A more complete explanation of how complete mix times and partial mixing factors are determined (when they are not provided by the user) may be found in Appendix A.

## 2.6 Background Pollutant Concentration

Background pollutant concentration is defined as the condition that occurs in the absence of controllable point source discharges. Background pollutant loadings can include loadings from nonpoint sources or other sources not covered by the NPDES program. Generally, at low flow conditions, nonpoint source loadings are not significant. Other point source loadings outside of the current analysis, on the same stream, or subject to control, would not be considered part of the background concentration. Users should refer to *Implementation Guidance for the Determination and Use of Background/Ambient Water Quality in the Determination of Wasteload Allocations and NPDES Effluent Limitations for Toxic Substances*, DEP ID: 391-2000-022, for assistance in determining when and how to use this field.

The background concentration entered should be the concentration expected to occur at the design stream flow condition (Q7-10 or Qh). If the data are not available to determine background at the design condition, then it may be necessary to compute the long-term average background concentration and, if necessary, apply a coefficient of variation. Background pollutant loadings can be entered for the reach being evaluated (stream concentration). In addition, a first-order decay rate can be entered for each reach and this will be used to decay the stream loads as the simulation takes place. Therefore, if it is necessary to keep the concentration constant throughout the stream, no fate coefficient should be entered. The background concentration computed and/or entered for the current reach is used to determine the available assimilation capacity and the water quality objective.

If the background concentration is greater than water quality criteria the recommended effluent limit will be set to the water quality criterion.

## 2.7 Hardness, pH and Dissolved Water Quality Criteria

Some fish and aquatic life (FAL) water quality criteria are hardness dependent (e.g., most toxic metals) or pH dependent (e.g., pentachlorophenol). This means that before WLAs can be computed, the criteria, at the point of application, must be calculated. Generally, this is at the criteria compliance time.

FAL criteria for certain toxic metals are expressed in terms of dissolved rather than as total recoverable concentrations. Chemical translators must be applied to determine the water quality objective and NPDES effluent limitations, both of which are expressed in the total recoverable form. 25 Pa. Code § 16.24 provides that chemical translators may be based on site-specific studies, or in the absence of site-specific information, on a series of default conversion factors. Where applicable, the TMS checks to see if a site-specific chemical translator has been entered, and if it has, uses the entered value to determine the water quality objective and the resulting recommended WLAs and effluent limitations. Where a site-specific value is not provided, a default value, consistent with the values and formulas presented in 25 Pa. Code § 16.24 is used.

The TMS provides two different methods for determining instream hardness and pH. First, an analysis hardness and/or pH can be entered directly by the user. The analysis hardness and pH are the final values used to adjust the criteria for any hardness or pH-



dependent criteria. Second, the user can input separate discharge and stream values, which are then mass balanced to determine the analysis values. The mass balance between the discharge values and the stream values considers how much mixing has occurred between the discharge and the stream at the criteria compliance time.

Discharge values must be entered by the user but will be ignored if the user also enters analysis values. If no analysis or stream values are manually entered, the default hardness of 100 mg/L and a default pH of 7 is assigned to the stream flow.

All measurements of hardness and pH, entered by the user, should be representative of the values expected to occur at the design stream flow condition (i.e., Q7-10).

## **2.8 Potable Water Withdrawals**

DEP's regulation at 25 Pa. Code § 96.3(d) specifies pollutants whose human health criteria should only be applied at potable water supply intakes. This is an exception to the general rule that water quality criteria apply at all locations. The TMS implements this when a PWS is entered on the Stream worksheet. The evaluation of human health criteria for the PWS only parameters will always be at the nearest downstream water supply intake. Fate coefficients are not applicable for these PWS parameters. The TMS uses the stream flow, with a PMF applied, at the potable water supply intake to evaluate these parameters instead of the stream flow at the discharge.

Additionally, if a PWS withdrawal occurs before the CCT for THH criterion, the THH criterion will be applied at the PWS.

## **2.9 Point of First Aquatic Life Use**

Generally, Fish and Aquatic Life (FAL) criteria apply to all surface waters. However, for specific situations, such as acid mine affected streams that meet the requirements of 25 Pa. Code § 95.5, the TMS allows the user to indicate that FAL criteria should not be applied to a location. When the user does this, the FAL criteria are applied at the downstream location where FAL criteria do apply (if applicable). The stream flow used in this case will be the flow at the location where FAL criteria apply, instead of the stream flow at the point of discharge location. The partial mix factors for the aquatic life criteria are set to one, assuming complete mix. If fate coefficients are entered, the travel time up to the point of first use is computed and used in the first order decay relationship.

## **2.10 Pollutant Fate**

Instream pollutant fate can be an important consideration and application of fate has been incorporated into the TMS. Discharge and stream loads may be decayed from the discharge location downstream to the criteria compliance time. The TMS applies first-order decay kinetics. Fate coefficients can be entered by the user into the TMS.

## **2.11 Factor of Safety**

This factor may be used to account for the uncertainties in the input data for the discharge being evaluated. It is applied to the WLA which is used to determine the final maximum WQBEL. A default value of zero (0) is used and can be adjusted by the user.

## **2.12 Water Quality Criteria**

The TMS has a Reference worksheet which contains the FAL and human health criteria published in Chapters 93 and 16 for statewide application; Great Lakes Initiative (GLI) criteria for Lake Erie basin; and Ohio River Valley Water Sanitation Commission (ORSANCO) pollution control standards for the Ohio River. For most parameters, there are FAL criteria (or formulas for determining the criteria) for both Continuous (Chronic) and Maximum (Acute) concentrations. In addition, for a majority of parameters there is at least one Human Health criterion. The TMS uses these criteria to determine WLAs and recommended NPDES effluent limitations for each parameter that is evaluated.

When GLI or ORSANCO criteria are applied in the TMS no dilution is allowed for Bioaccumulative Chemicals of Concern (BCCs). Limits will be derived as the most stringent criterion of GLI/ORSANCO and statewide criteria.

DEP regulations allow for the use of site-specific criteria that are developed in accordance with 25 Pa. Code § 93.8(d). Site-specific criteria must be manually entered into the TMS or be determined with the use of a criteria modifier.

## **2.13 Water Quality Objective**

Normally, the water quality objectives DEP seeks to achieve through the development of WLAs are the water quality criteria published in Chapter 93. However, there is an exception where criteria are expressed as dissolved rather than as total recoverable values; in such cases the TMS uses a chemical translator (either user supplied or default) to determine the water quality objective.

## **2.14 Background Pollutant Variability**

There may also be variability in the background concentrations taken in the stream. If this is the case, then the background concentration (Stream Concentration) is entered as a long-term average. The variability is estimated by performing a statistical summary of the data, provided that enough is available. Variability is used to adjust the background concentration so that it has the same duration as the criterion. When this adjustment is made, the statistical equations used are the same ones used for effluent variability, except that the 95th percentile probability basis is used. In addition, a background coefficient of variation (Stream CV) is used to make the adjustment from the long-term average background to the appropriate criterion duration. In the absence of enough data, the default background coefficient of variation is 0, meaning that background is constant over all criteria durations. The user may enter a coefficient of variation to reflect the variability of background concentration above the discharge.

## 2.15 Effluent Variability

The TMS uses the effluent variability to translate WLAs to average monthly and maximum daily permit limits. The procedures used are recommended by EPA and are applied to FAL criteria only. They can be found in the EPA TSD Sections 5.4 and 5.5. A summary of the procedure used is described below.

The TMS first translates each FAL WLA to a long-term average (LTA) and then to an average monthly concentration. These statistical translations are made using the 99th percentile probability basis, and in the case of average monthly concentrations, the number of samples per month selected by the user. The TMS also computes the maximum daily limit using similar statistics and the same probability basis.

When the TMS computes the LTA for acute fish criterion, an hourly coefficient of variation (CV) is used. The justification for using an hourly CV is that this is consistent with the expression of the water quality criterion for AFC as a 1-hour average. The TMS uses the daily CV in all other circumstances. The discharge CV is determined by assuming that effluent variability is log-normally distributed. In the absence of a site-specific CV, a default value of 0.5 is used for both the daily CV and hourly CV. However, the user has the option of overriding both default CVs, based on site-specific data.

### 3 Data Input Requirements

**Table 1: TMS Data Inputs**

Data Field	Type	Default	Units	Notes	Section Reference
<b>STREAM DATA – (Separate data inputs for each design flow condition, Q7-10 and Qh)</b>					
Receiving Water Name	Optional				
Stream Code	Required				
River Mile Index	Required		miles		
Elevation	Required		feet		
Drainage Area	Required		sq miles		
Slope	Optional		ft/ft		4.5.1
PWS Withdrawal	Optional		mgd		2.8, 4.3
Apply Fish Criteria	Required	Yes	Yes/No		2.9
Incremental Low Flow Yield (LFY)	Optional	0.1	cfs/sq mile	For Q7-10 Only	4.3, 4.3.1
Stream Flow	Optional		cfs		2.1, 4.3
Reach Width/Depth Ratio (W/D)	Optional				4.5.2, 4.5.3
Reach Width	Optional		feet		4.5.2, 4.5.3
Reach Depth	Optional		feet		4.5.2, 4.5.3
Reach Velocity	Optional		fps		2.4, Table 2
Reach Travel Time	Optional		days		2.3.1, 2.3.2, 2.3.3, 4
Stream Hardness	Required	100	mg/L		2.7, 4.8
Stream pH	Required	7	pH units		2.7, 4.8
Analysis Hardness	Optional		mg/L	At point of criteria compliance	2.7, 4.8
Analysis pH	Optional		pH units	At point of criteria compliance	2.7, 4.8

Data Field	Type	Default	Units	Notes	Section Reference
<b>DISCHARGE DATA – (Separate data inputs for each discharger)</b>					
Facility	Optional				
NPDES Permit No.	Optional				
Outfall No.	Optional				
Evaluation Type	Optional			Drop-down menu	
Wastewater Description	Optional				
<b>Design Flow</b>	Required		mgd		2.2
Discharge Hardness	Required		mg/L		2.7
Discharge pH	Required		pH Units		2.7
AFC Partial Mix Factor	Optional		Decimal percent		2.5, 4.5.5
CFC Partial Mix Factor	Optional		Decimal percent		2.5, 4.5.5
THH Partial Mix Factor	Optional		Decimal percent		2.5, 4.5.5
CRL Partial Mix Factor	Optional		Decimal percent		2.5, 4.5.5
Q7-10 Complete Mix Time	Optional		minutes		2.4, 4.5.4
Qh Complete Mix Time	Optional		minutes		2.4, 4.5.4
Max Discharge Concentration	Required		µg/L or mg/L		3
Stream Concentration	Optional	0	µg/L or mg/L		2.6, 4
Daily CV	Optional	0.5			2.16
Hourly CV	Optional	0.5			2.16
Stream CV	Optional	0			
Fate Coefficient	Optional	1	1/day	First Order Decay Coefficient	2.10
Factor of Safety	Optional	0.0	Decimal percent		2.11
Criteria Modifier	Optional	1			2.12, 4.2
Chem Transl	Optional	25 Pa. Code §16.24		Applies only to metals criteria	2.13, 4.2

Data Field	Type	Default	Units	Notes	Section Reference
<b>RESULTS</b>					
Number of Samples	Required	4	Number of discharge samples per month	User selects 4, 8, 12, 20, or 30	5.5

Table 1 lists required and optional data inputs. Required data inputs are listed and must be provided by the user since there are no default values or equations for them. Required inputs are marked with an asterisk in the TMS.

Where optional data inputs are not supplied, default values are used for some of them. The default values are listed in Table 1. For the other data, values are computed using one or more of the equations described in Sections 4 and 5.

## 4 Determining Wasteload Allocations

The complete first-order decay mass-balance WLA equation is presented below. This equation computes a WLA for each criterion.

$$wla = \left( \frac{cx}{\exp[-k \times tc/1440]} + \frac{yc \times qs \times (cx - cb)}{qd \times \exp[-k \times tc/1440]} \right) \times (1 - fos) \quad (4)$$

where,

- wla = WLA (µg/L)
- qd = Discharge analysis flow (cfs)
- yc = Partial mixing factor (decimal percent)
- qs = Design stream flow (cfs)
- cx = Water quality objective (µg/L)
- cb = Background concentration (µg/L)
- k = Instream fate coefficient (1/day)
- fos = User-supplied factor of safety (decimal percent)
- tc = Criteria compliance time (minutes)

- For AFC = Minimum of [15, cmt]
- For CFC = Minimum of [720, cmt]
- For THH = Minimum of [ttpws, 720, cmt]
- For CRL = Minimum of [720, cmt]

where,

- cmt = Complete mix time (See Section 4.5.4, below)
- ttpws = Travel time to nearest potable water supply intake

**Special Condition:**

For PWS parameters (see Section 2.8)

$$tc = ttpws * 1440$$

If FAL do not apply at the point of discharge (see Section 2.9)

$$tc = ttaq * 1440$$

where,

ttpws = Travel time to nearest potable water supply intake

ttaq = Travel time to point of first aquatic life use

All of the variables listed on the right-hand side of equation 4, except for the water quality objective, can be overridden with site-specific data. Methods and procedures for estimating each of the variables on the right side of this equation are described below. Depending on the data inputs supplied by the user, some of these equations require intermediate computations before the value can be determined. These intermediate computations must be performed first.

#### 4.1 Background Concentration (cb)

The background concentration is the stream concentration entered directly by the user.

When the user enters the stream concentration directly, the value may be adjusted to the criteria duration. This adjustment is made if the user also enters the stream coefficient of variation.

If the user enters the stream concentration measured above the current discharge, then:

If the criterion being evaluated is AFC or CFC:

$$cb_{crit} = \left( \frac{cs}{\exp \left[ 0.5 \times 1n[cvb^2/n + 1] - z \times \sqrt{(1n[cvb^2/n + 1])} \right]} \right) \quad (4.1a)$$

where,

cs = User-supplied natural water quality, as defined in Section 2.6 (µg/L)

cvb = Stream CV- daily (dimensionless)

n = 1 for AFC, 4 for CFC (criteria duration)

z = Z-Score = 1.645 @ 95th Percentile

If the criterion being evaluated is THH or CRL or where a Steam CV is not entered:

$$cb_{crit} = cs \quad (4.1b)$$

If a fate coefficient is applied, then the instream background concentration,  $cb$ , at the criteria compliance time is:

$$cb = qt * cb_{crit} * \exp(-k * ti) \quad (4.1c)$$

where,

$cb_{crit}$  = User-supplied stream concentration from Eq. 4.1a or b, above ( $\mu\text{g/L}$ )  
 $qt$  = Stream flow in the reach (from Eqs. 4.3b, 4.3c or 4.3d) (cfs)  
 $k$  = User-supplied decay coefficient for the upstream reach (1/days)  
 $ti$  = User-supplied travel time through the upstream reach (days)

where,

$$ti = \left( \frac{rmi_i - rmi_{i+1}}{v_i \times 16.3636} \right) = (days) \quad (4.1d)$$

$rmi_i$  = User-supplied river mile index at the discharge (miles)  
 $rmi_{i+1}$  = User-supplied river mile index at the downstream reach (miles)  
 $v_i$  = Reach velocity (from DEP Velocity Equation or entered by the user at each reach (ft/sec))  
 16.36 = Conversion from ft/sec to miles/day

## 4.2 Water Quality Objective (cx)

For non-dissolved metals, the FAL water quality objective is:

$$cx = wqx \quad (4.2a)$$

For dissolved metals, the FAL water quality objective is:

$$cx = (wqx / chem\_trans) \quad (4.2b)$$

where,

$wqx$  = applicable water quality criterion.  
 $chem\_trans$  = User-supplied or default chemical translator

$$wqx = wqc \times cm \quad (4.2c)$$

where,

$wqc$  = Chapter 16 or 93 water quality criterion (formula or value) ( $\mu\text{g/L}$ )  
 $cm$  = Site-specific criterion modifier (dimensionless – default = 1)



For human health criteria:

$$cx = wqx = wqc \quad (4.2d)$$

### 4.3 Design Stream Flow (qs)

The design stream flow, qs, is either the stream flow entered directly by the user or if no data are entered, then the program computes the design flow at the current reach by using the drainage areas and low-flow yield factors. The equations below illustrate what the program does when the user enters either the flow directly or no flow at all.

#### 4.3.1 Q7-10 Design Flow Condition

If Q7-10 is entered at the point of discharge, then:

$$qs = qr_{(710)} \quad (4.3a)$$

where,

$qr_{(710)}$  = User-supplied Q7-10 design stream flow at the current discharge (cfs)

If Q7-10 is not entered at the point of discharge, then:

$$qs = da \times gwy \quad (4.3b)$$

where,

da = User-supplied drainage area (mi<sup>2</sup>)

gwy = User-supplied or default low-flow yield factor (cfs/mi<sup>2</sup>)

#### 4.3.2 Harmonic Mean Design Flow

If Harmonic Mean Flow is entered at the point of discharge, then:

$$qs = qr_{(hm)} \quad (4.3c)$$

where,

$qr_{(hm)}$  = User-supplied harmonic mean design stream flow at the point of discharge (cfs)

If Qh is not entered at the point of discharge, then:

$$qs = 7.43 \times (qr_{(7-10)})^{.874} \quad (4.3d)$$

where,

$qr_{(710)}$  = User-supplied Q7-10 design stream flow (4.3a) or Q7-10 design stream flow calculated by the TMS (4.3b)

### 4.3.3 Special Conditions

If the user enters a potable water supply intake, then:

$Q_s$  = Entered or calculated Stream flow at the PWS minus the PWS intake flow

This flow is only used for PWS parameters.

If the point of first aquatic life use is not the current reach, then:

$Q_s$  = Entered or calculated Stream flow at the end of the reach (i.e. at the point of first use)

This flow is used for AFC and CFC calculations.

The equations used to determine the stream flow are the same as shown above. However, the stream flow used for evaluation purposes is the stream flow at the specified PWS or point of first use, instead of at the discharge.

## 4.4 Discharge Analysis Flow ( $qd$ )

The discharge analysis flow,  $qd$ , is used to compute the allowable load for each parameter. This value is the design discharge flow.

$$qd = qd_{design} \times 1.547 \quad (4.4a)$$

where,

$qd_{design}$  = User-supplied design discharge flow (mgd)  
1.547 = Conversion from mgd to cfs

## 4.5 Partial Mixing Factor ( $yc$ )

Depending on what data are entered by the user, partial mixing (mix) factors ( $yc$ , PMFs) can be estimated in a variety of ways. If a mix factor is entered for each criterion, then the value is used directly. If complete mix times (CMTs) are entered instead of mix factors, then they are used to compute PMFs. If neither are entered, then the PMFs are estimated by first determining the complete mix time. In this case, the complete mix time is computed using the width, depth and slope of the stream. The latter may be entered directly or computed using the default equations. The applicable equations are presented below assuming that no optional inputs are entered.

#### 4.5.1 Reach Slope (sl)

The reach slope,  $sl$ , can be entered directly. Where not entered directly, it is calculated using the equation below.

If the user enters slope directly, then:

$$sl = slr \tag{4.5.1a}$$

where,

$slr$  = User-supplied slope (ft/ft)

If the user does not enter the slope, then:

$$sl = \left( \frac{elev_i - elev_{i+1}}{[rmi_i - rmi_{i+1}] \times 5280} \right) \tag{4.5.1b}$$

where,

$elev_i$  = User-supplied elevation at the Point of Discharge (ft)  
 $elev_{i+1}$  = User-supplied elevation at the End of Reach 1 (ft)  
 $rmi_i$  = User-supplied river mile at the Point of Discharge (mi)  
 $rmi_{i+1}$  = User-supplied river mile at the End of Reach 1 (mi)  
5280 = Conversion from miles to feet

#### 4.5.2 Reach Depth (d)

The reach depth,  $d$ , can be entered directly. If not, it is estimated in a number of ways, depending on what other information was entered. For example, if width is entered, then depth is computed based on the entered width.

For reach depth the possible combinations are presented below. Only one is selected.

If the user enters the depth, then:

$$d = dr \tag{4.5.2a}$$

where,

$dr$  = User-supplied depth (ft)

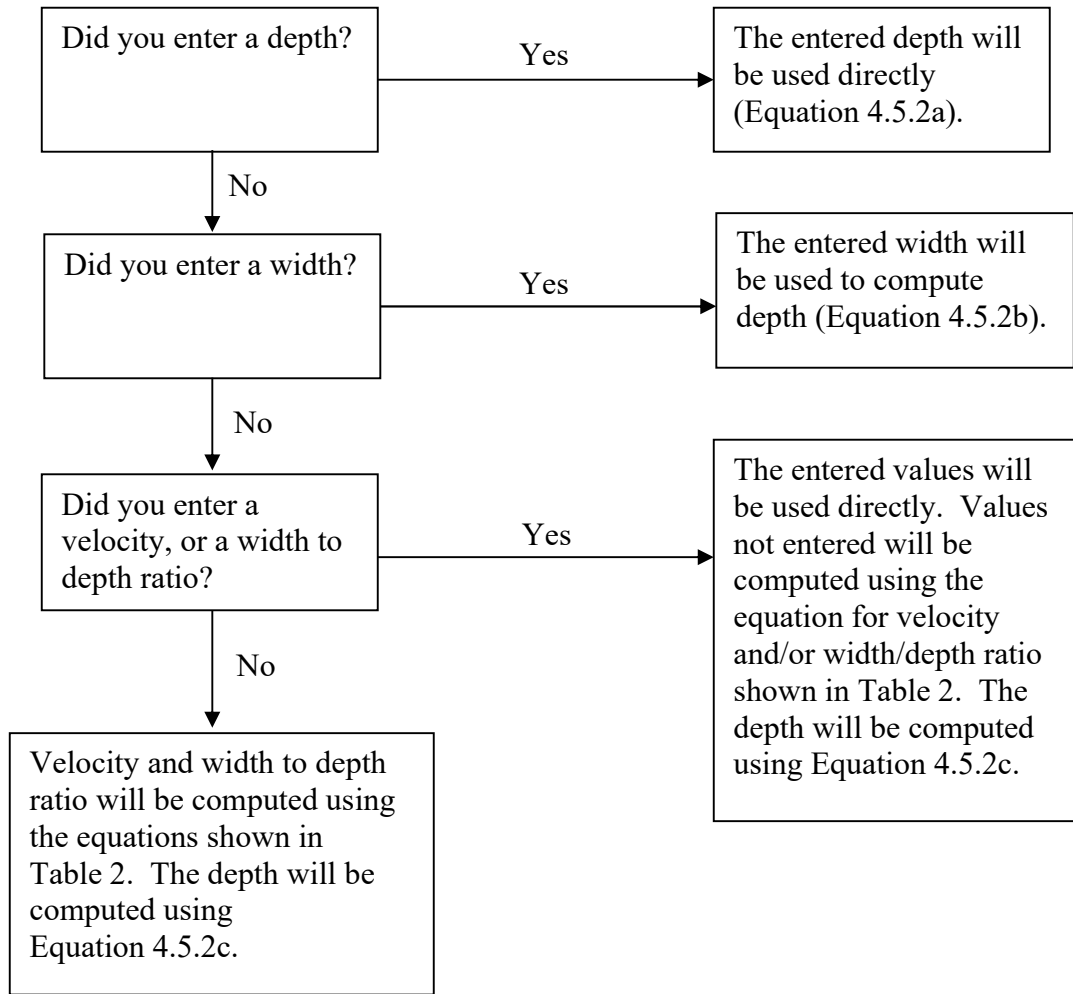
If the user enters reach width, then:

$$d = \left( \frac{qs + qd}{v \times w} \right) \tag{4.5.2b}$$

where,

qs	=	Design stream flow from equations in Section 4.3 (cfs)
qd	=	Discharge analysis flow from equation 4.4a (cfs)
v	=	DEP Velocity Equation or entered by the user (ft/sec)
w	=	User-supplied width (ft)

**Figure 1: Determining Reach Depth**



If the user does not enter width, but enters velocity and/or width/depth ratio, then:

$$d = \sqrt{\left( \frac{[qs + qd]}{[v \times w\_d]} \right)} \tag{4.5.2c}$$

where,

- qs = Design stream flow from equations in Section 4.3 (cfs)
- qd = Discharge analysis flow from Equation 4.4a (cfs)
- v = DEP Velocity Equation or entered by the user (ft/sec)
- w\_d = DEP Width/Depth Equation or entered by the user (dimensionless)

If the user does not enter any other optional data, then:

Use Equations 4.5.2c & 4.5.3d

### 4.5.3 Reach Width (w)

The reach width, w, can be entered directly. If it is not entered directly, it is estimated in a number of ways. This will depend on what other information was entered. For example, if the user enters depth, then width is computed based on the entered depth.

For reach width the possible combinations are presented below. Only one is selected.

If the user enters the width, then:

$$w = wr \tag{4.5.3a}$$

where,

wr = User-supplied width

If the user enters reach depth, then:

$$w = \frac{(qs + qd)}{(v \times d)} \tag{4.5.3b}$$

where,

qs = Design stream flow from equations in Section 4.3 (cfs)  
qd = Discharge analysis flow from Equation 4.4a (cfs)  
v = DEP Velocity Equation or entered by the user (ft/sec)  
d = User-supplied depth (ft)

If the user does not enter depth, but enters velocity and/or width/depth ratio, then:

$$d = \sqrt{\left(\frac{[qs + qd]}{[v \times w\_d]}\right)} \tag{4.5.3c}$$

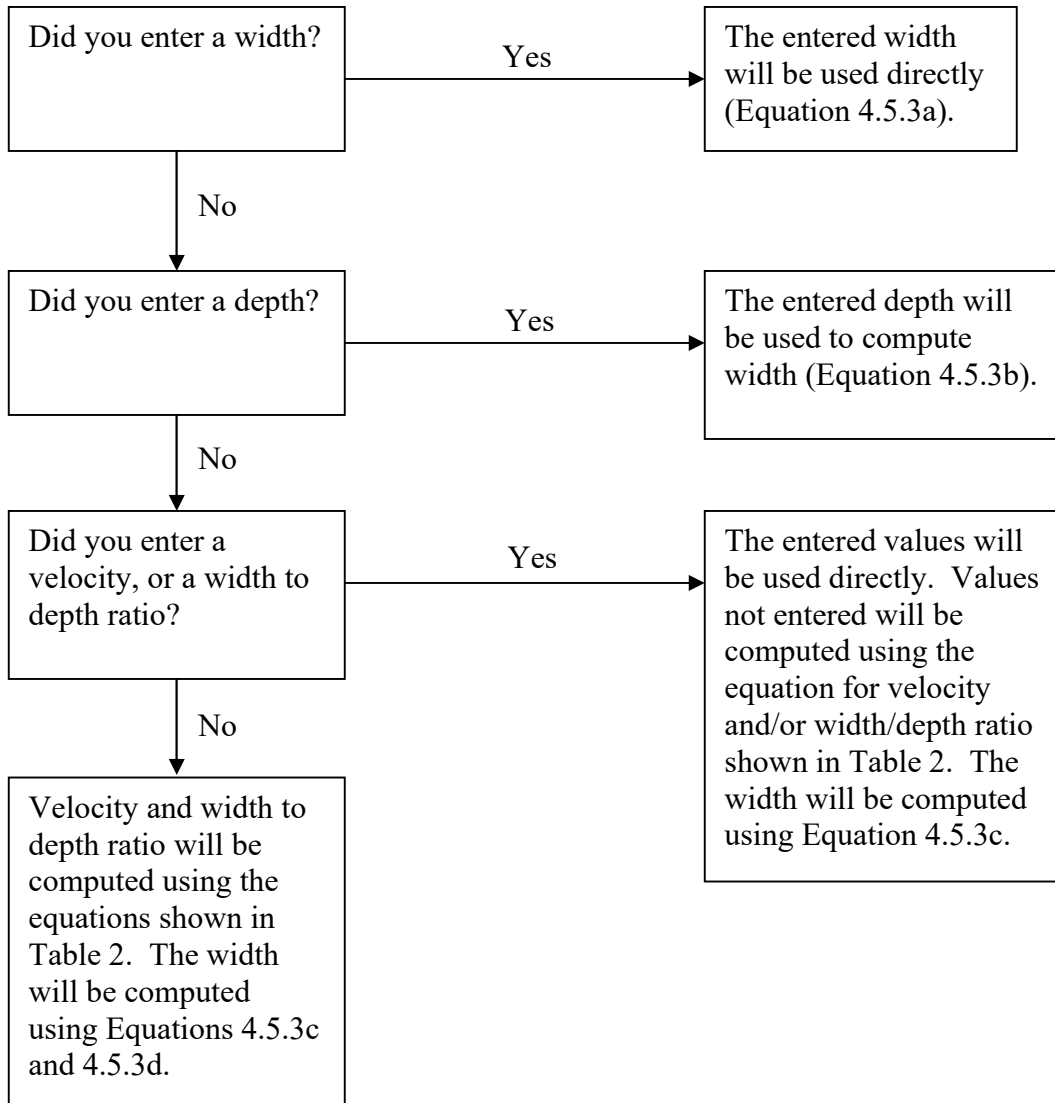
and

$$w = (d \times w\_d) \tag{4.5.3d}$$

where,

qs = Design stream flow (cfs)  
qd = Discharge analysis flow (cfs)  
v = DEP Velocity Equation or entered by the user (ft/sec)  
w\_d = DEP Width/Depth Equation or entered by the user (dimensionless)

**Figure 2: Determining Reach Width**



If the user does not enter any other optional data, then:

Use Equations 4.5.3c & 4.5.3d

**Table 2: Width, Depth, Width/Depth Ratio, and Velocity Computations**

		When the user enters					
		Width (w)	Depth (d)	W/D Ratio (w_d)	Velocity (v)	Width (w) & Depth (d)	Nothing
<b>TMS computes</b>							
	Velocity (v)	Velocity Equation (1)	Velocity Equation (1)	Velocity Equation (1)	-	(qs + qd)/(w x d)	Velocity Equation (1)
	W/D Ratio (w_d)	(w / d)	(w / d)	-	W/D Equation (2)	(w / d)	W/D Equation (2)
	Depth (d)	(qs+qd)/(v×w)	-	(qs + qd) / (v × w_d) <sup>-5</sup>	(qs + qd) / (v × w_d) <sup>-5</sup>	-	(qs + qd) / (v × w_d) <sup>-5</sup>
	Width (w)	-	(qs+qd)/(vxd)	(d×w_d)	(d×w_d)	-	(d×w_d)

$$(1) \text{ Velocity Equation} = \frac{(A \times (qs + qd)^{0.56} \times (sl \times 5280)^B \times da^C)}{16.3636}$$

	da > 500 sq.mi.	da < 500 sq.mi.
A	1.64	2.62
B	0.055	0.083
C	-0.15	-0.22

and,

$$(2) \text{ W/D Equation} = \left[ -0.073 + 0.141 \times (qs + qd)^{-0.077} + 0.06 \times da^{-0.445} + 0.0001 \times (5280 \times sl)^{1.075} \right]^{-1.429}$$



where,

qs = design stream flow

qd = discharge analysis flow

sl = reach slope

da = cumulative drainage area

w\_q7-10 = width computed at Q7-10 design flow

d\_q7-10 = depth computed at Q7-10 design flow

v-q7-10 = velocity computed at Q7-10 design flow

q7-10 = design stream flow at Q7-10

qh = design stream flow at harmonic mean condition

(Note: The constant 16.3636 is used to change units from mi/day to feet/sec)

<b>Computing width, depth and velocity at the Qh flow condition</b>
---

<u>If width, depth and/or velocity are not entered at Harmonic Mean Flow, then:</u>
---

Width = w_q7-10
-----------------

Depth = d_q7-10 × [(qh+qd)/(q7-10+qd) <sup>0.44</sup>
---

Velocity = v_q7-10 × [(qh*qd)/(q7-10*qd)] <sup>0.56</sup>
---

Note:
-------

The purpose of these equations is to maintain continuity with the relationship that Q = W x D x V, where some or all of these values may be entered by the user
---

#### 4.5.4 Complete Mix Time (cmt)

Complete mix time, cmt, can be entered directly, or estimated based on the width, depth, design stream flow, discharge analysis flow, and slope of the stream at the point of discharge.

If the user enters the complete mix time, then:

$$cmt = cmt_r \quad (4.5.4a)$$

where,

cmtr = User-supplied complete mix time (minutes)

If the user does not enter the complete mix time, then:

$$cmt = \frac{0.28 \times (w \times (qs / (qs + qd)))^2}{0.6 \times d \times (\sqrt{32.2 \times d \times sl}) \times 60} \quad (4.5.4b)$$

where,

qs = Design stream flow  
qd = Discharge analysis flow  
sl = Stream slope  
d = Stream depth  
w = Stream width

**Note:** The constant 0.28 in Equation 4.5.4b represents the degree of uniformity expected in the channel that also produces a complete mix relationship with the variability in instream concentration of 20 percent. The value of 0.6 represents the amount of discharge diffusion associated with an average discharge.

#### 4.5.5 Partial Mixing Factor (yc)

The partial mix factor, PMF or yc, represents the fraction of design stream flow (qs) that mixes with the discharge at the criteria compliance time (tc). This factor may be estimated using results from an instream mixing study. Separate values are determined for each criterion and can be entered directly by the user except for the PWS PMF.

If the user enters the partial mix factor, then:

$$yc = ycr \quad (4.5.5a)$$

where,

ycr = User-supplied partial mix factor (decimal percent)

If the user does not enter the partial mix factor, the equation for computing it is:

$$yc = \min \left[ \sqrt{tc/cmt}, 1 \right] \quad (4.5.5b)$$

where,

tc = Criteria compliance time (minutes)

cmt = Complete mix time (See Section 4.5.4) (minutes)

min[ ] is the minimum of the two values or expressions separated by a comma

#### 4.5.6 Special Conditions

If the user enters a PWS withdrawal at the End of Reach 1, for the PWS parameters only:

$$yc = \min [yc\text{-PWS}, 1] \quad (4.5.6.a)$$

where,

yc-PWS = the partial mix factor at the PWS withdrawal

where,

$$yc\text{-PWS} = (TT_{PWS}/cmt)^{0.5}$$

where

TT<sub>PWS</sub> = travel time from the discharge to the PWS withdrawal (Point of Discharge to the End of Reach 1)

Unless the user entered a partial mix factor for THH criteria, in which case the user defined ycr is used.

If FAL criteria do not apply at the point of discharge, then at the point of first aquatic life use:

$$yc = 1 \quad (4.5.6b)$$

#### 4.6 Instream Pollutant Fate Coefficient (k, Fate Coeff)

The instream pollutant fate coefficient, k, may be estimated by conducting the appropriate field surveys. If it is not entered, the program assigns the value of zero (0) for each decay coefficient.

#### 4.7 Factor of Safety (FOS)

The factor of safety, FOS, may be entered into the program. If it is not entered, the program assigns the default value of 0.

#### 4.8 Hardness & pH (Used for computing water quality criteria)

If the user enters the analysis hardness or pH then:

$$xc = \text{Analysis Hardness or Analysis pH} \quad (4.8a)$$

where,

$$\begin{aligned} \text{Analysis Hardness} &= \text{User-supplied analysis hardness} \\ \text{Analysis pH} &= \text{User-supplied analysis pH} \end{aligned}$$

If the user enters the discharge and stream conditions, then:

$$xc = \frac{((yc \times qs \times xs) + (qd \times xd))}{((yc \times qs) + (qd))} \quad (4.8b)$$

where,

$$\begin{aligned} qs &= \text{Net stream flow at current reach (cfs)} \\ qd &= \text{Discharge analysis flow (mgd)} \\ yc &= \text{Partial mix factor for each criterion} \\ xs &= \text{User-supplied stream hardness (mg/L) or pH} \\ xd &= \text{User-supplied discharge hardness (mg/L) or pH} \end{aligned}$$

**Note:** pH is converted to hydrogen ion concentration and the mass-balance is computed. The resulting value is then converted back to pH units.

## 5 Determining Final Effluent Limitations

In the previous section, the equations were presented that compute each WLA. These allocations have a specific duration associated with them. As can be seen from the box below, a separate allocation is done for each water quality criterion.

Criteria	Duration	Wasteload Allocation
AFC	1 hour	1-hour
CFC	4 days	4-day

THH	30 days	Long-term average
CRL	Long-term average	Long-term average

None of these can be placed directly into the NPDES permit. This is because the NPDES permit requires an average monthly and maximum daily effluent limit. Therefore, some of these allocations must be translated and compared at intermediate steps in the process so that the most stringent limit can end up in the NPDES permit.

The recommended procedures involve the use of statistics and, particularly, include the effluent variability (coefficient of variation) for each parameter. These procedures are contained in the TSD. In particular, the reader is referred to TSD Chapter 5, Pages 102-103 for determining the average monthly limit. The reader is referred to TSD Chapter 5, Page 106 for determining the maximum daily limit.

WLAs are determined for each applicable criterion using Equation 4. WLAs for AFC and CFC are first converted to long-term averages, and then to 30-day averages, while WLAs for THH and CRL are treated as 30-day averages directly. These four 30-day average values (or as many of them as are appropriate) are then compared to determine which value is the most stringent. This most stringent value is the recommended effluent limitation.

### 5.1 Determining the Average Monthly Effluent Concentration for Aquatic Life Criteria

If the WLA is for AFC, then:

$$LTAMULT = \exp\left(0.5 \times 1n(cvh^2 + 1) - z \times \sqrt{1n(cvh^2 + 1)}\right) \quad (5.1a)$$

Compute the long-term average for acute fish criterion:

$$lta\_afc = wla \times LTAMULT \quad (5.1b)$$

where,

- wla = WLA for AFC criterion (µg/L)
- cvh = Discharge hourly coefficient of variation (dimensionless)  
(Default = 0.5)
- cvd = Discharge daily coefficient of variation (dimensionless) (Default = 0.5)
- z = Z-Score = 2.326 @ 99th percentile

If the WLA is for CFC, then:

$$LTAMULT = \exp\left(0.5 \times 1n(cvd^2/4 + 1) - z \times \sqrt{1n(cvd^2/4 + 1)}\right) \quad (5.1c)$$

And

$$lta\_cfc = wla \times LTAMULT \quad (5.1d)$$

where,

wla = WLA for CFC criterion (µg/L)  
 cvd = Discharge daily coefficient of variation (dimensionless) (Default = 0.5)  
 z = Z-Score = 2.326 @ 99th percentile

Determine More Stringent Long-Term Average

$$gov\_lta = \min [ lta\_afc, lta\_cfc ] \quad (5.1e)$$

where,

gov\_lta = Most stringent (governing) LTA  
 min[ ] is the minimum of the two values or expressions separated by a comma

Convert to an Average Monthly Effluent Concentration

$$AMLMULT = \exp \left( z \times \left( \sqrt{1n(cvd^2/n + 1)} \right) - 0.5 \times 1n(cvd^2/n + 1) \right) \quad (5.1f)$$

$$AML_{aquatic} = gov\_lta \times AMLMUL \quad (5.1g)$$

where,

cvd = Discharge daily coefficient of variation (dimensionless) (Default = 0.5)  
 z = Z-Score = 2.326 @ 99th percentile  
 n = Number of samples per month in NPDES permit (4, 8, 12, 20, or 30)

**5.2 Determining the Average Monthly Limit for Human Health Criteria**

If the WLA is for THH or CRL then:

$$AMLMULT = 1.0 \quad (5.2a)$$

Convert to an Average Monthly Effluent Concentration

$$AML_{human} = wla \times AMLMUL \quad (5.2b)$$

**5.3 Determining the “Governing” Water Quality-Based Effluent Limit (WQBEL)**

$$WQBEL = \min [ AML_{afc}, AML_{cfc}, AML_{thh}, AML_{crl} ] \quad (5.3)$$

Limits below the most stringent criterion will not be recommended. If the calculated WQBEL is below criteria, the recommended limit will be the most stringent criteria:

$$WQBEL = \text{most stringent criterion} \quad (5.4)$$

If the background concentration is greater than criteria, the recommended effluent limit will be set to criteria.

## 5.4 Calculate the Maximum Daily Effluent Limit

### 5.4.1 Calculate Ratio of Max Daily/Final Limit

$$R = \frac{\exp \left[ z \times \sqrt{\ln(cvd^2 + 1)} - 0.5 \times \ln(cvd^2 + 1) \right]}{\exp \left[ z \times \sqrt{\ln(cvd^2 / n + 1)} - 0.5 \times \ln(cvd^2 / n + 1) \right]} \quad (5.4.1)$$

where,

- cvd = Discharge daily coefficient of variation (Default = 0.5)
- z = Z-Score = 2.326 @ 99th percentile
- n = Number of samples per month in NPDES permit (4, 8, 12, 20, or 30)

### 5.4.2 Calculate Maximum Daily Limit

$$C_{MaxDaily} = FinalLimit \times R \quad (5.4.2a)$$

where,

- CMaxDaily = Calculated maximum daily effluent limit (µg/L)
- Final Limit = Final average monthly effluent limit (µg/L)
- R = Ratio of calculated maximum daily effluent limit to final average monthly effluent limit (dimensionless)

If the AFC AML is below the water quality criteria and the effluent is AFC governed, the MDL will be based on the calculated WQBEL for the parameter if it less stringent than the water quality criteria.

### 5.4.3 Calculate IMAX

The instantaneous maximum concentration (IMAX) is calculated as follows, if applicable:

$$C_{IMAX} = Final\ Limit * 2.5$$

Where,

C<sub>IMAX</sub> = Calculated IMAX limit (µg/L)

#### 5.4.4 Calculate Mass Based Limits

If an AML is determined for a pollutant, then the mass-based AML will be calculated as:

$$M_{AML} = AML * 8.34 * qd\_design$$

where

$M_{AML}$	=	Mass-based AML (lb/d)
8.34	=	Conversion factor (L/(mg-million gal))
$qd\_design$	=	User-supplied design discharge flow (mgd)

If a MDL is determined, then a mass-based MDL is calculated as:

$$M_{AML} = CMaxDaily * 8.34 * qd\_design$$

#### 5.5 Recommended Effluent Limits

The TMS makes recommendations for effluent limitations in permits if RP is demonstrated.

RP is demonstrated where the effluent concentration equals or exceeds 50% of the WQBEL. The TMS will recommend monitoring of the parameter if the effluent concentration of non-conservative pollutants is between 25% - 50% of the WQBEL or if the effluent concentration for conservative pollutants is between 10% - 50% of the WQBEL.



## Appendix A Derivation of Mixing Relationships

EPA's *Technical Support Document for Water Quality-Based Toxics Control*<sup>(1)</sup> contains the following general purpose equation for determining complete mix distance for a discharge to a free-flowing stream:

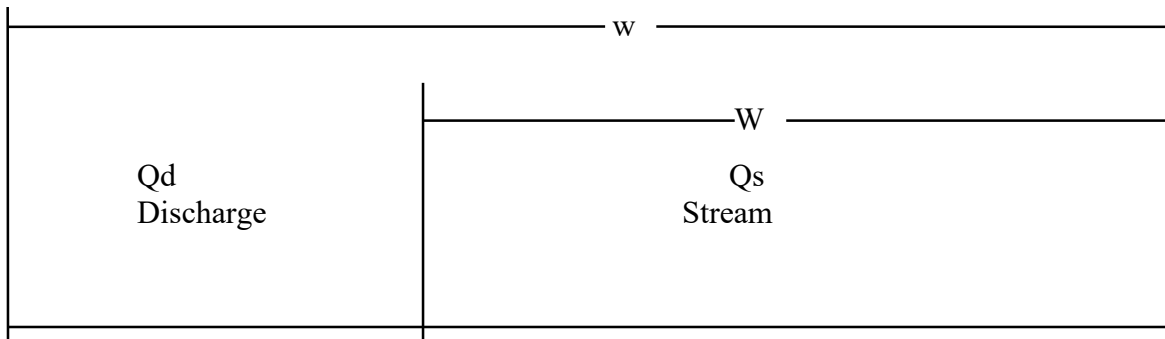
$$X_m = \frac{m \times w^2 \times u}{D_y} \quad (A1a)$$

where,

- $X_m$  = Distance to complete mix
- $m$  = A parameter whose value defines the degree of uniformity used to define complete mix
- $w$  = Stream width
- $u$  = Flow velocity for critical design condition
- $D_y$  = Lateral dispersion coefficient

The above equation is for ambient mixing only. It does not consider discharge induced mixing. Therefore, it provides a conservative estimate of complete mix time.

The EPA ambient mixing equation is an empirical relationship designed primarily for conditions where the discharge flow to stream flow ratio is very small.<sup>(2)</sup> In many discharge situations found in Pennsylvania this is not the case. Because of this, an adjustment of stream width has been made to the mixing equation. In essence, this adjustment assumes that before ambient mixing begins, the discharge flow is within a defined rectangular channel, as illustrated in the figure below.



Thus the width of the stream is adjusted using the following relationship:

$$W = w \times (Q_s / (Q_s + Q_d)) \quad (A1b)$$

where,

- W = Adjusted width of the stream channel
- w = Actual/computed width of the effected stream channel
- Qs = Total stream flow (cfs) including the addition of flow augmentation from upstream discharges
- Qd = Analysis discharge flow (cfs) for the current discharge being evaluated.

This adjustment avoids obtaining overly long complete mix time for situations where the discharge flow represents a significant portion of the total system flow. The adjustment is made in Equation 4.5.4b .

For any set of design conditions, an estimate of complete mix time (i.e., travel time from point of discharge to point of complete mix) may be obtained by dividing distance by velocity. Therefore,

$$\frac{X_m}{u} = t_m = \frac{m \times W^2}{D_y} \quad (A2)$$

where,

$t_m$  = complete mix time

In the TMS, complete mix travel time is expressed in minutes. Another basic assumption made in the TMS is that the free-flowing stream consists of a uniform rectangular channel, whose length is at least equal to  $X_m$ . In such a channel, the amount of flow Q is equal to:

$$Q = u \times W \times D \quad (A3)$$

where,

D = depth of channel

If it is assumed that velocity (u) and depth (D) are held constant, then the amount of flow (Q') in any portion of the channel (W') is:

$$Q' = u \times W' \times D \quad (A4)$$

where,

W' = portion of stream channel width

Q' = partial stream flow at width W'

By using equations (2) and (4), one can estimate the amount of time it takes a discharge to mix with a given portion of the stream, and the ratio of this (partial mix) time to the complete mix time.

$$t' = \frac{m \times W'^2}{D_y} \quad (A5)$$

$$\frac{t'}{t_m} = \frac{m \times W'^2}{D_y} \times \frac{D_y}{m \times W^2} = \frac{W'^2}{W^2} = \left(\frac{W'}{W}\right)^2 \quad (A6)$$

Since, based on equation (A4), W and W' are proportional to Q and Q' respectively, we have:

$$\frac{t'}{t_m} = \left(\frac{Q'}{Q}\right)^2 \quad (A7)$$

$$\frac{Q'}{Q} = \sqrt{\left(\frac{t'}{t_m}\right)} \quad (A8)$$

Equation (A8) is the basic equation used in the TMS to determine the amount of stream flow (Q') which mixes with a discharge in a given time (t'). In the TMS, (t') is set equal to the maximum criteria compliance times for each of the criteria being evaluated. These are listed in the Table below:

Criteria	Maximum Compliance Time Used in the TMS
AFC	15 minutes
CFC	12 hours
THH	12 hours, or travel time to the nearest downstream water supply
CRL	12 hours

Since (Q') cannot be greater than Q, a boundary condition is added such that:

$$\frac{Q'}{Q} = \text{minimum} \left[ \sqrt{\left(\frac{t'}{tm}\right)}, 1 \right] \quad (A9a)$$

In the TMS, this equation is modified slightly in order to solve for the analysis stream flow at the point of compliance. Thus, the equation is written:

$$Q' = Q \times \text{minimum} \left[ \sqrt{\left(\frac{t'}{tm}\right)}, 1 \right] \quad (A9b)$$

where,

Q' = Analysis stream flow at the point of compliance

The relationship:  $\text{minimum} \left[ \left(\frac{t'}{tm}\right)^{.5}, 1 \right]$  is known in the TMS as the partial mix factor.

If the compliance time (t') for the criteria being evaluated is less than the complete mix time (tm), then the stream flow used in the analysis will be less than the total stream flow available for dilution. This

results in a partial mix analysis. If the compliance time ( $t'$ ) for the criteria being evaluated is greater than or equal to the complete mix time ( $t_m$ ), then complete mix is assumed at the point of discharge.

### References

- (1) Page 36, Technical Support Document for Water Quality-Based Toxics Control, U.S. EPA, September 1985.
- (2) Telephone Conversation with Professor G. Jirka, Cornell University, January 1988.

## Appendix B Input Data

### *Stream Worksheet*

**Stream Code** - Stream code is a required input. Every stream in Pennsylvania has a stream code associated with it. Stream codes are most easily obtained from the *Pennsylvania Gazetteer of Streams* (3900-BK-DEP2929) or from GIS software. The model requires the user to select the stream code before entering the input data form.

**RMI** (River Mile Index) - RMI is a required input. RMIs typically start at 0.0 at the mouth of each stream and proceed upstream to the source of the stream. The upstream RMI is the Point of Discharge. This RMI will define the top of the reach to be modeled. The downstream RMI is the End of Reach 1 and may be set to any other downstream RMI where the user knows or can measure the elevation and drainage area. Generally, the model will use only the flow, drainage area and elevation data from the Point of Discharge to the End of Reach 1 when calculating important hydrodynamic parameters. RMIs may be measured using Geographic Information System (GIS) software, a map wheel or dividers. RMIs should not be set to very small or very precise values – round off RMIs to the nearest 0.01 river mile. A RMI of zero (0.0) will be accepted by the model, and can be used to describe the mouth of the stream.

**Elevation** - Elevation is a required input at each RMI and is expressed in feet above mean sea level. Elevations typically decrease as you travel downstream. If you enter an elevation at End of Reach 1 that is higher than one at the Point of Discharge, the model will generate an error. An accurate input for elevation is important because the model normally will calculate the slope of the stream channel based on the elevation that you input. Stream channel slope will have a direct effect on the mixing calculations and the recommended effluent limits. The slope calculated based on elevation inputs can be overridden by directly inputting the channel slope on the Stream worksheet, but even if you input the slope of the channel as an override, the model will still require that you input the elevation. The elevation may be determined using a topographic map or GIS software.

**Drainage Area** - Drainage Area is a required input and is expressed in square miles. Each point in a stream has an associated drainage area – the geographical area that drains to (is uphill of) that point in the stream. The drainage areas typically increase as you travel downstream, so the End of Reach 1 should have a higher drainage area than the Point of Discharge. The model will generate an error if the End of Reach 1 drainage area is less than the Point of Discharge drainage area. An accurate input for Drainage Area at each node is important, because the TMS may use your input of drainage area to estimate the stream flow at low-flow (Q7-10) and normal flow (Qh) conditions. It is important that the model get the best estimate of the stream flows under these conditions as you can manage, because stream flow is important in determining effluent limits. The Q7-10 and Qh flows that the model calculates based on drainage area inputs may be overridden by directly entering the stream flow or the tributary flow in the Stream worksheet. But the model will still require that you input the drainage area, because even though the model will allow you to override the calculation of stream flow, the drainage area values normally will still be used to configure the stream channel and satisfy continuity (i.e., width, depth, velocity). This process can affect the WLA results. The drainage area of a stream node may be determined using a topographic map and planimeter or GIS software.

**Slope** - Slope is an optional input. Slope is the slope of the stream channel expressed in feet of vertical descent per foot of horizontal travel downstream. Slopes typically are numbers in the range 0.01

to 0.0001. The default value is an empty cell, which tells the model to calculate the slope for the stream reach based on the elevations entered for the RMIs. If you enter the slope directly, the model will use this slope instead of the calculated value. Note that, while RMI, elevation and drainage area refer to conditions at the upstream location of a reach, the slope refers to the stream channel slope along the length of the reach until the downstream location.

**PWS Withdrawal** (Potable Water Supply Withdrawal) - PWS Withdrawal is an optional input expressed in units of millions of gallons per day (MGD). PWS Withdrawal refers to a point on the stream where water is withdrawn for human consumption. When you enter a positive value for PWS Withdrawal, you are saying that potable water is removed from the stream at that RMI, and the model will balance the stream flow to account for the consumptive water use. PWS Withdrawal must be entered for the End of Reach 1— otherwise it will have no effect. If a downstream PWS exists within 12 hours travel time (at Q7-10), it should always be entered into the analysis.

The model treats THH criteria differently when a downstream PWS is entered. THH criteria will be evaluated at the first downstream PWS, the point at which CMT occurs, or 12 hours, whichever occurs first. If the PWS occurs first, the travel time between the discharge and the PWS becomes the CCT, and the PMF will be calculated based on this CCT. The model will use the stream flow at the Point of Discharge as the flow available for mixing. Under some conditions, it may be appropriate to override this default method for determining the PMF. For example, if the PWS intake is on the opposite bank from the discharge, and the CMT is downstream of the PWS, the user should consider forcing complete mix at the PWS. To accomplish this, the user could set the THH PMF to 1 to force complete mixing at the point of discharge, or run the parameters with THH criteria in a separate analysis and set the CMT for Q7-10 or Qh equal to the travel time to the PWS. The results would then be compared to those produced by leaving that PWS out of the analysis in case normal mixing or another downstream PWS is the limiting condition. On a large river with the PWS intake located on the opposite bank from and just downstream of the discharger, it may be obvious that the discharge plume could not impinge upon the intake. In this case, the user may justify leaving the PWS out of the analysis altogether. The presence of a PWS has no effect on AFC, CFC or CRL criteria.

Another purpose of this input field is to allow for the evaluation of certain water quality criteria that appear in § 96.3 (d), with numeric criteria listed in § 93.7, Table 3. These are fluoride, phenolics, total dissolved solids (TDS), nitrite plus nitrate (NO<sub>2</sub>-NO<sub>3</sub>), sulfate, and chloride. The water quality criteria for these six parameters are evaluated only at PWS withdrawal points. The water quality criteria for all other parameters apply anywhere in the river or stream, based on the computed CCT. If your discharge flow contains any of these six parameters in concentrations exceeding the associated water quality criteria, the user should determine where the nearest downstream PWS withdrawal is and enter it in the TMS. The TMS will then be able to evaluate the concentration of the pollutant at the PWS withdrawal and recommend effluent limits accordingly. Note that almost any discharge will contain TDS, and you should consider adding TDS to your analysis only if the concentration in the discharge exceeds the § 93.7 limit of 500,000 µg/L for TDS. For these six parameters only, the model will use the stream flow minus the PWS flow to determine the net stream flow available for mixing.

**Apply Fish Criteria** - This is a drop-down menu that allows you to turn off aquatic life criteria (AFC and CFC). The default value is Yes (aquatic life criteria do apply). If you select No at the Point of Discharge, you are telling the model it is OK to exceed aquatic life criteria in that reach. The model will then calculate AFC and CFC WLAs based on the End of Reach 1 if aquatic life criteria do apply (if 'Yes' is selected). The model sets PMF to 1 for AFC and CFC at the End of Reach 1 in which aquatic

life criteria do apply. The model will use the stream flow from the End of Reach 1 rather than the stream flow at the Point of Discharge when calculating AFC and CFC WLAs.

You need a firm basis to turn off water quality criteria for a stream segment and most likely this will involve § 95.5. This section provides for stream segments that are so impacted by acid mine drainage that aquatic life essentially is excluded from that stream segment. DEP Water Quality Assessment staff would need to concur with any determination to disregard water quality criteria in a stream segment.

## **Flow**

**General Information:** These data describe the hydrodynamic characteristics of the stream at two flow conditions Q7-10 (7-day, 10-year flow, which represents low flow conditions) and Qh (harmonic mean flow, which represents normal flow conditions). The model needs to calculate how much stream flow is available for mixing with the discharge flow, and then how much of the available stream flow does mix with the discharge flow at the point where the various water quality criteria are evaluated. The majority of inputs for the stream flow data are optional, except the low flow yield (LFY) which can be a default of 0.1 cfs/mi<sup>2</sup>. If you don't enter anything in those cells, the model will use or calculate default values based on the RMI, drainage area and elevation data that you entered. But if you have data on the measured or previously established Q7-10, Qh, or any of the channel characteristics (width, depth, velocity, etc.) you should enter them in the Stream worksheet. Since mixing and dilution are the primary processes that affect the WLA process in the TMS, it is important to assure that you have a good estimate of the Q7-10 flow. The default Low Flow Yield value of 0.1 cfs/mi<sup>2</sup> should be used only as a last resort. Be careful that the data that you enter is representative of the applicable flow condition. You don't want to enter the depth of the stream channel that was measured under normal stream flow conditions as the Q7-10 depth.

The TMS will first estimate the flow, velocity, stream width, and stream depth at Q7-10, and then estimate the flow, velocity, stream width, and stream depth at Qh based on the Q7-10 values. You may override any of these values based on known data and the model will make everything else fit. For example, if you enter the Q7-10 flow or the LFY as a known value, you will affect the determination of all the other hydrodynamic characteristics at both Q7-10 and Qh, and you will affect all recommended effluent limits produced by the model. If you enter the Qh flow as a known value, you will affect only the other Qh hydrodynamic characteristics, and you will affect only recommended effluent limits based on CRL as the governing criteria.

**LFY (Low Flow Yield)** - Low Flow Yield is the amount of river flow per square mile of drainage area that the model will use to estimate the Q7-10 in the absence of any other flow inputs. It is expressed in cubic feet per second per square mile (cfs/sq mile), and the default value is 0.1. LFY is an input for Q7-10 only, since it only applies to low stream flow conditions as represented by Q7-10. The recommended effluent limits that the model produces are sensitive to Q7-10, so it is important to enter a site-specific LFY if available for your stream or river. Any value entered for Stream Flow (see below) will override the calculation of Q7-10 based on LFY. Any time the model encounters a location where the user has not entered Stream Flow, it will automatically add flow to the stream based on the increase in drainage area between the upstream and the downstream location.

**Stream Flow** - Stream Flow is the absolute amount of stream flow in cubic feet per second (cfs) that is known to exist at a location. If you make an entry in this field, the model will ignore all other sources of flow (such as LFY), and the stream flow will be set to your input value for the stream location. Discharge flow is considered separately and is not included in stream flow.

**Width/Depth Ratio, Reach Width (feet), Reach Depth (feet), Reach Velocity (feet per second), Reach Travel Time (days)** - Input values of stream width, depth, velocity and travel time define conditions along the entire length of the reach. For example, if you input a width of 100 feet and a depth of 2 feet, the model considers the stream channel to be a rectangular section with those dimensions between the Point of Discharge and End of Reach 1. It will calculate what the velocity and travel time would have to be based on the flow that has been input or calculated, and these values will apply along the length of the reach. Be careful that the data that you enter is representative of the applicable flow condition. You don't want to enter the depth of the stream channel that was measured under normal stream flow conditions as the Q7-10 depth. Also, recognize that you are entering the average value for these characteristics assuming a rectangular cross-section of the stream. You don't want to enter the maximum depth at the center of the stream channel as the average depth.

**Stream Hardness (mg/L) / Stream pH** - These fields allow you to override the default hardness of 100 mg/L and pH of 7. The model will consider these values as representative of natural background conditions, and will set the hardness and pH of the stream flow to these values. The model will then calculate the resultant instream hardness and pH (Analysis Hardness/pH) after mixing with the discharge hardness and pH on a flow-weighted basis. Any entry in the Analysis Hardness/pH input data cells would override this flow-weighted calculation of hardness and pH.

**Analysis Hardness (mg/L) / Analysis pH** - These fields allow you to override the default mixing calculation of the Analysis Hardness/pH, which are the values used to determine hardness and pH-dependent water quality criteria. Normally, the model will consider mixing between the Discharge Hardness/pH and the Stream Hardness/pH in determining the Analysis Hardness/pH. But when you enter data in these cells, you are forcing the Analysis hardness and pH to these values for the entire reach. Analysis hardness and pH are important for certain parameters whose toxicity varies with hardness or pH (most toxic heavy metals and pentachlorophenol). Note that it is the Analysis Hardness/pH values at the Point of Discharge that determine the values that will be used to calculate the toxicity and water quality criterion that will apply for that discharge and parameter. Entries of different hardness/pH values in locations downstream of the discharge will have no effect under most conditions.

### ***Discharge Worksheet***

#### **Discharge Input Data**

**Facility** - This is the name of the discharger, industry, sewage treatment plant, or site that is the source of the pollutants. It is an optional input.

**NPDES Permit Number** - The NPDES permit number should be entered in this field in the format PA1234567 (PA followed by seven numeric characters). Please ensure that you follow this format, including any zeros needed after "PA" to form seven numeric characters. This field, however, will accept any combination of alphanumeric characters up to the field limit.

**Outfall No.** - This is the outfall number for the discharge and is an optional input.

**Evaluation Type** - This is a drop-down menu to choose the type of discharge (Major Sewage/Industrial Waste or Custom/Additives) but is an optional input.

**Wastewater Description** - is an optional input where you can describe the wastewater.



**Design Flow (Discharge)** - This field allows you to enter the flow rate of the discharge (source of the pollution) in millions of gallons per day (mgd). This is a required field. The model uses the discharge flow rate to calculate recommended effluent limits.

**Discharge Hardness (mg/L) / Discharge pH** - These fields contain the hardness/pH of the discharge flow and are required inputs. Normally, the model will consider mixing between the Discharge Hardness/pH and the Stream Hardness/pH in determining the Analysis Hardness/pH. This calculation may be overridden by entering the Analysis Hardness/pH directly (see previous discussion). Analysis hardness and pH is important for certain parameters whose toxicity varies with hardness or pH (most toxic heavy metals and pentachlorophenol).

**Partial Mix Factors (AFC, CFC, THH, and CRL PMFs)** - The partial mix factor tells you how much of the stream has mixed with the discharge flow at the CCT, which is the point at which compliance with water quality criteria is evaluated. A higher PMF means that there has been more dilution of the discharge flow, which will result in higher recommended effluent concentrations. An input to any of these fields overrides the normal mixing calculations and forces the partial mix factor to the input value for the applicable water quality criterion. These input values should be used with caution. Any input to these fields forces the PMF for those criteria to the input value at the point of discharge. The PMF remains at the input value for the entire simulation – no further downstream mixing is calculated. For example, entering a THH PMF of 1 will force complete mixing at the point of discharge for THH criteria only. This renders any reported values of CCT and CMT for THH criteria irrelevant (since the only purpose of these values is to calculate the PMF). AFC, CFC and CRL calculations would be unaffected.

Generally, it is best to let the model determine the appropriate PMF, and you should override these values only if site-specific data exist or you want to perform “what-if” calculations. The PMF is optional and the cell can be left empty, which means the model will calculate the appropriate PMF. Only positive decimal values between 0 and 1 should be entered. A PMF of 1 means complete mix of the discharge and stream, and 0.01 means that the discharge has mixed with only 1 percent of the stream. For all water quality criteria, recommended effluent limits are sensitive to changes in the PMF. If the governing criterion is CRL or THH, there is a direct linear relationship between PMF and recommended effluent limits (i.e., doubling the PMF results in doubling of the recommended effluent limits). If the governing criterion is AFC or CFC, increasing the PMF normally results in a lesser increase in effluent limits.

**Complete Mix Times (CMTs)** - These fields allow you to override the calculated CMT for Q7-10 or Qh conditions with an input value. This value is expressed in minutes and defines the time at which the discharge has completely mixed with the stream. Normally, you would need the results of a site-specific mixing study to justify entering an override value for CMT. Dischargers may want to perform such a study, because the TMS does not consider turbulent mixing effects at the point of discharge, and the discharger can get credit for additional mixing if it can be quantified. But it may be difficult to translate the results of a mixing study at typical flow conditions to Q7-10 (low flow) conditions. Input values of Q7-10 CMT will affect only AFC, CFC and THH-governed parameters and input values of Qh CMT will affect only CRL-governed parameters. Input values of CMT directly influence the model’s calculation of PMF. If you input a CMT that is less than that calculated by the model, the model would calculate higher PMFs for affected criteria and parameters, typically resulting in higher recommended effluent limits. Note that if the PMF is manually input as an override value, this PMF value will be used without regard to CMT inputs.

## Discharge Pollutant Data

The parameters listed in the model mostly are from the major sewage and industrial permit applications. The GLI criteria from § 93.8e and ORSANCO Pollution Control Standards are integrated into the model and can be selected by the user. The more stringent of the GLI/ORSANCO and statewide criteria will be applied whenever the Great Lakes Criteria or ORSANCO Criteria indicator is selected. Additionally, when the Great Lakes Criteria or ORSANCO Criteria indicator is selected no mixing will be allowed for BCCs.

If you select any of the special PWS parameters (fluoride, phenolics, NO<sub>2</sub>-NO<sub>3</sub>, TDS, sulfate, or chloride), you need to input a PWS Withdrawal at the End of Reach 1. Otherwise, the model has no basis to evaluate the parameter. These parameters are handled differently than other parameters because § 96.3(d) stipulates that the water quality criteria for these parameters apply only at PWS intakes.

The model handles Osmotic Pressure as an acute criterion and Total Iron as CFC-governed parameters. However, for these two parameters only, the effluent limits are set equal to the WLA (any statistical adjustments that might normally be made to a CFC-governed parameter, based on the number of samples, are not applied).

Some parameters will trigger a summary parameter to become active. For instance, 2,4 Dinitrotoluene has effluent limits, the model will automatically produce recommended effluent limits for both 2,4 Dinitrotoluene and Total Dinitrotoluene. The model will consider any other isomers of dinitrotoluene that you input in producing a recommended limit for Total Dinitrotoluene. Note that it would not be unusual for the model to produce a lower limit for Total Dinitrotoluene than for any one isomer of dinitrotoluene. In this case, the recommended effluent limit for Total Dinitrotoluene would be the controlling limit for the permit.

**Maximum Discharge Concentration** - Discharge Concentration is a required input in mg/L or µg/L (as designated on the worksheet) for any parameter that you want evaluated by the TMS. A parameter without a maximum discharge concentration entered will not be evaluated. Before the model recommends an effluent limit for a parameter, it will compare the WQBEL that it has just calculated (based on flow and mixing) to whatever value has been entered in this field. The TMS recommends effluent limits only if RP is demonstrated.

The ideal situation is if the discharger has provided actual discharge data so that the actual monthly average and CV of a given parameter is known. Maximum Discharge Concentration may be used in combination with the Discharge CV field to generate the lowest effluent limit that the discharger can still meet.

**Stream Concentration** - This is the background concentration of a given parameter in the stream in µg/L or mg/L at the Point of Discharge. These data normally are not available unless instream sampling has been performed previously. This is optional and the default Stream Concentration is zero if left blank. Only positive values should be input. The Stream Concentration value will be modeled as a steady-state background concentration unless a Stream CV also is entered. This Stream Concentration value is subject to decay if a Fate Coefficient is entered. If a positive value is input for Stream Concentration, recommended effluent limits typically will decrease as compared to a Stream Concentration of zero.

**Discharge Daily CV/Discharge Hourly CV** - This is the coefficient of variation of the concentration of a given parameter in the discharge flow. These data normally would be available only if the discharger has provided them. If known, the site-specific CV for each parameter should always be used, because it will allow the model to recommend a more accurate limit for that parameter. Otherwise, the default value is 0.5. Mathematically, changing the discharge CV will affect recommended (average monthly) effluent limits only if the governing criterion is AFC or CFC. Usually, a noticeable effect on recommended effluent limits occurs only when the governing criterion is AFC. For AFC-governed parameters, recommended effluent limits are very sensitive to changes in discharge CV. When the Discharge Daily CV is reduced below the default 0.5, the recommended effluent limit for AFC-governed parameters will decrease. When the Discharge Hourly CV is reduced below the default 0.5, the recommended effluent limit for AFC-governed parameters will increase. NOTE: Changing the Discharge Daily CV will affect the recommended daily maximum effluent limits for all parameters, even when it has no effect on the recommended (average monthly) effluent limit. NOTE: Changing the Discharge Daily CV or the Discharge Hourly CV from the default value may change the governing criterion, so these CVs should always be used if available.

**Stream CV** - This is the coefficient of variation of the stream concentration of a given parameter in the stream at the Point of Discharge before any mixing between the stream and the discharge. The default Stream CV is 0. Only positive values should be input. If a value  $> 0$  is input, and assuming that some positive Stream Concentration for that parameter has been entered, recommended effluent limits based on a governing criterion of AFC or CFC may decrease as compared to a Stream CV of 0. The Stream CV value will have no effect on recommended effluent limits based on a governing criterion of THH or CRL.

**Fate Coefficient** - This is an optional input, expressed in units of  $\text{day}^{-1}$ , with a default value of 0. In the model, the Fate Coefficient provides for first-order decay of a parameter in the stream. Positive fate coefficients will result in increased recommended effluent limits because the parameter is decayed (reduced in concentration) in the stream before it reaches the CCT. Fate coefficients should not be entered unless the parameter is subject to natural degradation or volatilization within the time frame defined by the CCT for the applicable criterion (a maximum of 12 hours). A site-specific study or published studies may provide a basis to enter a decay coefficient for a given parameter. NOTE: Fate coefficients may not be applied against special PWS parameters (fluoride, phenolics,  $\text{NO}_2\text{-NO}_3$ , TDS, sulfate, or chloride).

**Factor of Safety (FOS)** - This is an optional input expressed as a decimal fraction, with a default value of 0. This factor provides a mechanism to guard against uncertainties in the input data for the discharge being evaluated. If you input 0.10 as an FOS, the water quality-based effluent level calculated by the model will be ten percent lower than it would have been with the default FOS of 0. The FOS will reduce the calculated WQBEL for any governing criterion. This reduced WQBEL may still be superseded by a lower effluent limit.

**Criteria Modifier** - This is an optional input expressed as a decimal fraction, with a default value of 1. This factor provides a mechanism to increase or decrease the AFC or CFC criteria for a given parameter based on site-specific data or studies. The Criteria Modifier field will only modify AFC or CFC criteria -- the model will not allow you to modify THH or CRL criteria. If you enter 2 as the Criteria Modifier, the normal AFC and CFC criteria will be doubled, and the WQBELs calculated for that parameter will increase by some proportion. There are two primary ways to justify a change in AFC or CFC criteria. The first way involves a recalculation of the original EPA basis for the criterion, based on changes to the data used to produce the criterion. For example, if trout are not viable in the stream, you

might delete the portion of the data based on trout studies and then recalculate the criterion based on a subset of the original data. The second way involves a Water Effects Ratio (WER) study, which is a biological study of the toxicity of the effluent to designated species. In a WER, you are trying to show that the toxicity of a parameter in your effluent differs from the toxicity demonstrated under the conditions used to produce the criterion. For example, you might show that the aluminum in your effluent may not be as toxic as it usually is because it is being bound up somehow. WER studies usually involve toxic metals, but the model will allow you to apply this field to any parameter.

**Chemical Translator** - This is an optional input expressed as a decimal fraction less than one, with a default value of 1. This factor provides a mechanism to modify the calculations used to determine the WLA for a toxic metal. This may be justified if a laboratory study of the effluent indicates that the dissolved portion of the total recoverable metal is different than the default values in the model (which are from § 16.24). The dissolved portion of the metal generally is the portion that is available and toxic to fish and aquatic life, so if there is a lower dissolved portion than that used by the model, toxicity should be reduced. For example, the model uses 0.960 as the proportion of dissolved metal to total recoverable metal for copper for both AFC and CFC. If site-specific studies determined that 0.800 of the metal exists in the dissolved phase instead of 0.960, you would enter 0.800 as the Chemical Translator. In this case, this would result in a 20 percent increase (.960/.800 is 1.2, which represents a 20 percent increase over default values) in the recommended effluent limit for copper. The Chemical Translator field will only affect AFC and CFC-based calculations for the metals listed in § 16.24. The default value of “NA” means that the model will use the Chemical Translator values listed in § 16.24.

### ***Results Worksheet***

#### **Recommended WQBELs & Monitoring Requirements**

This section shows the TMS’s recommended average monthly, maximum daily and instantaneous maximum NPDES concentration (effluent) limits in µg/L. Limits are only recommended when RP is demonstrated.

The model evaluates all parameters for all applicable criteria and then selects the criterion that results in the most restrictive effluent limit. This criterion is called the Governing WQBEL and is reported in this section. Normally, there are six candidates for Governing Criterion: AFC, CFC, THH, CRL, THH-PWS, and N/A. AFC, CFC, THH, and CRL are all water quality-based criteria. If one of these is reported as the Governing WQBEL, it means that the model has determined that the recommended effluent limit shown for that parameter is the maximum allowable discharge concentration that is permissible while still meeting water quality criteria, and the water quality criterion displayed is the most limiting of the four criteria. The Governing Criterion may also be reported as “THH-PWS” for a PWS parameter. The WQBEL basis field is the governing criteria. The Comments field displays the reason for the recommended effluent limit or monitoring.

#### **Wasteload Allocations**

This section shows the intermediate results of the calculations used to support the recommended effluent limits. This information is useful if you need to see detailed results on the various criteria-specific calculations: how much mixing has occurred (PMF), how much time has elapsed to the CCT, the time required for complete mix at Qh, etc. These data would help you isolate the problem if there is something obviously wrong with the results. The CCT and PMF are reported for each water quality criterion, if applicable.

**Analysis Hardness (mg/L) / Analysis pH** - These are the flow-weighted values for hardness and pH that exist in the stream and are used to correct for the variable toxicity of certain parameters (most toxic heavy metals and pentachlorophenol). The TMS does this by calculating water quality criteria for the reach in the analysis based on the Analysis Hardness and Analysis pH. Unless the user has entered override values for Analysis Hardness and Analysis pH, the model will take the discharge flow, hardness and pH and mix it with the stream flow hardness and pH to produce these values. The amount of stream flow used in this calculation depends on the PMF.

**Water Quality Criterion (µg/L), Water Quality Objective (µg/L), and Wasteload Allocation (µg/L)** - The difference between the Water Quality Criterion and the Water Quality Objective reflects any adjustments that are required. For instance, if a Water Quality Criterion of 4.264 µg/L for cadmium has been calculated based on the Analysis Hardness, the Water Quality Objective may be adjusted to 4.517 µg/L based on the determination that only 94.4 percent of cadmium is biologically available (existing in the dissolved state). The Water Quality Objective is then used to determine the WLA. The WLA is then used to determine the recommended effluent limits for that parameter. The WLA may or may not be the same as the recommended effluent limit for that parameter. The model will report the nature of any adjustments between the Water Quality Criterion and the Water Quality Objective in the “Comments” field in this form.

## **Hydrodynamics**

These data sections show the hydrodynamic data that the model used to produce the recommended effluent limits. Calculated values as well as override values that have been input by the user are shown. For most of these parameters, a value is reported for both Q7-10 and Qh design flow conditions.

**Stream Flow (cfs), PWS Withdrawal (mgd) and Net Stream Flow (cfs)** - The only difference between Stream Flow and Net Stream Flow is that, if there is a PWS Withdrawal at the End of Reach 1, this will be subtracted from the Stream Flow to produce the Net Stream Flow. Net Stream Flow is the value used in mixing calculations used to produce the recommended effluent limits. Net Stream Flow does not include the discharge flow.

**Discharge Analysis Flow (cfs)** - This value is the flow of the discharge effluent that was used by the model to produce the recommended effluent limits. Normally, it is equal to the discharge flow input by the user (and converted from mgd to cfs).

**Slope (ft/ft), Depth (ft), Width (ft), Width/Depth Ratio, Velocity (fps), Travel Time (days)** - These values define how the model sees the receiving water at Q7-10 and Qh flow. If the model reports that your stream is 60 feet wide at Q7-10, but you know that it is no more than 25 feet wide at Q7-10, you should rerun the analysis after editing the input data.

**Complete Mix Time** - This value is what the model predicts is the amount of time in minutes required for the discharge flow and the stream flow to completely mix. Mixing is nearly instantaneous for very small streams (less than 2 cfs), and relatively rapid for small streams (less than 25 cfs). But for larger streams complete mix will not occur within the time frame defined by the CCT for the applicable criterion (a maximum of 12 hours, or 720 minutes). The model will report CMT only for the Point of Discharge.

## **Use of Control Buttons for Analysis Results**

The ***Print*** control button will print the worksheet. The ***Save as PDF*** control button will print the worksheet to a PDF file. The ***Return To Inputs*** control button will exit the Results worksheet, and return you to the main worksheet where you can edit input data.

***Notes:***

CMT: Complete Mix Time, the time required for the discharge flow to mix completely with the receiving stream flow.

CCT: Criteria Compliance Time, the amount of time allowed for mixing before the model will apply the relevant water quality criterion (AFC, CFC, THH, CRL). For instance, the CCT for an AFC for benzene may be applied after 15 minutes of mixing has occurred.

AFC, CFC, THH, CRL: These are the possible water quality criteria that may be applied by the TMS: Acute Fish Criterion, Chronic Fish Criterion, Threshold Human Health, and Cancer Risk Level. These correspond to the *Criteria Continuous Concentrations*, *Criteria Maximum Concentrations* and *Human Health Criteria* contained in Title 25 Chapter 16.

PMF: Partial Mix Factor, the amount of mixing on a scale between 0.0 and 1.0 that represents how much of the receiving water has mixed with the discharge flow at a given point in time. For instance, a PMF of 0.4 would indicate that the discharge flow has mixed with 40 percent of the receiving water at that point in time.