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APPENDICES

Appendix A

Minimum Protected Flow Policy Statement

The department will use the exception clause in Section 61.2(5) (departmental rules) to develop wasteload allocations (WLAs) for dischargers on intermittent and low flow streams. “Exceptions may be made for intermittent or low flow streams classified as significant resource warm waters or limited resource warm waters. For these waters, the department may waive the design low flow requirement and establish a minimum flow in lieu thereof. Such waiver shall be granted only when it has been determined that the aquatic resources of the receiving waters are of no significance at flows less than the established minimum, and that the continued maintenance of the beneficial uses of the receiving waters will be ensured. In no event will toxic conditions be allowed to occur in the receiving waters outside of mixing zones established pursuant to subrule 61.2(4)”(Chapter 61.2(5)).

The department will establish a minimum protected flow for the calculation of WLAs in selected Significant Resource and Limited Resource streams where it has been determined that the aquatic resources of the receiving waters are of limited significance at flows less than the established minimum. The use of minimum protected flows to calculate WLAs on intermittent and low flow streams will supersede the use of the natural design low stream flow. Calculation of WLAs will still use the procedures described previously.

Only the Significant Resource and Limited Resource stream segments with a natural design low flow of less than 2 cfs will be considered for establishing a protected flow. For the low flow streams, DNR Fish and Wildlife Division or Water Resources Section staff members will evaluate the fisheries’ potential and other related aquatic organisms in the stream at the natural design low flow. The staff evaluation of the aquatic resources of low flow streams would place the streams in one of three categories:

Category 1: The first stream category would be typical meandering to channelized streams with silt to silt/sand beds in which water temperature equaled or exceeded 32°C during low flow periods. At this low flow condition, most higher tropic aquatic life has moved to deeper pools or to the main stream reaches. Thus, aquatic life for which the design use was considered for would not be present in significance numbers in the stream.

Category 2: The second stream category would consist of reaches where the background flow originated largely from spring or bedrock outcrops. Stream beds consist of silt/sand to sand and gravel. The stream temperature may range between 20° to 32°C with high tropic level aquatic life staying in the stream reach in small pools and underbank cuts.

Category 3: The third stream category would consist of reaches capable of supporting cold water aquatic organisms. Stream flow originates from springs with water temperatures less than 20°C. Stream beds consist of sand to sand and gravel. These stream reaches may be classified as cold water or tributaries to such stream reaches.

For those stream reaches under the first category, staff will recommend the specific protected flow level for each stream reach. This protected flow value may range from 1 to 2 cfs of natural background flow depending upon the normal aquatic organisms inhabiting the reach. Protected stream flows higher than 2 cfs would be considered if unique conditions have limited the normal aquatic organisms from inhabiting the stream reach at 2 cfs. Such conditions as depth of water, temperature, velocity, and substrate may be considered. Department staff will make careful documentation on such limiting conditions. For the second category streams, a protected flow of 1 cfs or less may be allowed. For the third category of streams, no protected flow will be used to calculate the WLA.

The effluent limitation, including ammonia, for any domestic discharger would be based upon this protected flow level added to any discharge flow originating from a point source discharger. The protected flow level will only be applicable along downstream reaches until the naturally occurring design low flow level is demonstrated to be greater than the protected flow level as determined above, or a significant source of stream flow entered the reach to support the designated aquatic uses. The establishment of protected flows will not apply to facilities that discharge to High Quality Resource waters.

Appendix B

Procedure for Gathering Site Specific Data:
pH and Temperature Data and Mixing Zone Study for a NPDES Applicant

Wastewater treatment facilities are encouraged to plan ahead when considering any data gathering effort. Many of these efforts require seasonal data particularly collected during low stream flow conditions. A time span of several years may be necessary to gather adequate data during the critical stream flow conditions.

A. Effluent pH and Temperature Data

Facilities are encouraged to obtain site specific field data of the receiving stream's pH and
temperature conditions. This data would be used in place of the statewide default data used in the WLA calculations. Where the discharge is into a shallow or marshy area that has no clear channel or there are considerable backwater effects from a downstream dam or river, information should be obtained on the waterbody and discharge pH and temperature. The facility can provide information on the actual effluent pH and temperature during various months to demonstrate that the statewide values used by the department were not representative of the facility and/or the receiving stream. This may help reduce the need for stringent ammonia limits.

Approximately two years of data may be necessary to establish representative site specific data. Discussions between Department staff and the wastewater facility staff should occur before performing the data collection to establish an acceptable scope of work. Information should be obtained in a similar manner to that stated in the Ammonia section (pages 13-16). More information about collecting pH and temperature is contained in the Ammonia section.

Simplified Mixing Zone Study

The following are the basic field data requirements for two types of mixing zone (MZ) studies. This field data is to be provided by a National Pollutant Discharge Elimination System (NPDES) applicant for recalculation of the local MZ. The purpose of the recalculation is to more closely approximate the local MZ using site specific data instead of statewide data. Contact should be made with the department's Water Quality Resources Section staff prior to beginning any field study.

1. Stream Characteristics

It should be noted that the terms low flow and low stream flow are used in the following discussion. These terms are not synonymous with the design low flow or protected flow. The facility can provide information on the actual mixing zone characteristics during **low stream flow conditions** to demonstrate that a greater percentage of the low stream flow is mixing with the effluent than projected by the Department.

Stream surveys to gather mixing zone data should be collected as near to the design low flow or protected flow as is normally feasible during the summer months of the year. A mixing zone study should be performed at stream flows not exceeding 3 to 5 times the design low flow or protected flow. Stream flow conditions closer to the design low flow are desirable for those locations where normal flows during the year approach the design low flow or where the flows are controlled by impoundments. This type of study may help reduce the need for stringent ammonia (or metals) limits. Several different field efforts are being considered in obtaining the mixing zone information, Visible Assessment, Dye Injection – Visible Boundary, and Dye Injection – Fluorometric Measurements.

a. **Visible Assessment:** This procedure is a simple field documentation of the effluent's mixing with the stream under low stream flow conditions. Pictures, video, drawings, or a more detailed map along with some physical stream data should be provided to illustrate how the two waters (effluent and receiving stream) are combining. Typically, the effluent can be seen (foam, turbidity, or color differences) to mix with the stream. Some facilities have added dye to the effluent to facilitate the visible assessment. This approach should be adequate on a smaller, shallow stream. A letter of authorizing the discharge of dye will be required from the Department before dye can be introduced into the stream.

Several municipal facilities have seen the effectiveness of this approach. The objective is to demonstrate whether or not the effluent flow is completely mixing with the stream within the allowed mixing zone length. Therefore, if this approach provides valid data, the facility would receive all of the design low flow or protected flow for waste assimilation of ammonia and toxics. With no additional documentation on the mixing characteristics in the zone of initial dilution, default of 5% design low flow will be used for the ZID in the WLA calculation.

- The visible assessment description should include the following items for a distance of 2000 feet downstream (unless other distance limitation is known to apply) and 200 feet upstream of the outfall:
  (1) Describe the stream bed materials: sand, fine or coarse gravel, mud, or rock.
  (2) Note pools and riffles and areas of uniform depths. Estimate length and number thereof and the rapidity of the variations (i.e. gradual, alternating occasionally, or alternating frequently).
  (3) Describe the amount of weed growth and snags in the stream in terms of negligible effects on the stream flow to severe effects on the stream flow.
  (4) Describe the amount of meandering within the 2000 feet distance.
  (5) Describe other features which might effect the MZ such as delta formation at the stream mouth, other discharges, perennial springs, etc.

- A description is needed of the outfall during a low stream flow period. This should include an indication of the discharge flow during the period being described, preferably with pictures. Describe such things as the size and configuration of splash pools, outfall height or depth, outfall diameter (if normally filled during discharging), and/or average velocity of flow exiting outfall when submerged.

- The Department encourages the submission of additional field data. This would include at least two cross sections of the stream at low flow, one at an upstream location and one at the anticipated MZ. Each cross section should include a minimum of 10 depth measurements (depths taken at least every two feet if stream width is less than 40 feet and at least every 5 feet if less than 100 feet, otherwise every 10 feet). Stream velocities should be provided if the dilution ratio is less than 3:1, one upstream, one at the anticipated mixing zone, and one spaced evenly downstream of the outfall and the MZ. If there are several pools and riffles, additional cross sections are needed to provide a more accurate indication of average depths.

b. Dye Injection – Visible Boundary Measurements: The objective of this procedure is to provide greater accuracy in characterizing the mixing of an effluent with the receiving stream by using a visible dye injected into the effluent. The following is a brief summary of the procedures that should be followed:

1. Lay out downstream station locations along shoreline at interval of 50', 100', 200', 500', 1000', 1500', and 2000' below the outfall.
2. Assemble boundary marking floats or stakes. Test stream depth for float line length and ability to wade.
3. Run short test of dye introduction into the effluent. The dye introduction is normally poured as a slug of dye into the effluent at the last manhole or at the outfall.
4. Run actual dye study and set out markers. Time of travel between stations may also be obtained, if desired.
5. Measure stream flow, (depth, velocity, cross section) at selected downstream sites and upstream of outfall. It is important to determine the amount of flow in the dye

plume at both the MZ and ZID locations. Obtain effluent flow measurement at time of dye injection.

6. Prepare a report of the findings.

This will take a field crew of three people approximately two days to complete. The data assembly and preparation of the report will take several days. This is not a widely used type of study, but it is able to provide quantifiable data, particularly on larger waterbodies. The procedures may be modified if needed for specific stream conditions. Data results need not show 100% mixing. The key is to perform the study at or near design low stream flow conditions. Models are available to project the percentages of mixing obtained during field flow conditions to design low flow regime.

c. **Dye Injection - Fluorometric Boundary Measurements:** The objective of this procedure is to provide even greater accuracy in characterizing the mixing of an effluent with the receiving stream by using a florescence dye injected into the effluent. This is a rarely used approach as it is more staff intensive, but it has provided very quantifiable results.

This study is very similar to the Visible Dye effort noted above, however, the actual measurement of dye concentrations (or collection of water samples for later analysis) will be made at various locations in the mixing zone. The dye will be fed into the effluent at a constant rate/concentration over the duration of time required to collect all dye samples. The collection of dye samples (or measurement of concentrations) will be made across the stream from the shoreline until a point in the stream where no additional dye is expected. The same station locations will be used starting at the lower location and proceeding upstream. Stream flow measurements as noted above also will be required. This will take a field crew of three to four people approximately two to three days to complete. The data assembly, analysis, and preparation of the report will take several days.

2. Use of Mixing Zone Study Results

The Department will use the mixing zone study results to recalculate WQ-based permit limits. It is important to note that the level of accuracy is greatly improved by providing site specific data of the Mixing Zone (and ZID if applicable) while still ensuring that the WQS are met at any point along the mixing zone boundary. It is recommended that the Mixing Zone study be performed prior to NPDES Permit re-issuance. This makes re-issuance less controversial. When it is not feasible to complete a Mixing Zone study prior to the permit re-issuance, the Mixing Zone may be an item of the compliance schedule. The Water Resources Section can provide the facility with preliminary WQ-Based permit limits to aid in evaluating the need for Mixing Zone study. It is recommended that contact be made with the Water Resources Section staff to discuss the scope of a mixing zone study and receive necessary variances if dye is to be injected into the stream.

C. Installation of a Diffuser

Several facilities have constructed an instream diffuser to disperse their effluent across a more significant portion of the stream. This is an artificial means to increase the mixing zone. Typically 75 - 80% of the low stream flow is passed across a diffuser. Several facilities have designed diffusers to force 100% of the low flow across the diffuser. Partially buried pipe with risers or rock encased perforated pipe are being used. Several permits may be required for this type of structure. No mixing zone study is needed for the use of a diffuser. However, a follow-up stream study will be required to demonstrate that the diffuser is working properly.

Mixing Zone Calculations

The mixing zone (MZ) dispersion model used by the department staff is based upon an equation obtained from EPA contractors involved with toxics modeling. This equation is a ‘Far Field’ analytical solution for mixing in a river where the discharge is uniformly mixed from top to bottom of the river. The original equation has been adjusted to incorporate a near shore discharge rather than a mid-channel discharge. The equation used is:

$$C = \frac{Q_o C_o e^J}{(2)(d)(K)} \qquad (1)$$

where:

C = Concentration in the river at location x, y, mg/l
C_o = Concentration of the discharge, mg/l
Q_o = Discharge flow, cubic feet per second
d = Average stream depth, ft.
u = Average stream velocity, ft./sec.
x = Distance downstream from the discharge, ft.
y = Distance from the discharge side of the shore, ft.
$K = (\pi D_y u x)^{0.5}$
$J = (-uy^2) / (4D_y x)$
D_y = The lateral dispersion, square feet per second

The lateral dispersion is found from the equation:

$$D_y = (\alpha)(d)(u_s) \qquad (2)$$

where:

α = A proportionality variable which varies with the stream. It is normally about 0.6 ± 0.2, but it can vary from a value of 0.1, which has been found in experimental plumes, to larger than 0.8, which has been found in natural channels. For most rivers in Iowa it is expected to be larger than 0.4, and will normally be assumed to be 0.6.

u_s = The shear velocity = $(1/8fu^2)^{0.5}$ (3)

f = The Fanning or Darcy-Weisbach friction factor, which can be found from diagrams in various references. Note: To facilitate the development of wasteload allocations, an approximation for f was developed. The developed equation is not accurate for f at all Reynold's numbers or (e/d)'s. The equation is:

$$f = (4)(0.01895)(e/d)^{0.5} + 0.001701 \qquad (4)$$

e = Is the size of the roughness of the channel. An equation was developed from limited experimental data which indicated

reasonable

fit to an equation for:

$$(e/d) = 1/(L + 0.001)(Q_r + 2.6) \qquad (5)$$

$$L = (15{,}000^{1.2})(Q_r^{2})$$

Q_r = River flow rate, cfs

Equation (1) is solved for C at varying locations (x, y) and rounded to five decimal places. The y locations where C equals zero are then taken to be the width of the plume. The flow in the plume at that point is calculated to be the plume width times the average river depth times the average river velocity.

The acute and chronic wasteload allocations (WLAs) are determined using the flow in the MZ or Zone of Initial Dilution (ZID) from the previous criteria, the discharge flow, the background concentration, and the water quality standard. The equation for the WLA is:

$$C_o = [C_s (Q_b + Q_o) - Q_b C_b] / Q_o \qquad (6)$$

where:

C_o = WLA
C_s = The acute or chronic water quality standard
Q_b = Stream flow in the MZ or ZID
Q_o = Discharge flow
C_b = The background concentration

Inputs Into the Mixing Zone Calculations

Development of the flow, width, average depth, and average velocity values used in the above equations is developed either from a separate set of equations or from actual field data. Where a cross section of the river and flow rate is known at or close to the point of discharge, the field cross section and velocities are used along with slopes from U.S.G.S. topographic maps to determine Manning's "n" for the river at that flow. (If slope is measured in the field this may improve the quality of the information from these equations since significant differences in slope from the topographic map may occur). The equations used are:

$$Q_r = (W)(d)(u) \quad (7)$$

where:

W = Width of river

$$d = W / (W/d) \quad (8)$$

where:

(W/d) = A ratio determined from the field data

$$rH = \text{Hydraulic radius} = (W)(d) / (2W) + (2d) \quad (9)$$

Note: The hydraulic radius is actually a ratio of the area of stream cross section to the wetted perimeter of the stream. Improvements in the equation used to obtain the hydraulic radius will probably improve the quality of the information from this set of equations. The above equation is based on the hydraulic radius for a rectangle (Perry's Chemical Engineers' Handbook 4th Edition, pages 5-20).

$$u = (1.49 /n)(r_H^{\ 2/3})(S^{\ 0.5}) \quad (10)$$

where:

n = Manning's n

S = Slope

The Manning's n and (W/d) ratio determined from the above equations are then adjusted to the design low flow (dlf) using:

$$n_{dlf} = (n_{orig})(Q_r / Q_{dlf}) \quad (11)$$

$$(W/d)_n = (W/d)_{orig}(Q_r / Q_{dlf})(d/d_a) \quad (12)$$

where:

d_a = The average depth without the first and last reading in the cross section

These are then used with the above equations to determine the average velocity and average depth of the river at the design low flow. A line can then be plotted across the previous cross section to represent the new surface level. The new surface level is found by subtracting the new average depth from the old average depth. The method used has normally shown less than 10 percent difference between the length of the new line representing the new surface width and the calculated width of the river obtained using equation (7).

Where no field information exists, it is difficult to predict the width, depth, and velocity of a river. The department will normally adjust W, (W/d), and n to predict a width, depth, and velocity using equation (7), (9), and (10) to provide a range of acceptable numbers.

Appendix C

Iowa Permit Derivation Methods

Definition of Variables:

WLA_a = Acute Wasteload Allocation
WLA_c = Chronic Wasteload Allocation
CV = Coefficient of Variation
n = Sampling Frequency
MDL = Maximum Daily Limit
AML = Average Monthly Limit

Statistical-Based Procedure:

The modified 1991 EPA Technical Support Document (TSD) methodology is adapted for the Iowa statistical-based procedure to derive the permit limits from the wasteload allocations. The following section describes the different procedures used to derive the permit limits for ammonia and toxics.

1. Ammonia

   MDL = WLA_a
   If $WLA_c < WLA_a$, AML = WLA_c
   Otherwise, AML = MDL = WLA_a

2. Toxics

First, a treatment performance level (LTA and CV) needs to be determined to allow the effluent to meet the WLA requirement. Where two requirements are specified based on different duration periods (i.e., WLA_a and the WLA_c), two performance levels are calculated.

The LTA_a is determined by the following equation:

$$LTA_a = WLA_a e^{[0.5\sigma^2 - z\sigma]}$$

$$\text{where } \sigma^2 = \ln(CV^2 + 1)$$

The LTA_c is determined by the following equation:

For 4-day chronic averaging period (i.e., for toxics):

$$LTA_c = WLA_c e^{\left[0.5\sigma_4^2 - z\sigma_4\right]}$$

$$\text{where } \sigma_4^2 = \ln\left(CV^2 / 4 + 1\right)$$

The z value for the LTAs is based on a 0.01 probability basis, i.e. the 99th percentile level, with a value of 2.326. The default CV value is 0.6 unless applicable data is provided by the wastewater treatment facility.

Next, permit limits are derived directly from the corresponding LTA value; in other words, the MDL is calculated from LTA_a and the AML is calculated from the LTA_c.

The MDL is calculated by the following equation:

$$MDL = LTAe^{\left[z\sigma - 0.5\sigma^2\right]}$$

$$\text{where } \sigma^2 = \ln\left(CV^2 + 1\right)$$

The z value for MDL is based on a 0.01 probability basis, i.e. the 99th percentile level, with a value of 2.326.

The AML is calculated using the equation:

$$AML = LTAe^{\left[z\sigma_n - 0.5\sigma_n^2\right]}$$

$$\text{where } \sigma_n^2 = \ln\left(CV^2 / n + 1\right)$$

The z value for AML is based on a 0.01 probability basis, i.e. the 99th percentile level, with a value of 2.326. The monitoring frequency (n) will follow the requirements noted in the department's rule, Chapter 63. However, the n value used to calculate the AML should always be greater or equal to **4/month** to guarantee meeting the criterion.

If the above calculated AML is greater than the MDL, set AML = MDL.