The ADEM Spreadsheet
Water Quality Model

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Water Division – Water Quality Branch
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Introduction

Water quality modeling is an attempt to relate specific water quality conditions to natural processes using mathematical relationships. A water quality model usually consists of a set of mathematical expressions relating one or more water quality parameters to one or more natural processes. Water quality models are most often used to predict how changes in a specific process or processes will change a specific water quality parameter or parameters.

Water quality models vary in complexity from simple relationships which attempt to model a few processes under specific conditions to very complex relationships which attempt to model many processes under a wide range of conditions. The simpler models are usually much easier to use and require only limited information about the system being modeled but are also limited in their applicability. Steady-state models in which certain relationships are assumed to be independent of time fall into this category. More complex models may relate many natural processes to several water quality parameters on a time-dependent basis. These models are usually harder to apply, require extensive information about the system being modeled, but also have a broader range of applicability. Dynamic models fall into this category.

One water quality model sometimes used by the Alabama Department of Environmental Management (ADEM) to develop waste load allocations (WLAs) and total maximum daily loads (TMDLs) for oxygen demanding wastes is the Spreadsheet Water Quality Model (SWQM). The model is derived from an earlier steady-state dissolved oxygen model used by ADEM and variously referred to as DOMOD2 and W2EL. The earlier versions of the model, still in use by ADEM and others, were written

in the BASIC computer language and were executed in the Disk Operating System (DOS) for personal computers.

The version of SWQM sometimes used by ADEM in the development of TMDLs for dissolved oxygen is a steady-state model relating dissolved oxygen concentration in a flowing stream to carbonaceous biochemical oxygen demand (CBOD), nitrogenous biochemical oxygen demand (NBOD), sediment oxygen demand (SOD) and reaeration. The model allows the loading of CBOD, NBOD and SOD to the stream to be partitioned among different land uses (nonpoint sources) and wastewater treatment facilities (point sources).

Description of the Water Quality Model

The SWQM is based on the Streeter-Phelps dissolved oxygen deficit equation with modifications to account for the oxygen demand resulting from nitrification of ammonia (nitrogenous oxygen demand) and the organic demand found in the waterbody sediment. Equation (1) shows the Streeter-Phelps relationship with the additional components to account for nitrification and SOD.

(1) $$D = \frac{K_1 L_0}{K_2 - K_1}\left(e^{-K_1 t} - e^{-K_2 t}\right) + \frac{K_3 N_0}{K_2 - K_3}\left(e^{-K_3 t} - e^{-K_2 t}\right) + \frac{SOD}{K_2 H}(1 - e^{-K_2 t}) + D_0 e^{-K_2 t}$$

where: D = dissolved oxygen deficit at time t, mg/l
L_0 = initial CBOD, mg/l
N_0 = initial NBOD, mg/l (NBOD = NH$_3$-N x 4.57)
D_0 = initial dissolved oxygen deficit, mg/l
K_1 = CBOD decay rate, 1/day
K_2 = reaeration rate, 1/day
K_3 = nitrification rate, 1/day
SOD=sediment oxygen demand, g O$_2$/ft^2/day
H=average stream depth, ft
t = time, days

The CBOD concentration, expressed as L_0 in Equation (1), is the ultimate carbonaceous biochemical oxygen demand. The CBOD concentration remaining at any time, t, can be expressed by the following first-order equation.

$$(2) \quad L = L_u e^{-K_1 t}$$

where: L = CBOD remaining at any time, t, mg/l
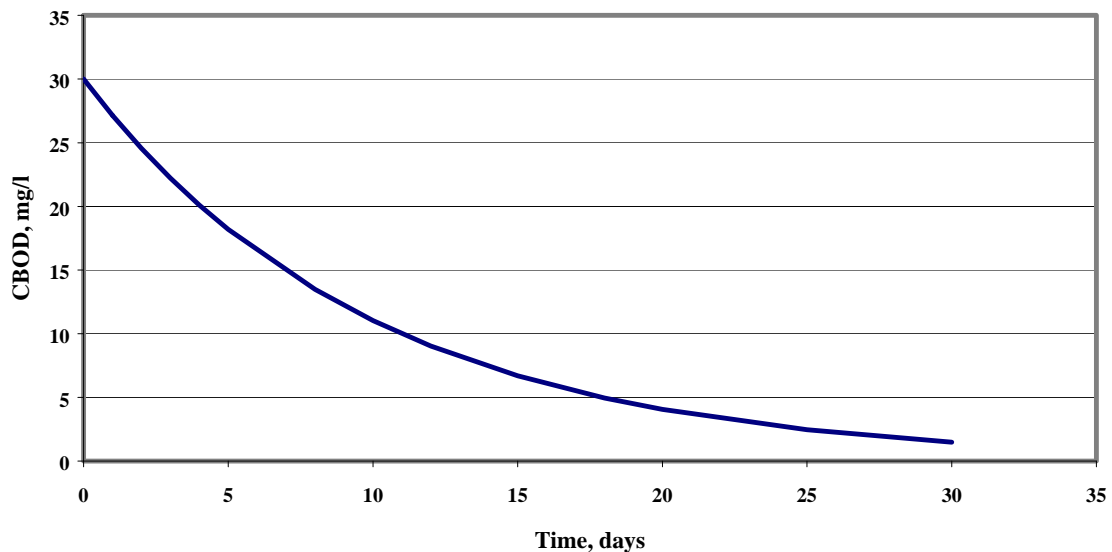 L_u = ultimate carbonaceous biochemical oxygen demand, mg/l = Lo (in Eqn 1)
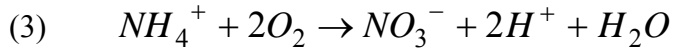 K_1 = CBOD decay rate, 1/day
   t = time, days

Figure 1 illustrates a typical CBOD curve described by Equation (2).

Figure 1
CBOD versus Time

In the presence of nitrifying bacteria, ammonia is oxidized first to nitrite, then to nitrate. The overall reaction is given in the following equation.

(3) $NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O$

The stoichiometric requirement for oxygen in the above reaction is 4.57 mg of O_2 per mg of NH_4^+-N oxidized. The oxidation reaction is assumed to be first order and would have the form shown in Equation (4).

(4) $N = N_0 e^{-K_3 t}$

where: N = NBOD remaining at any time, t, mg/l
        N_0 = initial NBOD, mg/l
        K_3 = nitrification rate, 1/day
          t = time, days

Organic nitrogen, primarily in the form of amino acids, is a potential source of ammonia as a result of deamination reactions that occur during the metabolism of organic material. Organic nitrogen does not exert a direct oxygen demand but an indirect demand as proteins are hydrolyzed and ammonium ions are released. The following example shows the deamination reaction for aspartic acid.

(5)   COOH   COOH
          | |
       H-C-NH$_3$ C=O
          | → | + NH_4^+
         CH$_2$ ←   CH$_2$
         /   /
       COOH   COOH
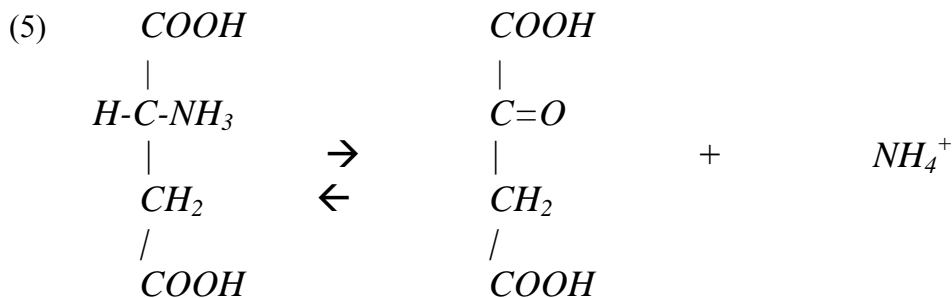
The conversion of organic nitrogen to ammonia is assumed to follow first-order kinetics and is represented by the following equation.

(6) $NH_3 - N = ORG\left(1 - e^{-K_4 t}\right)$

where: NH$_3$-N = ammonia nitrogen produced by hydrolysis of organic nitrogen, mg/l

ORG = initial organic nitrogen concentration, mg/l
K_4 = organic nitrogen hydrolysis rate, 1/day
t = time, days

Oxygen demand by benthic sediments and organisms can represent a significant portion of oxygen consumption in surface water systems. Benthic deposits at a given location in an aquatic system are the result of the transportation and deposition of organic material. The material may be from a source outside the system, such as leaf litter or wastewater particulate CBOD, or it may be generated inside the system as occurs with plant growth. In addition to oxygen demand caused by decay of organic matter, the indigenous invertebrate population can generate significant oxygen demand through respiration. The sum of oxygen demand due to organic matter decay plus demand from invertebrate respiration is equal to the sediment oxygen demand (SOD). SOD is averaged over the water column depth, as indicated by the third term (to the right of the equal sign) in equation 1.

The process by which oxygen enters a stream is known as reaeration. Equation (1) shows the net effect on dissolved oxygen concentration of the simultaneous processes of deoxygenation through the decay of carbonaceous organic matter, nitrification of ammonia, SOD and reaeration. The resulting pattern in dissolved oxygen concentration versus distance downstream from a waste source is known as the dissolved oxygen sag curve. Figure 2 shows a typical dissolved oxygen sag curve. The shape of the curve is dependent upon the magnitude of the reaeration rate relative to the concentration of oxygen demanding materials and the magnitude of their decay rates.

Figure 2
Dissolved Oxygen Versus Distance
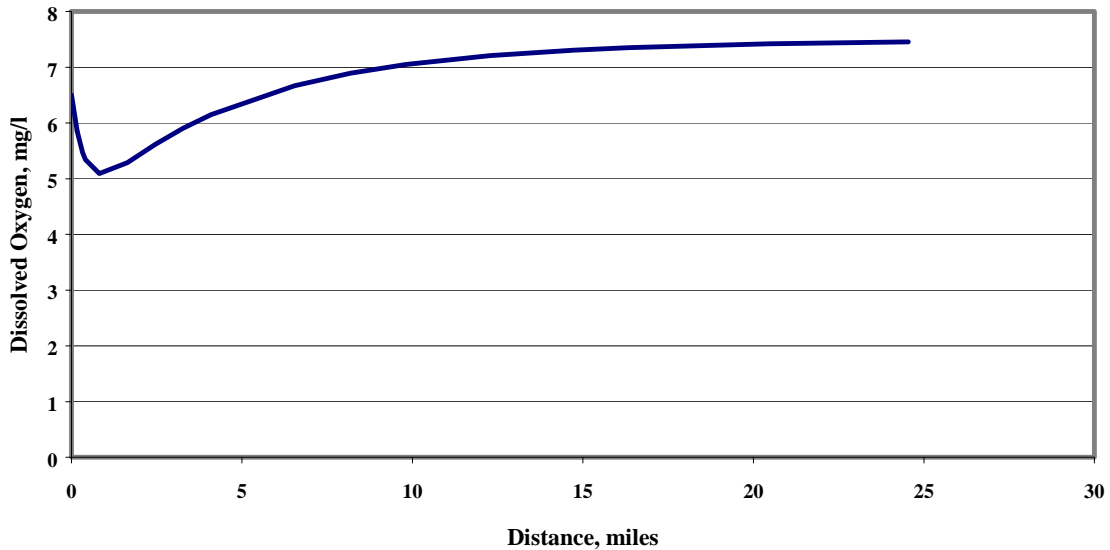
Numerous equations for estimating a stream's reaeration rate have been developed and many are presented in *Rates, Constants, and Kinetic Formulations in Surface Water Quality Modeling*, 2nd edition, USEPA. Reaeration rates in the SWQM can be either entered directly or computed using the formula developed by E.C. Tsivoglou and shown in Equation (7).

(7) $K_2 = C(Slope)(Velocity)$

where: K_2 = reaeration rate at 20°C, 1/day
        C = Tsivoglou Coefficient
        C = 1.8 when stream flow < 10 cfs
        C = 1.3 when stream flow > 10 cfs and < 25 cfs
        C = 0.88 when stream flow > 25 cfs
    Slope = water surface slope, feet/mile
    Velocity = water velocity, feet/second

Another commonly used method for estimating a stream's reaeration rate is the O'Conner-Dobbins formulation shown in Equation (8). This formulation generally

works best for streams with a depth of greater than 5 feet and a slope of less than 2 feet/mile.

$$(8) \qquad K_2 = \frac{12.9U^{0.5}}{H^{1.5}}$$

where: K_2 = reaeration rate at 20°C, 1/day
$\qquad$ U = stream velocity, feet/second
$\qquad$ H = stream depth, feet

$\qquad$ Temperature affects the rate at which reactions proceed. Reaction rates are generally expressed with units of per day at 20°C. If the reactions are occurring at a temperature other than 20°C, then the reaction rates must be corrected for the new temperature. The most commonly used expression to adjust reaction rates for temperature is the modified Arrhenius relationship shown in Equation (9).

$$(9) \qquad K_{T_2} = \left(K_{20°C}\right)\Theta^{\left(T_2 - 20\right)}$$

where: K_{T2} = reaction rate at the new temperature, 1/day
$\qquad$ $K_{20°C}$ = reaction rate at 20°C, 1/day

The Θ values for each of the reaction rates shown in Equation (1) vary slightly from reference to reference but those used in the SWQM are listed in the following table.

Table 1
Temperature Correction Factors Used in the SWQM

Rate, 1/day	Temperature Correction Factor, Θ
CBOD decay, K_1	1.047
Reaeration, K_2	1.024
Nitrification, K_3	1.080
Organic Nitrogen Hydrolysis, K_4	1.047
Sediment Oxygen Demand, SOD	1.060

The dissolved oxygen saturation concentration at a pressure of 1 atmosphere and a given temperature is computed using Equation (10) taken from _Standard Methods for the Examination of Water and Wastewater_, 16th Edition.

(10)
$$\ln C^* = -139.34411 + \left(\frac{1.575701 X 10^5}{T}\right) - \left(\frac{6.642308 X 10^7}{T^2}\right)$$
$$+ \left(\frac{1.243800 X 10^{10}}{T^3}\right) - \left(\frac{8.621949 X 10^{11}}{T^4}\right)$$

where: C^* = equilibrium oxygen concentration at 1 atm, mg/l
   T = temperature, K

Table 2 shows the saturation concentration of dissolved oxygen in fresh water at various temperatures.

Table 2
Solubility of Oxygen in Fresh Water Exposed to Water-Saturated Air at Standard Pressure (101.3 kPa)*

Temperature, °C	Oxygen Solubility, mg/l
4.0	13.107
5.0	12.770
6.0	12.447
7.0	12.139
8.0	11.843
9.0	11.559
10.0	11.288
11.0	11.027
12.0	10.777
13.0	10.537
14.0	10.306
15.0	10.084
16.0	9.870
17.0	9.665
18.0	9.467
19.0	9.276
20.0	9.092
21.0	8.915
22.0	8.743
23.0	8.578
24.0	8.418
25.0	8.263
26.0	8.113
27.0	7.968
28.0	7.827
29.0	7.691
30.0	7.559
31.0	7.430
32.0	7.305
33.0	7.183
34.0	7.065
35.0	6.950
36.0	6.837
37.0	6.727
38.0	6.620

*From *Standard Methods for the Examination of Water and Wastewater*, 16th Edition.

The dissolved oxygen saturation concentration computed by Equation (10) and shown in Table 2 is also corrected for the effect that increasing altitude has on air pressure. Equation (11) estimates the change in atmospheric pressure as altitude increases and Equation (12) estimates the change in dissolved oxygen saturation concentration as atmospheric pressure changes.

$$(11) \quad P = 1 - (3.78436 X 10^{-5})(A) + (6.17149 X 10^{-10})(A^2)$$

where: P = atmospheric pressure, atm
A = altitude above mean sea level, feet

$$(12) \quad C_p = C * P \left(\frac{1 - \dfrac{P_{wv}}{P}}{1 - P_{wv}} \right) \left(\frac{1 - \Theta P}{1 - \Theta} \right)$$

where: C_p = equilibrium oxygen concentration at nonstandard pressure, mg/l
$C*$ = equilibrium oxygen concentration at standard pressure of 1 atm, mg/l
P = nonstandard pressure, atm
P_{wv} = partial pressure of water vapor, atm

The partial pressure of water vapor, P_{wv}, is computed using the following equation.

$$(13) \quad \ln P_{wv} = 11.8571 - \left(\frac{3840.70}{T} \right) - \left(\frac{216961}{T^2} \right)$$

where: T = temperature, K

In Equation (12), Θ is computed using the following equation.

$$(14) \quad \Theta = 0.000975 - (1.426 X 10^{-5} t) + (6.436 X 10^{-8} t^2)$$

where: t = temperature, °C

The velocity at which a stream is flowing is another important factor affecting the dissolved oxygen sag curve. Generally, higher velocities result in higher reaeration rates and a less pronounced "sag" in the dissolved oxygen sag curve. On the other hand,

higher velocities may shift the location at which the minimum dissolved oxygen concentration occurs downstream as more organic material is transported downstream by the higher velocities. Velocity at any given point on a stream can be computed using the continuity equation shown in Equation (15).

(15) $\quad V = \dfrac{Q}{A}$

where: V = velocity, feet/second
    Q = stream flow, cubic feet/second
    A = cross-sectional area, square feet

Velocity through any given stream reach is usually a function of stream flow and can be written in the form of Equation (16).

(16) $\quad V = aQ^b$

where: V = velocity, feet/second
    a = coefficient of velocity versus flow relationship
    b = exponent of velocity versus flow relationship
    Q = stream flow, cubic feet/second

The coefficient, a, and the exponent, b, in Equation (16) are estimated by plotting velocity versus flow on a log-log chart and computing the intercept (a) and slope (b) of the line. Velocity or time-of-travel measurements for a stream segment are usually estimated using a dye tracer, typically rhodamine WT dye. Flow measurements can be obtained directly from United States Geological Survey (USGS) stream gauges or measured directly using a current meter or dye tracer technique.

The SWQM has an option to compute stream velocity using an empirical relationship developed by EPA for streams in the Southeast. The equation has been used

by ADEM for many years in "desk-top" water quality models and is shown as Equation (17).

(17) $V = 0.144Q^{0.4}(Slope)^{0.2} - 0.2$

where: V = velocity, feet/second
        Q = stream flow, cubic feet/second
        Slope = stream slope, feet/mile

Equation (1) presents a very simple approach to describing the relationship between factors that influence the dissolved oxygen deficit in a stream. It would be impossible to model all of the processes that affect a stream's dissolved oxygen concentration. In addition to carbonaceous BOD, ammonia, organic nitrogen, SOD and reaeration, many models include photosynthesis. However, for most small streams, Equation (1) describes the major processes affecting dissolved oxygen.
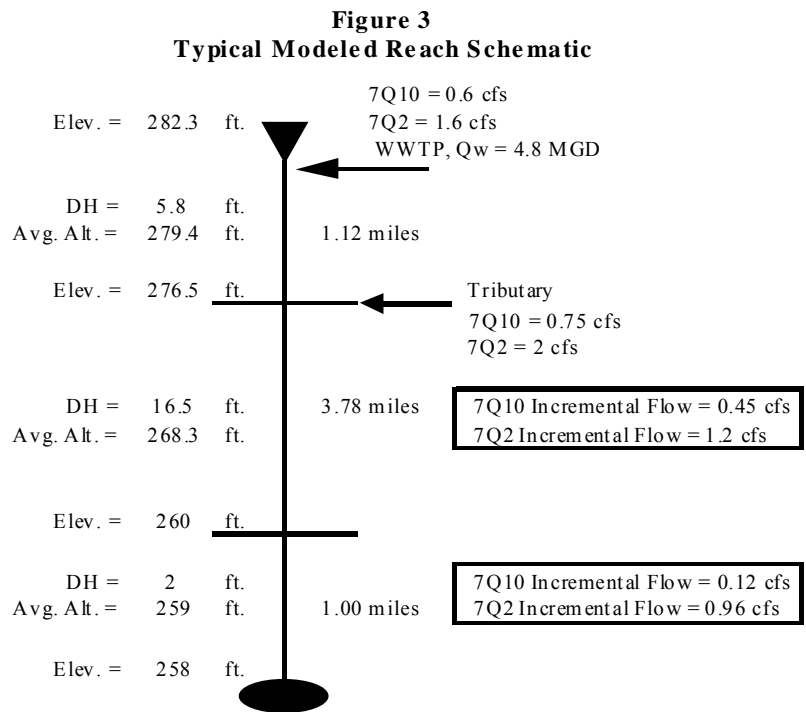
As discussed earlier, SWQM is based on the modified Streeter-Phelps equation shown as Equation (1). Mass balance calculations and the dissolved oxygen balance calculations are written in cells on a Microsoft™ Excel 97 spreadsheet. The spreadsheet is completely interactive and easily tailored to a particular application. Mass balance calculations are used to compute the concentration of a substance in the stream after two or more sources of the substance flow together and are completely mixed. Equation (18) shows the mass balance calculation for two sources.

(18) $C_{mixed} = \dfrac{(C_1)(Q_1) + (C_2)(Q_2)}{Q_1 + Q_2}$

where: C_{mixed} = concentration of the substance after mixing from two sources
        C_1 = concentration of the substance from the first source
        C_2 = concentration of the substance from the second source
        Q_1 = flow of the first source
        Q_2 = flow of the second source

The SWQM also allows the user to assign organic loadings on the basis of land use. The model assigns differing pollutant concentrations to flows from headwaters, tributaries, and incremental inflow according to the major land use percentages in the watershed. For example, if the land use in a given wateshed was 80% forest, then 80% of the flow would be from the forest land use and assigned CBOD, ammonia, organic nitrogen, and dissolved oxygen concentrations typical of forest runoff.

Once the stream reach to be modeled has been selected, the reach can be subdivided into individual segments. Subdivision of the reach allows for the model to account for changing physical features of the stream. These would include the addition of flow and pollutants from tributaries, incremental inflow, and point sources, changes in stream slope, velocity, and any of the reaction rates. Figure 3 illustrates an example of a reach with three sections.

Figure 3
Typical Modeled Reach Schematic

				7Q10 = 0.6 cfs
Elev. =	282.3	ft.	▼	7Q2 = 1.6 cfs
				WWTP, Qw = 4.8 MGD ←
DH =	5.8	ft.		
Avg. Alt. =	279.4	ft.	1.12 miles	
Elev. =	276.5	ft.		Tributary ←
				7Q10 = 0.75 cfs
				7Q2 = 2 cfs
DH =	16.5	ft.	3.78 miles	7Q10 Incremental Flow = 0.45 cfs
Avg. Alt. =	268.3	ft.		7Q2 Incremental Flow = 1.2 cfs
Elev. =	260	ft.		
DH =	2	ft.		7Q10 Incremental Flow = 0.12 cfs
Avg. Alt. =	259	ft.	1.00 miles	7Q2 Incremental Flow = 0.96 cfs
Elev. =	258	ft.		

9.4.18

The first information required by the model concerns the headwater conditions. These are the physical and chemical stream characteristics immediately upstream of the reach to be modeled and include ultimate carbonaceous BOD, ammonia nitrogen, organic nitrogen, dissolved oxygen, stream flow, and water temperature. For each section the same information will be required for tributaries, incremental flow, and point sources.

Additional information required for each section includes section length, elevation at the beginning and end of each section, and decay rates for CBOD, ammonia nitrogen, organic nitrogen and SOD. The reaeration rate can be input directly or computed using Equation (7). Velocity can also be input directly or computed by Equation (17).

The SWQM can also account for reaeration that occurs as water flows over a small dam. Equation (19) developed by Gameson and discussed in EPA's *Rates, Constants, and Kinetic Formulations in Surface Water Quality Modeling* (Second Edition) is used to compute reaeration over a dam.

(19) $\quad r = 1 + 0.11(a)(b)(1 + 0.046(T))h$

where: r = ratio of upstream dissolved oxygen deficit to downstream deficit
a = water quality factor (0.65 for grossly polluted streams; 1.8 for clean streams)
b = weir dam aeration coefficient (a function of the type of structure, see Table 3 below)
T = water temperature, °C
h = water level difference across the dam, feet

Table 3
Weir Dam Aeration Coefficients

Dam Type	Aeration Coefficient
Flat Broad-Crested Regular Step	0.70
Flat Broad-Crested Irregular Step	0.80
Flat Broad-Crested Vertical Face	0.80
Flat Broad-Crested Straight-Slope Face	0.90
Flat Broad-Crested Curved Face	0.75
Round Broad-Crested Curved Face	0.60
Sharp-Crested Straight-Slope Face	1.05
Sharp-Crested Vertical Face	0.80
Sluice Gates with Submerged Discharge	0.05

USING THE SPREADSHEET MODEL

The ADEM spreadsheet model has been incorporated into a Microsoft Excel workbook file named "WQ Tool.xls." The workbook consists of 12 worksheets. Four of the worksheets require input – WQ MODEL, Land Use, Chronic NH3 Tox, and Acute NH3 Tox. Cells in these worksheets requiring input are unlocked and available to the user. Those not requiring input are unavailable to the user and are locked and protected. WQ Model consists of both input and output areas. The output area lists instream model predictions for as many as 24 segments for the following parameters: CBODu, NH_3-N, TON, D.O., flow, temperature, velocity and travel time. The input area of WQ MODEL can be further subdivided into the following sections: headwaters conditions, tributary conditions, incremental inflow conditions, effluent conditions, section and dam characteristics, and reaction rates.

Input requirements for each section will be discussed separately below. It should be noted that the words "section" and "segment" are used interchangeably in the following discussion.

HEADWATERS SECTION

The headwaters section begins on the second page of WQ MODEL. Required input for the headwaters section includes flow, temperature and dissolved oxygen concentration (D.O.). Flow input will normally be the stream's $7Q_{10}$ and $7Q_2$ values for summer and winter TMDLs, respectively, at the headwaters location. Summer is typically defined as consisting of the time interval from May through November of each year; winter, the other five months. The $7Q_{10}$ flow represents the minimum 7-day flow

that occurs, on average, over a 10-year interval. Likewise, the $7Q_2$ is the minimum 7-day flow that occurs, on average, over a 2-year period. The $7Q_{10}$ is typically assumed to be the critical condition flow for the summer season and the $7Q_2$ for winter. Where a continuous USGS gaging record is available, monthly $7Q_{10}$ flows can be computed. The minimum monthly $7Q_{10}$ during each season is used as headwaters flow in the model.

If a continuous USGS gaging record is not available, the $7Q_{10}$ and $7Q_2$ flows can be estimated by using one of two procedures. The first procedure employs use of the Bingham Equation. The Bingham Equation can be found on page 3 of a publication from the Geological Survey of Alabama entitled, **Low-Flow Characteristics of Alabama Streams, Bulletin 117**. Low flow estimates employing this equation are based on the stream's recession index (G, no units), the stream's drainage area (A, mi^2), and the mean annual precipitation (P, inches):

(19) $\qquad 7Q_2 = 0.24 \times 10^{-4} (G-30)^{1.07} (A)^{0.94} (P-30)^{1.51}$

(20) $\qquad 7Q_{10} = 0.15 \times 10^{-5} (G-30)^{1.35} (A)^{1.05} (P-30)^{1.64}$.

The range of applicability of the Bingham Equation is 5-2,460 mi^2.

The second procedure makes use of statistical streamflow data from the State's network of USGS gages. If a USGS gage with similar streamflow characteristics exists in the area of the modeled reach, its $7Q_{10}$ and $7Q_2$ values can be employed to estimate the headwaters values by ratioing flows for the two respective drainage areas.   If both procedures are employed, the value used in the TMDL is typically the most conservative value.

Temperature input is based on historical weather data, and is normally assumed to be equal to an average maximum value for each season (in °C).

Headwaters water quality characteristics include CBODu, NH_3-N, and TON. These parameters are model-calculated. CBODu represents ultimate carbonaceous biochemical oxygen demand and is a measure of the total amount of oxygen required to degrade the carbonaceous portion of the organic matter present in the stream. Before going further, an additional CBOD parameter should be explained – $CBOD_5$. $CBOD_5$ is the amount of oxygen required to degrade carbonaceous organic matter in the first five days. Though it is not a modeled pollutant, it is a required parameter for permitting purposes. The assignment of $CBOD_5$ limits in National Pollutant Discharge Elimination System (NPDES) permits requires a knowledge of the ultimate-to-five-day CBOD ratio ($CBODu/CBOD_5$). Once this ratio is known, the $CBOD_5$ value can be determined. Because organic nitrogen can be converted to ammonia, it represents a potential source of NH_3-N. Unless the headwater is known to be degraded, its water quality characteristics are typically assumed to be in the range of background conditions for unimpacted streams. Background conditions for unimpacted streams typically have the following ranges: 2-3 mg/l CBODu, 0.11-0.22 mg/l NH_3-N, 0.22-0.44 mg/l TON, and a D.O. concentration of 80-90% of the D.O. saturation value. Specific headwaters concentrations for unimpacted streams are normally assumed to be as follows: 2 mg/l CBODu, 0.11 mg/l NH_3-N, 0.22 mg/l TON, and 85% of the D.O. saturation value. If field data is available for these parameters, water quality inputs will normally be assumed to be average values of the available field data.

TRIBUTARY SECTION

The tributary section requires flow, temperature, and D.O. as inputs. Methodology employed for these inputs is similar to that used for headwaters.

9.4.22

INCREMENTAL INFLOW SECTION

Incremental inflow (IF) refers to all natural streamflow not considered by the other two sources of natural flow – headwaters and tributaries. It encompasses flows from groundwater recharge, small tributaries not considered in the model, and nonpoint source runoff. Required inputs for incremental flow are the same as those for tributaries (i.e., flow, temperature, and D.O.). D.O. is normally assumed to be 70% of its saturation value. This is 15% lower than what is normally assumed and creates an additional implicit margin of safety in the TMDL model.

The formula for calculation of **total** incremental inflow can be summarized as follows:

(21) Total IF = X - (Σtrib flows+HW flow),

Where Total IF=total incremental inflow (cfs),

X=total flow at end of modeled reach (cfs),

Σtrib flows=sum of all tributary flows (cfs), and,

HW flow=headwaters flow (cfs).

Incremental inflow for each reach is assumed to be proportional to the length of the reach.

POINT SOURCE SECTION

The point source section encompasses all treated wastewater discharges from point source facilities. Required input for point sources are pollutant concentrations, flows and temperatures.

Temperatures are normally assumed to be the same as those estimated for ambient conditions (i.e., the receiving stream). Pollutant concentrations are taken from the

wastewater treatment facility's permit. A CBODu/CBOD$_5$ ratio must be known (or assigned) for each point source effluent in order to convert the CBOD$_5$ permit value to a CBODu model value. This ratio is determined experimentally through a time-series laboratory test on the treated effluent known as the longterm (or ultimate) CBOD test. If the ratio is not measured experimentally, then one must be assumed using typical literature values. In the absence of laboratory data, the value is assumed to be 1.5 for municipal effluents.

Wastewater flows for municipal facilities are assumed to be the design, or permitted, values. Flows for industrial facilities are based on either current production or production at the time of issuance of the current permit.

SECTION CHARACTERISTICS

Required input for section characteristics are segment lengths, upstream elevation for segment 1, and all segment downstream elevations. Upstream elevations for all other segments will be model-calculated once all downstream elevations have been entered. Elevations and lengths are typically estimated from USGS 7½-minute quadrangle maps. The user has the option of inputting velocity values directly or allowing the model to calculate them.

RATES SECTION

The rates section consists of two parts – a mandatory input section and an optional one. Input requirements for the mandatory section are the CBOD, NH$_3$-N and TON decay rates, all assumed to be at 20°C. The 20°C reaeration rate may be calculated by the model, or input manually by the user. The user may input the following parameters in the optional portion of the rates section: average stream depth, SOD, CBOD settling rate, and

TON settling rate. SOD, CBOD settling and TON settling should be the 20°C values. If SOD is being simulated, then average stream depth must also be included as an input.

LAND USE

Land usage is entered as a percentage of total watershed drainage area. Nonpoint source impacts from different land uses are broken down into three groups – headwaters, tributary and incremental inflow impacts. Eight categories of land usage are included. They are forest, pasture, row crops, urban/commercial, open/barren, residential, open water, and "other". The model also has the capability to include one additional land use. It is shown as a blank column on the Land Use worksheet and is adjacent to the open water land use column. The "other" land use is employed to include all uses not listed in the other categories and is typically a very small percentage of the total.

In addition to percentages, pollutant concentrations for CBODu, NH3-N and TON are required as inputs for each land use. Background concentrations are normally assumed for the forest land use since forests typically have a good filtering mechanism with respect to runoff. A small level of pollutant concentrations are normally assumed for open water. This is because an open water area can contribute a small amount of pollutant loading by way of two mechanisms – groundwater recharge and waste from waterfowl. Pollutant concentrations assumed for open water are typically 1 mg/l CBODu, 0.005 mg/l NH_3-N, and 0.01 mg/l TON. The relative concentrations of pollutants for the other land uses are assigned on the basis of available field data.