GUIDELINES ON STIPULATION OF ACCOMMODATING CAPACITY OF LOAD OF WATER POLLUTION IN WATER SOURCES

(Decree of the State Minister for Environmental Affairs No. 110/2003 dated June 27,2003)

THE STATE MINISTER FOR ENVIRONMENTAL AFFAIRS,

Considering:

that in order to implement the provision in Article 23 paragraph (4) of Government Regulation No. 82/2001 on the management of quality of water and control over water pollution, it is necessary to stipulate a decree of the State Minister for Environmental Affairs on guidelines on accommodating capacity of load of water pollution in water sources;

In view of:

1. Law No. 23/1997 on environmental management (Statute Book of 1997 No. 68, Supplement to Statute Book No. 3699);

2. Law No. 22/1999 on regional administration (Statute Book of 1999 No. 60, Supplement to Statute Book No. 3839);

3. Government Regulation No. 25/2000 on the authority of the government and the authority of provinces as autonomous regions (Statute Book of 2000 No. 54, Supplement to Statute Book No. 3952);

4. Government Regulation No. 82/2001 on management of water quality and control over water pollution (Statute Book of 2001 No. 153, Supplement to Statute Book No. 4161);

5. Presidential Decree No. 2/2002 on the amendment to Presidential Decree No. 101/2001 concerning the status, tasks, functions, authority, organizational structures and working arrangements of state ministers;

DECIDES:

To stipulate :
THE DECREE OF THE STATE MINISTER FOR ENVIRONMENTAL AFFAIRS ON GUIDELINES ON STIPULATION OF ACCOMMODATING CAPACITY OF LOAD OF WATER POLLUTION IN WATER SOURCES.

Article 1
Referred to in this decree as:

a. Accommodating capacity of Load of Water Pollution is the capability of water in a water source to receive load of pollution without causing the water to get polluted;

b. Load of pollution is the volume of pollutant contained in water or waste water;

c. Weight Scale Method is a method of stipulation of accommodating capacity of load of water pollution by using the calculation of weigh scale of components being sources of pollution;

d. Streeter-Phelps Method is a method of stipulation of accommodating capacity of load of water pollution in water source by using a mathematics model developed by Streeter-Phelps;

Article 2

(1) Regents/mayors stipulate the accommodating capacities of load of water pollution in water sources.

(2) The accommodating capacities of load of water pollution in water sources as meant in paragraph (1) are stipulated on the basis of minimal debit in the said year or the previous year.

(3) The accommodating capacities of load of water pollution in water sources as meant in paragraph (1) are stipulated by calculation methods already tested scientifically, namely:
a. Weight Scale Method;
b. Streeter-Phelps Method.

Article 3

(1) Method and example of stipulation of accommodating capacities of load of water pollution in water sources by using the weight scale method are as contained in Attachment I.

(2) Method and example of stipulation of accommodating capacities of load of water pollution in water sources by using the Streeter-Phelps method are as contained in Attachment II.

Article 4

(1) In the case of other methods also based on scientific and technological norms being needed for adjusting to regional situations and conditions as well as capacities, methods other than those mentioned in Article 2 are applicable.

(2) The methods as meant in paragraph (1) are used after securing recommendations from the institution in charge of environmental management and environmental impact management.

Article 5

The decree comes into force as from the date of stipulation.

Stipulated in Jakarta
On June 23,2003
THE STATE MINISTER FOR ENVIRONMENTAL AFFAIRS
sgd
NABIEL MAKARIM, MPA,MSM

ATTACHMENT I

Method of stipulation of accommodating capacities of
load of water pollution in water sources by
the weight scale method

I. Introduction

The accommodating capacities of load of pollution can be stipulated by simple method, namely using weight scale method. Mathematics model using the calculation of weight scale can be used to determine the average concentration of down stream originating from pollutant sources being point sources and not point sources, the calculation also can be used for determining percentage of change in the flowing speed or load of pollutant. If several flows meet and result in a final stream, or if the quantity of water and weight of constituent is calculated separately, weight scale analysis is needed for determining the quality of final stream with the calculation as follows:

$$CR = \frac{\Sigma\, Ci\, Qi}{\Sigma\, Qi} = \frac{\Sigma\, Mi}{\Sigma\, Qi}$$

CR = average concentration of constituent for combined stream

Ci = concentration of constituent in stream i

Qi = flowing speed of stream i

Mi = weight of constituent in stream i

The weight scale method also can be used for determining the influence of erosion on the quality of water during the construction or operational phase of a project and also can be applied a segment of stream, a cell in lake and ocean. Yet, the application of the weight scale method is only appropriate to conservative components, namely components not changing (not degraded, not disappearing because of sedimentation, evaporation, or other activities) as long as the mixing process is underway, such as salts. The application of the method to other components, such as BO, BOD and NH3 - N, only constitutes an approach.

II. Operating Procedures

In order to determine load of accommodating capacities by using the weight scale method, the following steps must be taken:

1. Measuring concentration of every constituent and flowing speed in river stream before mixing with pollutant source;

2. Measuring concentration of every constituent and flowing speed in every stream of pollutant source;

3. Determining average concentration in final stream after the stream mixes with pollutant source with the calculation as follows:

$$CR = \frac{\Sigma\, Ci\, Qi}{\Sigma\, Qi} = \frac{\Sigma\, Mi}{\Sigma\, Qi}$$

III. Example

III. Example of Calculation

To make it clearer, the following example of calculation of the use of the Weight Scale Method is provided: A river stream flows from point 1 to point 4. Between the two points, there are two other streams coming into the main river stream, respectively called streams 2 and 3. If data on streams 1, 2 and 3 are known, we want to calculate the condition in stream 4.

Profile of river stream
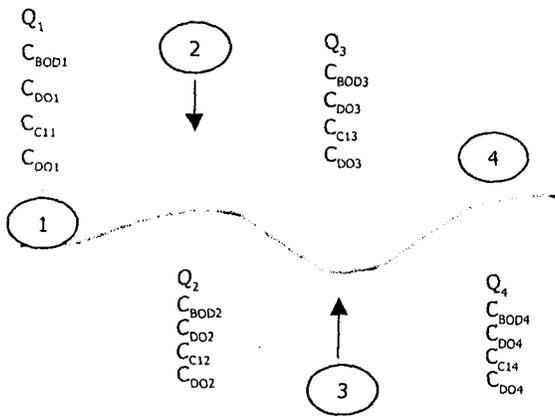
Remark:

1. River stream before mixing with pollutant sources
2. Stream of pollutant source A
3. Stream of pollutant source B
4. River stream after mixing pollutant sources

Data on analysis and debit in streams 1, 2 and 3 are provided in the following table:

Table 1.1. Data on analysis and debit

Stream	Flowing Speed m/sec	DO mg/L	COD mg/L	BOD mg/L	C1- mg/L
1.	2.01	5.7	20.5	9.8	0.16
2.	0.59	3.8	16.5	7.4	0.08
3.	0.73	3.4	16.6	7.5	0.04

By using the above mentioned data, DO in point 4 can be calculated as follows:

The average concentration of DO in point 4 is:

$$CRDO = \frac{(5.7 \times 2.01) + (3.8 \times 0.59) + (3.4 \times 0.73)}{2.01 + 0.59 + 0.73}$$

$$= 4.86 \text{ mg/L}$$

The average concentration of COD, BOD and C1 in point 4 can be determined by the same calculation method, namely 18.94 mg/L, 8.87 mg/L and 0.12 mg/L respectively. If data in stream 4 are included into Table 1.1, it will be as presented in Table 1.2

Table 1.2. Data on analysis and debit

Stream	Flowing Speed m/sec	DO mg/L	COD mg/L	BOD mg/L	C1- mg/L
1.	2.01	5.7	20.5	9.8	0.16
2.	0.59	3.8	16.5	7.4	0.08
3.	0.73	3.4	16.6	7.5	0.04
4.	3.68	4.86	18.94	8.87	0.12
BM X	-	4	25	3	600

BM X - Standard quality of waters, for cetegory/class X If the stream in point 4 has standard quality BM X, the point 4 fails to meet the standard quality of waters for BOD so that point 4 has no longer capacity to accommodate BOD. Yet, in the case of other stream (e.g stream 5) coming between points 1 and 4 and the incoming waste stream containing a high quantity of C1 and not containing BOD, stream 5 still can be allowed to come into the said stream. Surely, it needs to be re-calculated to ascertain that content of C1 is lower than 600 mg/L in point 4.

THE STATE MINISTER FOR ENVIRONMENTAL AFFAIRS

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ATTACHMENT II (To be continued ....)

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GUIDELINES ON STIPULATION OF
ACCOMMODATING CAPACITY OF LOAD OF WATER POLLUTION IN WATER SOURCES
(Decree of the State Minister for Environmental Affairs No. 110/2003 date June 27,2003)
[Continued from Business News No. 7065 pages 21A - 23A]

ATTACHMENT II

Method of stipulation of accommodating capacity of load of water pollution in water sources by Streeter-Phelps Method.

I. Introduction

Modeling of quality of river water has developed significantly since software DOSAG1 was introduced in 1970. The basic principle of the modeling is application of weight scale to river with assumption of dimension 1 and soft condition. The consideration used in the modeling is the oxygen need in life of the water (BOD) to measure pollution in water body. The modeling of river is introduced by Streeter and Phelps in 1925, using oxygen sag curve wherein the method of water quality management is determined on the basis of critical oxygen deficit Dc.

II. Description

The Streeter and Phelps method is only limited to two phenomena, namely reduction of soluble oxygen (de-oxidation) arising from activities of bacteria in degrading organic substances in water and the increase in soluble oxygen (re-aeration) caused by turbulence in river stream.

De-oxidation

Streeter-Phelps states that the speed of bio-chemical oxidation of organic compounds is determined by concentrate of remaining organic substances (residual).

$$dL/dt = -K'.L \dots (2-1)$$

L = concentrate of organic compound (mg/L)
t = time (day)
K' = constanta of reaction for one order (day-1)

If the initial concentrate of organic compound as BOD is Lo specified as ultimate BOD and Lt is BOD at moment t, the equation (2-1) is declared as follows:

$$dL/dt = -K'.L \dots (2-2)$$

Result of integration of equation (2-2) during the de-oxidation period is:

$$Lt = Lo.e (K'^1) \dots (2-3)$$

K' can be determined by:
(1) logarithmic difference method,
(2) moment method (Moore and partner method), and
(3) Thomas method.

The speed of de-oxidation resulting from organic compound can be declared by the following equation:

$$r_o = -K'L \dots (2-4)$$

K' = constanta of speed of first-order reaction, day^{-1}
L = ultimate BOD at the requested point, mg/L

If L is replaced by Loe-k-t, the equation 2-4 will become:

$$rp = -K'Loe^{-k \cdot t} \dots (2-5)$$

Lo = Ultimate BOD at the discharge point (after mixing), mg/L

Re-aeration

The content of oxygen in water will receive addition as a result of turbulence so that oxygen moves from air to water and the process is re-aeration. The shift of oxygen is specified by equation of re-aeration speed:

$$rR = K'2 (Cs-C) \dots (2-6)$$

K'2 = constanta of re-aeration, day^{-1} (basis of natural figure)
Cs = concentrate of fully soluble oxygen, mg/L
C = concentrate of soluble oxygen, mg/L

Constanta of re-aeration can be predicted by determining characteristic of stream and using any of the empirical equations. Equation O'Conner and Dobbins is an equation generally used for calculating constanta of re-aeration (K'_2)

$$K'_2 = \frac{294 (D_l U)^{1/2}}{H_{3,2}} \dots (2-7)$$

D_L = molecular diffusion coefficient of oxygen, m2/day
U = average stream speed, m/second
H = average stream depth, m

Variation of molecular diffusion coefficient to temperature can be determined by equation:

DLT- = 1.760 x 10⁻¹ m2/dx1.037 $^{T-20}$ ...... (2 - 8)

DLT = molecular diffusion coefficient of oxygen at temperature T, m/day

1.760 x 10⁻⁴ = molecular diffusion coefficient of oxygen at a temperature of 200C

T = temperature 0C

Price K_2 has been estimated by Engineering Board of Review for the Sanitary District of Chicago for various kinds of water body (table 2-1)

Table 2-1 (Constanta of re-aeration)

Water body	K^2 at 20°C (base e) [a]
Small ponds and backwaters	0.10 - 0.23
Sluggish streams and large lake	0.23 - 0.35
Large streams of low velocity	0.35 - 0.46
Large streams of normal velocity	0.46 - 0.69
Swift streams	0.69 - 1.15
Rapid and waterfall	> 1.15

$K_{2T} = K_{2.20} \cdot 1.024^{-1/2\ T-20}$

1.8 (°C) + 32 = $_o$F

Oxygen Sag Curve
If the two above mentioned processes are channeled by concentrate of soluble oxygen as the vertical axis and the time or distance as horizontal axis, the cumulative channeling result certifying interaction of de-oxidation and re-aeration is a curve of oxygen content soluble in water body. The curve is known oxygen sag curve.

If we assume that river and water mix completely at disposal point, concentrate of constituent at the mixture of waste water in x = 0 is:

$$C0 = \frac{Qr\ Cr + Qw\ Cw}{Qr + Qw} \quad .... \ (2\text{-}9)$$

C_o = concentrate of initial constituent at disposing point after mixing, mg/L

Q_r = speed of river stream, m3/second

C_r = concentrate of constituent in river before mixim, mg/L

C_w = concentrate of constituent in waste water, mg/L

Any change in content of oxygen in river can be modeled by assuming river as clogged stream reactor

Oxygen weight scale:
Accumulation = incoming stream - outgoing stream + de-oxidation + re-oxidation

$$\frac{\partial C}{\partial t}\ dV = QC - Q\left(C + \frac{\partial C}{\partial x}\ dx\right) + rD\ dV + rR\ dV \quad ...... \ (2\text{-}10)$$

Substitution rD and rR, equation 2 - 10 becomes

$$\frac{\partial C}{\partial t}\ dV = QC - Q\left(C + \frac{\partial C}{\partial x}\ dx\right) - K'L\ dV + K2\ dV \quad ...... \ (2\text{-}10)$$

If the condition is assumed unchanged, $\partial C / \partial t = 0$,

$$0 = -Q\ \frac{dc}{dx}\ dx - K'L + K12\ (Cs - C) \quad ...... \ (2 \text{-} 12)$$

Substituting dV to become A dx and A dx/Q to become dt, equation 2-12 becomes:

$$\frac{dC}{dt} = -K'L + K_2\ (Cs - C) \quad .... \ (2 \text{-} 13)$$

If the deficit of oxygen D is defined as

$$D = (Cs - C) \quad .... \ (2 \text{-} 14)$$

Later the change in deficit against time is:

$$\frac{dD}{dt} = \frac{-dC}{Dt} \quad .... \ (2 \text{-} 15)$$

equation 2 - 13 becomes:

$$\frac{dD}{dt} = K'L + K'_2 D \quad .... \ (2 \text{-} 16)$$

Substitution ....

Substitution L

$$\frac{dD}{dt} + K'_2 D = K^1 L_0 \, e^{-kit} \quad \dots\dots\dots\dots\dots\dots\dots\dots (2 - 17)$$

if at t = 0, D = Do, result of integration of equation 2 - 17 becomes:

$$Dt = \frac{K^1 L_0}{K^1_2 - K'} (e^{-k^{1t}} - e^{-kt_2'}) + Doe^{-kit} \quad \dots\dots\dots\dots (2 - 18)$$

Dt = oxygen deficit at time t, mg/L

Do = initial oxygen deficit in disposal point at time t = 0, mg/L

Equation 2 - 18 constitutes Streeter-Phelps oxygen-sag equation usually used in river analysis. The picture of oxygen sag curve is shown by picture 2 -1 as follows

Waste disposal point
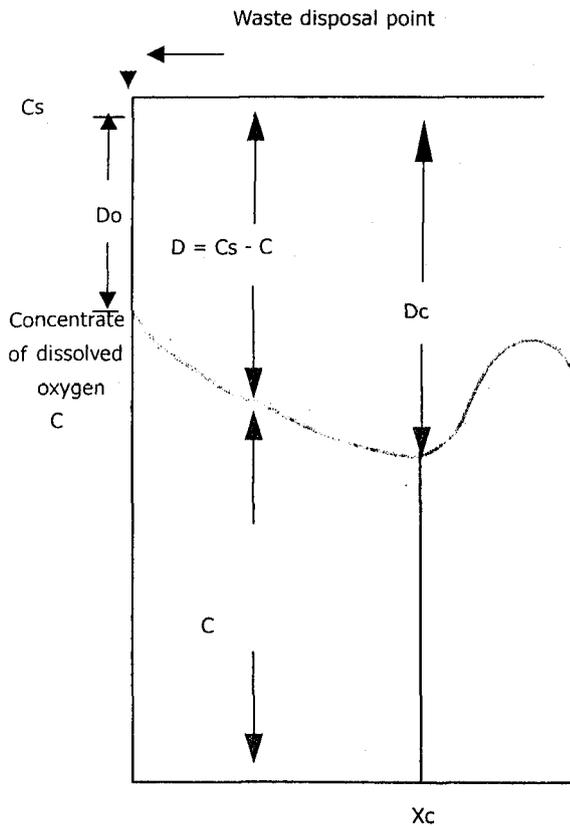
Picture 2 -1 curve of oxygen sag characteristic is based on Streeter - Phelps equation

A method of water quality management can be applied on the basis of critical oxygen deficit Dc, namely condition of the lowest DO deficit achieved as a result of load given to the stream. If dD/dt in equation 2 - 17 is zero,

$$Dc = \frac{K'}{K'2} \, Lo \, e^{-kit} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2 \ 19)$$

tc = time needed for achieving critical point

Lo = ultimate BOD at upstream after mixing, mg/L

If dD/dt in equation 2 - 17 is zero,

$$tc = \frac{1}{K'2 - K'} \, \ln \left[\frac{K'2}{K'} \left[1 - \frac{Do \, (K'2 - K')}{K'Lo} \right] \right] \quad ..(2 - 20)$$

$$Xc = tc \, v \quad \dots\dots\dots\dots\dots\dots (2.21)$$

v = speed of river stream

Equations 2.19 and 2.20 constitute important equations to determine the lowest (critical) DO deficit of the time needed for achieving the critical condition. Based on the time, position (xc) of the critical condition can be determined by using equation 2.21

Other important equation is to determine the maximum permitted load.

The equation is announced from equation 2.18. The equation is:

$$\log La = \log DaU + \left[1 + \frac{K'}{K'2-K'} \left[1 - \frac{Do}{DaU} \right] \right]^{0,418} \log \frac{K'2}{K'} \quad ..(2.22)$$

DaU = the permitted DO deficit, mg/L = saturating DO - standard quality DO

III. Procedures . . . . . (To be continued)

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GUIDELINES ON STIPULATION OF ACCOMMODATING CAPACITY OF LOAD OF WATER POLLUTION IN WATER SOURCES

(Decree of the State Minister for Environmental Affairs No. 110/2003 dated June 27,2003)

[Continued from Business News No. 7066 - 7067 pages 14A - 16A]

III. Operating procedures

The supporting power can be stipulated by two methods, namely, first, determining whether the supplied loan causes critical DO deficit to surpass the tolerable DO deficit or not. In this case, equations 2.19 and 2.20 are needed. If the answer is yes, it needs the second method, namely determining the maximum tolerable load of BOD to prevent the critical DO deficit from surpassing the tolerable limit. In this case, equation 2.22 is needed. In order to use equations 2.19, 2.20 and 2.22, data on K' and K'2 and ultimate BOD are needed. K' can be determined by using the available method, any of the relatively simple methods is Thomas Method, namely using trial data. K'2 can be determined by using empirical equations such as equation 2.7 and 2.8 or that presented in Table 2.1.

It is necessary to note that the price of K' and K'2 constitute the function of temperature. The equations widely used to observe the function of temperature are:

$$K'_t = K'_{20} (1.047)^{T-20} \quad\quad (2.23)$$
$$K'_{t} = K'_{(20)} (1.016)^{T-20} \quad\quad (2.24)$$

T = temperature of water, 0C and K'20, K'2(20) certify the respective prices at 200C

The value of ultimate BOD at the temperature can be determined from the value of BOD520, namely BOD determined at 200C for five days by using the following equation:

K'' states the speed of de-oxidation and 5 certifies the duration of determination of BOD.

1. To determine the speed of de-oxidation (K') of river water which is examined.

   The price of K' is basically determined by using equation 2.3. Later, a series of laboratory tests are needed. Since the determination is relatively complicated, the determination of K' is recommended to refer to Metcalf and Eddy Book. According to Metcalf and Eddy, the value of K' (logarithmic basis, 200C) ranges from 0.05 to 0.3 day-1. Basically, the measurement of K' involves a series of test of measurement of BOD with the different duration of observation days. If Thomas Method is used, the data can be manipulated to obtain the value of K'.

   Here are examples taken from Metcalf and Eddy.

T, day	2	4	6	8	10
Y, mg/L	11	18	22	24	26
(t/y)1/3	0.57	0.61	0.65	0.69	0.727

t certifies the period of observation and y is the value of BOD (exerted)

Thomas Method channels $(t/y)^{1/3}$ to t in accordance with the following equation:

$$(t/y)^{1/3} = (2.3 \, K'La)^{-1/3} + (K')^{-2/3}(t)/ 3.43 \, La)^{1/3} \quad\quad (2.26)$$

K' is the value of de-oxidation constanta by logarithmic basis (basis 10) and La certifies ultimate DOD. By using Thomas Method, the value of K' and La can be determined. Based on the above mentioned data, K = 0.228 day-1 and La = 29.4 mg/L. Since the value of K' is based on the value of BOD measured at a temperature of 200C, the value of K', which is obtained is data for the same temperature.

2. Determining the speed of aeration (K'2) by using equation 2.7 and 2.8 or data on table 3.1.

3. Determining critical time by equation 2.20:

$$tc = \frac{1}{K'2 - K'} \ln \left[\frac{K'2}{K'} \left[1 - \frac{Do(K'2 - K1)}{K'Lo} \right] \right] \quad\quad (2.20)$$

   Do = oxygen deficit when t = 0
   Lo = ultimate BOD when t = 0

4. Determining critical oxygen deficit by equation 2.19

$$Dc = \frac{K' \; Lo \, e^{ktc} \; C}{K'2}$$

5. If the value of Dc is bigger than the value of Dall, the maximum tolerable load of BOD needed to be calculated by using equation 2.22.

IV. Example of calculation

Here is an example of calculation for a river stream by a fixed point source.

1. Waste water from an industrial estate having an average debit of 115,000 m3/day (1.33 m3/second) is disposed to a river stream having a minimum debit of 8.5 m3/second.

2. The average temperatures of waste water and river are 35 and 230C respectively.

3. BOD$^5_{20}$ of waste water is 200 mg/L, while BOD of river is 2 mg/L. Waste water does not contain DO (Do = 0), while river water contains DO = 6 mg/L before mixing waste water.

4. Based ....

4. Based on trial data in laboratory, the value of K' at a temperature of 200C is 0.3 day-1.

5. The value of K'2, by using equation 2.7 and 2.8 at a temperature of 200C is 0.7 day-1.

Based on the above mentioned data, the followings are calculated:
1. The price of Dc, tc and Xc

2. If the quality standard of DO = 2 mg/L, determining maximum load of BOD^5_{20} in waste water still allowed to flow into the river.

Steps of adjustment:
1. Determining temperature, DO and DOD after mixing:
   a. Mixed temperature =
      $[(1.33)(35) = (8.5)(23)]/(1.33 + 8.5) = 24.6°C$
   b. Mixed DO
      $[(1.33)(0) = (8.5)(6)]/(1.33 + 8.5)$ 5.2 mg/L
   c. Mixed BOD =
      $[(1.33)(200)+(8.5)(2)]/(1.331 + 8.5) = 28.8$ mg/L
   d. Mixed Lo =
      $28.8/[-e^{(0-3)(5)}] = 37.1$ mg/L (equation 2.25)

2. Determining DO deficit after the mixing. Determining first saturated DO at the mixed temperature by using oxygen saturation table. Based on the table, the value of saturated DO = 8.45 mg/L.
   DO deficit in the initial condition (Do) = 8.45 - 5.2 = 3.25 mg/L.
3. Correcting the speed of reaction to temperature of 24.60C
   a. $K' = 0.3 (1.047)^{24.6 - 20} = 0.37$ day^1
   b. $K'2 = 0.7 (1.016)^{24.6 - 20} = 0.75$ day^{-1}

4. Determining tc and Xc by using equation 2.20 and 2.21
   a. $tc = \{17(075-037)\}1n [0.75)/(0.37)\{1-3.25(0.75-037)/(0.37)(3.71)] = 161$ day^{-1}
   b. $Xc = (1.61)(3.2)(24) = 123.6$ km

5. Determining Dc by using equation 2.19
   a. $Dc = (0.37)/(0.75)[37.1 e^{(-0.37)(1.61)}]$
      $= 10.08$ mg/L
   b. Concentrate of DO at tc = 8.45 - 10.08 = -1.63 mg/L. Since the value of DO is negative, it means that the river has no longer DO at a distance of 123.6 km (Xc) from the mixing point.

6. Determining the maximum load of BOD in waste water if the standard quality of DO is 2 mg/L.
   a. Dall = tolerable DO = 8.45 - 2 = 6.45 mg/L
   b. Using equation 2.22 to calculate the maximum load of ultimate BOD
      $\log La = \log 6.45 + [1 + [0.37(0.75 - 0.37)]$
      $\{1 - 3.25)/(6.45)\}^{0.418} \log (0.75)1(0.37)$
      $La = 21.85$ mg/L
   c. The maximum load of BOD (equation 2.25) = $21.85 (1 - e^{(-03)(5)}) = 16.97$ mg/L
   d. The tolerable BOD in waste is:
      $16.97 = [(1.33)(X) + (8.5)(2)]/(1.33 + 8.5)$
      $1.33 X = 166.81 - 17 = 149.81$
      $X = 112.6$ mg/L
      It means that the tolerable BOD in waste is 112 mg/L.

Note:
1. Therefore, the tolerable content of BOD in waste must be lowered to 112.6 mg/L so that DO of river water is not less than 2 mg/L.

2. The example given in this calculation assumes that the point source is only one.

THE STATE MINISTER FOR ENVIRONMENTAL AFFAIRS
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ATTACHMENT III

The method of determining the carrying capacity of water pollution load in water sources is QUAL2E Method.
1. Introduction
   QUAL2E is a very comprehensive and widely-used program for the modelling of river water quality. QUAL2E was developed by US Environmental Protection Agency. The use of modelling is aimed at simplifying a case to know its characteristics. Through this QUAL2E, the condition along a river (DO and BOD) can be known. This way, further steps can be taken, such as allowing industries along the river to discharge their waste at certain load.
   The benefit of QUAL2E modelling is:
   1. to know the characteristics of the river to be modelled by comparing data directly taken from the river.
   2. to know the behaviour of stream along the river in case of additional load from pollutant sources, either those detected or those not detected.
   3. to predict which of load the waste of an industry can be discharged into the river in order not to endanger other creatures according to the standard quality of drinking water.

II. Descriptions

QUAL2E software is a very comprehensive program for the modelling of river water quality. This program can be applied to steady and dynamic conditions. In addition, it can also simulate up to 15 constituent parameters by including the calculation of streams of polluted tributaries. This model can also be used for dendritic and well-mixed current by putting emphasis on the mechnamism of movement parallel to the current.

In addition to simulating the afore-mentioned oxygen balance sheet calculation, QUAL2E program can simulate nitrogen and phosphorus balance sheet. Picture 3.1. illustrate the relations among constituents using a QUAL2E simulation program.
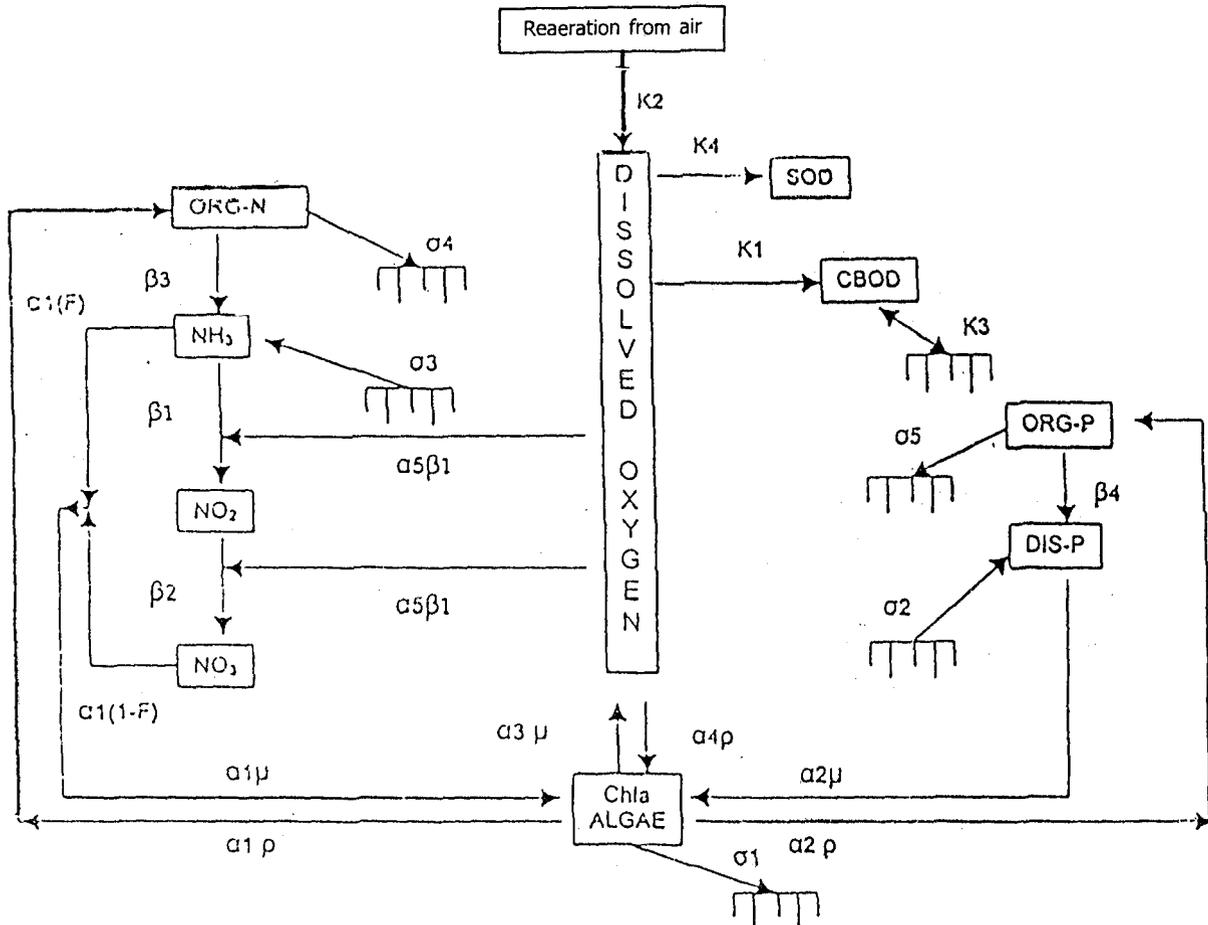
Picture 3.1. Interaction among main constituents in QUAL2E

Notes:

a1 = Fraction from algae biomass in the form of nitrogen, mg-N/mg-A

a2 = Algae content in the form of phosphorous, mg-P/mg-A

a3 = Oxygen production rate at each algae photosynthesis process unit, mg-O/mg-A

a4 = Oxygen production rate at algae respiratory process unit, mg-O/mg-A

a5 = Oxygen absorption rate at each process of oxide from ammonia, mg-O/mg-N

a6 = Oxygen absorption rate at each process of oxide from nitrate, mg-O/Mg-N

o1 = Sedimentation rate for algae, ft/day

o2 = Benthos source rate for soluble phosphorous, mg-P/ft - day

o3 = Benthos source rate in ammonia in the form of nitrogen, mg-N/ft - day

o4 = Coefficient of nitrogen sedimentation rate, day

o5 = Phosphorous sedimentation rate, day

μ = Algae growth rate, depending on temperature, day
μ = Algae respiratory rate, depending on temperature, day
K1 = BOD Deoxygenation rate, temperature influence, day
K2 = Reaeration rate based on defusion analogue, temperature influence, day
K3 = Soluble BOD disappearence rate, temperature factor, day
K4 = Soluble oxygen dependence rate, temperature factor, g
β1 = Coefficient of ammonia oxide rate, temperature factor, day
β2 = Coefficient of nitrate oxide rate, temperature factor, day
β3 = Hydrolysis and nitrogen rate, day
β4 = Lost phosphorous rate, day.

The modelling for soluble oxygen (DO) using QUAL2E Equation for determining DO change rate

$$\frac{dO}{dt} = K2(O^{*}-O)+(\alpha^{3}\mu\ \alpha4\rho)A-K_{1}L-\frac{K4}{d}-\alpha_{6}\beta_{1}N_{1}-\alpha_{6}\beta_{2}N_{2} \quad ....(3.1)$$

where O = soluble oxygen concentration (mg/L)
O* = saturated soluble oxygen concentration, in local P and T (mg/L)
A = concentration of biomass from algae (mg-A/1)
L = BOD carbon compound concentration (mg/L)
d = average depth of stream (ft)
N1= ammonia concentration in the form of nitrogen (mg/L)
N2= nitrate concentration in the form of nitrogen (mg/ L)

The equation used to determine saturated soluble oxygen concentration:

$$\ln O^{*} = 139.344410 + (1.575701 \times 10^{5}/T) - (6.642308 \times 10^{7}/T^{2}) + (1.2438/10^{10}/T^{3}) (8.6219494 \times 10^{11}/T^{4}) \quad .... (3.2)$$

where O* = saturated oxygen concentration in 1 atm (mg/ L)
T = temperature (K) = ($^{\circ}$C + 273.15) and $^{\circ}$C in a span of 0 - 40°C

Method of determining reaeration rate (K)

1. K_{2} = 0.05 for river surface covered with ice, K_{2} = 1 for river surface not covered with ice

2. The price of K at a temperature of 20oC (Churcil et. al) (1962) :
$K_{2}^{20} = 5.026 \mu^{0.969}.d^{-1.673} \times 2.31$
where u = average speed in stream (ft/second)
d = average depth of stream (ft)
K = Reaeration coefficient

3. O'Connor and Dobbin (1958), with character of turbulent stream

3.1. For stream with high speed and isentropic condition
$$K_{2}^{20} = \frac{(Dm.u)\ 0.5}{d^{1.5}} \quad .... (3.3)$$

3.2. For stream with high speed and isentropic condition
$$K_{2}^{20} = \frac{4800D_{m}^{0.5}.So^{0.25}}{d^{1.25}} \times 2.31 \quad .... (3.4)$$

where : So = declivity degree of the river along stream (ft/ft)
Dm = coefficient of molecular diffusion (ft^{2}/day)
Dm = 1.91×10^{3} (1.037) T^{-20}

4. Owens (1964) for shallow and quickly flowing stream with a limited depth of 0.4 - 11.0 ft and speed of 0.1 - 5 ft/ second.
$$K_{2}^{20} = 9.4 \left(\frac{\mu.O.^{67}}{d^{1.85}}\right) \times 2.31 \quad .... (3.5)$$

5. Thacktor and Krenkel (1966)
$$K_{2}^{20} = 10.8 (1 + F^{0.5}) \frac{\mu^{*}}{d} \times 2.31 \quad .... (3.6)$$

$$F = \frac{\mu^{*}}{g.d} \quad .... (3-7)$$

$$\mu^{*} = d.Se.g = \frac{U.n\ g}{1.49d\ 1.^{167}} \quad .... (3.8)$$

where : F = Froude numeral
g = gravitation speed (ft/sec)
Se = angle of height difference
N = coefficient for fraction

6. Langbien and Durun (1967)
$$K_{2}^{20} = 3.3 \left(\frac{\mu}{d^{1.33}}\right) \times 2.31 \quad .... (3.9)$$

7. Empirical relations between speed, depth and stream column in hydraulic part will be correlated:
$$K_{2} = aQ^{b} \quad .... (3.10)$$
where a : coefficient for stream column for K
Q : stream column (ft/second)
b : exponent for stream column K

8. Tsivoglou and Wallace (1972) K is influenced by height difference as long as the stream and time needed along the stream
$$K_{2}^{20} = c\frac{Ah}{tf} = (3600 \times 24)\ c.Se.u \quad ....(3.11)$$

$$Sc = \frac{u^{2}.n^{2}}{(1.49)^{2}\ d^{4/3}} \quad .... (3.12)$$

The price of c (coefficient of lost DO at each ft of river) is limited by stream column
* for stream column 1-5 ft³/second the price of c = 0.054 (ft⁻¹ (20° C)
* for stream column 15-3000 ft³/second the price of c = 0.110ft⁻¹ (20° C)

III. Procedure of Use

Program on, method of using, and example of using QUAL2E modelling can be downloaded in the Internet on website:

1. http://www.epa.gov/docs/QUAL2E WINDOWS/Index html or
2. http://www.oky.com/downloads/qual2eu.htm

The phases of the use of QUAL2E for simulating DO along a river stream is as follows:

1. QUAL2E simulation
   1.1. Write a title and simulation to be conducted
   1.2. Type of expected simulation with 2 choices, namely steady condition and dynamic condition.
   1.3. Unit to be used, namely English unit and SI unit
   1.4. The maximum amount of iteration to be conducted with a maximum of 30 iteration.
   1.5. The number of streams to be made
2. Explanations on streams to be made with requested data
   2.1. No. of stream
   2.2. Name of stream
   2.3. Initial river point
   2.4. Last river point
   2.5. whether or not it is river source
   2.6 river cross to be modelled.
3. Simulation of expected quality
   3.1. There is alternative temperature, BOD, Algae, Phosphorous, Nitrogen, DO
   3.2. BOD with coefficient of BOD conversion for BOD concentration
4. Climate and geographical data to be entered
   4.1. Location of river (longitute and latitude)
   4.2. Angle formed by the river from the initial point to the last point to determine when using coefficient of reaeration (K_2) choice 4
   4.3. measured height of river from the initial point to last point for K_2 choice 5

5. Make several points for limitation by picking price sample of minimim, average and maximum DO.
6. Conversion of temperature against
   6.1. BOD for decay and settling
   6.2. DO for reaeration and SOD
7. Hydraulic data of river with need:
   7.1. Equation for speed $u = a.Q^b$ data on speed in several points in the river with volumetric stream rate are needed to know its coefficient and constant. These data influence coefficient of reaeration (K2), especially choices 2,3,4,5,6,8
   7.2. Equation for depth $d = c.Q^d$ data on the depth of river in several points with volumentric stream rate are needed to know its coefficient and constant. These data influence choice K_2 which greatly constitutes empirical equation.
   7.3. Manning factor with data available in manual.
8. Data on reaeration constant
   8.1. BOD with data on decay, settling time (1/day)
   8.2. SOD rate (g/m2-day)
   8.3. Type of reaeration equation using available equation (see the method of determining reaeration constant rate K_2)
   8.4. If the equation used for K_2 is choice 7 for equation K2 = $e.Q^f$ data for data entered K_2 with the price of e and f are available.
9. The initial condition with data entered to temperature DO, BOD.
10. The increase in the rate of stream along the river with data entered to stream rate (m³/S), temperature (° C), DO, BOD.
11. Data for the initial stream needed for stream rate (m³/S), temperature (° C), DO, BOD.
12. The prices for global climate condition according to latitude and longitude with data needed
    12.1. Time (hour, day, month, year)
    12.2. Wet and dry ball temperature (K)
    12.3. Pressure (mbar)
    12.4. Wind speed
    12.5. Sun ray degree (Langley, hr) and river brightness

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