UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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Documentation for

SNSIM1/2

"A Computer Program for the Steady-State
Water Quality Simulation of a Stream Network

Environmental Systems Section
Data Systems Branch
Planning & Management Division

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Fifth Edition

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INTRODUCTION

The formulation of a mathematical model of any system is greatly determined by two factors: the nature of the system itself and the purposes and perspective of the investigator. The modeler must strike a balance between objective reality and the subjectivity of his needs to attain a successful analysis. This problem is further compounded when dealing with the high complexity of the natural world.

One of the more prevalent misconceptions among neophytes in the field of water quality modeling is that there is one analytical technique which is superior in depicting the water quality in a natural body of water. This may be partially due to the fact that the field straddles several more or less hard sciences and engineering disciplines and as such can be perceived from a variety of perspectives.

For instance, hydrodynamicists, who are essentially interested in the movement of fluids, often tend to emphasize the obviously important effect of water motion on the transport of matter in a system. Ecologists and aquatic biologists on the other hand stress the equally important reactions between the community of organisms which populate the system. The danger in these or in any particular approach comes from the automatic exclusion or underestimation of viewpoints outside the area of expertise of the modeler.

One of the older approaches to water quality modeling which rather effectively incorporates a number of perspectives in representing the causal relationships of stream pollution is that of the sanitary engineering profession. Due to their interest in designing waste treatment facilities, sanitary engineers were rather early introduced to the problems of wastes and their impact on the environment. A classic study in this profession was that done by Streeter and Phelps[1] on the Ohio River in 1925.

By making a variety of simplifying assumptions in the hydrodynamic and biological areas, these investigators arrived at a very utilitarian approach to water quality analysis which still stands as a viable technique for answering many questions about the relationship between pollution and the aquatic environment of a stream. In the hydrodynamic area, they assumed that the waste load was delivered by a pipe into a channel which could be described as having constant geometrical dimensions and constant flow. As well it was assumed that the pollutant was instantaneously mixed in the lateral and vertical directions and that the simple continuity equation, $Q=AV$, applied. From the biological standpoint, it was decided that a chemical parameter upon which most species depend for life, namely, dissolved oxygen could be modeled as an indicator of the health of the biota. To do this, they had to use a measure of the oxygen demand of the waste, the biochemical oxygen demand (BOD), as the input to the system and formulated relationships between dissolved oxygen and BOD in terms of first order kinetics. The result is what is now called the Streeter-Phelps equation which in its basic form is:

$$D = \left[\frac{K_d}{K_a - K_r}\left(e^{-K_r x/u} - e^{-K_a x/u}\right)\right] L_o + D_o e^{-K_a x/u} \quad \text{.........(I-1)}$$

where:

D=dissolved oxygen deficit= DO_s -DO

DO_s=saturation concentration of dissolved oxygen

DO=actual concentration of dissolved oxygen

Lo=initial concentration of BOD at point of introduction of waste

Do=initial concentration of dissolved oxygen deficit at point of introduction of waste

Kr=BOD removal rate

Kd=Deoxygenation rate

Ka=Reaeration rate

U=stream velocity

x=distance downstream from point of introduction of waste

The result of the Streeter-Phelps equation is called the "D.O. sag" and is illustrated in figure I-1.

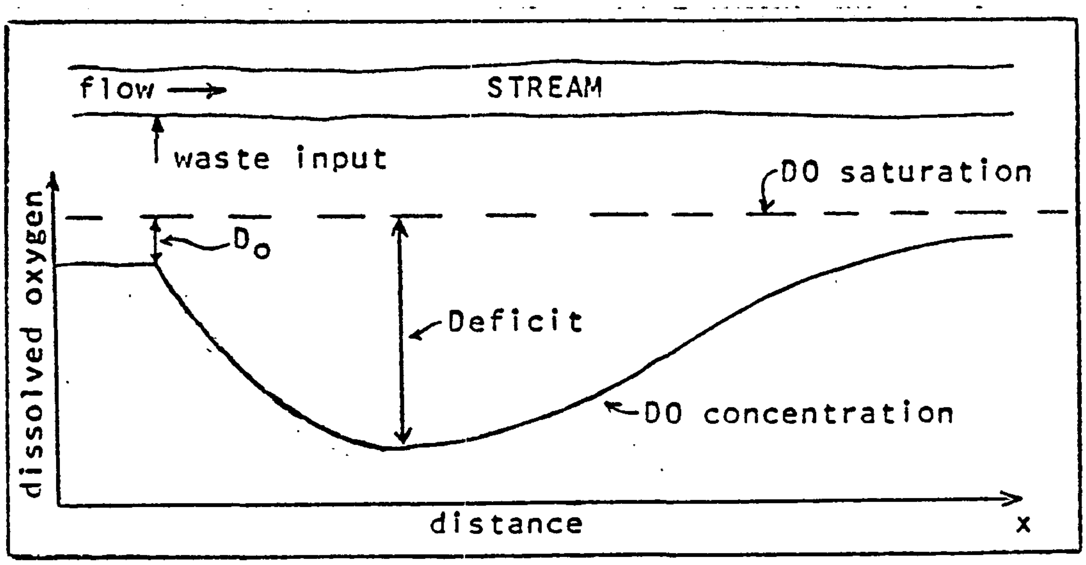


Figure I-1: D.O. sag generated by Streeter Phelps equation

This environmental model is ideal for the evaluation of various treatment schemes as its basic control variable is the waste input. This emphasis on relating man's waste inputs to the aquatic environment with the express purpose of managing the inputs and thus the water quality is what typifies the sanitary engineering approach. This can be contrasted with an aquatic biologist who might be more interested in the interraction between the organisms with a mind to prediction and description rather than control.

An expanded form of the Streeter-Phelps equation is the basis of the SNSIM computer program. SNSIM can be used to formulate a steady-state, one dimensional, simulation model of a stream network. It is designed to evaluate and/or predict the dissolved oxygen, and the carbonaceous and nitrogenous BOD profiles in a river or stream where the effects of dispersion can be assumed to be insignificant.

The stream network consists of a river and its tributaries which are segmented into sections of constant hydrologic, physical, chemical and biological parameters. Loads may be applied pointwise at the ends of the section or as distributed sources along its length. A summary of the loads is given below:

BOD Loads

Point loads-carbonaceous and/or nitrogenous

(e.g., and industrial waste)

Distributed loads-carbonaceous and/or nitrogenous

(e.g., agricultural runoff)

D.O. Deficit Loads

Distributed Loads - Benthal Demand

- Photosynthetic Demand

As well, point sources of both BOD and DO deficit from minor tributaries can be input at the ends of a section and background loads of BOD and DO deficit can be introduced at the system's upstream ends.

The expanded Streeter-Phelps equation is then applied to each section to determine their CBOD, NBOD and DO deficit response to the loadings. Mass balances are applied at the junction of sections as well as the more complex junction of the systems tributaries. In this way the program generates results for the entire system.

This documentation consists of a description of the program as well as its input. A listing of both versions of the program (SNSIM1 being compatible with the IBM 370/155 while SNSIM2 is compatible with the IBM 1130) and an example problem are included in the appendices.

As a final note, SNSIM is meant to be used to either furnish insight into particular phenomena, or as a predictive device for use in water quality planning. Care must be taken at all times to consider all the assumptions underlying its formulation and by no means could it ever be construed to apply to any and every aquatic system or problem. With this in mind it is an excellent tool for the use of those interested in applying rational approaches to the problems of the deterioration of the environment.

The System: Definition of Terms

- A REACH is that part of a stream from its source (furthest upstream point of interest) or confluence to the next confluence. Figure 1 shows a hypothetical river network. As can be seen the branches of the river are numbered and each is referred to as a "reach".

- A CONFLUENCE is the point at which two or more reaches join. At present, SNSIM allows up to 4 reaches to be joined at a confluence.

- A SECTION is that part of a reach which can be described by constant physical, chemical, hydrological and biological characteristics. An example of sectioning is shown in the example problem (Appendix B). Each section in a reach may have a waste source and/or minor tributary at each of its boundaries.

- A MINOR TRIBUTARY is one which is not to be described by the model but only serves as an input to the system. "Silverload Run" from the example problem in Appendix B is a minor tributary.

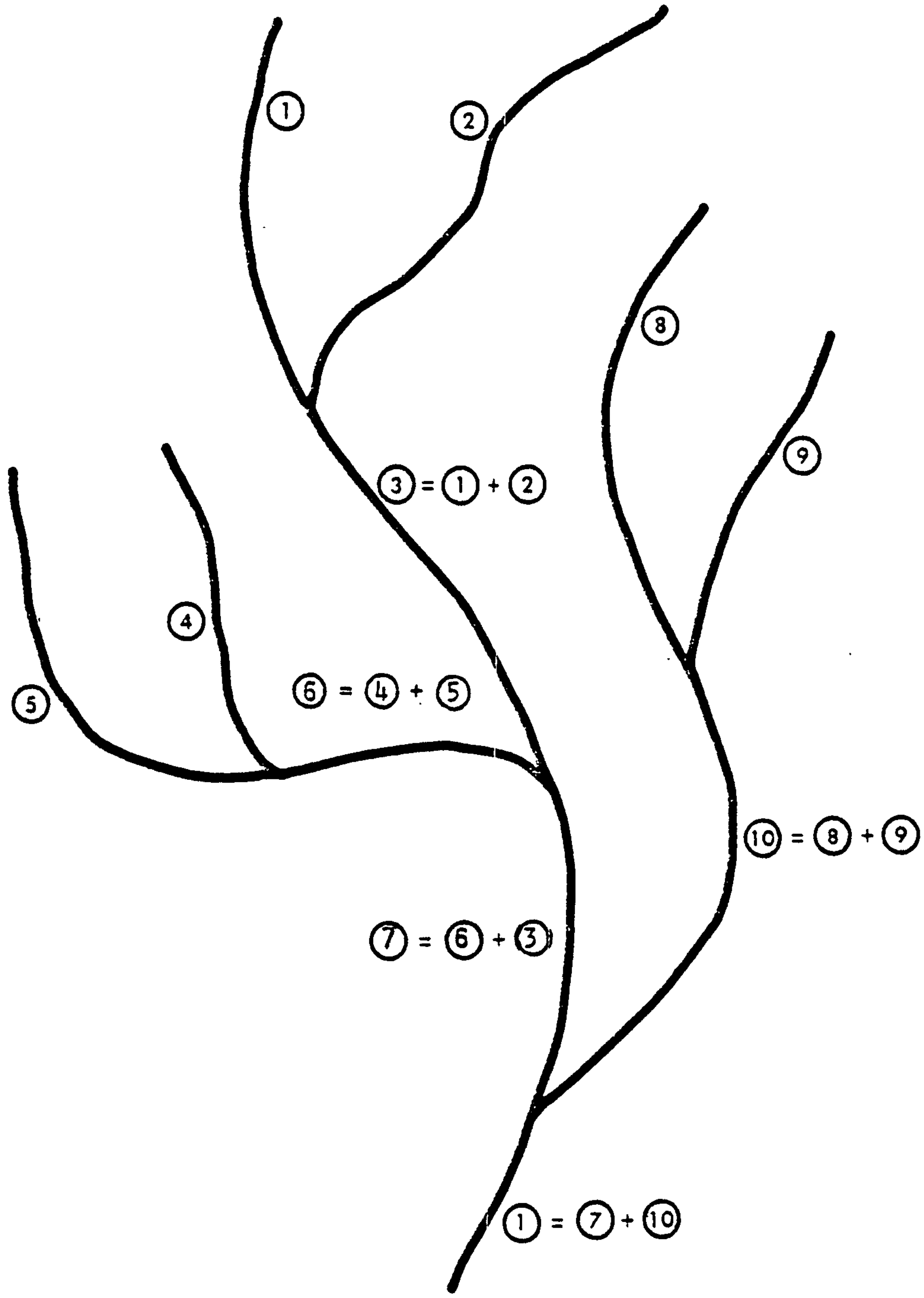


FIGURE 1

Theory

The equations for the calculation of the distribution of CBOD, NBOD and DO deficit in a Section are as follows:

$$CBOD=CBOD_o \exp[-(K_r/u)x]+(CBOD_d/Kr)(1-\exp[-(K_r/u)x])^* \qquad (1)$$

$$NBOD=NBOD_o \exp[-(K_n/u)x]+(NBOD_d/K_n)(1-\exp[-(K_n/u)x]) \qquad (2)$$

$$D=D_o \exp[-(Ka/u)x] \qquad (3a)$$

$$+\frac{Kd}{Ka-Kr}(\exp[-(Kr/u)x]-\exp[-(Ka/u)x])CBOD_o \qquad (3b)$$

$$+\frac{Kn}{Ka-Kn}(\exp[-(Kn/u)x]-\exp[-(Ka/u)x])NBOD_o \qquad (3c)$$

$$+\frac{Kd}{KaKr}(1-\exp[-(Ka/u)x])CBOD_d$$

$$-\frac{Kd}{(Ka-Kr)Kr}(\exp[-(Kr/u)x]-\exp[-(Ka/u)x])CBOD_d \qquad (3d)$$

$$+\frac{1}{Ka}(1-\exp[-(Ka/u)x])NBOD_d$$

$$-\frac{1}{(Ka-Kn)}(\exp[-(Kn/u)x]-\exp[-(Ka/u)x])NBOD_d \qquad (3e)$$

$$-(1-\exp[-(Ka/u)x])\frac{Algal}{Ka} \qquad (3f)$$

$$+(1-\exp[-(Ka/u)x])\frac{Sb}{Ka} \qquad (3h)$$

$^*\exp[y]=e^y$

where the elements of the deficit equation are interpreted as follows:

(3a) point source* of DO deficit and initial value of DO deficit

(3b) deficit due to point source* of CBOD

(3c) deficit due to point source* of NBOD

(3d) distributed source of CBOD deficit input with no significant addition to river flow

(3e) distributed source of NBOD deficit input with no significant addition to river flow.

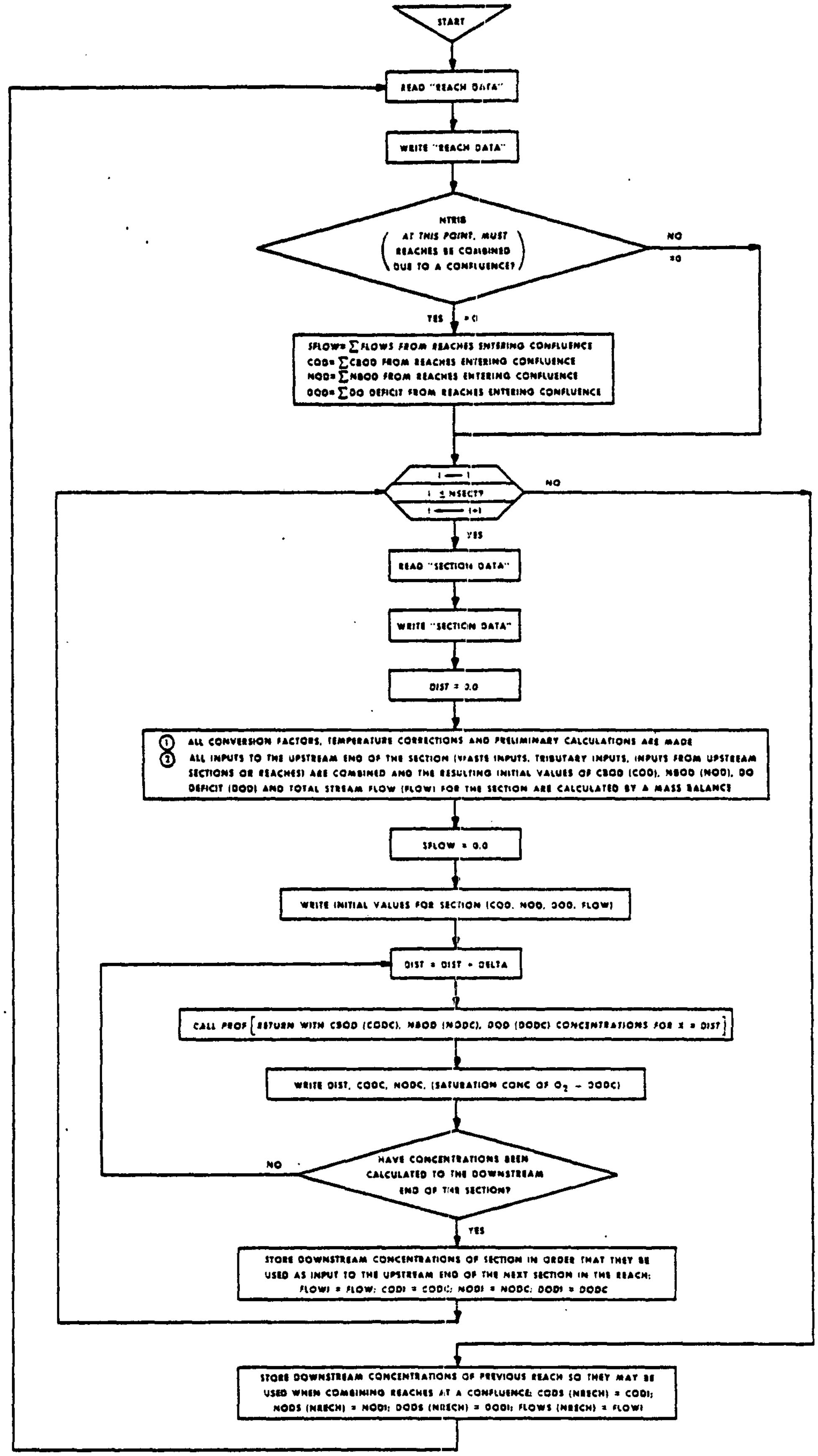
(3f) deficit due to distributed net algal oxygen production

(3h) distributed benthal demand effect

Definitions of the various terms in the equations can be found in the nomenclature (page 19). For a concise discussion of these equations and stream modelling in general see Thomann.[2]

* Point source in the equation refers to all input which occurs at the upstream end of the section to which the equation applies. This may include effluent point loads, minor tributary loads, and all input from the downstream ends of the sections directly upstream from the section in question. In other words, the total point source is the boundary condition at the upstream end of the section.

THE COMPUTER PROGRAM



FLOW CHART FOR SNSIM
Figure 2

The Computer Program

The program begins by reading and writing the name of the river (TITLE). Then the general data for the initial stream conditions upstream of the first section are read. These are the instream flow (FLOWI), the instream carbonaceous demand (CODI), instream nitrogenous demand (NODI), instream dissolved oxygen deficit (DODI), the increment size for a section output (DELTA), an integer (NDIST) representing the reach number of the starting milepoint, the number of sections in the reach (NSECT), the reach number (NRECH), the number of tributaries or reaches to be combined (NTRIB), the reach numbers (NT(I), I=1,2,3,4) which are to be combined, and the indicator (NREAR) which designates if the reaeration rate is to be input or computed. A control variable ICOR is also read, which indicates if the stream depth, flow and velocity are to be computed by exponential correlation equations in the form:

$$\text{FLOW(reach)} = \text{qcoef1*FLOW(gauge)}^{\text{qcoef2}} \quad (1)$$

$$\text{DEPTH(section)} = \text{hcoef1*FLOW(reach)}^{\text{hcoef2}} \quad (2)$$

$$\text{VEL(section)} = \text{vcoef1*FLOW(reach)}^{\text{vcoef2}} \quad (3)$$

where:

FLOW(gauge) = stream flow at gauging station site (CFS)
FLOW(reach) = the average stream flow over the reach (CFS)
QCOEF1 and QCOEF2 = coefficients of correlation for the flow at a particular reach.
DEPTH(section) = correlated section depth (ft)
VEL(section) = correlated section velocity (ft/sec.)
hcoef1, hcoef2, vcoef1, vcoef2 = correlation coefficients for depth and velocity respectively.

The above correlation coefficients are available from the U.S. Geological Survey. The second option of the control variable ICOR indicates the stream depth, flow and velocity will be inputted directly.

SNSIM is capable of stream network simulation. Each reach must be assigned a reach integer (NRECH) between 1 and 10. At a confluence of two reaches, three reach numbers will be required—one for each of the 2 reaches before the confluence, and 1 to represent the reach after confluence. In this program, only the data for the combined effects will be required to continue computations for the stream network. It is only necessary to use the 3rd reach number for further computations, once the program has read in data for the confluence. The two reach numbers representing reaches before the confluence may be reassigned elsewhere in the stream network.

In Figure 1, Reach 1 is the uppermost reach, and includes all river sections from the source to the confluence with Reach 2. The data for Reach 3 represents the combined effects of 1 and 2, so that Reach numbers 1 and 2, may now be used to represent other reaches. In this diagram, consecutive reach numbers are used (up to 10) and at the confluence of Reaches 7 and 10 "1" is used again. At this point any of the other reach numbers (besides 7 and 10) could also have been used.

Having read the initial values, SNSIM now tests NTRIB. For a negative NTRIB the program ends. Usually NTRIB is the number of tributaries to be combined at a confluence and therefore SNSIM enters a do loop from 1 to NTRIB where the sum of the flow (SFLOW), and the COD, NOD, and DOD concentrations are computed by a mass balance. Then control will go to statement 9. At an upstream end of the system, NTRIB will be zero, and control will also go to statement 9. In either case at statement 9 the initial instream flow (FLOWI) is converted from cfs to cfd, and the total distance along a reach (TDIST) is initialized as zero or as the distance at which a previous reach terminated. SNSIM then enters a do loop from 1 to the number of sections in the reach (NSECT). The do loop begins by reading the section name (SNAME), section length (SLGTH), stream depth (DEPTH), stream velocity (VEL), waste or effluent flow at the head of the section (FLOWW), effluent COD (CODW), effluent NOD (NODW), effluent D.O. Deficit (DODW), tributary flow at the head of the section (FLOWT), the ratio of ultimate to 5-day BOD (FF), tributary COD (CODT), tributary NOD (NODT), tributary D.O. Deficit (DODT), water temperature (TEMP), carbonaceous BOD decay rate (KC), carbonaceous BOD deoxygenation rate (KD), nitrogenous BOD decay rate (KN), reaeration rate (KR)*, algal oxygen rate (ALGAL), benthic oxygen demand (BENTH), the carbonaceous (BANKC) and nitrogenous (BANKN) bank loads (agricultural and storm water runoff) and the altitude above sea level (ALT). The section distance is initialized as zero, and then the saturation constant[3] (CS) is computed from:

$$C_s = 14.652 - 0.41022\ (TEMP) + 0.007991\ (TEMP)^2 - .000077774(TEMP)^3 \qquad (4)$$

where

TEMP = Temperature in °C

this is then adjusted for elevation by:[4]

$$C_s = C_s * (1. - .00000687 * ALT^{5.29}) \qquad (4a)$$

where

ALT = altitude above sea level in feet

The stream velocity is then converted from ft/sec to ft/day. The tributary and effluent flows are converted to cfd. If the tributary flow is negative (water being taken out) then this amount of flow will be subtracted from the incoming flow. This negative tributary flow is used for <u>flow uptakes</u> such as the intake of a nuclear power plant.

Flow diversions from the system are handled by defining reaches with initial negative flows. In this case the diverted flow is subtracted from the previously adjoining reach. The COD, NOD and DO deficit of the diverted flow will also be that of the previously adjoining reach. For this diverted reach we can also define tributaries and waste flows as in the rest of the stream.

* SNSIM has the option of either directly inputting the reaeration rate or calculating it according to the following two functional relationships:

$$Kr = \frac{aVEL^b}{DEPTH^c} \quad \ldots\ldots (5)$$

Several investigators have proposed the coefficients for use in the above equation:

INVESTIGATORS	a	b	c
O'Connor and Dobbins (5) 1958	12.90	0.50	1.50
Churchill, et al., (7) 1962	11.573	0.969	1.673
Langbein and Durun,(8) 1967	7.60	.50	1.33
Owens and Gibbs. (9) 1969	21.65	0.67	1.85

It should be noted that this functional relationship may not be applicable to all streams. For instance, it was not designed for fast turbulent shallow streams. Therefore it is cautioned that users become familiar with the limitations of this relationship before assuming that it applies to the stream which is to be modelled. The second functional relationship defines the reaeration rate constant in terms of the rate of energy expenditure in a fresh water stream, and is given by Tsivoglou and Wallace (6) as:

$$Kr = c \frac{\Delta h}{t_f} \quad \ldots\ldots (5a)$$

where c is a constant of proportionality designated the "escape coefficient", Δh is the change in surface water elevation and t_f is the time of travel. This type of relationship is independent of the depth of the stream, and hence is very useful where the other functional relationships are limiting. The range of numerical values of the escape coefficient are very small. In a study of five rivers with a very wide variety of stream flows, BOD, temperature and Kr; the range of individual c values was from .0374/ft to .0804/ft at 25° C (6). As a third option, SNSIM offers the users this approach to compute the reaeration rate constant.

As well, the following temperature correction factors are applied.[2]

```
    KC=KC*1.047**(T-20.)
    KN=KN*1.08 **(T-20.)
    KD=KD*1.047**(T-20.)
BENTH = BENTH *1.065**(T-20.)
    KR=KR*1.024**(T-20.)
```

All section input data is output in a clearly labelled form.

The CODW and the NODW are then converted from lb/day to mg/l by a conversion factor:

$$CODW(mg/l) = \frac{CODW(\#/day)}{FLOWW(cfd)} * 454000 mg/\# * 3.531 \times 10^{-2} ft.^3/l * FF \quad (6)$$

$$CODW(mg/l) = \frac{CODW(\#/day)}{FLOWW(cfd)} * 16026.5\ mgft^3/\#l * FF \quad (7)$$

$$NODW(mg/l) = \frac{NODW(\#/day)}{FLOWW(cfd)} * 16026.5\ mgft^3/\#l \quad (8)$$

The total flow for the section is computed as the sum of the instream (FLOWI), effluent (FLOWW), tributary (FLOWT), and stored flows (SFLOW). The initial COD, NOD, and DOD are computed by a mass balance, for example:

$$COD = \frac{(CODI)(FLOWI) + (CODW)(FLOWW) + (CODT)(FLOWT) + (COD)(SFLOW)}{FLOW} \quad (9)$$

The carbonaceous and nitrogenous bank loads are then converted to compatible units as follows:

$$BANKC(mg/l/day) = \frac{BANKC(\#/mile/day) * VEL(ft/day)}{FLOW(cfd) * 28.32\ l/ft^3} * \frac{454000\ mg/\#}{5280.ft/mile} \quad (10)$$

$$BANKN(mg/l/day) = \frac{BANKN * VEL * 454000}{28.32 * FLOW * 5280.} \quad (11)$$

and the benthal demand is:

$$BENTH(mg/l/day) = \frac{BENTH(gm/M^2/day) * (1000\ mg/gm)}{28.32\ l/ft^3 * DEPTH(feet)(3.281ft)^2/(M)^2} \quad (12)$$

$$= \frac{BENTH(gm/M^2/day) * 3.28}{DEPTH(feet)} \quad (13)$$

For output purposes the flow (FLOWA) is converted to cfs including a correction factor for round-off errors.* The actual D.O. level is computed by subtracting the D.O. deficit from the saturation constant. A variable (DIS) is defined for output as equal to the total downstream distance (TDIST) + 0.005, a round-off correction.

* This round-off correction is only for computers (e.g. IMB 1130) which truncate when outputting.

The section number (I), name (SNAME), distance (DIS), COD, NOD, DO level (C), total flow (FLOWA) and total deficit (DOD), are printed. The section (DIST) and total (TDIST) distances are then incremented by DELTA, and the section distance (DIST) is tested against the section length.

If the section distance is greater than or equal to the section length, the total distance is redefined. This could happen if the distance was greater than the section length, so the difference between these two is subtracted from TDIST. DIST is then set equal to the section length, and DISTN is defined from DIST as the section distance in feet. PROF is then called.

Subroutine PROF

The CALL and SUBROUTINE statements for PROF are:

```
    CALL PROF (CODC, COD, KC, NODC, NOD, KN, DODC, KR, DOD, DISTN, VEL,

               ALGAL, BENTH, BANKN, BANKC, KD, A3, B3, C3, D3, E3, F3,

               H3)

SUBROUTINE PROF (EL, ELO, DKC, EN, ENO, DKN, D, R, DO, X, U, ALG, B, WN,
                 WL, DKD, A3, B3, C3, D3, E3, F3, H3)
```

Equations (1), (2) and (3) are computed in PROF with (3) being computed by component and then added to get the total deficit, e.g. equation 3a would correspond to A3.* The components are computed separately to aid in verification.

Returning to SNSIM, the actual DO level is computed based on the calculated DO deficit and the saturation concentration, and all computed values are output in a clearly labeled form. The corresponding stream distance is computed and the stream distance covered by SNSIM is checked against the stream length. If these two variables are not equal, control returns to statement 1, and changes in DIST will be computed, along with a new COD, NOD, and D.O., until DIST = SLGTH. Then the total flow becomes the initial flow for the next section, and the same changes are also made for COD, NOD, and DOD. SNSIM continues until all sections in the reach have been read in.

The total flows, distance, and computed COD, NOD, and DOD at the end of the reach are stored by FLOWS, SDIST, CODS, NODS, and DODS, respectively. Initial data is now read in for the next reach, and the process continues until the system is completed.

* NOTE: See equation 3 and the nomenclature section for a precise definition of the components.

RESTRICTIONS

1) SNSIM is limited to combining a maximum of 4 tributaries at one confluence. This limit may be expanded to 9 by changing the dimension statement for NT. For more than 9 tributaries at one confluence, a change must be made in the stored variables as well.

2) The number of reaches that may be stored at one time is 10. This limit may be changed by expanding the dimensions of FLOWS, CODS, DODS, and NODS.

3) Dissolved oxygen deficit is calculated as a weighted average at a junction for input to the next downstream section. As a consequence, mass may not be conserved when there are significant temperature changes for adjacent reaches.

Additional Comments:

- When inputting an effluent waste source (CODW, NODW, DODW) the accompanying waste flow (FLOWW) must be input even when it is negligible.

- When there is no nitrification taking place in a reach, the NBOD removal rate constant Kn can not be set equal to zero; a negligible value should be used instead.

- If the user desires to compute the stream inflow, depth and velocity by correlation equations in any particular reach, the input values for these parameters may be left blank. The depth and velocity can be correlated to a directly inputted reach flow by letting the correlation coefficients of the gauge flow equal to one.

- Some users have commented that the deficit components shown in the output may be misleading.

  The deficit components printed for a section are the components for that section alone and do not reflect the effect of upstream sections. At the end of a section the various components are combined in a mass balance with all other deficit sources at that point and input to the next section downstream as a boundary condition. Each individual component is set to zero and new components for the section are computed.

INPUT REQUIREMENTS AND DATA DESCRIPTION

Column	Variable	Description	Format
Card One:			
1-80	TITLE	River Name	20A4
Card Two:	"Reach Data"		
1	ICOR	CONTROL VARIABLE - ICOR=1 indicates that instream flow, Depth and velocity for each section within this reach will be computed by correlation equations (optional "section data card FIVE" will be read). ICOR=0: Instream flow, Depth & velocity will be inputted directly for each section within this reach	I1
2-10	FLOWI	Instream Flow (CFS)	F9.0
11-20	CODI	Instream COD (mg/l)	F10.0
21-30	NODI	Instream NOD (mg/l)	F10.0
31-40	DODI	Instream D.O. Deficit (mg/l)	F10.0
41-44	DELTA	Section Increment Size (miles)	F4.0
45-46	NDIST	Reach number of starting milepoint	I2
47-48	NSECT	No. of Sections in Reach	I2
49-50	NRECH	Reach Number	I2
51-52	NTRIB	No. of Reaches to Combine	I2
53-60	NT(1-4)	Reach Numbers to be Combined	4I2
61-62	NREAR	CONTROL VARIABLE: NREAR=1 indicates the reaeration rate constant will be input directly. NREAR=0 indicates that the reaeration rate constant will be computed by the functional relationship: $Ka = aVEL^{b}/DEPTH^{c}$	I2
63-68	ACOEF	Reaeration Parameter a	F6.3
69-74	BCOEF	Reaeration Parameter b	F6.3

Column	Variable	Description	Format
75-80	CCOEF	Reaeration Parameter c	F6.3
		NREAR = -1 indicates that the reaeration rate will be computed by the Tsivoglou and Wallace relationship	
		$Ka = C \Delta H/t_f$	
63-68	ESCOEF	Escape Coefficient at 25°C (1/ft)	F6.3

Card Three: "Section Data"

Column	Variable	Description	Format
1-4	SNAME	Section Name	A4
9-16	SLGTH	Section Length (miles)	F8.0
17-24	DEPTH	Stream Depth (ft)	F8.0
25-32	VEL	Stream Velocity (f/s)	F8.0
33-40	FLOWW	Waste Flow (MGD)	F8.0
41-48	CODW	Effluent COD (#/day)	F8.0
49-56	NODW	Effluent NOD (#/day)	F8.0
57-64	DODW	Effluent D.O. Deficit (mg/l)	F8.0
65-72	FLOWT	Minor tributary flow (cfs)	F8.0
73-80	FF*	Ratio of ultimate to five day BOD	F8.0

Card Four:

Column	Variable	Description	Format
1-6	CODT	Concentration of CBOD in minor tributary (mg/l)	F6.0
7-12	NODT	Concentration of NBOD in minor tributary (mg/l)	F6.0
13-17	DODT	Concentration of D.O. deficit in minor tributary (mg/l)	F5.0
18-22	TEMP	Water temperature of section (°C)	F5.0
23-28	KC	CBOD removal rate (1/day)	F6.0

Column	Variable	Description	Format
29-34	KD	Carbonaceous deoxygenation rate (1/day)	F6.0
35-40	KN	NBOD removal rate (1/day)	F6.0
41-46	KR	Reaeration rate (1/day) - optional (only if NREAR=1)	F6.0
47-52	DELHT**	Water surface elevation change (ft) - optional (only if NREAR* -1)	
53-57	ALGAL***	Algal oxygen rate (mg/l/day)	F5.0
58-62	BENTH	Benthal oxygen demand (gm/M^2/day)	F5.0
63-68	BANKC	Uniform CBOD load (#/Mi/day)	F6.0
69-74	BANKN	Uniform NBOD load (#/Mi/day)	F6.0
75-80	ALT	Altitude above sea level (feet)	F6.0

* if left blank, the program assumes a value of 1.0

** only required if using the Tsivoglou & Wallace relationship to compute reaeration rate constant

*** this is equal to the oxygen production rate due to photosynthesis minus the oxygen depletion rate due to respiration of algal.

Card Five: Optional - must be preceded by ICOR=1 in "Reach" data card

Column	Variable	Description	Format
1-10	FLOWG	Gauge flow (CFS)	F10.0
11-15	QCEF1	Correlation coefficients for instream flow	F5.3
16-20	QCEF2	in the form:	F5.3
		FLOW(reach)= QCEF1 * FLOWG ** QCEF2	
21-25	HCEF1	Correlation coefficients for section depth	F5.3
26-30	HCEF2	in the form:	F5.3
		DEPTH = HCEF1 * FLOW (reach) ** HCEF2	
31-35	VCEF1	Correlation coefficients for stream veloc-	F5.3
36-40	VCEF2	ity in the form:	F5.3
		VEL - VCEF1 * FLOW(reach) ** VCEF2	

Repeat cards 3 and 4 until NSECT sections have been included in the data deck.

For a new reach begin with card 2.

NOMENCLATURE

VARIABLE NAME Program	Other	DESCRIPTION		UNITS*
ALT	ALT	Altitude above sea level		L
A3	Equation 3a	Deficit due to point source of DO deficit and initial value of DO deficit		M/L^3
ALG	ALGAL	Net algal oxygen production rate		$M/L^3/T$
B3	Equation 3b	Deficit due to point source or initial value of CBOD		M/L^3
BANKC & WL	$CBOD_d$	Distributed source of CBOD	(as input) (as converted)**	M/L/T $M/L^3/T$
BANKN & WN	$NBOD_d$	Distributed source of NBOD	(as input) (as converted)**	M/L/T $M/L^3/T$
BENTH & B	Sb	Benthal oxygen demand	(as input) (as converted)**	$M/L^2/T$ $M/L^3/T$
C3	Equation 3c	Deficit due to point source of NBOD		M/L^3
CODC & EL	CBOD	Carbonaceous biochemical oxygen demand		M/L^3
COD & ELO	$CBOD_o$	Point source of CBOD		M/L^3
CS	Cs	Saturation value of dissolved oxygen		M/L^3
CODW	CODW	Point source of CBOD due to a waste load		M/T
CODT	CODT	Point source of CBOD due to a minor tributary		M/L^3
CODI	CODI	Initial point source of CBOD at an upstream end of the system		M/L^3
D3	Equation 3d	Deficit due to distributed source of CBOD with no significant addition to river flow		M/L^3
D & DODC	D	Dissolved oxygen deficit		M/L^3
DELHT	Equation 5a	Change in water surface elevation		L
DEPTH	DEPTH	Depth of stream		L

*M: mass, L: length, T: time

** : see page 9

VARIABLE NAME Program	Other	DESCRIPTION	UNITS*
DIST & DISTN X	X	Distance from an initial point at which calculations are to be made	L
DODW	DODW	Amount of deficit from a point waste source	M/L^3
DODT	DODT	Concentration of deficit in a point source minor tributary	M/L^3
DODI	DODI	Initial point source of deficit at the upstream end of the system	M/L^3
DOD & DO	D_o	Point sources of deficit	M/L^3
ESCOE	Equation 5a	Escape coefficient	1/L
E3	Equation 3e	Deficit due to distributed source of NBOD with no significant addition to river flow	M/L^3
FF	FF	Ratio of ultimate to 5-day BOD	
FLOW	FLOW	Total flow	L^3/T
FLOWG	Equation 1	Reference gauge flow	L^3/T
FLOWI	FLOWI	Initial flow at the head end of the system	L^3/T
FLOWT	FLOWT	Flow of a minor tributary	L^3/T
FLOWW	FLOWW	Flow of a waste source	L^3/T
F3	Equation 3f	Deficit due to distributed net algal oxygen production	M/L^3
H3	Equation 3h	Distributed benthal demand effect	M/L^3
KC & DKC	K_r	CBOD removal rate	1/T
KD & DKD	K_d	Deoxygenation rate (caused by CBOD)	1/T
KN & DKN	K_n	NBOD removal rate - deoxygenation rate (NBOD)	1/T
KR & R	K_a	Reaeration rate	1/T

VARIABLE NAME		DESCRIPTION	UNITS*
Program	Other		
NODC & EN	NBOD	Nitrogenous Biochemical Oxygen Demand	M/L^3
NOD & ENO	$NBOD_o$	Point source of NBOD	M/L^3
NODW	NODW	Point source of NBOD due to waste load	M/T
NODT	NODT	Point source of NBOD from a minor tributary	M/L^3
NODI	NODI	Point source of NBOD from an initial source at the upstream end of the system	M/L^3
TEMP	TEMP	Temperature	°C
VEL	VEL	Velocity of stream	L/T

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APPENDIX A

(listing of source deck)

The following listing of the source program was written in FORTRAN IV for use on the IBM 370/155 computer using a fortran G compiler.

To modify it so that it can be run on another computer (e.g. the IBM 1130) statements SNSIM055 and SNSIM056 which designate the input and output devices may have to be changed.

As well, if a computer is used which truncates it output *(as opposed to round-off which is employed by the IBM 370) the following changes should be made:

Make the following modifications:

```
   REAL NODI,NODW,NODT,NOD,NODC,KC,KN,KR,NODS(10),KD,NXD,NXDC        SNSIM010
   FLOWA=FLOW/86400.+0.005                                           SNSIM129
14 DIS=TDIST+0.005                                                   SNSIM149
```

Remove SNSIM136 and replace it with the following cards:

```
   CXD=COD+0.005
   NXD=NOD+0.005
   DXD=DOD+0.005
   S=C+0.005
   WRITE(NX,106)I,SNAME,DIS,CXD,NXD,S,FLOWA,DXD
```

Remove SNSIM150 and replace it with the following cards:

```
   S=C+0.005
   AX=A3+0.005
   BX=B3+0.005
   CX=C3+0.005
   DX=D3+0.005
   EX=E3+0.005
   HX=H3+0.005
   CXDC=CODC+0.005
   NXDC=NODC+0.005
   DXDC=DODC+0.005
   WRITE(NX,105)DIS,CXDC,NXDC,S,AX,BX,CX,DX,EX,F3,HX,DXDC
```

Modify 7th card after SNSIM089 to read:

```
   FLOWA=FLOWI+.005
```

*e.g. IBM 1130

APPENDIX A

```
C*********************************************************************SNSIM000
C                                                                      SNSIM001
C   THIS LISTING OF SNSIM HAS BEEN DESIGNATED AS SNSIM1 AND IS         SNSIM002
C   COMPATIBLE WITH THE IBM 370/155                                    SNSIM003
C                                                                      SNSIM004
C                                                                     *SNSIM005
C      PROGRAM SNSIM IS A ONE-DIMENSIONAL, STEADY-STATE, STRAIGHT-RUN *SNSIM006
C      STREAM NETWORK SIMULATION MODEL.                               *SNSIM007
C                                                                     *SNSIM008
C*********************************************************************SNSIM009
      REAL NODI,NODW,NODT,NOD,NODC,KC,KN,KR,NODS(10),KD                SNSIM010
      DIMENSION TITLE(20),FLOWS(10),CODS(10),DODS(10),NT(4),SDIST(10)  SNSIM011
   33 FORMAT(/,' INPUT FOR SECTION ',A4,//,'    SLGTH =',F8.3,         SNSIM012
     1' MILES', 5X,'DEPTH=',F8.3,' FEET',10X,'VEL=',F8.3,1X,           SNSIM013
     2'FPS'/'    FLOWW=',F8.3,' MGD', 8X,'CODW=',F12.3,1X              SNSIM014
     3'LBS/DAY', 4X,'NODW=',F12.3,' LBS/DAY', 4X,'DODW=',F8.3,1X,      SNSIM015
     4'MG/L'/'    FLOWT=',F8.3,' CFS', 8X,'CODT=',F8.3,' MG/L',11X,    SNSIM016
     1'NODT=',F8.3,' MG/L',11X,'DODT=',F8.3,' MG/L')                   SNSIM017
   34 FORMAT('    ALGAL=', F8.3,'MG/L/DAY     ',23X                    SNSIM018
     1,6X,'BANKC=',F8.3,' LBS/MI/DAY',4X,'BANKN=',F8.3,' LBS/MI/DAY'/' SNSIM019
     1 FF=',F6.3,17X,'ALT=',F8.2,' FEET'//'****************************SNSIM020
     1*****************************************************************SNSIM021
     6*******************'               /'  REACTION RATES AS INPUT (TEMP =SNSIM022
     2 20 C)')                                                         SNSIM023
   35 FORMAT( '    KC=',F8.3,' /DAY',10X,                              SNSIM024
     3            'KD=',F8.3,' /DAY',13X,                              SNSIM025
     3            'KN=',F8.3,' /DAY',13X,                              SNSIM026
     3            'KR=',F8.5,' /DAY'/'    BENTH=',F7.4, ' GM/M **2/DAY') SNSIM027
   36 FORMAT(/,'  REACTION RATES AS CONVERTED (TEMP = ',F5.1,' C)',/   SNSIM028
     4     '    KC=',F8.3,' /DAY',10X,                                 SNSIM029
     3            'KD=',F8.3,' /DAY',13X,                              SNSIM030
     3            'KN=',F8.3,' /DAY',13X,                              SNSIM031
     3            'KR=',F8.5,' /DAY'/'    BENTH=',F7.4, ' GM/M **2/DAY') SNSIM032
   37 FORMAT(' ********************************************************SNSIM033
     1*******************************************************    '/)  SNSIM034
  100 FORMAT(20A4)                                                     SNSIM035
  101 FORMAT('1',26X,20A4//)                                           SNSIM036
  102 FORMAT(I1, F9.0,3F10.0,F4.0,9I2,3F6.0)                           FEB 75
  103 FORMAT(A4,4X,9F8.0/2F6.0,2F5.0,5F6.0,2F5.0,3F6.0)                FEB 75
  104 FORMAT(2X,'SECTION SECTION  DISTANCE    CBOD      NBOD      DO     FLSNSIM039
     1OW                  DEFICIT COMPONENTS              TOTAL'       SNSIM040
     2/3X,'NUMBER   NAME  DOWNSTREAM',36X,'A3    B3    C3    D3    E3  SNSIM041
     2 F3    H3   DEFICIT')                                            SNSIM042
  105 FORMAT(15X,F10.2,3X,3F8.2,8X,                                    SNSIM043
     27F6.2,F9.2)                                                      SNSIM044
  106 FORMAT(/,  I6,6X,A4, F9.2,3X,4F8.2,41X,F10.2)                    SNSIM045
  107 FORMAT(//,' INPUT FOR REACH ',I2,//,'    FLOWI =',F10.2,' CFS    SNSIM046
     1          CODI =',F10.2,' MG/L'/'    NODI =',F10.2,' MG/L       'SNSIM047
     2,7X,'DODI =',F10.2,' MG/L'/'    DELTA =',F10.2,' MILES           FEB 75
     3 NDIST =',I5,/,'     NSECT =',I5,25X,'NTRIB =',I2,/              SNSIM049
     4'    NT(1)=',I2,'    NT(2)=',I2,'    NT(3)=',I2,'    NT(4)=',I2  SNSIM050
     5,'       NREAR = ',I2,5X,'ICOR= ',I2,//)                         MAR 75
  108 FORMAT(F10.0,6F5.3)                                              FEB 75
  109 FORMAT(//,' INPUT FOR REACH ',I2//3X,'CODI =',F10.2,' MG/L',12X, FEB 75
```

```
   1'NODI =',F10.2,' MG/L',4X,'DODI =',F10.2,' MG/L'/'    DELTA =',     FEB 75
   2 F10.2,' MILES',10X,'NDIST =',I5,/,'    NSECT =',I5,21X,            FEB 75
   3 'NTRIB =',I2,/,3X,'NT(1)=',I2,'    NT(2)=',I2,'    NT(3)=',I2,3X,  FEB 75
   4'NT(4)=',I2,2X,    'NREAR = ',I2,5X,'ICOR =',I2)                    FEB 75
110 FORMAT(3X,'FLOWI =',F10.2,' CFS',//)                                FEB 75
111 FORMAT(3X,'FLOWG =',F8.2,' CFS',7X,'QCEF1 =',F6.3,16X,              FEB 75
   1'QCEF2 =',F6.3,/,'    HCEF1 =',F6.3,13X,'HCEF2 =',F6.3,16X'VCEF1=',FEB 75
   2F6.3,17X,'VCEF2 =',F6.3)                                            FEB 75
112 FORMAT(10X,A4,' SECTION  HAS ZERO REAERATION COEFFICIENT')          DEC 74
113 FORMAT('    ALGAL=', F8.3,' MG/L/DAY   BANKC=',F8.3,                FEB 75
   1' LBS/MI/DAY',4X,'BANKN=',F8.3, ' LBS/MI/DAY',4X,'ALT=',F8.2,1X,   FEB 75
   1'FEET'                                                              FEB 75
   2/,'    FF=',F6.3,17X,'ESCAPE COEF=',F7.4,' /FT', 6X,'DELTA HT=',    FEB 75
   3F7.2,' FEET'//)                                                     FEB 75
114 FORMAT('    ALGAL=', F8.3,' MG/L/DAY   BANKC=',F8.3,                FEB 75
   1' LBS/MI/DAY',4X,'BANKN=',F8.3, ' LBS/MI/DAY',4X,'ALT=',F8.2,1X,   FEB 75
   1'FEET'                                                              FEB 75
   2/,'    FF=',F6.3,17X,'ACOEF=',F7.3,16X,'BCOEF=',F7.3,16X,'CCOEF=', FEB 75
   3 F7.3,//)                                                           FEB 75
134 FORMAT(' ***********************************************************FEB 75
   1*********************************************************    '/,  FEB 75
   2'  REACTION RATES AS INPUT (TEMP = 20 C)')                          FEB 75
902 FORMAT('1')                                                         SNSIM052
    DO 51 I=1,10                                                        SNSIM053
 51 SDIST(I)=0.0                                                        SNSIM054
    MX=5                                                                SNSIM055
    NX=6                                                                SNSIM056
    SFLOW=0.0                                                           SNSIM057
    COD=0.0                                                             SNSIM058
    NOD=0.0                                                             SNSIM059
    DIS=0.                                                              SNSIM060
    DOD=0.0                                                             SNSIM061
    READ(MX,100)TITLE                                                   SNSIM062
    WRITE(NX,101)TITLE                                                  SNSIM063
 12 READ(MX,102)ICOR,FLOWI,CODI,NODI,DODI,DELTA,NDIST,NSECT,NRECH,      FEB 75
   1NTRIB,NT,NREAR,ACOEF,BCOEF,CCOEF                                    FEB 75
    IF(NSECT)28,11,28                                                   SNSIM064
 28 IF(ICOR)915,915,913                                                 FEB 75
913 WRITE(NX,109)NRECH,CODI,NODI,DODI,DELTA,NDIST,NSECT,NTRIB,NT,       FEB 75
   1NREAR,ICOR                                                          FEB 75
    GO TO 917                                                           FEB 75
915 WRITE(NX,107)NRECH,FLOWI,CODI,NODI,DODI,DELTA,NDIST,NSECT,NTRIB,NTFEB 75
   1,NREAR,ICOR                                                         MAR 75
917 IF(NTRIB)11,9,8                                                     FEB 75
  8 DO 10 I=1,NTRIB                                                     SNSIM070
    J=NT(I)                                                             SNSIM071
    SFLOW=SFLOW+FLOWS(J)                                                SNSIM072
    COD=COD+FLOWS(J)*CODS(J)                                            SNSIM073
    NOD=NOD+FLOWS(J)*NODS(J)                                            SNSIM074
 10 DOD=DOD+FLOWS(J)*DODS(J)                                            SNSIM075
    COD=COD/SFLOW                                                       SNSIM076
    NOD=NOD/SFLOW                                                       SNSIM077
    DOD=DOD/SFLOW                                                       SNSIM078
  9 FLOWI=FLOWI*86400.                                                  SNSIM079
```

```
      IF(NDIST)11,16,15                                                    SNSIM080
   15 TDIST=SDIST(NDIST)                                                   SNSIM081
      GO TO 17                                                             SNSIM082
   16 TDIST=0.0                                                            SNSIM083
   17 DO 5 I=1,NSECT                                                       SNSIM084
      READ(MX,103)SNAME,SLGTH,DEPTH,VEL,FLOWW,CODW,NODW,DODW,FLOWT,FF,     SNSIM085
     1CODT,NODT,DODT,TEMP,KC,KD,KN,KR,DELHT,ALGAL,BENTH,BANKC,BANKN,ALT FEB 75
      IF(FF)11,210,211                                                     SNSIM087
  210 FF=1.                                                                SNSIM088
  211 DIST=0.0                                                             SNSIM089
      IF(ICOR)910,910,911                                                  FEB 75
  911 READ(MX,108)FLOWG,QCEF1,QCEF2,HCEF1,HCEF2,VCEF1,VCEF2                FEB 75
      FLOWI=QCEF1*FLOWG**QCEF2                                             FEB 75
      FLOW=FLOWI+FLOWT+FLOWW*1.54723                                       FEB 75
      DEPTH=HCEF1*FLOW**HCEF2                                              FEB 75
      VEL=VCEF1*FLOW**VCEF2                                                FEB 75
      FLOWA=FLOWI                                                          MAR 75
      FLOWI=FLOWI*86400.                                                   MAR 75
      IF(NTRIB)11,910,920                                                  FEB 75
  920 CODI=COD                                                             FEB 75
      DODI=DOD                                                             FEB 75
      NODI=NOD                                                             FEB 75
      SFLOW=0.0                                                            FEB 75
  910 WRITE(NX,33)SNAME,SLGTH,DEPTH,VEL,FLOWW,CODW,NODW,DODW,FLOWT,        FEB 75
     1CODT,NODT,DODT                                                       SNSIM091
      IF(ICOR)914,914,916                                                  FEB 75
  916 WRITE(NX,110)FLOWA                                                   MAR 75
      WRITE(NX,111)FLOWG,QCEF1,QCEF2,HCEF1,HCEF2,VCEF1,VCEF2               FEB 75
  914 IF(NREAR)918,919,921                                                 FEB 75
  918 ESCOE=ACOEF                                                          FEB 75
      WRITE(NX,113)ALGAL,BANKC,BANKN,ALT,FF,ESCOE,DELHT                    FEB 75
      WRITE(NX,134)                                                        FEB 75
      GO TO 922                                                            FEB 75
  919 WRITE(NX,114)ALGAL,BANKC,BANKN,ALT,FF,ACOEF,BCOEF,CCOEF              FEB 75
      WRITE(NX,134)                                                        FEB 75
      GO TO 922                                                            FEB 75
  921 WRITE(NX,34)ALGAL,BANKC,BANKN,FF,ALT                                 FEB 75
  922 IF(NREAR)912,201,203                                                 FEB 75
  912 KR=ESCOE*DELHT/(SLGTH/(VEL*16.36364))*.8882                          FEB 75
      GO TO 233                                                            FEB 75
  203 IF(KR)233,91,233                                                     DEC 74
   91 WRITE(NX,112)SNAME                                                   DEC 74
      CALL EXIT                                                            DEC 74
  201 KR=ACOEF*VEL**BCOEF/DEPTH**CCOEF                                     FEB 75
  233 WRITE(NX,35)KC,KD,KN,KR,BENTH                                        DEC 73
      KR=KR*1.024**(TEMP-20.)                                              OCT 74
      KN=KN*1.08**(TEMP-20.)                                               SNSIM096
      KC=KC*1.047**(TEMP-20.)                                              SNSIM097
      KD=KD*1.047**(TEMP-20.)                                              SNSIM098
      BENTH=BENTH*1.065**(TEMP-20.)                                        SNSIM099
      CS=14.652-0.41022*TEMP+0.0079910*TEMP**2.-.000077774*TEMP**3.        SNSIM100
      CS=CS*(1.-(6.87/10.**6. )*ALT)**5.29                                 SNSIM101
      WRITE(NX,36)TEMP,KC,KD,KN,KR,BENTH                                   DEC 74
      WRITE(NX,37)                                                         SNSIM105
```

```
      WRITE(NX,104)                                                     SNSIM106
      VEL=VEL*86400.                                                    SNSIM107
      FLOWT=FLOWT*86400.                                                SNSIM108
      FLOWW=FLOWW*133056.                                               SNSIM109
      IF(FLOWT)6,19,19                                                  SNSIM110
    6 IF(NSECT-1)26,25,26                                               SNSIM111
   25 CODT=COD                                                          SNSIM112
      NODT=NOD                                                          SNSIM113
      DODT=DOD                                                          SNSIM114
      GO TO 19                                                          SNSIM115
   26 CODT=CODI                                                         SNSIM116
      NODT=NODI                                                         SNSIM117
      DODT=DODI                                                         SNSIM118
   19 IF(FLOWW)7,18,7                                                   SNSIM119
    7 CODW=16026.5*CODW/FLOWW*FF                                        SNSIM120
      NODW=16026.5*NODW/FLOWW                                           SNSIM121
   18 IF(FLOWI)907,908,908                                              DEC 74
  907 J=NT(1)                                                           DEC 74
      FLOWS(J)=FLOWS(J)+FLOWI                                           DEC 74
      FLOWI=-FLOWI                                                      DEC 74
      CODI=COD                                                          DEC 74
      NODI=NOD                                                          DEC 74
      DODI=DOD                                                          DEC 74
      SFLOW=0.0                                                         DEC 74
  908 FLOW=FLOWI+FLOWW+FLOWT+SFLOW                                      DEC 74
      COD=(CODI*FLOWI+CODW*FLOWW+CODT*FLOWT+COD*SFLOW)/FLOW             SNSIM123
      NOD=(NODI*FLOWI+NODW*FLOWW+NODT*FLOWT+NOD*SFLOW)/FLOW             SNSIM124
      DOD=(DODI*FLOWI+DODW*FLOWW+DODT*FLOWT+DOD*SFLOW)/FLOW             SNSIM125
      BANKC=(454000.*BANKC*VEL)/(28.32*FLOW*5280.)                      SNSIM126
      BANKN=(454000.*BANKN*VEL)/(28.32*FLOW*5280.)                      SNSIM127
      BENTH=3.28*BENTH/DEPTH                                            SNSIM128
      FLOWA=FLOW/86400.                                                 SNSIM129
      SFLOW=0.0                                                         SNSIM130
      C=CS-DOD                                                          SNSIM131
      IF(C)23,24,24                                                     SNSIM132
   23 C=0.0                                                             SNSIM133
      DOD=CS                                                            SNSIM134
   24 DIS=TDIST                                                         SNSIM135
      WRITE(NX,106)I,SNAME,DIS,COD,NOD,C,FLOWA,DOD                      SNSIM136
      DIS=TDIST+DELTA                                                   SNSIM137
    1 DIST=DIST+DELTA                                                   SNSIM138
      TDIST=TDIST+DELTA                                                 SNSIM139
      IF(DIST-SLGTH)3,2,2                                               SNSIM140
    2 TDIST=TDIST-(DIST-SLGTH)                                          SNSIM141
      DIST=SLGTH                                                        SNSIM142
    3 DISTN=DIST*5280.                                                  SNSIM143
      CALL PROF(CODC,COD,KC,NODC,NOD,KN,DODC,KR,DOD,DISTN,VEL,ALGAL,    SNSIM144
     1BENTH,BANKN,BANKC,KD,A3,B3,C3,D3,E3,F3,H3)                        SNSIM145
      C=CS-DODC                                                         SNSIM146
      IF(C)13,14,14                                                     SNSIM147
   13 C=0.0                                                             SNSIM148
   14 DIS=TDIST                                                         SNSIM149
      WRITE(NX,105)DIS,CODC,NODC,C,A3,B3,C3,D3,E3,F3,H3,DODC            SNSIM150
      IF(DIST-SLGTH)1,4,1                                               SNSIM151
```

```
    4 FLOWI=FLOW
      CODI=CODC
      NODI=NODC
      DODI=DODC
    5 CONTINUE
      FLOWS(NRECH)=FLOWI
      CODS(NRECH)=CODI
      NODS(NRECH)=NODI
      DODS(NRECH)=DODI
      SDIST(NRECH)=TDIST
      WRITE(NX,902)
      GO TO 12
   11 STOP
      END
      SUBROUTINE PROF(EL,ELO,DKC,EN,ENO,DKN,D,R,DO,X,U,ALG,B,WN,WL,
     1DKD,A3,B3,C3,D3,E3,F3,H3)
      EN= (ENO*(EXP(-DKN*X/U)))+(WN/DKN)*(1-EXP(-DKN*X/U))
      EL= (ELO*(EXP(-DKC*X/U)))+(WL/DKC*(1-EXP(-DKC*X/U)))
      A3=  DO*  EXP(-R/U*X)
      B3=  (DKD/(R-DKC))*  (EXP(-  DKC/U*X)  -EXP(-R/U*X)) *ELO
      C3=  (DKN/(R-DKN))*  (EXP(-  DKN/U*X)  -EXP(-R/U*X)) *ENO
      D3=DKD/(R*DKC)*(1.-EXP(-R/U*X))*WL   -DKD/  ((R-DKC)*DKC)*(EXP(
     1-DKC/U*X)  -EXP(-R/U*X))*WL
      E3=1. / R     *(1.-EXP(-R/U*X))*WN   -1. /   (R-DKN)*    (EXP(
     1-DKN/U*X)  -EXP(-R/U*X))*WN
      F3=  -(1.-EXP(-R/U*X))*ALG/R
      H3=   (1.-EXP(-R/U*X))*B/R
      D=A3+B3+C3+D3+E3+F3+H3
      RETURN
      END
/*
```

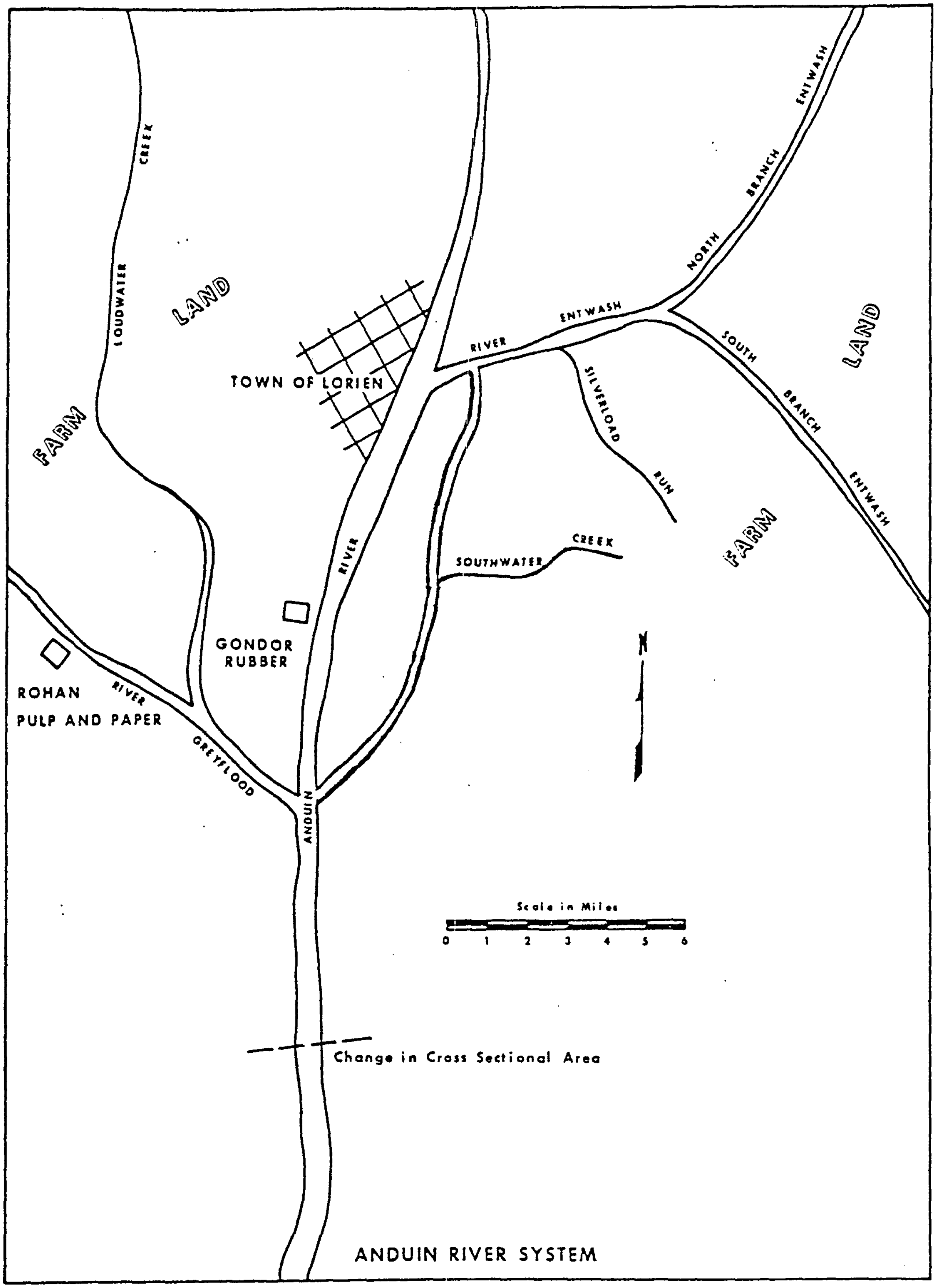
APPENDIX B

(example problem)

The Anduin is a fictitious river system that can be modelled using SNSIM. As shown in figure B-1, it consists of a main stream which is fed by several tributaries. In figure B-2, a schematic of the system illustrates a segmentation scheme which could be used for this application. Each segment is given an acronym and each reach is given a number to identify it. For instance, reach 5 consists of segments LORI and MDAN. The physical, hydrologic and biological parameters which describe these sections are tabulated in Table B-1.

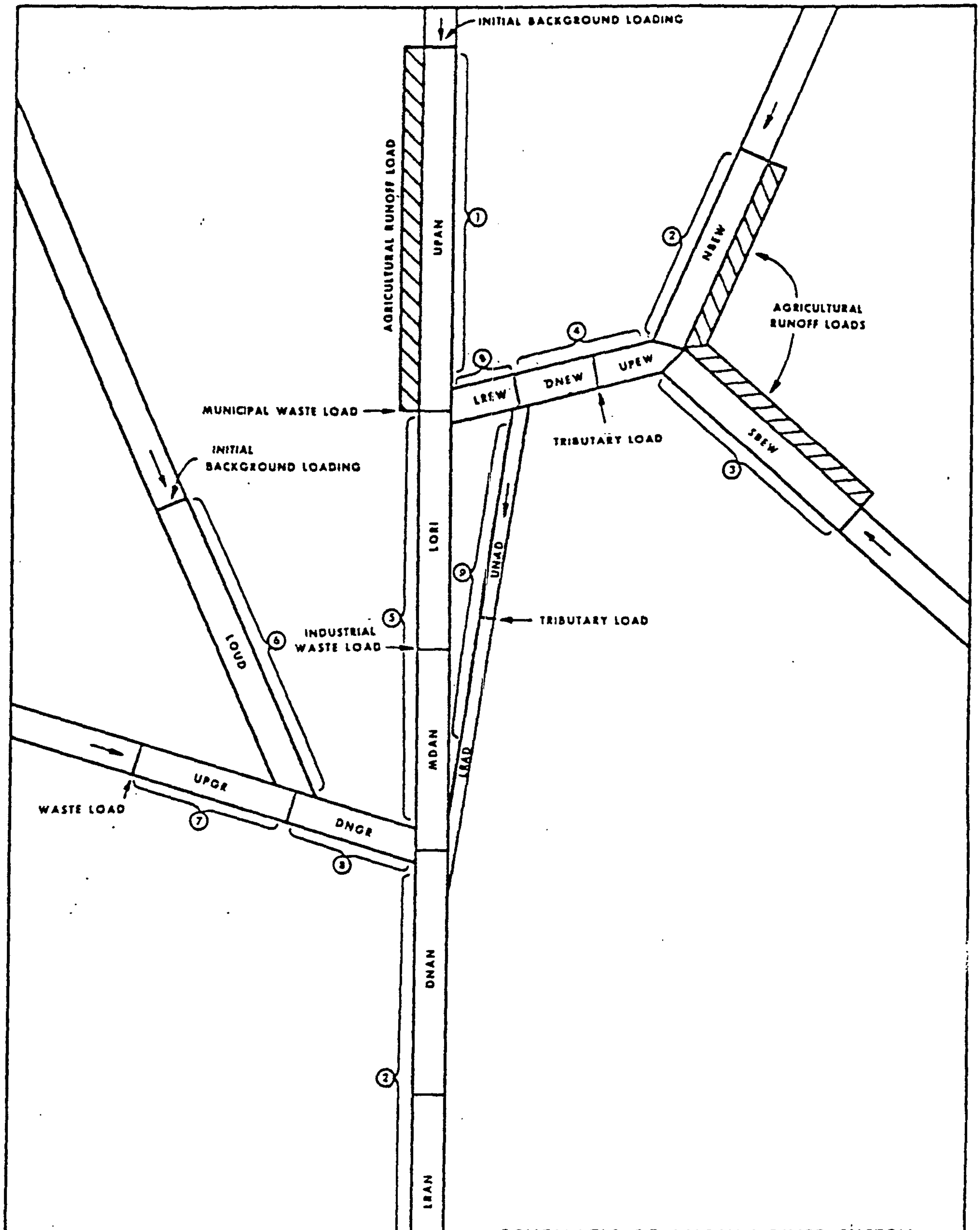
Various types of oxygen demanding loads are exerted along the Anduin System, including point waste loads from municipalities and industries, benthal loads due to sludge deposits, effects due to algal blooms in the lower reaches and initial background and runoff loadings due to agriculture in the headwaters. These loads are summarized in table B-2.

Finally, the data is punched onto computer cards as described on page 13 and as shown in figure B-3 and SNSIM is run. The resulting output is attached.



CREEK
LOUDWATER
LAND
FARM
TOWN OF LORIEN
RIVER
ENTWASH
NORTH
BRANCH
ENTWASH
SOUTH
BRANCH
ENTWASH
LAND
FARM
SILVERLOAD
RUN
SOUTHWATER
CREEK
RIVER
GONDOR
RUBBER
ROHAN
PULP AND PAPER
RIVER
GREYFLOOD
ANDUIN
N
Scale in Miles
0 1 2 3 4 5 6
Change in Cross Sectional Area
ANDUIN RIVER SYSTEM

Figure B-1



SCHEMATIC OF ANDUIN RIVER SYSTEM SHOWING REACHES (ENCIRCLED NUMBERS), SECTIONS AND LOADS

Figure B-2

REACH	SECTION	SLGTH (MILES)	DEPTH (FEET)	VEL (FPS)	TEMP °C	FLOWI (CFS)	FLOWT (CFS)	KC (1/DAY)	KD (1/DAY)	KN (1/DAY)
1	UPAN	9	10	.6	20	100		.3	.3	.1
2	NBEW	5	5	1.2	18	30		.3	.3	.1
3	SBEW	6	5	1.1	18	30		.3	.3	.1
4	UPEW	3	8	1.0	19			.3	.3	.1
	DNEW	3	8	1.0	19		2	.3	.3	.1
9	UNAD	8	7.1	1.5	19	-20		.3	.25	.10
	LRAD	11	7.3	1.1	19		3.	.3	.26	.10
8	LREW	4	8.3	1.4	18.2			.3	.28	.12
5	LOR1	6	15	.5	20			.3	.2	.1
	MDAN	5	15	.5	21			.3	.3	.1
6	LOUD	8	1	1.0	18	10		.3	.3	.1
7	UPGR	4	8	.9	18	22		.3	.3	.1
8	DNGR	3	10	.8	19			.3	.3	.1
2	DNAN	6	20.	.4	20			.3	.3	.1
	LRAN	20	20.	.2	21			.3	.3	.1

TABLE B-1 SECTION PARAMETERS

REACH	SECTION	CODI	NODI	DODI	FLOWW	CODW	NODW	DODW	CODT	NODT	DODT	ALGAL	BENTH	BANKC	BANKN
1	UPAN	1.	1.	1.0										100.	100.
2	NBEW													100.	100.
3	SBEW													100.	100.
4	UPEW														
	NDEW								5.	5.	5.				
9	UNAD														
	LRAD								4.5	3.	5.0				
8	LREW														
5	LORI				1.	5000.	5000.	7.					3.9		
	MDAN				1.	100.	0.	0.							
6	LOUD	2.	2.	.5											
7	UPGR				2.	1000.	0.	0.							
8	DNGR														
2	DNAN											.45			
	LRAN											.9			

TABLE B-2: SUMMARY OF LOADS*

*For units see input description

```
    ANDUIN RIVER BASIN
0   100.00       1.00       1.00       1.00 2.0 1 1 1 0 0 0 0 0 012.900 0.500 1.500
UPAN         9.0  10.00     0.60     0.00      0.0      0.0    0.00    0.00   0.000
   0.0   0.0 0.0020.00 0.300 0.300 0.100 0.000  0.00 0.00 0.00100.00100.00    0.0
0   30.00       0.00       0.00       0.00 2.0 0 1 2 0 0 0 0 0-1 .053
NBEW         5.0   5.00     1.20     0.00      0.0      0.0    0.00    0.00   0.000
   0.0   0.0 0.0018.00 0.300 0.300 0.100 0.000 9.7 0 0.00 0.00100.00100.00    0.0
0   30.00       0.00       0.00       0.00 2.0 0 1 3 0 0 0 0 0 012.900 0.500 1.500
SBEW         6.0   5.00     1.10     0.00      0.0      0.0    0.00    0.00   0.000
   0.0   0.0 0.0018.00 0.300 0.300 0.100 0.000  0.00 0.00 0.00100.00100.00    0.0
0    0.00       0.00       0.00       0.00 1.0 0 2 4 2 2 3 0 0 012.900 0.500 1.500
UPEW         3.0   8.00     1.00     0.00      0.0      0.0    0.00    0.00   0.000
   0.0   0.0 0.0019.00 0.300 0.300 0.100 0.000  0.00 0.00 0.00  0.00  0.00    0.0
DNEW         3.0   8.00     1.00     0.00      0.0      0.0    0.00    2.00   0.000
   5.0   5.0 5.0019.00 0.300 0.300 0.100 0.000  0.00 0.00 0.00  0.00  0.00    0.0
0  -20.00       0.00       0.00       0.00 1.0 0 2 9 1 4 0 0 0 1
UNAD        8.0    7.10     1.50     0.00      0.0      0.0    0.00    0.00   1.047
   0.0   0.0 0.0019.00 0.300 0.250 0.100 0.150  0.00 0.00 0.00  0.00  0.00    0.0
LRAD       11.0    7.30     1.10     0.00      0.0      0.0    0.00    3.00   1.047
   4.5   3.0 5.0024.00 0.300 0.260 0.100 0.150  0.00 0.00 0.00  0.00  0.00    0.0
0    0.00       0.00       0.00       0.00 1.0 0 1 8 1 4 0 0 0 012.900 0.500 1.500
LREW         4.0   8.30     1.40     0.00      0.0      0.0    0.00    0.00   0.000
   0.0   0.0 0.0018.20 0.300 0.280 0.120 0.000  0.00 0.00 0.00  0.00  0.00    0.0
0    0.00       0.00       0.00       0.00 2.0 1 2 5 2 1 4 0 0 012.900 0.500 1.500
LORI         6.0  15.00     0.50     1.00   5000.0   5000.0    7.00    0.00   0.000
   0.0   0.0 0.0020.00 0.300 0.200 0.100 0.000  0.00 0.00 3.9   0.00  0.00    0.0
MOAN         5.0  15.00     0.50     1.00    100.0      0.0    0.00    0.00   0.000
   0.0   0.0 0.0021.00 0.300 0.300 0.100 0.000  0.00 0.00 0.00  0.00  0.00    0.0
0   10.00       2.00       2.00       0.50 2.0 0 1 6 0 0 0 0 0 012.900 0.500 1.500
LOUD         8.0   1.00     1.00     0.00      0.0      0.0    0.00    0.00   0.000
   0.0   0.0 0.0018.00 0.300 0.300 0.100 0.000  0.00 0.00 0.00  0.00  0.00    0.0
0   22.00       0.00       0.00       0.00 2.0 0 1 7 0 0 0 0 0 012.900 0.500 1.500
UPGR         4.0   8.00     0.90     2.00   1000.0      0.0    0.00    0.00   0.000
   0.0   0.0 0.0018.00 0.300 0.300 0.100 0.000  0.00 0.00 0.00  0.00  0.00    0.0
0    0.00       0.00       0.00       0.00 2.0 7 1 8 2 7 6 0 0 012.900 0.500 1.500
DNGR         3.0  10.00     0.80     0.00      0.0      0.0    0.00    0.00   0.000
   0.0   0.0 0.0019.00 0.300 0.300 0.100 0.000  0.00 0.00 0.00  0.00  0.00    0.0
0    0.00       0.00       0.00       0.00 2.0 5 2 2 2 5 8 0 0 012.900 0.500 1.500
DNAN         6.0  20.00     0.40     0.00      0.0      0.0    0.00    0.00   0.000
   0.0   0.0 0.0020.00 0.300 0.300 0.100 0.050  0.00 0.45 0.00  0.00  0.00    0.0
LRAN        20.0  20.00     0.20     0.00      0.0      0.0    0.00    0.00   0.000
   0.0   0.0 0.0021.00 0.300 0.300 0.100 0.100  0.00  .90 0.00  0.00  0.00    0.0
```

Figure B-3: Input deck for example problem

ANOUIN RIVER BASIN

INPUT FOR REACH 1

```
FLOWI =    100.00 CFS            CODI =      1.00 MG/L
NODI =      1.00 MG/L            DODI =      1.00 MG/L
DELTA =      2.00 MILES          NDIST =    1
NSECT =    1                     NTRIB = 0
NT(1)= 0   NT(2)= 0   NT(3)= 0   NT(4)= 0     NREAR =  0     ICOR=  0
```

INPUT FOR SECTION UPAN

```
SLGTH =   9.000 MILES     DEPTH=  10.000 FEET         VEL=   0.600 FPS
FLOWW=   0.0   MGD        CODW=        0.0   LBS/DAY  NODW=        0.0   LBS/DAY   DOOW=   0.0   MG/L
FLOWT=   0.0   CFS        CODT=   0.0   MG/L          NODT=   0.0   MG/L           DODT=   0.0   MG/L
ALGAL=   0.0   MG/L/DAY   BANKC= 100.000 LBS/MI/DAY   BANKN= 100.000 LBS/MI/DAY    ALT=    0.0  FEET
FF= 1.000                 ACOEF= 12.900               BCOEF=  0.500                CCOEF=  1.500
```

```
****************************************************************************************************
REACTION RATES AS INPUT (TEMP = 20 C)
KC=   0.300 /DAY        KD=   0.300 /DAY            KN=   0.100 /DAY            KR= 0.31598 /DAY
BENTH= 0.0    GM/M **2/DAY

REACTION RATES AS CONVERTED (TEMP =  20.0 C)
KC=   0.300 /DAY        KD=   0.300 /DAY            KN=   0.100 /DAY            KR= 0.31598 /DAY
BENTH= 0.0    GM/M **2/DAY
****************************************************************************************************
```

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	H3	TOTAL DEFICIT
1	UPAN	0.0	1.00	1.00	8.02	100.00								1.00
		2.00	1.30	1.35	7.99		0.94	0.06	0.02	0.01	0.00	0.0	0.0	1.03
		4.00	1.58	1.69	7.94		0.88	0.11	0.04	0.04	0.01	0.0	0.0	1.08
		6.00	1.85	2.02	7.87		0.82	0.15	0.05	0.09	0.03	0.0	0.0	1.15
		8.00	2.10	2.35	7.78		0.77	0.19	0.07	0.15	0.05	0.0	0.0	1.24
		9.00	2.22	2.51	7.73		0.75	0.21	0.08	0.19	0.07	0.0	0.0	1.29

INPUT FOR REACH 2

```
 FLOWI =      30.00 CFS                CODI =      0.0  MG/L
 NODI =      0.0  MG/L                 DODI =      0.0  MG/L
 DELTA =      2.00 MILES               NDIST =     0
 NSECT =     1                         NTRIB = 0
 NT(1)= 0   NT(2)= 0   NT(3)= 0   NT(4)= 0     NREAR = -1     ICOR=  0
```

INPUT FOR SECTION NBEW

```
 SLGTH =   5.000 MILES     DEPTH=   5.000 FEET          VEL=   1.200 FPS
 FLOWW=   0.0    MGD       CODW=       0.0   LBS/DAY    NODW=       0.0   LBS/DAY    DODW=   0.0   MG/L
 FLOWT=   0.0    CFS       CODT=   0.0   MG/L           NODT=   0.0   MG/L           DODT=   0.0   MG/L
 ALGAL=   0.0   MG/L/DAY   BANKC= 100.000 LBS/MI/DAY    BANKN= 100.000 LBS/MI/DAY    ALT=    0.0   FEET
 FF= 1.000                 ESCAPE COEF= 0.0530 /FT      DELTA HT=   9.70 FEET
```

```
********************************************************************************************************
 REACTION RATES AS INPUT (TEMP = 20 C)
  KC=   0.300 /DAY          KD=   0.300 /DAY                KN=   0.100 /DAY              KR= 1.79328 /DAY
  BENTH= 0.0    GM/M **2/DAY

 REACTION RATES AS CONVERTED (TEMP =  18.0 C)
  KC=   0.274 /DAY          KD=   0.274 /DAY                KN=   0.086 /DAY              KR= 1.71021 /DAY
  BENTH= 0.0    GM/M **2/DAY
********************************************************************************************************
```

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	H3	TOTAL DEFICIT
1	NBEW	0.0	0.0	0.0	9.40	30.00								0.0
		2.00	1.22	1.23	9.38		0.0	0.0	0.0	0.02	0.01	0.0	0.0	0.02
		4.00	2.41	2.45	9.32		0.0	0.0	0.0	0.06	0.02	0.0	0.0	0.08
		5.00	2.99	3.06	9.28		0.0	0.0	0.0	0.09	0.03	0.0	0.0	0.12

INPUT FOR REACH 3

```
FLOWI =     30.00 CFS              CODI =      0.0  MG/L
NODI =     0.0  MG/L               DODI =      0.0  MG/L
DELTA =     2.00 MILES             NDIST =    0
NSECT =    1                       NTRIB = 0
NT(1)= 0   NT(2)= 0   NT(3)= 0   NT(4)= 0     NREAR =  0     ICOR=  0
```

INPUT FOR SECTION SBEW

```
SLGTH =   6.000 MILES     DEPTH=   5.000 FEET         VEL=   1.100 FPS
FLOWW=   0.0   MGD        CODW=        0.0  LBS/DAY   NODW=        0.0  LBS/DAY    DODW=   0.0   MG/L
FLOWT=   0.0   CFS        CODT=   0.0   MG/L          NODT=   0.0   MG/L           DODT=   0.0   MG/L
ALGAL=   0.0   MG/L/DAY   BANKC= 100.000 LBS/MI/DAY   BANKN= 100.000 LBS/MI/DAY    ALT=   0.0  FEET
FF= 1.000                 ACOEF= 12.900               HCOEF=  0.500                CCOEF=  1.500
```

```
************************************************************************************************************
REACTION RATES AS INPUT (TEMP = 20 C)
 KC=   0.300 /DAY          KD=   0.300 /DAY            KN=   0.100 /DAY            KR= 1.21013 /DAY
 BENTH= 0.0    GM/M **2/DAY

REACTION RATES AS CONVERTED (TEMP =  18.0 C)
 KC=   0.274 /DAY          KD=   0.274 /DAY            KN=   0.086 /DAY            KR= 1.15407 /DAY
 BENTH= 0.0    GM/M **2/DAY
************************************************************************************************************
```

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	H3	TOTAL DEFICIT
1	SBEW	0.0	0.0	0.0	9.40	30.00								0.0
		2.00	1.22	1.23	9.38		0.0	0.0	0.0	0.02	0.01	0.0	0.0	0.02
		4.00	2.40	2.45	9.31		0.0	0.0	0.0	0.07	0.02	0.0	0.0	0.09
		6.00	3.55	3.66	9.21		0.0	0.0	0.0	0.14	0.05	0.0	0.0	0.19

INPUT FOR REACH 4

```
FLOWI =      0.0  CFS                  CODI =      0.0  MG/L
NODI =     0.0  MG/L                   DODI =      0.0  MG/L
DELTA =      1.00 MILES                NDIST =    0
NSECT =    2                           NTRIB = 2
NT(1)= 2   NT(2)= 3   NT(3)= 0   NT(4)= 0    NHEAR =  0     ICOR=  0
```

INPUT FOR SECTION UPEW

```
SLGTH =   3.000 MILES     DEPTH=   8.000 FEET        VEL=   1.000 FPS
FLOWW=   0.0   MGD        CODW=        0.0  LBS/DAY  NODW=        0.0  LBS/DAY   DODW=   0.0   MG/L
FLOWT=   0.0   CFS        CODT=   0.0   MG/L         NODT=   0.0   MG/L          DODT=   0.0   MG/L
ALGAL=   0.0  MG/L/DAY    BANKC=   0.0  LBS/MI/DAY   BANKN=   0.0  LBS/MI/DAY    ALT=   0.0  FEET
FF= 1.000                 ACOEF= 12.900              BCOEF=  0.500               CCOEF=  1.500
```

```
*****************************************************************************************************
REACTION RATES AS INPUT (TEMP = 20 C)
 KC=   0.300 /DAY        KD=   0.300 /DAY            KN=   0.100 /DAY          KR= 0.57011 /DAY
 BENTH= 0.0    GM/M **2/DAY

REACTION RATES AS CONVERTED (TEMP =  19.0 C)
 KC=   0.287 /DAY        KD=   0.287 /DAY            KN=   0.093 /DAY          KR= 0.55674 /DAY
 BENTH= 0.0    GM/M **2/DAY
*****************************************************************************************************
```

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	H3	TOTAL DEFICIT
1	UPEW	0.0	3.27	3.36	9.05	60.00								0.16
		1.00	3.21	3.34	8.98		0.15	0.06	0.02	0.0	0.0	0.0	0.0	0.23
		2.00	3.15	3.32	8.92		0.15	0.11	0.04	0.0	0.0	0.0	0.0	0.29
		3.00	3.10	3.30	8.86		0.14	0.16	0.05	0.0	0.0	0.0	0.0	0.35

INPUT FOR SECTION DNEW

```
SLGTH =   3.000 MILES     DEPTH=   8.000 FEET        VEL=   1.000 FPS
FLOWW=   0.0   MGD        CODW=        0.0  LBS/DAY  NODW=        0.0  LBS/DAY   DODW=   0.0   MG/L
FLOWT=   2.000 CFS        CODT=   5.000 MG/L         NODT=   5.000 MG/L          DODT=   5.000 MG/L
ALGAL=   0.0  MG/L/DAY    BANKC=   0.0  LBS/MI/DAY   BANKN=   0.0  LBS/MI/DAY    ALT=   0.0  FEET
FF= 1.000                 ACOEF= 12.900              BCOEF=  0.500               CCOEF=  1.500
```

```
*****************************************************************************************************
REACTION RATES AS INPUT (TEMP = 20 C)
 KC=   0.300 /DAY        KD=   0.300 /DAY            KN=   0.100 /DAY          KR= 0.57011 /DAY
 BENTH= 0.0    GM/M **2/DAY

REACTION RATES AS CONVERTED (TEMP =  19.0 C)
 KC=   0.287 /DAY        KD=   0.287 /DAY            KN=   0.093 /DAY          KR= 0.55674 /DAY
 BENTH= 0.0    GM/M **2/DAY
*****************************************************************************************************
```

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	H3	TOTAL DEFICIT

2	DNEW	3.00	3.16	3.36	8.71	62.00									0.50
		4.00	3.11	3.34	8.65		0.49	0.05	0.02	0.0	0.0	0.0	0.0		0.56
		5.00	3.05	3.32	8.60		0.47	0.11	0.04	0.0	0.0	0.0	0.0		0.61
		6.00	3.00	3.30	8.55		0.45	0.15	0.05	0.0	0.0	0.0	0.0		0.66

INPUT FOR REACH 9

```
FLOWI =     -20.00 CFS                 CODI =       0.0  MG/L
NODI =        0.0  MG/L                DODI =       0.0  MG/L
DELTA =       1.00 MILES               NDIST =     0
NSECT =     2                          NTPIB = 1
NT(1)= 4    NT(2)= 0   NT(3)= 0   NT(4)= 0      NREAR =  1      ICOR=  0
```

INPUT FOR SECTION UNAD

```
SLGTH =   8.000 MILES     DEPTH=   7.100 FEET          VEL=   1.500 FPS
FLOWW=   0.0   MGD        CODW=        0.0  LBS/DAY    NODW=        0.0  LBS/DAY    DODW=   0.0   MG/L
FLOWT=   0.0   CFS        CODT=   0.0   MG/L           NODT=   0.0   MG/L           DODT=   0.0   MG/L
ALGAL=   0.0  MG/L/DAY                                 BANKC=   0.0   LBS/MI/DAY    BANKN=   0.0   LBS/MI/DAY
FF= 1.047                 ALT=    0.0  FEET
```

```
****************************************************************************************************
REACTION RATES AS INPUT (TEMP = 20 C)
 KC=   0.300 /DAY          KD=   0.250 /DAY             KN=   0.100 /DAY             KR= 0.15000 /DAY
 BENTH= 0.0     GM/M **2/DAY

REACTION RATES AS CONVERTED (TEMP =  19.0 C)
 KC=   0.287 /DAY          KD=   0.239 /DAY             KN=   0.093 /DAY             KR= 0.14648 /DAY
 BENTH= 0.0     GM/M **2/DAY
****************************************************************************************************
```

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	H3	TOTAL DEFICIT
1	UNAD	0.0	3.00	3.30	8.55	20.00								0.66
		1.00	2.96	3.29	8.51		0.66	0.03	0.01	0.0	0.0	0.0	0.0	0.70
		2.00	2.93	3.28	8.47		0.65	0.06	0.02	0.0	0.0	0.0	0.0	0.74
		3.00	2.90	3.26	8.44		0.65	0.09	0.04	0.0	0.0	0.0	0.0	0.77
		4.00	2.86	3.25	8.40		0.65	0.11	0.05	0.0	0.0	0.0	0..	0.81
		5.00	2.83	3.24	8.37		0.64	0.14	0.06	0.0	0.0	0.0	0.0	0.84
		6.00	2.80	3.23	8.33		0.64	0.17	0.07	0.0	0.0	0.0	0.0	0.88
		7.00	2.76	3.21	8.30		0.63	0.19	0.08	0.0	0.0	0.0	0.0	0.91
		8.00	2.73	3.20	8.26		0.63	0.22	0.10	0.0	0.0	0.0	0.0	0.94

INPUT FOR SECTION LRAD

```
SLGTH =  11.000 MILES     DEPTH=   7.300 FEET          VEL=   1.100 FPS
FLOWW=   0.0   MGD        CODW=        0.0  LBS/DAY    NODW=        0.0  LBS/DAY    DODW=   0.0   MG/L
FLOWT=   3.000 CFS        CODT=   4.500 MG/L           NODT=   3.000 MG/L           DODT=   5.000 MG/L
ALGAL=   0.0  MG/L/DAY                                 BANKC=   0.0   LBS/MI/DAY    BANKN=   0.0   LBS/MI/DAY
FF= 1.047                 ALT=    0.0  FEET
```

```
****************************************************************************************************
REACTION RATES AS INPUT (TEMP = 20 C)
 KC=   0.300 /DAY          KD=   0.260 /DAY             KN=   0.100 /DAY             KR= 0.15000 /DAY
 BENTH= 0.0     GM/M **2/DAY

REACTION RATES AS CONVERTED (TEMP =  24.0 C)
 KC=   0.361 /DAY          KD=   0.312 /DAY             KN=   0.136 /DAY             KR= 0.16493 /DAY
 BENTH= 0.0     GM/M **2/DAY
****************************************************************************************************
```

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	H3	TOTAL DEFICIT
2	LRAD	8.00	2.96	3.18	6.86	23.00								1.47
		9.00	2.90	3.15	6.80		1.46	0.05	0.02	0.0	0.0	0.0	0.0	1.53
		10.00	2.85	3.13	6.74		1.45	0.10	0.05	0.0	0.0	0.0	0.0	1.59
		11.00	2.79	3.10	6.68		1.43	0.15	0.07	0.0	0.0	0.0	0.0	1.65
		12.00	2.73	3.08	6.63		1.42	0.19	0.09	0.0	0.0	0.0	0.0	1.71
		13.00	2.68	3.06	6.57		1.41	0.24	0.12	0.0	0.0	0.0	0.0	1.76
		14.00	2.63	3.04	6.52		1.39	0.28	0.14	0.0	0.0	0.0	0.0	1.81
		15.00	2.57	3.01	6.47		1.38	0.33	0.16	0.0	0.0	0.0	0.0	1.87
		16.00	2.52	2.99	6.42		1.37	0.37	0.18	0.0	0.0	0.0	0.0	1.91
		17.00	2.47	2.97	6.37		1.36	0.41	0.20	0.0	0.0	0.0	0.0	1.96
		18.00	2.42	2.94	6.32		1.34	0.44	0.22	0.0	0.0	0.0	0.0	2.01
		19.00	2.38	2.92	6.28		1.33	0.48	0.24	0.0	0.0	0.0	0.0	2.05

INPUT FOR REACH 8

```
FLOWI =      0.0  CFS                   CODI =      0.0  MG/L
NODI =      0.0  MG/L                   DODI =      0.0  MG/L
DELTA =      1.00 MILES                 NDIST =    0
NSECT =    1                            NTRIB = 1
NT(1)= 4   NT(2)= 0   NT(3)= 0   NT(4)= 0     NREAR =  0     ICOR=  0
```

INPUT FOR SECTION LREW

```
SLGTH =   4.000 MILES     DEPTH=   8.300 FEET          VEL=  1.400 FPS
FLOWW=   0.0   MGD        CODW=        0.0   LBS/DAY   NODW=        0.0   LBS/DAY   DODW=   0.0   MG/L
FLOWT=   0.0   CFS        CODT=   0.0   MG/L           NODT=   0.0   MG/L           DODT=   0.0   MG/L
ALGAL=   0.0   MG/L/DAY   BANKC=   0.0   LBS/MI/DAY    BANKN=   0.0   LBS/MI/DAY    ALT=    0.0  FEET
FF= 1.000                 ACOEF= 12.900                BCOEF=  0.500                CCOEF=  1.500
```

```
*****************************************************************************************************************
REACTION RATES AS INPUT (TEMP = 20 C)
 KC=   0.300 /DAY        KD=   0.280 /DAY          KN=   0.120 /DAY          KR= 0.63832 /DAY
 BENTH= 0.0    GM/M **2/DAY

REACTION RATES AS CONVERTED (TEMP =  18.2 C)
 KC=   0.276 /DAY        KD=   0.258 /DAY          KN=   0.104 /DAY          KR= 0.61164 /DAY
 BENTH= 0.0    GM/M **2/DAY
*****************************************************************************************************************
```

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	H3	TOTAL DEFICIT
1	LREW	0.0	3.00	3.30	8.70	42.00								0.66
		1.00	2.96	3.29	8.67		0.64	0.03	0.01	0.0	0.0	0.0	0.0	0.69
		2.00	2.93	3.27	8.64		0.63	0.06	0.03	0.0	0.0	0.0	0.0	0.72
		3.00	2.89	3.26	8.61		0.61	0.10	0.04	0.0	0.0	0.0	0.0	0.75
		4.00	2.86	3.24	8.59		0.59	0.12	0.06	0.0	0.0	0.0	0.0	0.78

```
INPUT FOR REACH  5

 FLOWI =       0.0  CFS                  CODI =       0.0  MG/L
 NODI =       0.0  MG/L                  DODI =       0.0  MG/L
 DELTA =       2.00 MILES                NDIST =     1
 NSECT =     2                           NTRIB = 2
 NT(1)= 1   NT(2)= 8   NT(3)= 0   NT(4)= 0      NREAR =  0      ICOR=  0


INPUT FOR SECTION LORI

 SLGTH =   6.000 MILES     DEPTH=  15.000 FEET          VEL=    0.500 FPS
 FLOWW=   1.000 MGD        CODW=    5000.000 LBS/DAY    NODW=     5000.000 LBS/DAY    DODW=   7.000 MG/L
 FLOWT=   0.0   CFS        CODT=  0.0    MG/L           NODT=   0.0    MG/L           DODT=   0.0    MG/L
 ALGAL=   0.0   MG/L/DAY   BANKC=   0.0   LBS/MI/DAY    BANKN=   0.0   LBS/MI/DAY     ALT=    0.0  FEET
 FF= 1.000                 ACOEF= 12.900                BCOEF=  0.500                 CCOEF=  1.500

*************************************************************************************************************
REACTION RATES AS INPUT (TEMP = 20 C)
 KC=   0.300 /DAY          KD=    0.200 /DAY             KN=    0.100 /DAY               KR= 0.15701 /DAY
 BENTH= 3.9000 GM/M **2/DAY

REACTION RATES AS CONVERTED (TEMP =  20.0 C)
 KC=   0.300 /DAY          KD=    0.200 /DAY             KN=    0.100 /DAY               KR= 0.15701 /DAY
 BENTH= 3.9000 GM/M **2/DAY
*************************************************************************************************************
```

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	A3	B3	C3	D3	E3	F3	H3	TOTAL DEFICIT
1	LORI	9.00	8.84	9.16	7.82	143.54								1.20
		11.00	8.22	8.94	7.04		1.16	0.41	0.22	0.0	0.0	0.0	0.20	1.99
		13.00	7.64	8.72	6.31		1.11	0.77	0.42	0.0	0.0	0.0	0.40	2.71
		15.00	7.10	8.51	5.65		1.07	1.10	0.61	0.0	0.0	0.0	0.59	3.37

(A3 through H3: DEFICIT COMPONENTS)

```
INPUT FOR SECTION MDAN

 SLGTH =   5.000 MILES     DEPTH=  15.000 FEET          VEL=    0.500 FPS
 FLOWW=   1.000 MGD        CODW=      100.000 LBS/DAY   NODW=          0.0   LBS/DAY    DODW=   0.0    MG/L
 FLOWT=   0.0   CFS        CODT=  0.0    MG/L           NODT=   0.0    MG/L           DODT=   0.0    MG/L
 ALGAL=   0.0   MG/L/DAY   BANKC=   0.0   LBS/MI/DAY    BANKN=   0.0   LBS/MI/DAY     ALT=    0.0  FEET
 FF= 1.000                 ACOEF= 12.900                BCOEF=  0.500                 CCOEF=  1.500

*************************************************************************************************************
REACTION RATES AS INPUT (TEMP = 20 C)
 KC=   0.300 /DAY          KD=    0.300 /DAY             KN=    0.100 /DAY               KR= 0.15701 /DAY
 BENTH= 0.0     GM/M **2/DAY

REACTION RATES AS CONVERTED (TEMP =  21.0 C)
 KC=   0.314 /DAY          KD=    0.314 /DAY             KN=    0.108 /DAY               KR= 0.16078 /DAY
 BENTH= 0.0     GM/M **2/DAY
*************************************************************************************************************
```

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	A3	B3	C3	D3	E3	F3	H3	TOTAL DEFICIT

(A3 through H3: DEFICIT COMPONENTS)

2	MDAN	15.00	7.15	8.42	5.51	145.08								3.33
		17.00	6.62	8.20	4.90		3.21	0.52	0.22	0.0	0.0	0.0	0.0	3.94
		19.00	6.13	7.99	4.37		3.08	0.98	0.42	0.0	0.0	0.0	0.0	4.48
		20.00	5.90	7.88	4.12		3.02	1.19	0.51	0.0	0.0	0.0	0.0	4.72

INPUT FOR REACH 6

```
FLOWI =      10.00 CFS              CODI =       2.00 MG/L
NODI =      2.00 MG/L               DODI =       0.50 MG/L
DELTA =      2.00 MILES             NDIST =     0
NSECT =    1                        NTRIB = 0
NT(1)= 0   NT(2)= 0   NT(3)= 0   NT(4)= 0     NREAR =  0     ICOR=  0
```

INPUT FOR SECTION LOUD

```
SLGTH =  8.000 MILES     DEPTH=   1.000 FEET          VFL=   1.000 FPS
FLOWW=   0.0   MGD       CODW=       0.0   LBS/DAY    NODW=       0.0   LBS/DAY    DODW=   0.0   MG/L
FLOWT=   0.0   CFS       CODT=   0.0   MG/L           NODT=   0.0   MG/L           DODT=   0.0   MG/L
ALGAL=   0.0   MG/L/DAY  BANKC=   0.0   LBS/MI/DAY    BANKN=   0.0   LBS/MI/DAY    ALT=    0.0  FEET
FF= 1.000                ACOEF= 12.900                BCOEF=  0.500                CCOEF=  1.500
```

```
****************************************************************************************************
REACTION RATES AS INPUT (TEMP = 20 C)
KC=   0.300 /DAY          KD=   0.300 /DAY            KN=   0.100 /DAY             KR=12.90000 /DAY
BENTH= 0.0    GM/M **2/DAY

REACTION RATES AS CONVERTED (TEMP =  18.0 C)
KC=   0.274 /DAY          KD=   0.274 /DAY            KN=   0.086 /DAY             KR=12.30242 /DAY
BENTH= 0.0    GM/M **2/DAY
****************************************************************************************************
```

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	H3	TOTAL DEFICIT
1	LOUD	0.0	2.00	2.00	8.90	10.00								0.50
		2.00	1.93	1.98	9.25		0.11	0.03	0.01	0.0	0.0	0.0	0.0	0.16
		4.00	1.87	1.96	9.33		0.02	0.04	0.01	0.0	0.0	0.0	0.0	0.08
		6.00	1.81	1.94	9.34		0.01	0.04	0.01	0.0	0.0	0.0	0.0	0.06
		8.00	1.75	1.92	9.35		0.00	0.04	0.01	0.0	0.0	0.0	0.0	0.05

INPUT FOR REACH 7

```
FLOWI =     22.00 CFS                CODI =       0.0  MG/L
NODI =      0.0  MG/L                DODI =       0.0  MG/L
DELTA =      2.00 MILES              NDIST =    0
NSECT =     1                        NTRIB = 0
NT(1)= 0   NT(2)= 0   NT(3)= 0   NT(4)= 0      NREAR =  0     ICOR=  0
```

INPUT FOR SECTION UPGR

```
SLGTH =   4.000 MILES     DEPTH=   8.000 FEET          VEL=   0.900 FPS
FLOWW=   2.000 MGD        CODW=    1000.000 LBS/DAY    NODW=        0.0   LBS/DAY    DODW=   0.0   MG/L
FLOWT=   0.0   CFS        CODT=   0.0   MG/L           NODT=   0.0   MG/L            DODT=   0.0   MG/L
ALGAL=   0.0   MG/L/DAY   BANKC=   0.0   LBS/MI/DAY    BANKN=   0.0   LBS/MI/DAY     ALT=    0.0  FEET
FF= 1.000                 ACOEF= 12.900                BCOEF=  0.500                 CCOEF=  1.500
```

```
************************************************************************************************************
 REACTION RATES AS INPUT (TEMP = 20 C)
 KC=   0.300 /DAY          KD=   0.300 /DAY             KN=    0.100 /DAY             KR= 0.54085 /DAY
 BENTH= 0.0     GM/M **2/DAY

 REACTION RATES AS CONVERTED (TEMP =  18.0 C)
 KC=   0.274 /DAY          KD=   0.274 /DAY             KN=    0.086 /DAY             KR= 0.51579 /DAY
 BENTH= 0.0     GM/M **2/DAY
************************************************************************************************************
```

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	H3	TOTAL DEFICIT
1	UPGR	0.0	7.40	0.0	9.40	25.08								0.0
		2.00	7.13	0.0	9.14		0.0	0.26	0.0	0.0	0.0	0.0	0.0	0.26
		4.00	6.87	0.0	8.91		0.0	0.49	0.0	0.0	0.0	0.0	0.0	0.49

INPUT FOR REACH 8

```
  FLOWI =       0.0  CFS                  CODI =       0.0  MG/L
  NODI =       0.0  MG/L                  DODI =       0.0  MG/L
  DELTA =       2.00 MILES                NDIST =     7
  NSECT =     1                           NTRIB = 2
  NT(1)= 7   NT(2)= 6   NT(3)= 0   NT(4)= 0     NREAR =  0     ICOR=  0
```

INPUT FOR SECTION DNGR

```
  SLGTH =   3.000 MILES    DEPTH=  10.000 FEET       VEL=   0.800 FPS
  FLOWW=   0.0    MGD      CODW=        0.0   LBS/DAY   NODW=        0.0   LBS/DAY   DODW=   0.0   MG/L
  FLOWT=   0.0    CFS      CODT=   0.0    MG/L          NODT=   0.0    MG/L           DODT=   0.0   MG/L
  ALGAL=   0.0   MG/L/DAY  BANKC=   0.0   LBS/MI/DAY    BANKN=   0.0   LBS/MI/DAY     ALT=    0.0  FEET
  FF= 1.000                ACOEF= 12.900                BCOEF=  0.500                 CCOEF=  1.500
```

```
*************************************************************************************************************
 REACTION RATES AS INPUT (TEMP = 20 C)
  KC=   0.300 /DAY        KD=   0.300 /DAY           KN=   0.100 /DAY           KR= 0.36487 /DAY
  BENTH= 0.0    GM/M **2/DAY

 REACTION RATES AS CONVERTED (TEMP =  19.0 C)
  KC=   0.287 /DAY        KD=   0.287 /DAY           KN=   0.093 /DAY           KR= 0.35632 /DAY
  BENTH= 0.0    GM/M **2/DAY
*************************************************************************************************************
```

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	DEFICIT COMPONENTS A3	B3	C3	D3	E3	F3	H3	TOTAL DEFICIT
1	DNGR	4.00	5.41	0.55	8.84	35.08								0.37
		6.00	5.18	0.54	8.63		0.35	0.23	0.01	0.0	0.0	0.0	0.0	0.58
		7.00	5.06	0.54	8.53		0.34	0.33	0.01	0.0	0.0	0.0	0.0	0.68

INPUT FOR REACH 2

```
FLOWI =      0.0  CFS              CODI =      0.0  MG/L
NODI =      0.0  MG/L              DODI =      0.0  MG/L
DELTA =     2.00 MILES             NDIST =     5
NSECT =     2                      NTRIB = 3
NT(1)= 5   NT(2)= 8   NT(3)= 9   NT(4)= 0     NREAR =  0     ICOR=  0
```

INPUT FOR SECTION DNAN

```
SLGTH =   6.000 MILES      DEPTH=  20.000 FEET         VEL=   0.400 FPS
FLOWW=   0.0   MGD         CODW=        0.0   LBS/DAY  NODW=        0.0   LBS/DAY   DODW=   0.0   MG/L
FLOWT=   0.0   CFS         CODT=   0.0   MG/L          NODT=   0.0   MG/L             DODT=   0.0   MG/L
ALGAL=   0.450 MG/L/DAY    BANKC=   0.0   LBS/MI/DAY   BANKN=   0.0   LBS/MI/DAY    ALT=    0.0  FEET
FF= 1.000                  ACOEF= 12.900               BCOEF=  0.500                  CCOEF=  1.500
```

```
*****************************************************************************************************
REACTION RATES AS INPUT (TEMP = 20 C)
KC=   0.300 /DAY         KD=   0.300 /DAY          KN=   0.100 /DAY          KR= 0.09122 /DAY
BENTH= 0.0    GM/M **2/DAY

REACTION RATES AS CONVERTED (TEMP =  20.0 C)
KC=   0.300 /DAY         KD=   0.300 /DAY          KN=   0.100 /DAY          KR= 0.09122 /DAY
BENTH= 0.0    GM/M **2/DAY
*****************************************************************************************************
```

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	A3	B3	C3	D3	E3	F3	H3	TOTAL DEFICIT
1	DNAN	20.00	5.36	6.05	5.30	203.16								3.72
		22.00	4.89	5.87	4.90		3.62	0.46	0.18	0.0	0.0	-0.14	0.0	4.13
		24.00	4.46	5.69	4.55		3.52	0.87	0.35	0.0	0.0	-0.27	0.0	4.47
		26.00	4.07	5.52	4.25		3.42	1.23	0.51	0.0	0.0	-0.40	0.0	4.77

INPUT FOR SECTION LRAN

```
SLGTH =  20.000 MILES      DEPTH=  20.000 FEET         VEL=   0.200 FPS
FLOWW=   0.0   MGD         CODW=        0.0   LBS/DAY  NODW=        0.0   LBS/DAY   DODW=   0.0   MG/L
FLOWT=   0.0   CFS         CODT=   0.0   MG/L          NODT=   0.0   MG/L             DODT=   0.0   MG/L
ALGAL=   0.900 MG/L/DAY    BANKC=   0.0   LBS/MI/DAY   BANKN=   0.0   LBS/MI/DAY    ALT=    0.0  FEET
FF= 1.000                  ACOEF= 12.900               BCOEF=  0.500                  CCOEF=  1.500
```

```
*****************************************************************************************************
REACTION RATES AS INPUT (TEMP = 20 C)
KC=   0.300 /DAY         KD=   0.300 /DAY          KN=   0.100 /DAY          KR= 0.06450 /DAY
BENTH= 0.0    GM/M **2/DAY

REACTION RATES AS CONVERTED (TEMP =  21.0 C)
KC=   0.314 /DAY         KD=   0.314 /DAY          KN=   0.108 /DAY          KR= 0.06605 /DAY
BENTH= 0.0    GM/M **2/DAY
*****************************************************************************************************
```

SECTION NUMBER	SECTION NAME	DISTANCE DOWNSTREAM	CBOD	NBOD	DO	FLOW	A3	B3	C3	D3	E3	F3	H3	TOTAL DEFICIT

2	LRAN	26.00	4.08	5.53	4.08	203.16								4.76
		28.00	3.37	5.18	3.76		4.58	0.70	0.35	0.00	0.00	-0.53	0.00	5.08
		30.00	2.78	4.85	3.60		4.40	1.25	0.66	0.00	0.00	-1.05	0.00	5.24
		32.00	2.30	4.54	3.57		4.22	1.67	0.93	0.00	0.00	-1.55	0.00	5.28
		34.00	1.90	4.25	3.64		4.05	2.00	1.18	0.00	0.00	-2.03	0.00	5.20
		36.00	1.56	3.98	3.79		3.89	2.25	1.40	0.00	0.00	-2.49	0.00	5.05
		38.00	1.29	3.72	4.01		3.74	2.42	1.59	0.00	0.00	-2.93	0.00	4.83
		40.00	1.07	3.48	4.29		3.59	2.55	1.76	0.00	0.00	-3.35	0.00	4.55
		42.00	0.88	3.26	4,61		3.45	2.63	1.91	0.00	0.00	-3.76	0.00	4.23
		44.00	0.73	3.05	4.96		3.31	2.68	2.04	0.00	0.00	-4.15	0.00	3.88
		46.00	0.60	2.86	5.34		3.18	2.70	2.15	0.00	0.00	-4.52	0.00	3.50

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Steven C. Chapra
George A. Nossa