ARC020036

STREAM ASSIMILATIVE CAPACITY STUDY

Mill Creek
Melbourne, Arkansas

December 13, 1983

STATE OF ARKANSAS
DEPARTMENT OF POLLUTION CONTROL AND ECOLOGY
8001 NATIONAL DRIVE, P.O. BOX 9583
LITTLE ROCK, ARKANSAS 72209

PHONE: (501) 562-7444

June 22, 1984

Ms. Anna Dunbar
U.S. Environmental Protection Agency
Region VI
1201 Elm Street
InterFirst Two Building
Dallas, Texas 75270

Dear Anna:

Please find enclosed an additional computer run for the City of Melbourne's proposed discharge to Mill Creek. This shows that a discharge of 30/30/12/6, BOD_5/TSS/NH_3-N/D.O. is sufficient to maintain a D.O. of 6 mg/l during a seasonal period of less than or equal to 20°C in the receiving stream.

If you have any questions on this matter, please call.

Sincerely,

Niall O'Shaughnessy

Niall O'Shaughnessy, P.E.
Engineer Supervisor
Water Division

NO'S/kw

Enclosure

cc: Mr. Gary Bondy, EPA, Region VI, w/enclosure

MELBOURNE SEASONAL LIMITS 30-30-12

```
STREAM TEMPERATURE =  20.00
STREAM FLOW, cfs   =   0.30
STREAM D.O.        =   7.40
STREAM UOD, mg/l   =   3.00

WASTE TEMPERATURE  =  20.00
WASTE FLOW, mgd    =   0.41
WASTE FLOW, cfs    =   0.63
WASTE D.O., mg/l   =   6.00
WASTE UOD, mg/l    =  69.00

BENTHAL DEMAND, g/m^2/day= 0.30
  MEAN DEPTH, ft.        = 0.50

AMMONIA NITROGEN, mg/l    =12.00
  NUOD, mg/l              =54.84
TOTAL UOD of waste, mg/l =123.84

RATE CONSTANTS, per day, (base e)
Kd = 0.90         Kd CORRECTED = 0.90
Ka =16.60         Ka CORRECTED =16.60
KN = 0.40         KN CORRECTED = 0.40
 S = 1.97          S CORRECTED = 1.97

TEMPERATURE OF MIX =  20.00
D.O. SATURATION, mg/l =    9.20
INITIAL DEFICIT, mg/l =    2.75
CRITICAL DEFICIT, mg/l =   3.32
MINIMUM D.O., mg/l =       5.88
CRITICAL TIME, days =      0.11
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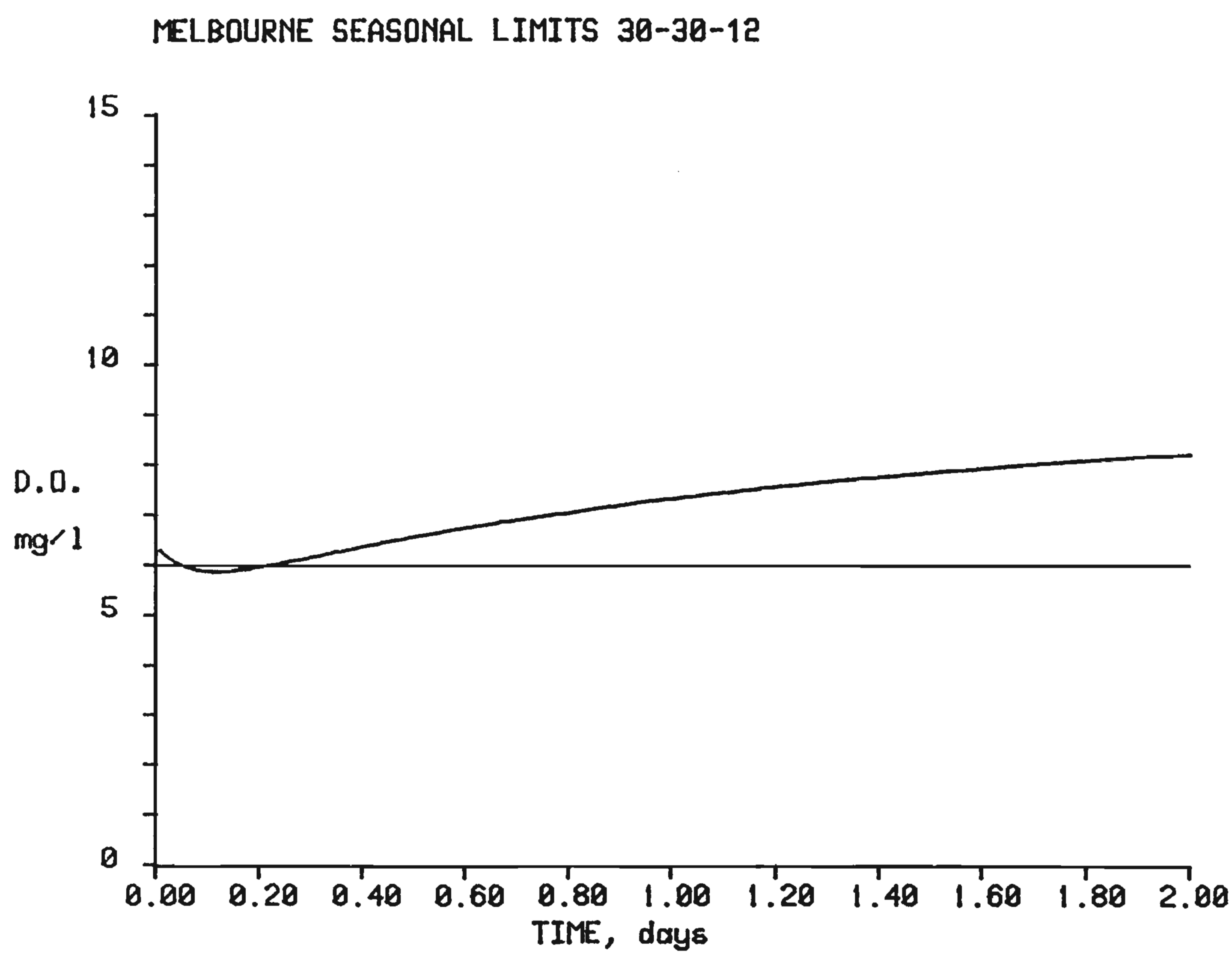
MELBOURNE SEASONAL LIMITS 30-30-12
15
10
5
0
D.O.
mg/l
0.00 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00
TIME, days

-;=?

```
A>dir
Bdos Err On A: Bad Sector
```

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MELBOURNE SEASONAL LIMITS 30-30-12

STREAM TEMPERATURE =  20.00
STREAM FLOW, cfs   =   0.30
STREAM D.O.        =   7.40
STREAM UOD, mg/l   =   3.00

WASTE TEMPERATURE  =  20.00
WASTE FLOW, mgd    =   0.41
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WASTE D.O., mg/l   =   7.40
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BENTHAL DEMAND, g/m^2/day= 0.30
  MEAN DEPTH, ft.        = 0.50

AMMONIA NITROGEN, mg/l   =12.00
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RATE CONSTANTS, per day, (base e)
Kd = 0.90          Kd CORRECTED = 0.90
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 S = 1.97           S CORRECTED = 1.97

TEMPERATURE OF MIX =  20.00
D.O. SATURATION, mg/l =    9.20
INITIAL DEFICIT, mg/l =    1.80
CRITICAL DEFICIT, mg/l =   3.22
MINIMUM D.O., mg/l =       5.98
CRITICAL TIME, days =      0.16
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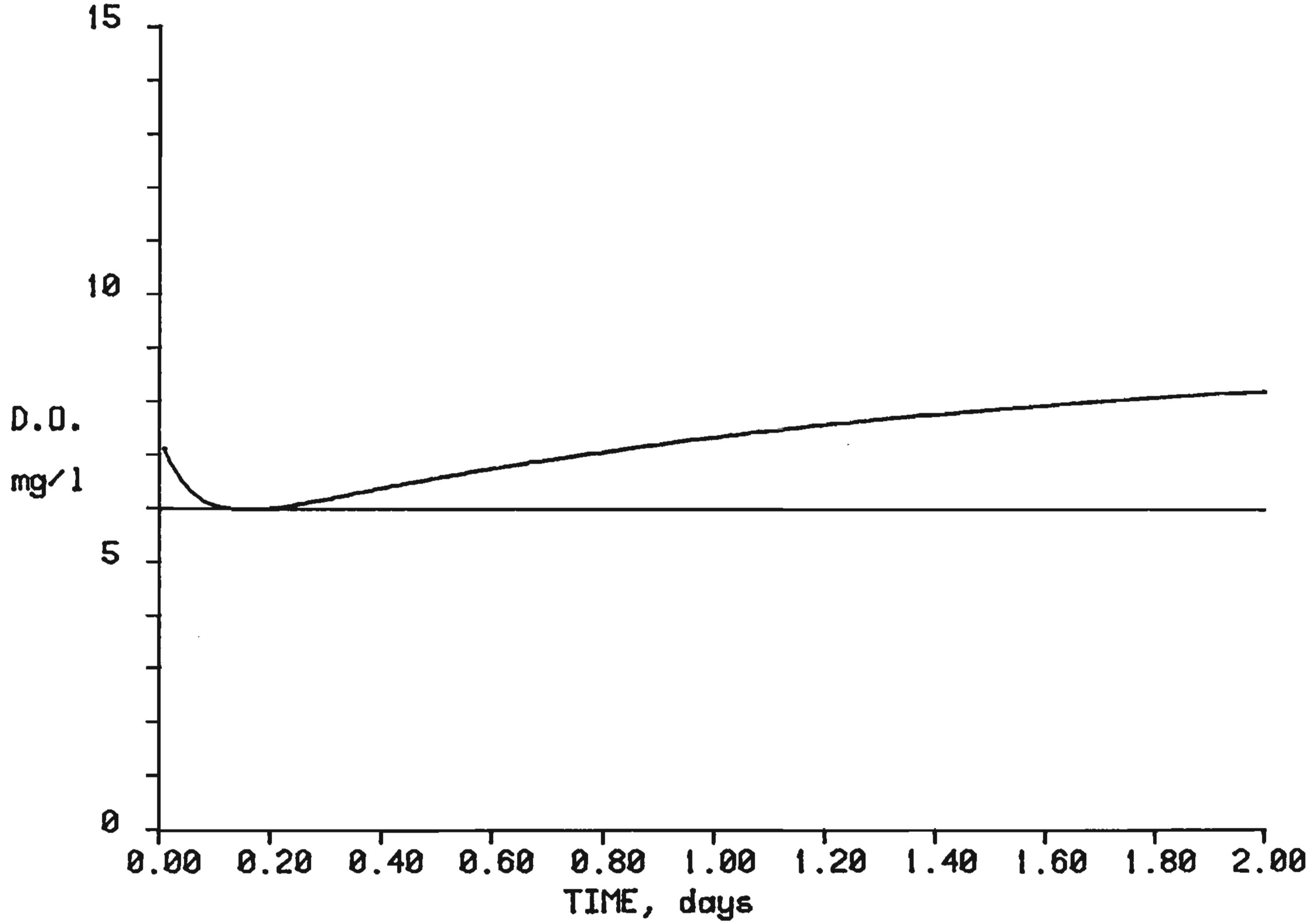
MELBOURNE SEASONAL LIMITS 30-30-12



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STREAM ASSIMILATIVE CAPACITY STUDY

Mill Creek
Melbourne, Arkansas

INTRODUCTION

This report contains the results of a survey conducted during July 11-12, 1983 on Mill Creek - the receiving stream for the municipal waste from the City of Melbourne. Melbourne is currently involved in the process of acquiring a new wastewater treatment facility, thereby necessitating a wasteload assimilative capacity study on Mill Creek in the vicinity of their proposed STP site. The proposed design flow for the new plant is .41 MGD (.63 cfs) which accoring to EPA, Region VI criteria, requires a desk top model to be performed on the receiving stream.

SUMMARY AND RECOMMENDATIONS

Treatment schemes have been evaluated for the existing dissolved oxygen standard of 6 mg/l for Mill Creek, as well as the effluent-dominated option of 4 mg/l. Seasonal limits have been recommended for each of these schemes in order to provide some economic relief for the city while also taking advantage of the generally greater assimilative capacity of the stream during the cooler months of the year. According to the desk top model, Melbourne may discharge a 10-15-4-6 (BOD_5/TSS/NH_3-N/Effluent D.O.) effluent into Mill Creek during the critical period of May through October and still maintain the existing D.O. standard. Seasonal limits that will maintain that stream D.O. are 20-20-15-6. These apply the remainder of the year when the stream temperature is 20°C or less. Based on a 5 year period of record from a nearby stream (Middle Fork of Little Red River at Shirley) the stream temperature is 20°C or less during the months of November through April.

The effluent limits necessary to maintain the 4 mg/l effluent dominated option are 20-20-7-4 critical and 20-20-15-6 seasonal. The effluent dominated option (where 50% or more of stream flow consists of wastewater) is achieved through a request by the city, complaince with ADPC&E procedures for the option and subsequent approval by the appropriate agencies.

The input data and oxygen sag curves for the critical limit treatment schemes are found in Tables 1 and 2 and Figures 2 and 3, while the effluent dominated sets are found in Tables 3 and 4 and Figures 4 and 5. Critical limits for Mill Creek include a maximum temperature of 28°C and a minimum flow of .1 cfs. The temperature is based on the data record from the Middle Fork of the Little Red River at Shirley, Arkansas, while the flow is based on USGS low flow data and visual observation. Effluent dominated seasonal limits are required to meet the existing standard for dissolved oxygen in order to protect the spawning potential of Mill Creek.

TABLE 1

MELBOURNE 10-15-4

Stream temp deg C=	28.00			
Oxygen Sat. for temp of	28.00	is		7.90
UOD upstream=	3.00			
CFS flow of stream=	0.10			
DO of stream mg/L=	6.30			
Waste temp deg C=	28.00			
DO of waste mg/L=	6.00			
UOD of waste mg/L=	23.00			
CFS flow of waste=	0.63			
K1= (base 10)	0.39		(base e)=	0.90
K2= (base 10)	7.21		(base e)=	16.60
Benthal Uptake g/M↑2/d=	0.30			
Mean depth ft.=	0.50			
NUOD=	18.28		Ammonia-N=	4.00
Kn=	0.17		(base e)=	0.40
Total UOD of waste=	41.28			
INITIAL DEFICIT=	1.86			
DO of MIX=	6.04			
UOD of MIX=	36.07			

CRITICAL DO=	6.02
CRITICAL DEFICIT=	1.88
CRITICAL TIME=	0.04
K1CORR=	0.56
K2CORR=	8.71
KnCORR=	0.26
S CORR=	3.43

MELBOURNE 10-15-4

FIGURE 2

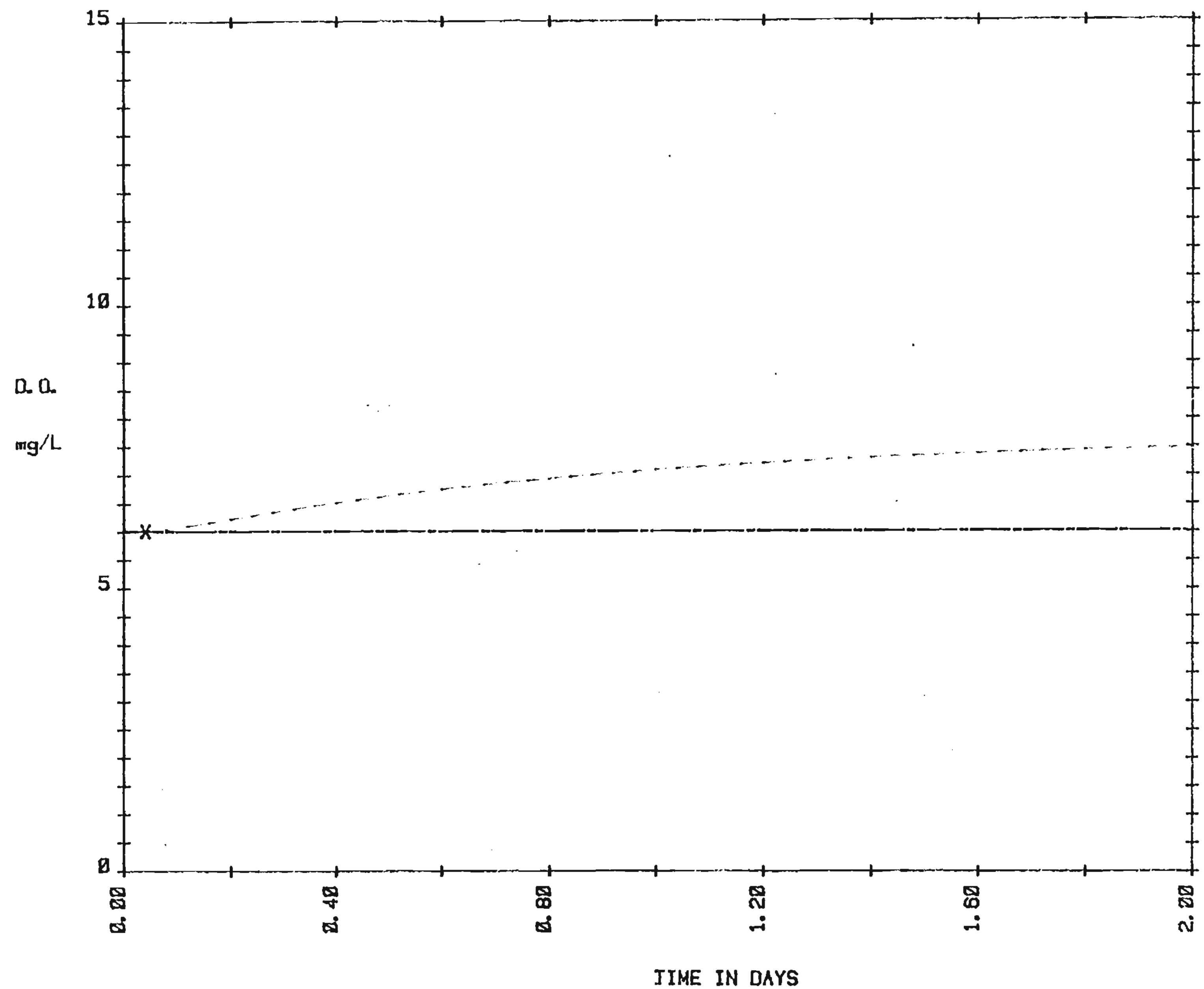


TABLE 2

MELBOURNE SEASONAL 20-20-15

Stream temp deg C=	20.00		
Oxygen Sat. for temp of	20.00 is		9.20
UOD upstream=	3.00		
CFS flow of stream=	0.30		
DO of stream mg/L=	7.40		
Waste temp deg C=	20.00		
DO of waste mg/L=	6.00		
UOD of waste mg/L=	46.00		
CFS flow of waste=	0.63		
K1= (base 10)	0.39	(base e)=	0.90
K2= (base 10)	7.21	(base e)=	16.60
Benthal Uptake g/M↑2/d=	0.30		
Mean depth ft.=	0.50		
NUOD=	68.55	Ammonia-N=	15.00
Kn=	0.17	(base e)=	0.40
Total UOD of waste=	114.55		
INITIAL DEFICIT=	2.75		
DO of MIX=	6.45		
UOD of MIX=	78.75		

CRITICAL DO=	6.35
CRITICAL DEFICIT=	2.85
CRITICAL TIME=	0.08
K1CORR=	0.39
K2CORR=	7.21
KnCORR=	0.17
S CORR=	1.97

MELBOURNE SEASONAL 20-20-15

FIGURE 3

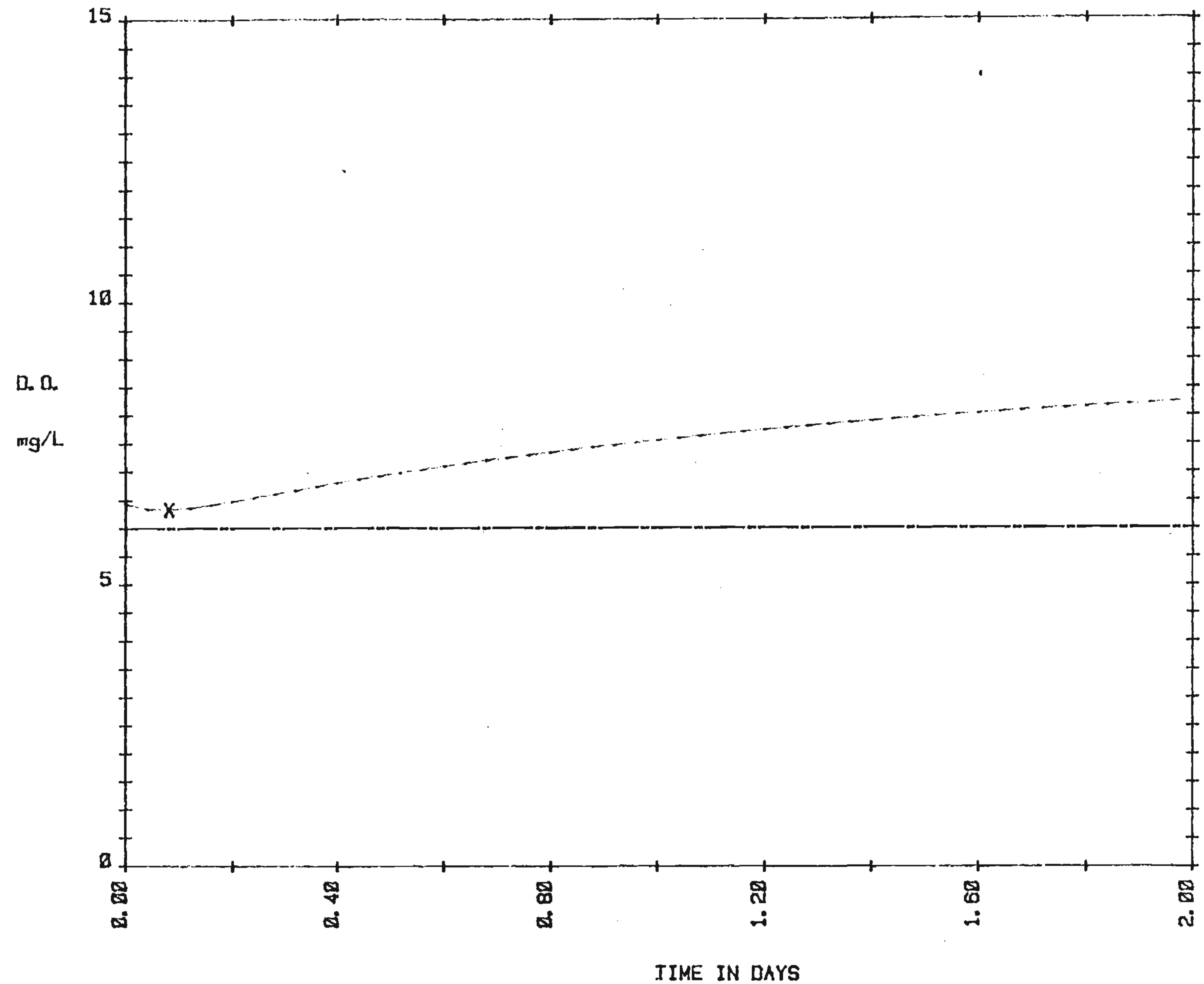


TABLE 3

MELBOURNE EFF DOM 20-20-7

Stream temp deg C=	28.00		
Oxygen Sat. for temp of	28.00 is		7.90
UOD upstream=	3.00		
CFS flow of stream=	0.10		
DO of stream mg/L=	6.30		
Waste temp deg C=	28.00		
DO of waste mg/L=	4.00		
UOD of waste mg/L=	46.00		
CFS flow of waste=	0.63		
K1= (base 10)	0.39	(base e)=	0.90
K2= (base 10)	7.21	(base e)=	16.60
Benthal Uptake g/M↑2/d=	0.50		
Mean depth ft.=	0.50		
NUOD=	31.99	Ammonia-N=	7.00
Kn=	0.17	(base e)=	0.40
Total UOD of waste=	77.99		
INITIAL DEFICIT=	3.59		
DO of MIX=	4.31		
UOD of MIX=	67.78		

CRITICAL DO=	4.30
CRITICAL DEFICIT=	3.60
CRITICAL TIME=	0.04
K1CORR=	0.56
K2CORR=	8.71
KnCORR=	0.26
S CORR=	5.71

MELBOURNE EFF DOM 20-20-7

FIGURE 4

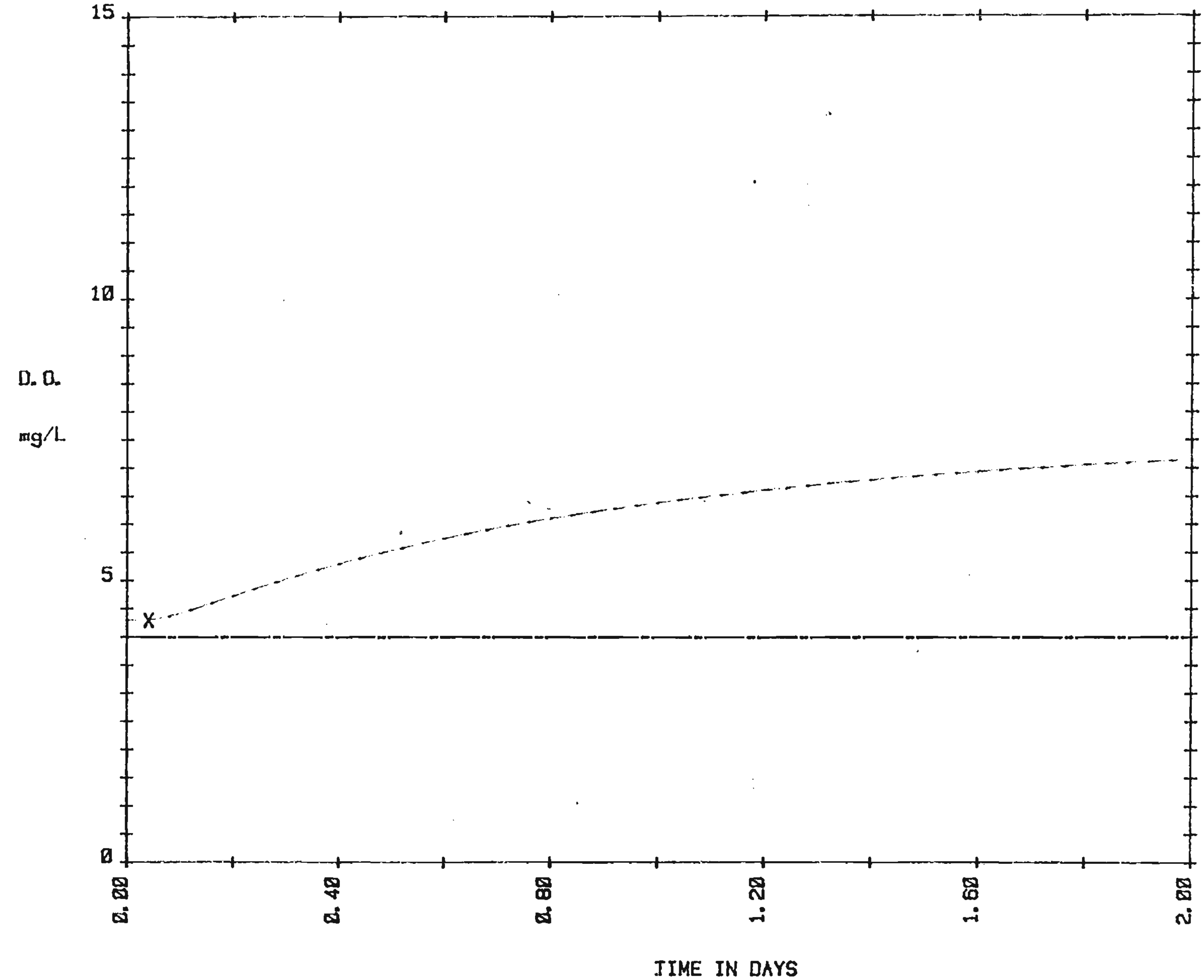


TABLE 4

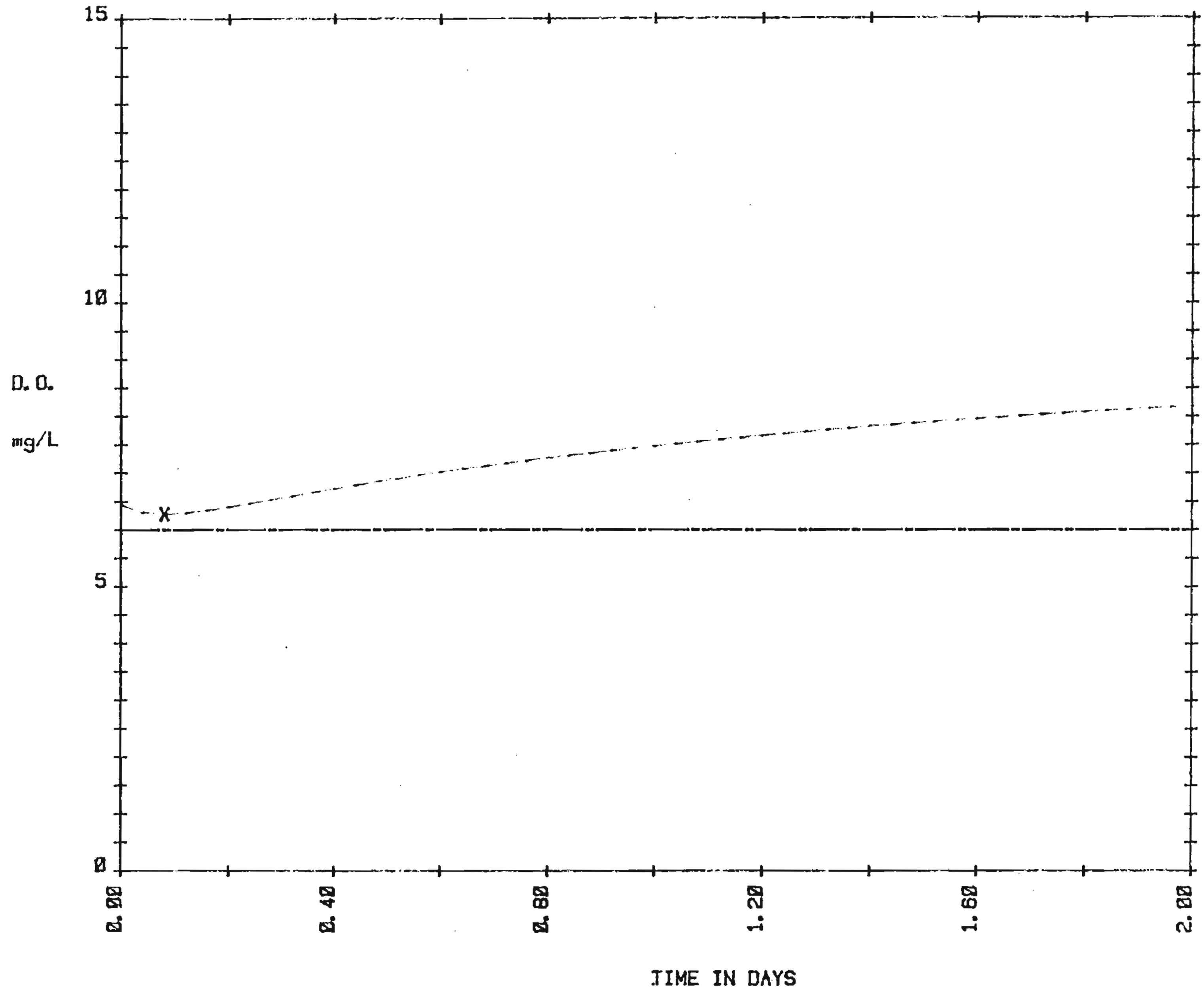
MELBOURNE EFF DOM SEASONAL 20-20-15

Stream temp deg C=	20.00		
Oxygen Sat. for temp of	20.00 is		9.20
UOD upstream=	3.00		
CFS flow of stream=	0.30		
DO of stream mg/L=	7.40		
Waste temp deg C=	20.00		
DO of waste mg/L=	6.00		
UOD of waste mg/L=	46.00		
CFS flow of waste=	0.63		
K1= (base 10)	0.39	(base e)=	0.90
K2= (base 10)	7.21	(base e)=	16.60
Benthal Uptake g/M↑2/d=	0.50		
Mean depth ft.=	0.50		
NUOD=	68.55	Ammonia-N=	15.00
Kn=	0.17	(base e)=	0.40
Total UOD of waste=	114.55		
INITIAL DEFICIT=	2.75		
DO of MIX=	6.45		
UOD of MIX=	78.75		

CRITICAL DO=	6.29
CRITICAL DEFICIT=	2.91
CRITICAL TIME=	0.08
K1CORR=	0.39
K2CORR=	7.21
KnCORR=	0.17
S CORR=	3.28

MELBOURNE EFF DOM SEASONAL 20-20-15

FIGURE 5



GENERAL DISCUSSION

Waterway Description

Mill Creek originates approximately 2 miles northeast of Melbourne in south cental Izard County and flows in a westerly direction for 16 miles to its junction with Piney Creek. Piney Creek flows another two miles before its' confluence with the White River.

Mill Creek lies within the Salem Plateau of Ozark Highlands Physiographic Region at elevations of approximately 500 feet with surrounding hills approaching 800 to 1,000 feet in altitude. The geologic structural formation consists mainly of Blakely Sandstones as evidenced by the slab rock-gravel nature of the streambed. The stream morphology consists of alternating riffles and pools in a winding, fast-dropping channel. The stream slope in the region of the proposed site is 33 feet/mile. Average stream width is about 10 feet while the average depth is 4 to 6 inches. Background stream flow is due to small springs in the watershed which aid in keeping the stream temperature low. Stream velocity was measured at .28 cfs during the survey. There is cattle access periodically all along the mile that was surveyed, with this activity resulting in some sediment deposits in the streambed. Mill Creek has approximately 6 square miles of watershed at the proposed STP site. This watershed is about 75% cleared and 25% wooded, with the cleared portion consisting of 80% pasture and 20% urban development. Below the proposed STP site the stream length to Piney Creek is about 13 miles.

Figure 1 depicts the existing site, proposed site and general topography of the region. Overall the water quality at the time of the survey was very good in Mill Creek. The present STP was impacting the stream for a short distance downstream; however, the reaeration rate through the riffle areas is good and the stream appeared to recover fairly quickly. With the exception of turbidity and some sediment accumulation in the stream reach just below the outfall, there was little discernable difference between the stream habitat above and below the effluent discharge.

Water Quality Standards and Designated Beneficial Uses

Mill Creek, being an unlisted stream, assumes the classification of the stream (Piney Creek) to which it is a tributary. In this case a small mouth bass fishery is applicable which has a dissolved oxygen standard of 6 mg/l. The designated beneficial use classification is Class A which is suitable for primary contact recreation, propagation of desirable species of fish, wildlife, and other aquatic life, raw water source for public water supplies and other compatible uses.

Water Quality Violations

There were no dissolved oxygen violations occuring at the time of the survey, however, the stream temperature was cool, averaging only 17.5 degrees centigrade. Under critical temperature and flow conditions a pre-dawn D.O. violation is quite possible. Not other water quality standards appeared to be in violation at the time of the survey.

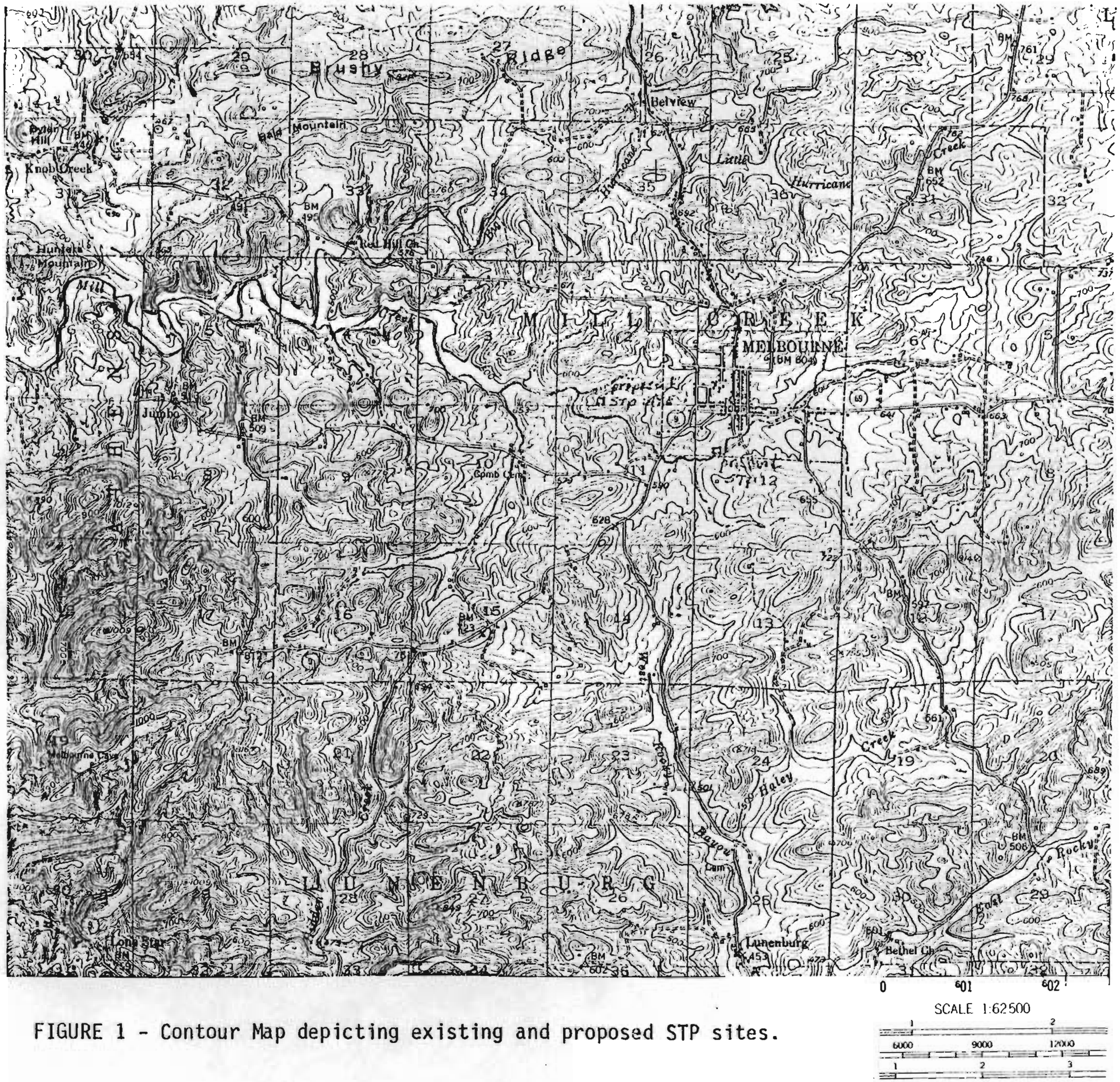


FIGURE 1 - Contour Map depicting existing and proposed STP sites.

Existing and Proposed Treatment Facilities

Melbourne is currently served by a single cell five acre oxidation lagoon that was constructed in 1962. This lagoon is overloaded both organically and hydraulically. This pond is located just south of Melbourne approximately ¼ mile east of the Highway 9 bridge over Mill Creek.

The proposed treatment facility will be located just west of town and will discharge into Mill Creek approximately one ile below the present discharge location. The new system will consist of an oxidation ditch followed by rapid sand filters and chlorine contact chamber. The proposed design flow for this treatment system is .41 MGD.

Other Point Sources - Non-Point Source Loadings

There are no other known point source discharges into Mill Creek in the vicinity of Melbourne. A deposit of sawdust was found in the stream bed approximately 300 yards downstream of the Highway 9 bridge, which was assumed to be deposited from a sawmill on the hill above the stream during and following rainfall events. Other non-point source loadings include deposits from urabn runoff above the STP discharge point and nutrients and sediment from cattle access below the discharge point.

STREAM MODEL

The following equation has been utilized in this desk top model. This steady state Streeter-Phelps equation is identified as:

$$D = D_o e^{-Kat} + \frac{Kd\ Lo}{Ka - Kr}(e^{-Krt} - e^{-Kat}) + \frac{Kn\ Ln}{Ka - Kn}(e^{-Knt} - e^{-Kat}) + \frac{S}{Ka}(1 - e^{-Kat})$$

Where D = oxygen deficit at location X, given a particular stream velocity u, or after time $(\frac{x}{u})$

Do = initial instream oxygen deficit after mixing

Lo = initial CBODu concentration (CBODu = BOD_5 X 2.3)

Ln = initial NBOD concentration (NBODu = NH_3N X 4.57)

Lo, Ln are calculated through a mass balance with background ultimate CBOD and NBOD; Do is calculated from a mass balance using upstream and effluent dissolved oxygen.

Ka = reaeration rate.

Kr = CBOD removal rate (Kr = Kd + Ks)

Kd = CBOD oxidation rate

Ks = CBOD settling rate

Kn = NBOD decay rate

S = Sediment oxygen demand in grams/meter^3/day

s = B/H where B = benthal demand in grams/m^2/day and

H = average depth in meters.

DATA USED FOR MODEL

Observed Field Data

Avg. Stream Width - 10 feet

Avg. Stream Depth - .5 feet

Avg. Stream Velocity - .28 fps (feet per second)

Stream Slope - 33 feet per mile

Stream Bed - slab rock, gravel, sediment

Assumed Data

Critical Conditions (May through October)

Stream Temperature - 28°C

Stream Flow - .1 cfs (cubic feet per second)

Effluent D.O. - 6 mg/1

Seasonal Conditions (November through April)

Stream Temperature - 20°C

Stream Flow - .1 cfs

Effluent D.O. - 6 mg/1

DISCUSSION OF COEFFICIENTS

Deoxygenation Rate (Kd or K_1)

The deoxygenation rate for Mill Creek was obtained by evaluating the substrate type, average stream depth, and the type of treatment facility proposed for the Melbourne project. The substrate is a stable rocky formation and the average stream depth is approximately .5 feet. The proposed treatment facility design consists of an oxidation ditch system which provides a high degree of treatment to the wastewater. Based on this information a Kd of .9 was selected from figure 3-6 of Reference #1.

Reaeration Rate (Ka or K_2)

The reaeration rate used in the Mill Creek study is the Tsivoglou formula which is:

K_2 = CVS at 20^oC Where:

K_2 = Reaeration rate (1/day)

V = Stream velocity (ft./sec.)

S = Stream slope (ft./mile)

C = Proportionality constant with the values shown below.

C = 1.8 for flows from 1 to 10 cfs

C = 1.3 for flows from 10 to 25 cfs

C = 0.88 for flows from 25 to 300 cfs

K_2 = 1.8 (.28) 33

K_2 = 16.6 day^{-1} base e at 20^o

Nitrogenous Deoxygenation Rate (Kn)

The nitrogenous decay rate was derived from EPA literature values for treatment systems achieving greater than secondary treatment. In order to maintain the current stream D.O. standard of 6 mg/l a low level of ammonia is projected by the model (4 mg/l) therefore, a relatively low Kn is indicated. The model input value for this reaction rate .4 day^{-1} base e.

Benthal Demand (S)

The benthal demand was also taken from EPA literature values. This coefficient is dependent on the amount of settleable solids in the effluent, the substrate type, and stream velocity. Since Mill Creek is a clean, shallow fast-flowing stream, and considering the value of the total solids in the model projection, a benthal demand of .3 day^{-1} base e was used for this study. This value was increased to .5 day^{-1} base e for the effluent dominated treatment schemes because of the elevated suspended solids for those model projections.

Temperature Correction Factors

The general equation used to correct the rate coefficient from their values at 20°C to the expected temperature is as follows:

$$Kt = K_{20}\theta^{T-20}$$

Where: Kt = rate coefficient at temperature T (C°) day $^{-1}$

K_{20} = rate coefficient at 20°C, day^{-1}

θ = temperature correction factor

Correction factors for the coefficients used in this study are:

Kd = 1.047 Ka = 1.024 Kn = 1.05 S = 1.07

Determination of Allowable Load

A steady state Streeter-Phelps model was used to determine the assimilative capacity of Mill Creek at Melbourne. A Hewlett Packard 9825A computer was used for model development, along with a 9872A plotter for producing the graphics for the study. Seasonal limits were evaluated in order to provide a more cost effective treatment scheme, and yet maintain the existing dissolved oxygen standard for Mill Creek. Two sets of treatment schemes were evaluated in regard to the dissolved oxygen concentration. The existing standard of 6 mg/l was used as the minimum in one set while the effluent dominated standard of 4 mg/l was evaluated also. Both sets of treatment schemes utilize seasonal limits.

CONCLUSION

According to the model performed on Mill Creek the following options will meet the dissolved oxygen standard that now exists, or will maintain the effluent dominated standard of 4 mg/l.

Set	Restrictions	Effluent Limits (BOD_5, TSS, NH_3-N)
1	D.O. Standard = 6	10-15-4
	Effluent D.O. = 6	
	Critical Temp. = 28°C	
	Seasonal Limits (20°C)	20-20-15
2	D.O. Standard = 4	20-20-7
	Effluent D.O. = 4	
	Critical Temp. = 28°C	
	Seasonal Limits (20°C)	20-20-15

REFERENCES

1. Tetra Tech, Inc., 1978. Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling. EPA 600/3-78-105.

2. E.P.A. Region VI. "Criteria for Performing Wasteload Analysis", September 1983.