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NEW HAMPSHIRE
DEPARTMENT OF
Environmental
Services

LAMPREY RIVER TMDL STUDY

OCTOBER 1995

NHDES-WSPCD-95-8

LAMPREY RIVER TOTAL MAXIMUM DAILY LOAD STUDY

STATE OF NEW HAMPSHIRE
DEPARTMENT OF ENVIRONMENTAL SERVICES
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OCTOBER 1995

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NHDES

October 31, 1995

Edward J. Schmidt, P.E., Ph.D., Director
Department of Environmental Services
Water Supply & Pollution Control Division
Hazen Drive
Concord, New Hampshire 03301

Re: Total Maximum Daily Load Study

Dear. Dr. Schmidt:

Please find attached the Lamprey River Total Maximum Daily Load Study. This report is being submitted in partial fulfillment of the FY95 EPA workplan. This study represents a two year effort by Gregg Comstock and Jim Herrick, and will be used as a prototype for all future TMDL's.

Major findings of this study reveal:

- many reported dissolved oxygen exceedances of water quality standards in the Lamprey River are attributable to natural sources; in this case, wetland areas.

- that for the Lamprey River to meet water quality standards, additional treatment is needed at the Epping Wastewater Treatment Facility.

Cordially,

Raymond Carter

Raymond P. Carter, P.E., Administrator
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EXECUTIVE SUMMARY

PURPOSE

Section 303 (d) of the Clean Water Act (CWA) requires States to identify those surface waters for which technology based controls, such as secondary treatment, are not stringent enough to ensure that surface waters meet their legislated classification and their intended uses. The process to achieve this goal is known as the Total Maximum Daily Load (TMDL) process.

Although the Town of Epping has a secondary wastewater treatment facility (WWTF), low dissolved oxygen concentrations below the discharge indicated the potential need for additional treatment. Accordingly, this stretch of the Lamprey River has been designated by the Department of Environmental Services (DES) as water quality limited and was included on DES's 303 (d) list. Accordingly, the purpose of this report and the TMDL is to:

- Determine the maximum daily load of treated wastewater which can be assimilated by the Lamprey River.
- Determine the load allocation among point sources, nonpoint sources and a margin of safety (MOS) such that the Lamprey River will meet water quality standards.
- Although not required in a TMDL study, we also took the opportunity to resolve other isolated exceedances of water quality standards that have been observed in the Lamprey River.

STUDY AREA

The Lamprey River watershed is located in the coastal basin and encompasses an area of about 214 square miles. The tributary drainage area to the river is about 81% forest and wetlands, and only about 19% in various stages of development. Overall the Lamprey River watershed can be characterized as rural in nature.

SOURCES OF POLLUTION

Field surveys, canoe trips and evaluation of USGS and GIS maps revealed:

- The only major point source on the Lamprey River is the Epping WWTF.
- The major nonpoint source (NPS) is stormwater runoff.

WET WEATHER MODELING

From field studies of the entire Lamprey River, and based on the preceding findings, the study area for the TMDL concentrated from reach 22 to 24.

Wet weather modeling in this reach reveals a total maximum daily load of:

TMDL

$CBOD_5$	**1752 lbs/day**
NH_3-N	**178 lbs/day**

DRY WEATHER MODELING

Dry weather modeling in the same reach during winter and summer seasons revealed a maximum daily load of:

TMDL

Parameter	Summer (lb/day)	Winter (lb/day)
$CBOD_5$	41	55
NH_3-N	14.3	19

It is clear that dry weather is the controlling period. Therefore, development of the following proposed permit limitations for the Epping WWTF were based on dry weather conditions and a design flow rate of 0.35 MGD.

PROPOSED PERMIT LIMITS

Parameter	Average Monthly		Average Weekly		Average Daily	
	mg/l	lbs/day	mg/l	lbs/day	mg/l	lbs/day
$CBOD_5$	11	31	13	37	14	41
NH_3-N	4	11			5	15

The existing National Pollutant Discharge Elimination System (NPDES) permit limits, established in 1985, are shown below.

Existing NPDES Permit Limits

Paramter	Average Monthly		Average Weekly		Average Daily	
	mg/l	lbs/day	mg/l	lbs/day	mg/l	lbs/day
BOD	30	68	45	101	50	113
TSS	30	68	45	101	50	113

It should be noted that Epping's existing NPDES permit was based on 0.27 MGD, while the proposed discharge limits were developed for 0.35 MGD. Further, the existing permit includes a limit for BOD_5, while the proposed limits are for $CBOD_5$. For a basis of comparison, about 30 mg/l of BOD_5 is equivalent to 25 mg/l of $CBOD_5$.

ALLOCATION

Based on future allowances for the Epping WWTF, the following allocation of wastewater during wet weather is shown below:

Parameter	Point Source (lb/day)	Non-point Source (lb/day)	MOS * (lb/day)
$CBOD_5$	60	1517	175
NH_3-N	25	135	18

* MOS - Margin of Safety

WETLANDS

Past ambient surveys conducted by DES, noted several low DO concentrations along much of the Lamprey River, and some of its tributaries. At the start of this study, it was noticed that many of the low DO locations were near and downstream of wetlands. To determine if there was a direct correlation between wetland areas and low DO's, the Department conducted field sampling above, in and below virgin wetland areas. Based on this study it is clear that wetland areas serve as a DO sink. Accordingly, small streams that flow through or from wetland areas usually have low DO's in the area near the wetlands. It was also observed that the DO's usually recovered to normal concentrations within a relatively short distance downstream of the wetlands.

METALS

Zinc, aluminum, lead and copper exceedances were listed on DES's 303 (d) list. However, further sampling during this study revealed no water quality exceedances for aluminum and lead.

To address the remaining zinc and copper exceedances, DES will conduct additional testing using "clean techniques" to determine the source of these metals, and to determine if the source is natural. Preliminary testing to date has indicated some apparent high metal observations in rainwater. Theses findings need to be verified, along with possible contributions from wetlands.

CONCLUSIONS

- Because of the limited capacity of the Lamprey River to assimilate treated wastewater, additional treatment will be required for the Epping WWTF.
- Although wetland areas act as a DO sink, the river DO has recovered to normal values upstream of the Epping discharge. Therefore, wetland areas did not unduly influence modeling in the area of the Epping discharge and are not the cause for additional treatment as originally suspected.
- Because of the rural nature of the Lamprey River watershed and the lack of urban development, dry weather or low flow conditions are more restrictive than wet weather conditions.
- Additional study by the Department will be needed to resolve apparent metal exceedances for copper and zinc.

INTRODUCTION

Section 303 (d) (1) (A) of the Clean Water Act (CWA) requires each State to identify waters for which secondary or technology effluent limitations are not stringent enough to meet water quality standards. Further, Section 303 (d) (1) (C) requires each State to establish a Total Maximum Daily Load (TMDL), for such waters identified in Section 303 (d) (1) (A). [1]

Although the Town of Epping has a secondary treatment facility, dissolved oxygen (DO) violations in the vicinity of the discharge in the Lamprey River indicate that further treatment may be needed. In accordance with the CWA, the Lamprey River has been designated as water quality limited, and is listed on the Department of Environmental Services' (DES) 303 (d) list.

In addition to DO violations, algal blooms have also been reported downstream of the Epping WWTP. It is suspected that the Epping WWTP is a source of excessive nutrients (nitrogen and phosphorus). Therefore, advanced wastewater treatment (AWT) may be needed for nutrient removal. This factor also requires that this same stretch of the river be included on the Department's 303 (d) list.

Ambient sampling studies have shown a number of DO violations in other reaches of the river. Although this would not necessarily require these stretches of the river to be included on the 303 (d) list, DES decided to investigate and resolve, if possible, these violations by studying the entire Lamprey River Watershed as part of this TMDL study.

Sporadic heavy metal exceedances of State Water Quality Standards were also found. A discussion of the metal exceedances is contained in the Results/Findings section.

GOAL

The ultimate goal of the TMDL study is to ensure that water quality limited surface waters meet their legislated classification and use by:

1. Determining the maximum wastewater load that a receiving water can accommodate, and to apportion any existing and future loads such that the water quality standards will be met.

2. Allocating wastewater loads among the Nonpoint Sources, Point Sources and a Margin of Safety (MOS). The allocation process will be explained in detail in section VI of this report.

SECTION II

STUDY AREA

STUDY AREA

The study area for this TMDL is the Lamprey River Watershed. The Lamprey River originates at Meadow Lake in Northwood, NH and flows through Deerfield, Raymond, Epping, Lee, Durham, Newmarket and into Great Bay. Figure I-1 shows a map of the study area.

WATERSHED CHARACTERISTICS

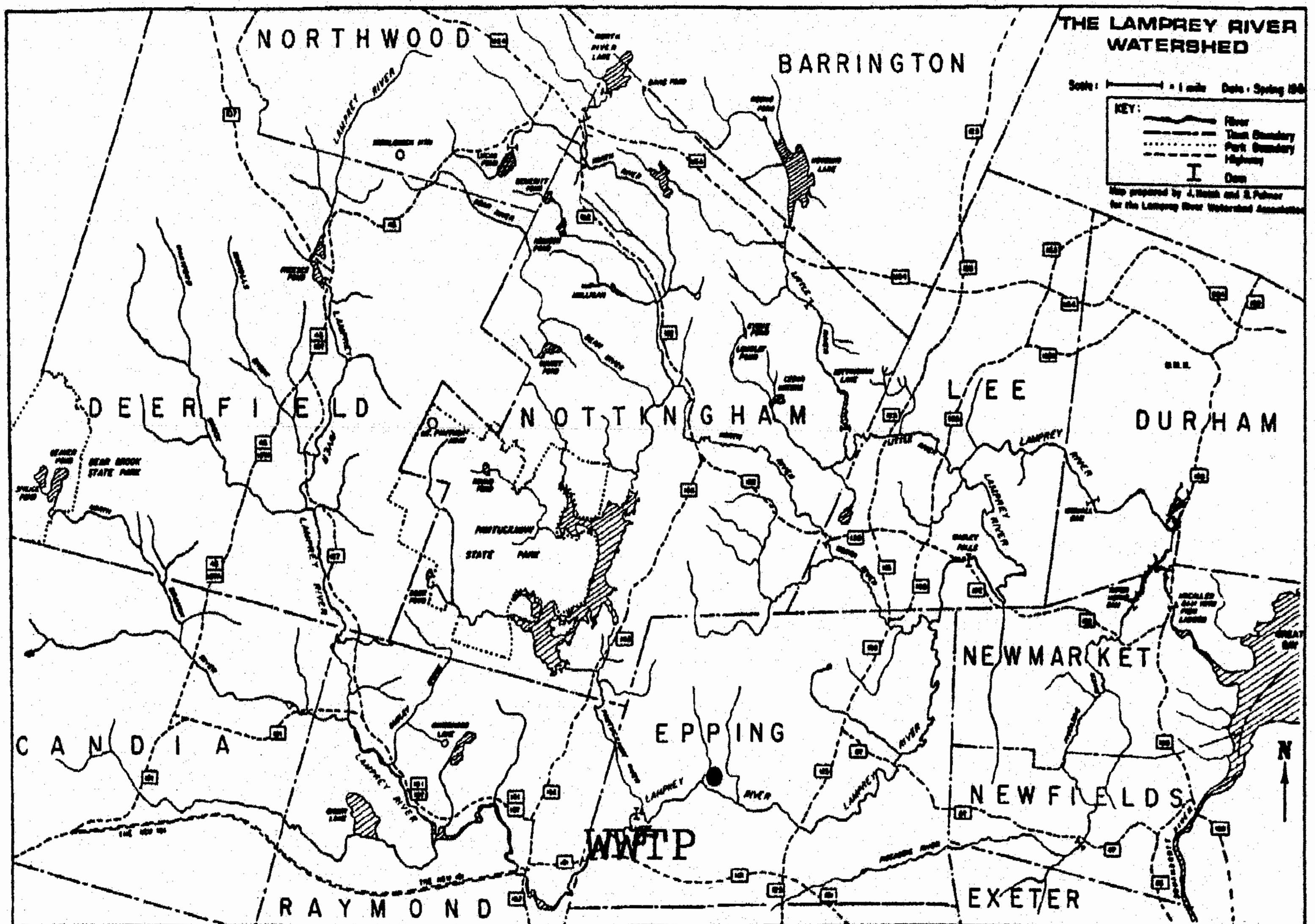
- The Lamprey River watershed is located ....in the coastal basin.
- The Lamprey River is approximately ....46 miles long.
- The watershed has a total area of approximately .... 214 square miles.
- Land uses for the Lamprey River watershed include:
    - 70% forested/mixed
    - 11% wetlands
    - 9% urban
    - 5% active agriculture
    - 3 % surface water
    - 2 % cleared/open/disturbed
- There are five dams along the river, which include:
    - Freeses Pond Dam, DeerField
    - Bunker Pond Dam, Epping
    - Wadley Falls Dam, Epping
    - Wiswell Road Dam, Durham
    - Tidal dam at the confluence of the Lamprey River and Great Bay.
- There are thirteen tributaries that flow into the Lamprey River. The major tributaries include:
    - The major tributaries are (upstream to downstream) Hartford Brook, North Branch River, Onway/Governors Lakes tributaries, Pawtuckaway River, North River, Little River and Piscassic River.

- The banks of the Lamprey River mainly consist of forested land with a scattering of houses, farms and cleared areas.

- The majority of the wetlands are located in the upper reaches of the watershed.

- A recent study of the Lamprey River found that 23.5 miles of the River are eligible for inclusion in the National Wild and Scenic Rivers System. This was based on free-flowing character of the river, the presence of outstanding ecological, anadromous fish and historical resources. The eligible portion of the Lamprey River extends from Bunker Pond Dam in Epping to the confluence of the Lamprey and Piscassic rivers in Newmarket.[11]

Figure II-1
Map of Study Area



SECTION III

SOURCES OF POLLUTION

SOURCES OF POLLUTION

1. *Point Sources (PS)* - The only known major point source in the entire watershed is the Epping Wastewater Treatment Plant (WWTP). It is an aerated lagoon system, with flow ranging from 70,000 to 230,000 gpd. The high variation in flow is due primarily to infiltration. The current summertime operation is to not discharge to the Lamprey River when the flow is less than 2 times 7Q10 (6 cfs). The Town of Epping has requested to increase their flow to 350,000 gpd (0.54 cfs). Accordingly, all modeling was performed with the WWTP discharging 0.54 cfs.

2. *Nonpoint Sources (NPS)* - Nonpoint Pollution is generated from many scattered sources rather than a single point. It develops when storm water washes over lawns, parking lots, city streets, farm fields, construction sites and picks up pollutants. Polluted runoff then travels to the river by natural drainage or through a storm drain system. NPS activities, which could result in a buildup of contaminats prior to a rain storm event are listed below [3]:

    1. Stormwater runoff
    2. Construction
    3. Agriculture
    4. Landfills and junkyards
    5. Silviculture
    6. Septage and subsurface disposal systems
    7. Storage tanks
    8. Hydro modification
    9. Groundwater

    Field surveys were conducted over the entire river to determine the categories of NPS pollution. In addition, a five mile section (Bunker Pond Dam to the Epping WWTP) was canoed to look for sources of NPS pollution. Based on these surveys, the primary source of NPS pollution in the Lamprey Watershed is stormwater runoff.

    Concentration of pollutants in the runoff were calculated based on land use (land use information was obtained from NH DES GIS). The three (3) land use classifications are rural, agricultural, and urban. An assumption was made to classify the urban areas as high, medium or low, to account for differences in population density and/or traffic volumes.

    Runoff pollutant concentrations were based on limited storm water samples taken in NH, rather than published runoff values for larger cities such as Baltimore and Washington D.C., as they are not indicative of smaller communities in New Hampshire like Epping and Raymond. Table III-1 lists the loadings by land use in mg/l/square mile.

Table III-1
Runoff Loadings Based on Land Use [5,6]

LAND USE	CBOD (mg/l/sq. mile)	NH_3-N (mg/l/sq. mile)
RURAL	———	0.19
AGRICULTURAL	5.0	5.04
URBAN - HIGH	30.0	1.00
URBAN - MEDIUM	26.0	0.75
URBAN - LOW	11.0	0.50

SECTION IV

MODEL APPROACH

MODEL APPROACH

- **MODELING APPROACH**

The use of mathematical models to determine the concentration of DO in a river began in the 1920s. The first model developed, by Streeter and Phelps, described the degradation of organic waste using exponential decay. The model selected for this TMDL study includes the effects of reaeration, nitrogenous oxygen demand, photosynthesis, respiration and sediment oxygen demand in addition to the carbonaceous oxygen demand. Modeling of the DO concentration was performed using EPA's dissolved oxygen deficit model (EPA 600/6/82-004a).

The basic model equation which determines the in-stream DO concentration while taking into account the above factors is as follows:

DO MODEL

$$\mathbf{D = Do\, e^{-Kat} + Kd/(Ka - Kd)(Lo - Lrd/Kd)(e^{-Kdt} - e^{-Kat}) + Kn/(Ka - Kn)(No - Nrd/Dn)(e^{-Knt} - e^{-Kat}) + (R + Sb + Lrd + Nrd - P)/Ka(1 - e^{-Kat})}$$

Where:

Do	=	initial DO deficit (mg/l)
Ka	=	reaeration rate (1/day)
Kd	=	rate of decay of CBOD (1/day)
Lo	=	initial ultimate CBOD (mg/l)
Lrd	=	mass rate of CBOD entering reach per unit volume of river water (mg/l/day)
No	=	initial ultimate NBOD (mg/l)
Kn	=	decay rate of NBOD (1/day)
Nrd	=	mass rate NBOD entering reach per unit volume of river water (mg/l/day)
R	=	oxygen utilization rate due to respiration (mg/l)
P	=	oxygen production rate due to photosynthesis (mg/l)
Sb	=	sediment oxygen demand (gm/m^2/day)

To solve this model, it is necessary to determine each of the above parameters. Determination of each parameter is discussed in this section.

2. The Lamprey River was modeled under the following conditions:

   A. Wet weather modeling was performed with nonpoint sources and Point sources with the river at the summer average flow .*

B. Dry weather modeling was performed for winter conditions with the river at 7Q10 * and summer conditions with the river at twice the 7Q10. Currently there is an agreement with the Town of Epping, that the WWTP discharges in the summer only when the river flow is at least twice the 7Q10.

* A discussion of the summer average flow and 7Q10 is contained the Model Parameter section (page IV-2).

- **REACHES**

The assimilation capacity of a river varies with the size and characteristics of each reach of the river. Reaches are defined between all major point loads or whenever the river geometry, hydraulic conditions or biochemical processes are expected to change significantly. Reach segments were determined by conducting field surveys and reviewing flood insurance studies, USGS maps and aerial photos. The Lamprey River was divided into 32 reaches, based on the above conditions.

Although the study reach area which was used in the modeling is a 7.5 miles stretch including the Epping WWTP to Wadley Falls Dam, (segments 22 through 24), the remaining reaches were used to study and investigate sources, if any, of NPS pollution and other DO violations listed on the 303(d) list. Table IV-1, on page IV-4 lists the reach number and the reach description. Figure IV-1 is a schematic of the 32 reaches, highlighting the major tributaries, dams as well as the Epping WWTP.

- **MODEL PARAMETERS**

1. To increase the reliability of the model, assumptions were kept to a minimum. The basis of model parameters is as follows:

    a. The upstream DO value was assumed to be 90% of saturation.

    b. The DO (in mg/l) of the stormwater runoff entering the river was assumed to be 7 mg/l (25 ° C).

    c. Initial upstream river UCBOD and NBOD values were assumed to be 2 mg/l and 1 mg/l respectively. These values were based on sampling conducted by Dufresne-Henry, Inc.(D-H) dated April 1995. These same values were used by NHDES to determine preliminary permit limits, prepared in November 1994. A discussion of the limits determined in the above two studies is contained in the Permit Limits section.

Figure IV-1
Schematic of Reaches

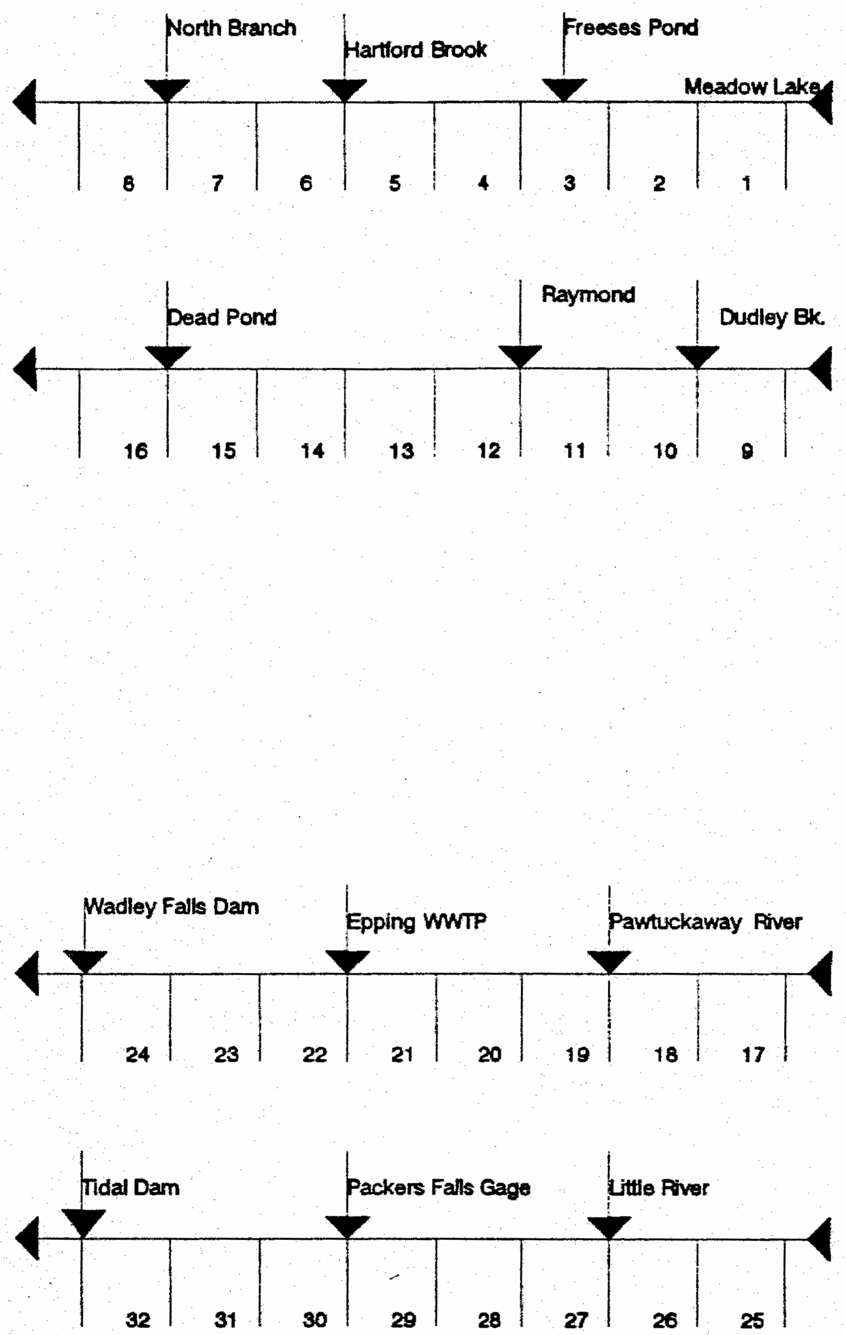


Table 2
Reach Number and Description

1	Meadow Lake to end of large wetlands	17	Dead Pond to Bunker Pond
2	Large wetlands to Freeses Pond	18	Bunker Pond to Pawtuckaway River
3	Freeses Pond	19	Pawtuckaway River downstream 1.72 miles
4	Freeses Pond - 1.33 miles downstream	20	End of 19 to Hoar Pond
5	End of 4 to Nichols Brook	21	Hoar Pond to Epping WWTP
6	Nichols Brook to Hartford Brook	22	Epping WWTP to Rum Brook
7	Hartford Brook to campground (24-LMP)	23	Rum Brook to North River
8	24-LMP to North Branch River	24	North River to Wadley Falls
9	North Branch to Dudley Brook	25	Wadley Falls to Tuttle Swamp
10	Dudley Brook to Langford Rd. (21-LMP)	26	Tuttle Swamp to Little River
11	21-LMP to pond in Raymond	27	Little River downstream 1.67 miles
12	End of 11 to Onway Tribs.	28	End of 27 to Wiswell Dam
13	End of 12 downstream 1.24 miles	29	Wiswell Dam to Packer Falls Gage
14	End of 13 downstream 0.67 miles	30	Gage to Ellison Brook
15	End of 14 to Dead Pond	31	Ellison Brook to Piscassic River
16	Dead Pond	32	Piscassic River to tidal dam

2. The 7Q10 river flow was calculated to be 5 cfs at Packer Falls Gage (reach 30). 7Q10 calculations were based on "Hydrologic Data for Gaged Watersheds of New Hampshire and Vermont", by S. L. Dingman and G. K. Capsis.

3. The Summer Average Flow was calculated to be 89 cfs at Packer Falls Gage (reach 30). This flow is equal to the historical average daily flow that occurs during the period from July 1 through September.

4. Velocity - As the river flow changes, velocity changes. The velocity of the river is needed to develop rate coefficients.

   A flow rating curve was developed at an existing sampling location within the reach study area. The location chosen was 15-LMP which is on Blake Road in Epping. To establish the curve, depth, velocity and width measurements were recorded on four different days; 5/30/95, 6/23/95, 6/28/95 and 7/11/95. From the data collected, a graph (see Appendix A) was developed. Based on a measured or calculated flow, a corresponding velocity can be determined.

5. Rate Coefficients needed for the model are the reaeration rate, deoxygenation rate and nitrification rate. Values of rate coefficients used in the model are presented in Table IV-4, Model Parameters.

a. Reaeration Rate Coefficient

There are two primary sources of dissolved oxygen in a river. The first being the DO contained in the river flow and the other being reaeration from the atmosphere and dams. K_a is the rate at which oxygen can be transferred from the atmosphere to the river. Depth, velocity, turbulence, temperature and the amount of oxygen in the river are the factors which effect K_a.

The K_a values used in modeling the dry weather conditions were based on information provided by Dufresne-Henry, Inc.(D-H) dated April 1995. These K_a values were calibrated to data collected by D-H in the summer of 1993 and 1994. The same K_a values were used by NHDES to determine preliminary permit limits, prepared in November 1994.

A K_a value was also determined for modeling wet weather conditions. Appendix B contains a discussion of the method used to calculate the wet weather K_a .

b. Deoxygenation Rate Coefficient

The reduction of BOD in a river is a function of settling, biochemical oxidation and absorption by bottom deposits. The rate of removal of BOD is defined as the deoxygenation rate coefficient (K_1). K_1 can generally be expressed as:

$$K_1 = K_s + K_d + K_b$$

Where:

K_1	=	total removal rate of BOD
K_s	=	settling losses
K_d	=	biochemical oxidation
K_b	=	absorption from bottom deposits

K_s is not a significant factor in the Lamprey River because the Epping WWTP discharge has a low total suspended solids concentration of less than 10 mg/l. Further, much of the tributary area to the Lamprey River is undeveloped. Therefore, K_s can be dropped from the general equation.

During low flow conditions, the Lamprey River is quite shallow. Therefore, it was assumed that any BOD samples obtained would reflect the effects of not only the biochemical oxidation but also bottom absorption losses. Thus, the K_b rate is inherently included in the overall K_d rate factor. In this study. K_1 was assumed to be equal to K_d.

As with K_a the values of K_d used in modeling dry weather conditions were obtained from the D-H WLA study (April 1995) and the preliminary limits prepared by NHDES (November 1994). The K_d value used for modeling wet weather conditions within the reach study area is contained in Appendix B.

c. Nitrification Rate Coefficient

The rate at which nitrification (K_n) occurs is an important element in the solution of the DO model. Although, nitrification causes a drain on DO, it does not represent a permanent loss of oxygen. This is because nitrate oxygen is available as "stored dissolved oxygen", a reserve asset that is again available when the DO is depleted.

The values of K_n used in modeling the dry weather conditions were based on the WLA study (April 1995) and the preliminary limits prepared by NHDES (November 1994). The K_n value used for modeling wet weather conditions within the reach study area may also be found in Appendix B.

6. Photosynthesis/Respiration - During photosynthic cell synthesis, algae produce DO, whereas algal respiration consumes DO. Photosynthesis, which is dependent on sun light, occurs only during daylight hours while respiration occurs continuously. Therefore, allowances should be made for these parameters to properly model the river.

   Since DO sampling was conducted in the early morning hours, the photosynthesis rate was assumed to be zero. Respiration rates must be calculated since respiration occurs around the clock. The calculation of the respiration rate for the reach study area is included in Appendix C.

7. Toxicity limits for ammonia and chlorine also need to be determined. This is to ensure that the in-stream concentration, downstream of the Epping WWTP, does not violate the State's Water Quality Standards. Both of theses limits are based on the following equation:

$$\mathbf{D.F. = [(Qr + Qp) / Qr] * .90}$$

Where:

D.F.	=	dilution factor with 90% of assets
Qr	=	river flow
Qp	=	WWTP flow

The critical dilution factor occurs during dry weather conditions when river flows are lowest and the WWTP is assumed to be discharging at 0.54 cfs. The resulting dilution factor is multiplied by State Water Quality Standards for chlorine or ammonia to determine the discharge limit.

In addition to being flow dependent, effluent limits for ammonia are also temperature dependent. Tables IV-2 and IV-3 list the toxicity limits for ammonia and chlorine for both winter (river flow at 7Q10) and summer (river at twice 7Q10).

Table IV-2
Chronic Toxicity Limits - Ammonia (NH_3-N)

WWTP FLOW cfs	RIVER FLOW cfs	TEMP C	Dilution Factor	WQS NH_3-N mg/l	CHRONIC LIMIT mg/l	NBOD (mg/l)
0.54	3 .0	25	5.9	1.01	5.96	27.3
0.54	3.0	10	5.90	2.21	13.04	59.6
0.54	6.0	25	10.90	1.01	11.01	50.3
0.54	6.0	10	10.90	2.21	24.09	110.1

Table IV-3
Chronic and Acute Toxicity Limits - Chlorine

WWTP FLOW cfs	RIVER FLOW cfs	Dilution Factor	WQS Chlorine mg/l	LIMIT mg/l
0.54	6.0	10.9	0.011	0.12 chronic
0.54	6.0	10.90	0.019	0.21 acute
0.54	3.0	5.90	0.011	0.07 chronic
0.54	3.0	5.90	0.019	0.11 acute

9. Table IV-4 is a summary of the model parameters.

Table IV-4
Model Parameters

PARAMETER	SUMMER AVG. FLOW	WINTER (7Q10)	SUMMER (2 x 7Q10)
RIVER FLOW (cfs) at WWTP	51	3.0	6.0
RIVER DO (mg/l)	7.4	10.2	7.4
RIVER CBOD (mg/l)	2.0	2.0	2.0
RIVER NBOD (mg/l)	1.0	1.0	1.0
WWTP FLOW (cfs)	0.54	0.54	0.54
WWTP DO (mg/l)	7.0	7.0	7.0
Ka	5.3	1.0	1.5
Kd	0.6	0.5	1.0
Kn	6.5	0.29	1.0
TEMP ©	25.0	10.0	25.0
VELOCITY (fps)	0.63	0.06	0.12
RESPIRATION	0.035	0.035	0.035

SECTION V

SAMPLING

SAMPLING

The goal was to sample the river at different times during summer conditions, so model parameters as well as background conditions could be established.
The following parameters were sampled:

pH
Temperature
DO (mg/l)
Specific Conductivity
BOD5 (5-day)
Nutrients
Total phosphorus
Chlorophyll "a"
UCBOD (ultimate)

Sampling was to be conducted during wet and dry weather.

a. ***Wet weather*** - Unfortunately, wet weather sampling was not accomplished due the lack of rain this past summer.

b. ***Dry weather*** - Dry weather sampling was conducted over the entire length of the river. The following sampling was completed.

- At 24 locations, DO, pH, Temp and, Specific Conductivity were recorded once a hour for a six hour period (6:00 am to 12:00 pm). This was done to determine the change in the variables over time.
- Ultimate CBOD and Chlorophyll "a" samples were taken within the reach study area. The ultimate CBOD results were used in the calculation of K_d and K_n. The Chlorophyll "a" results were used in the calculation of the respiration rate coefficient.
- Velocity, depth and width measurements were recorded at a location within the reach study area on four different dates to develop a rating curve. This curve was used in calculating the velocity for the different modeling conditions as well as the development of rate coefficients.

SECTION VI

RESULTS/FINDINGS

RESULTS/FINDINGS

1. Areas where DO was sampled included a large wetland area located in the upper reaches of the river. The wetland selected is approximately 2 miles downstream of Meadow Lake, and is in an area of little development. DO readings were taken above (1000 feet), in, and downstream (300 feet) of the wetlands. The results show that wetlands act as a DO sink, with the DO recovering farther downstream. Results from the other 21 locations selected indicated the same trend. River segments immediately downstream of wetlands consistently show low DO readings or violations. Farther downstream the DO recovers. Appendix D contains the results and graphs of the DO sampling effort.

   On the basis of this study, wetland areas serve as natural DO sinks. Accordingly, all DO exceedances in such areas will be attributed to natural causes and will be removed from the 303(d) list.

2. NPS pollution sources - the major source is storm water runoff. No other major sources were found.

3. Wet weather modeling (river flow at summer average flow) was performed to determine the total maximum load in the reach receiving the discharge of the Epping WWTP. The TMDL was determined by running the DO Model until the 75% saturation value (6.2 mg/l) was exceeded. Results of the model output are contained in Appendix E. Based on these results, the TMDL for $CBOD_5$ and NH_3-N are as follows:

Table V I-1
Wet Weather TMDL

$CBOD_5$	**1752 lbs/day**
NH_3-N	**178 lbs/day**

(Max day)

4. Once the wet weather total loads have been determined, dry weather (summer and winter) loads must be determined. The total load is the sum of the background conditions and any point sources (PS). The total loads for both summer and winter conditions are the following:

Table VI-2
Dry Weather TMDL

Parameter	Summer lbs/day	Winter lbs/day
$CBOD_5$	41	55
NH_3-N	14.3	19

(Max day)

The total loadings obtained from the dry weather are more restrictive than the total loading determined from the wet weather condition. **Therefore; Epping WWTP permit limits must be based on dry weather modeling.**

5. The next step is to allocate the total load between the PS and NPS with a margin of safety. The goal of the allocation process is to proportion the allowable pollution load among the various pollution sources such that water quality standards are not violated. The allocation process is a relatively straight forward process, wherein the total load is the sum of the PS, NPS, natural background and a margin of safety. The margin of safety can be either explicit or implicit and accounts for the uncertainty in the relationship between pollutant loads and impairment of the receiving river. In terms of a mathematical expression:

TMDL = WLA + LA + MOS [2]

where:

WLA: Wasteload Allocation - A receiving water loading capacity that is allocated to existing and future point sources (PS) of pollution.

LA: Load Allocation - A receiving waters loading capacity attributed to existing and future non point sources (NPS) of pollution, including a portion attributable to natural background conditions.

MOS: Margin of Safety - A LA attributable to uncertainty of pollutional loads, assumptions used in modeling, and uncertainty in receiving water quality data. In this TMDL a MOS of 10% was used.

Results of the allocation process are shown in table VI-3.

Table VI-3
Allocation Results

Parameter	Point Source (lb/day)	Non-point Source (lb/day)	MOS * (lb/day)
$CBOD_5$	60	1517	175
NH_3-N	25	135	18

* MOS = Margin of Safety

METALS

Zinc, aluminum, lead and copper exceedances were listed on DES's 303 (d) list. However, further sampling during this study revealed no water quality exceedances for aluminum and lead.

To address the remaining zinc and copper exceedances, DES will conduct additional testing using "clean techniques" to determine the source of these metals, and to determine if the source is natural or not. Preliminary testing to date has indicated some apparent high metal observations in rainwater. These findings need to be verified, along with possible contributions from wetlands.

SECTION VII

PERMIT LIMITS

PERMIT LIMITS

The existing National Pollutant Discharge Elimination System (NPDES) permit limits for BOD and TSS, which was last issued in 1985, are shown in table VII-1. The WWTP flow used in determining these limits was 0.27 MGD.

Table VII-1
Existing Permit Limits
WWTP Flow = 0.27 MGD

Parameter	Average Monthly		Average Weekly		Average Daily	
	mg/l	lbs/day	mg/l	lbs/day	mg/l	lbs/day
BOD	30	68	45	101	50	113
TSS	30	68	45	101	50	113

The results of the dry weather TMDL modeling were used to determine effluent limits for the Epping WWTP. The following table show the proposed WWTP limits based on the modeling efforts of this report.

Table VII-2
Epping's Proposed Discharge limits
WWTP Flow = 0.35 MGD

Parameter	Concentration (mg/l)			Mass Limits (lbs/day)		
	Avg month	Avg week	Max day	Avg month	Avg week	Max day
DO	No less	than	7.0			
$CBOD_5$	11	13	14	32	37	41
NH_3-N	3.7		4.9	10.8		14.3
Total - P			0.75			2.2
Chlorine	0.12		0.21			
Flow Limitations	**Summer (June 1 through October 31) with the river flow at 2 x times 7Q10 (6 cfs) at WWTP. No discharge when river flow is less than 6 cfs at WWTP.**					

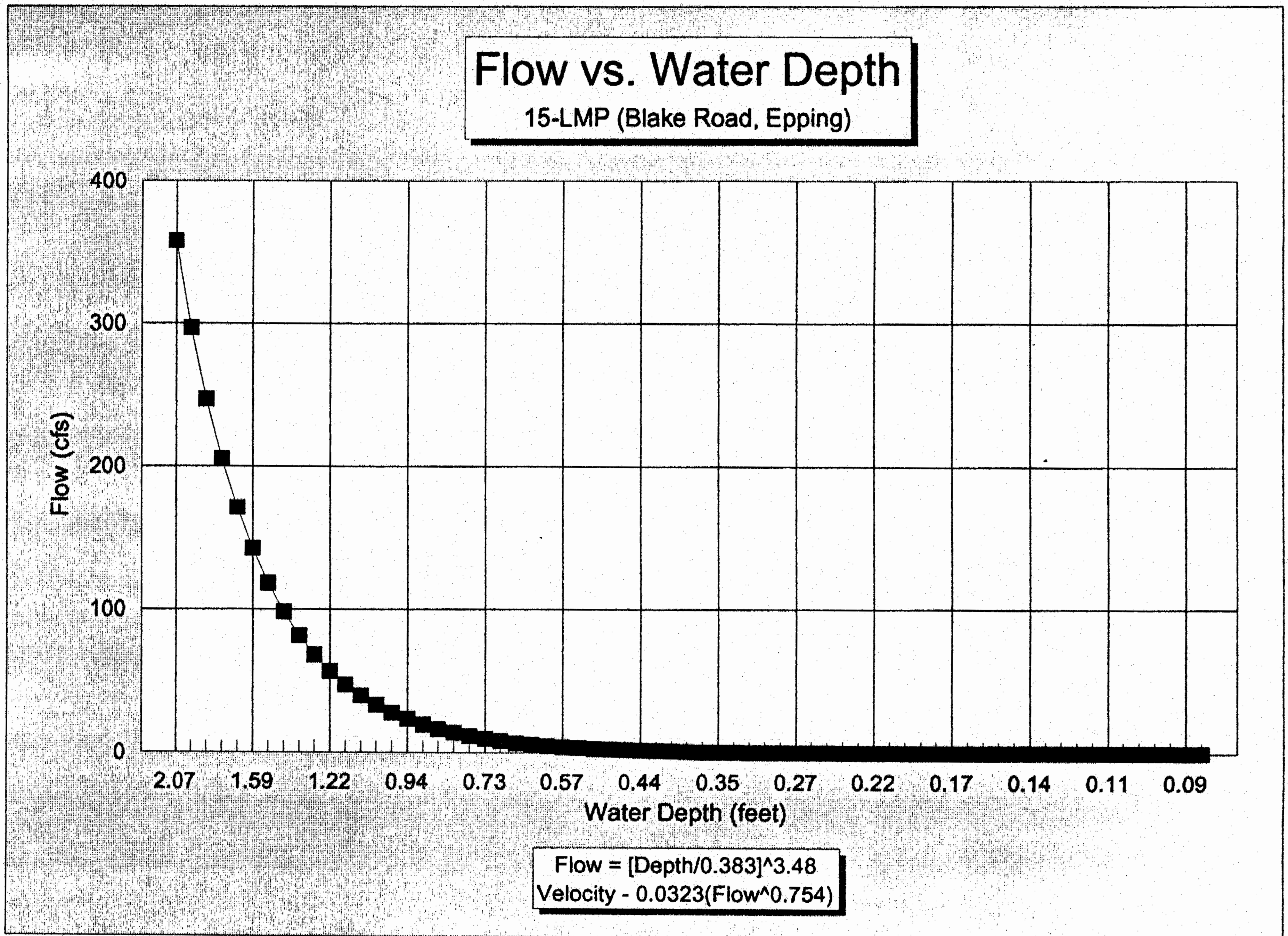
Parameter	Concentration (mg/l)			Mass Limits (lbs/day)		
	Avg month	Avg week	Max day	Avg month	Avg week	Max day
DO	No less	than.	7.0			
$CBOD_5$	16	17	19	47	49	55
NH_3-N	5.2		6.5	15		19
Total - P			0.75			2.2
Chlorine	0.06		0.11			
Flow Limitations	**Winter (November 1 through May 31) with river flow at 7Q10 (cfs).**					

Footnotes:

1. The above limits only address $CBOD_5$, NH_3-N, Total P, Chlorine and DO in the WWTP effluent. The final permit will also include limits for other required parameters.

2. It should be noted that Epping existing NPDES permit was based on 0.27 MGD, while the proposed discharge limits were developed for 0.35 MGD. Further, the existing permit includes a limit for BOD_5, while the proposed limits are for $CBOD_5$. For a basis of comparison about 30 mg/l of BOD_5 is equivalent to 25 mg/l of $CBOD_5$.

APPENDIX A
RATING CURVE


Flow vs. Water Depth
15-LMP (Blake Road, Epping)
Flow (cfs)
400
300
200
100
0
2.07
1.59
1.22
0.94
0.73
0.57
0.44
0.35
0.27
0.22
0.17
0.14
0.11
0.09
Water Depth (feet)
Flow = [Depth/0.383]^3.48
Velocity - 0.0323(Flow^0.754)

APPENDIX B
RATE COEFFICIENTS

REAERATION COEFFICIENT - K_a

The calculated K_a value was based on actual measurements (flow, depth and cross sectional width) of the river. O'Connor-Dobbins (1958), Churchill et al. (1962) and Owens et al. (1964) developed equations using depth and velocity which are contained in EPA/600/3-85/040 "Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (second edition)". Each one of the above equations apply for a specific range of velocity and depth. The Covar chart (figure B-1) is used to estimate a K_a values.

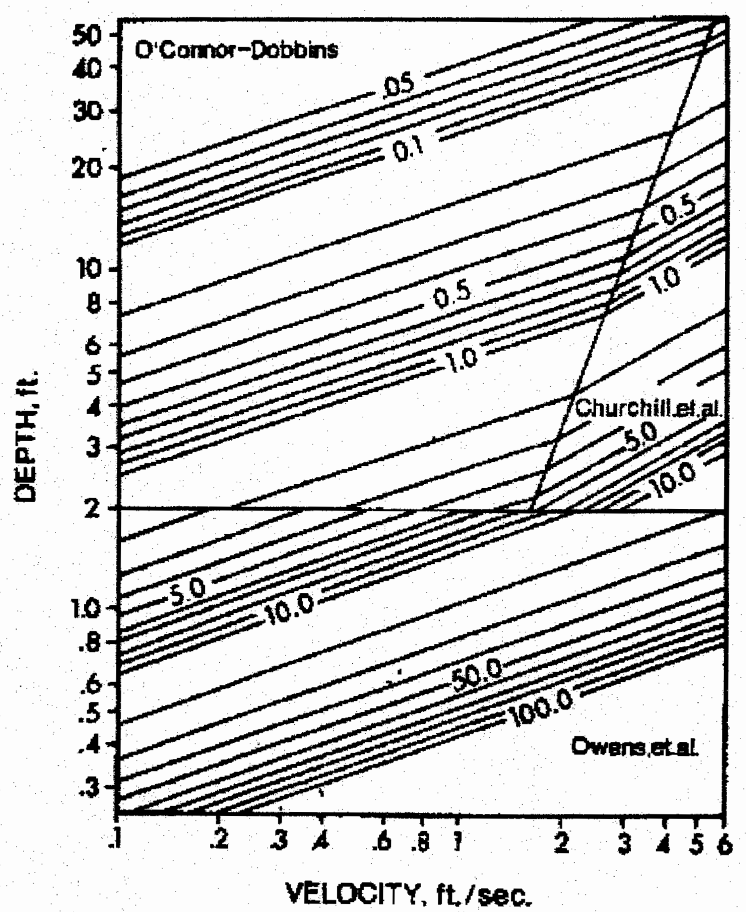


Figure B-1
Reaeration coefficient (1/day) vs. Depth and velocity using suggested method of Covar (1976)

The river flow at the Epping WWTP based on the summer average flow at Packer Falls Gage (89 cfs) was calculated to be 51 cfs. Using the rating curve, the calculated velocity and depth upstream of the Epping WWTP are 0.63 fps and 1.18 feet respectively. From the Covar chart, the equations developed by Owens et al. (1964) was used to calculate the K_a value. Owens et al developed two equations based on ranges of velocity and depth. The equation selected is based on a velocity range of 0.1 to 1.8 fps and a depth range of 0.4 to 11 feet, and is the following:

$$\mathbf{K_a = \frac{23.3\,U^{0.73}}{H^{1.75}}}$$

Where: **U = velocity (fps)**
H = depth (feet)

Therefore the calculated K_a value is 5.3.

DEOXYGENATION and NITRIFICATION COEFFICIENTS - K_d and K_n

In order to calculate the K_d and K_n coefficients NHDES sampled within the reach study area at four locations for the following parameters:

- ultimate carbonaceous biochemical oxygen demand (UCBOD)
- nitrogenous biochemical oxygen demand (NBOD)
- average velocity between sampling points
- temperature

The sampling locations are listed below:

1. 15-LMP (Blake Rd. Epping)
2. 14-LMP (Main St. Epping)
3. 13-LMP (Rte. 125, Epping)
4. 12-LMP (Rte. 87, Epping)

The total BOD is composed of two components, a carbonaceous (UCBOD) and nitrogenous oxygen demand (NBOD). The methodology used to determine the UCBOD and NBOD was to perform a 20 day BOD test and measure an initial and final nitrogen series (TKN, NH_3 and NO_3). The amount of nitrification that occurred is then convert to NBOD. This was then subtracted from the total BOD to determine the UCBOD.

The equations used to calculate K_d and K_n are shown below.

$$K_d \text{ (1/day, base e)} = \{\ln (UCBOD2/UCBOD1)\}/t$$

$$K_n \text{(1/day, base e)} = \{\ln(NBOD2/NBOD1)\}/t$$

where:

UCBOD1: UCBOD at upstream location
UCBOD2: UCBOD at downstream location
NBOD1: NBOD at upstream location
NBOD2: NBOD at downstream location
t: travel time in days between upstream and downstream location

Table B-1 shows the sampling results at the preceding locations. The velocity was determined for the summer average flow using the rating curve.

Table B-1

Station	NBOD (mg/l)	UCBOD (mg/l)	Velocity (fps)	Temperature ©
15-LMP	1.12	.088	0.63	20.8
14-LMP	1.19	0.46	0.63	20.8
13-LMP	0.27	1.33	0.63	20.8
12-LMP	1.51	1.14	0.63	20.8

The upstream station for the calculation K_d was 13-LMP and the downstream station was 12-LMP. Likewise, for the calculation of K_n the upstream station used was 15-LMP and the downstream station was 13-LMP.

K_d calculation:

UCBOD1	=	1.33 mg/l
UCBOD2	=	1.14 mg/l
Distance between stations	=	3.15 miles
Travel time in days	=	0.31 days
K_d at 20.8 deg C	=	0.5

Temperature correction for 25 deg C is accomplished by using the following equation:

$$K_{25} = K_{20.8} \times 1.047^{(25-20.8)}$$

Therefore K_d at 25 deg C equals ... 0.63

K_n calculation:

NBOD1	=	1.12 mg/l
NBOD2	=	0.27 mg/l
Distance between stations	=	3.37 miles
Travel time in days	=	0.33 days
K_n at 20.8 deg C	=	4.31

Temperature correction for 25 deg C is accomplished by using the following equation:

$$K_{25} = K_{20.8} \times 1.085^{(25-20.8)}$$

Therefore K_n at 25 deg C equals ... 6.5

APPENDIX C
PHOTOSYNTHESIS/RESPIRATION

PHOTOSYNTHESIS/RESPIRATION

Photosynthesis, which is dependent on sun light, occurs during daylight hours while respirations occurs continuously. Since most sampling efforts were conducted in the early morning hours, the photosynthesis rate was assumed to be zero. NHDES sampled for chlorophyll "a" at the same time sampling for the ultimate BOD. The following equation was used to derive the respiration rates (R) for the reach study area (see table C-1).

$$\mathbf{R = a_o\ D_p\ A}$$

where:

$a_o = 0.133$ mg O_2/ug Chlor a

D_p is the rate of algae as determined by the following relationship:

$$D_p = 0.1\ (1.08)^{T-20} = 0.1(1.08)^{25-20} = 0.147$$

A = chlorophyll "a" measurement

Table C-1
Respiration Rate

Station	A (ug/l)	a_o mg O_2/ug Chlor a	D_p day-1	R mg O^2/l-day
15-LMP	1.42	0.133	0.147	0.028
14-LMP	2.16	0.133	0.147	0.042
13-LMP	1.8	0.133	0.147	0.035
12-LMP	2.87	0.133	0.147	0.056

The value of **0.035** was used in the model. As station 13-LMP is less than a half mile upstream of the Epping WWTP.

APPENDIX D
WETLANDS

INTRODUCTION

On August 1st and 2nd 1995, NHDES personnel conducted DO measurements from 6:00 am to 12:00 pm on the Lamprey River. The River flow was calculated to be approximately 15 cfs at Pager Falls Gage (reach 30). Eighteen (18) locations along the main stem of the river (with one being a large wetland area), eight (8) of the major tributaries and two (2) other tributaries were sampled. Graphs were created showing the change in DO over the six hour period.

WETLANDS

Initially, it was thought that the wetlands might be contributing to some of the DO violations. In an attempt to prove or disprove this theory, DO measurements were taken above (1000'), in and below (300') a large area of wetlands. The wetland area chosen (reach #2) is in the upper reaches of the river in undeveloped area. Graph 1-1 shows the results of sampling over the six hour period. A consistent trend that can be seen is the DO starting out above 75% saturation and dropping below 75% as the river travels through the wetlands. The DO starts to recover once the river leaves the wetlands. In the wetlands the % DO saturation is fairly constant at about 40%. Accordingly, virgin wetland areas appear to be a natural DO sink. Thus, the DO violations in areas similar to this area have been classified as natural.

LAMPREY RIVER - MAIN STEM

Sixteen (16) locations were selected along the main stem of the river so that the entire river could be monitored for percent saturation of DO. The locations extend from the upper reaches (C29-LMP reach #2) to upstream of the tidal dam (5-LMP reach #32). Graphs 2-1, 2-2 and 2-3 show the results of the six hour period along the main stem.

Graph 2-1 covers reaches 2 through 14.

- C29-LMP is downstream of a large area of wetlands (same wetlands as above) and the low DO is due to the wetlands upstream.
- 26-LMP is downstream of Freeses' Pond Dam; however, there was little or no water flowing over the dam on the days of sampling..
- There is a pronounced decreased in DO at 22-LMP, which is located upstream of the confluence with North Branch River. Upstream of 22-LMP there is an area of wetlands. It is fairly rural in this area, so the decrease in % saturation of DO is attributable to the wetlands.
- The DO recovers at 21-LMP, Raymond Town line, to 75% or better.
- The DO drops again at 19-LMP, located downstream of Raymond. There are some wetland areas scattered between 21-LMP and 19-LMP. Accordingly, we believe that the cause of the DO violations is due to the wetlands.

Graph 2-2 covers reaches 14 through 24.

- 17-LMP is downstream of Dead Pond. The river is slow moving throughout this area with an area of wetlands upstream of Dead Pond. Cause of the DO violation is a result of wetlands, low velocities and impounded water (Dead Pond).
- 15-LMP, Blake Road Epping, is downstream of Bunker Pond Dam. The water is relatively fast moving and there are no wetland areas in this reach. The cause for the low DO value at 6:00 am is not known. Subsequent DO sampling have not shown early morning DO violations.
- The Epping WWTP is located between stations 14-LMP and 12-LMP. The river does not flow through any wetland areas, so DO violation are due to Epping WWTP.
- Station 11a-LMP is upstream of Wadley Falls Dam. The DO violations are due to the impounded water at the dam.

Graph 2-3 cover reaches 24 through 32.

- The remaining stations (11, 9, 8, 7 & 5) show no DO violations.

MAIN TRIBUTARIES

The following tributaries were sampled and results are shown in graphs 3-1 through 3-8. A brief discussion of each tributary and the possible causes of the low DO is included.

Nichols Brook 3-1
Hartford Brook..................... 3-2
North Branch River 3-3
Dudley Brook 3-4
Tributary from
Onway Lake 3-5
UNN Tributary upstream
Pawtuckaway River 3-6
North River 3-7
Little River 3-8

- Both Nichols Brook and Hartford Brook (graphs 3-1 & 3-2) flow through wetland areas or have wetlands draining into them which would result in low DO values.
- Three sampling locations were selected on the North Branch River (see graph 3-3). 3-Nbr is downstream from a wetland area, and as expected the DO is low and recovers at 2-Nbr and 1-Nbr. DO violation at 3-Nbr are due to the wetlands.
- Dudley Brook (graph 3-4) flows through several wetland areas, which are

causing low DO's.

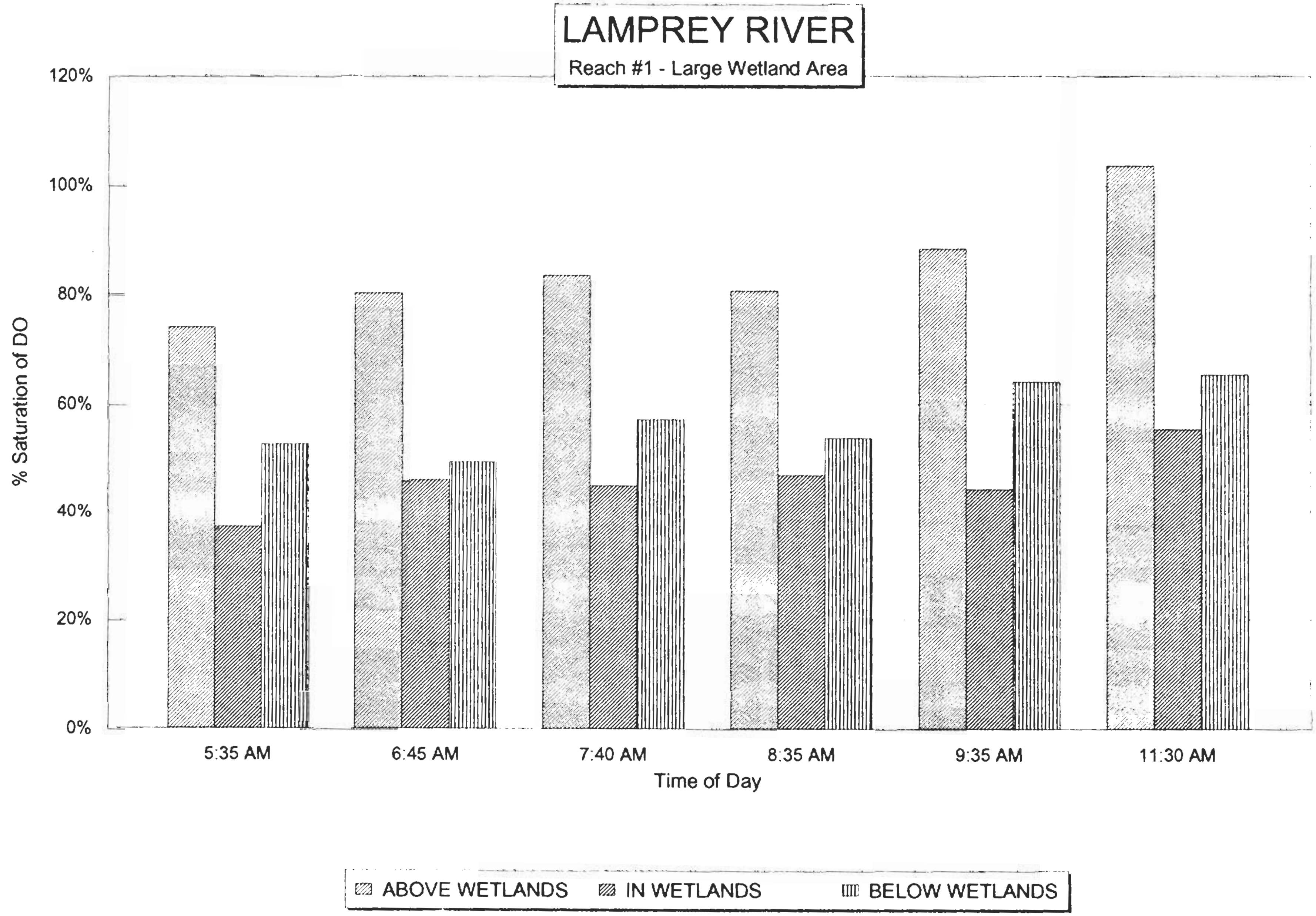
- The tributary from Onway Lake (graph 3-5) and the UNN tributary (graph 3-6) are both upstream of the Pawtuckaway River. Both of theses tributaries are influenced by wetlands and result in low DO's.
- Two locations were selected on the North River (graph 3-7) 1-Nor and 2-Nor. With the exception of the 6:38 am reading at 2-Nor the DO was found to be above 75% saturation.
- The last tributary is the Little River (graph 3-8) and two sampling locations were selected 2a-Ltr and 1a-Ltr. 2a-Ltr is downstream from wetlands, which caused the low DO. The DO recovered to 75% or greater at 1a-Ltr.

OTHER TRIBUTARIES

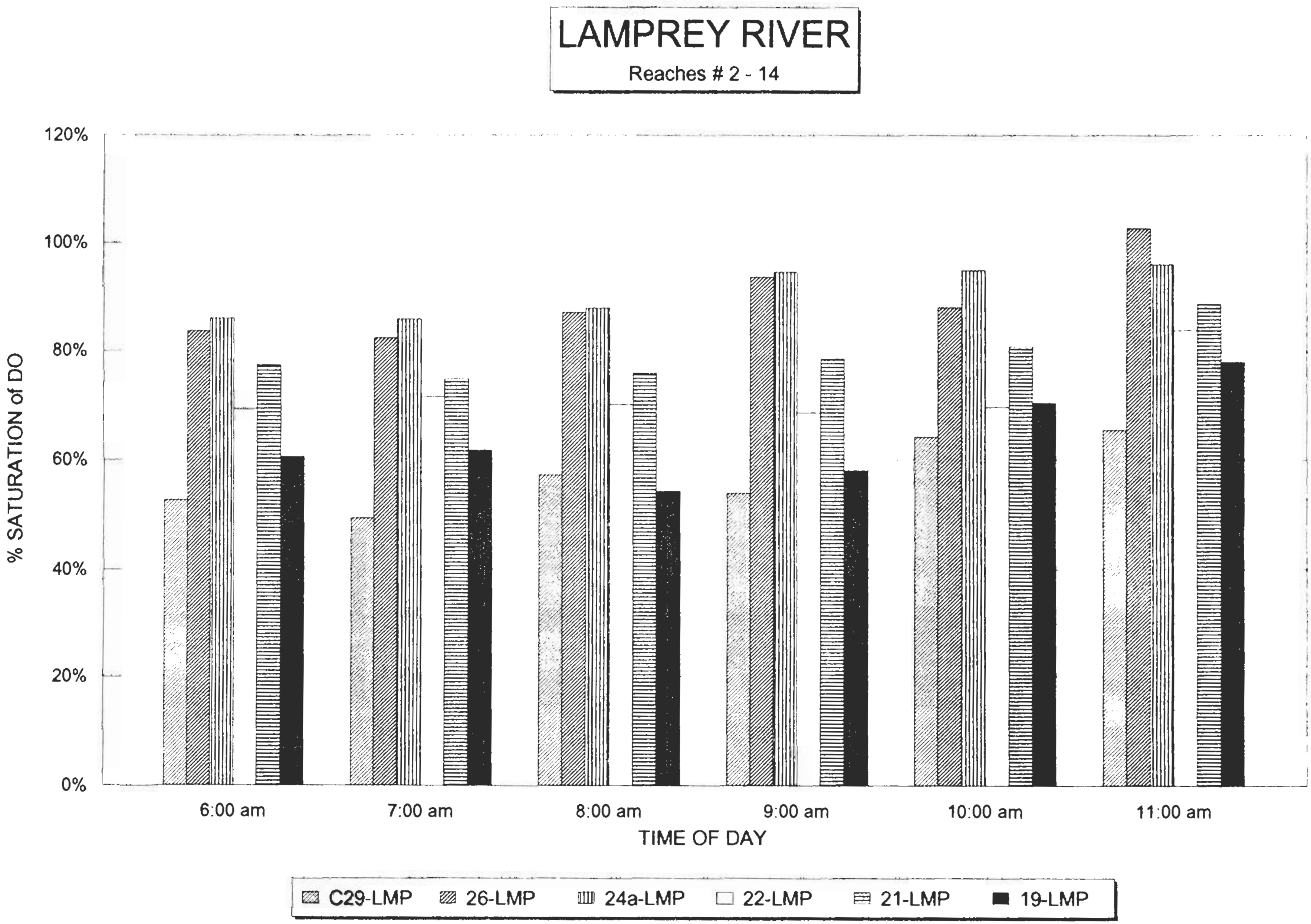
The two other tributaries selected to be sampled were the Bean River (graph 4-1) and Pea Porridge Brook (graph 4-2). The Bean River flows into the North River and Pea Porridge Brook flows into the Little River. Both of these tributaries flow through wetland areas, which caused the low DOs.

CONCLUSIONS

Based on our findings, the impacts of the wetlands on the DO is very apparent. DO exceedances in relatively undeveloped wetland areas have been attributable to natural causes. Accordingly, these areas will be taken off the State's 305 (b) and 303 (d) lists.


LAMPREY RIVER
Reach #1 - Large Wetland Area
120%
100%
80%
60%
40%
20%
0%
% Saturation of DO
5:35 AM
6:45 AM
7:40 AM
8:35 AM
9:35 AM
11:30 AM
Time of Day
ABOVE WETLANDS
IN WETLANDS
BELOW WETLANDS

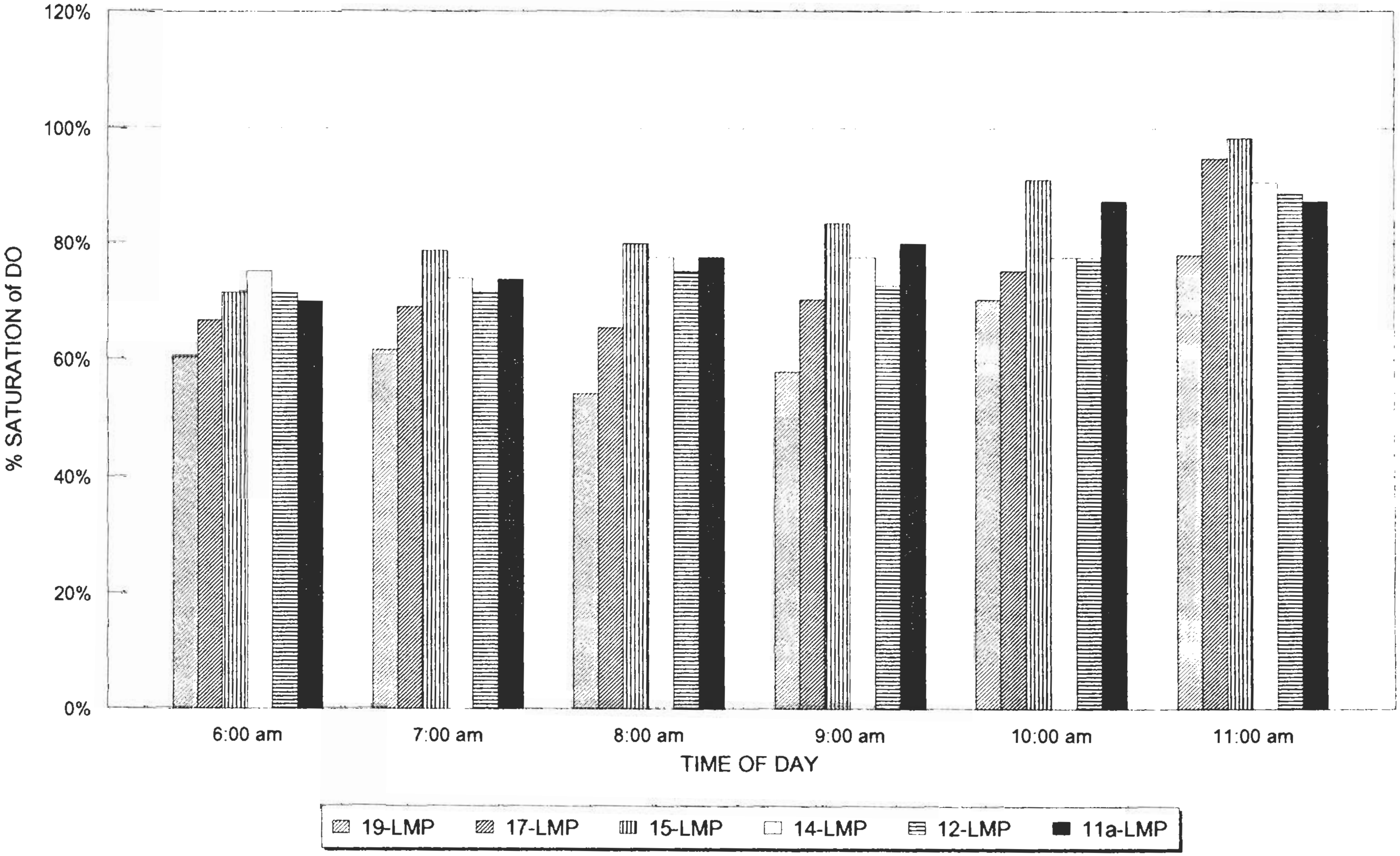
GRAPH 1-1


LAMPREY RIVER
Reaches # 2 - 14
120%
100%
80%
60%
40%
20%
0%
% SATURATION of DO
6:00 am
7:00 am
8:00 am
9:00 am
10:00 am
11:00 am
TIME OF DAY
C29-LMP
26-LMP
24a-LMP
22-LMP
21-LMP
19-LMP

GRAPH 2-1

LAMPREY RIVER

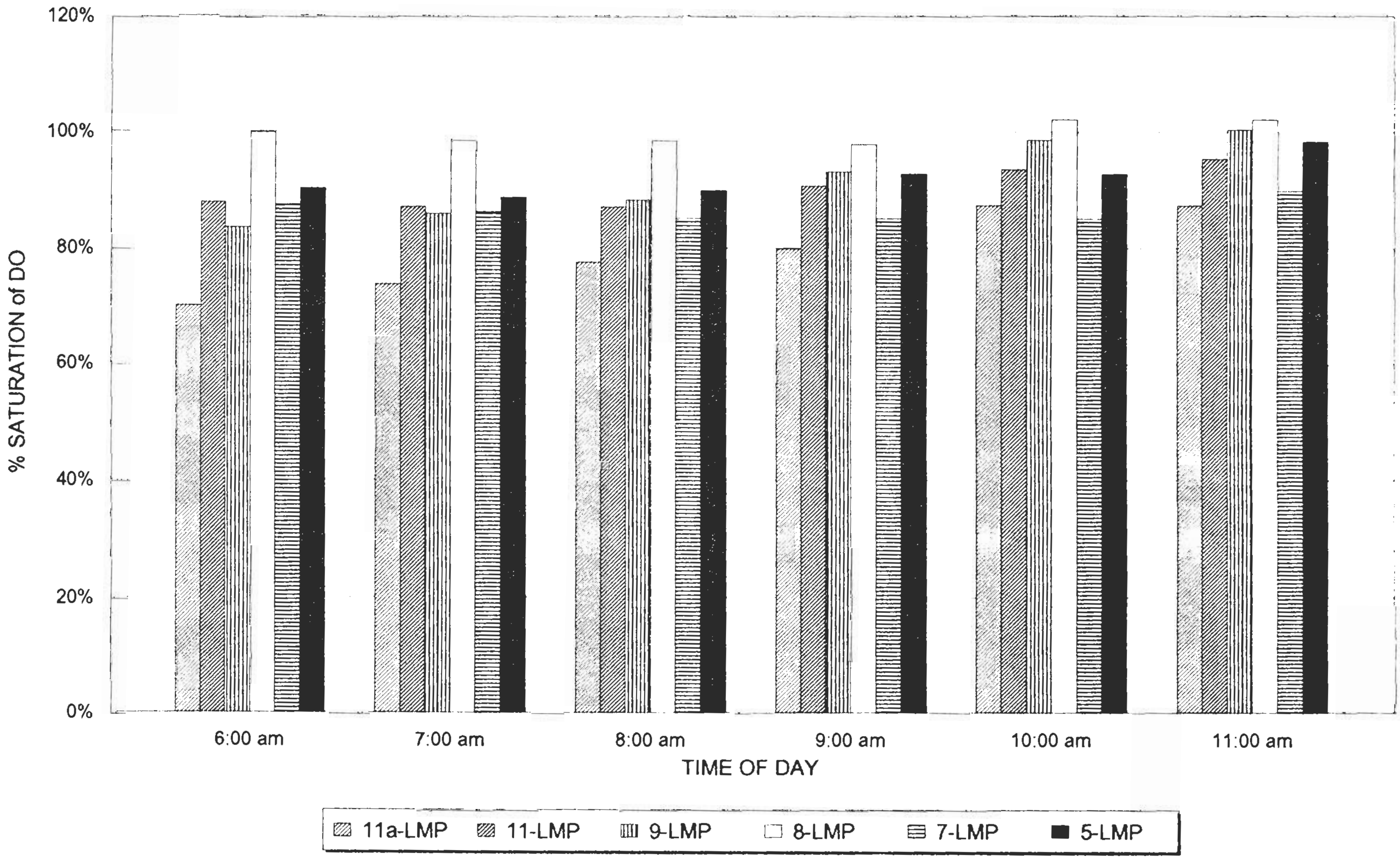
Reaches # 14 - 24



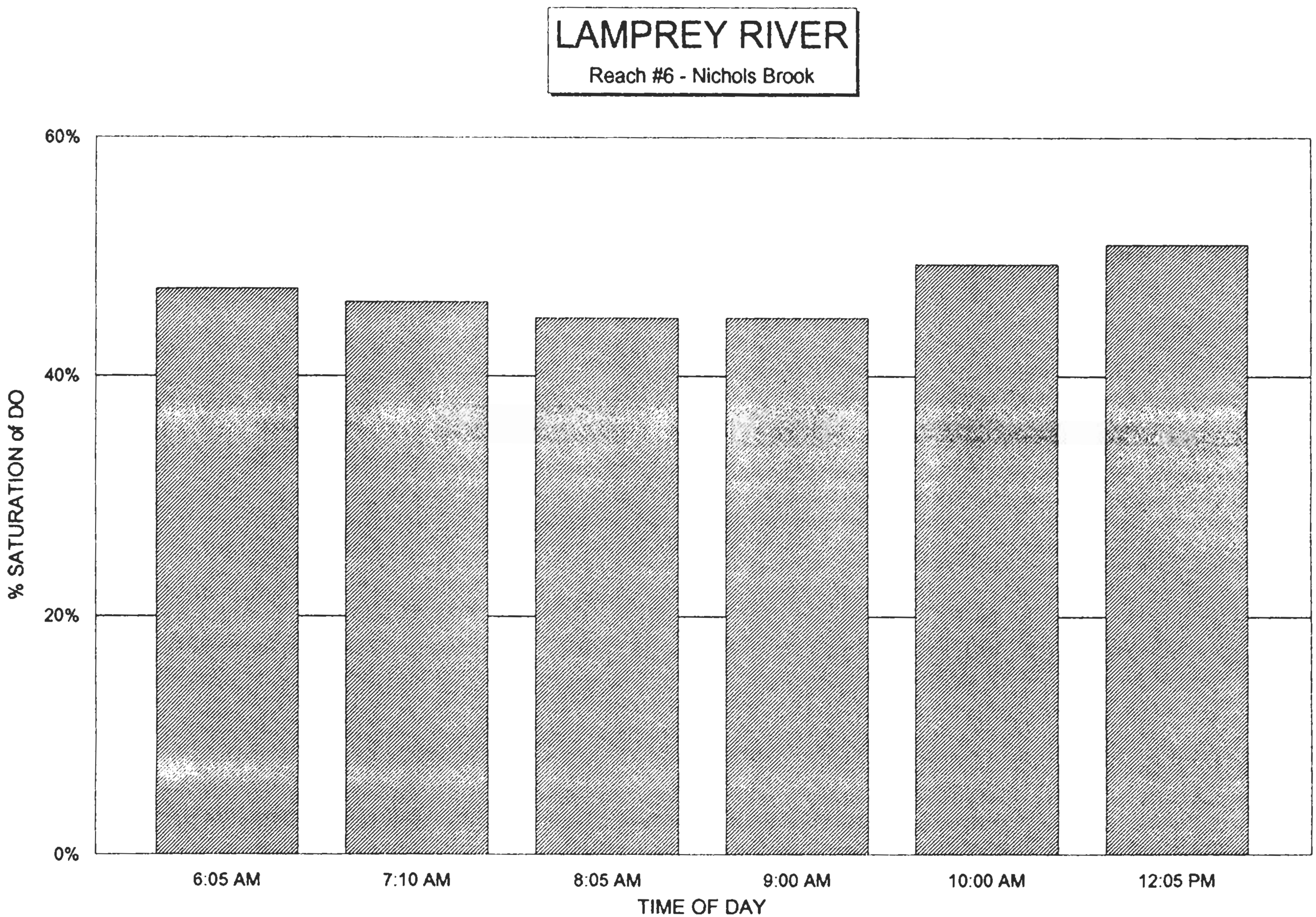
GRAPH 2-2

LAMPREY RIVER

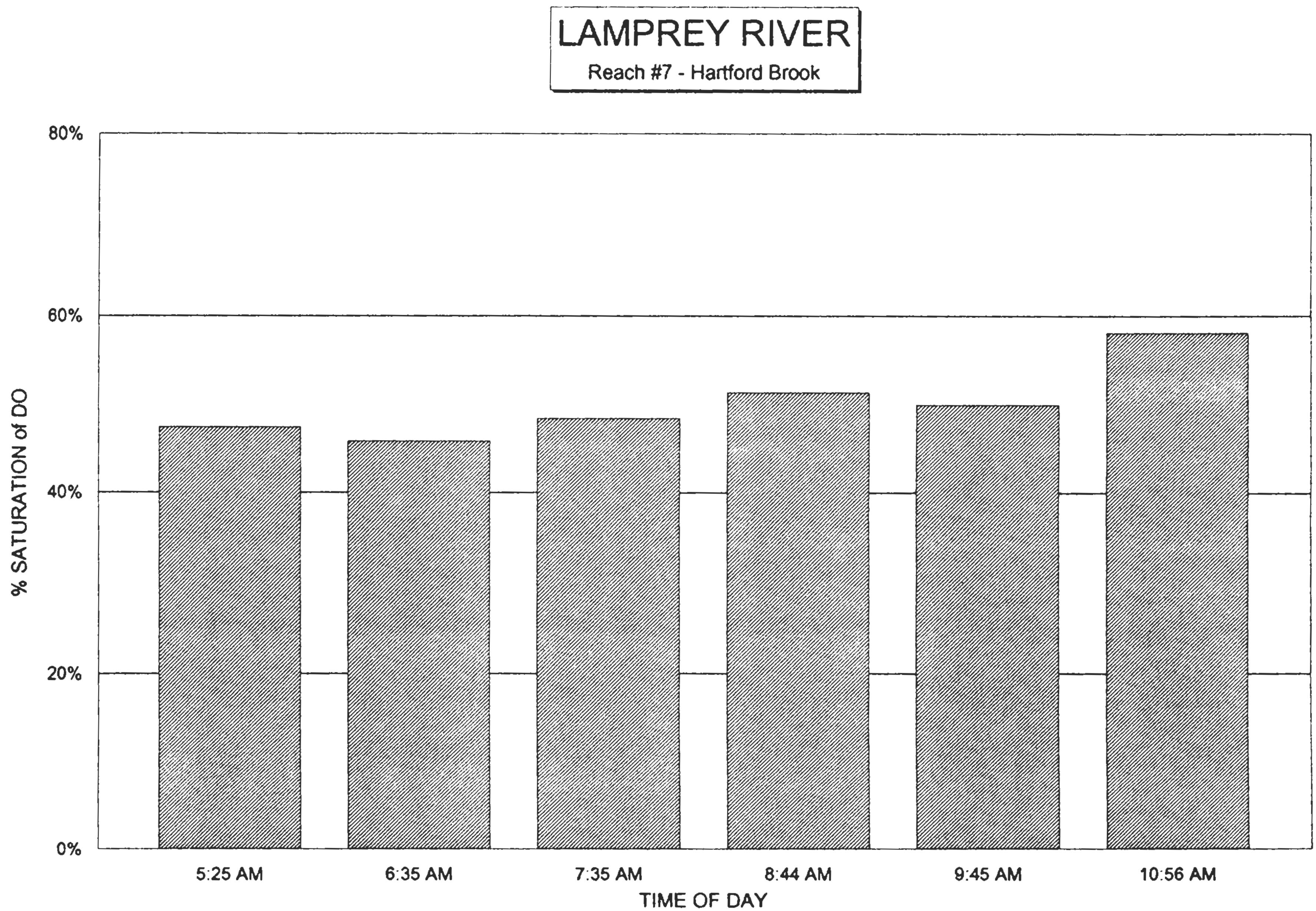
Reaches # 24 - 32



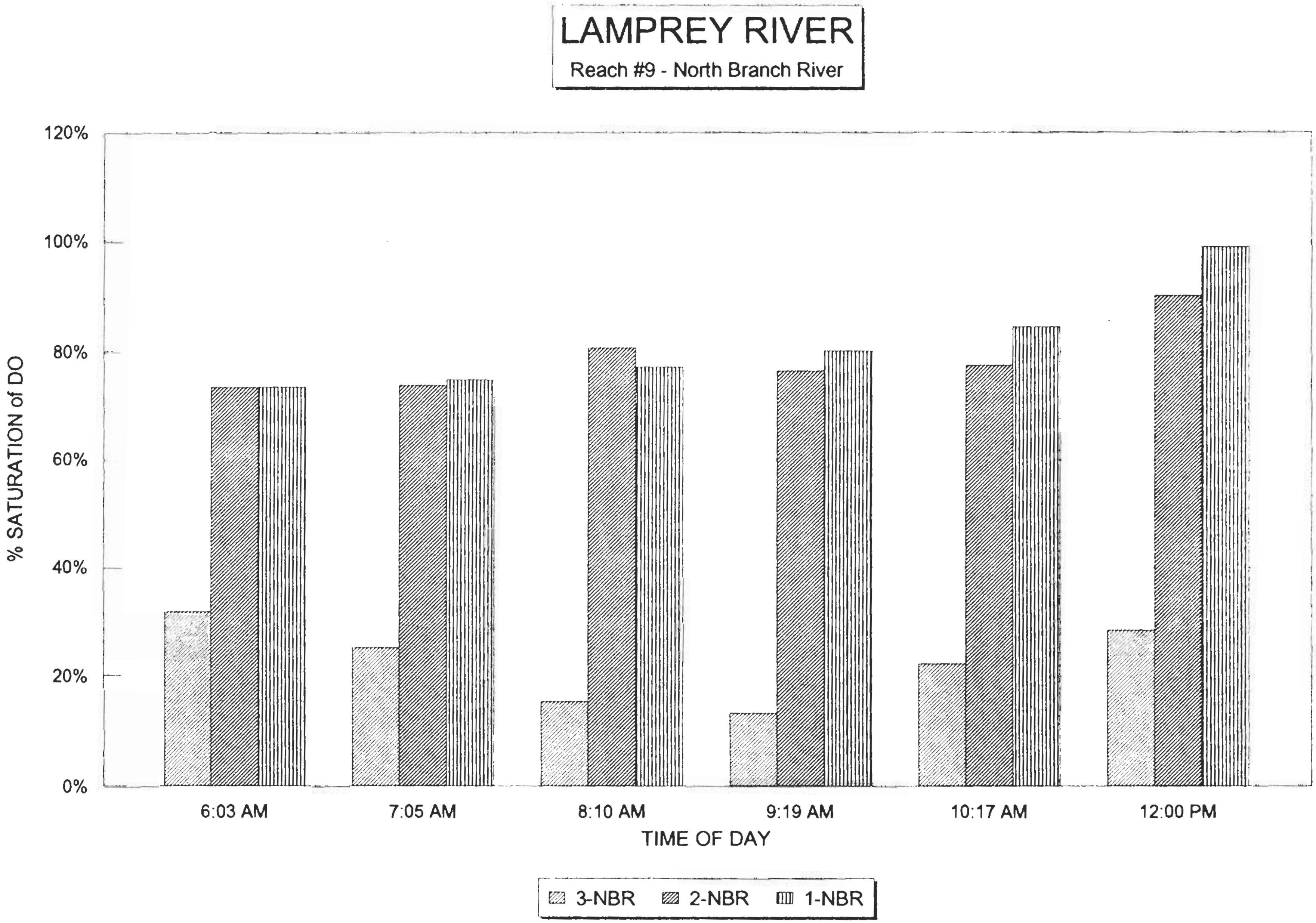
GRAPH 2-3


LAMPREY RIVER
Reach #6 - Nichols Brook
60%
40%
20%
0%
% SATURATION of DO
6:05 AM
7:10 AM
8:05 AM
9:00 AM
10:00 AM
12:05 PM
TIME OF DAY

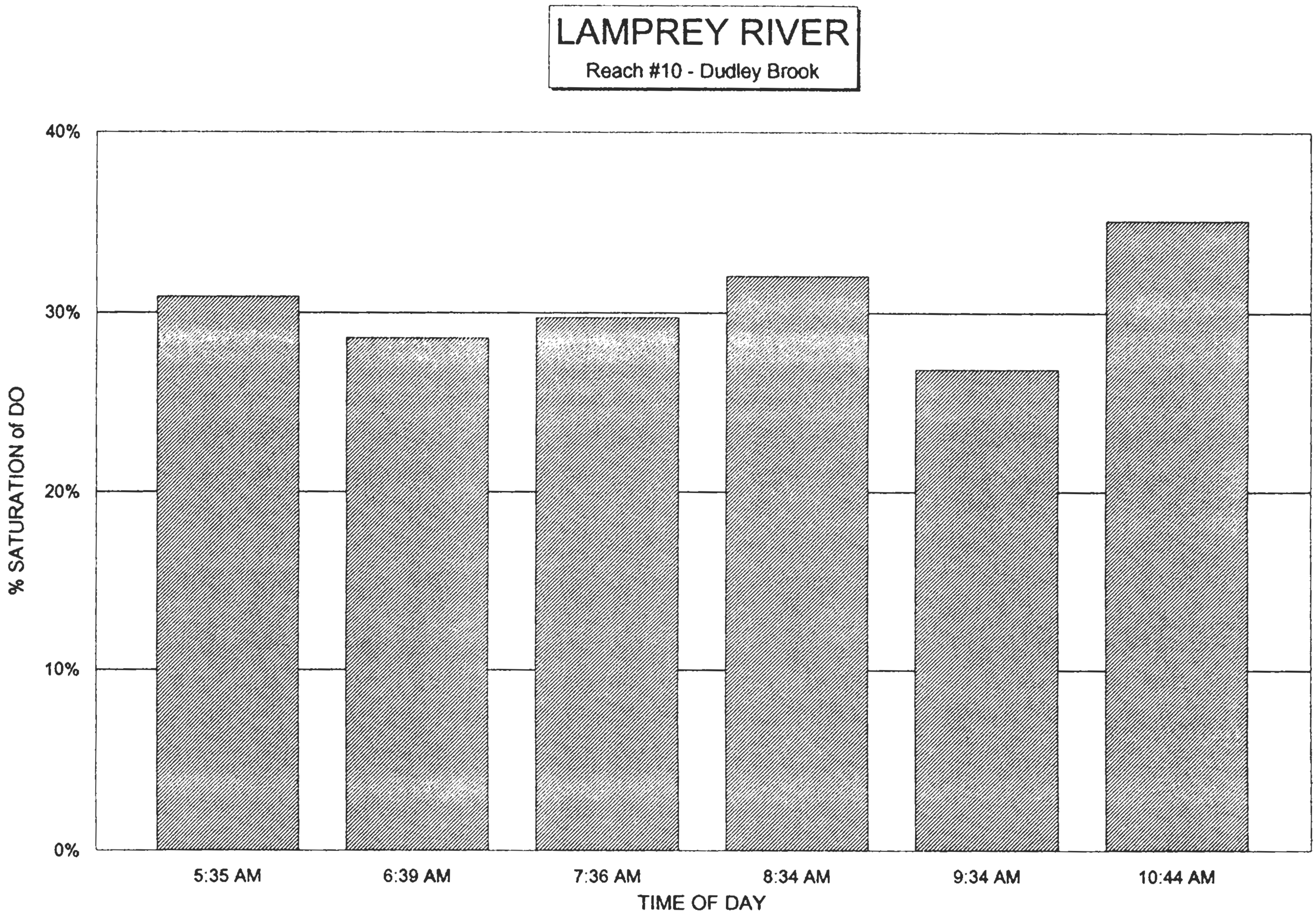
GRAPH 3-1


LAMPREY RIVER
Reach #7 - Hartford Brook
80%
60%
40%
20%
0%
% SATURATION of DO
5:25 AM
6:35 AM
7:35 AM
8:44 AM
9:45 AM
10:56 AM
TIME OF DAY

Graph 3-2


LAMPREY RIVER
Reach #9 - North Branch River
120%
100%
80%
60%
40%
20%
0%
% SATURATION of DO
6:03 AM
7:05 AM
8:10 AM
9:19 AM
10:17 AM
12:00 PM
TIME OF DAY
3-NBR
2-NBR
1-NBR

GRAPH 3-3

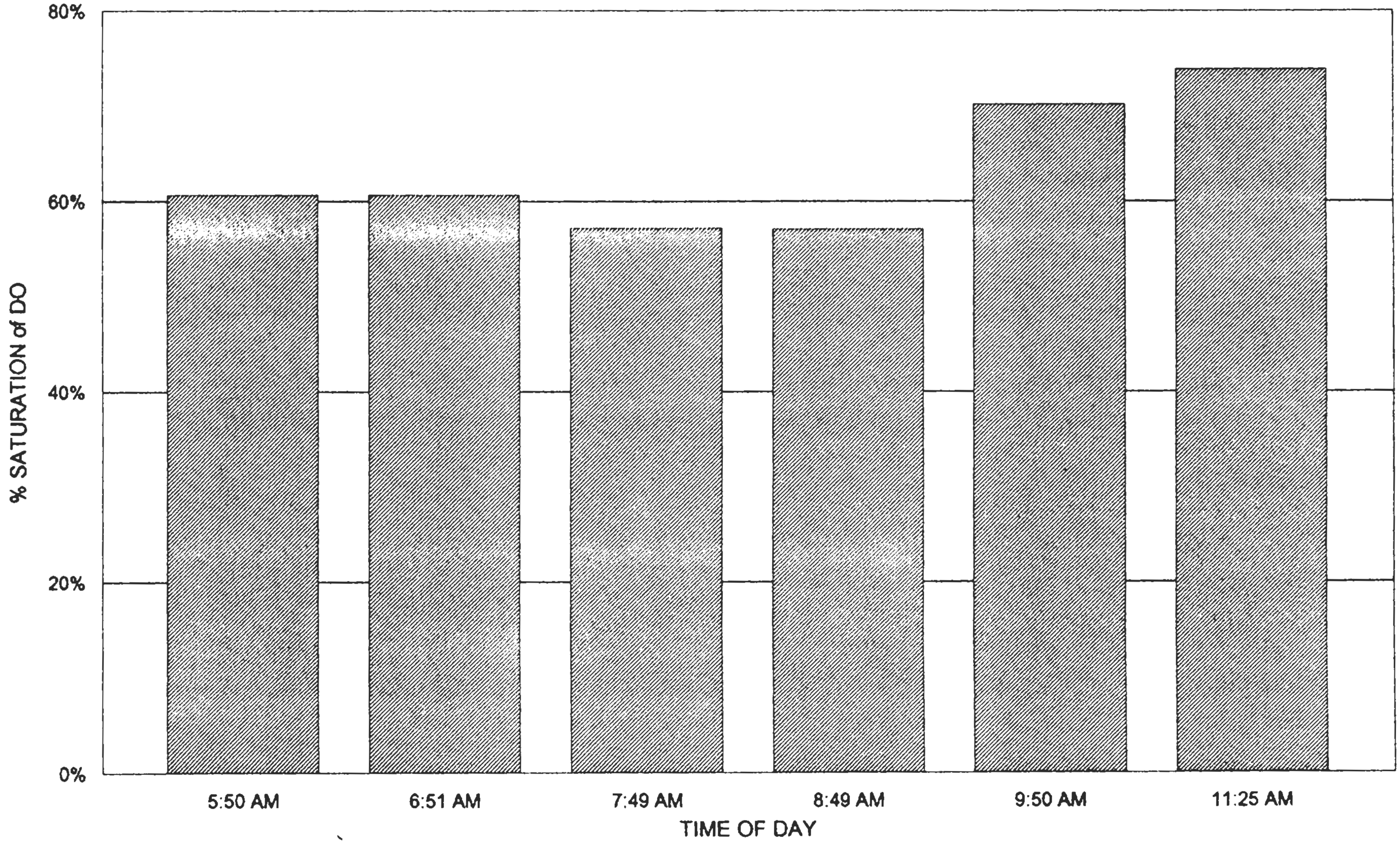


LAMPREY RIVER
Reach #10 - Dudley Brook
40%
30%
20%
10%
0%
% SATURATION of DO
5:35 AM
6:39 AM
7:36 AM
8:34 AM
9:34 AM
10:44 AM
TIME OF DAY

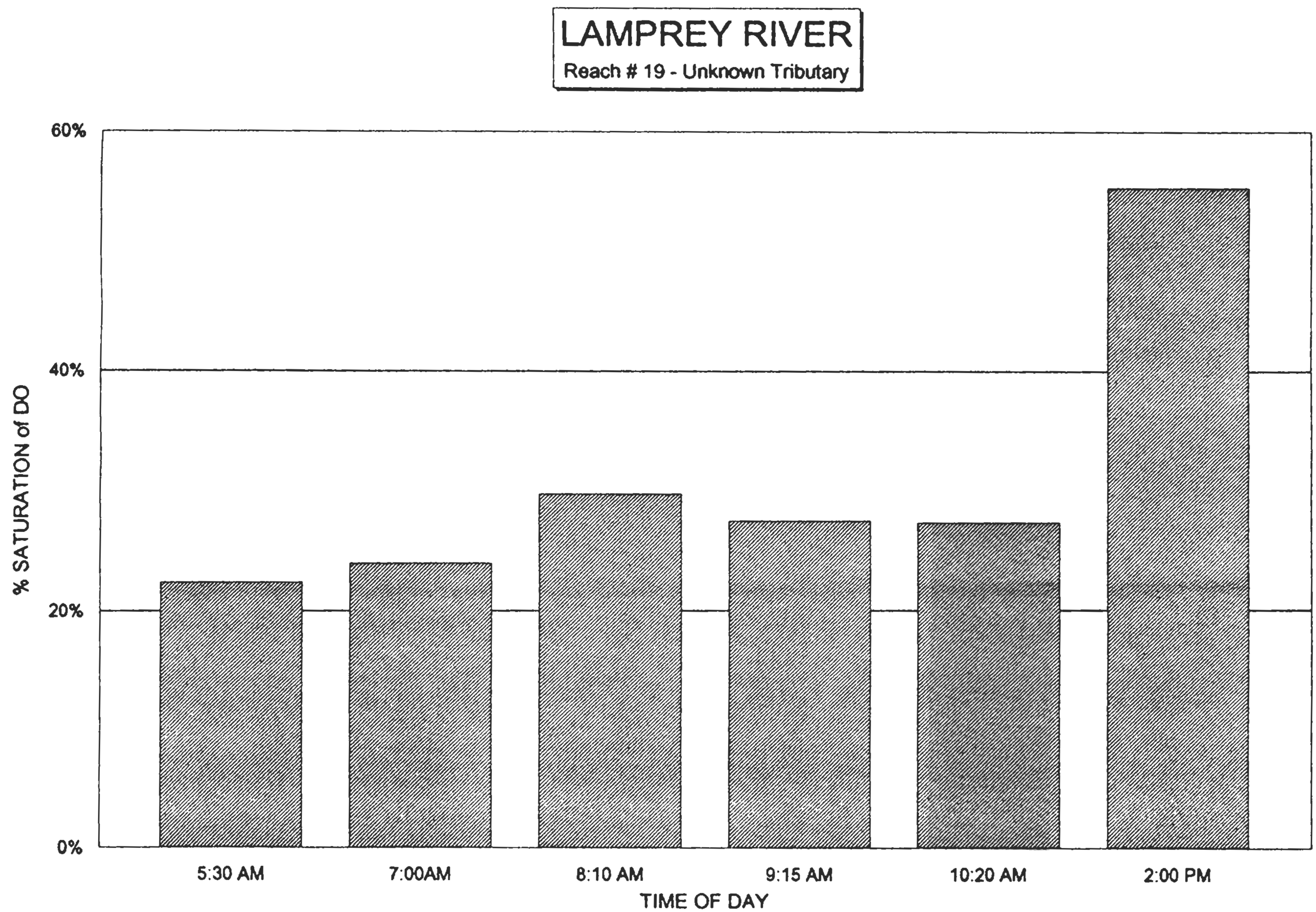
Graph 3-4

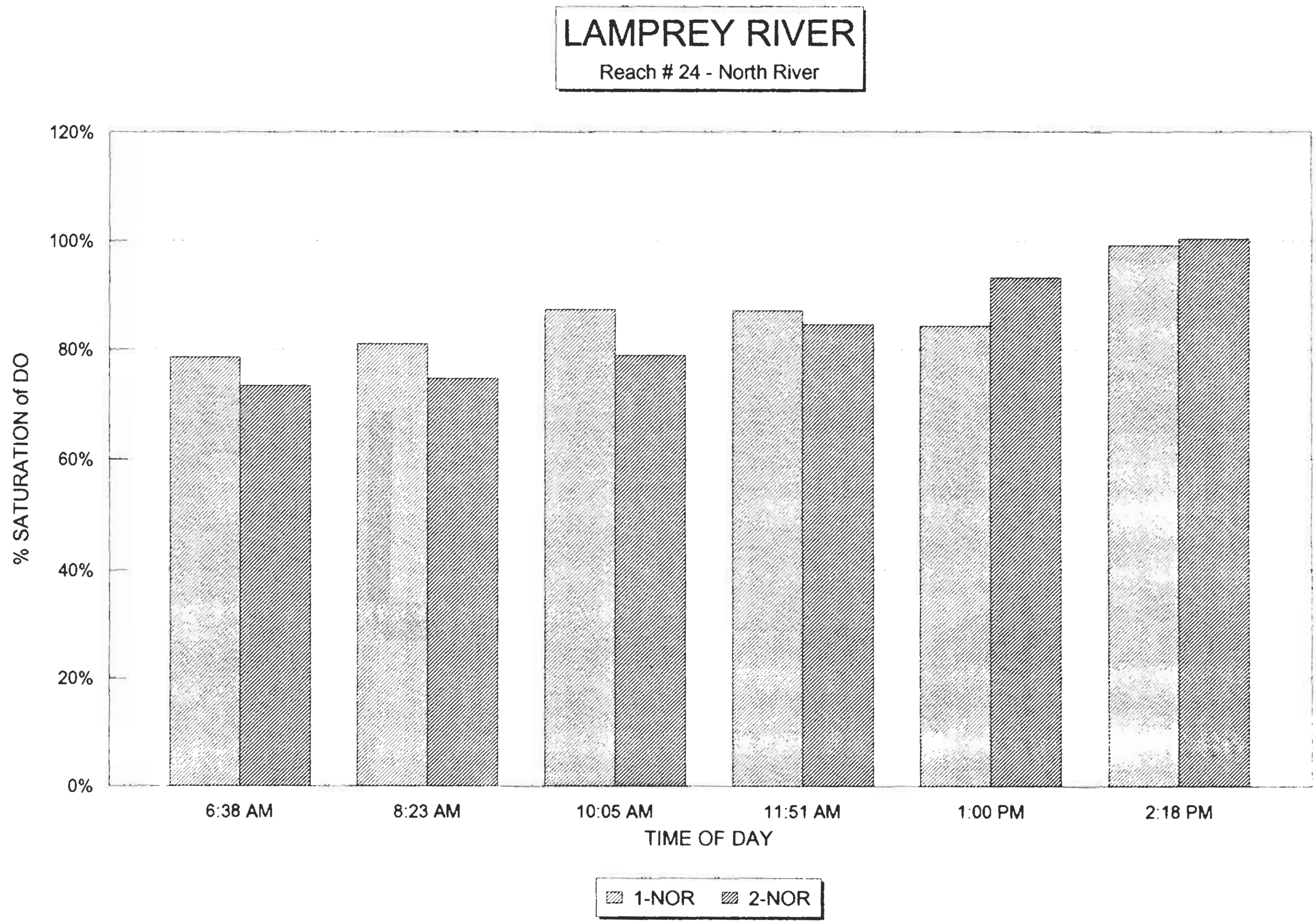
LAMPREY RIVER

Reach #13 - Onway Tributary

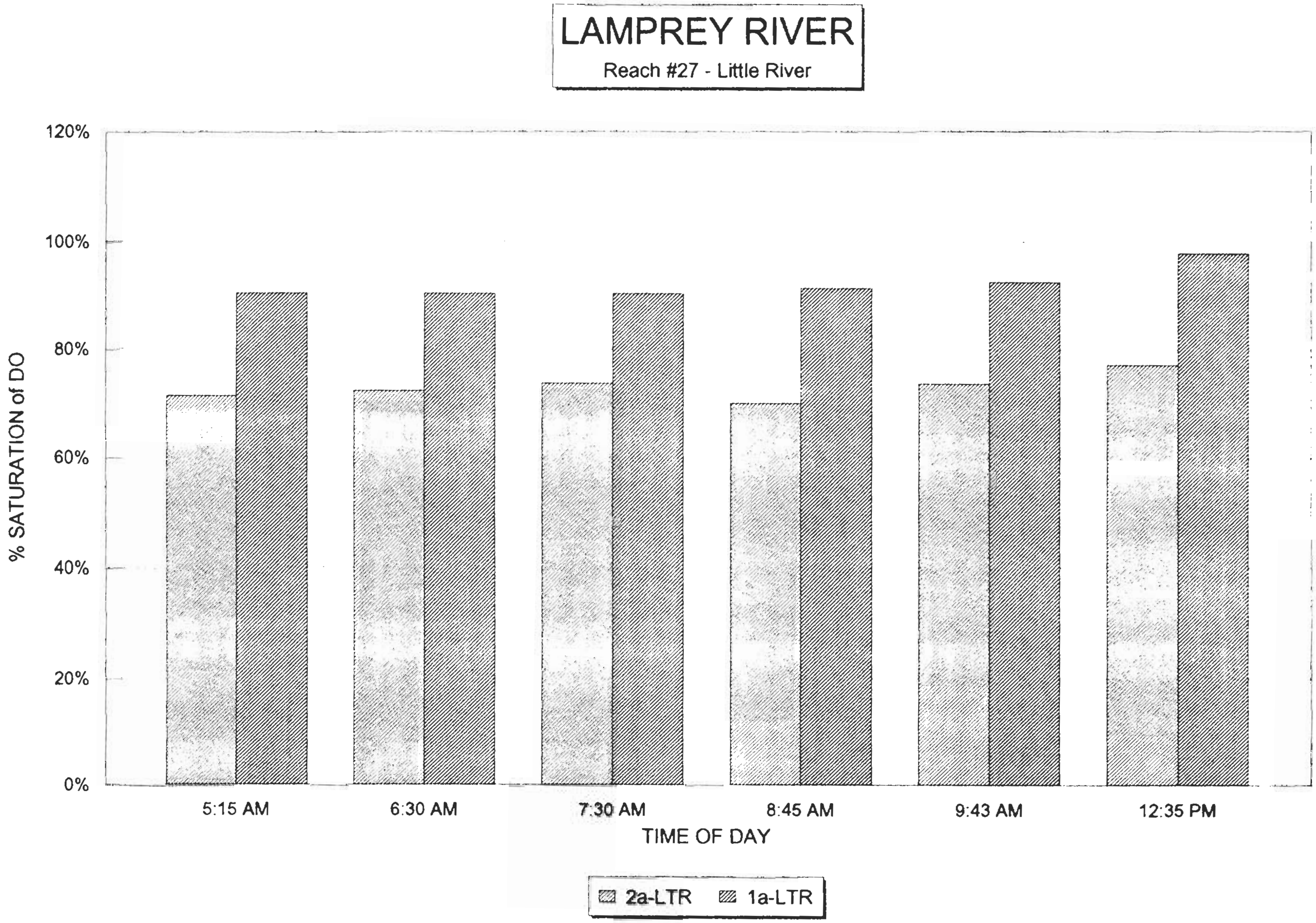


GRAPH 3-5

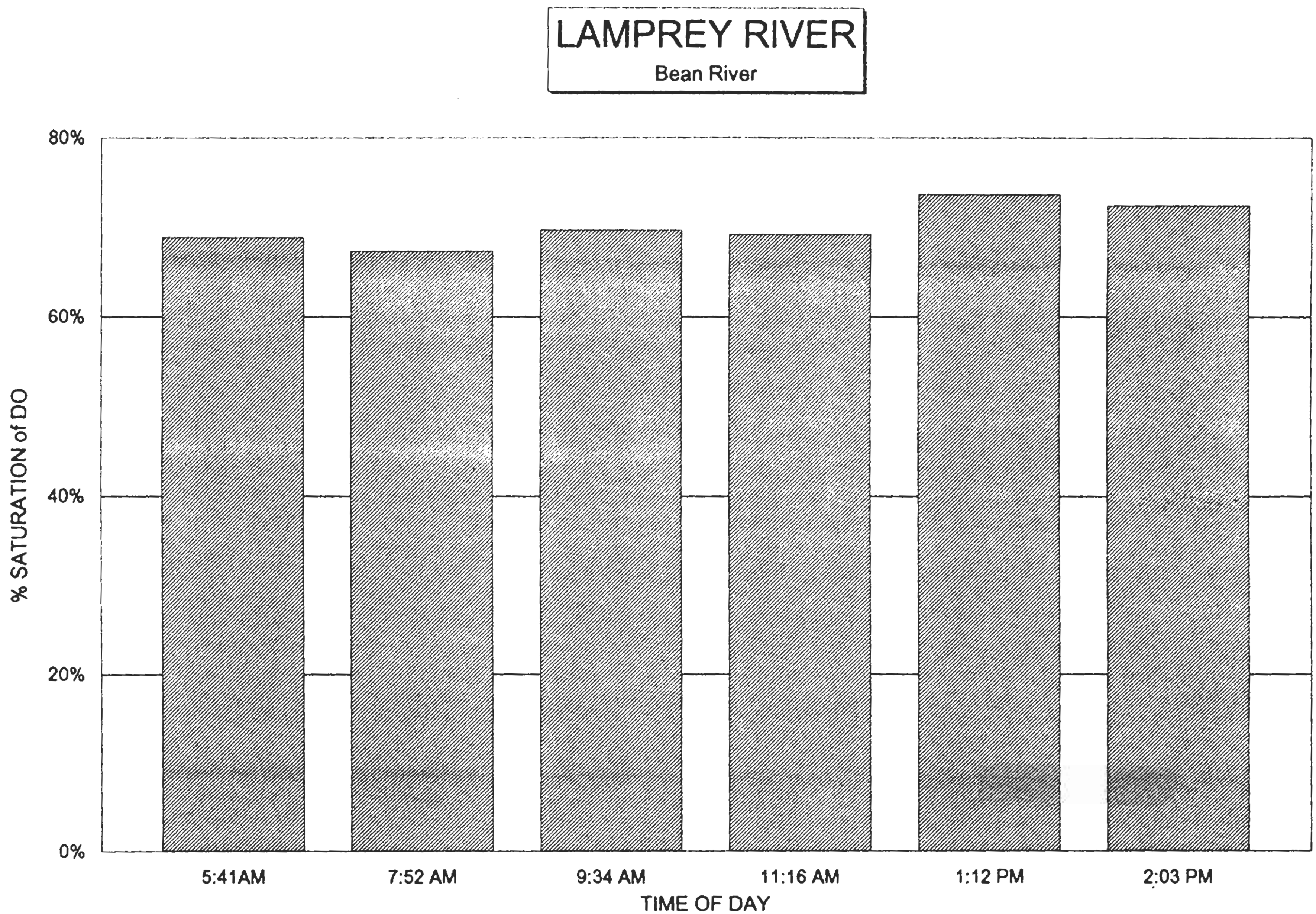

LAMPREY RIVER
Reach # 19 - Unknown Tributary
60%
40%
20%
0%
% SATURATION of DO
5:30 AM
7:00AM
8:10 AM
9:15 AM
10:20 AM
2:00 PM
TIME OF DAY
GRAPH 3-6


LAMPREY RIVER
Reach # 24 - North River
120%
100%
80%
60%
40%
20%
0%
% SATURATION of DO
6:38 AM
8:23 AM
10:05 AM
11:51 AM
1:00 PM
2:18 PM
TIME OF DAY
1-NOR
2-NOR

GRAPH 3-7

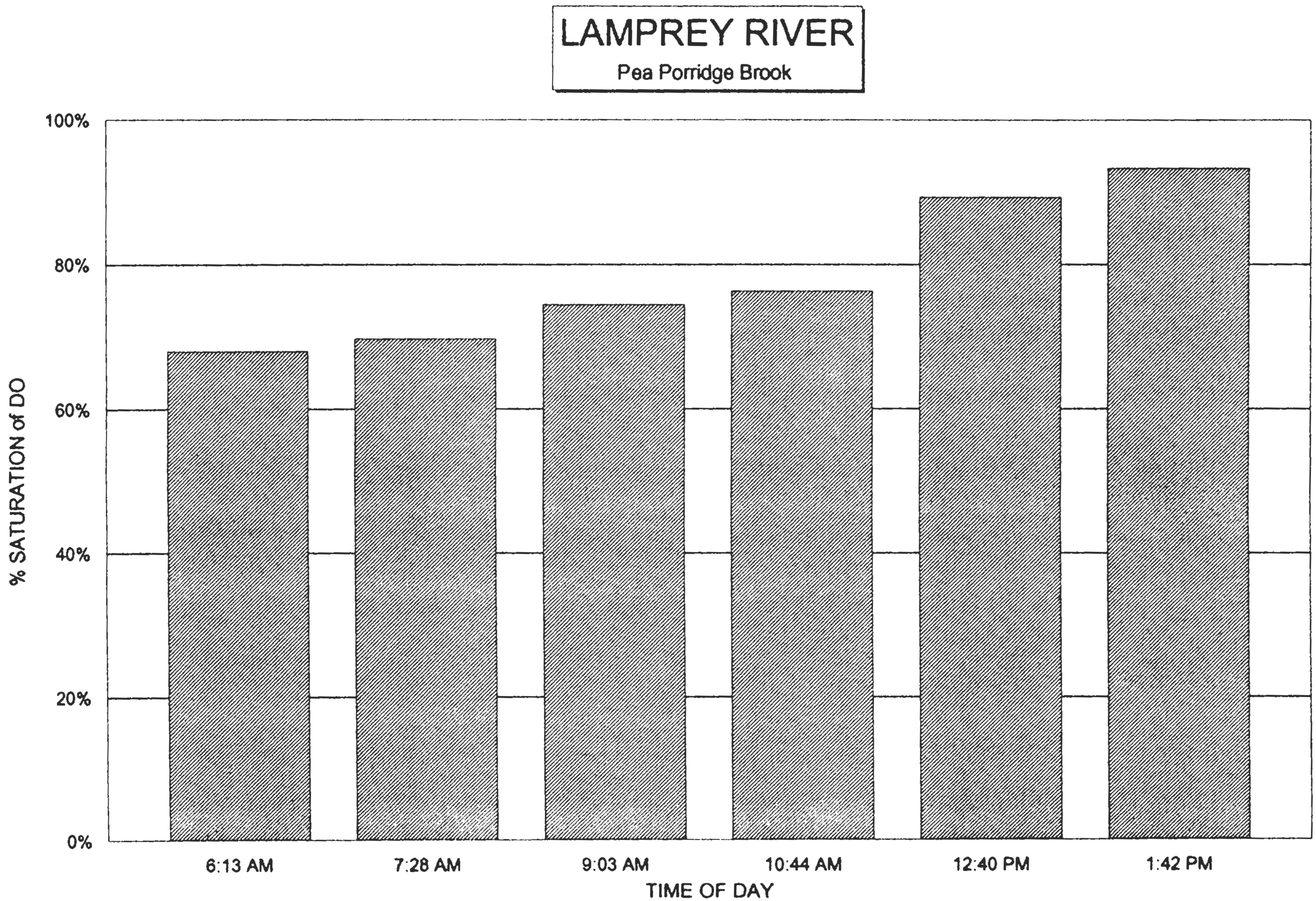

LAMPREY RIVER
Reach #27 - Little River
120%
100%
80%
60%
40%
20%
0%
% SATURATION of DO
5:15 AM
6:30 AM
7:30 AM
8:45 AM
9:43 AM
12:35 PM
TIME OF DAY
2a-LTR
1a-LTR

Graph 3-8



LAMPREY RIVER
Bean River
80%
60%
40%
20%
0%
% SATURATION of DO
5:41AM
7:52 AM
9:34 AM
11:16 AM
1:12 PM
2:03 PM
TIME OF DAY

Graph 4-1


LAMPREY RIVER
Pea Porridge Brook
100%
80%
60%
40%
20%
0%
% SATURATION of DO
6:13 AM
7:28 AM
9:03 AM
10:44 AM
12:40 PM
1:42 PM
TIME OF DAY

GRAPH 4-2

APPENDIX E
MODELING RESULTS

*** RIVER MODEL PROGRAM ** EPA (600/6/82-004a) ***
PC BASIC,   DESDORM1.BAS - LAST REVISED 3/95

INPUT FILE.. C:\MODEL\LMP5

RIVER	LAMPREY RIVER	MODELER ..	HERRICK
REACH	22	DATE	10-17-95

COMMENTS.... WET WEATHER MODELING - RIVER @ SUMMER AVG. FLOW - 89 CFS

UP FLOW (cfs) ..	49.53	DISCHARGE FLOW (cfs) ..	23.084
UP DO (mg/l) ...	7.41	DISCHARGE DO (mg/l) ...	7
UP UCBOD (mg/l).	2	DISCHARGE UCBOD (mg/l).	22.5
UP NBOD (mg/l) .	1	UCBOD/CBOD5...........	1.6
		DISCHARGE NBOD (mg/l) .	6.5
		NBOD/NH3-N............	4.57
DILUTION X 0.9	2.831078	DISCHARGE CBOD5 (mg/l).	14.0625
		DISCHARGE NH3-N (mg/l).	1.422319
REAERATION Ka ..	5.3	SOD Sb	0
BOD DECAY Kd ...	.63	SOLUBILITY Cs	8.24
NBOD DECAY Kn ..	6.5	VELOCITY (fps)	.63
CBOD FLUX Lrd ..	0	WATER TEMPERATURE (C)..	25
NBOD FLUX Nrd ..	0	STARTING MILE	0
RESPIRATION R ..	.035	ENDING MILE	7.5
PHOTOSYNTHESIS P	0		
MIN. DO (75% Cs).....	6.179	INITIAL CBOD (Lo)	8.5169
MIN. DO (90% ASSETS).	6.303	INITIAL NBOD (No)	2.7484
INITIAL DO MIX.......	7.279661	ENDING CBOD (Le)	5.3855
INITIAL DO DEFICIT...	.9603	ENDING NBOD (Ne)	.0242

RIVER MILE	DISTANCE (miles)	DEFICIT (mg/l)	DISSOLVED OXYGEN (mg/l)
0	0	.9603	7.279661
.375	.375	1.49	6.748
.75	.75	1.817	6.422
1.125	1.125	1.991	6.247
1.5	1.5	2.065	6.173
1.875	1.875	2.069	6.17
2.25	2.25	2.023	6.215
2.625	2.625	1.949	6.29
3	3	1.858	6.381
3.375	3.375	1.758	6.48
3.75	3.75	1.654	6.585
4.125	4.125	1.554	6.684
4.5	4.5	1.458	6.781
4.875	4.875	1.368	6.871
5.25	5.25	1.282	6.956
5.625	5.625	1.205	7.034
6	6	1.133	7.105
6.375	6.375	1.07	7.169
6.75	6.75	1.011	7.228
7.125	7.125	.958	7.281
7.5	7.5	.911	7.328
7.875	7.875	.866	7.372

*** RIVER MODEL PROGRAM ** EPA (600/6/82-004a) ***
PC BASIC, DESDORM1.BAS - LAST REVISED 3/95

INPUT FILE.. C:\MODEL\LMP6

RIVER	LAMPREY RIVER	MODELER ..	HERRICK
REACH	22	DATE	10-17-95

COMMENTS.... DRY WEATHER - SUMMER - RIVER @ 2x7Q10

UP FLOW (cfs) ..	6	DISCHARGE FLOW (cfs) ..	.54
UP DO (mg/l) ...	7.41	DISCHARGE DO (mg/l) ...	7
UP UCBOD (mg/l).	2	DISCHARGE UCBOD (mg/l).	22.5
UP NBOD (mg/l) .	1	UCBOD/CBOD5...........	1.6
		DISCHARGE NBOD (mg/l) .	17
		NBOD/NH3-N............	4.57
DILUTION X 0.9	10.9	DISCHARGE CBOD5 (mg/l).	14.0625
		DISCHARGE NH3-N (mg/l).	3.719912
REAERATION Ka ..	1.5	SOD Sb	0
BOD DECAY Kd ...	1	SOLUBILITY Cs	8.24
NBOD DECAY Kn ..	1	VELOCITY (fps)	.12
CBOD FLUX Lrd ..	0	WATER TEMPERATURE (C)..	25
NBOD FLUX Nrd ..	0	STARTING MILE	0
RESPIRATION R ..	.035	ENDING MILE	7.5
PHOTOSYNTHESIS P	0		
MIN. DO (75% Cs).....	6.179	INITIAL CBOD (Lo)	3.6926
MIN. DO (90% ASSETS).	6.303	INITIAL NBOD (No)	2.3211
INITIAL DO MIX.......	7.376147	ENDING CBOD (Le)	.081
INITIAL DO DEFICIT...	.8638	ENDING NBOD (Ne)	.0509

RIVER MILE	DISTANCE (miles)	DEFICIT (mg/l)	DISSOLVED OXYGEN (mg/l)
0	0	.8638	7.376147
.375	.375	1.557	6.682
.75	.75	1.922	6.316
1.125	1.125	2.066	6.172
1.5	1.5	2.066	6.172
1.875	1.875	1.98	6.259
2.25	2.25	1.84	6.399
2.625	2.625	1.674	6.564
3	3	1.501	6.738
3.375	3.375	1.328	6.911
3.75	3.75	1.164	7.074
4.125	4.125	1.013	7.225
4.5	4.5	.878	7.361
4.875	4.875	.754	7.484
5.25	5.25	.648	7.592
5.625	5.625	.555	7.684
6	6	.474	7.765
6.375	6.375	.402	7.836
6.75	6.75	.342	7.896
7.125	7.125	.293	7.946
7.5	7.5	.248	7.99

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*** RIVER MODEL PROGRAM ** EPA (600/6/82-004a) ***
    PC BASIC,   DESDORM1.BAS - LAST REVISED 3/95

INPUT FILE.. C:\MODEL\LMP6

RIVER ...... LAMPREY RIVER          MODELER .. HERRICK
REACH ......  22                    DATE ..... 10-17-95

COMMENTS.... DRY WEATHER - SUMMER - RIVER @ 2x7Q10

UP FLOW (cfs) ..   6                DISCHARGE FLOW (cfs) ..    .54
UP DO (mg/l) ...   7.41             DISCHARGE DO (mg/l) ...    7
UP UCBOD (mg/l).   2                DISCHARGE UCBOD (mg/l).    17
UP NBOD (mg/l) .   1                UCBOD/CBOD5............    1.6
                                    DISCHARGE NBOD (mg/l) .    22.5
                                    NBOD/NH3-N.............    4.57

DILUTION X 0.9 ......    10.9       DISCHARGE CBOD5 (mg/l).    10.625
                                    DISCHARGE NH3-N (mg/l).    4.923413

REAERATION Ka ..   1.5              SOD Sb ................    0
BOD DECAY Kd ...   1                SOLUBILITY Cs .........    8.24
NBOD DECAY Kn ..   1                VELOCITY (fps) ........    .12
CBOD FLUX Lrd ..   0                WATER TEMPERATURE (C)..    25
NBOD FLUX Nrd ..   0                STARTING MILE .........    0
RESPIRATION R ..   .035             ENDING MILE ...........    7.5
PHOTOSYNTHESIS P   0

MIN. DO (75% Cs).....    6.179      INITIAL CBOD (Lo) .....    3.2385
MIN. DO (90% ASSETS).    6.303      INITIAL NBOD (No) .....    2.7752
INITIAL DO MIX.......    7.376147   ENDING  CBOD (Le) .....    .071
INITIAL DO DEFICIT...    .8638      ENDING  NBOD (Ne) .....    .0608
```

RIVER MILE	DISTANCE (miles)	DEFICIT (mg/l)	DISSOLVED OXYGEN (mg/l)
0	0	.8638	7.376147
.375	.375	1.557	6.682
.75	.75	1.922	6.316
1.125	1.125	2.065	6.173
1.5	1.5	2.065	6.173
1.875	1.875	1.978	6.26
2.25	2.25	1.84	6.399
2.625	2.625	1.674	6.564
3	3	1.5	6.739
3.375	3.375	1.328	6.911
3.75	3.75	1.166	7.073
4.125	4.125	1.013	7.225
4.5	4.5	.877	7.362
4.875	4.875	.754	7.484
5.25	5.25	.648	7.592
5.625	5.625	.555	7.684
6	6	.472	7.766
6.375	6.375	.404	7.835
6.75	6.75	.342	7.896
7.125	7.125	.291	7.947
7.5	7.5	.248	7.99

*** RIVER MODEL PROGRAM ** EPA (600/6/82-004a) ***
PC BASIC, DESDORM1.BAS - LAST REVISED 3/95

INPUT FILE.. C:\MODEL\LMP6

RIVER ...... LAMPREY RIVER
REACH 22

MODELER .. HERRICK
DATE 10-17-95

COMMENTS.... DRY WEATHER - SUMMER - RIVER @ 2x7Q10

UP FLOW (cfs) ..	6	DISCHARGE FLOW (cfs) ..	.54
UP DO (mg/l) ...	7.41	DISCHARGE DO (mg/l) ...	7
UP UCBOD (mg/l).	2	DISCHARGE UCBOD (mg/l).	17
UP NBOD (mg/l) .	1	UCBOD/CBOD5...........	1.6
		DISCHARGE NBOD (mg/l) .	17
		NBOD/NH3-N............	4.57
DILUTION X 0.9	10.9	DISCHARGE CBOD5 (mg/l).	10.625
		DISCHARGE NH3-N (mg/l).	3.719912
REAERATION Ka ..	1.5	SOD Sb	0
BOD DECAY Kd ...	1	SOLUBILITY Cs	8.24
NBOD DECAY Kn ..	1	VELOCITY (fps)	.12
CBOD FLUX Lrd ..	0	WATER TEMPERATURE (C)..	25
NBOD FLUX Nrd ..	0	STARTING MILE	0
RESPIRATION R ..	.035	ENDING MILE	7.5
PHOTOSYNTHESIS P	0		
MIN. DO (75% Cs).....	6.179	INITIAL CBOD (Lo)	3.2385
MIN. DO (90% ASSETS).	6.303	INITIAL NBOD (No)	2.3211
INITIAL DO MIX.......	7.376147	ENDING CBOD (Le)	.071
INITIAL DO DEFICIT...	.8638	ENDING NBOD (Ne)	.0509

RIVER MILE	DISTANCE (miles)	DEFICIT (mg/l)	DISSOLVED OXYGEN (mg/l)
0	0	.8638	7.376147
.375	.375	1.488	6.75
.75	.75	1.815	6.424
1.125	1.125	1.939	6.3
1.5	1.5	1.932	6.307
1.875	1.875	1.847	6.392
2.25	2.25	1.713	6.526
2.625	2.625	1.559	6.68
3	3	1.394	6.844
3.375	3.375	1.234	7.005
3.75	3.75	1.082	7.156
4.125	4.125	.941	7.297
4.5	4.5	.814	7.424
4.875	4.875	.701	7.538
5.25	5.25	.601	7.637
5.625	5.625	.515	7.723
6	6	.439	7.799
6.375	6.375	.375	7.864
6.75	6.75	.319	7.92
7.125	7.125	.272	7.967
7.5	7.5	.232	8.007

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*** RIVER MODEL PROGRAM ** EPA (600/6/82-004a) ***
    PC BASIC,   DESDORM1.BAS - LAST REVISED 3/95

INPUT FILE.. C:\MODEL\LMP7

RIVER ...... LAMPREY RIVER          MODELER .. HERRICK
REACH ......  22                    DATE ..... 10-17-95

COMMENTS.... DRY WEATHER - WINTER - RIVER @ 7Q10

UP FLOW (cfs) ..    3               DISCHARGE FLOW (cfs) ..    .54
UP DO (mg/l) ...    10.16           DISCHARGE DO (mg/l) ...    7
UP UCBOD (mg/l).    2               DISCHARGE UCBOD (mg/l).    26
UP NBOD (mg/l) .    1               UCBOD/CBOD5............    1.6
                                    DISCHARGE NBOD (mg/l) .    24
                                    NBOD/NH3-N.............    4.57

DILUTION X 0.9 ......    5.9        DISCHARGE CBOD5 (mg/l).    16.25
                                    DISCHARGE NH3-N (mg/l).    5.251641

REAERATION Ka ..    1               SOD Sb ................    0
BOD DECAY Kd ...    .5              SOLUBILITY Cs .........    11.29
NBOD DECAY Kn ..    .29             VELOCITY (fps) ........    .06
CBOD FLUX Lrd ..    0               WATER TEMPERATURE (C)..    10
NBOD FLUX Nrd ..    0               STARTING MILE .........    0
RESPIRATION R ..    .035            ENDING MILE ...........    7.5
PHOTOSYNTHESIS P    0

MIN. DO (75% Cs).....    8.467      INITIAL CBOD (Lo) .....    5.661
MIN. DO (90% ASSETS).    8.63675    INITIAL NBOD (No) .....    4.5084
INITIAL DO MIX.......    9.677966   ENDING  CBOD (Le) .....    .1242
INITIAL DO DEFICIT...    1.612      ENDING  NBOD (Ne) .....    .4919
```

RIVER MILE	DISTANCE (miles)	DEFICIT (mg/l)	DISSOLVED OXYGEN (mg/l)
0	0	1.612	9.677966
.375	.375	2.315	8.975
.75	.75	2.61	8.678
1.125	1.125	2.661	8.628
1.5	1.5	2.565	8.723
1.875	1.875	2.391	8.897
2.25	2.25	2.18	9.109
2.625	2.625	1.959	9.329
3	3	1.741	9.548
3.375	3.375	1.536	9.753
3.75	3.75	1.349	9.94
4.125	4.125	1.18	10.109
4.5	4.5	1.031	10.258
4.875	4.875	.901	10.388
5.25	5.25	.785	10.505
5.625	5.625	.685	10.604
6	6	.599	10.69
6.375	6.375	.523	10.765
6.75	6.75	.458	10.831
7.125	7.125	.404	10.885
7.5	7.5	.355	10.934

*** RIVER MODEL PROGRAM ** EPA (600/6/82-004a) ***
PC BASIC, DESDORM1.BAS - LAST REVISED 3/95

INPUT FILE.. C:\MODEL\LMP7

RIVER ...... LAMPREY RIVER
REACH 22

MODELER .. HERRICK
DATE 10-17-95

COMMENTS.... DRY WEATHER - WINTER - RIVER @ 7Q10

UP FLOW (cfs) ..	3	DISCHARGE FLOW (cfs) ..	.54
UP DO (mg/l) ...	10.16	DISCHARGE DO (mg/l) ...	7
UP UCBOD (mg/l).	2	DISCHARGE UCBOD (mg/l).	30
UP NBOD (mg/l) .	1	UCBOD/CBOD5...........	1.6
		DISCHARGE NBOD (mg/l) .	24
		NBOD/NH3-N............	4.57
DILUTION X 0.9	5.9	DISCHARGE CBOD5 (mg/l).	18.75
		DISCHARGE NH3-N (mg/l).	5.251641
REAERATION Ka ..	1	SOD Sb	0
BOD DECAY Kd ...	.5	SOLUBILITY Cs	11.29
NBOD DECAY Kn ..	.29	VELOCITY (fps)	.06
CBOD FLUX Lrd ..	0	WATER TEMPERATURE (C)..	10
NBOD FLUX Nrd ..	0	STARTING MILE	0
RESPIRATION R ..	.035	ENDING MILE	7.5
PHOTOSYNTHESIS P	0		
MIN. DO (75% Cs).....	8.467	INITIAL CBOD (Lo)	6.2711
MIN. DO (90% ASSETS).	8.63675	INITIAL NBOD (No)	4.5084
INITIAL DO MIX.......	9.677966	ENDING CBOD (Le)	.1375
INITIAL DO DEFICIT...	1.612	ENDING NBOD (Ne)	.4919

RIVER MILE	DISTANCE (miles)	DEFICIT (mg/l)	DISSOLVED OXYGEN (mg/l)
0	0	1.612	9.677966
.375	.375	2.401	8.888
.75	.75	2.743	8.546
1.125	1.125	2.812	8.477
1.5	1.5	2.717	8.572
1.875	1.875	2.536	8.753
2.25	2.25	2.312	8.977
2.625	2.625	2.078	9.211
3	3	1.845	9.444
3.375	3.375	1.626	9.663
3.75	3.75	1.426	9.862
4.125	4.125	1.246	10.043
4.5	4.5	1.087	10.203
4.875	4.875	.948	10.342
5.25	5.25	.824	10.465
5.625	5.625	.718	10.571
6	6	.625	10.663
6.375	6.375	.546	10.743
6.75	6.75	.477	10.812
7.125	7.125	.42	10.869
7.5	7.5	.368	10.921

*** RIVER MODEL PROGRAM ** EPA (600/6/82-004a) ***
PC BASIC, DESDORM1.BAS - LAST REVISED 3/95

INPUT FILE.. C:\MODEL\LMP7

RIVER	LAMPREY RIVER	MODELER ..	HERRICK
REACH	22	DATE	10-17-95

COMMENTS.... DRY WEATHER - WINTER - RIVER @ 7Q10

UP FLOW (cfs) ..	3	DISCHARGE FLOW (cfs) ..	.54
UP DO (mg/l) ...	10.16	DISCHARGE DO (mg/l) ...	7
UP UCBOD (mg/l).	2	DISCHARGE UCBOD (mg/l).	26
UP NBOD (mg/l) .	1	UCBOD/CBOD5............	1.6
		DISCHARGE NBOD (mg/l) .	30
		NBOD/NH3-N.............	4.57
DILUTION X 0.9	5.9	DISCHARGE CBOD5 (mg/l).	16.25
		DISCHARGE NH3-N (mg/l).	6.564551
REAERATION Ka ..	1	SOD Sb	0
BOD DECAY Kd ...	.5	SOLUBILITY Cs	11.29
NBOD DECAY Kn ..	.29	VELOCITY (fps)	.06
CBOD FLUX Lrd ..	0	WATER TEMPERATURE (C)..	10
NBOD FLUX Nrd ..	0	STARTING MILE	0
RESPIRATION R ..	.035	ENDING MILE	7.5
PHOTOSYNTHESIS P	0		
MIN. DO (75% Cs).....	8.467	INITIAL CBOD (Lo)	5.661
MIN. DO (90% ASSETS).	8.63675	INITIAL NBOD (No)	5.4237
INITIAL DO MIX.......	9.677966	ENDING CBOD (Le)	.1242
INITIAL DO DEFICIT...	1.612	ENDING NBOD (Ne)	.5918

RIVER MILE	DISTANCE (miles)	DEFICIT (mg/l)	DISSOLVED OXYGEN (mg/l)
0	0	1.612	9.677966
.375	.375	2.394	8.895
.75	.75	2.736	8.552
1.125	1.125	2.81	8.479
1.5	1.5	2.724	8.565
1.875	1.875	2.552	8.737
2.25	2.25	2.335	8.954
2.625	2.625	2.105	9.184
3	3	1.877	9.413
3.375	3.375	1.662	9.628
3.75	3.75	1.465	9.824
4.125	4.125	1.286	10.003
4.5	4.5	1.126	10.163
4.875	4.875	.986	10.302
5.25	5.25	.862	10.427
5.625	5.625	.755	10.534
6	6	.662	10.628
6.375	6.375	.579	10.71
6.75	6.75	.509	10.779
7.125	7.125	.449	10.84
7.5	7.5	.394	10.895

APPENDIX F

REFERENCES

1. The Clean Water Act of 1987, section 303 (d).

2. Total Maximum Daily Load Guidelines, State of New Hampshire Department of Environmental Services, Water Supply and Pollution Control Division, August 9, 1994.

3. Lamprey River Nonpoint Source Assessment, New Hampshire Department of Environmental Services, October, 1994.

4. Hydrologic Data for Gaged Watersheds of New Hampshire and Vermont, S. L. Dingman and G. K. Capsis, October 1981.

5. Characterization of Stormwater Runoff from Concord, New Hampshire, New Hampshire Department of Environmental Services, August 1979.

6. Durham Urban Runoff Program Summary Report, New Hampshire Department of Environmental Services, June 1983.

7. 1994 and 1995 sampling data from Manchester and Exeter, New Hampshire. Manchester sampling was done in conjunction with their CSO facility plan.

8. U.S. EPA. 1985. U.S. Environmental Protection Agency. Rates, Constants, and Kinetics Formulation in Surface Water Quality Modeling, Second Edition, EPA/600/3-85/040, pages 90 - 205.

9. NHWSPCC. March 1993. Sugar River WLA Study. Staff Report.

10. Lamprey River Wasteload Allocation Study, The town of Epping Wastewater Treatment Facility, Dufresne-Henry, Inc., April 1995.

11. Lamprey Wild and Scenic River Study, Draft Report, June 1995.