THE EFFECTS OF ELEVATED HIGHWAY CONSTRUCTION ON WATER QUALITY IN LOUISIANA WETLANDS

INTERIM REPORT NO. 1

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ABSTRACT

This study is to determine by physical, chemical and biological means the effects of bridged highway construction techniques on water quality in wetlands. Water quality was monitored before, during and after construction. The data shows the increase in pollution that occurred during construction. The areas where construction has been completed have shown gradual improvement towards the preconstruction ambient. The information obtained may be useful in predicting the degree and duration of impacts of future construction projects on wetland environments.

INTRODUCTION AND OBJECTIVES

The effects of highway construction on the water quality of wetland areas have been studied only to a limited degree. The apparent signs of water degradation, such as siltation and sedimentation, have been seen many times in similar construction situations. The degree of degradation is dependent upon construction techniques and watershed characteristics. Knowledge of the sedimentation process is necessary to assess the effects on the aquatic ecosystem. Chabreck (4)[1] observed that sedimentation and the resulting turbidity were dependent upon the vegetative cover and the soil type for a particular area. Hopkins (7) concluded that highway construction near watercourses should be watched very closely for silting and sedimentation. Other information concerning changes involved before, during and after construction in a wetland situation is insufficient.

The primary objectives of this research are as follows:

1. To provide a baseline or ambient condition for the existing water quality.
2. To determine the changes in the wetland water quality due to the dredging and construction of an elevated roadway.
3. To determine any residual effect on water quality, if any, due to the construction and the time rate of change caused by the construction.

The area selected as a typical wetland was the new alignment for Interstate Route 55 beginning at the Interstate 10 junction north of LaPlace, Louisiana and ending a few miles north of Pass Manchac between Lake Maurepas and Lake Pontchartrain (see Figure 1). This corridor offered an excellent opportunity for study, as it contained areas not yet under construction, areas where construction was in process, and areas where construction was complete.

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[1] *Please see references on Page 32 for this and all other citations.*

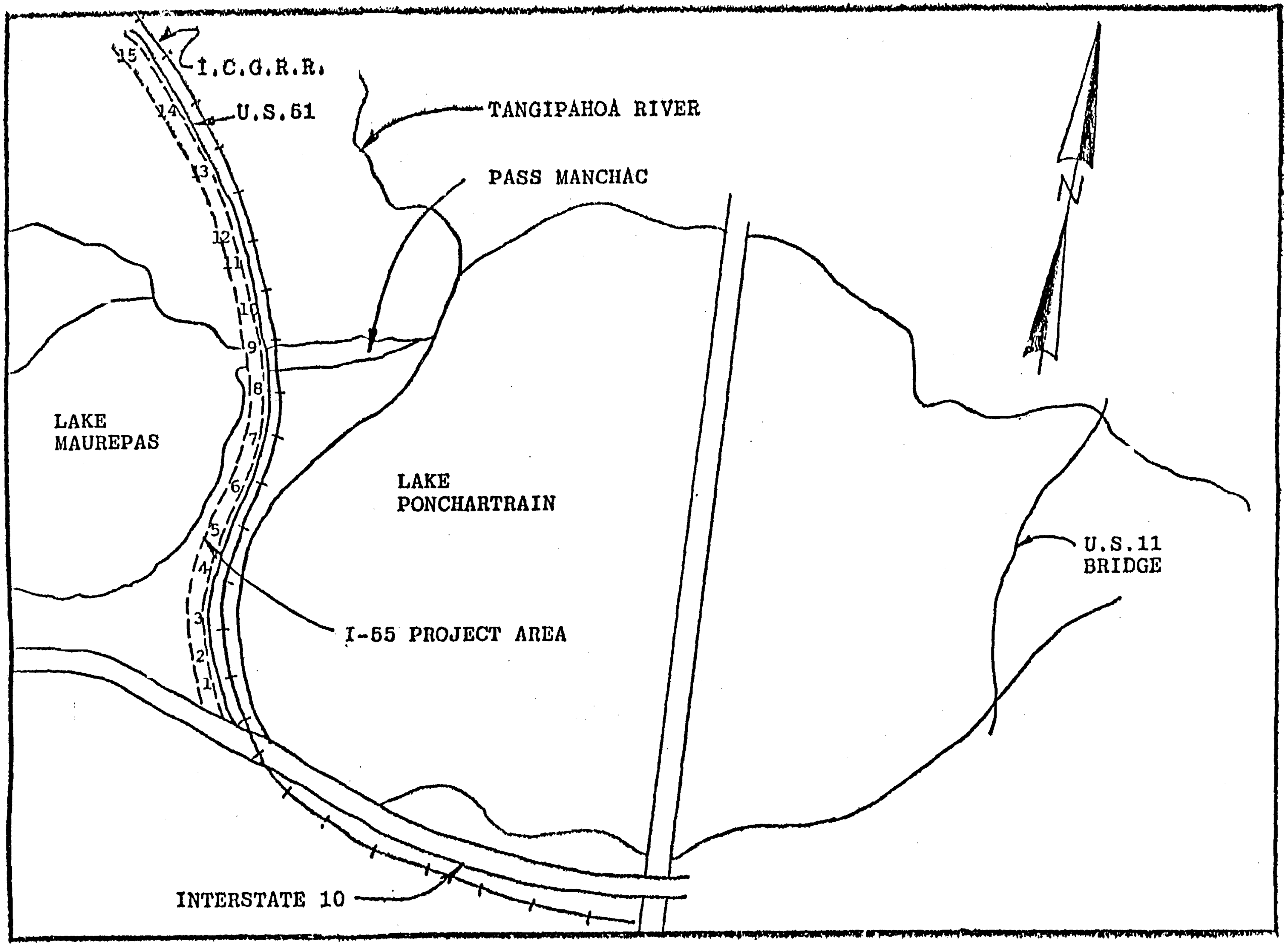

FIGURE 1
I-55 PROJECT AREA
Numbers represent sampling sites.

The construction technique employed in this construction project consisted of using a dredge barge to construct an access canal between the existing borrow canal for Highway 51 and the Highway 51 roadway. This canal provides access for construction of the new bridged highway supported by concrete piles. In later years, the canal will provide access for maintenance of the structure as well as an area for a new aquatic habitat.

Two mitigation techniques were used on this construction project. The first technique required the placement of the spoil from the canal excavation to be placed in spoil areas such that drainage from the dredging operation returned to the channel being excavated. The spoil, a highway organic clay, was later dressed to a uniform appearance. Vegetative cover was not provided for the spoil banks, as the native vegetation grows very rapidly, and covered the spoil very quickly.

The second technique was the use of earth plugs to minimize exchange of water along the new construction canal. The earth plugs were placed at intervals of approximately 2,000 feet (610 m).

STUDY AREA

The location of the study area is between 89° 44' and 90° 36' longitude and 30° 02' and 30° 25' latitude. The area consists of the Lake Maurepas and Lake Pontchartrain basin, which lies approximately 48.1 miles (77.4 Km) southeast of Baton Rouge and 29.1 miles (46.1 Km) northwest of New Orleans. Specifically, the microscale analysis for this research study was conducted in the old U.S. 51 borrow canal. The canal is approximately 200 yards (182.8 meters) west of U.S. 51, and is immediately adjacent to the alignment for the Interstate 55 construction.

The area is located in the Mississippi River deltaic plain. Formation of the lakes occurred when two former deltas of the Mississippi River, St. Bernard and Cocodrie, filled in a formerly open bay with clay and silt from high water flows. Only two passes, Chef Menteur and Rigolets, still serve as natural water routes to Lake Borne and the Gulf of Mexico. At the present time, there are eight major tributaties flowing into the Pontchartrain Basin. The surface area of Lakes Pontchartrain and Maurepas is approximately 5,098, 490 acres (629,159 hectares) of water. These two lakes represent the largest contiguous esturine area in the coastal zone of Louisiana. Both of these lakes are surrounded by fresh-water marsh, cypress-tupelo swamp and brackish-water marsh.

The wetlands of the area have undergone a number of changes in the past. In the late 1800's - early 1900's, logging and the Illinois Central Gulf railroads were two of the first man-made threats to this sensitive area. The railroads built along the shores of Lake Pontchartrain formed barriers which limited the flushing action of the wetland ecosystem. Cypress logging activities from approximately 1910 to approximately 1935 left scars which may be seen even now as the area is viewed from the air. In 1954, the muck-fill construction of U.S. Highway 51 added to the problem of water movement within this marsh system. These alterations of the drainage patterns have contributed to the spread of the now overpopulated water hyacinth (Eichhornia crassipes).

Another major change occurring in this area is a rather rapid decline in the amount of trees, shrubs, and grasses growing in the swamp. During the past ten to fifteen years, there has been a noticeable decline in at least the following: Three Corner Grass (Dulichium arundinaceum), Saw Grass (Cladium jamaicense), Young Cypress Trees (Taxodium distichum), Wax Myrtle (Myrica cerifera), Palmetto (Sabal minon), Marsh Grass (Spartina alterniflora), Cinnamon Fern (Osmunda cinnamonea), and Black Gum Tree (Nyssa sylvatica).

What was once a thickly vegetated swamp, providing habitat for an abundance of wildlife, is now considered "open swamp" which is less productive. This has become a topic of great concern for many local residents, especially those who make a living off of these resources. The area of sparse vegetation is moving from south to north. The cause of this phenomena has not been identified.

TIDALFLOW AND CURRENTS

The major tidal flows and currents are in the lakes, east-west in direction. Normal tidal fluctuations are one to two feet with storm tides of three to four feet. The borrow canal being studied generally travels in a north-south direction. Therefore, the tidal actions and currents from Lake Pontchartrain and Lake Maurepas exert a minimal effect on the study waterway. There are two major exceptions, one being the unusual phenomenae of nature (floods, drought and hurricanes), and two, a little bayou (Ruddock Canal) which serves as a bypass from Lake Maurepas thereby flushing the study area from sampling sites 5 through 8 inclusive.

MATERIALS AND METHODS

The objectives of this research as outlined in Section 1 dictated that a monitoring study be conducted in order to assess the pollution impact of wetland construction. In establishing a monitoring program, water sampling sites that will adequately represent the characteristics of the watershed must be selected, so that an assessment of environmental impacts can be made. This section discusses the elements involved in the selection of sampling locations and water quality parameters used in the monitoring program.

RECONNAISSANCE

An aerial reconnaissance of the research area was made by helicopter in order to identify land features, tributaries, and adjacent watersheds. Figure 1 (Page 2) shows the major elements of the study area which have an influence on the water quality of the swamps and marshes of the Manchac Peninsula. Also shown are the transportation systems affecting the area and the initial sampling sites.

The entire Pontchartrain Basin, including Lake Maurepas, Pass Manchac and Lake Pontchartrain west of U.S. 11, is considered suitable for primary and secondary water usage as well as fish and wildlife propagation. Primary water usage is defined as: waters which may be used for swimming and other water contact sports where water may be accidentally ingested, raw water source for public water supplies, as well as for agricultural, irrigation, industrial usage, navigation, and the propagation of aquatic flora and fauna. Secondary water usage is defined as: water wading, fishing, boating, or other activities where ingestion of water is not probable. The general chemical criteria for the study area, as established by the Louisiana Stream Control Commission, is shown in Table 1.

TABLE 1

GENERAL CHEMICAL CRITERIA

WITHIN THE PONTCHARTRAIN BASIN

SOURCE: WATER QUALITY CRITERIA, LOUISIANA
STREAM CONTROL COMMISSION, 1977

Segment Description	Criteria						
	Chloride (ppm) Maximum	Sulfate (ppm) Maximum	Dissolved Oxygen (ppm) Minimum	pH Range	Bacteria Standard	Temperature °C Maximum	Total Dissolved Solids (ppm) Maximum
Lake Maurepas	1000	200	5.0	6.0 to 8.5	1	32	3000
Pass Manchac - Lake Maurepas to Lake Pontchartrain	1000	1000	5.0	6.5 to 9.0	1	32	3000
Lake Pontchartrain - West of Highway 11 Bridge	--	--	4.0	6.5 to 9.0	1	35	--

Projected land use studies showed that within a short period of time, Lake Maurepas-Lake Pontchartrain-Pass Manchac area will be widely used as an area for primary and secondary recreation (U.S. Army Corps of Engineers) (12). The Louisiana Wildlife and Fisheries Commission has recently opened the Manchac Wildlife Management Area in the marsh between the present U.S. Highway 51 and the shore of Lake Pontchartrain near Manchac offering waterfowl hunting for the public. Many camps can be seen in the area and a large number of area residents work as commercial fishermen.

SAMPLING

Sampling sites were established in three different areas: one area not yet under construction, one area under construction, and one area where construction was completed. Fifteen sites were selected for the monitoring study (Figure 1, Page 2). Sites which exhibited the stream characteristics most "typical" or representative of the area were chosen. Stream characteristics include depth, velocity of flow, stream bottom substrate, vegetation and aquatic and wildlife habitat. Other factors used in site selection were the type of construction in the area and accessibility of the site.

SAMPLING FREQUENCY

The sampling frequency should include the collection of a sufficient number of samples over a wide range of stream-flows that would enable the researcher to present a valid discussion of the water quality characteristics of a given area. Sampling frequency is dependent upon such factors as the number of parameters, defined controlled variables, non-controlled variables, sound scientific and statistical evaluation of the requirements to be satisfied in order to achieve the objectives of the study, and the in-house abilities to meet those requirements.

The sampling program set up was such that samples could be taken and processed within a one-week period.

The original sampling frequency as shown in Table 2 was based on seasonal and climatic factors and construction activities. This sampling schedule was modified to the one shown in Table 3. This was done in order to better achieve the objectives of the study.

The new sampling program was not fully carried out due to work load and personnel turnover within the Research Staff, and unusual natural phenomena, such as floods and hurricanes.

Photographs showing representative sites before, during and after construction, and construction activities may be seen in Plates I-VII.

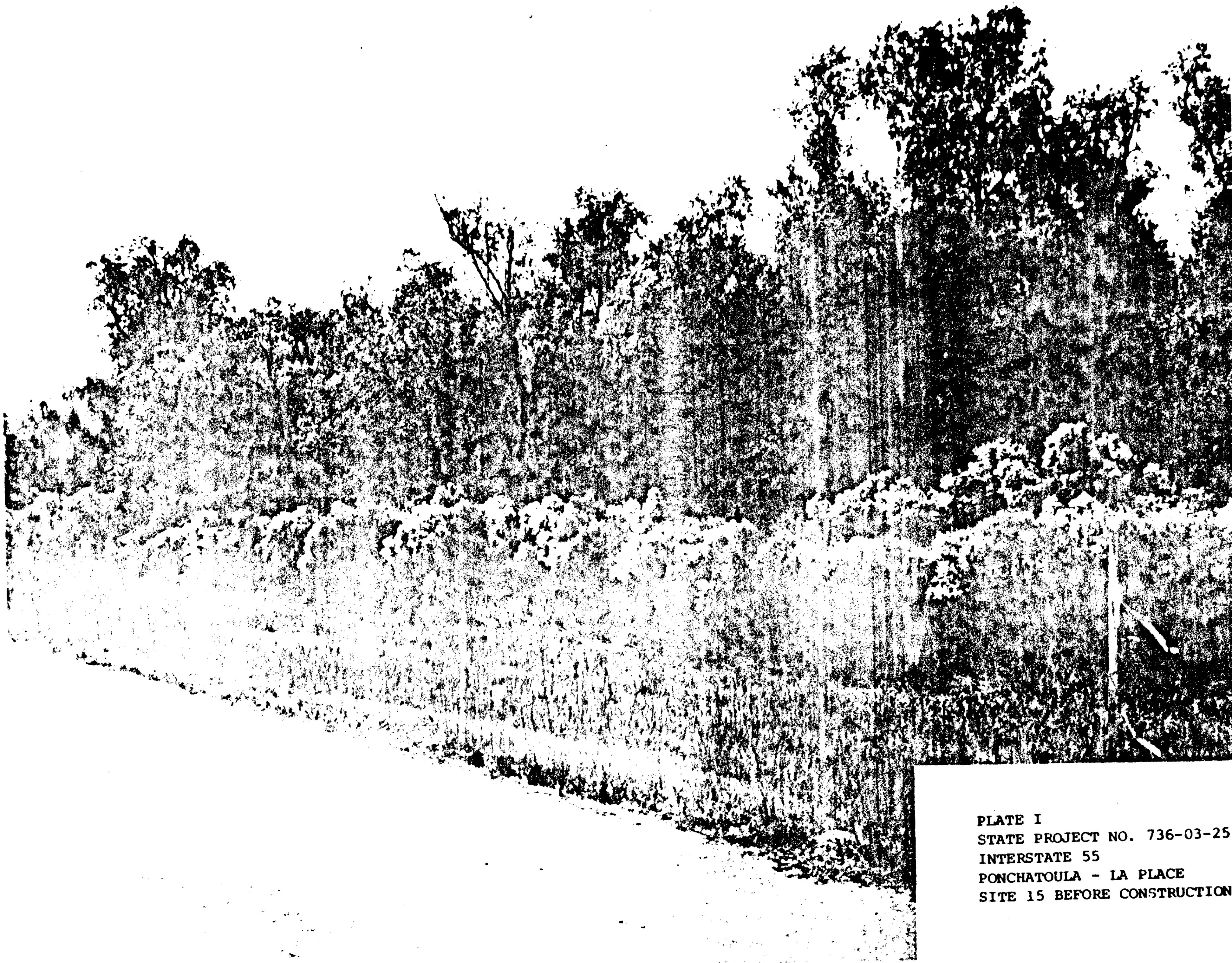

PLATE I
STATE PROJECT NO. 736-03-25
INTERSTATE 55
PONCHATOULA - LA PLACE
SITE 15 BEFORE CONSTRUCTION

PLATE II
STATE PROJECT NO. 736-03-25
INTERSTATE 55
PONCHATOULA - LA PLACE
SITE 13 - DREDGED WORK CANAL

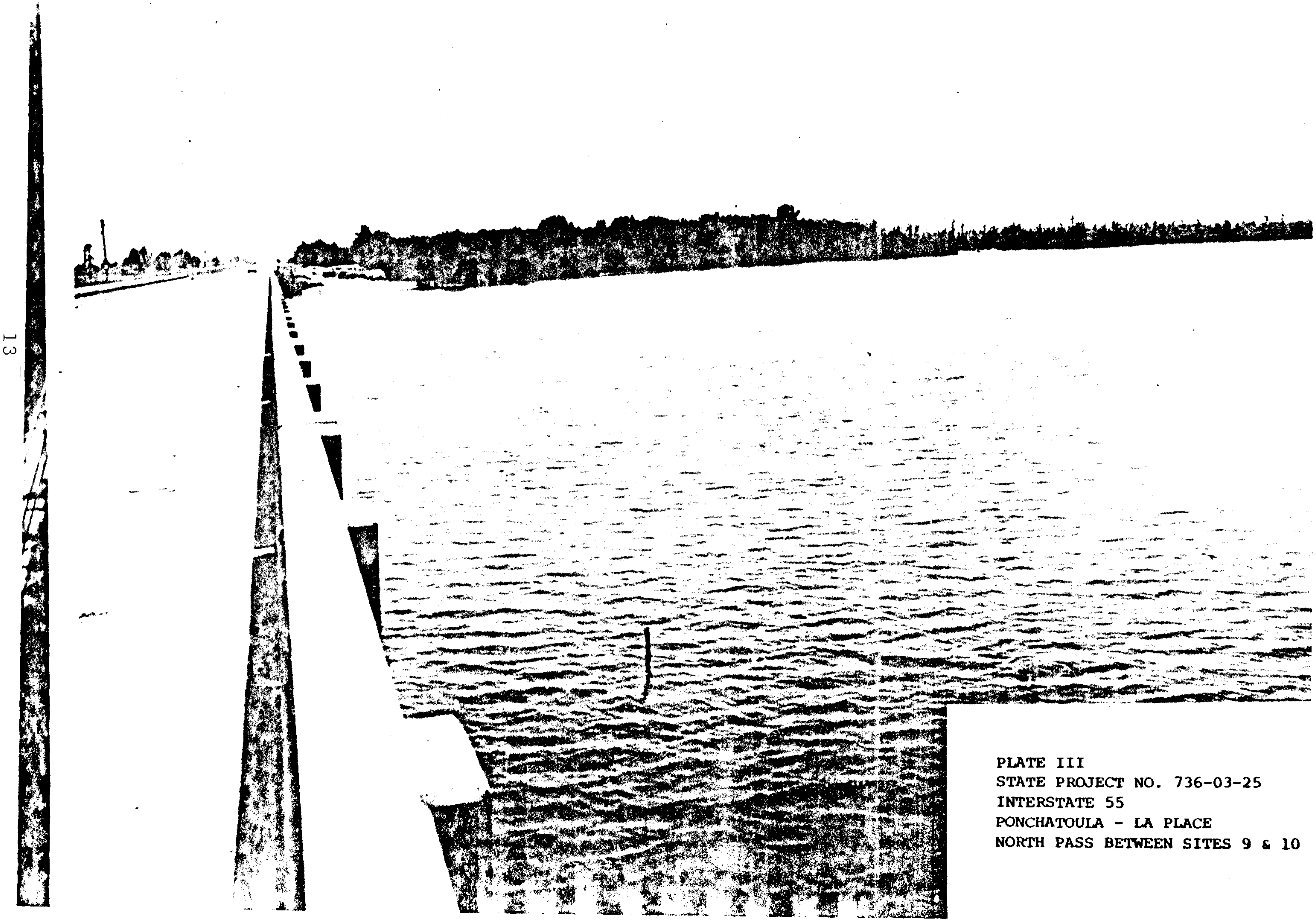

PLATE III
STATE PROJECT NO. 736-03-25
INTERSTATE 55
PONCHATOULA - LA PLACE
NORTH PASS BETWEEN SITES 9 & 10

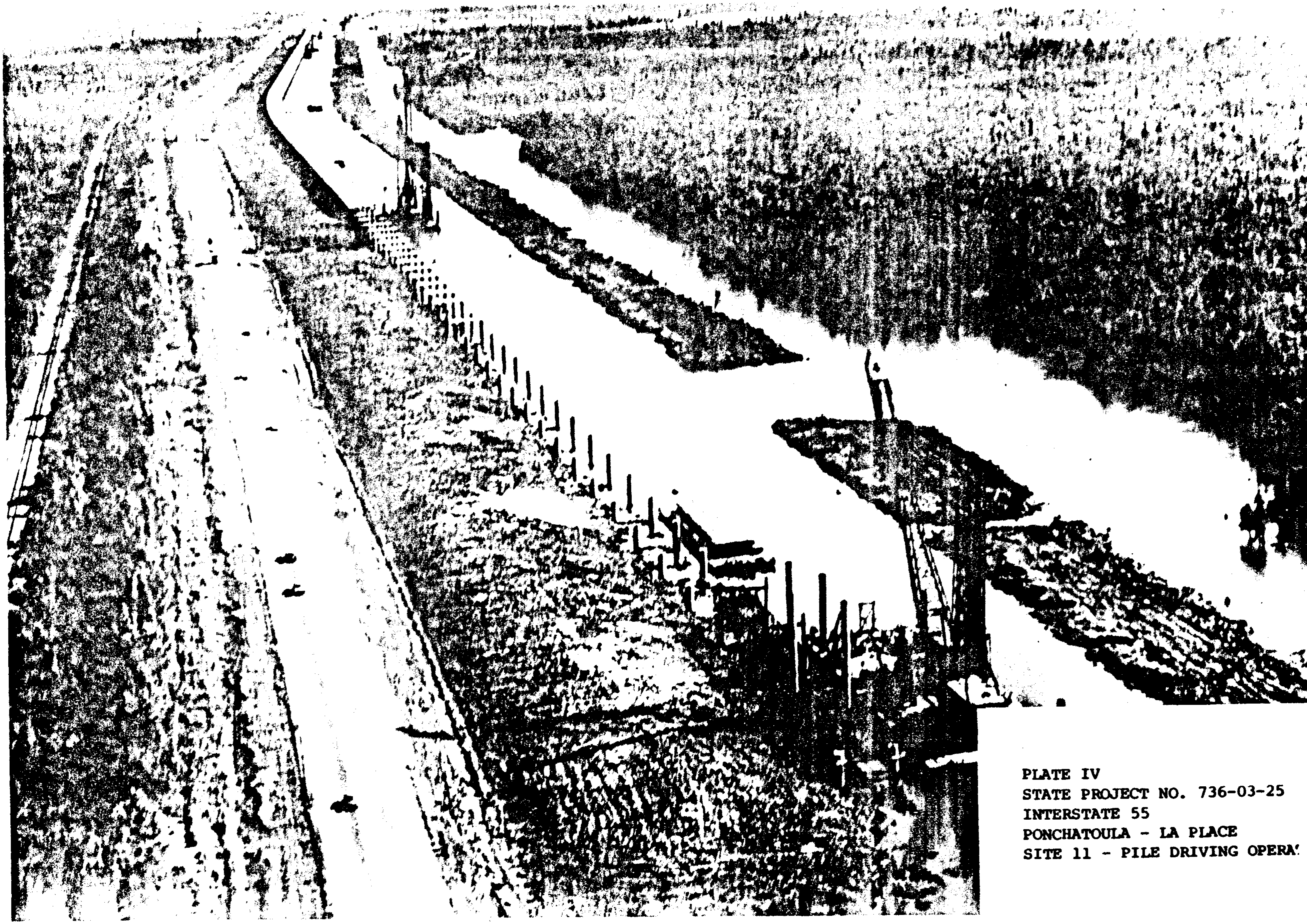

PLATE IV
STATE PROJECT NO. 736-03-25
INTERSTATE 55
PONCHATOULA - LA PLACE
SITE 11 - PILE DRIVING OPERA'

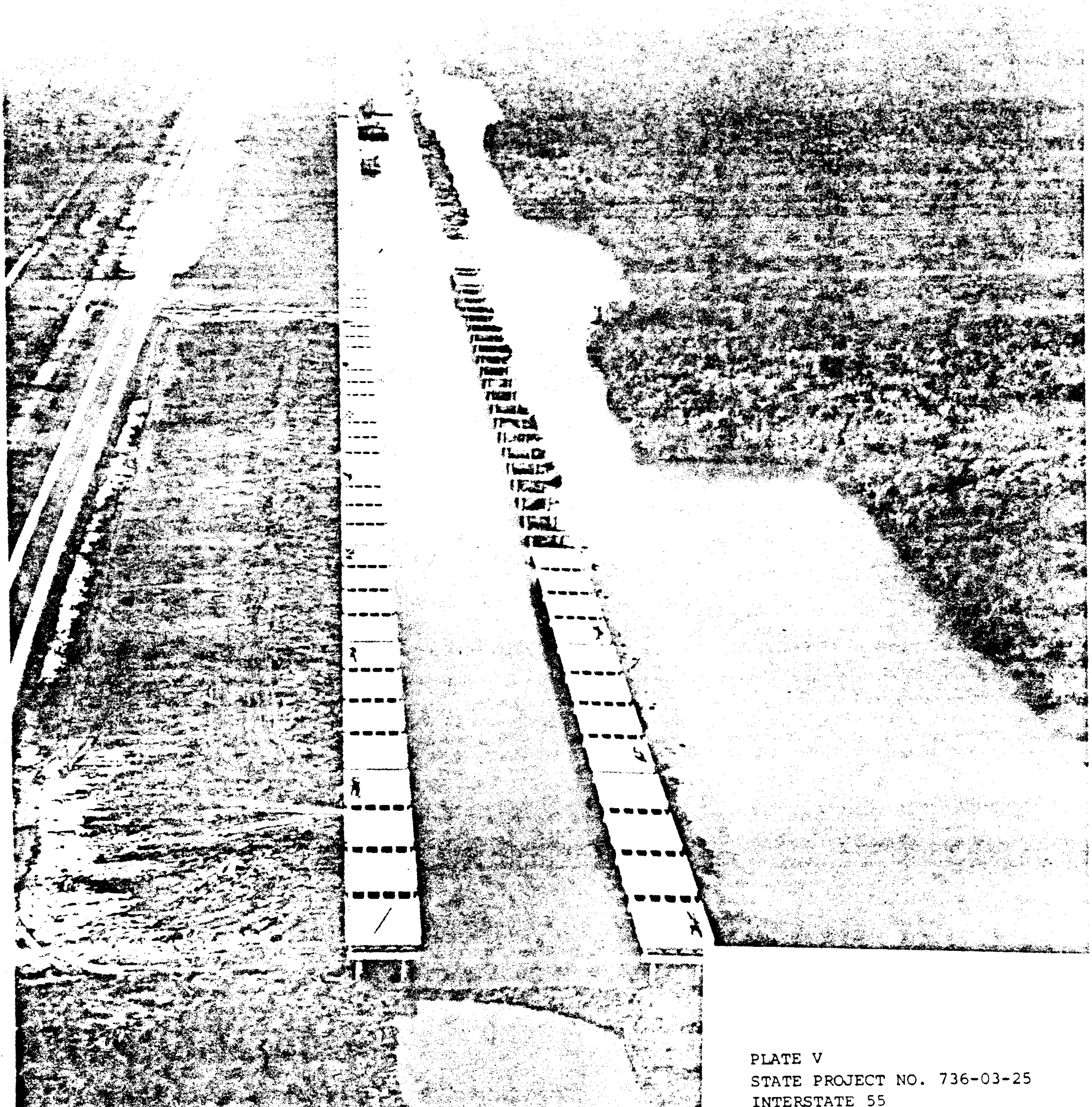

PLATE V
STATE PROJECT NO. 736-03-25
INTERSTATE 55
PONCHATOULA - LA PLACE
SITES 7 & 6 - DECKING OPERATION

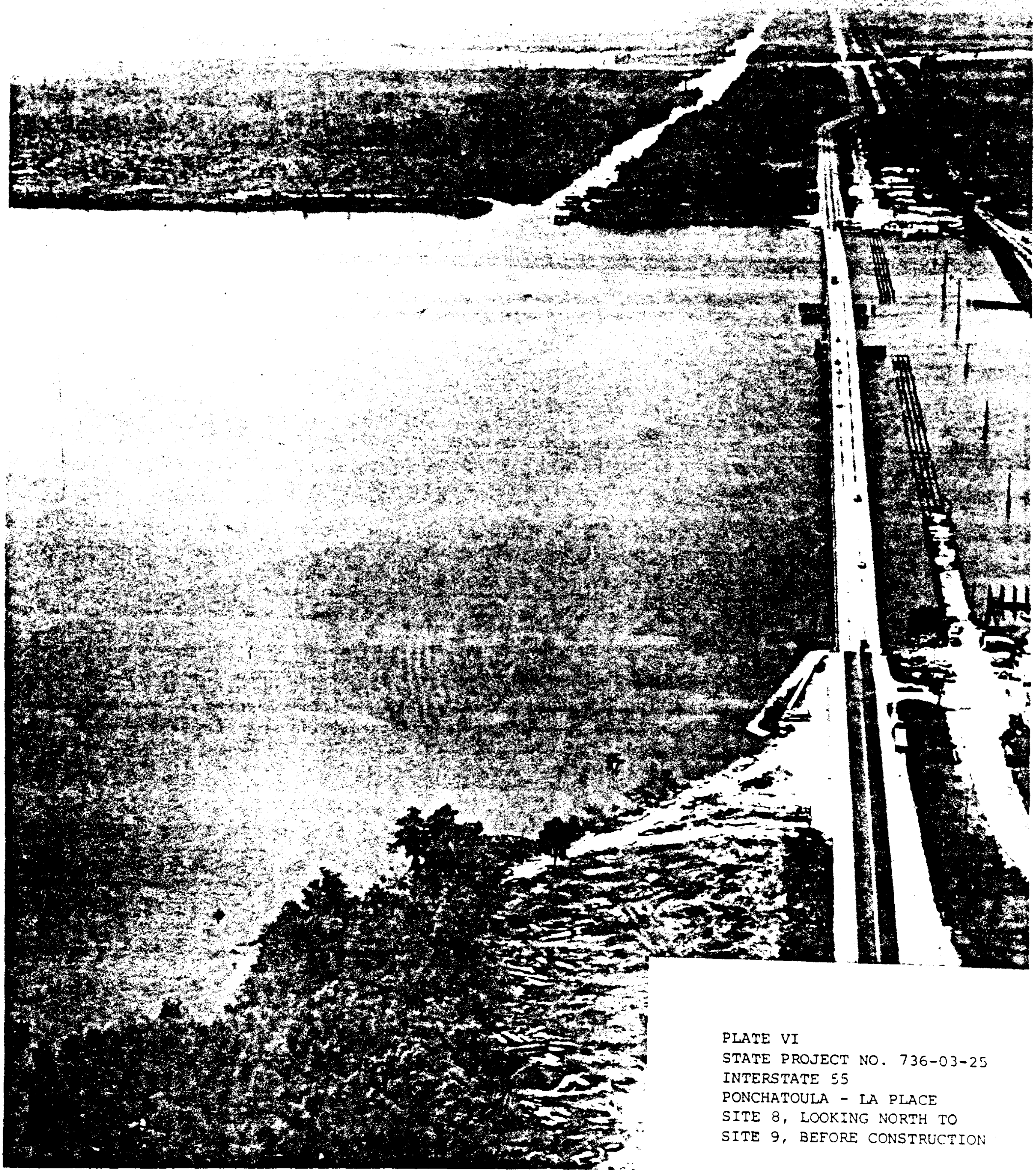

PLATE VI
STATE PROJECT NO. 736-03-25
INTERSTATE 55
PONCHATOULA - LA PLACE
SITE 8, LOOKING NORTH TO
SITE 9, BEFORE CONSTRUCTION

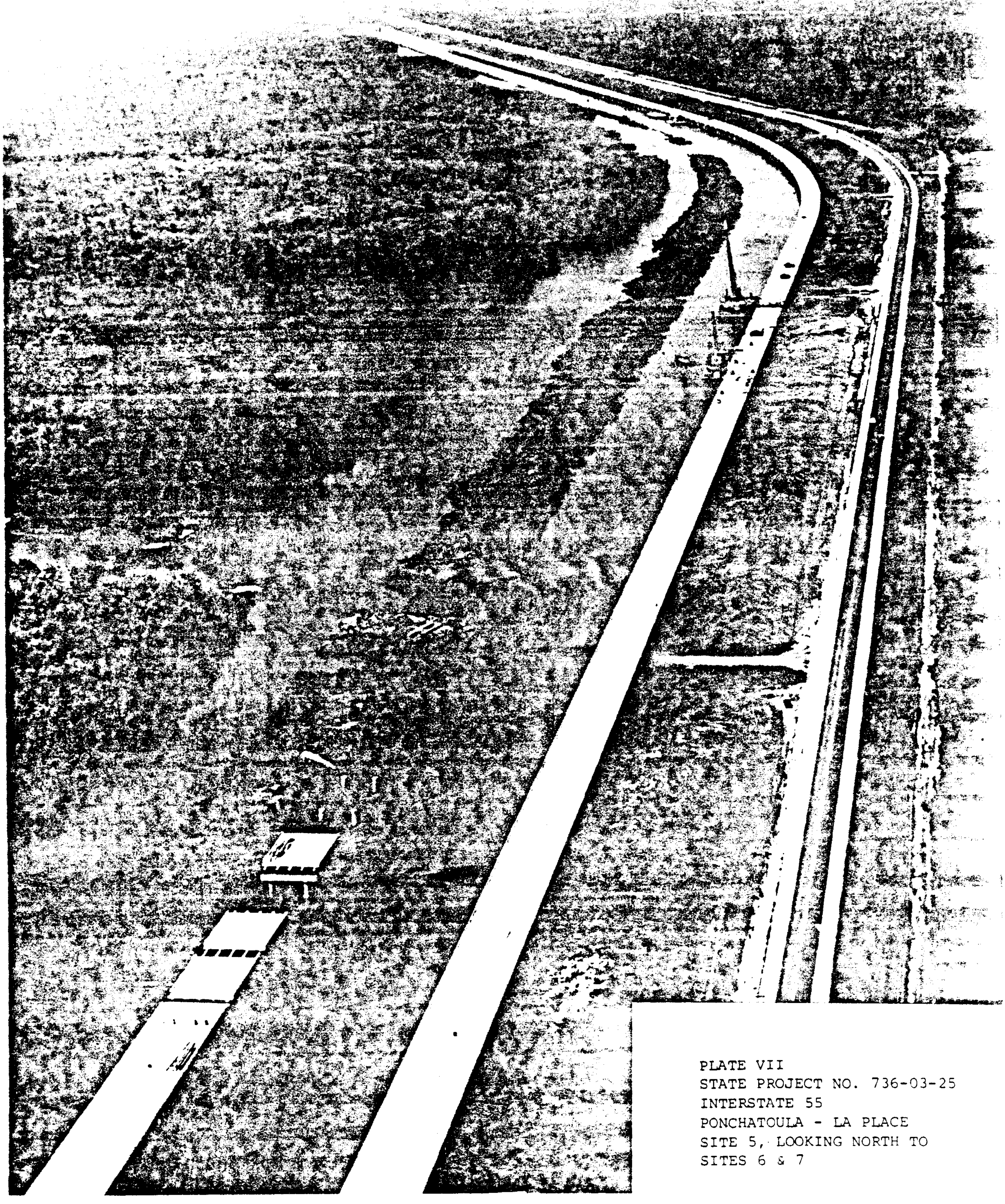

PLATE VII
STATE PROJECT NO. 736-03-25
INTERSTATE 55
PONCHATOULA - LA PLACE
SITE 5, LOOKING NORTH TO
SITES 6 & 7

CONSTRUCTION

For the purposes of this study, construction is defined as any activity preparatory to or a part of the actual erection of the superstructure. This includes such activities as clearing, grubbing, grading, filling, embankment development, and all structural work on the superstructure. This does not include finish work such as barrier rails, signs, safety markers, etc.

Non-construction indicates that none of the above activities were in progress at the time of sampling.

EQUIPMENT

All of the equipment used in this monitoring study was furnished by the Environmental Testing Section of the Louisiana Department of Transportation and Development. The equipment may be broken down into two usage categories, namely field and laboratory equipment.

Field equipment included the following: 20' water research boat, Hach DR-EL field kit, YSI model 51B dissolved oxygen meter, YSI SCT meter, and a water sample collector.

Laboratory equipment used in the water analysis for this research included the following: nephelometer for measuring turbidity, spectrophotometer for measuring color, Corning pH meter.

MEASURED PARAMETERS

The parameters selected for monitoring in this study were grouped into two categories. The first category included all parameters measured in the field study such as temperature, salinity, conductivity and dissolved oxygen. The second category was the laboratory study in which turbidity, color, pH, nutrients, and periodic oil and grease samples were evaluated.

While there are many parameters to explore in a water monitoring study, it was concluded that the ones mentioned above, specifically turbidity, salinity, and dissolved oxygen would be most directly affected by a highway-related construction project.

TABLE 2

ORIGINAL SAMPLING SCHEDULE

PARAMETER	BEFORE CONSTRUCTION	DURING CONSTRUCTION	AFTER CONSTRUCTION
Turbidity	1 per week	2 per week	1 per week
Chemical Analysis	2 per month	2 per month	2 per month
Algae	Quarterly	Quarterly	Quarterly

NOTE: More frequent sampling would occur in the case of increased runoff or unusual events.

TABLE 3

MODIFIED SAMPLING SCHEDULE

PARAMETER	BEFORE CONSTRUCTION	DURING CONSTRUCTION	AFTER CONSTRUCTION
Turbidity	2 per week	2 per week*	2 per week**
Conductivity	2 per week	2 per week*	2 per week
Dissolved Oxygen	2 per week	2 per week*	2 per week

* Sampling rates listed are minimum figures and are only used as guidelines.

** Rate of sampling may be decreased to 1 sample per month while trying to establish the return rate to the ambient condition.

PRELIMINARY DATA ANALYSIS AND INTERPRETATION

The only parameters considered at the publication of this interim report are those of turbidity, salinity, and dissolved oxygen. These parameters are interrelated and are discussed as such. Other parameters will be included and analyzed in the final report. The results of sampling and testing at each site for these three parameters are summarized in Appendix B. For each parameter, these tables give: the total number of samples taken at each site for the period of May, 1975 to December, 1977, the mean for each site, and the standard deviation of the samples taken during this period of time for each site. The data have been divided and analyzed in relationship to preconstruction, construction, and post construction time frames.

DATA ANALYSIS

Table 4 is a listing of the data on various water quality criteria at selected construction sites. The sites (5-7) are those which had the most complete data in the before, during, and after construction time frames. The data represent means of samples at the sites. The variability of the pooled data is expressed sigma, the standard deviation of the observations. The magnitude of the standard deviation should be considered as a measure of the variability associated with material, sampling, and testing. Because of problems with the sampling plans as designed, it is difficult to isolate the magnitude of this variable assignable to these various components.

In order to determine the effect of construction on water quality, the statistical "t" test was applied to the water quality data at hand. Basically, it is desired to determine whether the means of two different samples could have come from the same populations, or from populations with the same means. In the present case of water quality, it is important to know whether the mean water quality before construction, as measured by some criteria, is significantly affected due to construction activity. Appendix B is a listing of the means obtained on various water quality criteria before or after construction and during construction.

SITE & PARAMETER*	NON CONSTRUCTION			CONSTRUCTION			T-TEST
	N 1	X1 BAR	SIGMA 1	N 2	X2 BAR	SIGMA 2	T
SITE 5							
Turbidity (NTU's)	25	13.40	7.72	22	16.19	11.33	-0.97 (NS)
Salinity (PPT)	18	0.41	0.28	17	0.81	1.35	-1.20 (NS)
Dissolved O_2 (ppm)	19	3.87	1.66	13	5.53	2.30	-2.38 *
SITE 6							
Turbidity (NTU's)	29	17.45	13.30	16	29.58	21.59	-2.04 *
Salinity (PPT)	25	0.66	0.85	11	0.90	1.42	-0.52 (NS)
Dissolved O_2 (ppm)	20	3.99	1.62	12	4.55	1.99	-0.87 (NS)
SITE 7							
Turbidity (NTU's)	30	17.18	11.12	15	28.65	15.38	-2.86 *
Salinity (PPT)	23	0.58	0.82	11	0.87	1.15	-0.84 (NS)
Dissolved O_2 (ppm)	19	4.26	1.51	11	5.94	1.99	-2.61 *

(NS) means not significant.

* means significant at the .05 probability level.

TABLE 4
COMPARISON OF POOLED DATA
FOR NON CONSTRUCTION AGAINST CONSTRUCTION

The t test was applied to data from sites 5 through 8 only. The pre- and post construction data were pooled to give the mean value (X1 BAR) representing non-construction activity and the construction activity mean is represented by the column X2 BAR. The calculated T values are also shown in the table. These values are compared to the tabulated T values. When the calculated values do not exceed the tabulated values, it is concluded that the difference between the means is not significant in a statistical sense.

From the table it is seen that at least one of the water quality criteria at sites 5, 6 and 7 indicate significantly greater mean during construction than before or after construction activity.

At site 8, the water quality criteria are responding atypically, that is, there were no significant changes during construction; however, the turbidity increased significantly after construction was completed. It should be noted here that site 8 is at the junction of Pass Manchac and the borrow canal, and that periods of high turbidity have been observed in the Pass. When no inference is drawn, it is really saying that with the observed variation of the measurements involved it is not possible to tell whether the observed difference between the means is due to some real cause or is due to fluctuation in measurements.

CONSTRUCTION DATA

Construction progress is presented in the form of a graph (Appendix A) showing the activity that occurred at each of the sampling sites during each month of the study period. The construction progress as presented in the graph was used to determine the time frame and therefore, the construction phase to be associated with each site at all sampling times.

TEST DATA

TURBIDITY

Turbidity is the term used to describe the degree of opaqueness produced in the water by suspended particulate matter. It is measured in NTU's (nephelmetric turbidity units), an expression of the optical properties of a sample which causes light rays to be scattered at a 90° angle. The major effects of high turbidity are (1) the quenching of light penetration, thereby inhibiting photosynthesis and the production of oxygen by plants, (2) the building of zones of mud, silt, other sediments and detritus and (3) depletion of the dissolved oxygen as a result of respiration in the breaking down of suspended organic materials.

In an activity such as highway construction, an increase in turbidity may be caused by the introduction into the water of such materials as humus, clay, silt, organic detritus, colloidal matter and plant matter or resuspension of materials already in the sediments.

It must be noted that turbidity is not a uniform parameter even within a specific body of water. Seasonal increases in rainfall, runoff and stream discharge, for example, may introduce considerable amounts of silt and other sediments and materials, thereby altering the water's color and turbidity.

Preliminary results of the turbidity sampling are shown in Appendix B. The results given are the periodic - construction phase means and standard deviations for each site. The sites (Nos. 1-15) are identified in the introduction followed the construction which generally proceeded from south to north.

The data seem to show that the naturally high turbidities were probably intensified by construction activities such as clearing and grubbing which expose the soil. The most probable indicator of the degree of the effects of construction on water turbidity is the change in the range of variation (standard deviation) of the turbidity values.

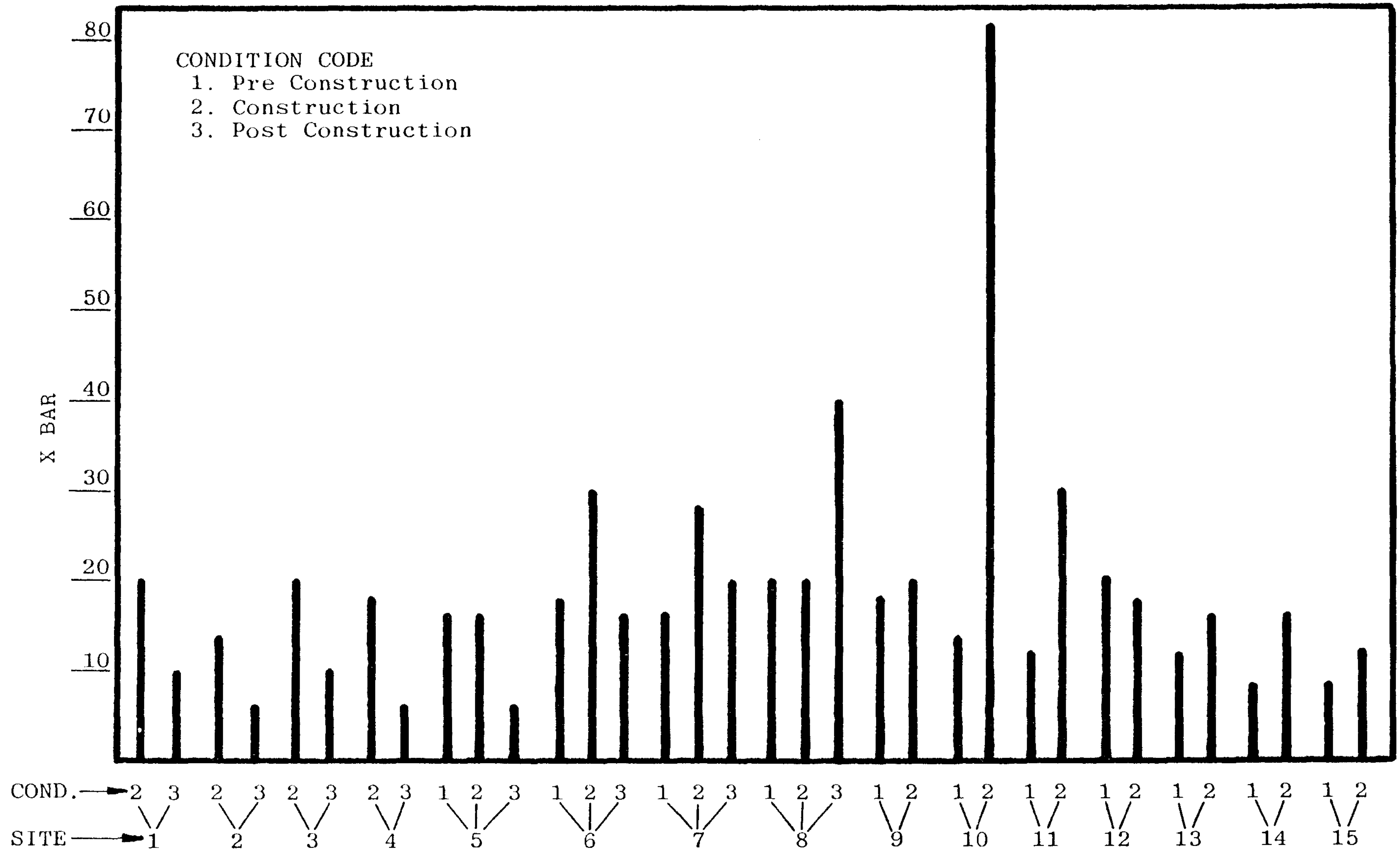

FIGURE 2

COMPARISON OF MEAN TURBIDITY VALUES AT DIFFERENT LEVELS OF CONSTRUCTION

At the sampling sites (1-4) in the southern part of the study area, construction was well under way when sampling began in May of 1975. These areas had high turbidities and large variations in turbidity at the start of the study but have generally shown continuing decreases in both turbidity and turbidity instability to the end of 1977. This is graphically represented in Figure 2, and statistically presented in Appendix B.

In the northern part of the study area (sites 9-15), construction began some time after sampling was under way and is presently in progress. These areas showed a tendency towards increases in turbidity and turbidity fluctuations when construction began and have not yet shown significant decrease toward ambient conditions.

The middle sites (5-7) show the same trends indicated earlier, that is: (1) turbidities may be increased by construction activities, (2) turbidity instability may be increased even more drastically by construction activity, and (3) after construction activity is completed, the turbidity and the variation in it tend to return towards that of preconstruction conditions. Trends 1 and 3 may be seen in graphic form in Figure 2, and Trend 2 statistically in Appendix B.

SALINITY

Salinity is a measure of the concentration of dissolved salts in water and is expressed as parts per thousand (0/00). The salinity of sea water averages about 35 0/00 while fresh water is generally less than 0.3 0/00.

Construction may influence salinity by allowing salt water to intrude into fresh water areas through dredged canals. "Salinity affects the numbers and kinds of animals that can live in the area. Salinity also affects the amount of oxygen that can be dissolved in the water" (Cole) (5).

Salinity is naturally high at sites 8 and 9 which are located at Pass Manchac. Other sites were generally below 1 0/00 but experienced occasional short periods of high salinity. This

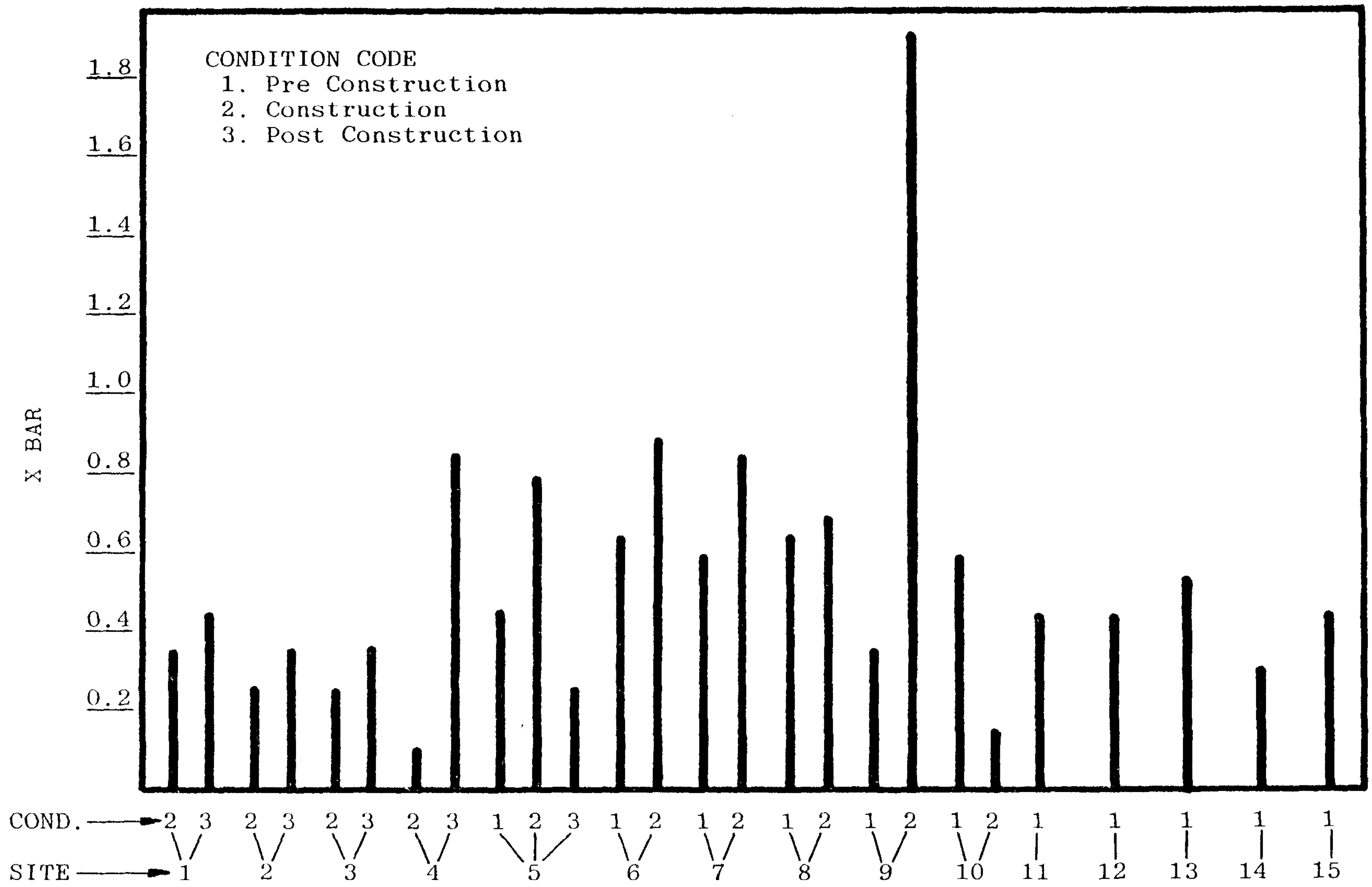

FIGURE 3

COMPARISON OF MEAN SALINITY VALUES AT DIFFERENT LEVELS OF CONSTRUCTION occurs naturally when esturine waters are brought in by tidal flow and wind action. "However, the magnitude of this flushing action can be increased by man-made canals" (Odom) (10). The preliminary data indicate there is a fluctuation in salinity; however, the data is insufficient to attribute the fluctuation to any activities or controlled variables. The data is shown in graphical form in Figure 3, and statistically in Appendix B. Further study is recommended.

DISSOLVED OXYGEN

The amount of oxygen found in the water and available for use by aquatic flora and fauna is termed dissolved oxygen. Dissolved oxygen is reported as parts per million (ppm). "The volume of oxygen dissolved in water at a given time is dependent upon (1) the temperature of the water, (2) the partial pressure of the air in contact with the water, (3) the concentration of dissolved salts (Salinity) in the water, and (4) the amount of suspended material in the water" (Cole) (5). "The solubility of oxygen in water is increased by a decrease in temperature and would decrease with an increase in salinity" (Cole) (5). "Dissolved oxygen concentrations are also influenced by the flow of water, wind action, photosynthesis and respiration" (Cole) (5).

"Highway construction affects dissolved oxygen by primarily introducing materials into the water which deplete the oxygen supply when they are decomposed" (Hopkins) (7).

The data show that the lowest dissolved oxygen concentrations occurred in the late summer months. This is caused by several factors: "water temperatures reaching their maxima in late summer hold less oxygen in solution; decreased discharge results in diminished physical mixing and reoxygenation; and greater decomposition of summer-produced organic material consumes much of the available oxygen" (Cole) (5). This is the time of year when construction activities could have the potential for greatest harm.

The data also show some extremely low dissolved oxygen concentrations in the far northern section of the study area (sites 14 and 15). These low concentrations caused fish kills in the

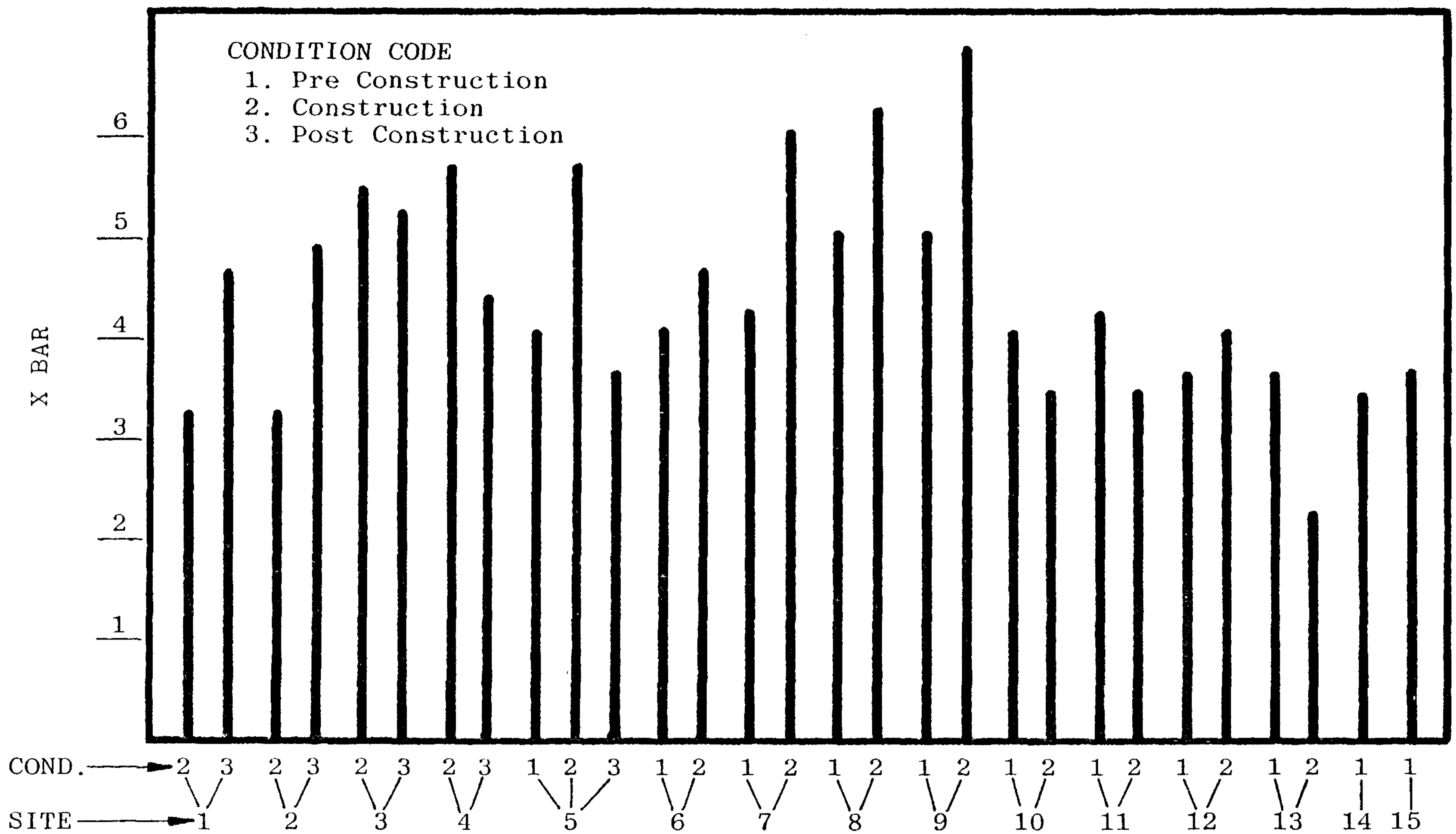

FIGURE 4

COMPARISON OF MEAN DISSOLVED OXYGEN VALUES AT DIFFERENT LEVELS OF CONSTRUCTION late summer of 1976. Investigation of this problem showed the presence of coliform bacteria; an indicator of the presence of raw sewerage. The exact source of this pollution has not been determined but the coliform counts were highest at site 15 (south slough).

Further investigation is needed to determine the effects of construction on dissolved oxygen, since the data shows no trends or tendencies that can be identified and related to any of the controlled variables with the two exceptions shown above, and the possible influence of mixing and aeration caused by supply boat activity in the construction areas.

The dissolved oxygen data is shown graphically in Figure 4, and statistically in Appendix B.

PRELIMINARY CONCLUSIONS

The preliminary study shows that construction does have at least some temporary impacts on water quality.

The data also indicates that in those areas where construction is complete there is a continuing trend towards returning to the ambient, preconstruction water quality conditions. See Table 4, Figures 2, 3, 4 and Appendix B. From this we can conclude that the impact of construction on water quality is probably of a temporary nature. However, in order to better assess the degree of impact and the rate of recovery, the study should be continued for some time after all construction is complete.

With further research in this area, there is the possibility of developing a mathematical model for the prediction of the effects of public works on wetlands, and the ability of the wetlands to recover. However, before this can be attempted, the sequence of events in the wetlands that are affected by construction needs greater isolation, identification, and understanding.

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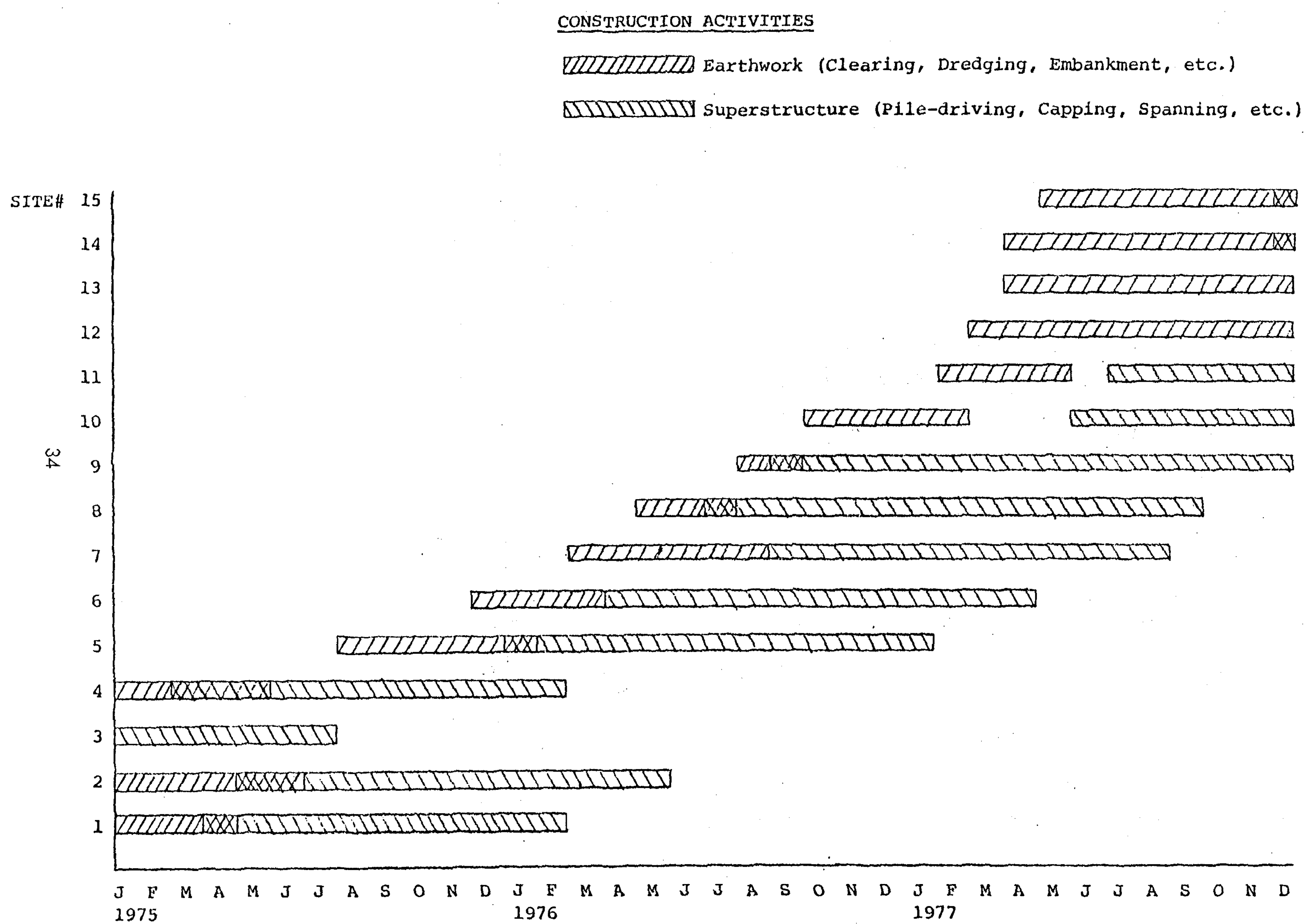
APPENDIX A

Graph of
Progress of Construction Activities


CONSTRUCTION ACTIVITIES
Earthwork (Clearing, Dredging, Embankment, etc.)
Superstructure (Pile-driving, Capping, Spanning, etc.)
SITE# 15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1975
1976
1977

APPENDIX B

Water Quality Data Recap
by Construction Phase

SITE & PARAMETER	PRECONSTRUCTION			CONSTRUCTION			POST CONSTRUCTION		
	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.
SITE 1									
Turbidity*	N/A			33	20.71	20.67	15	9.52	7.13
Salinity*	N/A			28	0.33	0.41	7	0.46	0.42
Dissolved O_2*	N/A			25	3.14	2.07	9	4.50	1.63
SITE 2									
Turbidity	N/A			29	14.14	17.41	12	5.08	2.66
Salinity	N/A			28	0.24	0.25	6	0.37	0.38
Dissolved O_2	N/A			25	3.17	1.95	7	4.86	1.88
SITE 3									
Turbidity	N/A			16	19.19	14.38	29	9.08	5.64
Salinity	N/A			13	0.27	0.23	19	0.36	0.34
Dissolved O_2	N/A			15	5.42	1.43	16	5.17	1.55
SITE 4									
Turbidity	N/A			29	18.12	20.57	17	6.77	4.49
Salinity	N/A			27	0.12	2.39	8	0.84	1.32
Dissolved O_2	N/A			23	5.69	1.60	9	4.49	2.03
SITE 5									
Turbidity	17	15.82	7.61	22	16.19	11.33	8	6.00	2.78
Salinity	16	0.43	0.27	17	0.81	1.35	2	0.25	0.35
Dissolved O_2	16	3.91	1.48	13	5.53	2.30	3	3.67	2.89

**Units of measure:* turbidity - NTUS, salinity - parts per thousand, dissolved oxygen - parts per million.

SITE & PARAMETER	PRECONSTRUCTION			CONSTRUCTION			POST CONSTRUCTION		
	N	$\overline{X}$	S.D.	N	$\overline{X}$	S.D.	N	$\overline{X}$	S.D.
SITE 6									
Turbidity	24	17.94	10.83	16	29.58	21.59	5	15.06	23.55
Salinity	25	0.66	0.85	11	0.90	1.42	N/A		
Dissolved O_2	20	3.99	1.62	12	4.55	1.99	N/A		
SITE 7									
Turbidity	25	16.73	7.79	15	28.65	15.38	5	19.44	22.90
Salinity	23	0.58	0.82	11	0.87	1.15	N/A		
Dissolved O_2	19	4.26	1.51	11	5.94	1.99	N/A		
SITE 8									
Turbidity	31	19.15	11.00	14	19.69	15.64	2	39.00	22.63
Salinity	29	0.66	1.10	8	0.71	0.77	N/A		
Dissolved O_2	24	5.05	2.28	9	6.12	2.27	N/A	N/A	
SITE 9									
Turbidity	37	18.62	12.68	11	19.90	20.19	N/A		
Salinity	33	0.36	0.32	5	1.96	2.26	N/A		
Dissolved O_2	23	4.96	2.22	6	6.82	2.20	N/A		
SITE 10									
Turbidity	39	13.00	11.39	8	82.34	137.20	N/A		
Salinity	34	0.61	1.11	3	.13	0.23	N/A		
Dissolved O_2	24	4.01	1.46	3	3.40	2.23	N/A		

SITE & PARAMETER	PRECONSTRUCTION			CONSTRUCTION			POST CONSTRUCTION		
	N	$\overline{X}$	S.D.	N	$\overline{X}$	S.D.	N	$\overline{X}$	S.D.
SITE 11									
Turbidity	39	11.54	10.62	9	29.96	38.76	N/A		
Salinity	30	0.45	0.49	2	0.00	0.00	N/A		
Dissolved O_2	22	4.13	1.88	2	3.40	2.26	N/A		
SITE 12									
Turbidity	37	19.84	39.39	6	17.27	21.72	N/A		
Salinity	31	0.45	0.64	2	0.00	0.00	N/A		
Dissolved O_2	27	3.67	1.79	2	4.00	2.55	N/A		
SITE 13									
Turbidity	41	12.29	16.05	7	16.64	21.68	N/A		
Salinity	35	0.53	0.89	1	0.00	1.00	N/A		
Dissolved O_2	27	3.62	3.28	1	2.20	1.00	N/A		
SITE 14									
Turbidity	19	7.47	6.76	4	15.28	19.96	N/A		
Salinity	13	0.31	0.57	N/A			N/A		
Dissolved O_2	10	3.42	2.35	N/A			N/A		
SITE 15									
Turbidity	20	8.70	8.52	6	12.12	6.41	N/A		
Salinity	14	0.43	0.71	N/A			N/A		
Dissolved O_2	10	3.54	2.53	N/A			N/A		