St. Mary's River Remedial Action Plan

St. Mary's Rapids Hydrology Study

by Environmental Hydraulics Group
for the St. Mary's River RAP Team
March 1995

ST. MARYS RIVER
REMEDIAL ACTION PLAN

PREFACE

This report has been prepared under the auspices of the Canada-Ontario Great Lakes Remedial Action Plan Program. Financial support for the preparation of this report was provided by Environment Canada through the Great Lakes 2000 Cleanup Fund, and the Canada Department of Fisheries and Oceans.

This report is part of a series of investigations conducted in support of the Lake Superior Remedial Action Plan Program. It represents the findings, recommendations and conclusions of the authors and individuals cited, and does not necessarily represent the views or policies of the supporting agencies.

EXECUTIVE SUMMARY

St. Marys River Area of Concern has historically experienced reductions in fish habitat due to the reduction of flow and size of the rapids area. In order to guide the design of remedial options, information on the rapids hydraulics is required.

It was the purpose of the present study to define the hydraulic characteristics and constraints pertaining to increasing the watered area in the Rapids with a minimum possible flow requirement.

In this study, the advanced analytic technique, two dimensional computer model, was applied to improve the conventional one dimensional model. Better understanding and more accurate calculation were achieved with this 2-D modelling application.

For the Rapids north of the berm, the current gate operation has been providing flow passage and spawning areas for various species of fish. With the proposed remedial work, e.g. berm improvement together with the increase of gate discharge or channel alteration, significant increase of watered area and more optimal flow velocity can be achieved.

For the Rapids south of the berm, high flow velocity and shallow water have been experienced at the steep fall areas. With the gate opening closer to the south, more area of the Rapids would be watered. Virtually all the existing dry area in the Rapids will be submerged if discharge can be increased from 1/2 to 2 gate opening. For 1 gate opening condition, almost all the central islands would disappear while most of the dry areas along U.S. shore and the berm would remain.

The proposed pseudo-rapids type habitat adjacent to the base of the Rapids will not affect materially the flow, hydraulic and substrate characteristics of the upstream Rapids area.

The near shore area east of Whitefish Island is a good location for the potential wetland creation and this is strongly recommended.

Field tests and surveys have been proposed as a supplement to the present hydraulic analysis. A combined effort of both the numerical model and the full scale physical model analysis (i.e. field test) should provide an accurate and cost effective solution to increase the valuable watered area in the St. Mary Rapids.

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1. INTRODUCTION

1.1 Study Area

The study area, St. Marys Rapids, is bounded to the west by the Compensating Works to the east by the end of the concrete berm, to the north by the water edge of Whitefish Island and to the south by the U.S. river bank. The total rapids area, 29.68 ha, is separated by the 800 m long concrete berm. (Figure 1.1)

Flow over the 6.25 ha rapids north of the berm is supplied by Gate #1 of the Compensating Works and the 23.43 ha rapids south of the berm receives water from the other 15 gates (Gate #2 to #16).

1.2 Study Background

The reduction in size of the St. Marys Rapids and the reduction in discharge over these reduced rapids have been identified as potentially the most important historical reductions in fish habitat in the St. Marys River Area of Concern. Preliminary remedial options have been developed for increasing the watered area of the remaining Rapids as well as the creation or enlargement of rapids habitat elsewhere in the St. Marys River Area of Concern. Further information on rapids hydraulics is required before refining these options into an implementable form.

Historically the rapids emptied into a large area of wetland, virtually all of which has been removed or in-filled. The possibility of constructing a wetland or wetland-like habitat adjacent to the base of the Rapids needs to be investigated for the re-establishment of a rapids/nursery habitat linkage.

1.3 Study Objectives

The main objective of this study is:

> To regain the maximum possible watered area from St. Mary Rapids with the minimum possible flow requirement.

In order to fulfil this objective, the following tasks have to be undertaken:

- i) Determine the watered area for different discharges from the Compensating Works.
- ii) Optimize the location and alternative gate opening combinations for the rapids south of the berm.
- iii) Allocate a flow passage (i.e. flow pattern, depth and velocity) for fishery movement.
- iv) Investigate the hydraulic impact of the proposed remedial work at the base of the rapids.
- v) Assess the potential for creation of a wetland area east of Whitefish Island.

1.3 Study Approach

Based on the objective and tasks of the project, the study approach encompasses the following steps:

i) A review of the St. Marys Rapids hydrologic and hydraulic data including the historical discharge rate to the Rapids and the flow distribution to different navigation and power facilities, and water level fluctuations.

ii) A review of existing and previously proposed remedial measures within the Rapids areas.

iii) A literature search with respect to hydraulics and sediment movement and other characteristics of rapids, as well as review with regulatory agencies and other fellow professionals to understand the rapids formation in general.

iv) The determination of flow pattern, velocity, depth and watered areas of the Rapids.

v) The assessment of remedial measures potential to improve the hydraulic conditions for fishery habitat.

vi) The presentation of conclusions with respect to the Rapids hydraulics and appropriate remedial measures to be undertaken.

1.4 Organization of Report

This introductory section, Section 1, provides a description on the general description and background of the study, the objectives, study approaches and the organization of the report. Following this section, Section 2 presents a number of methodologies for the study of the rapids characteristics. Section 3 provides a more detailed account of the data review and design conditions adopted in the present study. In Section 4, the hydraulic performance along the Rapids north of the berm is determined for the existing and proposed berm improvement condition. Section 5 determines the hydraulic characteristics and the impact of different gate combination on the Rapids south of the berm. Potential wetland creation east of Whitefish Island is discussed in Section 6. A future field test program is then presented in Section 7.

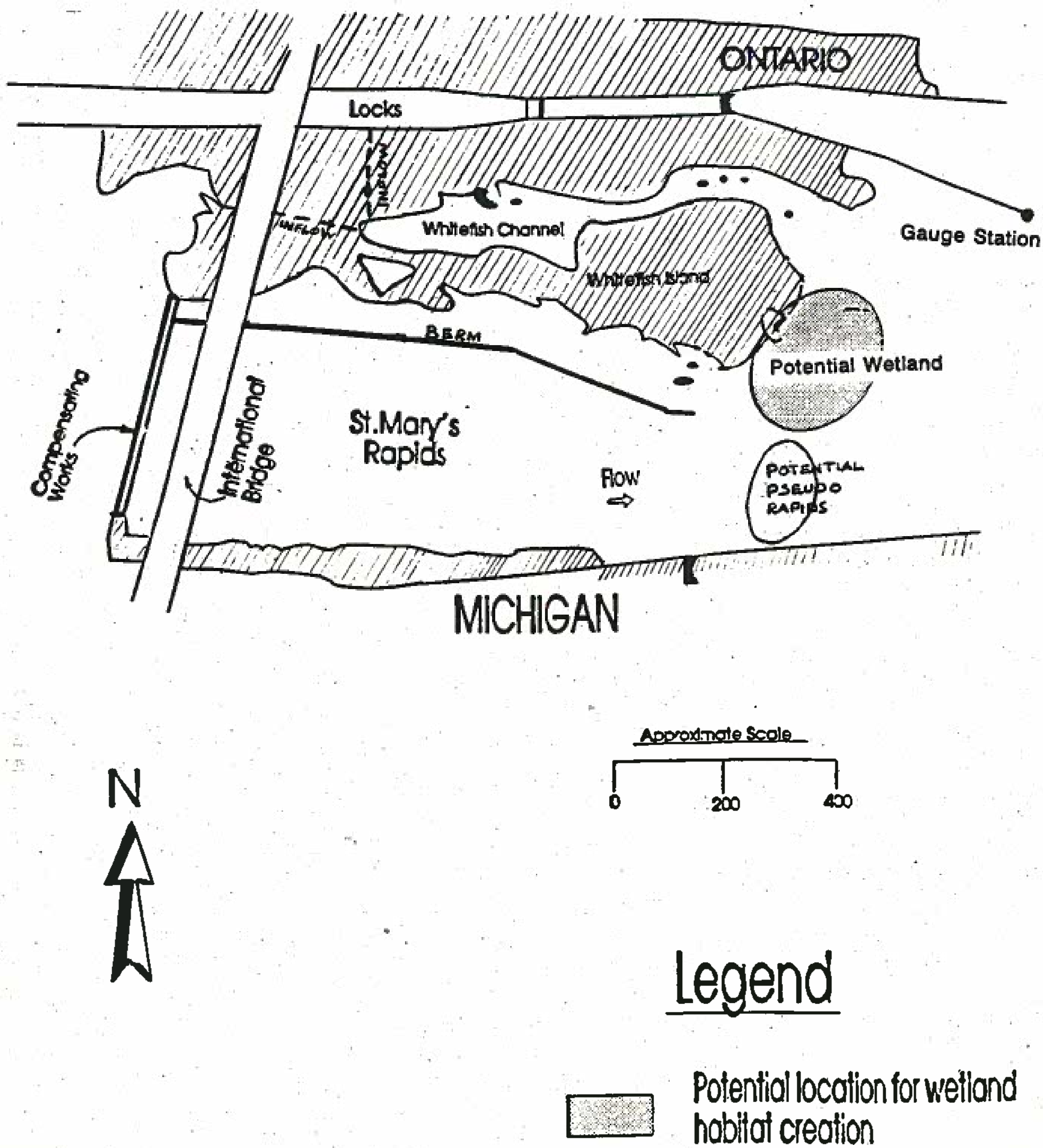


FIGURE 1.1 LOCATION MAP OF STUDY AREA

2. METHOD OF ANALYSIS

2.1 Alternative Methods of Rapids Hydraulic Analysis

There are a number of problem solving tools available for tackling the hydrology and hydraulics of St. Marys Rapid. These include:

i) A semi-empirical method which applies design charts or nomographs on the basis of past observations in laboratory, field and numerical simulations.

   This method is not recommended in this study because it is most likely to be useful only for a preliminary and conceptual analysis. Further, too many interpretations and adjustments have to be made in order to apply this method to a fast flowing river system.

ii) Numerical modelling which integrates the physical and hydraulic phenomenon in a complex river system, such as river rapids. A number of computer models can be used to investigate river hydraulics, including 1-D and 2-D (Dimensional) conditions. Both 1-D and 2-D numerical simulations have been included in the present study.

   This method can be used to carry out an extensive number of simulations and assess a wide range of alternative hydraulic conditions (such as the combination of gate openings). However, the lack or proper field data (e.g. topographic and bathymetric maps, flow rate and sediment movement) may handicap the application and the accuracy of this method.

iii) Physical Modelling - which observes and measures directly the river hydraulics in a smaller scale river system.

   This method is not recommended to be undertaken because of the complex geometry of the St. Marys Rapids, scale effect and not being cost-effective.

iv) Field Testing - This represents a full scale model study to obtain a large quantity of data at a reasonable cost. While the findings from the numerical model simulations (the present study) can be used to drastically reduce the number of field test requirements, the field testing is strongly recommended to verify or adjust the numerical models to cover a wider range of hydraulic and gate opening conditions.

   The scope of field work will be outlined in the Section 7.

2.2 Professional Discussions

General discussions were held with a number of individual professionals in the area of open channel hydraulic aspect, and their comments were solicited to evaluate the general characteristics and requirements of flow pattern, depth and velocity. The specialists who were contacted during this study are:

Dr. B.G. Krishnappan	Sr. Scientist	National Water Research Institute
Dr. A. McCorquodale	Professor	University of Windsor

Mr. J. Anderson	Hyd. Specialist	Golder Associates Ltd.
Mr. S. Bridgeman	Executive Engr.	Acres International Ltd.

Based on these discussions, it was felt that the semi-empirical and physical model methods may not be best suited for the present rapids hydraulic analysis. The field testing alternative would be the best to investigate hydraulic phenomenon in the rapids area. For the numerical modelling consideration, the two dimensional (2-D) model technique has not been fully established. The one dimensional (1-D) model should be used to provide guidelines for the preparation and set-up of the 2-D numerical modelling.

2.3 Numerical Model Selection

2.3.1 One Dimensional (1-D) Model

The most widely applied and documented 1-D model for backwater profiles in natural or man-made watercourses is the HEC-2 computer model, developed by the U.S. Army Corps of Engineers. The model requires a series of cross sections and hydraulic parameters depicting the main reaches of the river, usually established by changes in slope conveyance, roughness, or man-made structures. The basic computational procedure used in the model is the solution of the one-dimensional energy equations with energy losses due to friction, contraction and expansion. Full details of the HEC-2 model and its underlying theory are given in the user's manual (Ref. 8).

2.3.2 Two Dimensional (2-D) Model

The 2-D computer model, FESWMS-2DH, was adopted for the present hydraulic analysis in St. Marys Rapids. The model was developed by the U.S. Geological Survey, Water Resources Division. The numerical technique used to solve the governing equations is based on the Galerkin finite element method. With discharge and rapid geometries (i.e. river bed slope, elevation and roughness) given, the FESWMS-2DH model calculates depth-averaged horizontal velocities and water depth of watered areas, accounting for river bed and bank friction, fluid stresses caused by turbulence and other complicated hydraulic conditions that are difficult to evaluate using conventional methods. Full details of the FESWMS-2DH model and its underlying theory are given in the user's manual (Ref. 9).

Apart from the subject site, the FESWMS-2DH model can also be used for other rapid sites to determine the rapids characteristics for rapids habitat creation or enlargement.

2.3.3 Model Application

In this study, the HEC-2 model has been used for the entire Rapids area, both north and south of the berm. The more sophisticated FESWMS-2DH model has also been used for the investigation of different locations and combinations of gate openings in the Rapids areas where the two dimensional flow regime phenomenon govern. These areas include the rapids immediately downstream of the Compensating Works and the dry areas along the U.S. shoreline.

2.4 Model Files

All the input and output files of HEC-2 and FESWMS-2DH models have been documented in the floppy diskettes enclosed at the back of the report.

The modulus file of FESWMS-2DH is attached in the user's manual which was forwarded to the Department of Fisheries and Oceans separately.

3. DATA REVIEW AND ASSESSMENT

3.1 Literature Search

Valuable data and information have been extracted from books, papers and reports related to the subject of hydraulics in rapids. A list of the literature, manuals and references collected for the study from different sources is stated as below:

1. Acres International Ltd., November, 1988, "St. Mary's Rapids Remedial Measures - Study Description and Completion Report"

2. Acres International ltd., May, 1985, "St. Mary's Rapids Remedial Measures, Dyke Design and Hydraulic Modelling of the Upstream Reach"

3. International Lake System Board of Control, Sept. 1974, "Feasibility Study of Remedial Works in the St. Mary's Rapid at Sault Ste. Marie"

4. Lake Superior State University, July 1994. Unpublished Electrofishing Survey Data for U.S.Side of St. Marys River.

5. Krishka, Brian A., March 13, 1989, "St. Marys River Remedial Action Plan Background Fish Community, Habitat and User Information"

6. Koshinsky, G.D., and Edwards C.J., March 1983, "The Fish and Fisheries of St. Marys Rapids: An Analysis of Status with Reference to Water Discharge"

7. Stolyarenko, D.A., October 31, 1994, "Development of a Detailed Digital Bathymetric Map of the St. Marys River for Sea Lamprey Larval Sampling and Analysis with Survey Designer"

8. US Army Corps of Engineers, Hydrologic Engineering Center, 1989, "HEC-2 Water Surface Profiles of User's Manual".

9. US Dept. of Transportation, April, 1989, "FESWMS - 2DH, Finite Element Surface Water Modelling system: Two Dimensional flow in a Horizontal Plan",

Apart from the above listed, numerous existing reports on the St. Marys Rapids Remedial Measures, RAP reports, and electrofishing data collected by LSSU (Roger Greil and Dr. Dave Behmer) have been reviewed for pertinent information.

3.2 Individual and Agency Contact

A significant number of agencies and individuals were contacted during the course of the study in order to collect a large quantity of information and gain a more complete understanding of the Rapids hydraulics. The names of the persons that were contacted directly concerning the project are listed below:

Persons	Address	Telephone
Doug Geiling Bill Gardner	Department of Fisheries & Oceans Sault Ste. Marie	705-942-2848
Sue Greenwood	Ontario Min. Nat. Resources Sault Ste. Marie	705-949-1231
Harvey Walsh Tim Lee	Ontario Min. Nat. Resources Sudbury	705-675-4120
Mike Shaw	Environment Canada CCIW, Burlington	905-336-4957
Hans Demeel Stu Bridgeman	Acres Ltd. Niagara	904-374-5200
Peter Yee David Fay	St. Lawrence Regulation Environment Canada, Cornwall	613-938-5725
Stanley Jacek	US Corps of Engineers Sault Ste. Marie	906-635-3464
Ron Wilshaw Scott Thieme	US Corps of Engineers Detroit	313-226-6440 313-226-2395
Andy McPhee Rick Atkins Jim Beluzio	Great Lakes Power Sault Ste. Marie	705-941-5670 705-759-7622 705-941-5659
Robert Myslik Brian Magee	Environment Canada Monitoring & System, Guelph	519-823-4204 519-821-5002 (fax)
Doug Macmaster	Legal Survey Section Mine and Energy, Toronto	416-973-7514
Mike Murphy	Canadian Heritage Sault Ste. Marie	705-942-6262
Joe Cain	Municipal Hatchery Sault Ste. Marie	705-759-5446
Ken Dance	Dance Environmental Kitchener	519-570-1777 519-570-2233
Jim Anderson	Golder Asso. Ltd. Mississauga	905-723-2727
Rick Sandilands	Department of Fisheries & Oceans Burlington	905-336-4844

Dmitri Stolyarenko	University of Moncton, N.B.	244-239-4684 (Fax) 244-233-9482
Robert Young	Sea Lamprey, Control Centre Sault Ste. Marie	705-941-3003 705-941-3025 (Fax)
Gerral Conan	Environment Canada Moncton, N.B.	506-851-6227
John Cooley	Department of Fisheries & Oceans Burlington	905-336-4568
Victor Gillman	Department of Fisheries & Oceans Burlington	905-336-4567
Earl Brown	Hydrographic Survey	905-336-4567
Don Robertson	Hydrographic Survey	905-336-4731 905-336-8916 (Fax)

3.3 Field Investigation

Two field trips to St. Marys Rapids were made by the study team staff in November, 1994. The followings tasks have been carried out:

i) Field reconnaissance or inspection to the east end of Whitefish Island, concrete berm, Compensating Works and shoreline (U.S. side). Apart from foot patrol, the berm and potential wetland areas were also examined from a boat or by wading. A number of photos were taken during the field work.

ii) A Ponar dredge was used to sample soft substrate around the shallow water area east of Whitefish Island. These samples were examined in the lab for organic matter, aquatic plant debris and aquatic invertebrates. Water depth was measured. Shoreline vegetation and macrophyte occurrence were described and substrate conditions were noted.

iii) Water level differences between the two sides of the berm were observed and measured. The partial submergence of the berm and the turbulence condition north of the berm were also noted.

iv) Meetings were held with staff from various agencies in Sault Ste. Marie, including Ministry of Natural Resources, Department of Fisheries and Oceans and Sea Lamprey office.

v) Files of correspondences, reports, maps, aerial photos and other project related materials were reviewed and copied.

3.4 Data Collection and Evaluation

Among numerous data collected, the following three (3) items are the most relevant to the study and these are discussed as below:

3.4.1 Topographic Map

Topographic information in the St. Marys Rapids area is very limited. In this study, a contour map on the Rapids (Figure 3.1) was manually prepared by the study team based on the following information:

i) An aerial photo taken in April 1994 was used to interpret the rapid turbulence, fast and slow moving water bodies, dry and wet area during the 1/2 gate opening condition (Figure 3.2).

ii) Spot ground elevation marked on a 1:1200 scaled topographic map (Figure 3.1).

iii) Water depth sounding taken in 1988, for the Rapids along the south edge of Whitefish Island.

iv) As built data of the concrete berm.

v) Water depth sounding across the Rapids at about 100 m downstream of the concrete berm. Only one (1) cross section was taken by U.S. Army Corps of Engineers in August 1991.

3.4.2 Flow Released From Compensation Work

Flow rate discharged from the Compensating Work was calibrated for different gate opening conditions, varying from 1/2 to 16 gates by both U.S. Army Corps of Engineers and Environmental Canada (Figure 3.3). As shown in the figure, data from both sources are very close and their averaged values have been adopted in the present study.

During the all gates closed condition, leakage of 14 to 28 m3/s was estimated by the two agencies and other authors of previous studies. In the present hydraulic analysis, an average of 20 m3/s was assumed to account for this gate leakage flow rate.

Review of available data also suggest that the normal flow rates discharged from the Compensating Works are 14 m3/s (about 0.2 m Gate #1 opening) and 95 m3/s (equivalent to 1/2 gate opening) to the Rapids north and south of the berm respectively.

3.4.3 Water Level At Gauge Station

A Water Survey of Canada gauge was located about 500 m downstream of the Rapids area (Figure 1.1). As shown in Figure 3.4, the extreme water level may vary about two metres within the 85 years record. However, for most of the time, the water level fluctuates in a range of 0.5 m around 177.0 m above Sea Level.

Sensitivity tests were carried out to evaluate the backwater impact due to the extremely high and low starting water level. It was found that there is no hydraulic impact due to low water level. For high water level, the backwater effect does not extend more than 100 m upstream from the end of the berm, where the rapids area is completely submerged. In this hydraulic analysis, the normal water level of 177.0 m was used as the starting level.

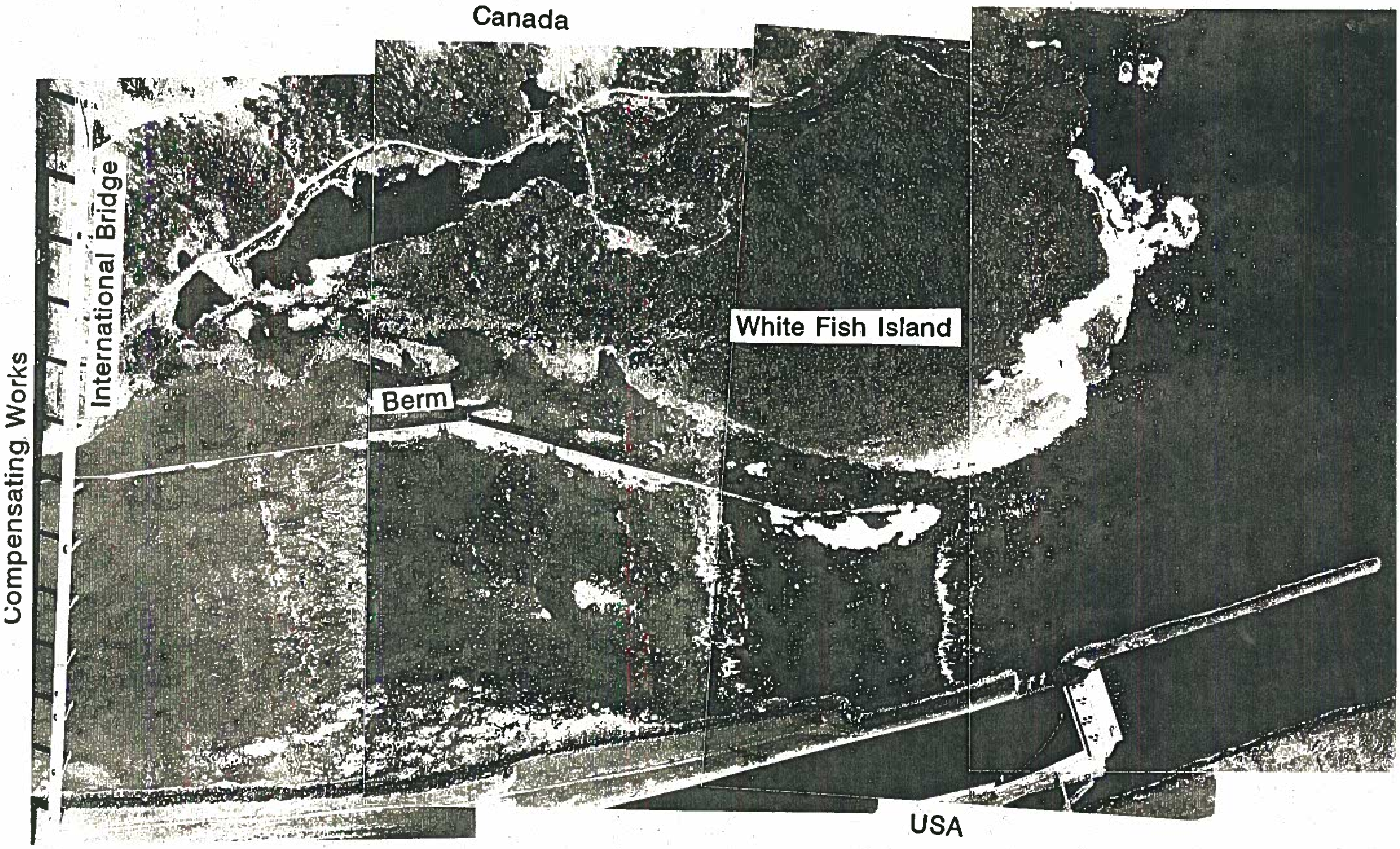
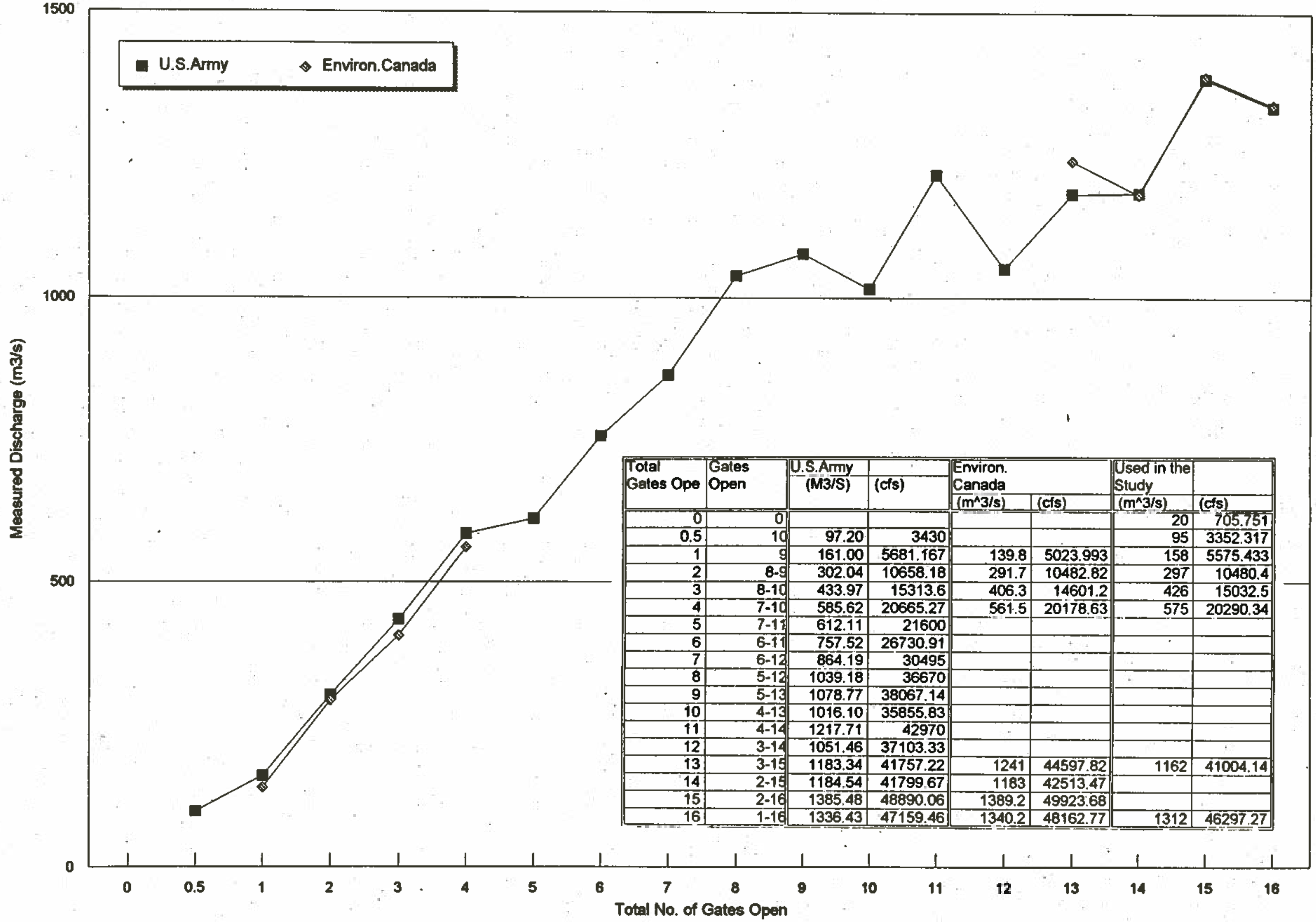


Figure 3.2: Aerial Photo of Study Area



Total Gates Ope	Gates Open	U.S.Army (M3/S)	(cfs)	Environ. Canada (m^3/s)	(cfs)	Used in the Study (m^3/s)	(cfs)
0	0					20	705.751
0.5	10	97.20	3430			95	3352.317
1	9	161.00	5681.167	139.8	5023.993	158	5575.433
2	8-9	302.04	10658.18	291.7	10482.82	297	10480.4
3	8-10	433.97	15313.6	406.3	14601.2	426	15032.5
4	7-10	585.62	20665.27	561.5	20178.63	575	20290.34
5	7-1[illegible]	612.11	21600				
6	6-11	757.52	26730.91				
7	6-12	864.19	30495				
8	5-12	1039.18	36670				
9	5-13	1078.77	38067.14				
10	4-13	1016.10	35855.83				
11	4-14	1217.71	42970				
12	3-14	1051.46	37103.33				
13	3-15	1183.34	41757.22	1241	44597.82	1162	41004.14
14	2-15	1184.54	41799.67	1183	42513.47		
15	2-16	1385.48	48890.06	1389.2	49923.68		
16	1-16	1336.43	47159.46	1340.2	48162.77	1312	46297.27

FIGURE 3.3 DISCHARGE vs. NUMBER OF GATES OPEN

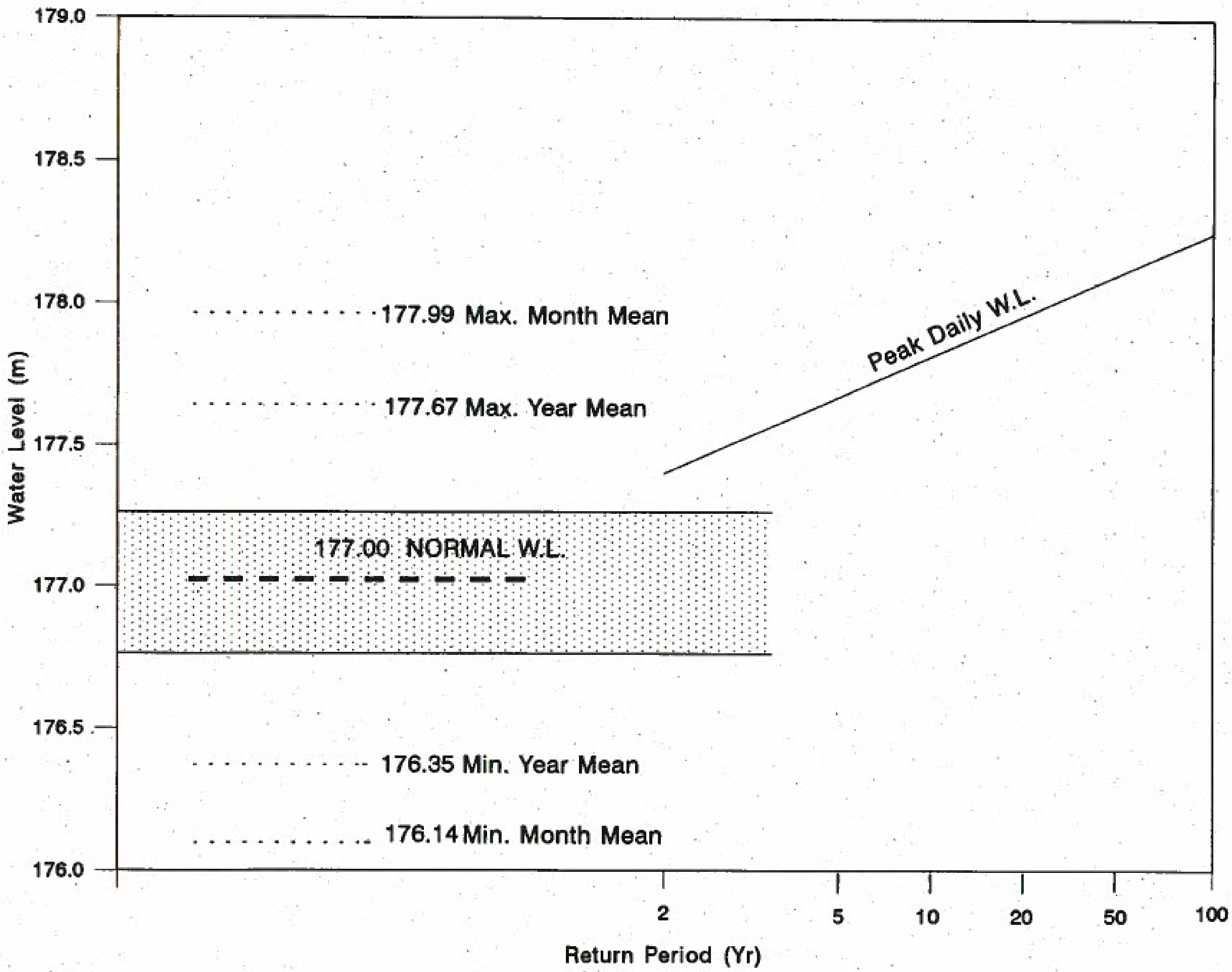


FIGURE 3.4 WATER LEVELS AT GAUGE STATION

4. HYDRAULIC ANALYSIS ALONG RAPIDS, NORTH OF BERM

4.1 Existing Hydraulic Condition

4.1.1 Model Application

HEC-2 was used in the analysis. This one dimensional (1-D) model is adequate in the hydraulic analysis for the Rapids north of the berm based on the following reasons:

i) Only one gate (Gate #1) supplies water to the area. The effect of different gate opening combination does not exist.

ii) With the berm in place, the width of the flow passage along the berm is relatively narrow (about 70 m) compared to its length (about 800 m). An open channel with elongated shape would not be subjected to significant hydraulic impact from the two dimensional flow pattern.

The location of cross sections used in HEC-2 is marked on Figure 4.1.

4.1.2 Backwater Level

Water levels along the Rapids north of the berm were determined for flows ranging from 5 to 100 m3/s and these have been documented in Table 4.1. Backwater profiles of 5, 14, 50 and 100 m3/s flow rates were plotted on Figure 4.2 and flood lines of 14 and 50 m3/s discharge were traced in Figure 4.1. Cross sectional profiles at Chainage 0+480 and 0+808 were also plotted in Figure 4.3..

As shown in the above table and figures, during the normal flow condition (i.e. 14 m3/s), water level is below the top of the berm for most of the Rapids. Spilling over the berm to the south may occur around Chainage 0+600. The spill area increases with increasing flow rate. For a discharge of 50 m3/s, about half of the berm towards the downstream end will experience significant spilling.

As shown in Figure 4.2, only a short section for water depth reduced to almost 0.3 m exists at Chainage 6+000.For most of the rapids area north of the berm, the water depth is greater than 0.6 m during the normal flow condition (14 m3/s). The flow depth criteria of 0.6 m enables the larger species of fish to spawn in the Rapids area.

4.1.3 Flow Velocity

Flow velocity along the waterway is documented in Table 4.2. As shown, for most of the Rapids area, the flow velocity varies from 0.3 to 0.9 m/s. The minimum velocity criteria of 0.3 m/s ensures that gravel remains free of silt and algae which could inhibit spawning activities. The maximum velocity criterion of 0.9 m/s provides a flow passage attractive to fish.

Flow velocity below 0.3 m/s occurs at the large ponded water body area, such as Chainage 9+000 and 6+000.

Flow velocity higher than 0.9 m/s occurs at the following locations:

i) Chainage 1+000 where all the flow is confined in a narrow (about 20 m wide) channel downstream of Gate #1.

ii) Rock outcrops and sandbars block large part of the waterway near the berm during the low flow condition (14 m3/s or lower) at several locations near Chainage 0+900, 0+750, 0+650, 0+450 and 0+350.

4.1.4 Watered Area

The dry or watered area was planimetered for flows of 14 and 50 m3/s. For flows greater than 50 m3/s, backwater level and consequently watered area does not materially increase due to the spilling over the berm.

Watered area vs flow rate was plotted in Figure 4.4. Only about half (52%) of the Rapids area is watered for flow of 14 m3/s. However, for flow of 50 m3/s, 78.6% Rapids will be submerged.

4.2 Proposed Condition With Remedial Work

4.2.1 Berm Improvement

Hydraulic conditions can be significantly improved if the top of the berm is raised towards the downstream section. Assuming the berm being raised to the proposed level (maximum of 0.4 m) as shown in Figure 4.5, backwater level of all flow rates will be increased. The water levels and flow velocity with the proposed berm improvement were documented in Tables 4.3 and 4.4 respectively. No spilling would occur for flows less than 50 m3/s.

As shown in Figures 4.1 and 4.4, after the berm improvement, the watered area will increase to 59.8% (net increment of 7.8%) for flow of 14 m3/s. For a flow of 50 m3/s, the watered area north of the berm will be 89.1%, covering virtually the entire rapids except several rock outcrops and sand bars near the Whitefish Island shoreline.

Most of the enlargement of watered areas occur near the berm along the main flow passage. This effectively increases the flow depth and conveyance area along the waterway. As shown in Table 4.3, flow depth will be larger than the minimum criterion of 0.6 m during the normal flow condition (14 m3/s). Table 4.4 documents the flow velocity along the Rapids. In general, the magnitude of high flow velocity at some narrow flow passage section can be reduced considerably while velocity in most of the rapids does not change significantly after the berm improvement. If the flow velocity listed in Table 4.4 is greater than the fish bursting speed, some form of dredging needs to be considered.

4.2.2 Channel Dredging

In order to achieve an optimal flow velocity (e.g. 0.9 m/s and below) for fish habitat, dredging may be desired around the spots of rock outcrop area as indicated previously. The magnitude of the dredging should be relatively minor and could be carried out together with the implementation of the berm improvement.

During the discussion with public agencies, it was understood that some dredging work has already been undertaken at a number of locations to obtain a continuous flow passage along the Rapids north of the berm.

Should this dredging program be adopted, a better and more up-to-date topographic map needs to be provided for the more accurate determination of flow velocity and, location and volume of excavation.

TABLE 4.1 RESULTS OF BACKWATER LEVEL ANALYSIS ALONG RAPIDS, NORTH OF BERM (EXISTING CONDITION)

X-Section No.	Chainage (m)	High pt. (m)	Low pt. (m)	Berm (m)	Water Level (m) For Different Flow Rates						
					5 m3/s	10 m3/S	14 m3/s	20 m3/s	35 m3/s	50 m3/s	100 m3/s
19	0.091	172.85	172.85		177.00	177.00	177.00	177.00	177.00	177.00	177.00
18	0.222	174.05	174.05		177.00	177.00	177.00	177.00	177.00	177.00	177.00
17	0.306	177.40	177.40		177.46	177.49	177.51	177.54	177.59	177.64	177.77
16	0.376	178.35	177.90	178.75	178.24	178.33	178.38	178.44	178.57	178.67	178.83
15	0.480	179.57	178.61	179.22	178.99	179.11	179.19	179.23	179.27	179.28	179.30
14	0.536	179.57	179.22	179.90	179.68	179.78	179.83	179.85	179.93	179.94	179.96
13	0.602	179.80	179.80	180.10	180.11	180.13	180.14	180.16	180.17	180.19	180.25
12	0.693	180.79	179.64	180.63	180.29	180.35	180.38	180.36	180.47	180.56	180.70
11b	0.712	180.79	179.62	180.81	180.31	180.41	180.46	180.54	180.75	180.87	180.88
11	0.734	179.94	179.94	180.78	180.37	180.49	180.57	180.66	180.85	180.90	180.96
10	0.808	181.25	180.05	181.29	180.74	180.90	180.96	181.03	180.95	181.02	181.34
9	0.838	180.55	179.86	181.40	180.77	180.94	181.01	181.09	181.19	181.32	181.47
8	0.881	181.40	180.21	181.45	180.79	180.96	181.04	181.13	181.27	181.41	181.56
6	0.907	181.16	180.02	181.52	180.81	180.99	181.07	181.17	181.34	181.50	181.59
5	0.952	180.98	179.36	181.60	180.82	181.01	181.10	181.21	181.39	181.56	181.63
4	0.977	181.10	179.52	181.62	180.82	181.01	181.10	181.21	181.39	181.56	181.63
3	1.004	180.76	180.39	181.64	180.83	181.01	181.10	181.21	181.41	181.58	181.72
1	1.108	179.81	179.81	181.78	180.88	181.07	181.18	181.30	181.52	181.70	181.88
0	1.160	179.36	179.36	181.93	180.89	181.10	181.22	181.37	181.64	181.87	181.91

* NOTE: Shading indicates water level above berm elevation

BXTNOR.WK1

TABLE 4.2 RESULTS OF FLOW VELOCITY ANALYSIS ALONG RAPIDS, NORTH OF BERM (EXISTING CONDITION)

X-Section No.	Chainage (m)	High pt. (m)	Low pt. (m)	Berm (m)	Flow Velocity (m/s) For Different Flow Rates						
					5 m3/s	10 m3/S	14 m3/s	20 m3/s	35 m3/s	50 m3/s	100 m3/s
19	0.091	172.85	172.85		0.01	0.01	0.02	0.02	0.04	0.05	0.11
18	0.222	174.05	174.05		0.01	0.02	0.03	0.04	0.07	0.10	0.21
17	0.306	177.40	177.40		0.71	0.88	0.98	1.09	1.30	1.44	1.76
16	0.376	178.35	177.90	178.75	0.60	0.82	0.96	1.14	1.50	1.78	>1.78
15	0.480	179.57	178.61	179.22	0.95	1.11	1.20	1.13	>1.13	>1.13	>1.13
14	0.536	179.57	179.22	179.90	0.77	0.92	0.97	1.25	>1.25	>1.25	>1.25
13	0.602	179.80	179.80	180.10	0.31	0.24	0.22	0.20	0.27	0.29	0.33
12	0.693	180.79	179.64	180.63	0.42	0.69	0.88	1.35	1.78	2.09	>2.09
11b	0.712	180.79	179.62	180.81	0.42	0.63	0.79	0.93	1.08	>1.08	>1.08
11	0.734	179.94	179.94	180.78	0.89	0.90	0.94	0.98	>0.98	>0.98	>0.98
10	0.808	181.25	180.05	181.29	0.52	0.56	0.63	0.72	1.65	1.90	>1.90
9	0.838	180.55	179.86	181.40	0.22	0.28	0.35	0.42	0.64	0.75	0.87
8	0.881	181.40	180.21	181.45	0.37	0.48	0.57	0.69	0.84	0.90	>0.90
6	0.907	181.16	180.02	181.52	0.39	0.47	0.55	0.64	0.84	0.84	>0.84
5	0.952	180.98	179.36	181.60	0.07	0.12	0.15	0.19	0.29	0.37	0.67
4	0.977	181.10	179.52	181.62	0.16	0.23	0.29	0.36	0.51	0.62	1.16
3	1.004	180.76	180.39	181.64	0.32	0.37	0.43	0.51	0.67	0.79	0.98
1	1.108	179.81	179.81	181.78	0.34	0.53	0.65	0.82	1.17	1.46	>1.46
0	1.160	179.36	179.36	181.93	0.31	0.48	0.59	0.72	0.93	1.06	2.06

BXTNOR.WK1

TABLE 4.3 RESULTS OF BACKWATER LEVEL ANALYSIS ALONG RAPIDS NORTH OF BERM (WITH BERM IMPROVEMENTS)

X-Section No.	Chainage (m)	High pt. (m)	Low pt. (m)	Exis. Berm (m)	Prop. Berm (m)	Water Level (m) For Different Gate Openings					
						5 m3/s	10 m3/s	14 m3/s	20 m3/s	35 m3/s	50 m3/s
19	0.091	172.85	172.85			177.00	177.00	177.00	177.00	177.00	177.00
18	0.222	174.05	174.05			177.00	177.00	177.00	177.00	177.00	177.00
17	0.306	177.40	177.40			177.46	177.49	177.51	177.54	177.59	177.64
16	0.376	178.35	177.90	178.75	As Exis.	178.24	178.33	178.38	178.44	178.57	178.67
15	0.480	179.57	178.61	179.22	179.62	178.99	179.11	179.20	179.29	179.48	179.62
14	0.536	179.57	179.22	179.90	180.12	179.68	179.78	179.84	179.90	180.02	180.12
13	0.602	179.80	179.80	180.10	180.59	180.18	180.27	180.32	180.38	180.49	180.59
12	0.693	180.79	179.64	180.63	180.95	180.35	180.49	180.57	180.66	180.83	180.95
11b	0.712	180.79	179.62	180.81	181.00	180.36	180.51	180.59	180.70	180.87	181.00
11	0.734	179.94	179.94	180.78	181.07	180.40	180.55	180.64	180.76	180.93	181.07
10	0.808	181.25	180.05	181.29	As Exis.	180.73	180.89	180.94	181.02	181.19	181.32*
9	0.838	180.55	179.86	181.40	As Exis.	180.76	180.93	181.00	181.08	181.27	181.41*
8	0.881	181.40	180.21	181.45	As Exis.	180.78	180.95	181.02	181.12	181.32	181.47*
6	0.907	181.16	180.02	181.52	As Exis.	180.81	180.98	181.06	181.17	181.38	181.54*
5	0.952	180.98	179.36	181.60	As Exis.	180.82	181.00	181.09	181.20	181.43	181.59
4	0.977	181.10	179.52	181.62	As Exis.	180.82	181.00	181.09	181.20	181.43	181.59
3	1.004	180.76	180.39	181.64	As Exis.	180.82	181.01	181.10	181.21	181.44	181.60
1	1.108	179.81	179.81	181.78	As Exis.	180.88	181.07	181.17	181.30	181.54	181.72
0	1.160	179.36	179.36	181.93	As Exis.	180.89	181.10	181.21	181.36	181.66	181.88

NOTE: Shading indicates water level above berm elevation

NBWNOR.WK1

* – Water level at 50 m3/s are less than 0.02 m higher than the existing berm elevation:
No berm improvement is required at these areas

TABLE 4.4 RESULTS OF FLOW VELOCITY ANALYSIS ALONG RAPIDS NORTH OF BERM (WITH BERM IMPROVEMENTS)

X–Section No.	Chainage (m)	High pt. (m)	Low pt. (m)	Exis. Berm (m)	Prop. Berm (m)	FLOW VELOCITY (m/s) For Different Gate Openings					
						5 m3/s	10 m3/s	14 m3/s	20 m3/s	35 m3/s	50 m3/s
19	0.091	172.85	172.85			0.01	0.01	0.02	0.02	0.04	0.05
18	0.222	174.05	174.05			0.01	0.02	0.03	0.04	0.07	0.10
17	0.306	177.40	177.40			0.71	0.88	0.98	1.09	1.30	1.44
16	0.376	178.35	177.90	178.75	As Exis.	0.60	0.82	0.96	1.14	1.50	1.78
15	0.480	179.57	178.61	179.22	179.62	0.95	1.10	1.21	1.31	1.47	1.57
14	0.536	179.57	179.22	179.90	180.12	0.77	0.92	0.96	1.07	1.22	1.37
13	0.602	179.80	179.80	180.10	180.59	0.52	0.65	0.74	0.85	1.07	1.23
12	0.693	180.79	179.64	180.63	180.95	0.35	0.49	0.56	0.66	0.82	0.95
11b	0.712	180.79	179.62	180.81	181.00	0.36	0.50	0.59	0.68	0.87	1.02
11	0.734	179.94	179.94	180.78	181.07	0.78	0.73	0.74	0.75	0.88	0.99
10	0.808	181.25	180.05	181.29	As Exis.	0.52	0.59	0.66	0.75	0.90	0.95
9	0.838	180.55	179.86	181.40	As Exis.	0.22	0.29	0.35	0.43	0.57	0.66
8	0.881	181.40	180.21	181.45	As Exis.	0.38	0.49	0.59	0.70	0.77	0.78
6	0.907	181.16	180.02	181.52	As Exis.	0.40	0.48	0.56	0.65	0.80	0.80
5	0.952	180.98	179.36	181.60	As Exis.	0.07	0.12	0.15	0.20	0.29	0.36
4	0.977	181.10	179.52	181.62	As Exis.	0.16	0.23	0.29	0.36	0.49	0.61
3	1.004	180.76	180.39	181.64	As Exis.	0.32	0.38	0.44	0.51	0.65	0.76
1	1.108	179.81	179.81	181.78	As Exis.	0.34	0.53	0.66	0.82	1.16	1.45
0	1.160	179.36	179.36	181.93	As Exis.	0.31	0.48	0.60	0.72	0.91	1.05

NBWNOR.WK1

FILE: EXTNOR.CH3

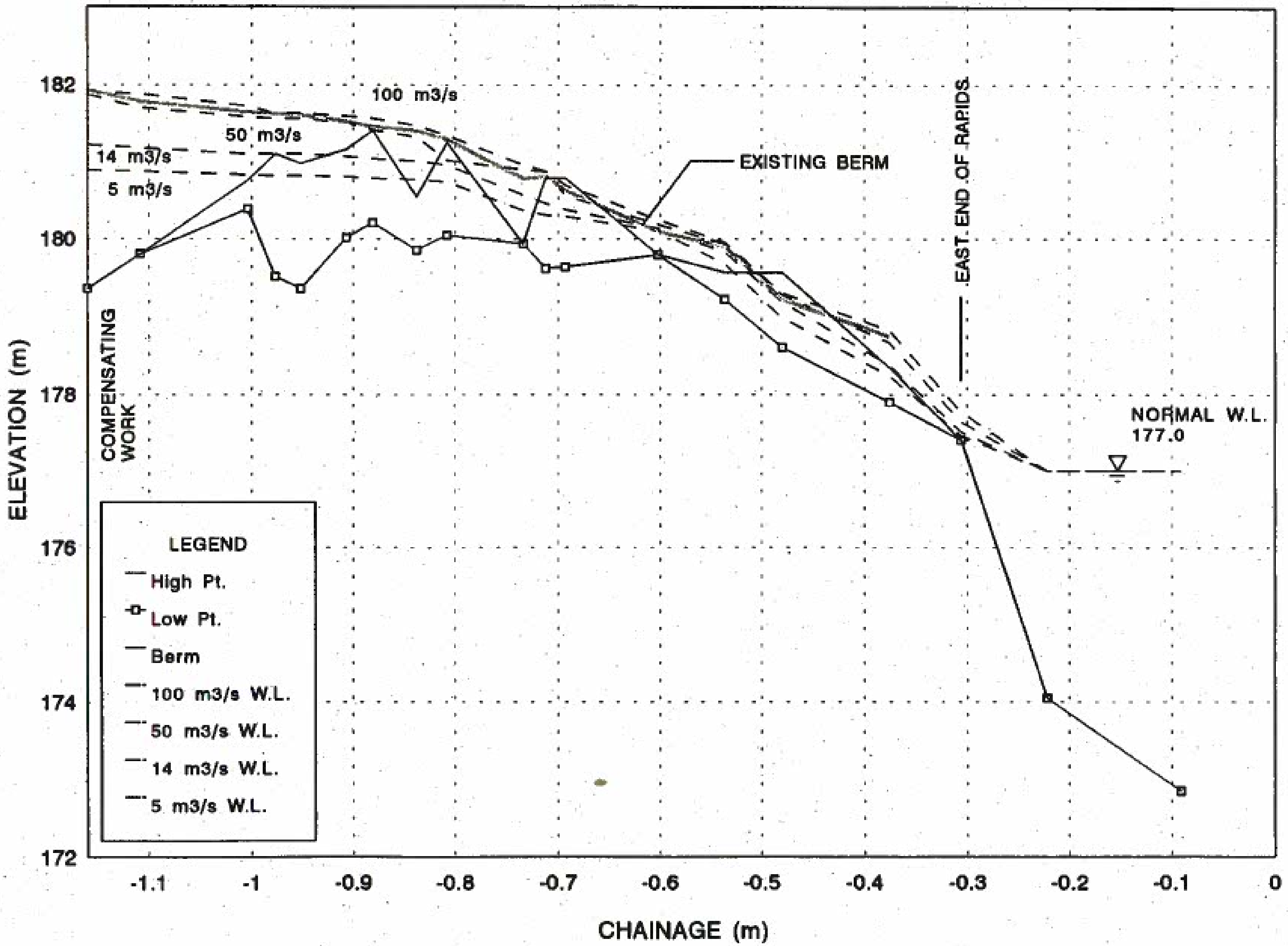


FIGURE 4.2 BACKWATER PROFILES ALONG RAPIDS NORTH OF CONCRETE BERM (EXISTING CONDITION)

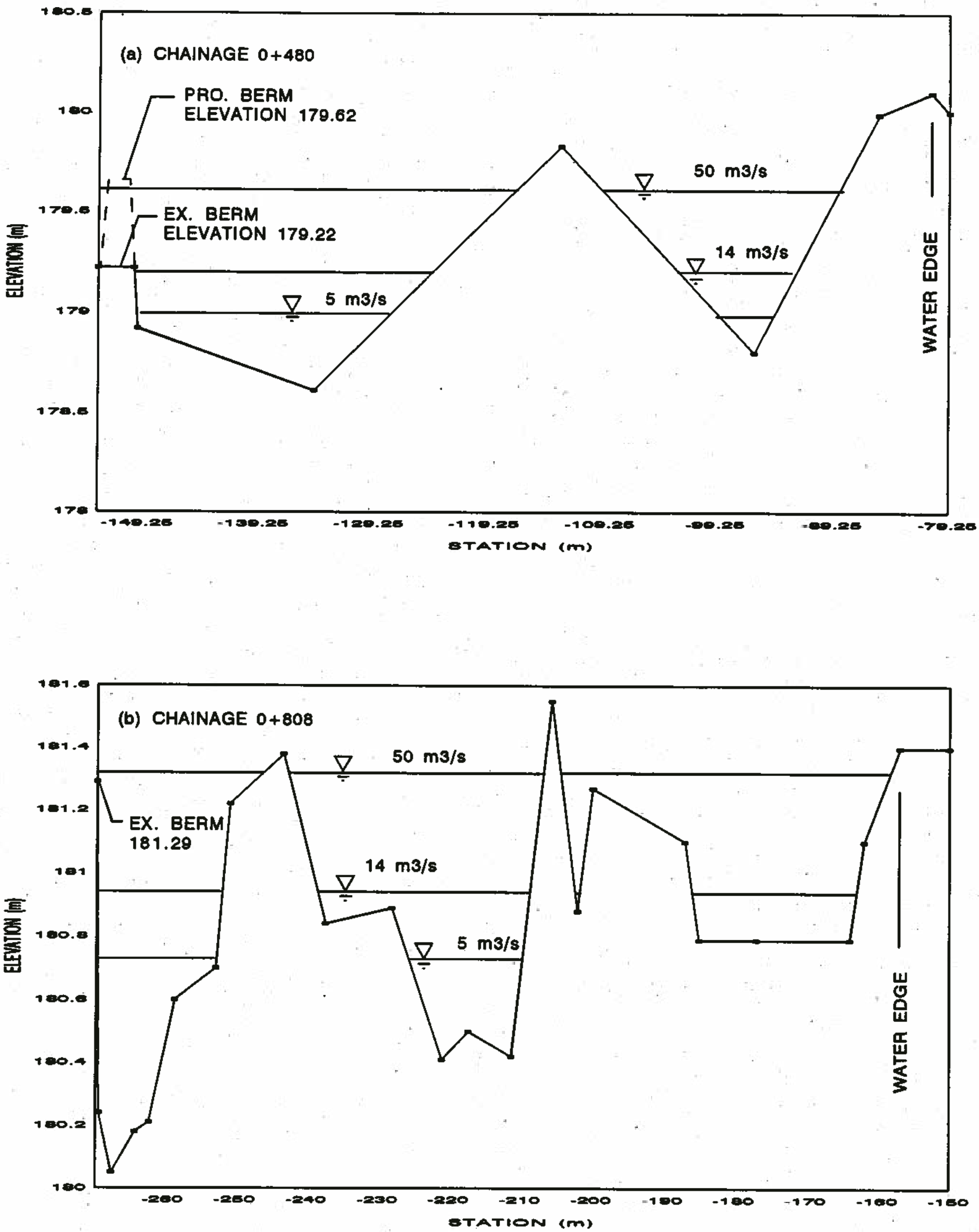
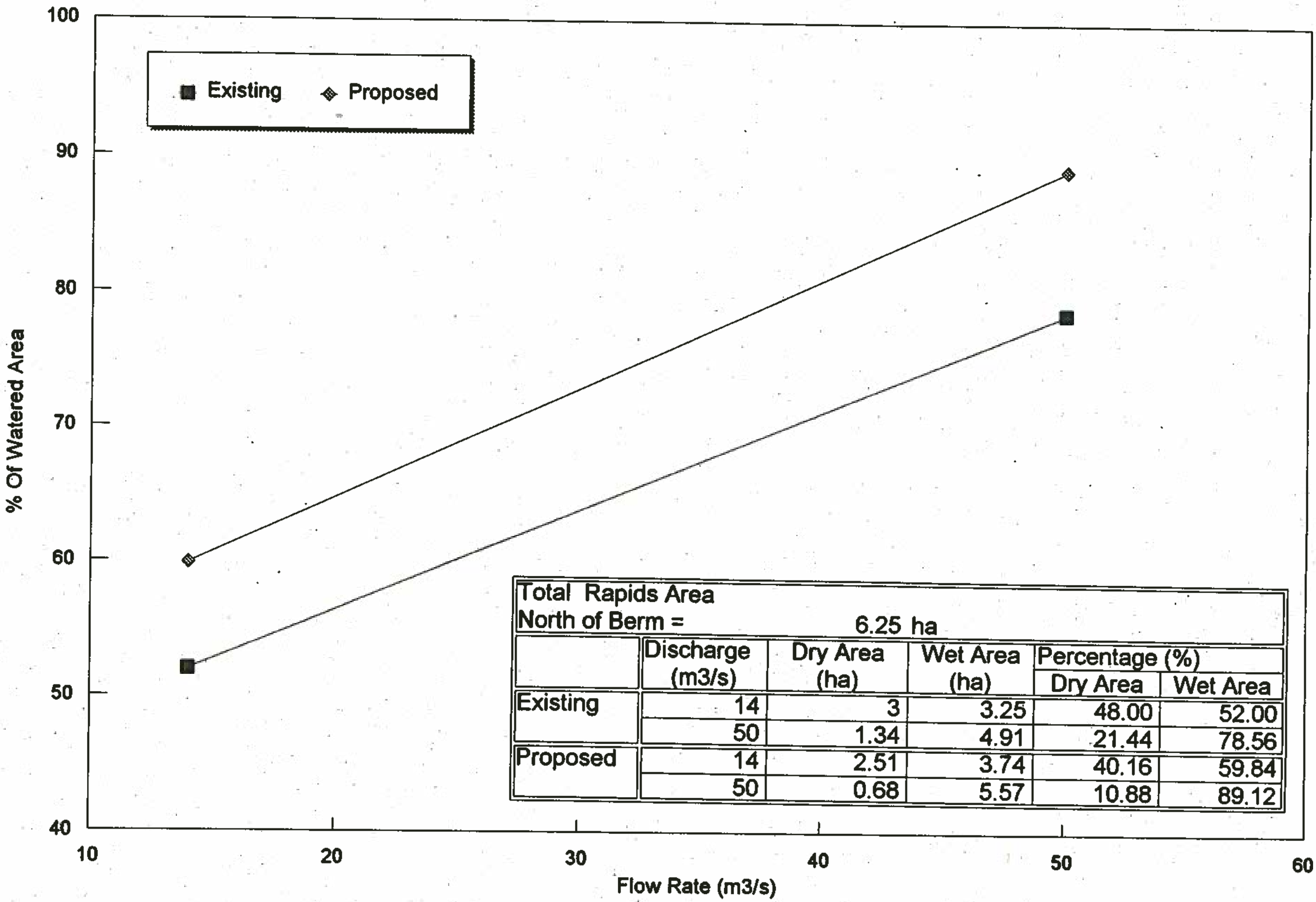


FIGURE 4.3 CROSS SECTION OF RAPIDS, NORTH OF BERM



Total Rapids Area North of Berm =		6.25 ha			
	Discharge (m3/s)	Dry Area (ha)	Wet Area (ha)	Percentage (%)	
				Dry Area	Wet Area
Existing	14	3	3.25	48.00	52.00
	50	1.34	4.91	21.44	78.56
Proposed	14	2.51	3.74	40.16	59.84
	50	0.68	5.57	10.88	89.12

FIGURE 4.4 WATERED AREA vs. GATE DISCHARGE, NORTH OF BERM

FILE: NEWNOR.CH3

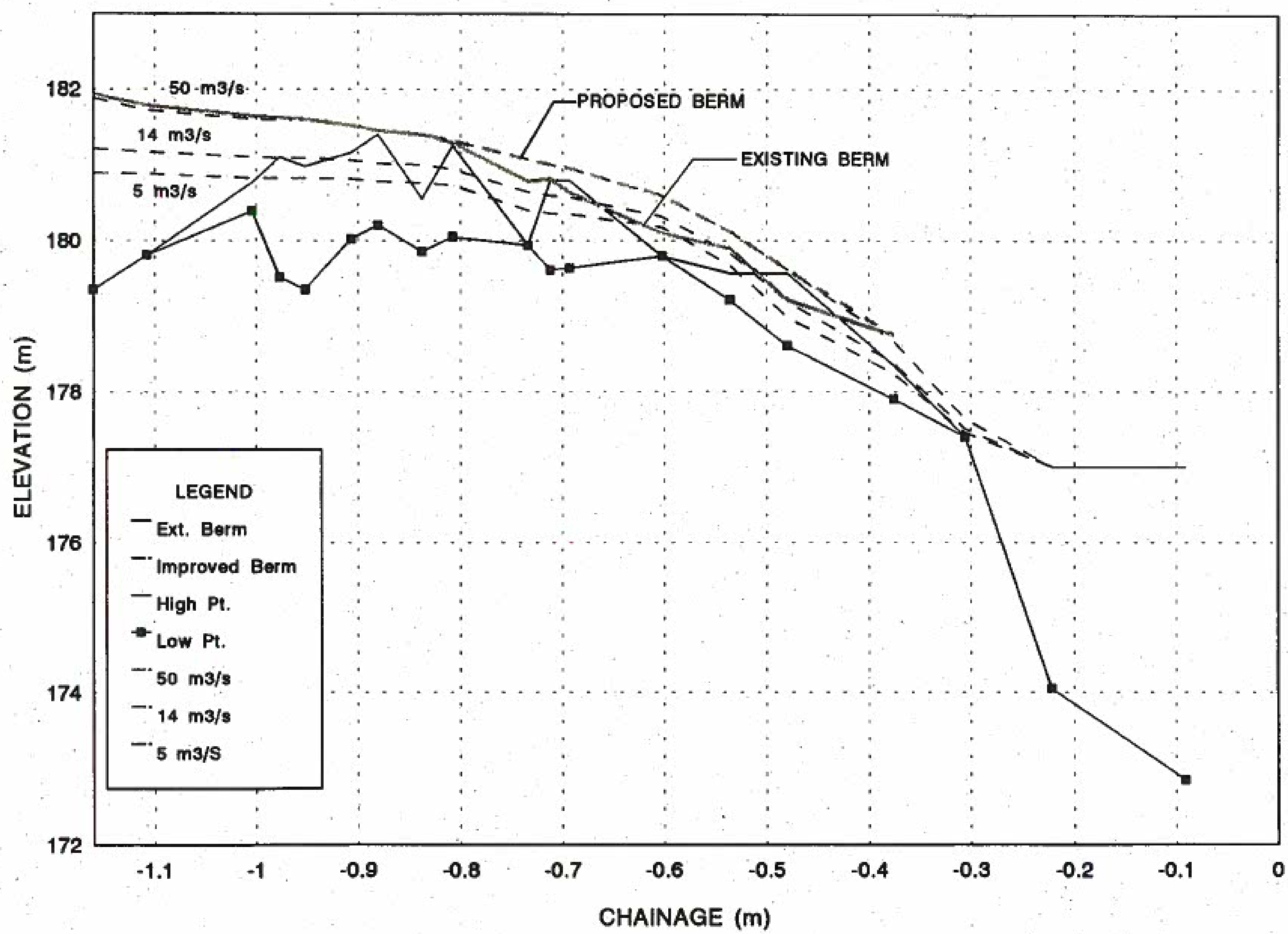


FIGURE 4.5 BACKWATER PROFILES ALONG RAPIDS NORTH OF CONCRETE BERM (PROPOSED BERM IMPROVEMENTS)

5. HYDRAULIC ANALYSIS ALONG RAPIDS, SOUTH OF BERM

5.1 Results of HEC-2 Hydraulic Analysis

5.1.1 Model Application

Hydraulic analysis in this Section 5.1 is based on the results of HEC-2 model simulation. This is required for the investigation on Rapids south of the berm based on the following reasons:

i) Preliminary modelling analysis (from both 1-D and 2-D) suggested that the downstream half of the Rapids area south of the berm would not be affected by the influence of different location and gate opening combination. The HEC-2 simulation is considered to be adequate for the hydraulic analysis.

ii) Prior to the 2-D model simulation, result from the HEC-2 model can be used to assist the set-up preparation of the complex grid-network system required in FESWMS-2DH computer.

The location of cross sections used in HEC-2 was marked on Figure 5.1.

5.1.2 Backwater Level

Water levels along the Rapids south of the berm were determined for the number of gate opening ranging from 0 to 16 gate and these have been documented in Table 5.1. Backwater profiles of 1/2, 2, 4 and 16 gate opening were plotted on Figure 5.2 and flood lines of 0, 1/2, 1 and 2 gate opening were traced in Figure 5.1. Cross sectional profiles at Chainage 1+295 and 1+495 were also plotted in Figure 5.3.

As shown in the above table and figures, during the normal gate opening condition (i.e. 1/2 gate), water level is below the top of the berm along the entire Rapids. Spilling overtop the berm to the north starts with 1 gate opening at Chainage 1+638. For four (4) or more gate openings, spilling will virtually occur over the whole 800 m berm.

As shown in Figure 5.2 and Table 5.1, during normal flow of 1/2 gate opening, flow depth exceeds 0.6 m along the Rapids south of the berm, except for five (5) locations with steep drop in elevation. These locations are at chainage 1+295, 1+586, 1+688 1+853 and 1+899. For some of these steep falls, a natural barrier to migration may exist to some species of fish in the Rapids area.

5.1.3 Flow Velocity

Flow velocity along the Rapids is documented in Table 5.2. Except for the above mentioned steep falls, for most part of the Rapids area the flow velocity varies from 0.3 to 0.9 m/s. The minimum velocity greater than 0.3 m/s existed in the Rapids ensures that gravel remains free of silt and algae which could inhibit spawning activities. The maximum velocity of 0.9 m/s provides a flow passage attractive to many species of fish. As discussed, flow velocity greater than 1 m/s does exist in all the steep falls.

5.1.4 Watered Area

The dry or watered area was planimetered from the flood plain map (Figure 5.1) for flows of 0, 1/2, 1 and 2 gate opening. Watered area vs. number of gate opening was plotted in Figure 5.4. Even during the all gate closed condition, over 75% of the Rapids south of the bern is still wet. This is due to the existence of large water bodies in the area, water back-up due to rock outcrops and flow leakage. For the normal flow condition (1/2 gate opening), about 90% of the Rapids would be watered.

The dry area could be reduced to half if the discharge can be increased from 1/2 to 1 gate opening.

For flows greater than 2 gate opening, virtually all the Rapids south of the berm will be submerged.

5.2 Results of FESWMS-2DH Hydraulic Analysis

5.2.1 Model Application

Hydraulic analysis in this Section 5.2 is based on the results of FESWMS-2DH model simulation. This two dimensional (2-D) model was undertaken for the upstream half of the Rapids south of the berm based on the following reasons:

i) Preliminary modelling analysis (from both 1-D and 2-D) suggested that the upstream half of the Rapids area south of the berm would be subjected to the influence of different location and gate opening combination. The FESWMS-2DH simulation is considered to be appropriate for the hydraulic analysis.

ii) River bed along the U.S. shoreline is higher than the Canadian's side. Hence, a two dimensional flow pattern can be expected in the Rapids area.

The network grids used in FESWMS-2DH are plotted on Figure 5.5. The river bed contour map is presented in Figure 5.6.

5.2.2 Backwater Level

Water levels along the upstream half of Rapids south of the berm were determined for the number of gate openings ranging from 0 to 2 gates. Water level contour maps of 1/2 gate opening were plotted on Figures 5.7 and 5.8 with respect to Gate #15 and Gate #3 opening. These two gate opening conditions represent the two possible most distant locations of Compensating Works operation. Because of their extreme end location, the Gate #16 and Gate #2 flow may induce overly severe turbulence along the US bank to the south and the concrete berm to the north.

As shown, the water level around the dry area along the U.S. shoreline would be higher during the Gate #15 opening than that during Gate #3 opening.

Figures 5.9 and 5.10 show the water level contours with 1 gate opening with respect to Gate 15 and Gate #3 opening condition. Similar findings as in the 1/2 gate opening are found.

The water cross sectional profile at Chainage 1+197 was plotted in Figure 5.11. In general, the average water level across the Rapids does not deviate greatly in comparison with that modelled by HEC-2. However, the impact of different Gate opening locations and the 2 dimensional modelling is apparent.

As shown in Figures 5.7 to 5.10, the influence of the gate opening location diminishes with distance from the Compensating Works. For area downstream of Chainage 1+295, the gate opening location becomes irrelevant.

5.2.3 Flow Velocity

Flow velocity pattern along the upstream half of Rapids was plotted in Figure 5.12 and 5.13 with respect to Gate #15 and Gate #3 opening under 1/2 gate flow condition. In general, the magnitude of flow velocity is in the same order of that modelled in HEC-2. However, higher flow velocity can be observed immediately downstream of the operating gate and the steep fall areas. The effect of river bed contour on flow direction is also evident.

Flow velocity pattern along the upstream half of Rapids was plotted in Figure 5.14 and 5.15 with respect to Gate #15 and Gate #3 opening under 1 gate flow condition. Similar findings as the 1/2 gate flow were observed.

5.2.4 Watered Area

The dry or watered area was planimetered from the flood plain map (Figures 5.7 to 5.10) for flows of 1/2 and 1 gate flows with Gate #15 and Gate #3 opening location. Watered area vs. number of gate opening was also plotted in Figure 5.4.

In general, the FESWMS-2DH model predicts water level in the same order of HEC-2. However, opening Gate #15 may result in a higher water level at the dry areas along the U.S. shoreline. For the dry areas near the centre line (Chainage 1+495) of Rapids, the influence of gate opening location disappears.

5.3 Impact of Downstream Remedial Work

The possibility of constructing a wetland, wetland-like or pseudo-rapids type habitat adjacent to the base of the Rapids was investigated. A number of backwater model simulations (HEC-2) have been carried out with rock outcrops, sandbars or other objects placed on the river bed. Results of modelling indicates that as long as materials are placed below the top of the most downstream steep fall, i.e. about 177.5 m above Sea Level, no impact to the upstream Rapids will be observed. The steep river bed through the Rapids area and the relatively low water level in St. Marys River downstream from Sault Ste. Marie ensures the backwater effect from the proposed remedial work will be insignificant.

TABLE 5.1 RESULTS OF BACKWATER LEVEL ANALYSIS ALONG RAPIDS, SOUTH OF BERM

X-Section No.	Chainage (m)	Berm (m)	Low pt. (m)	High pt. (m)	Water Level (m) For Different Gate Openings					
					0	1/2	1	2	4	16
1	1.000	181.79	179.36	179.61	180.82	181.19	181.41	181.76	182.10	182.95
2	1.015	181.79	179.36	179.61	180.82	181.19	181.40	181.75	182.09	182.94
3	1.044	181.79	179.36	179.61	180.82	181.18	181.39	181.73	182.06	182.90
4	1.068	181.78	179.36	180.36	180.81	181.17	181.37	181.70	182.01	182.81
5	1.109	181.74	180.42	180.88	180.80	181.14	181.34	181.66	181.94	182.71
6	1.187	181.64	180.42	180.68	180.67	181.00	181.20	181.51	181.78	182.54
7	1.259	181.60	179.27	180.27	180.57	180.93	181.11	181.40	181.68	182.45
8	1.295	181.44	180.33	181.04	180.47	180.69	181.81	181.00	181.43	182.18
9	1.391	181.30	178.52	179.53	180.19	180.52	180.69	180.97	181.31	182.04
10	1.495	180.63	179.88	180.37	180.16	180.35	180.44	180.66	181.00	181.71
11	1.586	180.50	179.57	179.57	179.66	179.94	180.15	180.47	180.85	181.57
12	1.600	180.40	177.91	177.91	179.59	179.97	180.18	180.49	180.87	181.61
13	1.638	180.10	179.27	180.12	179.57	179.89	180.70	180.34	180.69	181.35
14	1.661	180.07	178.99	179.23	179.43	179.71	179.87	180.13	180.45	181.10
15	1.688	179.79	178.96	178.96	179.10	179.31	179.42	179.63	179.94	180.49
16	1.726	179.60	177.90	178.35	178.29	178.68	178.87	179.20	179.56	180.30
17	1.733	179.40	177.19	178.35	178.28	178.64	178.83	179.16	179.53	180.27
18	1.739	179.08	177.90	178.57	178.16	178.50	178.70	179.03	179.29	180.00
19	1.765	179.08	176.89	177.90	178.16	178.53	178.73	179.07	179.36	180.08
20	1.787	178.82	176.89	177.77	178.16	178.52	178.71	179.02	179.28	179.94
21	1.835	178.75	177.90	177.93	178.15	178.47	178.65	178.95	179.22	179.92
22	1.853	178.75	177.75	177.75	177.86	178.06	178.18	178.41	178.79	179.57
23	1.882		176.43	176.63	177.65	177.99	178.18	178.48	178.87	179.60
24	1.899		177.44	177.44	177.57	177.80	177.94	178.17	178.49	179.12
25	1.905		177.14	177.13	177.27	177.51	177.67	177.90	178.25	178.88
26	2.120		174.05	174.21	177.00	177.00	177.00	177.00	176.98	176.88
27	2.184		172.85	174.05	177.00	177.00	177.00	177.00	177.00	177.00

* NOTE: Shading indicates water level above berm elevation

RAPID0-4.WK1

TABLE 5.2 RESULTS OF FLOW VELOCITY ALONG RAPIDS, SOUTH OF BERM

X–Section No.	Chainage (m)	Berm (m)	Low pt. (m)	High pt. (m)	Flow Velocity (m/s) For Different Gate Openings					
					0	1/2	1	2	4	16
1	1.000	181.79	179.36	179.61	0.09	0.29	0.40	0.60	0.91	1.44
2	1.015	181.79	179.36	179.61	0.09	0.28	0.40	0.60	0.88	1.39
3	1.044	181.79	179.36	179.61	0.13	0.37	0.50	0.72	1.00	1.51
4	1.068	181.78	179.36	180.36	0.19	0.47	0.61	0.84	1.18	1.78
5	1.109	181.74	180.42	180.88	0.22	0.51	0.64	0.88	1.25	1.86
6	1.187	181.64	180.42	180.68	0.95	0.91	1.00	1.20	1.45	1.97
7	1.259	181.60	179.27	180.27	0.19	0.55	0.73	1.02	1.10	1.64
8	1.295	181.44	180.33	181.04	1.09	1.64	1.85	1.85	1.86	2.29
9	1.391	181.30	178.52	179.53	0.12	0.40	0.56	0.85	1.26	1.87
10	1.495	180.63	179.88	180.37	0.67	1.53	1.87	2.06	2.12	2.52
11	1.586	180.50	179.57	179.57	0.95	1.07	1.12	1.30	1.58	2.17
12	1.600	180.40	177.91	177.91	0.09	0.30	0.42	0.65	0.97	1.54
13	1.638	180.10	179.27	180.12	0.58	1.10	1.27	1.56	1.84	2.44
14	1.661	180.07	178.99	179.23	0.47	0.91	1.13	1.47	1.94	2.59
15	1.688	179.79	178.96	178.96	1.09	1.65	1.93	2.36	2.77	3.63
16	1.726	179.60	177.90	178.35	1.14	1.12	1.29	1.56	2.18	3.00
17	1.733	179.40	177.19	178.35	0.35	0.76	0.96	1.29	1.84	2.63
18	1.739	179.08	177.90	178.57	1.03	1.17	1.30	1.55	2.26	3.04
19	1.765	179.08	176.89	177.90	0.13	0.42	0.60	0.91	1.45	2.30
20	1.787	178.82	176.89	177.77	0.19	0.59	0.82	1.20	1.79	2.74
21	1.835	178.75	177.90	177.93	0.42	0.84	1.03	1.34	1.69	2.31
22	1.853	178.75	177.75	177.75	1.04	1.73	2.05	2.47	2.55	2.92
23	1.882		176.43	176.63	0.18	0.57	0.80	1.17	1.66	2.47
24	1.899		177.44	177.44	1.11	1.80	2.05	2.43	2.89	3.67
25	1.905		177.14	177.13	1.15	1.90	2.07	2.43	2.91	3.76
26	2.120		174.05	174.21	0.04	0.20	0.33	0.62	1.16	2.75
27	2.184		172.85	174.05	0.02	0.10	0.17	0.32	0.56	1.27

RAPID0–4.WK1

Figure 5.1 in map pocket at back

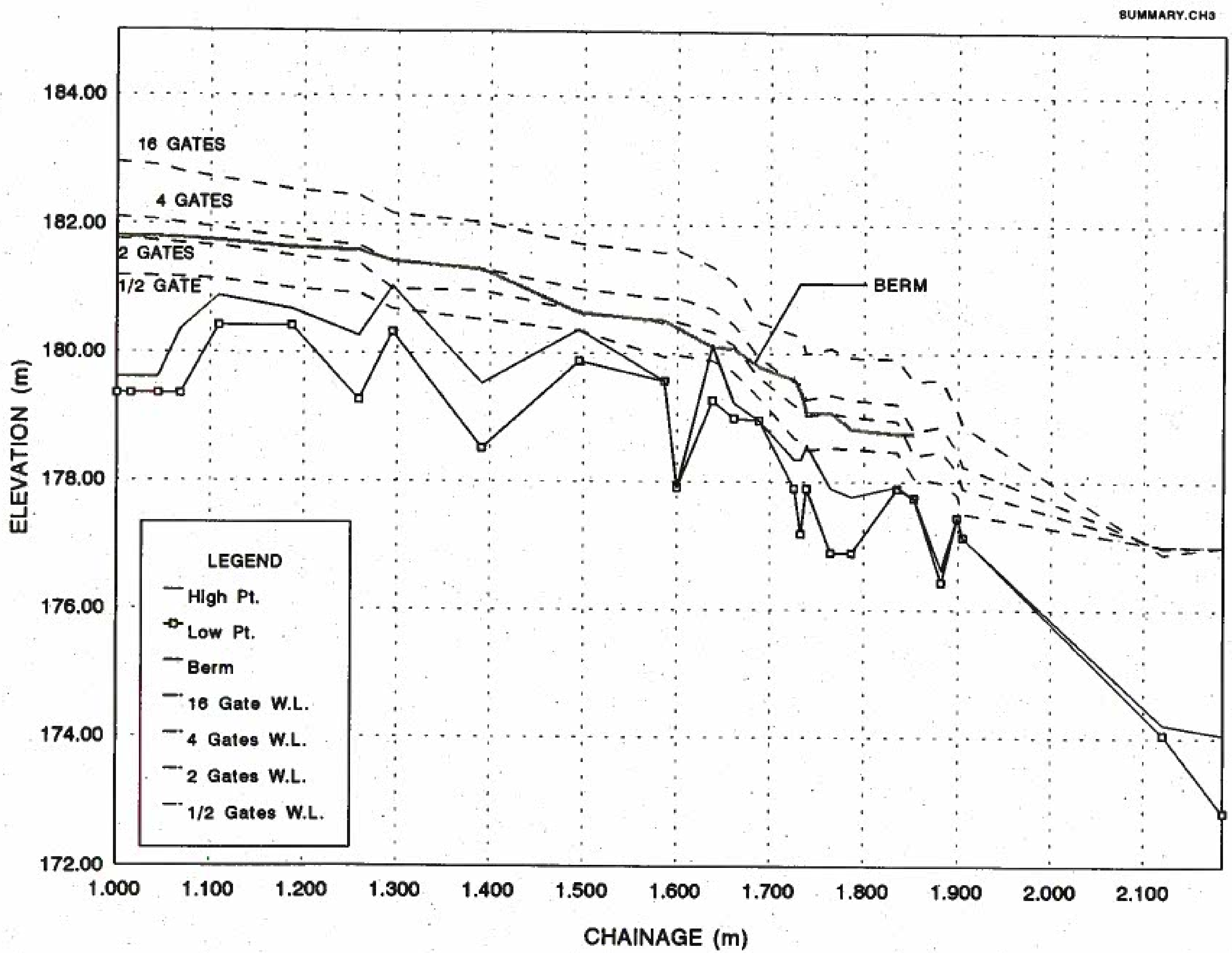
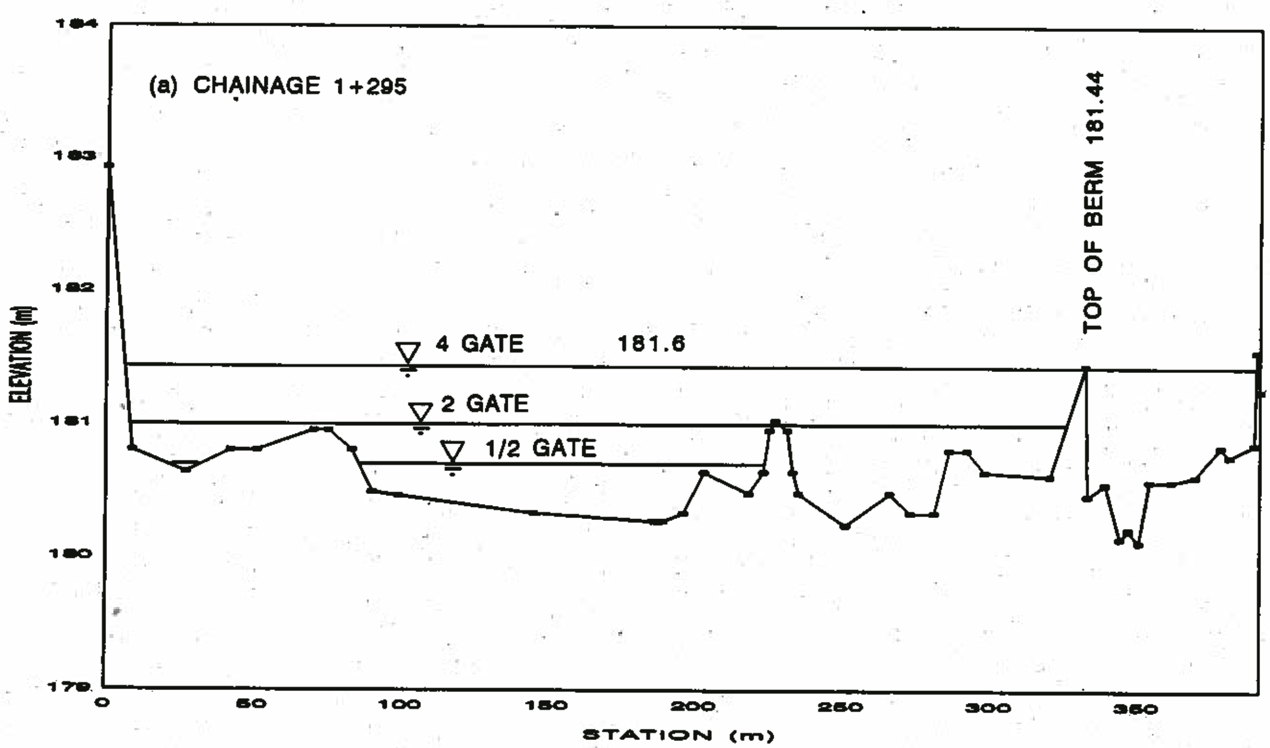


FIGURE 5.2 BACKWATER PROFILES ALONG RAPIDS, SOUTH OF BERM



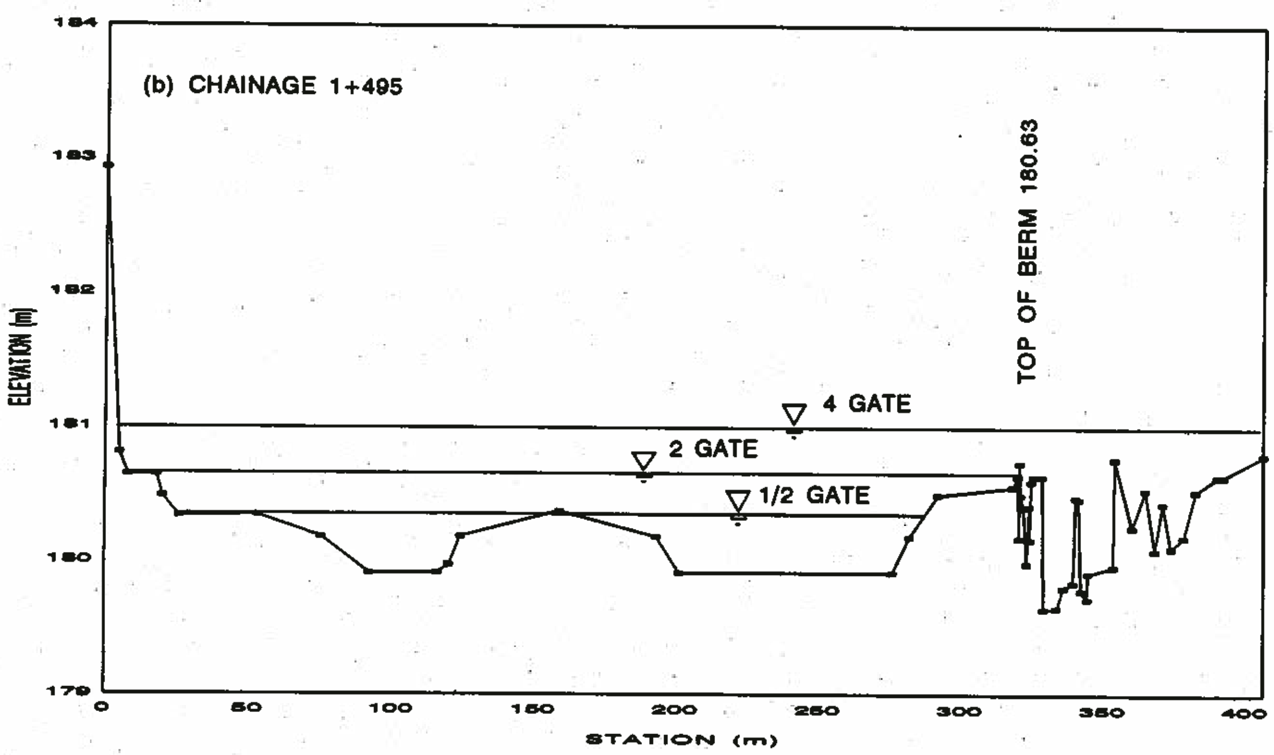
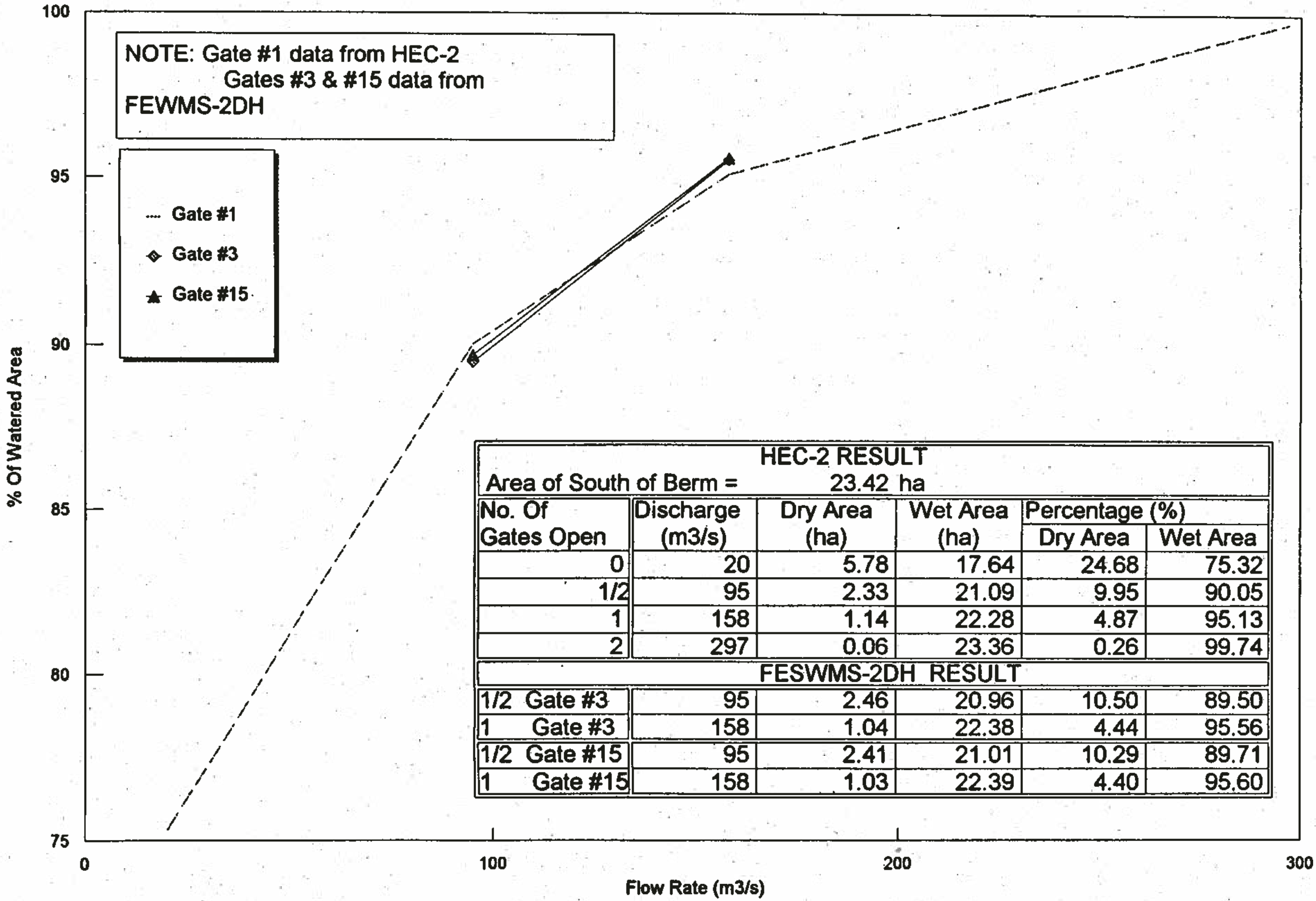


FIGURE 5.3 CROSS SECTION OF RAPIDS, SOUTH OF BERM



HEC-2 RESULT					
Area of South of Berm =		23.42 ha			
No. Of Gates Open	Discharge (m3/s)	Dry Area (ha)	Wet Area (ha)	Percentage (%) Dry Area	Percentage (%) Wet Area
0	20	5.78	17.64	24.68	75.32
1/2	95	2.33	21.09	9.95	90.05
1	158	1.14	22.28	4.87	95.13
2	297	0.06	23.36	0.26	99.74
FESWMS-2DH RESULT					
1/2 Gate #3	95	2.46	20.96	10.50	89.50
1 Gate #3	158	1.04	22.38	4.44	95.56
1/2 Gate #15	95	2.41	21.01	10.29	89.71
1 Gate #15	158	1.03	22.39	4.40	95.60

FIGURE 5.4 WATERED AREA vs. GATE DISCHARGE, SOUTH OF BERM

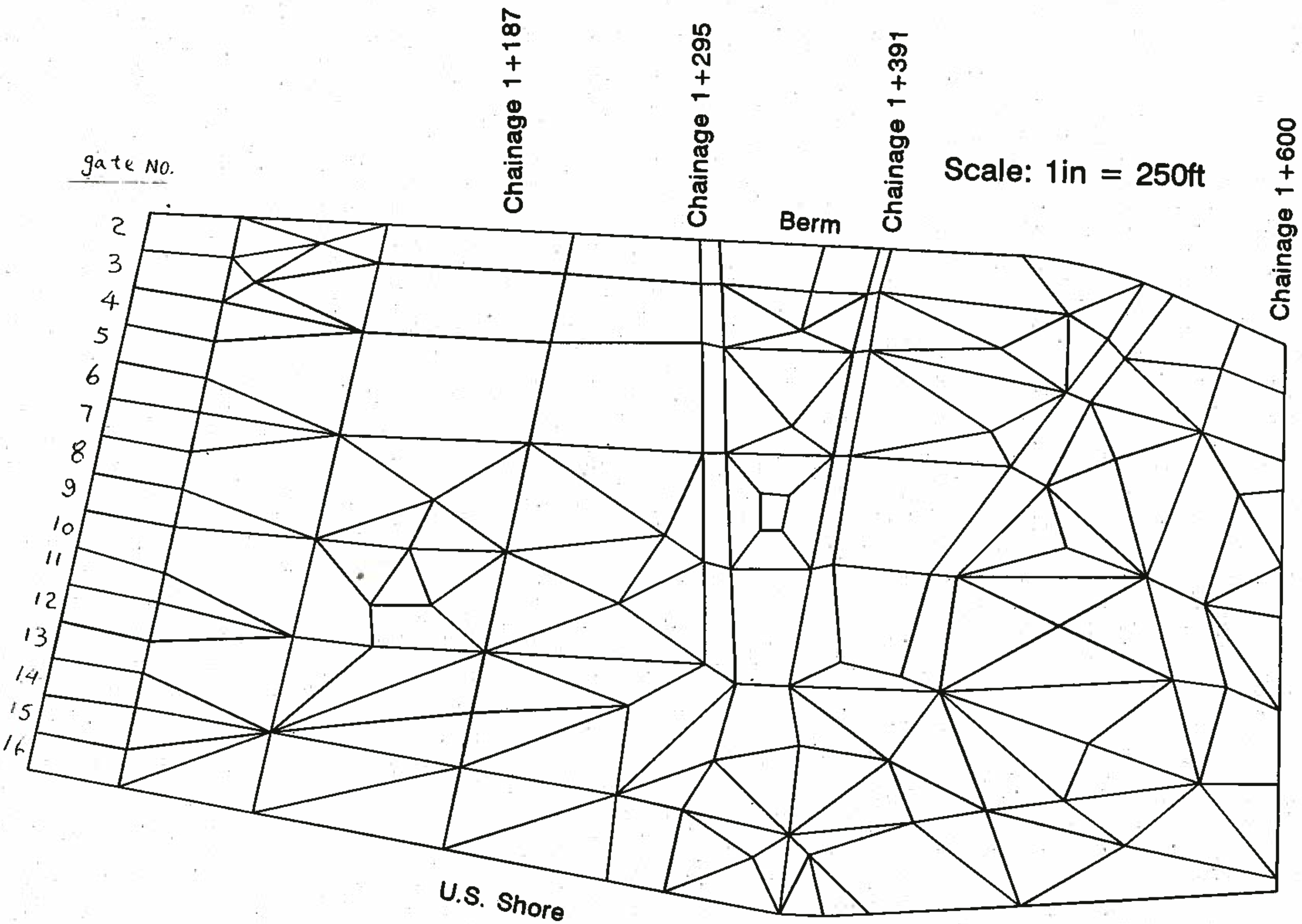


Figure 5.5 FESWMS-2DH Grid Network of Rapids, South of the Berm

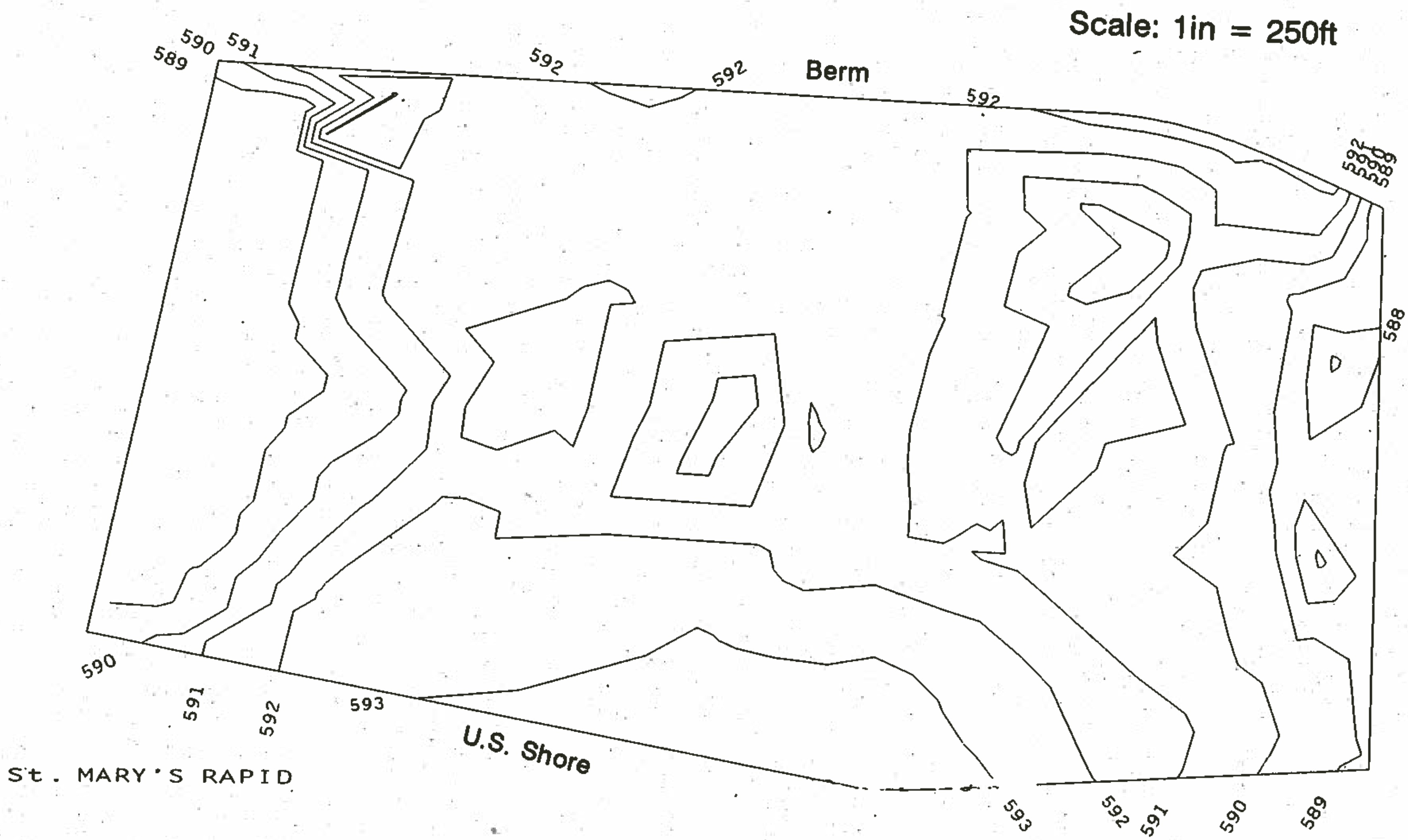


Figure 5.6 River Bed Contour Map of Rapids, South of the Berm

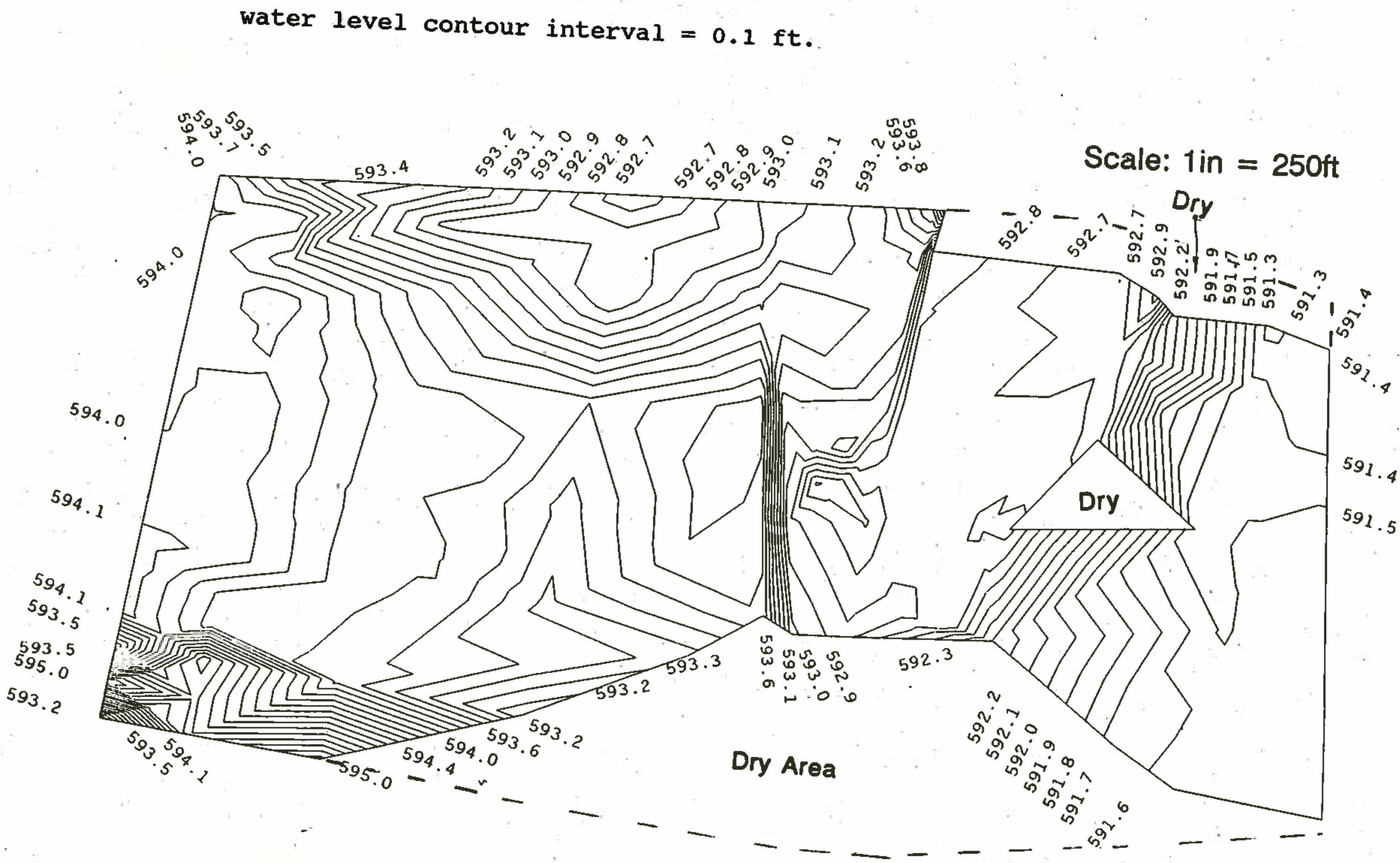


Figure 5.7 Water Level Contour Map of Rapids, South of the Berm (Gate #15, 1/2 Gate Flow Rate)

water level contour interval = 0.1 ft.

Scale: 1in = 250ft

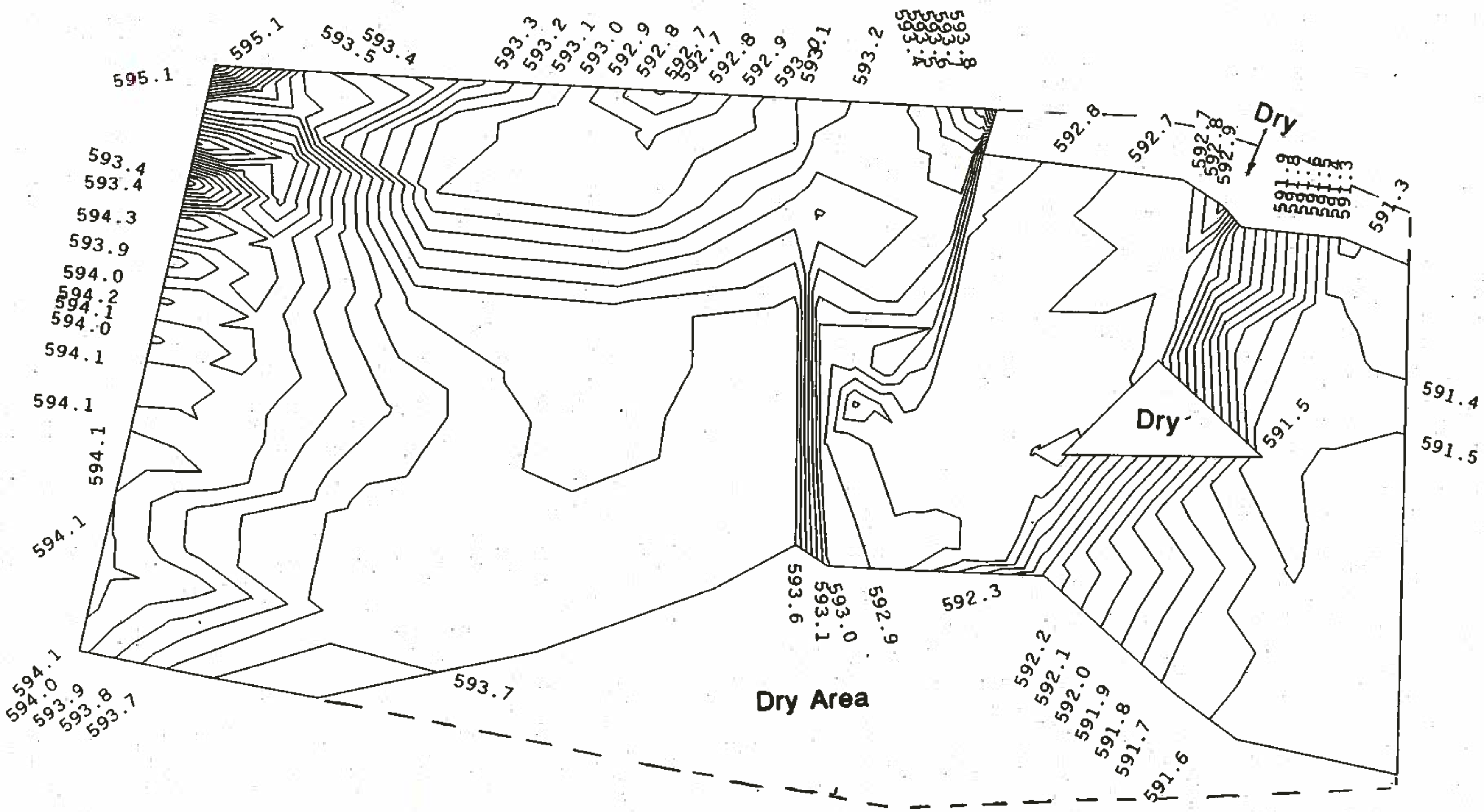


Figure 5.8 Water Level Contour Map of Rapids, South of the Berm (Gate #3, 1/2 Gate Flow Rate)

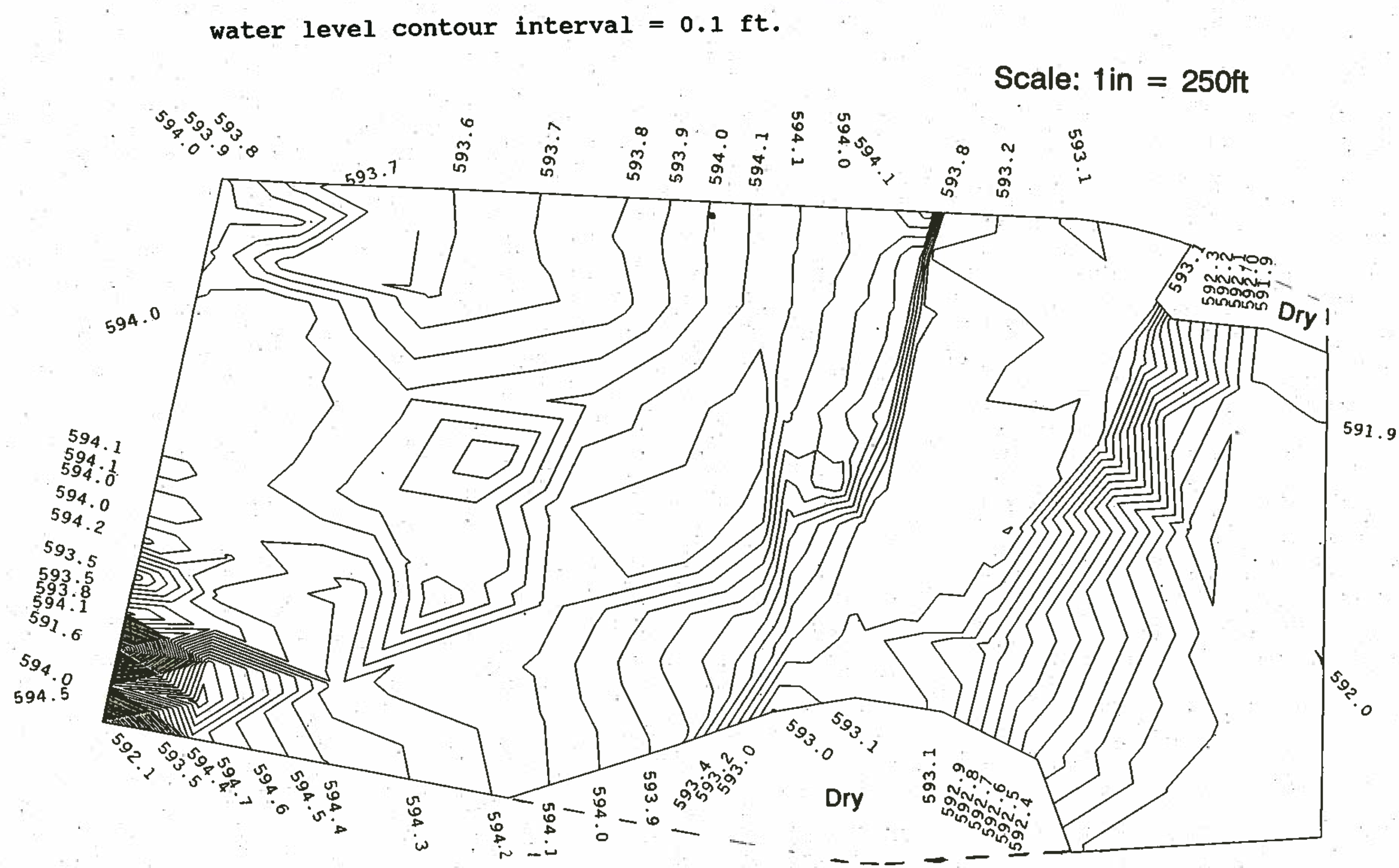


Figure 5.9 Water Level Contour Map of Rapids, South of the Berm (Gate #15, 1 Gate Flow Rate)

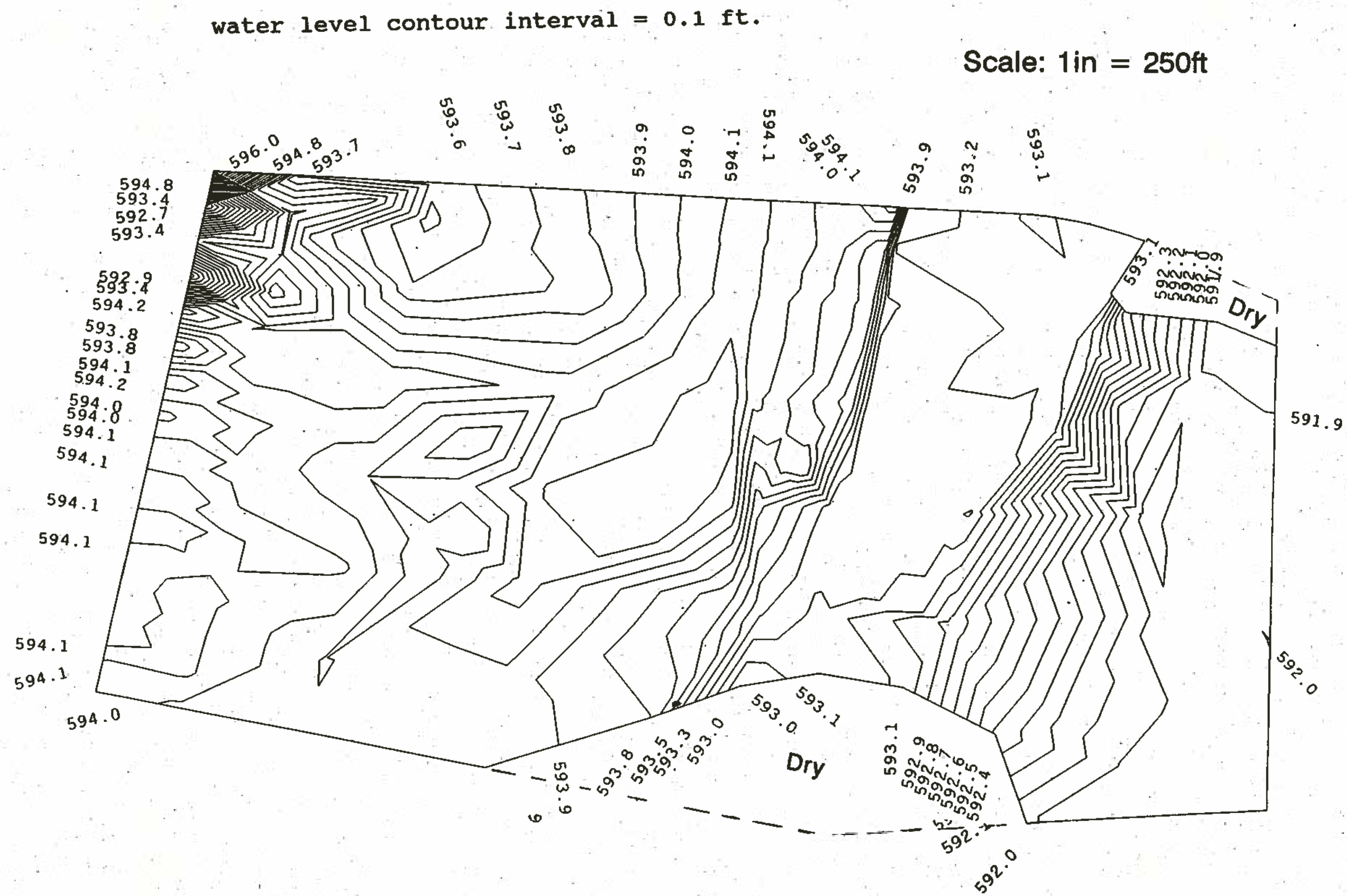
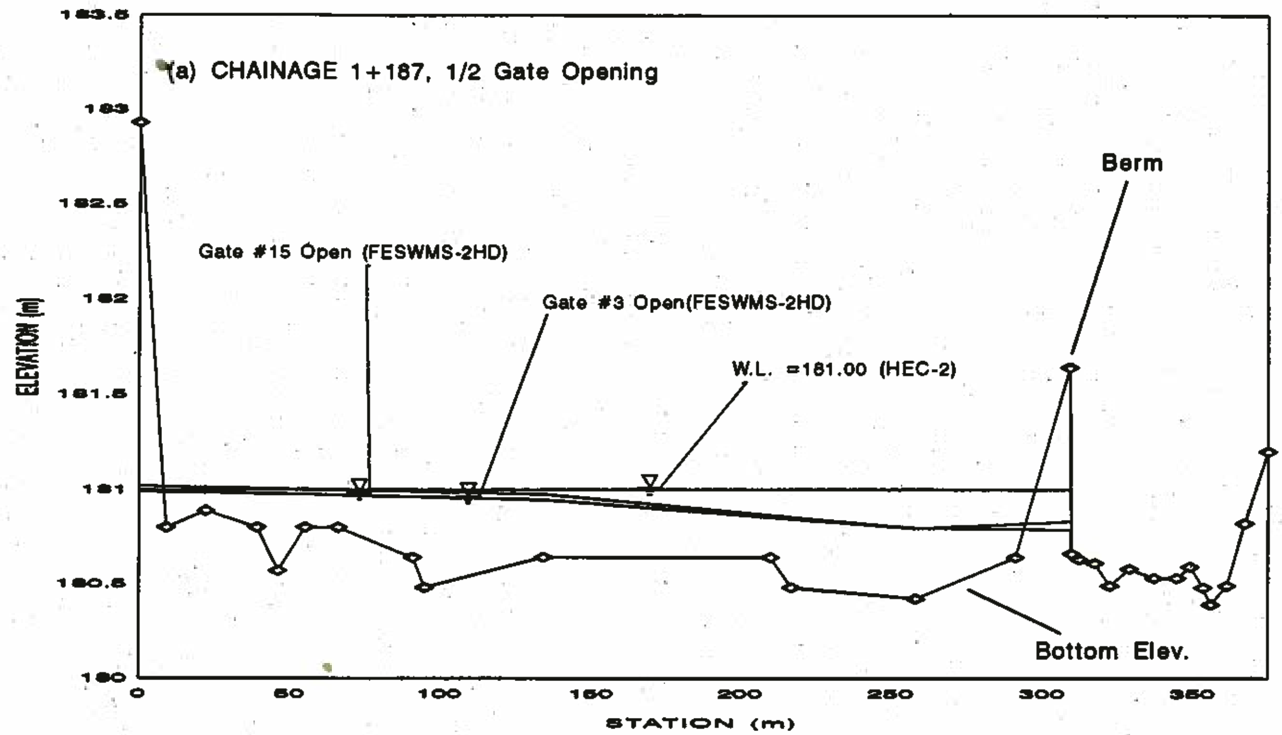


Figure 5.10 Water Level Contour Map of Rapids, South of the Berm (Gate #3, 1 Gate Flow Rate)



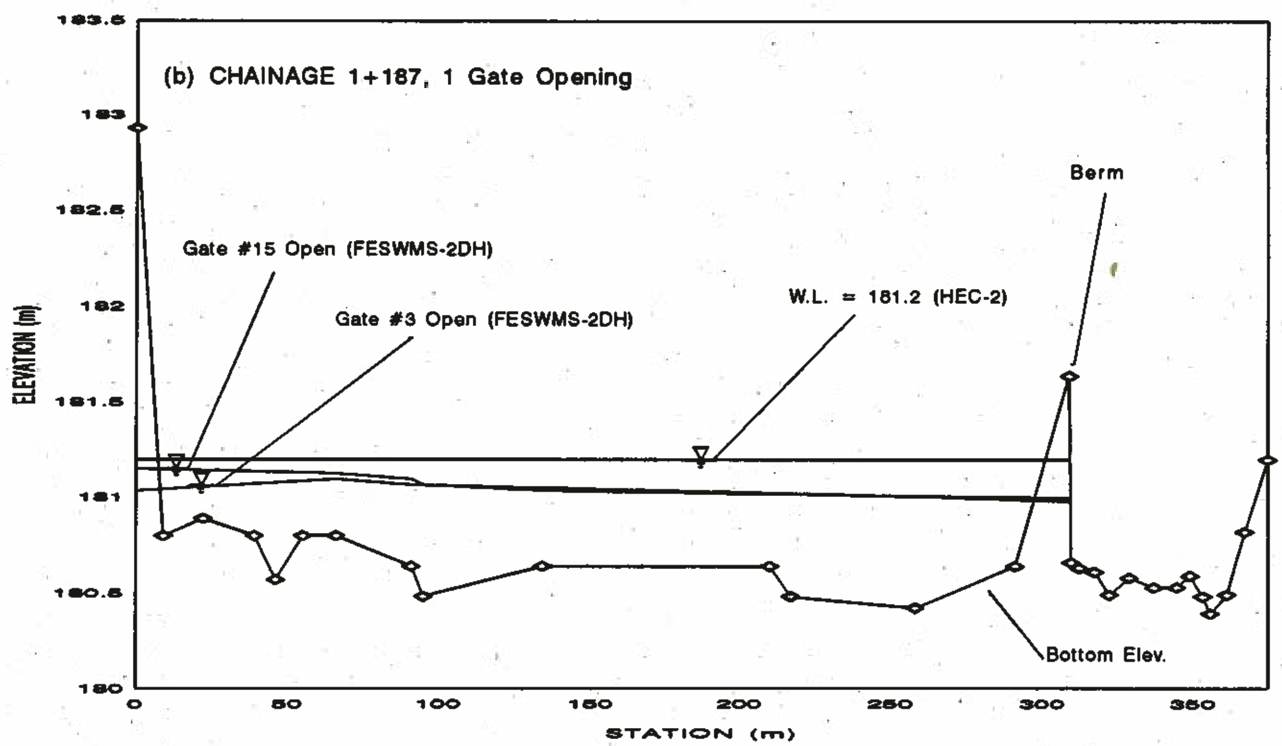


FIGURE 5.11 CROSS SECTION AT CHAINAGE 1+187 (1/2 and 1 GATES FLOW RATES)

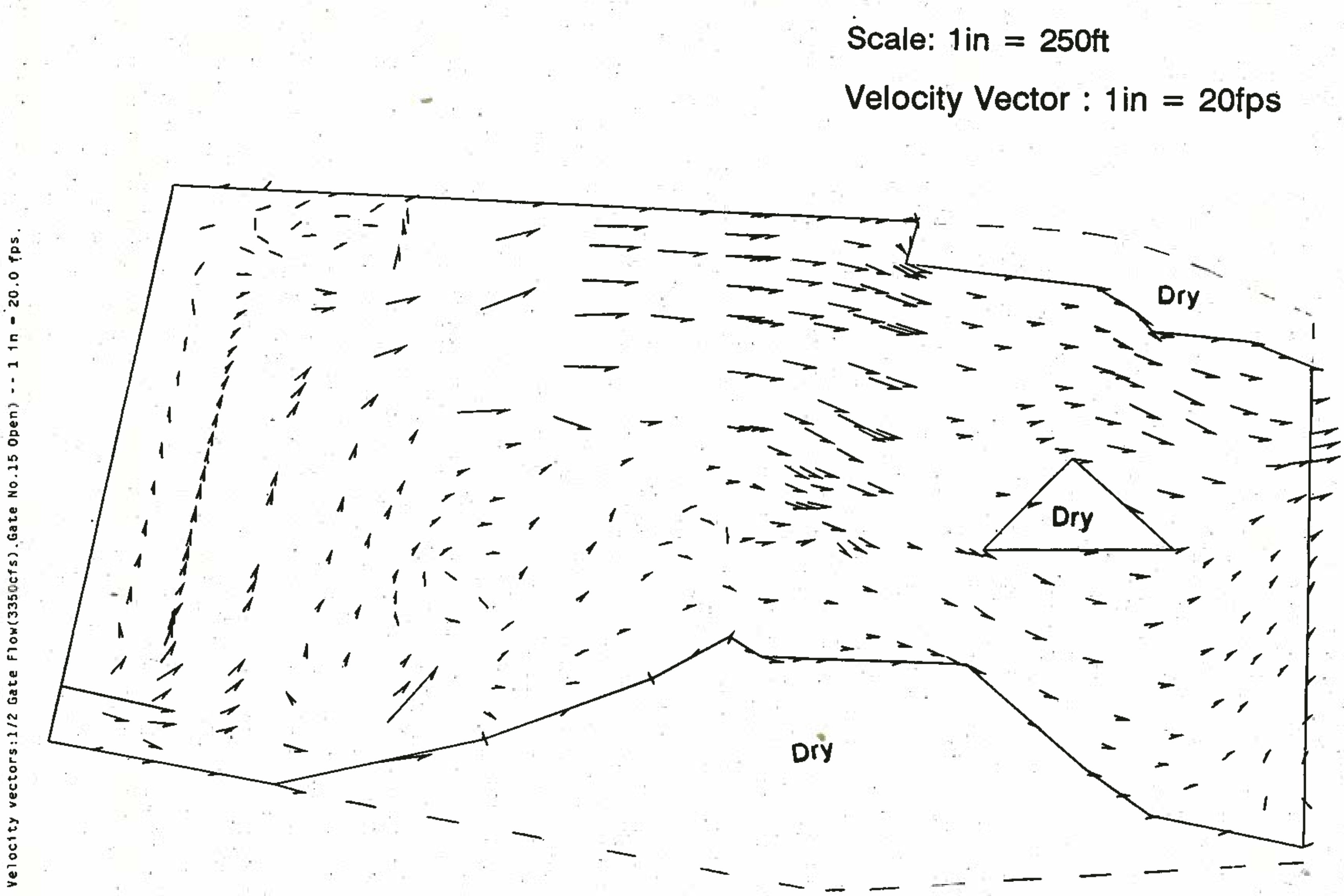


Figure 5.12 Flow Velocity Pattern Map of Rapids, South of the Berm (Gate #15, 1/2 Gate Flow Rate)

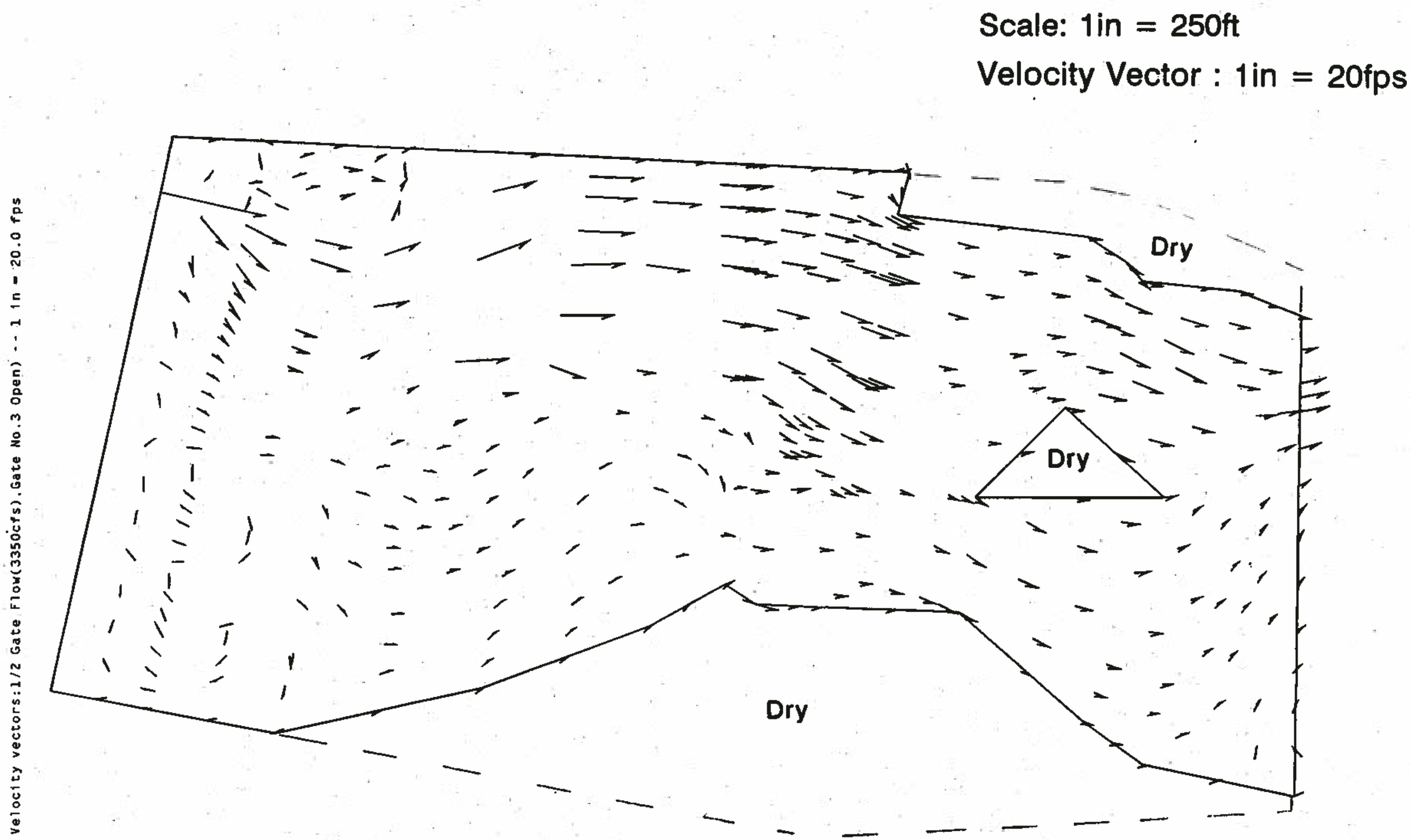


Figure 5.13 Flow Velocity Pattern Map of Rapids, South of the Berm (Gate #3, 1/2 Gate Flow Rate)

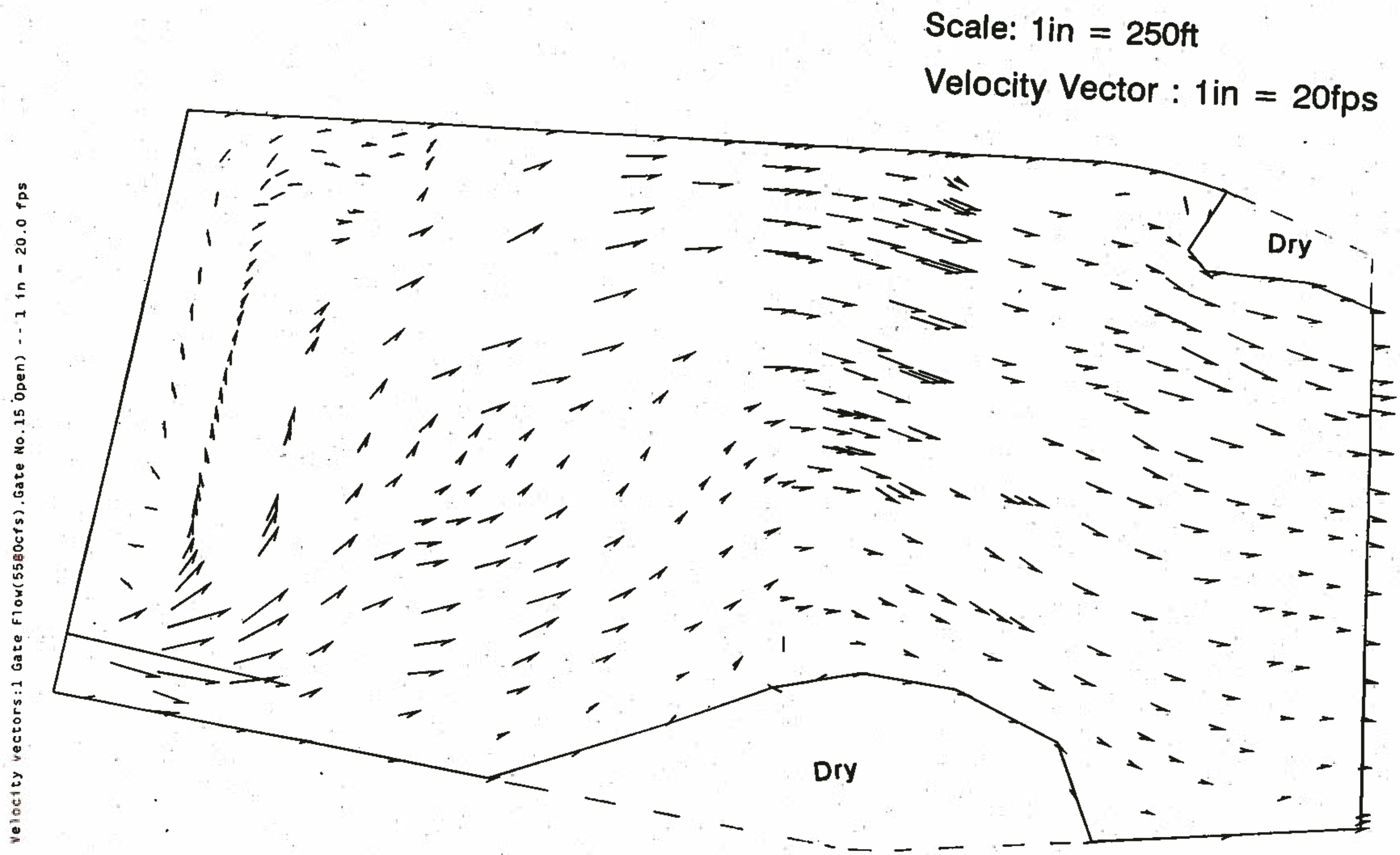


Figure 5.14 Flow Velocity Pattern Map of Rapids, South of the Berm (Gate #15, 1 Gate Flow Rate)

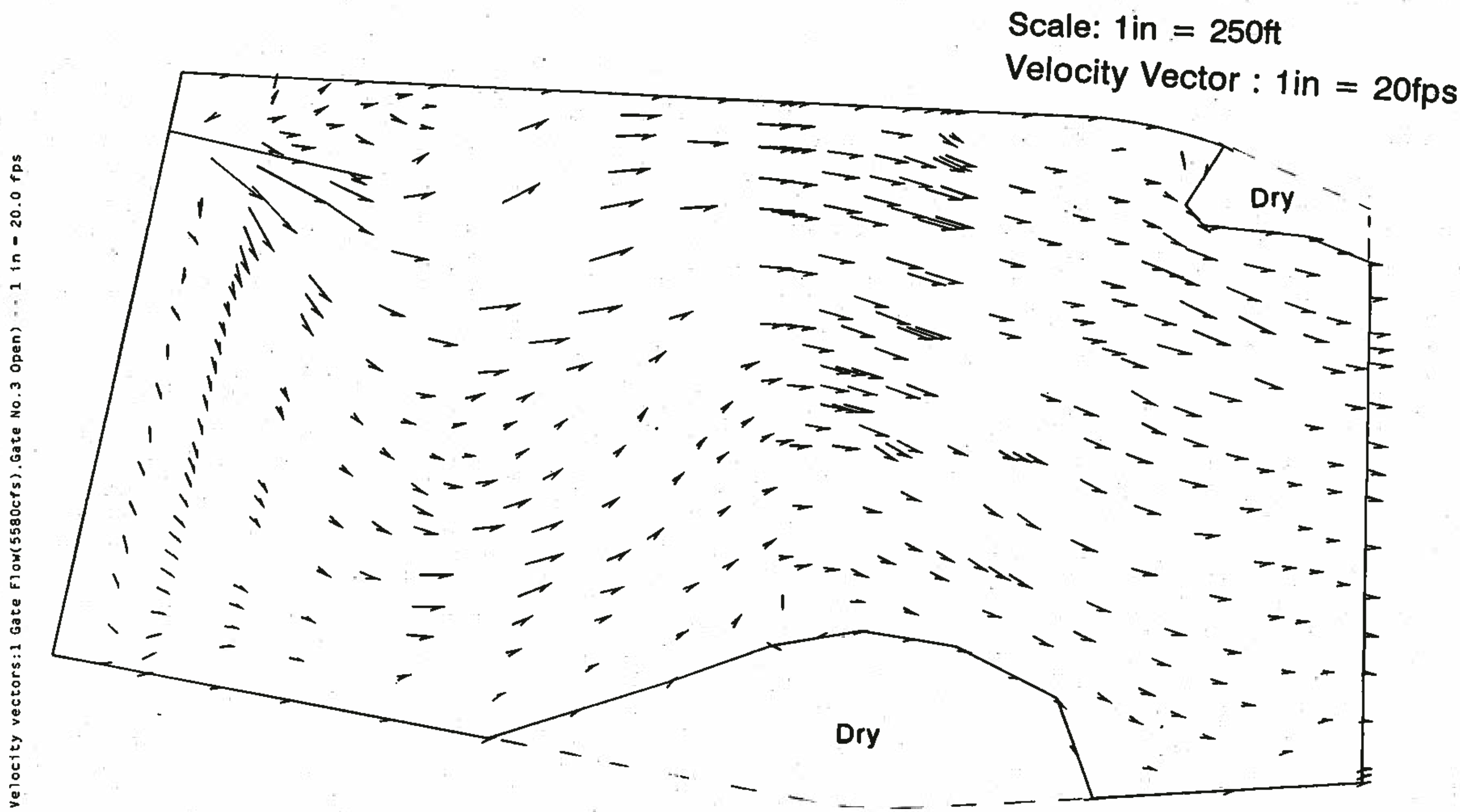


Figure 5.15 Flow Velocity Pattern Map of Rapids, South of the Berm (Gate #3, 1 Gate Flow Rate)

6. ASSESSMENT OF POTENTIAL WETLAND CREATION

6.1 Near Shore Characteristics

The characteristics of flow pattern, water levels, ice and sediment deposit at the near shore areas east of Whitefish Island are documented in the section. Field photos taken around the area are shown in Figure 6.1

6.1.1 Flow Pattern and Velocity

Topographic map (Figure 3.1) and field inspection suggest that no large quantity of flow can enter into Whitefish Channel from the St. Marys Rapids area. Sand bars and rock outcrops effectively cut off the link between two areas. As shown in Figure 1.1, Whitefish Channel, located north side of Whitefish Island, receives most of water supply from the Navigation Lock or the headwaters upstream of the Compensating Works.

In the lee of Whitefish Island there is no current caused by the river flow. Cross river or up river winds may create some wave action but the area is generally characterized by quiet water. Quiet water is also present in most of the area downstream of the mouth of Whitefish Channel.
A small flow volume passes through Whitefish Channel, but this influence dissipates quickly with distance from the Channel mouth. Flows from this Channel will be beneficial to the quiet water areas in that they will carry detritus from the wooded stream banks.

6.1.2 Ice Scour Potential

There is little potential for scour caused by ice moving down the St. Marys River. The Compensating Works may interfere with passage of ice from upstream sections of the river and the potential wetland area is protected by Whitefish Island from the channel where flood flows and moving ice will be concentrated.

Ice which forms along the downstream shore of Whitefish Island and rocks present off shore may cause local short term scour impacts during spring break up, but the ecosystem will have adapted to these natural impacts.

6.1.3 Water Level Fluctuations

Water level fluctuations caused by seasonal changes in flow volumes and flow manipulations by the power corporations will alter water depths in the study area. As discussed in Section 3.3.3, extreme water level fluctuation may range in an order of 2 meters. Normal water level remains around 177.0 m above Sea Level in the area.

Under low flow conditions the wetland area will decline and the perimeter where the vegetated shoreline interfaces with the water will be reduced.

6.1.4 Substrate Conditions

In the near shore areas where water depths are $\leq$1 meter sand is the dominant substrate type, but frequent areas of cobbles and individual boulders are also present (Figure 6.1). Bedrock is also encountered. The hard substrate provide habitat for primary producers which are a food source of a variety of grazing invertebrates.

The sands contained remnants of what appear to be macrophytic plants. Also leaves and stems of little watermilfoil (Myriophyllum alterniflorum) and common elodea (Elodea canadensis) were found in the study area. Most of the sands were firm and held the weight of a person walking over them. There were also a few locations where one would sink into the sand.

Close to shore (within 40 m) there was plant detritus which provides food for invertebrates. A variety of chironomids and amphipods were present in the substrate sample.

6.1.5 Shoreline Vegetation

The following plant taxa were found along the downstream margin of Whitefish Island: sweetgale, willow, alder, and red-osier dogwood. A 5 to 10 m wide sparse band of herbaceous wetland plant species is present at the land/water interface. Plant taxa present include: rush (Juncus), spikerush (Eleocharis), bulrush (Scirpus) and sedge (Carex).

6.2 Existing Habitat and Fish Community

6.2.1 Existing Habitat

Currently there are terrestrial, aquatic and wetland habitat components present in the study area and these are discussed below:

i) The terrestrial habitat of Whitefish Island is important because the trees, shrubs and herbs drop leaves into the St. Marys River and Whitefish Channel. These leaves create detritus which is an important food source for invertebrates.

ii) The open water aquatic habitat is important for aquatic invertebrates, fish and birds (ducks, gulls etc.)

iii) Wetland habitat consists of the narrow band of vegetation along the Whitefish Island shoreline and off shore macrophyte beds. A summer survey would be required to determine the extent of these beds and the dominant plant species present.

The variety of substrate types (sand, cobble, boulders, bedrock) and the interspersion of the bottom types provides cover for fish and sites for primary and secondary production.

The fairly extensive shallow water area (9 ha ±) should provide good habitat for bait fish and nursery habitat for sport fish. The area < 1 m deep is approximately 300 meters wide and extends along the downstream end of Whitefish Island (320 m long).

6.2.2 Existing Fish Community

A review of existing information revealed the following about fish occurrence in the study area. Over 35 fish species have been recorded from the St. Marys Rapids area (Koshinsky and Edwards 1983).

Species known to use the habitat in the Whitefish Channel and/or off the eastern (downstream) end of Whitefish Island include: sea lamprey, brook trout, rainbow trout, and Pacific salmon. Forage fish and young sport fish undoubtedly use the habitat east of Whitefish Island.

Fish eating birds such as gulls and mergansers have been observed foraging at the mouth of the Whitefish Channel.

6.3 Wetland Creation East of Whitefish Island

The nature and extent of existing wetland in the form of aquatic macrophytes has not been adequately documented to date. Creation of any additional wetland features would have to be designed to complement and not to damage existing aquatic vegetation beds.

The area east of Whitefish Island appears to be a feasible location for wetland creation/enhancement. Physical factors such as flow pattern and velocity, sediment deposition, ice scour, water level fluctuations, and existing substrate do not appear to preclude wetland creation/enhancement.

Until the extent of existing macrophyte growths are documented it is difficult to define the maximum area of wetland which the site could support - but the preliminary survey has revealed that a 300 m ± band off the western shore of the island (which is 300 m ± long) may provide suitable conditions for a wetland project (see Figure 1.1).

Considerable cover is already present for fish and aquatic life. The structural nature of the wetland to be created would depend on the purpose of the wetland. Specific objectives and target species should be established which would guide the wetland design process.

Figure 6.2 shows one potential habitat creation concept. Small islands which would be planted to provide overhanging vegetation and leaf energy inputs could be created. A ring of rock would form the island margins, soil fill would provide a substrate for plant growth. Alders and sedges or other wetland/riparian species could be planted.

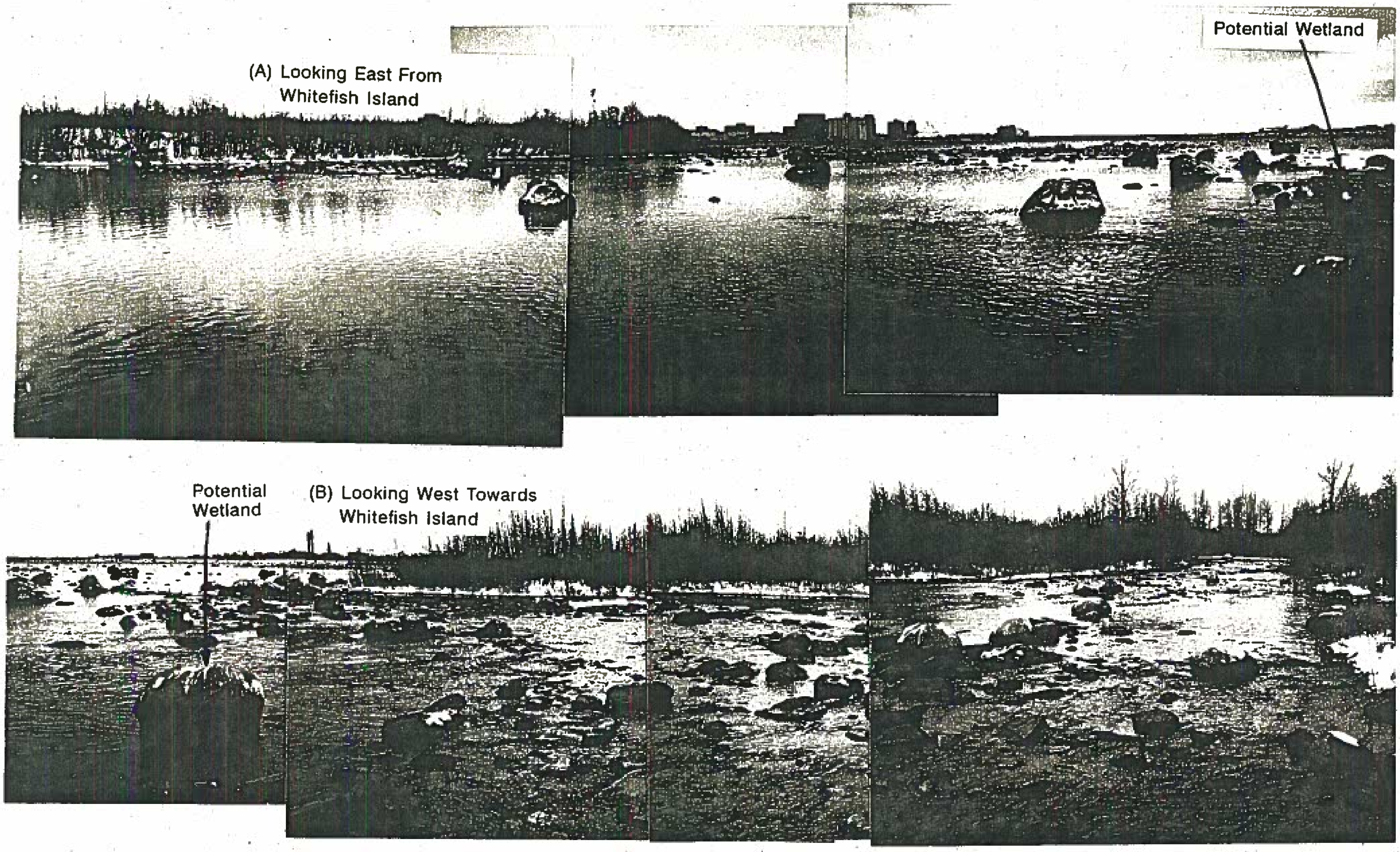


Figure 6.1 Field Photo of Potential Wetland Area

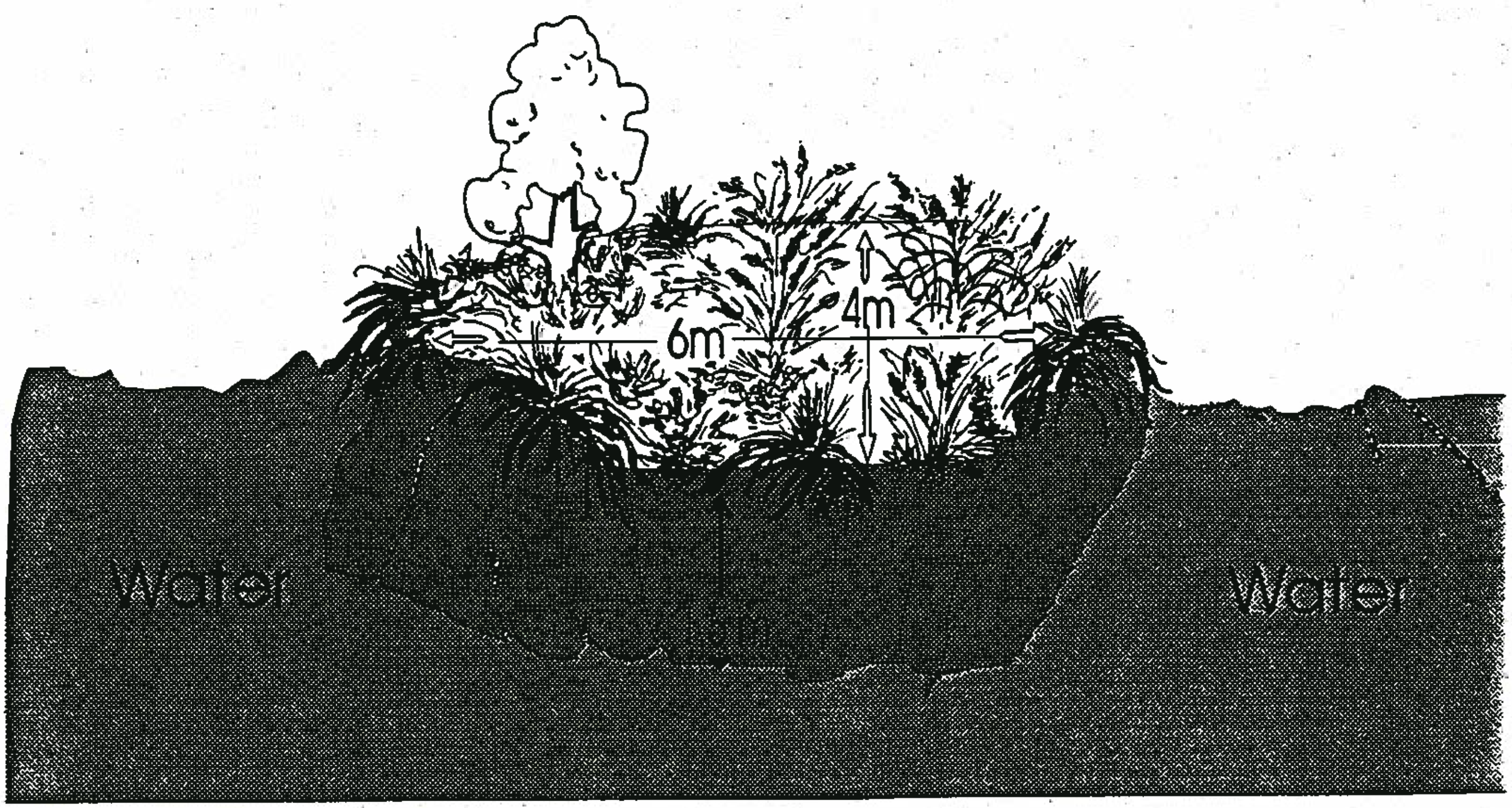


FIGURE 6.2 CONCEPTUAL WETLAND ISLAND HABITAT FEATURE

7. DISCUSSIONS OF FIELD TEST REQUIREMENTS

7.1 Constraints of Present Numerical Model Analysis

The lack of the following field data limits the accuracy of the numerical modelling:

i) Accuracy of topographic map - The topographic map (Scale 1:1200) of the study area was prepared from the aerial photos from 1971. There was no instrumental control of the height or angle of the photographs. Manual control was taken to maintain constant flight altitude and to take vertical photographs. As observed from the topographic map, spot ground elevations were marked only on some dry lands. Ground elevations at many critical areas, such as the upper edges of rapids, are missing.

ii) There is virtually no bathymetric data for the area below water surface. Water sounding were taken in 1988 along the Rapids area along the south edge of Whitefish Island. About 15 transects were sounded from the berm to the water edge of Whitefish Island.

iii) A number of inconsistent data have been observed among the available topographic map (1971), the aerial photos (1990's) and the water sounding (1988). Some field checking needs to be undertaken.

iv) Water edge map - All the available water edge maps were developed in the vicinity of Whitefish Island. No water line was marked south of the berm.

v) Flow pattern data, velocity and depth are mostly missing from the study area. This makes the model calibration or verification difficult.

vi) Sediment, rock and boulder movement data are absent from most of the study area. This restricts the optimal design for the creation of spawning areas.

7.2 Proposed Work Program

The proposed work plan for field testing consists of a number of task components as discussed below:

7.2.1 Field Work During Gate Closing Period

All gates are required to be closed for two (2) days during the daylight time. The following work needs to be carried out:

i) Conduct a field survey on land and water to produce accurate contours. Detailed survey work needs to be carried out in the dry areas and the hydraulic controlled areas, such as the upper edges of falls along the Rapids. Additional sounding and elevations will be measured throughout the Rapids.

ii) Mark down the location and size of the boulders or large rocks. Visually check the trace of boulder, rock and sediment movement.

iii) Mark the distribution of the plane fractured bedrock.

iv) Mark the water edge around the dry areas for the use as a bench mark.

v) Install a number of staff gauges for water level measurement

7.2.2 Field Work During Gate Opening

Only one set (one or several) of gate opening combinations is operated on the same day. There will be three (3) sets of gate operation for a 3 days period. Flow discharge rates will vary from an equivalent of 0.5, 1, 1.5 and 2 gate openings. The following measurements will be taken:

i) Floats can be used to trace the flow direction and stream lines from the Compensating Works through the Rapids area by following their moving paths with a video camera.

ii) Measure nearshore flow velocity and depth in shallow and wadeable areas along the concrete berm or the water edges of both river banks. If possible, current meters with data loggers can be placed at some spots within the potential fish moving passages to measure flow velocity and direction. This is to make sure that fish can reach the wetland areas against the flow current. The equipment can be retrieved at the end of the field test period (with all gates closed)

iii) Mark the water edges around the dry land areas, and visually measure the water level from the staff gauges.

7.2.3 Model Calibration and Adjustment

The proposed field work should obtain very valuable field data from a number of field testings. After the field testing, the numerical model will be calibrated and adjusted in order to cover a broader range of gate opening combination and hydraulic conditions, and improve the accuracy of model prediction.

7.2.4 Furnished Data Requirements

The following equipments may be required for the proposed field test program:

i) A total station transit with a team of survey crew.

ii) A boat with crew.

iii) A number of flow velocity meters and if feasible, a couple of current meters.

iv) A number of staff gauges.

v) A number of floats.

vi) Photo and movie cameras equipped with wide angle and long distance lens.

vii) Sediment sampler.

viii) Several helicopter trips for photo takings.

APPENDIX: COMPUTER FILES

A) FESWMS-2HD Modelling

<u>1/2 Gate Flow (Gate No. 15 Open)</u>

Input Files

marydi14.dat	--	grid & elevation input files for DINMOD
maryfl14.dat	--	flow input files for FLOMOD
maryan14.dat	--	input files for plotting for ANOMOD

Output Files

marydi14.prt	--	output files from DINMOD
maryfl14.prt	--	output files from FlOMOD
maryan14.prt	--	output files from ANOMOD

Plotting Files

marydi14.plt	--	screen plotting file from DINMOD (with contour & grid)
maryfl14.plt level)	--	screen plotting file from ANOMOD (with velocity vector & water
mardi14g.plt	--	from marydi14.plt (grid only)
mardi14c.plt	--	from marydi14.plt (contour only)
marfl14v.plt	--	from maryfl14.plt (velocity vector only)
marfl14w.plt	--	from maryfl14.plt (water level only)
mardi14g.cdr report)	--	CorelDRAW plotting files, imported from mardi14g.plt (fig 5.5 in
mardi14c.cdr report)	--	CorelDRAW plotting files, imported from mardi14c.plt (fig 5.6 in
marfl14v.cdr report)	--	CorelDRAW plotting files, imported from mardi14v.plt (fig5.12 in
marfl14w.cdr report)	--	CorelDRAW plotting files, imported from mardi14w.plt (fig 5.7 in

Intermediate output files

marydi14.grd	--	intermediate output file in DINMOD
maryfl14.flw	--	intermediate output file in FLOMOD

<u>1/2 Gate Flow (Gate No. 3 Open)</u>

Input Files

marydi15.dat	--	grid & elevation input files for DINMOD
maryfl15.dat	--	flow input files for FLOMOD
maryan15.dat	--	input files for plotting for ANOMOD

Output Files

marydi15.prt	--	output files from DINMOD
maryfl15.prt	--	output files from FlOMOD
maryan15.prt	--	output files from ANOMOD

Plotting Files

marydi15.plt	--	screen plotting file from DINMOD (with contour & grid)
maryfl15.plt	--	screen plotting file from ANOMOD (with velocity vector & water level)
marfl15v.plt	--	from maryfl15.plt (velocity vector only)
marfl15w.plt	--	from maryfl15.plt (water level only)
marfl15v.cdr	--	CorelDRAW plotting files, imported from mardi15v.plt (fig5.13 in report)
marfl15w.cdr	--	CorelDRAW plotting files, imported from mardi15w.plt (fig 5.8 in report)

Intermediate output files

marydi15.grd	--	intermediate output file in DINMOD
maryfl15.flw	--	intermediate output file in FLOMOD

<u>1 Gate Flow (Gate No. 15 Open)</u>

Input Files

marydi26.dat	--	grid & elevation input files for DINMOD
maryfl26.dat	--	flow input files for FLOMOD
maryan26.dat	--	input files for plotting for ANOMOD

Output Files

marydi26.prt	--	output files from DINMOD
maryfl26.prt	--	output files from FlOMOD
maryan26.prt	--	output files from ANOMOD

Plotting Files

marydi26.plt	--	screen plotting file from DINMOD (with contour & grid)
maryfl26.plt	--	screen plotting file from ANOMOD (with velocity vector & water level)
marfl26v.plt	--	from maryfl26.plt (velocity vector only)
marfl26w.plt	--	from maryfl26.plt (water level only)
marfl26v.cdr	--	CorelDRAW plotting files, imported from mardi26v.plt (fig5.14 in report)
marfl26w.cdr	--	CorelDRAW plotting files, imported from mardi26w.plt (fig 5.9 in report)

Intermediate output files

marydi26.grd	--	intermediate output file in DINMOD
maryfl26.flw	--	intermediate output file in FLOMOD

1 Gate Flow (Gate No. 3 Open)

Input Files

marydi27.dat -- grid & elevation input files for DINMOD
maryfl27.dat -- flow input files for FLOMOD
maryan27.dat -- input files for plotting for ANOMOD

Output Files

marydi27.prt -- output files from DINMOD
maryfl27.prt -- output files from FlOMOD
maryan27.prt -- output files from ANOMOD

Plotting Files

marydi27.plt -- screen plotting file from DINMOD (with contour & grid)
maryfl27.plt -- screen plotting file from ANOMOD (with velocity vector & water level)

marfl27v.plt -- from maryfl27.plt (velocity vector only)
marfl27w.plt -- from maryfl27.plt (water level only)

marfl27v.cdr -- CorelDRAW plotting files, imported from mardi27v.plt (fig5.15 in report)
marfl27w.cdr -- CorelDRAW plotting files, imported from mardi27w.plt(fig5.10 in report)

Intermediate output files

marydi27.grd -- intermediate output file in DINMOD
maryfl27.flw -- intermediate output file in FLOMOD

B) HEC-2

North Rapid

Input Files

extnor.dat -- existing Condition of North Rapid
newnor.dat -- proposed Condition of North Rapid (with proposed Berm)

Output Files

extnor.out -- output files from extnor.dat
newnor.out -- output files from newnor.dat

Plotting Files

extnor.tap -- screen Plotting files from extnor.dat
newnor.tap -- screen Plotting files from newnor.dat

South Rapid

Input Files

rapid0-3.dat	--	ex. Condition of South Rapid (flow for 0,1/4, 1/2,1,2 & 3 gates open)
rapid416.dat	--	ex. Condition of South Rapid (flow for 4, 13 & 16 gates open)

Output Files

rapid0-3.out	--	output files from rapid0-3.dat
rapid416.out	--	output files from rapid416.dat

Plotting Files

rapid0-3.out	--	screen plotting files from rapid0-3.dat
rapid416.out	--	screen plotting files from rapid416.dat