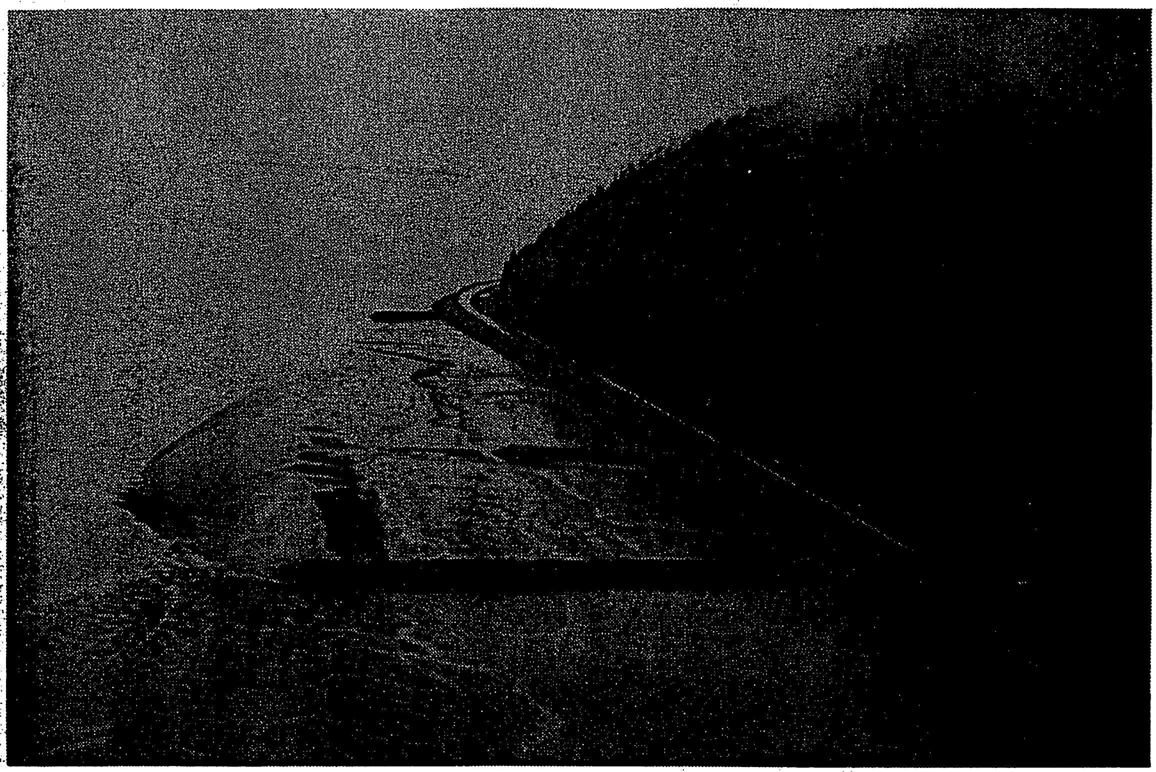
Khyex-Tyee: Foreshore Habitat Re-construction Works



Prepared for

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Executive Summary

This report documents the foreshore habitat compensation works constructed by the Ministry of Transportation and Highways as part of the Highway 16 Re-construction Project, located near Prince Rupert, B.C.

Original habitat compensation designs were presented to, and accepted by, both the Ministry and the Department of Fisheries and Oceans in 1988. These designs were based on permanent intertidal vegetation losses of 1.65 ha and temporary impacts to a further 1.2 ha. Total re-created habitat was to be 4.9 ha, resulting in an ultimate compensation/loss ratio of 2:1. These original designs entailed habitat re-creation at 3 sites. All sites were to be protected by rock spurs.

Due to contractual, timing and materials constraints, major changes to the compensation scheme were proposed by the Ministry in the summer of 1988.

In the revised design, all compensation habitat was to be created at one site. Surface elevations of the created habitat would be -0.5 to +0.25 m geodetic with surface slopes varying between 10:1 and 20:1. Total re-created habitat area would be 2.6 ha, resulting in a compensation/loss ratio of 1.6:1.

There would be no temporary impacts during habitat re-creation. The rock spurs would still be built at the 3 sites originally proposed, but they would be modified to minimize habitat impacts and maximize natural sedimentation.

These design changes were accepted by the Department of Fisheries and Oceans in the late summer of 1988. Construction of the compensation site was completed in March, 1989. Construction of the rock spurs at the other sites was completed in the summer of 1989.

The compensation site was surveyed in March, April and July, 1989. The surveys documented changes in the surface elevations, indicating that sedimentation within the site was occurring. In some places the surface elevations increased of up to 1.5 m. Sedimentation of a similar magnitude also occurred adjacent to and downstream of the compensation site.

Some sedimentation appears to be occurring at the other sites but not of the same magnitude. These sites will be re-surveyed as part of the monitoring program.

The sedimentation has resulted in unexpected impacts to the intertidal vegetation, mostly within the compensation site and immediately downstream of the site. There has been a loss of 2.15 ha of intertidal vegetation since construction. The author anticipates that these areas will become vegetated and recover naturally within the time frame of the monitoring program. Overall, this sedimentation is expected to result in a "natural" increase in intertidal vegetation, above and beyond the compensation habitat created directly.

A pilot scale transplant operation was completed in April, 1989. Donor plant material of three plug sizes was planted in 5 plots within the compensation site. Survival and growth data were collected in July, 1989. Survival and growth were excellent.

The information gathered from the pilot program was incorporated into the design of 1990 transplant operations. These operations were designed to minimize the risk of transplant failure through sedimentation and/or erosion and to maximize the establishment of vegetation within the compensation site.

A monitoring program is presented. This program is a modified version of the program presented in White, 1988. It includes site assessment visits in 1990, 1991, 1993 and 1995. Site visits in 1992 and 1994 would be undertaken only if warranted.

Acknowledgements

The author would like to acknowledge the help and assistance of the following people:

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I would also like to extend special thanks to the hardworking survey crew - Rob Cooper, Rob Ohman, Harry Halladay and Rob Magdanz.

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1.0 Introduction

The purpose of this report is to document foreshore fish habitat compensation works constructed by the Ministry of Transportation and Highways as part of the Highway 16 re-construction project, located near Prince Rupert, B.C. The project entailed widening the road bed and increasing the separation of the highway from the railway. This resulted in encroachment into the river over near-shore habitats, including 1.65 ha of intertidal vegetation.

The Department of Fisheries and Oceans "Policy for the Management of Fish Habitat" states that there shall be no net loss of the productive capacity of fish habitat through the impacts of any construction works. This is the long-term working principle. The practical interpretation of this principle is that compensation designs should replace lost intertidal vegetation at a ratio of 2:1 by area (i.e., re-created compensation habitat should be twice the area of the lost habitat), and un-vegetated habitat should be replaced at a ratio of 1:1 by area. The higher replacement rate for vegetated habitat is a reflection of the technical uncertainty of habitat re-creation and the loss in productivity during re-establishment.

The compensation scheme presented in this report is essentially bimodal. 2.6 ha of compensation habitat is re-created directly, resulting in an immediate compensation/loss ratio of 1.6:1. However, more intertidal vegetated habitat is expected to develop "naturally" as the existing vegetation expands onto new sediments - sediments deposited as a result of the compensation works. It is, therefore, expected that the compensation/loss ratio will increase with time.

2.0 Habitat Compensation Designs

2.1 Original Compensation Design

The original habitat compensation concepts and designs for this project have been presented in two reports : "Khyex to Tyee Hydrological Mitigation Study" (Kellerhals, 1983), and "A Wetlands Mitigation Proposal to Compensate for Highway 16 Re-Construction Impacts Near Prince Rupert, B.C." (White, 1988). The designs presented in White, 1988 were reviewed and accepted by both the Department of Fisheries and Oceans and the Ministry of Transportation and Highways in 1988, and are summarized below.

Intertidal vegetation losses would be incurred at three areas within the project, and replacement habitat was to be constructed at each area. Each site would be protected by rock spurs. A bench would be constructed between the spurs, elevating the substrate into the range suitable for plant growth.

Two types of habitat losses would be incurred during this project. In addition to habitat that would be buried under the highway and permanently alienated, some otherwise undisturbed marsh would be buried during construction of replacement habitat. This would happen in areas where intertidal vegetation extended beyond the fill limits of the new road bed. After discussions with the Department of Fisheries and Oceans it was decided that permanently alienated habitat was to be replaced at a ratio of 2:1, whereas temporarily impacted habitat would be replaced at a 1:1 ratio.

The original designs called for a total of 4.9 ha of habitat to be re-created, in compensation for 1.65 ha of permanently lost habitat and 1.2 ha of temporarily impacted habitat.

Following the acceptance of these designs major changes were required due to contractual, timing and materials constraints. These changes were discussed with and approved by the Department of Fisheries and Oceans in the summer of 1988.

2.2 Revised Compensation Design

The revised design specified that 2.6 ha of compensation habitat would be built at a single site, between rock spurs located at chainages 983+00 and 985+20 (moved from 986+00). The site is bounded by the highway and by a vegetated sandbar offshore. The 983+00 spur was to be lengthened to 200 metres, extending beyond the offshore vegetation.

Within the compensation site three habitat pads would form a series of ridges running parallel to the highway. These habitat pads would be constructed of quarried rock capped by at least 0.30 m of fine material from the channelization works on Inver, Antigonish and Ekumsekum creeks. They would be located 62, 100 and 138 metres off centerline. Surface elevations would vary from -0.5 m to +0.25 m geodetic. Substrate slopes would be in all cases less than 10:1 and generally 20:1. This compensation site design is summarized in Figure 1.

This revised design eliminates the burial of undisturbed marsh through habitat re-construction.

In an effort to maximize the potential for long-term marsh expansion through further sedimentation, all other rock spurs were extended to reach the -4.5 m geodetic contour. Also, the rock spur located at chainage 1023+00 was to be moved to 1023+65 to avoid unnecessary impacts to existing vegetation. Over the long-term, it is expected that these changes will result in increases in the substrate elevation and a subsequent expansion of the existing wetland vegetation.

In summary: this revised design differed from the initial design in three ways: it decreased the temporary impacts of the project, decreased the amount of compensation habitat that would be constructed and enhanced the potential for long term "natural" marsh expansion through increased sedimentation.

2.3 Habitat Construction

Rock spurs at the compensation site were constructed according to the revised design, and were completed in September, 1988. The remaining rock spurs were completed by July, 1989. All were constructed as designed, except those located at chainages 995+00 and 996+00.

The 995+00 and 996+00 rock spurs were built at non-design angles from shore. The 995+00 spur was built at right angles to shore, instead of being angled downstream, and the 996+00 spur was built at with an upstream orientation, rather than at right angles to shore. These changes were allowed to stand as they would not change the protective capabilities of the spurs (Kellerhals, 1989, personal communication).

The rock spurs, as constructed, are shown in Figure 2.

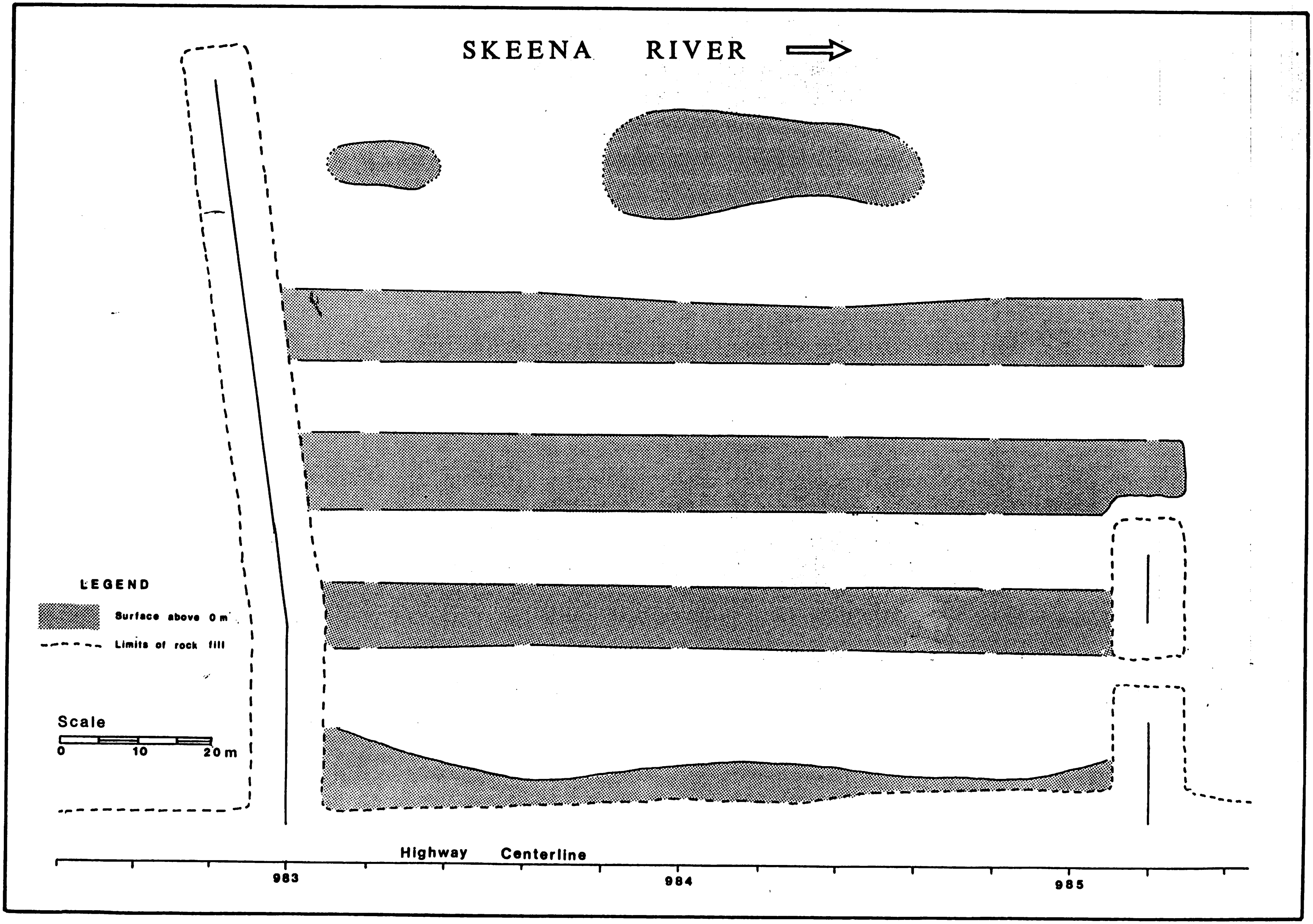


Figure 1: Foreshore habitat compensation site - revised design.

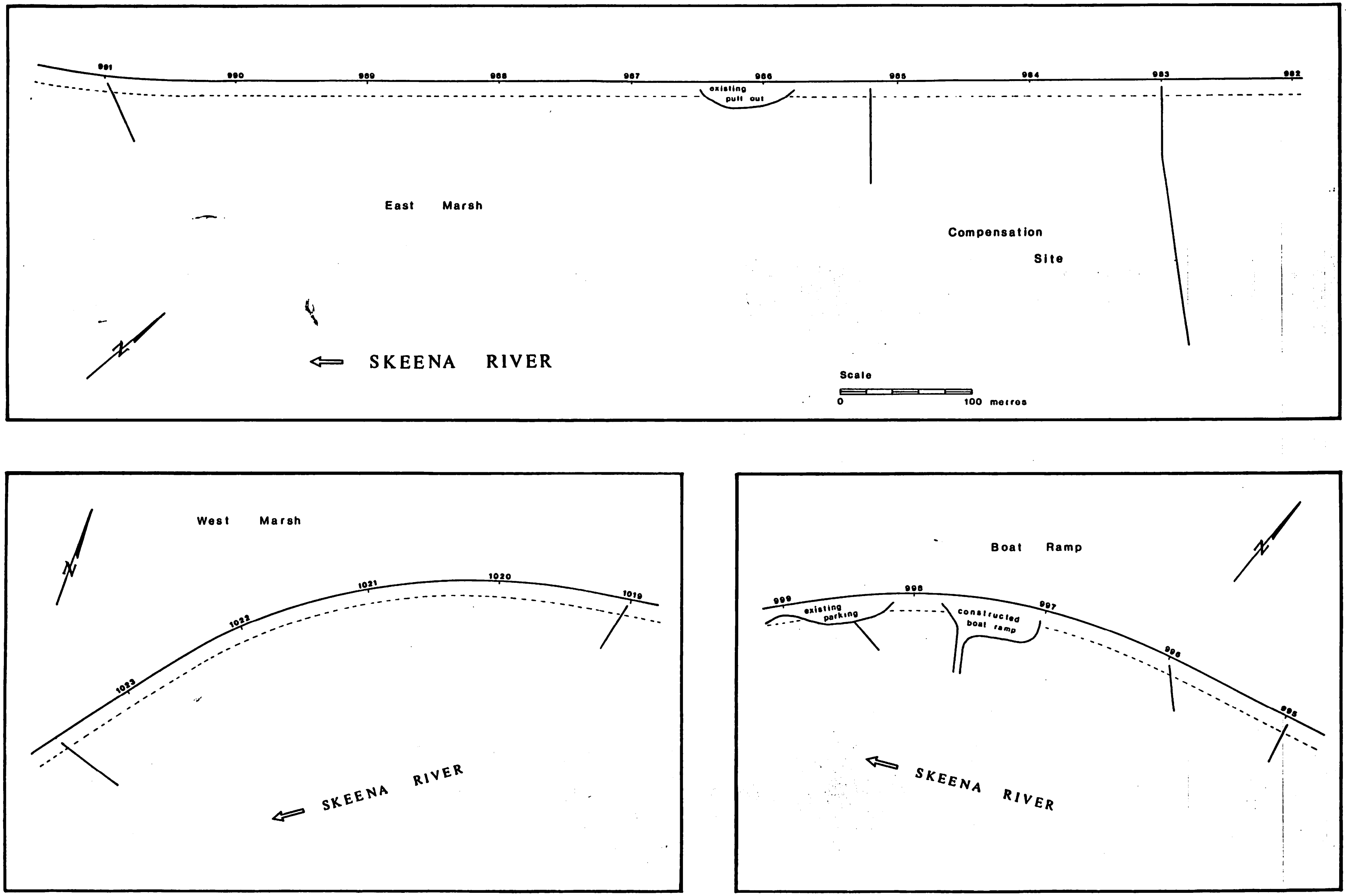


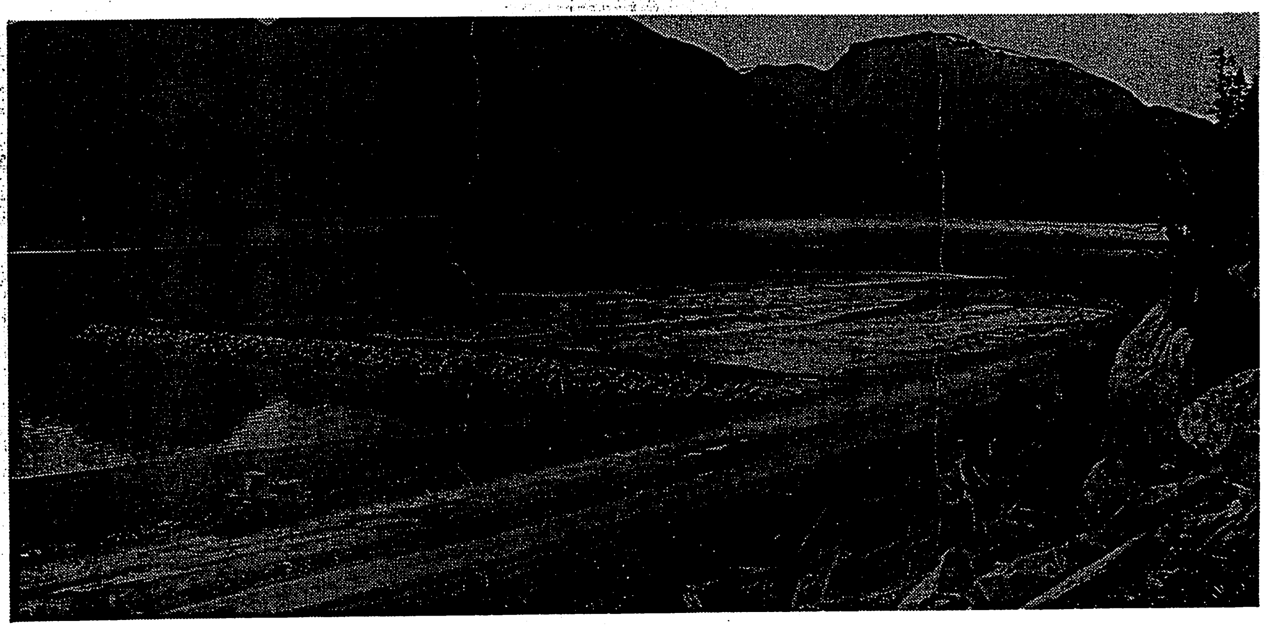
Figure 2: Foreshore habitat compensation works showing new highway centerline, rock spurs and limits of highway fill.

Habitat construction followed the revised design closely. Design elevations of the re-created foreshore surfaces were achieved with approximately 50 cm of fine material over all rock fill, with the exception of the third habitat pad. The amount of quarried rock placed for the third habitat pad was increased due to a shortage of salvaged creek material. Due to the extra rock and difficulties in its placement, some coarse material remained exposed on completion of construction. Construction of the first pad was completed in September, 1988 and the remaining pads were completed by early March, 1989.

Drainage from the compensation site was improved by cutting a channel around the toe of the downstream spur.

The compensation site rock spurs were capped with waste organic material salvaged from the west marsh area. A seed mix designed for intertidal use was used to dry seed the spurs during July, 1989. They were also planted with alder whips. These initial alder plantings were largely unsuccessful. Alder whip planting was repeated in November, 1989 (on Ron Thompson's initiative) and, at the time of writing (April, 1990), appears to have been successful.

Photograph 1 shows the completed construction.



Photograph 1: The compensation site on July 17, 1989.

2.4 Post-construction Geomorphic Changes

Compensation site construction was documented photographically and by surveying established cross-sections. These were surveyed in March, April, and July of 1989.

Cross-sections were also established, and surveyed, at the other sites in July, 1989. These will be re-surveyed during the monitoring program, to document the effect of the rock spurs. The cross-section locations are given in Appendix 1.

The compensation site survey data was used to compile contour maps of the site. These maps are presented in Appendices 2, 3 and 4. Changes in the area above 0.0 m geodetic within the site are illustrated in Figure 3.

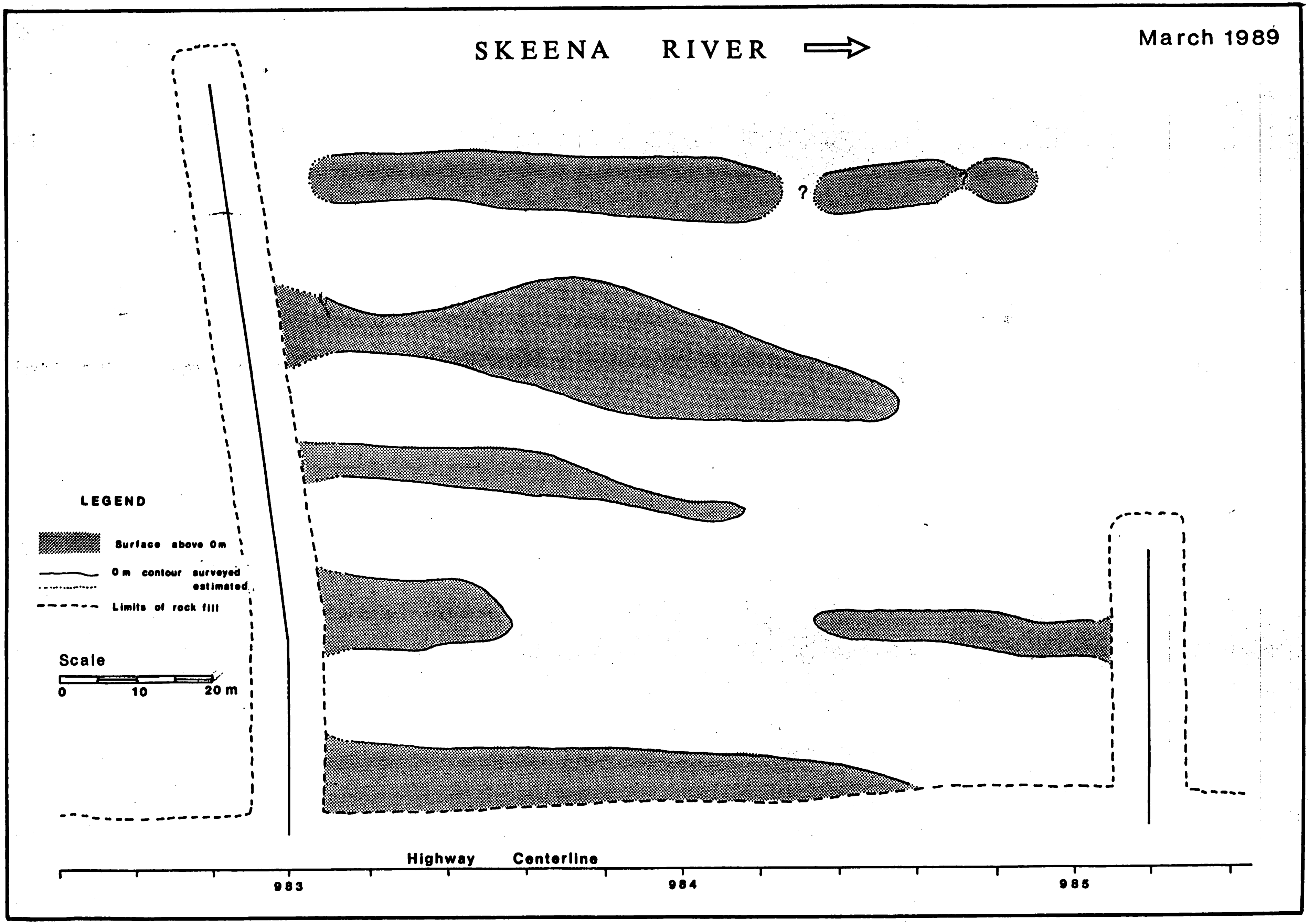


Figure 3: Changes in the area above 0.0 m geodetic elevation within the compensation site between March and July, 1989.

These survey results show major changes in surface elevations throughout the compensation site. By July 1989 there was an obvious increase in the amount of area above 0.0 m geodetic. In general, the low points had been filled in and there was a decrease in the surface roughness of the site. Importantly, there was no observed decrease in the elevation of the high areas. This would indicate that the filling in of the low points was not due to the simple re-distribution of the placed material, but was from sedimentation within the site.

Increased substrate elevations have also been observed downstream of the site. The area involved extends approximately 300 m downstream of the compensation site and 80 - 100 m offshore.

The average elevation change appears to be in the order of 0.75 m both within and downstream of the compensation site. This indicates that a substantial amount of new material - in the order of 20 - 40 000 m^3 - has been deposited by the river.

3.0 Changes in Foreshore Vegetated Habitat

Changes in the total area of foreshore vegetation area changes have been determined by comparing a pre-construction survey (July, 1987) with a post-construction survey (July, 1989). The results and the expected habitat loss, are given in Table 1. Changes in vegetated areas within the compensation site following construction are illustrated in Figure 4.

Table 1: Foreshore Wetland Vegetation Changes (in m^2)

Site	Pre-construction Vegetated Area	Design Loss	Post-construction Vegetated Area	Total Decrease
East Marsh	23 016	10 702	27 481	15 534
Boat Ramp Marsh	570	559	0	570
West Marsh	10 652	5 297	5 189	5 464
Total	34 238	16 558	12 670	21 568

The amount of permanently lost habitat appears to be consistent with the design loss figure presented in White, 1988. However, the amount of lost habitat as of July, 1989 is greater than the anticipated.

This increase appears to be due to increased sedimentation (up to 50 - 80 cm), apparently resulting from the effect of the rock spurs. Although this is an immediate negative impact, it does have positive long-term ramifications. Foreshore marsh area should increase as vegetation colonizes the new habitat. This new habitat will be created as the substrate surface rises to elevations compatible with plant growth.

The geomorphic changes observed within the compensation site also bode well for its future. Surface elevations within the site are increasing and the substrate appears stable. Results of similar projects in the Campbell and Fraser river estuaries indicate that if the surface sediments are stable then vegetation will grow, even if the transplant operation is initially unsuccessful (N.K. Dawe, 1988, personal communications; Eric White, personal observations, 1986 & 1987).

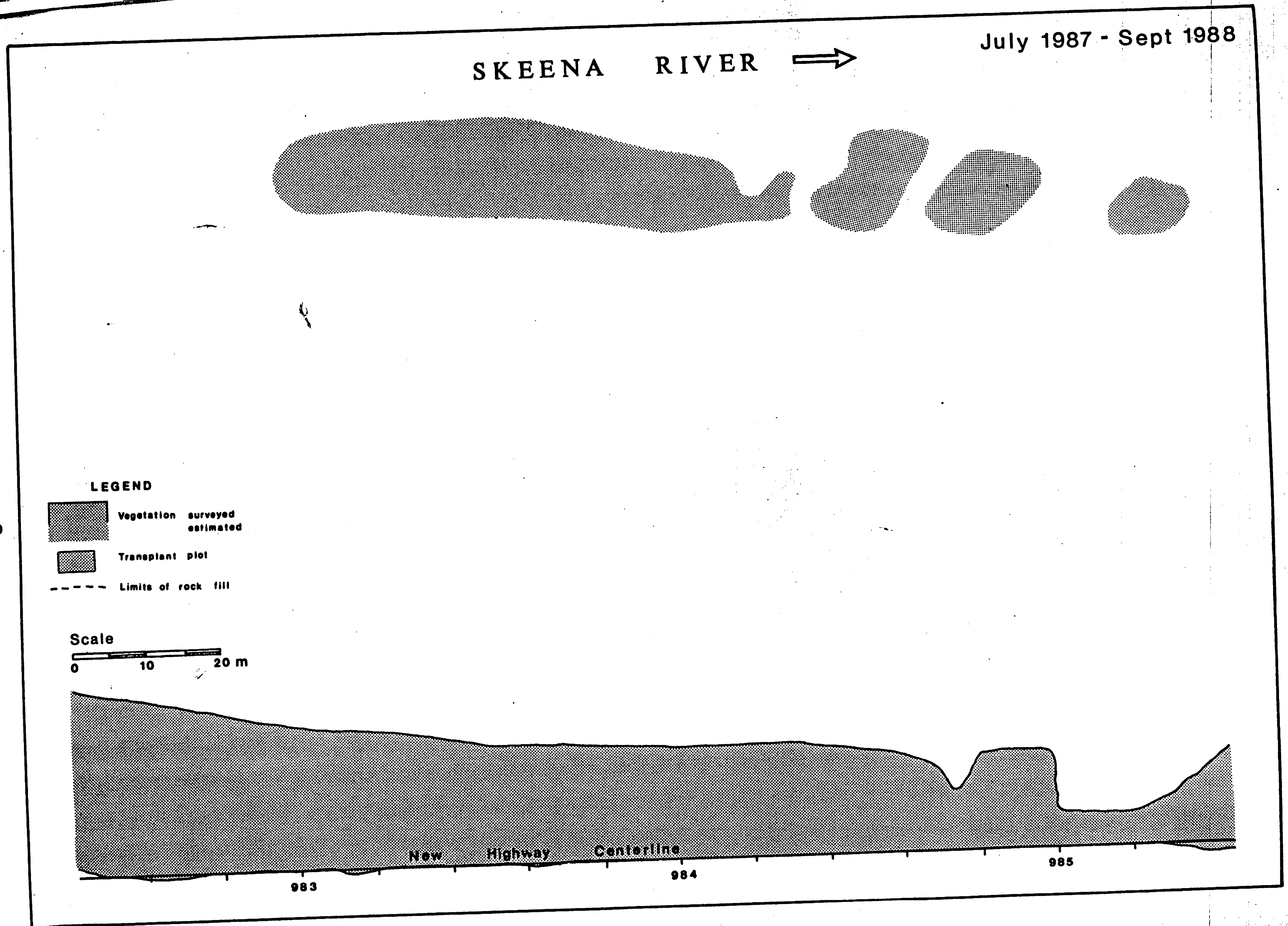


Figure 4: Changes in the vegetated area with the compensation site following highway widening.

3.1 Compensation/Loss Ratio

As of March, 1989, these compensation works have created approximately 2.6 ha capable of supporting wetland vegetation in the compensation site. This results in an initial compensation/loss ratio of about 1.6:1. However, for the reasons explained above, the amount of vegetated habitat created as a result of these works should increase over time.

1.1 km of shoreline, excluding the compensation site, has been protected with rock spurs. If a band of marsh vegetation 10 m wide were to develop throughout this length, a further 1.1 ha of compensation habitat would result. While a continuous 10 m band of new vegetation is not likely, an increase of vegetated area of that magnitude seems reasonable. In such a case, the long term compensation/loss ratio would exceed 2:1.

4.0 1989 Transplant Program

A pilot scale transplant program within the compensation site was undertaken in March 1989. Its purpose was to determine best plug size with respect to growth success and transplant methods, and to see what practical problems would arise in such an operation.

The original design called for the sites to left unplanted through one winter to allow them to stabilize. The first habitat pad was completed in September/October, 1988 and therefore met this criterion. Five transplant plots were established on the first habitat pad (62 m off centerline, see Figure 4).

Plugs of donor material were taken from the undisturbed marsh upstream of the compensation site. Donor vegetation consisted of predominantly spike-rush (Eleocharis palustris) and Lyngbyei's sedge (Carex lyngbyei). The donor material was taken from elevations comparable to those within the compensation site.

Three types of donor plugs were taken using both a modified golf course cup cutter and shovels. The physical characteristics of each type are given in Table 2.

Table 2: Physical characteristics of transplant plugs

Plug Type	Shape	Diameter/Width (cm)	Surface Area (cm^2)	Volume (liters)
10 cm	round	10.5	86.6	1.732
16 cm	round	15.5	188.7	3.774
shovel	square	20	400	8.0

Each transplant plot was laid out on a 1 m grid, 5 m by 11 m. Within each plot, 4 rows of each plug type were planted.
Each plot contained a total of 72 plugs (24 of each type). Due to area constraints, only 3 rows of each type (18 plugs) were planted in plot 5.

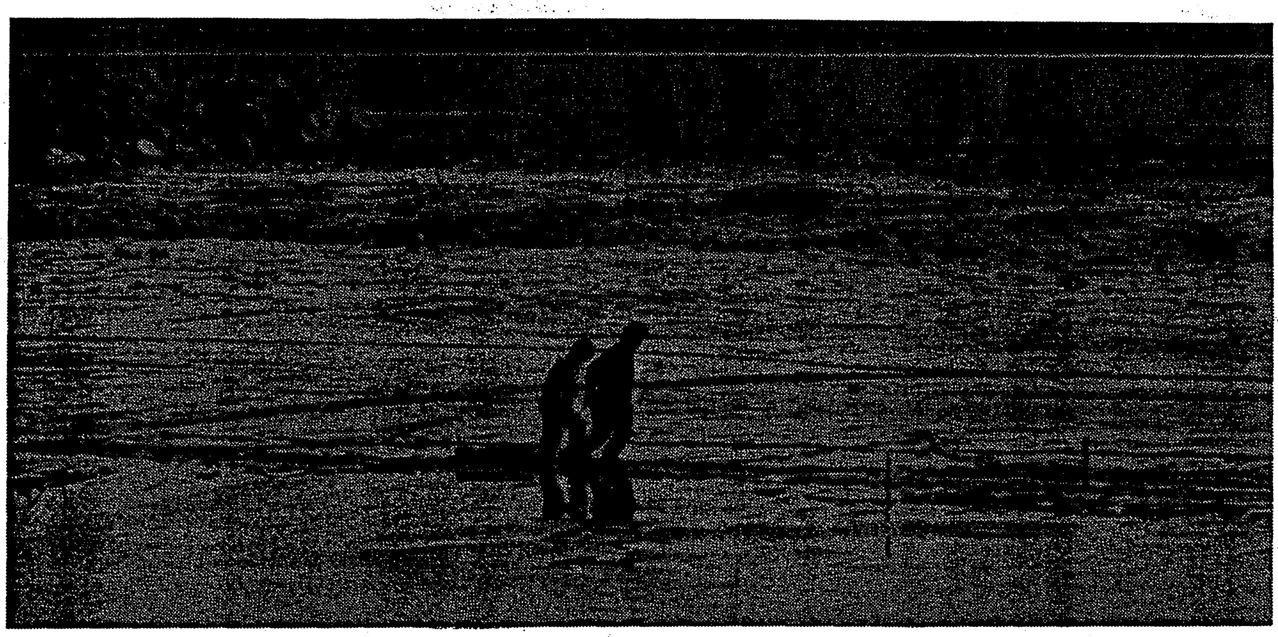
Plug survival and plant growth were assessed in July 1989. Stem density measurements were made by counting all stems within a 625 cm^2 quadrat, and 5 replicates of each sample were made. Five stem lengths within each replicate were measured.

4.1 Results

4.1.1 Operations

It was significantly easier to take plugs with the cup cutter than with shovels. The shovel plugs were difficult to cut, difficult to extract from the ground and difficult to carry - due to their bulk and height.

Plug transport within the compensation site proved extremely difficult. Surface sediments were unconsolidated, making walking strenuous at the best of times and carrying plugs by hand impossible. This problem was solved by using a plastic toboggan to transport plugs over the marsh and the compensation site. The toboggan floated on the muck when loaded, and could be pulled to the planting areas (Photograph 2).



Photograph 2: Transporting plugs using plastic toboggan.

4.1.2 Survival

All plugs showing visible signs of growth in July, 1989 were deemed to have survived. Survival was excellent throughout (Table 3). This is not surprising, given that the surface sediments over the apex of the pad were stable, and the site was apparently filling in rather than eroding. For the most part, non-surviving plugs had washed out, as only one plug was found dead in situ.

4.1.3 Growth

The stem density and stem length data are summarized in Figure 5. The complete data set is presented in Appendix 5.

Figure 5 shows a positive correlation between growth and plug size. However the relationship is not statistically significant due to the large variability within the data set.

Table 3: Plug survival within the plots, showing number of surviving plugs and percentage survival.

Plot Number	10 cm Plugs	16 cm Plugs	Shovel Plugs	Plot Survival
1	20 (93.3%)	22 (91.7%)	24 (100%)	91.7%
2	23 (95.8%)	22 (91.7%)	24 (100%)	95.8%
3	24 (100%)	24 (100%)	24 (100%)	100%
4	23 (95.8%)	23 (95.8%)	24 (100%)	97.2%
5	15 (83.3%)	17 (94.4%)	18 (100%)	92.6%
Plug size Survival	92.1%	94.7%	100%	

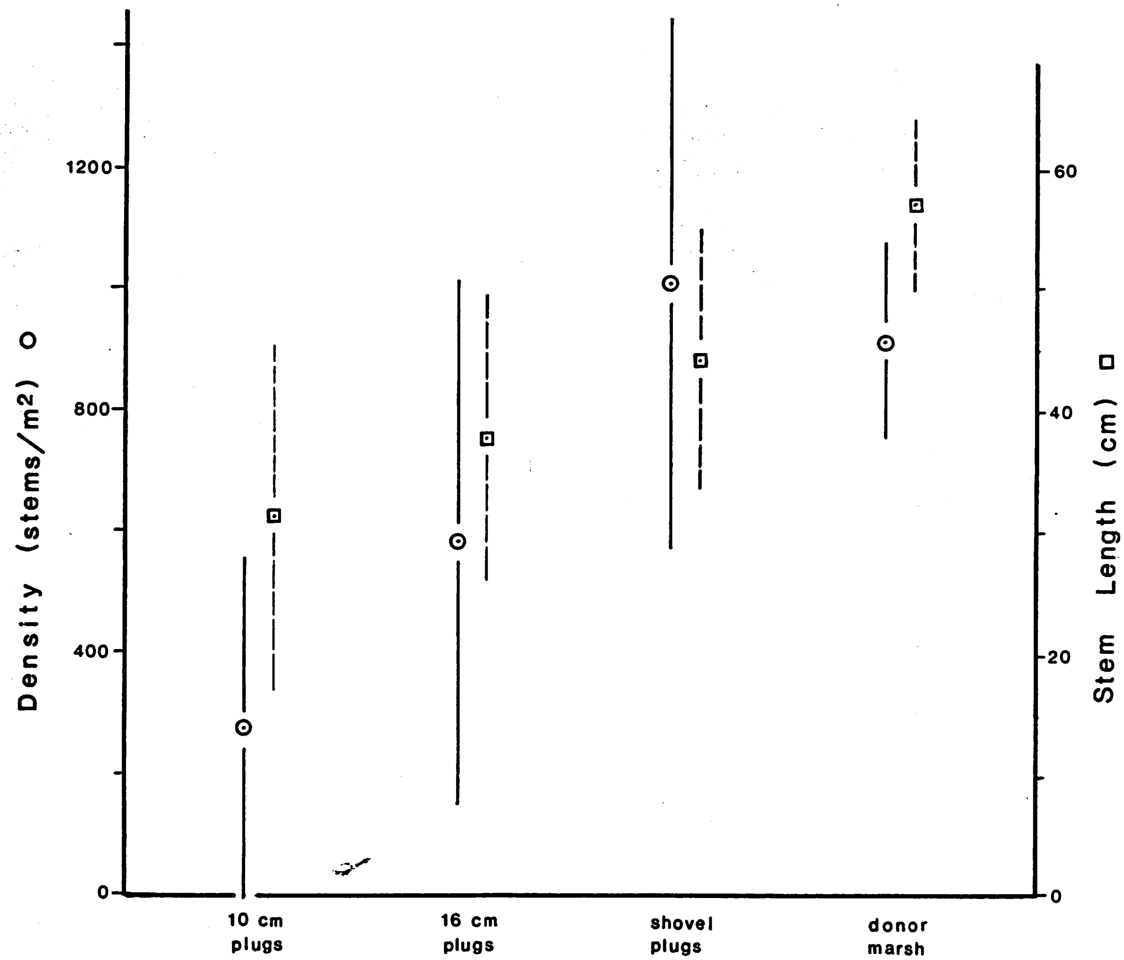


Figure 5: Stem length and stem density of transplanted material and donor marsh.

Indeed, the apparent relationship of stem density with plug size may be a relict of the sampling methodology used, reflecting the increasing portion of the surface area of the plug within the sampling quadrat size, not a difference in plant growth.

Sedge stems were healthy but had little or no rhizome growth away from the planted material. The spike-rush, on the other hand, was both healthy and had, in many cases, extended rhizomes well beyond the donor material. Stem lengths of both species were lower than that found in the donor marsh. Stem density was highly variable - a result of the almost explosive growth of spike-rush stems from plugs in which it was present.

The difference between the sedge and spike-rush growth rates is not unexpected and can be explained by differences between the two life cycles.

Sedges extend new shoots in the late summer. These shoots remain dormant through the winter, giving the marsh its characteristic "brushcut" look. In early spring these shoots elongate extremely quickly. However this is not new growth - as in the creation of new plant material from raw materials. It results from the relocation and utilization of material stored below ground in the roots and rhizomes of the plant. Actual new growth occurs late in growing season (mid summer). In August the plant moves nutrients from the leaves and stems down to the rhizomes for winter storage. Next season's shoots appear at ground level at this time as well.

Sedge colonization of new ground requires many above ground shoots to generate new growth in the late summer. The number of shoots, in turn, depends on the existence of a large underground biomass reservoir - from the previous season. It will take transplanted material a couple of seasons to establish such a reservoir. Once it is established the plant will colonize suitable ground readily.

Spike-rush, on the other hand, grows in the classic manner, i.e., new growth is a result of the conversion of soil and light into plant material. Spike-rush in virgin substrate, with little competition for either space or light, will burst into vigorous growth producing both new stems and rhizomes as it goes. (Photographs 3 & 4).

Photograph 3: A 10 cm plug showing robust spike-rush growth. Note stems up to 30 - 50 cm away from the plug.

For our purposes, the most important point is that the plugs are healthy, that both species are growing and that the spike-rush rhizomes are extending out into the unconsolidated sediments around the plugs. This rhizome growth will help stabilize the substrate and hold the donor plugs in place.

Photograph 4: Test plot #1: shovel plugs in the near rows, 16 cm plugs in center and 10 cm plugs in rear.

4.2 Conclusions

From a handling and logistics point-of-view the best plugs to use for transplanting were the 10 cm plugs, due to their small size and weight. The 16 cm plugs were still viable but the shovel plugs were significantly more difficult on all counts.

On the other hand, growth vigour apparently corresponded positively to with plug size, though the variability within the data set makes this difference statistically insignificant. Nevertheless, 16 cm plugs will be used in the remaining transplant work. This size plug is a reasonable compromise between the ease of handling and vigorous growth.

5.0 1990 Transplant Program

The compensation site and all cross-sections at the other sites were re-surveyed in March 1990 to determine what areas would be suitable for planting in April 1990. Criteria used to locate the transplant plots was that the substrate be at suitable elevations for plant growth and that there be no established vegetation nearby.

This program was primarily concerned with re-establishing vegetation on the compensation site, however, some plots were completed at the other habitat impact sites.

The 1990 transplant operation was completed during March 30 and April 2, 1990. A four man field crew will planted 19 plots of 40 or 50 plugs (14 @ 50, 5 @ 40) on the outer habitat pads of the compensation site. A further 199 plugs were planted at the other wetland sites - 50 in the lee of the 1019+00 rock spur; 99, in 3 plots of 25 (1 of 24) at the boat ramp site; and 2 plots of 25 in the lee of the 985+20 rock spur. All plugs were 16 cm diameter. The total planting was 1099 plugs.

This transplant operation is designed to establish viable plant colonies from which the vegetation will expand naturally over the habitat. It consists of a series of small dense plantings in suitable areas within the compensation site. The immediate area around the 1989 test plots was be left unplanted, allowing measurement of the re-colonization rate to be made as part of the monitoring program.

Other operations have demonstrated that plugs planted on a 1 m grid, as in the Campbell River estuary rehabilitation project, took 2 to 4 years to establish 100% vegetation cover. During that time, vegetation appeared naturally in the unplanted areas of the estuary, approaching 100% cover in 4 to 5 years. (N.K. Dawe, personal communication)

Within the context of the Skeena River, the lag time between habitat loss and the establishment of compensation habitat should have little effect on overall salmonid productivity. There are extensive areas of similar but undisturbed habitat both immediately upstream and close downstream of the project site.

This habitat compensation scheme will result in a minimum 1.6:1 increase in intertidal marsh within the project area. It will likely result in a substantially greater long-term net increase. It is expected that the magnitude of this long term increase will become apparent within the time frame of the monitoring period. The temporary habitat loss incurred by the highway construction should have a minimal effect on overall salmonid productivity in the river.

6.0 Monitoring Program

The monitoring program is presented below. This program follows the format and rationale presented in White, 1988, but has been modified to reflect the changed circumstances.

1990 - July, re-measure all cross-sections, photograph field observations, measure stem length and density of 1989 plots and 1990 plots

1991 - July, re-measure all cross-sections, photograph, take field observations, measure stem length and density of 1989 plots and 1990 plots

1992 - optional, take field observations, photograph

1993 - July, re-measure all cross-sections, photograph, take field observations, measure stem length and density of 1989 plots and 1990 plots

1994 - optional, take field observations, photograph

1995 - July, re-measure all cross-sections, photograph, take field observations, measure stem length and density of 1989 plots and 1990 plots
- compare above ground biomass of undisturbed marsh and compensation marsh
- determine total amount of vegetated foreshore habitat within the project area
- document success/failure of project in a final report.

It is recommended that the project be re-evaluated in 1998 or 1999. The compensation works constructed here have the potential to continue to contribute to the creation of vegetated intertidal habitat for years to come. An accurate documentation of such habitat formation will be of great value to both the Department of Fisheries and Oceans and the Ministry of Transportation and Highways in evaluating and designing future compensation schemes.

References

Kellerhals Engineering Services Ltd. 1984. Khyex to Tyee Hydrological Mitigation Study. Unpublished report prepared for the Ministry of Transportation and Highways.

White, E.R. 1988. A Wetlands Mitigation Proposal to Compensate for Highway 16 Reconstruction near Prince Rupert, B.C. Unpublished Report prepared for the Ministry of Transportation and Highways.

Appendix I - Location of surveyed cross sections

Area	Chainage	
Donor Marsh	981+00	
	982+00	
	982+60	
Compensation Site channels opposite 984+80	981+00	also surveyed: the island 983+60 and 985+00
	984+00	
	984+40	
	984+80	
East Marsh	985+40	
	986+80	
	988+00	
	989+40	
	990+60	
Boat Ramp Site	994+90	
	995+20	
	995+55	
	996+00	
	996+40	
	996+85	
	997+80	
	998+00	
	998+15	
	998+60	
West Marsh	1018+90	
	1019+30	
	1020+10	
	1021+00	
	1022+00	
	1023+00	
	1023+65	