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LAKE ONTARIO NEARSHORE SEDIMENTS, AT OSHAWA, ONTARIO

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NWRI Contribution Number 00-53

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NWRI Contribution No. 00-053

MANAGEMENT PERSPECTIVE

This study was done on behalf of Environment Canada's Environmental Protection Branch, the Ontario Region. Mr. Paul Mudroch of the branch arranged for the study and secured the funding. Its status as an Environment Canada priority is Business Line- Nature, Outcome- Conservation of biodiversity in healthy ecosystems, Result-Priority ecosystems are conserved and restored.

This report describes a survey of the Lake Ontario nearshore zone adjacent to Oshawa harbour. It was conducted by NWRI to provide the Environmental Protection Branch with information about the bottom sediments and bathymetry of the site. Data are needed to improve the understanding of local sediment transport so that it can be used to reduce the frequency of harbour dredging. The benefit to NWRI is a detailed update of the original nearshore survey of the site in 1968. The report presents maps of bottom-sediment type and bathymetry, and data on their areal coverage.

Future work at this site will depend upon whether recommendations for further mapping and monitoring are approved and funded. The current study is complete.

SOMMAIRE À L'INTENTION DE LA DIRECTION

La présente étude a été réalisée pour le compte de la Direction de la protection de l'environnement de la région de l'Ontario d'Environnement Canada. Paul Mudroch qui travaille à la Direction s'est occupé de son déroulement et a trouvé les fonds nécessaires. Le secteur d'activité dans lequel s'inscrit l'étude est la nature; l'objectif est la conservation de la diversité biologique dans des écosystèmes sains, et le résultat, la conservation et la restauration des écosystèmes prioritaires.

Ce rapport décrit une étude faite dans la zone côtière du lac Ontario adjacente au port d'Oshawa. Cette initiative de l'INRE visait à fournir à la Direction de la protection de l'environnement de l'information sur les sédiments de fond et la bathymétrie du site. Des données sont requises pour mieux comprendre le transport local des sédiments de manière à réduire la fréquence des activités de dragage dans le port. L'INRE pourra aussi procéder à une mise à jour détaillée de l'étude initiale faite en 1968. Le rapport contient des cartes des types et de la profondeur des sédiments de fond ainsi que des données sur leur superficie.

Les travaux futurs qui seront effectués sur le site dépendront de l'approbation et du financement des activités de cartographie et de surveillance. L'étude actuelle est terminée.

ABSTRACT

NWRI's RoxAnn™ seabed-classification system has been used to map the sediment types and bathymetry of the nearshore zone of Lake Ontario adjacent to Oshawa Harbour on behalf of Ontario Region's Environmental Protection Branch. The new data are needed to improve the understanding of nearshore-sediment transport at the site and to use it to try to reduce the frequency of harbour dredging. The data will also be useful to NWRI as an update of the original nearshore survey of this area in 1968.

The acoustic data were calibrated with samples and underwater-television and diver observations, and then analyzed and mapped with the geographic information system, ARC/INFO. The study area is an erosional zone composed mainly of glacial sediment with a patchy cover of lag sediments ranging in size from sand to boulders. The area offshore of the harbour entrance has a thin cover of recent sediments, primarily sands and muddy sands which thicken lakeward. Trends in grain size suggest net transport from west to east. Bathymetry mirrors the bottom types; contours are highly irregular in the boulder and cobble areas and smoother over the deposits of sand and muddy sand opposite the harbour entrance.

RÉSUMÉ

Le système de classification des fonds marins RoxAnn^{MC} de l'INRE a servi à cartographier les types de sédiments et la bathymétrie de la zone côtière du lac Ontario qui est adjacente au port d'Oshawa et ce, pour le compte de la Direction de la protection de l'environnement de la région de l'Ontario. Les nouvelles données permettront d'améliorer notre compréhension du transport des sédiments côtiers et de réduire la fréquence des activités de dragage dans le port. Elles permettront également à l'INRE de mettre à jour l'étude initiale de la région faite en 1968.

Les données acoustiques ont été comparées aux données d'échantillonnage et à celles recueillies par des plongeurs ou par un réseau sous-marin de télévision; ensuite, elles ont été analysées et portées sur une carte au moyen du système d'information géographique ARC/INFO. Le secteur d'étude est une zone d'érosion constituée principalement de sédiments glaciaires et d'une couverture éparse de sédiments de déflation dont la granulométrie varie du sable au bloc. La zone au large de l'entrée du port est caractérisée par une mince couche de sédiments récents, surtout des sables et des sables boueux, qui s'épaissit en direction du lac. La granulométrie laisse supposer un transport net d'ouest en est. La bathymétrie reflète les types de fond marin; les courbes de niveau sont très irrégulières dans les zones de galets et de blocs et sont plus lisses au-dessus des dépôts de sable et de sable boueux vis-à-vis de l'entrée du port.

1. Introduction

Environment Canada conducted a sediment-mapping survey of the Oshawa nearshore zone of Lake Ontario for Ontario Region's Environmental Protection Group in May 1999. The purpose of the survey was to provide the data on the distribution of bottom-sediment types and bathymetry needed to understand local sediment transport and reduce the frequency of harbour dredging. The new data are also being used to update the information from the original NWRI nearshore sediment survey of this area in 1968 (Rukavina 1969).

This report describes the field equipment and procedures used and discusses the results obtained by acoustic mapping of bottom types and bathymetry with a RoxAnn seabed-classification system supplemented by samples and underwater-television and diver observations.

2. Background

The sediments of the study reach were originally mapped in 1968 as part of Environment Canada's nearshore-sediment survey of Lake Ontario (Rukavina 1969). The dominant bottom type was found to be glacial drift and associated lag deposits inshore, and exposed bedrock offshore in depths greater than about 15 m. The lag deposits occur as a patchy veneer of sediments of sand to boulder size produced by selective erosion of the glacial sediment and removal of its finer grain sizes. The bedrock samples recovered were black shales of the Collingwood formation (Caley 1940).

The nearshore zone at Oshawa is predominantly erosional because it is exposed to waves from both the west and east. Sediment generated by erosion of the local bluffs and the nearshore slope generally moves through the zone without accumulating because of the strong littoral currents generated by the waves. The direction of littoral drift is east or west depending on the wave approach. Because the null point dividing net westward and eastward drift is just to the west of Oshawa, local drift direction should vary according to the wind direction with a small net transport from west to east (Donnelly and Brebner 1961, Rukavina 1976).

3. Field Equipment and Methods

Bottom-sediment type and morphology were surveyed in May 1999 with a RoxAnn acoustic seabed-classification system (Chivers et al 1990, Rukavina and Caddell 1997, Rukavina 1997, Rukavina 1998). Details of the survey schedule are shown in Appendix 1. RoxAnn analyzes echo-sounder returns to produce a classification of bottom-sediment type which is then confirmed with samples or diver and underwater-television observations. All survey data on bottom type and depth are logged to a computer file which can be used for further processing of the results with a geographic-information system (GIS).

No pre-calibration of RoxAnn was attempted. The default limits for the 8 bottom categories from previous surveys were used pending ground-truth data from follow-up underwater-television, diver and sampling surveys. Default categories were mud, muddy sand, sand, coarse sand, gravel, boulders/hard, weeds on soft and weeds on hard.

The RoxAnn sounder was an Atlas Deso 10™ operating at frequencies of 210 and 30 kHz. Both frequencies were used because they provide data on different parts of the sediment column. High-frequency penetration of surface sediments ranges from a few cm to about 50 cm depending on sediment type and porosity; the low-frequency data represent the integrated response from about the top 1-2 m of the sediment column. By comparing depths and acoustic roughness and hardness for the two frequencies, it is often possible to distinguish areas of relatively thin and thick sediments. The echo sounder was adjusted for transducer draft and operated at a constant rpm equivalent to a velocity of sound of 1480 m/s. No barchecks were taken to correct for the effect of temperature on sound velocity.

High and low-frequency data were collected simultaneously by two RoxAnn systems and recorded on notebook computers by the survey program, Microplot™. Microplot logs RoxAnn data and associated GPS positions at one-second intervals or at about 2-3 m intervals for the standard survey speeds of 2-3 m/s.

Navigation for the survey was provided by a Sercel differential GPS with corrections from a local shore receiver set up at a benchmark on the west pier of the harbour (Appendix 2). Periodic static checks of accuracy at a second benchmark on the pier showed only sub-metre differences, and the accuracy of survey fixes is assumed to be in the range of 2-4 m.

The requirement was for detailed coverage of the reach between Bonnie Brae Point, the point west of the harbour, and the centre of Second Marsh, and for the area between the shoreline and the 10-m contour (Figure 1). RoxAnn's minimum operating depth is 2 m so the 2-m contour was used as the inshore boundary. The survey began with a reconnaissance zig-zag traverse across the area to determine the sediment types. This was then followed with a detailed survey run along a series of E-W lines spaced at 10-m intervals. Total line coverage was about 120 km.

RoxAnn requires independent data on bottom-sediment type to convert its acoustic sediment labels to physical bottom types. Groundtruth in this case was provided by bottom samples and television and diver observations collected after the acoustic survey was complete, and by earlier sample data. Twenty-three sites were selected for inspection within areas of consistent RoxAnn type. Underwater-television records were collected at 18 of the sites (Figure 2) by several drops of the underwater-television frame within an circle of several metres of the target location. Television data were recorded on videotape and a mixer was used to superimpose the GPS coordinates on the video so that each record was georeferenced. Video records showed the type of surficial sediments and also the thickness of any unconsolidated sediments (Appendix 3). Bottom samples were collected with a Mini-Shipek sampler at 9 of the sites and sufficient sediment for size analysis was recovered at 7 sites. Figure 3 is the site map and sample descriptions are in Appendix 4. Divers inspected all of the 23 sites (Figure 4) and probed to determine sediment thickness. They also collected samples for size analysis at 21 sites and surface and sub-surface samples at 6 of the sites to check for vertical differences in grain size. Appendix 5 lists the diver sites and bottom descriptions. Additional data for the western part of the study area were available from a 1998 survey by GeoSea Consulting (McLaren 1999). Sample sites for that survey are shown in Figure 5 and size data are listed in Appendix 6.

4. Data Analysis

Samples collected with the Mini-Shipek sampler and by the divers were analysed for grain size in the NWRI Sedimentology Laboratory using standard sieve and Sedigraph™ procedures (La Haie and Duncan 1979). Summary size statistics of the size-fraction percentages, the modal size, and a size label (Folk 1974) are listed in Appendix 7.

The accuracy of the RoxAnn acoustic labels was checked with data from the sample, underwater-television and diver surveys, and with grain-size data from a detailed sampling survey in 1998 by GeoSea Consulting Ltd . The GeoSea survey sampled 302 sites in the western half of the current survey area and recovered samples at 280 sites with a ponar sampler. The remaining sites were assumed to be hard bottom with no sediment cover. Because the survey was conducted in the previous year, the data have to be used with caution because they may no longer be representative of the current bottom conditions.

All groundtruth data were reduced to a limited number of bottom types for comparison with the RoxAnn labels. Three classes were used for the grain-size data: sand (>67% sand), muddy sand (33-67% sand), and mud (<33% sand). Where no size data were available, sediment type was estimated from the underwater television or diver descriptions and additional labels were used for the types gravelly sand, sandy gravel, cobbles/boulders, and mixed (glacial sediment and lag deposits). The groundtruth data were compared with RoxAnn data within a 5-m radius of the groundtruth sites (5 m is the average radius of the RoxAnn footprint in the depth range surveyed). If the RoxAnn labels fell within the same size class as their matched sample, they were rated as good, if one size class removed fair, and otherwise poor.

Table 1 and Appendix 8 show the goodness-of-fit of the RoxAnn acoustic labels with the independent data on bottom type. Fit for the combined data averages 52% good, 37% fair and 11% poor, a reasonable level of agreement considering that it is based in part on a comparison of sample and television data both of which have a small footprint relative to that of RoxAnn. Better results are obtained for the diver data because they include information on both bottom morphology and sediment type over an extended area.

Table 1. Goodness-of-fit of RoxAnn labels with control data.

Control type	**Good**		**Fair**		**Poor**		**Total**
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	
GeoSea data	52	48.1	43	39.8	13	12.0	108
UWTV data	9	50.0	7	38.9	2	11.1	18
Shipek data	6	60.0	4	40.0	0	0.0	10
Diver data	13	76.5	2	11.8	2	11.8	17
Combined	80	52.3	56	36.6	17	11.1	153

Mislabelling by RoxAnn can occur for a number of reasons: heterogeneity of the substrate on a smaller scale than the RoxAnn footprint, the presence of algae or zebra mussels which shift the labels towards finer and coarser sediments respectively, and the presence of gas in the sediments which increases the acoustic roughness and hardness. In this case, the diver observations indicated that the bottom was a highly-variable complex of thin sands, exposed glacial sediments and scattered lag deposits of sand to boulder size without well-defined boundaries between bottom types (Appendix 5). Variations were also noted in the amount and thickness of algal cover on cobbles and boulders and in the algal mats associated with the finer sediments. RoxAnn cannot discriminate changes smaller than its footprint which has a diameter approximately equal to the water depth. Data within the footprint are averaged and have to be interpreted from the independent data on bottom type in order to be properly understood. The groundtruth data indicate that returns from a mixture of glacial sediment and coarse lag deposits generally register as gravel. Concentrated areas of cobbles or boulders are properly classified unless there is thick algal cover which can result in a shift towards the gravel class. There is usually no difficulty in identifying thick (>10 cm) sands, muddy sands and muds but thinner sediments are averaged with the underlying glacial sediment and may appear to be coarser or finer according to its texture and water content. Exposed glacial clay will be classified as mud if it is smooth or as weeds on soft or hard if it has high relief. Finally, muddy sediments like those in the harbour or just offshore from its entrance can appear coarser if the muds have a high gas content.

To prepare the RoxAnn file for GIS analysis, all the data were checked, fixes with poor GPS quality were removed, and depths were corrected to IGLD85. The edited file was then imported into an ARC/INFO™ GIS for voronoi-polygon analysis of the RoxAnn bottom types and roughness and hardness parameters and the GeoSea grain-size data. This type of analysis produces a chloropleth map by associating with each data point an area (polygon) extending half the distance to surrounding data points and grouping areas of the same type (Rukavina and Delorme 1992). The result is a map with georeferenced boundaries and a table of areas of coverage of the data classes. ARC/INFO was also used to produce two contour maps of bathymetry from the RoxAnn depth data- a map of the entire study area with a contour interval of 1m and a more detailed map of bathymetry of the approaches to the harbour and the dredged channel with a contour interval of 0.5 m.

Selected video clips from the underwater-television survey were extracted as digital files and edited in QuickTime™ to produce a mov-format file which can be viewed on a computer with Apple's free QuickTime player installed. The movie file of the assembled video clips (oshuwtv.mov) may be downloaded from CCIW's anonymous ftp site, ftp.cciw.ca. Each clip is labelled with a site number which is referenced in Figure 6. The QuickTime player is available from http://www.apple.com/quicktime/download/.

5. Results and Discussion

The GIS map of RoxAnn bottom types is shown in Figure 7 and the areal coverage of each type is listed in Table 2. The map legend shows the physical bottom types interpreted from the ground-truth data with the default labels in brackets if they differ.

Table 2. Areal coverage of RoxAnn bottom types

RoxAnn label	Area, sq m	Area %
lag and glacial sediments	1098196	38.5
sand	838249	29.4
muddy sand, gassy mud	411058	14.4
boulders	283169	9.9
glacial ridges	107743	3.8
coarse sand	67701	2.4
mud and glacial clay	43533	1.5
Total	2849649	100

Glacial sediment with lag deposits (RoxAnn gravel) is the dominant type and accounts for 39% of the total area of the zone. An extensive deposit of sand (29%), muddy sand (14%) and coarse sand (2%) covers the entire zone offshore from the harbour entrance and branches inshore at the eastern end of the area. The finer sediment (muddy sand) is present in the harbour as a continuous deposit and offshore from the harbour as a patchy distribution on sand. The harbour sediment also includes a small deposit of sand adjacent to the west pier which appears to be connected to the offshore sand deposit on its east side and which may derive from that deposit. Some of the RoxAnn "muddy sand" near the harbour mouth was shown by the video to be a thick accumulation of algae apparently in transit from behind the west pier where it was accumulating on the shoreline and in shallow water. A small deposit of the site's finest sediments, recent mud or glacial clay (2%), are present only within the southwestern part of the deposit. RoxAnn's "weeds on soft" and "weeds on hard" (4%) are actually ridges of glacial clay with high relief occurring along the eastern boundary of the sand deposit within the erosional area of glacial and lag deposits.

The RoxAnn map generally agrees well with the GeoSea grain-size map (Figure 8). Contacts between hard bottom and recent sediment are nearly identical on both maps, and there are only minor differences between the patterns of sands and muddy sands offshore. The major difference is the harbour sediment which RoxAnn classifies as muddy sand and which the GeoSea data show to be mud. The shift is likely the result of gas in the harbour muds which increases their acoustic roughness and hardness. GIS areal mapping of the GeoSea data from Figure 8 indicates that sand (41%) and hard bottom (30%) are the principal bottom types. Muddy sand (14%) and mud (12%) are also important components. Sandy gravel and gravelly sand account for less than 3% of the GeoSea study area.

Figure 9 shows the maps of the RoxAnn parameters E1 (acoustic roughness) and E2 (acoustic hardness). The roughness pattern is similar to that for bottom type. The highest values occur in the boulder areas, intermediate values in the glacial and lag deposits and lowest values in the sand deposit. Hardness is high mainly in the boulder and coarse-sand areas and low for both the sand and glacial/lag deposits. The low roughness and high hardness of the offshore mud/clay deposits suggest that they are mainly stiff glacial clay rather than soft recent mud.

Detailed data on the grain size of the recent sediments are available from the 1998 GeoSea samples. Harbour sediment is generally clayey silt with a principal size (modal size) of 0.016-0.022 mm. Slightly coarser sediments with a modal size of 0.022-0.044 mm occur just offshore from the harbour entrance. Most of the offshore deposit is muddy sand to sand. Sediment east of the harbour is uniform with size modes of 0.088-0.125 mm offshore and 0.177-0.354 inshore. Sediment west of the harbour has the same size range inshore but is coarser and more variable offshore with size modes ranging from 0.016-0.707 mm. The grain-size trend suggests net transport of sediment from the west to the east. This is the expected transport direction in this area because of its location east of the nodal point separating westward and eastward littoral drift.

Limited data on sediment thickness are available from the diver surveys and from RoxAnn dual-frequency records. Divers measured depth to refusal by probing with an 80-cm rod. Penetration ranged from 0 to more than 80 cm but most of the subsurface sediment appeared from its resistance to be stiff glacial clay rather than modern sediment. The amount of sand cover was difficult to estimate but appeared, from the differences between surface and subsurface grain size (Appendix 7), to be limited to the upper 5 to 20 cm of the probe depth. A comparison of the high and low-frequency RoxAnn maps (Figure 10) suggests that their pattern differences might also reflect the thickness of sand cover. The high frequency has limited penetration (5-50 cm depending upon water content); the low frequency can penetrate to depths of as much as 1-2 m. Similar responses from the two frequencies should occur when surface and subsurface materials are the same whereas returns from the lower frequency should be harder when sediment is thin and the hard substrate is near the surface. If Figure 9 is interpreted in this fashion, then the yellow and orange areas should represent thicker sand deposits and the brown and red areas thinner deposits. The pattern which emerges is increasing sand thickness in an offshore direction and very thin sand in the eastern branching deposit which is displayed only in the high-frequency data. Since no attempts were made to calibrate the low-frequency records with cores, this is a tentative interpretation which needs to be verified with further data.

The bathymetry of the study area is shown in Figure 11 as 1-m depth contours. The contour shape reflects the bottom types. Contours are smooth over the sand deposit, highly irregular in the areas of boulders and glacial ridges and variable in the glacial and lag deposits. Shoal areas occur east of the harbour entrance and at the eastern boundary of the area. The area dredged for navigation is evident within the harbour and offshore to the 8-m contour. The offshore slope is steeper inside the 7-m contour (0.7-1°) and shallower offshore (0.4-0.6°). Depth distribution is shown in Table 3.

Table 3. Areal distribution of depth.

Contour Interval, m	**Area, sq m**	**Area %**	**Cum Area %**
<2	50229	1.8	1.8
2-3	185591	6.5	8.3
3-4	216896	7.6	15.9
4-5	300760	10.6	26.4
5-6	273847	9.6	36.1
6-7	270502	9.5	45.5
7-8	368525	12.9	58.5
8-9	374852	13.2	71.6
9-10	222167	7.8	79.4
10-11	314111	11.0	90.4
11-12	209215	7.3	97.8
12-13	62948	2.2	100
Total	2849642	100	

About half of the area falls below a depth of 5 m and 20% is deeper than 10 m. More detailed information on the bathymetry of the harbour and approaches is shown in Figure 12 which is mapped with a contour interval of 0.5 m.

Conclusions

RoxAnn mapping of the nearshore zone of Lake Ontario offshore from Oshawa Harbour has shown it to consist mainly of eroding glacial sediment with a variable veneer of lag deposits ranging in size from sand to boulders. Underwater-television and diver observations indicate that the erosional area is highly variable in bottom type, lag thickness and algal cover. Recent deposits of sand and muddy sand occur mainly in the western half of the survey area where they extend across the zone offshore from the harbour entrance. Limited data from diver probing and from a comparison of RoxAnn high and low-frequency data suggest that the sand deposit is thin inshore and thickens lakeward. Size trends in the sand suggest net eastward drift which is in line with the expected drift direction for the area.

Independent data on bottom type from samples and underwater-television and diver observations show good to fair agreement with the RoxAnn bottom labels for 89% of the control sites. Where mislabelling occurs, it appears to be the result of averaging of highly variable sediments and of the effects of gas and algae on the acoustic returns.

Although the RoxAnn results agree reasonably well with sample data collected the previous year, it is important to note that they provide only a snapshot of the sediment distribution pattern at the time of the survey, in this case the relatively quiescent summer period. The same pattern may not apply during the spring and fall stormy seasons.

7. Suggestions for further work

The objective of the current study was to map the surficial sediments of the study area as a contribution to the understanding of local sediment transport and its effect on shoaling of the harbour. Although the survey results do provide detailed data on the sediment pattern and bathymetry and some inferences about sediment transport, the questions of transport rates and directions and of the frequency of transport and its relationship to wave state and water level remain. Several approaches can be used to improve the data on sediment transport. A series of RoxAnn surveys following major storms would provide a fast means of measuring the major changes in sediment distribution and bathymetry. NWRI's acoustic datalogger, a bottom-mounted sediment-level meter, could be used for time-series measurements of the rates of lakebed and harbour erosion and deposition, and a video logger, currently under development, for visual records of bottom processes. There is also expertise at NWRI on the tagging of sediments to measure their transport rates and directions, the use of a bottom-mounted flume to measure the critical shear stress needed to initiate sediment transport, and the hindcasting of littoral transport from wind and wave data.

Only limited data are currently available on sediment thickness and the volume of sediment available for transport. This could be improved by coring or further diver probing of the sand deposit possibly in combination with dual-frequency RoxAnn mapping or with sub-bottom profiler surveys.

8. Acknowledgements

P. Mudroch of the Environment Protection Branch requested the survey and arranged for funding. NWRI's Technical Operations Section provided the launch, coxswain (D. Gilroy), and the divers (B. Gray and D. Gilroy). The RoxAnn operator was B. Trapp of NWRI's Aquatic Ecosystem Restoration Branch. M. Dunnett, NWRI contractor was

responsible for reduction of much of the RoxAnn data. GIS analysis and mapping of the RoxAnn data was done in-house at Ontario Region's GIS Centre by R. Kay. Video clips were edited and assembled by B. Trapp. The development of RoxAnn as a sediment mapping tool is being funded by Environment Canada's Great Lakes 2000 Cleanup Fund.

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Figures

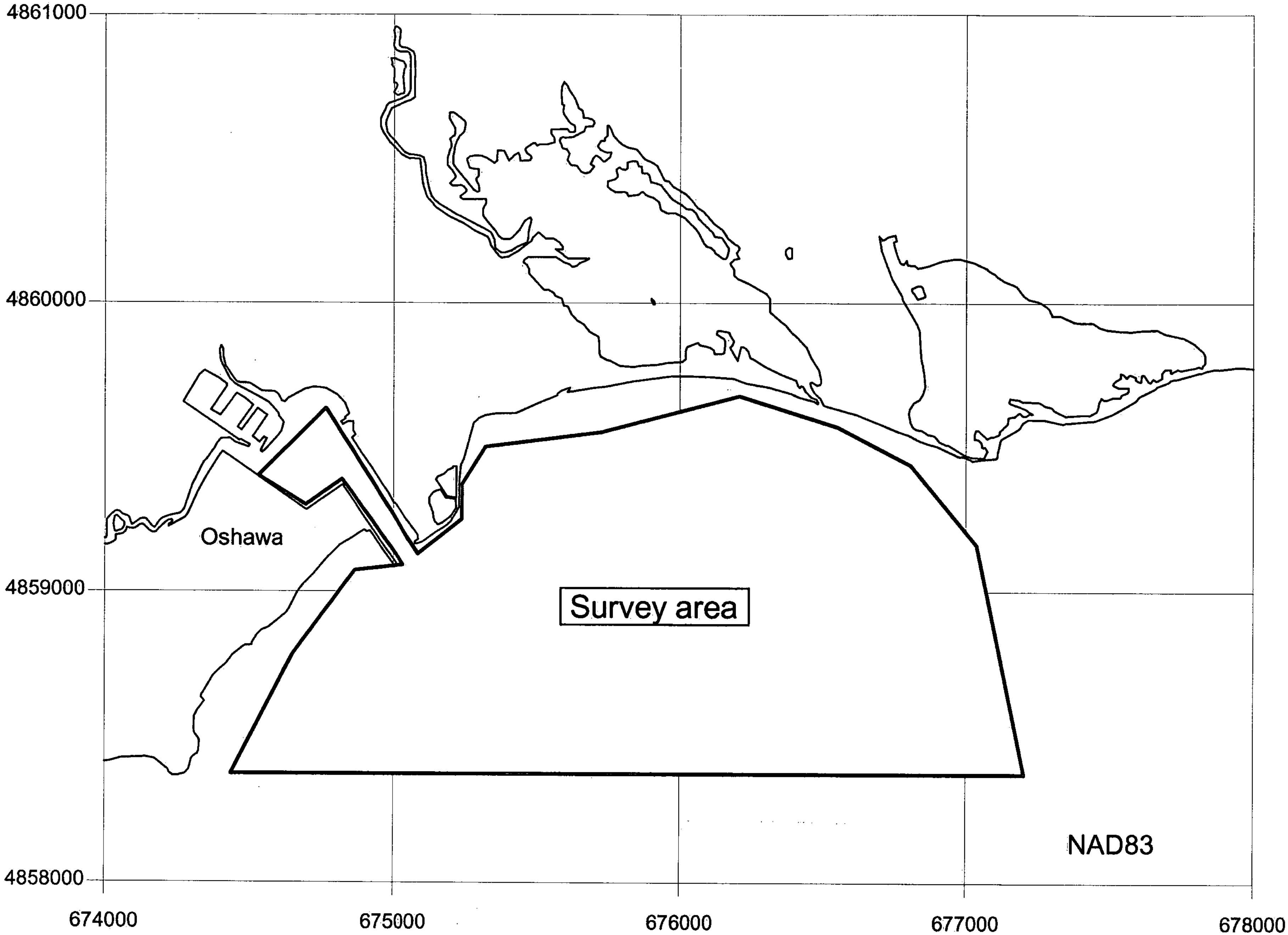


Figure 1. Site map

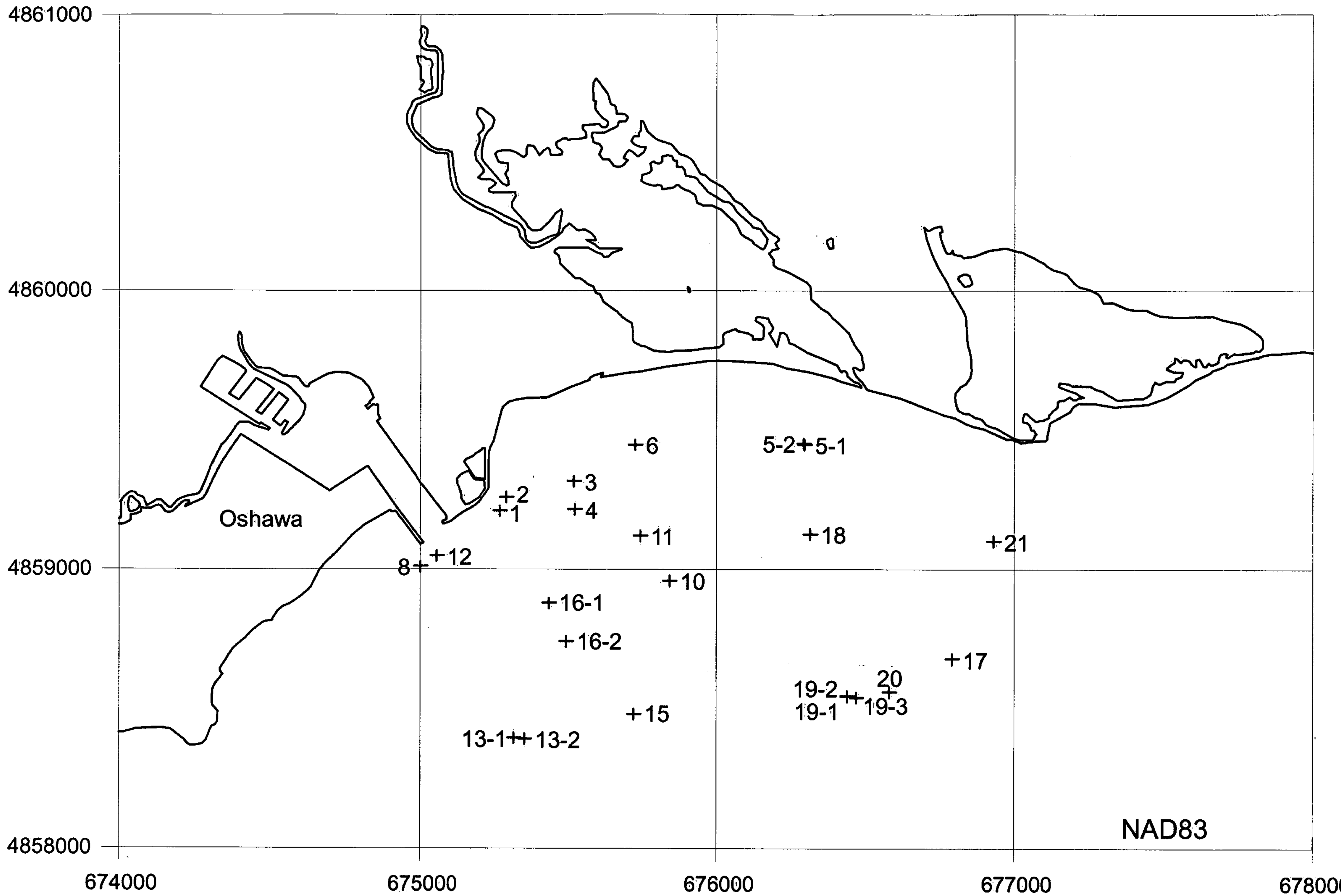


Figure 2. Underwater-television sites

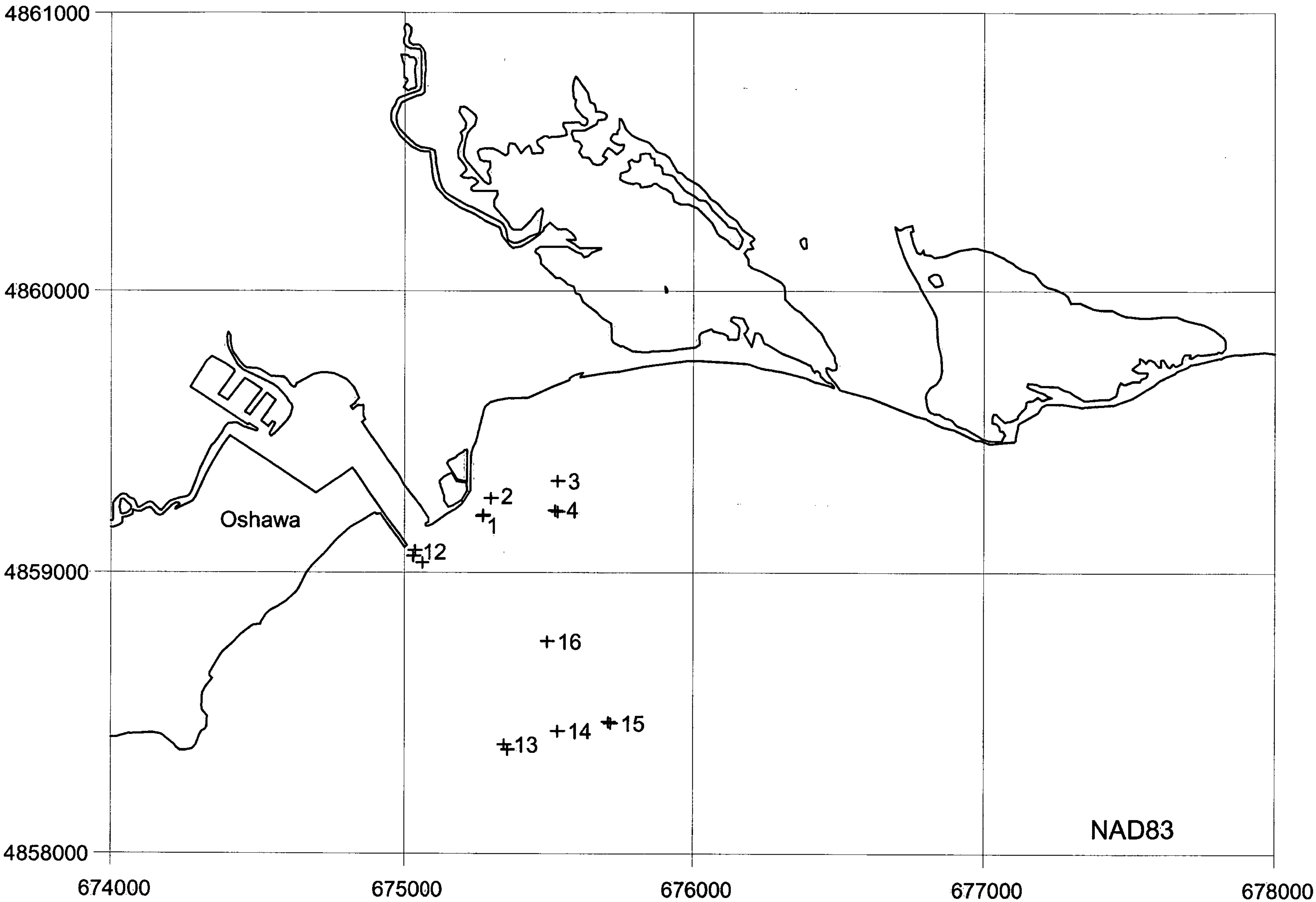


Figure 3. Mini-Shipek sample sites

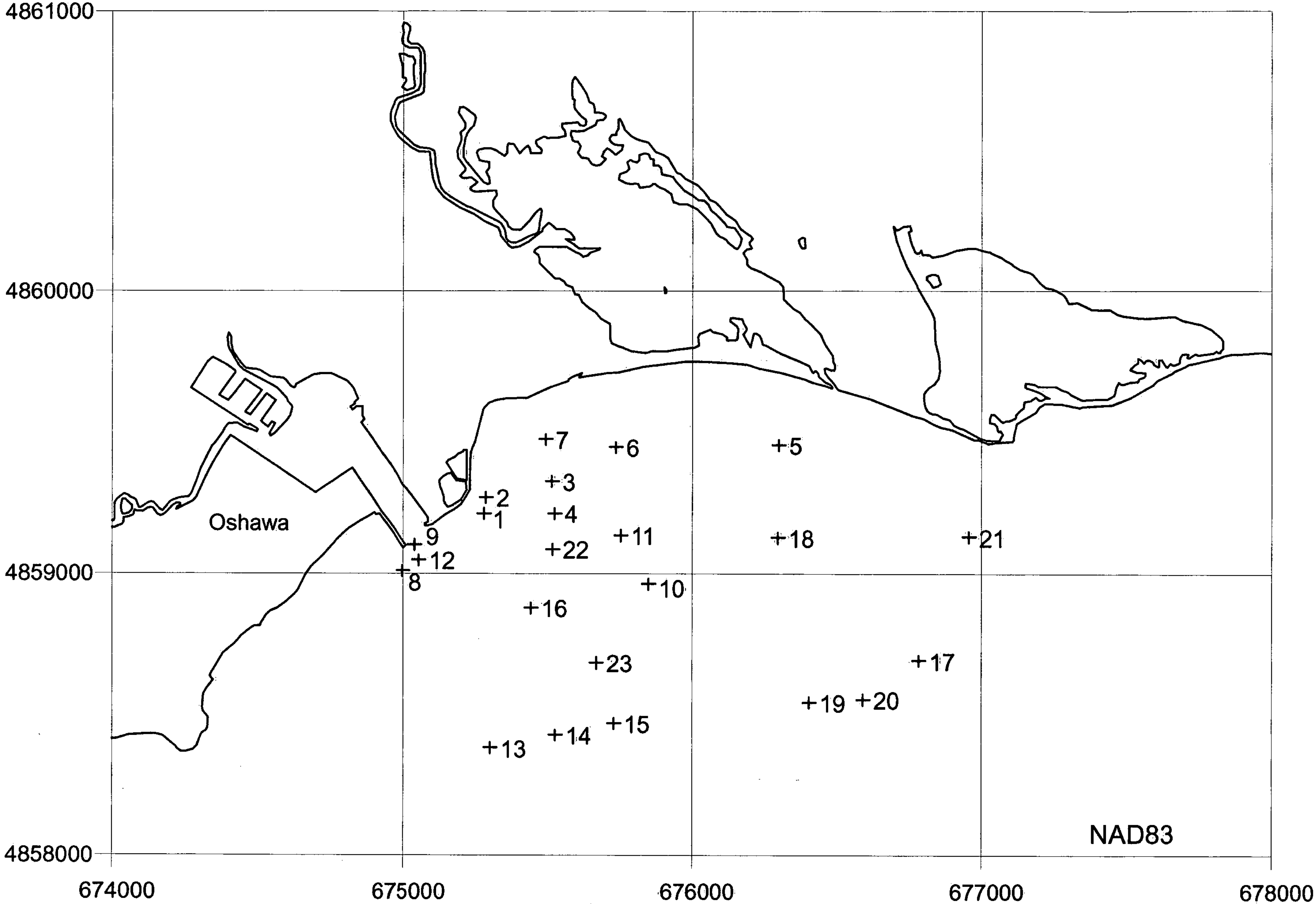


Figure 4. Dive sites

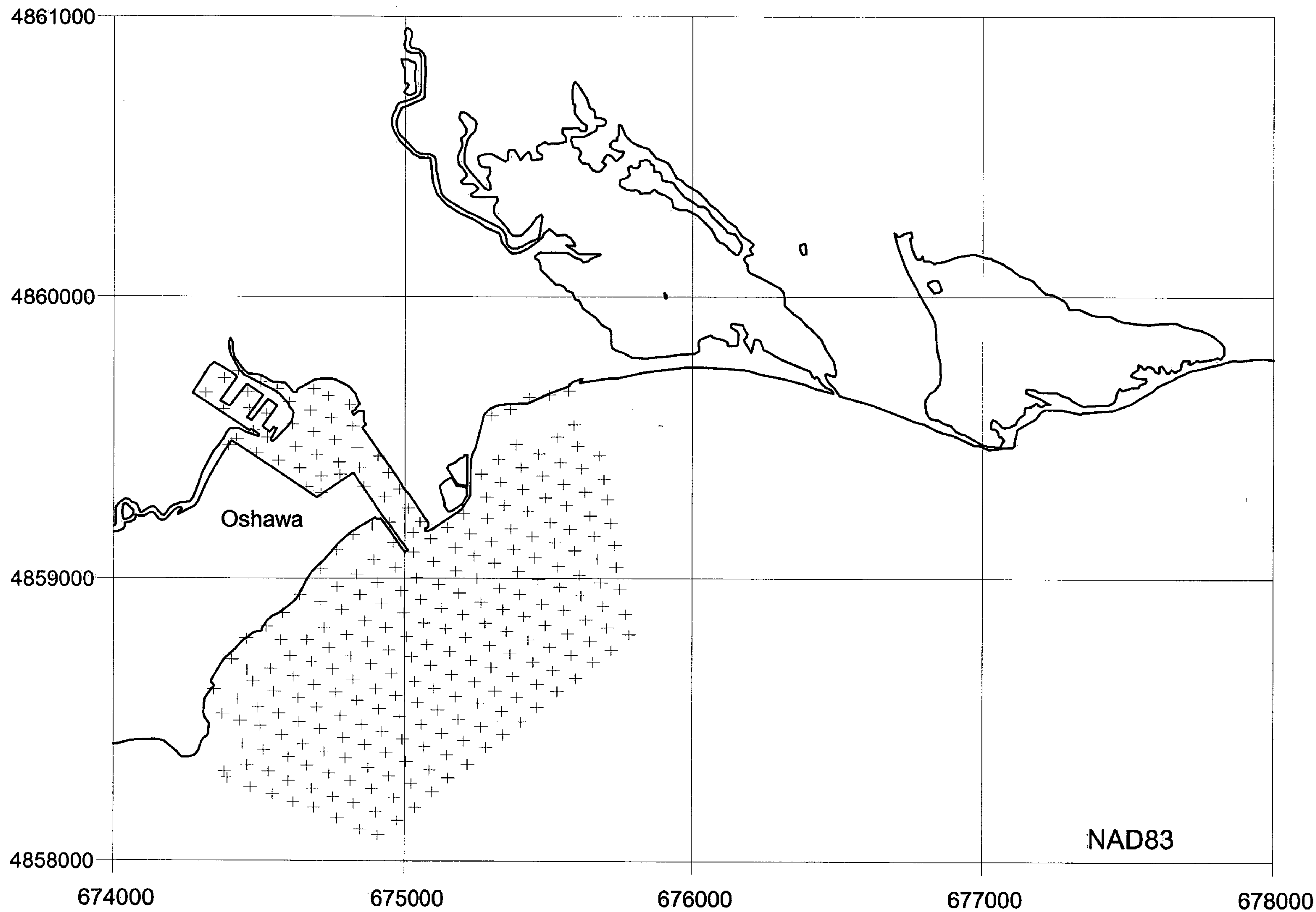


Figure 5. GeoSea sample sites

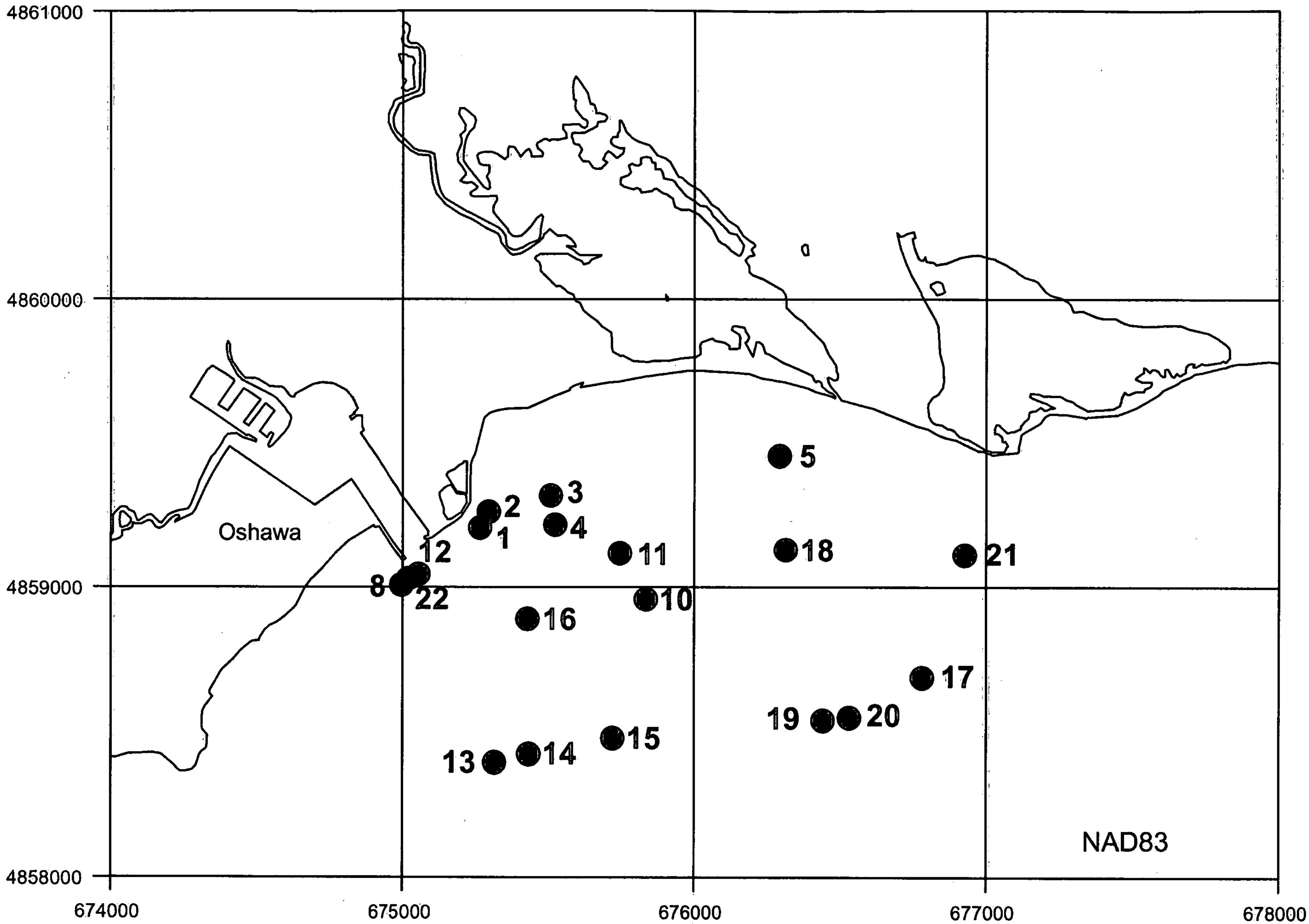


Figure 6. Sites of video clips of UWTV data.

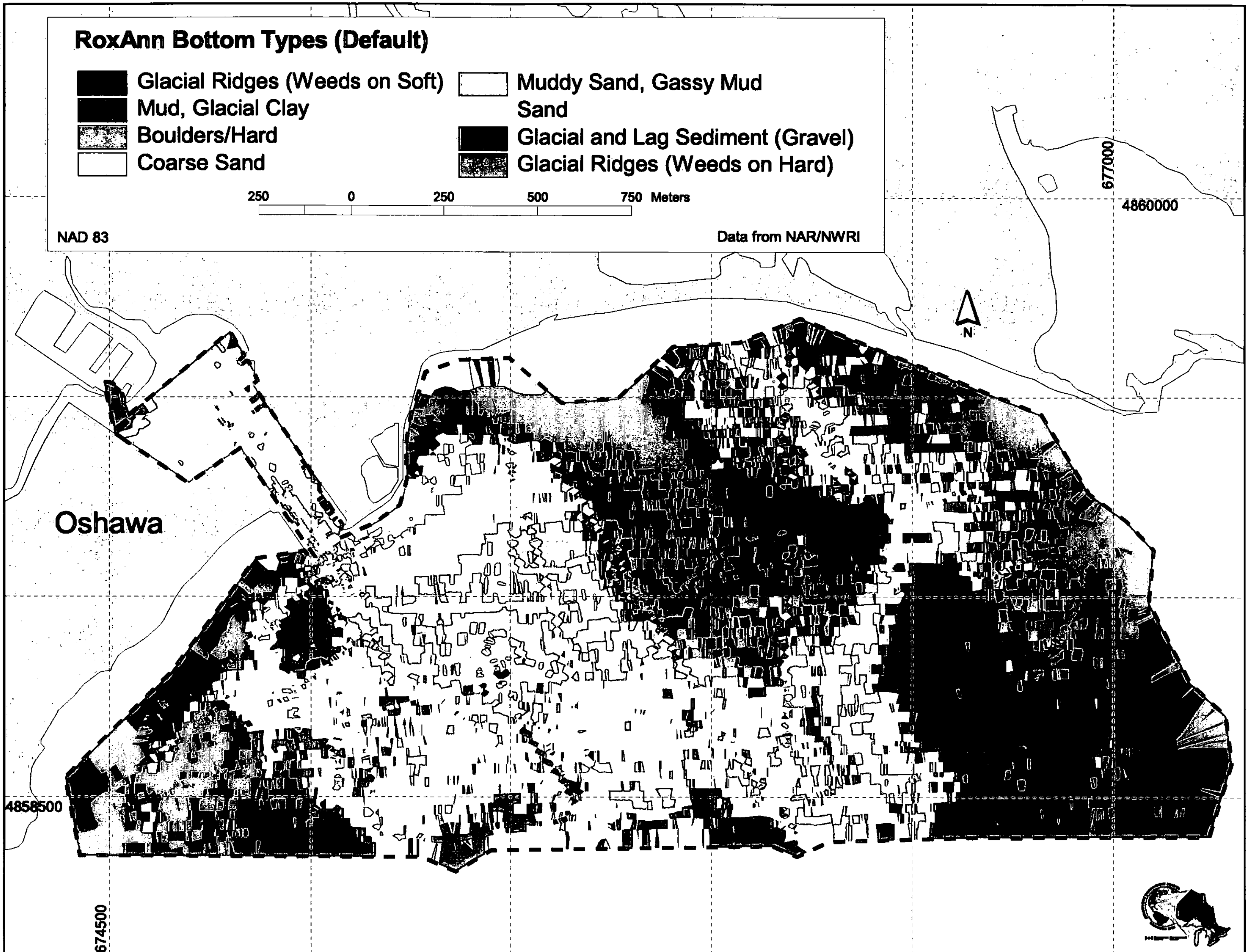


Figure 7. GIS map of RoxAnn bottom types

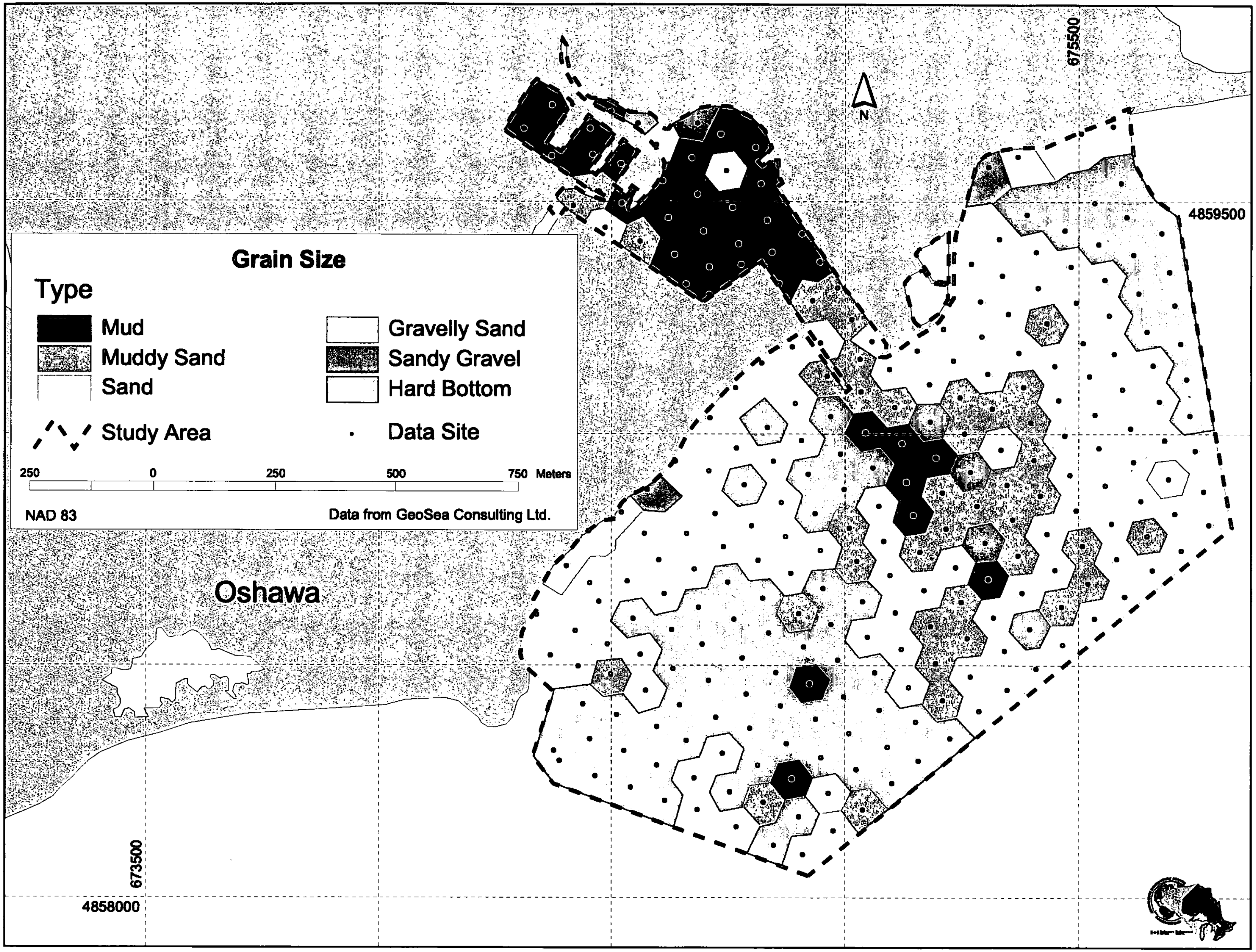
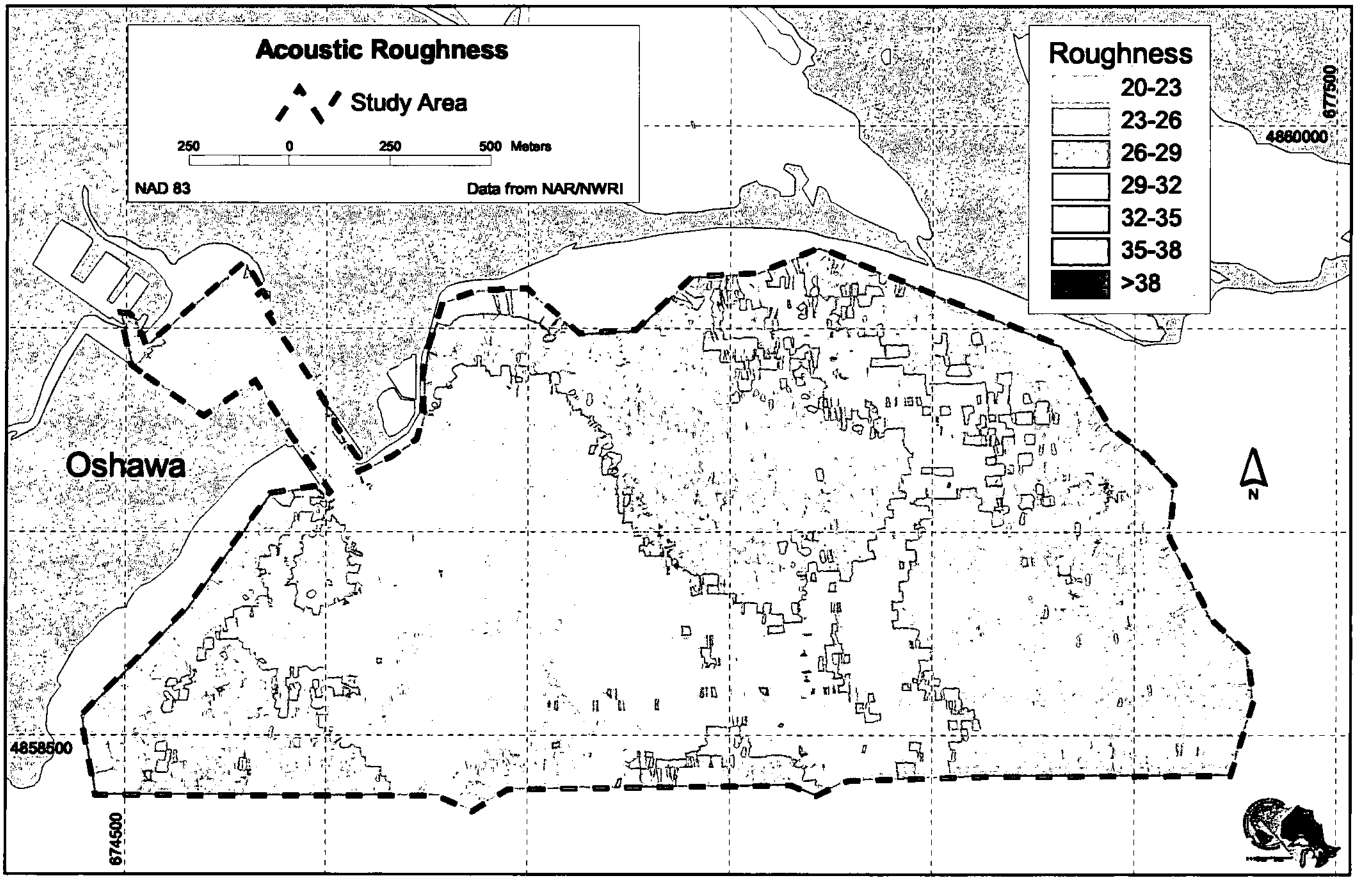


Figure 8. GIS map of GeoSea size data



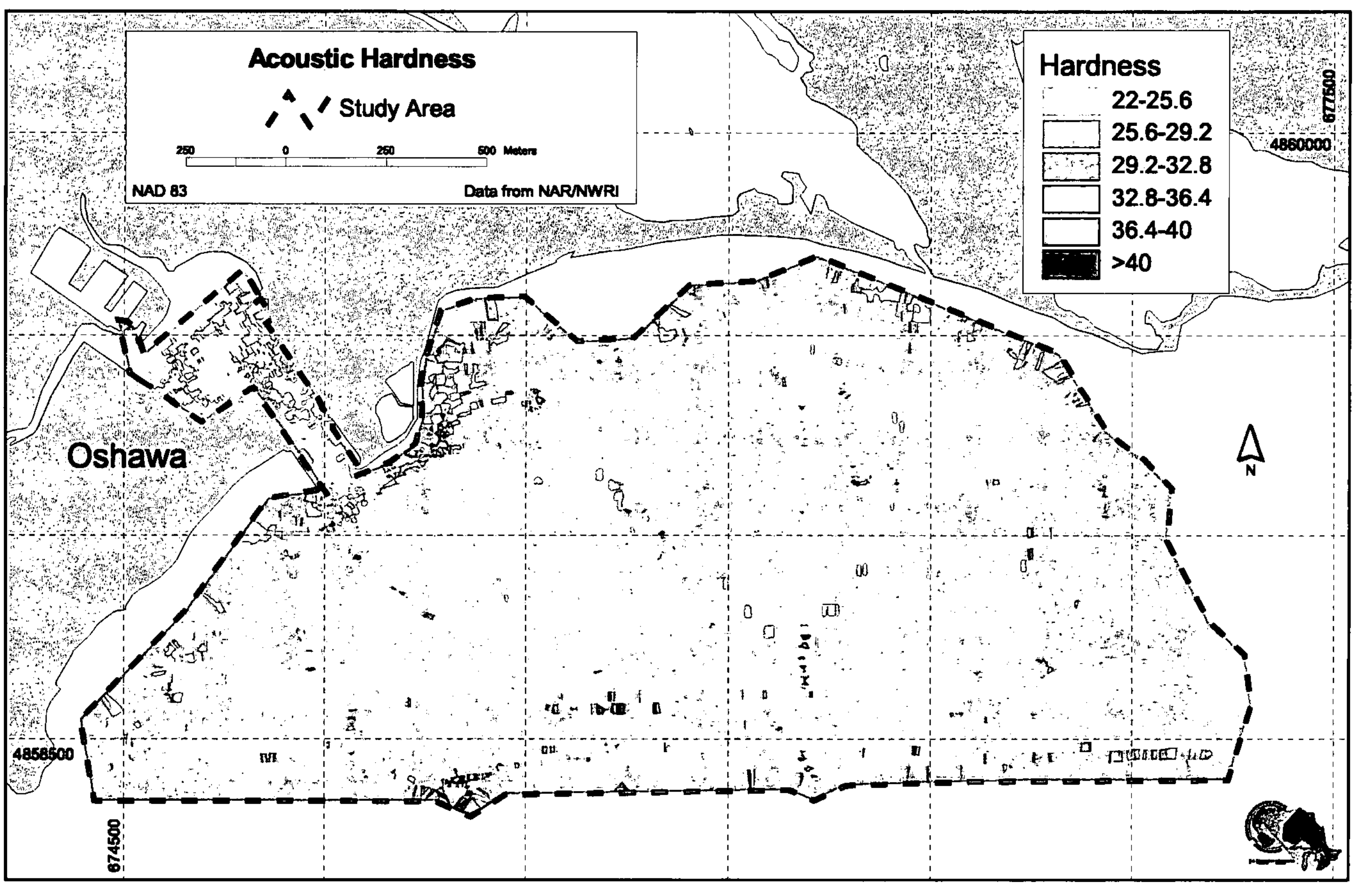


Figure 9. GIS map of RoxAnn acoustic roughness and hardness

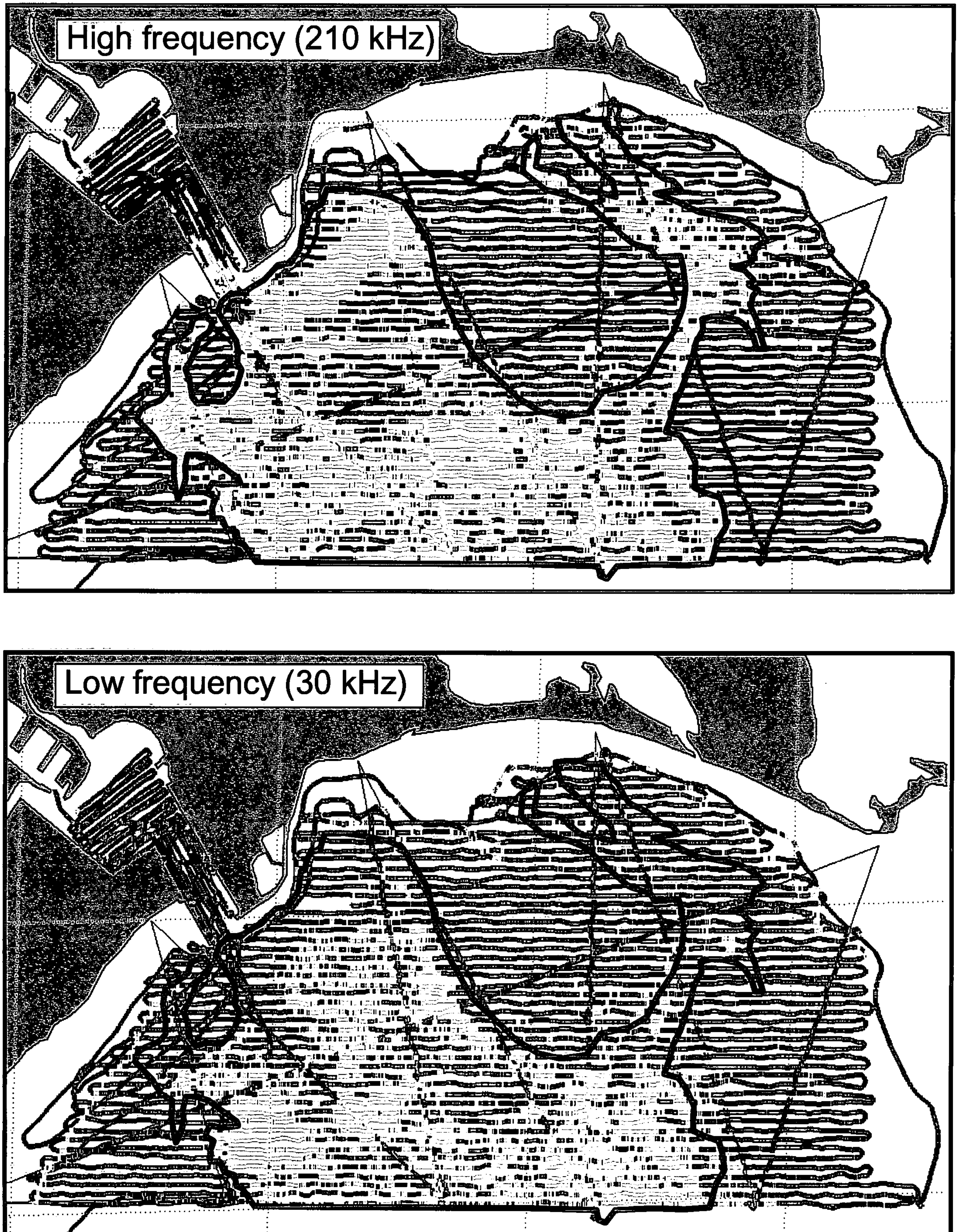


Figure10. RoxAnn low and high-frequency bottom types.

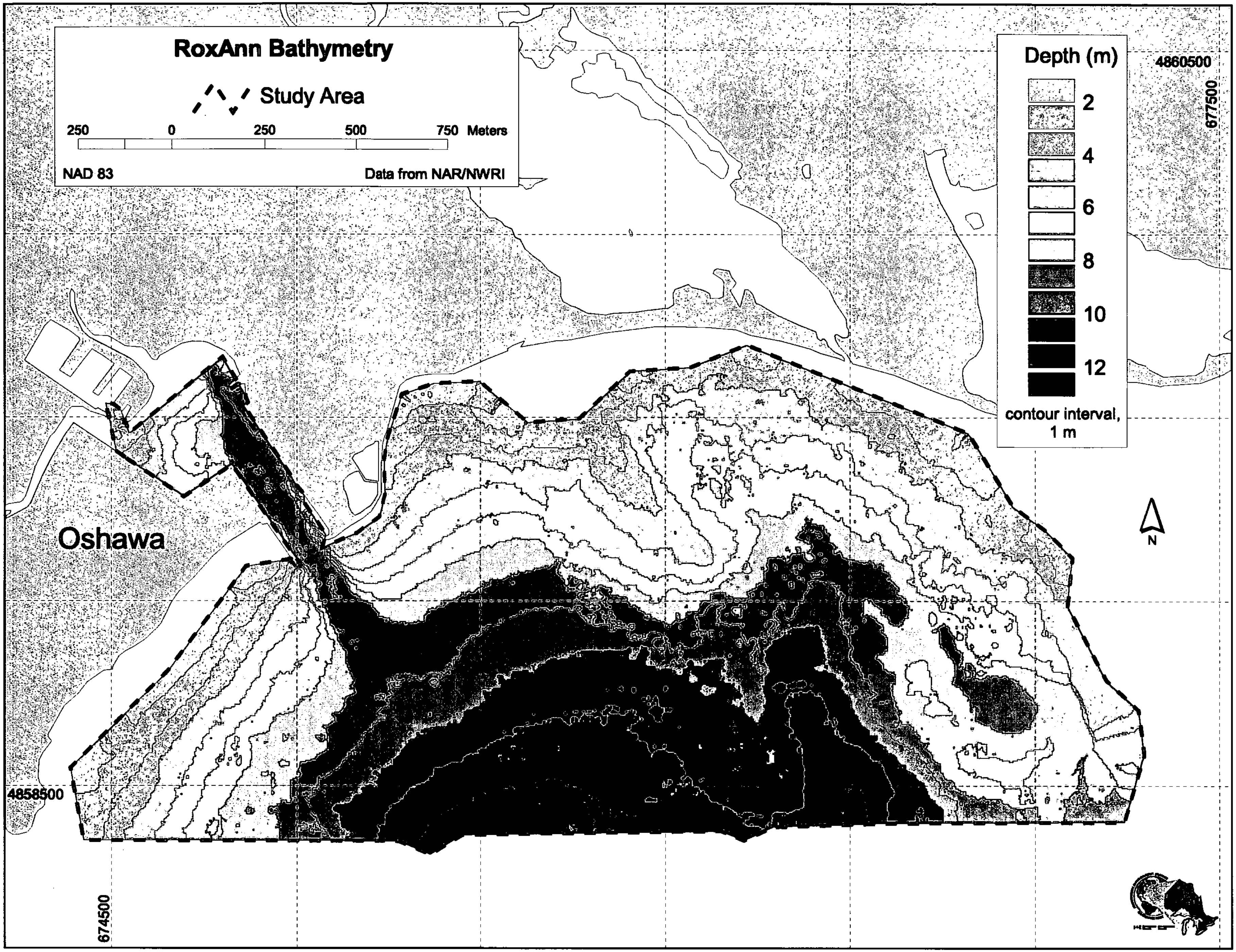


Figure 11. GIS map of RoxAnn bathymetry for the study area

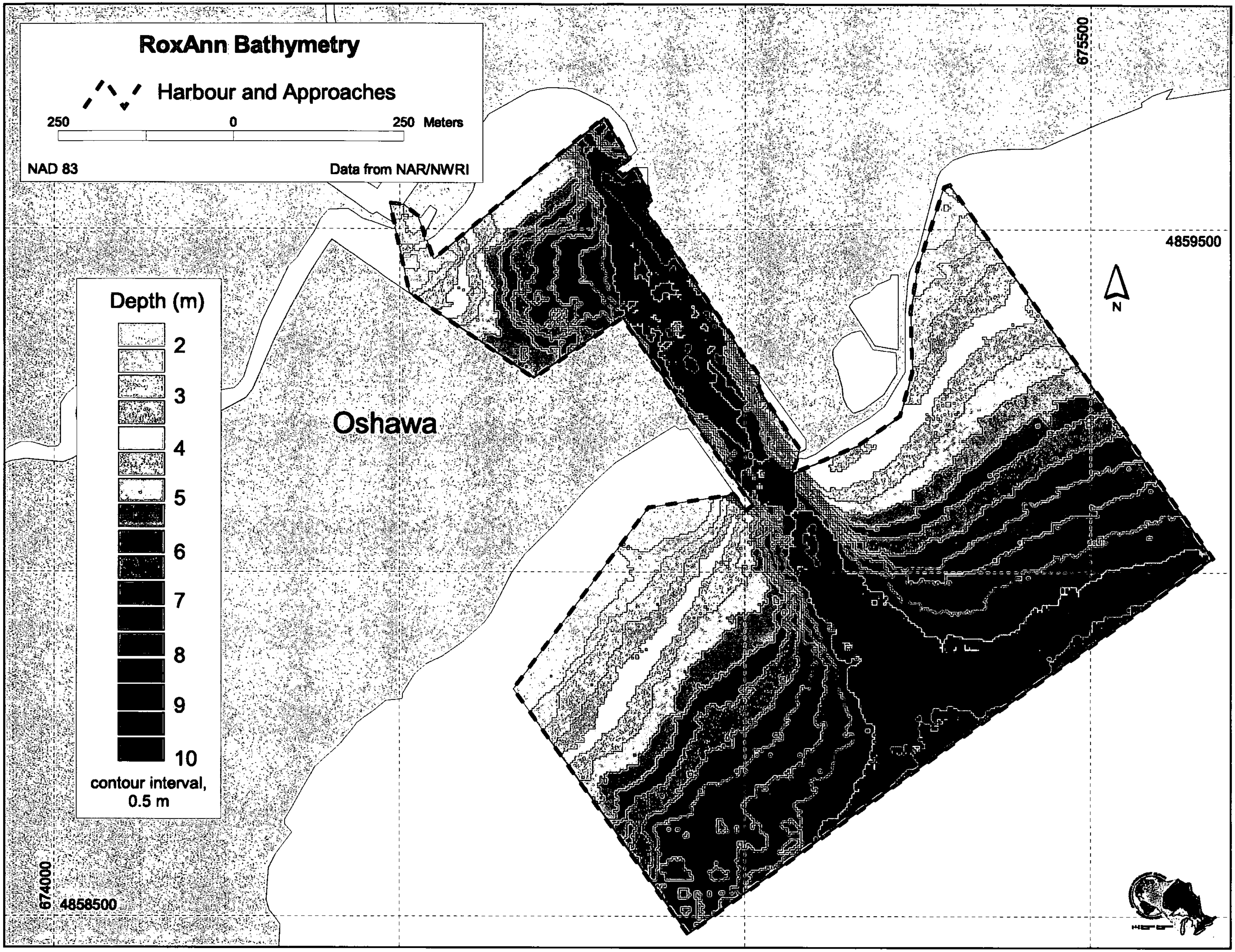


Figure 12. GIS map of RoxAnn bathymetry for the harbour and approaches

Appendix 1: Survey schedule

Wednesday, May 26, 1999

- left CCIW for Oshawa at 1325, arrived 1530, crew Dave Gilroy (coxswain), Brian Trapp (technician), Norm Rukavina (study leader)
- launched the workboat, Puffin, at the local marina and arranged dockage
- inspected the local benchmarks and selected NIBL on the west side of the harbour as the shore-reference site
- setup GPS at NIBL and confirmed OK at benchmark OSHA on the west pier
- ran dual-frequency RoxAnn along a zig-zag line across the target area to check the range of bottom types, complete by 1930, left the harbour at 2000
- discussion with Paul Mudroch over dinner of data available from the GeoSea survey of part of the nearshore area in 1998
- evening processing of the data collected on the zigzag line

Thursday, May 27, 1999

- started the offshore survey at 815, Paul Mudroch and student aboard during the morning to observe RoxAnn
- one-third of the survey completed by noon
- offshore survey continued in the afternoon till about 1500 when winds to high to continue, moved to harbour and completed the survey there by 1600
- met briefly with the Harbour Commission chief, Donna Taylor, to discuss the survey
- left the harbour at 1630
- evening processing of today's RoxAnn data

Friday, May 28, 1999

- early start at 750
- winds light but 1/3 to 1/2 m swell from yesterday
- continued with lines survey until 1140 when interrupted for refuelling
- restarted survey at 1225 and completed at 1430
- final GPS check at OSHA
- packed up the boat and truck, Puffin left in the slip for the weekend

– left for CCIW at 1545, arrived 1800

Monday, May 31, 1999

– left CCIW at 1000, same crew, arrived 1140, dead calm conditions
– on first site for underwater-television survey at 1310
– 23 sites completed by 1545, wind now freshening but waves still small, back to marina to pick up Mini-Shipek sampler
– completed 16 Shipek sites by 1700
– GPS check at OSHA
– packed and loaded the Puffin, picked up the GPS and left at 1815
– arrived CCIW at 2000

Thursday, June 3, 1999

– final adjustments to the diver mark file for Oshawa
– left CCIW for Oshawa at 930, arrived 1100, crew Brian Trapp, Tod Breedon (coxswain) and divers, Dave Gilroy and Bruce Gray
– launched the Puffin and setup the GPS shore station
– completed placement of buoys at the proposed dive sites by 1400
– diver observations and sampling at 11 sites completed by 1740
– left the marina at 1830

Friday, June 4, 1999

– early start at 730
– marked the remaining dive sites with buoys, completed by about 915
– diver observations and sampling at an additional 12 sites completed by noon
– final GPS check at OSHA
– left for CCIW at 1300

Appendix 2: GPS Site Data

The shore receiver for the differential GPS was at benchmark NIBL. A second benchmark, OSHA, was used as a check point. All survey coordinates were in NAD83.

GPS shore-receiver coordinates

benchmark NIBL (Sta. 8339181):

Located at the western end of the NE-SW trending pier on the west side of Oshawa Harbour.

Geographic NAD83	43.866175 (lat)	78.82544 (long)	Elevation 76.1 masl
UTM NAD83, metres	4859307.8 N	674736.5 E	

GPS check site

benchmark OSHA (Sta. 8339180):

Located on the east side of the west pier of the harbour near the lakeward end of the pier.

Geographic NAD83	43.864525 (lat)	78.822531 (long)	Elevation 76.0 masl
UTM NAD83, metres	4859130.7 N	674975.2 E	

Appendix 3: Underwater-television observations

Site	Easting	Northing	Depth	Description
	m, NAD83		m	
May 31, 1999				
19-1	676440	4858545	11.9	rippled sand, ~5 cm
19-2	676440	4858546	11.9	rippled sand, ~5 cm
19-3	676471	4858541	12.0	rippled sand, ~5 cm
20	676581	4858559	11.5	patchy sand (<10 cm) and cobbles
17	676792	4858679	7.5	algae-covered cobbles, scattered and tightly packed
21	676933	4859102	4.6	large algae-covered boulders
18	676316	4859129	8.3	patchy algae-covered cobbles on exposed till?
5-1	676297	4859450	5.4	thin sand (5-10 cm) on hard substrate, poor visibility
5-2	676295	4859455	5.3	thin sand (5-10 cm) on hard substrate, poor visibility
10	675842	4858960	8.8	very large algae-covered boulders with crevices of lighter material (till?)
11	675744	4859123	6.8	very large algae-covered boulders with crevices of lighter material (till?)
6	675727	4859450	2.8	hard bottom, poor visibility
3	675521	4859318	6.7	5-10 cm sand with algal patches over hard substrate (till?)
4	675525	4859218	4.8	<10 cm of hummocky sand with algae in troughs
1	675272	4859212	4.6	flat coarse sand (<10 cm) with algal cover, hard substrate
2	675292	4859261	4.6	sand (<5 cm) and algae on till?, poor visibility
12	675057	4859049	8.5	algae-covered soft mud or muddy sand (actually green slime), 40-50 cm thick
8	675002	4859012	4.9	algae-covered cobbles on exposed till?
13-1	675319	4858397	12.0	<10 cm mud on hard flat substrate (glacial clay?)
13-2	675354	4858391	12.4	<10 cm mud on hard flat substrate (glacial clay?)
15	675724	4858482	12.8	hard bottom with thin sand and algae cover (glacial clay?)
16-1	675437	4858879	9.4	10 cm rippled sand on hard substrate
16-2	675494	4858742	10.3	10 cm rippled sand on hard substrate

Appendix 4: Sample descriptions

Site	Northing	Easting	Depth	Notes
	NAD83		m	
May 31, 1999				
12-1	675037.9	4859079.8	~8.5	algae-covered bucket, did not trigger
12-2	675037.9	4859079.8	~7.6	algal slime only, discarded
12-3	675032.5	4859059.4	~8.9	algal slime only, discarded
12-4	675063.9	4859036.2	~8.3	full bucket, green algal slime, vial sample
13-1	675347.0	4858390.7	12.4	clear water, minor sand, exposed glacial clay?, no sample
13-2	675360.4	4858370.8	12.6	clear water, minor fine-medium sand, hard mud (glacial?), no sample
14	675532.2	4858437.3	12.8	clear water, minor sand, exposed glacial clay?, no sample
15-1	675715.0	4858464.5	12.8	clear water, minor sand, no sample
15-2	675707.6	4858468.2	12.8	<1 cm fine-medium sand, vial sample
16	675496.4	4858755.3	10.3	1 cm fine sand, vial sample
4-1	675522.9	4859221.4	6.8	did not trigger
4-2	675534.1	4859217.1	6.8	1 cm fine sand, vial sample
3	675533.2	4859326.9	5.5	1 cm fine sand, vial sample
2	675302.0	4859264.9	4.8	2 cm green algae and fine sand, vial sample
1-1	675275.1	4859205.3	4.9	clear water, minor fine-medium sand, no sample
1-2	675274.9	4859202.7	5.0	1 cm algae and fine sand, vial sample

Appendix 5: Diver observations

Stn#	Easting	Northing	Depth	Penetration	Description
	m, NAD83		m	cm	
June 3, 1999					
13	675302	4858382	12	80	flat bottom, algae on surface covering muddy sand, soft on surface, harder at depth
14	675528	4858427	12.8	80	sand ripples 15-20 cm apart, 2 cm of algal fluff on surface
15	675730	4858467	12.6	2	sand and cobbles, cobbles mainly 5-10 cm and covered with zebra mussels, some larger than 50 cm in size, sand to the west, cobbles to the east, and cobble patches with sand in between, surface algae
19	676407	4858543	NA	32	sand ripples, aligned north-south direction, 10-20 cm apart and 5-10 cm high, hard substrate at 32 cm
20	676593	4858553	11	40	more sand than site 19, 10-cm cobbles covered with algae and zebra mussels
17	676787	4858692	1/7	2-5	cobble and boulder bottom, fist to Basketball size, covered with algae and zebra mussels with sand and gravel in between, firm clay under the cobbles and sand
21	676960	4859130	4	0-80	10-15 cm layer of gravel over clay, boulders the size of basket balls covered with filamentous algae and zebra mussels, patches of clay with no covering material, 80 cm of penetration below boulders through clay, gravel and sand, then clay
18	676300	4859126	8.2	0	thin sand layer over firm clay, patchy boulders with a large clay ridge up to a metre high and 6-12 m wide
9	675042	4859102	NA	0	5-cm pebbles covered with zebra mussels, filamentous algae on surface
8	675000	4859009	NA	30-75	sand and pebbles coated with zebra mussels, clay at surface forming ridges 30 cm high and 20 m wide, penetration variable, from 30-75 cm in firm clay
June 4, 1999					
23	675671	4858683	11.2	80	sandy bottom with east-west trending ripples, penetrated to 80 cm through firm layers, 15 cm of clay on the bottom of the penetration rod
12	675056	4859047	NA	80+	30 cm of slimy algae on a soft layer of gassy mud, penetration >130 cm to sandy clay at the bas
16	675445	4858878	9.4	60	sand surface with no organized ripple pattern, filamentous algae on surface, 60 cm of penetration and then an abrupt stop, patches of clay on penetration probe, felt like layers as the probe was pushed through the sediment

Stn#	Easting	Northing	Depth	Penetration	Description
	m, NAD83		m	cm	
10	675851	4858964	9	0	hard clay ridges 2-3 m high and 15 m long, crevices up to 1.5 m wide, thin sand and boulder bottom with algae and zebra mussels covering the boulders, very little penetration, current seems to running the same direction as the crevice
11	675754	4859134	7	5	same type as site 10, clay ridges are generally smaller (1-1.5 meters high), one large ridge 12 m wide and 2 m high, crevices contain coarse gravel, sand, and boulders with algae, 5-cm penetration in crevices only
22	675520	4859086	8	60	hummocky sand bottom with clumps of filamentous algae 10 cm high in depressions, 60 cm penetration, felt like layers as probe was pushed through sediment, more clay than sand at depth
4	675527	4859211	6	35	hummocky sand bottom, filamentous algae on surface, clumps of algae 10 cm high in the depressions, 35 cm of penetration with an abrupt stop
3	675516	4859324	5.2	40	flat sandy bottom with no ripples, 40 cm penetration, 10-cm thick carpet of algae or algal patches over sand
7	675494	4859473	5.4	0	sand, pebbles and boulders on hard clay, boulders covered with algae and zebra mussels, sample of hard clay recovered
6	675737	4859445	2.8	0	boulders with gravel and cobbles, algae and zebra mussels on boulders, recovered sample of gravel between the boulders
5	676302	4859453	2.8	80	clay ridges 30-40 cm high with crevices 1-2 m wide, covered by a layer of sand and a few boulders, sand in the crevices, black material mixed in with the clay looks organic (possibly peat), full penetration with rod (80 cm) through sand, peat and then clay
2	675288	4859268	4.4	80	flat sand bottom with an algal carpet 5 cm thick, total penetration of 120-130 cm, appears to be a layer at 50 cm, a second one at 60 cm and then very stiff sediment below that
1	675280	4859211	4.8	80	flat sand about 30 cm thick and 60 to70 % covered with an algal carpet 2-3 cm thick, subsurface layering similar to site 2

Appendix 6: Size statistics, GeoSea samples

Stn ID	Easting	Northing	% Grav	% Sand	% Silt	% Clay	Mode
	m, NAD83						mm
1	674424.2	4859735.1	0.0	85.0	14.6	0.4	0.177
2	674372.2	4859708.1	0.0	2.2	81.8	16.1	0.008
3	674497.3	4859694.1	0.0	32.3	64.6	3.0	0.031
6	674555.3	4859669.1	53.8	37.4	8.0	0.7	4.000
7	675572.3	4859664.1	5.5	94.4	0.1	0.0	0.250
8	674453.3	4859658.1	0.0	9.0	83.6	7.4	0.011
9	674310.2	4859657.1	0.0	4.7	85.0	10.3	0.011
10	675504.3	4859648.1	0.0	99.9	0.0	0.0	0.250
11	674733.3	4859645.1	0.0	22.6	71.2	6.3	0.016
12	674596.3	4859623.1	0.0	73.3	24.1	2.6	0.125
14	674808.3	4859616.1	0.0	14.0	78.4	7.6	0.016
15	674459.3	4859601.1	0.0	12.6	80.8	6.7	0.016
16	674371.3	4859598.1	0.0	11.7	79.8	8.5	0.016
18	675369.3	4859597.1	23.6	76.3	0.1	0.0	0.354
19	674671.3	4859594.1	0.0	17.2	77.0	5.7	0.016
21	674519.3	4859581.1	0.0	14.5	78.3	7.2	0.016
22	675305.3	4859575.1	64.1	35.8	0.1	0.0	4.000
24	674745.3	4859566.1	0.0	11.2	81.8	7.0	0.016
25	674391.3	4859468.1	9.2	67.8	21.8	1.2	0.125
27	674609.3	4859544.1	0.0	14.0	78.8	7.2	0.016
29	674820.3	4859538.1	0.0	14.2	78.5	7.2	0.016
30	674417.3	4859491.1	0.0	60.1	37.1	2.8	0.088
31	674472.3	4859522.1	0.0	41.1	56.5	2.5	0.044
33	674684.3	4859515.1	0.0	9.6	82.9	7.5	0.016
37	674521.3	4859496.1	0.0	31.9	62.0	6.1	0.031
39	674758.3	4859487.1	0.0	8.2	83.7	8.1	0.016
42	674621.3	4859465.1	0.0	18.0	76.6	5.4	0.022
44	674833.3	4859459.1	0.0	17.7	77.2	5.1	0.016
46	674485.3	4859443.1	0.0	66.7	31.5	1.8	0.177
48	674696.3	4859436.1	0.0	11.0	81.8	7.1	0.016
50	674908.3	4859430.1	0.0	16.7	78.3	5.0	0.016
51	675329.3	4859419.1	0.0	70.7	28.4	0.8	0.125
52	674560.3	4859414.1	0.0	36.0	60.3	3.8	0.063
54	674771.3	4859408.1	0.0	15.2	77.2	7.6	0.016
55	675407.3	4859391.1	0.0	73.1	26.2	0.6	0.125
56	674634.3	4859386.1	0.0	15.7	79.1	5.2	0.022
58	674843.3	4859390.1	0.0	15.9	78.1	6.0	0.016
59	675269.3	4859366.1	0.0	97.3	2.6	0.1	0.177

Stn ID	Easting	Northing	% Grav	% Sand	% Silt	% Clay	Mode
	m, NAD83						mm
60	675482.3	4859360.1	0.0	90.1	9.5	0.4	0.125
61	674709.3	4859358.1	0.0	12.6	81.6	5.8	0.016
63	674945.3	4859370.1	0.0	15.2	79.6	5.1	0.016
64	674777.3	4859364.1	0.0	12.8	80.9	6.3	0.016
65	675336.3	4859340.1	0.0	88.4	11.3	0.2	0.125
66	675555.3	4859332.1	0.0	78.9	20.2	0.8	0.125
67	674659.3	4859321.1	0.0	13.9	81.1	5.0	0.022
68	674983.3	4859314.1	0.0	42.8	54.7	2.5	0.063
69	674858.3	4859323.1	0.0	16.8	77.4	5.9	0.016
70	675412.3	4859314.1	0.0	78.7	20.7	0.6	0.088
72	674709.3	4859299.1	0.0	10.3	82.6	7.1	0.016
73	675288.3	4859285.1	0.0	87.9	11.9	0.2	0.125
74	675493.3	4859283.1	0.0	72.2	26.9	0.9	0.088
76	674930.3	4859286.1	0.0	39.4	56.4	4.1	0.125
77	675348.3	4859258.1	0.0	66.8	31.6	1.6	0.088
78	675564.3	4859255.1	0.0	78.6	20.5	0.9	0.088
79	675013.3	4859246.1	0.0	51.5	46.0	2.5	0.125
80	675209.3	4859225.1	0.0	98.0	1.9	0.1	0.177
81	675430.3	4859238.1	0.0	60.8	37.7	1.5	0.088
83	675291.3	4859209.1	0.0	89.1	10.6	0.3	0.125
84	675509.3	4859196.1	0.0	83.0	16.6	0.4	0.125
85	675057.3	4859199.1	0.0	95.7	4.1	0.2	0.177
87	674947.3	4859196.1	0.0	99.3	0.6	0.0	0.250
88	675153.3	4859179.1	0.0	95.8	4.1	0.1	0.125
89	674887.3	4859187.1	0.0	99.2	0.7	0.0	0.177
90	675371.3	4859174.1	0.0	71.9	26.8	1.3	0.088
91	675575.3	4859172.1	0.0	70.0	28.6	1.4	0.125
92	675031.3	4859161.1	0.0	42.2	55.9	1.9	0.044
93	675231.3	4859157.1	0.0	84.2	15.4	0.4	0.125
94	675447.3	4859146.1	0.0	74.0	25.1	0.9	0.088
95	674822.3	4859152.1	0.0	99.8	0.1	0.0	0.250
96	675659.3	4859148.1	0.0	69.8	28.6	1.6	0.088
98	675095.3	4859139.1	0.0	93.7	6.2	0.2	0.125
99	675304.3	4859129.1	0.0	79.4	20.0	0.6	0.088
100	675522.3	4859124.1	0.0	76.4	22.8	0.8	0.125

Stn ID	Easting	Northing	% Grav	% Sand	% Silt	% Clay	Mode
	m, NAD83						mm
102	674961.3	4859124.1	0.0	66.5	32.8	0.7	0.177
103	675180.3	4859106.1	0.0	91.6	8.2	0.2	0.125
104	675381.3	4859100.1	0.0	45.9	51.1	3.0	0.088
105	674765.3	4859099.1	0.0	99.8	0.2	0.0	0.250
106	675593.3	4859096.1	0.0	75.9	23.1	1.0	0.125
108	675033.3	4859091.1	0.0	51.1	47.5	1.4	0.125
109	675245.3	4859078.1	0.0	61.5	36.9	1.5	0.088
110	675456.3	4859072.1	0.0	72.4	26.3	1.3	0.125
111	675672.3	4859069.1	0.0	82.3	17.1	0.7	0.125
112	674893.3	4859065.1	0.0	97.1	2.8	0.1	0.177
113	675106.3	4859057.1	0.0	40.5	57.6	1.9	0.044
114	675314.3	4859054.1	0.0	62.2	36.5	1.4	0.088
115	675534.3	4859041.1	0.0	81.8	17.5	0.7	0.125
119	674710.3	4859034.1	2.2	97.6	0.1	0.0	0.354
121	675396.3	4859024.1	0.0	65.5	32.9	1.6	0.088
122	675610.3	4859011.1	0.0	85.6	13.8	0.6	0.125
124	675044.3	4859002.1	0.0	30.6	65.8	3.7	0.044
125	675254.3	4859000.1	0.0	52.3	45.3	2.4	0.088
126	675469.3	4858995.1	0.0	76.0	22.9	1.2	0.177
128	675683.3	4858986.1	0.0	76.0	23.0	1.0	0.125
129	674907.3	4858985.1	0.0	96.4	3.5	0.1	0.125
130	675121.3	4858978.1	0.0	28.8	67.6	3.6	0.044
131	675333.3	4858965.1	0.0	71.9	26.9	1.2	0.125
132	675543.3	4858969.1	2.2	68.9	27.1	1.8	0.354
133	674767.3	4858969.1	0.0	98.7	1.3	0.0	0.125
134	675750.3	4858963.1	0.0	91.8	7.9	0.4	0.177
136	675194.3	4858947.1	0.0	20.3	76.3	3.4	0.022
137	675404.3	4858943.1	0.0	33.4	60.7	5.9	0.016
138	674636.3	4858941.1	0.0	99.9	0.1	0.0	0.250
139	675616.3	4858939.1	0.0	83.3	16.0	0.7	0.125
140	674846.3	4858941.1	0.0	97.2	2.7	0.1	0.125
143	675480.3	4858910.1	0.0	79.7	19.3	1.0	0.177
144	674708.3	4858919.1	0.0	99.6	0.4	0.0	0.177
145	675692.3	4858902.1	10.0	60.4	28.3	1.3	0.125
147	675131.3	4858895.1	0.0	19.9	77.5	2.6	0.022
148	675345.3	4858890.1	0.0	49.0	48.2	2.7	0.088
149	675556.3	4858888.1	0.0	78.4	20.3	1.3	0.125
151	675768.3	4858875.1	0.0	81.0	18.1	0.8	0.125
152	674576.3	4858879.1	64.2	35.6	0.1	0.0	4.000
154	675207.3	4858873.1	0.0	45.5	52.1	2.4	0.063
155	675417.3	4858866.1	0.0	65.9	32.1	2.0	0.125
157	675632.3	4858855.1	0.0	78.6	20.3	1.1	0.125
158	674863.3	4858851.1	0.0	96.5	3.4	0.1	0.125

Stn ID	Easting	Northing	% Grav	% Sand	% Silt	% Clay	Mode
	m, NAD83						mm
159	675072.3	4858843.1	0.0	89.8	9.7	0.5	0.354
160	675282.3	4858843.1	0.0	39.7	55.8	4.5	0.063
161	675493.3	4858834.1	0.0	74.1	24.5	1.5	0.125
162	674721.3	4858827.1	0.0	97.9	2.0	0.0	0.125
163	674520.3	4858830.1	12.8	87.1	0.1	0.0	0.250
164	675705.3	4858827.1	0.0	84.8	14.2	1.0	0.125
166	675146.3	4858823.1	0.0	15.8	80.7	3.5	0.016
167	675358.3	4858814.1	0.0	53.2	44.8	2.0	0.088
168	674570.3	4858784.1	0.0	99.2	0.8	0.0	0.177
169	675569.3	4858805.1	0.0	73.1	25.1	1.8	0.125
170	674800.3	4858801.1	0.0	95.6	4.2	0.2	0.177
171	675779.3	4858803.1	0.0	89.1	10.4	0.5	0.250
172	675009.3	4858796.1	0.0	58.8	39.3	1.9	0.125
173	675215.3	4858794.1	0.0	50.5	47.0	2.5	0.125
174	674450.3	4858789.1	19.5	80.3	0.1	0.0	0.250
175	675431.3	4858783.1	0.0	89.3	10.3	0.5	0.177
176	674661.3	4858784.1	0.0	96.8	3.2	0.1	0.125
177	675646.3	4858779.1	0.0	50.8	46.0	3.1	0.088
178	674873.3	4858777.1	0.0	92.8	6.9	0.4	0.125
179	675082.3	4858768.1	0.0	87.4	12.3	0.3	0.250
182	675507.3	4858757.1	0.0	66.6	28.6	4.9	0.125
183	674739.3	4858755.1	0.0	95.9	4.0	0.1	0.125
184	675719.3	4858748.1	0.0	75.1	23.3	1.6	0.354
185	674947.3	4858748.1	0.0	91.4	8.2	0.4	0.177
186	675160.3	4858744.1	0.0	60.7	37.8	1.5	0.177
187	675370.3	4858736.1	0.0	62.4	35.0	2.6	0.088
188	674601.3	4858727.1	0.0	97.1	2.9	0.1	0.125
189	675580.3	4858729.1	0.0	76.0	22.8	1.1	0.088
190	674814.3	4858726.1	0.0	81.6	17.7	0.7	0.125
191	675025.3	4858724.1	0.0	63.2	35.3	1.5	0.125
192	674403.3	4858714.1	15.4	84.2	0.4	0.0	0.354
193	675235.3	4858711.1	0.0	68.9	29.5	1.6	0.088
194	674453.3	4858677.1	0.0	99.3	0.7	0.1	0.177
195	675448.3	4858705.1	0.0	71.0	27.9	1.1	0.125
196	674677.3	4858707.1	0.0	92.6	7.2	0.2	0.125
197	675657.3	4858705.1	0.0	87.5	11.8	0.7	0.125
198	674884.3	4858698.1	0.0	82.3	16.9	0.8	0.177
199	675096.3	4858694.1	0.0	67.4	31.2	1.4	0.177
200	675305.3	4858685.1	0.0	32.1	62.2	5.8	0.063
201	674533.3	4858681.1	0.0	96.5	3.4	0.0	0.125
202	675519.3	4858676.1	0.0	65.9	32.0	2.1	0.088
205	675168.3	4858661.1	0.0	80.8	18.3	0.9	0.125
207	675378.3	4858655.1	0.0	68.4	29.7	1.9	0.088

Stn ID	Easting	Northing	% Grav	% Sand	% Silt	% Clay	Mode
	m, NAD83						mm
208	674613.3	4858654.1	0.0	96.3	3.7	0.1	0.125
209	675597.3	4858648.1	0.0	67.8	30.4	1.8	0.125
212	675248.3	4858635.1	0.0	54.3	43.1	2.5	0.088
213	674472.3	4858637.1	0.0	98.5	1.5	0.0	0.125
214	675462.3	4858626.1	0.0	58.1	38.8	3.1	0.125
216	674901.3	4858611.1	0.0	60.9	37.3	1.8	0.088
217	675107.3	4858613.1	0.0	70.6	27.8	1.6	0.125
218	674339.3	4858609.1	3.7	96.1	0.2	0.0	0.250
219	675317.3	4858602.1	0.0	84.7	14.6	0.6	0.125
221	675533.3	4858600.1	0.0	78.6	20.0	1.4	0.125
224	675183.3	4858583.1	0.0	45.5	51.3	3.2	0.125
225	674422.3	4858574.1	0.0	98.1	1.9	0.0	0.177
229	675047.3	4858561.1	0.0	76.1	22.8	1.0	0.177
230	675260.3	4858558.1	0.0	43.6	53.1	3.3	0.088
231	674491.3	4858545.1	0.0	96.8	3.2	0.0	0.125
232	675464.3	4858544.1	0.0	70.9	27.2	1.9	0.125
235	675120.3	4858534.1	0.0	70.3	28.3	1.4	0.125
236	674369.3	4858521.1	0.0	99.4	0.6	0.0	0.250
237	675340.3	4858530.1	0.0	72.2	26.5	1.3	0.125
238	674562.3	4858523.1	0.0	98.7	1.2	0.0	0.354
241	675193.3	4858504.1	0.0	62.1	35.2	2.7	0.125
242	674428.3	4858497.1	0.0	98.1	1.8	0.0	0.177
243	675407.3	4858493.1	0.0	83.9	15.4	0.7	0.125
247	675268.3	4858476.1	0.0	70.8	27.5	1.7	0.125
248	674497.3	4858480.1	0.0	41.7	56.8	1.4	0.354
250	674924.3	4858460.1	0.0	12.1	81.9	6.0	0.016
251	675135.3	4858452.1	0.0	84.9	14.7	0.3	0.250
253	675346.3	4858447.1	0.0	73.3	24.6	2.1	0.125
254	674573.3	4858445.1	0.3	96.8	2.8	0.2	0.354
257	675208.3	4858425.1	0.0	66.3	32.5	1.2	0.250
263	675286.3	4858401.1	0.0	69.3	28.7	2.0	0.177
279	674737.3	4858310.1	0.0	75.1	23.4	1.5	0.250
287	674677.3	4858257.1	0.0	88.6	11.1	0.3	0.354
288	674886.3	4858255.1	0.0	23.1	72.9	4.0	0.022
292	674964.3	4858224.1	10.2	75.1	14.2	0.6	0.707
294	674825.3	4858205.1	0.0	66.4	32.3	1.3	0.250
295	675037.3	4858189.1	0.0	37.6	57.0	5.4	0.250
296	674684.3	4858189.1	0.0	84.9	14.5	0.7	0.354
298	674767.3	4858152.1	0.0	71.1	27.7	1.2	0.250
299	674975.3	4858144.1	0.0	87.6	12.1	0.3	0.250
301	674909.3	4858093.1	0.0	89.0	10.7	0.3	0.250
A	675435.3	4859641.1	1.7	97.9	0.3	0.0	0.707

Appendix 7: Size statistics, diver and Mini-Shipek samples

Site	Grav	Sand	Silt	Clay	Slt+	Mud	Mode	Folk Labels
	%	%	%	%	Cly%	%	mm	
Diver samples								
13A (bottom)	0.7	95.8			3.5	3.5	0.177	slightly gravelly sand
13B (top)	0.0	95.1			4.9	4.9	0.177	sand
14	0.0	98.9			1.1	1.1	0.177	sand
15	10.5	87.1			2.3	2.3	0.177	gravelly sand
19	0.0	99.9			0.1	0.1	0.177	sand
20	0.3	98.1			1.6	1.6	0.500	slightly gravelly sand
17	9.4	83.1			7.5	7.5	0.707	gravelly sand
21	29.2	11.4			59.6	59.6	<.0002	gravelly sandy mud
18A (top)	14.3	84.4			1.2	1.2	0.354	gravelly sand
18B (bottom)	3.0	56.3	32.4	8.3		40.7	0.125	slightly gravelly muddy sand
9	30.1	25.4			44.5	44.5	<.0002	sandy gravelly mud
8A	6.2	37.8			56.1	56.1	0.031	gravelly mud
8B	0.1	74.0			25.9	25.9	0.125	slightly gravelly muddy sand
12A (top)	0.0	0.0			100.0	100.0	0.011	mud
12B (bottom)	0.0	99.7			0.3	0.3	0.177	slightly gravelly sand
2	0.0	97.4			2.6	2.6	0.125	sand
23	4.3	93.3			2.4	2.4	0.354	slightly gravelly sand
16	0.4	96.7			2.9	2.9	0.250	slightly gravelly sand
10A (top)	2.2	95.7			2.1	2.1	0.707	slightly gravelly sand
10B (bottom)	3.9	41.1	31.4	23.5		54.9	0.125	slightly gravelly sandy mud
11A (top)	58.4	41.4			0.2	0.2	1.414	sandy gravel
11B (bottom)	0.9	31.9	29.9	37.3		67.2	0.003	slightly gravelly sandy mud
22	0.2	95.0			4.8	4.8	0.125	slightly gravelly sand
4	0.1	91.8			8.1	8.1	0.125	slightly gravelly sand
3	2.5	90.7			6.8	6.8	0.125	slightly gravelly sand
7A (top)	1.5	98.1			0.4	0.4	0.354	slightly gravelly sand
7B (bottom)	0.0	4.7	32.5	62.7		95.2	0.001	mud
Mini-Shipek samples								
12-4	0.0	0.0	80.8	19.2		100.0	0.011	silt
15-2	0.7	98.1			1.2	1.2	0.125	slightly gravelly sand
16	0.1	94.5			5.3	5.3	0.125	slightly gravelly sand
4-2	0.2	88.0			11.9	11.9	0.125	slightly gravelly muddy sand
3	0.0	95.5			4.5	4.5	0.125	sand
2	0.0	95.3			4.7	4.7	0.125	sand
1-2	0.0	98.5			1.5	1.5	0.125	sand

Appendix 8: RoxAnn labels vs groundtruth data

RoxAnn label	Ground-truth data								
	mud	muddy sand	sand	sand on glacial	coarse sand	gravel	cobbles on glacial	boulders or hard	weeds on soft /hard
GeoSea									
7-weeds on soft								1	
8-mud									
9-boulders/hard		1						6	
10-coarse sand		1	4						
11-muddy sand	15	9	15					1	
12-sand	2	8	22		1			3	
13-gravel	1		5					11	
15-weeds on hard									
UWTV									
7-weeds on soft								2	
8-mud	1								
9-boulders/hard								2	
10-coarse sand				1	1				
11-muddy sand		1	4	2					
12-sand				2					
13-gravel							2		
15-weeds on hard									
Shipek									
7-weeds on soft									
8-mud	1			1					
9-boulders/hard									
10-coarse sand			3						
11-muddy sand	1	3							
12-sand			2						
13-gravel									
15-weeds on hard									
Diver									
7-weeds on soft									
8-mud			1						
9-boulders/hard								3	
10-coarse sand									
11-muddy sand			1	1					
12-sand			9						
13-gravel						1	2		
15-weeds on hard							2		
Combined									
7-weeds on soft								3	
8-mud	2		1	1					
9-boulders/hard		1						11	
10-coarse sand		1	7	1	1				
11-muddy sand	16	13	20	3				1	
12-sand	2	8	33	2	1			3	
13-gravel	1		5			1	4	11	
15-weeds on hard							2		

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