



**Habitat Assessment for Pallid Sturgeon Overwintering
Surveys,
Lower Missouri River**

August 2000

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by

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Contents

	Page
Abstract	4
Introduction	4
Purpose and Scope.....	4
Methods.....	7
Data Collection.....	7
Data Processing	11
Bathymetry and Substrate	11
ADCP Data	12
Relating Depth, Velocity and Substrate to Fish Collections	13
Results and Conclusions	13
Appendix. Habitat maps for all sites.....	15

Tables

Table 1. Site names, river miles, and dike numbers.....	3
Table 2. Substrate classes based on roughness and hardness values	10
Table 3. Substrate codes.....	11
Table 4. Summary statistics for habitat assessment sites.....	13

Figures

Figure 1. Location of habitat assessment sites	2
Figure 2. Discharge hydrographs, January 1999 – April 2000	4
Figure 3. Schematic diagram, data collection and processing.....	5
Figure 4. Example of orthogonal sampling transects	6
Figure 5. USGS habitat assessment boat schematic.....	7
Figure 6. Graphical representation of substrate classification system	7
Figure 7. Example of acoustic Doppler current profiler cross-channel transects	8
Figure 8. Edit screen for typical depth transect.....	9

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Abstract

This report documents methods and results of aquatic habitat analysis of pallid sturgeon overwintering habitat on the Lower Missouri River. Physical aquatic habitat – depth, velocity, and substrate – were assessed at 5 wing-dike sites along the lower Missouri River where pallid sturgeon have been caught historically. The resulting data document habitat complexity around engineered structures and provide critical contextual information to support fish sampling efforts and interpretation of habitat use.

Introduction

A cooperative study of pallid sturgeon occurrence in the Lower Missouri and Middle Mississippi rivers started in 1995 as a joint effort among the Iowa Department of Natural Resources, Nebraska Game and Parks Commission, Kansas Department of Wildlife and Parks, Missouri Department of Conservation, Southern Illinois University, U.S. Fish and Wildlife Service – Columbia Fishery Resources Office, Mississippi Interstate Cooperative Resource Association (MICRA), and the U.S. Geological Survey – Columbia Environmental Research Center (CERC)¹. CERC's role has been to assess habitats at sampling sites. High water and logistical constraints prevented study participants from completing the original scope of work. A revised scope of work for habitat assessment was drafted and accepted in September 1999. This report documents the methods and results of the habitat assessment conducted during November 1999 - January 2000.

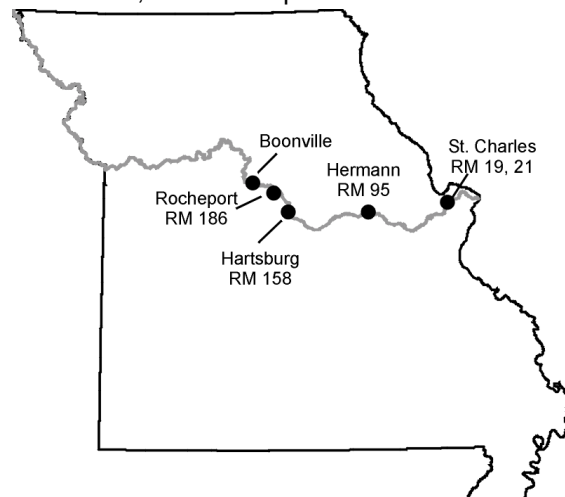


Figure 1. Location of habitat assessment sites in the Lower Missouri River valley. USGS gages at Boonville and Hermann are referred to in this report. RM = river mile.

Purpose and Scope

This report documents methods and results of aquatic habitat assessment of pallid sturgeon overwintering habitat on the Lower Missouri River.

Historically, physical aquatic habitat – depth, velocity, and substrate – have been poorly quantified on the Missouri River, and very little is understood about habitat dynamics. This project involves spatially intensive assessments of habitats associated with wing dikes (channel training structures). The resulting data provide an unprecedented level of detail of habitat complexity around engineered structures and provide critical contextual information to support fish sampling efforts.

Aquatic habitat was assessed at 5 sites along the lower Missouri River where pallid sturgeon sampling was carried out as part of the cooperative project (table 1). Three of the 5 sites encompassed the area around two wing dikes; these sites are Rocheport, Hartsburg, and Hermann (fig. 1). At St. Charles, Missouri, one site contained a single wing dike area and another site contained the area around three adjacent wing dikes. Within each site, at least one dike area was associated with a documented pallid

¹ Prior to October 1, 1995, CERC was part of the National Biological Service (NBS) as the Midwest Science Center. In 1995, NBS was merged with the U.S. Geological Survey.

sturgeon capture February 1999 – January 2000 (except the Hartsburg site where no pallid sturgeon were captured during the study period).

Dike habitat consists of the area extending downstream of a wing dike to the next wing dike or to a distance of 250 m, whichever is shorter, and extending laterally to the bank, and laterally approximately 50 m into the navigation channel. The habitat survey included all parts of the area that were approximately 1 m or greater in depth and that could be accessed safely by boat at the prevailing river stage.

Table 1. *Site names, river miles, and U.S. Army Corps of Engineers dike numbers for cross reference.*

Site name	Approximate river mile (Site number)	Corps of Engineers dike number
St. Charles	19.1	L 20.1, 20.2, 20.4
	21.4	L 21.9
Hermann	95.6	L 101.3
	95.7	L 101.6
Hartsburg	158.1	L 166.2
	158.5	L 166.4
Rocheport	186.4	R 194.75
	186.7	R 194.85

Habitat assessments were carried out during typical winter low-flow conditions, from November 1999 to January 2000 (fig. 2), and corresponded with fish sampling periods. Habitat assessment at each site included the following:

1. Mapping bathymetry of the dike areas to produce maps of depth at a nominal 0.5 m contour interval.
2. Mapping substrate using an acoustic classification system, yielding maps of classified substrate material.
3. Collection of velocity transects using acoustic Doppler velocimetry.

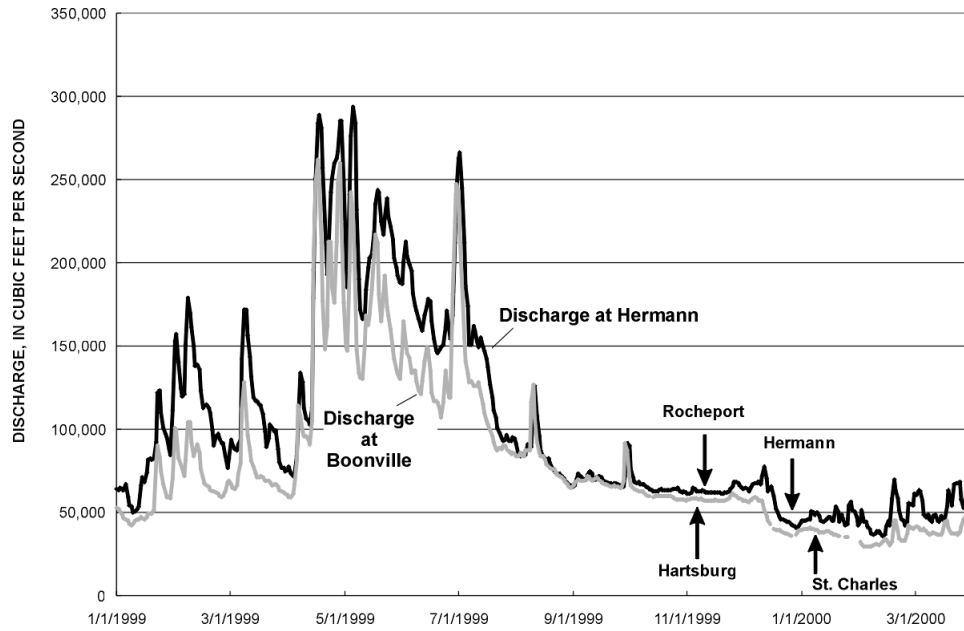


Figure 2. Discharge hydrographs from Boonville and Hermann, Missouri. Arrows indicate dates during which habitats were assessed at the four main sites. Navigation season ended December 1, 1999. To convert discharge in cubic feet per second to cubic meters per second, multiply by .0283.

Methods

Data were collected and processed using protocols currently under development by CERC. A collection and processing schematic is shown in figure 3.

Data Collection and Editing

Navigation base maps were compiled from digital U.S. Army Corps of Engineers Missouri River navigation charts for 1994. These maps were simplified and projected from state-plane coordinates to UTM coordinates, WGS84 datum, for concurrence with global positioning data. The digital maps were exported from a geographic information system (GIS) as georeferenced DXF files that could be imported into navigation software.

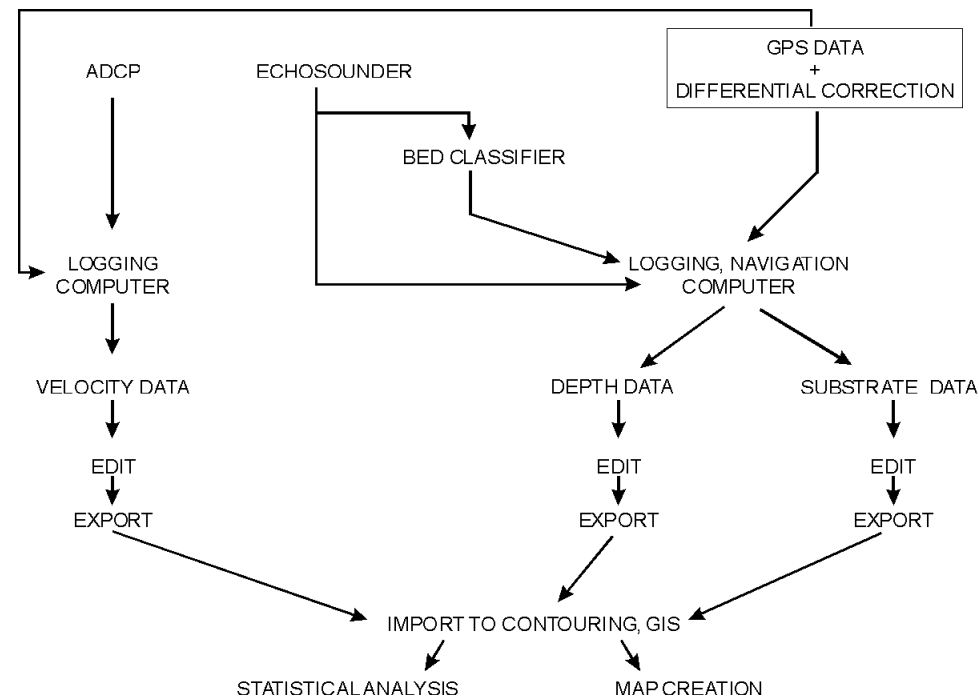


Figure 3. Schematic diagram of habitat assessment data collection and processing. ADCP = acoustic Doppler current profiler; GPS = global positioning system; GIS = geographic information system.

The digital maps were used as the basis for transect design and real-time navigation using HyPack Lite² navigation software. Because the navigation basemaps included all wing dikes used in this study, sampling transects could be constructed to cover all areas of interest using transect layout routines in HyPack. Two orthogonal sets of transects were constructed for each wing dike (fig. 4). The orientation was determined by constructing a line along the length of the wing dike, or in the case of curved wing dikes, from the intersection of the wing dike with the shore to the curved tip. Lateral transect lines were then generated at 20 m intervals upstream and downstream of the wing dike. A second set of longitudinal transects was generated perpendicular to the lateral transects, also at 20 m intervals. The 20-m orthogonal spacing was used to provide sufficient spatial coverage for creating continuous surface maps of depth and substrate data.

² Use of tradenames is for informational purposes only and does not constitute an endorsement by the U.S. Geological Survey.

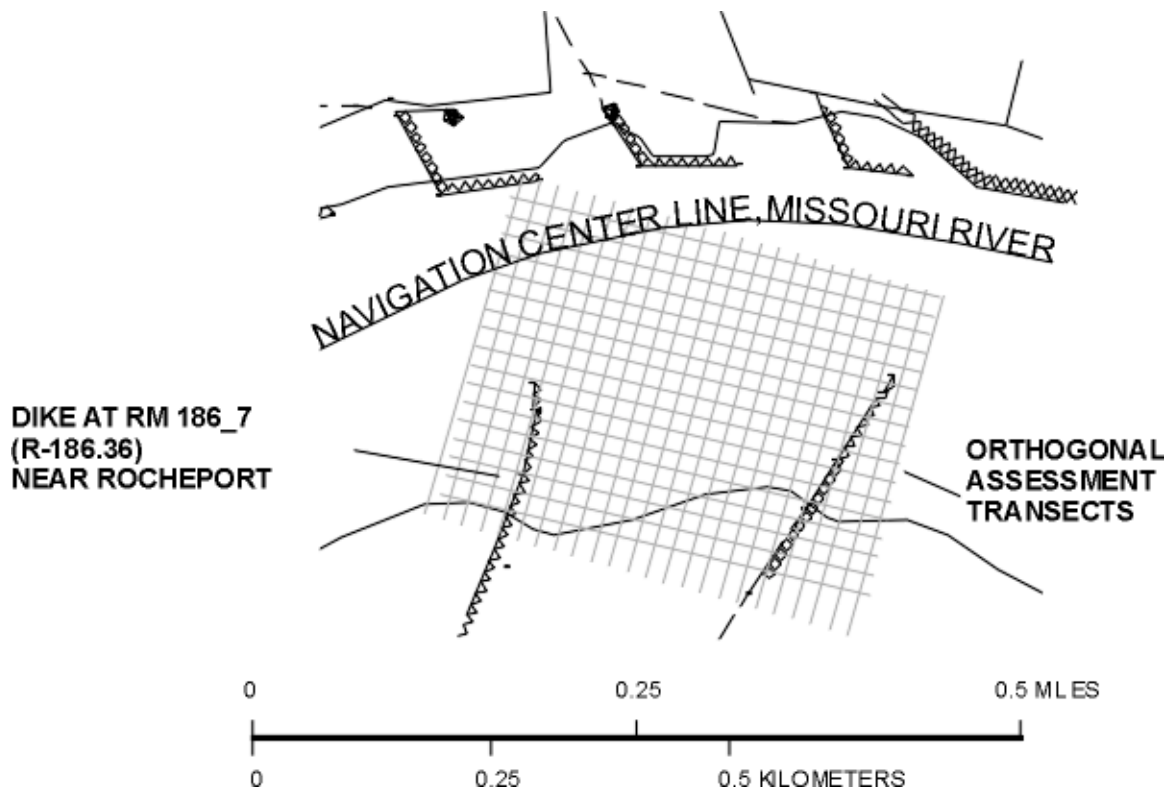


Figure 4. Example of orthogonal sampling transects, wing dike at RM 186.7 (R-186.36). Flow is from left to right.

All data were georeferenced in the field by a real-time, 12-channel differential global positioning system (DGPS) to sub-meter accuracy. Differential corrections were provided in real time by the Omnistar¹ satellite-based system. The DGPS data were collected at 100 millisecond (ms) intervals, resulting in positions approximately every 10 – 40 cm along each transect at typical boat speeds of 2 – 8 knots (1-4 meters per second, m/s); during data collection. Boat speeds were maintained at 5 knots or less most of the time.

Bathymetric data were collected with a 208 kHz Innerspace 449¹ echosounder equipped with an 8° transducer mounted in the center of the boat hull, directly below the DGPS antenna (fig. 5). The echosounder was calibrated by patch test to account for boat draft, blanking distance, and environmental conditions that could affect the speed of sound in water. Pitch and heave were not compensated; however these corrections are thought to be minor given typical calm-water working conditions. The precision of the echosounder data is 3 cm. Patch test results indicate that, under favorable bottom conditions, the depth accuracy is approximately 7 cm.

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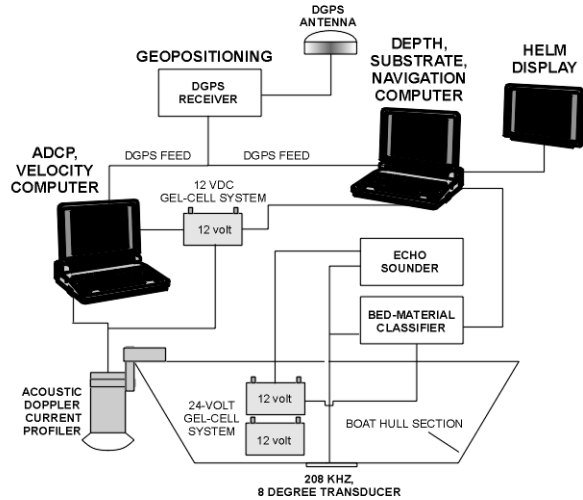


Figure 5. USGS habitat assessment boat system schematic. DGPS, differential global positioning system; ADCP, acoustic Doppler current profiler.

Bed material was classified into substrate classes using a Marine Microsystems RoxAnn¹ system which uses the transducer output from the Innerspace system. The RoxAnn analyzes the shape of the acoustic signal returned from the river bottom to calculate two parameters related to roughness and hardness (e_1 and e_2). Values of e_1 and e_2 collected over substrates of known composition were used to develop a classification matrix specific to the echosounder/transducer system and to the bottom conditions of the Missouri River (fig. 6). Deep, turbid water prevented sampling of some substrates; hence, confidence in assigned classes varies. For example, calibration is good for mud, sand, coarse sand, and gravelly sand classes because these substrate classes are based on first-hand observations. In contrast, classes like sand with dunes and very soft/very rough, could not be observed directly and their classification is therefore inferred. Depth, bed-material classification, and DGPS positions were logged into standardized HyPack files.

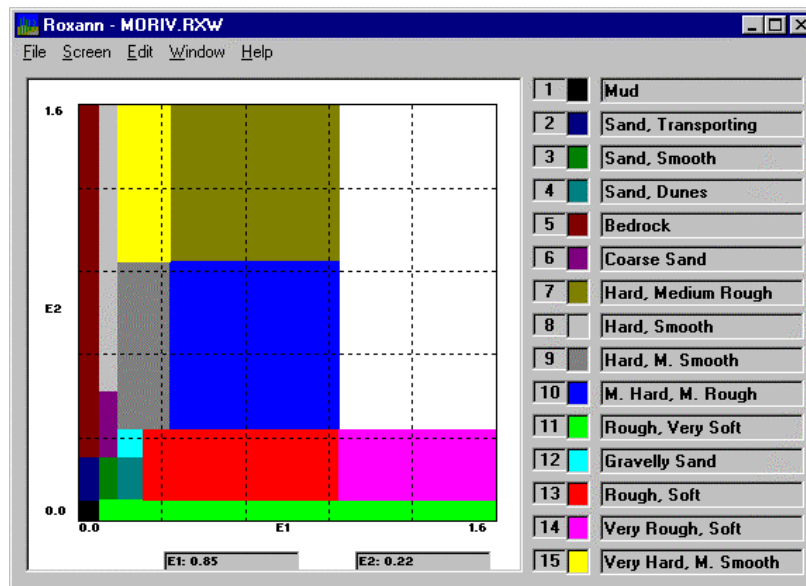


Figure 6. Graphical representation of RoxAnn substrate classification model used in this report, showing ranges of e_1 and e_2 values used to define substrate classes.

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Velocity data were collected with a Workhorse Rio Grande model 600 kHz acoustic Doppler current profiler (ADCP), manufactured by RDI, Inc.¹ These data were also georeferenced with DGPS data, but were collected on a separate laptop computer (fig. 5). The ADCP was set up to collect 3-dimensional water velocity data in 25-cm deep bins from the surface to the bottom. A column of bins (called an ensemble) was collected nominally every 2.5 seconds, resulting in an ensemble spacing that varied from approximately 2.5 – 10 m at typical boat speeds. For ADCP data collection, boat speeds were maintained below 3 knots, resulting in a maximum ensemble spacing of about 3.8 m. The ADCP was internally calibrated for measured water temperature and compensates automatically for pitch and roll. Typical velocity profile transects are illustrated in figure 7.

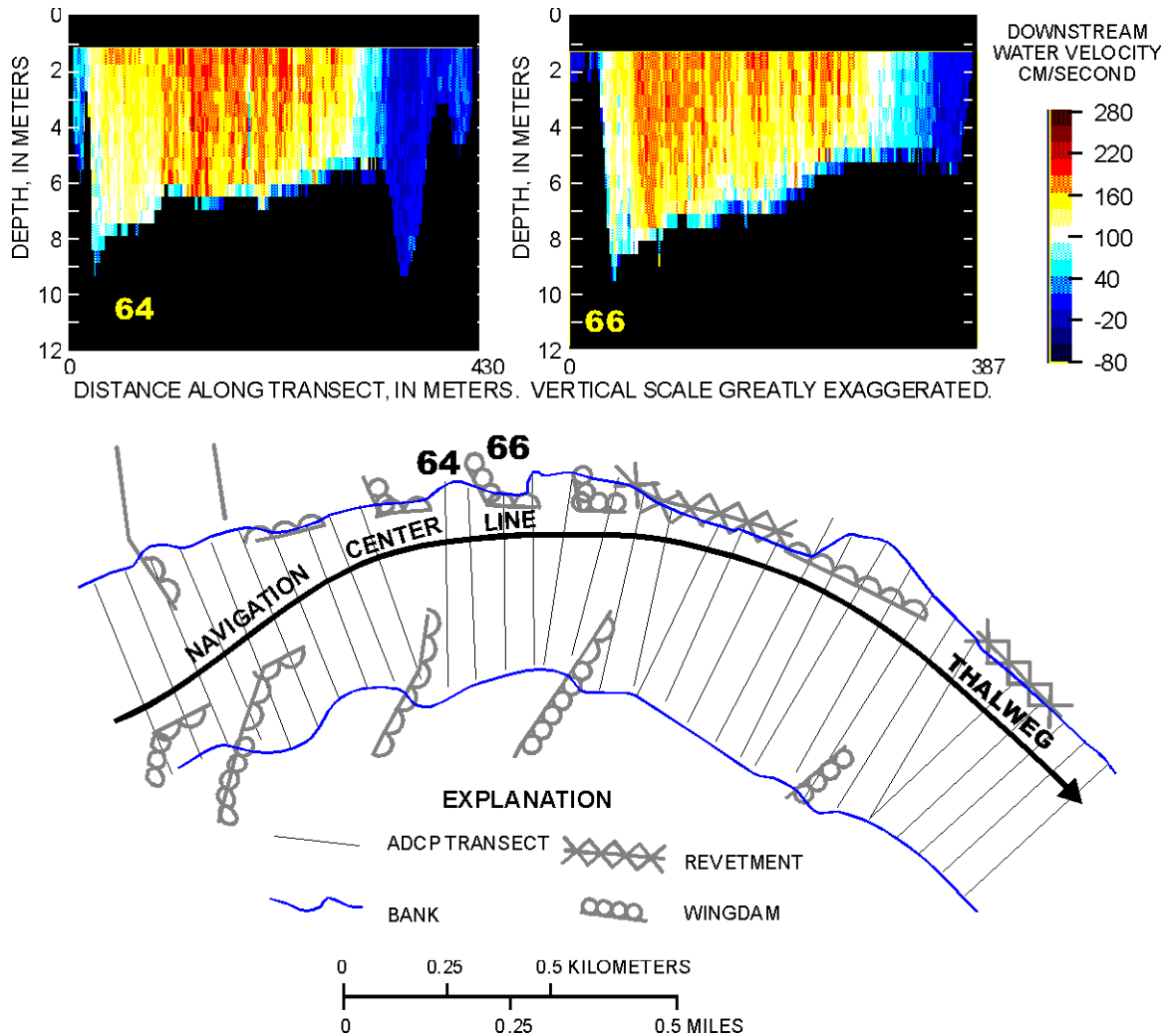


Figure 7. Acoustic Doppler current profile data for two cross-channel transects of the Missouri River near Rocheport, Missouri. Transects are viewed looking downstream with the current velocity projected into the line of the transect. Dark blue colors in the velocity profiles indicate negative velocities--that is, current velocity in the upstream direction. These areas occur in large eddies downstream of wing dikes. The main thread of current is shown in red to yellow colors, with velocities as much as 250 centimeters per second.

Depth and bed-classification data were edited using an editing routine included with HyPack. Typically, editing is required to remove spurious reflections from water-column turbulence or fish and to correct for places where bottom conditions prevented a good digitization (fig. 8). Also, the DGPS signal occasionally dropped out where high banks or trees interfered with satellite reception, thereby

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creating incorrect GPS positions. The high data input rates allowed spurious depths to be deleted without affecting the representation of bottom contours. In some places, substantial areas of spurious depths could be corrected by reference to the echosounder paper trace or to depths digitized by the RoxAnn unit. Positioning errors due to DGPS dropout could often be corrected in HyPack by linearly interpolating positions relative to adjacent correct positions.

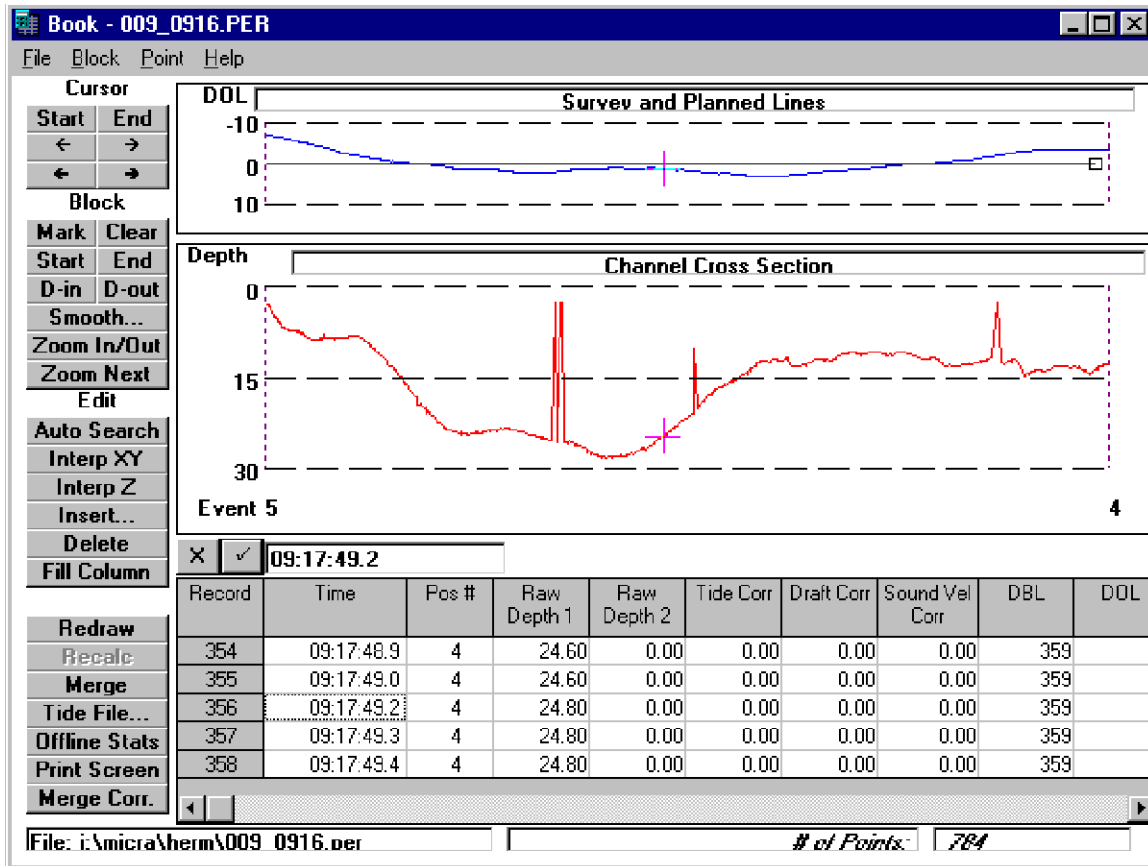


Figure 8. Edit screen from HyPack showing typical digitized depth transect. The blue line shows boat position relative to planned transect. The red line is the digitized depth trace. Spurious depth spikes are deleted and depths interpolated.

Data Processing

Bathymetry and Substrate

Several pre-processing steps were required prior to generating continuous surfaces for the bathymetric and substrate (e_1 and e_2) datasets. Following editing for accuracy and content, the datasets were exported as comma-delimited XYZ text files. The text files were then imported to a Microsoft Excel¹ spreadsheet through an internal Surfer 7¹ software interface. Surfer 7 is used to create continuous surfaces from the point data. The DXF file representing the channel and navigation structures was displayed and the point file(s) representing depth and substrate were overlaid. Break lines and a blanking file were digitized on the computer screen. Breaklines and blanking files aid in the surfacing process by limiting areas where data can be interpolated.

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Surfaces were interpolated using kriging, a standard surface interpolation method. A four quadrant search with a radius of 50-meters was used against the 20-meter spacing of transects. Break lines with a value of zero were inserted along the shorelines and wing dikes to influence the interpolation process. Spurious data points were eliminated from consideration and the output grid resolution was set to 1-meter. A blanking file was then used to clip the interpolated grid to the extent of the input data set.

The Surfer 7 grids were exported as ASCII files and edited to conform to ArcView¹ import requirements and then added to an ArcView project as a table. Each table was added to a view as a point event theme and was subsequently converted to a 1-m grid.

Separate themes for roughness (e_1) and hardness (e_2) were built using the ArcView Map Calculator based on the values found in table 2. Each substrate type was extracted as a new theme. The resultant files were then recoded to unique integer values (table 3) and recombined (added), using the Map Calculator.

Table 2. *Substrate classes based on ranges of roughness (e_1) and hardness (e_2)*

Substrate class	Selection criteria
Mud	$([e_1] \leq 0.08)$ and $([e_2] \leq 0.08)$
Sand, Transporting	$([e_1] \leq 0.08)$ and $([e_1] > 0.08)$ and $([e_2] \leq 0.25)$
Sand, Smooth	$([e_1] \geq 0.08)$ and $([e_1] \leq 0.15)$ and $([e_2] \geq 0.08)$ and $([e_2] \leq 0.25)$
Coarse Sand	$([e_1] \geq 0.08)$ and $([e_1] \leq 0.15)$ and $([e_2] \geq 0.25)$ and $([e_2] \leq 0.5)$
Sand dunes	$([e_1] \geq 0.15)$ and $([e_1] \leq 0.25)$ and $([e_2] \geq 0.08)$ and $([e_2] \leq 0.25)$
Gravelly Sand	$([e_1] \geq 0.15)$ and $([e_1] \leq 0.25)$ and $([e_2] \geq 0.25)$ and $([e_2] \leq 0.35)$
Bedrock	$([e_1] \leq 0.08)$ and $([e_2] \geq 0.25)$ and $([e_2] \leq 1.6)$
Rough, Soft	$([e_1] \geq 0.25)$ and $([e_1] \leq 1.0)$ and $([e_2] \geq 0.08)$ and $([e_2] \leq 0.35)$
Rough, Very Soft	$([e_1] \geq 0.08)$ and $([e_1] \leq 1.6)$ and $([e_2] \leq 0.08)$
Hard, Smooth	$([e_1] \geq 0.08)$ and $([e_1] \leq 0.15)$ and $([e_2] \geq 0.5)$ and $([e_2] \leq 1.4)$
Hard, Medium Smooth	$([e_1] \geq 0.15)$ and $([e_1] \leq 0.35)$ and $([e_2] \geq 0.35)$ and $([e_2] \leq 1.0)$
Med. Hard, Med. Rough	$([e_1] \geq 0.35)$ and $([e_1] \leq 1.0)$ and $([e_2] \geq 0.35)$ and $([e_2] \leq 1.0)$
Medium Hard, Rough	$([e_1] \geq 1.0)$ and $([e_1] \leq 1.6)$ and $([e_2] \geq 0.25)$ and $([e_2] \leq 1.0)$
Very Rough, Soft	$([e_1] \geq 1.0)$ and $([e_1] \leq 1.6)$ and $([e_2] \geq 0.08)$ and $([e_2] \leq 0.35)$
Very Hard, Med. Smooth	$([e_1] \geq 0.15)$ and $([e_1] \leq 0.35)$ and $([e_2] \geq 1.0)$ and $([e_2] \leq 1.6)$
Hard, Medium Rough	$([e_1] \geq 0.35)$ and $([e_1] \leq 1.0)$ and $([e_2] \geq 1.0)$ and $([e_2] \leq 1.6)$

ADCP Data

ADCP data were edited and post-processed using the following steps: 1) Navigation data and ADCP files were merged to georeference ADCP data; 2) Data were exported as ASCII-formatted files; and 3) ASCII file were reformatted for import into ArcView. The ensemble positions, east and north components of surface velocity, and the magnitude of the mean ensemble velocity were calculated and extracted during the reformatting step. These data were subsequently imported into ArcView for statistical analysis, mapping, and display. ADCP velocities and directions are displayed on maps in ArcView by rotating arrow symbols centered at each data point parallel to velocity direction and scaling the arrows according to velocity magnitude. The velocity point data were also converted to a gridded dataset to calculate zonal statistics.

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Table 3. Substrate codes

Code	Description
1	Mud
2	Sand, transporting
3	Sand, smooth
4	Coarse sand
5	Sand dunes
6	Gravelly sand
7	Bedrock
8	Rough, soft
9	Rough, very soft
10	Hard, smooth
11	Hard, medium smooth
12	Medium hard, medium rough
13	Medium hard, rough
14	Very rough, soft
15	Very hard, medium smooth
16	Hard, medium rough

Spatially Relating Depth, Velocity and Substrate to Fish Collection Locations

Habitat mapping occurred in November 1999, December 1999, and January 2000, concurrent with fish sampling by the U.S. Fish and Wildlife Services' Columbia Fishery Resources Office. Because of uncertainty as to the locations where the 33-m long, 2-m deep nets eventually came to rest, 20-meter by 60-meter rectangles were used to resample mapped habitat data for possible relations with fish data. The net box was overlain on the net line described by GPS coordinates of the upstream anchoring point (collected by the fishery crew) and assuming the net was oriented perpendicular to the wing dike. Additional areas (habitat1 and habitat2) were generated to resample larger areas adjacent to the wing dike. The size and orientation of habitat1 and habitat2 were based on the length and orientation of the wing dike. Habitat1 areas specifically target the habitats downstream and inboard of the wing dike. Habitat2 was defined to sample a broader area, to provide users of these data with the opportunity to evaluate relations of fish presence/absence with a more broadly defined habitat area, including potentially important patches that might support related biotic components. The digital datasets were designed to accommodate any arbitrary size and orientation for the resampling boxes, and these datasets are amenable to future resampling for different net orientations or hypotheses. Site maps of depth, velocity, substrate and the location of net and habitat rectangles are located in the Appendix.

Zonal statistics were calculated by querying the depth, velocity and substrate themes based on the geography of the net and habitat rectangles. For numeric data, statistics calculated included: mean, n, standard deviation, and range. For categorical data (substrate type), the dominant class and number of classes were calculated. The statistical summaries are located in Table 4.

Results and Conclusions

Results of habitat surveys are shown in maps in the Appendix and in statistical summary in Table 4. The data illustrate the broad range of physical habitat conditions among wing dikes, but also indicate systematic variation of habitats within and among wing dikes.

Typically, wing dikes have deep scour holes offshore and downstream from their tips and many wing dikes also have deeper and larger scour holes downstream of where the dike intersects with the shoreline (for example, see sites 186.4, 186.7). The tip scours are associated with convergent flow which is evident even at low discharge (for example, see the velocity plot for site 186.4). Presumably, the velocities are even more intense at higher flows. Water velocities over the tip scours are spatially

highly variable because they include downstream-directed velocities as high as 200 cm/s and much smaller magnitude upstream-directed velocities in the recirculating eddy.

The shoreline scours often are associated with embayments eroded laterally into the shoreline (for example, see site 158.5). Because water velocities measured over the shoreline scours are always small (typically less than 60 cm/s) and highly variable in direction, it can be inferred that these scour holes are not being maintained by low-discharge events. These scour holes probably owe their existence to large floods that overtop the wing dikes. The common presence of large-woody debris accumulations at these sites indicates that large woody debris may also contribute to flow convergence and scour during floods.

Scour holes also are associated with wing-dike notches (for example, see sites 186.7 and 158.1). Whether water velocities are elevated through notches depends on notch geometry and prevailing discharge. For example, mean flow velocity downstream of the notch at 186.7 (net sgn4) is 38 cm/s whereas mean flow velocity downstream of the notch at 158.1 is 54 cm/s.

Flow separation downstream from wing-dike tips can cause deposition of a sand bar because of lowered velocities and recirculation. A good example of a dike-field sand bar is shown at site 186.4. However, not all wing dikes have downstream sandbars because of variations in how channel geometry, dike orientation, and dike spacing affect the recirculation zone. For example, site 95.6 lacks a well-defined sandbar; the tip scour continues downstream to the next tip scour. In addition, notches provide a path for increased flow velocities that can disrupt the recirculation zone and prevent sand-bar deposition. The notch scour at site 186.7, for example, extends diagonally through the recirculation zone and connects with the tip scour at 186.4.

Predictably, areas in low velocity zones upstream and downstream of wing dikes tend to be dominated by muddy substrate whereas the main channel and zones of flow convergence around dike tips are dominated by coarser substrate. Sandy substrate in notch scours may reflect the increased flow velocities of those areas. Deeper and more extensive shoreline scours typically have muddy substrate, suggesting that they have filled with fine sediment subsequent to formation.

Comparison of channel substrate on the off-shore margins of sites 186.4 and 186.7 with sites 158.1 and 158.5 shows large variability within the main channel. Extensive areas at RM 186 were classified as hard, medium smooth, coarse sand, and gravelly sand classes, whereas similar areas at RM 158 were classified as transporting sand, smooth sand, and mud classes. The hard, medium smooth class at RM 186 is probably a smooth gravel armor left as a lag after sand was dredged at this site. Similar areas of gravel armor and patches of sand are apparent at sites 19.1 and 21.4 which also have been subjected to sand dredging. Gravel armor may be indicative of a lack of sand supply at these sites for forming and maintaining marginal habitats. Additional study would be needed to confirm these inferences.

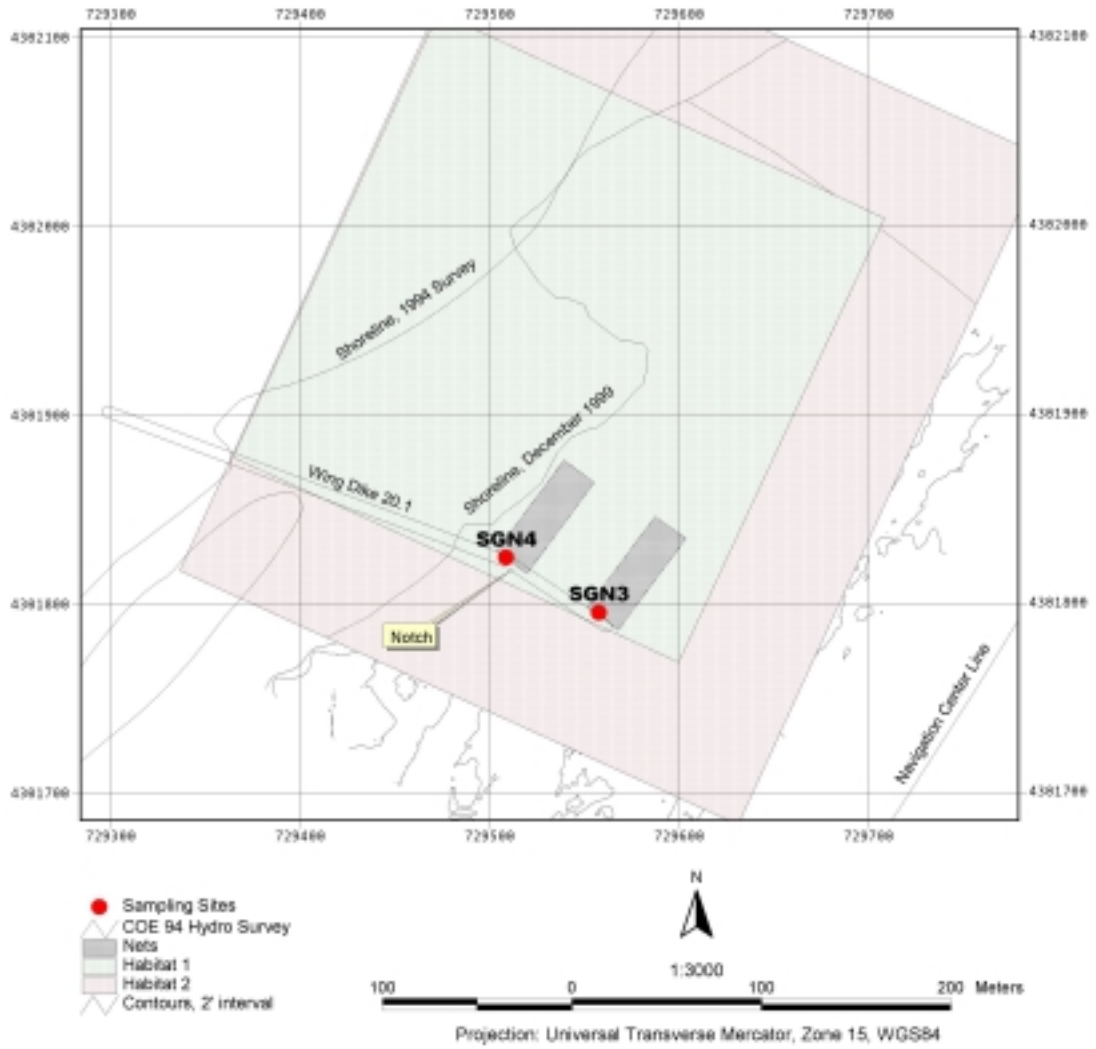
Table 4. Summary statistics for wing-dike habitats

[N, number in sample; SD, standard deviation; cm/s, centimeters per second]

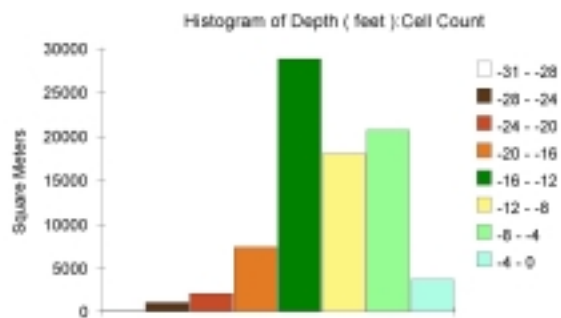
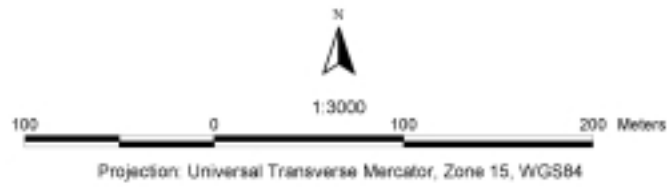
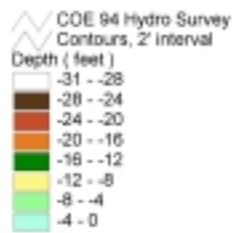
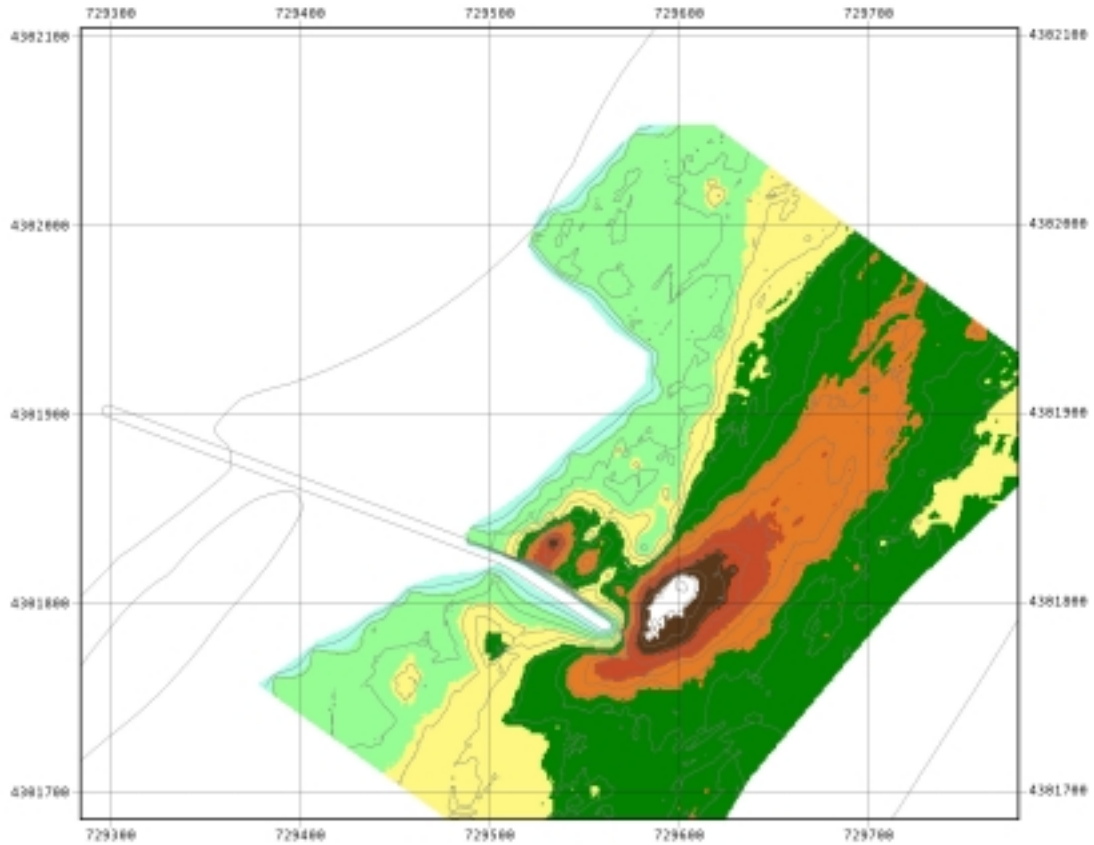
Site	Habitat sample area			Depth, feet				Velocity, cm/s				Substrate			
	Habitat 2	Habitat 1	Net	Mean	N	SD	Range	Mean	N	SD	Range	Dominant Class	No. Classes	N	
St. Charles	19_1	19_1		-11.6	59615	5.6	30.5	93.5	1404	59.9	630.9	Hard, Med. Smooth	14	59559	
				-9.5	30613	5.7	30.5	74.7	761	59.6	630.9	Hard, Med. Smooth	14	30640	
			SGN4	-9.0	1190	4.8	24.4	39.4	37	23.0	113.0	Med. Hard, Med. Rough	12	1195	
			SGN3	-11.8	1215	4.4	24.0	33.9	28	19.4	95.2	Rough, Soft	8	1212	
Hermann	21_4	21_4		-10.8	24693	5.2	30.7	66.0	697	42.4	352.0	Rough, Soft	13	24730	
				-10.4	15182	4.7	26.4	48.7	409	37.2	352.0	Sand, Smooth	13	15187	
Hartsburg	95_6	95_6		-14.7	57845	10.0	49.1	67.5	1126	42.9	386.9	Mud	8	57879	
				-18.7	30231	11.6	49.1	48.3	567	29.1	184.2	Mud	7	30291	
			SGN10	-35.3	1222	10.7	41.2	52.1	26	26.4	102.3	Mud	5	1224	
			SGN9	-10.9	1237	4.7	25.8	52.2	28	19.5	72.1	Mud	3	1237	
		95_7	95_7		-14.5	87489	8.8	45.1	72.6	3262	49.6	416.1	Mud	8	37497
					-15.7	53470	10.2	45.1	46.0	2142	32.5	416.1	Mud	5	13496
				SGN4	-21.8	1213	7.4	29.0	34.5	67	20.9	105.5	Mud	1	605
Rocheport	158_1	158_1		-7.3	49662	3.3	21.5	80.7	763	45.0	377.6	Sand, Smooth	7	49658	
				-6.5	27482	3.3	21.3	60.1	379	37.6	263.9	Mud	8	27488	
			SGN2	-5.0	1197	1.6	7.5	53.7	18	31.3	108.9	Mud	2	1196	
		158_5	158_5		-12.4	26258	7.3	38.0	69.1	474	52.9	368.6	Mud	12	26379
					-14.2	14091	8.6	38.0	42.3	272	30.6	196.8	Mud	11	14122
				SGN4	-13.7	1211	4.1	18.1	36.7	27	16.9	75.4	Mud	1	1210
		SGN3	-30.8	1200	5.8	29.6	30.0	22	17.3	80.4	Mud	4	1186		
Rocheport	186_4	186_4		-11.1	57843	6.8	43.4	69.1	1546	49.8	264.5	Mud	11	57838	
				-11.9	32457	7.9	43.4	48.8	1019	35.9	238.7	Mud	10	32402	
			SGN1	-10.8	1189	3.3	12.5	27.8	45	15.3	59.4	Mud	3	1182	
			SGN2	-27.1	1195	8.3	37.5	31.4	56	15.2	62.9	Mud	8	1189	
		186_7	186_7		-16.1	46741	8.0	42.9	76.8	1122	56.7	251.3	Mud	11	46741
						-20.0	24737	9.0	41.8	52.6	606	40.9	202.3	Mud	11
		SGN3	-28.3	1223	10.0	39.4	37.8	37	23.3	126.5	Mud	6	1223		
		SGN4	-34.1	1224	8.0	36.2	33.9	38	13.7	71.3	Sand, Transporting	8	1224		

Appendix

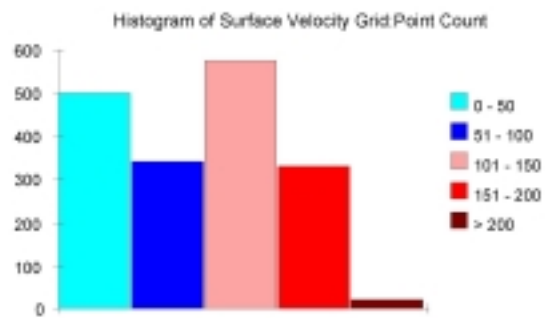
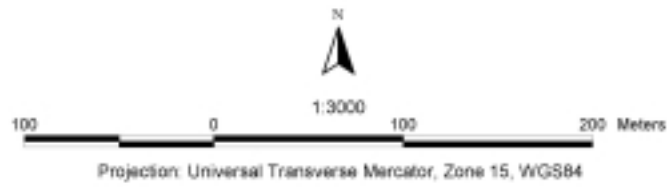
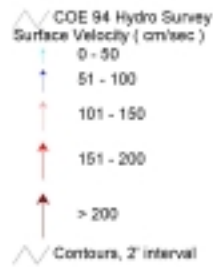
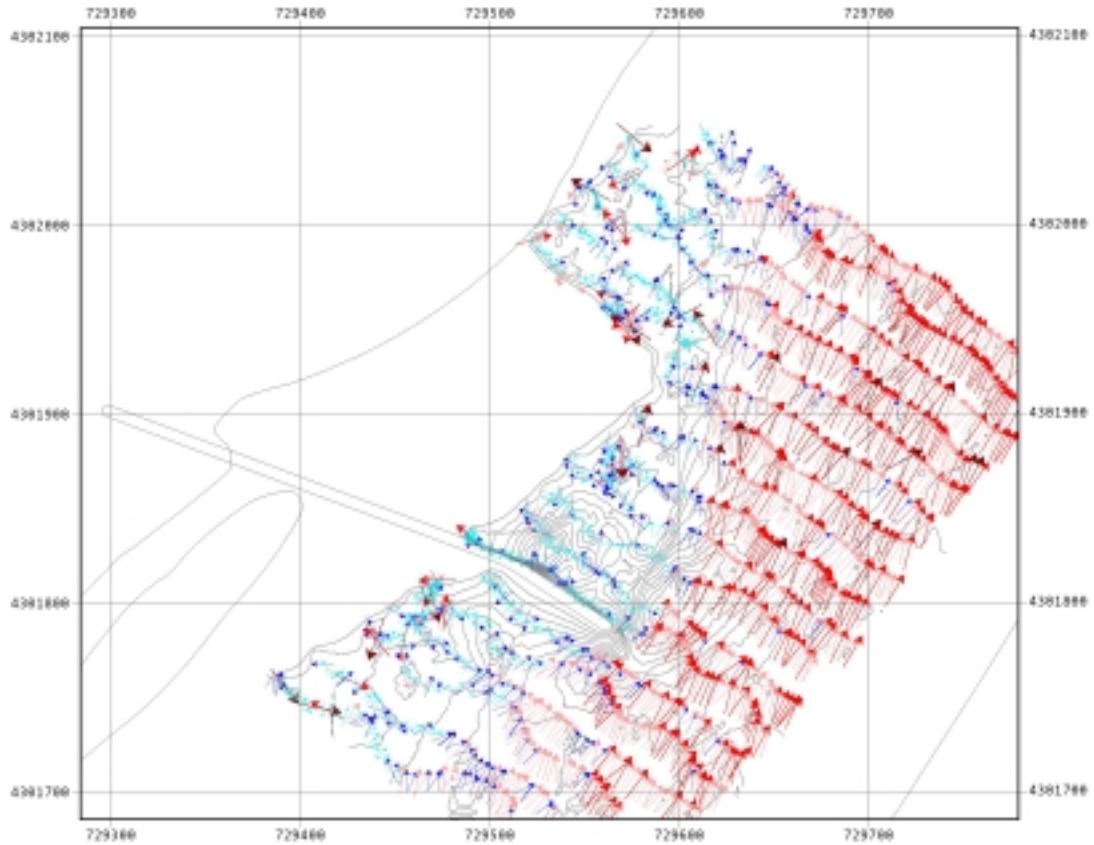
Site 19.1



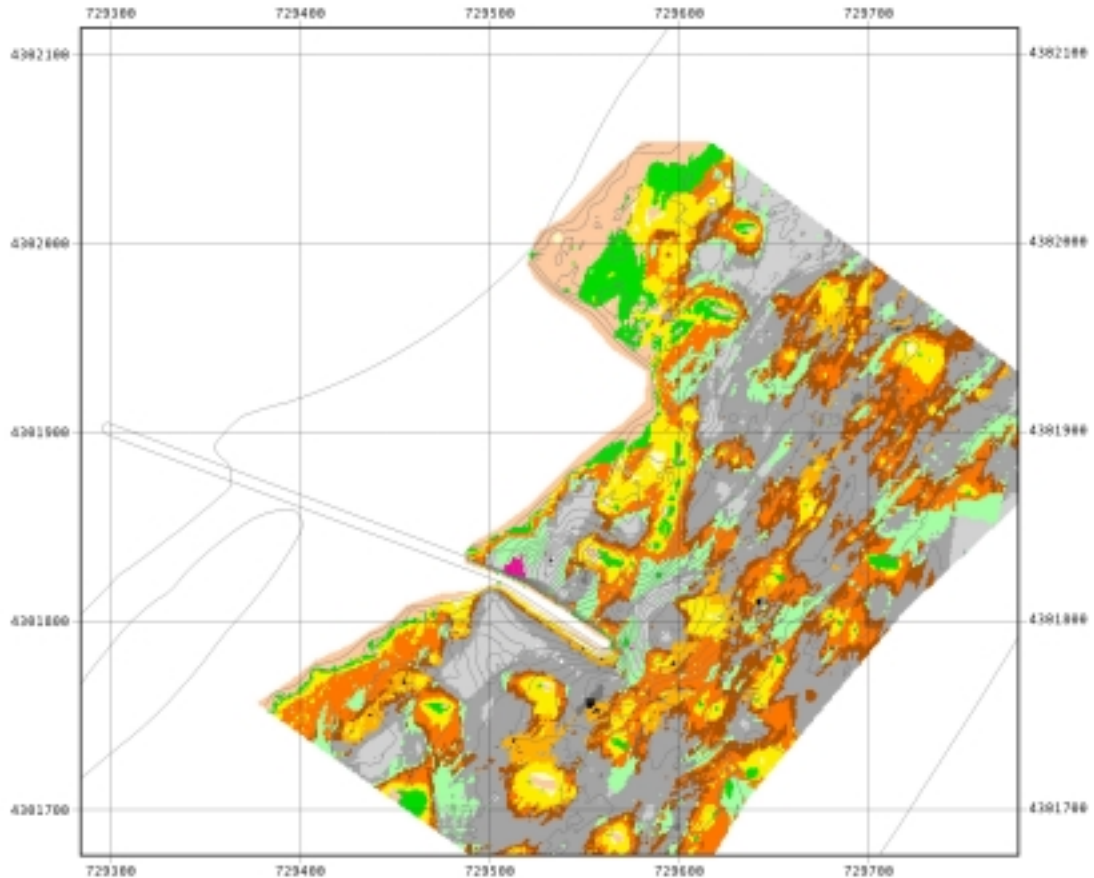
Site 19.1 - Depth



Site 19.1 - Surface Velocity



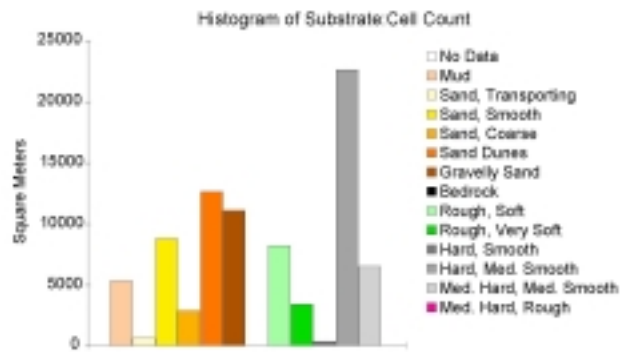
Site 19.1 - Substrate



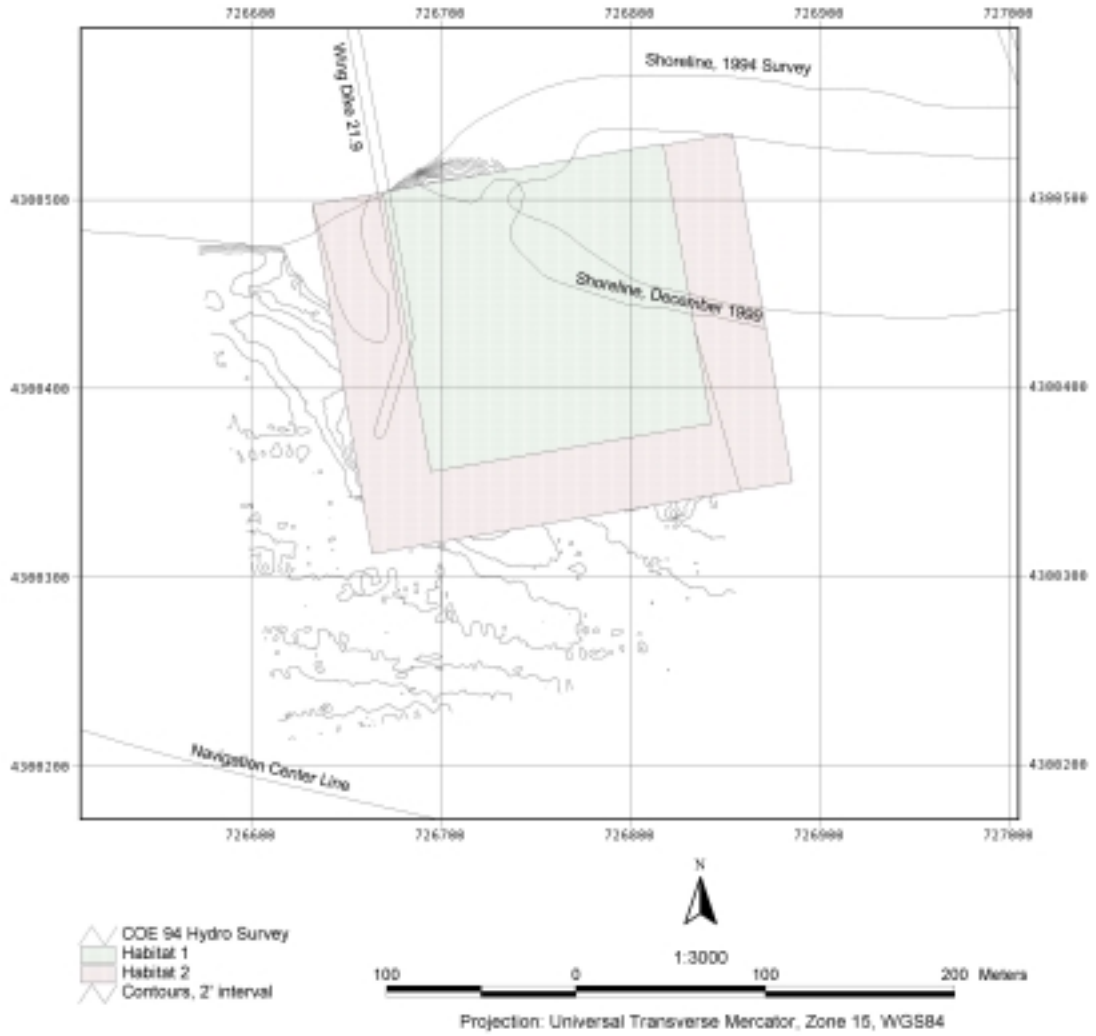
- COE 94 Hydro Survey Contours, 2' Interval
- Substrate
- No Data
- Mud
- Sand, Transporting
- Sand, Smooth
- Sand, Coarse
- Sand Dunes
- Gravelly Sand
- Bedrock
- Rough, Soft
- Rough, Very Soft
- Hard, Smooth
- Hard, Med. Smooth
- Med. Hard, Med. Smooth
- Med. Hard, Rough



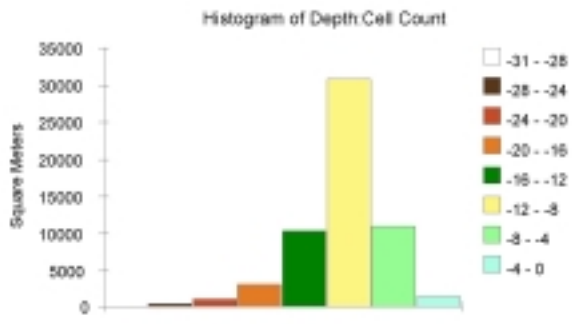
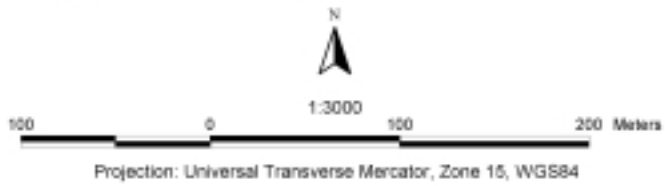
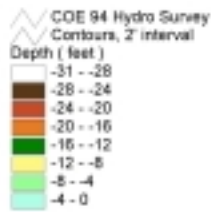
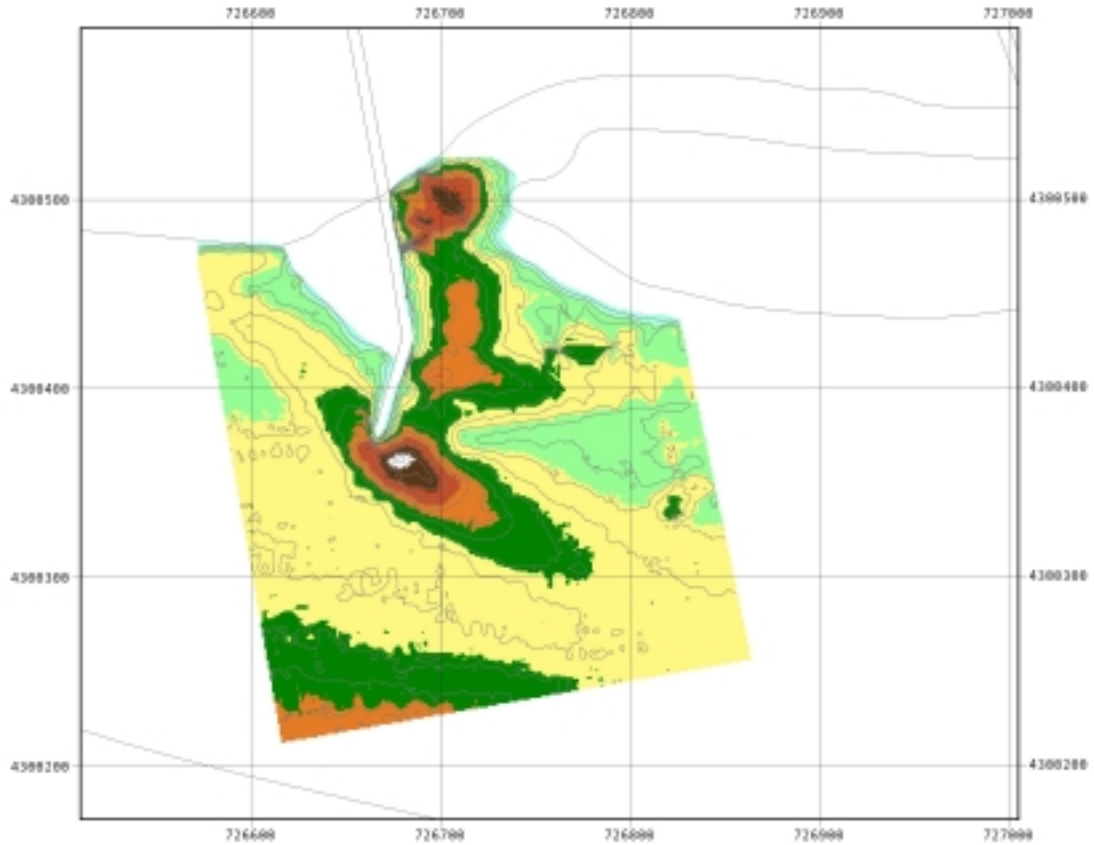
Projection: Universal Transverse Mercator, Zone 15, WGS84



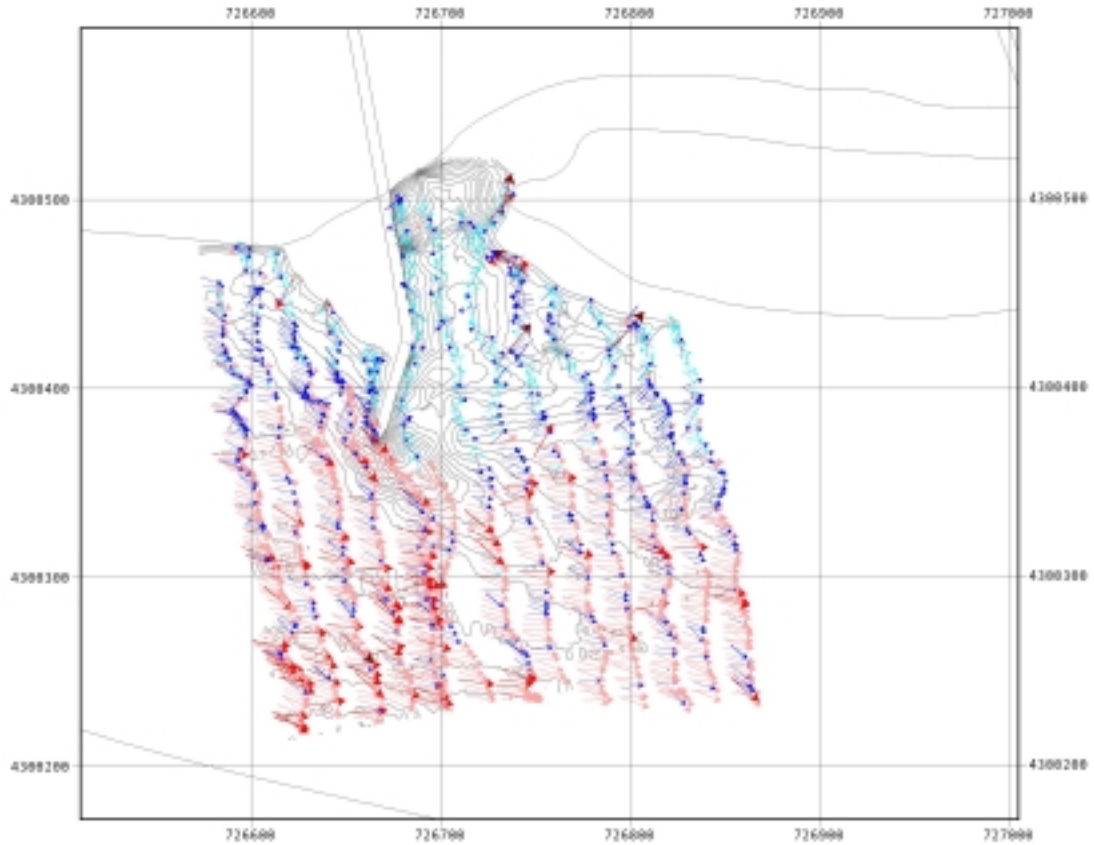
Site 21.4



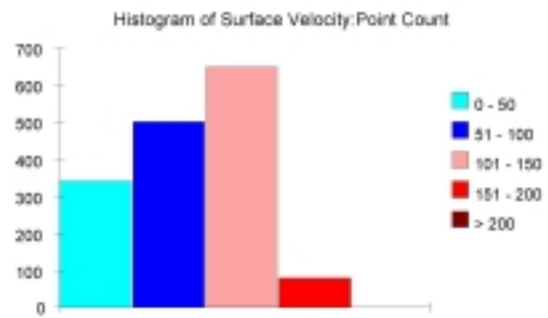
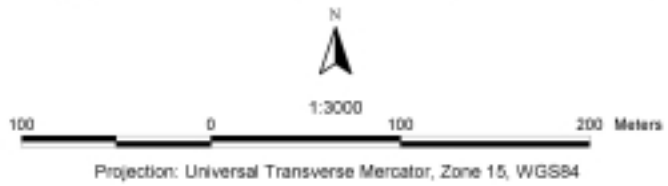
Site 21.4 - Depth



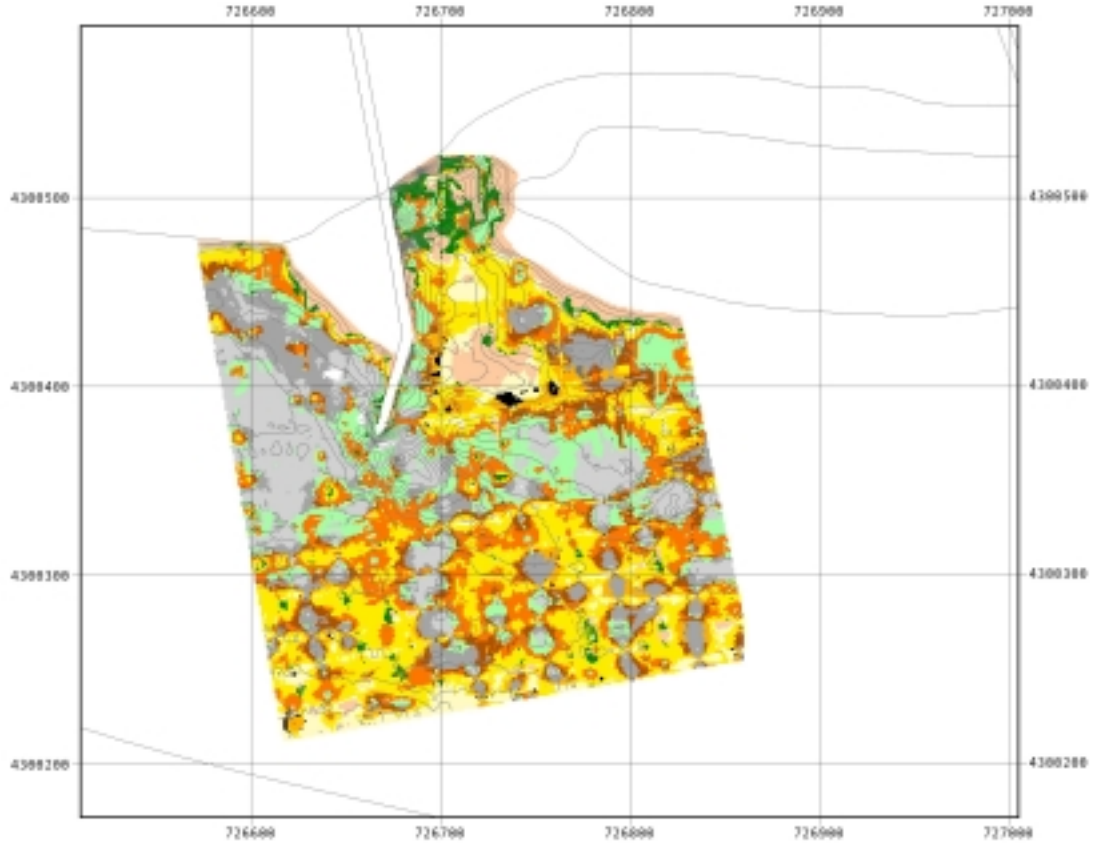
Site 21.4 - Surface Velocity



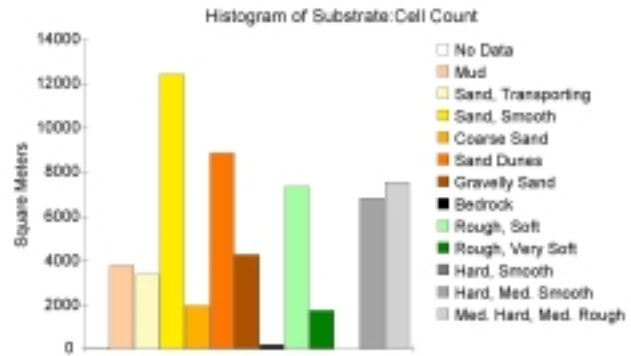
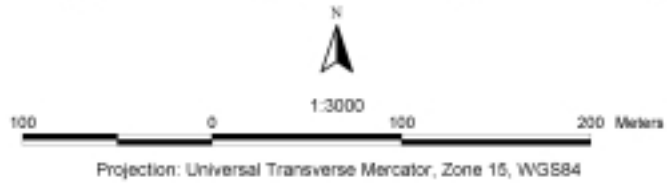
- CDE 94 Hydro Survey
 Surface Velocity (cm/sec)
- 0 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- > 200
- Contours, 2' interval



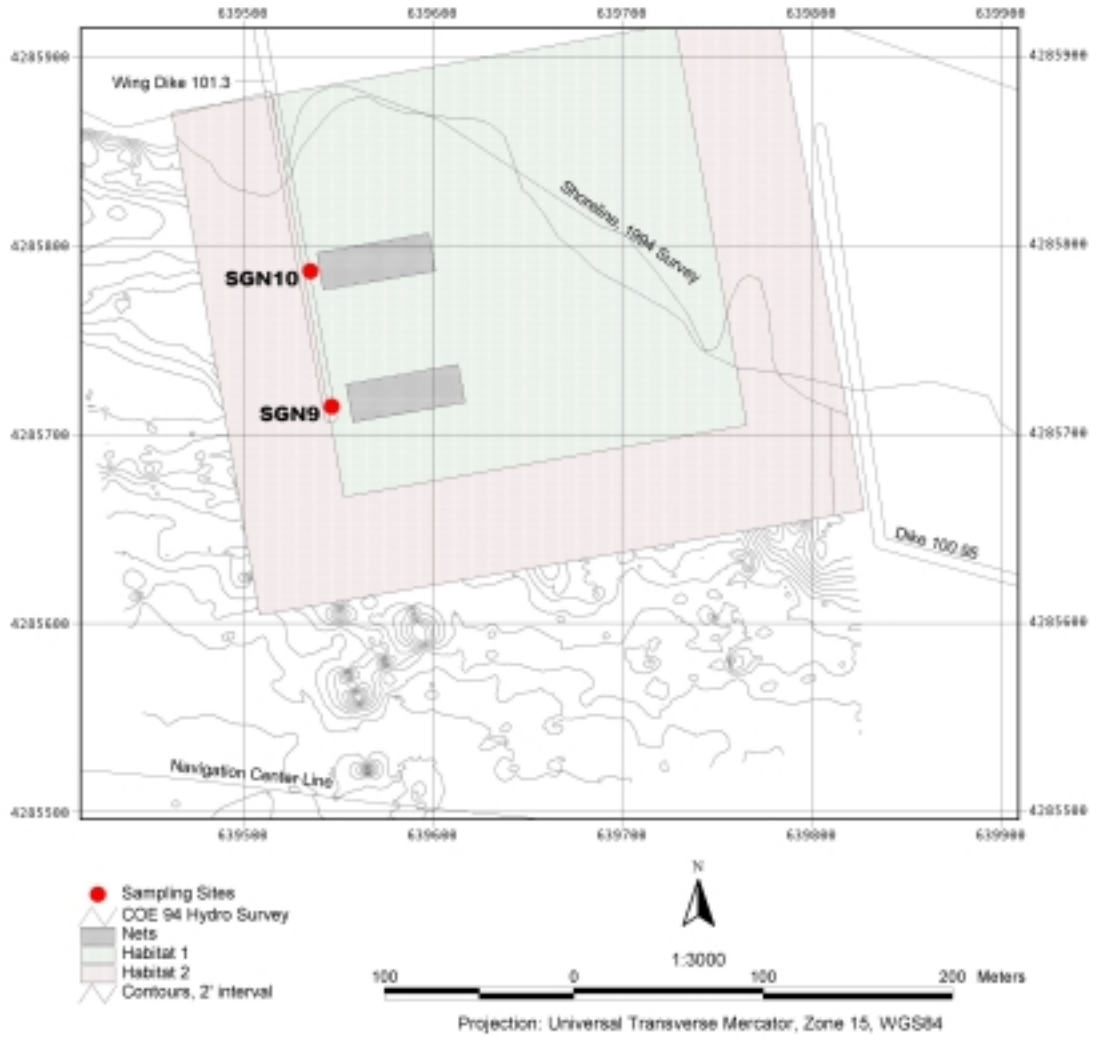
Site 21.4 - Substrate



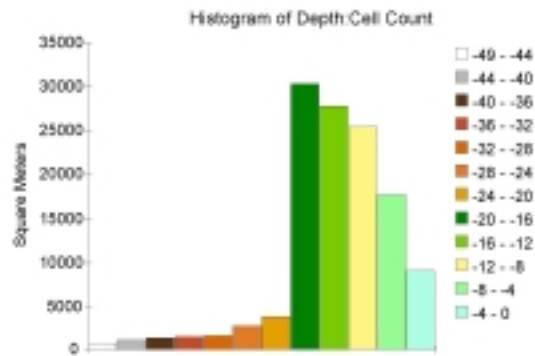
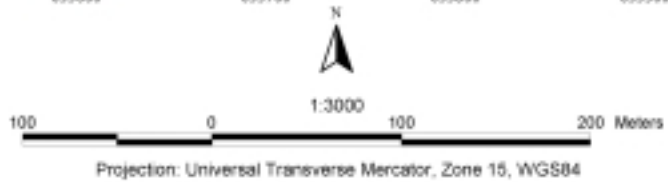
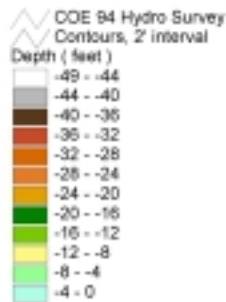
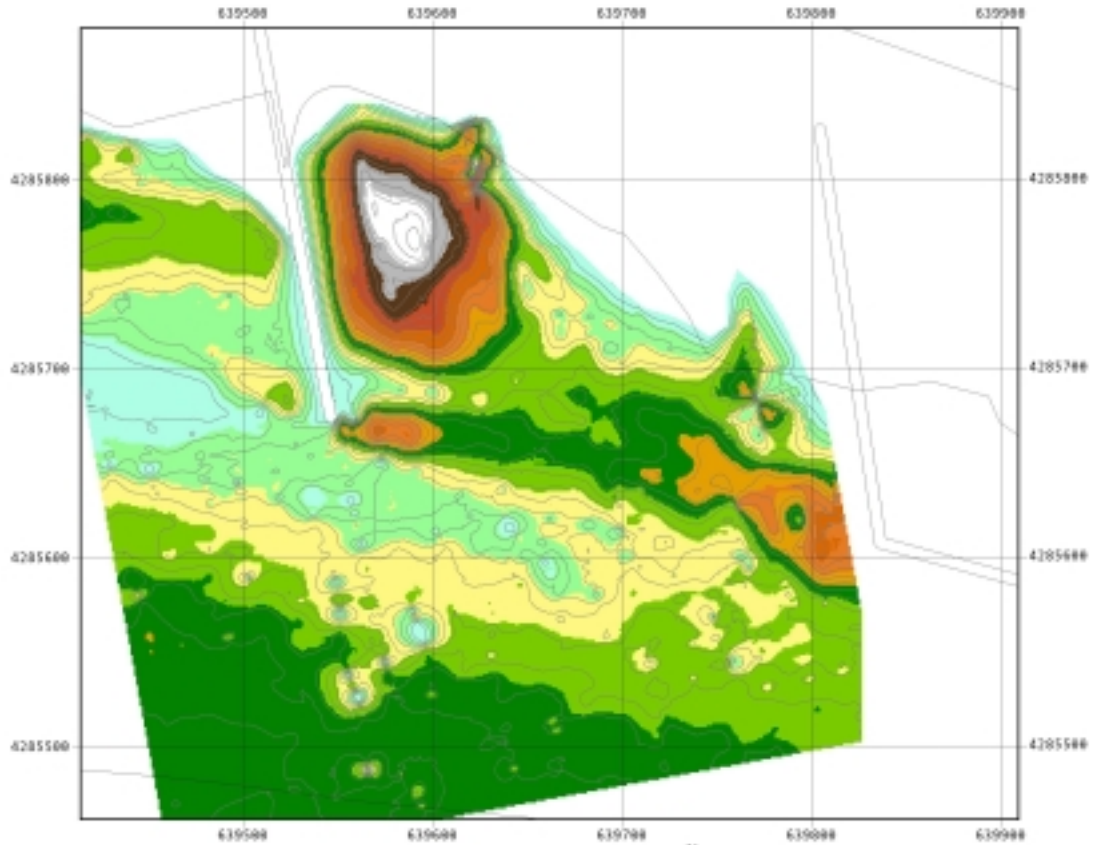
- CDE 94 Hydro Survey Contours, 2' interval
- Substrate**
 - No Data
 - Mud
 - Sand, Transporting
 - Sand, Smooth
 - Coarse Sand
 - Sand Dunes
 - Gravelly Sand
 - Bedrock
 - Rough, Soft
 - Rough, Very Soft
 - Hard, Smooth
 - Hard, Med. Smooth
 - Med. Hard, Med. Rough



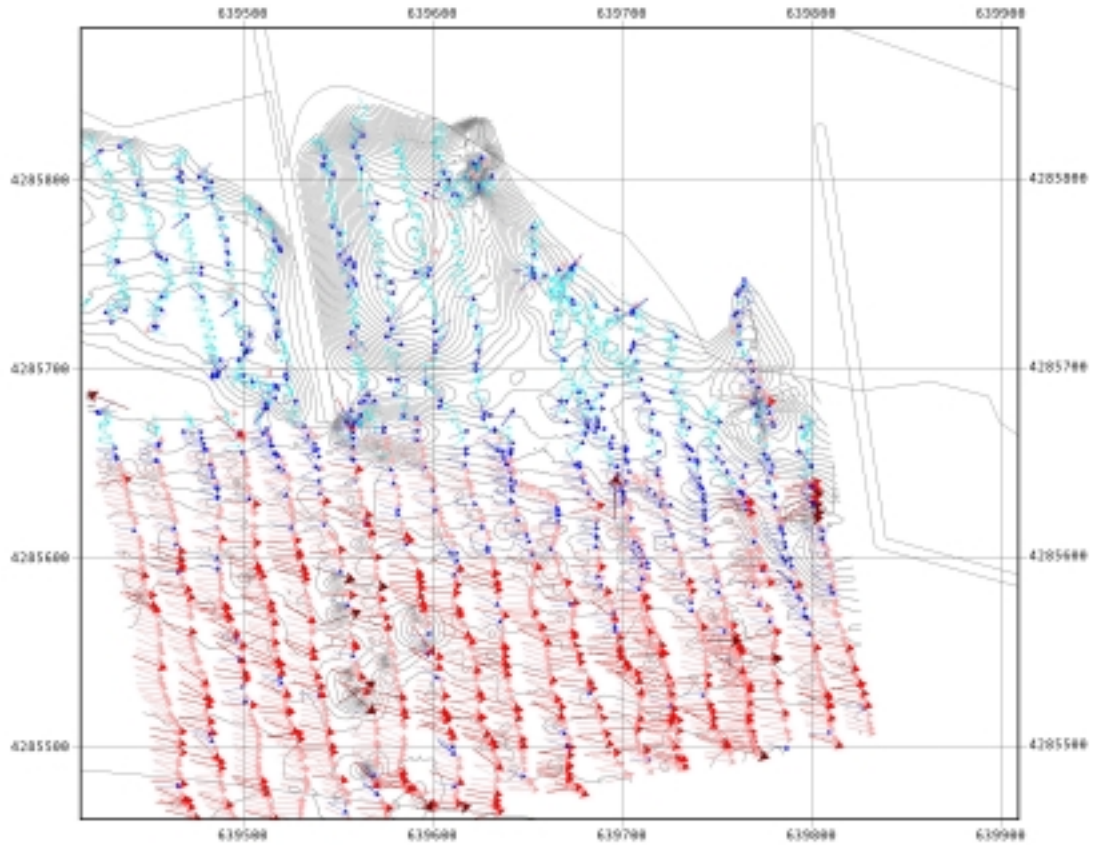
Site 95.6



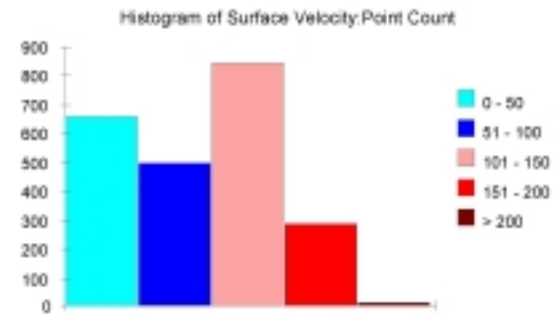
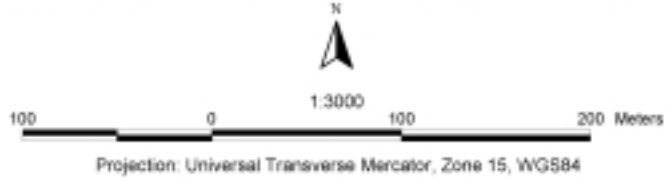
Site 95.6 - Depth



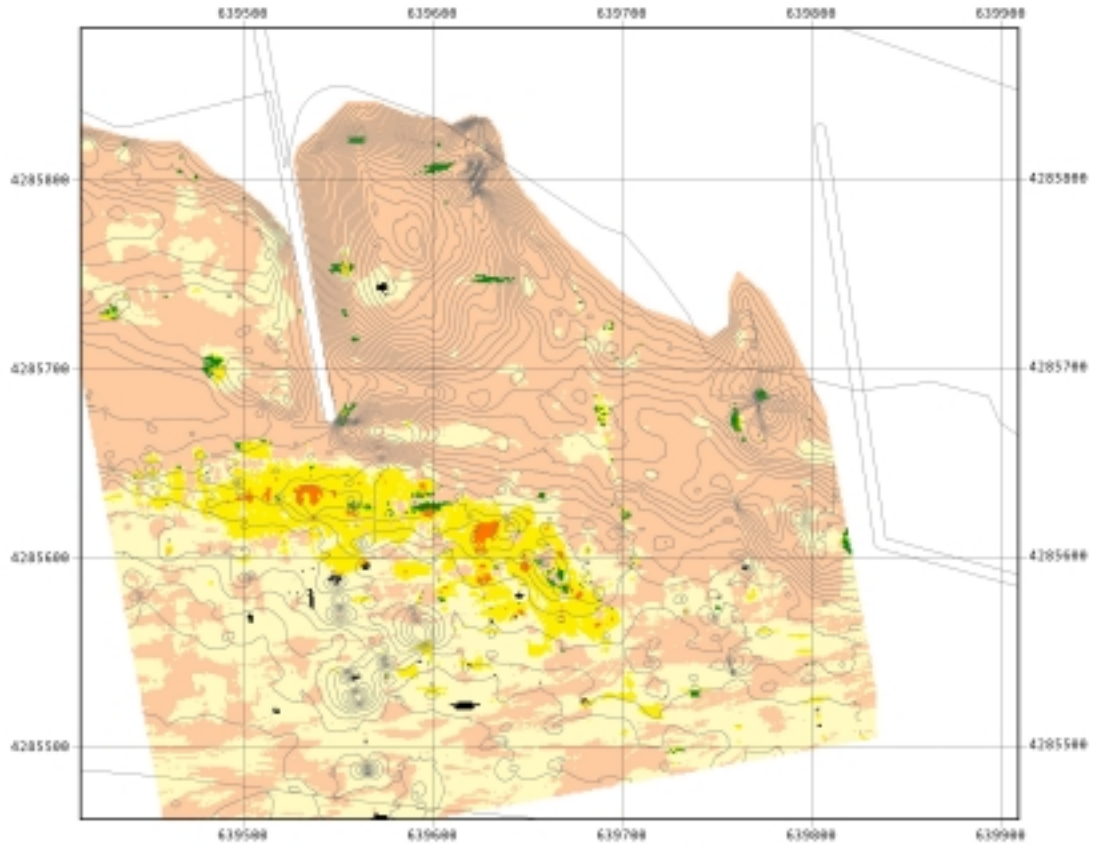
Site 95.6 - Surface Velocity



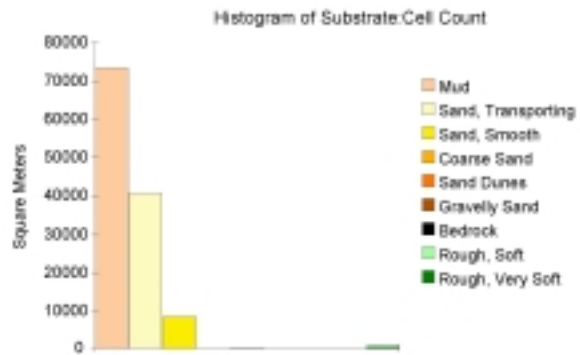
- COE 94 Hydro Survey
 Surface Velocity (cm/sec)
- 0 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- > 200
- Contours, 2' interval



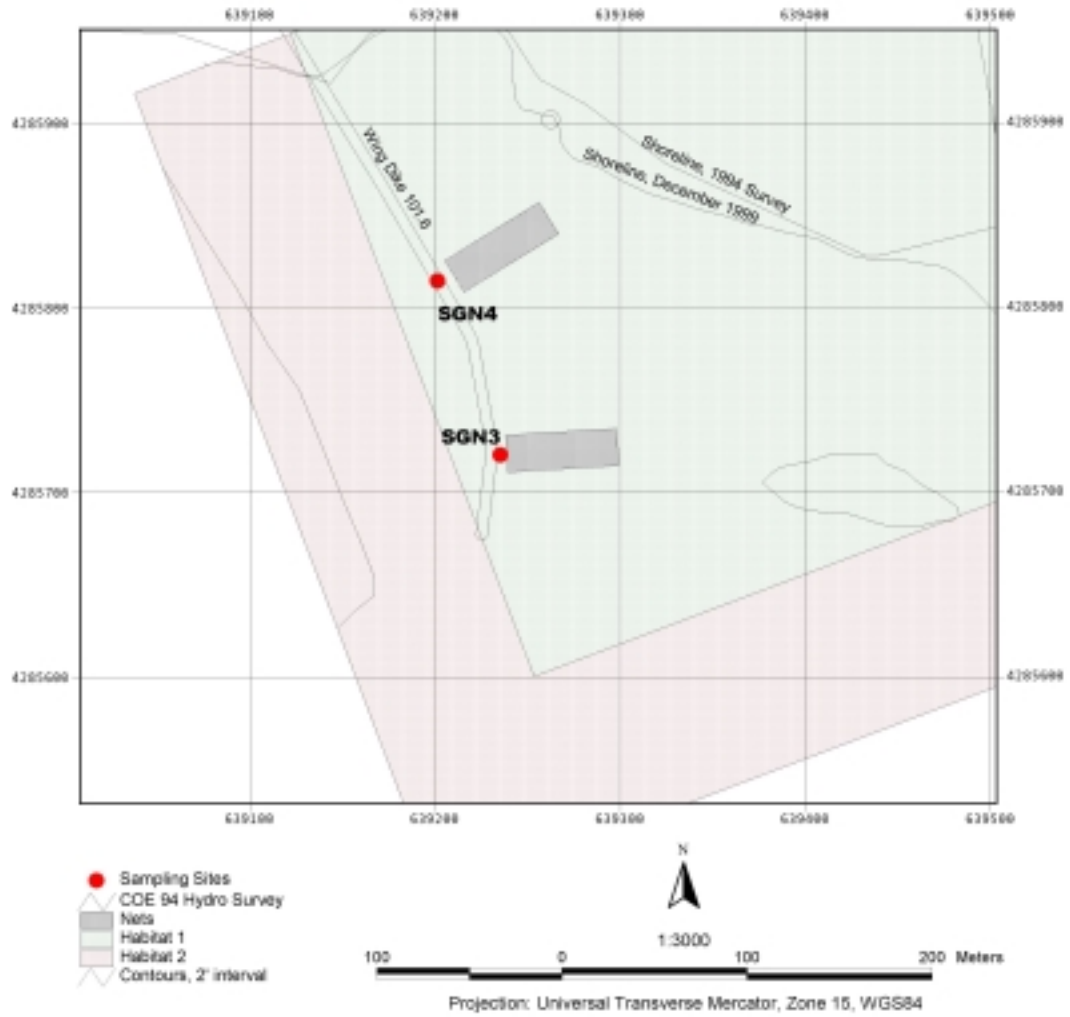
Site 95.6 - Substrate



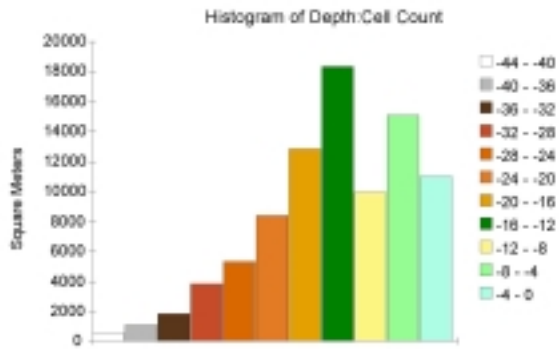
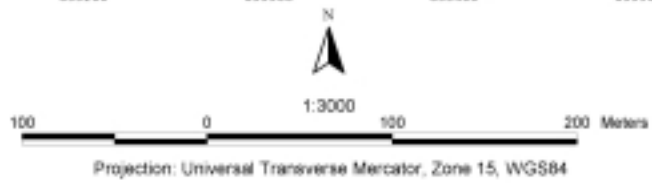
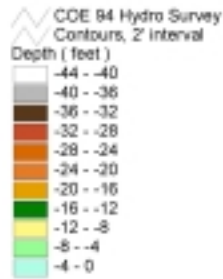
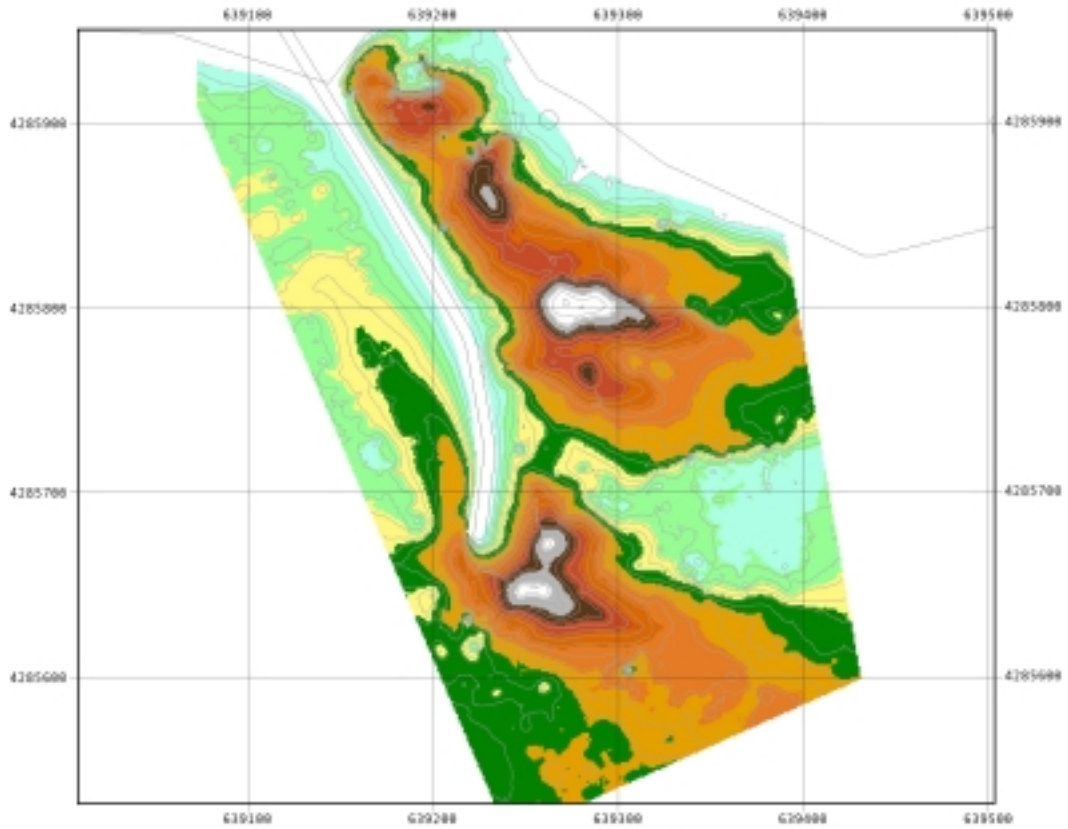
- COE 94 Hydro Survey Contours, 2' interval
- Substrate
- Mud
- Sand, Transporting
- Sand, Smooth
- Coarse Sand
- Sand Dunes
- Gravelly Sand
- Bedrock
- Rough, Soft
- Rough, Very Soft



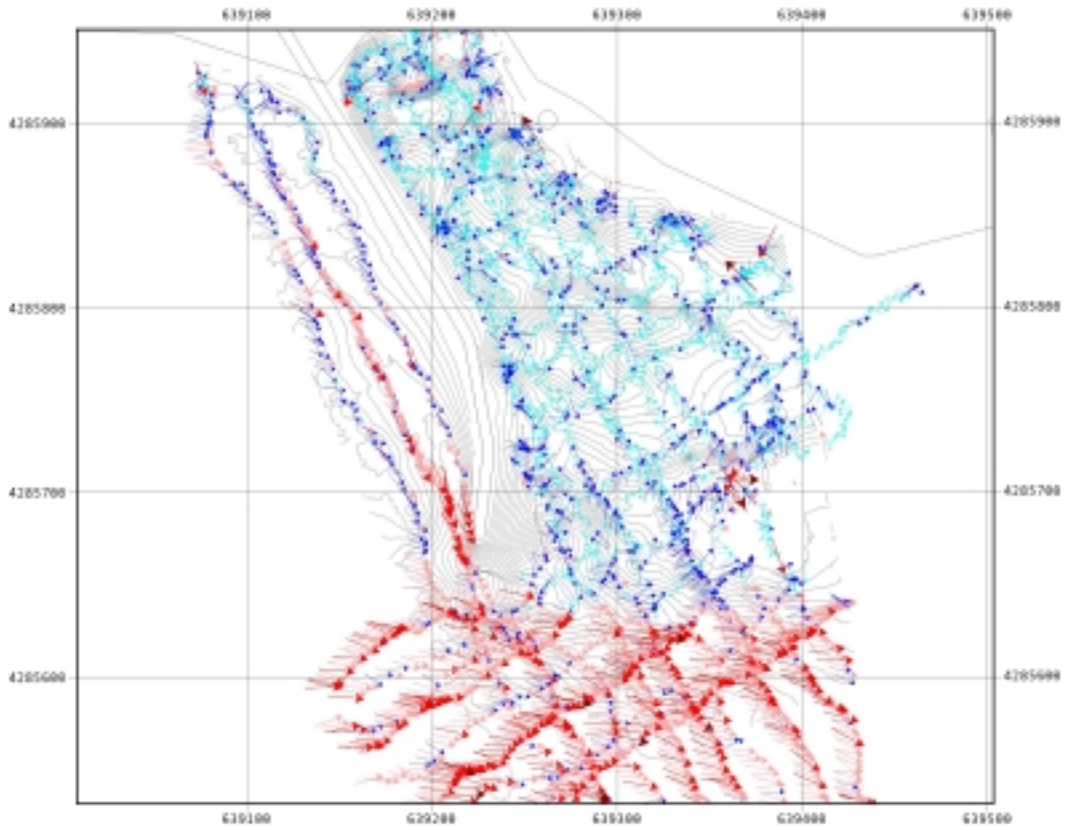
Site 95.7



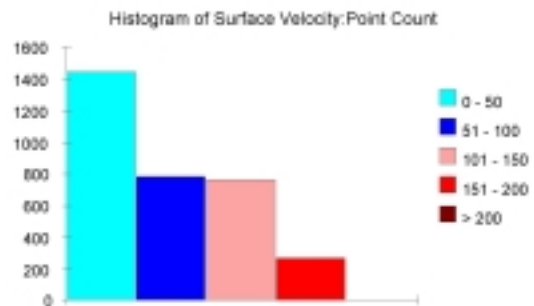
Site 95.7 - Depth



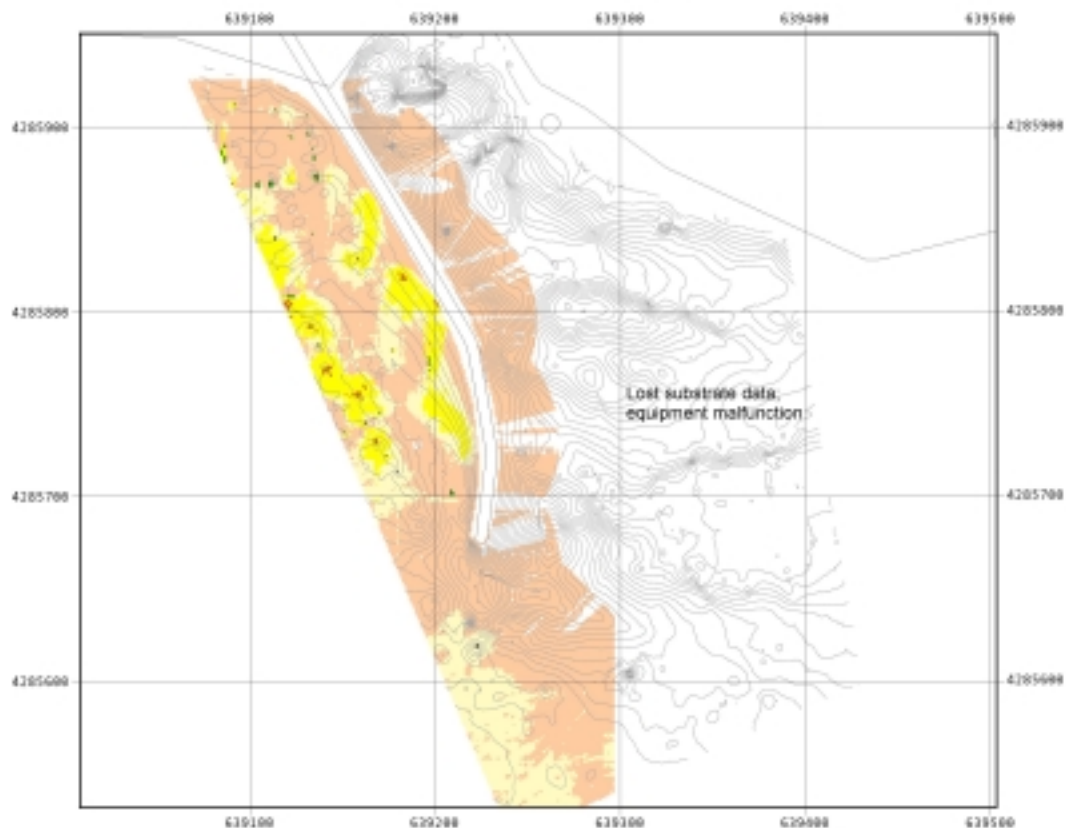
Site 95.7 - Surface Velocity



- COE 94 Hydro Survey
 Surface Velocity (cm/sec)
- 0 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- > 200
- Contours, 2' interval



Site 95.7 - Substrate



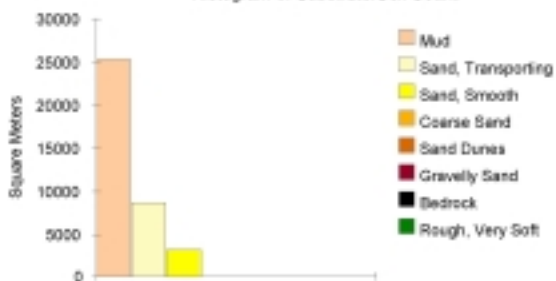
1:3000



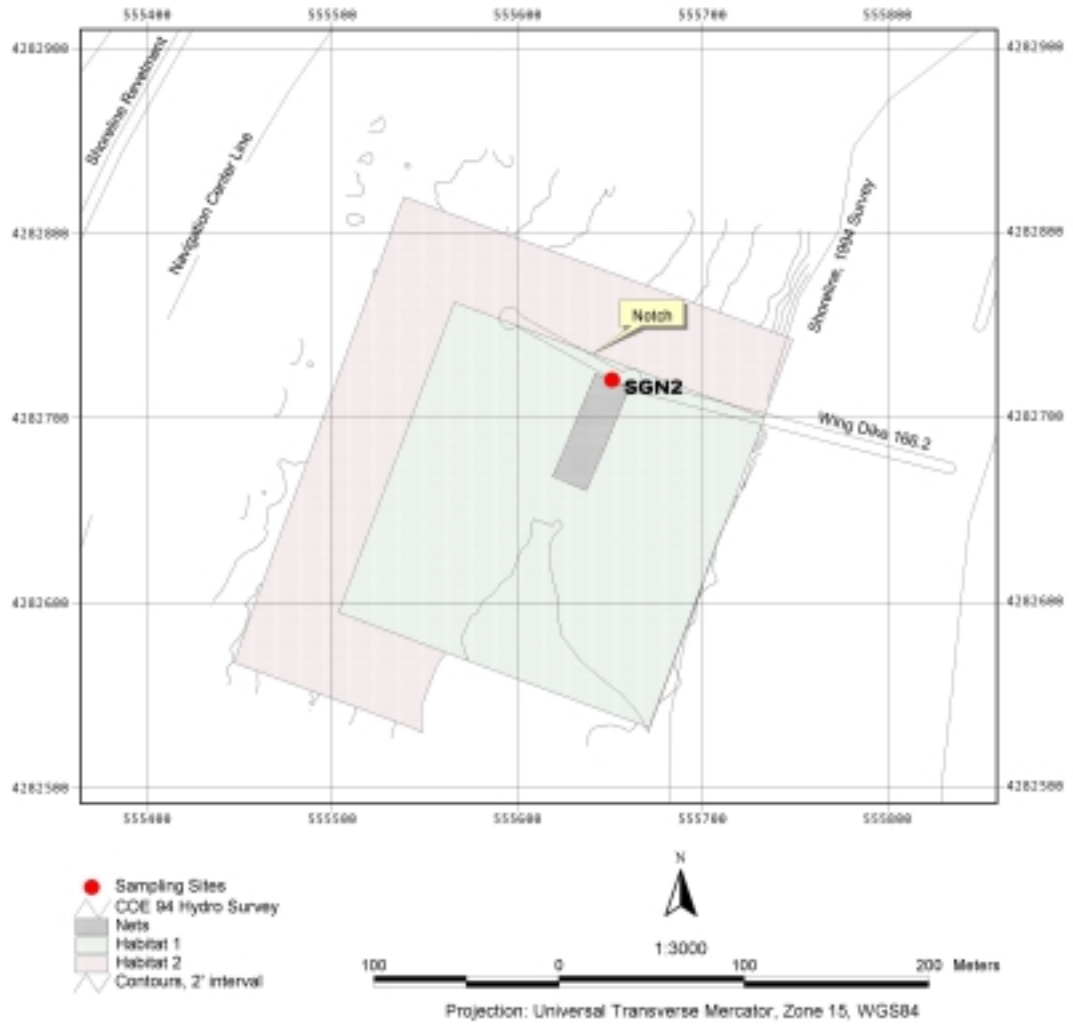
Projection: Universal Transverse Mercator, Zone 15, WGS84

- COE 84 Hydro Survey Contours, 2' interval
- Substrate
- Mud
- Sand, Transporting
- Sand, Smooth
- Coarse Sand
- Sand Dunes
- Gravelly Sand
- Bedrock
- Rough, Very Soft

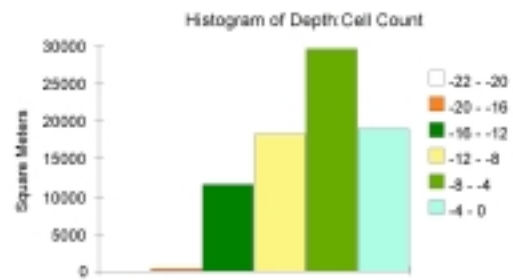
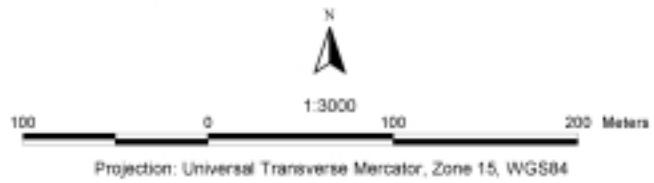
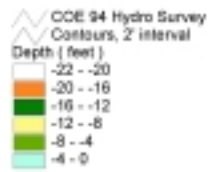
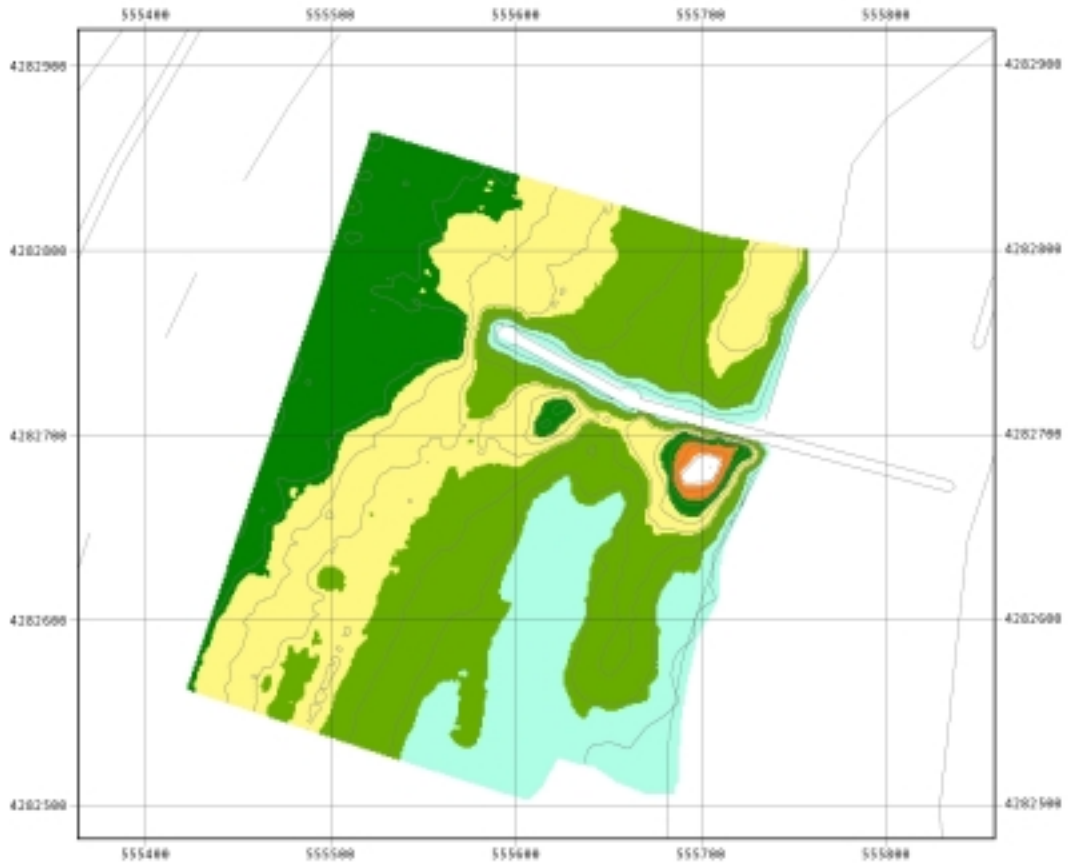
Histogram of Substrate Cell Count



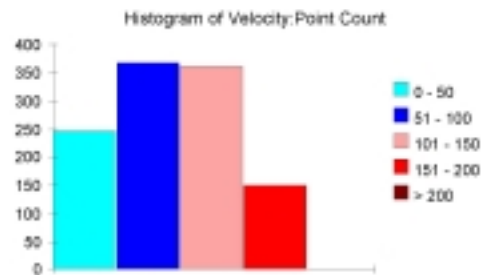
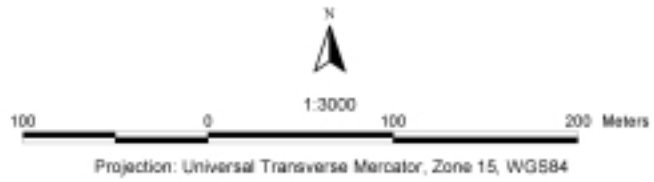
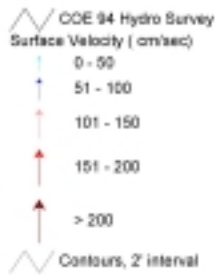
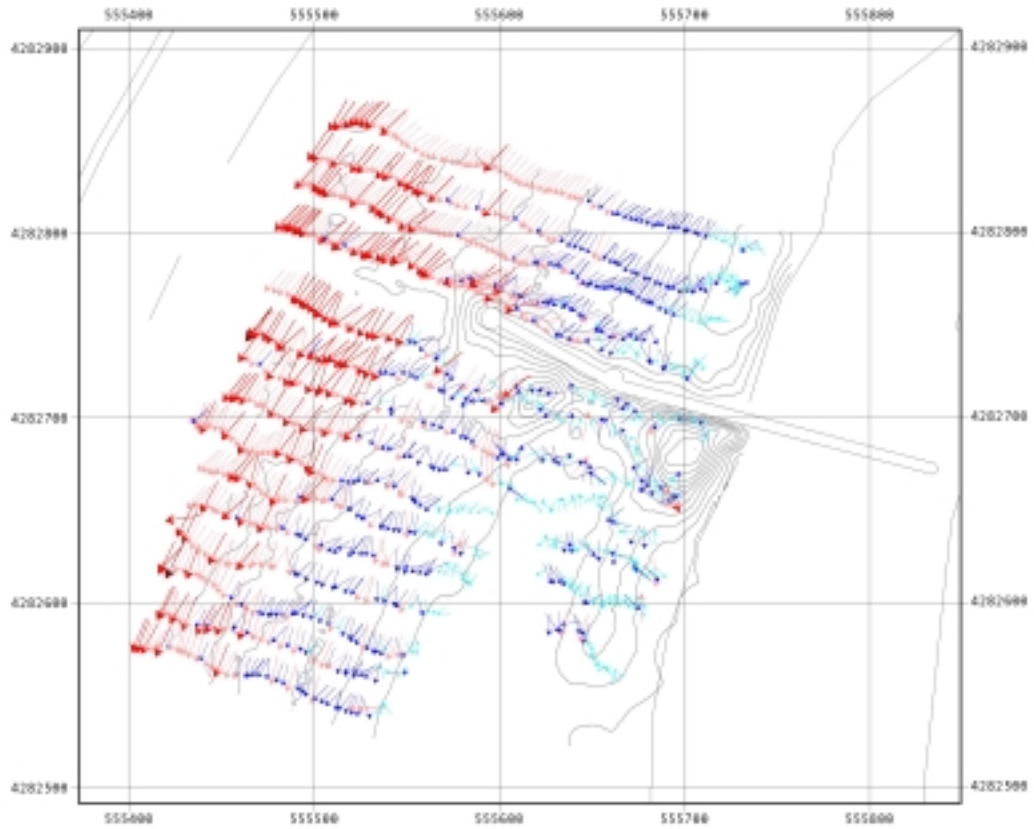
Site 158.1



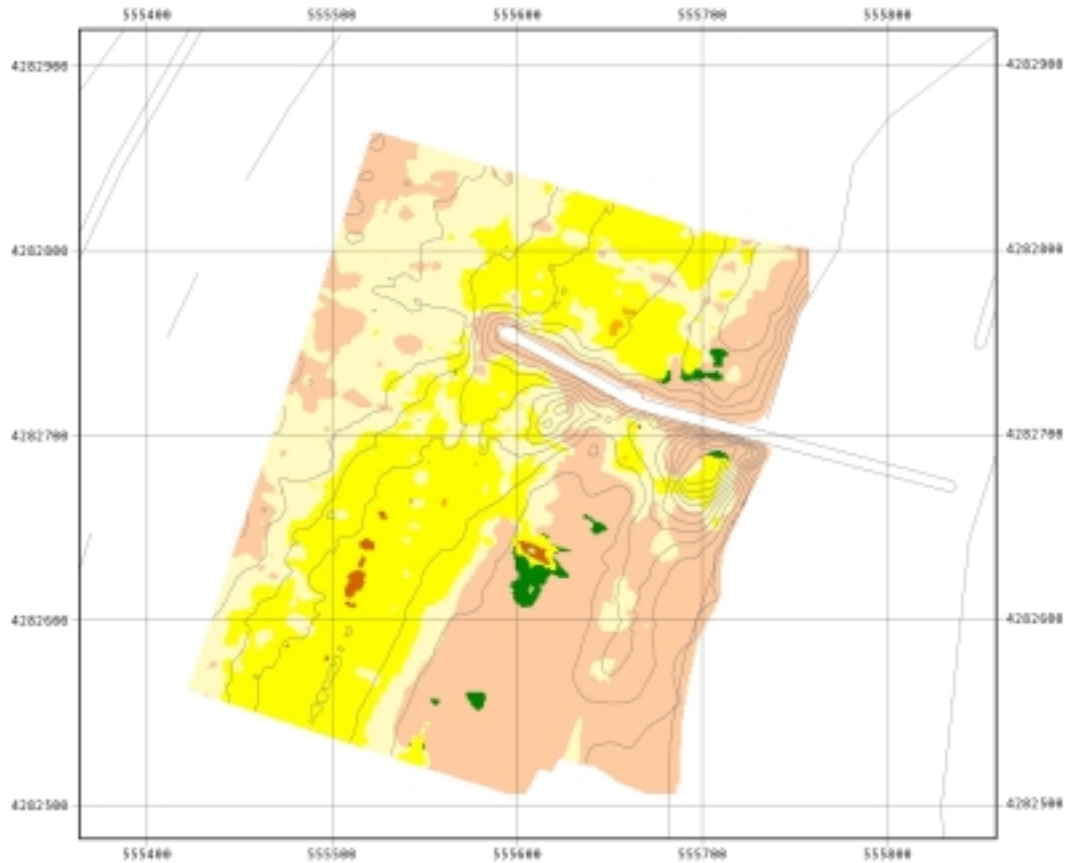
Site 158.1 - Depth



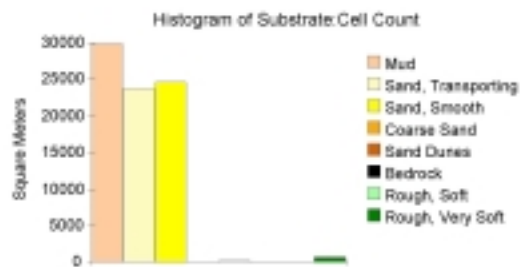
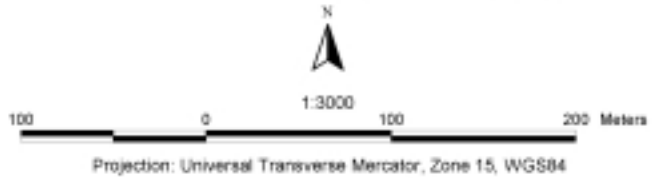
Site 158.1 - Surface Velocity



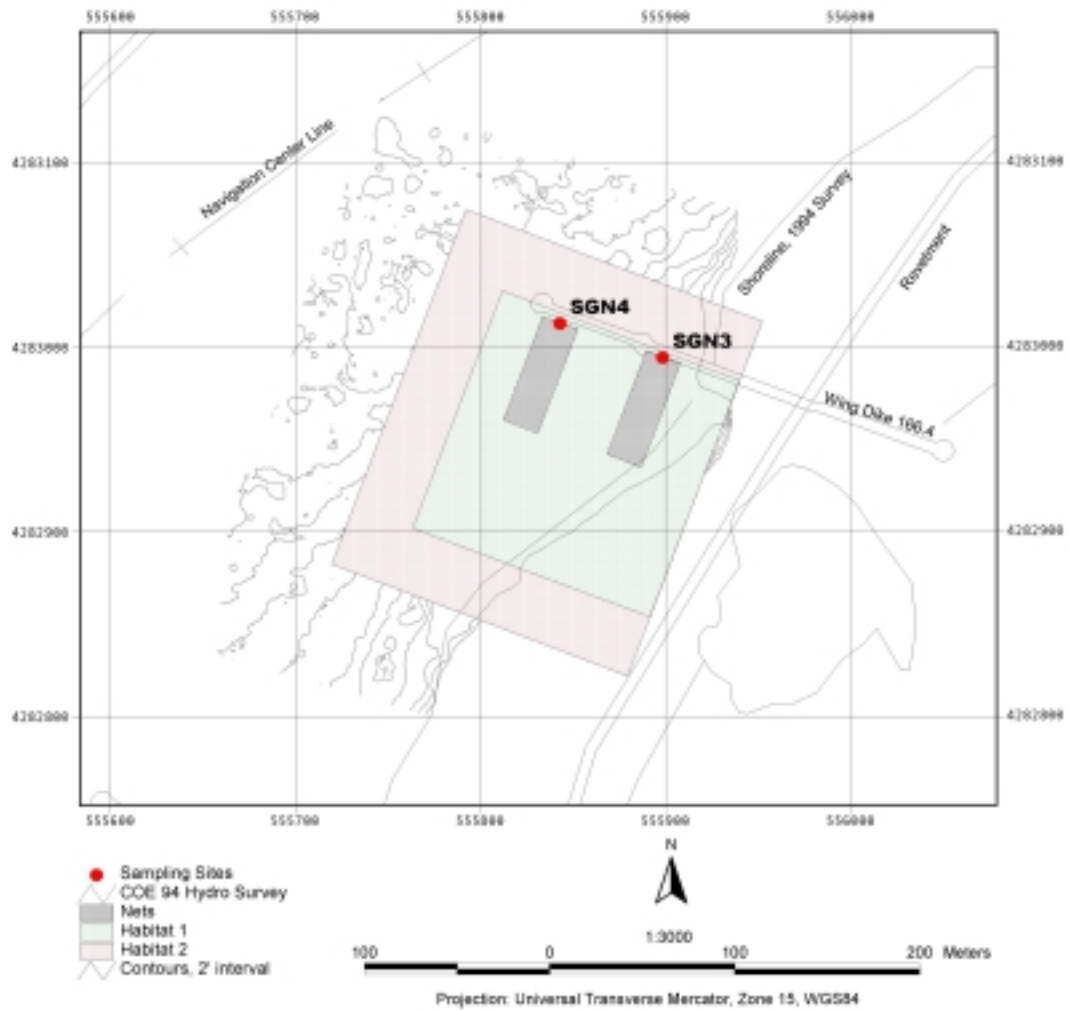
Site 158.1 - Substrate



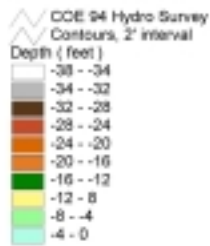
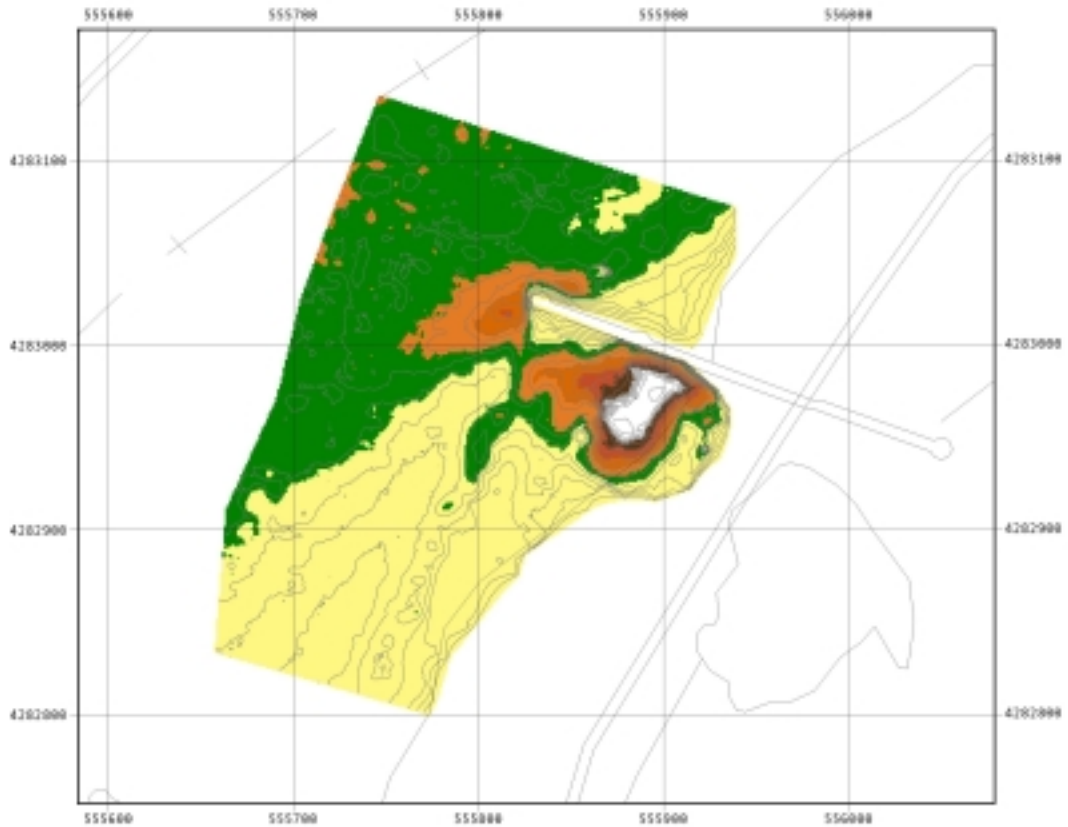
- COE 94 Hydro Survey
- Contours, 2' interval
- Substrate**
- Mud
- Sand, Transporting
- Sand, Smooth
- Coarse Sand
- Sand Dunes
- Bedrock
- Rough, Soft
- Rough, Very Soft



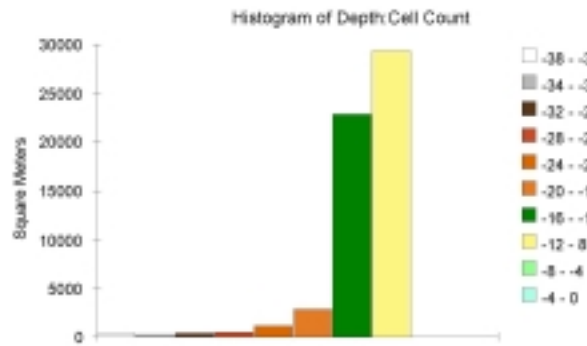
Site 158.5



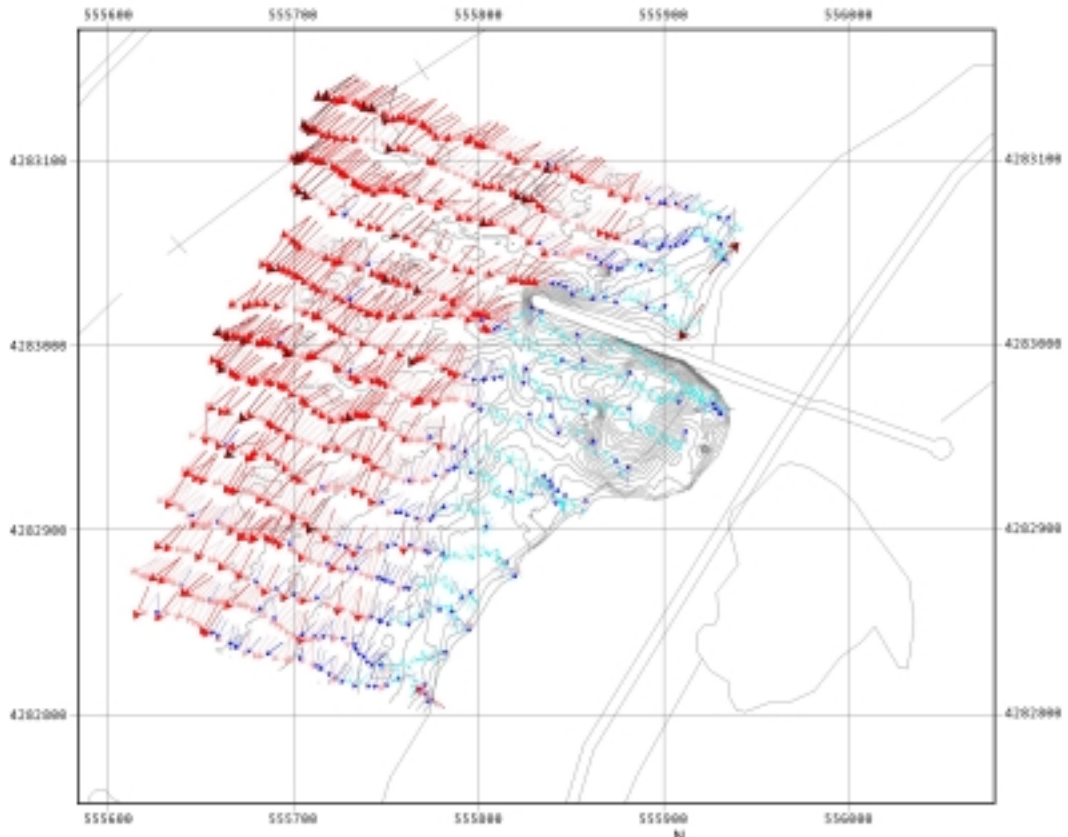
Site 158.5 - Depth



Projection: Universal Transverse Mercator, Zone 15, WGS84



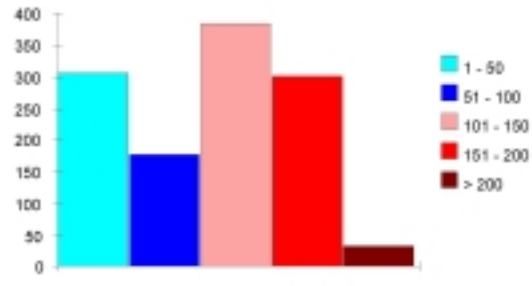
Site 158.5 - Surface Velocity



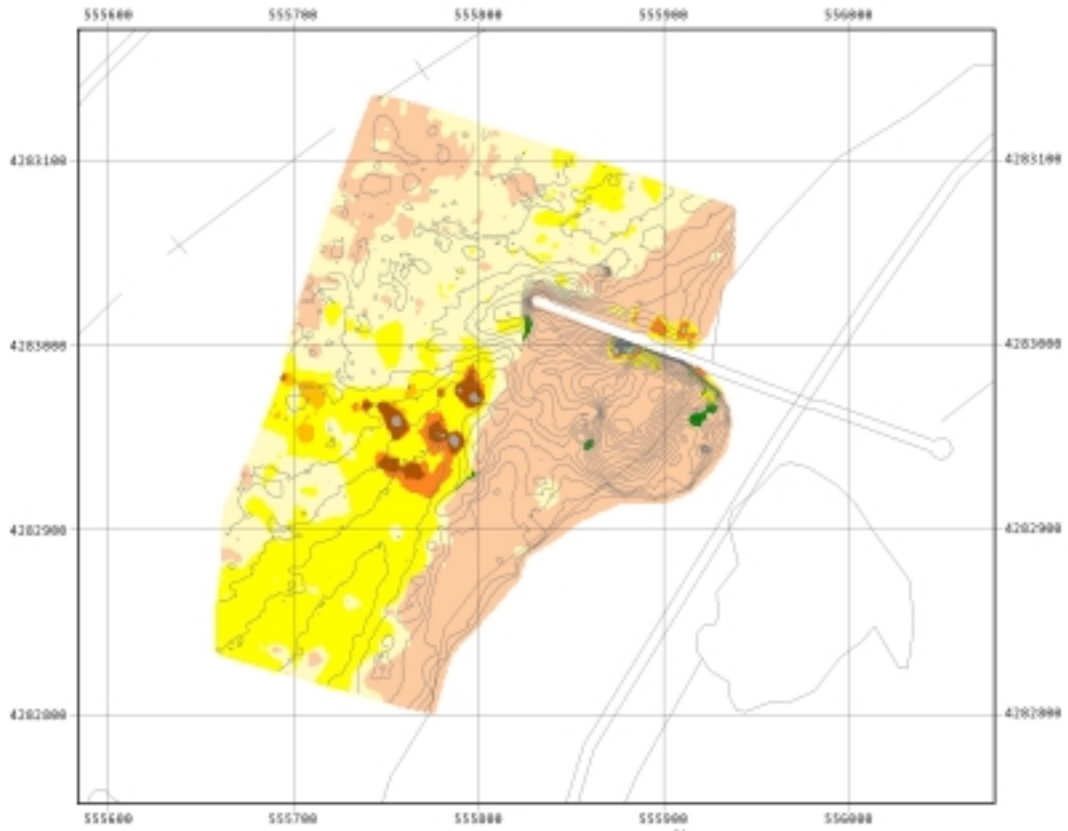
- △ COE 94 Hydro Survey
- Surface Velocity (cm/sec)
- 0 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- > 200
- ▽ Contours, 2' Interval



Histogram of Velocity:Point Count



Site 158.5 - Substrate

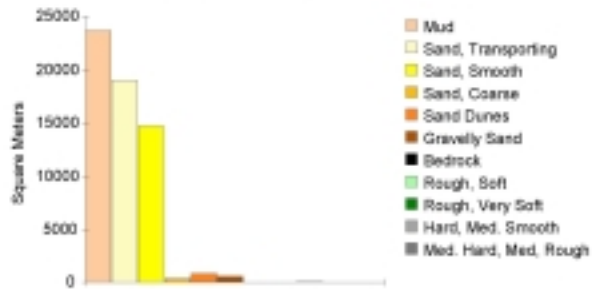


- COE 84 Hydro Survey
- Contours, 2' Interval
- Substrate**
- Mud
- Sand, Transporting
- Sand, Smooth
- Sand, Coarse
- Sand Dunes
- Gravelly Sand
- Bedrock
- Rough, Soft
- Rough, Very Soft
- Hard, Med. Smooth
- Med. Hard, Med, Rough

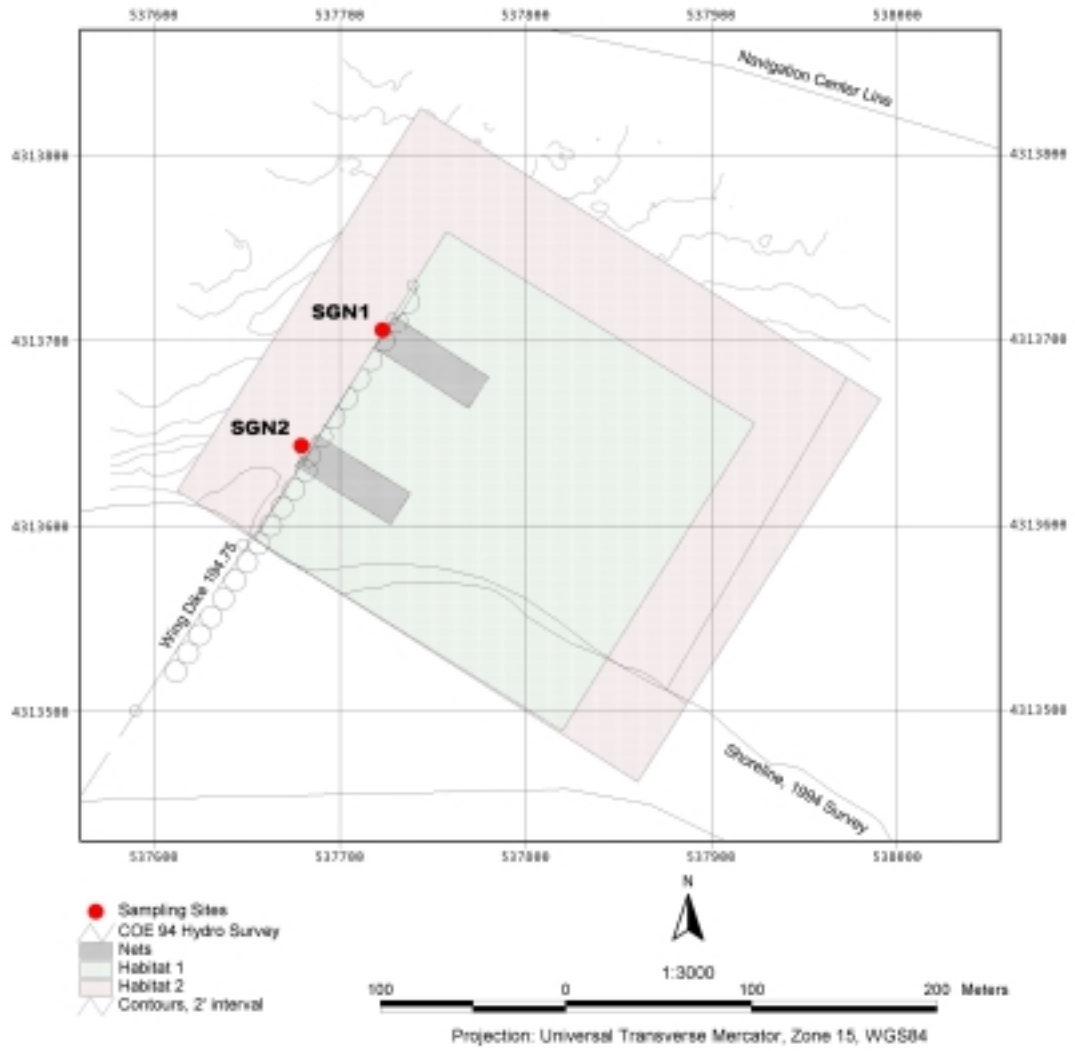


Projection: Universal Transverse Mercator, Zone 15, WGS84

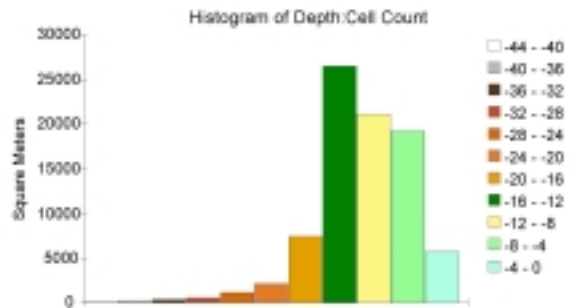
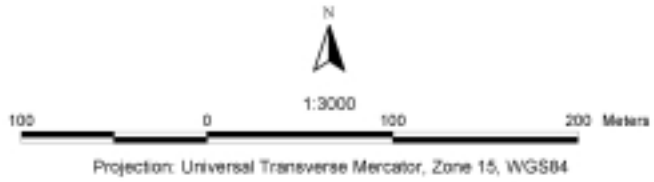
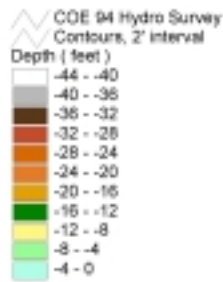
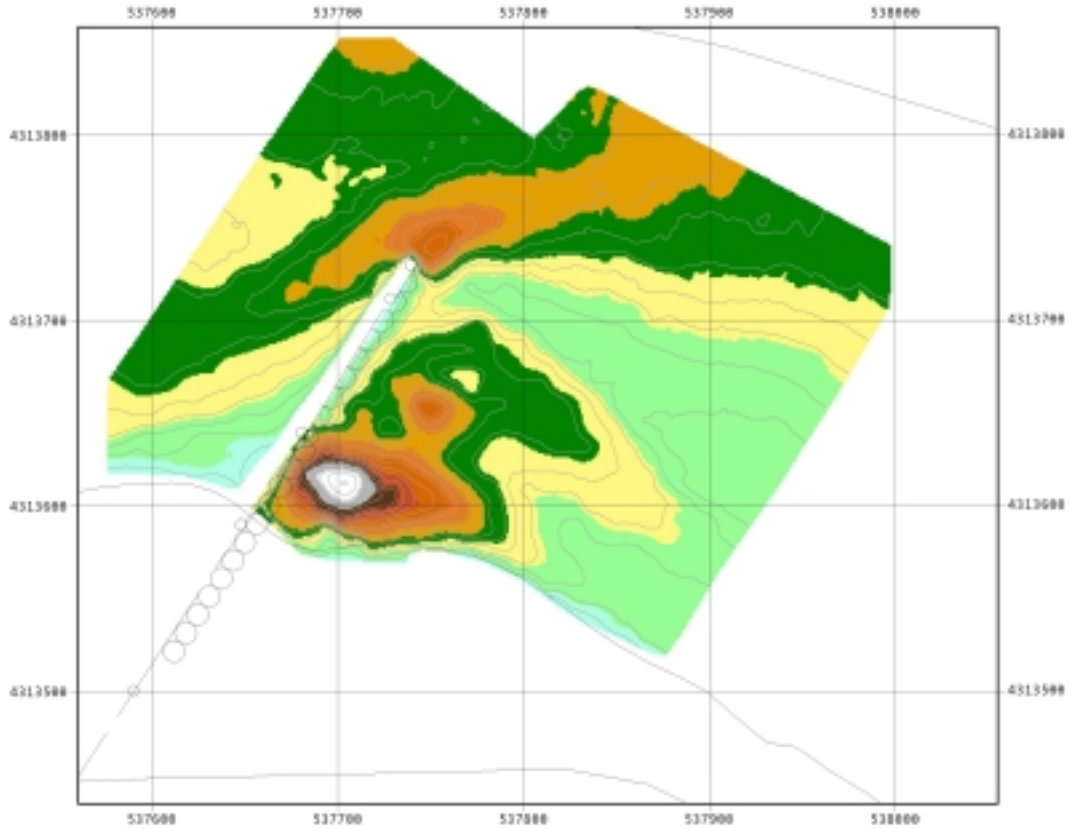
Histogram of Substrate Cell Count



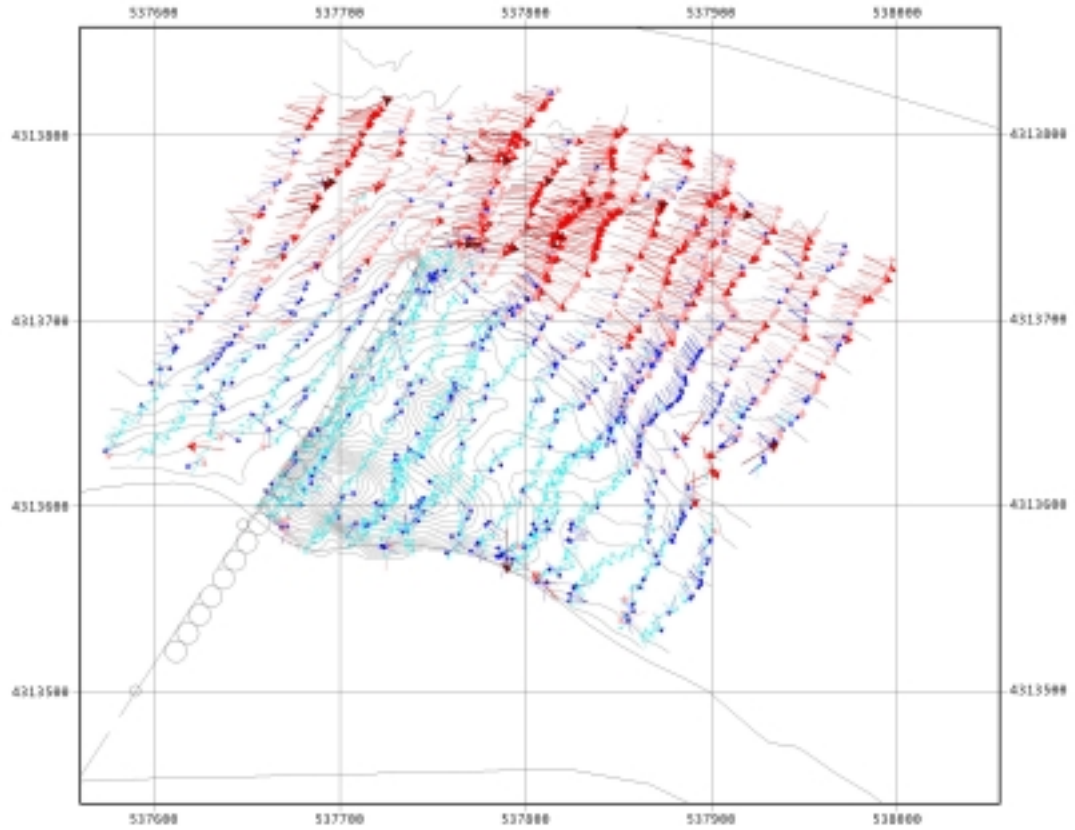
Site 186.4



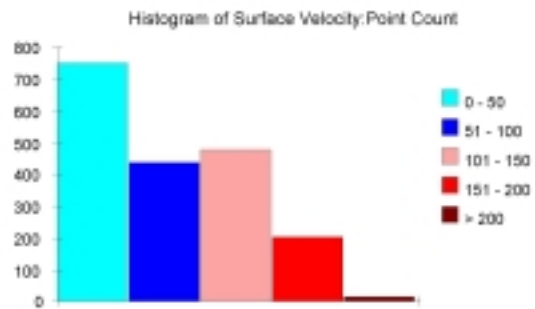
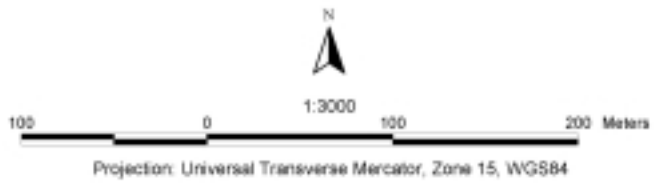
Site 186.4 - Depth



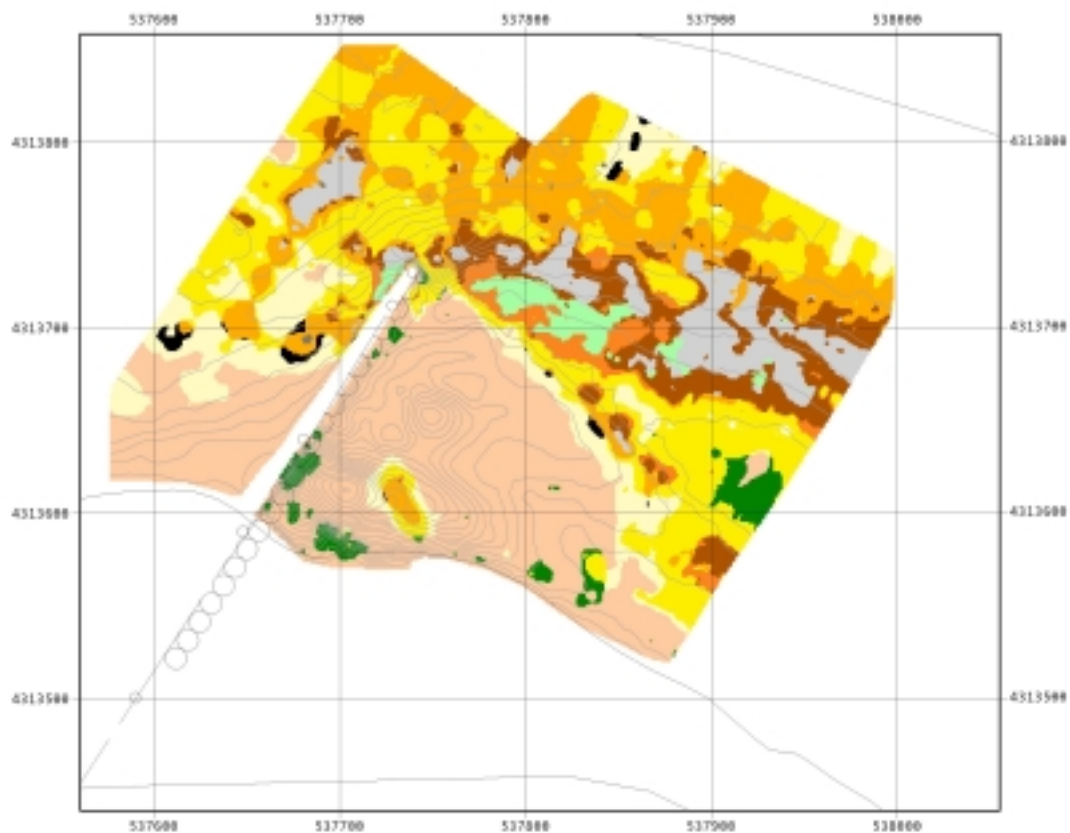
Site 186.4 - Surface Velocity



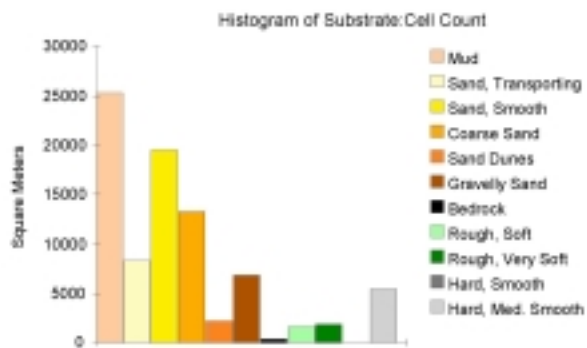
- △ COE 84 Hydro Survey
- Surface Velocity (cm/sec)
- 0 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- > 200
- ▽ Contours, 2' interval



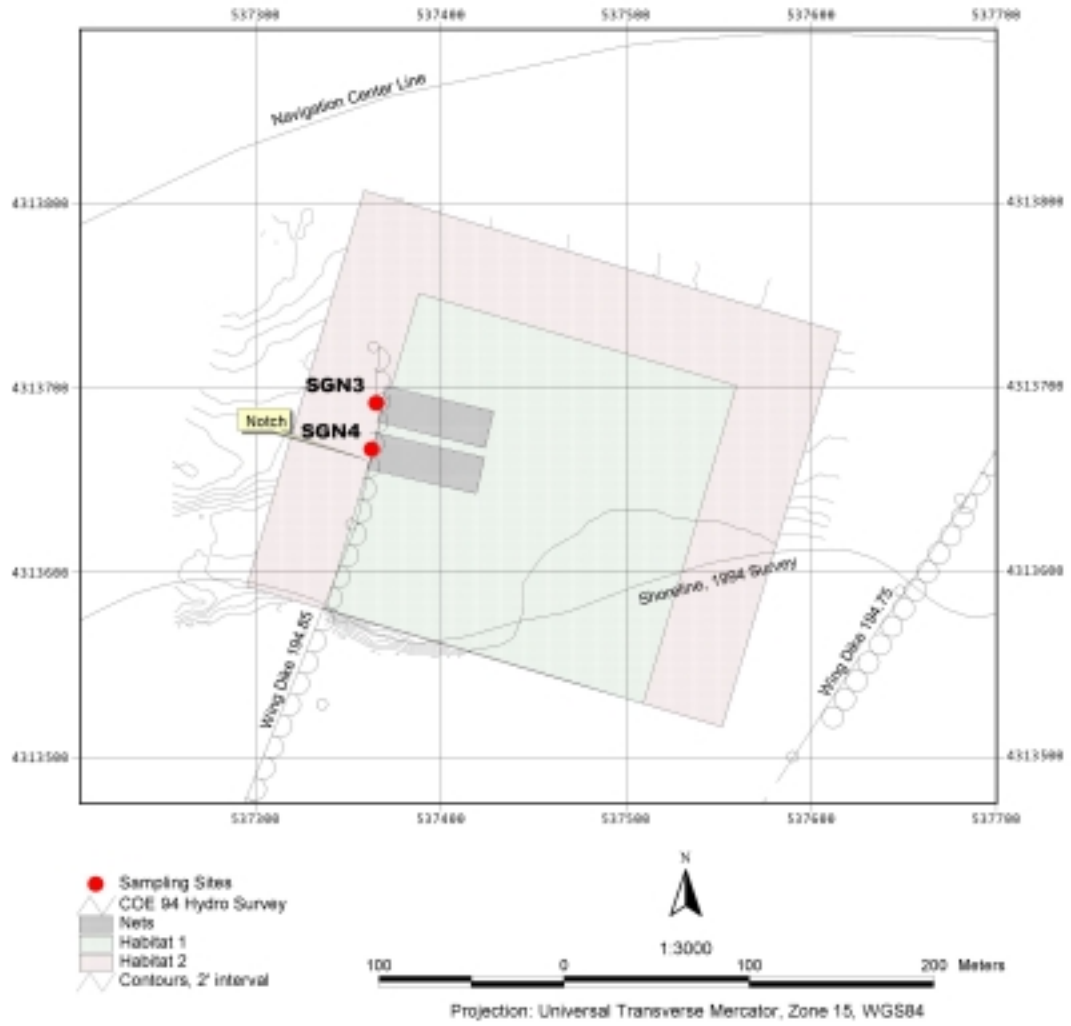
Site 186.4 - Substrate



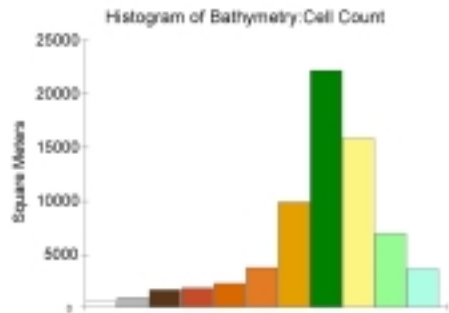
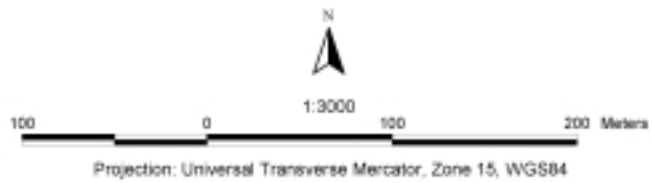
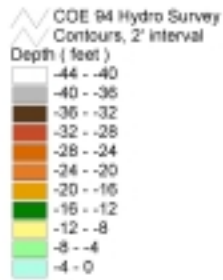
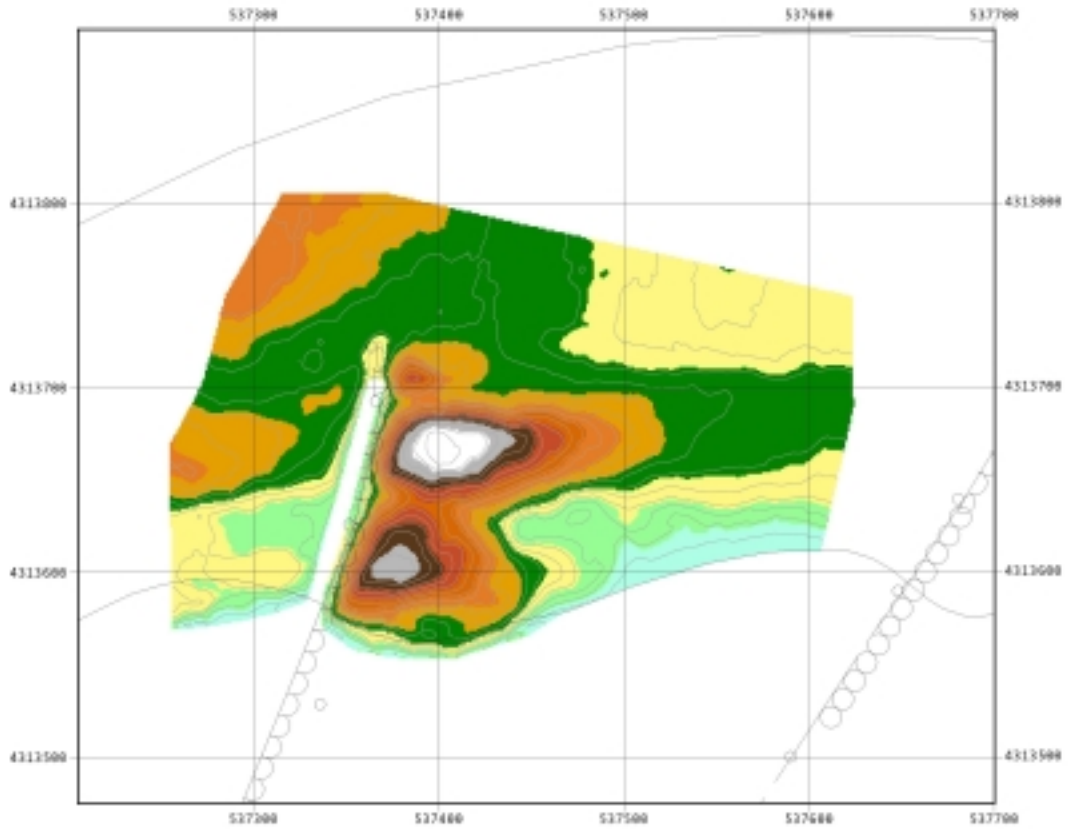
- COE 94 Hydro Survey
- Contours, 2' Interval
- Substrate
- Mud
- Sand, Transporting
- Sand, Smooth
- Coarse Sand
- Sand Dunes
- Gravelly Sand
- Bedrock
- Rough, Soft
- Rough, Very Soft
- Hard, Smooth
- Hard, Med. Smooth



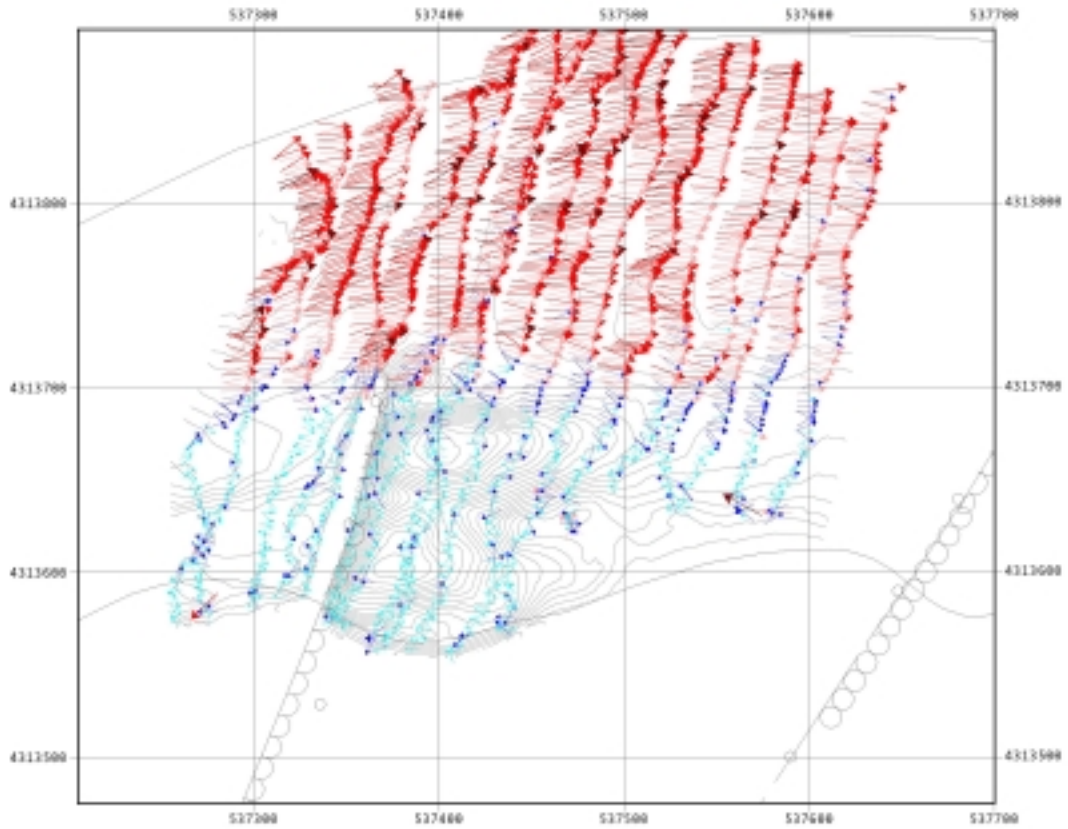
Site 186.7



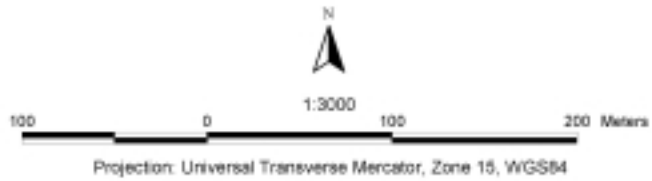
Site 186.7 - Depth



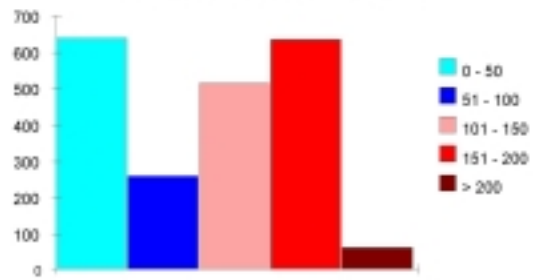
Site 186.7 - Surface Velocity



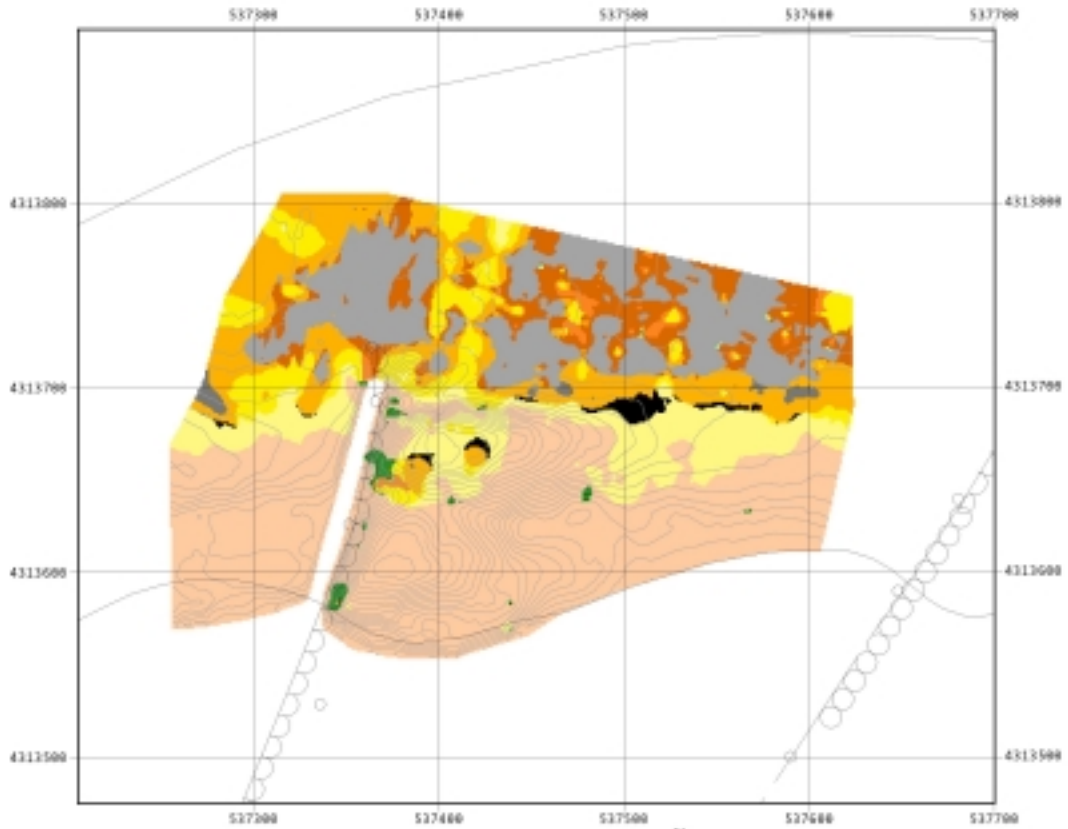
- △ COE 94 Hydro Survey
- Surface Velocity (cm/sec)
- 0 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- > 200
- ▽ Contours, 2' interval



Histogram of Surface Velocity Point Count



Site 186.7 - Substrate



- COE 94 Hydro Survey Contours, 2' interval
- Substrate
- Mud
- Sand, Transporting
- Sand, Smooth
- Coarse Sand
- Sand Dunes
- Gravelly Sand
- Bedrock
- Rough, Soft
- Rough, Very Soft
- Hard, Smooth
- Hard, Med. Smooth

