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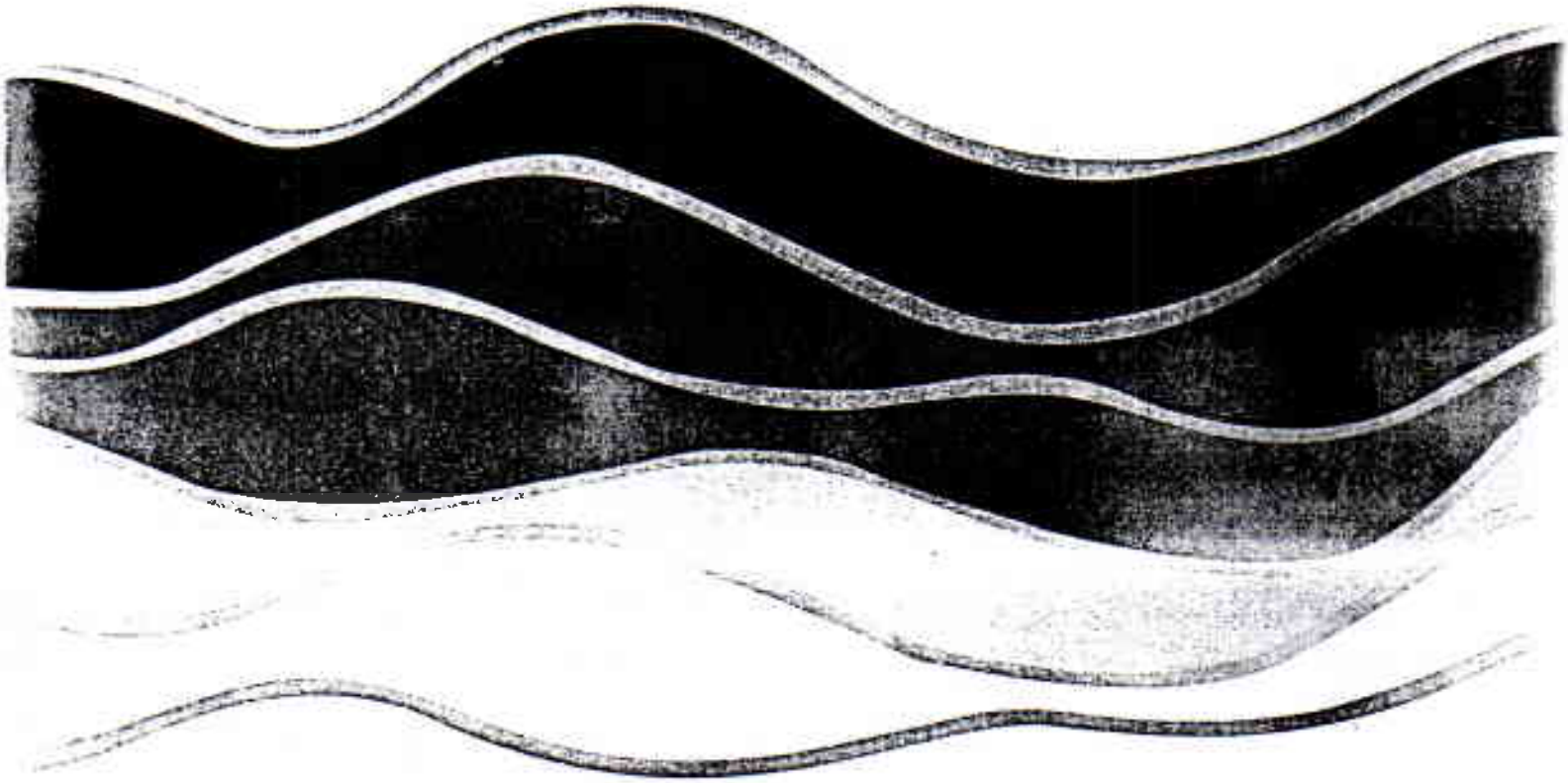

VOLUME AND PROPERTIES OF ST. LAWRENCE RIVER BED SEDIMENTS AT THE PROPOSED COURTAULD'S DREDGING SITE, CORNWALL, ONTARIO

Dr. Norm Rukavina

NWRI Contribution No. 94-154

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August 1994

Introduction

The Cornwall RAP committee has selected a site in east Cornwall opposite the Courtauld's plant for a contaminated-sediment removal project. This is an area of highly variable surface sediments (Rukavina 1993) in which levels of heavy metals are known to exceed the severe-effect-level criteria (Beak 1993; Biberhofer (Environment Canada), pers commun.) Good estimates of fine-sediment distribution and volume are required to permit selection of the appropriate technology for dredging and to estimate the costs of dredging and treatment.

The present study was undertaken to provide detailed direct measurements of sediment thickness and sediment type within a contaminated 1-hectare area just east of the Courtauld's pump house. Divers measured the sediment thickness by probing to refusal at 91 sites and characterized them in terms of water depth, grain size and weed cover. A smaller area with thicker sediment at the east end of the survey area was selected for an analysis of the distribution of thickness and sediment types and for GIS analysis of sediment volume. This report provides maps and data on sediment distribution and a preliminary estimate of sediment volume.

Survey Methods

Bottom sampling and underwater television and acoustic surveys by NWRI in 1993 showed the entire north-shore reach between Windmill Point and Pilon Island to be a very complex mix of muds, sands and gravels, weed beds and scattered cobbles and boulders (Rukavina 1993). Because the bed materials are so variable, it was decided to limit the current survey to a small area which could be mapped in detail and to use diver surveys to collect direct measurements of sediment properties. The survey was carried out during the weeks of June 20 and July 4, 1994. Data were collected at 91 sites.

The survey vessel was the Canadian Hydrographic Survey launch Pintail which is equipped for diving operations. Because of the need to limit diver contact with the bottom sediments, the divers were not free-swimming but worked from a platform suspended below the launch at a height of 30-50 cm above the bottom. The platform and diver stayed in place as the boat was moved from site to site. For safety reasons, the launch was anchored fore and aft and onshore and offshore and navigation was accomplished by adjusting anchor lines to produce a series of sample arcs across the survey area. Although this produces an irregular grid of samples, it does permit safe and fast collection of data and optimal use of diver time. With experience, it is possible to sample a site and move to the next site in 5 to 10 minutes. The only serious limitation of the procedure is that the need for clearance of the diver stage restricts the minimal depth of operation to about 3 m and does not permit measurements in the inner 25 to 50 m of the inshore zone.

Sites were located with a shore-based Navitrack laser-positioning system which is capable of 0.3-0.6 m accuracy. Fixes were taken from a target located directly above one corner of the diver platform and are considered to be accurate to within 1-2 m. A simple mapping program written in BASIC was used to track boat position and select sites from a real-time display of the survey area and to compute and log position data in UTM coordinates.

The Navitrack instrument position was originally located approximately with reference to the limited control data available. Corrections were applied later from a third-order [illegible] control points along the reach from

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The Navitrack instrument position was originally located approximately with reference to the limited control data available. Corrections were applied later from a third-order OLS survey arranged by contract. Five intervisible control points along the reach from the Tank Farm to Pilon Island are now available for future surveys.

Divers measured sediment thickness by pushing a calibrated stainless-steel rod into the bottom sediment to refusal and reading its penetration. The rod was marked at 5-cm intervals and readings are considered to be accurate to ±2 cm. Four readings

were taken, one at each corner of the dive stage, an 8 ft x 4 ft platform with its short dimension oriented parallel to the boat keel. Divers also estimated the sediment grain size and the percentage of bottom cover by weeds or boulders, and noted other bottom features including the release of gas bubbles from the sediment during probing and the firmness of the substrate below the soft-sediment cover. Water depth at each site was recorded to the nearest 0.3 m on an echo sounder corrected for transducer draft but not for water temperature. Depths are relative to the water level at the time of survey and have not been adjusted to the Great Lakes datum.

Figure 1 shows the distribution of sites. The large rectangle is the area originally specified for survey. When it became clear from the early data that the area was too large to cover in the time available, the survey was shifted to the smaller polygon further east and data were collected at 54 sites in the smaller area.

Results

Figure 2 is a classification of bottom type based on the diver observations. Sediments have been subdivided into five types: 1) silt (fine-grained sediment of silt or clay size), 2) slightly coarser sandy silts, 3) weed beds on fine sediment , 4) a mixed bottom of boulders, cobbles or gravel, and fine sediments and 5) a mixed bottom of weeds and fine and coarse sediments. Bed materials in the western half of the polygon are mainly types 3, 4 and 5. The eastern half consists of more uniform silts and sandy silts with only minor weed cover and no coarser materials. The curved line which divides the polygon is the approximate boundary between the two bottom types. The inshore area was not surveyed because it was too shallow but several launch traverses across it showed it to be mainly weed and boulder bottom with little fine sediment cover.

Water depth in the polygon ranges from 2.4 to 7.7 m and averages 5.3 m (Figure 3). The offshore profile has a low slope from the shoreline to a depth of about 4 m, steepens from 4 to about 7 m, and then flattens again beyond that depth. Profile slope increases across the area from southwest to northeast.

Figures 4 and 5 are maps of sediment thickness and variability in thickness. The data in Figure 4 are the averages of the 4 measurements taken at each site. Figure 5 shows the variability at each site expressed in terms of standard deviation. Sediment thickness within the polygon ranges from 9 to 69 cm and standard deviation from 0 to 31 cm. Average thickness is 33.6 cm. There is considerable variation in thickness between sites and a general trend of increasing thickness from southwest to northeast. The substrate below the soft-sediment cover is generally hard and likely represents buried boulders or cobbles since divers observed no bedrock exposures in the river bed. There were also a few instances of underlying gravel or stiff clay.

Penetration of the sediment often resulted in the release of gas bubbles which may be methane produced by decomposition of organic material. Figure 6 shows the sites at which gas was observed. The gas tends to be associated with thicker sediments but does not appear to be related to weed cover or sediment texture.

In water depths greater than 5 m, divers observed a black fibrous coating of the sediment which ranged in thickness from a few mm to a few cm. They described it as having the appearance of a motheaten carpet. No samples were taken and it is not clear whether the material is an algal layer or an industrial byproduct. Figure 7 shows estimates of bottom coverage of the material. Its distribution is limited to the offshore portion of the polygon and it does not coexist with weed beds.

Detailed listings of the data discussed above have been tabulated in appendices 1 and 2. Appendix 1 lists the information on date, position, water depth and diver notes. Appendix 2 is a listing of all sediment data.

Estimate of Sediment Volume

A preliminary estimate of the volume of sediment within the polygon has been obtained by using simple descriptive statistics (Appendix 3). Results should be used with caution. Because the thickness distribution is skewed towards lower values, its mean and standard deviation may not be reliable measures of average thickness and of the error in the thickness estimate.

Appendix 3 lists all the thickness data for the sites within the polygon and the summary statistics derived from them by assuming that they are normally distributed . Mean sediment thickness computed as the mean of site means is 33.6 cm and the standard deviation of site means is 18.3 cm. The 95% confidence interval for the mean is ± 4.9 cm. This indicates that there is a 95% probability that the true mean value for sediment thickness falls within the interval 33.6 ± 4.9 cm.

The area of the polygon is 7563 m^2. The sediment volume is computed as the product of the area and mean thickness. The resultant volume is 2541 m^3 and the extreme values based on the 95% confidence interval for thickness are 2172 m^3 and 2910 m^3. Note that this estimate uses an equal weighting for each thickness value and does not take into account the nonuniform distribution of the samples. The error in measurement of ± 2 cm has also been ignored for this preliminary estimate.

Conclusions

New data on sediment type and thickness at the proposed Cornwall dredge site have been used to map the distribution of bottom materials and to estimate the volume of fine-grained contaminated sediments. Bottom-sediment type tends to be a mix of fine sediments, weeds, and boulders in the western half of the area, and more uniform silts and clays in the eastern half. Gas is present at most of the eastern sites and a thin

black fibrous mat of unknown origin is common in the southeastern part of the area. Sediment substrate is generally hard (boulders?) and less commonly stiff clay or gravel.

Sediment thickness ranges from 6 to 73 cm across the area and varies by as much as 65 cm at individual sites. The mean thickness determined by simple averaging without weighting for site distribution is 33.6 ± 4.9 cm and the associated wet-sediment volume is 2541 ± 369 m^3. It should be possible to improve the estimate of volume by subjecting the same data to areal analysis in a GIS (geographic information system) where it is possible to deal with the site thicknesses and areas associated with them individually (Rukavina and Delorme 1992) . This will be the subject of a separate report.

References

Beak Consultants Limited 1993. Sediment quality survey of the St. Lawrence River between the Courtauld's intake and outfall pipes. Unpublished report for TransCanada Pipelines.

Rukavina, N.A. 1993. St. Lawrence River bottom-sediment distribution and stability at Cornwall, Ontario: progress report. NWRI Lakes Research Branch draft report.

Rukavina, N.A. and Delorme, R.J. 1992. GIS estimates of contaminated-sediment volume in Lac Saint-Louis and Lac Saint-Pierre, St. Lawrence River. NWRI Lakes Research Branch Contribution 92-64.

Acknowledgements

Diving operations were coordinated by H. Don, the NWRI dive officer, and carried out by NWRI divers B. Gray, M. Dahl and T. Breedon. The Central Region of the Canadian Hydrographic Service supplied the Navitrack Positioning System and the assistance of P. Millette in setup and training. B. Trapp of the New Technologies Research Branch, NWRI, assisted in the second part of the survey. H. Biberhofer, Ecosystem Health Division, Environment Canada, arranged for the survey of shore-reference sites and advised on the format and content of the report. Funding for the survey was arranged by J. Anderson of the Environment Canada's Restoration Programs Division.

Figures

Figure 1. Site Map
Figure 2. Bottom-sediment Types
Figure 3. Water Depth, m
Figure 4. Sediment Thickness, cm
Figure 5. Variability in Thickness, cm
Figure 6. Gas in Sediments
Figure 7. Algal? Carpet, % coverage

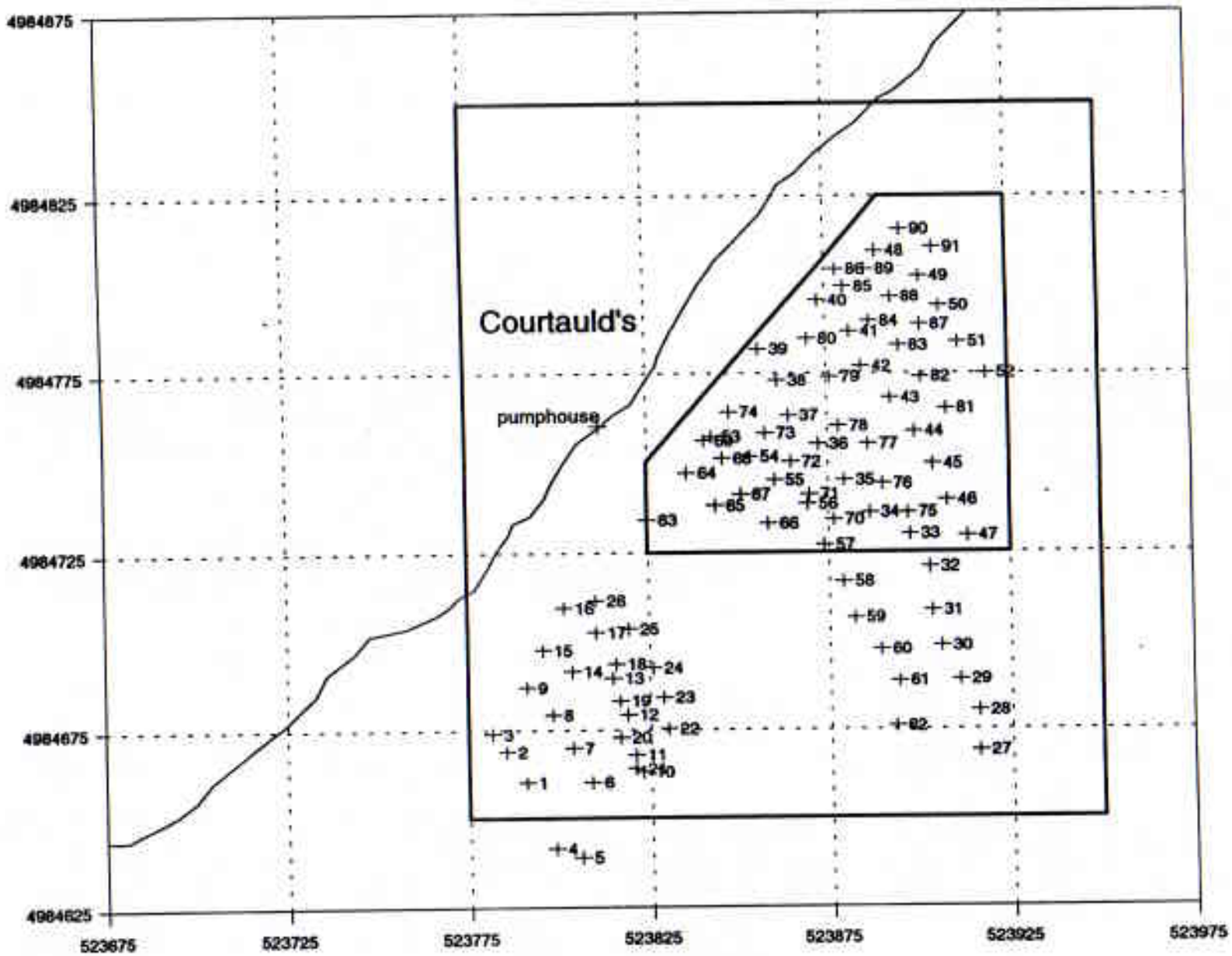


Fig. 1 Site Map

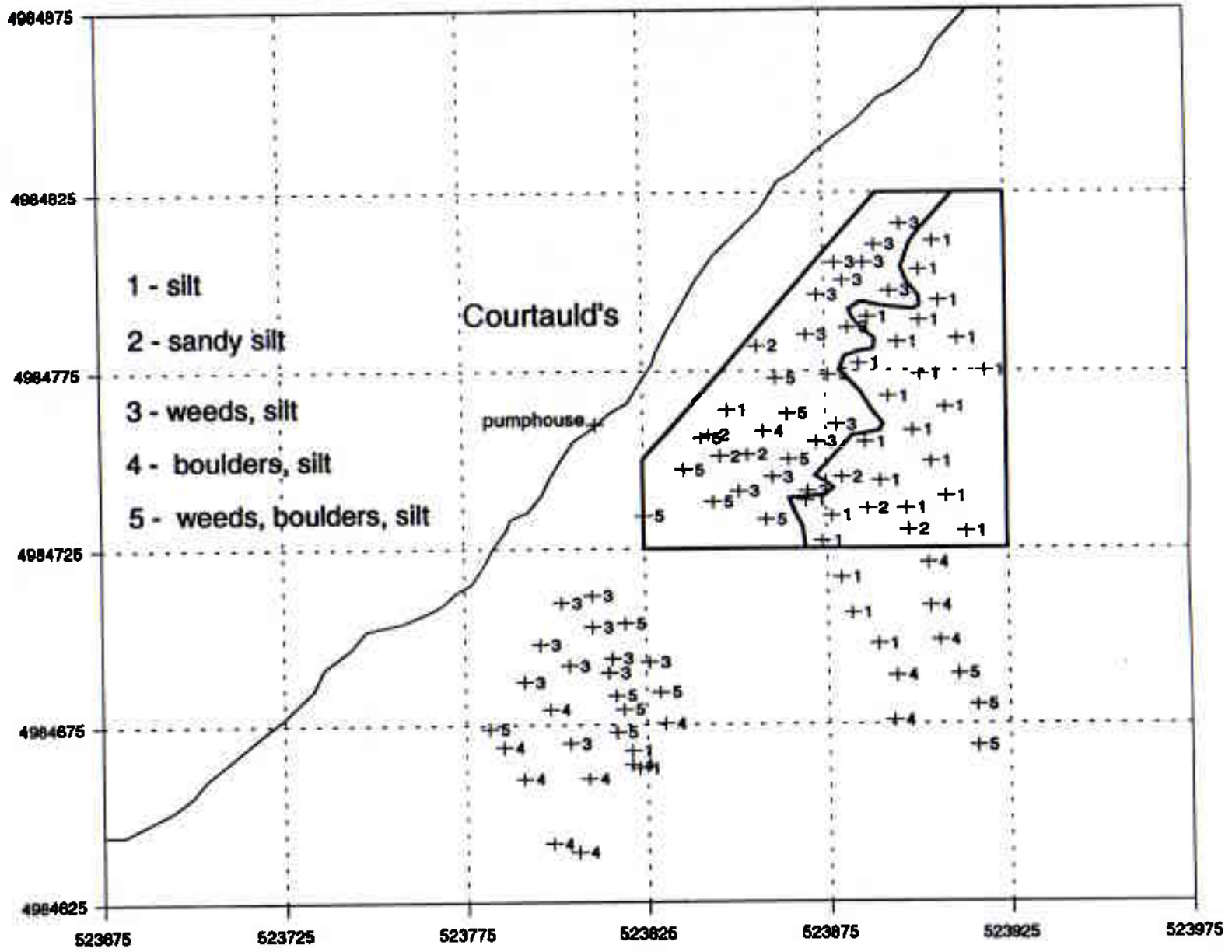


Fig. 2 Bottom-sediment Types

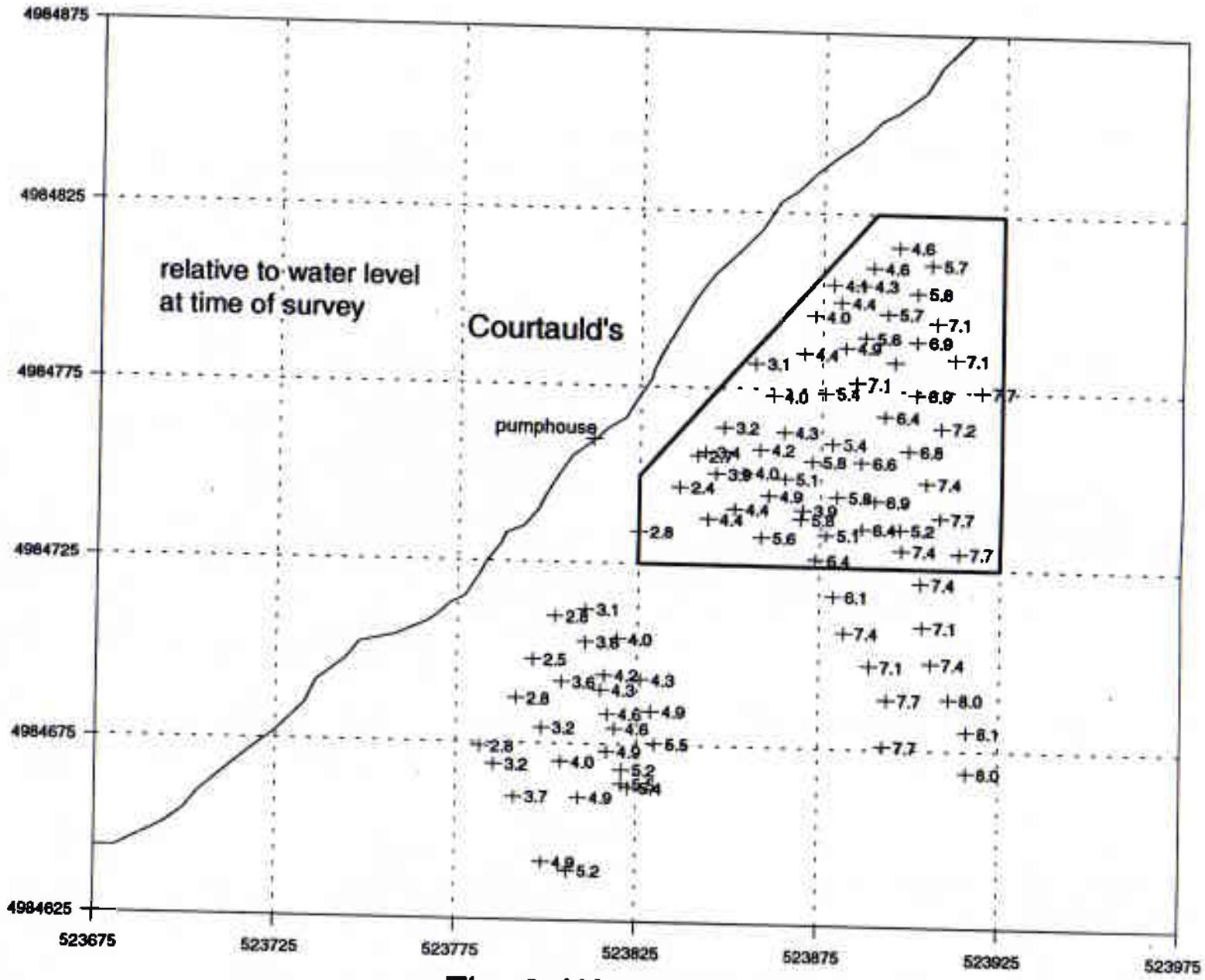


Fig. 3 Water Depth, m

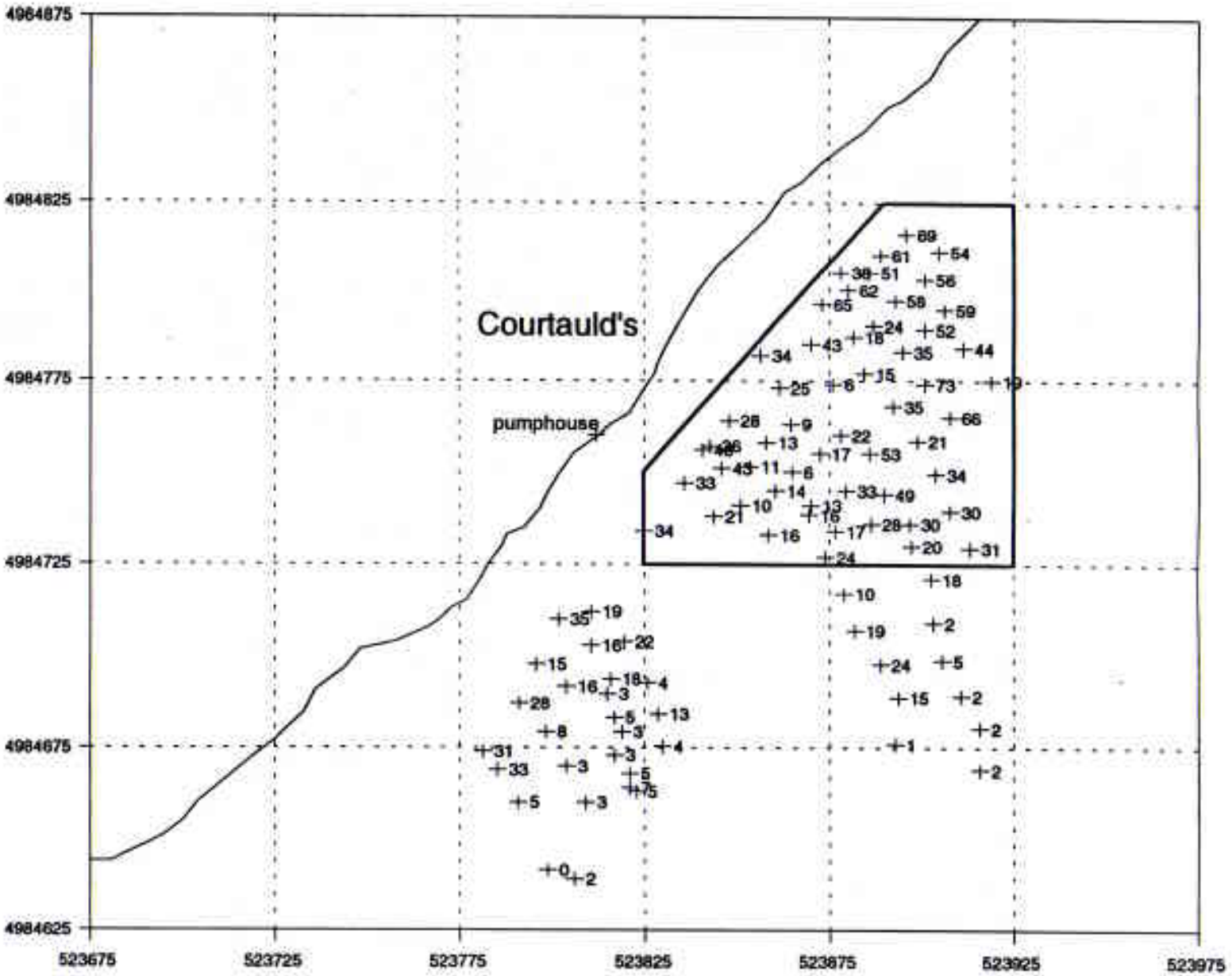


Fig. 4 Sediment Thickness, cm

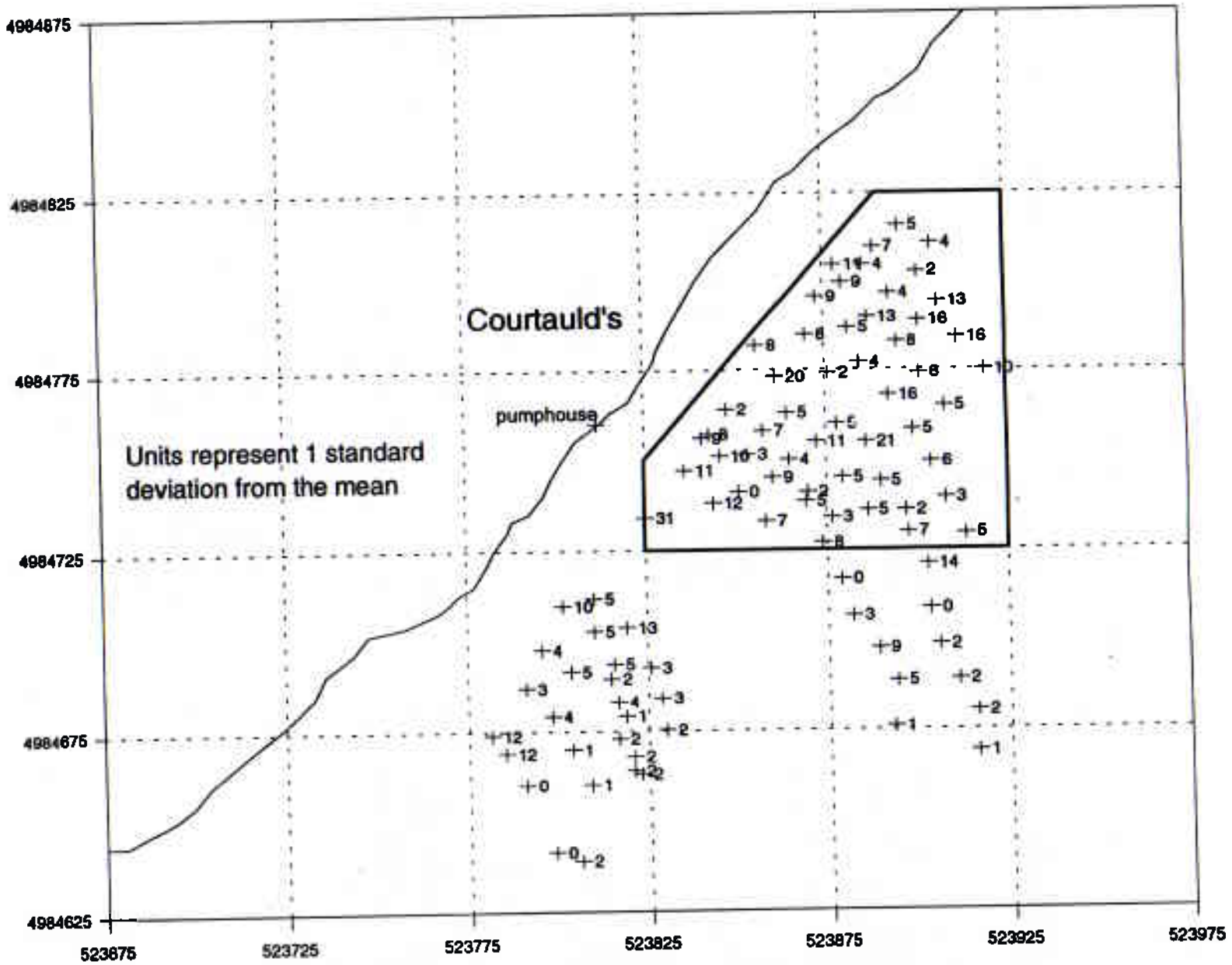


Fig. 5 Variability in Thickness, cm

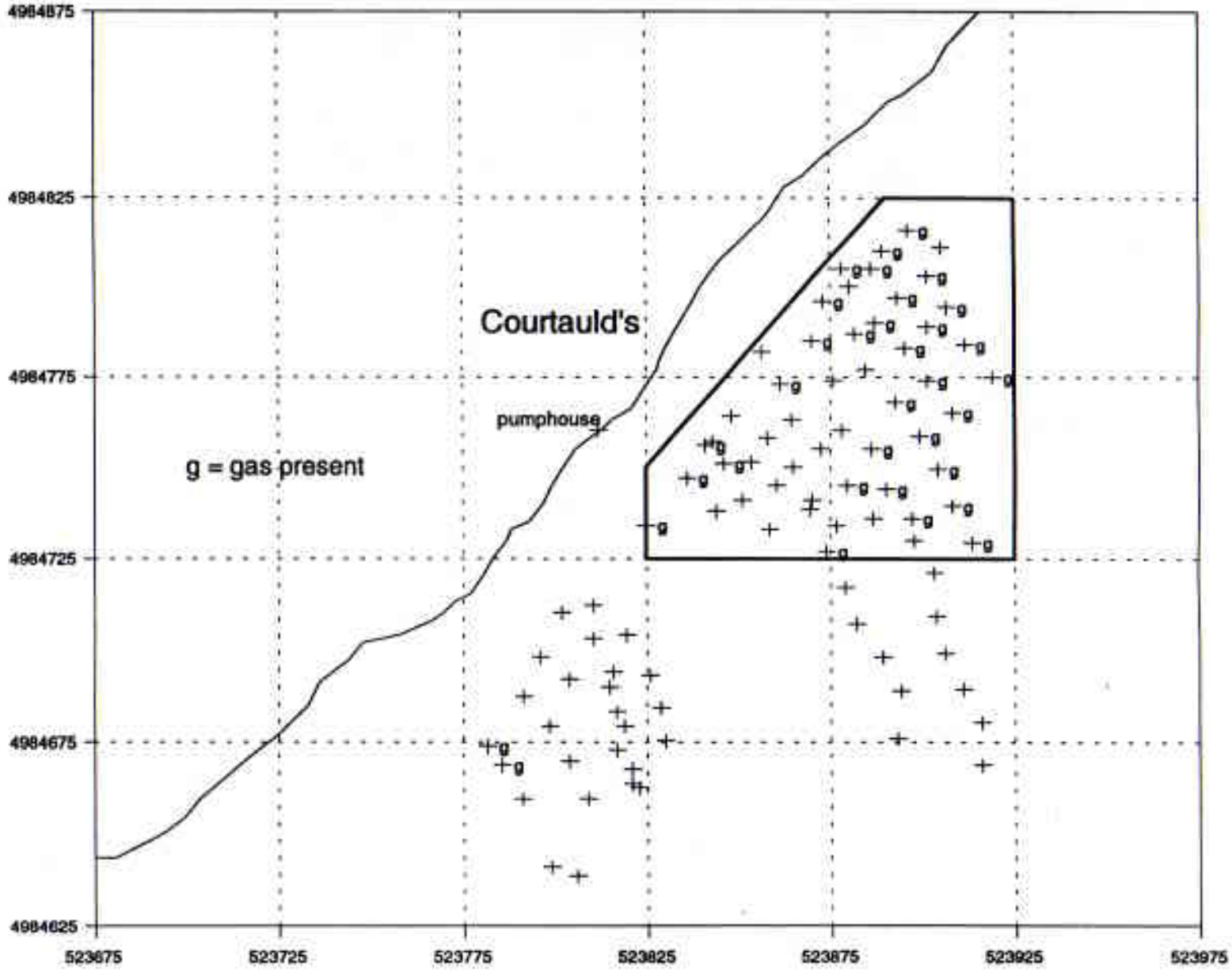


Fig. 6 Gas in Sediments

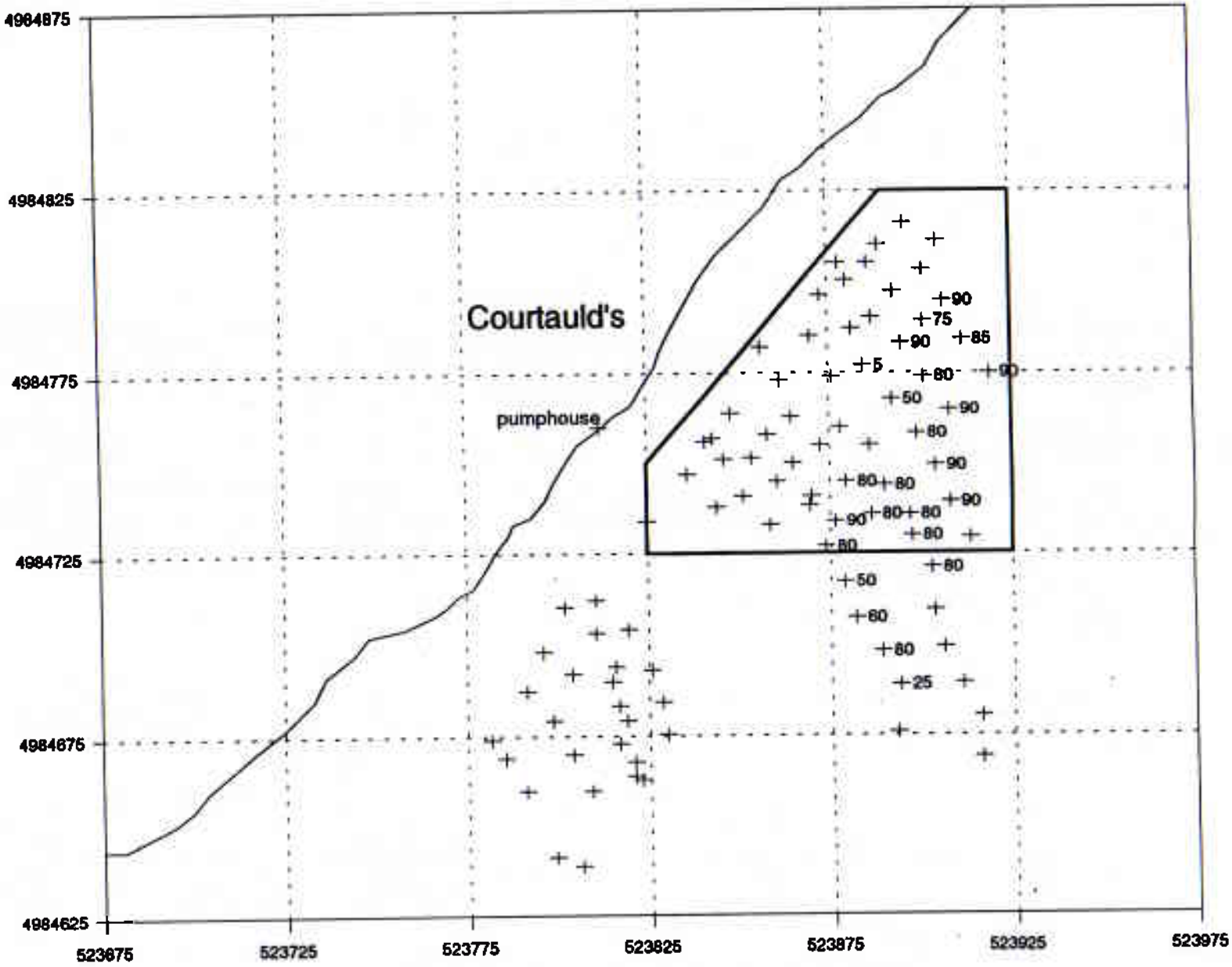


Fig. 7 Algal? Carpet, % coverage

Site	Date/ Time	Average Northing	Average Easting	Depth m	Notes
	94-06-22				
1	12:15	4984660	523791	3.7	
2	12:22	4984669	523786	3.2	
3	12:31	4984674	523782	2.8	railway tie
4	12:42	4984642	523799	4.9	tire
5	12:50	4984639	523806	5.2	
6	13:03	4984660	523809	4.9	
7	13:11	4984670	523804	4.0	small snail shells
8	13:20	4984680	523799	3.2	snail shells
9	13:28	4984688	523792	2.8	small snails
10	15:52	4984663	523823	5.4	small clam shells
11	16:02	4984668	523821	5.2	small clam shells
12	16:08	4984680	523819	4.6	
13	16:12	4984690	523815	4.3	
14	16:19	4984692	523804	3.6	
15	16:31	4984698	523796	2.5	
16	16:47	4984710	523802	2.8	
17	16:55	4984703	523811	3.6	
18	17:02	4984694	523816	4.2	
19	17:10	4984684	523817	4.6	
20	17:18	4984673	523817	4.9	
21	17:23	4984664	523821	5.5	
22	17:47	4984676	523830	5.5	
23	17:51	4984685	523829	4.9	
24	17:57	4984693	523826	4.3	
25	18:01	4984704	523820	4.0	
26	18:06	4984712	523811	3.1	
	94-06-23				
27	10:08	4984669	523916	8.0	small clams, snails, zebra mussels
28	10:15	4984681	523916	8.1	small clams, snails, zebra mussels
29	10:19	4984690	523911	8.0	
30	10:25	4984699	523906	7.4	
31	10:31	4984709	523904	7.1	small clams, snails, zebra mussels
32	10:39	4984721	523903	7.4	50-80% algal? carpet
33	10:45	4984730	523898	7.4	50-80% algal? carpet
34	10:54	4984736	523887	6.4	50-80% algal? carpet, many snails
35	11:01	4984745	523880	5.8	50-80% algal? carpet, some snails
36	11:07	4984755	523873	5.8	many snails
37	11:12	4984763	523865	4.3	
38	11:19	4984773	523862	4.0	
39	11:27	4984782	523857	3.1	opposite drain pipe; bottom debris
40	12:38	4984796	523873	4.0	
41	12:45	4984787	523882	4.9	
42	12:54	4984777	523885	7.1	5% green algae; 5% algal? carpet
43	13:03	4984768	523893	6.4	50% algal? carpet
44	13:09	4984759	523899	6.8	80% algal? carpet
45	13:15	4984750	523904	7.4	90% algal? carpet

Site	Date/ Time	Average Northing	Average Easting	Depth m	Notes
46	13:21	4984740	523908	7.7	90% algal? carpet
47	13:26	4984730	523914	7.7	
48	14:07	4984810	523889	4.6	
49	14:12	4984803	523901	5.8	
50	14:17	4984795	523907	7.1	90% algal? carpet
51	14:23	4984784	523912	7.1	85% algal? carpet
52	14:28	4984775	523919	7.7	90% algal? carpet, large depression
53	16:08	4984757	523843	3.4	
54	16:16	4984752	523854	4.0	
55	16:22	4984745	523861	4.9	
56	16:27	4984739	523870	5.8	a few small white shells
57	16:36	4984727	523874	6.4	80% algal? carpet, many small snail shells
58	16:40	4984717	523879	6.1	50% algal? carpet, many small snail shells
59	16:46	4984707	523882	7.4	60% algal? carpet, many tiny snail shells
60	16:51	4984698	523889	7.1	80% of algal? carpet
61	17:00	4984689	523894	7.7	25% algal? carpet
62	17:05	4984676	523893	7.7	
	94-07-06				
63	10:35	4984734	523825	2.8	
64	10:51	4984747	523836	2.4	
65	11:05	4984738	523844	4.4	
66	11:55	4984733	523859	5.6	
67	12:07	4984741	523851	4.4	
68	12:13	4984751	523846	3.9	
69	12:19	4984756	523841	2.7	
70	13:43	4984734	523877	5.1	90% algal? carpet
71	14:16	4984741	523870	3.9	
72	14:21	4984750	523865	5.1	
73	14:27	4984758	523858	4.2	100% weed cover just offshore
74	14:33	4984764	523848	3.2	
75	15:22	4984736	523897	5.2	80%f algal? carpet
76	15:33	4984744	523890	6.9	80%f algal? carpet
77	15:38	4984755	523886	6.6	
78	15:45	4984760	523878	5.4	
79	16:02	4984774	523876	5.4	
80	16:12	4984785	523870	4.4	patchy weeds
81	16:45	4984765	523908	7.2	90% algal? carpet
82	16:55	4984774	523901	6.9	80%f algal? carpet
83	16:59	4984783	523895		90% algal? carpet
84	17:04	4984790	523887	5.6	
85	17:08	4984800	523880	4.4	
86	17:15	4984805	523878	4.1	
87	17:56	4984789	523901	6.9	75% algal? carpet
88	18:10	4984797	523893	5.7	
89	18:14	4984805	523886	4.3	weed cover increases shoreward
90	18:22	4984816	523896	4.6	
91	18:34	4984811	523905	5.7	

Appendix 2: Sediment data

Site	Diver Description	Sed Type	Bottom Weeds	Substrate	Gas	Sediment Thickness, cm 1	2	3	4	Mean	StdDev
1	silty clay, few cobbles	4	thin	hard		5	5	5	5	5	0
2	silt, a few pebbles/cobbles	4	thin	hard	1&4	40	20	25	45	33	12
3	silt-clay, a few pebbles	5	thick	hard	4	35	20	22	45	31	12
4	boulders, cobbles, thin silt	4		hard		0	0	0	0	0	0
5	boulders, cobbles, thin silt	4		hard		0	3	3	0	2	2
6	boulders, few cobbles, thin silt	4	variable	hard		3	2	4	3	3	1
7	silt	3	thick	hard		3	4	3	3	3	1
8	silt, one large boulder	4	thin	hard		10	11	3	8	8	4
9	flat silt	3	thick	hard		30	25	25	30	28	3
10	flat silt	1	thin	hard		5	3	8	5	5	2
11	flat silt	1	thin	hard		8	3	5	5	5	2
12	large weed bed, sand and gravel	5	thick	hard		2	2	3	5	3	1
13	sand in weeds, thin silt layer	3	patchy	hard		5	2	2	2	3	2
14	large weed bed in silty sediment	3	thick	hard		12	20	20	12	16	5
15	silt bottom with weed beds	3	patchy	hard		15	19	15	10	15	4
16	sticky mud and weed beds	3	patchy	hard		50	30	30	30	35	10
17	sloping silt and weeds	3	patchy	hard; clay at 2,3		10	20	20	15	16	5
18	weeds with sediment patches	3	patchy	hard; clay at 1,4		20	10	20	20	18	5
19	patchy weeds, cobbles, boulders, thin-silt cover	5	patchy	hard; clay at 4		10	1	3	5	5	4
20	patchy weeds, boulders/cobbles with silt cover	5	patchy	hard		2	3	1	5	3	2
21	flat silt, scattered cobbles and pebbles	4		hard; clay at 4		5	8	5	10	7	2
22	flat silt, scattered cobbles and pebbles	4		hard		5	5	2	2	4	2
23	weed beds, silt patches, boulders, pebbles	5	patchy	clay		10	10	15	15	13	3
24	dense weeds with silt patches	3	thick	hard		8	2	2	5	4	3
25	dense weeds, silt patches, scattered cobbles	5	thick	hard		40	12	15	20	22	13
26	dense weeds	3	thick	hard		22	15	25	15	19	5
27	flat thin silt, boulders/gravel, weed patches	5	patchy	hard		3	1	3	1	2	1
28	flat thin silt, boulders/gravel, weed patches	5	patchy	hard		3	3	0	3	2	2
29	flat thin silt, boulders/gravel, weed patches	5	patchy	hard		3	1	3	0	2	2
30	flat silty sand, scattered boulders	4	thin	hard		5	8	3	5	5	2
31	flat soft silty sand, gravel, few cobbles	4	thin	hard		2	2	2	2	2	0
32	flat sandy silt, few boulders, black fibre	4		hard		8	30	30	3	18	14
33	flat sandy silt, wood fibre	2		hard; grav at 1,4		15	20	30	15	20	7

Site	Diver Description	Sed Type	Bottom Weeds	Substrate	Gas	Sediment Thickness, cm 1	2	3	4	Mean	StdDev
34	flat sandy silt	2		hard		30	20	30	30	28	5
35	flat sandy silt	2	thin	grav-2,3;clay-1,4	1-4	30	30	40	30	33	5
36	flat sandy silt	3	patchy	hard		8	30	20	8	17	11
37	sandy silt, some boulders	5	80%	hard		5	10	5	15	9	5
38	flat sandy silt, some boulders	5	50%	hard	1,4	45	10	5	40	25	20
39	sandy silt	2	thin	hard; clay at 1,4		40	25	40	30	34	8
40	sloping silt	3	30%	hard	1-4	70	60	55	75	65	9
41	flat silt	3	40%	hard	2,4	20	22	10	20	18	5
42	flat silt	1		hard		20	15	10	15	15	4
43	flat silt	1		hard; clay at 1,3	1-3	35	55	35	15	35	16
44	flat silt	1		clay	1,4	25	15	20	25	21	5
45	flat silt	1		hard; clay at 1,4	1-4	40	35	25	35	34	6
46	flat silt	1		hard	1-4	25	33	30	30	30	3
47	flat silt	1		hard	1-4	25	35	35	30	31	5
48	silt	3	100%	hard; clay at 1-3	1-4	60	70	60	53	61	7
49	sloping silt	1	5%	hard	1-4	55	55	58	55	56	2
50	gently sloping silt	1		hard	1-4	50	72	68	45	59	13
51	silt	1		clay	1-4	60	30	30	55	44	16
52	silt	1		hard; clay at 2-4	1,4	25	10	10	30	19	10
53	flat silt-sand	2	10%	hard		30	30	45	40	36	8
54	flat silty sand	2	20%	hard		10	15	10	10	11	3
55	sand-silt over gravel	3	90%	gravel		8	23	20	5	14	9
56	flat silt	1	5%	hard		20	15	10	20	16	5
57	flat silt	1		hard	3	20	15	30	30	24	8
58	flat silt	1		hard		10	10	10	10	10	0
59	flat silt	1		hard		20	20	20	15	19	3
60	flat silt	1	5%	hard		30	10	30	25	24	9
61	flat silt, some boulders/pebbles	4	5%	hard		12	20	17	10	15	5
62	flat silt, scattered boulders and cobbles	4	10%	hard		2	0	0	0	1	1
63	silt, some boulders	5	75%	hard	4	40	10	10	75	34	31
64	silt , some boulders	5	50%	hard	1	28	25	30	50	33	11
65	boulders, some sand, silt, steep slope	5	50%	hard		30	10	10	32	21	12
66	flat gravel bottom, some boulders	5	80%	hard		20	18	20	5	16	7
67	sandy silt	3	90%	hard		10	10	10	10	10	0
68	flat silt	2	20%	hard	1-4	40	52	30	50	43	10
69	sandy silt, pipeline visible	5		hard	1-4	35	55	50	50	48	9

Site	Diver Description	Sed Type	Bottom Weeds	Substrate	Gas	Sediment Thickness, cm 1	2	3	4	Mean	StdDev
70	silt veneer over clay	1		hard		20	18	12	18	17	3
71	silt	3	60%	hard		12	12	15	12	13	2
72	silt, 5% pebbles/cobbles	5	85%	hard		10	2	2	8	6	4
73	silt, some boulders, cobbles	4		hard		15	11	5	21	13	7
74	silt	1	5%	hard		25	27	29	30	28	2
75	silt	1		hard	1-4	30	28	29	32	30	2
76	silt, wood fibres?	1		hard	1-4	55	45	45	50	49	5
77	silt	1	2%	hard	2,3	30	70	72	40	53	21
78	silt	3	100%	hard		17	23	28	19	22	5
79	silt, large boulder, 5% cobbles	5	40%	hard		5	8	8	3	6	2
80	silt	3	70%	hard	1,3,4	48	32	42	50	43	8
81	silt	1		hard	1-4	70	60	70	65	66	5
82	silt	1		soft clay	1-4	70	75	80	65	73	6
83	silt	1	1%	hard	1-4	28	40	42	28	35	8
84	silt	1	5%	hard	1,2,4	27	34	5	28	24	13
85	silt	3	70%	hard		68	60	50	69	62	9
86	silt	3	100%	hard	1-4	30	28	50	45	38	11
87	silt	1		hard	1-4	30	62	65	50	52	16
88	silt	3	50%	hard	1-4	61	58	52	59	58	4
89	irregular silt bottom	3	50%	hard	1-4	53	55	48	48	51	4
90	silt bottom, 45-gal drum	3	50%	hard	1-4	62	72	73	70	69	5
91	flat silt	1	20%	hard		60	52	52	52	54	4

Appendix 3: Thickness data and volume computation

Thickness Data, Dredge Site

Site	Sediment Thickness, cm					
	1	2	3	4	Site Mean	Site Std Deviation
33	15	20	30	15	20	7
34	30	20	30	30	28	5
35	30	30	40	30	33	5
36	8	30	20	8	17	11
37	5	10	5	15	9	5
38	45	10	5	40	25	20
39	40	25	40	30	34	8
40	70	60	55	75	65	9
41	20	22	10	20	18	5
42	20	15	10	15	15	4
43	35	55	35	15	35	16
44	25	15	20	25	21	5
45	40	35	25	35	34	6
46	25	33	30	30	30	3
47	25	35	35	30	31	5
48	60	70	60	53	61	7
49	55	55	58	55	56	2
50	50	72	68	45	59	13
51	60	30	30	55	44	16
52	25	10	10	30	19	10
53	30	30	45	40	36	8
54	10	15	10	10	11	3
55	8	23	20	5	14	9
56	20	15	10	20	16	5
57	20	15	30	30	24	8
63	40	10	10	75	34	31
64	28	25	30	50	33	11

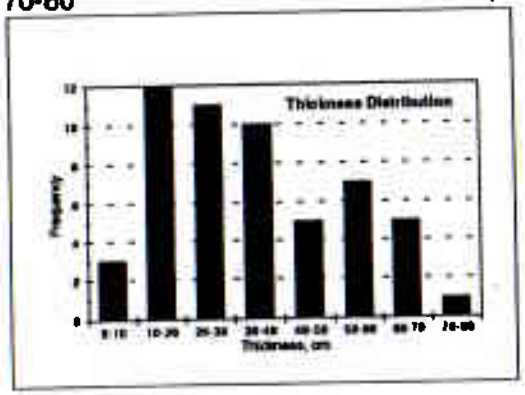
Site	Sediment Thickness, cm					
	1	2	3	4	Site Mean	Site Std Deviation
65	30	10	10	32	21	12
66	20	18	20	5	16	7
67	10	10	10	10	10	0
68	40	52	30	50	43	10
69	35	55	50	50	48	9
70	20	18	12	18	17	3
71	12	12	15	12	13	2
72	10	2	2	8	6	4
73	15	11	5	21	13	7
74	25	27	29	30	28	2
75	30	28	29	32	30	2
76	55	45	45	50	49	5
77	30	70	72	40	53	21
78	17	23	28	19	22	5
79	5	8	8	3	6	2
80	48	32	42	50	43	8
81	70	60	70	65	66	5
82	70	75	80	65	73	6
83	28	40	42	28	35	8
84	27	34	5	28	24	13
85	68	60	50	69	62	9
86	30	28	50	45	38	11
87	30	62	65	50	52	16
88	61	58	52	59	58	4
89	53	55	48	48	51	4
90	62	72	73	70	69	5
91	60	52	52	52	54	4

Site	Thickness, cm			Area,	Area x Volume,		Site	Thickness, cm			Area,	Area x Volume,	
	Average	Std Dev	Variance	sq m	Variance	cu m		Average	Std Dev	Variance	sq m	Variance	cu m
32	17.8	14.3	204.3	20.6	86717.6	3.66	64	33.3	11.4	128.9	198.7	5089489.7	66.07
33	20.0	7.1	50.0	119.2	710622.8	23.84	65	20.5	12.2	147.7	235.5	8188795.1	48.28
34	30.0	27.5	756.3	128.0	12399500.9	38.41	66	15.8	7.2	52.2	198.7	2062772.9	31.29
35	30.0	40.0	1600.0	108.9	18979266.5	32.67	67	10.0	0.0	0.0	94.2	0.0	9.42
36	16.5	10.6	113.0	100.1	1131854.0	16.51	68	43.0	10.1	102.7	78.0	624704.1	33.54
37	8.8	4.8	22.9	122.2	341981.4	10.69	69	47.5	8.7	75.0	85.4	546525.9	40.55
38	40.0	25.0	625.0	150.1	14085759.6	60.05	70	17.0	3.5	12.0	89.8	96725.4	15.26
39	33.8	7.5	56.3	128.0	922276.9	43.22	71	12.8	1.5	2.3	57.4	7413.2	7.32
40	65.0	9.1	83.3	123.6	1273718.6	80.36	72	5.5	4.1	17.0	82.4	115484.8	4.53
41	20.0	18.0	324.0	103.0	3439051.6	20.61	73	13.0	6.7	45.3	94.2	402228.9	12.25
42	15.0	4.1	16.7	126.6	267020.5	18.99	74	27.8	2.2	4.9	173.7	148296.4	48.19
43	35.0	16.3	266.7	142.8	5435159.0	49.97	75	29.8	1.7	2.9	100.1	29214.5	29.77
44	25.0	21.3	451.6	128.0	7403834.2	32.01	76	48.8	4.8	22.9	117.7	317706.7	57.40
45	33.8	6.3	39.6	216.4	1852875.7	73.02	77	40.0	53.0	2809.0	132.5	49287223.7	52.98
46	29.5	3.3	11.0	259.0	738101.9	76.42	78	21.8	4.9	23.6	123.6	360462.3	26.89
47	31.3	4.8	22.9	241.4	1335168.6	75.43	79	6.0	2.4	6.0	150.1	135223.3	9.01
48	60.8	7.0	48.9	125.1	765583.0	76.00	80	42.0	50.0	2500.0	159.0	63165935.3	66.76
49	55.8	1.5	2.3	114.8	29652.8	64.00	81	66.3	4.8	22.9	273.8	1717416.6	181.36
50	58.8	13.3	175.6	245.8	10607553.6	144.40	82	72.5	6.5	41.7	141.3	831821.3	102.44
51	43.8	16.0	256.3	228.1	13335978.6	99.81	83	34.5	7.5	57.0	119.2	810109.8	41.13
52	10.0	30.0	900.0	254.6	58348668.3	25.46	84	5.0	28.0	784.0	88.3	6113869.4	4.42
53	36.3	7.5	56.3	60.3	204828.7	21.87	85	61.8	8.8	77.6	70.6	387207.3	43.62
54	11.3	2.5	6.3	79.5	39478.7	8.94	86	38.3	10.9	118.9	75.1	670012.6	28.71
55	14.0	8.8	78.0	83.9	548966.8	11.75	87	51.8	15.9	252.2	89.8	2033248.1	46.46
56	16.3	4.8	22.9	75.1	129119.5	12.20	88	57.5	3.9	15.0	107.4	173153.5	61.78
57	30.0	23.8	564.1	103.0	5987160.6	30.91	89	51.0	3.6	12.7	73.6	68596.2	37.53
58	10.0	10.0	100.0	2.9	866.7	0.29	90	69.3	5.0	24.9	201.6	1013049.0	139.63
63	33.8	30.9	956.2	170.7	27873149.0	57.62	91	54.0	4.0	16.0	485.7	3774378.6	262.27

Total Area, sq m:	**7659**	**Average Thickness, cm:**	**35.5**
Total Volume, cu m:	**2718**	**95% Confidence Interval for Thickness**	**4.7**
95% Confidence Interval for Volume:	**360**		

Descriptive Statistics, Thickness	
Mean	33.6
Standard Error	2.5
Median	31.9
Mode	33.8
Standard Deviation	18.3
Variance	334.3
Kurtosis	-0.88
Skewness	0.43
Range	67
Minimum	5.5
Maximum	72.5
Sum	1814.3
Count	54
Confidence Level(0.950000)	4.9

Thickness, cm	Frequency
0-10	3
10-20	12
20-30	11
30-40	10
40-50	5
50-60	7
60-70	5
70-80	1



Dredge-site Sediment Thickness and Volume

Number of sites:	54
Range of Site Means:	5.5 - 72.5 cm
Range of Site Std Deviations:	0 - 30.9 cm
Mean Thickness: (mean of means)	33.6 ± 4.9 cm
95% Confidence Interval:	4.9 cm
Thickness Std Deviation: (standard deviation of means)	18.3 cm

Coordinates of Polygon:	Northing	Easting
northeast	4984825	523925
southeast	4984725	523925
southwest	4984725	523825
west	4984750	523825
northwest	4984825	523890

Area of polygon: 7563 sq m

Volume of sediment (area x thickness): 2541 ± 369 cu m