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PHYSIOGRAPHIC AND OCEANOGRAPHIC CHARACTERISTICS OF CHEZZETCOOK INLET, NOVA SCOTIA

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INTRODUCTION

There are many estuarine areas in the Maritime Provinces, varying from deep to extremely shallow water bodies, and these areas serve many functions, both recreational and commercial. It is important to understand the different types of estuarine regimes to assess effects that might occur with changing conditions. A considerable amount of information on deeper water bodies such as Halifax Harbour is available, but there is a distinct lack of data from very shallow estuaries.

Chezzetcook Inlet (Fig. 1) was chosen for study because it is a large, extremely shallow (mostly intertidal) estuary.

The data discussed in this paper represent only part of a large geological study of the area (Scott 1977). These data alone, in addition to their value as base-line information, permit comparison of this estuary with deeper, more stable environments and allow some predictions as to what might occur if conditions are altered.

METHODS OF DATA COLLECTION

Unfortunately most of the data from Chezzetcook Inlet were obtained only at one time interval (Fig. 2, Tables 1, 2). However, at five stations (22B, 23B, 49, 50, 51) at least two measurements of the salinity-temperature-depth profile were made on different tidal cycles. Since it was not possible to reach most mudflat areas by boat except at high tide, most of the measurements were taken in the interval of two hours before high tide to two hours following the high tide. It was impossible to obtain measurements at the same moment of the tidal cycle for each station so values in Tables 1 and 2 should be interpreted in the context of the tidal cycle. Maximum salinity values would be expected at, and just after flood tide.

An RS-5 salinity-temperature recorder was used to obtain the salinity-temperature values in Tables 1 and 2.

PHYSIOGRAPHY

The largest morphological features inside the inlet are the extensive intertidal mudflats and salt marshes. The intertidal areas are drained by a network of channels that dissect the mudflats. The channels begin at the head of the estuary as one large channel originating from the East Head (near Station 21, Fig. 2) which bifurcates just below Station 34. A small channel from the West Head (Stations 28 to 32) enters the main channel just above the bifurcation point and both continue down the estuary and empty into a large central area (Stations 51, 52). The upper part of the Channel system in the East Head appears to be the remnant of a river channel; however, the channels in the open part of the inlet appear to be formed by tidal currents.

The inlet can be subdivided into several general areas: the nearshore area (Stations 51 to 55) where the channels disappear into a large, turbulent, shallow zone that is no longer intertidal; a large central region containing large mudflats and many drumlin islands; and an upper region which has comparatively narrow channels and a well-developed marsh area (East and West Heads). Additionally, there is a "pond" (stations 42 to 44) that is normally supplied with sea water only by a narrow channel.

OCEANOGRAPHY

All currents in the inlet appear to be the result of tidal action. These currents are confined largely to the major channels and reach adjoining mudflats only during high tides. Although the estuary has a fairly large surface area its tidal prism is comparatively low because most of the water is contained in the channels which are small compared with the total area they supply. At low tide all of the water is contained in these channels and the mudflats are subaerially exposed. Consequently the freshwater input, though it is comparatively low due to the lack of any major rivers, dilutes the incoming seawater substantially, especially at low tide. This contrasts sharply with the LaHave estuary near Lunenburg, Nova Scotia, which is associated with a large river but has a smaller surface area. Seawater is not diluted as much as in Chezzetcook because LaHave is deeper and has a larger tidal prism (Allen and Roda 1977).

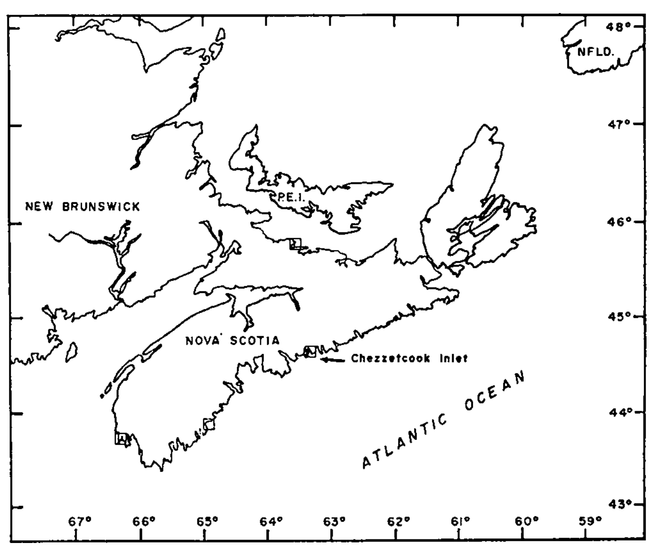

FIG. 1 Regional map of the Maritimes showing the location of Chezzetcook Inlet.

TABLE 1

The estuarine oceanographic information for the Chezzetcook station, including date of collection, time, salinity, temperature, water depth, % carbon.

			SALINITY ‰						TEMPERATURE °C							
DATE	TIME	STATION	0 m	1 m	2 m	3 m	4 m	5 m	0 m	1 m	2 m	3 m	4 m	5 m	% C	WATER DEPTH
6/3/76	1310	35B	27.9	28.75					12.7	11.2					1.9%	.5m
6/3/76	1320	35C	25.0	27.1					14.00	12.6					*	1 m
6/3/76	1330	35D	26.14	28.1					14.25	12.0					5.5%	1 m
6/3/76	1340	35E	24.3	27.00					14.45	12.90					3.9%	1 m
6/15/76	1210	36A	29.6	30.62					12.70	10.5					18.3%	1 m
6/15/76	1220	36B	29.62	31.0	30.78				11.75	8.69	8.65				3.2%	1.3m
6/15/76	1230	36C	30.6	31.0	31.0	30.8			10.45	9.3	8.98	8.75			*	3 m
6/15/76	1240	36D	30.95	30.94					9.95	9.55					7.5%	1 m
6/16/76	1130	36E	27.9	30.3					16.2	13.8					4.9%	1 m
6/16/76	1140	36F	30.8	30.6	30.9	30.8			12.6	12.3	12.0	12.0			*	3 m
6/16/76	1150	36G	30.7	30.4					12.2	12.2					3.0%	1 m
6/15/76	1255	37A	30.9	30.9					8.80	8.59					1.7%	1 m
6/15/76	1305	37B ≠	30.6	30.75	30.9				10.0	9.3	8.75				3.6%	5 m
6/15/76	1315	37C	29.65						13.75						13.0%	.1m
6/15/76	1420	37D	30.35	30.7					11.2	11.08					1.8%	1 m
6/15/76	1430	37E	31.3	30.82					12.9	11.47					1.5%	.7m
6/15/76	1440	37F ≠	29.9	29.8	30.0				13.25	12.9	13.0				*	4 m
6/15/76	1340	38A	30.7	30.75					9.5	9.45					3.3%	1 m
6/15/76	1350	38B	30.8	30.65					9.95	10.10					1.4%	1 m
6/15/76	1400	38C ≠	30.35	30.45					10.6	10.4					*	5 m
6/16/76	1200	39A	31.0	31.0					10.8	10.75					5.0%	1 m
6/16/76	1210	39B	31.3	31.8					8.0	7.7					2.4%	1 m
6/16/76	1220	39C	31.3	31.3	31.4	31.25	31.4		9.3	8.8	8.2	8.4	8.3		0.8%	4 m
6/16/76	1240	40A	31.0	31.2					9.85	9.2					2.0%	1 m
6/16/76	1250	40B	30.83	31.6	31.4	31.5	31.6	31.4	9.40	8.50	8.10	8.0	8.1	7.9	1.1%	5 m
6/16/76	1410	40C	31.6	31.2					11.4	11.2					3.0%	.75m
6/16/76	1420	40D	30.3	31.2					14.3	11.8					19.3%	1 m
6/16/76	1430	40E	30.8						14.7						6.6%	.1 m
6/16/76	1300	41A	31.7	31.5					7.1	7.4					2.2%	1 m
6/16/76	1310	41B	31.3	31.5	31.4	31.3	31.4		9.90	8.9	7.5	7.3	7.4		1.1%	4 m
6/16/76	1320	41C	31.7	31.7					9.00	7.6					3.1%	1 m
6/16/76	1330	41D	31.4	31.8	31.6	31.4			8.50	7.80	7.40	7.10			3.0%	3 m
6/16/76	1340	41E	31.7	31.8					8.10	8.20					4.6%	1 m
6/16/76	1530	42A	31.4	31.2					18.60	16.90					16.0%	1 m
6/16/76	1710	42B	31.4	31.3					15.0	14.40					15.8%	.5m
6/16/76	1600	43A	30.82	31.0					13.2	13.1					14.7%	.5m
6/16/76	1610	43B	31.2	31.0					12.10	12.50					11.4%	1 m
6/16/76	1620	43C	31.3	31.1					12.30	11.80					13.6%	1 m
6/16/76	1640	44A	31.2	31.2					13.70	13.45					17.4%	1 m
6/16/76	1650	44B	31.2	31.3					13.4	13.4					20.4%	1 m
6/16/76	1700	44C	31.4	31.3					14.3	14.1					20.7	1 m
9/30/76	1010	49	24.25	24.7	25.85	26.6			11.7	11.0	11.3	10.8			<1%	3 m
9/30/76	1334	49	31.0	31.15	31.3				11.3	11.4	11.0					
9/30/76	1030	50	27.25	27.0	27.2	27.2			11.27	11.95	11.1	10.85			<1%	3 m
9/30/76	1315	50	30.5	31.2	31.2				11.35	10.9	10.7					
9/30/76	1050	51	29.7	29.3	29.7				11.6	11.3	11.5				<1%	2 m
9/30/76	1300	51	31.9	31.4	31.1	31.7			10.45	10.2	10.3	10.3				
9/30/76	1110	52	30.05	30.27	30.5	30.2			11.35	11.64	11.4	11.50			<1%	3 m
9/30/76	1140	53	31.1	31.4	31.53	31.55			11.55	11.3	10.45	10.32			<1%	2.4m
9/30/76	1155	54	31.53	31.28	31.55	31.65	31.6		10.4	9.75	9.4	9.2	9.2		<1%	3.75m
9/30/76	1220	55	31.0	30.69	31.5	31.6	31.9	31.7	11.8	11.7	11.3	9.18	9.35	9.25	<1%	4.5m

≠ indicates no bottom values obtainable because of strong currents,

* indicates insufficient bottom material recovered for carbon analysis.

TABLE 2

The estuarine oceanographic information for the Chezzetcook station, including date of collection, time, salinity, temperature, water depth, % carbon.

			SALINITY ‰						TEMPERATURE °C							
DATE	TIME	STATION	0 m	1 m	2 m	3 m	4 m	5 m	0 m	1 m	2 m	3 m	4 m	5 m	% C	WATER DEPTH
5/24/76	1150	21A	0.00	0.00					12.75	12.65					15.5%	.5 m
5/24/76	1200	21B	0.00	0.00					12.55	12.48					13.6%	.75 m
5/24/76	1210	21C	0.00	0.00	1.82				12.55	12.50	12.45				10.6%	2 m
5/24/76	1215	21D	0.00	0.00					12.23	12.23					11.5%	.3 m
5/24/76	1230	22A	0.00	0.00					12.90	12.68					11.1%	.3 m
5/24/76	1240	22B	0.00	0.00	0.00				12.76	12.66	12.43				10.6%	1.5 m
6/3/76	1110	22B	1.6	11.55	12.95				15.6	13.9	13.65					
6/3/76	1405	22B	0.00	13.43	17.2				16.32	14.8	14.4					
5/24/76	1250	22C	0.00	0.00					12.80	12.97					8.9%	.3 m
5/24/76	1300	22D	0.00	0.00					13.16	13.22					12.3%	.3 m
5/24/76	1330	23A	0.00	0.00					13.25	13.22					8.1%	.3 m
5/24/76	1340	23B	0.00	0.00	0.00	0.00			12.95	12.70	12.70	13.20			5.1%	2.5 m
6/3/76	1120	23B	9.6	14.3	14.3				15.3	13.58	13.92					
5/24/76	1350	23C	0.00	0.00					13.04	13.00					7.9%	.3 m
5/28/76	1030	24A	4.13	12.95					11.80	10.65					9.6%	1 m
5/28/76	1045	24B	1.00		20.73				11.80	10.46	10.00				4.6%	2 m
5/28/76	1145	24C	2.55	9.93					12.40	11.55					7.3%	1 m
6/2/76	1130	25A	10.03	16.92	17.7				14.70	12.80	13.00				8.2%	1.5 m
6/2/76	1140	25B	12.40	17.83					14.20	12.9					11.4%	1 m
6/2/76	1150	25C	10.30	18.50					14.70	12.83					9.7%	1 m
6/2/76	1200	26A	15.95	19.1					14.02	13.15					10.0%	1.5 m
6/2/76	1210	26B	15.05	20.3	21.12				14.89	12.7	12.3				11.0%	1.5 m
6/2/76	1220	26C	18.28	19.8					13.93	13.35					9.7%	1 m
6/2/76	1240	27A	19.18	19.9					13.52	13.33					20.6%	1 m
6/2/76	1250	27B	17.03	21.16	23.0	23.3	22.0		14.55	12.62	12.06	11.70	11.92		7.9%	4 m
6/2/76	1300	27C	19.45	21.25					13.50	12.60					10.5%	1 m
6/2/76	1330	28A	11.52	11.6					15.52	15.70					14.5%	.5m
6/2/76	1340	28B	10.5	11.85	12.5				16.20	15.50	15.35				9.8%	1.5m
6/2/76	1350	28C	9.54	11.9					16.20	15.50					13.8%	1 m
6/2/76	1400	29A	10.5	12.07					16.50	16.10					6.2%	.75m
6/2/76	1410	29B	10.5	12.93	14.80				16.70	15.50	14.70				10.5%	1.5m
6/2/76	1420	29C	9.65	12.2					14.08	16.4					8.8%	.5 m
6/2/76	1430	30A	12.77	13.80					16.40	15.80					9.6%	1 m
6/2/76	1440	30B	12.33	15.3	16.7				16.91	14.70	14.23				10.3%	2 m
6/2/76	1450	30C	11.7	13.55					17.0	16.0					9.5%	.5m
6/2/76	1500	31A	15.13	13.6					17.0	16.5					12.7%	1 m
6/2/76	1510	31B	12.97	15.1	19.6	19.9			17.35	14.7	13.6	13.5			4.4%	2.5m
6/2/76	1520	31C	12.89	13.1					18.4	18.3					8.4%	.75m
6/2/76	1530	32A	14.8	14.9					16.73	16.70					7.5%	.25m
6/2/76	1540	32B	14.05	19.25	20.6				17.0	15.2	15.0				*	2 m
6/2/76	1550	32C	14.55	14.75					17.95	17.02					9.8%	.25m
6/3/76	1130	33A	15.7	19.2					15.65	14.6					7.9%	1 m
6/3/76	1140	33B	17.17	20.28	21.2	26.78			15.15	14.35	15.92	14.2			5.2%	3 m
6/3/76	1150	33C	21.5	21.43					14.05	13.93					4.0%	1 m
6/3/76	1200	33D	21.5	21.3					14.70	14.17					5.6%	1 m
6/3/76	1210	34A	22.28	22.75					14.6	14.25					14.3%	1 m
6/3/76	1220	34B	22.3	23.00					15.5	15.5					11.6%	1 m
6/3/76	1230	34C	25.25	25.8	25.8	26.4			13.55	12.90	12.80	12.72			7.3%	3 m
6/3/76	1240	34D	24.6	25.00					13.7	13.6					4.6%	1 m
6/3/76	1300	35A	25.9	28.9	28.9	28.75	26.8		13.89	11.20	11.3	11.00	11.3		0.9%	4 m

≠ indicates no bottom values obtainable because of strong currents,

* indicates insufficient bottom material recovered for carbon analysis.

Several zones can be recognized and briefly described in terms of maximum salinities recorded in these areas. The upper estuarine subzone A (Stations 21A to 27A, 28A to 30C) has an average salinity of 15.8 o/oo (SD. = 3.20 o/oo) with values from 11.6 to 21.1 o/oo, with the lowest values occurring in the West Head. The upper estuarine subzone B (Stations 27B, C, 31A to 34C) has an average salinity of 20.4 o/oo (SD = 4.31 o/oo), with values ranging between 13.1 and 26.4 o/oo, and the highest values occurring at the boundary with the lower estuarine zone. The lower estuarine zone (Stations 34D to 39A) has an average salinity of 29.7 o/oo (SD. = 1.71 o/oo) with values ranging between 25 and 31 o/oo with highest values on boundary with the open bay zone. The open bay zone (Stations 39B to 41E) has an average salinity of 31.4 o/oo (SD = .29 o/oo) with values between 30.8 and 31.8 o/oo. The nearshore zone is identical to the open bay zone in terms of salinity. The sparse data that could be obtained at low tide demonstrate that salinities can be much lower during low tide. Low tide bottom-water salinities at Stations 21 to 23 ranged from 0 to 2 o/oo, while high tide salinities for stations 22B and 23B ranged from 13 to 17 o/oo. These stations are at the head of the estuary where the maximum variability would be expected with decreasing variability down the estuary. However, in the bottom water, salinity variations remain surprisingly high even near the mouth of the estuary. At Stations 49, 50, and 51 values of 26, 27 and 29 o/oo respectively were obtained two hours before high tide. The same stations recorded values of 31, 31, and 31 o/oo one hour after high tide, showing increases of 5, 4 and 2 o/oo with high tide.

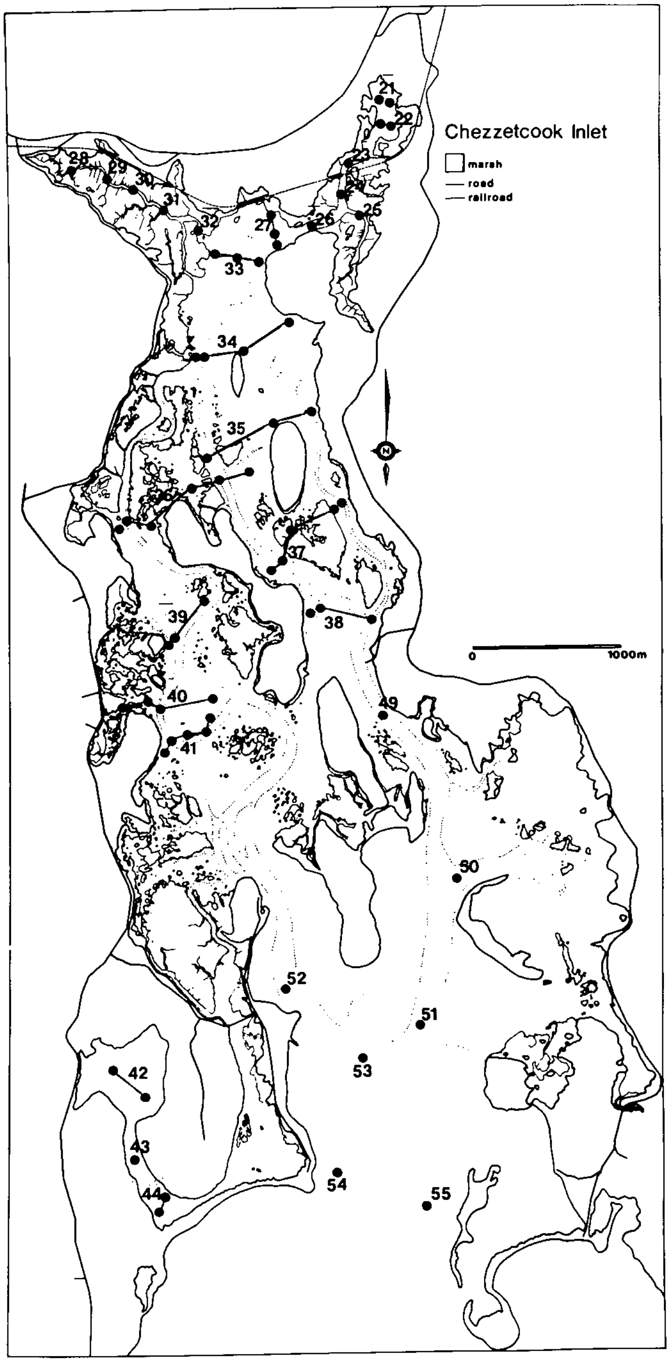

FIG. 2 Chezzetcook Inlet station locations. Dashed lines are channel boundaries; outside those lines the area is intertidal-mudflat and salt marsh. Because some sampling localities are close together, dots on the map may represent more than one locality.

Stations in the "pond" area (Stations 42-44) had uniformly high salinities (31 o/oo) at the time of sampling. Salinities here probably do not change substantially with the tidal cycle because of almost non-existent tidal action. At the time of measurement salinities were high because the sand barrier just seaward of Station 44 had recently been breached by storm waves, allowing large amounts of undiluted sea water to invade the area, but the "pond" was slightly brackish until recently as evidenced by the dead fresh-water plants that were observed during sampling.

The water temperatures in the inlet are controlled by two factors: atmospheric temperatures and ocean water temperatures. Atmospheric temperatures are the most variable. In areas where there is less oceanic influence (i.e. near the head of the estuary) water temperatures are close to air temperatures. The presence of a sharp halocline is usually associated with a well defined thermocline with warmer, less saline water on top and colder more saline oceanic water below. During the winter when the ocean is warmer than the atmosphere, there is probably a reverse thermocline with warmer, oceanic water below colder, less saline water. Because of ice conditions, this could not be verified. Bottom water temperatures at the head of the estuary probably vary from -0.5 (?) to $+20^{o}C$ over the year while temperatures at the mouth may vary between -.5 and $+12^{o}C$, approximately the same as the ocean.

The Chezzetcook estuary cannot be simply classified as stratified, partially stratified, or vertically mixed because all three types are present. The estuary tends to be more stratified near the head and less stratified seaward. The stratification depends on the supply of freshwater and this supply decreases seaward. Stratification is most pronounced at high tide at the head of the estuary (e.g. Sta. 22B, June 2) and at low tide near the mouth (e.g. Sta. 49, 1010 h)

The tidal range of the inlet varies between the upper and lower parts of the estuary. At the East Head of the estuary tidal gauge data taken at the railroad trestle show the maximum tidal range to be 186 cm with higher high water at +192 cm and lower low water at +6 cm with Z_o (mean sea level) at +107 cm. The mouth of the estuary is taken to be the same as that observed at Halifax which has a maximum range of 214 cm with higher high water at +226 cm and lower low water at +12 cm with Z_o being at 125 cm.

SURFICIAL SEDIMENTS

The distribution of sediments with respect to grain size followed the characteristic pattern of a shallow, marine-dominated, estuarine-lagoon system. Fine sediments at the head of the estuary grade to coarser sediments at the mouth (Phleger 1969, 1977). The modal grain size in the channels is at least one size class larger than sediments found on adjoining mudflats. In some river-dominated systems, such as Miramichi (Reinson 1976), the opposite occurs: finer sediments occur in channels and coarser sediments occur on adjoining shallow areas.

Organic carbon content of the sediments is 10 to 15% (dry weight) near the head and decreases to less than 1% at the mouth (Sta. 49-55). Values on the mudflats were generally higher than in the channels.

CONCLUSIONS

From the information discussed it is clear that shallow intertidal estuaries are subject to much greater environmental variations than deeper ones. In Miramichi estuary, New Brunswick, which is mostly subtidal but only 3 to 5 m deep, average salinities are comparable to those in Chezzetcook but short term variability is much lower (Krauel 1975, Scott *et al* 1977). In deeper estuaries, such as Halifax Harbour, short term variability is even less.

Because of Chezzetcook's relatively low tidal prism, the comparatively small amount of freshwater runoff substantially dilutes the seawater. If the flow of either fresh or seawater into the inlet was to be altered in any way, the salinity patterns could change dramatically. This is not true in larger systems such as the Miramichi where changes are buffered by the large volumes involved. Hence, Chezzetcook, and shallow systems such as this, are subject to more ecologic damage in instances of unusual drought or excessive runoff. This type of system is also more susceptible to damage by artificial means such as causeways. This is painfully obvious in the Lawrencetown inlet (a shallow inlet just west of Chezzetcook) where causeways have severely restricted tidal flow and caused a brackish-stagnant condition in most of the estuary.

Although shallow estuaries may appear unimportant, they usually are areas of high biologic production (e.g. natural incubators for many types of commercial fishes) and the adjoining salt marshes provide nutrients, not only to the estuary, but also to the ocean waters enhancing commercial fishing prospects. For this reason any manmade alterations to these systems must be carefully evaluated.

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APPENDIX 2

May 24, 1976:	High - 0555 (+ 162 cm) Low - 1155 (+ 76 cm) High - 1610 (+ 183 cm)
May 28, 1976:	High - 0850 (+ 180 cm) Low - 1440 (+ 73 cm) High - 2050 (+ 196 cm)
June 2, 1976:	Low - 0600 (+ 49 cm) High - 1155 (+ 192 cm) Low - 1830 (+ 79 cm)
June 3, 1976:	Low - 0655 (+ 49 cm) High - 1240 (+ 192 cm) Low - 1920 (+ 76 cm)
June 15, 1976:	Low - 0535 (+ 30 cm) High - 1115 (+ 205 cm) Low - 1805 (+ 67 cm)
June 16, 1976:	Low - 0630 (+ 40 cm) High - 1250 (+ 199 cm) Low - 1850 (+ 73 cm)
September 30, 1975:	High - 0045 (+ 183 cm) Low - 0730 (+ 70 cm) High - 1250 (+ 189 cm) Low - 2015 (+ 52 cm)

Tidal cycles for the days sampled in this study (from standard tide book for Halifax). Times adjusted to Atlantic Daylight Time.