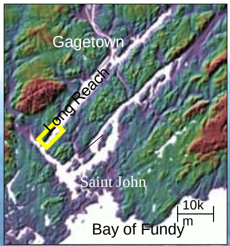

Figure 1

Internal waves and Interfacial mixing in the Saint John River Estuary New Brunswick, Canada

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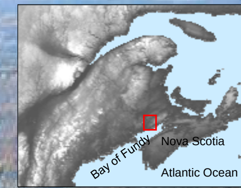


Mixing in coastal areas tends to be of a major concern due to its influence on the distribution of polluted waters, biological activity production, sedimentation, recreation and commercial activities. This study presents oceanographic results observed in the Saint John River Estuary New Brunswick, Canada where interfacial mixing and internal waves were observed. The Saint John River originates in Maine U.S.A. and flows in a southerly direction into New Brunswick, Canada where it empties into the Bay of Fundy (see Figure 1) via the town of Saint John. In the Bay of Fundy the tidal range can be as great as 16 m, however at Saint John it is ~8 m. When River discharge is low, salt water from the Bay of Fundy advects to ~60km upstream the River, creating estuarine conditions. This study concentrates on the upper section of the estuary in an area known as Long Reach. The study area is at 4.5 km stretch in Long Reach where the tidal range is 0.4 m and the bathymetry is very irregular with several shoals and deep hole areas existing (see Figure 2). The results of oceanographic surveys (using a CTD, echosounder and ADCP) performed for the duration of a tidal cycle show that soliton wave packets, Holmboe waves, the dipping of the pycnocline and interfacial mixing all occur in the estuary.

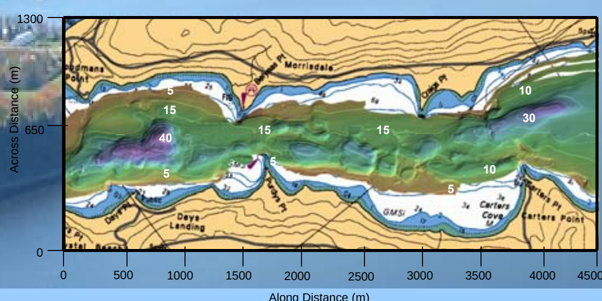


Figure 2: Bathymetry map of Long Reach

Generation and dissipation of soliton wave packets

- Soliton wave packets are observed from late falling tide when flow in both the surface and bottom layer are downstream. When a decrease in bottom velocity and a change in the bottom flow direction from downstream to upstream occurs, the solitons all diminish/disappear (see Figure 3).

Time	Phase of Tide	Observations
1608h	Falling	Soliton first appear at the 2500 m and 3400 m marker
1807h	Falling	Solitons appear at the 1700 m, 2300 m, 2500 m and 3400 m marker
1829h to 1949h	Falling	Solitons disappear at the 1700 m, 2300 m and 2500 m marker
2029h to 2048h	Rising tide	Soliton disappears at the 3400 m marker. Downward dip of the pycnocline first occurs at the 1700 m marker.

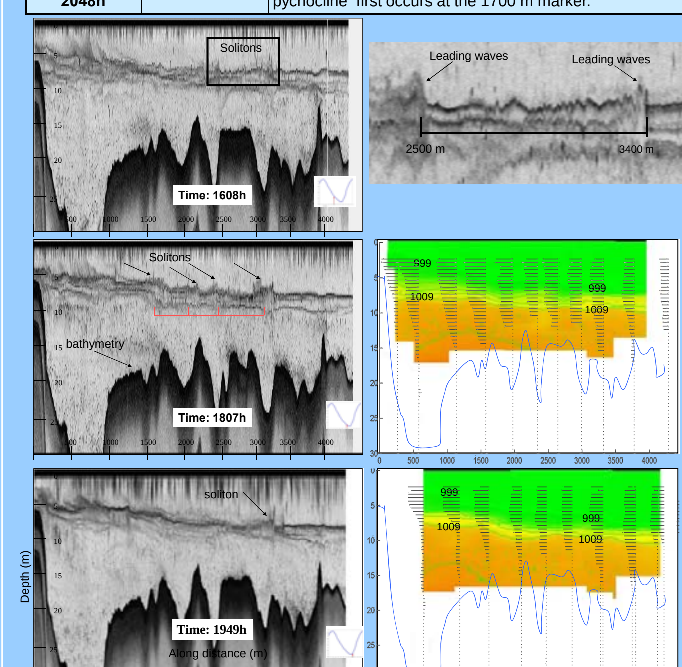


Figure 3: Echosounder and density images showing soliton wave packets

Downward Dip of Pycnocline and Holmboe waves

- At the onset of rising tide a downward dip of the pycnocline occurs in the locations where there are shoals followed by deep areas (see Figure 4).
- A decrease in density and thickening of pycnocline occurs in the locations where the downward dips takes place
- Holmboe waves are identified on the echosounder images and results of a linear stability analysis also suggest that they may be present.

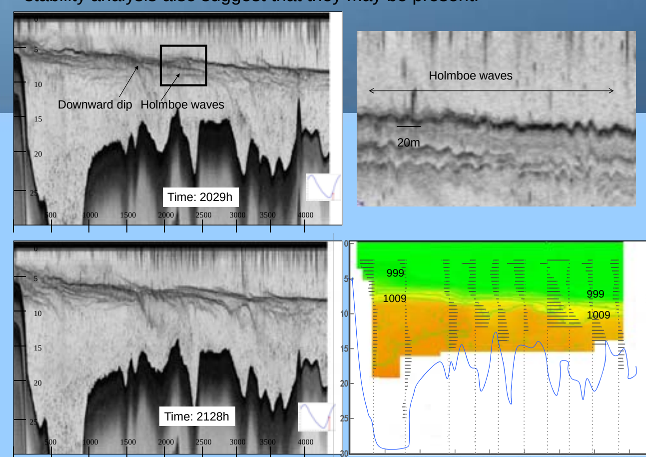
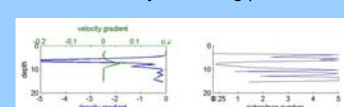


Figure 4: Echosounder and density profiles showing the downward dip of pycnocline and Holmboe waves

Gradient Richardson number and linear stability analysis

- Using the gradient Richardson number (Ri) interfacial mixing was identified to occur where the downward dips and decrease in density are taking place. This occurred at the base of the pycnocline

$$Ri = -\frac{\frac{g}{\rho}\frac{\partial \rho}{\partial z}}{(\partial u/\partial z)^2}$$



- Linear stability analysis using both piecewise approximation (P) and hyperbolic tangent approximation identified Holmboe waves as being present in the estuary

Time	ε Asymmetry of flow		J Bulk Richardson		Wave number (w)		Predicted wavelength k (m)		Observed wavelength k (m)
	P	H	P	H	P	H	P	H	
2041	-0.7	-0.7	1.43	1.44	2.2	1.3	10.47	16.9	12
2053	-0.5	-0.46	1.23	1.3	2.2	1.3	8.56	14.5	20
2055	-0.88	-0.88	0.93	0.9	1.75	0.9	9.68	18.85	15
2157	-0.66	-0.92	0.996	1.48	1.8	1	10.46	16.9	14

Conclusion

- The flow in the estuary was observed to be very complex with solitons wave packets, Holmboe waves, downward dips of the pycnocline and interfacial mixing occurring
- It is possible that the interfacial mixing observed was influenced by the soliton wave packets and/or Holmboe waves. However it is also possible that the interfacial mixing observed was influenced by the flow as it passed over the shoal and deep areas causing mixing to occur