

7.6 Stable Isotope Evidence for Water Mass Mixing in Jamaica Bay

James Rubenstone

7.6.1 INTRODUCTION: $\delta^{18}\text{O}$ AS A WATER MASS TRACER

Natural processes in the hydrologic cycle fractionate the heavier isotopes of oxygen from the lighter ones. Oxygen isotopes in water are conventionally given in δ notation, as per mil (‰; parts per thousand) deviation of $^{18}\text{O}/^{16}\text{O}$ relative to standard ocean water. The fractionation in surface waters of eastern North America exceeds 10‰ (e.g. Fairbanks, 1982). Stable isotopes then can serve as a tracer of freshwater mixing in estuaries such as Jamaica Bay. The surface water gradient in $\delta^{18}\text{O}$ means that different potential freshwater sources in Jamaica Bay will have distinct isotopic signatures: local precipitation, for example, is less isotopically depleted than freshwater advected from the Hudson River, which averages water from a large drainage in upstate New York. Freshwater outfalls from sewage treatment plants feeding into the bay will also show $\delta^{18}\text{O}$ values intermediate between local precipitation and Hudson River water, as New York City municipal water is drawn from upstate reservoirs.

In mid-latitudes $\delta^{18}\text{O}$ is conservative in water masses, and is positively correlated with salinity; fresh water is isotopically lighter (more negative $\delta^{18}\text{O}$) than seawater. As noted by Paren and Potter (1984), expressing ^{18}O as $\Delta = (\delta^{18}\text{O} * (1-S))$ gives linear mixing relations on plots of Δ against salinity.

7.6.2 SAMPLING AND METHODS

Water samples were taken on nine separate dates in 2000, during June, July and September. The September sampling included a contiguous four day period, during which stations were reoccupied several times over the course of the tidal cycle. Sampling locales are shown in Figure 7.6-1. Note that sampling for stable isotopes included portions of the bay which

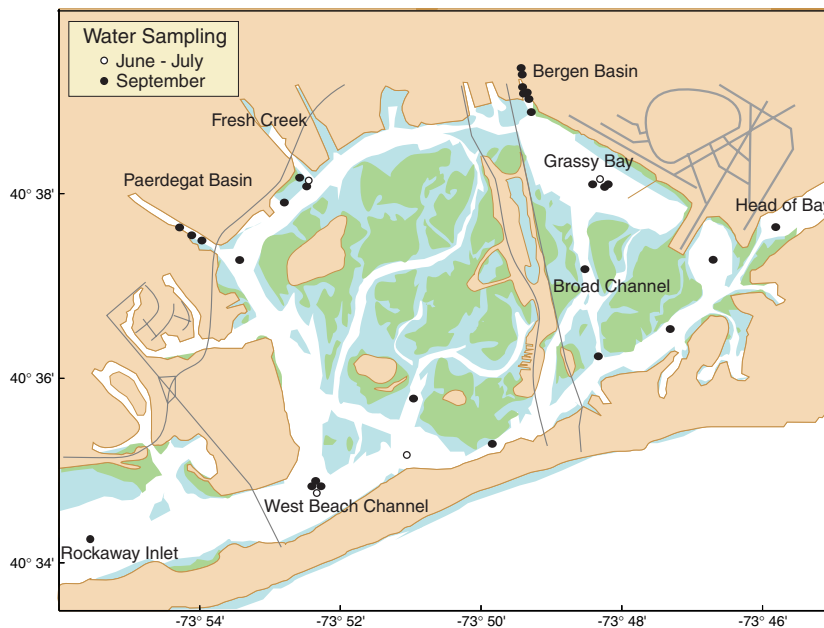


Figure 7.6-1 Water sampling locations in Jamaica Bay

were not subject to the detailed CTD studies described elsewhere in this report. Specifically, these are the small basins on the northern margin (Paerdegat Basin, Bergen Basin), and the eastern end of the bay (Head of Bay, Thurston Basin, and Grassy Bay east of the runway 4-22L extension). Depth profiles were sampled using a peristaltic pump with the water intake attached to a real-time monitored CTD for depth control.

Stable isotopes were measured on a VG Prism dual-inlet mass spectrometer, and are reported relative to V-SMOW water standard. Repeated analysis of standards indicates a measurement accuracy of better than 0.01‰. Salinity was measured on all samples on a Guildline Portasal, calibrated to IAPSO standard seawater.

7.6.3 RESULTS: $\delta^{18}\text{O}$ VARIATIONS AND VERTICAL STRUCTURE IN JAMAICA BAY

Although Jamaica Bay is relatively small and tidal exchange is strong, stable isotopes can resolve distinct water signatures within different portions of the bay. While not as sharply defined as traditional oceanographic water masses, these signatures have geographical coherence and appear to follow circulation (and isolation) patterns within the bay. The following discussion draws mostly on the more extensive sampling during September, when late summer conditions prevailed. Similar patterns are suggested for the earlier samplings, and differences will be discussed in a later section.

Four such signatures are discerned. Figure 7.6-2 shows the mean $\delta^{18}\text{O}$ of surface water at 9 representative stations sampled in September 2000, which illustrate the four sets described here.

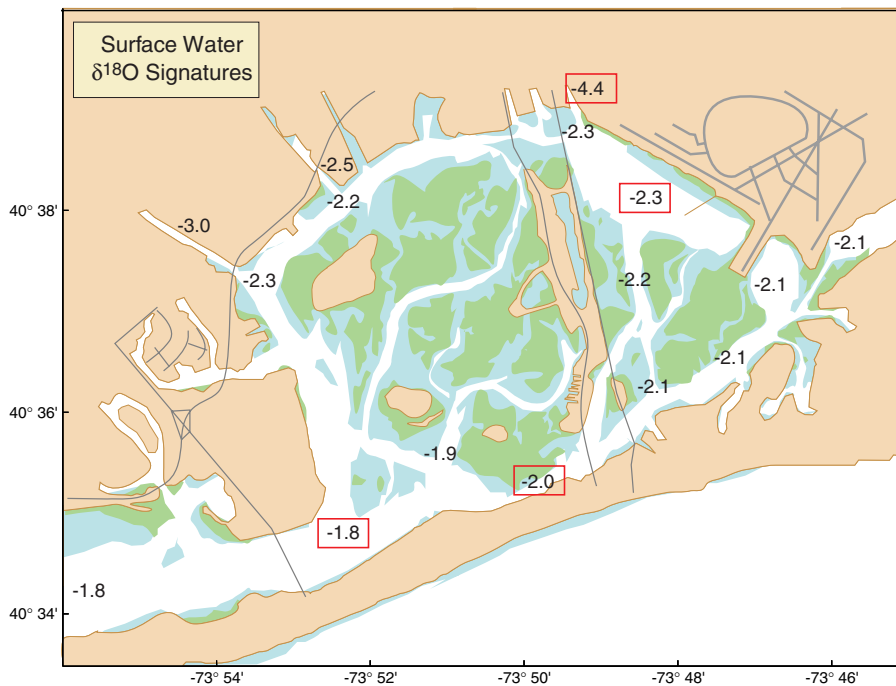


Figure 7.6-2. $\delta^{18}\text{O}$ signatures of Jamaica Bay surface water types. Values are shown (‰) for representative analyses, from the September survey. Red boxes mark the four “signatures” discussed in text: West Beach Channel (-1.8); South Channel (-2.0); Grassy Bay (-2.3); northern basins (-4.4).

The first is water that occupies western end of Beach Channel and Rockaway Inlet. Not surprisingly, this water is the most like the coastal marine waters found outside the bay, but is measurably fresher and isotopically lighter, reflecting the freshwater contribution from within the bay. During the September surveys this water had $\delta^{18}\text{O}$ of -1.8‰ , and showed essentially no stratification, with less than 0.05‰ difference in $\delta^{18}\text{O}$ in any profile. The vertical mixing is consistent with the strong tidal currents at the bay entrance.

Water filling the channel along the south side of the bay also appeared well mixed vertically and was fairly uniform in its stable isotope composition, although isotopically distinct from that in West Beach Channel. Water at a station about 3km east of the West Beach Channel station is slightly fresher and has $\delta^{18}\text{O}$ of -2.0‰ . A small gradient in salinity and $\delta^{18}\text{O}$ exists from this point east to Head of Bay and the east end of Grassy Bay (east of the runway extension), but with little if any vertical stratification. In these basins $\delta^{18}\text{O}$ was as low as -2.09‰ , reflecting a relatively small freshwater contribution. Values as low as -2.16 were measured in surface water of the small Thurston Basin at the far eastern end. Overall, mixing along this southern margin of the bay appears more complete than in the more restricted min part of Grassy Bay.

Grassy Bay represents the third isotopic signature. Water here showed the strongest vertical stratification in salinity and $\delta^{18}\text{O}$ within the bay (Figure 7.6-3). At its most stratified,

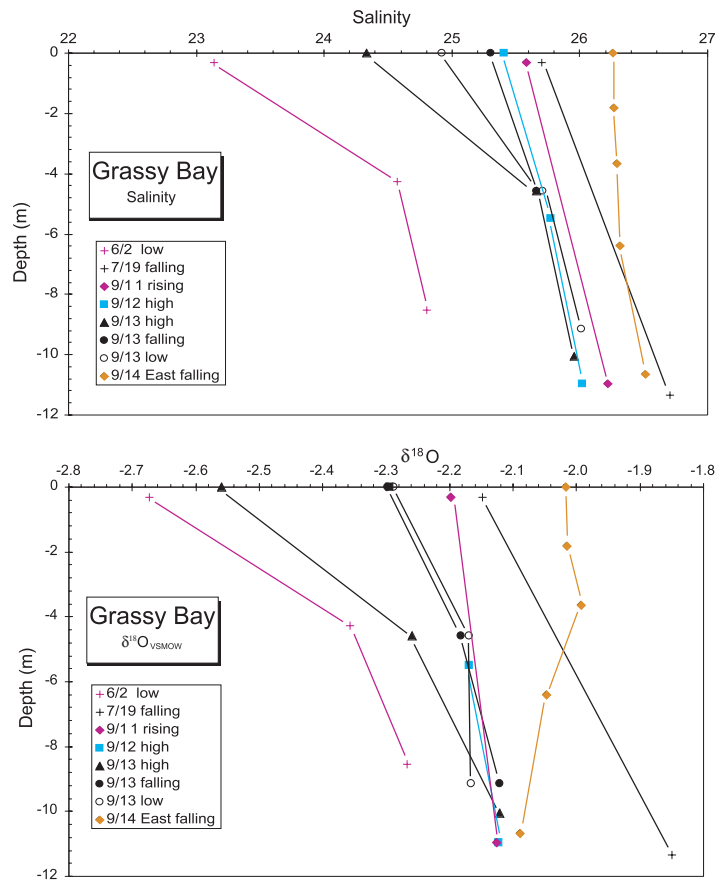


Figure 7.6-3. Salinity and $\delta^{18}\text{O}$ profiles in Grassy Bay, west of runway extension (one to east is noted). Date and tidal stage given in legend.

Grassy Bay surface water is about 1.4‰ fresher and 0.4‰ lower in $\delta^{18}\text{O}$ than at depth. The relatively low $\delta^{18}\text{O}$ of Grassy Bay surface water is similar to that seen in surface water along the north channel, consistent with this being the main flushing path for Grassy Bay. The gradient in surface $\delta^{18}\text{O}$ through Broad Channel, the other main opening to Grassy Bay, suggests that this route is of lesser significance. Notably, while their surface waters are distinct, the bottom waters on either side of the runway extension in Grassy Bay are more similar in salinity and $\delta^{18}\text{O}$.

The fourth distinct component observed in the bay is found in the small basins along the northern side, especially Bergen and Paerdegat Basins. The lowest salinity and $\delta^{18}\text{O}$ was found in Bergen Basin (15.8‰ and -4.4‰ , respectively), in a thin (<1 m) surface lens overlying saltier water. The other small basins show similar though less dramatic freshenings. These freshwater sources are presumed to be water treatment plants. These freshwater sources, that release into small restricted basins, persist until the water enters the main northern channel. In contrast, stations near treatment plant outfalls in deeper basins or channels (i.e., in Head of Bay, in Beach Channel and in Rockaway Inlet) do not show fresher or isotopically lighter water. Mixing within the latter areas is more robust and rapidly disperses the local input.

7.6.4 SEASONAL VARIATION

Waters in both Grassy Bay and Beach Channel showed greater variability but were generally fresher and isotopically lighter in June and July compared to the September sampling (Figure 7.6-4). The differences are more pronounced in Beach Channel, which shows a mean increase of 2‰ in salinity and 0.3‰ in $\delta^{18}\text{O}$ between the early summer and September. The covariation of salinity and $\delta^{18}\text{O}$ (or Δ) mostly follows the main trend of the Jamaica Bay data, but there is

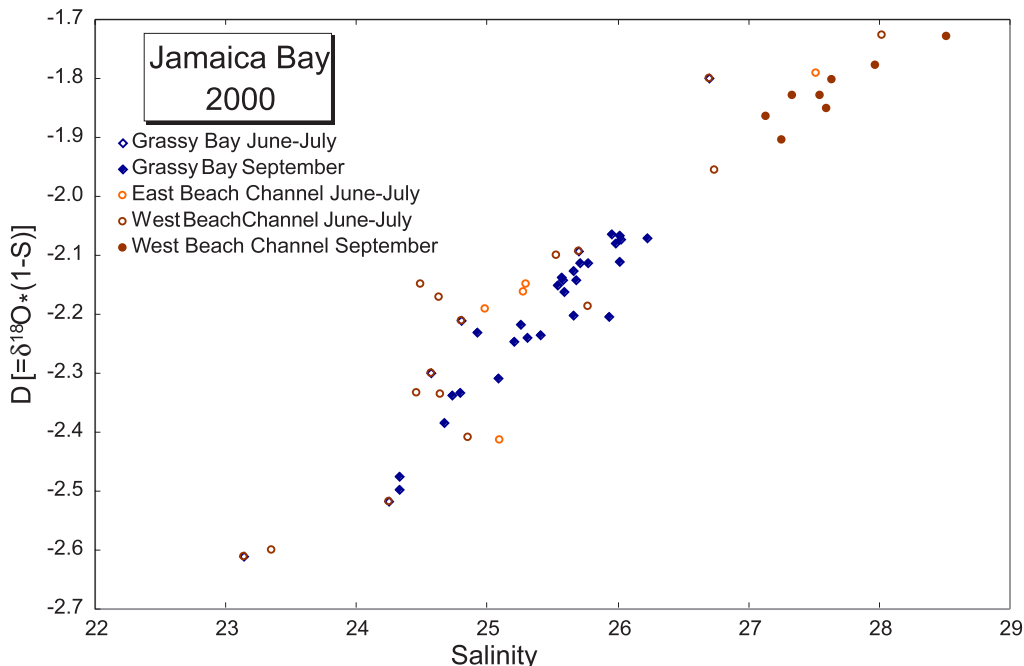


Figure 7.6-4. Changes in salinity and Δ between early and late summer in Grassy Bay and west Beach Channel.

some suggestion of a shallower slope in the shift between early June and September in Beach Channel. This may indicate that local precipitation was a more significant freshwater source early in the summer.

7.6.5 WATER SOURCES IN JAMAICA BAY

The present measurements in Jamaica Bay fit nicely into the known regional pattern of stable isotope in coastal waters. Figure 7.6-5 shows all of the Jamaica Bay data relative to water sampled off Breezy Point in September 2000, and to lines defined by previous studies of the offshore waters (Fairbanks, 1982). Surface waters of the New York Bight are mixtures of slope water and a freshwater component with $\delta^{18}\text{O} = -10$, identified as mean Hudson River outflow. The Breezy Point water is remarkably consistent with the New York Bight line, considering the samples were taken at different seasons (and more than 20 years later).

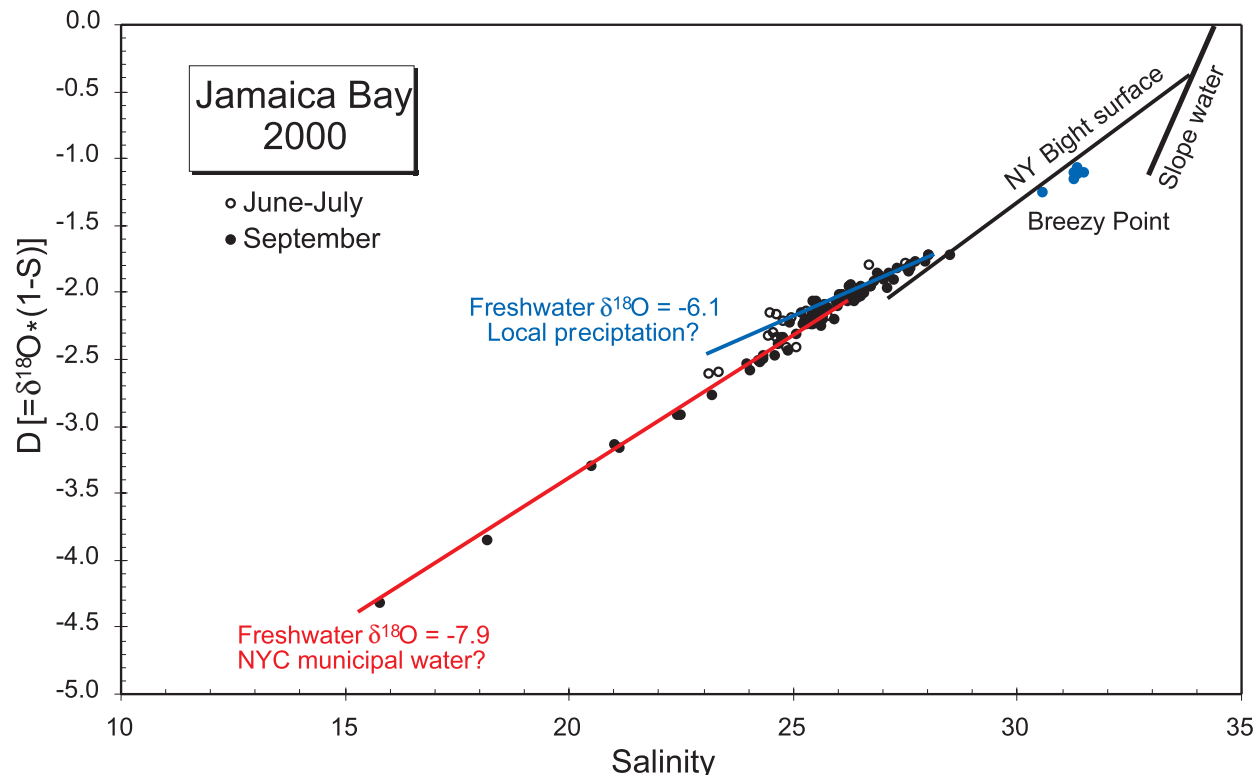


Figure 7.6-5. Salinity and Δ in Jamaica Bay in relation to nearby coastal waters. Black lines are defined for offshore slope water and surface water of the New York Bight (Fairbanks, 1982). The red line is a regression for the northern basins of Jamaica Bay, including Grassy Bay. The blue line shows the regression for the remainder of the Jamaica Bay samples.

Regressing the Jamaica Bay water data as a group in Δ -salinity gives a reasonably good line ($r^2 = 0.983$) whose intercept gives an average freshwater component with $\delta^{18}\text{O} = -7.4\text{‰}$. The scatter within the data however suggests that more than one freshwater component may be involved in Jamaica Bay. The waters found in the northern basins follow a mixing line with a slightly steeper slope than the entire data set, and indicate a freshwater endmember that is more depleted in ^{18}O than the average, with $\delta^{18}\text{O} = -7.9\text{‰}$. The spread within the remaining data are better fit with a shallower slope, whose freshwater intercept has $\delta^{18}\text{O} = -6.1\text{‰}$. These two endmembers may represent New York City municipal water and local precipitation (plus surface

runoff), respectively. The former is “imported” from upstate reservoirs and enters Jamaica Bay through treatment plants. We have no direct measurements of NYC water from September 2000. A sample taken in February 2001 had $\delta^{18}\text{O} = -8.45\text{‰}$; a seasonal offset of $\sim 0.5\text{‰}$ is reasonable based on seasonal sampling of New York rivers (Fairbanks, 1982). We likewise have no contemporary measurements of Jamaica Bay rainfall $\delta^{18}\text{O}$, but the inferred precipitation signal is also consistent with regional patterns.

These values can be used to quantitatively constrain the freshwater budgets within the bay. In Grassy Bay, 18-21% of the surface water and 14-15% of the bottom water is contributed by treated NYC municipal water, exclusive of any precipitation component. The data would require 21-24% freshwater if local precipitation were the only source. The main mass of water in West Beach Channel requires a freshwater component of 14% precipitation/runoff, or 10% NYC water. As both components contribute, these values represent limits for the total freshwater budget. As previously discussed, NYC water is a more significant contributor to Grassy Bay and the northern basins compared to the southern and eastern portions of Jamaica Bay.

7.6.6 REFERENCES

- Fairbanks, R. G., The origin of continental shelf and slope water in the New York Bight and Gulf of Maine: evidence from $\text{H}_2^{18}\text{O}/\text{H}_2^{16}\text{O}$ ratio measurements. *J. Geophys. Res.* 87, 5796-5808, 1982.
- Paren, J.G., and J.R. Potter, Isotopic tracers in polar seas and glacier ice. *J. Geophys. Res.* 89, 749-750, 1984.