Jamaica Bay Borrow Pit Evaluation Project
NYS DEC Water Quality Monitoring Report
2000-2002

NYSDEC Region 2
Marine Resources Program
Report on Field Monitoring Work
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1. Introduction

As ocean placement of dredged material is eliminated for an increasing proportion of NY Harbor sediment, alternative methods must be developed for managing dredged material. This means exploring an array of management techniques, considering not only their economic feasibility, but also their potential for ecological benefit. To explore all of the potential options, the New York District Corps of Engineers (US ACOE), in coordination with other federal, state and local agencies, including the New York State Department of Environmental Conservation, developed the Dredged Material Management Plan (DMMP) for NY/NJ Harbor. The DMMP identifies a number of options for management of dredged material, but has put a priority on options that employ beneficial re-use (as described in US ACOE, September 2001). One such option identified is restoration of subaqueous borrow pits in the Harbor, which are depressions on the bottom left from historical sandmining operations. Since it has been considered by many that raising the bottom in these areas to more natural conditions could have a beneficial environmental effect, placement of dredged material in borrow pits to improve ambient conditions would be consistent with the beneficial use concept of the DMMP.

Borrow pits have long been considered as possible sites for placement of Harbor dredged material. This was largely based on the supposition that borrow pits would tend to demonstrate impaired biological function due to conditions such as hypoxia or anoxia (little or no oxygen), and accumulation of contaminants associated with the small particle sediments that often settle there. These conditions would tend to develop due to the morphology or shape of these artificial deep pockets in the Harbor bottom. Water currents are reduced within the pits, creating relatively stagnant conditions at depth, and causing sediments to drop out of the water column and settle in the pit. Reduced oxygen and contaminated sediments lead to poor habitat function, and to the potential for creating an impacted area. These are generalizations, however, and conditions may differ in the various pits throughout the Harbor area. A careful analysis of any pit would have to be conducted in order to determine if a net environmental benefit could be achieved by recontouring.

Two pits in Jamaica Bay, located in Norton Basin and Little Bay, were identified in the DMMP as candidate sites, partly because of their isolated location (Little Bay is a sub-basin of Norton Basin, which is a secluded embayment in eastern Jamaica Bay), and because preliminary information indicated they were degraded environmentally. A pilot borrow pit evaluation project was developed to obtain the multi-discipline environmental information base needed in order to evaluate individual pits. To develop the program a technical committee was assembled, comprised of representatives from academic institutions, the National Marine Fisheries Service, the US Environmental Protection Agency, the National Park Service, the US Fish and Wildlife Service, the NYC Department of Environmental Protection, NYS Department of Environmental Conservation (DEC) and the US ACOE. This committee identified the relevant physical, chemical and biological parameters to be measured, and developed the scientific methods for field investigations to be conducted.

Commensurate with the larger study effort, the DEC Region 2 Marine Resources Program conducted water quality sampling throughout the study area over the past three years. This data-gathering effort was developed to be complementary to the overall investigations and the findings will be incorporated into the data set of the larger study. The subject of this report is the water quality data collected by the DEC Region 2 Marine Resources Program and the assessment of that information with respect to water quality in the Norton Basin and Little Bay pits and the reference areas in Jamaica Bay.

2. Study Area

Norton Basin and Little Bay are tributary embayments of Jamaica Bay (fig. 1). Both embayments have been artificially deepened in the past, partly to obtain material for the construction of Edgemere Landfill. There are a number of pit features within Norton Basin (figs. 2a & b) and Little Bay (fig. 2c). The major pits in Norton Basin are approximately 50 feet deep, while several pits in Little Bay are approximately 60 feet deep. These are relatively steep-sided pits, and are relatively sheltered from wind and currents that affect Jamaica Bay. The entrance channel to Norton Basin is shallow, thereby restricting tidal flows into the basins. The basins are not receiving any major land-based industrial inputs but there are municipal stormwater outfalls in Norton Basin, and Edgemere Landfill is a known source of leachate contamination. Figure 1 also shows the station locations for the study.

2.1 Borrow Pit Stations

Stations were established at the two dominant pit features in Norton Basin, Norton North (station 2), which is approximately 50' deep, and Norton South (station 3), which is approximately 42' deep. These deep features are separated by shallower depths which crest at approximately 34'. There are three distinct deep nodes in Little Bay, two of which exceed 60 feet. These two are within a few hundred feet of one another and are separated only by a minor sill feature, thus a single representative station, station 5 at 60' deep, was established in Little Bay.

2.2 Reference Areas

The interagency technical committee determined that more than one type of reference area should be included for comparison with the pits. Shallow and deep water reference stations were established both within Norton Basin/Little Bay and out in Jamaica Bay. The Norton Mouth station (1A), at 16’ deep, is a shallow reference of the basin, while the Norton Entrance station (1B), at 40’ deep, and Little Bay Entrance station (4), at 25’ deep, are intermediate reference areas within the basins. Reference stations in Jamaica Bay were established to allow comparison to areas of similar water depths as the pits but with different hydrological and physical conditions. Grass Hassock Channel (6), at 50' deep, is a deep water reference outside of the basins, and the Raunt stations (7 & 8), at 15' and 12' deep, respectively, are shallow water references outside the basins.

Figure 1

Station Locations

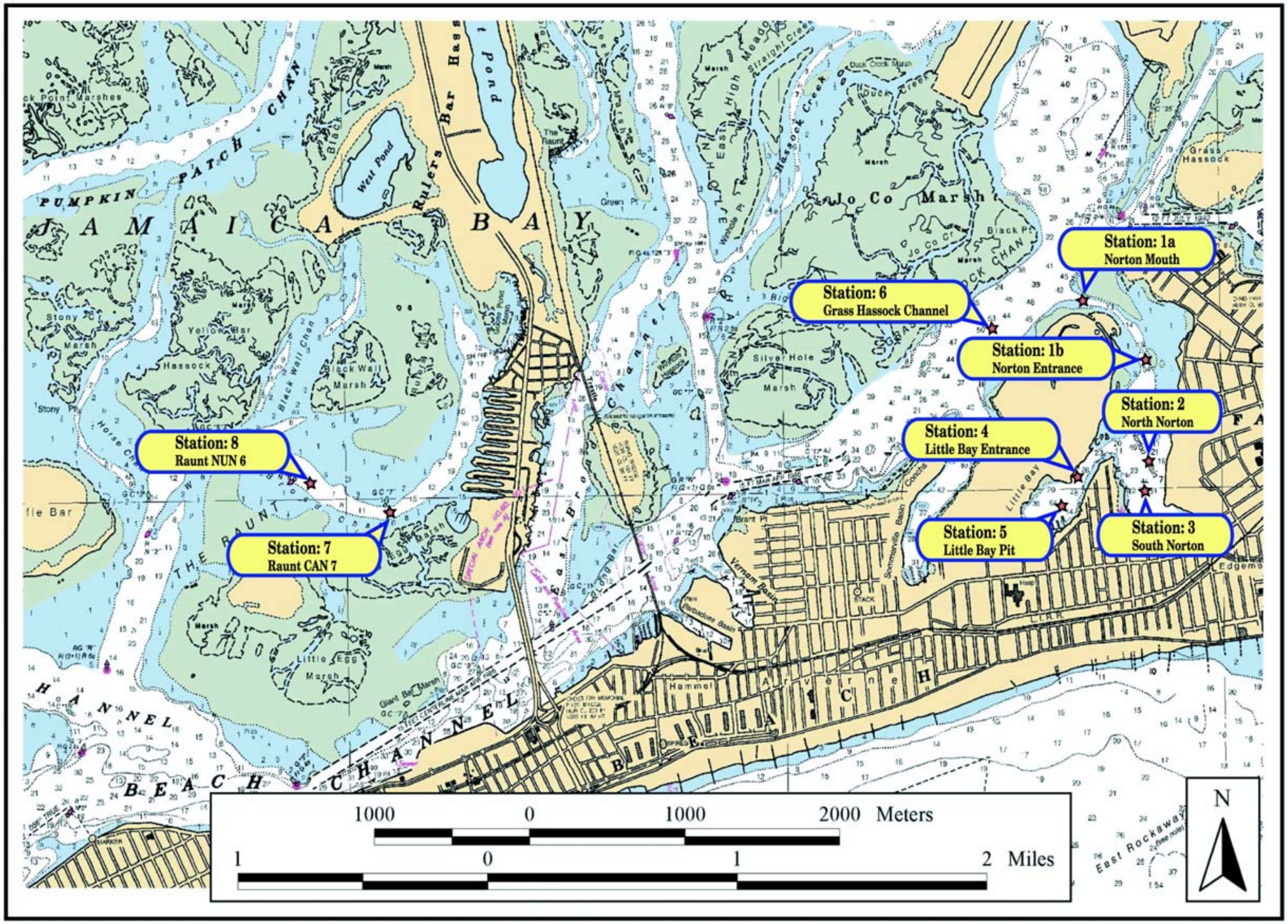


Figure 2a

Multibeam Bathymetry of Norton Basin (Northern Portion)

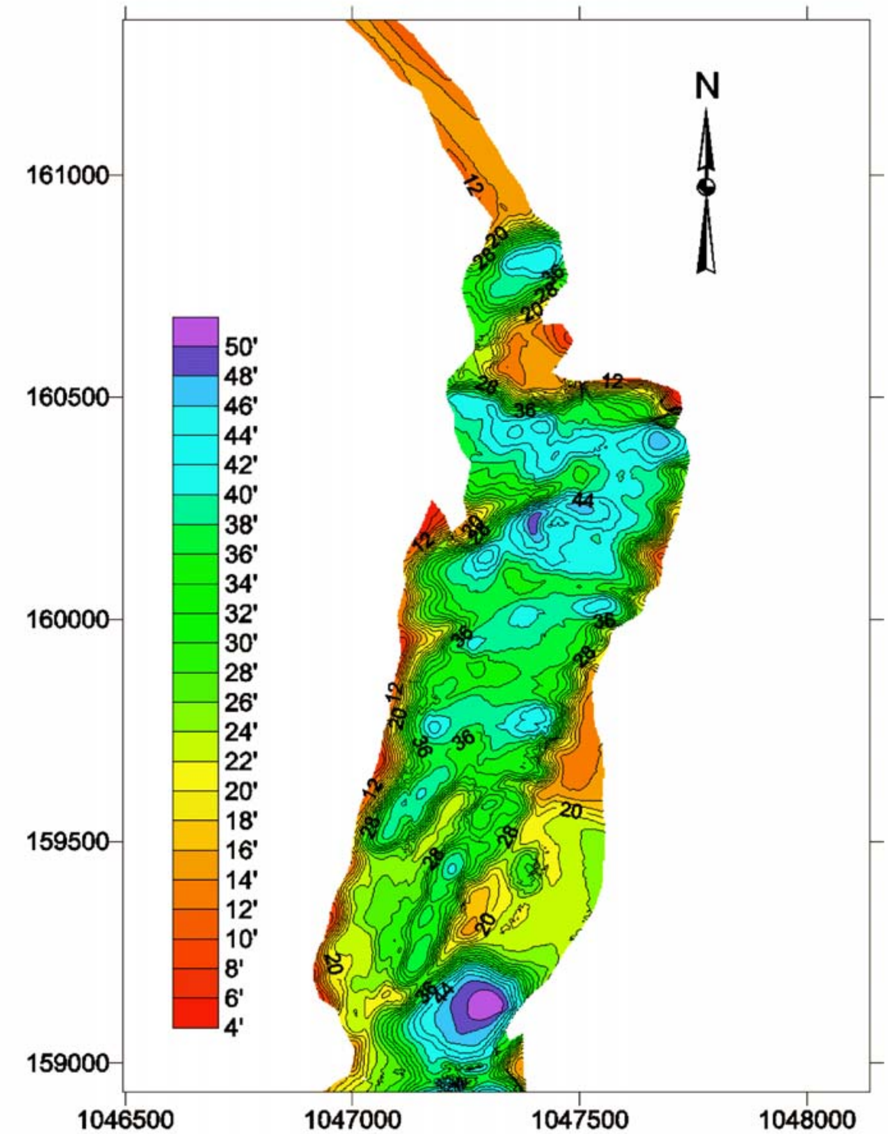


Figure 2b

Multibeam Bathymetry of Norton Basin(Southern Portion)

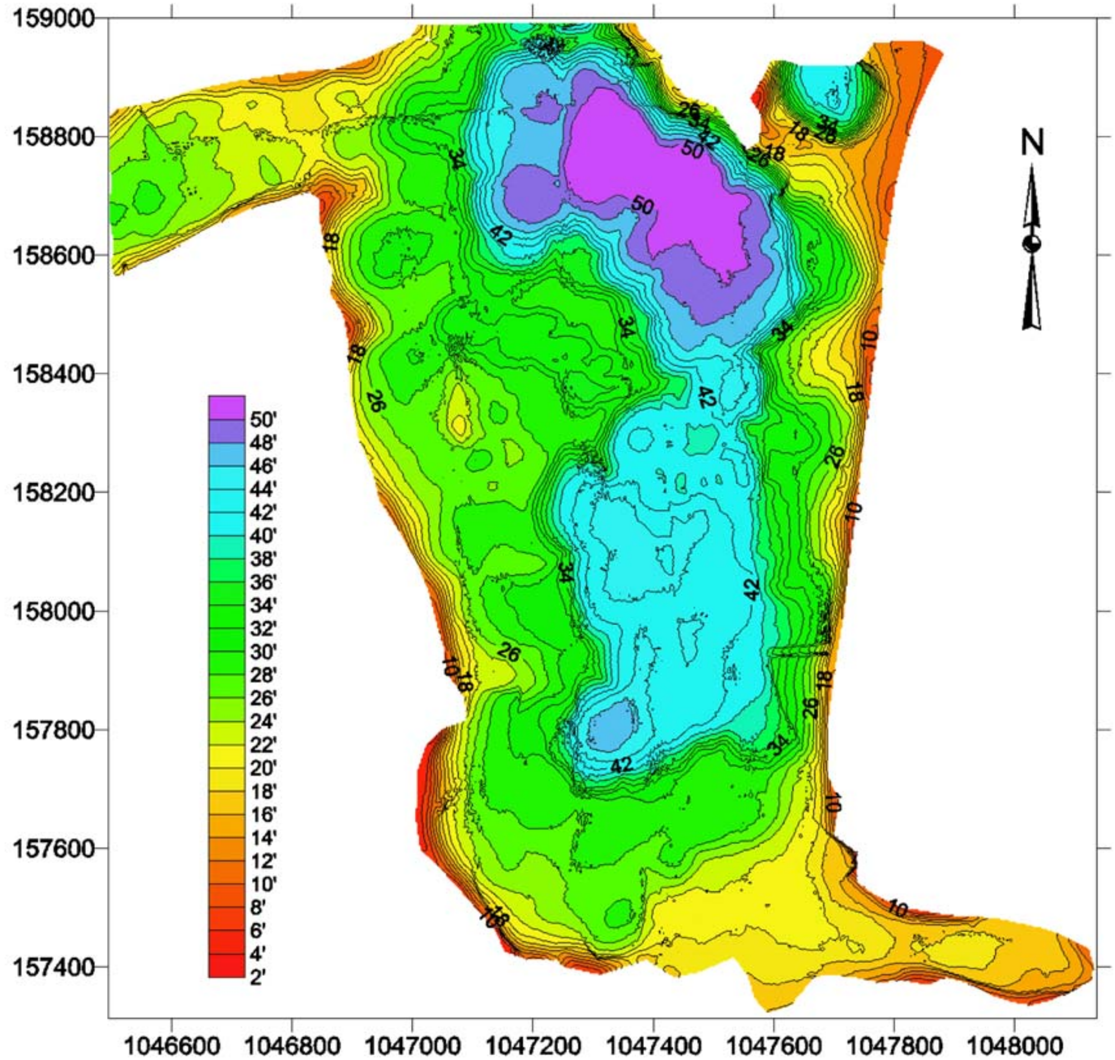
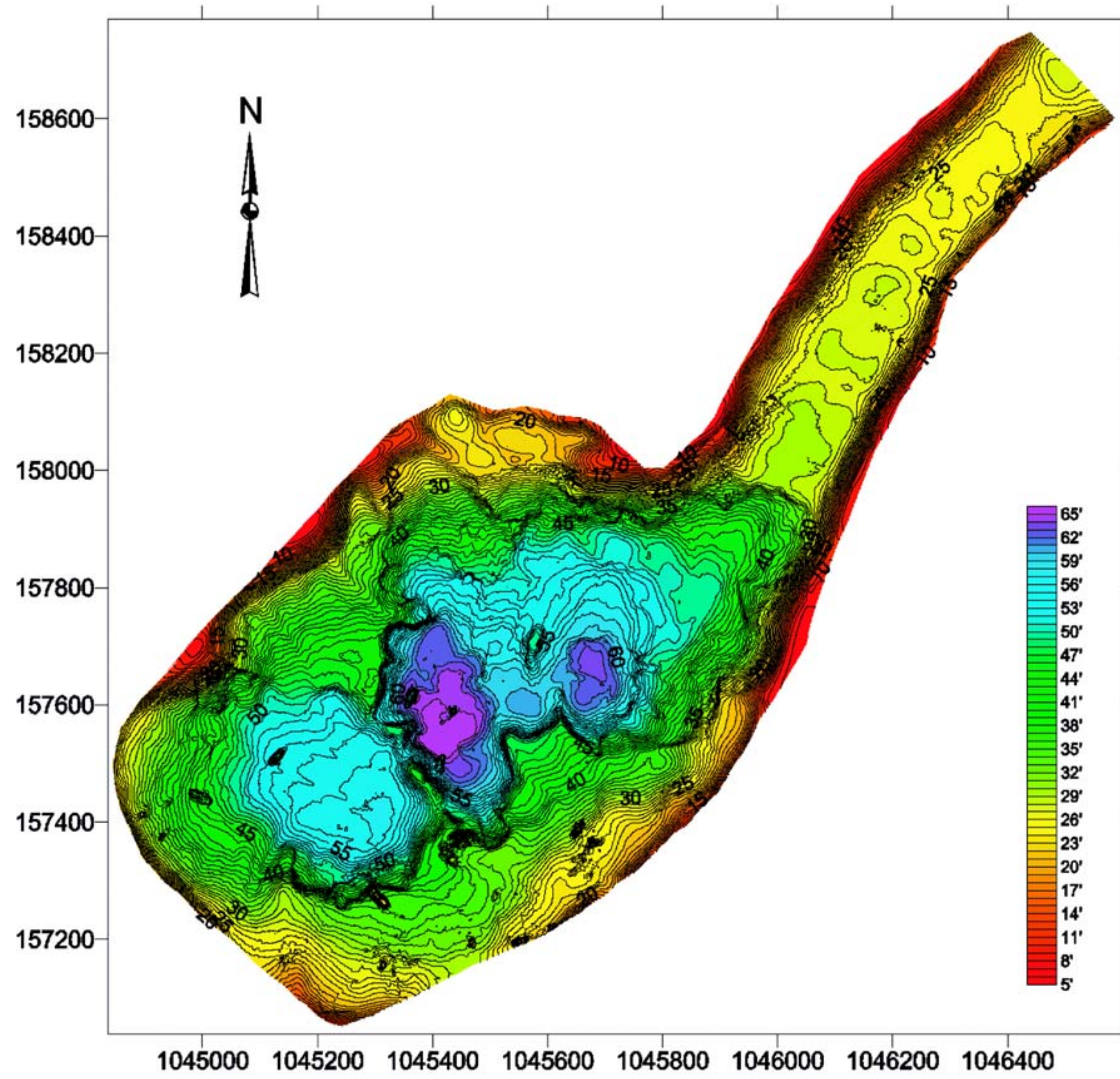


Figure 2c

Multibeam Bathymetry of Little Bay



3. Methods

The Department's Region 2 Marine Resources Program staff conducted water quality surveys during 2000-2002 of stations in the pits and reference areas using the Region 2 vessel, a 25 foot Grady White Trophy Pro. Surveys began in Summer (June/July) and continued into early November. The survey program called for weekly sampling at all station locations, though circumstances such as vessel mechanical problems, weather conditions, and US Coast Guard-imposed vessel operating restrictions following the 9/11/01 terrorist attacks, resulted in some gaps in the data record. Most surveys were scheduled to coincide with high tide conditions in Norton Basin, because the entrance channel to Norton Basin is unmarked, quite narrow, and shallow. The sample stations were located and identified with a Northstar GPS as well as by visual reference points.

The main focus of the study was dissolved oxygen, since this parameter is a vital indicator of ecological health. Temperature and salinity, however, have obvious relationships to dissolved oxygen - they are both generally inversely related to dissolved oxygen solubility. The principal sampling equipment was a YSI Model 85 Handheld Dissolved Oxygen, Temperature, Salinity and Conductivity System. Data on all of the above parameters were collected at all stations. Following the initial surveys, it was determined that sampling at ten foot depth intervals in the pit stations, and at near surface and near bottom only in the reference areas would sufficiently characterize station conditions. Data from intermediate sampling depths at the pit stations were rounded into the nearest 10-foot depth interval.

Anecdotal information suggested a persistent 10-20 foot thick "nepheloid layer" of very turbid water might exist at the base of the Norton Basin and Little Bay pits. During initial surveys, Niskin bottle water samples were collected at the pit stations to determine the presence and extent of such features. These casts were also used to verify the drastic decline in temperature measured by the YSI at the bottom of the Little Bay pit. Additional data recorded included Secchi disk readings on 2001-2002 surveys, and meteorological observations.

4. Results

Since our surveys were generally conducted at or near high tide, we initially compared our findings to those of the larger study, which included some diurnal data. Preliminary comparisons between these data sets showed little difference in water quality data values and trends across tidal cycles. This will be further assessed when the data reporting for the larger study is completed and a better comparison can be made regarding differences within the tidal cycle.

4.1 Salinity

Table 1 presents the minimum and maximum salinity values recorded at all sites throughout the study period. These values all fall within the expected range for an estuarine system such as Jamaica Bay. With the few exceptions described below, all stations exhibited a narrow salinity range (< 1 ppt) surface to bottom throughout the study period. The Little Bay pit exhibited a weak and time-varying halocline, appearing at about the 30-40 foot depth, with overall (surface to bottom) increases in salinity with depth of up to 2 parts per thousand (ppt). This was most common in July and August, however, during this same period in two of the years (2001 & 2002) a reverse trend of a 1 ppt decrease from surface to bottom was noted. The Norton Basin pits usually had less than a 1 ppt increase in salinity with depth, except for an event in early September 2002 when there was an increase of almost 4 ppt with depth in both the Norton and Little Bay pits.

4.2 Temperature

As seen in Table 2, the pit stations, Little Bay in particular, are distinguished from the reference areas to a larger degree with respect to temperature than with salinity. The reference areas, including the deep Grass Hassock channel station, rarely exhibited a surface-to-bottom temperature difference of greater than 1° to 2° C. Though a similar trend was generally seen in the Norton Basin pits, more stratified conditions were observed on several occasions. In late June and early July of 2001, the surface-to-bottom difference approached 9° C, and in early July 2002 a difference of about 5° C was measured. Overall, the temperature stratification in the Norton Basin pits was weak and temporary. In contrast, Little Bay pit exhibited a strong thermocline throughout the study period. During the 3 years of surveys, temperatures at the surface of Little Bay ranged from about 24° to 28° C from late June through early September, and decreased to between 3° to 5° C at the bottom. The thermocline occurred in mid-water (25-35) feet in the 60 foot deep pit. By late October/early November surface temperatures were approximately 10°-15° C and decreased to only about 7° C at the bottom. As Table 2 shows, the maximum temperature observed over the course of the study at the bottom of Little Bay pit was 12° C, recorded in November of 2001.

4.3 Niskin Bottle Water Samples

Niskin bottle samples were collected on two occasions in 2000, on August 4th and 31st. On August 4th, the North Norton pit sample was clear at 35 feet and turbid at 43 and 49feet (bottom depth). The South Norton pit sample was also clear at 35 feet and turbid at 39 feet (bottom). In the Little Bay pit, the sample was clear at 50 and 55 feet, and turbid at 60 feet (bottom). All of the bottom samples had an H_2S odor. On the 31st, samples were only taken near bottom, and all samples (48 feet and 39 feet at the Norton pits, and 58 feet in the Little Bay pit) were clear with no odor noted. Although the samples were not retained for suspended sediment or other water quality analyses, it appears from this limited sampling that a nepheloid or high turbidity layer is only a transient phenomenon near the very bottom of these pits.

Table 1. Maximum and minimum salinity (ppt) by month, 2000-2002

Sta	Sta #	Sta depth (ft)	reading depth	JUN		JUL		AUG		SEP		OCT		NOV	
				min	max	min	max	min	max	min	max	min	max	min	max
Norton Mouth	1A	16	Surface	24.8	26.0	23.6	28.3	25.2	28.9	26.2	28.0	25.7	27.4	25.4	27.5
			Bottom	25.2	26.2	26.3	28.3	25.9	29.2	26.1	27.6	25.6	27.6	25.4	27.4
Norton Entrance	1B	40	Surface	25.0	25.8	24.8	28.3	25.7	28.9	25.9	28.0	25.8	27.6	24.3	27.8
			Bottom	26.2	26.2	26.3	28.3	26.7	28.9	26.0	27.9	26.9	27.4	25.2	27.8
North Norton	2	50	Surface	25.1	25.8	26.2	28.2	25.1	28.7	23.4	28.0	25.7	27.3	24.1	27.1
			Mid-Depth	25.2	25.9	26.2	28.2	25.2	28.7	26.0	27.9	25.7	27.3	25.2	26.1
			Bottom	26.1	26.1	26.1	27.8	26.5	28.6	26.1	27.9	25.7	27.4	25.3	27.7
South Norton	3	40	Surface	25.0	25.8	24.7	27.9	25.3	28.7	24.0	27.9	25.7	27.2	25.2	27.0
			Mid-Depth	25.1	25.8	26.1	27.9	25.2	28.7	26.1	27.9	25.7	27.1	27.1	27.1
			Bottom	26.0	26.1	26.2	28.2	26.0	28.6	26.1	27.9	25.7	27.4	25.3	27.1
LB Entrance	4	25	Surface	25.1	25.6	24.6	28.0	25.6	28.6	25.9	28.0	25.8	27.1	25.2	27.6
			Bottom	25.8	25.8	26.1	28.1	25.7	28.5	26.0	27.9	25.7	27.2	25.4	27.6
Little Bay	5	60	Surface	25.0	25.7	26.2	28.0	25.6	28.6	23.8	27.9	25.9	27.1	25.2	27.6
			Mid-Depth	25.9	26.2	26.1	26.3	26.5	28.6	26.0	28.0	25.8	27.2	27.3	27.6
			Bottom	26.5	26.5	25.7	28.0	26.0	28.2	26.0	28.3	25.9	27.7	27.1	27.6
Grass Hassock	6	50	Surface	24.8	25.9	24.7	28.3	25.3	28.9	26.0	28.2	25.5	28.0	25.2	28.0
			Bottom	26.1	26.6	26.5	28.7	26.0	29.2	26.3	28.2	26.3	28.2	26.0	28.1
Raunt Can 7	7	15	Surface	26.2	26.9	25.7	29.2	26.1	29.3	24.9	28.3	26.7	28.0	26.2	28.0
			Bottom	26.2	27.0	25.7	29.2	26.2	29.3	25.6	28.3	26.6	28.0	26.3	28.1
Raunt Nun 6	8	12	Surface	26.1	27.0	26.0	29.3	26.1	29.3	26.4	27.9	26.9	28.8	26.4	28.6
			Bottom	26.3	27.5	26.0	29.7	26.3	29.5	25.9	28.4	26.9	29.5	26.4	29.1

Table 2. Maximum and minimum temperature (Celsius) by month, 2000-2002

Sta	Sta #	Sta depth (ft)	reading depth	JUN min	JUN max	JUL min	JUL max	AUG min	AUG max	SEP min	SEP max	OCT min	OCT max	NOV min	NOV max
Norton Mouth	1A	16	Surface	23.5	25.8	22.9	27.7	23.1	27.2	18.4	24.0	14.2	19.4	9.5	12.9
			Bottom	22.9	24.3	22.9	25.3	22.2	26.6	18.4	23.7	14.5	19.8	9.5	12.7
Norton Entranc	1B	40	Surface	23.7	26.3	23.1	27.3	22.6	27.5	18.8	23.8	14.5	19.8	9.6	13.2
			Bottom	23.2	24.4	23.3	25.3	22.5	26.6	18.1	23.5	14.5	20.0	9.3	12.6
North Norton	2	50	Surface	23.5	26.1	23.2	27.3	23.2	27.3	18.8	24.1	14.7	19.8	9.5	13.0
			Mid-Depth	21.2	24.2	23.2	29.3	22.3	26.3	18.3	24.0	14.7	20.2	9.4	12.4
			Bottom	17.1	17.2	16.0	24.4	21.5	25.0	18.2	24.2	14.8	19.9	9.5	12.5
South Norton	3	40	Surface	23.4	26.1	22.8	26.3	23.2	27.2	18.7	24.2	14.7	20.1	9.6	13.1
			Mid-Depth	23.1	23.9	23.3	25.3	23.3	26.4	18.4	23.7	14.7	20.2	12.5	12.5
			Bottom	17.2	18.1	22.6	25.3	22.2	25.1	18.3	24.2	14.7	20.1	9.5	12.4
LB Entranc	4	25	Surface	23.4	26.2	23.0	26.1	23.2	27.9	19.1	24.1	14.6	20.0	9.5	13.1
			Bottom	20.3	25.7	23.3	27.0	22.5	25.9	18.4	23.6	14.6	19.9	9.5	12.6
Little Bay	5	60	Surface	23.6	25.2	22.1	28.2	22.8	27.3	19.2	24.0	15.0	20.1	9.2	13.0
			Mid-Depth	10.3	19.2	10.2	23.2	12.6	25.9	18.1	24.0	14.8	20.2	11.1	12.5
			Bottom	4.2	5.0	2.8	6.5	2.8	6.5	3.4	6.9	3.9	8.2	4.0	12.1
Grass Hassock	6	50	Surface	23.9	25.8	22.9	27.2	22.5	27.6	18.8	23.9	14.2	19.7	9.7	12.9
			Bottom	22.8	24.2	22.5	25.0	23.0	26.5	17.4	23.6	14.0	19.7	9.1	12.5
Raunt Can 7	7	15	Surface	22.0	25.9	21.8	27.0	21.7	28.2	16.6	23.8	13.5	18.9	8.3	13.2
			Bottom	21.4	24.8	21.8	26.2	21.5	27.0	16.6	23.5	12.8	18.8	8.2	12.9
Raunt Nun 6	8	12	Surface	24.0	27.1	21.9	26.9	21.9	27.6	17.0	23.9	14.0	18.8	8.6	13.1
			Bottom	23.1	24.6	21.8	26.0	21.3	27.2	17.0	23.8	13.6	19.5	8.7	13.1

4.4 Secchi Disk

Turbidity estimates were made with a secchi disk during most of the 2001-2002 surveys. There were no obvious trends at any of the stations or in comparison between stations. The estimates ranged from slightly less than 1 meter to about 3 meters. The lowest estimates were in October, with ranges from about 0.8 - 0.9 meters (with an exception of higher readings in 2002), and the highest were in November, ranging from about 2 meters to 3 meters. During July and August, the estimates ranged from about 0.8 meter to 2 meters (the highest values were observed in only two sampling events in August 2001).

4.5 Dissolved Oxygen

The monthly average surface and bottom DO data is summarized in Table 3. All stations demonstrated an expected reduction in DO with depth, with the strongest difference occurring from June thru August. This trend was more substantial and extended into September for the deeper reference stations; into October for the Norton Basin pit stations; and through November at the Little Bay pit station. The significance of the decrease is explored below by comparing the data to established regulatory and ecological thresholds, and by reviewing the data for the magnitude and frequency of substandard DO levels.

NYSDEC's Division of Water (DoW) has classified the waters of the Norton Basin area (including Little Bay) as SB waters (NYSDEC, 2002). The best uses of these waters are primary and secondary contact recreation, fishing, and that they be suitable for fish propagation and survival (6NYCRR Part 701.11). NYSDEC's existing water quality standard for DO in Class SB waters is not less than 5.0 mg/L at any time. NYSDEC's least stringent water quality standard for DO in marine waters, 3.0 mg/l, is assigned to waters with the SD classification. The best uses for those waters are fishing and that they be suitable for fish survival (6NYCRR Part 701.14). The USEPA recently published recommended DO criteria for marine waters in the Virginian Province. The USEPA criteria for DO that correspond respectively to NYSDEC's DO standards for SB and SD waters are 4.8 mg/L DO (some limited, short term excursions below this value are allowed) and 2.3 mg/L DO. NYSDEC is determining whether or not to adopt EPA's recommended criterion as the state water quality standard for SB waters. However, NYSDEC's Division of Fish, Wildlife and Marine Resources (DFW&MR) currently considers 3.0 mg/l to be adequately supported by the best available scientific information as the appropriate water quality standard for DO in SD waters..

Based on the above, the data set was evaluated in terms of DO values that fell below 5 and 3 mg/l. Figure 3a shows the number of occurrences of DO readings below 5 mg/l. With the exception of the Raunt stations, the reference stations failed to attain this water quality standard on about half of the surveys. The failure rate in the pit stations was even higher at ~70% for the Norton Basin pits and 100% in the Little Bay pit. In Figure 3b, which shows the number of occurrences below 3 mg/l, a much stronger breakout of the pits stations is seen. The failure rate

Table 3. Average monthly dissolved oxygen (mg/l) 2000 through 2002. SD=standard deviation

Sta	Sta #	Sta depth (ft)	reading depth	JUN		JUL		AUG		SEP		OCT		NOV	
				AVG	SD	AVG	SD	AVG	SD	AVG	SD	AVG	SD	AVG	SD
Norton Mouth	1A	16	Surface	9.2	1.3	7.1	2.4	6.2	2.9	5.7	1.2	8.4	2.5	6.3	2.1
			Bottom	4.6	0.1	5.4	2.1	4.8	2.6	5.1	1.1	7.6	1.6	6.4	1.8
Norton Entrance	1B	40	Surface	9.5	0.4	8.0	3.0	6.8	2.9	6.5	2.1	8.7	2.5	8.9	4.5
			Bottom	6.2	0.3	4.4	2.3	4.4	3.6	5.3	1.4	7.7	1.6	8.6	4.5
LB Entrance	4	25	Surface	11.1	0.1	8.5	2.3	8.0	4.0	7.2	2.4	8.9	3.6	8.0	3.5
			Bottom	3.3	0.3	4.1	2.3	2.5	2.5	4.5	1.6	6.7	1.9	8.0	3.7
Grass Hassock	6	50	Surface	12.9	1.0	8.4	3.0	6.8	2.8	6.5	1.9	8.7	2.8	9.1	4.4
			Bottom	5.4	2.4	4.7	1.9	4.1	3.1	4.8	0.6	7.5	1.7	8.7	4.3
Raunt Can 7	7	15	Surface	9.4	1.9	8.9	2.4	7.9	2.8	7.5	2.1	9.5	3.4	7.8	1.0
			Bottom	7.5	2.0	7.2	2.4	6.1	3.2	6.5	1.9	8.5	2.1	7.1	1.4
Raunt Nun 6	8	12	Surface	10.4	2.0	8.8	3.0	7.9	2.8	7.4	2.1	9.3	3.1	9.8	4.1
			Bottom	8.5	2.9	8.0	2.4	6.9	3.0	6.8	1.8	8.7	2.4	9.8	4.0
North Norton	2	50	Surface	11.9	3.0	8.2	2.6	7.2	3.8	6.6	1.7	8.9	2.5	8.8	4.3
			Bottom	0.1	0.1	2.0	3.2	0.9	1.9	3.0	2.0	6.8	1.6	7.6	4.0
South Norton	3	40	Surface	12.9	5.2	7.3	2.3	7.2	3.1	7.1	2.1	9.0	2.5	6.5	1.8
			Bottom	0.2	0.1	2.2	2.5	1.7	2.7	2.5	2.3	6.7	1.4	5.9	1.6
Little Bay	5	60	Surface	11.9	2.3	8.3	1.9	7.7	3.4	7.1	2.5	8.4	3.3	8.0	3.7
			Bottom	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.8	1.3

Figure 3a. Number of observations with DO readings <5 mg/l.
n= total number of observations at the station

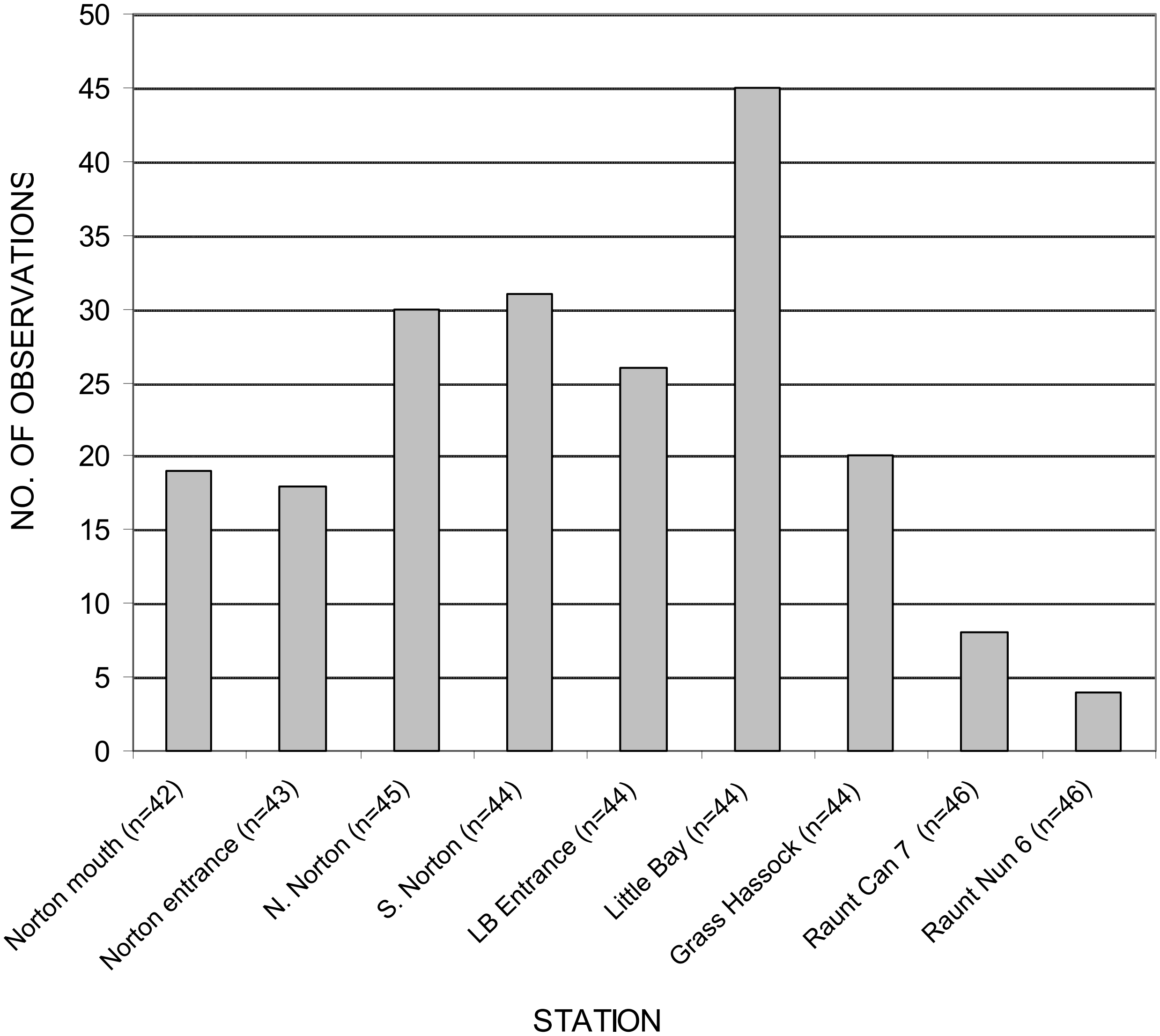
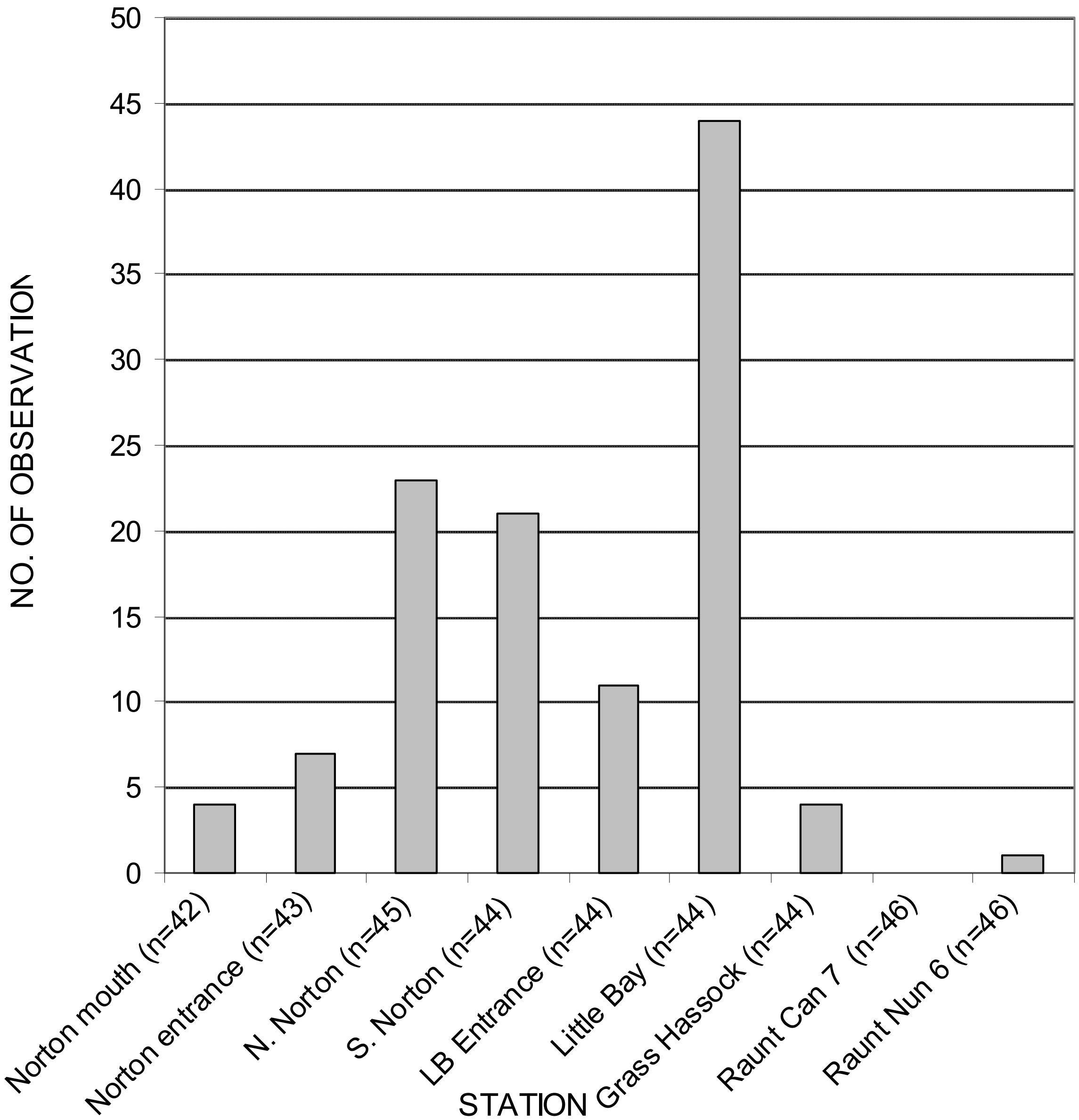


Figure 3b. Number of observations with DO readings < 3 mg/l.
n=total number ofobservations at the station



at the reference stations drops sharply, while the rate at the pit stations remains high. At the 3mg/l (hypoxic) threshold, the Norton Basin pits each have greater than 20 occurrences, which represents roughly 50% of the total sampling events, while Little Bay failed this standard 100% of the time. The DO distribution in the pits is described in closer detail in the following sections.

4.5.1 Norton Basin

The average DO concentration profiles at the Norton Basin pit stations are illustrated in Figures 4a-d and 5a-d. The Norton Basin pit stations are depicted as three year monthly averages (figs. 4a and 5a) as well as one year monthly averages (figs. 4b-d and 5b-d). The three year averages depict the overall longer term monthly DO trends in these pits; the one year plots depict the variations and deviations observed in each of those years, and better illustrate the sources of variability in the results.

The three year average charts for the Norton North pit (fig. 4a) and Norton South pit (fig. 5a) show a general trend of decreasing DO with depth from June through September. This trend is most striking for the months June through August, with an average DO at the surface of 9.1 mg/l compared to an average DO at the bottom of 1 mg/l (Norton North) and 1.4 mg/l (Norton South). The September 3-year average decreased from 6.6 mg/l at the surface to 3 mg/l at the bottom in Norton North (and from 7.1 mg/l to 2.5 mg/l in Norton South). October and November showed much smaller decreases in average DO with depth, decreasing from surface to bottom by about 2 mg/l in October and by about 1 mg/l in November at both Norton Basin pit stations.

During the Summer months, DO values declined sharply through the water column, typically reaching hypoxic levels (<3mg/l) at approximately 30 feet, with even further declines to the pit floor. The September profiles shows a similar, but less sharp, decline from the surface, reaching approximately 4 mg/l at 30 feet and declining to 3 mg/l at the bottom. DO values typically exceeded 5 mg/l throughout the water column in October and November.

The error bars in Figure 4a indicate the high degree of variability in the 3-year data. Figures 4b-d & 5b-d show that while the Summertime pattern of decreasing DO with depth was evident in each year, the mean values differed greatly between years and variability was high in all years. However, these variabilities are caused by relatively very few observations during June through August when DO was higher than 3 mg/l. During these Summer months in the three year period, near bottom DO in these pits exceeded 3 mg/l only 5 times out of 21 sampling events. In 2001 the pit near-bottom conditions remained hypoxic during all sampling events. In 2000 and 2002, there were several occasions of near bottom DO reaching or exceeding 3 mg/l, which were always followed by measurements below 3 mg/l on the next week's sampling. In each year hypoxic conditions were therefore generally quite persistent from June to August at depths of about 30 feet and below. By September, there began to be more observations (a little over half of all sampling events) when DO was above 3 mg/l, with a general persistence of these conditions into October and November.

Figure 4a. Average monthly DO (mg/l) v. depth (ft) at North Norton station, 2000 through 2002

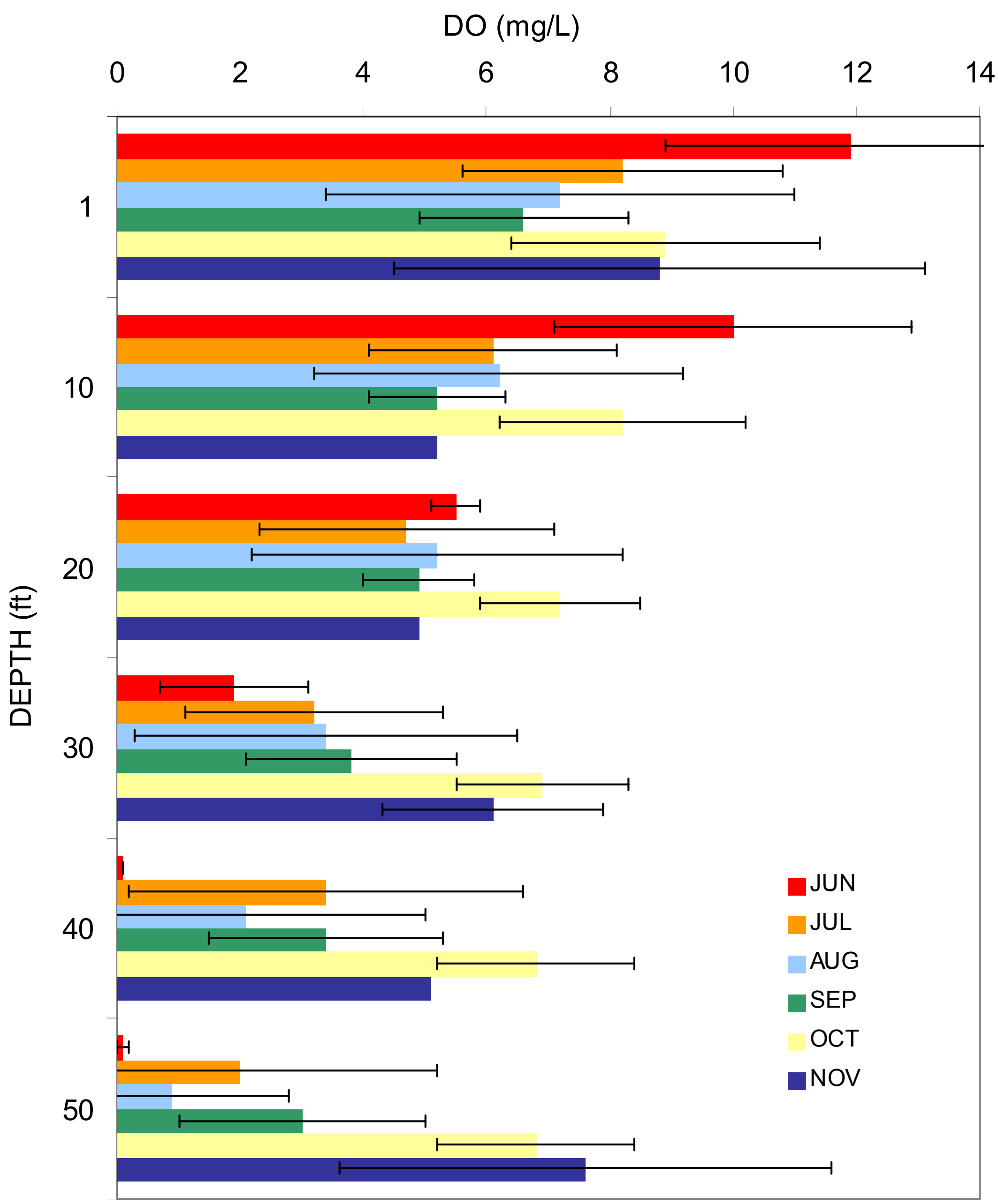


Figure 4b. Average monthly dissolved oxygen (mg/l) v. depth (ft) at North Norton station, 2000

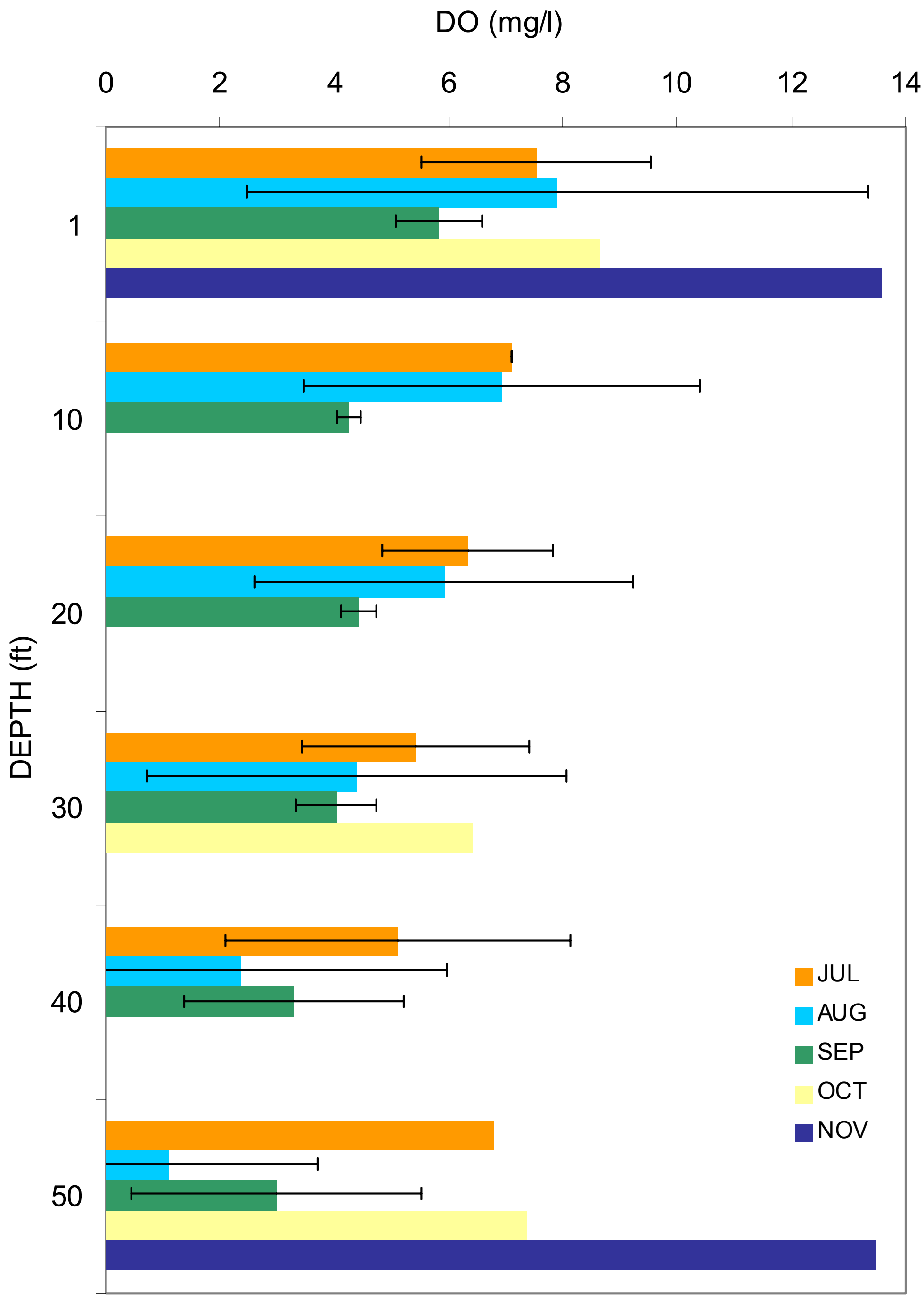


Figure 4c. Average monthly DO (mg/l) v. depth (ft) at North Norton station, 2001

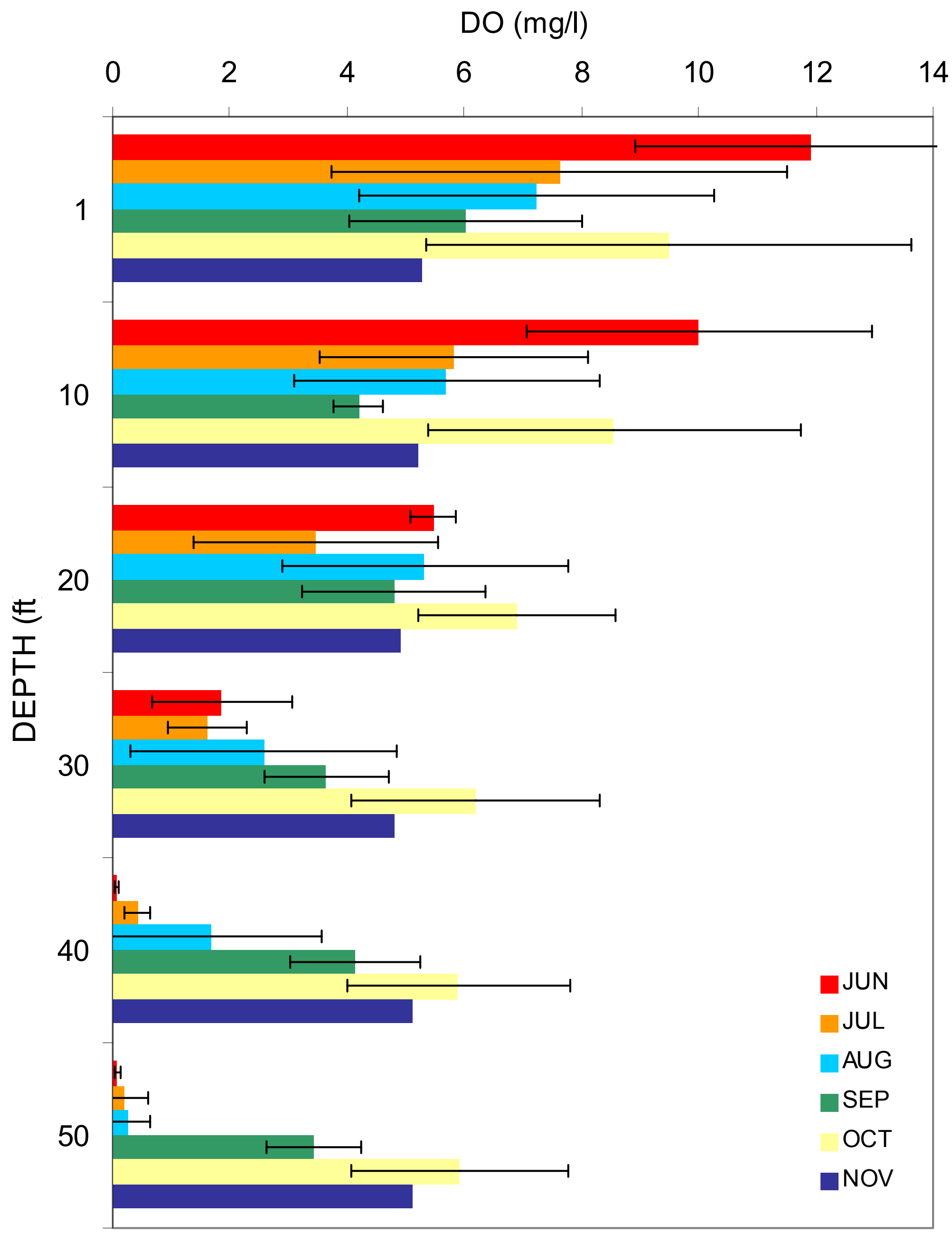


Figure 4d. Average monthly DO (mg/l) v. depth (ft) at North Norton station, 2002

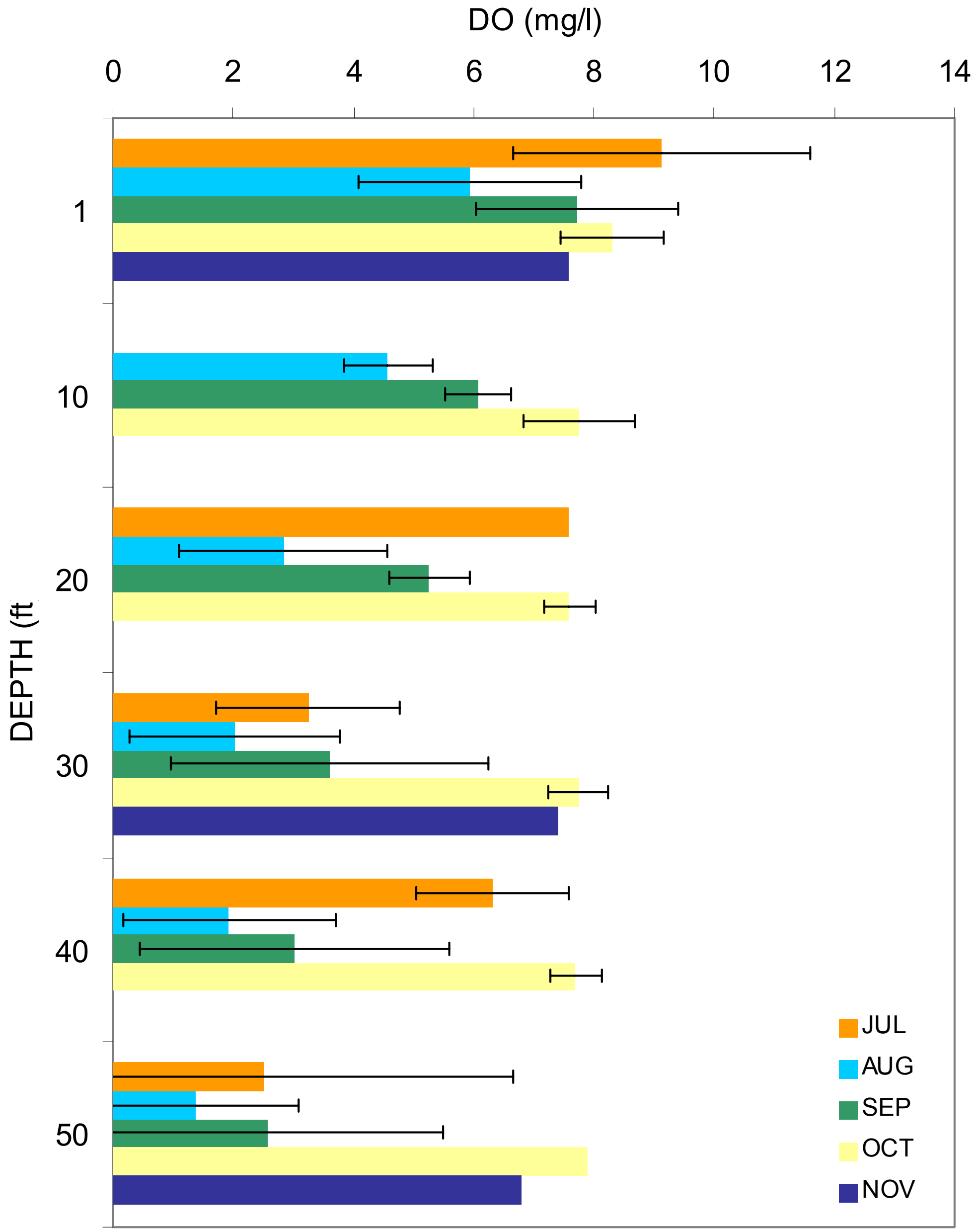


Figure 5a. Average monthly DO (mg/l) v. depth (ft) at South Norton station, 2000 through 2002

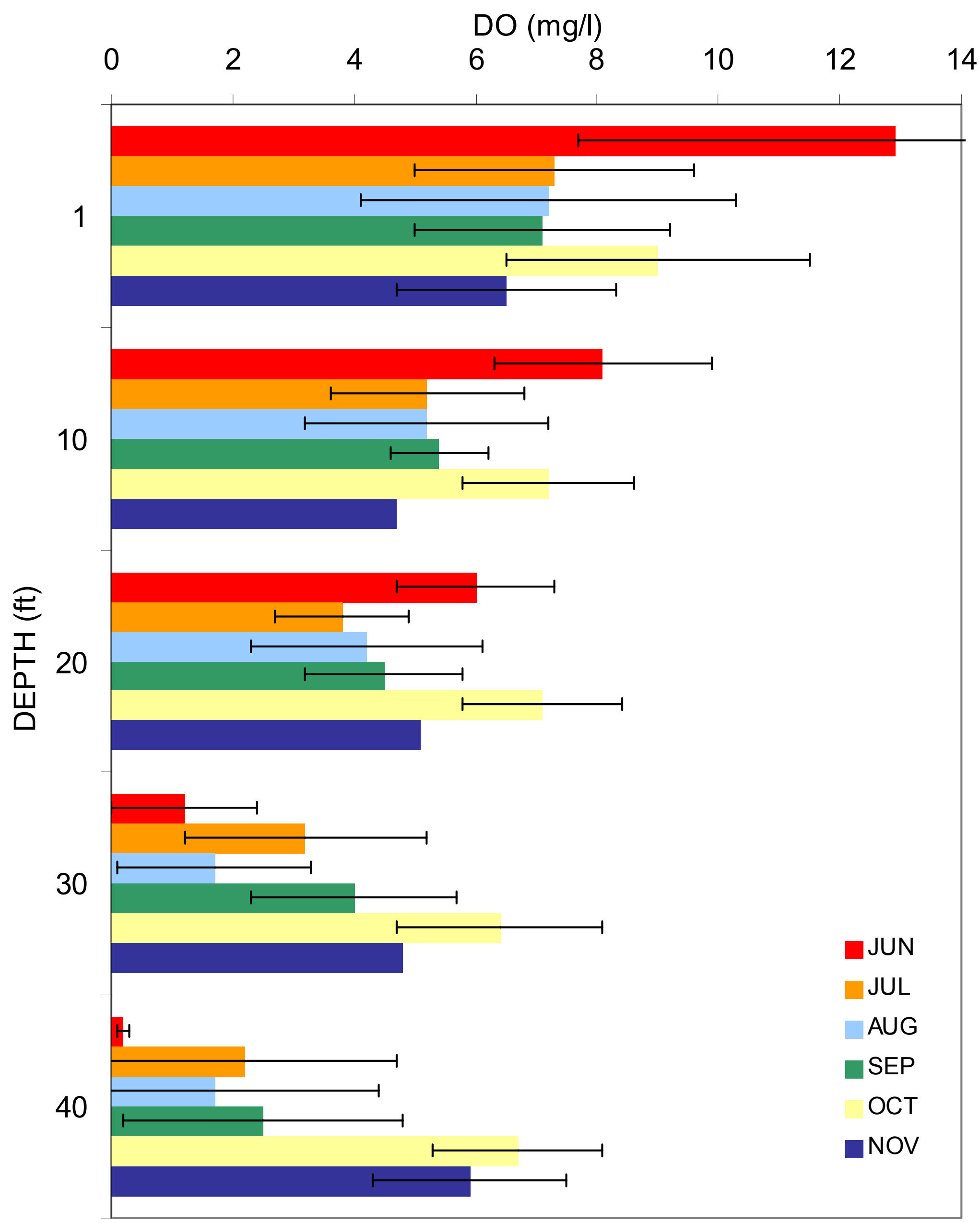


Figure 5b. Average monthly DO (mg/l) v. depth (ft) at South Norton station, 2000

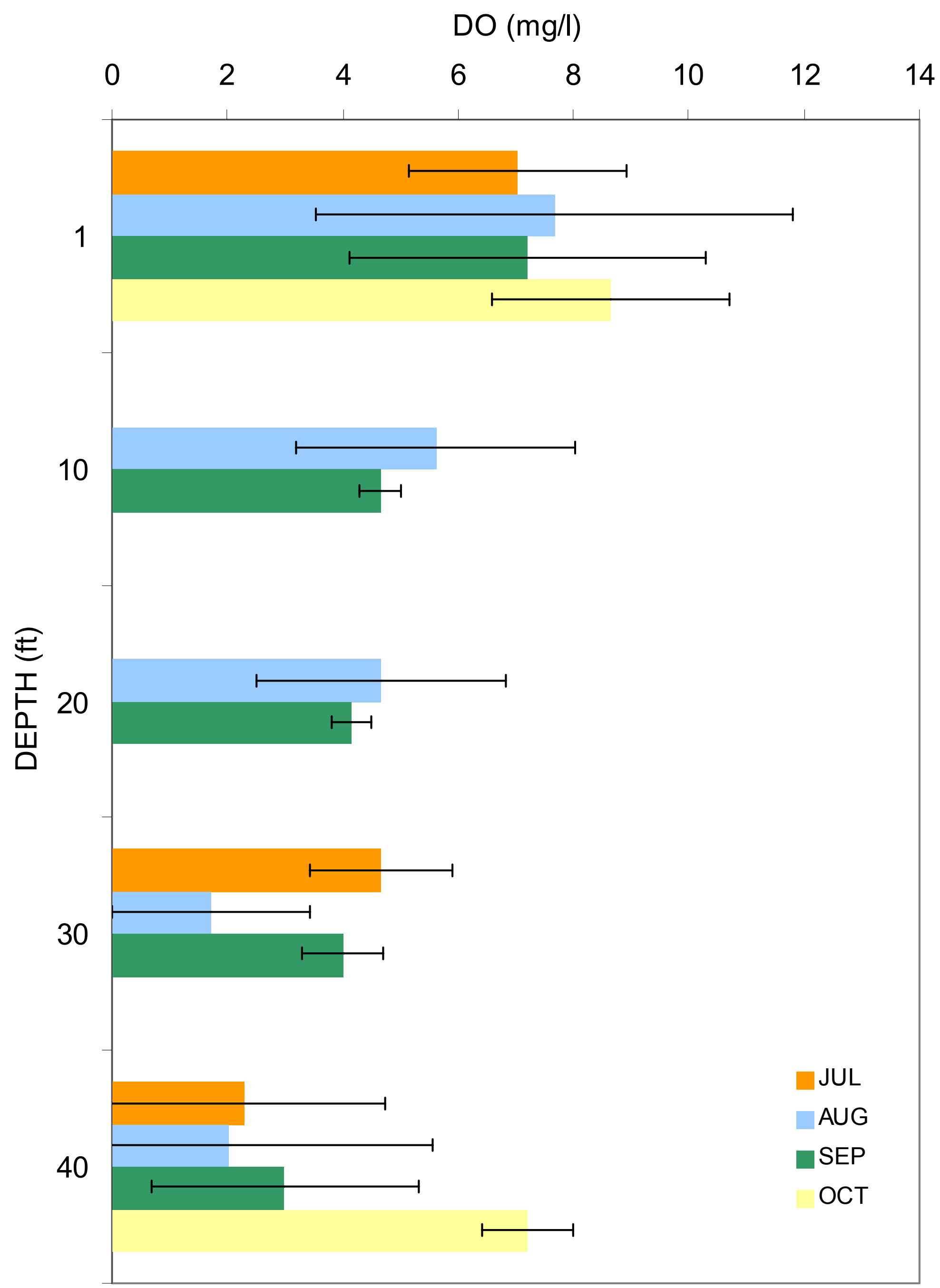


Figure 5c. Average monthly DO (mg/l) v. depth (ft) at South Norton station, 2001

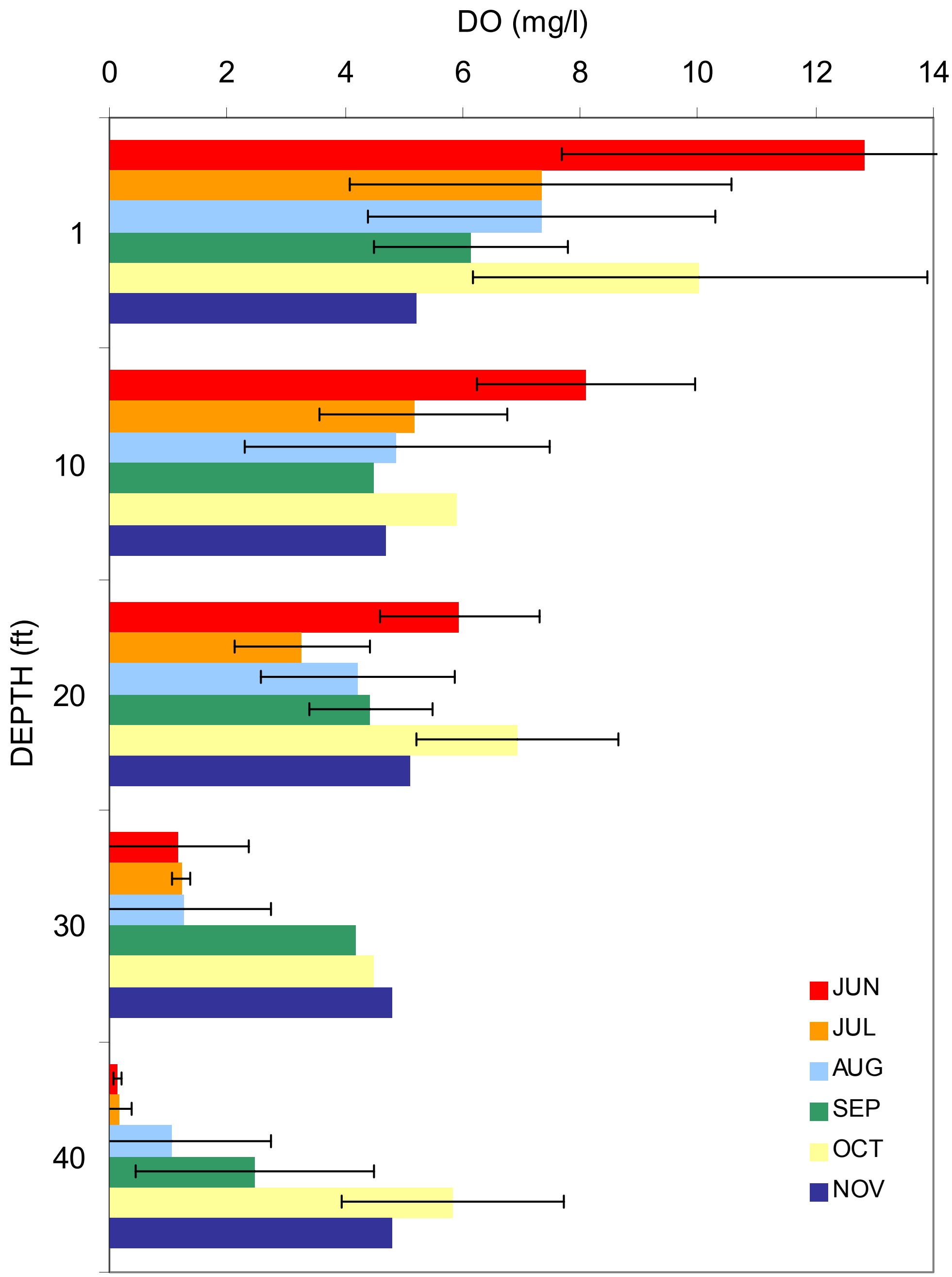
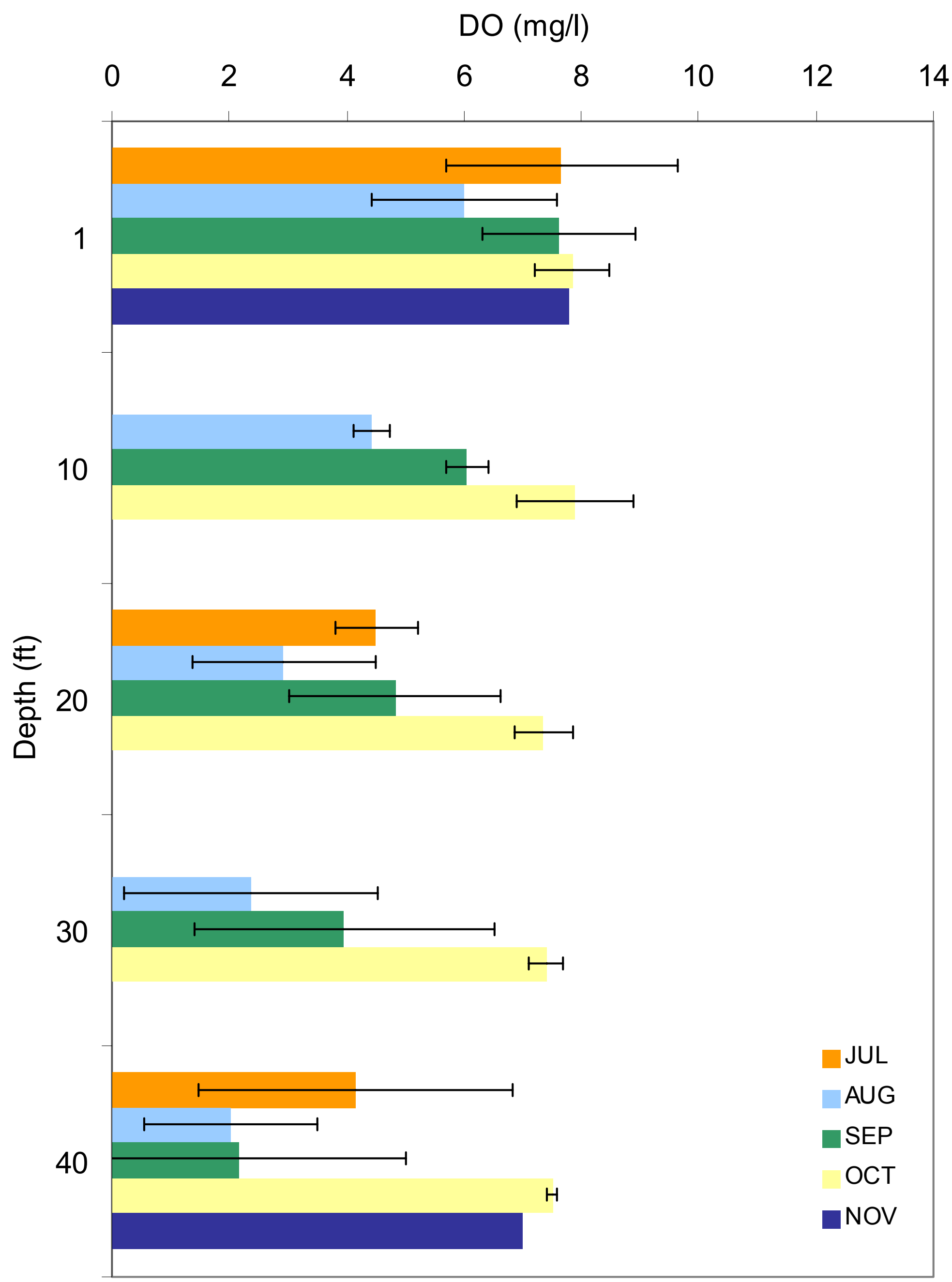


Figure 5d. Average monthly DO (mg/l) v. depth (ft) at South Norton station, 2002



4.5.2 Little Bay Pit

The Little Bay DO data is presented as a 3-year average in Figure 6. Annual plots were not generated because the depth-related decreases in DO in the Little Bay pit are much less variable than those in the Norton pits. The DO profile above the thermocline (i.e. above ~25') closely matches that seen in the Norton Basin pits, with relatively high values and high variability. Below the thermocline, however, an abrupt drop in DO with depth is seen consistently from June through September, with values near or below anoxic criteria (1 mg/l) from 30 feet to the pit floor. Higher DO values extend down through 30 feet in October, with generally anoxic or hypoxic conditions remaining below that depth. The limited November data suggest slight increases in DO at depth, but hypoxic/anoxic conditions were found. The overall 3-year average monthly surface DO for the pit is 8.6 mg/l, compared to an average bottom DO of less than 1 mg/l. There were no occurrences in the three year study when bottom DO in this pit was above 3 mg/l. There is more variation seen in the mid-depths for the Fall months over the three year period, as well as near the bottom in November, but the strong trend to anoxic conditions at the bottom throughout the study period is unmistakable.

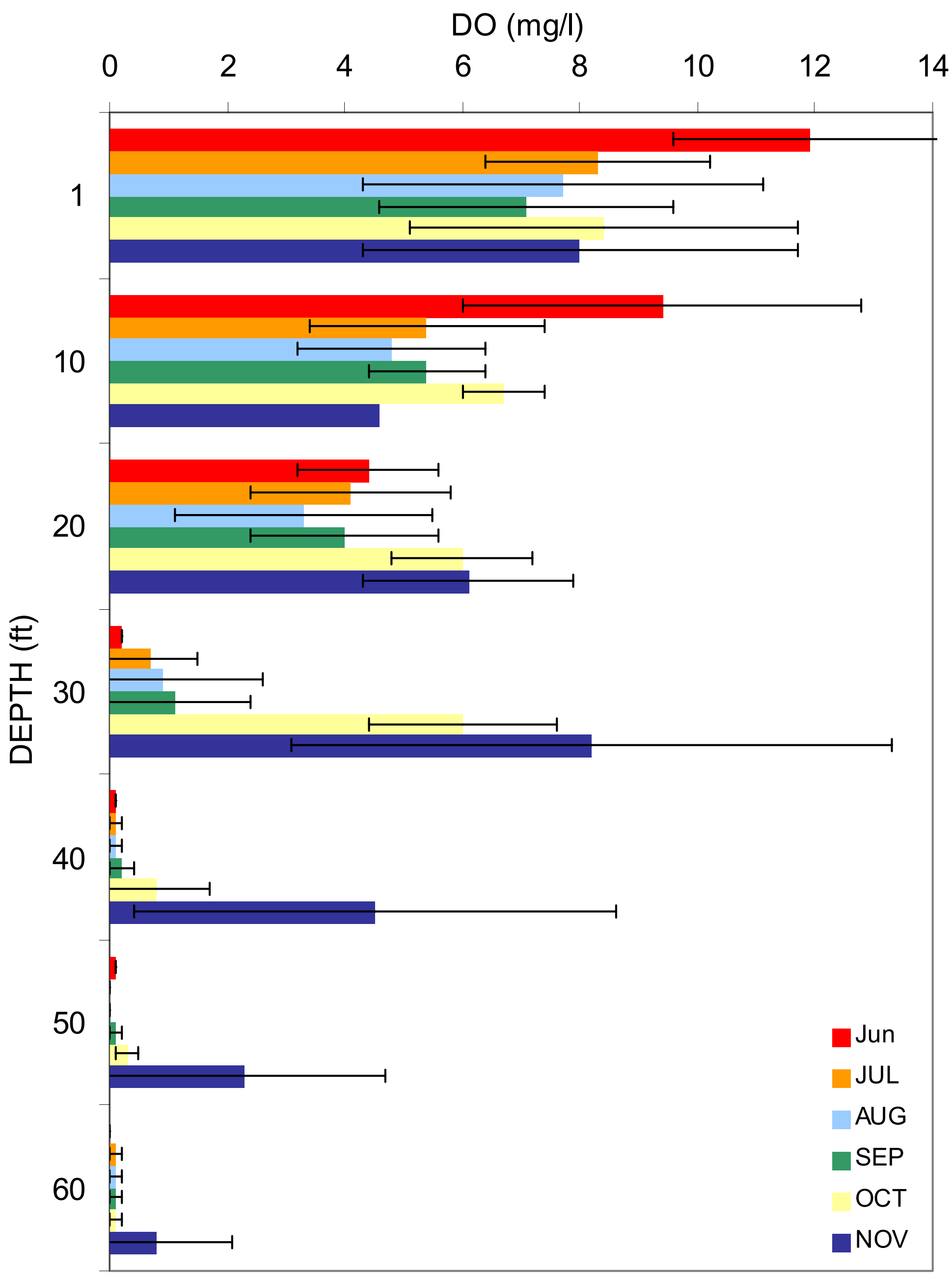
5. Discussion

Seasonal hypoxia is a common event in the coastal estuarine environment, with episodes generally tied to peak summer temperatures and mild climates (Alonghi). This condition is exacerbated in areas with high urban discharges and high residence times, both of which are characteristics of the Jamaica Bay system. Distinct patterns of hypoxia emerged during the study which revealed differences not only between the pits and reference stations, but also differences between reference stations in Jamaica Bay and those in the basins, as well as differences between pits in Norton Basin and those in Little Bay. These patterns suggest that the hydrologic isolation associated with basin morphology may be an important factor in the development and persistence of depressed dissolved oxygen conditions in Norton Basin and Little Bay.

Within estuaries, water movement is influenced by topographic and bathymetric features (Gross). Adjacent large land masses interrupt wind flow, which reduces surface water movement. Bathymetric highs, or sill features, can restrict bottom water movement. Both of these “landscape” features are present in the study area, and their influence on the system seems apparent in the data.

Reference areas in Jamaica Bay proper experienced the fewest hypoxic events. The Raunt stations, at 12 and 15 feet deep, went hypoxic on only one occasion. Grass Hassock, which approached 50 feet in depth, went hypoxic on only 4 occasions. These stations are located in relatively open sections of the bay, with only minor topographic relief on their periphery. Though the two stations are significantly different in depth, their surrounding bathymetry is fairly regular.

Figure 6. Average monthly DO (mg/l) v. depth (ft) at Little Bay station, 2000 through 2002



The upland landscape surrounding Norton Basin and Little Bay contains a great deal more relief than that surrounding the Jamaica Bay stations. The features include the Edgemere landfill in the northwest quadrant, a 30-foot high dune in the southeast quadrant, and dense residential development, including a high rise building complex on the Rockaway peninsula. The bathymetry in Norton Basin is highly irregular. The inlet from Grass Hassock Channel reaches a depth of only 10-15 feet, and is generally less than 30 feet in width. Past sandmining activities have created numerous deep pockets in Norton Basin which are separated by ridges that can be 20-30 feet shallower than the adjacent pit floor. Little Bay is more uniformly deep than Norton Basin, but is more isolated due to the substantial sill formed by the inlet from Norton Basin, and the proximity of the landfill. These physical attributes likely retard water movement within the basins. A related response in DO is noted in the reference stations located near the first hydrologic impediment, the inlet from Grass Hassock Channel, and becomes more evident further into the basins.

The incidence of hypoxia for reference areas within the basins, though still relatively low, was consistently higher than for comparably deep stations in Jamaica Bay proper. The shallow in-basin reference station, Norton Mouth(16 feet deep) went hypoxic on 4 occasions. The deep in-basin reference site, Norton Entrance (40 feet deep) went hypoxic on 7 occasions. The Little Bay Entrance reference site, though representing an intermediate depth (25 feet), had the highest number of hypoxic events (11) among all reference stations.

Hypoxic conditions occur persistently in both Norton Basin pits during the summer, at depths below 20-30 feet. Even during the summer, however, the lack of a strong thermocline or halocline, and the high variability in the DO data, indicate that some vertical mixing can occur in these pits, but not in a discernable pattern. Since higher DO values were rare, substantial exchange of bottom water does not appear to occur on a diurnal or lunar schedule - it is likely tied to more episodic events such as storms and strong wind events. With the onset of Fall, stratification breaks down even further, and bottom waters are replaced more regularly.

The Little Bay pit, the deepest and most isolated of all stations, was found to be in an hypoxic/anoxic state throughout the study. The strong thermocline and consistently low DO data suggest vertical mixing and exchange of bottom waters is almost non-existent. Malcolm Bowman, a professor of physical oceanography at the Marine Sciences Research Center at SUNY Stony Brook, likened the DO and temperature characteristics of Little Bay to those of a silled fjord system. In such systems, water cooled to near-freezing temperatures during winter sinks below the level of the entrance sill and is exchanged so slowly that the cold pool near the bottom is isolated and persists. Any mixing that occurs is probably molecular rather than turbulent, and therefore little heat exchange occurs. This would explain the extreme cold temperatures and minimal dissolved oxygen levels measured in the pit.

6. Conclusions

While much of the Jamaica Bay system occasionally fails to meet WQ standards, the occurrence of harmful dissolved oxygen depression is rare. Hypoxic and anoxic conditions are common, however, in the subaqueous pits within the tributary embayment complex of Norton Basin/Little Bay, with the Little Bay pit showing the worst and most persistent of these conditions. The data suggest a lack of vertical mixing within the pits that is likely related to the morphology of these artificial depressions in an otherwise shallow embayment. These low dissolved oxygen levels create an inhospitable environment for aquatic biota, thus impairing the overall ecological function of these pit habitats.

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