REPORT FOR THE SECOND YEAR OF THE NITRATE ADDITION PILOT TEST (2012) IN THE HYPOLIMNION OF ONONDAGA LAKE

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LIST OF ACRONYMS

CN-8	Calcium nitrate solution applied in the middle of Onondaga Lake during 2011 and 2012 (supplied by Yara Chemical)
DF	Dilution factor
DO	Dissolved oxygen
ISUS	*In situ* ultraviolet spectrophotometer
Metro	Metropolitan Wastewater Treatment Plant (located at the southern end of Onondaga Creek adjacent to the mouth of Onondaga Creek)
mg/kg	Milligram per kilogram
mg/L	Milligram per liter
MT	Metric ton
ng/L	Nanogram per liter
NO_2-N	Nitrite-nitrogen
NO_3-N	Nitrate-nitrogen
NYSDEC	New York State Department of Environmental Conservation
SMU	Sediment Management Unit
SRP	Soluble reactive phosphorus
SU	Syracuse University
SUNA	Submersible ultraviolet nitrate analyzer
UFI	Upstate Freshwater Institute (based in Syracuse, NY)
USEPA	United States Environmental Protection Agency

GLOSSARY OF TERMS

Deep Water (Profundal) – Offshore zone within a water body where water depths are greater than the depth to which sunlight can penetrate to support aquatic plants, in contrast with the littoral zone closer to shore. In Onondaga Lake, the profundal zone thermally stratifies typically from May to October.

Epilimnion - The upper portion of the water column during summer stratification where water temperatures are warmer than lower waters (typically in the portion of Onondaga Lake where water depths exceed 30 ft. [9 meters]). Epilimnion waters are warmer than the underlying hypolimnion layers and mixed by wind and waves.

Hypolimnion - The lower portion of the water column during summer stratification where water temperatures are cooler than upper waters (typically in the portion of Onondaga Lake where water depths exceed 30 ft. [9 meters]). There is less mixing in the hypolimnion than in the epilimnion.

Methylmercury - An organic form of mercury, which can be created from inorganic mercury by bacteria in sediments and water. Methylmercury is a potential neurotoxin, and the form of mercury that can most easily bioaccumulate in organisms.

Thermocline - Located within the interval of water between the epilimnion and hypolimnion corresponding to the water depth of the maximum rate of decrease in temperature with respect to depth.

EXECUTIVE SUMMARY

The second year of a three-year nitrate addition pilot test in Onondaga Lake was completed successfully and met its objective: to demonstrate the ability to maintain nitrate concentrations in the hypolimnion (i.e., water deeper than 30 ft.) at levels sufficient to inhibit release of methylmercury from lake sediment to the overlying waters during stratification. As a result of adding nitrate, methylmercury concentrations measured in deep waters during 2012 were lower than during any prior year on record.

Methylmercury release from Onondaga Lake bottom sediment occurs as oxygen and nitrate become depleted from lower waters during summer stratification. Stratification is the natural process in Onondaga Lake and other temperate lakes whereby upper waters are warm and well-mixed during the summer while lower waters remain cool and isolated. Temperature-induced water density differences are the primary cause of lake stratification. Dissolved oxygen and nitrate become depleted in the lower waters as stratification continues through the summer. Complete depletion of oxygen and nitrate takes place as a result of oxidation-reduction reactions that eventually lead to the release of methylmercury from bottom sediments to the overlying deep waters. Some of the released methylmercury eventually enters the food web where it can bioaccumulate in lake organisms. The presence of nitrate in the lower waters limits methylmercury release and thereby limits bioaccumulation.

As in the first year (2011), the second year of nitrate addition (2012) consisted of multiple applications of a diluted calcium nitrate solution (hereafter called nitrate) to bottom waters. Applications of nitrate in 2012 were completed during 37 non-consecutive days from July 3 to October 4, 2012. Nitrate application took between four and seven hours each day, and the equipment and procedures were virtually the same as those used during 2011. The most significant difference for 2012 was the use of larger dilution water pumps to increase dilution capacity. The liquid calcium nitrate applied in 2012 was the same commercially-available and commonly-used product applied to the lake in 2011. A self-propelled barge measuring approximately 40 ft. long and 24 ft. wide was again used to conduct each of the nitrate applications. The barge is designed to dilute full-strength liquid nitrate with near-surface lake water to achieve relative neutral buoyancy. The resulting solution is then pumped through piping to between 7 and 17 ft. (2 and 5 meters) above the lake bottom or water depths between approximately 42 and 52 ft. (13 and 16 meters) at the north basin site and between 45 and 55 ft. (14 and 17 meters) at the south basin sites. The target dose for each daily application was 4,800 gallons of full-strength liquid nitrate (2.3 metric tons of nitrate-nitrogen). The dose could be easily controlled and modified to meet target nitrate levels in the lake water. The added nitrate was able to spread laterally throughout the entire deep water area of the lake, as determined by extensive lake monitoring.

A potential water quality impact from adding nitrate is increased nitrite-nitrogen levels in the hypolimnion to concentrations above the applicable New York State Department of Environmental Conservation water quality standard protective of warm-water fish propagation. As in 2011, results from 2012 monitoring indicate that adding nitrate had no significant effect on nitrite concentrations in the lake.

SECTION 1

INTRODUCTION

This report describes the second year of a three-year pilot test being conducted on behalf of Honeywell International to maintain nitrate in the hypolimnion of Onondaga Lake in order to mitigate the release and/or production of methylmercury. Methylmercury is a substance that bioaccumulates in lake biota resulting in concentrations in some species and sizes of fish that make them unsuitable for human consumption.

With rising temperatures, Onondaga Lake becomes thermally stratified each year (typically from mid-May through mid-to-late October; see Section 4.1 for additional details). The hypolimnion waters (typically deeper than 30 ft. [9 meters]) of a stratified lake are subject to gradual depletion of dissolved oxygen followed by depletion of dissolved nitrate followed by other oxidation-reduction reactions. When concentrations of oxygen and nitrate are low enough, sediments can release methylmercury to the water column, and inorganic mercury in the water column can become methylated. Increased methylmercury concentrations in lower waters can reach upper waters during lake turnover or during occasional strong seiche events and adversely affect aquatic life.

During 2007 and 2008, releases of methylmercury to the hypolimnion were found to be substantially lower than in previous years due primarily to elevated nitrate concentrations in the lake. The increase in nitrate was a consequence of wastewater treatment upgrades implemented at the Onondaga County Metropolitan Wastewater Treatment Plant (Metro) located along the southern (upstream) shore of Onondaga Lake. Wastewater treated at Metro is discharged into the nearshore waters of the lake between the south shore and Sediment Management Unit (SMU) 8. In 2004, Onondaga County began operating a biologically-active filter system at Metro that converts ammonia to nitrate. As a result, the available pool of nitrate in the hypolimnion at the start of summer stratification roughly doubled. In 2005, Onondaga County activated a phosphorous-removal system resulting in decreased algal growth in the upper waters and reduced demand for electron acceptors in the hypolimnion. As a consequence of Metro's wastewater treatment process enhancements, nitrate persisted in the Onondaga Lake hypolimnion for a significantly greater time during the summer months of 2007 and 2008 compared to previous years, which inhibited the release of methylmercury from SMU 8 sediments (UFI and Syracuse University (SU) 2007, and Todorova et al. 2009).

The nitrate addition pilot test is being conducted in the hypolimnion of Onondaga Lake to further enhance benefits of nitrate that resulted from the 2004 Metro upgrades. The remedy for the Onondaga Lake bottom is described in a Record of Decision prepared by the New York Department of Environmental Conservation (NYSDEC) and the United States Environmental Protection Agency (USEPA) (2005). The Statement of Work appended to the Consent Decree for the Onondaga Lake remedy (United States District Court, Northern District of New York, 2007) specifies that Honeywell conduct a study to determine if nitrate addition would effectively reduce methylmercury in the water column while preserving the normal lake stratification cycle.

As described in the NYSDEC-approved work plan and work plan addendum for this effort (Parsons and Upstate Freshwater Institute [UFI] 2011 and 2012, respectively), the purpose of the nitrate addition pilot test is to demonstrate that a widely-available nitrate solution can be added and mixed with lake bottom waters to effectively limit the release of methylmercury from sediment when the lake is stratified and thereby reduce accumulations of methylmercury in hypolimnion waters. Results from this pilot test also provide additional information about the horizontal distribution of nitrate as a follow-up to the 2008 dye tracer tests (UFI 2009) and the 2009 nitrate application field trial (Parsons and UFI 2010).

For the 2012 pilot test season, as in 2011, liquid nitrate solution was diluted with upper lake waters and added directly to the lower waters of the lake at three locations. One application location was in the northern basin of Onondaga Lake, and the other two application locations were in the southern basin of the lake (Figure 1). The three application locations were the same as those where nitrate was applied in 2011 and were at or near the center of one third of the Onondaga Lake hypolimnion water volume.

Nitrate was added to the lower, stratified waters of Onondaga Lake during 37 non-consecutive, single-day applications from July 3 through October 4, 2012. During nearly all of the application days, a target one-day dose of liquid calcium nitrate solution[1] totaling 3,400 to 5,000 gallons was applied over a four to seven-hour period in one of the three locations. The one exception was a day when 2,400 gallons were applied before high winds forced that day's operation to shut down.

Work efforts within the 2012 portion of the nitrate addition pilot test also helped to assess lake conditions not directly associated with nitrate addition. Surface water samples for laboratory mercury analyses were collected at the South Deep location (see Figure 5). This monitoring of surface water mercury concentrations confirmed the effectiveness of adding nitrate and helped to assess compliance with the New York State water quality standard of 0.7 nanograms per liter (ng/L) for total dissolved (filtered) mercury. In addition, sediment trap samples collected at South Deep were analyzed to assist with the ongoing assessment of the natural recovery of Onondaga Lake profundal zone sediment.

Fall turnover usually occurs sometime from mid-October to early November each year, with the exact timing dependant on a complex set of lake and meteorological factors. In 2012, water stratification in Onondaga Lake ended on or about October 22, when the lake waters became completely mixed (referred to as turnover). The end of stratification in 2012 was about two weeks earlier than in 2011.

In addition to the Executive Summary and this Introduction, this report presents barge design and as-built information in Section 2, pilot test procedures and observations in Section 3, and a discussion and summary of results in Sections 4 and 5, respectively. Appendix A is a photographic log. Appendix B is an example of daily monitoring information generated and provided by UFI during a day when field data were collected. Appendix C is a summary of

[1] The liquid calcium nitrate used was labeled CN-8 by the supplier Yara Chemical, of Tampa, Florida

nitrate concentrations observed 1 meter above the lake bottom from late June through November 2012. Appendix D is the Data Usability and Summary Report for water quality data from samples collected at South Deep in 2012. Appendix E consists of water depth profile plots of dissolved oxygen, nitrate-nitrogen, total mercury and methylmercury results for each day water samples were collected at South Deep and analyzed in a laboratory.

SECTION 2

PILOT TEST DESIGN AND 2012 AS-BUILT SUMMARY

2.1 DESIGN BASIS AND SUMMARY

The first two years of nitrate addition were conservatively designed to commence just prior to hypolimnetic nitrate-nitrogen concentrations falling below 1 milligram per liter (mg/L) at the 18-meter depth and continue to a few weeks prior to fall turnover. Figures 3 and 4 in the approved work plan for this effort (Parsons and UFI 2011) show the nitrate and methylmercury concentration plots from 2008 through 2010. These plots indicate rapid nitrate depletion under anoxic conditions and subsequent increase in methylmercury concentration as nitrate concentrations in lower waters approach zero. These factors formed the basis for this pilot program design. The 2012 nitrate addition results reported herein further show that a target nitrate-nitrogen threshold of 1 mg/L effectively suppresses methylmercury water concentrations.

Nitrate additions were designed to be conducted at three predetermined locations in the lake (based on continuous monitoring results): North, South Location #1 (hereafter called South1), and South Location #2 (hereafter called South2). In order to maintain the desired minimum concentration of nitrate (1 mg/L), the maximum nitrate application rate was determined based on peak four-week rolling average nitrate uptake rates in the hypolimnion as measured by UFI during the summers of 2007, 2008, and 2009. Based on these data and an assessment of the potential for induced demand, the design demand was set at 1.0 metric ton (MT) of nitrate-nitrogen per day or about 7.0 MT per week. In order to meet the nitrate design demand, an average of 4,800 gallons of liquid calcium nitrate (2.3 metric tons) needed to be added to the lower waters of the lake during each application. The 2011 pilot test results indicated that the average demand for nitrate was approximately 0.8 MT per day (83 MT over 102 days between June 30 and October 10, 2011 (Parsons, 2012). Pilot test results for 2012 show the same demand for nitrate of 0.8 MT per day.

2.2 APPLICATION BARGE

The design objectives and basis for the barge used to deliver the nitrate are presented in the approved work plan and its addendum (Parsons and UFI 2011, 2012). The 2012 barge as–built drawing is presented in Figure 2, and Figure 3 presents the barge piping and instrumentation. The application system consisted of a modular barge made up of three joined 8.5-ft. by 40-ft. sections that housed the storage and delivery equipment. Three barge sections provided adequate space for all necessary equipment while allowing passage of the barge through Onondaga Creek to the onshore nitrate staging area at the Syracuse Inner Harbor. Nitrate is stored on the barge in two polyethylene nitrate holding tanks housed inside storage basins that provided secondary containment. Each of the two tanks had an 8-ft.-diameter footprint based on height limitations imposed by the need to pass beneath the railroad bridge at the outlet of Onondaga Creek between the Syracuse Inner Harbor and Onondaga Lake. Other equipment aboard the barge consisted of two dilution water pumps, two chemical pumps, a propulsion-driven power unit, a generator, a

manifold for delivering dilution water and calcium nitrate, a shed for storage and protection, a portajon, and a deck crane. Each of the two dilution water pumps were equipped with a 12-inch diameter suction line and discharge line connected to a chemical pump and associated piping. The barge was specifically designed and constructed to include essential equipment while minimizing potential hazards and obstacles affecting system operations and optimizing operating work space and efficiency. For example, the barge is suitably protected from ground fault circuit interruption.

The 2012 barge equipment layout is depicted in Figure 4. Positioning of the two nitrate holding tanks and the two dilution water pumps (labeled in Figure 4 as pumps) is based on distributing the total weight evenly throughout the surface area of the barge. The most significant difference in barge equipment between 2011 and 2012 was the use of larger-capacity dilution water pumps. Each of the two dilution water pumps used during 2012 could efficiently pump 3,500 gallons per minute of lake epilimnion dilution water and nitrate to the lake's lower hypolimnion. At the end of the 2012 season, the 2012 barge was kept intact for the winter months with the exception of the rented dilution water pumps and the rented portajon. The barge is being stored on the lake near the western shoreline until the 2013 application season begins.

SECTION 3

2012 PILOT TEST PROCEDURES AND OBSERVATIONS

3.1 NITRATE APPLICATION SEQUENCE

The 2012 lake water quality monitoring at South Deep on behalf of Honeywell International began in April for various lake parameters and on June 4 for mercury and continued through November 19. Measurements of dissolved oxygen, nitrate and other water quality parameters in the deep portion of Onondaga Lake prior to the first application provided information needed to determine when to start adding nitrate to the lake. Water quality measurements during the nitrate application period helped to guide how much nitrate to apply at each location. Water quality monitoring was also conducted on October 9, October 16, and October 22 and following lake turnover on November 5 and November 19, 2012.

Agencies were notified at least one week prior to the start of 2012 nitrate additions. The event schedules for Onondaga Lake Park and Syracuse Inner Harbor were checked in advance every week to be sure nitrate additions would not affect scheduled public activities.

An onshore support zone for storing and refilling the nitrate holding tanks on the barge was located at the Syracuse Inner Harbor from June until August 2012 when onshore support was moved to Honeywell property on the western shoreline of Onondaga Lake. Onshore support included a l6,000-gallon portable nitrate holding tank fitted with secondary containment and associated pumps and hosing.

In 2012, nitrate was applied continuously for approximately four to seven hours a day at one of three pre-determined locations. The daily duration for nitrate addition was determined based on how much nitrate was to be added that day and the extent of dilution required (increased dilution meant longer pumping times to apply the same volume of nitrate). A total of 37 applications of nitrate were completed during 2012, including 13 applications at South 1, 11 applications at the South 2, and 13 applications at the North location.

Each application of nitrate involved the same three basic steps in 2012 as in 2011. First, the barge was moved and anchored at the designated application location. A concrete block anchoring system held the barge stationary at that location for the duration of the application. Second, inflow and outflow piping with end-of-pipe diffusers were positioned deep within the lake water column. Third, the barge pumps were started that provided water from the epilimnion to mix with full-strength nitrate. The resulting neutrally buoyant nitrate-water mixture was directed to the lower waters in the lake hypolimnion via hoses and diffusers set in Step 2. Each application continued until the desired quantity of nitrate was applied. Photographs of the barge, equipment, and pumps are presented in Appendix A.

Table 1 summarizes work completed as part of each 2012 nitrate application. The initial application was conducted on July 3, 2012, and consisted of 3,697 gallons of full-strength nitrate (1.78 MT of nitrate-nitrogen) at South 1. In general, applications were conducted on Mondays, Wednesdays, and Thursdays, moving from location to location so that all three locations

received at least one application each week. Table 2 provides operational information, including application location, target dilution factor, lake water temperature and specific conductivity data, nitrate and dilution water flow rates, durations, and the total amount of calcium nitrate applied during each 2012 application. A total of 72 MT of nitrate-nitrogen were added to the lower waters of Onondaga Lake during 2012 compared to 83 MT during 2011. Full-strength liquid nitrate solution mixed with Onondaga Lake water during each 2012 application originated from a single batch produced by Yara Chemical.

3.2 IN-LAKE MONITORING

The extent of in-lake monitoring completed in association with each 2012 application of nitrate is summarized in Tables 3 and 4. In-lake monitoring was conducted by UFI deploying an *in situ* ultraviolet spectrophotometer (ISUS) or a submersible ultraviolet nitrate analyzer (SUNA) from a boat. UFI provided near real-time feedback on the vertical position of added nitrate several times each day during which an application occurred. Figure 5 illustrates the 2012 lake monitoring locations.

The objective of in-lake monitoring was to observe and characterize the distribution of nitrate in the vertical dimension and to monitor spreading of the nitrate horizontally across the lake. Lake monitoring of 2012 nitrate addition effects was completed consistent with 2011 monitoring and at the same locations. The monitoring boat used a global positioning system to locate a particular station, deploy the ISUS-SUNA monitor to within 3 ft. (1 meter) of the bottom, and then retrieve the ISUS-SUNA monitoring data over the course of two to three minutes. Measurements were collected every 0.25 meter vertically throughout the water column recording water depth, nitrate-nitrogen, sulfide, temperature, specific conductivity, turbidity and parameters associated with light penetration and primary productivity. These data were downloaded and processed, and a summary of the day's results was provided the same day nitrate was applied. Each data summary included nitrate-nitrogen profiles at each monitoring location (Figure 5), as well as bubble plots illustrating nitrate-nitrogen concentrations at particular depths within the hypolimnion, including one plot of all measurements taken 1 meter above the lake bottom across the footprint of the hypolimnion. A UFI monitoring boat was used to collect nitrate data in the lake near the barge about an hour or two after the start of each nitrate application to collect profiles to identify the effective water depth where the calcium nitrate solution was applied (see comments in Table 2).

The performance of the ISUS-SUNA optical nitrate probe in Onondaga Lake has been compared with laboratory measurements of nitrate in Onondaga Lake water since 2006. Results from the ISUS-SUNA and from UFI's laboratory compared closely demonstrating that ISUS-SUNA measurements are reliable (Figure 6).

In addition to monitoring during each nitrate application, surface water samples were collected at South Deep on 22 different dates from early June to late November 2012 and analyzed in a laboratory for numerous water quality parameters. These parameters included low-level total mercury and methylmercury consistent with lake water monitoring efforts since 2008. Selected surface water samples from the 2-meter and 14-meter water depths at South Deep were also analyzed for filtered (i.e., dissolved) total mercury. Surface water samples collected weekly

at South Deep from June 30 to October 10 (while nitrate was being added to the lake) were analyzed for total mercury, methylmercury, nitrogen forms, soluble reactive phosphorus and calcium. Samples collected from waters 14 meters and deeper were also analyzed for sulfide and ferrous iron.

SECTION 4

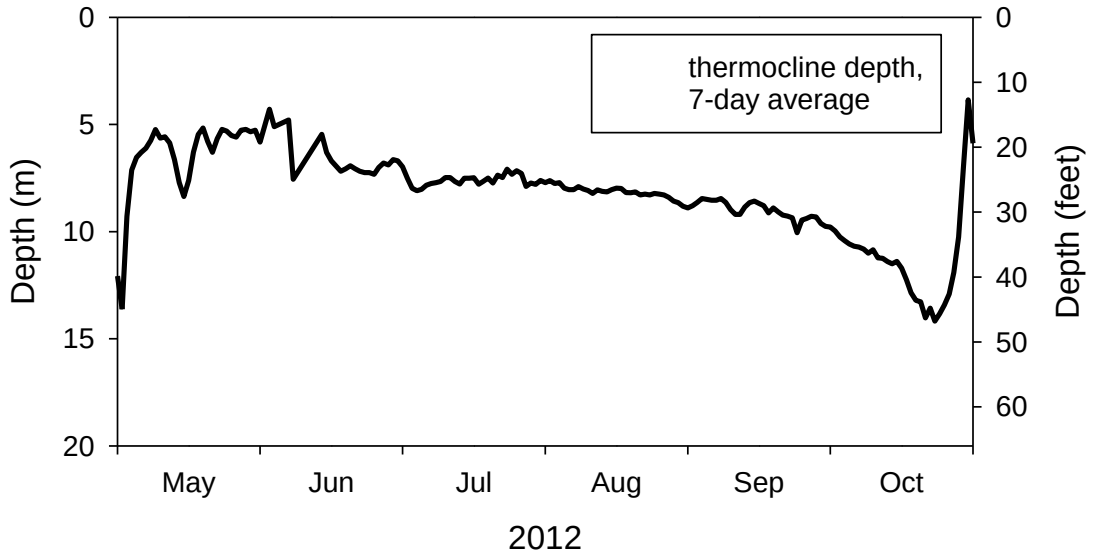
DISCUSSION OF 2012 PILOT TEST RESULTS

The objective for the nitrate addition pilot test in both 2011 and 2012 was to maintain summertime nitrate-nitrogen levels in the lower hypolimnion (below the 14-meter water depth) at or above 1 mg/L, thereby limiting accumulations of methylmercury in hypolimnion waters. This section describes:

- Natural development of thermal stratification over time
- Oxygen and nitrate resources of the hypolimnion
- Effect of nitrate applications on nitrate levels
- Nitrite concentrations in lake water
- Other related monitoring from June through early October 2012 when nitrate was being applied

4.1 THERMAL STRATIFICATION OBSERVED OVER TIME

The thermocline of a lake is located at the position of maximum temperature change with water depth and is the boundary between the epilimnion and the hypolimnion. Changes in average thermocline depth at the South Deep robotic monitoring location (ISUS-11 on Figure 5) during 2012 were as follows:



Stratification became established by mid-May 2012, shutting off further significant inputs of nitrate from the epilimnion downward to the hypolimnion (below the 30-ft. water depth in Onondaga Lake). Stratification initiates a period of oxygen depletion and locks in place the

"ambient" nitrate pool or supply that is available to support nitrate reduction in the sediments. The depth of the thermocline between the epilimnion and hypolimnion was relatively stable through June-July and then slowly descended through September, after which the rate of descent accelerated until the water column was effectively mixed by late October.

4.2 DISSOLVED OXYGEN AND NITRATE OBSERVATIONS

The average dissolved oxygen concentration at the time of stratification setup in 2012 was approximately 7.5 mg/L, yielding an oxygen pool of 350 MT in the hypolimnion. The oxygen pool on May 22, 2011, also near the time stratification set up in the lake, was 450 MT. The large difference in the size of the oxygen pools in 2011 and 2012 is something of an anomaly, because oxygen concentrations in early May of both years tracked fairly well. However, between May 20 and May 25, 2011 there was a significant increase in the hypolimnetic oxygen pool, while the oxygen pool declined as expected during the same timeframe in 2012. The oxygen pool increase in May 2011 could be explained by a seiche-induced upwelling event that may have delivered oxygen rich water to the hypolimnion, while sending water with depleted oxygen to the epilimnion. Whatever the cause, the change between the two years highlights the inter-annual differences that are to be expected in lake systems.

Figures 7 and 8 present 2012 dissolved oxygen and nitrate-nitrogen concentrations at the South Deep location for four different water depths. Figure 9 illustrates the depletion of the dissolved oxygen pool after the start of stratification, based on readings from the UFI robotic buoy located at South Deep. Most of the oxygen available in the hypolimnion prior to lake stratification was consumed by late June. The nitrate applications were successful in keeping the nitrate-nitrogen levels above 1 mg/L throughout the summer months and throughout the hypolimnion.

Figure 10 illustrates the average nitrate-nitrogen concentrations in the hypolimnion over time, along with the cumulative mass of nitrate-nitrogen applied to the lower hypolimnion over time. The average nitrate-nitrogen concentration in the lake prior to the start of stratification in mid May was 2.5 mg/L, corresponding to a pool of about 114 MT of nitrate-nitrogen. These concentrations were most likely related to a very dry spring in the watershed during 2012. Since Metro is the main source of nitrate-nitrogen to the lake, a dry spring translates to less dilution of Metro effluent, which contains on average about 10 mg/L of nitrate-nitrogen.

The red line in Figure 10 tracks cumulative additions of nitrate to the lower hypolimnion of Onondaga Lake during 2012. In general, the averaged rate of addition was 1.0 MT of nitrate-nitrogen per day (7.0 MT per week) for the first month of applications to establish control over the nitrate pool in the hypolimnion. Starting on July 18, applications of nitrate were reduced to an average daily loading rate of 0.8 MT per day (5.6 MT per week), the design basis for nitrate demand included in the approved work plan and its addendum (Parsons and UFI, 2011, 2012). Figure 10 also illustrates the Onondaga Lake response to these applications, with average nitrate concentrations leveling off and then starting to increase through the last application on October 4, 2012.

Figure 11 illustrates nitrate depletion rates in the hypolimnion of Onondaga Lake in 2012 represented by measurements at South Deep and at North Deep (see Figure 6 for locations).

Volume-weighted nitrate concentrations were calculated with respect to lake surface area and specific water volume and shown as a function of time. Nitrate depletion in the northern half of the lake averaged 12.9 micrograms of nitrate-nitrogen per liter per day, which was 9 percent lower than the rate of 14.0 micrograms of nitrate-nitrogen per liter per day in the southern half. This higher nitrate depletion rate in the southern half of the lake in 2012 was expected and has typically been observed based on data available since 2007.

Figure 12 is a vertical profile showing average nitrate concentrations in the hypolimnion from June through October 2012. Areas of the lake with water depths below 17.5 meters (57 ft.) were exposed to nitrate-nitrogen concentrations greater than 2.5 mg/L for most of the July to early October time period when nitrate was being applied. Sediments below the 14.5-meter (48-ft.) water depth were generally exposed to nitrate concentrations greater than 1.5 mg/L once applications were begun. Concentrations of nitrate in Onondaga Lake waters were appreciably higher in 2012 compared to 2011 due to higher nitrate concentrations in the spring of 2012 prior to the lake becoming stratified.

Figure 13 illustrates the spatial and temporal extent of the measured nitrate-nitrogen concentrations, at a water depth of 1 meter (3 ft.) above the sediments. Concentrations of nitrate-nitrogen in these deepest waters generally ranged from 1.5 to 3.5 mg/L throughout the 2012 nitrate application timeframe.

Nitrate levels in hypolimnion waters continued to increase unexpectedly following the last application of nitrate on October 4. This increase was caused by an increase in nitrate rich effluent reaching the hypolimnion from the Metro treatment plant. Brackish groundwater from one of the combined sewer overflow construction locations in the City of Syracuse was sent to Metro which increased the salinity and density of the effluent entering the lake. Starting in October, the denser Metro effluent was documented sinking into the lake's hypolimnion. The resulting increase in nitrate concentrations masked the depletion of the nitrate pool that was expected in the hypolimnion once nitrate applications were discontinued, as was seen in 2011. Nitrate-nitrogen concentrations throughout the hypolimnion were relatively uniform in October 2012.

4.3 DILUTION AND DISPERSION OF APPLIED NITRATE

Because the specific gravity of the full-strength liquid nitrate was 1.49, significant dilution was required to produce near neutrally buoyant nitrate, a characteristic essential to taking advantage of natural hydrodynamic forces that spread the nitrate around the lower depths of the lake. In 2011, the density of the diluted solution was estimated using the model developed by Chen and Millero (1978), which previously had been applied to Onondaga Lake (Effler, 1996). However, the Chen and Millero model under-predicted the required dilution rate. Fortunately, dilution rates did not vary significantly over short time periods, so that once an appropriate dilution factor was determined for an application of nitrate, the same dilution factor could be used as a starting point for the next application. Further subtle adjustments to dilution and pump rates were then used to achieve a neutrally buoyant plume.

Given the Chen and Millero equation is an empirical model based on a large database of measurements of sea water, data from the 2011 application season (i.e., temperatures, specific

conductivities, flow rates and associated dilution factors that produced near-neutrally-buoyant plumes) were applied to develop a multi-variable regression based on the use of liquid nitrate as the nitrate source. The regression relationship is expressed by the following equation for quantifying the dilution factor (DF), based on 16 applications of nitrate during 2011 that resulted in near-neutrally buoyant plumes:

$$DF = 651.89 - 21.58T_e + 10.59T_h + 0.1658SC_e + 0.03542SC_h$$

Where water temperature in the epilimnion and hypolimnion (T_e and T_h respectively) are in degrees Celsius and specific conductivity in the epilimnion and hypolimnion (SC_e and SC_h respectively) are in microsiemens per centimeter. The above regression relationship underestimated the required dilution for applications of nitrate in 2012 by about 12 percent, which was an improvement over the Chen and Millero equation. Data from nitrate applications in 2012 that produced near neutrally buoyant plumes will be added to the database that underlies the multivariate regression analysis to improve the estimates prior to the 2013 season. Figure 14 provides a timeline of water temperatures at relevant depths within the epilimnion and the hypolimnion, the calculated/predicted dilution factors for those dates, and the actual dilution factor that was needed to produce a near neutrally-buoyant nitrate-water mixture on those dates.

During the summer of 2012, dispersion by natural hydrodynamic forces was again adequate to distribute nitrate horizontally across the hypolimnion from the three application locations. Appendix B provides an example of the daily ISUS-SUNA data reports produced and issued by UFI to verify the application and distribution of the applied nitrate. Appendix C presents the bubble plots prepared by UFI illustrating conditions across the hypolimnion at a distance of 1 meter (3 ft.) above the lake bottom. The target nitrate-nitrogen concentration of 1 mg/L continued to be met in lower hypolimnion waters over the course of the 2012 season, and minimal concentrations of methylmercury were observed in the lower waters. Therefore, the project objectives were again successfully accomplished in 2012 using the same three fixed locations.

For the entire 2012 nitrate application season, the dilution water pumps were operating at their full capacity of approximately 3,500 gallons per minute. As of September 19, 2012, the temperature difference between the extraction depth for dilution water (2 meters) and the water depth where nitrate was applied (16 meters or more) had declined to such an extent that achieving near-neutral buoyancy was more difficult. No evident adverse effect on the lateral distribution of nitrate was observed after September 19, although the additional source of nitrate to the lower waters from the plunging Metro outflow may have been a contributing factor.

Applications of nitrate were terminated on October 4, 2012, based on an assessment of the size of the nitrate pool and expected uptake of nitrate in lower waters of the lake through an estimated late turnover date of November 6, 2012. Approximately 101 MT of nitrate-nitrogen remained in the lake's hypolimnion on October 4, 2012, compared to 71 MT on October 10, 2011, which was the last day of nitrate applications in 2011. The 2012 nitrate pool was larger because nitrate levels in the upper portion of the hypolimnion were elevated as a consequence of the declining thermocline and elevated nitrate-nitrogen concentrations in the epilimnion. Other contributing factors included the temporary plunging Metro discharge in late summer and a

conservatively-late estimate of November 5 for the lake to turnover. Lake turnover was actually completed by October 22, 2012.

4.4 SIGNIFICANCE OF 2012 NITRITE LAKE WATER CONCENTRATIONS

Nitrite-nitrogen (NO_2-N) concentrations measured in Onondaga Lake from 2006 through 2012 were compared to the New York State surface water quality standard established to protect warm water fish from effects of nitrite (Figure 15). Although the surface water quality standard for nitrite was exceeded in lower waters during each year, there was no evidence that these exceedances were associated with nitrate addition. Concentrations of nitrite remained below the New York State surface water quality standard in the upper waters where fish move and feed during the summertime period.

4.5 2012 MERCURY LAKE WATER CONCENTRATIONS

From the beginning of the 2012 nitrate applications in late June through turnover in the middle of the lake on October 22, the maximum concentration of methylmercury observed in the lower waters of the lake was 0.23 ng/L (where 1 ng/L is 0.000001 mg/L) observed on August 20, 2012, at the 18-meter water depth (Figure 16).

Volume-weighted average hypolimnion water concentrations for dissolved oxygen, nitrate-nitrogen, and methylmercury for the summer-fall time period from 2006 through 2010 were compared to concentrations observed during the two years of pilot testing. Methylmercury concentrations were considerably lower in the lake's hypolimnion in 2011 and 2012 compared to recent prior years (Figure 17). The low methylmercury concentrations in 2011 and 2012 are consistent with the higher nitrate concentrations (as a result of nitrate additions) in those years than in recent prior years.

Figures 18 and 19 present the methylmercury and unfiltered total mercury results measured at South Deep over time at water depths of 2 meters (epilimnion), 12 meters (near the top of the hypolimnion), 16 meters (mid-to-lower hypolimnion), and 18 meters (bottom of the hypolimnion). Total mercury and methylmercury concentrations in samples collected in water near the lake bottom from the South Deep location are summarized in Table 5. Table 6 summarizes dissolved mercury concentrations in samples collected at the 2-meter water depth in the epilimnion.

Methylmercury was not significantly released from underlying sediment to lower hypolimnion waters during the summer of 2012 when deep lake waters would be prone to methylmercury release in the absence of nitrate addition. The peak 2012 methylmercury concentration in the hypolimnion (0.23 ng/L) was observed on August 20, 2012 which demonstrates that nitrate addition was as effective in 2012 as it was in 2011. Figure 20 presents methylmercury concentrations in lake water at the 18-meter water depth at South Deep from 2007 through 2012. The highest methylmercury concentration measured in surface water at South Deep in 2012 was 0.29 ng/L on November 19 at a water depth of 2 meters.

Unlike recent years, a notable total mercury increase (to 16 ng/L) was detected in samples collected at the 18-meter water depth on October 16 and 22, 2012 (see Figure 19). There was no corresponding increase in methylmercury. The elevated total mercury concentrations appear to

coincide with complete mixing of the water column during fall turnover (Figure 21). A closer examination of the data indicated that total mercury concentrations also increased at the other sample depths (2, 10, 12, 14, and 16 meters) during this period, but to a lesser degree than at the 18 meter water depth. Multiple factors were examined to explain the observed increase in water column total mercury concentration. A temporary resuspension of surface sediments from deep water during the fall turnover appeared to be the most likely cause, since only a small amount of resuspended sediment would likely be required to increase water column concentrations of total mercury to the 16 ng/L documented. Figure 22 presents total mercury concentrations and turbidity levels measured at the 18-meter water depth at South Deep from September through November 2012 and shows that the increase in total mercury concentration coincided with a substantial increase in turbidity. Similar correlations were found at the other water column sample depths monitored during this period. In addition, sediment traps placed at the 10-meter water depth and at the 17-meter water depth exhibited notable increases in mercury deposition rates and large, compact, and diverse aggregate particles in traps at the 17-meter water depth during this same period suggesting that sediments resuspending from the lake bottom and settling out of the water column was the likely source (refer to Section 4.6.3, Table 7 and Appendix F). Other possible causes that were explored are summarized below and include increased tributary loadings to the lake combined with plunging inflows, plunging of Metro effluent, resuspension from the in-lake waste deposit (ILWD), and resuspension from dredging operations.

- An analysis of daily rainfall and tributary discharge data from the National Weather Service and the United States Geological Survey, respectively, found no significant storm events or increases in tributary discharges occurring in mid-to-late October that would explain the increases in water column mercury and turbidity.
- The effluent discharged from Metro plunged to the bottom during the fall. However, mercury concentrations in Metro effluent seem far too low to account for the water column spike and the plunging flows began prior to and continued well after the spike in water column mercury occurred. In addition the effluent appears to have been isolated to the very bottom of the lake whereas total mercury and turbidity increased throughout the water column.
- An analysis of local wind data available from the National Weather Service found that there were generally light winds in mid-to-late October from directions unlikely to result in mobilization of ILWD sediments and subsequent transport to deeper water.
- Data from monitoring of dredging and capping activities during 2012 show no significant effect in the middle of the lake from dredging or capping activities during 2012 (see Appendix G). A brief increase in lake turbidity noted on October 4 at two of the monitoring locations did not reach a level that warranted investigation a cause.

4.6 OTHER RELATED 2012 LAKE MONITORING

4.6.1 2012 In-Lake Water Velocity Measurements

Two acoustic doppler velocity meters were deployed during the summer of 2012 in the vicinity of two of the three nitrate application locations (approximately 100 ft. from the North and South 2 application locations). These velocity meters transmit a short pulse of sound and measure the change in pitch or frequency of the sound echo. A steel stationary frame was used to ensure that each meter's sensors remained at a fixed location from July through October 2012.

The two velocity meters were positioned approximately 1 meter above the sediment-water interface, or mudline. Both velocity meters were programmed to record data once every 30 minutes. Peak velocities of 0.24 meters per second at the North location and 0.29 meters per second at the South 2 location were recorded in late September and early October, respectively.

4.6.2 2012 Soluble Reactive Phosphorus Results

An additional benefit to maintaining nitrate levels in the hypolimnion during periods of anoxia is that release of phosphorus from deep lake sediments can be reduced. The presence of nitrate in waters near the lake bottom prevents the reduction of iron and manganese typical in an oxygen poor environment, which in turn reduces the release of phosphorus that was formerly bound to the those elements (Figures 23 and 24).

4.6.3 2012 Sediment Trap Mercury and Solids Results

Table 7 presents mercury in slurry, triplicate total suspended slurry solids results and calculated mercury on slurry solids collected from sediment traps during 2012. Average suspended solids contents in these samples ranged from 672 to 5,273 mg/L. Mercury concentrations on sediment trap solids ranged from 0.38 to 2.03 milligrams per kilogram (mg/kg) with a mean of 1.1 mg/kg. Mercury deposition rates based on sediment trap results averaged 7.5 micrograms per square meter per day.

Sediment trap results also support the explanation that the source of October increases in total mercury surface water concentrations in the hypolimnion was a temporary resuspension of sediment (see Section 4.5).

4.6.4 Zooplankton Mercury Results for 2012

Table 8 and Figures 25A and 25B present total mercury and methylmercury concentrations measured in zooplankton collected at South Deep in 2012. Figures 25A does not include results from September 12, 2012, because mercury results from September 12 show a concentration of methylmercury that is relatively small but higher than the concentration of total mercury.

The highest total mercury concentration observed in 2012 in zooplankton was 0.27 milligrams per kilogram (mg/kg) (or parts per million) on a wet-weight basis observed on September 4 more than a month prior to fall turnover. The highest methylmercury concentrations observed in 2012 in zooplankton was 0.014 mg/kg on August 6. The highest portion of methylmercury observed in 2012 as a percentage of total mercury was 21 percent prior to the start of fall turnover and ranged from 20 to 39 percent following fall turnover.

SECTION 5

SUMMARY OF 2012 (YEAR 2) PILOT TEST RESULTS

Results from this second year of a three-year nitrate addition pilot test (2012) demonstrated successful delivery of sufficient quantities of liquid calcium nitrate to the lower hypolimnion of Onondaga Lake during summer stratification to meet pilot test objectives and thereby minimize the release of methylmercury concentrations in deep waters of the lake. The minimum required nitrate-nitrogen concentration of 1 mg/L was maintained, on average, both vertically near the lake bottom and laterally throughout the lake, thus inhibiting the release of methylmercury from the sediments. Methylmercury release into the water column was effectively controlled throughout the profundal zone.

A total of 71.6 MT of nitrate-nitrogen were added to the hypolimnion of Onondaga Lake during 2012 at rates between 0.8 and 1.0 metric tons per day *(i.e.,* between 5.6 and 7.0 tons per week). Applications continued uninterrupted from late June until October 4. Nitrate concentrations in lower waters unexpectedly did not decline after October 4, most likely due to plunging of the treated Metro effluent when Metro received brackish groundwater from dewatering conducted at an upland combined sewer control facility construction site.

SECTION 6

REFERENCES

Chen, C.T. and Millero, F.J. 1978. *The Equation of State of Seawater Determined From Sound Speeds*. Journal of Marine Research 36:657-691.

Effler, S.W. 1996. *Limnological and Engineering Analysis of a Polluted Urban Lake*. Prelude to Environmental Management of Onondaga Lake, New York. Springer-Verlag, New York.

New York State Department of Environmental Conservation and United States Environmental Protection Agency Region 2. 2005. *Record of Decision*. Onondaga Lake Bottom Subsite of the Onondaga Lake Superfund Site. July 2005.

Parsons and UFI. 2010. *Report for the Nitrate Application Field Trial in the Hypolimnion of Onondaga Lake*. Prepared for Honeywell. March 2010.

Parsons and UFI. 2011. *Work Plan for Pilot Test to Add Nitrate to the Hypolimnion of Onondaga Lake*. Prepared for Honeywell. March 2011.

Parsons and UFI, 2012. Addendum 1 (2012) to Work Plan for Pilot Test to Add Nitrate to the Hypolimnion of Onondaga Lake. Prepared for Honeywell. May 2012.

Todorova, S.G., Driscoll, C.T., Matthews, D.A., Effler, S.W., Hines, M.E., and Henry, E.A. *Evidence for Regulation of Monomethyl Mercury by Nitrate in a Seasonally Stratified, Eutrophic Lake*. Environ. Sci. Technol., 2009, 43 (17), pp 6572–6578.

UFI. 2009. *Report on the 2008 Dye Tracer Study to Evaluate Transport and Mixing in the Hypolimnion of Onondaga Lake*. Prepared for Honeywell. July 2009.

UFI and SU. 2007. *Preliminary Feasibility Analysis for Control of Methylmercury Production in the Lower Waters of Onondaga Lake Through Nitrate Addition*. A report prepared for Honeywell by Upstate Freshwater Institute, Syracuse, NY and Syracuse University, Center for Environmental Systems Engineering, Syracuse, NY.

UFI and SU. 2008. *Interpretive Report. Evaluation of Nitrate Addition to Control Methylmercury Production in Onondaga Lake*. 2007 Study. Prepared for Honeywell. April 2008.

United States District Court, Northern District of New York. 2007. State of New York and Denise M. Sheehan against Honeywell International, Inc. *Consent Decree Between the State of New York and Honeywell International, Inc.* Senior Judge Scullin. Dated October 11, 2006. Filed January 4, 2007.

TABLES

TABLE 1

2012 NITRATE ADDITION SUMMARY

Date/Location[1]	Metric Tons (as N) of CN-8 Applied[2]	Application Water Depth[3] (feet)	Dilution Water to CN-8 Solution Volume Ratio	Date/Location	Metric Tons (as N) of CN-8 Applied	Application Water Depth (feet)	Dilution Water to CN-8 Solution Volume Ratio
July 3 / S1	1.78	52	307.7	Aug 23 / S2	1.85	57	344.22
July 10 / S2	2.3	57	298.54	Aug 27 / S1	1.84	57	336.69
July 11 / S1	2.29	56	292.02	Aug 29 / N	2.29	52.5	348.92
July 12 / S2	2.32	57	282.22	Aug 30 / S2	2.29	57	349.42
July 16 / N	1.97	53	279.99	Sept 5 / S1	2.29	57.3	352.20
July 18 / S1	1.87	56	269.97	Sept 6 / N	2.29	52.7	356.07
July 19 / S2	1.93	56.5	273.04	Sept 10 / S1	2.29	57	388.09
July 23 / S1	2.30	56	272.84	Sept 12 / N	1.85	52	400.32
July 25 / N	1.83	53	318.53	Sept 13 / S2	1.84	57	396.85
July 26 / S2	1.84	57	283.64	Sept 17 / S1	1.84	57	405.63
July 30 / S1	1.84	57	281.40	Sept 19 / N	1.85	52	444.83
Aug 1 / N	1.84	49	297.13	Sept 20 / S2	1.84	57	438.24
Aug 2 / S2	1.61	56.8	292.65	Sept 26 / S1	1.62	57	484.35
Aug 6 / S1	1.73	57	288.97	Sept 27 / N	1.62	52	486.19
Aug 8 / N	1.85	53.5	294.89	Oct 1 / N	1.88	54	275.9
Aug 9 / S2	1.84	57	283.45	Oct 4 / N	2.41	54	503.1
Aug 13 / S1	1.84	57	319.97				
Aug 15 / N	1.85	53	341.8				
Aug 16 / S2	1.84	57	329.34				
Aug 20 / S1	1.13	57	344.24				
Aug 22 / N	1.90	52.6	358.71				

Total nitrate applied = 71.61 Metric Tons

NOTES:

[1] S1 is the South Location 1, S2 is the South Location 2, and N is the North Location (see Figure 1).

[2] 2.3 metric tons = 4,800 gallons for CN-8.

[3] Water depth at the bottom of the 4-foot long diffuser at the lower end of each application pipe.

[4] Ratio utilizes the following values:

$$\frac{\text{H20 Pump A (gpm) + H20 Pump B (gpm)}}{\text{Chemical System A (gpm) + Chemical System B (gpm)}}$$

TABLE 2
Summary of 2012 Nitrate Application Data Collection and Calculations

Date		7/3/2012	7/10/2012	7/11/2012	7/12/2012	7/16/2012	7/18/2012	7/19/2012	7/23/2012	7/25/2012	7/26/2012	7/30/2012	8/1/2012	8/2/2012	8/6/2012
Location		S1	S2	S1	S2	N	S1	S2	S1	N	S2	S1	N	S2	S1
DF		307.7	298.54	292.02	282.22	279.99	269.97	273.04	272.84	318.53	283.64	281.40	297.13	292.65	288.97
Q_CN8_gauge	gpm	12	14.6	14.5	15.45	15.57	16.15	15.96	15.98	13.69	15.37	15.49	14.67	14.96	15.09
Q_CN8_Correction Factor	gpm	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Q_CN8_actual	gpm	9.60	11.68	11.60	12.36	12.46	12.92	12.77	12.78	11.90	12.30	12.39	11.74	11.97	12.07
Q_epi_Pump A	gpm	3481	3504	3450	3458	3580	3427	3461	3472	3415	3485	3439	3457	3462	3450
Q_epi_Pump B	gpm	3200	3527	3555	3446	3465	3478	3464	3396	3434	3463	3458	3407	3364	3450
T_epi	degreeC	24.9	25.5	25.9	26.2	26.6	26.5	26.5	26.7	24.8	26.0	26.1	26.0	26.2	26.2
SC_epi	uS/cm	1974	1585	1965	1962*buoy only	1760	1968	1979*buoy only	2022	1853	2038	2069	1980	1962	2034
Water depth	ft (m)	62.5	63	62	63	59	62	63	62	58.6	63	63	57.5	62.8	63
Target depth[8]	ft (m)	52	57	56	57	53	56	56.5	56	53	57	57	49	56.8	57
T_target depth	degreeC	9.8	10.5	10.9	10.4	11.5	9.5	10.0	10.7	11.2	9.9	9.9	12.1	11.9	11.5
SC_target depth	uS/cm[6]	1930	1186	1354	1925*buoy only	1771	1921	1933*buoy only	1895	1969	1918	1917	1825	1848	1822
Start time_dosing		830	955	1020	1215	1120	915	1035	1515	900	940	1240	928	1012	A: 1334, B: 1332
Start Volume_Tank A[7]	gallons	2569	2600.57	2537.9	2663.23	2240.25	2224.58	2193.25	2569.24	2506.57	2631.9	2569.24	2569.24	1629.27	1754.6
Start Volume_Tank B[7]	gallons	1503.94	2600.57	2600.57	2600.57	2185.42	2036.59	2193.25	2600.57	2537.9	2569.34	2569.24	2569.24	2139.25	2349.91
End Volume_Tank A[7]	gallons	187.99	250.66	187.99	250.66	166.06	187.99	187.99	187.99	610.98	689.31	657.98	357.98	219.33	250.66
End Volume_Tank B[7]	gallons	187.99	156.66	187.99	187.99	166.06	187.99	187.99	187.99	6262.64	689.31	657.98	657.98	250.66	250.66
Total CN8 Applied	gallons	3697	4794	4762	4825	4094	3885	4011	4794	3807	3823	3823	3823	3353	3603
Total Applied	MT NO3-N[9]	1.78	2.30	2.29	2.32	1.97	1.87	1.93	2.30	1.83	1.84	1.84	1.84	1.61	1.73
Comments		Plume detected high, around 15m, chemical feed turned down to 10 gpm.	Plume initially detected at around 16 m, turned chemical system down slightly to raise plume to 1-2 meters off bottom. Final CN8 Flow Rate (meter): 14.1 gpm, Final T_epi: 26.2	Chemical meter turned down slightly to start based on previous day plume behavior. Plume deteced ~1 meter off bottom. Final CN8 Flow Rate (meter): 14.5 gpm, Final T_epi: 26.1	Started chemical meter at 14.6 gpm based on previous trends. Plume detected slightly greater than meter off bottom, turned CN8 to 15 gpm. This was too high. Final CN8 Flow Rate (meter): 14.0 gpm, Final T_epi: 26.4	Plume detected at 16m, CN8 flow started and kept at 15 gpm	Started chemical meter at 15.5 gpm. Chemical turned down to raise the plume. Final CN8 Flow Rate (meter): 13.0 gpm, Final T_epi: 27.1	UFI equipment not working. Chemical system ran at (meter) 13 gpm based on previous day success. Final T_epi: 27.3	Started chemical meter at 13 gpm (meter) based on previous day success. Plume was hovering the bottom so turned chemical down to 11.5 gpm (meter). Plume still at bottom so turned chemcial to 11.0 gpm (meter) and raised the manifold a foot. The plume was then too high so turned chemical back to 13 gpm (meter). Plume back at bottom.	Started chemical meter at 13 gpm, plume was spotted at 16.5 m, turned chemical 10.5 gpm and plume rose to 13-15m. Chemical turned to 11.5 m and the plume remained between 14-15m. Final CN8 Flow Rate (meter): 11.5 gpm.	Started chemical meter at 15 gpm (meter). Plume observed at bottom, turned chemical down to 13 gpm (meter). Final CN8 Flow Rate (meter): 13.1 gpm, Final T_epi: 26.0.	Started chemical system at 13 gpm, plume initially observed at 16.7-16 meters. Final CN8 Flow Rate (meter): 13.1 gpm, Final T_epi: 26.9.	Started chemical system at 13.25 gpm, plume detected less than 1 meter off bottom, turned chemical to 12 gpm, plume now 2-2.5 meters off bottom. Final CN8 Flow Rate (meter): 12 gpm, Final T_epi: 26.5.	Started chemical system at 12 gpm, plume detected 1 m of the bottom, chemical turned to 11.5 gpm. Plume remained at 16.7 m. Final CN8 Flow Rate (meter): 11.5 gpm, Final T_epi: 26.8.	Started chemcial system at 12 gpm, plume detected at 18m, turned down to 11.5 gpm. Plume rose to 15-15m. Final CN8 Flow Rate (meter): 11.5 gpm, Final T_epi: 26.9.
End Time_dosing			1330	1330		1440	1220	1350	1915	1245	1235	1345	B:1234, A:1238	A: 1245, B: 1340	A: 1630, B: 1720

Note: Yellow-highlighted comments indicate that nitrate was near-neutrally buoyant detected off the bottom.

Definitions:

1 CN8: Liquid calcium nitrate as specified by Yara Chemical.

2 DF: Dilution factor, or the ratio of epilimnetic water flow to CN8 flow. The DF was quantified by utilizing the Chen and Millero (1978) model to calculate the densities of the lake water and of the CN8. Solution density is a function of temperature and salinity; the salinity input values were based on measured specific conductance values.

3 Q: Flow as measured in gallons per minute (gpm).

4 T: Temperature of lake water.

5 SC: Specific Conductance of lake water.

6 uS/cm: Microsiemens per centimeter, or the unit of measure of specific conductance.

7 Start Volume and End Volume: Applies to CN8.

8 Target Depth: The specific depth of release of the CN8 as controlled by the length of individual hoses which were manually connected to the manifold prior to each application. Early on in the season the target depth identified by a height of 2-3m off of the bottom depending on what the specific water depth was at N, S1 or S2 on a given day. Where the target depths are not consistent with being 2-3m off the botttom, the depths are based on insight from monitoring regarding specific depths at N, S1 or S2 within the hypolimnion that exhibited a higher nitrate demand between applications.

9 MT NO3-N: Metric tons of nitrate-nitrogen.

TABLE 2
Summary of 2012 Nitrate Application Data Collection and Calculations

Date		8/8/2012	8/9/2012	8/13/2012	8/15/2012	8/16/2012	8/20/2012	8/22/2012	8/23/2012	8/27/2012	8/29/2012	8/30/2012	9/5/2012	9/6/2012	9/10/2012
Location		N	S2	S1	N	S2	S1	N	S2	S1	N	S2	S1	N	S1
DF		294.89	283.45	319.97	341.8	329.34	344.24	358.71	344.22	336.69	348.92	349.42	352.2	365.07	388.09
Q_CN8_gauge	gpm	14.79	15.38	13.63	12.76	13.24	12.67	12.16	12.67	12.96	12.5	12.49	12.39	12.2	11.24
Q_CN8_Correction Factor	gpm	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Q_CN8_actual	gpm	11.83	12.30	10.90	10.21	10.59	10.14	9.73	10.14	10.37	10.00	9.99	9.91	9.8	9
Q_epi_Pump A	gpm	3405	3420	3480	3439	3461	3429	3455	3443	3456	3422	3451	3462	3419	3428
Q_epi_Pump B	gpm	3429	3425	3450	3430	3468	3520	3424	3473	3451	3469	3456	3446	3429	3437
T_epi	degreeC	26.1	26.2	24.9	24.2	24.4	23.9	23.2	23.6	24.1	23.5	23.4	23.6	23.4	22.0
SC_epi	uS/cm	2003	2006	2140	2091	2128	2080	2056	2078	2030	2093	2096	2165	2094	2211
Water depth	ft (m)	57.5	63	62.8	59	63	63	58.6	63	62.8	58.5	63	63.3	58.7	63
Target depth[8]	ft (m)	53.5	57	57	53	57	57	52.6	57	57	52.5	57	57.3	52.7	57
T_target depth	degreeC	12.1	10.6	11.8	12.8	11.5	12.1	11.9	11.0	11.6	11.4	11.1	12.3	12.2	12.3
SC_target depth	uS/cm[6]	1843	1843	1825	1860	1860	1778	1718	1745	1784	1754	1739	1775	1798	1850
Start time_dosing		1149	1037	1428	915	938	1226	933	1108	1110	955	1130	910	955	1310
Start Volume_Tank A[7]	gallons	2161.92	2255.91	2193.3	2193.25	2193.3	2193.25	2193.25	2193.25	2193.25	2569.24	2569.24	2569.24	2569.24	2569.24
Start Volume_Tank B[7]	gallons	2193.25	2255.91	2193.3	2224.58	2193.3	2193.25	2193.25	2224.58	2193.25	2569.24	2569.24	2569.24	2569.24	2569.24
End Volume_Tank A[7]	gallons	250.66	344.65	281.99	281.99	281.99	1033.96	219.33	281.99	281.99	187.99	187.99	187.99	187.99	187.99
End Volume_Tank B[7]	gallons	250.66	344.65	281.99	281.99	281.99	1002.63	219.33	281.99	281.99	187.99	187.99	187.99	187.99	187.99
Total CN8 Applied	gallons	3854	3823	3823	3854	3823	2350	3948	3854	3823	4762	4762	4762	4762	4762
Total Applied	MT NO3-N[9]	1.85	1.84	1.84	1.85	1.84	1.13	1.90	1.85	1.84	2.29	2.29	2.29	2.29	2.29
Comments		Started chemical at 11.5 gpm, plume initially detect 1 meter off the bottom, chemcial turned down to 11 gpm. Plume then detected at 15.5m and remained there. Final CN8 Flow Rate (meter): 11.0 gpm, Final T_epi: 26.45	Started chemical system at 11.5 gpm, plume detected at 17-18.5m. Chemcial turned to 11.25 gpm, plume detected between 15-17m. Final CN8 Flow Rate (meter): 11.25 gpm, Final T_epi: 26.7	Started chemcial system at 11 gpm, plume detected at 15.5-18m. Final CN8 Flow Rate (meter): 11.5 gpm, Final T_epi: 25.7.	Started chemical system at 10.5 gpm, plume detected at 15.5-17.5m. Final CN8 Flow Rate (meter): 10.5 gpm, Final T_epi: 24.9.	Started chemical system at 10.5 gpm, plume detected between 16.5-18.8m. Final CN8 Flow Rate (meter): 10.5 gpm, Final T_epi: 25.7	Started chemical system at 10.5 gpm, plume detected at 16-18m. Final CN8 Flow Rate (meter): 10.5 gpm, Final T_epi: 24.4. System shutdown early due to high winds.	Started chemical system at 10.0 gpm, plume detected between 15.5-17.5 m. Final CN8 Flow Rate (meter): 10.0 gpm, Final T_epi: 23.8	Started chemical at 10.o gpm, plume detected at 16-18 m. Final CN8 Flow Rate (meter): 10.0 gpm, Final T_epi: 24.7	Started chemical at 10.0 gpm, plume detected at 16-17m. CN8 Flow Rate (meter): 10.0 gpm, Final T_epi: 24.4	Started chemical at 9.75 gpm, plume detected at 13-16m. CN8 Flow Rate (meter): 9.75gpm, Final T_epi: 24.3	Started chemical at 9.75gpm, plume detected at 16.5-18.5m. CN8 Flow Rate (meter): 9.75gpm, Final T_epi: 24.3	Started chemical at 10.0 gpm, plume detected at 16.5 to bottom. Slightly buyant plume at NW corner sample location. CN8 Flow Rate (meter): 10gpm, Final T_epi: 23.8	Started chemical at 9.75 gpm, plume detected at 16m. CN8 Flow Rate (meter): 9.75gpm, Final T_epi: 24.5	Started chemical at 9.0 gpm, plume detected at 16.5-18m. CN8 Flow Rate (meter): 9gpm, Final T_epi: 22.2
End Time_dosing		1515	1400	1801	1255	1315	1445	1338	1505		A: 1450, B: 1501	A:1640, B:1628	1430	1450	1810

Note: Yellow-highlighted comments indica

Definitions:

1 CN8: Liquid calcium nitrate as specified by Yara Chemical.

2 DF: Dilution factor, or the ratio of epilimnetic water flow to CN8 flow. The DF was quantified by utilizing the Chen and Millero (1978) model to calculate the densities of the lake water and of the CN8. Solution density is a function of temperature and salinity; the salinity input values were based on measured specific conductance values.

3 Q: Flow as measured in gallons per minute (gpm).

4 T: Temperature of lake water.

5 SC: Specific Conductance of lake water.

6 uS/cm: Microsiemens per centimeter, or the unit of measure of specific conductance.

7 Start Volume and End Volume: Applies to CN8.

8 Target Depth: The specific depth of release of the CN8 as controlled by the length of individual hoses which were manually connected to the manifold prior to each application. Early on in the season the target depth identified by a height of 2-3m off of the bottom depending on what the specific water depth was at N, S1 or S2 on a given day. Where the target depths are not consistent with being 2-3m off the botttom, the depths are based on insight from monitoring regarding specific depths at N, S1 or S2 within the hypolimnion that exhibited a higher nitrate demand between applications.

9 MT NO3-N: Metric tons of nitrate-nitrogen.

TABLE 2
Summary of 2012 Nitrate Application Data Collection and Calculations

										Final Event			
Date		**9/12/2012**	**9/13/2012**	**9/17/2012**	**9/19/2012**	**9/20/2012**	**9/26/2012**	**9/27/2012**	**10/1/2012**	**10/4/2012**			
Location		**N**	**S2**	**S1**	**N**	**S2**	**S1**	**N**	**N**	**N**			
DF		400.32	396.85	405.63	444.83	438.24	484.35	486.19	275.9	503.1			
Q_CN8_gauge	**gpm**	10.9	11	10.7	9.81	9.95	9.01	8.98	15.8	8.75			
Q_CN8_Correction Factor	**gpm**	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8			
Q_CN8_actual	**gpm**	8.72	8.8	8.6	7.85	7.97	7.21	7.18	12.7	7			
Q_epi_Pump A	**gpm**	3496	3496	3473	3440	3413	3426	3476	3455	3489			
Q_epi_Pump B	**gpm**	3522	3435	3453	3419	3448	3434	3466	3422	3500			
T_epi	**degreeC**	21.4	21.5	21.3	20.4	19.6	17.9	17.9	17.0	17.5			
SC_epi	**uS/cm**	2228	2221	1956	2224	2288	2542	2265	2262	2231			
Water depth	**ft (m)**	58	63	63	58	63	63	58	58	58			
Target depth[8]	**ft (m)**	52	57	57	52	57	57	52	54	54			
T_target depth	**degreeC**	12.1	11.9	12.6	15.7	11.7	10.9	13.3	11.7	14.6			
SC_target depth	**uS/cm[6]**	1830	1917	1756	1992	1862	2110	2103	1954	2197			
Start time_dosing		950	920	1155	1015	1105	1105	935	915	915			
Start Volume_Tank A[7]	**gallons**	2569.24	2193.25	2193.25	2193.25	2193.25	2193.25	2193.25	2287.25	2663.23			
Start Volume_Tank B[7]	**gallons**	2569.24	2193.25	2193.25	2224.58	2193.25	2193.25	2193.25	2193.25	2663.23			
End Volume_Tank A[7]	**gallons**	626.64	281.99	281.99	281.99	281.99	501.31	501.31	281.99	156.66			
End Volume_Tank B[7]	**gallons**	657.98	281.99	281.99	281.99	281.99	501.31	501.31	281.99	156.66			
Total CN8 Applied	**gallons**	3854	3854	3854	3854	3823	3384	3384	3917	5013			
Total Applied	**MT NO3-N[9]**	1.85	1.84	1.84	1.85	1.84	1.62	1.62	1.88	2.41			
Comments		Started chemical at 10 gpm, plume detected at 15.5-18m. CN8 Flow Rate (meter): 10.25gpm, Final T_epi: 21.7	Started chemical at 9.0 gpm, plume detected at 16-18m. CN8 Flow Rate (meter): 9.0gpm, Final T_epi: 21.9	Started chemical at 8.5 gpm, plume detected at 16.5-18m. CN8 Flow Rate (meter): 8.5gpm, Final T_epi: 21.8	Started chemical at 8.0 gpm, plume detected at 14.5-15.5m. CN8 Flow Rate (meter): 8.5gpm, Final T_epi: 20.5	Injection objective is to target shrinking hypolimnion and near-neutral buoyancy. Started chemical at 8.0 gpm, plume detected at 16.5-18m. CN8 Flow Rate (meter): 8.0gpm, Final T_epi: 20.1	Injection objective is to target shrinking hypolimnion and near neutral-buoyancy. Started chemical at 7.5 gpm, plume reported to be on the bottom; CN8 flow rate reduced to 6.5 gpm; subsequently raised to 7.0 gpm. CN8 Flow Rate (meter): 7.0 gpm, Final T_epi: 18.1	Injection objective is to target shrinking hypolimnion and near-neutral buoyancy. Started chemical at 7.0 gpm, plume reported on the bottom; flow rate reduced to 6.0 gpm; plume still on bottom; flowrate reduced to 5.0 gpm; at 12-noon removed one-20' section of hose; flow set to 9pm; plume reported at 12-14m; increased flow to 12gpm; CN8 Flow Rate (meter): 12.0 gpm, Final T_epi: 18.1	Injection objective is to target shrinking hypolimnion and near-neutral buoyancy. Started chemical at 15.5 gpm, plume reported to be between 14m and the bottom; no adjustment to flowrateCN8 flow rate.. Over the injection period the flowrate crept up to 15.75 and, finally, 16.0 gpm. CN8 Flow Rate (meter): 16.0 gpm, Final T_epi: 17.0	Injection objective is to target shrinking hypolimnion and near-neutral buoyancy. Maintained 8.75 gpm flowrate. CN8 Flow Rate (meter): 8.75 gpm, Final T_epi: 18.0			
End Time_dosing		1350	1345	1630	A: 1500, B:1510	1600	1600	1425	1200	1552			

Note: Yellow-highlighted comments indic

Definitions:

1 CN8: Liquid calcium nitrate as specified by Yara Chemical.

2 DF: Dilution factor, or the ratio of epilimnetic water flow to CN8 flow. The DF was quantified by utilizing the Chen and Millero (1978) model to calculate the densities of the lake water and of the CN8. Solution density is a function of temperature and salinity; the salinity input values were based on measured specific conductance values.

3 Q: Flow as measured in gallons per minute (gpm).

4 T: Temperature of lake water.

5 SC: Specific Conductance of lake water.

6 uS/cm: Microsiemens per centimeter, or the unit of measure of specific conductance.

7 Start Volume and End Volume: Applies to CN8.

8 Target Depth: The specific depth of release of the CN8 as controlled by the length of individual hoses which were manually connected to the manifold prior to each application. Early on in the season the target depth identified by a height of 2-3m off of the bottom depending on what the specific water depth was at N, S1 or S2 on a given day. Where the target depths are not consistent with being 2-3m off the botttom, the depths are based on insight from monitoring regarding specific depths at N, S1 or S2 within the hypolimnion that exhibited a higher nitrate demand between applications.

9 MT NO3-N: Metric tons of nitrate-nitrogen.

TABLE 3
2012 ONONDAGA LAKE SURFACE WATER MONITORING SUMMARY FOR NITRATE ADDITION

Date	Water column		Zooplankton: South Deep	Sediment Trap Mercury South Deep (10-meter water depth)	Dissolved Gas Measurements
	South Deep	ISUS profiling 34 locations			
June 4	3 depths	10 Sites			
June 11			□	○	
June 18	3 depths	10 Sites			
June 25	2 depths	◊			⦿
July 2	5 depths	◊	□	○	
July 9	5 depths	◊	□	○	⦿
July 16	5 depths	◊			
July 23	5 depths	◊	□	○	⦿
July 30	5 depths	◊			
August 6	5 depths	◊	□	○	⦿
August 13	5 depths	◊			
August 20	5 depths	◊	□	○	⦿
August 27	5 depths	◊			
September 4	6 depths	◊	□	○	⦿
September 10	6 depths	◊	□ (Sept. 12)	○	
September 17	6 depths	◊	□	○	⦿
September 24	6 depths	◊	□	○	
October 2	6 depths	◊	□	○	⦿
October 9	6 depths	◊	□	○	
October 16	6 depths	◊	□	○	⦿
October 22	3 depths	10 Sites	□	○	
November 5	3 depths	10 Sites	□	○	⦿
November 19	3 depths	10 Sites	□	○	

Notes:
1. Sediment traps were deployed typically for seven days. Trap recovery dates are shown in this table.
2. ISUS-SUNA profiling was completed on an additional 16 days at 34 locations.
3. Samples were not collected on June 25 at the 18-meter water depth as a safety precaution due to high winds.
4. Lake turnover occurred on or just prior to October 22, so samples were collected at three water depths on that date.

TABLE 4

SUMMARY OF 2012 ISUS-SUNA MEASUREMENTS FOR ONONDAGA LAKE NITRATE ADDITION

Measurement period	May 29 to November 19
Frequency of profiling	Typically two days per week (54 days total)
Vertical resolution	Measurements every 0.25 meters from lake surface to bottom
Locations	34 locations were profiled per day, on average
Total profiles	1,479
Total measurements of nitrate	89,844
Selected parameters and accuracy	Nitrate to plus or minus 0.028 mg/L as nitrogen (N)
	Sulfide to plus or minus 0.064 mg/L as sulfur (S)
	Water temperature to plus or minus 0.1 degree Celsius
	Specific conductance to plus or minus 3 microsiemens per centimeter

Notes: ISUS – in situ ultraviolet spectroradiometer.

SUNA - Submersible ultraviolet nitrate analyzer

Other paramaters measured using the ISUS were turbidity, beam attenuation coefficient, backscattering, chlorophyll fluorescence, and photosynthetically-active irradiance.

TABLE 5
2012 MERCURY CONCENTRATIONS IN SURFACE WATER NEAR THE LAKE BOTTOM AT SOUTH DEEP

(Concentration (ng/l) at 18 Meter Water Depth)

2012 SAMPLING DATE	TOTAL MERCURY	METHYL-MERCURY
June 4	1.3 J	0.050 U
June 18	1.8	0.037 J
July 2	1.2	0.051
July 9	1.5	0.058
July 16	1.7	0.160
July 23	1.2	0.140
July 30	0.5 U	No data
August 6	1.1	0.120
August 13	0.16 J	0.110
August 20	1.5	0.230
August 27	0.5 UJ	0.110
September 4	1.5	0.140
September 10	1.9	0.110
September 17	1.5	0.180
September 24	1	0.140 U
October 2	1.4	0.160
October 9	3.7	0.082 U
October 16	16 J	0.160
October 22	15	0.140
November 5	3.8	0.100
November 19	5.6	0.086

U - not detected at reporting limit specified
J - estimated concentration

Note: Lake waters completely turned over by October 22.

TABLE 6

2012 DISSOLVED MERCURY WATER CONCENTRATIONS: SOUTH DEEP AT 2-METER WATER DEPTH

2012 SAMPLING DATE	DISSOLVED MERCURY, ng/L	
June 18	0.495	
July 2	0.94*	
July 16	1.4*	
August 13	0.5	UJ
August 27	0.36	J
September 10	0.315	J
September 24	0.27	J
October 9	0.36	J
October 22	0.25	J
November 5	0.14	J
November 19	0.5	U

* Exceeds New York State surface water qulaity standard of 0.7 ng/L for Class C/D waters based on human consumption of fish

U - not detected at reporting limit indicated
J - estimated value

Notes:

(1) Results are not available for July 31 due to a filtering mix-up in the laboratory.

(2) If a field duplicate was analyzed, the average concentrartion of both results is shown.

TABLE 7 2012 MERCURY AND CORRESPONDING SOLIDS RESULTS FOR SEDIMENT TRAP SLURRY (SEDIMENT TRAPS DEPLOYED AT SOUTH DEEP AT A WATER DEPTH OF 10 METERS)

Location	Trap Deploy Date	Trap Recover Date	Deployment Duration (Days)	Sample Volume (ml)	Slurry Mercury Results (µg/L)	Slurry Mercury Average (µg/L)	Triplicate TSS Results (mg/L)	TSS Average (mg/L)	TSS Deposition (mg per m^2 per day)	Mercury Concentration (mg/kg)	Mercury Deposition (µg per m^2 per day)
SD	06/04/12	06/11/12	7	130	1.0	0.96	688 / 632 / 696	672	2745	1.43	4.07
SD	06/25/12	07/02/12	7	133	1.7	1.70	1744 / 1548 / 1572	1621	6810	1.05	7.31
SD	07/02/12	07/09/12	7	140	1.5	1.50	4232 / 3484 / 3812	3843	16982	0.39	6.46
SD	07/16/12	07/23/12	7	139	1.0	0.99	2108 / 2256 / 2028	2131	9326	0.46	4.21
SD	07/30/12	08/06/12	7	133	0.9 / 1.4	1.15	1060 / 924 / 924	969	4019	1.19	5.19
SD	08/13/12	08/20/12	7	130	2.0	2.00	1056 / 1028 / 1104	1063	4354	1.88	8.24
SD	08/27/12	09/04/12	8	131	1.9 / 1.8	1.85	1424 / 1568 / 1800	1597	5767	1.16	6.83
SD	09/04/12	09/10/12	6	138	0.9	0.93	1072 / 1040 / 1016	1043	5311	0.89	4.93
SD	09/10/12	09/17/12	7	133	1.1	1.10	840 / 704 / 884	809	3369	1.36	4.53
SD	09/17/12	09/24/12	7	136	0.7	0.72	1504 / 1744 / 1904	1717	7360	0.42	3.17
SD	09/24/12	10/02/12	8	139	0.5 / 0.5	0.51	1332 / 1224 / 1468	1341	5140	0.38	1.97
SD	10/02/12	10/09/12	7	132	1.80	1.80	1044 / 744 / 868	885	3677	2.03	7.93
SD	10/09/12	10/16/12	7	138	1.5 / 2.6	2.05	1944 / 1624 / 1640	1736	7530	1.18	9.06
SD	10/16/12	10/22/12	6	137	4.3	4.30	2780 / 2516 / 2776	2691	13589	1.60	21.39
SD	10/22/12	11/05/12	14	139	4.2 / 4.3	4.25	5958 / 5010 / 4850	5273	11528	0.81	9.21
SD	11/05/12	11/19/12	14	136	7.2	7.20	5608 / 4140 / 4887	4878	10443	1.48	14.82
SD Arithmetic Mean			-	-	-	-	-	-	7370	1.1	7.5

SD – South Deep TSS – total suspended solids

Mercury concentration = slurry mercury average divided by TSS average times a units conversion of 1,000. Concentrations are based on dry weight. Calculations of TSS and mercury deposition include the surface area of the sediment traps (45 square centimeters).

TABLE 8

MERCURY CONCENTRATIONS IN ZOOPLANKTON SAMPLES COLLECTED AT SOUTH DEEP IN 2012

Field Sample ID	Date	Total mercury (mg/kg wet weight)	Methylmercury (mg/kg wet weight)	Methylmercury (Percent of Total Mercury)
OL-1706-01	6/11/12	0.045	0.0047	10
OL-1717-01	7/2/12	0.038	0.0041	11
OL-1721-01	7/9/12	0.065	0.0066	10
OL-1728-01	7/23/12	0.17	0.012	7.1
OL-1735-01	8/6/12	0.066	0.014	21
OL-1743-01	8/20/12	0.13	0.011	8.5
OL-1751-01	9/4/12	0.27	0.0083	3.1
OL-1755-01	9/12/12	0.0011U	0.0023	NA
OL-1759-01	9/17/12	0.15	0.0078	5.2
OL-1763-01	9/24/12	0.087	0.0099	11
OL-1767-01	10/2/12	0.11	0.0063	5.7
OL-1771-01	10/9/12	0.049J	0.0064	13
OL-1775-01	10/16/12	0.033J	0.009	27
OL-1779-01	10/22/12	0.033J	0.010	30
OL-1784-01	11/5/12	0.046J	0.0093	20
OL-1788-01	11/19/12	0.011J	0.0043	39

NA – not applicable; result for total mercury is less than the result for methylmercury.

FIGURES

Path: Q:\GIS\GIS_Lake\Baseline_Monitor\MXDs\2011_NitrateInjectLocs.mxd

Date Revised: 7/19/2013 2:06:22 PM

2012 Nitrate Application Locations

Bathymetry Contours For Water Depth

10 Foot Intervals

30 Foot Water Depth Contour

0 1,200 2,400 4,800 7,200

Feet

Figure 1

Honeywell

Onondaga Lake
Syracuse, New York

2012 Nitrate Application Locations

PARSONS

301 Plainfield Road, Suite 350; Syracuse NY 13212 Phone:(315)451-9560

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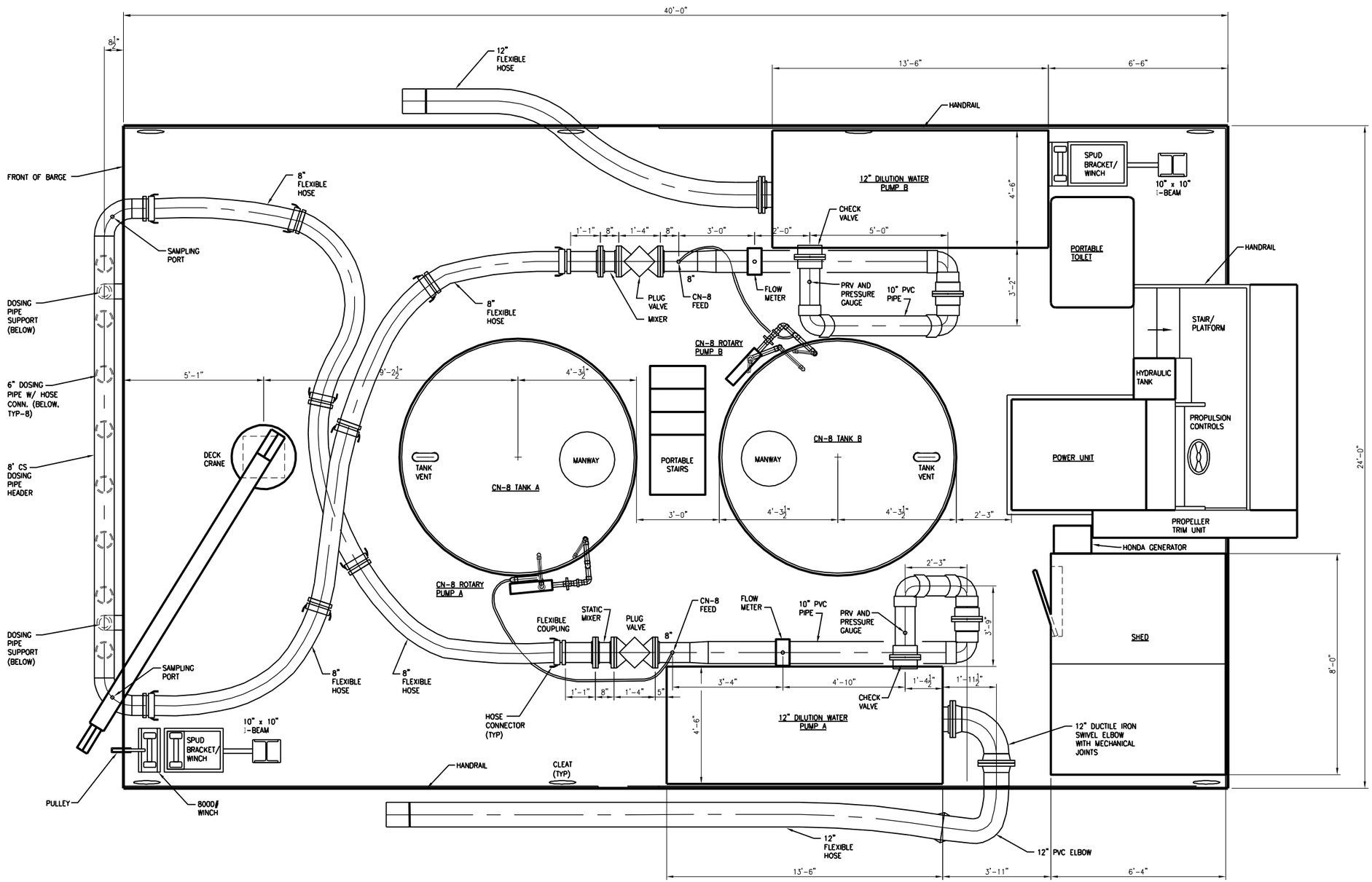

NO.	DESCRIPTION	DATE	DRAWN	CHK'D	APPV'D
A	FOR INFORMATION ONLY	1/7/13	JTS		

DRAWN BY — DATE
CHECKED BY — DATE
APPROVED BY — DATE
PROJECT MGR. — DATE
SEAL

PARSONS
COMMERCIAL TECHNOLOGY GROUP

OFFICE
301 PLAINFIELD ROAD
SYRACUSE, NY 13212
(315) 451-9560

JOB 446625
WBS 10001

PROJECT TITLE
Honeywell
ONONDAGA LAKE
NITRATE ADDITION PILOT TEST
SYRACUSE, NEW YORK

DRAWING TITLE
FIGURE 2
BARGE AS-BUILT 2012

SCALE NO SCALE

DRAWING NO. 446625-M-001 REV. A

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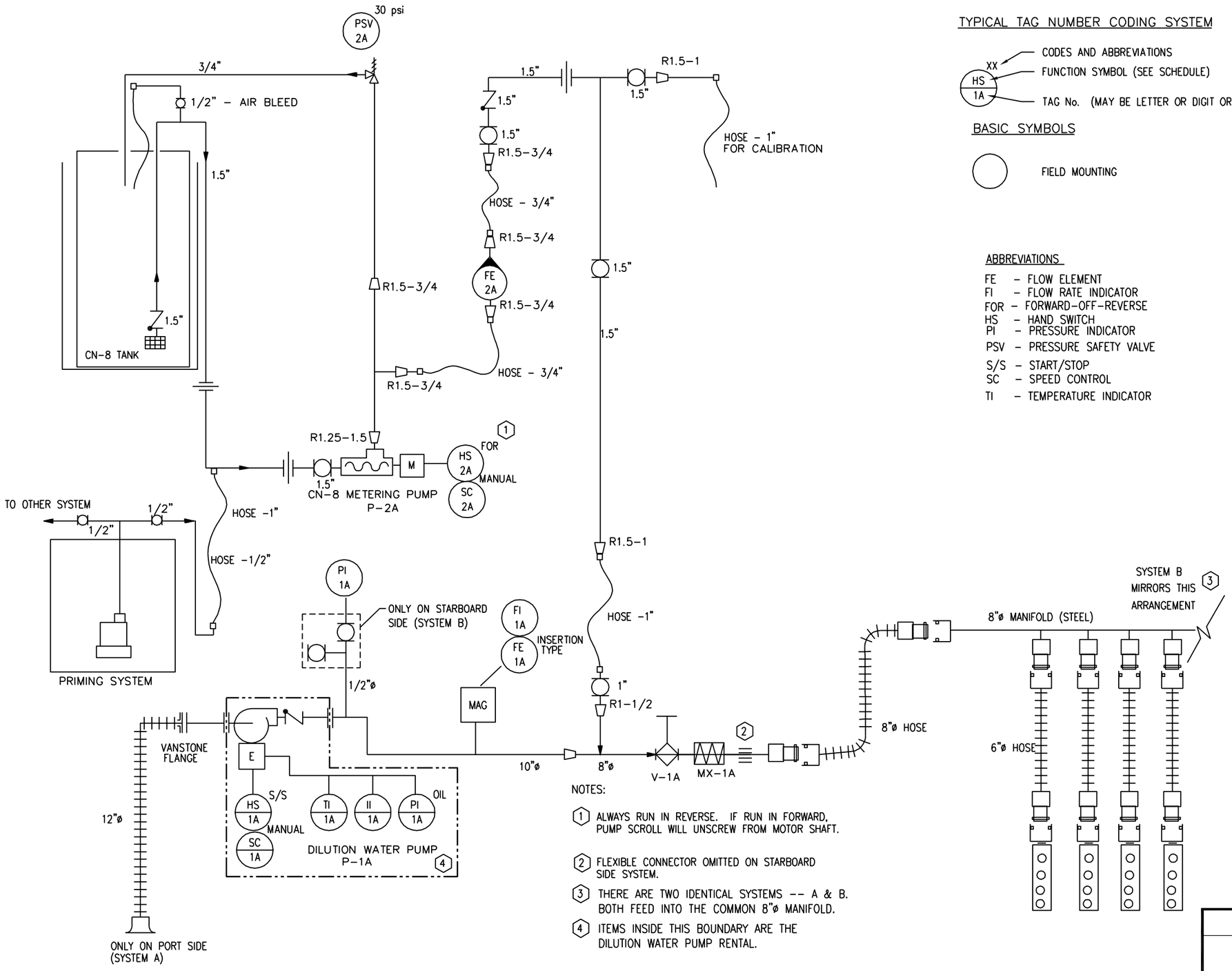
PLOT DATE: 1/10/2013 2:27 PM PLOTTED BY: GOLDTHWAIT, JAMES



NOTES:

1. ALWAYS RUN IN REVERSE. IF RUN IN FORWARD, PUMP SCROLL WILL UNSCREW FROM MOTOR SHAFT.
2. FLEXIBLE CONNECTOR OMITTED ON STARBOARD SIDE SYSTEM.
3. THERE ARE TWO IDENTICAL SYSTEMS -- A & B. BOTH FEED INTO THE COMMON 8"ø MANIFOLD.
4. ITEMS INSIDE THIS BOUNDARY ARE THE DILUTION WATER PUMP RENTAL.

TYPICAL TAG NUMBER CODING SYSTEM

XX — CODES AND ABBREVIATIONS
HS — FUNCTION SYMBOL (SEE SCHEDULE)
1A — TAG No. (MAY BE LETTER OR DIGIT OR BOTH)

BASIC SYMBOLS

FIELD MOUNTING

ABBREVIATIONS

FE – FLOW ELEMENT
FI – FLOW RATE INDICATOR
FOR – FORWARD-OFF-REVERSE
HS – HAND SWITCH
PI – PRESSURE INDICATOR
PSV – PRESSURE SAFETY VALVE
S/S – START/STOP
SC – SPEED CONTROL
TI – TEMPERATURE INDICATOR

LEGEND

GATE VALVE
CHECK VALVE (FLOW DIRECTION)
PLUG VALVE W/MANUAL OPERATOR
BALL VALVE
PRESSURE SAFETY VALVE
FLEXIBLE CONNECTOR (WATER PIPE)
BELL END
CAM -LOCK TYPE COUPLINGS
STATIC MIXER
POSITIVE DISPLACEMENT PUMP
CENTRIFUGAL PUMP
SUBMERSIBLE PUMP
FOOTVALVE W/ STRAINER
MAG — MAGNETIC METER
FE — ROTAMETER
M — M - MOTOR, E - ENGINE
DIFFUSER
UNION
R#-# — REDUCER/EXPANdER
FLEXIBLE HOSE

FIGURE 3

Barge Piping & Instrumentation Diagram
For 2012
Syracuse, NY

PARSONS

446625 Onondaga Lake P&ID-09-12-11.dwg

FILE NAME: P:\HONEYWELL -SYR\446625 - NITRATE ADDITION PILOT TEST 2011-2012\10.0 TECHNICAL CATEGORIES\10.16 CAD\2012\BARGE AS-BUILT\446625 ONONDAGA LAKE P&ID 11-16-12.DWG
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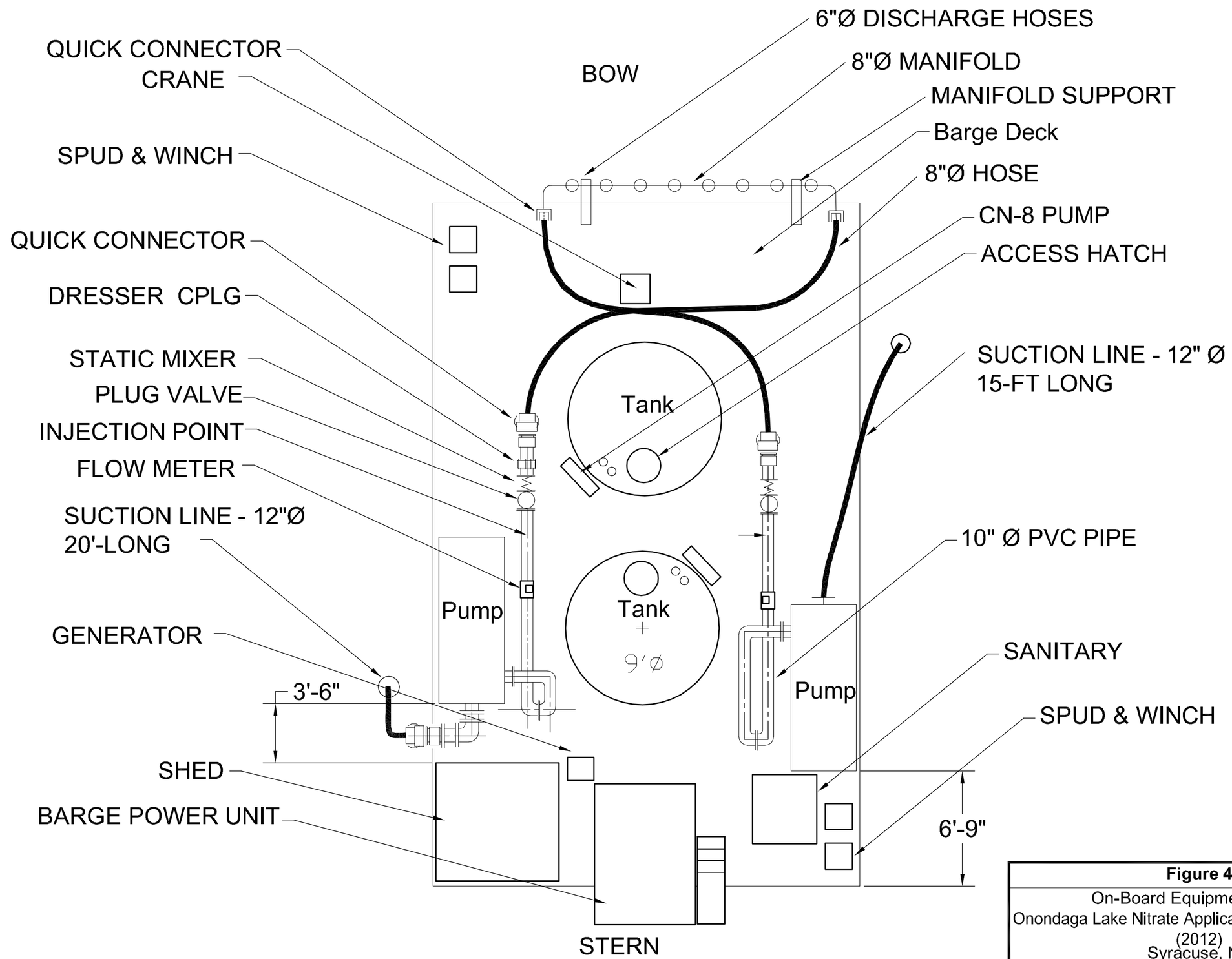

Figure 4

On-Board Equipment Layout
Onondaga Lake Nitrate Application Pilot Test Year 2 (2012)
Syracuse, NY

PARSONS

ON-BOARD LAYOUT 11-16-12.DWG

FILE NAME: P:\HONEYWELL -SYR\446625 - NITRATE ADDITION PILOT TEST 2011-2012\10.0 TECHNICAL CATEGORIES\10.16 CAD\2012\BARGE AS-BUILT\ON-BOARD LAYOUT 11-16-12.DWG
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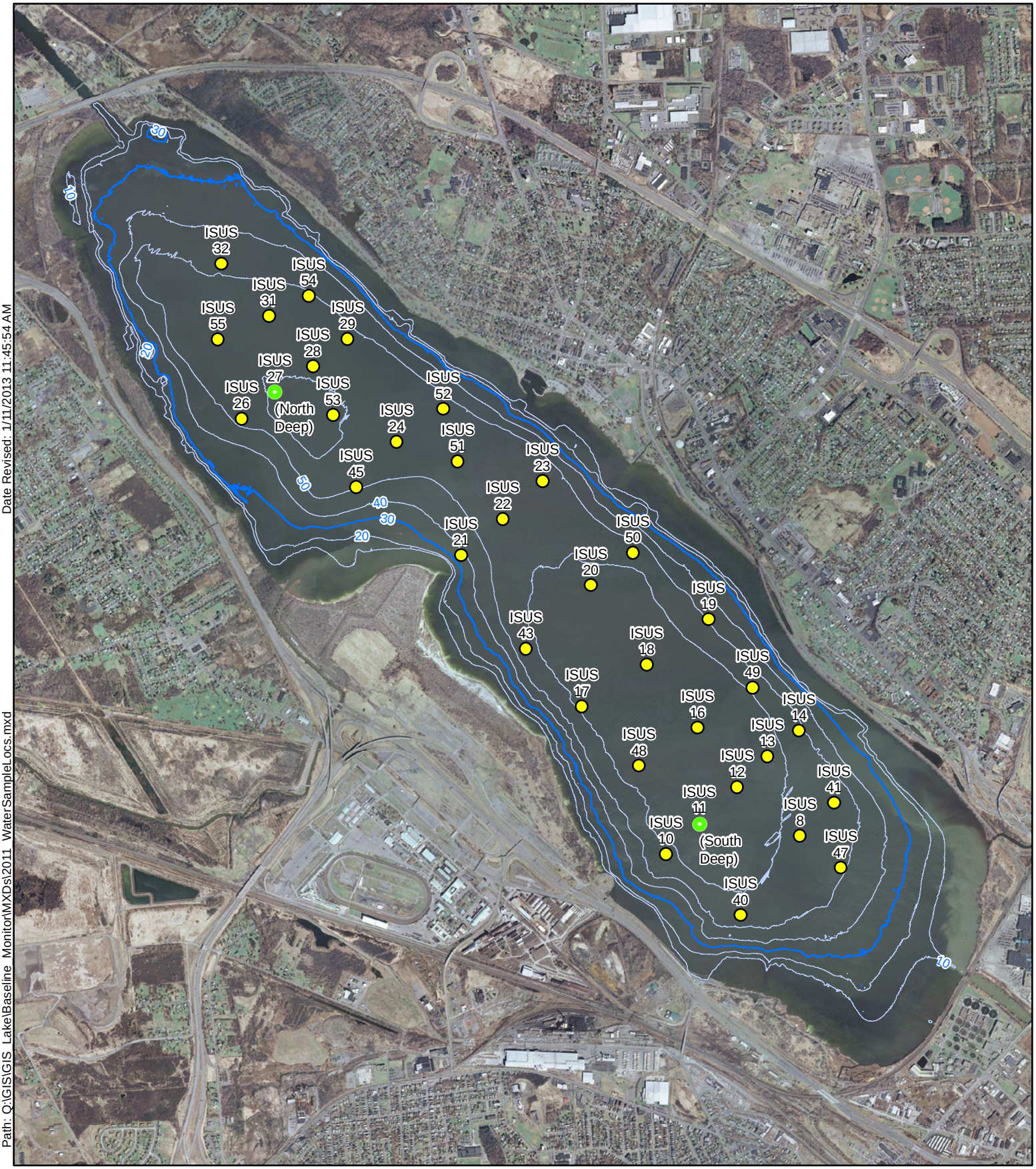


North and South Deeps

ISUS-SUNA Sample Location

Bathymetry Contours For Water Depth

10 Foot Intervals

30 Foot Water Depth Contour

0 1,200 2,400 4,800 7,200

Feet

Figure 5

Honeywell

Onondaga Lake
Syracuse, New York

2012 ISUS-SUNA
Monitoring Locations

PARSONS

301 Plainfield Road, Suite 350; Syracuse NY 13212 Phone:(315)451-9560

Path: Q:\GIS\GIS_Lake\Baseline_Monitor\MXDs\2011_WaterSampleLocs.mxd

Date Revised: 1/11/2013 11:45:54 AM

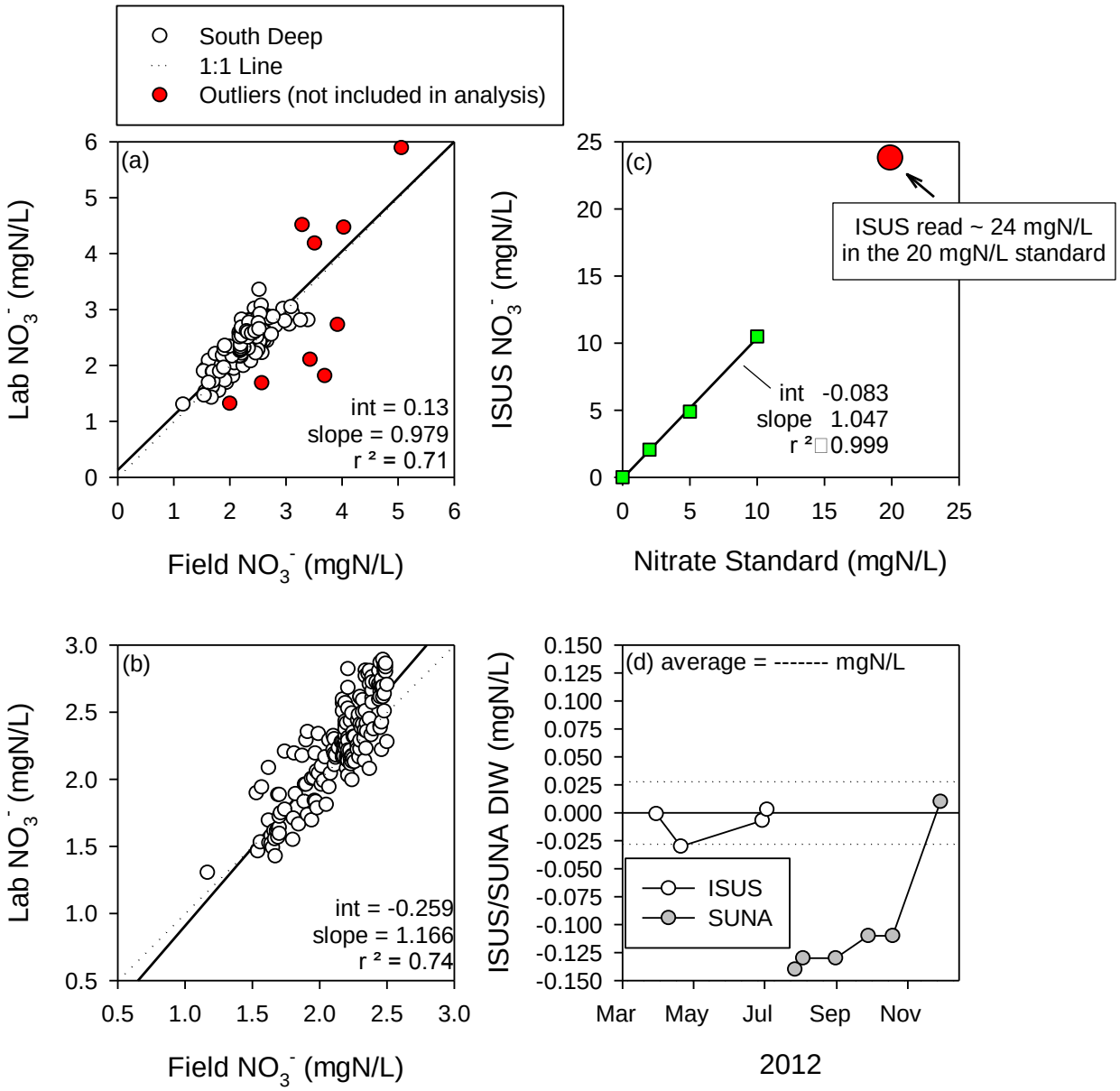


Figure 6 Comparison of Paired 2012 Field and Laboratory Surface Water Results for Nitrate (NO_3^-)

(a) all paired data from South Deep,
(b) paired data from South Deep in the 0-2.5 mgN/L range,
(c) ISUS verification with laboratory nitrate standards, and
(d) time series of nitrate distilled water (DIW) laboratory checks with the zero line and upper and lower bounds of ISUS accuracy (±0.028 mgN/L).

The average DIW reading for the SUNA over the July 19 through October 19, 2012 interval was -0.124 mgN/L, indicating that the SUNA was reading false low. Accordingly, nitrate measurements from the SUNA were adjusted 0.124 mgN/L higher over this period.

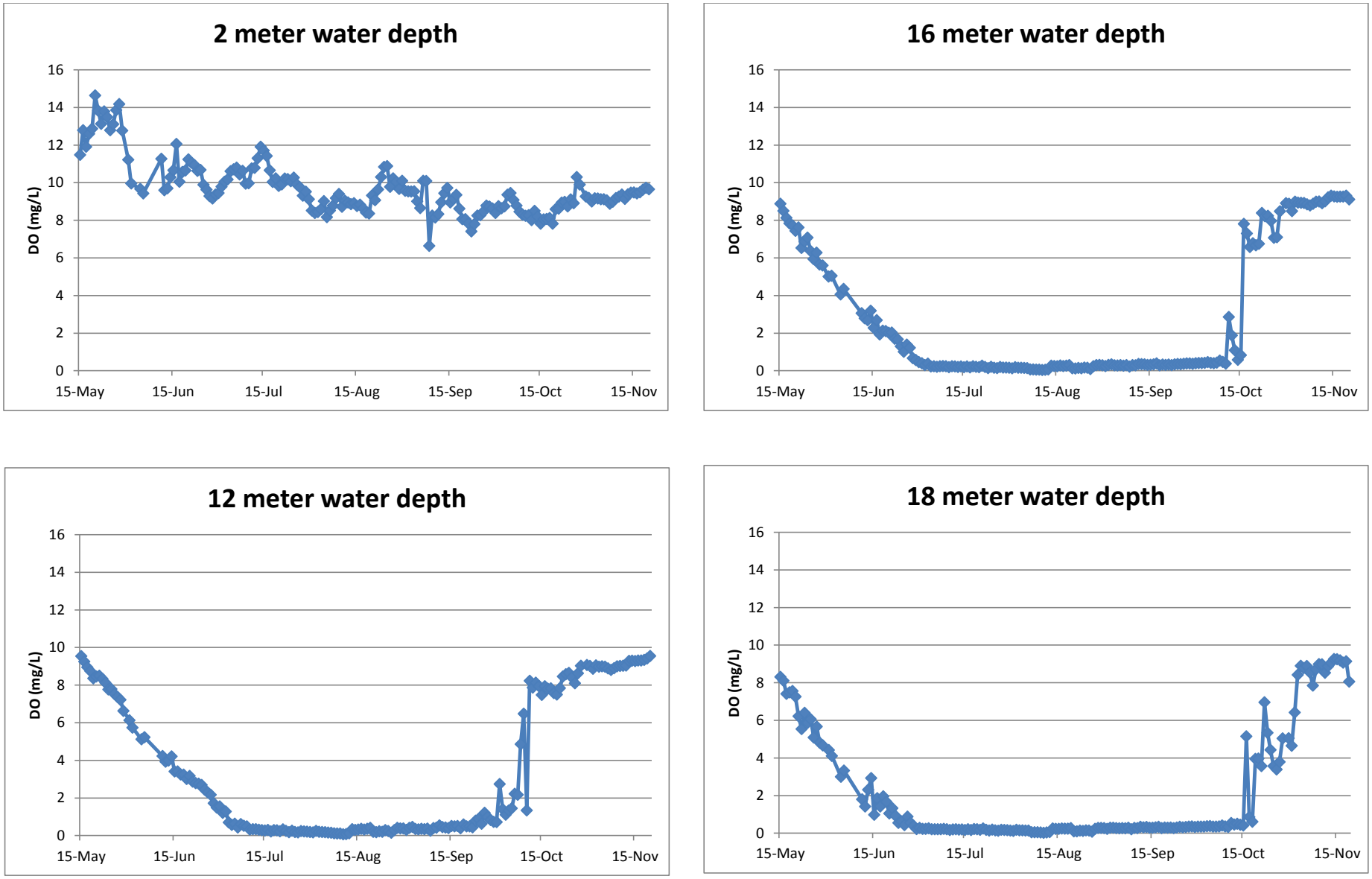
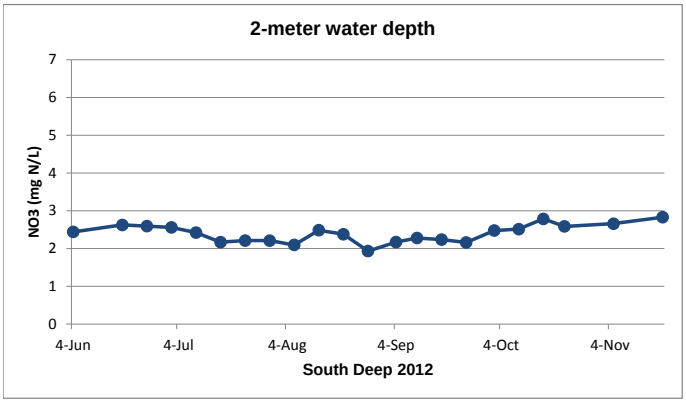
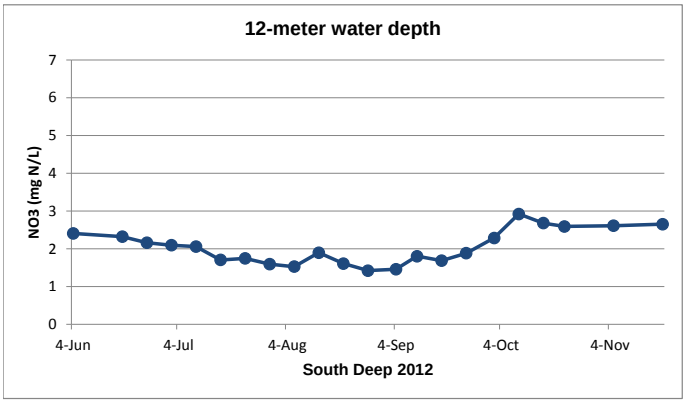
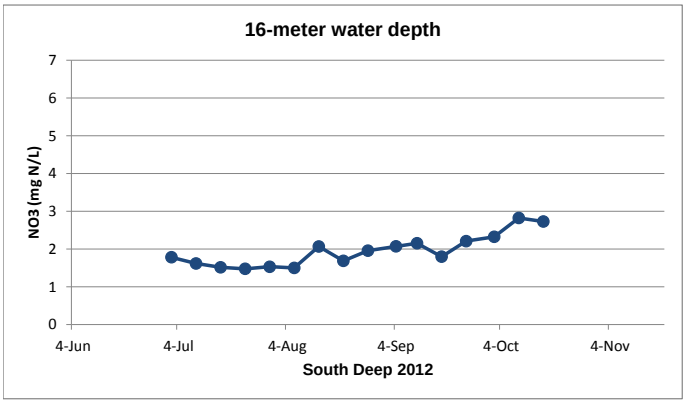


Figure 7 2012 Dissolved Oxygen (DO) Concentrations at 2, 12, 16 and 18-Meter Water Depths at South Deep







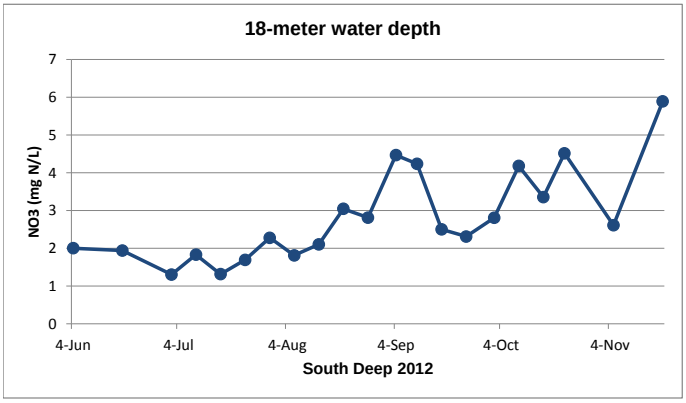


Figure 8 2012 Nitrate Concentrations at 2, 12, 16 and 18-Meter Water Depths at South Deep

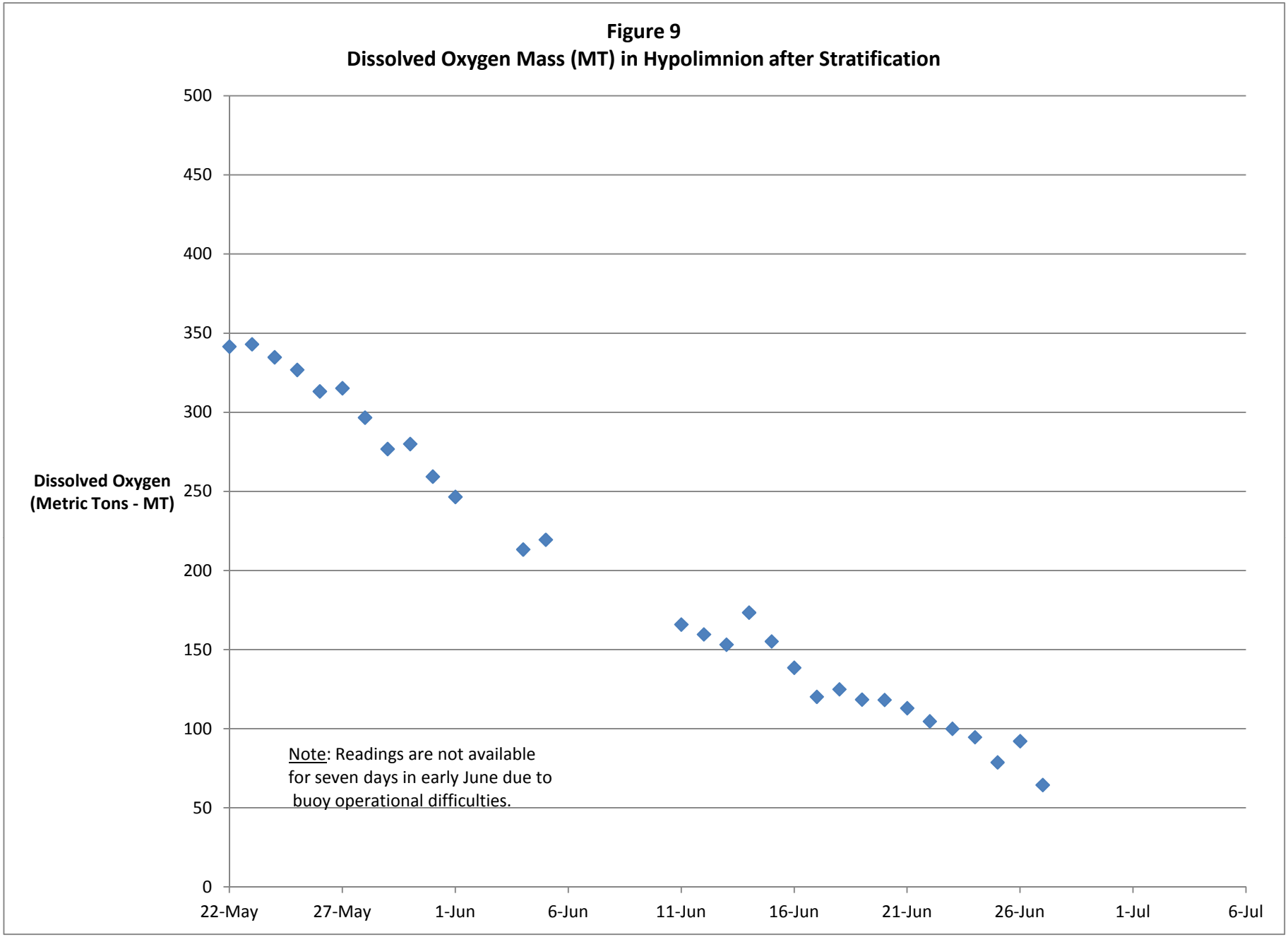
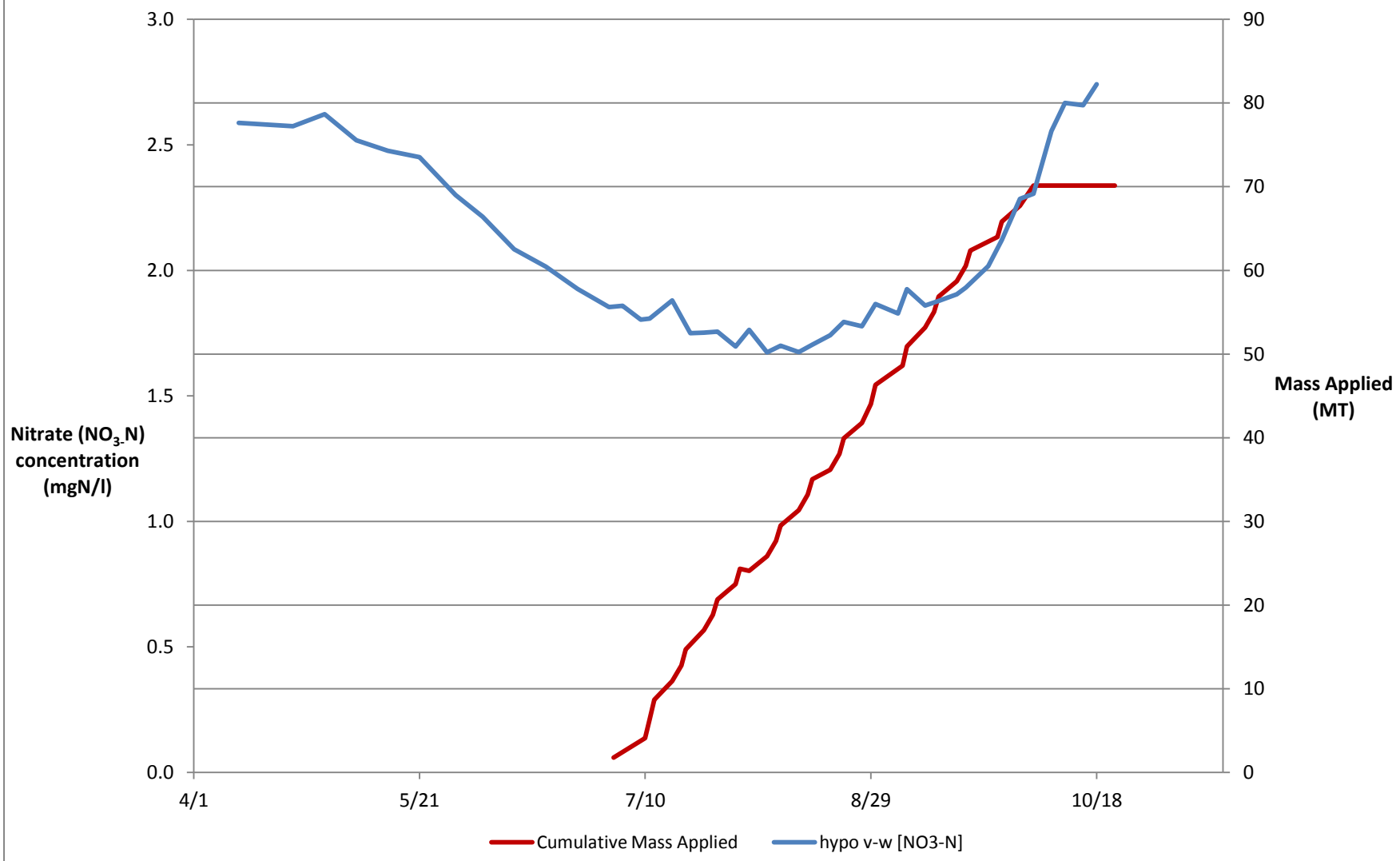


Figure 9
Dissolved Oxygen Mass (MT) in Hypolimnion after Stratification
Dissolved Oxygen (Metric Tons - MT)
500
450
400
350
300
250
200
150
100
50
0
22-May
27-May
1-Jun
6-Jun
11-Jun
16-Jun
21-Jun
26-Jun
1-Jul
6-Jul
Note: Readings are not available for seven days in early June due to buoy operational difficulties.

Figure 10
2012 Volume-Weighted Hypolimnetic Average Nitrate Concentrations and Cumulative Mass of Nitrate-Nitrogen Applied



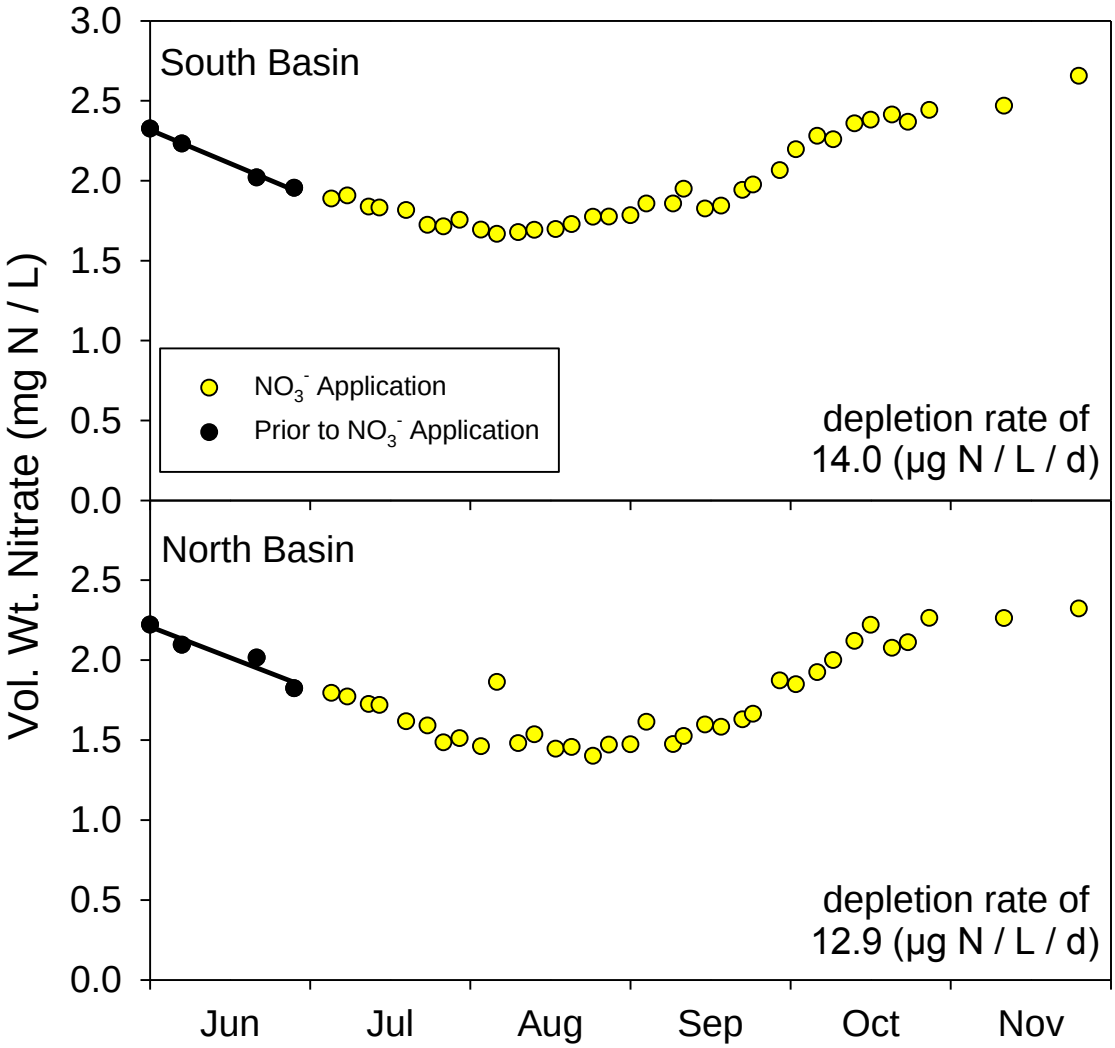


Figure 11 2012 Nitrate Depletion Rates in the Hypolimnion (10 to 19-Meter Water Depths)

Volume-weighted concentrations for the north and south basins were determined from ISUS profiles and the respective water volumes of the basins.