DRAFT INITIAL DESIGN SUBMITTAL FOR THE ONONDAGA LAKE PROFUNDAL ZONE (SEDIMENT MANAGEMENT UNIT 8)

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ACRONYMS

ARARs	Applicable or Relevant and Appropriate Requirements
BSQV	Bioaccumulation-based Sediment Quality Value
CHASP	Community Health & Safety Plan
CPOI	chemical parameter of interest
CPP	Citizen Participation Plan
CY	cubic yards
FS	Feasibility Study (an engineering analysis of remedial action alternatives)
GPS	global positioning system
IDS	Initial Design Submittal
ILWD	in-lake waste deposit
LCP	Linden Chemical and Plastics
MNR	monitored natural recovery
NAPL	Non-Aqueous Phase Liquids
NYSDEC	New York State Department of Environmental Conservation
OM&M	operation, maintenance, and monitoring
PEC	Probable Effect Concentration
PECQ	Probable Effects Concentration Quotient
PRG	preliminary remediation goals
RAO	remedial action objectives
RDWP	Remedial Design Work Plan
RI	Remedial Investigation
ROD	Record of Decision
SCA	sediment consolidation area
SMU	sediment management unit
UFI	Upstate Freshwater Institute
USEPA	United States Environmental Protection Agency

GLOSSARY OF TERMS

Epilimnion – During summer stratification, the upper portion of the thermally-stratified water column located between the 0- and 30-ft. (0- and 9-meter) water depth in Onondaga Lake. The epilimnion is warmer than the underlying stratified layers and relatively well-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]). Mixing levels are diminished in the hypolimnion relative to the epilimnion.

Methylmercury - An organic form of mercury, which can be produced from metallic inorganic mercury by bacteria in sediments and water.

Profundal Zone – The profundal portion of 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 stratifies each year from May to October based on water temperature. The profundal zone of Onondaga Lake occupies 64 percent of the lake surface area based on a minimum water depth of 30 ft. (9 meters).

Metalimnion – The stratum of water between the epilimnion and hypolimnion where a thermal gradient prevails. Mixing levels are minimal in this layer relative to other layers of the water column.

Thermocline - Is located within the metalimnion and corresponds to the water depth of the maximum rate of decrease in temperature with respect to depth.

UNITS OF MEASUREMENT

Part per million – One part per million (ppm) is equivalent to one milligram per kilogram (mg/kg) or one microgram per gram (ug/g). In water, assuming the concentration is well below one percent, one ppm is equivalent to as one milligram per liter (mg/L).

Part per billion – One part per billion (ppb) is equivalent to one microgram per kilogram (ug/Kg) or one nanogram per gram (ng/g). In water, assuming the concentration is well below one percent, one ppb is equivalent to as one microgram per liter (ug/L).

Part per trillion – One part per trillion is equivalent to one nanogram per kilogram (ng/Kg) or one picogram per gram. In water, assuming the concentration is well below one percent, one part per trillion is equivalent to as one nanogram per liter (ng/L).

EXECUTIVE SUMMARY

This initial design submittal (IDS) for the profundal (deep water) zone of Onondaga Lake, which includes sediment management unit 8 (SMU 8), continues Honeywell's progress toward achieving project goals and the community's vision for a restored Onondaga Lake. The profundal zone is the deeper water portion of the lake where water depths exceed 30 feet (ft.) (9 meters). Lake-bottom sediments in the deep water zone are referred to as "SMU 8" in the Record of Decision (ROD).

This IDS presents the initial analysis for the three design elements for SMU 8 outlined in the ROD:

- Nitrate addition to the lower waters of the deep water zone to minimize formation of methylmercury. Adding nitrate minimizes the release of methylmercury from SMU 8 sediment to overlying water where it becomes available for bioaccumulation in fish.

- Monitored natural recovery (MNR) of the top layer of the lake bottom (that is, the surface sediment). Surface sediment mercury concentrations in SMU 8 have been declining naturally for many years and are approaching the remediation goals for mercury determined in the ROD. Based on these reductions MNR was determined to be appropriate as a significant component of the SMU 8 remedy.

- Localized thin-layer capping. Thin-layer capping provides an immediate decrease in surface sediment contaminant concentrations by placing clean material on the lake bottom. The combination of a thin-layer cap over approximately 27 acres in SMU 8 and ongoing natural recovery will result in the burial or covering of older, more contaminated SMU 8 sediment and promote the natural recovery of the lake bottom.

Honeywell's design team has prepared this IDS in accordance with the *Remedial Design Work Plan for the Onondaga Lake Bottom Subsite* (Parsons, 2009a), the ROD (New York State Department of Environmental Conservation [NYSDEC] and United States Environmental Protection [USEPA] Agency Region 2, 2005) and the Consent Decree Statement of Work (U.S. District Court, 2006). As described in the RDWP, the remedial design includes preparation of four IDSs, each of which is being submitted separately to address various elements of the lake bottom remedy. The three other design submittals are:

- *Dredging, Sediment Management, and Water Treatment IDS* (Parsons, O'Brien & Gere and Anchor Environmental, 2009)
- *Sediment Consolidation Area Civil and Geotechnical IDS* (Parsons and GeoSyntec, 2009)
- *Capping and Dredge Area and Depth IDS* (Parsons and Anchor QEA, 2009)

Combined, these four submittals provide the initial design for all components of the Onondaga Lake remedy.

Separating the design into multiple submittals streamlined the schedule associated with critical path activities (e.g., sediment consolidation area [SCA] and water treatment) so that dredging can begin in 2012 as required by the Consent Decree Statement of Work. More specific design information will be provided in future design submittals to be completed prior to the start of remedial construction activities.

Community Input, Health, and Safety

Community input remains a vital component of Honeywell's design for the restoration of Onondaga Lake. Honeywell is committed to working with community leaders, interested stakeholders, and citizens to include input, recommendations, comments and perspectives into the design process. Community members have the opportunity to participate in the design, construction, and post-construction periods as detailed in the NYSDEC's *Citizens Participation Plan* (CPP) (NYSDEC 2009). Feedback received through the community participation process has already had a considerable influence on design-level decisions in several areas of the remedial design.

The design team will continue to work with the community to develop various performance criteria and work plans specifically designed to ensure that the health and safety of the surrounding community and environment are maintained throughout the execution of the remedy. The community health and safety plan relevant to capping activities that will be developed and presented in a future design submittal will consist of the following elements relevant to this design document:

- Site security for the onshore support area and for on-lake construction equipment
- Traffic management for onshore support activities
- Noise abatement
- Spill contingency
- Navigational protection

Honeywell is committed to minimizing the carbon footprint of remedial construction activities. Part of the design included evaluations to identify ways to incorporate sustainability concepts, including those presented in the *Clean and Green Policy* (USEPA, 2009) into all aspects of the remediation. To the extent practicable, using renewable energy sources, using locally produced/sourced materials and supplies, reducing and/or eliminating waste, efficiently using resources and energy, and other practices will be incorporated into the remedial design, and implemented during remedial construction.

SECTION 1

SITE DESCRIPTION AND DESIGN PROCESS OVERVIEW

1.1 FRAMEWORK

This IDS addresses SMU 8 of Onondaga Lake. SMU 8 is the portion of the lake bottom within the profundal zone , located below 30 ft. (9 meters) water depth. Honeywell's design team has prepared this IDS in accordance with the RDWP for the Onondaga Lake Bottom Subsite (Parsons, 2009a), the ROD (NYSDEC and USEPA Region 2, 2005) and the Consent Decree Statement of Work (U.S. District Court, 2006).

As described in the Remedial Design Work Plan (RDWP) (Parsons, 2009a), the remedial design includes preparation of four IDSs, each of which is being submitted separately to address various elements of the remedy. The three other design submittals are:

- *Dredging, Sediment Management, and Water Treatment IDS* (Parsons, O'Brien & Gere and Anchor Environmental, 2009)
- *Sediment Consolidation Area Civil and Geotechnical IDS* (Parsons and GeoSyntec, 2009)
- *Capping and Dredge Area and Depth IDS* (Parsons and Anchor QEA, 2009)

Combined, these four documents provide the initial design for all components of the Onondaga Lake remedy.

Separating the design into four submittals allows critical path activities (e.g., sediment consolidation area and water treatment) to be designed simultaneously to meet the schedule outlined in the Consent Decree Statement of Work that has dredging beginning in 2012. More specific design information will be provided in future design submittals to be completed prior to the start of remedial action within the lake currently scheduled to begin during 2012.

This design submittal for the profundal zone of Onondaga Lake is only a part of the comprehensive ongoing clean-up program. Hundreds of local scientists and engineers, a large team of national experts, and an involved and committed public have worked together to develop a remedial design for the lake bottom that achieves regulatory goals and is an integral part of returning this key resource to the people of central New York. This remedial design work for the lake bottom addresses remnants from former Honeywell predecessor operations and is separate from work ongoing by Onondaga County to address wastewater and combined sewer overflows entering Onondaga Lake.

1.2 ONONDAGA LAKE DESCRIPTION

Onondaga Lake is located in Central New York State immediately northwest of the City of Syracuse (Figure 1.1). The eastern shore of Onondaga Lake is urban and residential, while the northern shore is dominated by parkland, wooded acres, and wetlands. The northwest upland areas in Liverpool and Lakeland are mainly residential, with interspersed urban structures and several undeveloped areas. Much of the western and southern lakeshore is covered by historical containment areas that received wastes generated from Honeywell's former Allied Signal operations in Solvay (these areas are commonly referred to as "wastebeds"). Urban centers and industrial zones in Syracuse and Solvay dominate the landscape surrounding the southern and eastern shores of Onondaga Lake from approximately the New York State Fairgrounds south to Ley Creek. Land around the rest of the lake is recreational, providing hiking and biking trails, picnicking, sports, and other recreational activities.

The lake is approximately 4.5 miles long and 1 mile wide, with an average water depth of 36 feet (ft.) or 11 meters (m). The profundal zone of the lake (water depths greater than 30 ft. or 9 m) has two deep basins, a northern and southern, which have maximum water depths of approximately 61 and 65 ft. (19 and 20 m), respectively. These basins are separated by a saddle region which at the shallowest location has a water depth of approximately 56 ft. (17 m).

Ninemile Creek and Onondaga Creek are the tributaries that contribute the largest amounts of water to Onondaga Lake accounting for an average of 62 percent of the lake inflow from surface sources. Other tributaries in a clockwise direction from the southeast corner of the lake include Ley Creek, Harbor Brook, the East Flume, Tributary 5A, Sawmill Creek, and Bloody Brook (Figure 1.1). The treated effluent from the Onondaga County Metropolitan Wastewater Treatment Plant (referred to hereafter as Metro), located along the lakeshore between Onondaga Creek and Harbor Brook, contributes approximately 19 percent of the flow of water (80 million gallons of water per day) entering the lake (Parsons, 2004).

Waters within Onondaga Lake are more saline than in most inland lakes. Natural salt springs near the lake result in saline wetlands. These springs also discharge to Onondaga Creek, contributing to the salinity of the lake. In addition, Solvay wastebeds are known to contribute calcium, sodium, and chloride to Ninemile Creek and to the lake.

Onondaga Lake is part of a state system of canals maintained by the New York State Canal Corporation, which is part of the New York State Thruway Authority. A dam located approximately 15 miles downstream along the Oswego River in Phoenix, New York, maintains the water level in the lake. The current average surface elevation of Onondaga Lake is 362.8 ft. based on the North American Vertical Datum (established in 1988).

The current annual average water level elevation of the lake has been relatively uniform for the past 30 years; however, the lake level changes seasonally due to spring run-off and dry summers, and daily fluctuations occur due to weather events. The lake is generally at its highest elevation in the early spring due to increased tributary flows and at its lowest elevation during the summer months.

As part of the remedial alternative development and evaluation process during the Feasibility Study (FS), the lake bottom was divided into eight SMUs based on water depth, source of water entering the lake, and physical, ecological, and chemical characteristics. SMUs 1 through 7 are located in the littoral zone (shallow water) of the lake where most aquatic vegetation and aquatic life reside, while SMU 8 consists of sediment in the profundal zone (deeper than 30 ft.).

Characterization of water quality in the profundal zone of Onondaga Lake is ongoing as part of Honeywell's baseline monitoring program and also as part of monitoring programs conducted by the Onondaga County Department of Water Environment Protection and by the Upstate Freshwater Institute (UFI) that are summarized in the *Baseline Monitoring Scoping Document* (Parsons, Exponent, and Anchor QEA, 2010). As part of Honeywell's baseline monitoring program, samples of water, zooplankton, and settling solids are collected in the profundal zone from April through November at multiple depths from the deepest portion of the South Basin (at a station called "South Deep") and, in some years, from the North Basin (at a station called "North Deep"). Robotic monitoring at South Deep provides real-time water quality results at 1-meter depth intervals for multiple parameters including dissolved oxygen, temperature, and turbidity (see www.ourlake.org). Numerous studies, including data from 2007 (UFI and SU, 2008b), indicate that South Deep is a representative station for water and zooplankton in the two deep basins of Onondaga Lake. The Honeywell baseline monitoring program for the water column also includes regular in-place measurements of temperature, nitrate, hydrogen sulfide and other parameters collected from approximately 10 different locations and multiple water depths within a single day.

1.3 THE REMEDY

The Onondaga Lake Bottom, a subsite of the Onondaga Lake Superfund Site, is on the New York State Registry of Inactive Hazardous Waste Sites. The NYSDEC and Honeywell have agreed to conditions under which Honeywell will design and implement the selected remedy, as set forth in the Consent Decree (United States District Court, Northern District of New York, 2007) (89-CV-815) and outlined in the ROD for the lake bottom.

Documents appended to the Consent Decree are (1) the ROD, (2) an Explanation of Significant Differences which describes a revision to the remedy for an area along the southwest corner of the lake, (3) Statement of Work which describes a number of design-related elements for implementing the lake remedy, and (4) the NYSDEC draft generic Environmental Easement dated March 2005.

The remedial investigation (RI), planning, and design to date for the lake bottom remedy are the result of an intensive effort by scientists, engineers, and technicians working with the NYSDEC, USEPA, and numerous public interest groups, placing Onondaga Lake on a path toward a restored natural resource.

A key objective of all remedial activities is to ensure protection of on-site workers, the surrounding community, and the environment from potential risks associated with the completion of the remedy. The ROD also provides more specific objectives for remediating Onondaga Lake, called remedial action objectives (RAOs), which are listed below:

- "RAO 1: To eliminate or decrease, to the extent practicable, methylation of mercury in the hypolimnion."
- "RAO 2: To eliminate or reduce, to the extent practicable, releases of contaminants from the in-lake waste deposit (ILWD) and other littoral areas around the lake."

- "RAO 3: To eliminate or reduce, to the extent practicable, releases of mercury from profundal (SMU 8) sediments."
- "RAO 4: To be protective of fish and wildlife by eliminating or reducing, to the extent practicable, existing and potential future adverse ecological effects on fish and wildlife resources, and to be protective of human health by eliminating or reducing, to the extent practicable, potential risks to humans."
- "RAO 5: To achieve surface water quality standards, to the extent practicable, associated with chemical parameters of interest (CPOIs)."

As part of the FS process, USEPA guidance requires the establishment of preliminary remediation goals (PRGs) that can be used to select appropriate remediation technologies and to develop remedial alternatives within the FS. To achieve the RAOs stated above, three PRGs were developed to address the three primary affected media within the lake: sediment, biological tissue, and surface water. PRGs for Onondaga Lake, as per the ROD (NYSDEC and USEPA, 2005, p. 35), are listed below.

- "PRG 1: Achieve applicable and appropriate sediment effects concentrations for CPOIs and the bioaccumulation-based sediment quality value (BSQV) of 0.8 ppm (or milligrams per kilogram - mg/kg) for mercury, to the extent practicable, by reducing, containing, or controlling CPOIs in profundal and littoral sediments."
- "PRG 2: Achieve CPOI concentrations in fish tissue that are protective of humans and wildlife that consume fish. This includes a mercury concentration of 0.2 ppm in fish tissue (fillets) for protection of human health based on the reasonable maximum exposure scenario and USEPA's methylmercury National Recommended Water Quality criterion for the protection of human health for the consumption of organisms of 0.3 ppm in fish tissue. This also includes a mercury concentration of 0.14 ppm in fish (whole body) for protection of ecological receptors. These values represent the range of fish tissue PRGs."
- "PRG 3: Achieve surface water quality standards, to the extent practicable, associated with CPOIs."

PRG 1 addresses RAOs 1 through 4, PRG 2 addresses RAO 4, and PRG 3 addresses RAO 5.

The FS for the lake bottom (Parsons, 2004) evaluated a range of potential remedial technologies and alternatives for the Onondaga Lake cleanup to meet these objectives and goals. Through a comparative analysis, NYSDEC and USEPA selected the remedy documented in the ROD after assessing tradeoffs among the remedial alternatives. The selected remedy provides for:

- "Dredging of as much as an estimated 2,653,000 cubic yards (CY) of contaminated sediment/waste from the littoral zone in SMUs 1 through 7 to a depth that will prevent the loss of lake surface area, ensure cap effectiveness, remove Non-Aqueous Phase Liquids (NAPLs), reduce contaminant mass, allow for erosion protection, and re-establish the littoral zone habitat. Most of the dredging will be performed in the in-lake waste deposit (ILWD) (which largely exists in SMU 1) and in SMU 2."

- “Dredging, as needed, of an additional 3.3 ft. in the ILWD to remove materials within areas of hot spots (to improve cap effectiveness) and additional dredging, as needed, to ensure stability of the cap.”
- “Placement of an isolation cap over an estimated 425 acres of SMUs 1 through 7.”
- “Completion of a comprehensive lakewide habitat restoration plan.”
- “Habitat re-establishment will be performed consistent with the lakewide habitat restoration plan in areas of dredging/capping.”
- “Placement of a thin-layer cap over an estimated 154 acres of the profundal zone.”
- “A pilot study will be performed to evaluate the potential effectiveness of oxygenation at reducing the formation of methylmercury in the water column, while preserving the normal cycle of stratification within the lake. An additional factor which will be considered during the design of the pilot study will be the effectiveness of oxygenation at reducing fish tissue methylmercury concentrations. If supported by the pilot study results, the pilot study will be followed by full-scale implementation of oxygenation in SMU 8. Furthermore, potential impacts of oxygenation on the lake system will be evaluated during the pilot study and/or the remedial design of the full-scale oxygenation system.” In addition, as discussed in the Statement of Work, a study will be performed to determine if nitrification can effectively decrease formation of methylmercury in the water column while preserving the normal cycle of lake stratification. If NYSDEC determines from this study that nitrification is effective and appropriate, a nitrification program will be implemented in lieu of oxygenation.”
- MNR in SMU 8 to achieve the mercury probably effect concentration (PEC) of 2.2 milligrams per kilogram (mg/kg or ppm) in the lake’s profundal zone (where water depths exceed 30 ft. or 9 meters) and to achieve the bioaccumulation-based sediment quality value (BSQV) for mercury of 0.8 mg/kg on an area-wide basis, within 10 years following the remediation of upland sources, dredging and/or isolation capping of littoral sediment, and initial thin-layer capping in the profundal zone. “An investigation will be conducted during the remedial design to refine the application of an MNR model and determine any additional remedial measures (e.g., additional thin-layer capping) needed in the profundal zone.”
- “Investigation during the remedial design to determine the appropriate area-wide basis for the application of the BSQV of 0.8 mg/kg. During remedy implementation, additional remedial measures may be needed (e.g., thin-layer capping) to meet the BSQV on an area-wide basis.”
- “Implementation of institutional controls including the notification of appropriate governmental agencies with authority for permitting potential future activities which could impact the implementation and effectiveness of the remedy.” Honeywell will certify to NYSDEC that the institutional controls are in place and that Honeywell is conducting remedy-related operation, maintenance, and monitoring (OM&M) consistent with the approved OM&M Plan.

- "Implementation of a long-term OM&M program to monitor and maintain the effectiveness of the remedy".

In addition to designing the lake remedy, Honeywell has made significant progress with the remediation of upland sites. Honeywell has already completed construction of the remedy at the Linden Chemical and Plastics (LCP) Operating Unit 1 site, a former Allied Chemical property that was one of the primary sources of mercury contamination to Onondaga Lake. Honeywell has also made significant progress with the installation of an underground, hydraulic barrier wall along the southwest shoreline of the lake to prevent contaminated groundwater from entering the lake. Upon completion, the wall will extend 7,400 ft. in length. An approximately 1,200 ft. section of the wall (the Semet portion) was installed along the southwest shoreline of Onondaga Lake in 2006. Also in 2006, Honeywell completed construction of a groundwater treatment plant to collect, process, and treat contaminated groundwater that accumulates behind the barrier wall. An additional 1,600 ft. of barrier wall (the Willis portion) was completed in 2008. Installation of the third section (a 3,000 ft. section called the West Wall) was started in July 2010 and is scheduled to be completed in early 2011. The final portion is an additional 1,600 ft. scheduled to be installed beginning in 2011.

1.4 DESIGN PROCESS OVERVIEW

The primary elements of the selected remedy for Onondaga Lake, as documented in the ROD and as described above, include:

- Sediment removal (dredging) and transport to the SCA
- On-site management of dredged material at the SCA
- Sediment capping (isolation and thin-layer) including remediation area determination and definition of dredge areas, depths, and volumes
- Water treatment system
- Nitrate addition or oxygenation of the hypolimnion
- MNR
- Habitat restoration and enhancement
- Institutional controls
- Long-term operation, maintenance, and monitoring

For most of the remedial elements described above, design-related investigations, engineering assessments, and evaluation reports were completed before this IDS report to assess specific elements of the remedy, advance design decisions, and to obtain concurrence with NYSDEC and USEPA on critical path components.

Due to interaction between the various remedial elements, and varying design schedule considerations with specific design components, it was necessary to separate the design into several distinct submittals. Separating the design into several components allows for accelerated design submittals for critical path activities (e.g., SCA and water treatment), helps the agency review process by staggering the submission of large documents, and facilitates the schedule for starting and completing the remedial action consistent with the Consent Decree. Future design submittals and their associated submittal schedules have been developed and presented in each of the IDS reports.

The content of the four IDS Reports is as follows:

- The *Dredging, Sediment Management, and Water Treatment IDS* (Parsons, 2009b) provides conceptual design-level information pertaining to operational components of the remedy including the dredging, transportation, and dewatering of impacted lake sediments, and treatment of construction water generated during the process. This IDS was submitted to the NYSDEC in February 2009 and is available in the public repositories.
- The *SCA Civil & Geotechnical IDS* (Parsons and GeoSyntec, 2009) includes the civil and geotechnical design elements (*e.g.,* liner system) required for construction of the SCA. This IDS was submitted to the NYSDEC in August 2009 and is available in the public repositories.
- The *Capping and Dredge Area and Depth IDS* (Parsons and AnchorQEA, 2009) includes the conceptual-level design detail for the sediment cap components of the remedy. This submittal also includes the integration of conceptual-level design details pertaining to habitat restoration and also provides dredging volumes and removal areas and depths. This IDS was submitted to the NYSDEC in December 2009 and is available in the public repositories.
- The *IDS for the Profundal Zone* (this submittal) focuses on the profundal areas of the lake, and provides conceptual-level design details pertaining to thin-layer capping (including locations, extent, materials, and sequencing), nitrate addition and/or oxygenation for the purposes of inhibiting the formation of methylmercury within the lake, and the approach to MNR in specific areas of the lake.

After a period of agency review and comment on the first three IDS reports listed above, the separation of future design submittals based on remedial components has been refined into five design documents, which are currently in various stages of completion:

- SCA Civil and Geotechnical Design
- Water Treatment Plant Design
- Sediment Management Design
- Dredging, Capping, and Habitat Design
- Design for the Profundal Zone (SMU 8)

Figure 1.2 illustrates the relationships between the various remedial design components for the Onondaga Lake project, and illustrates the importance of citizen participation throughout the entire design process.

This IDS presents the design team's analysis for the three design elements for SMU 8 outlined in the ROD: (1) nitrate addition to the lower waters of the profundal zone to minimize formation of methylmercury; (2) monitored natural recovery of surface sediment; and (3) design of an effective thin-layer cap. The analyses are based on work performed during the feasibility study (Parsons, 2004) and extensive investigations related to the profundal zone conducted following issuance of the ROD. Results of these investigations were reported in data summary reports available in the public document repositories listed in the *Onondaga Lake Citizen Participation Plan* (CPP) (NYSDEC, 2009). The investigations include:

- Geophysical surveys to map the lake bottom
- Ongoing water quality sampling in the profundal zone on a regular basis from April to November
- Five dye tracer tests to quantify dispersion in the lower hypolimnion where nitrate is to be added
- A nitrate application field trial to confirm nitrate can be effectively placed and to provide additional measurements of dispersion
- Sediment sampling for chemical and geotechnical analyses to update the extent of natural recovery and determine the thin-layer capping areas
- Radioisotope analysis of sediment to quantify past and ongoing sedimentation rates
- Ongoing water velocity measurements in the lower hypolimnion
- Analysis of results from sediment traps to provide information about solids settling within the profundal zone
- Testing and placement of microbead markers to facilitate monitoring of subsequent sediment deposition

A summary of the documents pertinent to this IDS Report is included as Table 1.1. All of these documents are available in the document repositories or will be following final NYSDEC approval.

1.5 REPORT ORGANIZATION

This IDS is organized into nine sections and one appendix. A summary of each section and appendix is provided below.

- Section 1: Site Description and Design Process Overview – Presents background information, site description, remediation goals for the site, and a summary of the remedy and community outreach and citizen involvement efforts being conducted by Honeywell
- Section 2: Community Participation, Community Health and Safety, and General Project Requirements – Highlights Honeywell's community protection efforts and presents general requirements applicable to many aspects of the project applicable to the design
- Section 3: Nitrate Addition – Summarizes the basis for nitrate addition and provides an overview of the three-year pilot test to begin in 2011

- Section 4: Monitored Natural Recovery – Presents the evaluation of natural recovery ongoing in the profundal zone
- Section 5: Analysis of Mean Probable Effects Concentration Quotient (PECQ) – Presents the evaluation of mean PECQ for SMU 8 sediment and where thin-layer capping is needed based on the mean PECQ exceeding 1
- Section 6: Thin-Layer Capping – Presents the delineation of areas in the profundal zone to be thin-layer capped and thin-layer cap characteristics and placement considerations
- Section 7: Subcontracting Strategy – Summarizes the anticipated subcontracting strategy for profundal zone remedial efforts
- Section 8: Design Submittal and Construction Schedule – Presents the schedule for additional design submittals and presents the anticipated bidding, procurement, and construction schedule
- Section 9: References – Lists the references used to prepare this IDS
- Appendix A – Presents the modeling of natural recovery for SMU 8

SECTION 2

COMMUNITY PARTICIPATION, COMMUNITY HEALTH AND SAFETY, AND GENERAL PROJECT REQUIREMENTS

The health and safety of members of the community and consideration of community input are of paramount importance in designing the lake remedy. Section 2.1 of the *Dredging, Sediment Management, and Water Treatment IDS (*Parsons, 2009c) and the *Sediment Consolidation Area Civil and Geotechnical IDS* (Parsons, 2009d) summarize how community input has been incorporated into the design of those remedy components. The *Onondaga Lake Citizen Participation Plan (CPP) for the Remedial Design Program* (NYSDEC, 2009) provides details regarding community involvement for the entire Onondaga Lake Bottom Subsite remedial program. Community considerations and project requirements that pertain specifically to the sediment capping aspects of the remedy are discussed in the subsections below.

2.1 COMMUNITY PARTICIPATION AND HEALTH AND SAFETY

NYSDEC and Honeywell are continuing a Community Outreach Program designed to ensure transparency of the design process, incorporate community ideas and feedback, and to maintain awareness of remedial progress and milestones. This outreach was designed in recognition of the importance of the lake as a natural resource to the surrounding area, and the level of community interest in the progress of the Onondaga Lake remediation. This section discusses the importance of community feedback and some of the design aspects that have been modified based on feedback received to date, and outlines future plans and design components which will help ensure the health and safety of the surrounding community while remedial activities are ongoing.

2.1.1 Community Participation

The NYSDEC and Honeywell are required and committed to informing and involving the public during the remedial design and construction phases of the Onondaga Lake project. Continued involvement of the community is a critical component to the successful restoration of Onondaga Lake. Opportunities for further community participation have been summarized in the CPP and are incorporated into the design.

Feedback received through the community participation process has already influenced design-level decisions for other components of the lake remedy. Community interest and feedback have primarily focused on the restoration and end-use components of the remedial design. Significant effort has been spent to develop a lakewide plan for the incorporation of habitat restoration. These plans are presented in the *Onondaga Lake Remedial Design Elements for Habitat Restoration* (Parsons, 2009c). Community members and interest groups such as the Audubon Society, Ducks Unlimited, Citizens Campaign for the Environment, Salt City Bassmasters, New York Wildfowlers, Onondaga County Federation of Sportsmen, Sierra Club, Izaak Walton League of America, and NYSDEC have provided critical input to ensure that the vision for post-remediation Onondaga Lake fits with the goals of the community, and that the recreational opportunities facilitated by the remedial design are aligned to maximize the benefit to the surrounding community.

2.1.2 Community Health and Safety Protection

As part of the remedial design process, the design team will continue to work with the community to ensure that the health and safety of the surrounding community and environment are maintained throughout the execution of the remedy. Performance criteria developed for health and safety and for protection of the local environment will be approved by the NYSDEC prior to any remedial action taking place.

A comprehensive Community Health and Safety Plan (CHASP) for remedial construction operations will be presented for on-water and upland remedial efforts. Those elements of the plan relevant to remedial efforts in the profundal zone of the lake include the following:

- Site Security – Security provisions will be outlined for in-lake construction activities and for shoreline construction support to minimize risks to persons, property, and the environment. Specific security measures may include fences, gates, signs, remote cameras, security patrols, and lighting. Additionally, posting requirements for appropriate warning signs, barricades, and fences to protect members of the public from accidentally accessing the site will be outlined.
- Traffic Management – Traffic routes and incidence response measures for vehicle traffic associated with the delivery and handling of materials, equipment, supplies, and workers will be developed for the shoreline construction support area(s).
- Noise Abatement – Construction equipment requirements and hours and areas of required noise reduction will be identified. Noise monitoring and control will also be included.
- Spill Contingency – Spill prevention and control measures will be described as will procedures and equipment to be available in the unlikely event of a spill.
- Navigational Protection – Recreational boaters and other users of the lake (such as Canal Corporation barge operators) will need to be protected from work zones, navigational hazards, and construction equipment. Communication procedures for navigational protection will be outlined in the plan and may include posting and delineation of sensitive/restricted project areas, and procedures associated with the siting and illumination of on-water equipment.

This CHASP for operations will also include contingency plans to control potential hazards to the public posed by remedial activities taking place in Onondaga Lake, and in shoreline support areas areas.

2.2 GENERAL PROJECT DESIGN AND PERFORMANCE CRITERIA

General requirements applicable to the remedial design for the Onondaga Lake profundal zone are described below. Additional details on requirements pertaining to specific aspects of the remedy are provided in Sections 3 through 5.

2.2.1 Sustainability

Honeywell is committed to minimizing the carbon footprint of construction activities anticipated as part of the execution of the remedy. During the design phase, evaluations are being conducted to identify opportunities to incorporate sustainability concepts, including those presented in the *Clean and Green Policy* (USEPA, 2009) and the NYSDEC's DER-31/Green Remediation program policy into all aspects of the Onondaga Lake remediation. To the extent practicable, use of using renewable energy sources and locally produced/sourced materials and supplies, reducing and/or eliminating waste, efficient use of using resources and energy, and other practices will be incorporated into the remedial design, and implemented during remedial construction.

2.2.2 Federal and State ARARs

Compliance with federal and state Applicable or Relevant and Appropriate Requirements (ARARs) will ensure that the existing resources are protected during operations and provide for overall protection of human health and the environment. A comprehensive list of chemical-specific, action-specific and location-specific ARARs is included in the ROD.

2.2.3 Health and Safety Requirements

The health and safety of site personnel, visitors and members of the public are considered the top priority on this project. Written safety plans will be developed for each phase of the remediation project. Project Safety Plans will be developed and updated as needed to address changing activities and site conditions. The health and safety record of all bidding contractors will be evaluated as part of the bidding process. At a minimum, selected remedial contractors will be required to prepare Project Safety Plans, which will address potential safety issues associated with the specific tasks the contractor will be performing. Specific requirements, including audit procedures, employee drug and alcohol screening programs, and near-miss reporting protocols will also be specified as part of the upcoming submittals for the Capping, Dredging, and Habitat Design.

2.2.4 Property and Site Access and Right-of-Way Entry

Honeywell will secure access for several components of the remedy that may require the use of non-Honeywell owned property. These activities could include construction laydown and cap material storage areas, debris management, or placement processing areas. All remedial contractors whose scope requires use of these properties will be required to abide by the terms and conditions of the negotiated access agreements.

SECTION 3

NITRATE ADDITION

Honeywell will conduct a three-year pilot test beginning in 2011 to add supplemental quantities of nitrate to the lower hypolimnion of Onondaga Lake in order to decrease methylmercury production and release from deep zone (SMU 8) sediments. The pilot test will also include a monitoring program to assess the effectiveness of application and evaluate potential impacts to water quality and biota. Decreases in methylmercury concentrations in the hypolimnion are expected to lead to decreases over time in mercury concentrations in Onondaga Lake biota.

This pilot test is based on requirements included in the Statement of Work attached to the Consent Decree between Honeywell and the NYSDEC for the lake bottom remedy (United States District Court, 2006). The pilot test follows four years of extensive water column monitoring that documents the positive impacts of the nitrate added by Metro, an extensive bench test program (Exponent et al, 2009), dye tracer tests conducted on behalf of Honeywell during 2008 (UFI, 2009), and a nitrate application field trial conducted on behalf of Honeywell during 2009 (Parsons and UFI, 2010a). A work plan for this nitrate pilot test was submitted to NYSDEC and USEPA for review. The basis for nitrate addition and a summary of the proposed pilot test is provided in this section.

Adding calcium nitrate to deeper waters in the lake will be safe and protective of human health and the environment. Nitrate will be added as liquid calcium nitrate which is a commonly-used agricultural fertilizer with no known human health or biota effects. Adding liquid nitrate to the lower hypolimnion is not expected to stimulate growth of algae or other plants in the lake and will not result in exceeding any applicable water quality standards (Parsons and UFI, 2010b).

Prevention of any uncontrolled release of nitrate to the local environment is included in pilot test planning and will be included during implementation. The technology planned for adding nitrate during the pilot test is relatively simple and has been used effectively on a trial basis. Protocols for safe operations and spill prevention will be implemented, and water quality will be monitored throughout the pilot test. Spill contingency for nitrate addition operations will include design controls, preventive management practices for activities such as refueling of vehicles or transfer of chemicals, and spill response procedures to be documented prior to the start of the pilot test.

3.1 BASIS FOR NITRATE ADDITION

Methylmercury concentrations increase in the lower hypolimnion during late summer and early fall when oxygen and nitrate levels become depleted in the hypolimnion. Stratification is typically most pronounced in Onondaga Lake from mid-May until mid-to-late October due to vertical variations in temperature and results in isolation of the hypolimnion from the epilimnion. The hypolimnion receives organic and inorganic solids that settle by gravity from the epilimnion toward the lake bottom. Decomposition of organic matter proceeds through a sequence of metabolic pathways according to energetic favorability (oxic respiration, nitrate reduction, sulfate reduction, methanogenesis). As the summer progresses, biodegradation of organic matter and oxidation of reduced chemical species (e.g., H_2S, CH_4) depletes oxygen in the hypolimnion, creating anoxic conditions. In the absence of oxygen, biodegradation proceeds primarily through the nitrate reduction pathway (denitrification). Under anaerobic conditions (absence of oxygen and nitrate), organic matter is mineralized via sulfate reduction or methanogenesis.

When sulfate is used in biodegradation (i.e., reduced by bacteria from sulfate to sulfide), methylmercury is produced in SMU 8 sediments and may be released to overlying water in the hypolimnion, conditions permitting. The presence of oxygen or nitrate in the overlying waters results in the formation of an oxidized microzone at the sediment surface that may inhibit transport to the water column (Todorova et al. 2009). When profundal zone lake waters turn over (typically in mid-to-late October due to cooling temperatures and wind), the water column becomes well-mixed, and depletion of oxygen and nitrate ceases. Following fall turnover, total mercury concentrations in Onondaga Lake waters decline quickly as a result of adsorption to particulate matter and settle to the lake bottom (Jacobs et al. 1995). Methylmercury concentrations in Onondaga Lake can remain elevated throughout the water column for several weeks following fall turnover but then they also decline as methylmercury is degraded or immobilized in surface waters (Sellers et al. 1996).

Since Onondaga County implemented year-round nitrification (a biological process whereby ammonia is converted to nitrate) at Metro in 2004, nitrate concentrations in Onondaga Lake have approximately doubled (Effler et al., 2010) and the period of sulfate reduction (and therefore methylmercury production) has started later in the summer than it did prior to 2004 (Effler and Matthews 2009, Todorova et al. 2009). Accumulation of methylmercury in the hypolimnion has declined 50 percent from the combined effects of decreased deposition of organic matter (due to decreased primary production resulting from the Metro upgrade in phosphorus treatment) and the increased discharge of nitrate from the facility (Todorova et al. 2009) These improvements have led to decreases in methylmercury concentrations in the lake's upper waters, particularly during fall turnover (Figure 3.1).

The objective of the nitrate addition pilot test is to demonstrate the ability to maintain nitrate concentrations in the hypolimnion of Onondaga Lake at levels sufficient to further inhibit release of methylmercury from lake sediment to the overlying waters. This work supplements nitrate addition that is ongoing as a result of wastewater treatment upgrades at Metro described above.

3.2 PILOT TEST DESIGN AND PERFORMANCE CRITERIA

Based on detailed data collection and evaluation for the years 2007 through 2009 described in the work plan for the pilot test (Parsons and UFI, 2010b), a minimum nitrate concentration of 1.0 milligram per liter as nitrogen throughout the hypolimnion during summer stratification has been established as the pilot test goal. The target area for nitrate addition has been identified as the lake area with water depths greater than 46 ft. (14 meters) for reasons explained in the work plan for the pilot test.

In order to maintain the target minimum nitrate concentration of 1 milligram per liter, the maximum nitrate application rate that the pilot test equipment has been designed to achieve was conservatively determined based on peak four-week rolling average nitrate uptake rates in the hypolimnion water as measured at the South Deep station by UFI during the summers of 2007, 2008, and 2009. The maximum nitrate uptake rate over any four-week period from 2007 through 2009 was 0.8 metric tons of nitrate-nitrogen per day or 5.6 tons of nitrate-nitrogen per week. This rate for adding nitrate will be achieved over three 6-hour application periods each week at three profundal zone locations incorporating a 20 percent safety factor.

3.3 DESIGN EVALUATIONS AND TESTING

Large quantities of design data have been collected on behalf of Honeywell associated with nitrate addition. Water quality has been routinely monitored in the profundal zone since 2006 as reported in the annual baseline monitoring reports. Five different dye tracer tests were completed in the profundal zone during 2008 (UFI, 2009). Two nitrate application field trial applications of nitrate were completed during 2009 (Parsons and UFI, 2010a). Results from this work are summarized in the work plan for the nitrate pilot test (Parsons and UFI, 2010b).

The design evaluation for this nitrate pilot test has been largely completed and includes the basis for quantifying the nitrate inflow needed to meet the pilot test objective and the basis for how the inflow will be implemented to achieve sufficient spreading of nitrate throughout the lower hypolimnion. This design evaluation work is detailed in the work plan (Parsons and UFI, 2010b).

3.4 IMPLEMENTATION OF NITRATE ADDITION PILOT TEST

Calcium nitrate, a common agricultural fertilizer, is the source of nitrate that will be applied to the lower waters of the Onondaga Lake hypolimnion. The basis for selecting calcium nitrate is its liquid form, availability, common use, chemical content, and successful application of liquid calcium nitrate during the 2009 nitrate application field trial.

In order for the calcium nitrate solution to remain in the lower hypolimnion following release to the lake, the calcium nitrate solution needs to be diluted to the density of the hypolimnion water. The specific gravity of the calcium nitrate solution is 1.48, which is almost 50 percent higher than the density of water. Therefore, water that is less dense than hypolimnion water needs to be mixed with the calcium nitrate before being pumped to the lower hypolimnion. Water from shallower depths above the metalimnion (i.e., the epilimnion) is warmer and less dense than hypolimnion waters and therefore will be mixed with the calcium nitrate prior to application in the hypolimnion. Pumping rates into the lake will be determined prior to injection based on preceding water quality monitoring results. The pilot test field crew will adjust the flow rates of calcium nitrate and epilimnetic water to maintain the required dilution ratio based on field determinations of water temperature and specific conductance.

The nitrate addition pilot test will be conducted as by applying calcium nitrate mixed with the appropriate amount of water from shallower depths from a barge to the entire surface area of the lower hypolimnion. Nitrate will be added to the lower hypolimnetic waters in liquid form during the summer through early fall of 2011, 2012, and 2013. Applications of calcium nitrate will typically start in mid-to-late June before nitrate concentrations drop below 1.0 ppm at the 60-ft. (18 meter) water depth and continue until the lake waters turn over each fall. The addition of calcium nitrate has been designed based on three separate stationary applications per week of a diluted calcium nitrate solution to the hypolimnion. Each application of nitrate will be conducted continuously for up to eight hours during a single day at a single predetermined location. The expectation is that the application location will be moved to a different location within the profundal zone for each day nitrate is added. Monitoring of nitrate and related parameters will be conducted approximately two times each year during the week prior to the first application (as a baseline), three days each week during the application period and two times each year during the week following the last application.

The barge to be used to apply diluted calcium nitrate will be able to work in Onondaga Lake under weather conditions that occur commonly during summer and fall months in Central New York. The anticipated barge layout for the application equipment is presented in the work plan.

The barge will be approximately 32 ft. by 48 ft. and will be visible in the profundal zone for up to eight hours each of three days weekly at one location during summer months and into October. Adding calcium nitrate during lakewide recreational events will be avoided.

3.5 MONITORING DURING THE PILOT TEST

An in-lake monitoring program will be conducted before, during, and after each of the three years of nitrate addition as provided in the pilot test work plan. Data collected as part of the nitrate addition monitoring program will be used to guide rates and locations for application of the calcium nitrate solution, to track the fate of the nitrate addition and verify that there are no negative impacts to water quality, and to assess nitrate addition as a means of abating methylmercury accumulation in the hypolimnion. The monitoring program to support the nitrate pilot test has three components: (1) fixed frequency monitoring; (2) three-dimensional specification of nitrate and sulfide levels on a frequent basis during periods of nitrate addition; and (3) measurements on board the barge. The monitoring program for the pilot test is described in the work plan (Parsons and UFI, 2010b).

3.6 POST PILOT TEST CONSIDERATIONS

This nitrate addition pilot test will be followed by a year of monitoring (i.e., 2014) to allow for data evaluation, an assessment of recent changes in inputs to the profundal zone of the lake form tributaries, from Metro, and from the littoral zone of the lake, consideration of potential seasonal changes in lake water quality, and determination of the path forward, which may include nitrate addition or consideration of oxygenation. At a minimum, monitoring in the lake for methylmercury will continue beyond the year 2013.

SECTION 4

MONITORED NATURAL RECOVERY

Surface sediment mercury concentrations in SMU 8 have been declining naturally for many years and are approaching the remediation goals for mercury (i.e., the mercury PEC and mercury BSQV) determined in the ROD (Figure 4.1). Based on these reductions in mercury in surface sediments that were documented in the Feasibility Study (Parsons 2004), MNR was determined to be appropriate as a significant component of the SMU 8 remedy. MNR involves allowing ongoing naturally occurring physical, chemical, and/or biological processes to lower the concentration, mobility, bioavailability, toxicity, and/or exposure of chemicals in a media such as lake sediment. Some natural processes (e.g., deposition of cleaner sediments onto impacted sediments) act as containment mechanisms, while others (e.g., biodegradation of contaminants by native bacteria) act as *in situ* treatment mechanisms.

Natural recovery is monitored to verify that specified goals are achieved within an acceptable timeframe. For Onondaga Lake, natural recovery of sediments with elevated mercury concentrations in the profundal zone is expected to lower surface sediment mercury concentrations to below the ROD performance criteria (see below) within the 10-year monitoring period specified in the ROD following completion of the remediation of Honeywell upland sources and littoral sediments. The current projection is for these remediation activities to be completed by the year 2017; therefore, MNR will extend from current conditions through the year 2027.

Mercury PEC and mercury BSQV performance criteria presented in the ROD are predicted to be met naturally by the end of the 10-year MNR monitoring period (i.e., the year 2027), as described in this section. Based on model calculation, it is not anticipated that thin-layer capping will be needed to supplement MNR**.**

The MNR remedy for Onondaga Lake includes procedures in case sufficient natural recovery is not observed within the 10-year post-remediation monitoring period. Such procedures might involve a range of activities, including additional monitoring and/or modeling of natural recovery, and implementation of thin-layer capping in those areas where MNR does not appear to be achieving the required outcome.

4.1 DESIGN AND PERFORMANCE CRITERIA FOR MNR IN ONONDAGA LAKE

The design and performance criteria for MNR based on ROD requirements are listed below.

- Achieve the mercury PEC of 2.2 mg/kg in the profundal zone within 10 years following the remediation of upland sources, littoral sediments, and initial thin-layer capping in the profundal zone.
- Achieve the mercury BSQV of 0.8 mg/kg on an area-wide basis within 10 years following the remediation of upland sources, littoral sediments, and initial thin-layer

capping in the profundal zone.

Areas where surface sediments will not meet these goals based on MNR model predictions will require thin-layer capping prior to initiation of the 10-year MNR period. The reference in the criteria listed above to initial thin-layer capping refers to these areas as well as sediments which currently exceed a mean PECQ of 1, as discussed in Section 5.

The remediation goals for mercury PEC and BSQV need to be met within a vertical interval of surface sediment that is relevant to potential exposures to organisms intended to be protected. This vertical interval of sediment is referred to herein as a “compliance depth”. The appropriate compliance depth for mercury PEC, for BSQV, and for mean PECQ was determined to be the top 2 cm for SMU 8 sediment based on site-specific considerations as described in Appendix A.

The mercury PEC of 2.2 mg/kg needs to be met at each station because it is based on direct toxicity to sediment-dwelling organisms. The mercury BSQV of 0.8 mg/kg needs to be met over a larger area because it is based on bioaccumulation, a process that involves exposure to mercury from a large area. Areas of the lake over which the BSQV is applied are discussed in Section 4.4.2.

4.2 NATURAL RECOVERY PROCESSES IN ONONDAGA LAKE

The primary natural recovery mechanism operating in SMU 8 surface sediment is burial by incoming clean sediments that are continually being deposited from overlying water. This process is based on the extensive information available for the profundal zone of Onondaga Lake and the fact that mercury is strongly absorbed to sediment and is not degradable or substantially solubilized.

As shown in Figure 4.2, mercury concentrations in near-surface sediment in a core from the North Basin and a core in the South Basin collected during 2008 are substantially lower than mercury concentrations present in deeper sediments. The lower concentrations at shallower depths correspond to recent conditions when mercury loadings entering the lake are substantially higher. The ages of deeper sediments have been estimated by analysis of lead-210 and cesium-137 radioisotopes from cores collected during the 1990s as part of the lake RI (TAMS, 2002) and also from cores collected on behalf of Honeywell during 2008 (Parsons, 2010). The lower surface concentrations have resulted from subsequent deposition of cleaner sediments over time. Deposition rates are an important factor in determining how rapidly SMU 8 sediment is recovering, and can be estimated from sediment cores and sediment trap data, as described in Appendix A.

Laminations (also called layering or varves) were initially observed in SMU 8 sediment during the 1990s (Rowell, 1992 and Effler et al, 1996) and again during the 2010 PDI as described in Appendix A. The presence of laminations indicates only limited vertical mixing occurs in SMU 8 sediment, which contributes to natural recovery. This lack of vertical mixing results primarily from the lack of benthic organisms in the sediment (due to the lack of oxygen in the profundal zone during summer stratification each year) and the lack of resuspension by water currents (see Appendix A). Lake remediation efforts, including the nitrate addition, are not expected to change this condition, so natural recovery is projected to continue on an ongoing basis.

4.3 MONITORING AND CONTINGENCY APPROACH FOR NATURAL RECOVERY

The rate of natural recovery is predicted based on site-specific modeling, as discussed below in Section 4.4 and in Appendix A. To verify the accuracy of these projections, a long-term monitoring program will be implemented throughout the MNR period. In addition, contingency actions have been identified which would be evaluated and implemented if needed.

Given the objectives for natural recovery, mercury concentrations are based on surface sediments that will be analyzed over time to determine the effectiveness of natural recovery in the future in Onondaga Lake because the mercury PEC and BSQV are both based on total mercury concentrations in surface sediments. Important regulators of MNR will be reassessed on an as-needed basis in the future if MNR deviates from expected values. In such a situation, questions related to why MNR might be deviating from expected values are often best answered through examination of the mechanisms contributing to MNR.

The monitoring and contingency approach for MNR in SMU 8 consists of the following elements:

- Collect the same data types on regular intervals to track the course of MNR and provide early indication whether MNR is occurring as expected
- Provide a clear timing and decision framework for evaluating those data and making contingency decisions
- Provide a clear set of procedures, dependent on monitoring results, that allows for:
  - conducting additional analysis and/or modeling of existing data to better understand the implications of available results
  - collecting additional data and/or new types of data to help better understand existing results (with related additional data analyses/modeling as necessary)
  - evaluating and implementing (as warranted) additional remedial activities in the event that MNR is not progressing at a rate to meet lake remediation goals within the expected time period
- Consider additional procedures for unexpected or unknown events or circumstances (such as large storm events, unusual natural or anthropogenic discharge events, and other remedial activities affecting SMU 8 such as nitrate addition)

This monitoring and contingency approach will provide documentation of ongoing progress toward meeting remediation goals for mercury in profundal zone sediment. This approach also provides an assurance that contingency actions can be implemented in the future if remediation goals are not met.

A year-to-year summary schedule has been developed for implementing this monitoring and contingency approach (Table 4.1). Surface sediment data will be collected every 3 years and compared to the anticipated course of MNR as provided by the MNR model. Honeywell will provide updates to the agencies after each three-year monitoring interval to document work associated with implementing this monitoring and contingency approach and to provide recommendations for future sampling, modeling and/or remedial efforts.

Future simulations will be conducted using the MNR model as warranted when more information is collected. At each three-year interval, surface sediment mercury concentrations in SMU 8 will be compared to the estimated course of MNR as indicated by modeling results, as well as the theoretical trends needed to reach the remediation goals for mercury PEC and BSQV by the end of the 10-year monitoring period. If MNR is progressing as projected, little, if any, additional contingency work would be considered. If MNR is not progressing as projected, possible additional contingency actions would be discussed with the agencies and NYSDEC would subsequently determine what contingencies would be implemented, including potential placement of a thin-layer cap over a larger area of SMU 8.

4.4 DESIGN EVALUATIONS AND TESTING

Substantial design evaluation and testing work have been completed over several phases of PDI to support evaluation of MNR for SMU 8. Evaluations have included various types of specific data analyses, mathematical modeling, and GIS-based evaluation and presentation of results. Surface sediment samples have been collected over many years and analyzed for mercury at over 100 locations. Sediment samples have also been collected for other purposes including observations of layering and presence of benthic organisms. Deep sediment cores have been collected throughout SMU 8 and analyzed for certain radioisotopes to assess sediment age and deposition rates. Sediment traps have been set near the thermocline, retrieved and analyzed by UFI for many years to assess newly depositing sediment. Microbead markers have been placed at the surface of the sediment in select locations to serve as a reference point for future measurement of sediment which accumulates on top of the microbead markers. (Parsons and Environmental Tracing Systems, 2010). Each of these data sets has been assessed and evaluated as part of the design of natural recovery for SMU 8.

The primary MNR design evaluation conducted for this IDS has been to predict the rate of natural recovery in sediments using site-specific data and mathematical modeling to confirm that MNR will be effective for the profundal zone through the future 10-year MNR monitoring period.

A one-dimensional numerical model has been applied to simulate the potential natural recovery rates of SMU 8 sediments. The model is based on the extensive work done by Boudreau (1997). The model has been applied as part of this IDS to assess long-term fate and transport of mercury in sediment by simulating natural recovery processes ongoing within Onondaga Lake. The natural recovery process was modeled at over 80 locations in SMU 8 in order to quantify variations in model results throughout the profundal zone. A description of the MNR model, model inputs, and its governing equations is included in Appendix A.

To support this application of the MNR model, data collected on behalf of Honeywell as part of the PDI were used to develop conservative site-specific model input parameters. The primary inputs to the MNR model are sediment mixing depth, existing and estimated future sedimentation rates, and existing and future post-remediation mercury concentrations in settling sediment. These inputs and others have been evaluated based on extensive recent site data and other site information, as detailed in Appendix A.

ROD compliance requires the mercury PEC and BSQV remediation goals be met by 10 years following remediation which is anticipated to be the year 2027. The MNR model was therefore run for the time period ending in 2027.

4.4.1 Model Calibration

The MNR model described in Appendix A has been successfully calibrated to account for data collected by Honeywell during the pre-design investigation (since 2005). Calibration plots are presented in Appendix A. Results show the model correlates well with available pre-design data. Initial calibration work showed a consistent over-prediction of mercury concentrations observed in the North Basin, Saddle, Nine Mile Creek Area, and South Basin. To improve calibration, lower settling sediment mercury concentrations were applied to these areas. A settling sediment mercury concentration of 1.0 mg/kg was applied to the North Basin, and a settling sediment concentration of 1.4 mg/kg was applied to the Saddle, Ninemile Creek, and South Basin until the year 2017 when capping and dredging is scheduled to be completed. The South Corner was modeled with a settling sediment mercury concentration of 1.9 mg/kg for this time period (see Figures 5.1a and 5.1b for sub area boundaries applied to SMU 8 sediment).

The model calibration effort will be updated in the future if work under the monitoring and contingency approach for natural recovery demonstrates an update is appropriate.

4.4.2 MNR Modeling Results

Modeling results predict that mercury PEC and BSQV remediation goals will be met with natural recovery by the end of the 10-year MNR monitoring period (i.e., the year 2027). Therefore, thin-layer capping is not expected to be needed to meet natural recovery objectives. Monitoring of sediment conditions in SMU 8 will continue throughout the remediation and 10-year monitoring period (Table 4.1). If future monitoring shows that MNR model predictions are not being met, contingency actions will be implemented at that time as appropriate, as discussed in Section 4.3.

Modeling results summarized in Table 4.2 show future sediment mercury concentrations in the profundal zone are projected to range between 0.44 mg/kg and 0.45 mg/kg by the year 2027. The PEC of 2.2 mg/kg for mercury is projected to be achieved at all modeled locations by the year 2014 which is four years before the 10-year monitoring period for natural recovery will begin. This analysis assumes no temporary increases in sediment mercury concentrations in SMU 8 during dredging.

In addition to achieving the mercury PEC, one of the goals of MNR is to achieve the mercury BSQV of 0.8 mg/kg on an area-wide basis. Because the BSQV was developed on a lakewide basis in the FS, the MNR model results were combined with projected littoral zone surface sediment mercury concentrations following remediation to estimate the future lakewide average concentration of mercury in surface sediment (0 to 2 cm sediment depth). The average mercury concentration projected for the year 2027 is 0.43 mg/kg in surface sediment on a lakewide basis, well below the BSQV of 0.8 mg/kg. The lakewide average surface sediment mercury concentration is predicted to fall below the BSQV of 0.8 mg/kg by the year 2018.

Splitting the lake into subareas for development of area-weighted averages was considered; however, the basis for doing so is not apparent or consistent with the development of the BSQV. Nevertheless, for comparison, the BSQV was also evaluated for the north half and the south half of Onondaga Lake, with the north half including the North Basin, Ninemile Creek Outlet Area, and Saddle and the south half including the South Basin and South Corner (see Figures 5.1a and 5.1b for lake area delineations). The average mercury concentration in the top 2 cm of sediment is predicted to be 0.52 mg/kg in the north half of the lake (including littoral and SMU 8 sediments) and 0.37 mg/kg in the south half of the lake by the year 2027.

SECTION 5

ANALYSIS OF MEAN PECQ

In accordance with the ROD, surface sediments in the profundal zone of Onondaga Lake that exceed a mean PECQ of 1 will be capped with a layer of sand (referred to herein as thin-layer capping). Based on the extensive sediment sampling data set available for SMU 8 (Figure 5.1), thin-layer capping will be implemented in two areas where surface sediment samples exceed a mean PECQ of 1. The two areas to be thin-layer capped total 26.9 acres and border the littoral zone near the lake's southern shoreline.

The mean PECQ of 1 takes into consideration the 23 contaminants that showed significant contributions to toxicity on a lakewide basis. These 23 contaminants and the method for calculating the mean PECQ are provided in Table 5.1. The mercury PEC criterion of 2.2 mg/kg and the mean PECQ criterion of 1 are both based on considerations of benthic toxicity. The sediment compliance depth for the mean PECQ is 2 cm consistent with the mercury PEC compliance depth developed in Appendix A.

The extensive data set used to characterize the profundal sediment was developed as part of the RI and several phases of PDI. Table 5.2 summarizes the data sets available for assessing the mean PECQ for SMU 8 sediment. Many locations have been sampled more than once. At these locations, the most recent data were used in the evaluation. This is appropriate given that natural processes continue to lower surface sediment concentrations through gradual deposition of sediments with low contaminant concentrations entering the profundal zone of Onondaga Lake, as discussed in Section 4.

The 2010 data set includes results from 67 locations in SMU 8 collected from the top 4 cm of sediment. Use of data from the top 4 cm rather than the top 2 cm, which was identified as the mean PECQ compliance depth, is conservative given that contamination levels generally increase with depth (PDI Phase IV: Appendix F, Parsons, 2010). The 2010 data set includes chemical analyses from many locations sampled during 1992 that were not analyzed previously for the full suite of contaminants used to determine the mean PECQ. Each of the 1992 locations that were resampled had a mean PECQ less than 1 based on the 2010 results (Table 5.3). Therefore, it was assumed that results from the 1992 locations not resampled also have a mean PECQ less than 1. Over half of the 1992 locations were resampled during 2010.

Figures 5.1a and 5.1b present sediment mean PECQs based on the data set discussed above, and highlight locations where a mean PECQ of 1 is exceeded. Field duplicates were collected at two of the 2010 sampling locations in these areas; for both locations an exceedance of the mean PECQ of 1 has been included in these figures because one of the two duplicate results shows a mean PECQ greater than 1.

As shown in Figure 5.1b, an approximately 5.6 acre portion of SMU 8 along the north side of Remediation Area D will be remediated through the placement of an engineered cap consistent with portions of the littoral zone due to higher levels of contamination in this area.

The basis for delineation of this area and the design of the engineered cap to be placed in this area are addressed as part of the Sediment Capping, Dredging and Habitat Design submittals.

SECTION 6

THIN-LAYER CAPPING

As discussed in Section 4, contaminant levels in SMU 8 surface sediments are substantially lower than contaminant concentrations in littoral sediments that will be remediated, and contaminant concentrations are predicted to decrease even further over time as cleaner sediments settle from the overlying water column. However, to provide an additional level of protection, thin-layer capping will be implemented in localized areas of the profundal zone where sediments have elevated contaminant concentrations (i.e. mean PECQ above 1). The total area requiring thin-layer cap placement is 26.9 acres. The objective of the thin-layer capping is to provide an immediate decrease in surface sediment contaminant concentrations by introducing clean substrate at the surface of SMU 8 sediment. Details regarding the areas where a thin-layer cap will be applied and what the cap will consist of are provided below.

6.1 DESIGN AND PERFORMANCE CRITERIA

Thin-layer capping is required in areas of SMU 8 where the mean PECQ exceeds 1, and where MNR is not predicted to meet the mercury criteria required by the ROD (PEC of 2.2 mg/kg at each location and BSQV of 0.8 mg/kg on an area wide basis) within 10 years following the completion of upland source control and dredging and capping in the littoral zone. However, as discussed in Section 4, MNR is predicted to meet the mercury PEC and BSQV for SMU 8, therefore, the thin-layer cap area has been delineated based on exceedances of the mean PECQ of 1 (Figure 6.1). Areas of SMU 8 surface sediment where the mean PECQ requirement is not met total 26.9 acres and are directly adjacent to littoral zone Remediation Areas D and E (Figure 6.1). These two areas are delineated based on cap area boundary lines between locations where the mean PECQ is less than 1 and outside areas where the mean PECQ is greater than 1. Boundaries of the thin-layer cap areas have been delineated based on sediment sample locations with a current mean PECQ of less than 1 based on the analysis of mean PECQ presented in Section 5. Additional areas of thin-layer capping may be identified as part of contingency actions that may be appropriate during the MNR period as discussed in Section 4.

The required thickness of the SMU 8 thin-layer cap material is 0.8 inch (2 cm) based on the compliance depth for the mean PECQ, as discussed in Section 4. For construction convenience, the minimum thickness of the thin-layer cap has been set at 1 inch based on experiences of the cap placement contractor from sediment cap placement work at other sites.

6.2 THIN-LAYER CAP CONSTRUCTION

6.2.1 Cap Thickness

Due to the soft nature of the SMU 8 surface sediments, it is anticipated the minimum 1 inch of material that will be placed may mix with the underlying sediment during placement. This will achieve the remediation goal and provide an immediate decrease in surface sediment contaminant concentrations in SMU 8. Construction goals will include minimization of over placement. However, an allowance for over placement across the area of the cap during construction is included based on experience at other sites. An average over placement of up to 3 inches results in an average thickness including over placement of 4 inches (10 cm). The extent of over placement will be assessed further based on the cap placement methods being considered and an updated extent of over placement will be presented in a future design submittal.

6.2.2 Cap Materials, Sources, and Transport

Thin-layer cap materials to be placed in SMU 8 as part of the Onondaga Lake remedy will be natural particles of medium-sized sand. The sand used for thin-layer capping will come from local sources and will be used with minimal processing in order to reduce the carbon footprint and amount of waste material generated. Materials will be transported to Onondaga Lake in a manner that minimizes handling and stockpiling of materials. Transported cap materials will be staged in conjunction with other temporary Honeywell shoreline facilities that will be placed to support littoral zone capping efforts. Additional details regarding cap material specifications, sources and transport will be included in a future design submittal.

6.2.3 Cap Placement

Cap placement methods are being developed as part of the chemical isolation cap design under development for the littoral area, and will be included in a future design submittal. It is currently anticipated that cap materials will be placed using a hydraulic spreader system, with the cap materials being placed in slurry form.

6.2.4 Debris and Utility Management in Thin-Layer Cap Areas

The goal of thin-layer capping is to provide an immediate decrease in surface sediment contaminant concentrations by introducing clean substrate at the surface of SMU 8 sediment. Evaluation or management of debris within the thin-layer cap area is not required in order to meet this objective.

Figure 6.1 from the *Sediment Capping and Dredge Areas and Depths IDS* (Parsons and Anchor QEA, 2009) shows pipeline locations within the lake determined from available records and from 2005 geophysical survey work conducted on behalf of Honeywell (CR Environmental, 2007). Two cooling water intake pipes and three water inlet pipes are known to remain in place in SMU 8 within one of the areas delineated for thin-layer capping adjacent to the western portion of Remediation Area D. These pipelines are owned by Honeywell and are not in use nor is use of any of these pipes anticipated in the future. A decision whether to remove these pipes or abandon them in place will be made as part of the littoral area capping and dredging design. Thin-layer capping over these inactive utilities would be appropriate if they are abandoned in place.

6.2.5 Quality Assurance/Control During Placement

Quality control measurements will be performed throughout cap placement to verify that the cap materials have been placed to the thickness and lateral limits specified by the design and in accordance with the performance criteria (*e.g.* within specified construction tolerances). Multiple quality control procedures will be implemented to ensure compliance with the placement criteria. The following methods may be used for quality control:

- Accurate material volume tracking: Cap placement will include monitoring the quantity and rate of cap material being placed. Volumes of material placed within a known area will be used to compute theoretical cap thickness, which can be used to validate other thickness verification methods. This may include tracking of the number of excavator buckets loaded to the hopper of the hydraulic spreading system, weight-metered conveyor belts, or other appropriate techniques.
- Real-time tracking of horizontal position: Cap placement equipment will be outfitted with a positioning system that will accurately measure and track the position of the placement in real-time through the cap construction to verify that cap materials have been placed within the specific horizontal limits. This typically includes the use of global positioning system (GPS) sensors, inclinometers, tilt sensors, and/or other positioning equipment mounted directly on the placement equipment (e.g. the boom of a mechanical excavator). The positioning equipment will be connected to a computer software package specifically designed for tracking and logging the position and movement of the equipment.
- Physical samples: Post-placement cores or “catch pans” may be used to collect a physical sample of the cap material placed. Visual observations of the cap thickness will be made.

Each of these items can be used to help evaluate whether the specified cap thickness has been placed. Specific details and utility of the various quality control procedures will be further developed as needed in a future design submittal.

6.3 MANAGEMENT OF WATER QUALITY DURING THIN-LAYER CAPPING

Water quality will be monitored during placement of the thin-layer cap consistent with cap placement monitoring to be conducted on behalf of Honeywell in the littoral zone of Onondaga Lake.

Water quality criteria for in-lake remedial construction activities will be specified in a future design submittal. Capping is inherently a low impact activity. Based on experience at numerous other capping sites, cap placement does not result in noteworthy disturbance of contaminated sediments or release of significant contamination to the water column. This is especially the case for placement of sand that slowly settles naturally to the bottom of the Onondaga Lake profundal zone. For example, placement of a sand tracer material during 2009 at representative plots form within SMU 8 was confirmed to have been completed with the sand marker resting uniformly on top of the sediment with little disturbance (Parsons and Environmental Tracing Systems, 2010).

Water column turbidity may be evaluated in the short term while the cap is being placed, but effects of this turbidity form clean cap material would be minimal. For example, recent sediment capping work for a St. Lawrence River site in Massena, New York, included water quality measurements at several downstream locations that showed relatively modest increases in turbidity and suspended solids and insignificant contaminant concentrations in the water. Water quality measurements throughout the project were below project-specific criteria, yet a visual turbidity plume persisted (Alcoa, 2010).

After water quality criteria are established, a water quality monitoring plan will be developed. Components of the monitoring plan and contingency and response action levels that will be undertaken to assure environmental protectiveness during the project will be presented in the future as part of the Capping, Dredging, and Habitat Design.

SECTION 7

SUBCONTRACTING STRATEGY

An integrated team of in-house resources, teaming partners, and key subcontractors will complete the Capping, Dredging, and Habitat Design and implement the entire remedial action. The design team will interact with construction and operations personnel to assure that the Capping, Dredging, and Habitat Design components are complete, implementable, and meet the project objectives. The design under this approach will incorporate agency review and public input into the subsequent design phase. In addition, key members of the design team will have functional quality assurance/quality control responsibilities during the construction efforts.

Parsons will implement the nitrate pilot test using a design-bid-build approach working with a barge supplier, calcium nitrate supplier, tank supplier, and with UFI for monitoring and data analysis. Each of the entities working on the nitrate pilot test will be contracted through Parsons who will be responsible for safe and high-quality work performance.

The design and subcontracting strategy for the thin-layer capping work that is part of the lake bottom remedy will also be a design-bid-build approach. Sevenson Environmental Services, Inc. (hereafter called Sevenson) has been selected by Honeywell and contracted through Parsons to provide dredging and capping construction services for the Onondaga Lake remedy. Based on its construction role, Sevenson is also providing input to the ongoing cap design work including input to the design of the thin-layer cap for SMU 8.

SECTION 8

DESIGN SUBMITTAL AND CONSTRUCTION SCHEDULE

This section discusses sequencing and timing for future remedial design and remedial action work for the profundal zone of Onondaga Lake. The efforts outlined in this section are in addition to the monitoring and contingency approach for MNR outlined in Section 4.3. Nitrate addition will be implemented on a pilot test basis beginning in 2011. Other remedial work for the profundal zone will be addressed in the future as part of the capping, dredging, and habitat design and remedial action.

Nitrate will be added to the lower hypolimnion of the profundal zone beginning in mid-June of 2011, 2012, and 2013 and continue each of those three years until deep zone waters turn over in the fall (typically mid-to-late October) and the pilot test is completed in late 2013. The NYSDEC has reviewed and provided comments on the draft work plan for the nitrate pilot test. The final work plan will be submitted before mobilizing for the first year of this pilot test. No further design submittals will be required for the nitrate pilot test. Following the three-year pilot test, results will be assessed, a report will be issued, and decisions will subsequently be made about the need for nitrate addition or oxygenation beyond 2013.

Future MNR evaluation updates and thin-layer cap design details will be incorporated into a future capping, dredging and habitat design submittal. The MNR evaluation will be a separate appendix within a future design submittal.

Construction sequencing for thin-layer capping to address exceedances of the mean PECQ criteria will be determined in the future as the overall sequencing for Onondaga Lake remediation work is advanced. It is anticipated that the littoral zone adjacent to each of the two thin-layer cap areas will be covered with some clean cap material before starting to place the thin-layer cap in the profundal zone.

SECTION 9

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TABLE 1.1
DESIGN-RELATED DOCUMENTS ASSOCIATED WITH ONONDAGA LAKE SMU 8

Date*	Name of Document	Prepared for	Prepared by
General			
2004, November	Onondaga Lake Feasibility Study Report. Draft Final	Honeywell	Parsons in association with Anchor Environmental and Exponent
2007, May	Preliminary Feasibility Analysis for Control of Methylmercury Production in Lower Waters of Onondaga Lake Through Nitrate Addition	Honeywell	Upstate Freshwater Institute and Syracuse University
2007, September	Cultural Resource Management Report Phase 1A CRA Onondaga Lake Project Oct. 29, 2004	Honeywell	Christopher D. Hohman, RPA, Public Archaeology Facility,
2008, April	Interpretive Report Evaluation of Nitrate Addition to Control Methylmercury Production in Onondaga Lake: 2006 Study	Honeywell	Upstate Freshwater Institute and Syracuse University
2008, April	Data Usability and Summary Report Evaluation of Nitrate Addition to Control Methylmercury Production in Onondaga Lake: 2007	Honeywell	Exponent, in association with Upstate Freshwater Institute and
2008, October	Draft Citizen Participation Plan for the Onondaga Lake Bottom Subsite Remedial Design Program	Honeywell	NYSDEC, Region 7
2009, March	Remedial Design Work Plan for the Onondaga Lake Bottom Subsite	Honeywell	Parsons
Phase I PDI			
2005, September	Onondaga Lake Pre-Design Investigation: Phase I Work Plan	Honeywell	Parsons
2007, November	Onondaga Lake Phase 1 Pre-Design Investigation Geophysical Survey Report	Honeywell	CR Environmental
2007, May	Onondaga Lake Pre-Design Investigation: Phase I Data Summary Report	Honeywell	Parsons
Phase II PDI			
2006, September	Onondaga Lake Pre-Design Investigation: Phase II Work Plan	Honeywell	Parsons
2009, August	Onondaga Lake Pre-Design Investigation: Phase II Data Summary Report	Honeywell	Parsons
Phase III PDI			
2007, May	Onondaga Lake Pre-Design Investigation: Phase III Work Plan	Honeywell	Parsons
2007, October	Onondaga Lake Pre-Design Investigation Phase III Work Plan - Addendum 6	Honeywell	Parsons
2008, June	Onondaga Lake Pre-Design Investigation: Phase III Addendum 6 Data Summary Report	Honeywell	Parsons, Exponent and Anchor Environmental
2009, October	Onondaga Lake Pre-Design Investigation: Phase III Data Summary Report	Honeywell	Parsons
Phase IV PDI			
2008, November	Onondaga Lake Pre-Design Investigation: Phase IV Work Plan Addendum/8 SMU 8 High-Resolution Cores	Honeywell	Parsons, Anchor Environmental and Exponent
2010, July	Onondaga Lake Pre-Design Investigation: Draft Phase IV Data Summary Report Appendix F SMU 8 High-Resolution Cores	Honeywell	Parsons in association with Flett Research
Phase V PDI			
2009, August	Onondaga Lake Pre-Design Investigation: Phase V Work Plan	Honeywell	Parsons
Phase VI PDI		Honeywell	Parsons, Exponent and Anchor QEA
2010, April	Onondaga Lake Pre-Design Investigation: Phase VI Work Plan-Addendum 5 SMU 8 PECQ Sediment Sampling	Honeywell	
Baseline Monitoring			
2008, May	Onondaga Lake Baseline Monitoring Book 1 Deep Basin Water and Zooplankton Monitoring Work Plan for 2008	Honeywell	Upstate Freshwater Institute and Syracuse University
2009, September	Addendum 1 (2009) to Onondaga Lake Baseline Monitoring Book 1 Deep Basin Water and Zooplankton Monitoring Work Plan for	Honeywell	Upstate Freshwater Institute and Syracuse University
2010, April	Addendum 2 (2010) to Onondaga Lake Baseline Monitoring Book 1 Deep Basin Water and Zooplankton Monitoring Work Plan for	Honeywell	Parsons and Exponent
2009, June	Draft Onondaga Lake Baseline Monitoring Report for 2008	Honeywell	Parsons, Exponent and Anchor QEA
2010, July	Draft Onondaga Lake Baseline Monitoring Report for 2009	Honeywell	Parsons, Exponent and Anchor QEA
2010, July	Baseline Monitoring Scoping Document for the Onondaga Lake Bottom Subsite	Honeywell	Parsons, Exponent and Anchor QEA
Microbead Placement			
2008, September	Onondaga Lake Microbead Marker Work Plan for Monitoring Natural Recovery in SMU 8	Honeywell	Parsons, Anchor Environmental and Environmental Tracing Systems
2009, August	Onondaga Lake Microbead Marker 2008 Pre-Mobilization Field Test Data Summary Report	Honeywell	Parsons and Environmental Tracing Systems
2010, May	Draft Onondaga Lake Microbead Marker Placement Report	Honeywell	Parsons and Environmental Tracing Systems
Nitrate Addition (including Dye Tracer Tests)			
2008, June	Work Plan to Perform a Dye Tracer Study to Evaluate Transport and Mixing in the Hypolimnion of Onondaga Lake	Honeywell	Upstate Freshwater Institute
2009, June	Work Plan to Perform a Nitrate Application Field Trial in the Hypolimnion of Onondaga Lake	Honeywell	Parsons
2009, July	Report on the 2008 Dye Tracer Study to Evaluate Transport and Mixing in the Hypolimnion of Onondaga Lake	Honeywell	Upstate Freshwater Institute
2010, March	Report for the Nitrate Application Field Trial in the Hypolimnion of Onondaga Lake (Sediment Management Unit 8)	Honeywell	Parsons and Upstate Freshwater Institute
2010, June	Work Plan for Pilot Test to Add Nitrate to the Hypolimnion of Onondaga Lake	Honeywell	Parsons and Upstate Freshwater Institute

Note: Dates provided may represent draft versions of appendices and addenda provided electronically to NYSDEC.

TABLE 4.1
MONITORING AND CONTINGENCY SCHEDULE
FOR IMPLEMENTING MNR IN ONONDAGA LAKE

Project Phase	Year	Planned Sampling		Data Eval. And Decisions		Conduct Contingencies		Implementation Notes
		Number of Surface Sediment Locations	Sampling to Assess Sedimentation Rate[a]	Track MNR[b]	Evaluate Contingency Actions[c]	Monitoring or Modeling	Thin-Layer Capping or Other Construction	
Design	2007	26						
	2008	7	High-Resolution Cores					
	2009		Markers deployed					
	2010	70	Cores	Yes	Yes			
	2011	~10	Cores	Yes	Yes			
Construction	2012					If Needed		Start Dredging
	2013					If Needed	If Needed	Start Capping
	2014	~20-30	Cores	Yes	Yes			
	2015					If Needed		Revise TLC Area
	2016					If Needed	If Needed	Complete Cap+TLC
	2017	~20-30	Cores	Yes	Yes			MNR Baseline
MNR Period	2018					If Needed		
	2019					If Needed	If Needed	
	2020	~20-30	Cores	Yes	Yes			
	2021					If Needed		
	2022					If Needed	If Needed	
	2023	~20-30	Cores	Yes	Yes			
	2024					If Needed		
	2025					If Needed	If Needed	
	2026	~20-30	Cores	Yes	Yes			
	2027					If Needed	If Needed	TLC any remainder

Notes:

[a] Sampling may include high resolution cores as well as marker cores.

[b] Tracking MNR will involve updating the MNR model and other projections as warranted based on new data.

[c] Contingency actions may include additional monitoring, modeling, and/or additional thin-layer capping (TLC).

TABLE 4.2

SUMMARY OF FINAL PREDICTED MERCURY SEDIMENT CONCENTRATIONS FOR PROFUNDAL ZONE SEDIMENT (YEAR 2027)

Portion of Profundal Zone	Number of Locations Modeled	Final Predicted Mercury Sediment Concentration (mg/kg)
North Basin	14	0.44
Nine Mile Creek	8	0.45
Saddle	3	0.45
South Basin	22	0.45
South Corner	42	0.45

TABLE 5.1

CONTAMINANTS USED IN MEAN PECQ CALCULATION

	PEC
Metals (mg/kg)	
Mercury	2.2
Organic Compounds	
BTEX Compounds (µg/kg)	
Ethylbenzene	176
Xylenes	560.8
Chlorinated Benzenes (µg/kg)	
Chlorobenzene	428
Dichlorobenzenes	239
Trichlorobenzenes	347
PAH Compounds (µg/kg)	
Acenaphthene	861
Acenaphthylene	1301
Anthracene	207
Benz[a]anthracene	192
Benzo[a]pyrene	146
Benzo[b]fluoranthene	908
Benzo[ghi]perylene	780
Benzo[k]fluoranthene	203
Chrysene	253
Dibenz[a,h]anthracene	157
Fluoranthene	1436
Fluorene	264
Indeno[1,2,3-cd]pyrene	183
Naphthalene	917
Phenanthrene	543
Pyrene	344
Polychlorinated Biphenyls (µg/kg)	
Total PCBs	295

The PECQ for a given contaminant is calculated as the concentration of that contaminant in a given location within the lake divided by the PEC value associated with that contaminant. The PECQ is first calculated for the first five chemical parameter of interest (CPOI) groups (mercury, ethylbenzene and xylenes, chlorinated benzenes, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs) using detections. These values are then averaged to get the final mean PECQ for the station. For example, in a simplified hypothetical case where all contaminants for the five CPOI groups are detected at a station and PECQs of 1.0, 2.0, 3.0, 4.0 and 5.0 were calculated for the five groups, the mean PECQ for the station would be the average of the five PECQ values (i.e., (1.0+2.0+3.0+4.0+5.0)/5 = 3), resulting in a mean PECQ of 3.0 (i.e., 15/5) for the overall station.

TABLE 5.2

PECQ DATA AVAILABLE FOR SMU 8 SEDIMENT

Sampling Year	Sample Depths (cm)	Number of Locations	Comments
1992	0 to 2	43	33 locations[(2)] without PAH data
2000	0 to 15 (one sample per location)	5	Two locations without BTEX data (S302 and S303)
2006	0 to 15 (one sample per location)	29	Adjacent to southwest shoreline
2007	0 to 15 as one sample per location for all but two locations[(1)]	19	--
May 2010	0 to 4 and 4 to 15	41	Included eight locations sampled during 1992[(3)] and one location sampled during 2000 (S355). Also included 12 locations sampled during 2006 and three locations sampled during 2007 (see Table 5.2).
August 2010	0 to 4 and 4 to 15	26	Included 14 locations sampled during 1992[(4)] and two locations sampled during 2000 (S303 and S354). Also included eight locations sampled during 2006 and five locations sampled during 2007 (see Table 5.2).

(1) For the other two locations (OL-STA-80070 and 80079), PECQ data are available for 0 to 2, 2 to 4, 4 to 10, and 10 to 15 cm sediment depths.

(2) These 33 locations sampled during 1992 were S30 through S33, S41 through S44, S49, S50, S52, S57 through S60, S63 through S65, S69, S78 through S80, S85, S88, S89, S91, S96 through S99, S102, S106, and S107.

(3) These eight locations were S25, S27, S31, S32, S40, S56, S63, and S85.

(4) These 14 locations were S24, S30, S50, S52, S58, S60, S69, S86, S89, S96 through S98, S102, and S103.

TABLE 5.3
BASIS FOR FOCUSING ON MOST RECENT SMU 8 PECQ RESULTS FOR SEDIMENT FROM THE SAME LOCATION

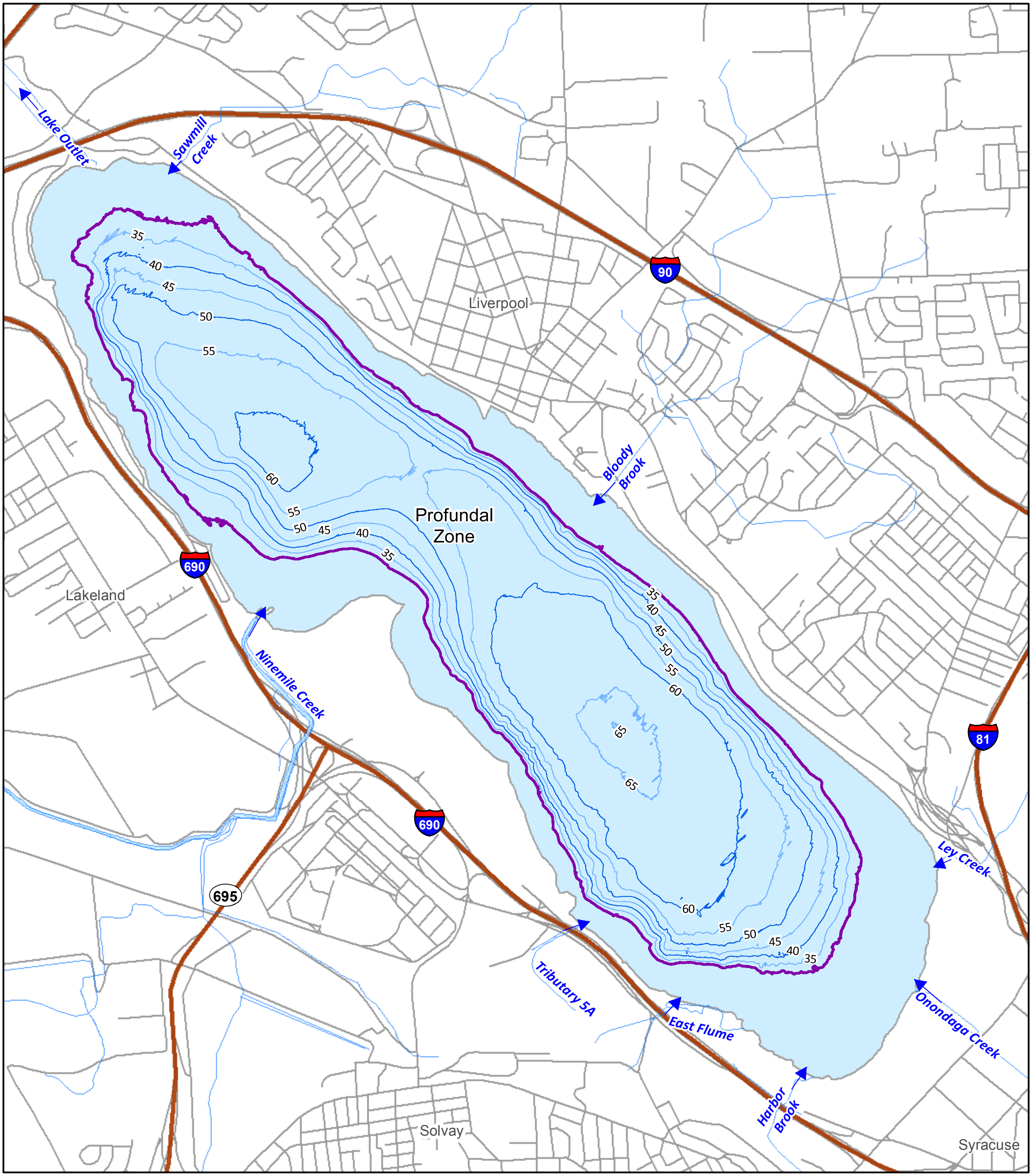
Sample ID / Year (and mean PECQ)	Most Recent Sample ID / Year at Same Location (and mean PECQ for 0 to 4 cm)	Basis for Focusing Analysis on Most Recent Results for Mean PECQ
North Basin		
S103 / 1992 (0.69)	OL-VC-80198 / 2010 (0.27)	More recent result
S102 / 1992 (0.86)	OL-VC-80199 / 2010 (0.22)	More recent result with all PECQ parameters measured
S98 / 1992 (0.63)	OL-VC-80200 / 2010 (0.34)	More recent result with all PECQ parameters measured
S97/1992 (1.6) OL-VC-80023 / 2006 (0.55) OL-STA-80070 / 2007 (1.2)	OL-VC-80201 / 2010 (0.27)	More recent result from more representative sediment depth
Ninemile Creek Outlet Area (NMC Outlet)		
OL-VC-80046 / 2006 (1.4)	OL-VC-80162 / 2010 (0.75)	More recent result from more representative sediment depth
S303 / 2000 (0.79)	OL-VC-80205 / 2010 (0.24)	More recent result with all PECQ parameters measured
OL-VC-80048 / 2006 (0.77)	OL-VC-80164 / 2010 (0.3)	More recent result from more representative sediment depth with all PECQ parameters measured
Saddle		
S69 / 1992 (0.76)	OL-VC-80206 / 2010 (0.28)	More recent result with all PECQ parameters measured
South Basin		
S63 / 1992 (0.81)	OL-VC-80166 / 2010 (0.28)	More recent result with all PECQ parameters measured
OL-VC-80045 / 2006 (7.4)	OL-VC-80167 / 2010 (0.33)	More recent result from more representative sediment depth
S58 / 1992 (0.84)	OL-VC-80208 / 2010 (0.36)	More recent result with all PECQ parameters measured
S60 / 1992 (0.85)	OL-VC-80207 / 2010 (0.27)	More recent result with all PECQ parameters measured
S56 / 1992 (1.1) OL-VC-80024 / 2006 (0.85)	OL-VC-80169 / 2010 (0.26)	More recent result from more representative sediment depth with all PECQ parameters measured

TABLE 5.3
BASIS FOR FOCUSING ON MOST RECENT SMU 8 PECQ RESULTS FOR SEDIMENT FROM THE SAME LOCATION

Sample ID / Year (and mean PECQ)	Most Recent Sample ID / Year at Same Location (and mean PECQ for 0 to 4 cm)	Basis for Focusing Analysis on Most Recent Results for Mean PECQ
South Basin (Continued)		
S52 / 1992 (0.77)	OL-VC-80209 / 2010 (0.5)	More recent result with all PECQ parameters measured
S50 / 1992 (0.88)	OL-VC-80210 / 2010 (0.51)	More recent result with all PECQ parameters measured
South Corner		
S32 / 1992 (0.5)	OL-VC-80172 / 2010 (0.43)	More recent result with all PECQ parameters measured
S40 / 1992 (0.78)	OL-VC-80171 / 2010 (0.46)	More recent result
S31 / 1992 (0.68)	OL-VC-80177 / 2010 (0.51)	More recent result with all PECQ parameters measured
OL-VC-80037 / 2006 (1.2)	OL-VC-80211 / 2010 (1.27)	More recent result from more representative sediment depth
S27 / 1992 (1.1) S355 / 2000 (0.92) OL-VC-80020 / 2006 (1.3)	OL-VC-80178 / 2010 (0.40)	More recent result from more representative sediment depth with all PECQ parameters measured
OL-VC-80038 / 2006 (1.9)	OL-VC-80179 / 2010 (0.40)	More recent result from more representative sediment depth
OL-VC-80049 / 2006 (1.1)	OL-VC-80212 / 2010 (0.33)	More recent result from more representative sediment depth
OL-VC-80039 / 2006 (1.7)	OL-VC-80223 / 2010 (0.34)	More recent result from more representative sediment depth
S30 / 1992 (0.7) S354 / 2000 (0.87)	OL-VC-80214 / 2010 (0.32)	More recent result from more representative sediment depth with all PECQ parameters measured
OL-VC-80050 / 2006 (1.1)	OL-VC-80186 / 2010 (0.68)	More recent result from more representative sediment depth
OL-VC-80068 / 2007 (1.2)	OL-VC-80187 / 2010 (0.41)	More recent result from more representative sediment depth
OL-VC-80067 / 2007 (1.5)	OL-VC-80192 / 2010 (0.78)	More recent result from more representative sediment depth
OL-VC-80051 / 2006 (1.6)	OL-VC-80193 / 2010 (0.79)	More recent result from more representative sediment depth

TABLE 5.3
BASIS FOR FOCUSING ON MOST RECENT SMU 8 PECQ RESULTS FOR SEDIMENT FROM THE SAME LOCATION

Sample ID / Year (and mean PECQ)	Most Recent Sample ID / Year at Same Location (and mean PECQ for 0 to 4 cm)	Basis for Focusing Analysis on Most Recent Results for Mean PECQ
South Corner (Continued)		
OL-VC-80040 / 2006 (1.6)	OL-VC-80194 / 2010 (0.50)	More recent result from more representative sediment depth
OL-VC-80065 / 2007 (1.5)	OL-VC-80213 / 2010 (0.42)	More recent result from more representative sediment depth
OL-VC-80057 / 2007 (1.1)	OL-VC-80217 / 2010 (0.26)	More recent result from more representative sediment depth
OL-VC-80070 / 2007 (1.1)	OL-VC-80219 / 2010 (0.49)	More recent result from more representative sediment depth
OL-VC-80064 / 2007 (1.6)	OL-VC-80221 / 2010 (0.51)	More recent result from more representative sediment depth
OL-VC-80028 / 2006 (1.3)	OL-VC-80215 / 2010 (0.33)	More recent result from more representative sediment depth
OL-VC-80033 / 2006 (0.99)	OL-VC-80216 / 2010 (0.43)	More recent result from more representative sediment depth
OL-VC-80034 / 2006 (1.5)	OL-VC-80218 / 2010 (0.38)	More recent result from more representative sediment depth
OL-VC-80035 / 2006 (1.6)	OL-VC-80195 / 2010 (0.63)	More recent result from more representative sediment depth
OL-VC-80036 / 2006 (1.6)	OL-VC-80196 / 2010 (0.59)	More recent result from more representative sediment depth
S24 / 1992 (1.1) OL-VC-80027 / 2006 (1.7)	OL-VC-80220 / 2010 (0.54)	More recent result from more representative sediment depth
OL-VC-80032 / 2006 (1.8)	OL-VC-80222 / 2010 (0.59)	More recent result from more representative sediment depth
OL-VC-80071 / 2007 (2.2)	OL-VC-80197 / 2010 (0.77)	More recent result from more representative sediment depth



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Profundal Zone Boundary (30 Foot Water Depth Contour)

Creek or Brook

Water Flow Direction in Streams and Lake Outlet

Bathymetry Contours (in ft.)

Minor Contour

Major Contour

Note: Water depth based on average lake elevation of 362.82 feet.

Roads

Major Road

Minor Road

N W E S

2,500 1,250 0 2,500

Feet

Figure 1.1

Honeywell

Onondaga Lake
Syracuse, New York

Onondaga Lake Profundal Zone Area and Water Depths

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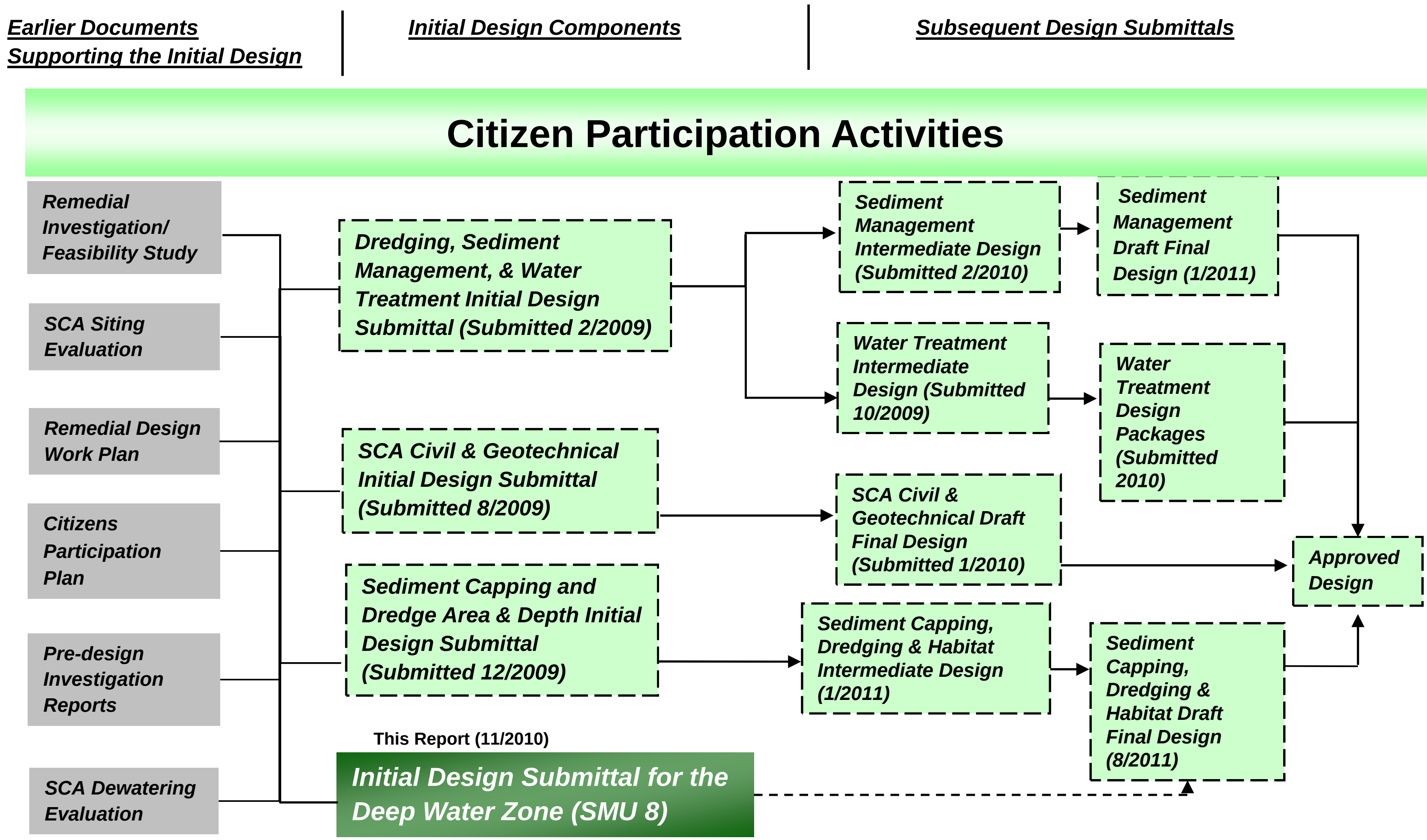


Figure 1.2

Honeywell ONONDAGA LAKE SYRACUSE, NEW YORK

Onondaga Lake Remedial Design Components

PARSONS

301 PLAINFIELD ROAD, SUITE 350, SYRACUSE, NY 13212 PHONE: (315) 451-9560

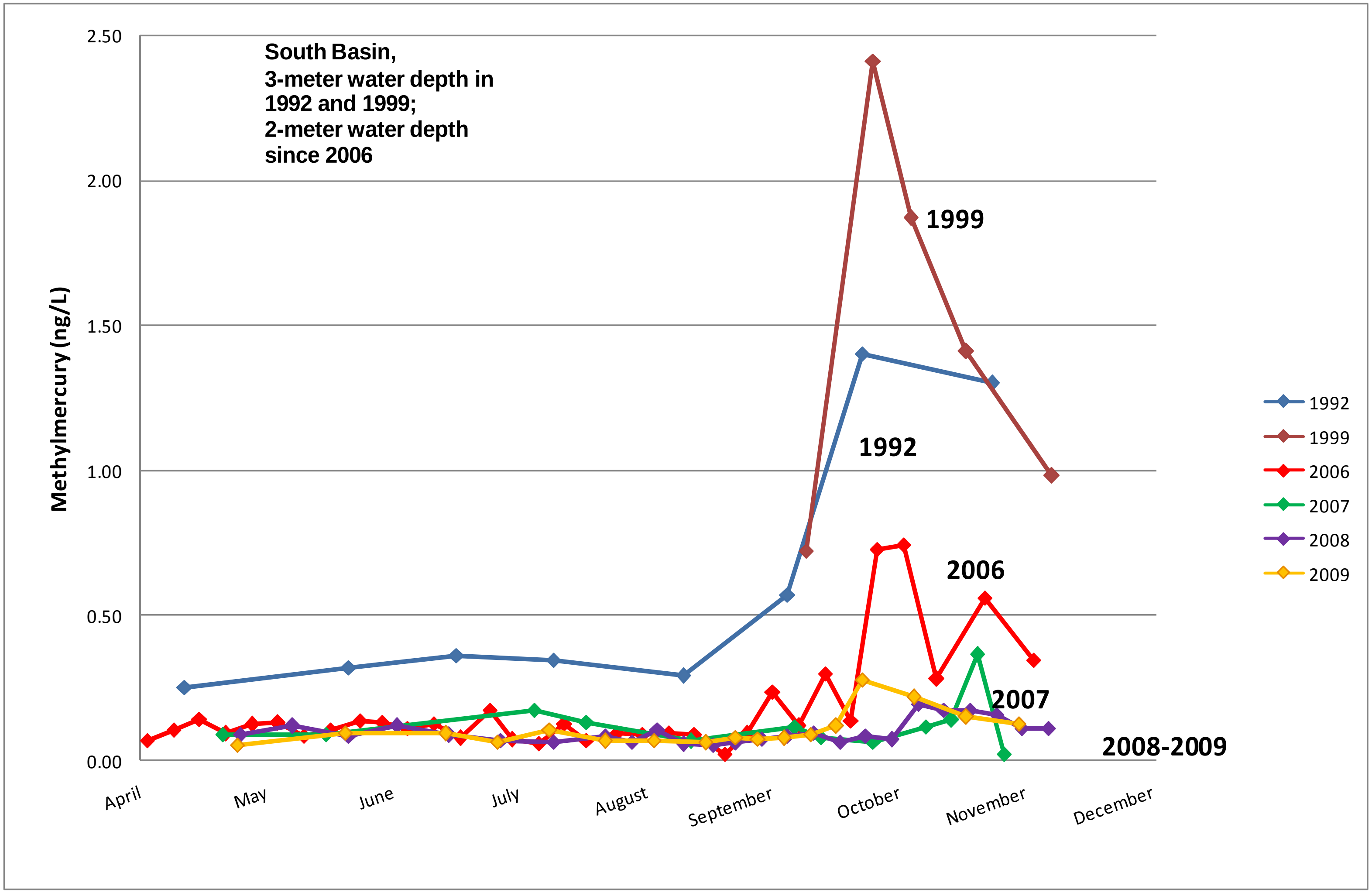
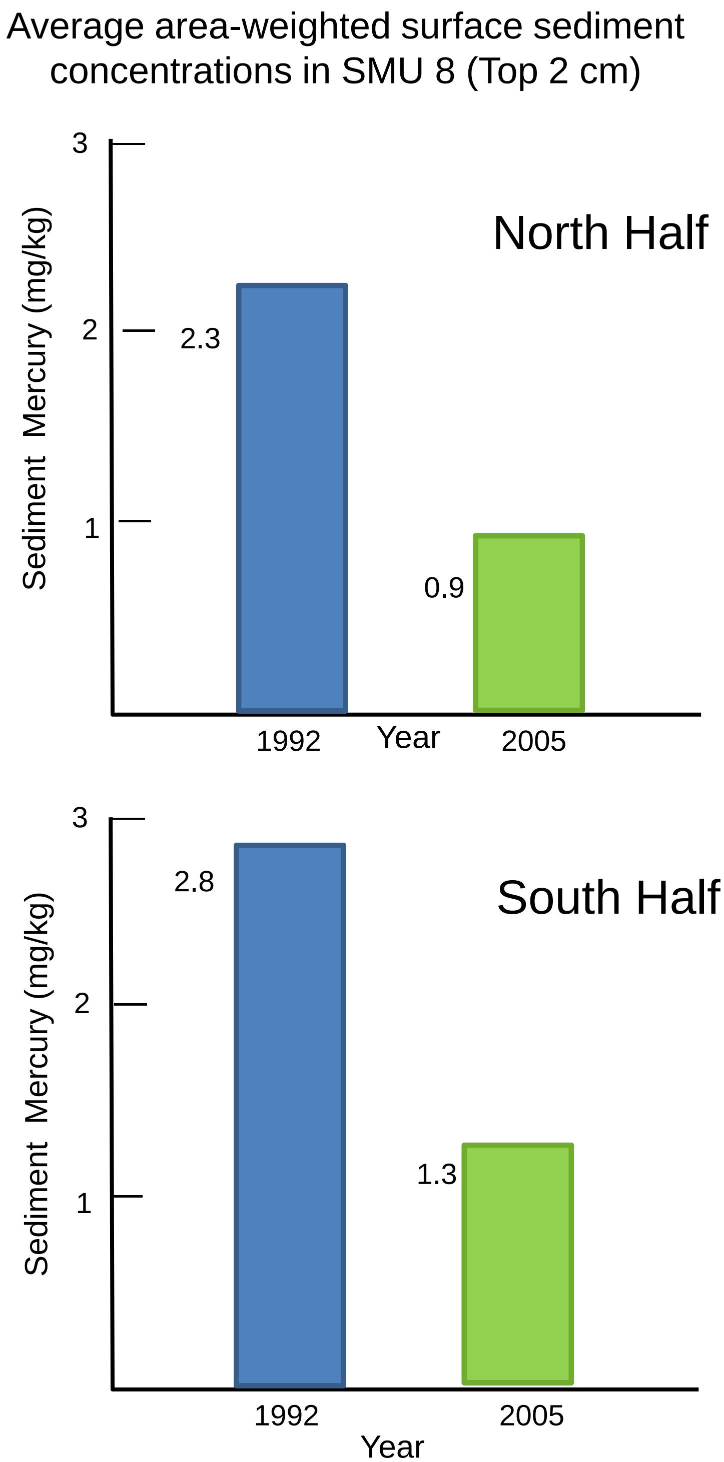


Figure 3.1 Methylmercury Concentrations in Onondaga Lake Epilimnion Water : 1992-2009
(based on water samples collected on behalf of Honeywell and its predecessor companies)



Notes: (1) The north half of the lake includes the saddle area in the middle of SMU 8.
(2) Data applied in this figure were collected on behalf of Honeywell.

Figure 4.1 Demonstration of Ongoing Natural Recovery in Onondaga Lake SMU 8 Sediment

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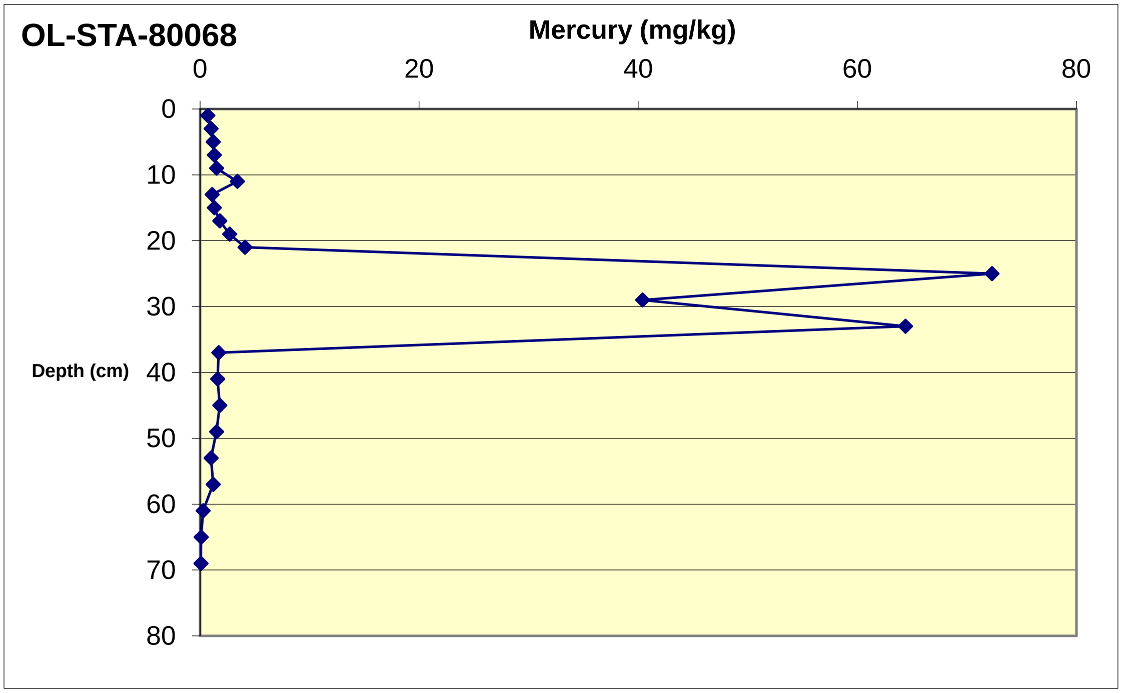
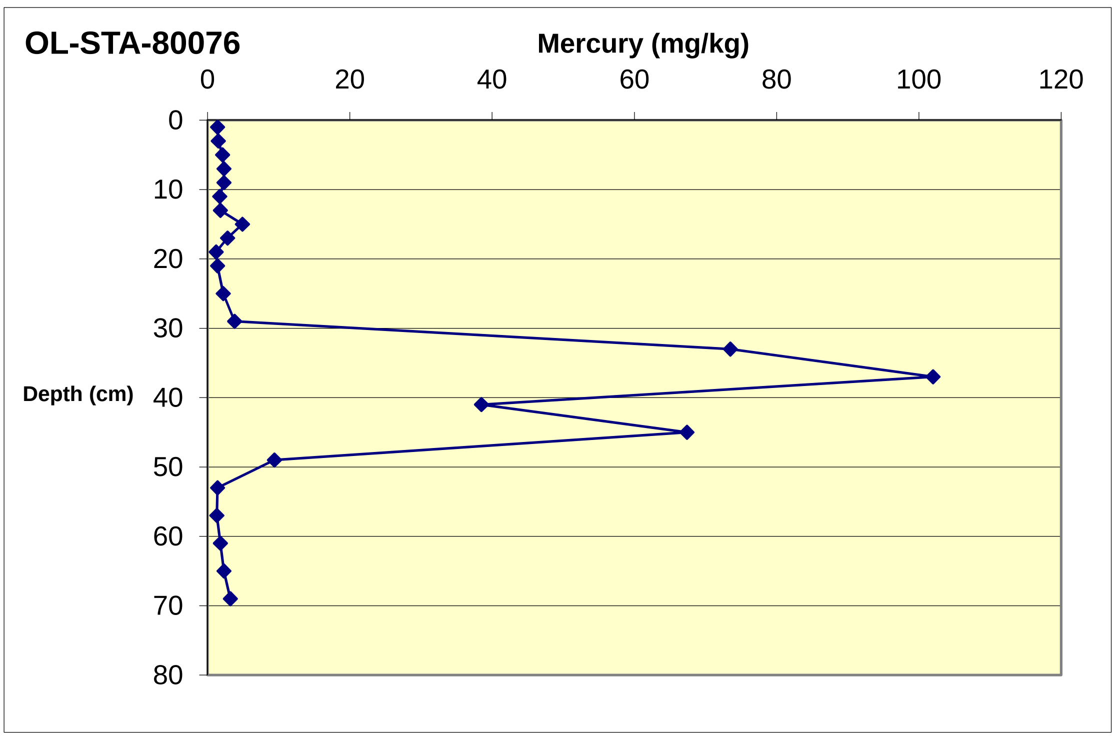
(North Basin)

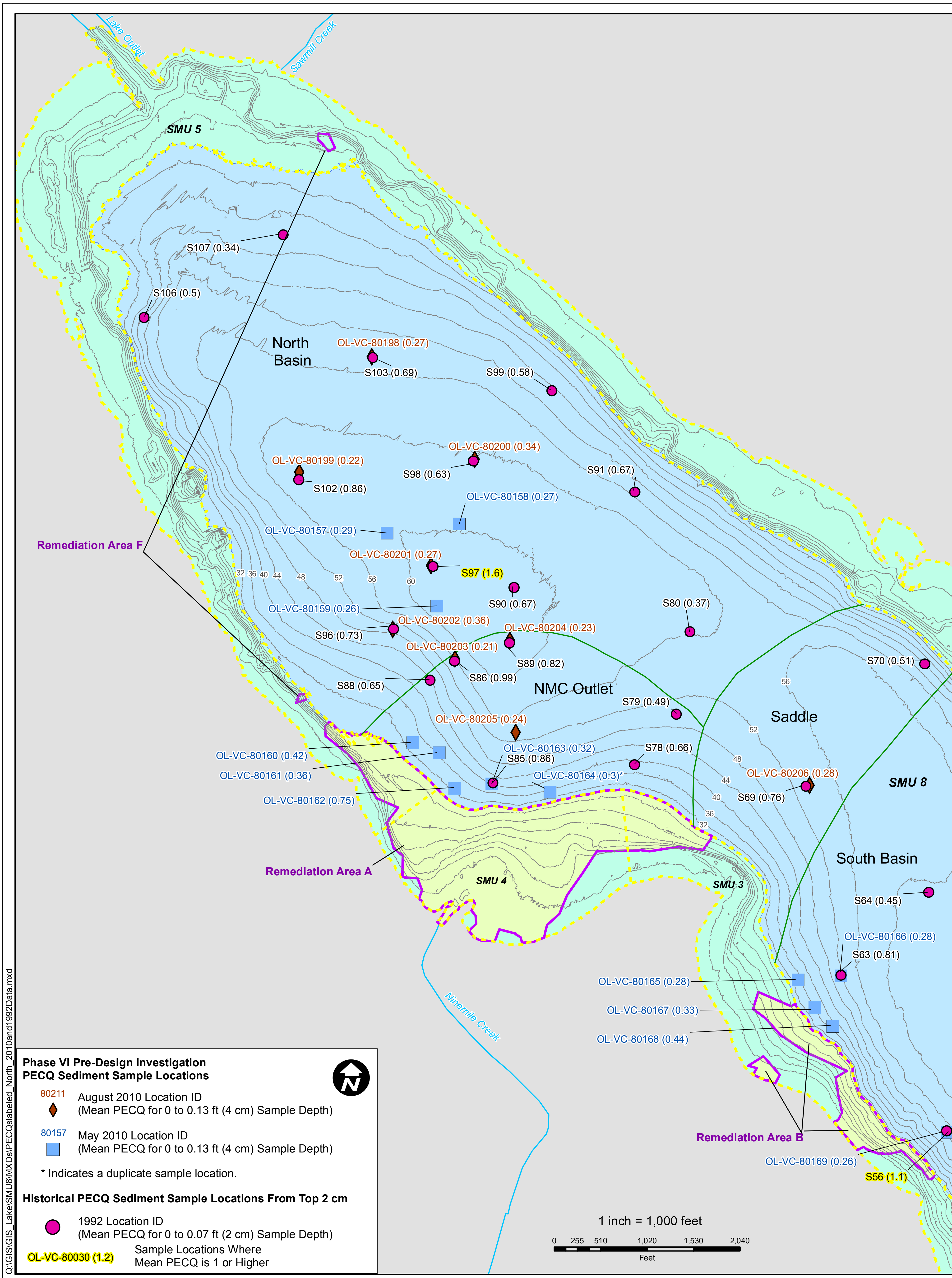


(South Basin)



Note: The mercury concentrations were plotted based on the midpoint of the depth interval from which the sample was collected.

Figure 4.2 Example SMU 8 Sediment Mercury Vertical Profiles (from 2008)



Preliminary Potential Remediation Area in Littoral Zone-
Final Delineation To Be Determined

Preliminary Capping Area

SMU Boundary

4 ft. Bathymetric Contour

NYSDEC Demarcation for SMU 8

NOTES:

1. Numbers in parentheses are mean probable effects concentration quotients (mean PECQs).
2. Maximum mean PECQs displayed.
3. Bathymetry in 4 ft. intervals.
4. Water depth based on average lake elevation of 362.82 feet.

Revised:10/22/2010 by JDF

FIGURE 5.1a

Honeywell

Onondaga Lake
Syracuse, New York

SMU 8 Surface Sediment Sample Locations with Mean PECQ Results in the North Half of Onondaga Lake

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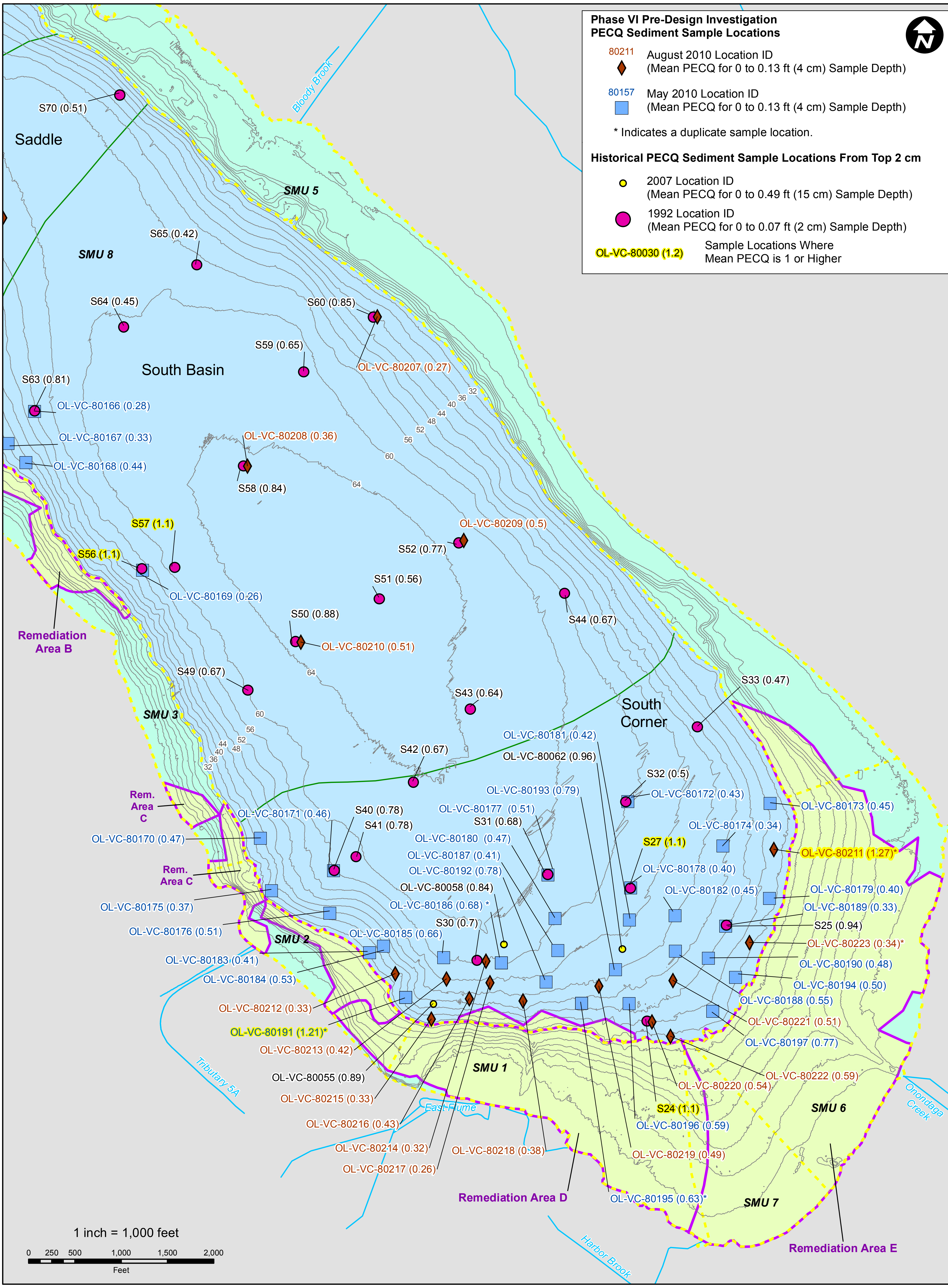

Preliminary Potential Remediation Area in Littoral Zone-
Final Delineation To Be Determined

Preliminary Capping Area

SMU Boundary

4 ft. Bathymetric Contour

NYSDEC Demarcation for SMU 8

NOTES:

1. Numbers in parentheses are mean probable effects concentration quotients (mean PECQs).
2. Maximum mean PECQs displayed.
3. Only the 2007 sample locations not sampled again during 2010 are shown.
4. Bathymetry in 4 ft. intervals.
5. Water depth based on average lake elevation of 362.82 feet.

Revised:10/22/2010 by JDF

FIGURE 5.1b

Honeywell

Onondaga Lake
Syracuse, New York

SMU 8 Surface Sediment Sample Locations with Mean PECQ Results in the South Half of Onondaga Lake

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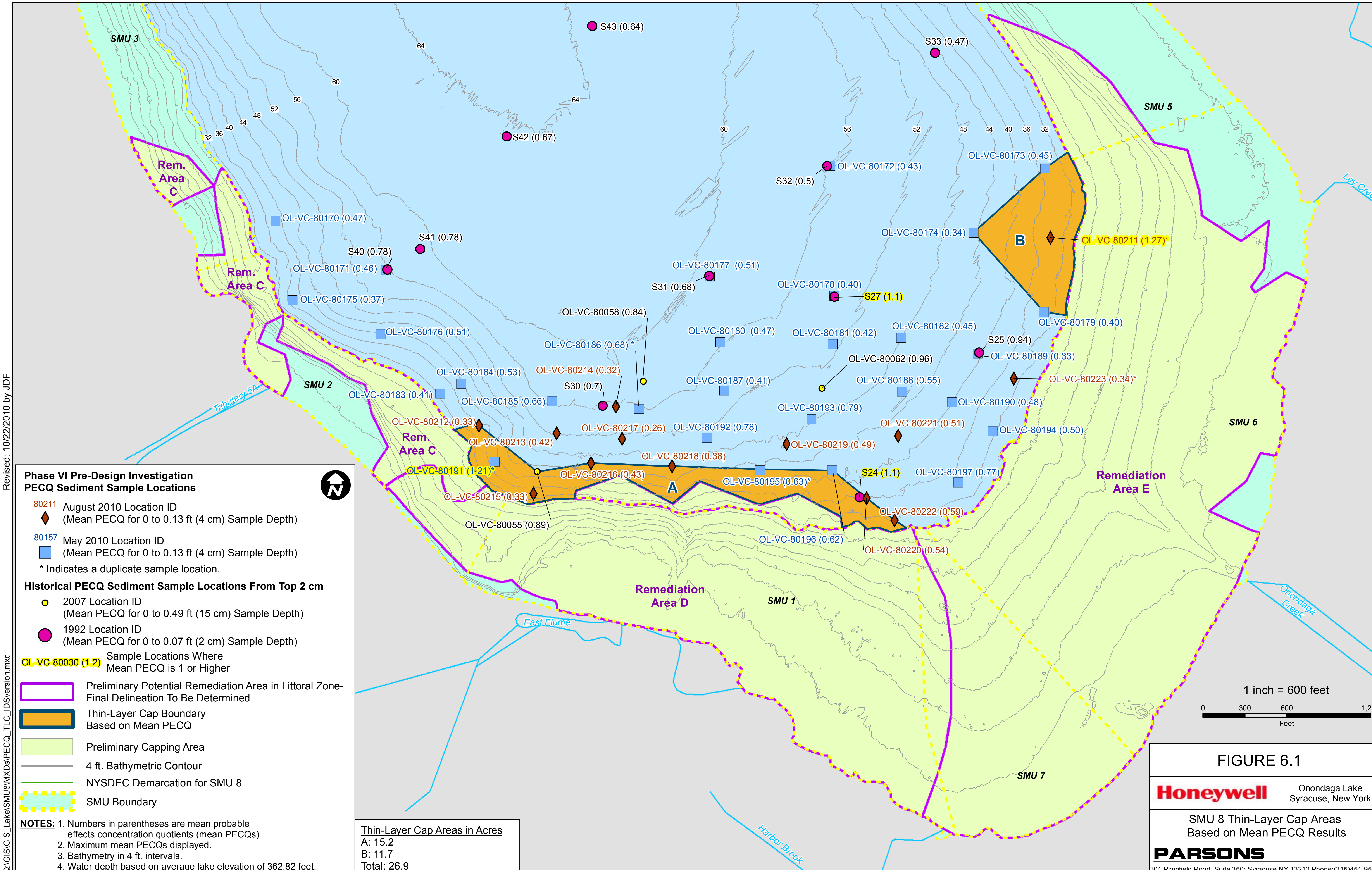

Revised: 10/22/2010 by JDF

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APPENDIX A

MODELING OF NATURAL RECOVERY FOR SMU 8

INITIAL DESIGN SUBMITTAL FOR THE ONONDAGA LAKE DEEP WATER ZONE (SEDIMENT MANAGEMENT UNIT 8)

APPENDIX A–MNR MODELING

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NOVEMBER 2010

APPENDIX A

MNR MODELING FOR ONONDAGA LAKE

As discussed in Section 4 of the main text of this Initial Design Submittal (IDS) for the profundal zone of Onondaga Lake including Sediment Management Unit (SMU) 8, surface sediment mercury concentrations in SMU 8 have been declining naturally for many years and are approaching remediation goals set forth in the Record of Decision (ROD). The primary process resulting in natural recovery of SMU 8 sediment is burial of older sediment by newer, cleaner sediment that settles in the deep water zone of the lake over time. Consistent with USEPA (2005) sediment guidance and Department of Defense monitored natural recovery (MNR) evaluation recommendations (Magar et al. 2009), multiple lines of evidence including detailed evaluations of empirical data and computer modeling together define the role of natural processes in reducing risk over time. Evaluations of the considerable empirical MNR data available for SMU 8 are discussed in Section 4. Predicting future natural recovery rates typically requires site-specific numerical models, which quantify key fate and transport processes to estimate the time to recovery and to determine the likely future effectiveness of MNR. The site-specific MNR model employed for this initial design evaluation is based on the peer-reviewed work of Boudreau (1997) as described in the following subsections.

A.1 DESCRIPTION OF MNR MODEL

A one-dimensional numerical model was used to quantify natural sediment recovery rates in SMU 8. The model is based on the extensive peer-reviewed models developed by Boudreau (1997) on diagenetic[1] processes in sediments. The one-dimensional Boudreau mass balance/process model was used to assess the long-term solid and dissolved contaminant fate and transport associated with natural sediment recovery by representing the effects of diffusion, bioturbation, groundwater mediated advection, settling, and burial in SMU 8. The model assesses fate and transport along the vertical axis of the sediment bed.

The governing equations for the model have been extensively peer-reviewed in the literature (Boudreau 1997). In addition, the model has been used and accepted for remedial design at other similar sediment Superfund sites, including the Middle Waterway in Tacoma, Washington, (Anchor Environmental and Foster Wheeler, 2001) and Duwamish/Diagonal Combined Sewer Overflow in Seattle (Anchor Environmental, 2002), among others.

This natural recovery model is based on Boudreau's Equations 3.80 and 3.83 (1997), which determine the integral conservation balances (i.e., conserves mass) of a species (e.g., a chemical of interest which in this case is mercury) for dissolved and solid phases in a thoroughly mixed

[1] Diagenesis refers to the sum total of processes that bring about changes in a sediment or sedimentary rock subsequent to deposition in water.

layer of surface sediments in SMU 8. The governing equation for the natural recovery model, referred to here as the "standard model," is:

$$\frac{\partial M}{\partial t} = D_0\left[\frac{\varphi}{\theta^2}\frac{\partial C}{\partial x}\right]_L + \left[\varphi D_B\frac{\partial C}{\partial x}\right]_L + [\varphi u C]_L + [\varphi_s w B]_0 - D_0\left[\frac{\varphi}{\theta^2}\frac{\partial C}{\partial x}\right]_0 - \left[\varphi D_B\frac{\partial C}{\partial x}\right]_0 - [\varphi u C]_0 - [\varphi_s w B]_L - \sum\int_0^L R\,dx$$

where:

M = mass of chemical of interest (mg)

T = time (years)

D_0 = molecular diffusion coefficient (cm^2/yr)

φ = porosity of sediments (unitless)

θ = tortuosity of sediments (unitless)

C = concentration of chemical in dissolved phase (mg/L)

x = spatial variable (along the depth of sediments) (cm)

L = where x = L; the bottom of the mixed layer (cm)

D_B = biodiffusion or mixing coefficient for sediments (cm^2/yr)

μ = velocity of porewater (cm/yr)

φ_s = solid fraction volume (unitless)

w = burial velocity of solids (or settling rate) (cm/yr)

B = concentration of chemical in solid phase (mg/kg)

0 = where x = 0; top of the mixed layer (sediment water interface) (cm)

R = reaction of chemical through depth interval (i.e. biodegradation loss) (mg)

The governing equation provides the change in chemical mass over the specified time interval. By assuming a unit volume of mixed layer sediment, this equation can be used directly to calculate concentrations of the chemical of interest in the mixed layer over the same time. The net change in mixed layer mass is determined by the sum of changes produced by diffusion, biodiffusion (diffusion driven by bioturbation of sediments), groundwater advection, sediment settling, burial, and biodegradation (for organic chemicals). The model does not incorporate conversion of mercury to methylmercury. To the extent that methylmercury can flux to the water column more readily than total mercury, this is a conservative assumption in terms of estimating sediment total mercury concentrations (i.e., the model will likely overestimate the total mercury concentrations in sediments over time).

Following numerous examples in Boudreau (1997), the partial differential equation noted above was converted to a series of ordinary differential equations. The resulting ordinary differential equations are solved numerically in the model using Euler's method. The model was executed in Microsoft Excel. The visual basic for applications (VBA) code in Microsoft Excel used to execute the model incorporated additional quality control measures. For each time-step, each model variable used in the model equations (both input and calculated) was compared to the model variables output from STELLA, an independent model platform used to execute the model. The model variables and final model results outputs from the two platforms match well.

The variable R represents the total mass change due to all chemical production/destruction reactions that occur in the mixed layer. The only such reaction typically considered is anaerobic biodegradation for organic chemicals. Biodegradation was not specifically employed for this modeling effort, because total mercury was modeled.

The model defines two sediment layers: a buried layer and a surface mixed layer. The model assumes that mixing of sediments within the surface layer is essentially instantaneous within each time step. Generally, mixing of surface sediments due to physical and biological activity (bioturbation) takes place during a sufficiently short time scale that this assumption is reasonable for the purpose of predicting natural recovery over a period of years (Boudreau 1997, Berner 1980). The depth of the mixed layer itself can be varied within the model temporally and is dependent on observations of mixed layer depths (e.g. depth of first occurrence of observed laminations) in the sediments and/or predictions of future changes in those mixed layer depths. The applicability of the mixed layer assumptions to this system is discussed more below.

The governing equation includes processes for both dissolved-phase and solid-phase chemicals. Consequently, equilibrium-partitioning assumptions are used to quantify the mass of chemical present in each phase at any given time in the model.

The model was used to simulate mercury concentration over the period ending in 2027. Based on the schedule for remediating the littoral zone outlined in the Statement of Work attached to the ROD, remediation is anticipated to be completed in 2017. ROD compliance requires the mercury probable effect concentration (PEC) and bioaccumulation-based sediment quality value (BSQV) remedial goals be met by 10 years following remediation, which is anticipated to be the year 2027.

A.2 MODEL INPUTS

Model inputs were derived from extensive site sampling efforts, bench scale testing, and literature. Key parameters in the model are mixed layer depth, sedimentation rates, and mercury concentration in settling sediment. These parameters and others are summarized in Table A.1 and are discussed more in the following paragraphs.

A.2.1 Mixing Depth

The model input for sediment mixing depth is denoted as the mixed layer depth. Mixing of relatively clean sediments that settle from the water column with underlying sediments is one of the key processes involved in predicting natural recovery in SMU 8. Mixing of sediments can result from physical processes, such as currents driven by wind, and from movement of bottom-dwelling (benthic) organisms in the sediment, denoted as bioturbation. As discussed below for each process, movement of profundal zone waters due to wind is insufficient to cause noteworthy physical surface sediment mixing and little, if any, bioturbation due to the anoxic conditions of the profundal zone that persist typically for three months each summer. Based on these conditions and visual evidence of currently and historically undisturbed surface sediment described below, 2 centimeters (cm) was determined to be a conservatively high estimate of the mixed layer depth.

A factor that could potentially change the 2 cm mixed layer depth is future increases in dissolved oxygen (DO) within the hypolimnion, as DO increase could result in greater colonization of SMU 8 sediment by benthic organisms and, consequently, increased bioturbation and associated mixing. Analysis of the possibility of this scenario indicates it to be highly unlikely, even in the future. The analysis was based on historic measurements of oxygen depletion and comparisons with a suitable reference system (i.e., Otisco Lake). The rate of hypolimnetic oxygen depletion reflects the decomposition of settling and deposited particulate organic matter that is formed mostly through primary production in the overlying photic zone, and is a widely recognized indicator of trophic state in dimictic lakes (Wetzel 2001). In lakes with large legacy deposits of degradable organic matter in the sediments, the rate of oxygen depletion may reflect historic, as well as contemporary levels of primary production (Matthews and Effler 2006). The rate of loss of dissolved oxygen from the hypolimnion can be represented on an areal basis as the areal hypolimnetic oxygen deficit (AHOD, $g/m^2/d$), or on a volumetric basis as the volumetric hypolimnetic oxygen deficit (VHOD, $g/m^3/d$). The VHOD representation is generally preferred for comparisons amongst lakes (Burns 1995, Denkenberger et al. 2007). Water temperature and lake morphometry, particularly the dimensions of the hypolimnion, influence the rate of oxygen depletion. Lakes with warm, shallow hypolimnia generally have higher rates of volumetric oxygen depletion.

Dramatic decreases in the rate of hypolimnetic oxygen depletion were observed in Onondaga Lake from the 1980s through the early 2000s (Figure A.1). No systematic trend is evident in the later years of the record, as VHOD values have remained in the range 0.15 to 0.23 $g/m^3/d$ since 2000. The timing of the onset of complete hypolimnetic anoxia in Onondaga Lake was computed for specified values of VHOD (Figure A.2). This analysis indicates that VHOD would have to decrease below 0.10 $g/m^3/d$ in order for the hypolimnion to remain oxic through the summer. This would represent a decrease of approximately 50 percent from contemporary VHOD values and a rate of hypolimnetic oxygen depletion lower than observed for nearby, mesotrophic Otisco Lake (see Denkenberger et al. [2007] for a more thorough comparison of hypolimnetic oxygen depletion in these two lakes). The highly non-linear relationship between the timing of hypolimnetic anoxia and the rate of volumetric oxygen depletion is particularly noteworthy. Further decreases in VHOD would result in progressively larger delays in the onset of anoxia. Such decreases would require further major reductions in nutrient loading, beyond those accomplished to date at Metro, and/or time (e.g., decades) for the sediments to come into a new steady-state with contemporary levels of particulate organic matter deposition (Matthews and Effler 2006). At this time, a scenario whereby the hypolimnion of Onondaga Lake will remain oxic throughout the summer does not appear to be realistic. It should be noted that oxygenation of the lake is still being considered as a means to reduce methylmercury flux from profundal sediment. However, as discussed in Section 3 of this IDS, nitrate addition has been very successful at reducing methylmercury formation in SMU 8 sediment and supplemental nitrate addition to the hypolimnion is currently being evaluated as the preferred method for minimizing methylmercury flux with a three-year nitrate addition pilot test commencing during the year 2011 (Parsons and UFI, 2010). If the pilot test proves nitrate addition to be successful, full-scale implementation of nitrate addition will likely be implemented as needed in place of oxygenation.

In the unlikely event that the profundal zone remains oxic in the future during the summer months (through natural or engineered means) or factors change such that this condition is predicted to occur, the appropriateness of the sediment mixed layer depth of 2 cm would be reassessed as part of the ongoing MNR monitoring and contingency plan. Long-term monitoring and contingency actions are discussed in Section 4 of this IDS.

A.2.1.1 Evidence of Layering / Laminations

Visual evidence based on freezing and slicing shallow sediment cores collected during 1992 and 2010 in SMU 8 shows that mixing of sediment is not taking place at depths below the top 1.5 cm (Figure A.3a and A.3b). In all but one core[2], laminations were first observed at a depth of 1.5 cm or less (some began at the surface). The presence of layers or laminations in the SMU 8 sediment is primary evidence that SMU 8 sediment is relatively undisturbed and not affected by bioturbation or resuspension of lakebed sediment. Layering of SMU 8 sediment was observed by Rowell (1992) and during the remedial investigation and has been attributed to deposition of calcite, clays, and diatoms (silica) associated with erosion of the watershed, productivity cycles within the lake, and other annual events (Effler and Harnett, 1996).

To update and confirm prior observations, Parsons collected and processed three shallow sediment cores from the North Basin and three shallow sediment cores from the South Basin in 2010. The cores were collected in an undisturbed manner, kept vertical, frozen with dry ice once onshore, and then sliced vertically while frozen to examine layering. Each of these 2010 cores showed thin layering (laminations) from the sediment surface downward. This evidence of layering (Figure A.3a and A.3b) demonstrates that mixed layer depth in SMU 8 shallow sediment is less than 2 cm. Use of a 2 cm mixed layer depth in modeling is conservative in the sense that a thicker mixed layer depth slows down the calculated rate of natural recovery, as shown in the sensitivity analysis in Section A.3.4. Consequently, the assumption of a 2 cm mixed layer will show a slower rate of natural recovery as compared to the recovery of the thinner mixed layer that actually appears to exist in the profundal sediments.

[2] In core OL-MB-100, collected during 2010, the first clearly defined varve is visible faintly at a sediment depth of 5 cm. This core, however was not frozen completely and as a result there may have been distortion of the upper portion of the core during storage and/or handling.

A.2.1.2 Lack of Benthic Organisms

The profundal zone of Onondaga Lake typically lacks oxygen from mid-June until fall turnover in mid-October each year (Parsons Exponent, and Anchor QEA 2010). While some benthic organisms can persist for relatively short periods in anoxic sediment, they require oxygen in overlying water to propagate. The annual anoxia in Onondaga Lake precludes long-term activity and colonization of benthic organisms in SMU 8 sediment. This position is supported in multiple studies of Onondaga Lake.

Benthic macroinvertebrates were collected in 2008 as part of baseline monitoring program (Parsons, Exponent and Anchor QEA, 2009). Of the 20 locations sampled during 2008, two SMU 8 locations adjacent to the littoral zone SMUs were sampled to assess community composition. Five replicates (petite ponar dredge samples) making up a sample were collected at each location in August, with a goal of collecting 100 macroinvertebrates from each replicate for a total of 500 individuals in each sample (Parsons et al., 2008). Very few macroinvertebrates were found in 2008 in the SMU 8 sediments; 32 and 34 macroinvertebrates per sample were collected from the two SMU 8 locations at 13.4 m and 14.3 m water depth, respectively, where overlying water is anoxic compared to 500+ macroinvertebrates per sample collected at littoral-area SMU locations where overlying water contains oxygen.

Benthic macroinvertebrates were also sampled in 1998 along an east-west transect of Onondaga Lake under the direction of Dr. Nelson Hairston of Cornell University and Dr. Steve Effler of the Upstate Freshwater Institute (UFI). Samples were collected with an Ekman dredge at water depths of 2, 5, 10, 15, and 19 meters in May and August. Results indicate relatively few benthic macroinvertebrates in sediment at water depths of 10 m and greater (Figure A.4).

A.2.1.3 Lack of Physical Mixing

Physical mixing of sediment can occur if water currents are strong enough to resuspend sediment particles; however, such mixing is not evident in sediment cores from Onondaga Lake (i.e., presence of laminations) and water currents in the hypolimnion are not strong enough to cause noteworthy resuspension of SMU 8 sediment. The depth of the profundal zone provides protection from wind that controls movement of shallower water in Onondaga Lake (Owens and Effler, 1996).

Cowen and Rusello (2008) of Cornell University measured water current velocities near the SMU 8 sediment surface during October 2008 and performed a preliminary assessment of turbulence in the bottom boundary layer of Onondaga Lake. Their findings concur with the conclusions of Owens and Effler (1996) that velocities near the sediment bed are weak. Wind data collected at the South Deep location by UFI show that the most frequent (10 percent of the time) wind direction is out of the west and can reach up to 10 meters per second (22 miles per hour). The highest wind speeds of greater than 10 meters per second are measured from the south winds, which occur about 6 percent of the time (Cowen and Rusello 2008). Cowen and Rusello observed mostly weak turbulence levels and currents. Burst mean currents measured ranged from

0.2 to 9.6 cm per second, with a mean of 3.0 cm per second (0.07 miles per hour) at the Saddle and were double the measurements at South Deep (between 0.1 and 4.4 cm per second, with a mean of 1.4 cm per second). The bed shear stress due to skin friction derived from the maximum velocities measured at the Saddle and South Deep locations equal 0.0276 and 0.0058 Pa (1 Pa = 1.4508 x 10^{-4} psi), respectively. Scour is unlikely to occur given these small shear stress values (Ziegler 2002).

Parsons confirmed similar velocities during two nitrate field trial applications in July 2009 by deploying an acoustic doppler velocimeter at South Deep and at North Deep at 1 m above the lake bottom. Water velocities measured at the two locations through 2009 peaked at approximately 4 cm per second (Parsons and UFI, 2010a). Given the typical particle size typical of SMU 8 sediments and the observed near-bed velocities, the Hjulstrom Diagram shows that water velocities observed at the two locations are in the range of suspended sediment transport (i.e., sediment already in suspension) (Figure A.5) but are not high enough to move the fine-grained sediment present in SMU 8 (i.e. bedded sediment erosion).

Fluorescent microbead markers have been placed at representative locations in SMU 8 in part to evaluate mixing of SMU 8 sediments over time. The fluorescent microbead markers were applied during mid-2009 on behalf of Honeywell to nine different 1,400 square foot plots of Onondaga Lake profundal zone sediments. Two types of markers were applied in 2009: a sand tracer, which marks the mudline (top of sediment) as of mid-2009 when the microbead particles were applied, and a silt tracer, which mimics the sediment type present in the profundal zone. This silt tracer will, in the future, be another tool to evaluate potential mixing of SMU 8 sediment over time. Sampling of the sediments in the area of the microbead plots took place during late 2009 and 2010 and is scheduled for 2011 and every three years thereafter in accordance with an approved work plan (Parsons, Anchor Environmental and ETS, 2008). The ability to slice SMU 8 surface sediment into 1 cm thick slices means measureable newly-settled sediment above the sand microbead marker should be evident by approximately 2011, two years following microbead marker placement. The results of this on-going study may be used to reassess the appropriateness of the sediment mixed layer depth of 2 cm as part of the ongoing MNR monitoring and contingency plan.

A.2.2 Compliance Depth

Compliance depth is the depth of sediment that will be considered in assessing compliance with sediment criteria. This sediment depth will be monitored over the course of the 10-year MNR period following dredging and capping. The sediment goals for SMU 8 are the mercury PEC of 2.2 mg/kg on a point-by-point basis and the BSQV for mercury of 0.8 mg/kg on an area-wide basis.

A.2.2.1 Mercury PEC

The PEC remediation goal for mercury was developed in consideration of potential toxicity to benthic macroinvertebrates that are exposed directly to mercury in sediment. In order to have exposure, benthic macroinvertebrates must be present. The discussion of mixing depth above clearly indicates that SMU 8 sediments do not mix vertically and benthic macroinvertebrates are not present in significant numbers in SMU 8 sediment and are not expected to be present in significant numbers in the future. Therefore, the use of a 2 cm mixed layer depth to assess compliance with the mercury PEC has been identified as an appropriately conservative compliance depth.

A.2.2.2 BSQV

The BSQV remediation goal for mercury was developed in consideration of potential bioaccumulation of methylmercury from sediment to fish. Unlike the PEC, the exposure pathway is indirect and multiple factors influence the relationship between mercury in sediment and methylmercury in fish. A key factor is methylmercury release from SMU 8 sediment to overlying water where it can eventually be bioaccumulated. This release occurs when oxygen and nitrate are depleted from overlying water. Another potential route of methylmercury bioaccumulation is from sediment to benthic macroinvertebrates to fish; however, such bioaccumulation is not relevant to SMU 8 sediment because benthic macroinvertebrates are generally not present.

Recent Onondaga Lake sediment incubation work by Michigan Technological University, UFI, and Syracuse University conducted on behalf of Honeywell evaluated the flux of methylmercury from SMU 8 sediment (Exponent et. al. 2009). The researchers measured concentrations of total mercury, methylmercury, and key redox parameters in sediment cores and water overlying the sediment cores under three conditions: 1) oxic (DO and nitrate in overlying water), 2) anoxic (nitrate but no DO in overlying water), and 3) anaerobic (no oxygen and no nitrate in overlying water). Microelectrode probes and fine resolution slicing and analysis of cores showed that the main sulfate-reduction zone and maximum methylmercury concentration occurs at approximately the 2- to 3-cm depth in the sediment when DO is present in overlying water. However, the methylmercury produced within the 2- to 3-cm depth interval does not diffuse to overlying water due to the intervening sediment layers containing DO and/or nitrate that can sorb or demethylate methylmercury. Under anoxic and anaerobic conditions that mimicked the progress of stratification as DO and then nitrate are depleted from overlying water, the sulfate reduction (and mercury methylation) zone moved upward toward the sediment/water interface. Under anoxic conditions, where nitrate, but not DO, was present in overlying water, the maximum methylmercury concentration was found at the 1 to 2-cm depth (Figure A.6). When methylmercury release occurs under anaerobic conditions, the methylmercury production zone is likely within very near surface sediment (i.e., within 0 to 1 cm depth interval) or at the sediment surface. Total mercury concentrations deeper in the sediment are irrelevant to the release of methylmercury. Mercury partitioning to sediments is strong and therefore, the movement of mercury from deeper sediments towards the surface sediment/water column interface, where the methylmercury production occurs, is limited.

Given that the release of methylmercury, the form of mercury that bioaccumulates in biota is from very near surface sediment (i.e., within 0 to 1 cm depth interval) or at the sediment surface, a 2 cm compliance depth for BSQV modeling and mercury monitoring is a conservative basis for assessing mercury that could be contributing to methylmercury flux to the water column.

A.2.3 Sedimentation Rates

Sedimentation is the physical process by which particulate matter settles out of the water column and deposits on top of the existing sediment bed, such that the current surface sediments (and contaminants contained within those sediments) are buried over time beneath the new sediment surface.

A.2.3.1 Existing Sedimentation Rates

Sedimentation rates were estimated from historical RI and more recent data collected using two basic techniques: high resolution cores (including radioisotope analyses and use of mercury markers) and sediment traps.[3] "Recent" sedimentation rates from the 2008 high resolution core data average 0.26 g/cm^2/yr, with a range of 0.13 to 0.35 g/cm^2/yr (Parsons, 2010, Appendix F) across the various cores measured. These "recent" rates were derived from the high resolution core sections representing the most recently deposited sediment. Recent sedimentation rates are derived from the top two sections of these seven cores (0 to 2 and 2 to 4 cm intervals). Rates derived from the deeper core sections were not used for the purposes of quantifying recent sedimentation rates. Sedimentation rates from the most recent sediment trap data (collected during 2009) average 0.28 g/cm^2/yr, with a range of 0.08 to 0.79 g/cm^2/yr across the seasons sampled (i.e., not including winter). It should be noted that the ranges provided throughout this section for cores are based on spatial variations in data collected, while the ranges provided from sediment traps represent temporal (monthly) variations at one location that were converted to g/cm^2/yr for consistent comparison to core sedimentation rates. A sedimentation rate of 0.25 g/cm^2/yr, consistent with the findings from the analyses described below, was used as an input to the MNR model.

High Resolution Cores

Radioisotope cores were collected in the north and south portions of the profundal zone of Onondaga Lake during 1988 by Rowell (1992). As reported in the Remedial Investigation Report (TAMS Consultants, 2002), five of the six cores sampled show a clear trend of cesium-137 (^{137}Cs) radioisotope deposition consistent with historical sources of this isotope, and subsequent preservation of the sediment column that maintained that historical record. Figures of these cores are shown in Figure N.6 of Appendix N of the Feasibility Study (FS; Parsons, 2004). The demarcations of interest, such as the appearance of ^{137}Cs associated with nuclear testing that started in 1954 and the peak of that testing in 1963, have good resolution. This indicates little

[3] As discussed more fully in Section A.2.1, the profundal zone of Onondaga Lake is quiescent, and given the low near-bed velocities the likelihood of resuspension is low; therefore, for the purposes of this discussion, sedimentation rate refers to "net" sedimentation rate, rather than the "gross" sedimentation. Because of the relatively low resuspension rates in the profundal zone of Onondaga Lake, for most purposes, net and gross sedimentation rates can be assumed to be nearly the same.

disturbance to the sediments since that time (i.e., the sediment column was stable and did not exhibit signs of significant erosion events or large-scale re-working).[4]

Effler (1996) and Hairston et al. (1999) present radioisotope results from three additional cores. The two Effler (1996) cores were collected during 1988 and were subjected to both ^{137}Cs and lead-210 (^{210}Pb) radioisotope analysis. The Hairston et al. (1999) core was collected in 1997 and was analyzed for ^{210}Pb. (Sharpe [2003] subsequently obtained archived samples of this core and analyzed them for mercury as well to evaluate mercury markers). All three of these cores show clear evidence of long-term undisturbed deposition (i.e., stability), consistent with the findings from Rowell's cores. Sedimentation rates from these cores are listed in Table A.2. In addition to the high resolution core data described above, Honeywell collected more recent high resolution cores during 2008 to evaluate sedimentation rates using both ^{137}Cs and ^{210}Pb analyses (Table A.2).

Sedimentation results are typically reported in either grams per square centimeter per year (g/cm^2/yr) or in centimeters per year (cm/yr). In order to review and compare sedimentation rates, data reported in cm/yr were converted to g/cm^2/yr based on a typical bulk density of 0.243 grams per cubic centimeter (g/cm^3) derived from a porosity of 0.91 and a specific gravity of 2.7 g/cm^3.

Historical core sedimentation rates presented in the FS (pre-2008) are shown in Table A.2. Mid-range sedimentation rates on a g/cm^2/yr basis range between 0.07 g/cm^2/yr and 0.30 g/cm^2/yr. The maximum of the range (0.30 g/cm^2/yr) is from evaluation of a core horizon dating to approximately 1984 from a core collected in 1997 core reported by Hairston et al. (1999). The low end value of 0.07 g/cm^2/yr is from TAMS Consultants, 2002 (a discussion of Rowell's cores from the early 1990's). Sedimentation rates from recent high resolution cores collected during 2008 range from 0.13 to 0.35 g/cm^2/yr (average of 0.26 g/cm^2/yr).

Sediment Traps

Sediment trap data also provide a reasonable measure of net sedimentation rates[5]. Sediment trap data collected from the Onondaga Lake profundal zone between 1986 and 2009 were compiled for this assessment of sedimentation rates (UFI, 2010). Table A.1 lists the sediment

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4 One core collected in the Ninemile Creek Outlet Area does not follow this pattern, although it shows a clear increase of ^{137}Cs activity with depth. This profile is probably related to deposition of ^{137}Cs from the creek itself, which could have occurred in more sporadic events associated with periodic watershed runoff and erosion that blurred the concentration profile. Dredging conducted during the 1960s may have also affected this profile.

5 Typically, sediment traps capture all sediment regardless of whether it might normally resuspend at some later time, and therefore provide a measure of the "gross" sedimentation rate. Sediment traps also intercept sediments higher in the water column before solids have settled to the sediment bed. Consequently, with sediment traps there is also an assumption that the particles intercepted by the traps will eventually settle to the sediment bed. Also, sediment traps are only able to be deployed and measured during months when ice is not present on the lake surface. Finally, individual trap measurements may cover periods of less than a month and should not be assumed to represent annual overall deposition rates. However, despite these limitations, sediment traps provide a reasonable indication of "net" deposition rates, because very little of the sediments are expected to be resuspended and most of the sediments intercepted by the traps would be expected to eventually deposit on the sediment surface under normal quiescent conditions in the profundal zone.

trap data. Sedimentation rates post-1986 are lower than 1986 rates (soda ash was being produced in Syracuse in earlier years and likely contributed to higher sedimentation rates). Thus, the 1986 rates are not used further in this analysis except for comparative purposes, as they are not representative of current conditions.

Historical trap sedimentation rates presented in the RI and FS were obtained from sediment traps collected mostly during summer months, and vary in a range of approximately 0.11 to 1.4 $g/cm^2/yr$ (average 0.52 $g/cm^2/yr$) after 1986. The high value in this range represents the seasonal maximum result from sediment trap samples from Effler (1996) collected during 1988. The low-end value is based on the seasonal minimum value obtained from sediment traps deployed during 1996 for one month in the summer. Thus, it is unlikely that this low value is representative of overall annual deposition rates within the lake. Recent sediment trap samples collected by UFI from April until fall turnover in October of 2009 were collected in triplicate and subsequently averaged. Sedimentation rates from the averaged triplicates ranged from 0.08 to 0.79 $g/cm^2/yr$ (seasonal average of 0.28 $g/cm^2/yr$). It should be noted that while these sedimentation rates from the sediment traps have been extrapolated to annual rates, they do not consider sedimentation rates during the winter months, which may be lower. Also, as noted above, these temporal ranges should not be confused with the spatial annual rate ranges discussed for the cores.

Figure A.7 presents a summary of the sedimentation rates from Table A.2. Average sedimentation rates (mid-range values of pre-2008 data, and average of triplicate sediment trap data collected during 2009) were summarized statistically. As Figure A.7 shows, the recent 2009 sediment trap mean and median seasonal sedimentation rates are less than mean and median rates from the 1988 to 2000 seasonal sediment trap data. For core sedimentation rates, this pattern is reversed with the recent 2008 core mean and median rates being higher than the core-based sedimentation rates collected prior to 2008. The recent median and mean 2009 seasonal trap rates and 2008 core rates are all 0.25 $g/cm^2/yr$ or greater. Weekly sediment trap data have been collected by UFI between the months of April and October since 1980. Focusing on data post-closure of the soda ash facility (1987 through 2009), the data show similar sedimentation rates as discussed above (Figure A.8). While the mean seasonal downward flux of suspended solids varies year to year, the average annual downward flux of suspended solids ranged from 0.22 to 0.46 $g/cm^2/yr$, with a mean of 0.37 $g/cm^2/yr$. Note that the bars shown in Figure A.8 represent ranges of the temporal measurements, not an estimate of error of confidence in each individual measurement. As discussed in Section A.3, the model has been calibrated to date using a sedimentation rate of 0.25 $g/cm^2/yr$, which is also similar to the average sedimentation rate of 0.28 $g/cm^2/yr$ for 2009 sediment trap data and the average rate of 0.26 $g/cm^2/yr$ for the 2008 high resolution cores noted above. Although, for the reasons stated above, rates in cores and sediment and the variability of the measurements are not exactly analogous, taken together this information suggests that an overall rate of 0.25 $g/cm^2/yr$ is a reasonable estimate.

The microbead markers applied during mid-2009 on behalf of Honeywell to nine different 1,400 square foot plots of Onondaga Lake profundal zone sediments may also be used to establish sedimentation rates. The sand tracer marks the top of sediment as of mid-2009 when the microbead particles were applied. As discussed in Section A.2.1, the depth of the newly settled sediment above the sand marker should be measurable by approximately 2011, based on the ability to slice the cores in 1-cm vertical intervals. The results of this on-going study may be used to reassess the appropriateness of the sedimentation rate of 0.25 g/cm^2/yr as part of the ongoing MNR monitoring and contingency plan.

A.2.3.2 Anticipated Future Sedimentation Rate

Sedimentation rates are influenced by internally generated sources of solids and external upland/watershed sources of solids that enter the lake. As described in Subsection A.2.3.1, the current average sedimentation rate based on the 2008 high resolution core data is 0.26 g/cm^2/yr and the 2009 sediment trap data is 0.28 g/cm^2/yr. Based on considerations presented in the following paragraphs, it is possible that future sedimentation rates could be lower than the current 0.26 g/cm^2/yr and 0.28 g/cm^2/yr average noted above; however, these reductions are difficult to predict, in part because the current contributions to overall net deposition in the profundal zone from external and internal sediment loads are difficult to quantify. Thus, sedimentation rates used in the modeling described in Subsection A.3 are kept constant throughout the projection period. The appropriateness of this assumption will be reassessed as new data are available as part of the ongoing MNR monitoring and contingency plan. The first scheduled reassessment of model parameters will occur prior to the start of the MNR period and should provide an early warning to any sedimentation rate changes should they occur. Long-term monitoring and contingency actions, including additional assessment of modeling approaches and appropriate input parameter values, are discussed in Section 4 of this IDS.

The FS Appendix N discusses the potential for external sources of suspended solids from tributaries to decrease over time. Some researchers have hypothesized reductions in future sedimentation rates are possible due to mechanisms such as phosphorus reductions due to wastewater system upgrades, changes in internal production of calcium carbonate, and influence of *Daphnia* sp, grazing (Hurteau et al., 2010). However, Onondaga Lake Ambient Monitoring Program suggest that no decreases in tributary suspended solids inputs have occurred (Figure A.9). The temporal pattern observed in these data shows year-to-year variations, but overall the pattern appears steady over time. Overall, current evidence for decreasing sedimentation rates is limited, and hypotheses of future potential conditions are difficult to predict and quantify in terms of appropriate variations in the model sedimentation rate. Therefore, the rate of 0.25 g/cm^2/yr derived from recent data are used in the model described in Subsection A.3, and this rate is kept constant throughout the model projection period, subject to future adaptive management as appropriate.

A.2.4 Mercury Concentration in Settling Sediment

Current settling sediment mercury concentrations are estimated to be between 1.0 mg/kg and 1.9 mg/kg based on mercury concentration in surface sediment (0 to 2 cm) data collected from SMU 8 during 2007 and 2008. Shallow surface sediment data are a good indication of mercury concentrations in recently settled sediment, given that the lake bottom acts as a natural "sediment trap," and as noted above little or no mixing occurs in these bottom surface sediments. Settling sediment mercury concentrations are assigned to three sub-areas of SMU 8 based on variability observed in the 0 to 2 cm recent surface sediment data. Sediment concentrations in the North Basin range from 0.7 mg/kg to 1.3 mg/kg (one outlier at 3.1 mg/kg was removed), with a mean of 1.1 mg/kg. To improve model calibration in the North Basin calibration stations (which were selected for calibration based on their longer available record of surface sediment concentrations), a slightly lower value of 1.0 mg/kg was used. Concentrations in recent surface sediment data in Ninemile Creek Outlet Area, the Saddle area, and the South Basin range from 1.0 mg/kg to 1.8 mg/kg, with an average concentration of 1.5 mg/kg. A value of 1.4 mg/kg was used for calibration stations in these areas to provide a better calibration at those points. Concentrations in the South Corner tend to be higher than other areas of the lake. Mercury concentrations measured on sediments collected from the 2009 sediment traps deployed at South Deep range from 0.18 mg/kg to 3.5 mg/kg, with an average of 1.66 mg/kg. Concentrations from surface sediment data range from 1.5 mg/kg to 2.3 mg/kg, with an average of 1.9 mg/kg. This latter value was used for calibration in South Corner stations.

After remediation of the littoral zone and upland sources are complete, the incoming mercury sediment concentration is expected to decrease significantly. To estimate a future incoming mercury concentration post-remediation of 0.4 mg/kg, information related to potential future mercury sources was considered, including tributary influences and resuspended sediments from the littoral zone, as discussed below.

Future mercury concentrations in settling sediment were estimated based in part on tributary sediment mercury concentrations. Sediment in tributaries or portions of tributaries outside the area being remediated by Honeywell can be assessed to quantify sediment mercury concentration settling in the lake profundal zone in the future after Honeywell sites are remediated. Tributaries outside the areas being remediated by Honeywell have an average surface sediment concentration of 0.4 mg/kg. Average surface sediment mercury concentrations in four different tributaries are similar. Surface sediment mercury concentrations in lower Onondaga Creek are available from samples collected and analyzed at nine locations on behalf of Honeywell during 2009; the arithmetic average of those concentrations is 0.4 mg/kg (Parsons, Exponent, and Anchor QEA, 2010). Surface sediment mercury concentrations in upper Geddes Brook are available from samples collected and analyzed at approximately 10 locations over many years; those concentrations ranged from 0.03 to 0.18 mg/kg with the exception of two samples at one location that contained 1.3 and 1.6 mg/kg of mercury (TAMS Consultants, 2003 and Parsons, 2005). Surface sediment mercury concentrations in upper Ninemile Creek are available from over 40 samples collected and analyzed from various locations over many years; the arithmetic average of those concentrations is also 0.4 mg/kg. Finally for lower Ley Creek, surface sediment mercury concentrations are available from samples collected and analyzed at six locations on behalf of Honeywell during 2009 (Parsons, Exponent and Anchor QEA, 2010) and from many locations collected and analyzed the same year for USEPA. Sediment mercury results from sediment samples collected in lower Ley Creek on behalf of Honeywell ranged from 0.04 to 0.56

mg/kg. Sediment mercury results from sediment samples collected in lower Ley Creek on behalf of USEPA ranged from 0.028 to 0.8 mg/kg with the exception of 9 of the 120 results that had a maximum sediment mercury concentration of 2.1 mg/kg. As part of the baseline monitoring program conducted on behalf of Honeywell, mercury concentrations on solid particles were measured at Spencer Street in Onondaga Creek. The results of these two samples are 0.2 mg/kg and 0.6 mg/kg for mercury on solid particles based on total and filtered mercury and TSS results from the Book 3 baseline monitoring work. As part of a snowmelt and storm event sampling conducted by Syracuse University in April, June, and August of 2009, particulate mercury concentrations were measured in Onondaga Creek (Driscoll, 2010). The concentrations at the Spencer site were highly variable with a mean particulate mercury concentration of 0.28 mg/kg (standard deviation of 0.81 mg/kg). Particulate mercury concentrations measured at the Dorwin site are much lower and more uniform with a mean particulate mercury concentration of 0.083 mg/kg (standard deviation of 0.059 mg/kg). The average particulate mercury concentration for the two Onondaga Creek sites is 0.17 mg/kg (standard deviation of 0.56 mg/kg).

Sediment mercury concentrations in the littoral zone will change substantially as a result of active sediment remediation, and this will reduce the overall average littoral sediment mercury concentration available for resuspension and possible deposition in the profundal. The future littoral sediment concentration following remediation was estimated to be 0.4 mg/kg based on average mercury concentrations in areas of the littoral zone that will not be remediated and based on a mercury concentration in the cap material of 0.1 mg/kg for areas that will be remediated. The average mercury concentration in areas of the littoral zone that will not be remediated is also based on surface sediment mercury data collected in the littoral zone since 1992. The cap material mercury concentration of 0.1 mg/kg is the same concentration as fill material applied as part of the remediation at LCP (Parsons, 2009).

Based on this tributary and post-remediation littoral area information, a conservative mercury concentration of 0.4 mg/kg on settling sediment is used for MNR modeling of the 10-year MNR period that will begin following completion of active remediation efforts.

The value of 0.4 mg/kg is higher and more conservative than the estimate of 0.28 mg/kg provided in the Onondaga Lake feasibility study, which was estimated based on a 70.5 percent reduction in mercury load due to the following remediation scheduled to be completed by 2017:

- Remediation of Harbor Brook, LCP, and Ninemile Creek
- Metro upgrades
- Elimination of groundwater inputs to the lake from Willis Ave., Semet Ponds, and Harbor Brook

A.2.5 Upwelling Velocity of Porewater

Upwelling velocities of porewater observed in the profundal zone are below 1 cm/yr, with the exception of two boring locations (provided by S.S. Papadopulos and Associates to Parsons/Anchor QEA via email on September 29, 2010). A conservative estimate of 1 cm/yr is therefore used in the modeling presented here. In a depositional environment such as the profundal zone of Onondaga Lake, sediment deposition provides a substantially greater flux of mass than the upwelling velocity, given the high partition coefficient; therefore, predicted mercury concentrations in the mixed layer are relatively insensitive to changes in upwelling velocity.

A.2.6 Mercury Partition Coefficient (Kd)

During the PDI, paired porewater and sediment samples were collected from SMUs 1, 3, 4, 6, and 7 and analyzed for mercury. Calculations were performed on these data to develop site-specific mercury partitioning coefficients (Kd). Samples from SMU 4 stations were used to calculate a representative Kd, as sampling in SMU 8 for this purpose was not conducted. SMU 4 was selected for its lack of Solvay waste material. The site-specific log Kd calculated from the Phase IV pre-design data was 5.6 L/kg (Kd of approximately 400,000 L/kg; Parsons 2010). The model has been updated to these more accurate values (Table A.1), which do not appreciably impact the model calibration as shown in the model calibration discussed in Section A.3.3).

A.2.7 Initial Buried Layer Sediment Mercury Concentration

Generally, buried total mercury concentrations (deeper than 10 cm) have higher concentrations in the profundal sediments than more shallow sediment, consistent with recent natural recovery. A range of potential values for the buried layer sediment mercury concentration is shown in Table A.1. To be conservative, an upper value of 20 mg/kg was used for the buried layer.

A.2.8 Molecular Diffusion Coefficient

This value was obtained using the following equation using the molecular weight (MW) of elemental mercury (DiToro, et al. 1981).

$$D_o = 6935 \times MW^{-2/3}$$

A.2.9 Mixed Layer Porosity

The porosity value of 0.91 was used based on an evaluation of density data provided by TAMS Consultants/NYSDEC during preparation of the feasibility study. That evaluation used percent moisture data from Hairston et. al.'s 1997 core (provided by TAMS Consultants to Honeywell/Anchor Environmental via email on July 16, 2004) in the top 0 to 4 cm and an assumed specific gravity (noted below).

A.2.10 Buried Layer Porosity

The porosity value of 0.86 was used based on the density evaluation provided by TAMS Consultants/NYSDEC during preparation of the feasibility study using the same evaluation noted for the mixed-layer porosity and slightly deeper layers in those cores.

A.2.11 Biodiffusion (or Mixing) Coefficient

Boudreau presents a relationship between this parameter and burial velocity based on empirical data (1997).

$$D_b = 15.7 * s^{0.69}$$

A settling sediment flux of g/cm^2/yr (w) was converted to a burial velocity in cm/yr based on porosity (j) and particle specific gravity (SG) of the sediment using the following equation:

$$S = \frac{w}{(1-j) * SG}$$

A.2.12 Specific Gravity of Dry Sediment

This value is known as particle density, and values observed from 2007 PDI cores range from 2.5 to 2.8 g/cm^3. A typical value of 2.7 g/ cm^3 is used for this model. Specific gravity is used to determine the *in situ* density of the mixed layer using the porosity (derived from water content as noted above) and relationship noted for biodiffusion (e.g. (1-j)*SG).

A.2.13 Initial Mixed Layer Sediment Mercury Concentrations

To assess the rate of natural recovery of sediments relatively to the mercury PEC and BSQV goals, sediment mercury concentrations in the top 2 cm were applied as model input for the initial mercury concentration in the mixed layer. In an effort to include data from more recent sampling in 2010, which were not segmented from 0 to 2 cm, the mercury concentrations measured in the 0 to 4 cm intervals were used. While this may over-estimate the mercury concentrations likely to be seen in the top 2 cm of the sediment, they are considered to be a reasonable conservative estimate for general comparative purposes. Table A.4 lists the mercury concentrations in the 0 to 2 cm depth interval used for the initial mercury concentrations in sediment. Concentrations of mercury in the top 2 or 4 cm of the core locations modeled, as shown in Figure A.10, range from 0.64 to 3.9 mg/kg (Table A.4).

A.3 MODEL CALIBRATION AND SENSITIVITY ANALYSES

A.3.1 Boundary Conditions

The one-dimensional sediment mixed layer mass or concentration, which is the primary focus of the model, is bounded by surface water at the top (x=0) and buried layer at the bottom (x=L).

The concentration of mercury in lake surface water is assumed to be zero. Generally, surface water concentrations are well below porewater chemical concentrations (particularly for contaminated sediments), so the use of a zero value for the surface water boundary condition does not significantly affect predictions of natural recovery. That is, the model is insensitive to small changes in surface water concentration. The primary input from the surface water is the flux of suspended sediment (and associated chemicals) settling on the mixed-layer bed. The chemical concentration in the buried layer boundary was held constant at 20 mg/kg, which is generally representative of the higher range of buried mercury concentrations in SMU 8. As shown in Section A.3.4, the model is also insensitive to changes in buried sediment mercury concentrations. The model is also relatively insensitive to changes in the dissolved advection/diffusion over the subsurface boundary. Consequently, the general assumption of 20 mg/kg of mercury in buried sediment was applied for each modeled location.

A.3.2 Sediment Locations Modeled

Locations sampled during the Preliminary Design Investigation (PDI; 2005 to 2010) were considered as model projection locations, because they represent the most recent surface sediment data set. While it is most useful to select sample locations having mercury data from the 0 to 2 cm interval, consistent with the sediment mixing depth of 2 cm, locations from the 2010 sampling that included the 0 to 4 cm interval were also used to maximize the comparative data set at each model location. Although these deeper sections likely contain higher mercury concentrations than would be observed from the 0 to 2 cm depth, the concentrations are assumed to be equal to that observed in the 2 cm sediment mixing depth for the purpose of this conservative modeling. Figure A.10 shows these SMU 8 locations by sample year for each portion of the lake's profundal zone. The one-dimensional model assesses the fate and transport of mercury along the vertical axis of the sediment bed and therefore, each location shown in Figure A.10 was modeled separately. Modeled locations provide good coverage of the various sections of the lake: North Basin, Saddle, Ninemile Creek Outlet Area, South Basin, and South Corner.

A.3.3 Model Calibration

The model was calibrated during the FS effort based on empirical time series sediment mercury data available at that time. More recent surface sediment mercury data are available as noted in the previous subsection, so more recent model calibration work was performed as part of this initial design effort. This model calibration accounts for new data collected by Honeywell during the PDI (2005 through 2010). Results show the model calibrates well to the pre-design data from the top 2 cm using settling sediment mercury concentrations noted in Section A.2.4 (Figure A.11). In general, the model is conservatively calibrated, meaning that it is within the range of data or typically over-predicts the observed mercury concentrations in sediment. At location S24 the model under-predicts the mercury concentrations in sediment, which may be due to its closer proximity to the remediation areas in the littoral zone as compared to any other location modeled (Figure A.12).

A.3.4 Model Sensitivity

The model was evaluated for sensitivity to various input parameters. Because all model parameters were varied, including the site-specific parameters such as initial porewater concentration and settling mercury concentrations, it was necessary to select only one model location for this analysis: OL-STA-80070, with an initial mercury concentration of 3.1 mg/kg. The model was evaluated one parameter at a time; while one parameter was varied, the other model input parameters were set to the calibrated values, as described in Section A.2. The exception is for the initial settling sediment mercury concentrations, which was kept constant throughout the model period. Results of this sensitivity analysis are provided in Table A.3.

The model is sensitive to variations in sedimentation rate, settling sediment mercury concentrations (initial and future concentrations after 2017), mixed-layer depth, buried layer partition coefficient, and mixed layer porosity inputs. The mixed-layer depth sensitivity is expected, because sediment mixing depth defines the size of the "reservoir" that is impacted by transport processes. A larger reservoir will show less responsiveness to variations in flux to and from the mixed layer over time. Porosity is sensitive for the same reason; it is the primary factor determining the *in situ* density of sediments present in the mixed layer. The model is sensitive to the sediment settling mercury concentrations because the settling concentration largely defines the sediment concentration that will eventually make up the mixed layer (sediment settling mercury concentrations). As particles from the water column deposit on the sediment bed, the settling particles become part of the mixed layer. The sedimentation rate defines the speed at which the newly deposited particles build up to the mixed layer depth. The model is sensitive to the buried layer partition coefficient at high buried layer concentrations. Advection of mercury in the dissolved phase is calculated from the buried layer concentration and the partitioning from the solid phase concentration input into the model. The less mercury partitions to the sediment, the more dissolved mercury is released via advection to the mixed layer from the buried layer. At buried layer concentrations less than 10 mg/kg mercury, the change in buried layer partition coefficients has little impact on the mixed layer mercury concentrations.

The model is relatively insensitive to changes in mixed layer mercury partition coefficient, buried layer mercury concentration, and upwelling velocity. Additional runs of the model indicated that the mixed layer mercury partition coefficient would have to be considerably lower (in the 1,000 to 10,000 L/kg) range before any of these parameters would have a substantial effect on the model. Thus, because mercury appears to be strongly associated with the sediment particles, processes involving particule movement dominate over dissolved-phase transport processes like porewater advection. This means that stable layers of new sediment will effectively isolate older layers of even highly contaminated sediment. This finding is consistent with the distinct variations with depth in the mercury concentration core profiles, indicating that dissolved phase transport has not "smeared" these profiles over time. This finding also indicates that the particulate phase processes of sedimentation and incoming concentrations of settling sediments have the greatest impact on the model results. As noted before, there is a considerable amount of information to support the values used in the modeling for these two inputs (Table A.1). Therefore, the uncertainty associated with use of the mid-range value is low.

A.4 MODEL RESULTS

The one-dimensional numerical model was applied to predict the mercury concentrations in sediment at multiple locations 10 years following dredging and capping. The sediment mercury concentration at that time, which is assumed to be the year 2027, was compared to the BSQV of 0.8 mg/kg mercury (for the top 2 cm) and the PEC of 2.2 mg/kg mercury (also for the top 2 cm).

As discussed in Section A.3.2, locations modeled were those where 0 to 2 cm samples were taken, and 0 to 4 cm samples when 0 to 2 cm samples were not available (Figure A.10).

A.4.1 Comparison to Mercury PEC

Based on model results, all SMU 8 sediments are predicted to achieve the mercury PEC remediation goal within the 10-year MNR period (Table A.4). Results from the modeling predict that sediment mercury concentrations in the top 2 cm will be 0.44 to 0.45 mg/kg at the end of the 10-year MNR period (the year 2027). The PEC of 2.2 mg/kg for mercury is predicted to be achieved at all modeled locations by the year 2014 which is four years prior to the start of the 10-year MNR monitoring period. Consequently, this result is not reliant on the assumption of reduced mercury concentration in settling sediment after sediment remediation is completed. That is, natural recovery to the mercury PEC is expected to have taken place during the remedial construction period scheduled to end in 2017.

A.4.2 Comparison to BSQV

Based on model results, all SMU 8 sediments are also predicted to achieve the mercury BSQV remediation goal within the 10-year MNR period (Table A.4). Unlike the PEC, the BSQV is meant to be applied on an area-wide basis, therefore, the BSQV of 0.8 mg/kg was compared to sediment mercury concentrations on a lakewide basis. Areas of influence (Thiessen polygons generated in GIS) for each modeled profundal zone location are presented in Figure A.13. The area-weighted surface sediment mercury concentration in the littoral zone is projected to be 0.4 mg/kg following remediation of the littoral zone based on cap cover material containing 0.1 mg/kg and based on parceling the littoral zone into Thiessen polygons and applying surface sediment mercury concentrations measured in the littoral zone outside the remediation areas since 1992. On an area-weighted basis following the calculation method described in Section 4.3, the lakewide mercury concentration is 0.43 mg/kg, which is well below the BSQV of 0.8 mg/kg. The lakewide average surface sediment mercury concentration is thus predicted to fall below the BSQV of 0.8 mg/kg by the year 2018 which is the first year of the 10-year MNR monitoring period.

Splitting the lake into subareas for development of area-weighted averages was considered; however, the basis for doing so is not apparent or consistent with the development of the BSQV. Nevertheless, for comparison, the BSQV was also evaluated for the north half and the south half of Onondaga Lake, with the north half including the North Basin, Ninemile Creek Outlet Area, and Saddle and the south half including the South Basin and South Corner (see Figures 5.1a and 5.1b in the main text of the IDS for lake area delineations). The average mercury concentration in the top 2 cm of sediment is predicted to be 0.52 mg/kg in the north half of the lake (including littoral and SMU 8 sediments) and 0.37 mg/kg in the south half of the lake by the year 2027.

A.5 APPENDIX A REFERENCES

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Table A.1 Input Parameters and Source Information for Natural Recovery Modeling of Total Mercury

Parameter	Symbol	Units	Range of Input Values Low	Mid	High	Information Sources	MNR Model Input Parameters
Initial Mixed Layer Concentration	B_{LT}	mg/kg	0.64	1.75	3.9	Range of values found in surface layer profundal sediments throughout lake (PDI).	The input varies for each model location. The initial mixed layer concentration is set to the mercury concentration from latest sampling year at that model location, using the 0 to 2 cm interval, except for 2010 data, which uses the 0 to 4 cm interval (see Table A.3)
Initial Buried Layer Concentration	B_{BT}	mg/kg	1.5	4	20	Range of values found in profundal and deep littoral sediments throughout lake (TAMS, 2002).	20 as a conservative assumption[a]
Existing Settling Sediment Concentration	B_0	mg/kg	0.7	1.6	3.1	Concentrations observed in the 0-2cm depth interval from 2007/2008 PDI cores. Mid-range is the mean of the samples, and low and high values represent the range of concentrations.	Until upland remediation is complete in 2017: 1.4 mg/kg for Saddle, Nine Mile Creek, and South basin portions of SMU 8 1.0 mg/kg for North Basin 1.9 mg/kg for South Corner
Future Settling Sediment Concentration	B_0	mg/kg	--	0.4	--	Considerations include tributary influences and resuspended sediments from the littoral zone	0.4 after upland remediation is complete in 2017
Partition Coefficient, Mixed Layer	K_d	L/kg	145,332	398,107	1,161,971	SMU 4 paired sediment and porewater data (PDI Phase IV).	398,107[a,b]
Partition Coefficient, Buried Layer	K_d	L/kg	145,332	398,107	1,161,971	SMU 4 paired sediment and porewater data (PDI Phase IV).	398,107[a,b]
Molecular Diffusion Coefficient	D_o	cm^2/yr	--	202	--	Calculated per DiToro *et al*., 1981 ($D_o = 6935 * MW^{-2/3}$)[c]	202
Mixed Layer Porosity	*j*	unitless	--	0.91	--	Calculated from estimates of bulk density provided by NYSDEC (0.25 g/cm^3, which is the NYSDEC recommended value - Based on Hairston 1997 core, percent moisture and assumed SG value (2.7) for 0 - 4 cm and consistent with 2007 Honeywell analyses).	0.91
Buried Layer Porosity	*j*	unitless	--	0.86	--	Calculated from estimates of bulk density provided by NYSDEC (0.39 g/cm^3, which is the NYSDEC recommended value - Based on Hairston 1997 core, percent moisture and assumed SG value (2.7) for 4-10 cm and consistent with 2007 Honeywell analyses).	0.86
Biodiffusion Coefficient	D_b	cm^2/yr	--	16.01	--	Boudreau, 1997, Equation 4.148. $D_b = 15.7 * s^{0.69}$ and $s = w / ((1-j)*SG)$[d]	16.01
Velocity of Porewater	*u*	cm/yr	0		4.6	Values presented by S.S. Papadopulos. All but two upwelling velocities from SMU 8 boring locations sampled during the RI are less than 1 cm/yr.	1[a]
Settling Sediment Flux	*w*	$g/cm^2/yr$	0.080	0.280	0.780	Post-1986 sediment trap and core data (See Table A.2).	0.25
Specific Gravity of Dry Sediment	SG	g/cm^3	--	2.7	--	Typical value.	2.7

Notes:

[a] Model simulations are not significantly sensitive to this parameter (see Section A.3.4). Adjusting these values across a wide range will not significantly affect model results.

[b] Partition coefficient consistent with more recent SMU 4 partition coefficient data based on paired sediment and porewater cores collected from SMU 4 during Phase IV of the PDI.

[c] D_o is the molecular diffusion coefficient, MW is the molecular weight of mercury.

[d] D_b is the biodiffusion coefficient; s is the burial velocity (cm/yr), w is the settling sediment flux ($g/cm^2/yr$), j is porosity, SG is specific gravity.

Table A.2 Sedimentation rates from core and sediment trap data.

Type	Source	Evaluation Period Start Year	End Year	Minimum	Mid-Range	Maximum	Units	Sedimentation Rates ($g/cm^2/yr$)[a, b,c]
Core Data	Direct evaluation of RI 1996 Core Data	1953	1963	0.625	0.75	0.875	cm/yr	0.18
Core Data	Direct evaluation of RI 1996 Core Data	1964	1970	0.536	0.714	0.893	cm/yr	0.17
Core Data	Direct evaluation of RI 1996 Core Data	1971	1996	0.577	0.721	0.769	cm/yr	0.18
Core Data	Effler, 1996 (Cs 137 Cores pp. 648, 655)	1954	1963	0.444	0.722	1	cm/yr	0.18
Core Data	Effler, 1996 (Cs 137 Cores pp. 648, 655)	1964	1988	0.574	0.595	0.616	cm/yr	0.14
Core Data	Effler, 1996 (mercury cor p. 634)	1946	1970	-	0.42	-	cm/yr	0.10
Core Data	Effler, 1996 (Pb 210 cores p. 649)	1955	1988	0.909	1.212	1.515	cm/yr	0.29
Core Data	Hairston et al. 1999	1981	1981	0.667	0.756	0.874	cm/yr	0.18
Core Data	Hairston et al. 1999	1984	1984	1.052	1.244	1.481	cm/yr	0.30
Core Data	Hairston et al. 1999	1987	1987	0.504	0.563	0.622	cm/yr	0.14
Core Data	Hairston et al. 1999	1993	1993	0.341	0.37	0.385	cm/yr	0.09
Core Data	Hairston et al. 1999	1997	1997	0.293	0.326	0.341	cm/yr	0.08
Core Data	TAMS, 2002 (discussion of RI 1992 deep cores)	1954	1964	-	1.1	-	cm/yr	0.27
Core Data	TAMS, 2002 (discussion of Rowell 1992 cores)	1954	1964	-	0.28	-	cm/yr	0.07
Core Data	TAMS, 2002 (discussion of Rowell 1992 cores)	1964	1988	-	0.83	-	cm/yr	0.20
Core Data	TAMS, 2002 Fig. 6-28 (RI 1992 cores)	1954	1963	0.9	1.1	1.5	cm/yr	0.27
Core Data	TAMS, 2002 Fig. 6-28 (RI 1992 cores)	1963	1992	0.828	0.897	1.034	cm/yr	0.22
Core Data	TAMS, 2002 Fig. 6-29 (RI 1996 Cores)	1954	1963	0.7	0.8	1	cm/yr	0.19
Core Data	TAMS, 2002 Fig. 6-29 (RI 1996 Cores)	1964	1996	0.697	0.827	0.788	cm/yr	0.20
Core Data	TAMS, 2002 Fig. 6-30 (Rowell 1992)	1954	1963	0.333	0.556	0.778	cm/yr	0.14
Core Data	TAMS, 2002 Fig. 6-30 (Rowell 1992)	1964	1988	0.833	0.875	0.917	cm/yr	0.21
Core Data	2008 High Resolution Core Data (OL-STA-80068)	2008	2008	0.13	0.13	0.14	$g/cm^2/yr$	0.13
Core Data	2008 High Resolution Core Data (OL-STA-80073)	2008	2008	0.34	0.35	0.35	$g/cm^2/yr$	0.35
Core Data	2008 High Resolution Core Data (OL-STA-80076)	2008	2008	0.22	0.25	0.27	$g/cm^2/yr$	0.25
Core Data	2008 High Resolution Core Data (OL-STA-80089)	2008	2008	0.26	0.26	0.27	$g/cm^2/yr$	0.26
Core Data	2008 High Resolution Core Data (OL-STA-80103)	2008	2008	0.26	0.28	0.31	$g/cm^2/yr$	0.28
Core Data	2008 High Resolution Core Data (ST-51)	2008	2008	0.25	0.25	0.26	$g/cm^2/yr$	0.25
Core Data	2008 High Resolution Core Data (ST-51A)	2008	2008	0.25	0.27	0.30	$g/cm^2/yr$	0.27
Sediment Trap Data	TAMS, 2002 1992 Sediment Traps (Table 6-19)	1992	1992	0.27	0.487	0.762	$g/cm^2/yr$	0.49
Sediment Trap Data	TAMS, 2002 1992 Sediment Traps (Table 6-19)	1992	1992	0.27	0.448	0.654	$g/cm^2/yr$	0.45
Sediment Trap Data	Direct evaluation of RI 1996 Sediment Trap Data	1996	1996	0.106	0.48	1.153	$g/cm^2/yr$	0.48
Sediment Trap Data	Effler, 1996 Sediment Traps 1986 (pp. 606-607)	1986	1986	0.806	2.049	3.558	$g/cm^2/yr$	2.05
Sediment Trap Data	Effler, 1996 Sediment Traps 1986 (pp. 606-607)	1988	1988	0.162	0.622	1.373	$g/cm^2/yr$	0.62
Sediment Trap Data	Sharpe, 2003 Sediment Traps 2000	2000	2000	0.138	0.317	0.53	$g/cm^2/yr$	0.32
Sediment Trap Data	2009 Sediment Trap Data	2009	2009	0.08	0.28	0.79	$g/cm^2/yr$	0.28

Notes:

(a) Mid-Range values used for sedimentation rates. Conversion from cm/yr to $g/cm^2/yr$ based on dry bulk density values.

(b) Dry density values for high resolution cores from Appendix N converted to $g/cm^2/yr$ assuming a dry bulk density equal to 0.243 g/cc based on a porosity of 0.91 and a specific gravity of 2.7 g/cc. 2008 High resolution core data statistics are reported for the top two sections of the core.

(c) Although shown as annual averages, the sediment trap data do not consider sedimentation rates during the winter months, which may be lower.

Table A.3. Sensitivity analysis of model inputs.

Input Parameter	Input Value	Mercury Concentration (mg/kg) at the end of the MNR Period (2027)	Sensitivity Ratio
Settling Sediment Flux (g/cm2/yr)			
Minimum	0.02	1.97	
Maximum	6.22	0.40	
Relative Percent Difference	-199%	132%	0.67
Settling Sediment Mercury Concentration (mg/kg)[1]			
Minimum	0.65	0.69	
Maximum	1.9	1.94	
Relative Percent Difference	-98%	-95%	0.97
Reduced Settling Sediment Mercury Concentration (mg/kg)[2]			
Minimum	0.1	0.15	
Maximum	0.8	0.84	
Relative Percent Difference	-156%	-141%	0.91
Partition Coefficient in Mixed Layer (L/kg)			
Minimum	158,489.3	0.44	
Maximum	1,258,925.4	0.44	
Relative Percent Difference	-155%	0%	0.00
Partition Coefficient in Buried Layer (L/kg)			
Minimum	158,489.3	0.56	
Maximum	1,258,925.4	0.43	
Relative Percent Difference	-155%	25%	0.16
Buried Layer Mercury Concentration			
Minimum	1	0.40	
Maximum	20	0.44	
Relative Percent Difference	-181%	-9%	0.05
Porewater Velocity (cm/yr)			
Minimum	0	0.44	
Maximum	4.6	0.45	
Relative Percent Difference	-200%	-2%	0.01
Mixed Layer Depth (cm)			
Minimum	1	0.44	
Maximum	10	0.91	
Relative Percent Difference	-164%	-70%	0.43
Porosity Mixed Layer (unitless)			
Minimum	0.5	1.00	
Maximum	0.99	0.44	
Relative Percent Difference	-66%	78%	1.18

Notes:

[1] Unlike predictive modeling performed, the parameter held constant throughout the model period for the purposes of this sensitivity analysis.

[2] Reduced settling sediment mercury concentration begins after upland remediation is complete in the year 2017. Concentration from start of model to 2017 is 1.0 mg/kg at this North Basin Location.

Table A.4. Initial and final mercury sediment concentrations from model locations.

Area of Profundal Zone	Location ID	Sample Depth of Initial Mercury Concentration (cm)[1]	Initial Mercury Sediment Concentration (mg/kg)[2]	Final (2027) Mercury Sediment Concentration (mg/kg)	Year Mercury Sediment Concentration Is Below PEC (2.2 mg/kg)[3]	Year Mercury Sediment Concentration Is Below BSQV (0.8 mg/kg)[3]
North Basin	OL-SS-80002-SS	2	0.64	0.44	2005	2005
North Basin	OL-STA-80067	2	1.00	0.44	2007	2018
North Basin	OL-STA-80068	2	0.70	0.44	2008	2008
North Basin	OL-STA-80069	2	1.20	0.44	2007	2018
North Basin	OL-STA-80070	2	3.10	0.44	2008	2018
North Basin	OL-STA-80071	2	1.30	0.44	2007	2018
North Basin	OL-STA-80072	2	1.10	0.44	2007	2018
North Basin	OL-VC-80157	4	1.30	0.44	2010	2019
North Basin	OL-VC-80158	4	1.20	0.44	2010	2019
North Basin	OL-VC-80159	4	1.30	0.44	2010	2019
North Basin	OL-VC-80199	4	0.87	0.44	2010	2018
North Basin	OL-VC-80200	4	1.00	0.44	2010	2018
North Basin	OL-VC-80201	4	0.85	0.44	2010	2018
North Basin	OL-VC-80202	4	0.86	0.44	2010	2018
Nine Mile Creek	OL-STA-80073	2	1.00	0.45	2008	2019
Nine Mile Creek	OL-STA-80074	2	1.60	0.45	2007	2019
Nine Mile Creek	OL-STA-80091	2	1.70	0.45	2007	2019
Nine Mile Creek	OL-VC-80160	4	2.40	0.45	2010	2020
Nine Mile Creek	OL-VC-80161	4	2.00	0.45	2010	2020
Nine Mile Creek	OL-VC-80162	4	2.60	0.45	2011	2020
Nine Mile Creek	OL-VC-80203	4	1.10	0.45	2010	2019
Nine Mile Creek	OL-VC-80204	4	1.00	0.45	2010	2019
Saddle	OL-STA-80075	2	1.60	0.45	2007	2019
Saddle	OL-STA-80103	2	1.50	0.45	2008	2019
Saddle	OL-VC-80206	4	1.80	0.45	2010	2019
South Basin	OL-SS-80007-SS	2	1.00	0.45	2005	2019
South Basin	OL-STA-80076	2	1.40	0.45	2008	2019
South Basin	OL-STA-80077	2	1.30	0.45	2007	2019
South Basin	OL-STA-80078	2	1.60	0.45	2007	2019
South Basin	OL-STA-80078	2	1.60	0.45	2007	2019
South Basin	OL-STA-80080	2	1.40	0.45	2007	2019
South Basin	OL-STA-80081	2	1.60	0.45	2007	2019
South Basin	OL-STA-80082	2	1.60	0.45	2007	2019
South Basin	OL-STA-80083	2	1.60	0.45	2007	2019
South Basin	OL-STA-80084	2	1.70	0.45	2007	2019
South Basin	OL-VC-80165	4	1.90	0.45	2010	2020
South Basin	OL-VC-80166	4	2.00	0.45	2010	2020
South Basin	OL-VC-80167	4	1.50	0.45	2010	2020
South Basin	OL-VC-80168	4	2.30	0.45	2010	2020
South Basin	OL-VC-80169	4	1.70	0.45	2010	2020
South Basin	OL-VC-80207	4	1.20	0.45	2010	2019
South Basin	OL-VC-80208	4	1.30	0.45	2010	2019
South Basin	OL-VC-80208	4	1.30	0.45	2010	2019
South Basin	OL-VC-80209	4	1.20	0.45	2010	2019
South Basin	OL-VC-80210	4	1.20	0.45	2010	2019
South Basin	ST51	2	1.00	0.45	2008	2019
South Basin	ST51A	2	1.30	0.45	2008	2019
South Corner	OL-SS-80020-SS	2	2.80	0.45	2007	2020
South Corner	OL-STA-80085	2	1.90	0.45	2007	2020
South Corner	OL-STA-80086	2	1.50	0.45	2007	2020
South Corner	OL-STA-80087	2	1.60	0.45	2007	2020
South Corner	OL-STA-80088	2	2.30	0.45	2008	2020
South Corner	OL-STA-80090	2	2.30	0.45	2008	2020
South Corner	OL-VC-80170	4	1.90	0.45	2010	2021
South Corner	OL-VC-80171	4	1.70	0.45	2010	2021
South Corner	OL-VC-80173	4	1.40	0.45	2010	2021
South Corner	OL-VC-80174	4	1.30	0.45	2010	2021
South Corner	OL-VC-80175	4	1.70	0.45	2010	2021
South Corner	OL-VC-80176	4	1.90	0.45	2010	2021
South Corner	OL-VC-80179	4	1.40	0.45	2010	2021
South Corner	OL-VC-80180	4	1.60	0.45	2010	2021
South Corner	OL-VC-80181	4	2.00	0.45	2010	2021
South Corner	OL-VC-80182	4	1.80	0.45	2010	2021
South Corner	OL-VC-80183	4	2.50	0.45	2011	2021
South Corner	OL-VC-80184	4	2.30	0.45	2011	2021
South Corner	OL-VC-80185	4	2.20	0.45	2010	2021
South Corner	OL-VC-80186	4	2.10	0.45	2010	2021
South Corner	OL-VC-80187	4	1.70	0.45	2010	2021

Table A.4. Initial and final mercury sediment concentrations from model locations.

Area of Profundal Zone	Location ID	Sample Depth of Initial Mercury Concentration (cm)[1]	Initial Mercury Sediment Concentration (mg/kg)[2]	Final (2027) Mercury Sediment Concentration (mg/kg)	Year Mercury Sediment Concentration Is Below PEC (2.2 mg/kg)[3]	Year Mercury Sediment Concentration Is Below BSQV (0.8 mg/kg)[3]
South Corner	OL-VC-80188	4	2.80	0.45	2012	2021
South Corner	OL-VC-80190	4	1.80	0.45	2010	2021
South Corner	OL-VC-80191	4	3.20	0.45	2013	2021
South Corner	OL-VC-80192	4	2.40	0.45	2011	2021
South Corner	OL-VC-80193	4	3.60	0.45	2014	2021
South Corner	OL-VC-80194	4	1.80	0.45	2010	2021
South Corner	OL-VC-80195	4	3.20	0.45	2013	2021
South Corner	OL-VC-80196	4	2.80	0.45	2012	2021
South Corner	OL-VC-80197	4	3.40	0.45	2013	2021
South Corner	OL-VC-80211	4	1.70	0.45	2010	2020
South Corner	OL-VC-80212	4	1.90	0.45	2010	2020
South Corner	OL-VC-80213	4	1.80	0.45	2010	2020
South Corner	OL-VC-80214	4	1.50	0.45	2010	2020
South Corner	OL-VC-80215	4	2.20	0.45	2010	2020
South Corner	OL-VC-80216	4	2.10	0.45	2010	2020
South Corner	OL-VC-80217	4	1.40	0.45	2010	2020
South Corner	OL-VC-80218	4	1.90	0.45	2010	2020
South Corner	OL-VC-80219	4	2.10	0.45	2010	2020
South Corner	OL-VC-80221	4	2.00	0.45	2010	2020
South Corner	OL-VC-80222	4	3.90	0.45	2014	2020
South Corner	OL-VC-80223	4	1.50	0.45	2010	2020

Notes:

[1] *Model mixed layer depth is 2 cm for all locations.*

[2] *Initial mercury sediment concentration from LWA concentrations from 0 -2 cm or 0 - 4 cm PDI data. Model mixed depth is 2 cm for all locations.*

[3] *Year model predicted concentrations reach the PEC or BSQV are rounded to the nearest whole year.*

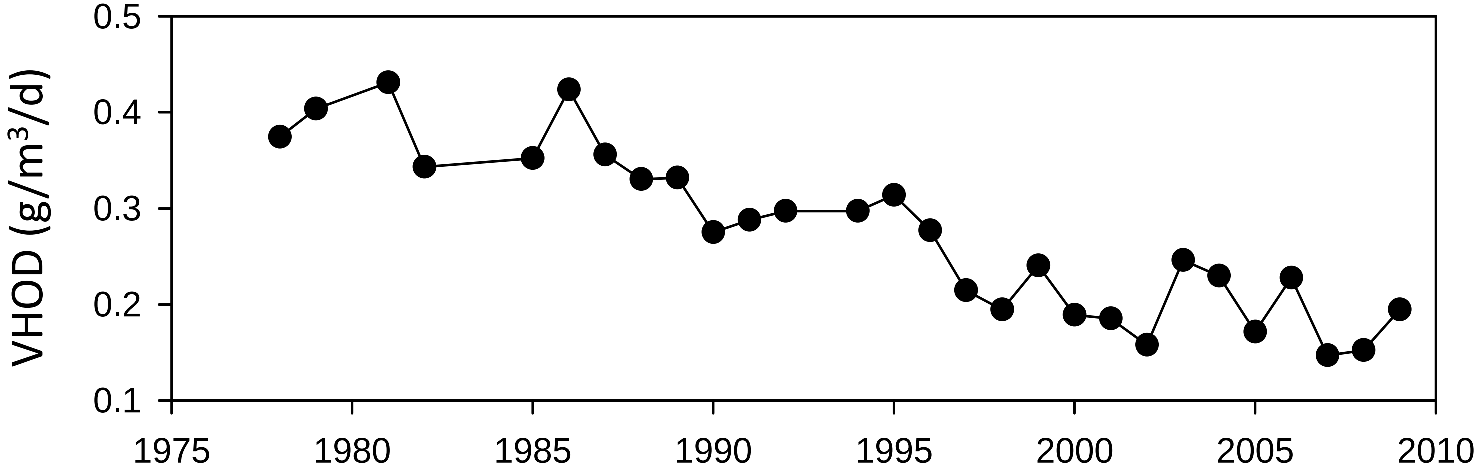


Figure A.1 Time series of the volumetric hypolimnetic oxygen deficit (VHOD) for Onondaga Lake over the 1978 – 2009 interval.

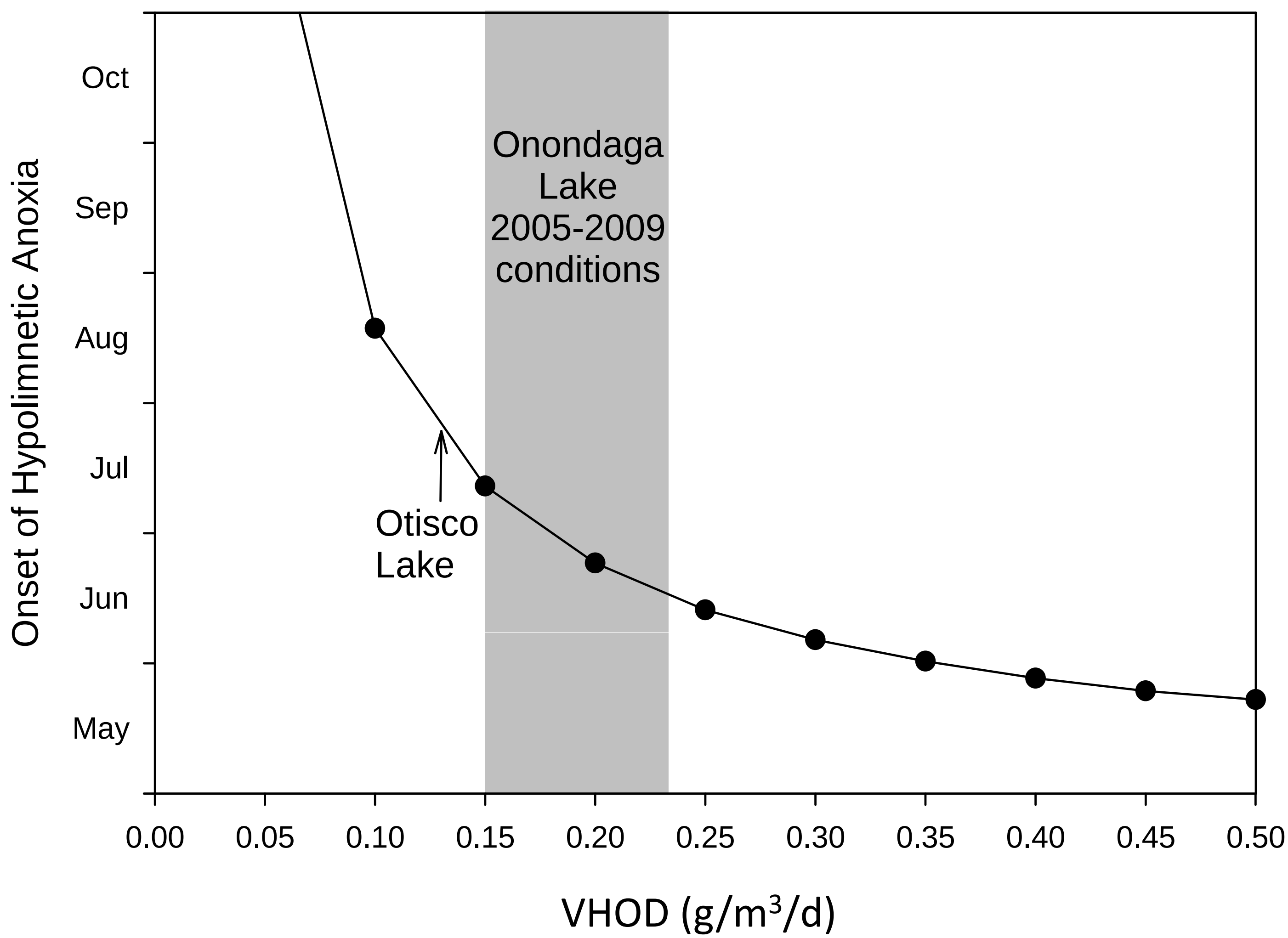


Figure A.2 Evaluation of the relationship between the timing of the onset of complete hypolimnetic anoxia and the volumetric hypolimnetic oxygen deficit (VHOD) for Onondaga Lake. Average VHOD conditions observed in Otisco Lake during 2002 – 2004 (Denkenberger et al. 2007) are presented for reference.

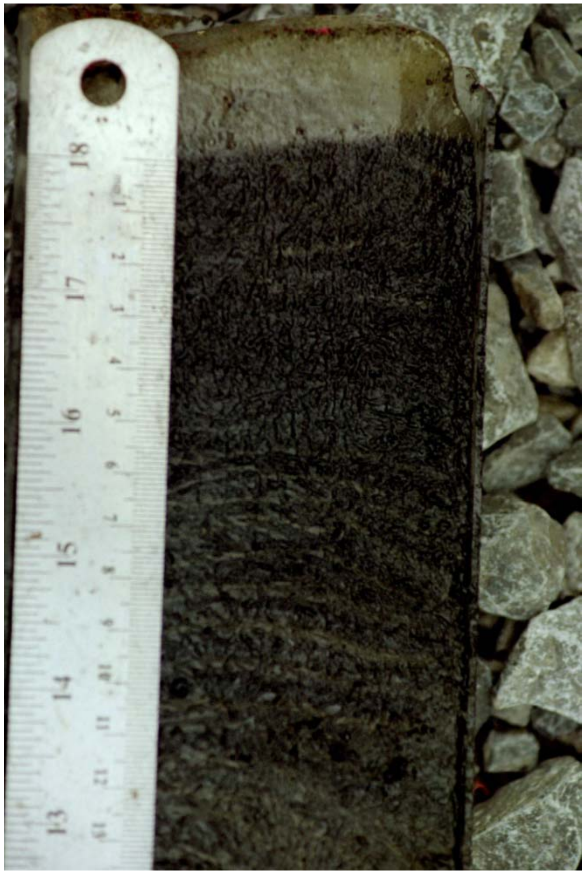
- No mixing in sediment from deep water areas based on tight layering observed during 2010 in North and South Basin cores (see horizontal lines in photos)

North Basin (S90 and QL-STA-80068)

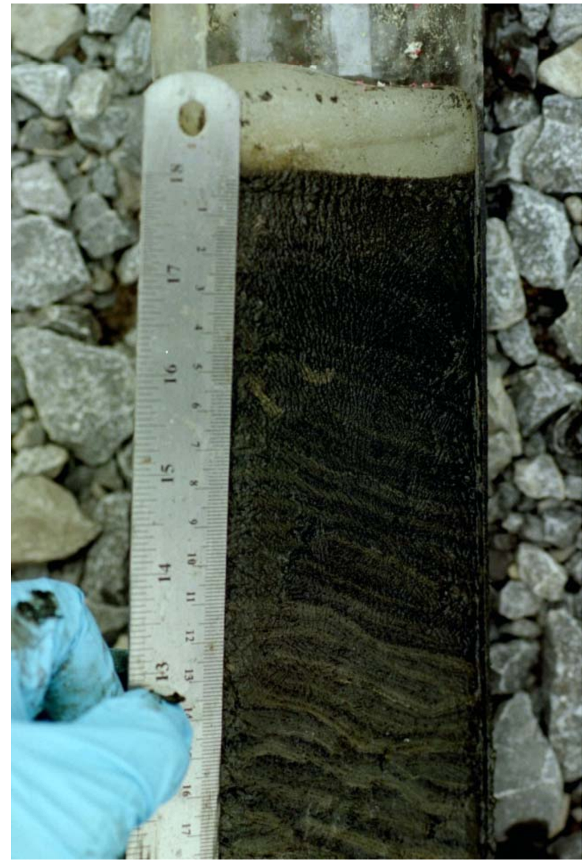
Ninemile Creek Outlet Area (OL-MB-80096)

- Sediment layering also noted in top 18 cm of S90 core as “black, occasional subtle 1 cm bands” (from Rowell and Effler, 1996)

Figure A.3a Layering/Laminations within SMU 8 Sediment Cores

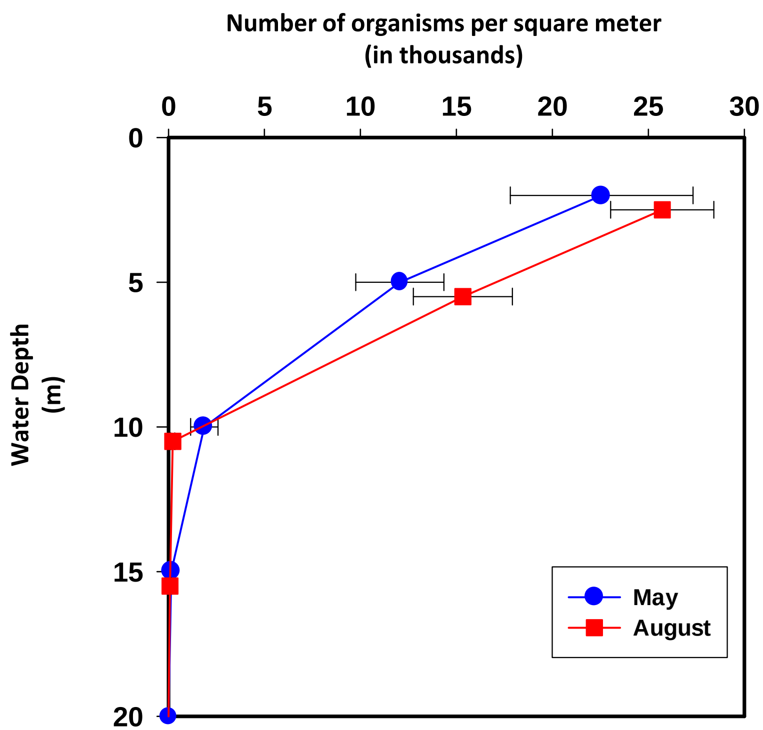


South Basin (OL-VC-80168)



South Basin (S51)

Figure A.3b Layering/Laminations within SMU 8 Sediment Cores



Source : Hairston and Effler, 1998.

Figure A.4 Macroinvertebrates Observed in Onondaga Lake as a Function of Water Depth (1998)

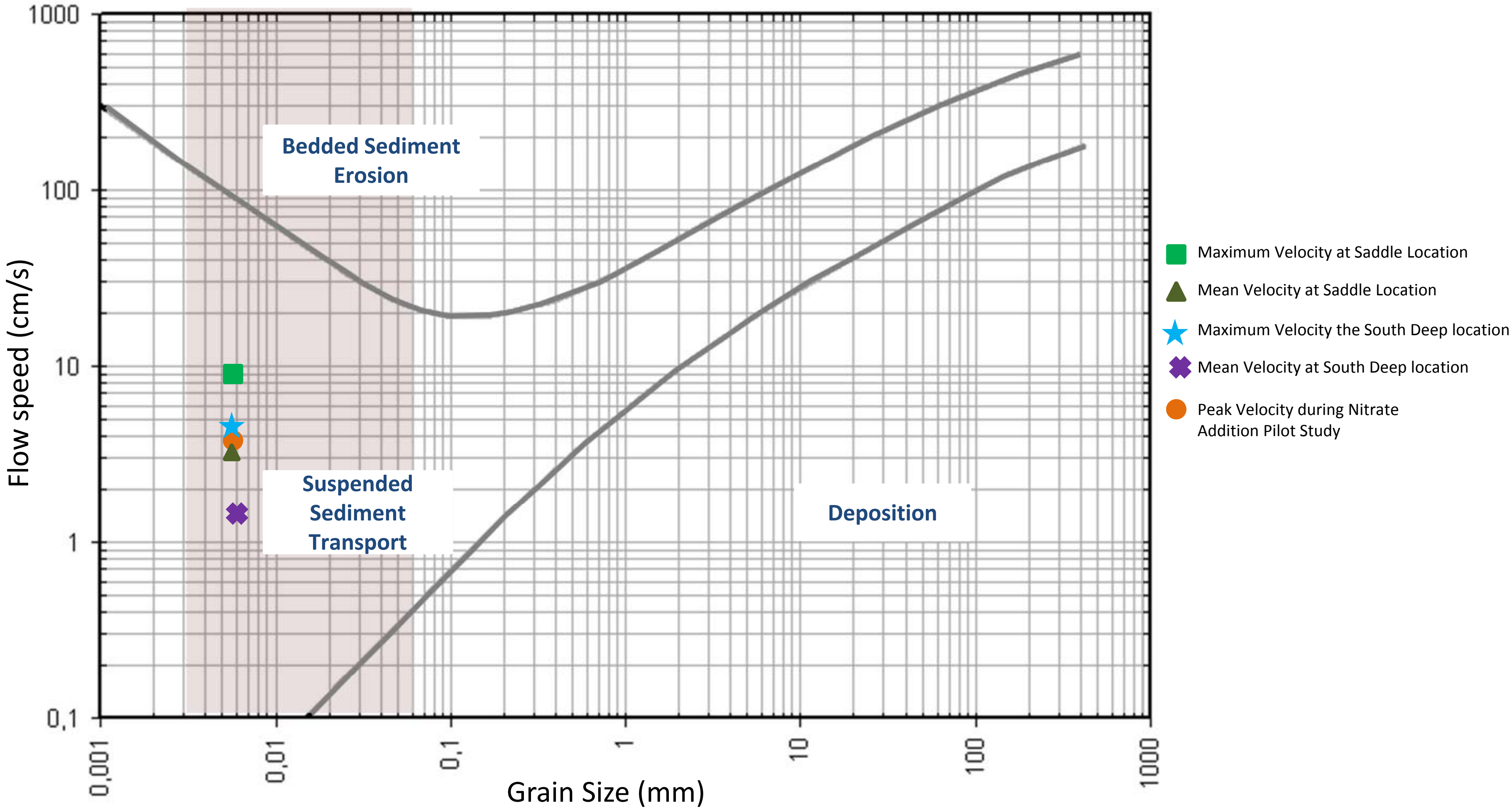
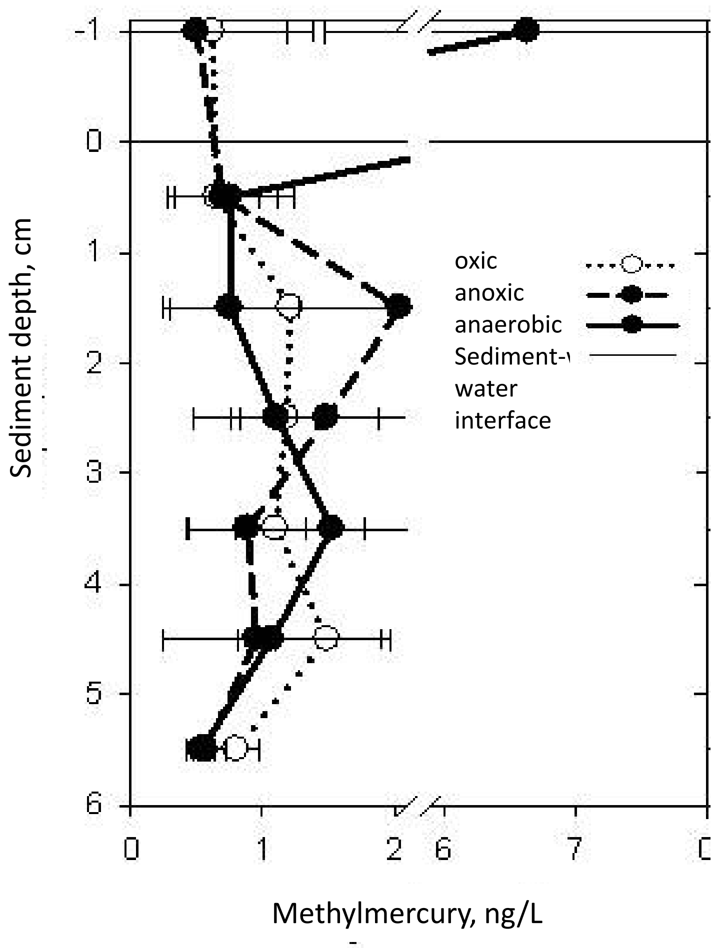


Figure A.5 Hjulstrom Diagram

Area shaded pink is the typical size range for silt.



Depth profiles for methylmercury under oxic, anoxic, and anaerobic conditions. *(From Figure 3.6, Draft Sediment Incubation Data Report, Exponent et al 2009)*

Figure A.6 Basis for 2 cm BSQV Compliance Depth in SMU 8

Honeywell

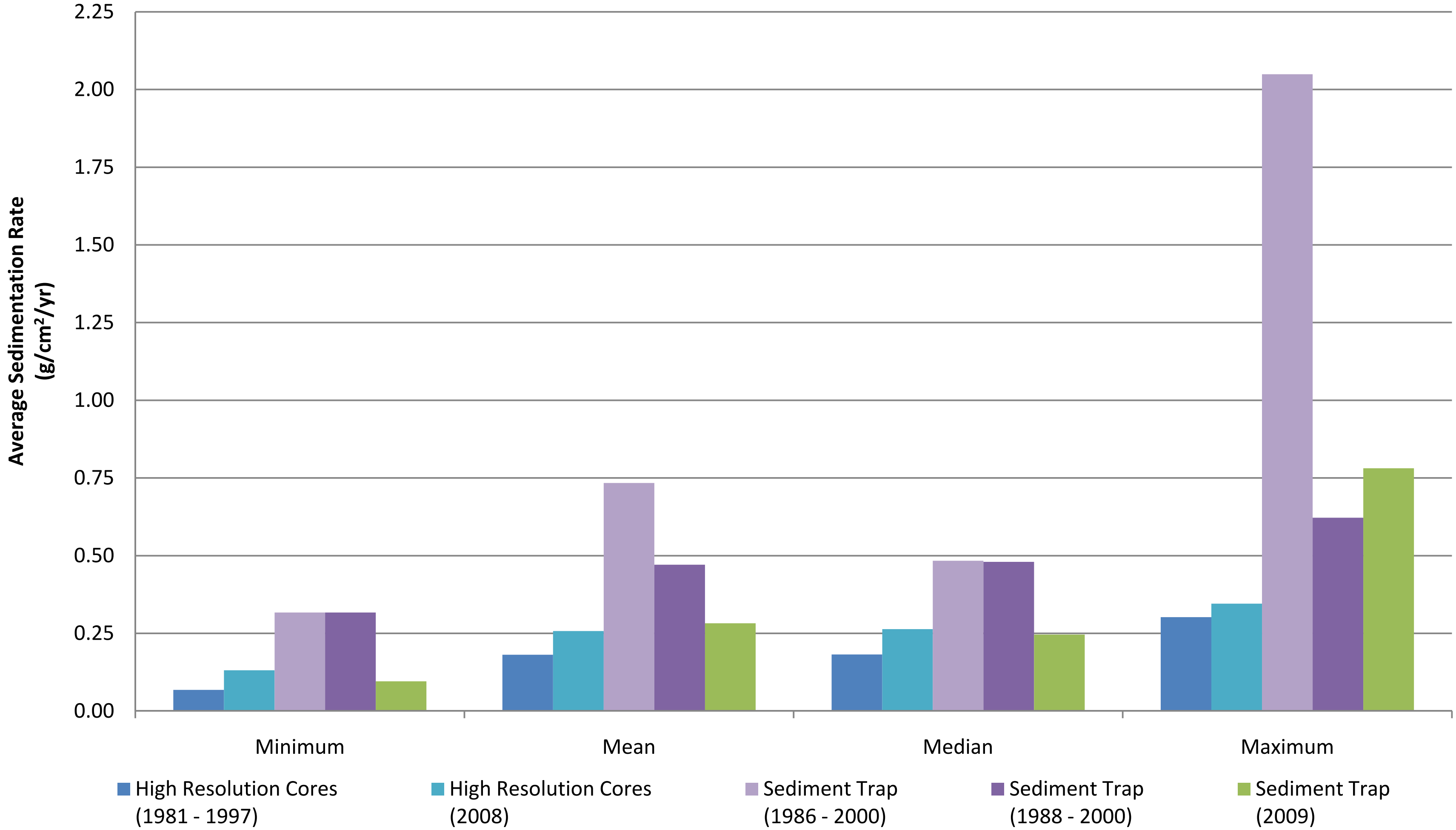


Figure A.7 Comparison of average sedimentation rates from various collection methods and years.

High resolution cores (1981-1997) converted to g/cm²/yr assuming a dry bulk density equal to 0.243 g/cc based on a porosity of 0.91 and a specific gravity of 2.7 g/cc. High resolution cores (2008) include surface intervals represented by the top 0-4 cm. Sediment trap data have been extrapolated to annual rates; they do not consider sedimentation rates during the winter months, which may be lower.

Honeywell

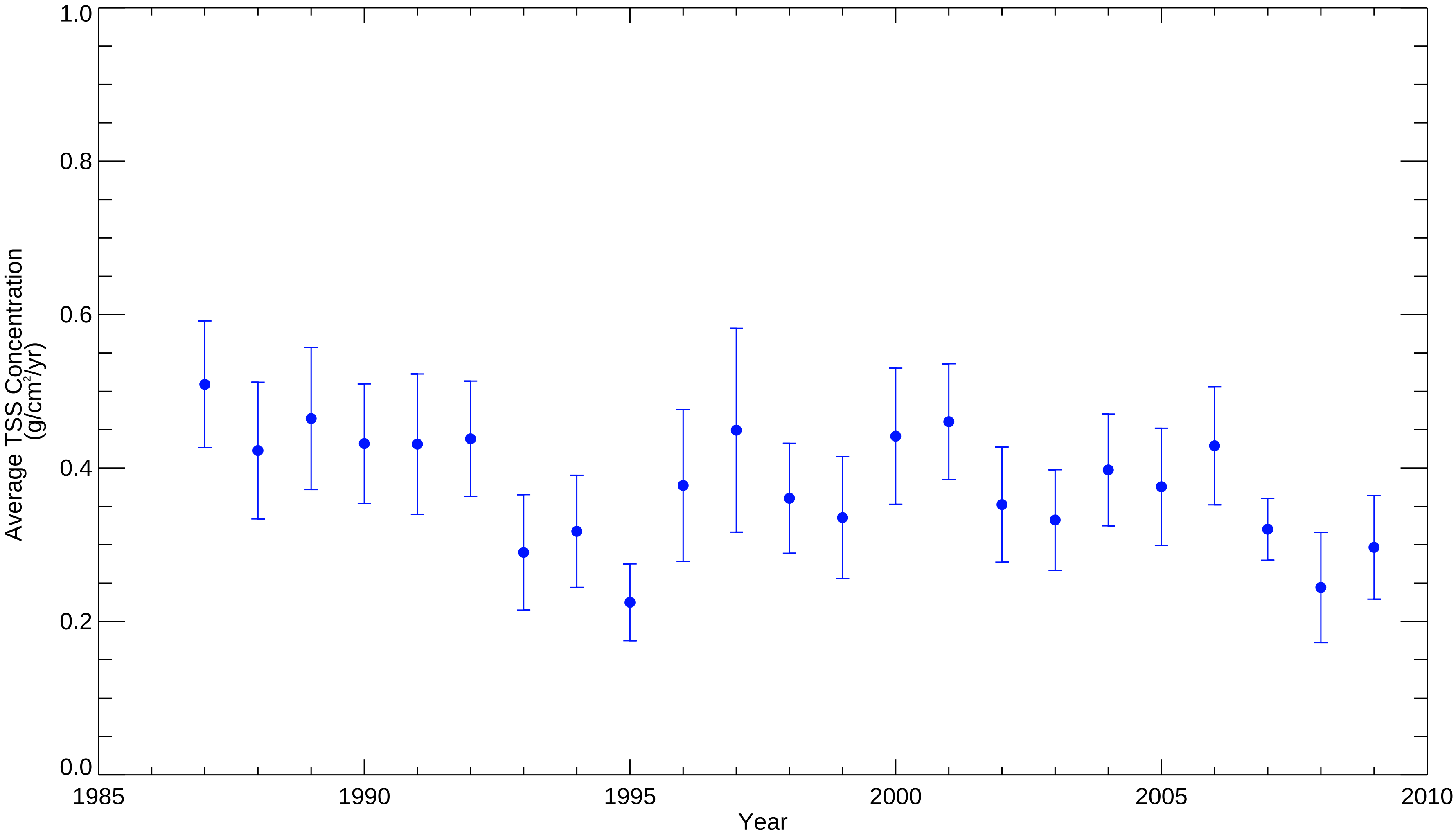


Figure A.8 Average Annual Sedimentation Rates From Sediment Trap Data Collected Between 1987 and 2009

Note: These plots are based on weekly sediment trap data collected by UFI from April through October of most years (1993 collection from May through September).
Plots show the average +/- 2 standard error (SE) of the mean, which is one way of representing the variability in the weekly values obtained for the year noted.
Although shown as annual averages, the sediment traps do not consider sedimentation rates during the winter months, which may be lower.

Honeywell

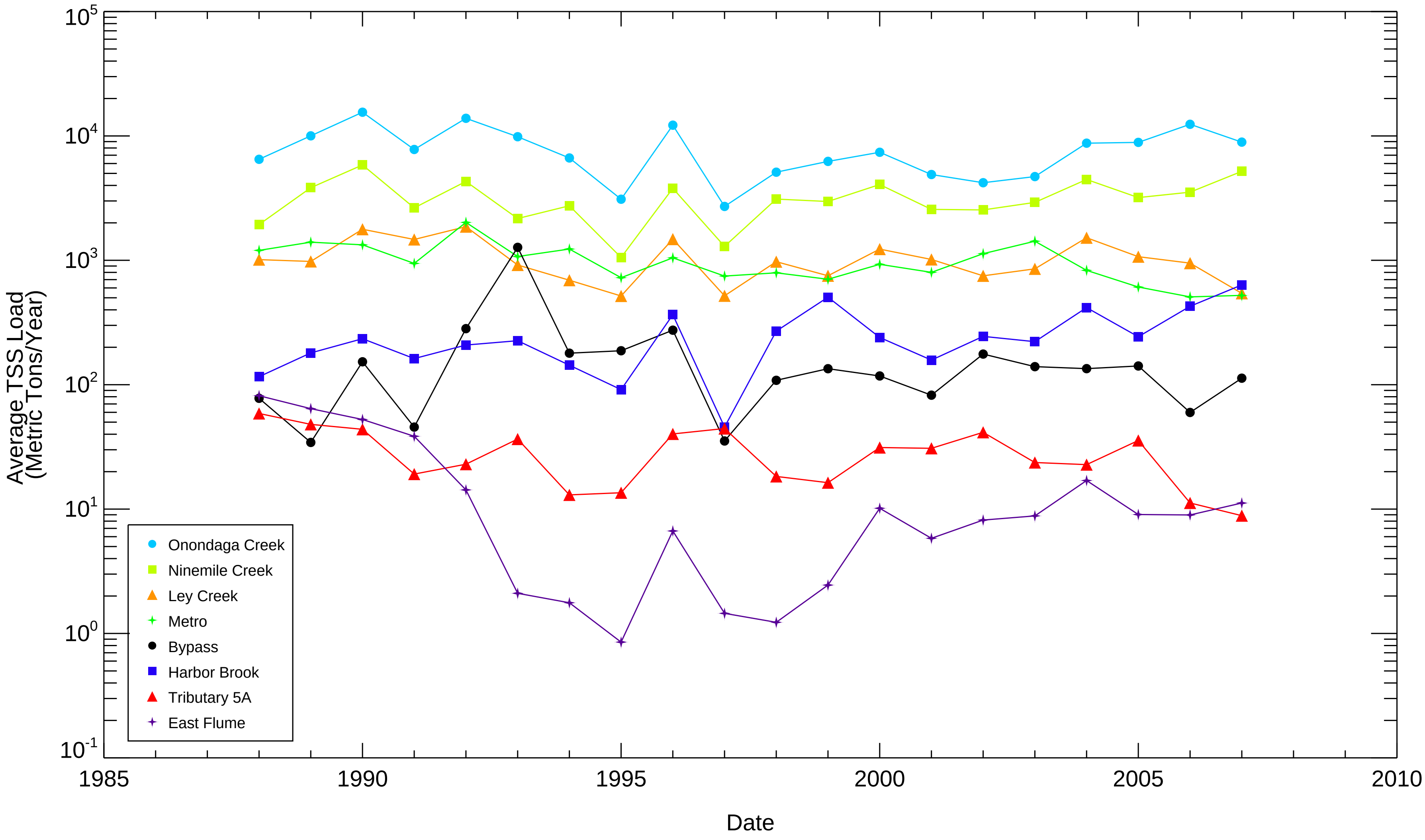


Figure A.9 Temporal Trends in TSS Loads to Onondaga Lake

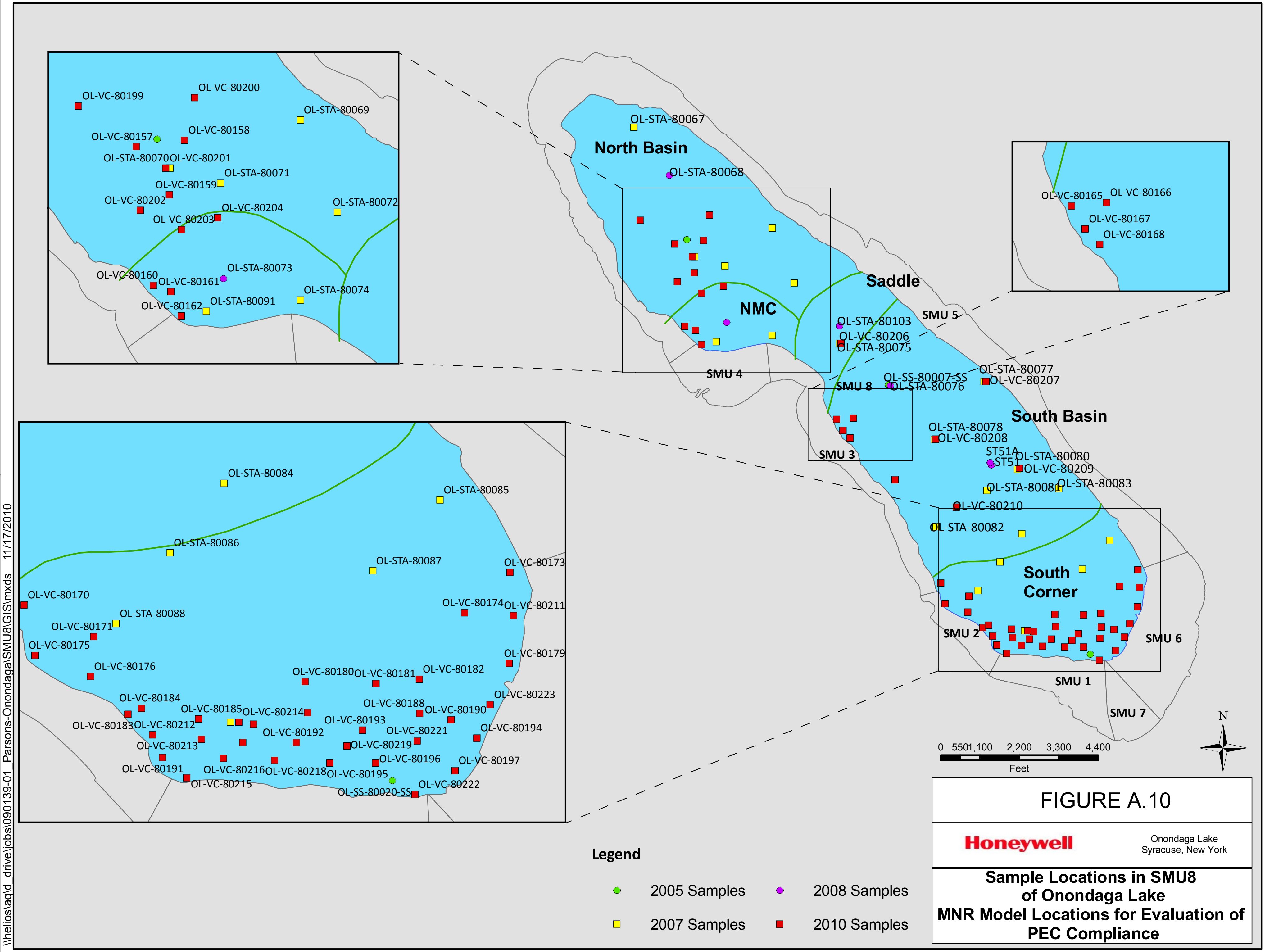


FIGURE A.10

Honeywell

Onondaga Lake
Syracuse, New York

Sample Locations in SMU8 of Onondaga Lake MNR Model Locations for Evaluation of PEC Compliance

Honeywell

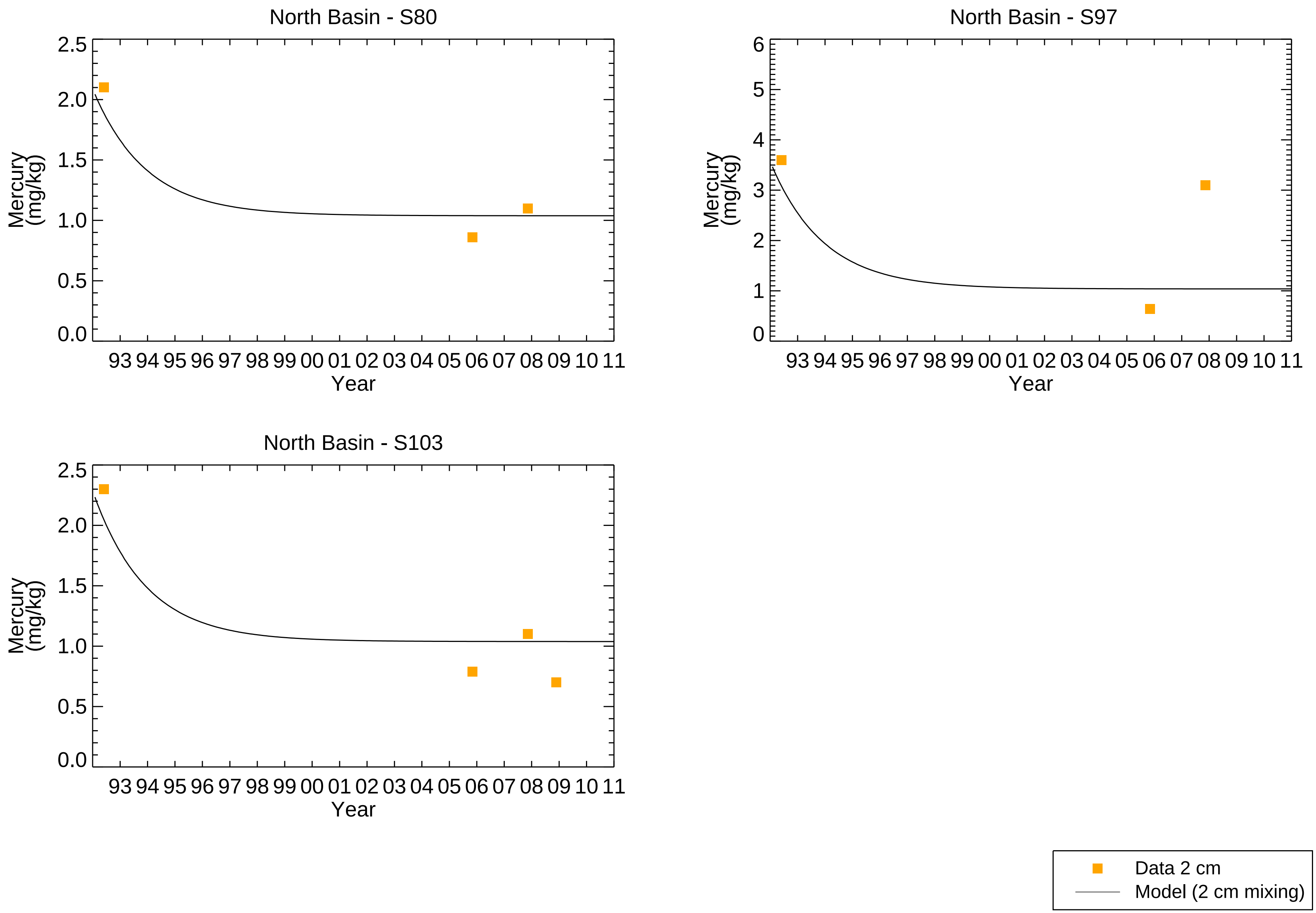


Figure A.11 Model Calibration: Model Predicted Mercury Concentrations Compared to Observed Concentrations

Honeywell

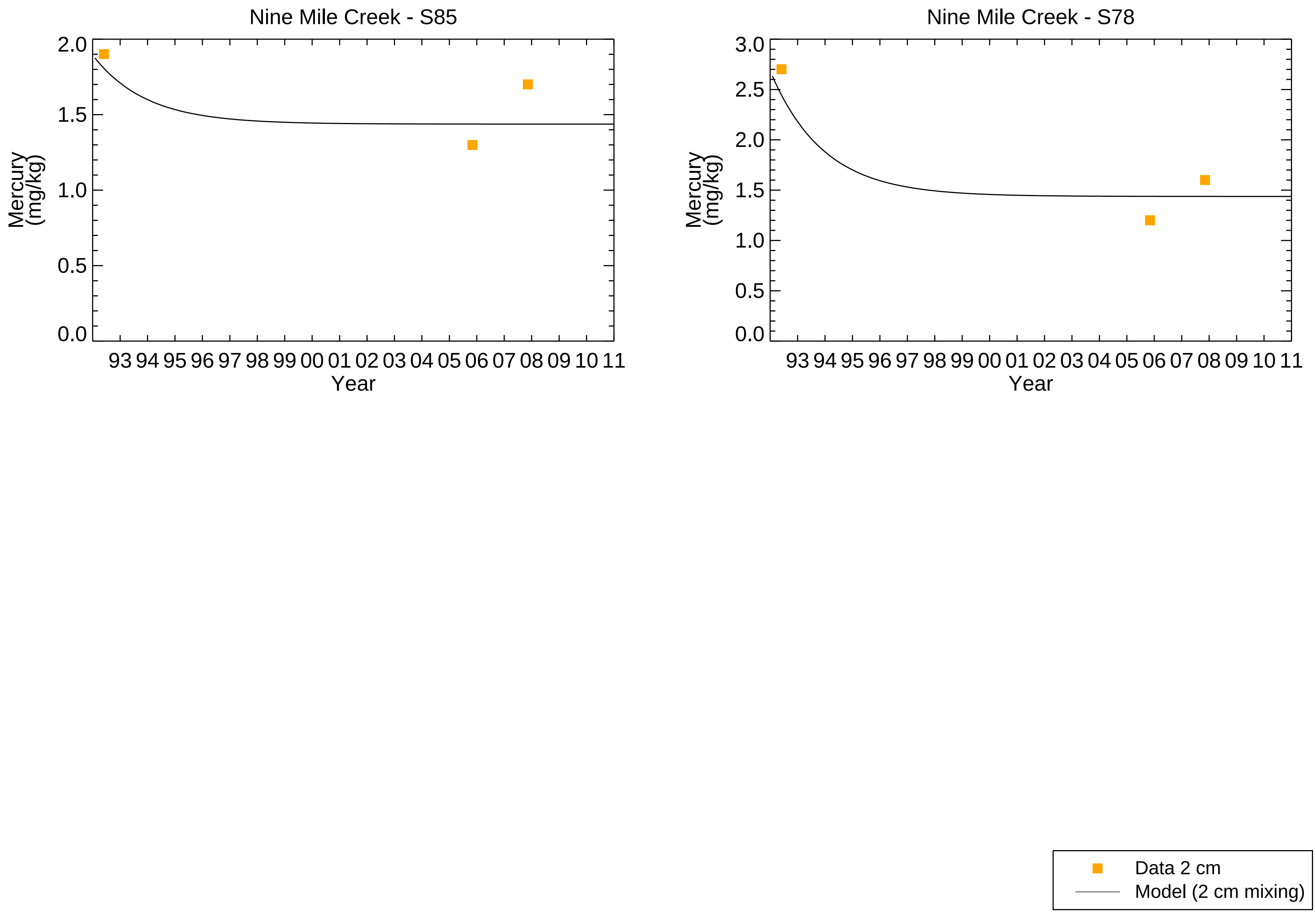
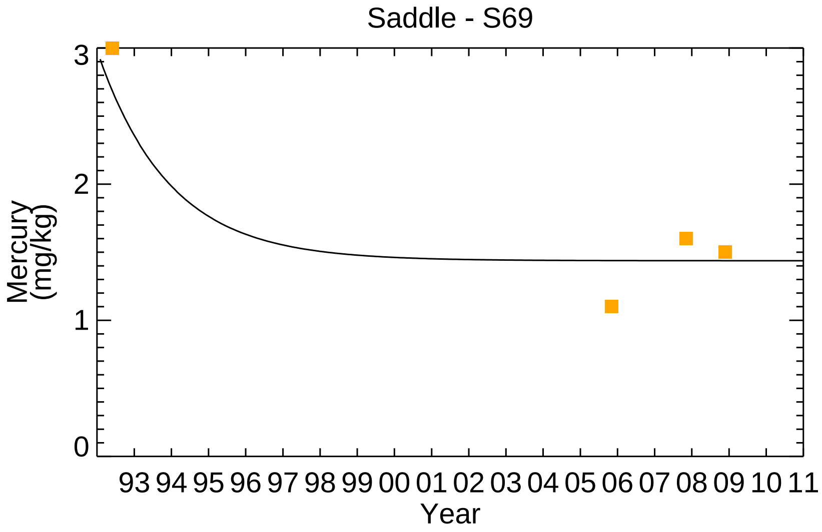


Figure A.11 Model Calibration: Model Predicted Mercury Concentrations Compared to Observed Concentrations

Honeywell



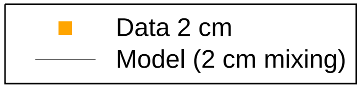


Figure A.11 Model Calibration: Model Predicted Mercury Concentrations Compared to Observed Concentrations

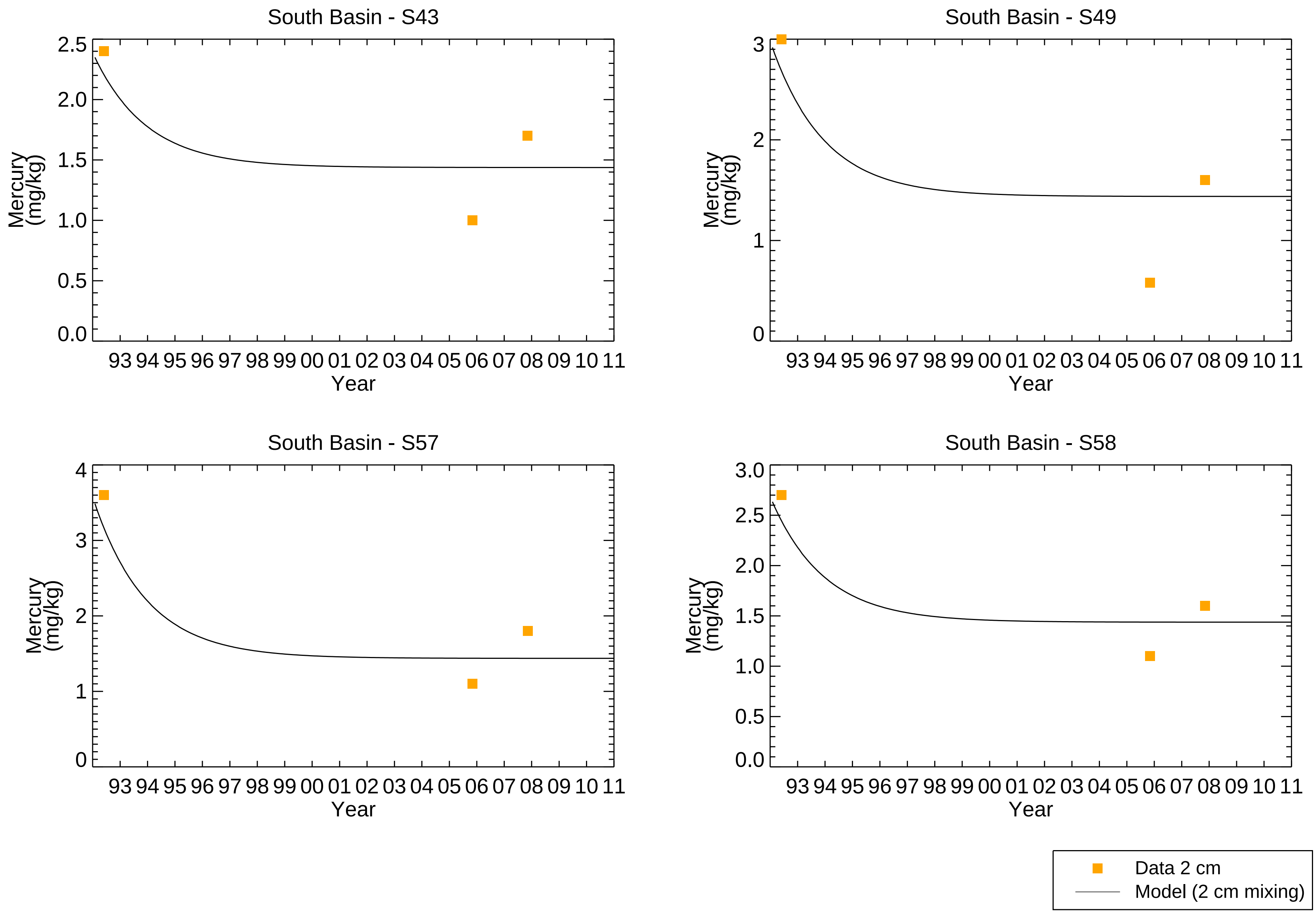


Figure A.11 Model Calibration: Model Predicted Mercury Concentrations Compared to Observed Concentrations

Honeywell

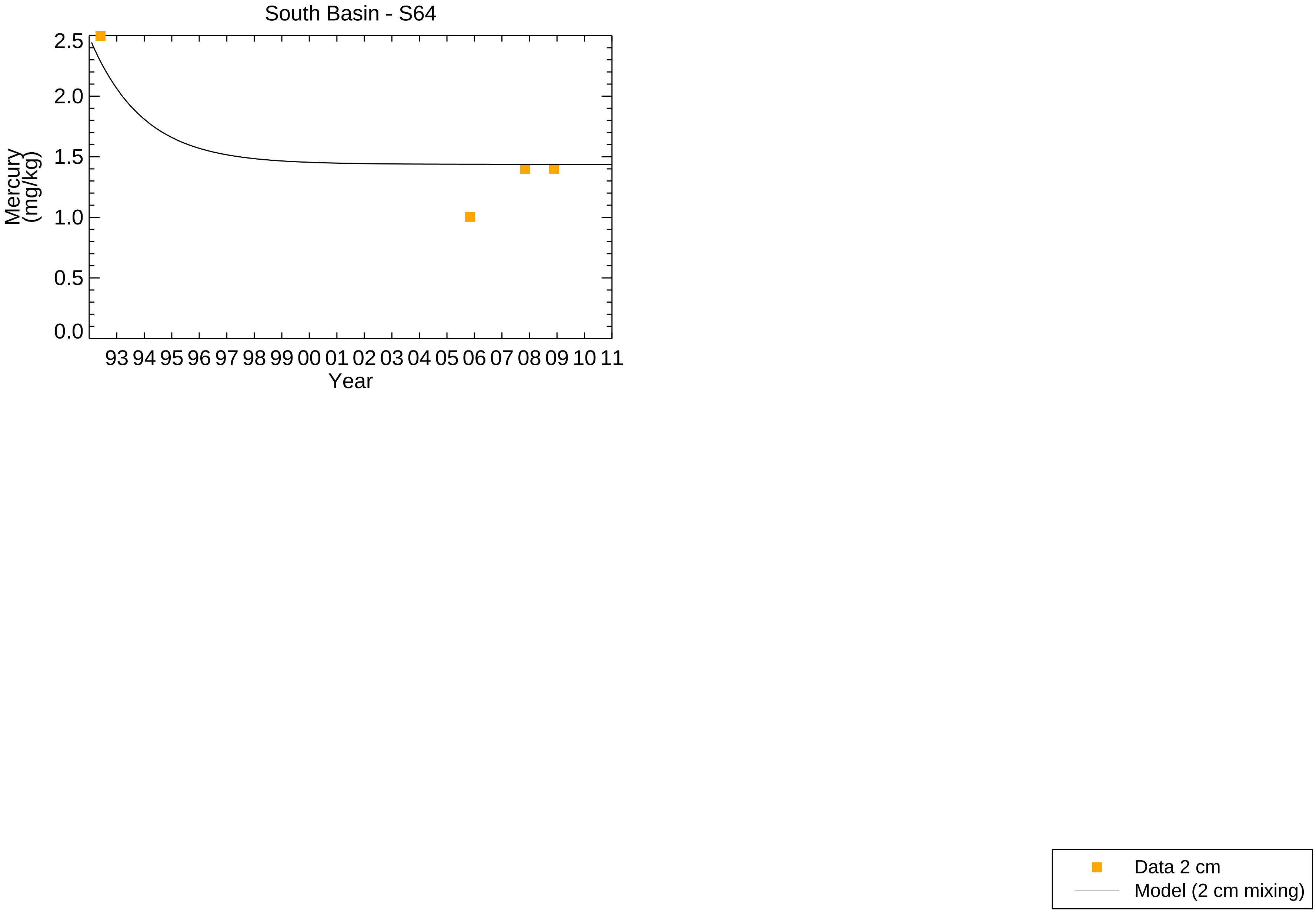


Figure A.11 Model Calibration: Model Predicted Mercury Concentrations Compared to Observed Concentrations

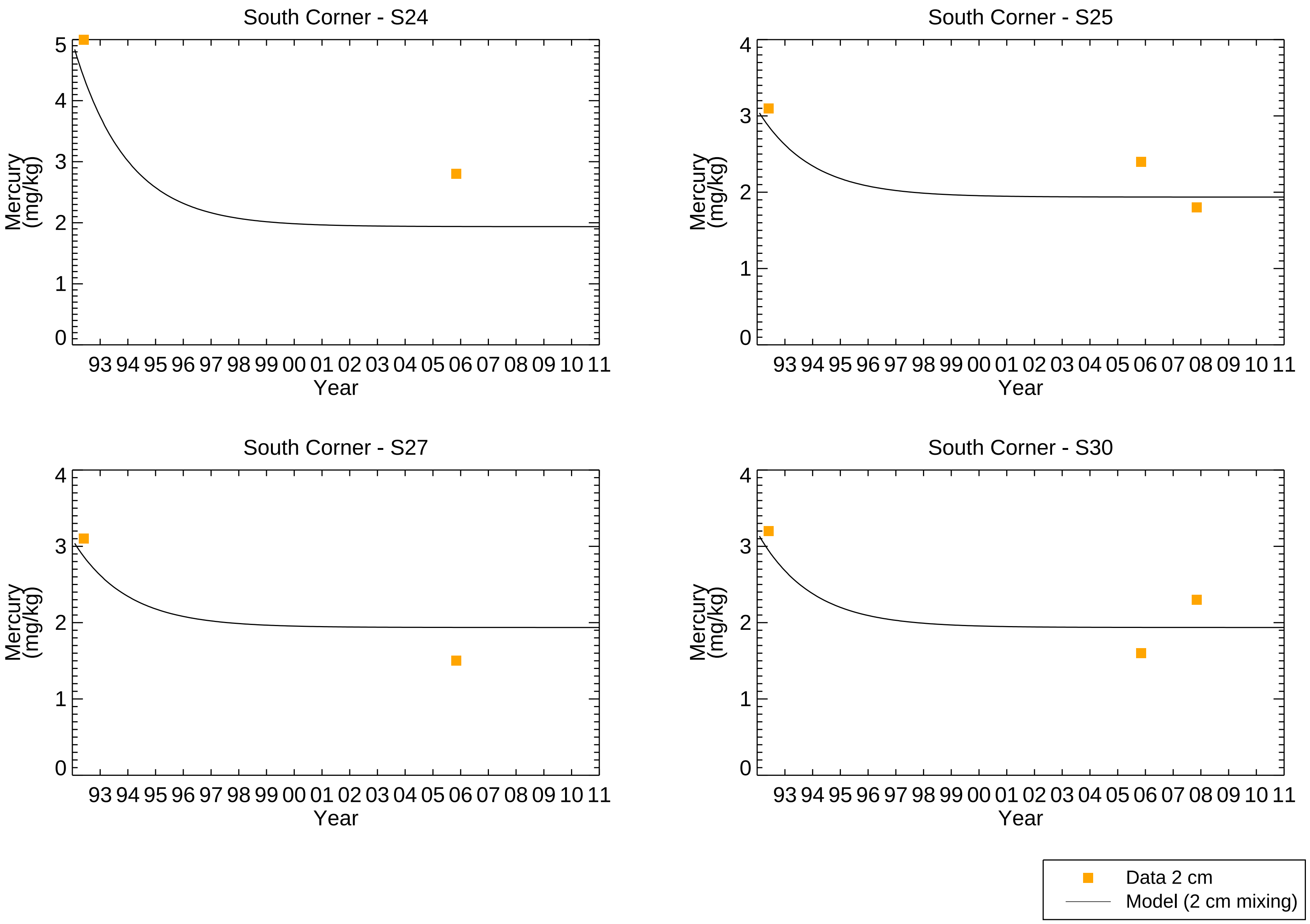


Figure A.11 Model Calibration: Model Predicted Mercury Concentrations Compared to Observed Concentrations

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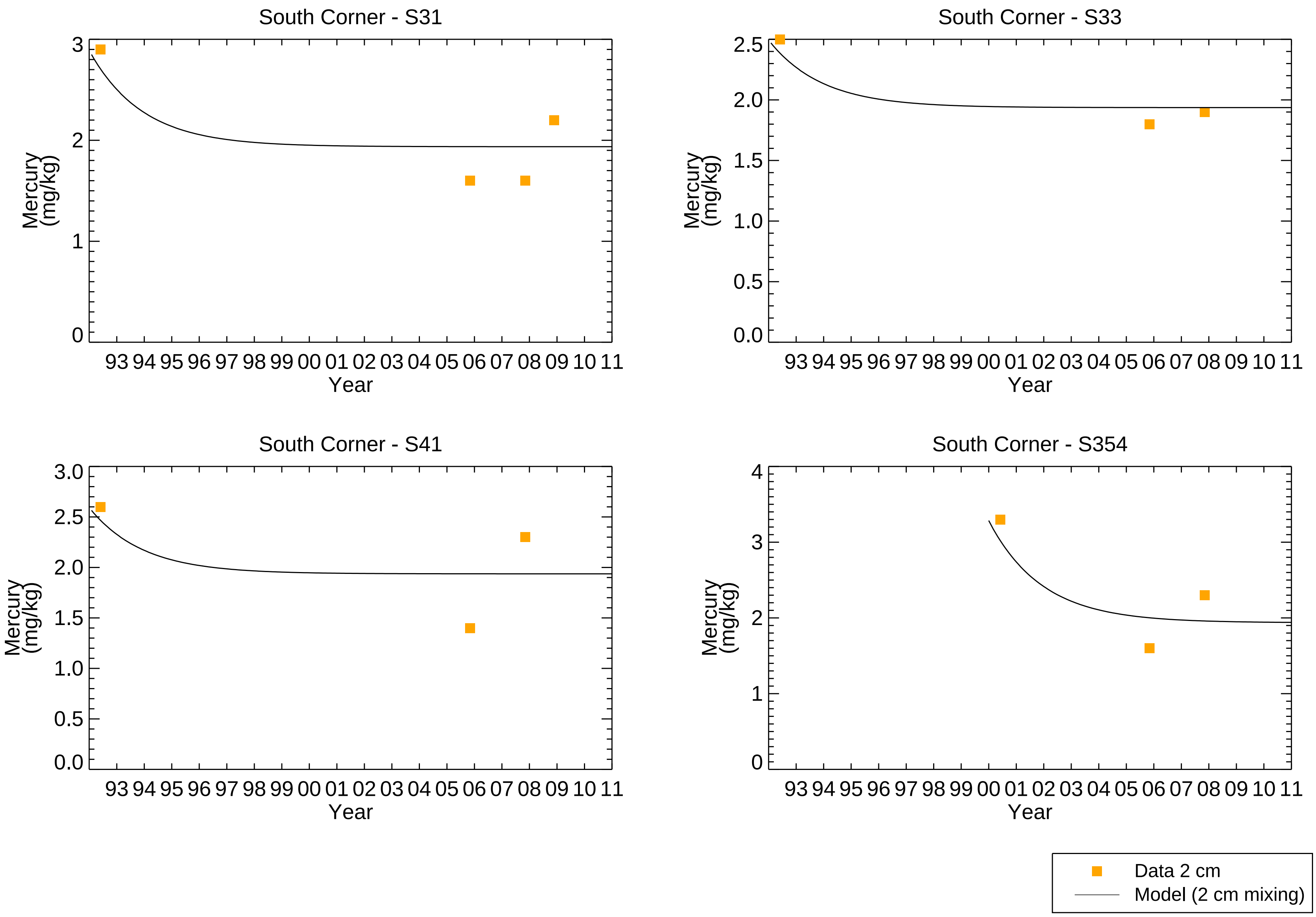


Figure A.11 Model Calibration: Model Predicted Mercury Concentrations Compared to Observed Concentrations

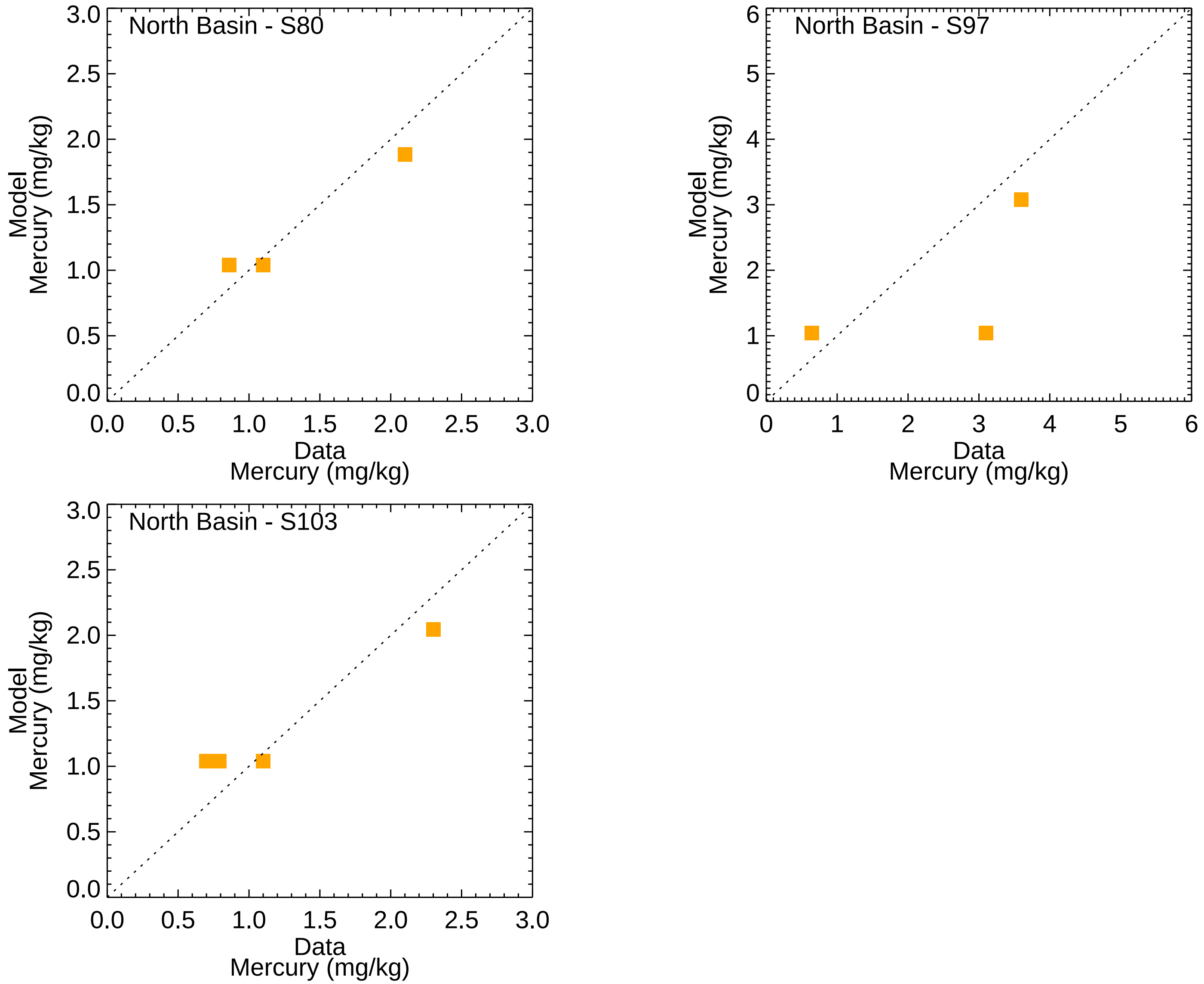
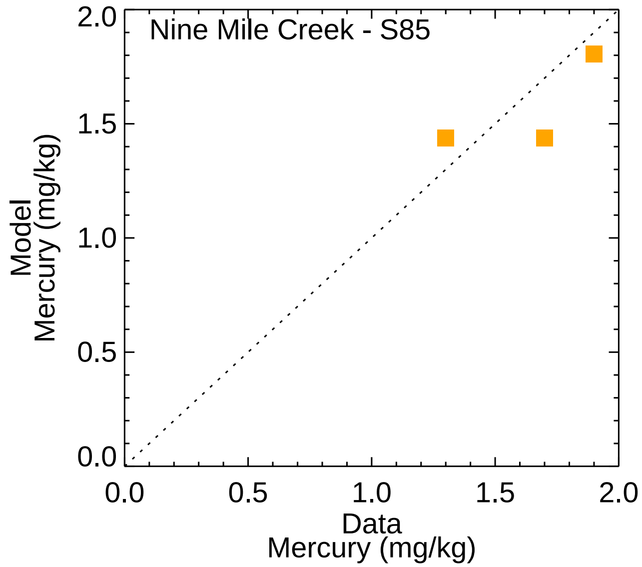


Figure A.12 MNR Model Calibration: Model Predictions Versus Data
SMU 8 Onondaga Lake



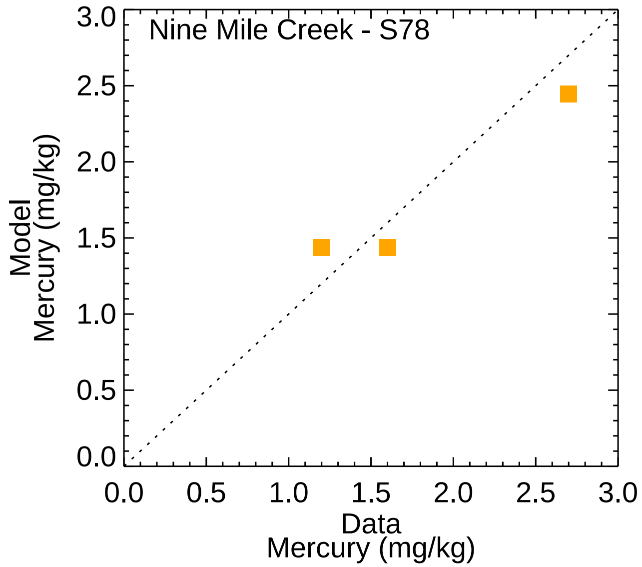


Figure A.12 MNR Model Calibration: Model Predictions Versus Data
SMU 8 Onondaga Lake

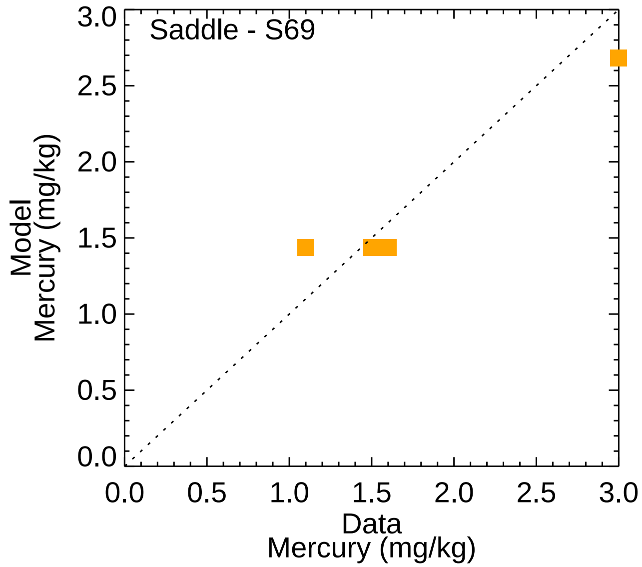


Figure A.12 MNR Model Calibration: Model Predictions Versus Data
SMU 8 Onondaga Lake

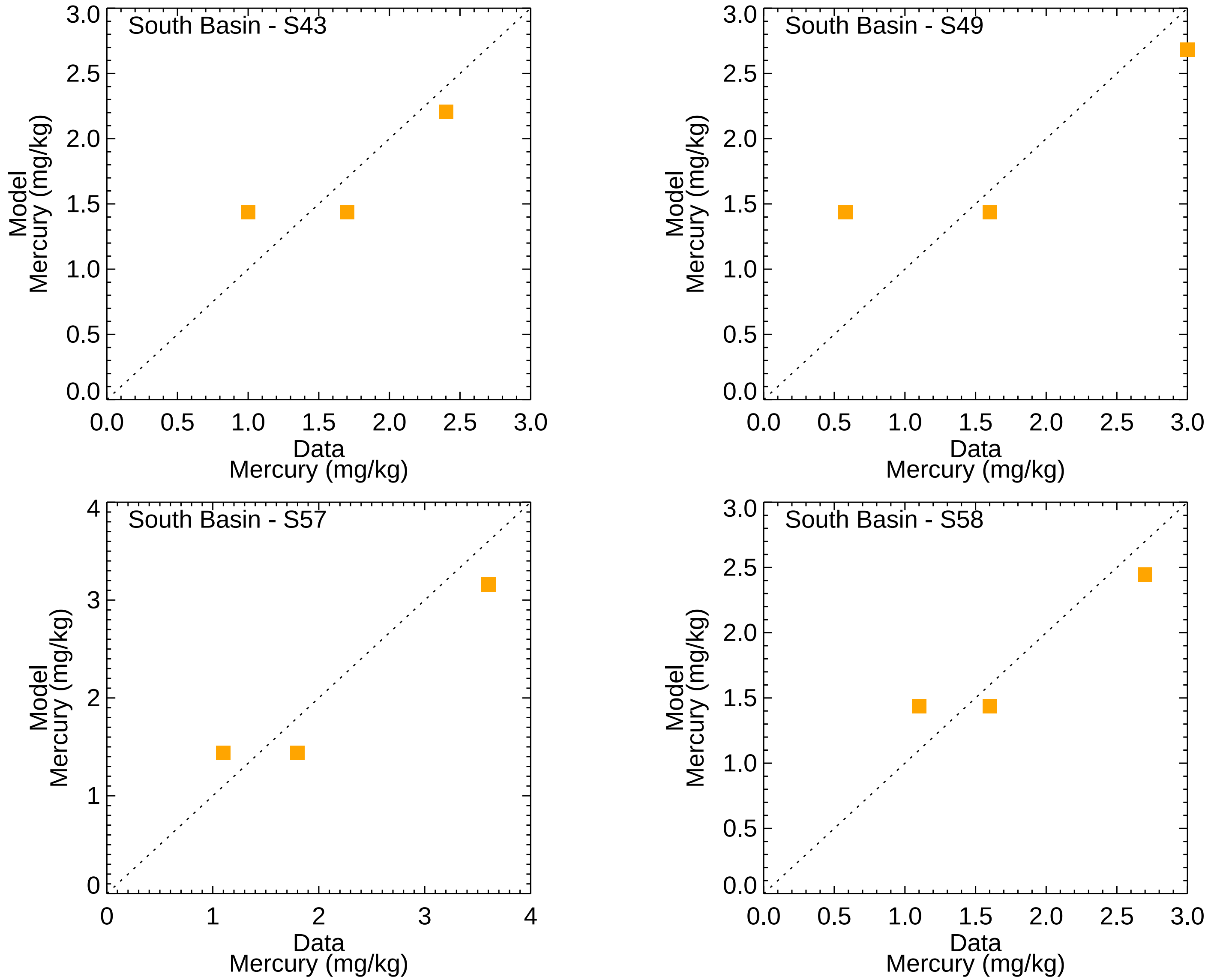


Figure A.12 MNR Model Calibration: Model Predictions Versus Data
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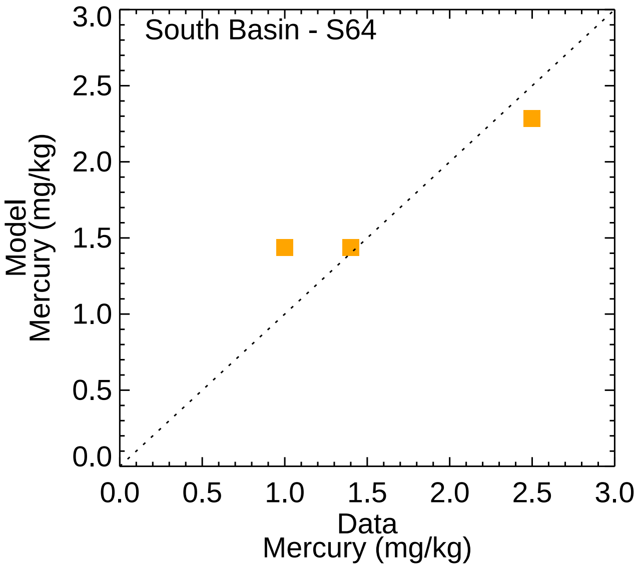

Figure A.12 MNR Model Calibration: Model Predictions Versus Data
SMU 8 Onondaga Lake

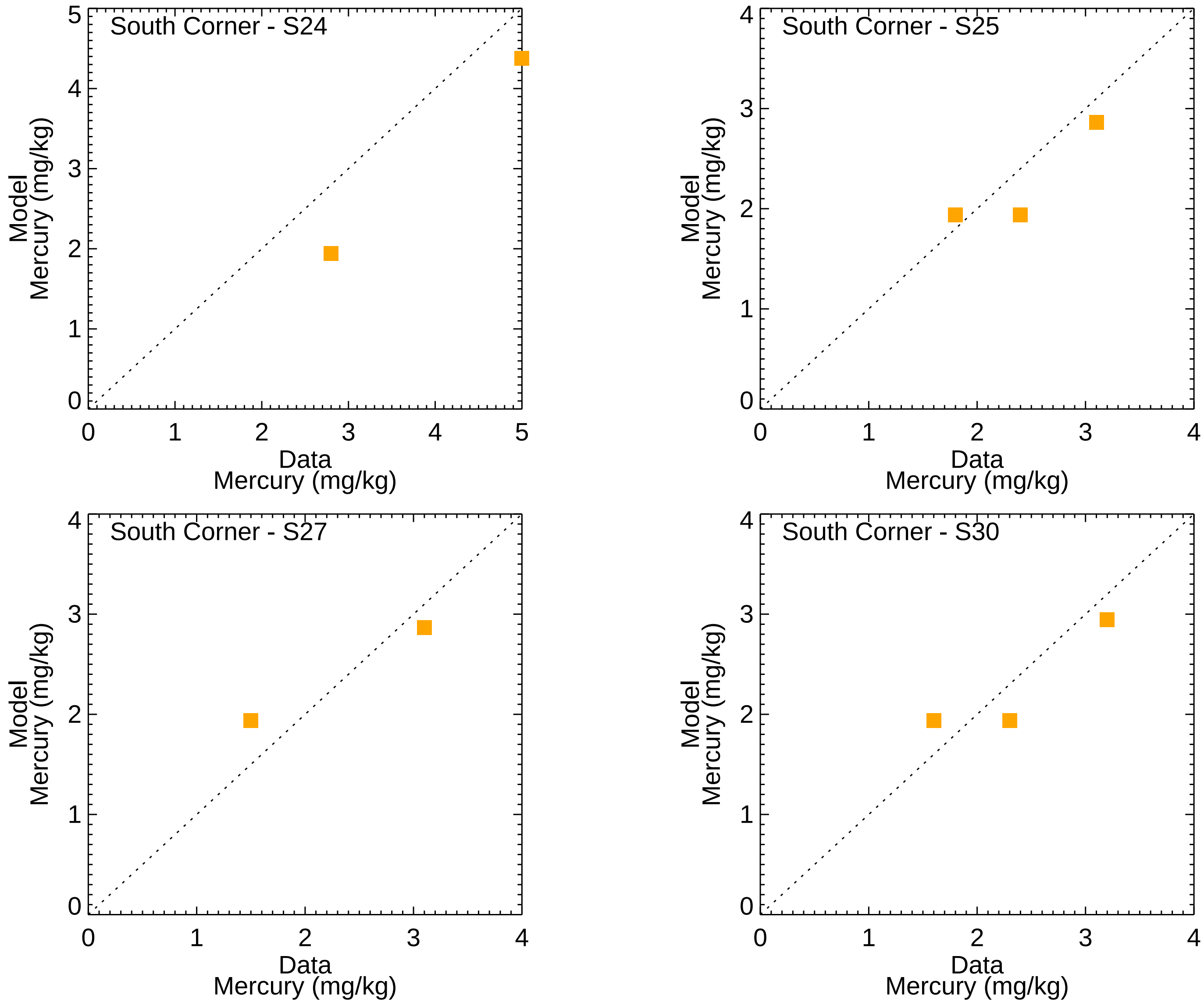

Figure A.12 MNR Model Calibration: Model Predictions Versus Data
SMU 8 Onondaga Lake

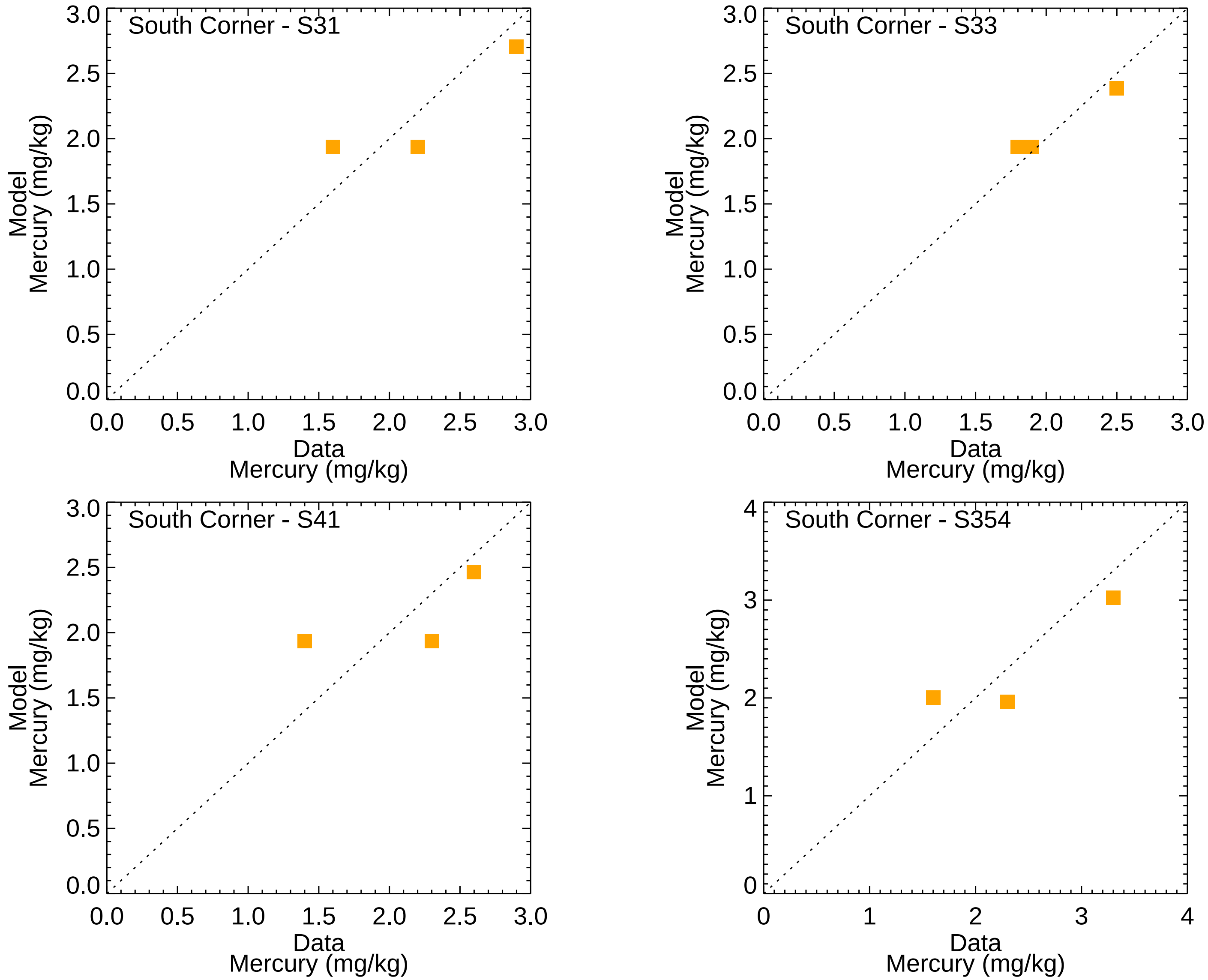

Figure A.12 MNR Model Calibration: Model Predictions Versus Data
SMU 8 Onondaga Lake

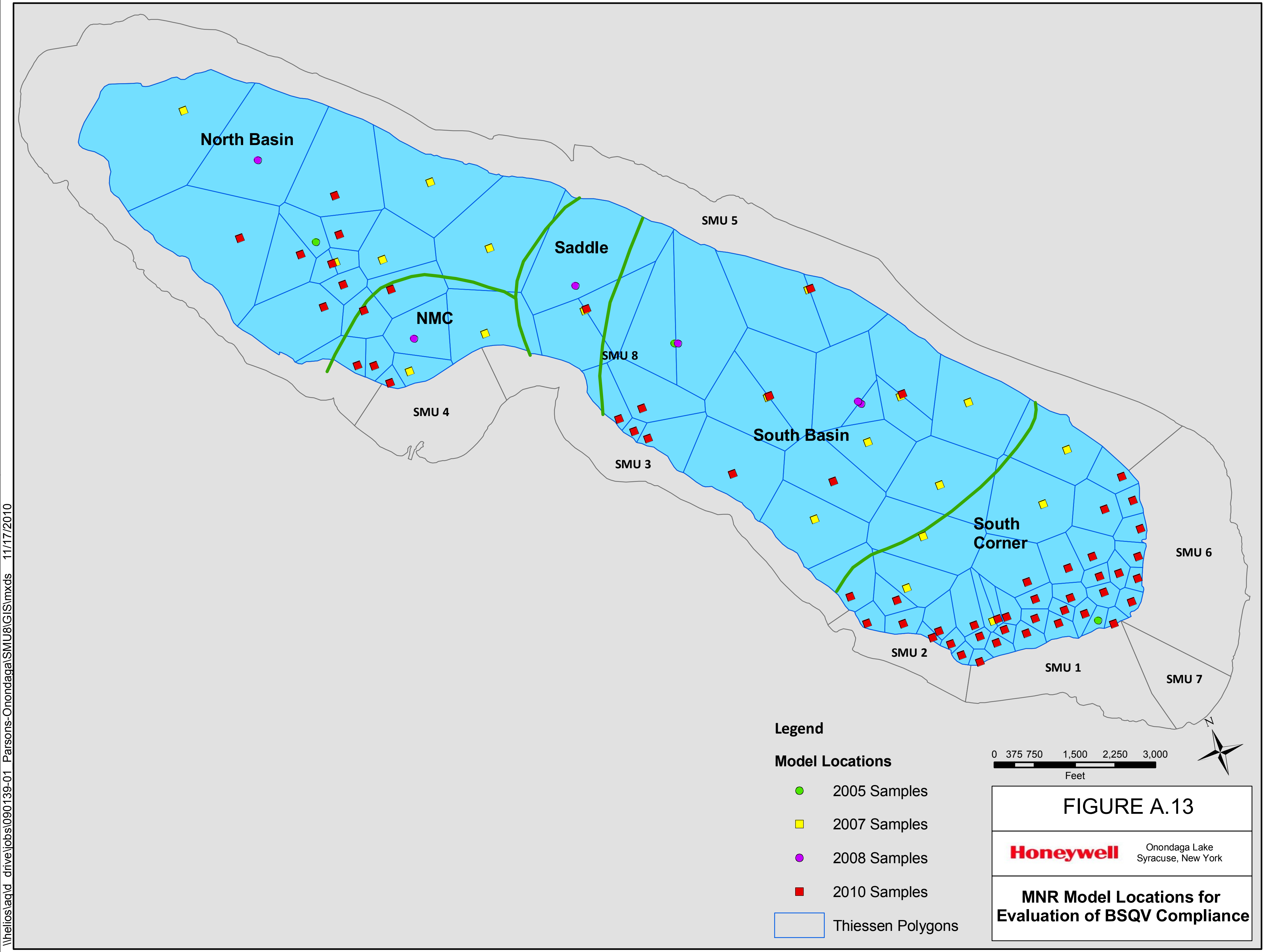

FIGURE A.13

MNR Model Locations for Evaluation of BSQV Compliance

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