EXECUTIVE SUMMARY

Honeywell International Inc. (Honeywell; formerly AlliedSignal) is currently conducting a comprehensive remedial investigation/feasibility study (RI/FS) of Onondaga Lake, located near Syracuse, New York (Chapter 1, Figures 1-1 and 1-2). The RI/FS is being conducted under a Consent Decree with the State of New York dated January 9, 1992, as amended (Index No. 89-CV-815). The scope and details of the RI/FS were originally developed through negotiations between Honeywell, the New York State Department of Law (NYSDOL), and the New York State Department of Environmental Conservation (NYSDEC), and are specified in the Consent Decree and the approved Onondaga Lake RI/FS Work Plan (PTI, 1991c), which is an appendix to the Consent Decree. Over time, NYSDEC approved numerous modifications to the work plan, which are identified in Chapter 2 of this RI report.

This rewrite of Honeywell's revised RI report was prepared by NYSDEC and TAMS Consultants, Inc. (TAMS), with the assistance of the New York State Department of Health (NYSDOH), NYSDOL, and the US Environmental Protection Agency (USEPA) following New York State's disapproval of two draft RI reports prepared by Honeywell and its consultants in 1998 and 2001. The reasons for disapproval of Honeywell's revised RI report (Exponent, 2001c) are outlined in the determination accompanying this document. The primary objectives of this Onondaga Lake RI, as identified in the RI/FS Work Plan (PTI, 1991c), were to:

- Define the areal extent of contamination with respect to Honeywell-related substances for the Onondaga Lake system and related areas and identify and quantify other substances of potential concern.
- Identify and quantify sources of Honeywell-related substances to the Onondaga Lake system.
- Characterize the distribution of Honeywell-related substances and other substances in the Onondaga Lake system under past, present, and future conditions.
- Estimate the potential human health risks posed by mercury and other substances.
- Determine the ecological significance of mercury, calcite ($CaCO_3$) deposits, and other substances in the Onondaga Lake system.

This RI was governed by project work plans approved by, or finalized by, NYSDEC and incorporates comments provided by NYSDEC on the draft RI reports for Onondaga Lake prepared by Honeywell. The Onondaga Lake Baseline Ecological Risk Assessment (BERA) and Onondaga Lake Human Health Risk Assessment (HHRA), which are components of the RI, are included under separate cover (TAMS, 2002a,b) and are summarized in this report.

This executive summary is organized as follows: the structure and a summary of the key findings of this RI are presented first, followed by summaries of the field investigations; site description; the sources of contamination to the lake; the nature and extent of contamination in the lake, adjoining wetlands, and dredge spoils area; the transport and fate of contaminants; the baseline risk assessments; and, finally, the preliminary remedial action objectives (RAOs).

1. Key Findings

Chapters 1 through 3 of this Onondaga Lake RI report present information on site history, field and laboratory investigations, and physical characteristics of the site. Chapter 4 provides information on the Honeywell sources and potential sources of contamination, as well as the non-Honeywell sources and potential sources. The key findings of Chapter 4 include:

- Based on site histories and extent of contamination, the most significant upland sources of mercury to the lake include the various Honeywell sites.

- The major routes of migration of chemical parameters of interest (CPOIs), as defined in Chapter 1, Section 1.6, from these sources include tributaries affected by these sites and contaminated sediments/wastes in the lake.

- Honeywell wastes discharged to Onondaga Lake include mercury; benzene, toluene, ethylbenzene, and xylenes (BTEX); chlorinated benzenes; polycyclic aromatic hydrocarbons (PAHs) (primarily low molecular-weight PAHs [LPAHs], but also some high molecular weight PAHs [HPAHs]); polychlorinated biphenyls (PCBs); polychlorinated dibenzo-*p*-dioxins and furans (PCDD/PCDFs); and Solvay waste (which was primarily composed of calcium carbonate, calcium silicate, and magnesium hydroxide, with lesser amounts of calcium oxide-calcium chloride complex, silicon dioxide, salt [NaCL], calcium chloride, aluminum or iron oxides, calcium hydroxide, calcium sulfate, ammonia, and metals [e.g., aluminum, arsenic, copper, lead, nickel, and zinc]) (PTI, 1992d). Honeywell wastes were discharged primarily through the West Flume/Geddes Brook/Ninemile Creek system and the East Flume.

- There are dense non-aqueous phase liquid (DNAPL) sources containing BTEX, chlorinated benzenes, and LPAHs at, and adjacent to, the Honeywell shoreline area.

- There were other industries in the area which discharged various contaminants including metals (e.g., chromium), PCBs, and HPAHs.

Chapter 5 characterizes the nature and extent of contamination in lake sediments, tributary sediments, wetland sediments, dredge spoils area material, sediment porewater, lake water, tributary water, groundwater, and biological tissue. The key findings of this chapter include:

Lake Sediments

- Mercury contamination is found throughout the lake, with the most elevated concentrations detected in sediments in the Ninemile Creek delta and in the Honeywell in-lake waste deposit along the southwestern shoreline between Tributary 5A and extending beyond Harbor Brook.

- Mercury contamination is widespread in the upper 2 m of the sediments in the lake, and it is even deeper in sediment in the Ninemile Creek delta and the Honeywell in-lake waste deposit. At the Ninemile Creek delta, mercury contamination extends to a depth of at least 5 m into the sediments. At the in-lake waste deposit, mercury contamination extends to a depth of about 8 m into the sediments.

- Chromium is concentrated north of Tributary 5A, in front of the Crucible Materials Corporation facility to a depth of at least 2 m (the depth of the cores in this area). Chromium contamination extends to a depth of at least 6 m in sediments around the Ninemile Creek delta and the Honeywell in-lake waste deposit.

- Cadmium is widespread in the lake in the top 2 m of sediments, with the highest concentrations located in the Ninemile Creek delta and the Honeywell in-lake waste deposit. Cadmium contamination in the Ninemile Creek delta and the in-lake waste deposit extends to a depth of at least 8 m in the sediments.

- Elevated concentrations of lead, nickel, and zinc are widespread in the upper 2 m of the sediments in the lake. From below 3 m to at least 7 m, elevated concentrations of these metals occur mostly in the Ninemile Creek delta, the Honeywell in-lake waste deposit, and, in the case of zinc, in the vicinity of Harbor Brook.

- The organic contaminants (e.g., BTEX, chlorinated benzenes, LPAHs, PCBs, and PCDD/PCDFs) are primarily found in the Honeywell in-lake waste deposit and the shoreline area of the Honeywell sites, with concentrations of these CPOIs in the waste several orders-of-magnitude higher than in most of the lake. At the in-lake waste deposit, elevated concentrations of these CPOIs extend to at least a depth of 8 m. HPAHs are concentrated in the sediments throughout much of the southern basin, with the highest concentrations occurring off the Oil City shoreline region and the Honeywell shoreline area.

- Elevated contaminant concentrations and visual evidence (liquids, droplets, sheens) indicate that DNAPL exists throughout the Honeywell in-lake waste deposit. Because the in-lake waste deposit is essentially a continuation of disposal on the shoreline, it is unclear if the DNAPL is actually migrating into the lake or was directly disposed of there. In the areas far from shore (200 to 300 m), it is most likely that these DNAPLs were disposed of directly into the lake with the other wastes. Closer to shore, it is possible that some of these DNAPLs migrated from the shoreline.

Tributary Sediments

- Mercury concentrations were highest in the West Flume, Ninemile Creek, Geddes Brook, and Harbor Brook. Tributary 5A and Ley Creek contained the highest concentrations of other metals, while the East Flume, Tributary 5A, and Harbor Brook had the highest concentrations of organic contaminants.

Wetland Sediments

- Wetland SYW-19, which is adjacent to the Wastebed B disposal area, contains elevated concentrations of mercury, lead, chlorinated benzenes, PAHs, PCBs, and PCDD/PCDFs. This area is being further investigated as part of the Wastebed B/Harbor Brook RI/FS.

- Wetland SYW-12 between the mouths of Ley Creek and Onondaga Creek contains the highest concentrations of cadmium and chromium.

- Wetland SYW-6 in the northern part of the lake contains elevated concentrations of mercury, LPAHs, and HPAHs in the 15 to 30 cm interval of Station SYW6-3.

Dredge Spoils Area

- The elevated concentrations of mercury (up to 100 mg/kg) in the dredge spoils area confirmed the reported historic disposal of mercury-contaminated sediments dredged from the Ninemile Creek delta in the late 1960s.

Water Column

- Concentrations of total mercury in lake water were highest in the nearshore areas around both Ninemile Creek and the Honeywell in-lake waste deposit. In the deep basins, water column total mercury concentrations increased significantly in the hypolimnion during summer stratification, with a high fraction of this hypolimnetic total mercury occurring in the dissolved phase.

- Concentrations of benzene, chlorobenzene, and dichlorobenzenes in lake water were highest near the Honeywell source areas in the vicinity of the East Flume and Harbor Brook.

Biota

- Mercury, PCBs, and PCDD/PCDFs have bioaccumulated in Onondaga Lake fish, and likely in other biota as well.

Chapter 6 describes the transport and fate of the CPOIs, and addresses three major chemical groups: mercury, non-mercury compounds, and ionic wastes (calcite precipitation).

General

- The lake is a sink for essentially all contaminants. For every CPOI examined, the estimated loads of contaminants entering the lake are at least five times greater than the loads leaving the lake.

- Several important contaminant source areas or mechanisms have been identified. These transport routes serve to deliver multiple contaminants to the lake. Among the more important routes and mechanisms are the following:

  - Ninemile Creek: This tributary has been and continues to be the single most important external source for total mercury. It has also been a source of PCDD/PCDFs, PCBs, lead, and chromium to the lake.

  - Harbor Brook: This tributary has been and continues to be a major source of LPAHs, particularly naphthalene, to the lake.

  - Ley and Onondaga Creeks: These tributaries appear to be ongoing sources of PCBs, and possibly PCDD/PCDFs, and are among the most important sources of lead to the lake.

  - East Flume: This tributary has been an important conduit for mercury, chlorinated benzenes, PAHs, and PCDD/PCDFs.

  - Honeywell lakeshore area groundwater: Transport of contaminants to the lake via groundwater represents the most important loading route for several CPOIs, including LPAHs such as naphthalene (from the Wastebed B/Harbor Brook site), chlorobenzene and dichlorobenzenes (from the Willis Avenue site), and all four BTEX compounds (from the Willis Avenue, Semet Residue Ponds, and Wastebed B/Harbor Brook sites).

The DNAPL plumes, which lie beneath the Willis Avenue and Wastebed B/Harbor Brook sites, contribute to the groundwater contamination and may also be contributing DNAPL directly to the lake.

- Honeywell in-lake waste deposit: Resuspension of these materials presents a potentially important source of mercury to the lake, perhaps representing the main internal source to the water column. It is also a potentially important source of PCDD/PCDFs and other CPOIs such as BTEX, chlorinated benzenes, PCBs, PAHs, and other non-mercury CPOIs. Surface concentrations of several CPOIs are highly elevated in this waste area relative to the rest of the lake.

- Profundal sediments: These sediments appear to be responsible for the increase in the hypolimnetic mercury inventory during summer stratification. This increase is believed to be the source of dissolved mercury for production of methylmercury in the lake.

Mercury

- The lake sediments represent a huge reservoir of mercury. Both profundal and littoral sediments have high mercury inventories. Significant inventories of mercury exist in the littoral zone near the Honeywell lakeshore area. This inventory of mercury cannot be considered sequestered as it is in an area subject to wind-driven waves. Indeed, the in-lake waste deposit is located in this region, representing a clear source of contamination to the water column of the lake. The inventory of mercury within the profundal sediments is also not considered sequestered, based on the evidence for mercury release from these sediments.

- External loads, in particular tributary loads, of mercury to Onondaga Lake are relatively well known. However, these loads do not constitute the only sources of mercury to the water column of the lake.

- Internal loads of mercury, generated via sediment resuspension and other mechanisms, probably yield a net load to the water column similar in magnitude to the externally derived loads, at least during the period of summer stratification.

- Internally derived loads of mercury impact all major regions (i.e., both the hypolimnion and epilimnion) of the lake during the period of stratification.

- The primary removal mechanism for mercury in the water column of Onondaga Lake is particle settling. Deposition to the profundal sediments is the ultimate fate of mercury in the lake.

- The total mercury loads from the external sources identified in the initial RI/FS Work Plan (PTI,1991c) (tributaries and the Metropolitan Syracuse Sewage Treatment Plant [Metro] discharge, groundwater, porewater, precipitation) account for about 3,500 g out of the total budget of 11,000 g for the stratified period.

- The total mercury budget for waters of Onondaga Lake during the 1992 stratified period is estimated at11,000 g, based primarily on the losses from the system (specifically, the estimates of mercury transport via particle settling). The uncertainties in this value arise primarily from uncertainties involved in the estimates of mercury losses via particle settling. The actual budget for the lake during the period is expected to lie between the inputs (estimated at 3,500g) and the settling losses (estimated at 11,000 g).

- For the sources identified in the initial RI/FS Work Plan (PTI, 1992c), the tributaries and Metro provided the largest total mercury loads, with groundwater loads being the next largest. Among the tributaries, Ninemile Creek is the largest contributor of total mercury. During the 1992 stratified period of May 25 to September 21, 1992, Ninemile Creek contributed about 51 percent (about 1,270 g of mercury) of the total mercury load from the tributaries and Metro.

- Likely internal sources of total mercury not previously identified in the RI/FS Work Plan (PTI, 1992c) include: the resuspension and transfer of materials from the Honeywell in-lake waste deposit and the transfer of dissolved and particulate mercury from the profundal sediments. Resuspension and transfer of materials from the Honeywell in-lake waste deposit likely contributes a significant flux to the epilimnion mercury budget, while the transfer of materials from profundal sediments is a likely additional source of total mercury to the hypolimnion.

- The uncertainties in the mercury budget during the stratified period are chiefly associated with the magnitudes of the internal release and recapture of mercury within the lake. Despite this uncertainty, the main areas of mercury release to the lake are relatively well known based on the data accumulated to date.

  - Littoral sediments: The elevated surface concentrations, the historical records, and the direct measurements of water column increases over the littoral sediments adjacent to the Honeywell sites clearly identify this region as a major source of mercury to the epilimnion. Regardless of the transfer process, this area probably represents the most important internal source of mercury to the epilimnion.

- Profundal sediments: Studies completed by Honeywell have effectively eliminated all other possible sources to the hypolimnion. Thus, regardless of the transfer mechanism, the profundal sediments are the likely source of the hypolimnetic inventory increase as well as the observed increase in the particle settling flux of mercury through the hypolimnion.

- Wind-driven resuspension is a likely major mechanism for the release of contaminants from the Honeywell in-lake waste deposit and possibly other littoral zone sediments. Groundwater advection through these materials may also transport significant quantities of mercury as well as other CPOIs to the lake.

- Particle resuspension and increased diffusion associated with methane gas ebullition in the anoxic sediments (i.e., disturbance of the lake bottom sediments by escaping methane bubbles) are the likely mechanisms for the release of mercury from profundal sediments to the hypolimnetic water column.

- During fall turnover, the hypolimnetic inventory of total mercury does not escape to the epilimnion, but is rapidly removed from the lake water column and returned to the lake sediment, presumably by precipitation and deposition of suspended matter.

- The primary source of methylmercury to the water column is the methylation of total mercury in the hypolimnetic water column during the recurring anoxic stratified period. Diffusion of methylmercury across the thermocline during this period probably provides the majority of the methylmercury budget to the epilimnion.

- The production of methylmercury within the water column appears to be focused in the region just below the thermocline, at the top of the hypolimnion. This location appears to represent a dynamic balance of conditions, since this region was observed to rapidly move away from the deepening epilimnion during fall turnover.

- The methylmercury inventory developed in the hypolimnion during stratification escapes to the oxic waters of the lake after fall turnover, resulting in a substantial increase in the epilimnetic concentrations.

- Ninemile Creek and the Metro facility discharges represent the largest external loads of methylmercury. However, these loads are believed to be substantially smaller than those produced within the lake.

- Methylmercury production within the littoral sediments of the lake is not well documented, but may provide an alternate pathway for exposure to the benthic food chain.

Non-Mercury Compounds

- Like mercury, the lake sediments represent a huge reservoir of contaminant mass for many other contaminants. Significant inventories of contamination exist in the littoral zone near the Honeywell lakeshore area, extending along the shore as far as Ley Creek for some compounds. This inventory of contamination cannot be considered sequestered as it is in an area subject to wind-driven waves. Indeed, the in-lake waste deposit is located in this region, representing a clear source of contamination to the water column of the lake.

- Low molecular weight organics, such as BTEX, chlorinated benzenes, and LPAHs, tend to be found in sediments closest to the Honeywell facilities. An apparent combination of rapid deposition and rapid biodegradation, as well as groundwater-based releases, results in a sediment inventory that is primarily located near the source area.

- High molecular weight organics (i.e., PAHs, PCDD/PCDFs, PCBs) are present at elevated levels throughout the lake bottom sediments, reflecting their resistance to biodegradation as well as the extended period of discharge to the lake by Honeywell and possibly other sources.

- The likely sources of the current loads of BTEX, chlorinated benzenes, and LPAHs include groundwater and DNAPL from the various Honeywell upland sites and the Honeywell in-lake waste deposit area.

- The primary fate processes of the Honeywell-related lighter organic compounds (e.g., BTEX, chlorobenzene) include volatilization and likely biodegradation. These fate processes tend to limit the extent of these compounds to the general vicinity of their source areas.

- The likely primary sources of PCBs to the lake are the Honeywell in-lake waste deposit and Ley Creek.

- The likely primary sources of PCDD/PCDFs to the lake are Ninemile Creek (octachlorodibenzodioxin- [OCDD-] and tetrachlorodibenzofuran [TCDF-] dominant), the East Flume (TCDF-dominant), and Ley Creek (OCDD-dominant).

- The primary fate of PCBs and PCDD/PCDFs is deposition to the sediments.

- Elevated levels of cadmium, chromium, copper, lead, nickel, and zinc can be found in the lake sediments. The pattern of contamination suggests sources other than, or in addition to, Honeywell for many of these metals. In part because of their longevity in the environment, these metals can be found at levels above background throughout the sediments of the lake bottom.

- The loadings of metals (e.g., cadmium, chromium, lead, and mercury) to the lake have decreased from peak values in the 1960s, based on the sediment records in the deep basins.

Calcite Precipitation and Ionic Wastes

- The rate of calcite formation has diminished by at least half since the closure of Honeywell's Main Plant. This, along with remediation of the Tully Mudboils, has reduced the sedimentation rate in the lake by at least half.

- Currently, ionic concentrations remain elevated with respect to other nearby water bodies, but overall, ionic concentrations in the lake water have been drastically reduced from conditions in the 1980s and earlier.

- Oncolites are found throughout the littoral zone along most of the northern part of the lake.

Chapters 7 and 8 summarize the Onondaga Lake Human Health Risk Assessment (HHRA) and the Onondaga Lake Baseline Ecological Risk Assessment (BERA), respectively (TAMS, 2002b,a). The key findings of the risk assessments include:

- As discussed in the HHRA, contamination in Onondaga Lake presents risks to human health that are above USEPA guidelines. In addition, the primary sources of cancer risks and non-cancer hazards are due to mercury, PCBs, and PCDD/PCDFs as a result of the consumption of Onondaga Lake fish. The finding of elevated risk and hazard estimates for mercury and PCBs is consistent with the fact that concentrations of these chemicals in fish tissues collected from Onondaga Lake exceed US Food and Drug Administration (US FDA) action limits.

- As discussed in the BERA, contamination in the lake presents risks to all trophic levels of the Onondaga Lake ecosystem. Comparisons of measured tissue concentrations and modeled doses of chemicals to toxicity reference values (TRVs) show exceedances of hazard quotients (HQs) for site-related chemicals throughout the range of the point estimates of risk. Many of the contaminants in the lake are persistent and therefore, the risks associated with these contaminants are unlikely to decrease significantly in the absence of remediation. On the basis of these comparisons, it has been determined through the BERA that all receptors of concern are at risk due to site impacts. Based on sediment toxicity testing, the most toxic sediments are found in the nearshore zone in the southern part of the lake between Tributary 5A and Ley Creek. These sediment locations have the highest number of compounds that exceed the site-specific sediment effect concentrations. The contaminants presenting the greatest risk from chemical toxicity are mercury, chlorinated benzenes, PAHs, PCBs, and PCDD/PCDFs. In addition, ionic waste, including oncolites, has ongoing impacts on the ecological communities in the lake.

Chapter 9 of this RI presents the report's conclusions, including the preliminary RAOs and identification of potential applicable or relevant and appropriate requirements (ARARs) and to-be-considered (TBC) criteria. Chapter 10 presents references for all documents and personal communications cited in the main body of the report.

2. Summary of Investigations

As set forth in detail in Chapter 2, field investigations for this RI were conducted in Onondaga Lake and its associated tributaries, wetlands, and dredge spoils area from 1992 to 2000 by Honeywell and its consultants. The initial five major field investigations (geophysical survey, substance distribution, mercury and calcite mass balance, ecological effects, and bioaccumulation) were performed in 1992. Investigations of the East Flume, the West Flume, and Ninemile Creek were conducted from 1993 through 1995. Additional studies of mercury methylation/remineralization were conducted for this RI in 1996. Supplemental lake water sampling was performed in 1999. The Phase 2A investigation in 2000 involved extensive lake sediment sampling along with sampling of four wetlands and the dredge spoils area on the northwest shore of the lake.

In addition to the sampling performed by Honeywell and its consultants from 1992 to 2000, limited sampling of lake water and wetland sediment was performed by NYSDEC/TAMS in 2001 and 2002 as part of this RI. The results of the investigations performed from 1992 through 1996 were previously submitted as individual data reports. Data reports or tabulations for the 1999 through 2002 investigations are included as appendices with this RI report. More than 6,000 samples of water, sediments, and organisms were collected during the RI, and more than 130,000 data points have been generated from those samples.

3. Site Description

Onondaga Lake is located in the Oswego River drainage basin in Onondaga County, in central New York State (latitude 43°06′54″; longitude 76°14′34″). The lake has been designated as a National Priorities List (NPL) site (CERCLIS ID number NYD986913580). Ninemile Creek and Onondaga Creek combined and the discharge from Metro supply approximately 65 and 25 percent, respectively, of the annual water inflow to the lake.

The southern end of Onondaga Lake borders the city of Syracuse and is a heavily developed urban and industrial area. The lake has received municipal and industrial discharges for more than 100 years. For consistency with the terminology in the Consent Decree, the site includes Onondaga Lake, its outlet, and tributaries that may have been directly affected by Honeywell operations. Among the tributaries directly affected by Honeywell are Ninemile Creek and its tributaries, Geddes Brook and the West Flume; Tributary 5A; the East Flume; and Harbor Brook (Chapter 1, Figure 1-3). To the extent that any of the tributaries have released and continue to release CPOIs to the lake, this RI addresses these contaminants. Honeywell has entered into consent orders to perform separate, comprehensive RI/FSs for each of the tributaries known to have been affected by Honeywell. Tributaries were evaluated by measuring sediment and water quality conditions at the mouths of the tributaries, and were also considered by evaluating their loadings of contaminants to the lake.

NYSDEC has also required that Wetlands SYW-6 and SYW-12 be included in the site. In addition to the areas of the site listed above, this RI and the risk assessments include an evaluation of limited data that were collected in Wetlands SYW-10 and SYW-19 and an upland area associated with the dredge spoils area located north of the mouth of Ninemile Creek. The nature and extent of contamination and risks associated with Wetlands SYW-10 and SYW-19 and the dredge spoils area will be further evaluated as part of separate sites and, therefore, the analysis associated with these areas in this RI is considered preliminary, pending the finalization of the studies associated with these other sites. Specifically, Wetland SYW-10 will be further evaluated as part of the RI/FS for the Geddes Brook/Ninemile Creek site; Wetland SYW-19 will be further evaluated as part of the RI/FS for the Wastebed B/Harbor Brook site; and the dredge spoils area will be further evaluated as a separate site with its own investigation. The site description is fully addressed in Chapter 1.

4. Sources and Potential Sources of Chemical Parameters of Interest

The analysis of sources and migration pathways of contaminants in Onondaga Lake, discussed in detail in Chapter 4, includes:

- A summary of existing information on the migration of contaminants to the lake and its tributaries from upland sites associated with former Honeywell activities.

- A summary of existing information on the migration of contaminants to the lake and its tributaries from upland sites associated with non-Honeywell activities.

Chemical parameters of interest include a broad range of chemicals (e.g., hazardous substances, such as mercury, chlorinated benzenes, and PCBs and potentially less hazardous stressors, such as calcium and chloride) that are investigated and evaluated in this RI in order to determine the nature and extent of contamination within the Onondaga Lake site. These CPOIs are defined at Chapter 1, Section 1.6 and are those elements or compounds that were selected as contaminants of potential concern (COPCs), contaminants of concern (COCs), or stressors of concern (SOCs) in the BERA and HHRA (TAMS, 2002a,b).

The description of migration or potential migration of contaminants to Onondaga Lake from upland sites does not reflect current or planned remedial activities at these sites. An objective for remediation of upland sites, in addition to improving conditions at the sites themselves, is to reduce or eliminate site-related loading of contaminants to Onondaga Lake.

Upland Honeywell sources of contaminants are summarized as follows:

- The LCP Bridge Street site contributes mercury to Onondaga Lake via the West Flume, Geddes Brook, and Ninemile Creek.

- Sediment, and possibly floodplain soils, in Geddes Brook and Ninemile Creek transports mercury and other contaminants to Onondaga Lake under high-flow conditions.

- The Honeywell Lakeshore area (Semet Residue Ponds, Willis Avenue, and Wastebed B/Harbor Brook sites) contributes mercury, BTEX, chlorinated benzenes, and PAHs to Onondaga Lake via surface water (i.e., Tributary 5A, the East Flume, and Harbor Brook) and groundwater discharge, as well as DNAPL discharge (associated with the Willis Avenue and Wastebed B/Harbor Brook sites).

- The Solvay Wastebeds contribute various contaminants, including, among others, sodium, calcium, ammonia, and chloride, to groundwater, Ninemile Creek, and to Onondaga Lake.

- Historical evidence indicates that Honeywell disposed of a combined waste stream (Solvay waste, mercury, organics, sewage) into the lake through the East Flume and other discharge points, creating a large (approximately 3 million cubic meters) delta of wastes in the lake from Tributary 5A to beyond Harbor Brook (Honeywell in-lake waste deposit area).

There are several other industrial and municipal facilities or sites that are either contributors or potential contributors of CPOIs to the lake or its tributaries. Sites along Ley Creek include the General Motors – former Inland Fisher Guide (GM – IFG) facility and Ley Creek Deferred Media site, the GM Old Ley Creek Channel site, the GM Ley Creek Dredgings site, and the Town of Salina Landfill. Between Ley Creek and Harbor Brook are sites on the lakefront area or on Onondaga Creek, including historical operations from facilities in the Oil City area, the former Niagara Mohawk Power Corporation manufactured gas plants (MGPs) on Hiawatha and Erie Boulevards, Metro, the American Bag and Metal site, and Roth Steel. North of Tributary 5A are the Crucible Materials Corporation facility and the Crucible Lake Pump Station disposal site. The Electronics Park facility (formerly operated by General Electric and currently operated by Lockheed Martin) potentially contributed to contamination in Bloody Brook. The

Maestri 2 and Doring Property sites, in the vicinity of lower Ninemile Creek, contain mill scale and possibly other wastes.

5. Nature and Extent of Contamination

As set forth in Chapter 5, the RI involved chemical analysis of sediment, water (surface water, groundwater, and porewater), zooplankton, benthic macroinvertebrates, and fish from Onondaga Lake; sediment and water from tributary mouths; sediment from wetlands (New York State-regulated Wetlands SYW-6, 10, 12, and 19) adjacent to the lake and relevant to this study; and soil from the dredge spoils area on the northwest shoreline. These chemical data were used to define the nature and extent of contamination. In conjunction with data from upland sites, these data were also used to identify and quantify, to the extent possible, the loading of substances to Onondaga Lake from Honeywell-related sources. They were also used to characterize the historical distribution of Honeywell-related substances and estimate potential future releases from contaminated media.

The most contaminated areas in Onondaga Lake with elevated concentrations of contaminants are the Honeywell in-lake waste deposit in the southern end of the lake and near the mouth of Ninemile Creek. Elevated concentrations of mercury are found throughout the lake in the upper 2 m of sediment. The highest concentrations of mercury are found in the Ninemile Creek delta and in the Honeywell in-lake waste deposit. In these two locations, mercury contamination is found much deeper in the sediments than in other parts of the lake. At the Ninemile Creek delta, mercury contamination extends to a depth of at least 5 m into the sediments. At the in-lake waste deposit, mercury contamination extends to a depth of about 8 m into the sediments.

In the deep basins of the lake, mercury (and other metals such as chromium, cadmium, and lead) concentrations were elevated at the surface, and even more so at depth (approximately 18 to 45 cm below the sediment surface). The highest concentrations of chromium in sediments are found just north of Tributary 5A. The highest concentrations of organic substances (including chlorinated benzenes, BTEX, PAHs, PCBs, PCDD/PCDFs) were found in the in-lake waste deposit located between Tributary 5A and Harbor Brook. Sediments in other areas of the lake contain significantly lower concentrations (orders-of-magnitude lower, and often not detectable) of these organic CPOIs. Exceptions to this pattern are PAHs as there are also elevated concentrations in the sediments in front of the Oil City area and PCBs as there are also elevated concentrations in the sediments in front of Ley Creek. Even in these areas, the contamination is limited to the upper 1 to 2 m of sediment. Elevated organic contaminant concentrations in the in-lake waste deposit in front of the Honeywell sites extend from the surface of the waste to the deepest samples collected (8 m).

In tributary sediments, Tributary 5A and Ley Creek contained the highest concentrations of metals, while the East Flume, Tributary 5A, and Harbor Brook had the highest concentrations of organic contaminants. The highest mercury concentrations occurred in the West Flume (131 mg/kg), Ninemile Creek (118 mg/kg), and Geddes Brook (89 mg/kg). The West Flume will be remediated in accordance with the remedy selected in the Record of Decision (ROD) for Honeywell's LCP Bridge Street site and a separate RI/FS is being performed for Geddes Brook and Ninemile Creek.

In wetland sediments, Wetland SYW-19, which is adjacent to the Wastebed B disposal area, contains elevated concentrations of mercury, lead, chlorinated benzenes, PAHs, PCBs, and PCDD/PCDFs. This wetland is being further investigated as part of Honeywell's Wastebed B/Harbor Brook RI/FS. Wetland SYW-12, between the mouths of Ley Creek and Onondaga Creek, contains the highest concentrations of cadmium and chromium. In Wetland SYW-6 in the northern part of the lake, elevated concentrations of mercury, LPAHs, and HPAHs occurred in the 15 to 30 cm interval of Station SYW6-3.

For the dredge spoils area, mercury concentrations were highest in Basins 1 through 3 (up to 100 mg/kg), indicating, along with historical accounts, the presence of dredged material from the Ninemile Creek delta of Onondaga Lake. The maximum concentrations of PAHs were detected in Basin 4, at intervals greater than 180 cm below the surface. The source of the fill in Basin 4 is not known.

Porewater from Onondaga Lake sediment contained elevated concentrations of dissolved total mercury and methylmercury. Concentrations were highest at two stations located offshore of the East Flume at concentrations up to 50,000 ng/L, more than three orders-of-magnitude greater than surface water concentrations.

In lake water, most metals were measured near or below detection limits, with the exception of mercury, which has an extremely low detection limit (i.e., less than 1 ng/L). Mercury concentrations in water varied seasonally with depth in the water column. The highest concentrations of mercury were found in the littoral zone in the southwest corner of the lake. The highest mercury concentrations in the deep basins of the lake were observed in the hypolimnion during summer stratification. With some exceptions, all of the organic contaminants were measured below detection limits in lake water. In 1992, one lake water sample (out of 98 total) contained dichlorobenzenes and trichlorobenzenes. In 1999, the two water samples taken offshore of the East Flume contained benzene and chlorobenzene. Dichlorobenzenes were detected in 1999 at nearly all stations in the lake, with the highest concentrations near the East Flume and Harbor Brook.

Unlike lake water, most contaminants were detected in water from tributaries and Metro effluent. Most metal CPOIs (other than mercury) were detected occasionally. Cadmium was detected infrequently, while copper, lead, and zinc were frequently detected. The majority of the metal CPOIs were most frequently detected in Tributary 5A and the East Flume. The East Flume and Geddes Brook exhibited the highest concentrations of total mercury, while the East Flume and Metro effluent exhibited the highest concentrations of methylmercury. Organic contaminants were occasionally detected in Tributary 5A (e.g., benzene, toluene, and xylenes), the East Flume (e.g., benzene, xylenes, and chlorinated benzenes), and Harbor Brook (e.g., xylenes). These compounds were found at less than detection limits in all other tributaries and Metro effluent.

Groundwater at sites adjacent to Onondaga Lake has been demonstrated to be moving toward and into the lake, and is contaminated with various CPOIs (e.g., mercury and organic contaminants), including, but not limited to (by site):

- Semet Residue Ponds site: mercury, benzene, toluene, xylenes, and naphthalene.
- Willis Avenue site: chlorinated benzenes, benzene, toluene, xylenes, naphthalene, and metals (mercury, arsenic, copper, chromium, and lead).
- LCP Bridge Street site: mercury and other metals.
- Wastebed B/Harbor Brook site: mercury, chlorinated benzenes, BTEX, naphthalene, and other PAHs.
- Wastebeds 1 through 8: BTEX, PAHs, phenols, calcium, sodium, and chloride.
- Wastebeds 9 through 15: chlorinated benzenes, calcium, chloride, and sodium.

Site contamination has impacted biota in and near the lake. Methylmercury concentrations in fillets of all fish species sampled by Honeywell/Exponent in Onondaga Lake and its tributaries in 1992 ranged from less than 0.1 to 3.2 mg/kg wet weight (PTI, 1993a). In 2000, total mercury concentrations in fish fillets ranged from 0.2 to 0.9 mg/kg wet weight. Methylmercury and total mercury concentrations in fish tissue are usually equivalent because total mercury is predominantly (greater than 95 percent) methylmercury in fish tissue (Bloom, 1992).

Total PCB concentrations in fillets of all species of fish sampled by Honeywell/Exponent in Onondaga Lake and its tributaries ranged from 0.02 to 4.7 mg/kg wet weight in 1992 and 0.09 to 1.8 mg/kg wet weight in 2000. Dioxins and furans (reported as toxicity equivalence quotient [TEQ] with risk to mammals) in adult fish ranged from 1.8 to 79 ng/kg. While pre-investigation data are available for mercury and PCBs in fish tissue, it is difficult to compare these data to the current data because of lack of standardization (i.e., differences in fish species, age, preparation, and laboratory methods).

6. Transport and Fate of Chemical Parameters of Interest

An analysis of total mercury loading, fate, and transport to Onondaga Lake during the stratified period of 1992 (May 25 to September 21) indicates that total mercury loss from the lake was about 11,000 g. During the stratified period, the mass of total mercury in the lake's water column increased from 640 to 1,500 g, a gain of 860 g. Input to the lake during the period of stratification from sources that had been identified in the RI/FS Work Plan (PTI, 1991c) (tributaries/Metro, groundwater, porewater, precipitation) was estimated as 3,500 g, or less than 30 percent of the total budget. The tributaries and Metro account for about 72 percent of that 3,500 g of total mercury input to the lake, while groundwater contributes approximately 22 percent, with the remainder from porewater diffusion and precipitation. Chapter 6, Table

6-1 presents inputs broken down into the individual tributaries. Ninemile Creek was the dominant tributary source of total mercury to the lake, followed by Metro and Onondaga Creek. Based on data provided by Onondaga County, concentrations of mercury and methylmercury in the Metro discharge have declined since this 1992 investigation.

While many of the fluxes are relatively well known, the mass balance as a whole has a large degree of uncertainty. Specifically, the whole-lake mass-balance calculations yield a discrepancy of 8,800 g (70 percent of the total budget) of total mercury loss from the lake that is not accounted for in the lake inputs that were identified in the RI/FS Work Plan (PTI, 1991c). These results suggested the existence of an additional source(s) of total mercury whose contribution to the lake is equivalent to or greater than the sum of all external inputs to the lake identified in the RI/FS Work Plan. Analysis of data from the RI and information from other references identified sources of mercury of the same order-of-magnitude as the imbalance in the mercury budget. These additional sources include:

- Resuspension and transport of waste materials from the Honeywell in-lake waste deposit. This source may explain a significant fraction of the additional inputs of mercury to the epilimnion.

- Releases from the profundal sediments by mechanisms not identified in the RI/FS Work Plan (PTI, 1991c). These mechanisms include:

    - In-situ production of dissolved-phase mercury near the sediment-water interface.

    - Enhanced diffusion and profundal sediment transfer into the water column of the hypolimnion due to ebullition of methane gas in the sediments.

While the exact magnitude of the "missing" source of mercury is not well known, the inputs from the additional sources (resuspension of Honeywell in-lake waste deposit and releases from the profundal sediments) are of the order-of-magnitude required to explain the discrepancy in the mercury budget.

For methylmercury, production in the lake is the major source, contributing at least 51 percent of the total load to the lake. Methylmercury production occurs in anoxic waters (and sediment), so any factors that contribute to oxygen consumption during stratification will enhance methylmercury production.

During fall turnover, when the water column becomes thoroughly mixed, total mercury rapidly settles to the sediments. However, the methylmercury concentration in the Onondaga Lake water column remained elevated by a factor of about three (compared to the epilimnion) for a period of several weeks during the 1999 fall turnover sampling.

The non-mercury CPOIs in Onondaga Lake consist primarily of metals, BTEX, chlorinated benzenes, PAHs, PCBs, and PCDD/PCDFs. Their current distribution reflects historical and ongoing sources from groundwater, surface water, and direct disposal into the lake. The highest concentrations of these non-mercury CPOIs are found in the Honeywell in-lake waste deposit from Tributary 5A to Harbor Brook. Analysis of the loads of these CPOIs suggests that the groundwater from the Honeywell shoreline area is the largest source of the lighter organics (BTEX, chlorinated benzenes, and LPAHs). The DNAPL (chlorinated benzenes, LPAHs, and possibly BTEX) in the immediate shoreline certainly is a source to groundwater/porewater, and its presence suggests that transport into the lake is also occurring. The in-lake waste deposit is the largest source for those CPOIs that are more heavily bound to sediments (PCBs, PCDD/PCDFs, metals). Additional sources have also been identified, based on the sediments at the following locations: PCBs at Ley Creek, chromium north of Tributary 5A, and HPAHs near Oil City.

7. Baseline Risk Assessments

Contaminants of potential concern (COPCs) were identified for Onondaga Lake, select wetlands adjacent to the lake, and the dredge spoils area during the course of the BERA and HHRA (TAMS, 2002a,b). Potential risks posed by these contaminants were further evaluated in the risk assessments.

In the HHRA, the primary driver for potential human health risks associated with Onondaga Lake is consumption of fish based on a limited number of contaminants; specifically, PCBs, PCDD/PCDFs, and mercury in fish tissue were estimated to pose unacceptable risks to persons eating such fish. In the BERA, it was determined that contaminants and stressors in the lake have either impacted or potentially impacted every trophic level and feeding preference examined.

7.1 Human Health Risk Assessment

The objective of the HHRA was to evaluate the potential for adverse human health effects associated with current or potential future exposures to chemicals present in Onondaga Lake surface water, sediments, fish, certain portions of the adjacent wetlands, and the dredge spoils area in the absence of any action to control or mitigate those chemicals. Under this no remedial action scenario, the HHRA principally focused on current and future lake conditions that further assumed unrestricted recreational use of the lake and the absence of a specific, restrictive fish consumption advisory. A total of 60 COPCs or groups of COPCs (including mercury and methylmercury) were identified for further analysis in the HHRA. Consistent with USEPA guidance, reasonable maximum exposure (RME) and central tendency (CT) scenarios for these COPCs were evaluated for several pathways, including a recreational fish consumption pathway, as summarized below:

- Cancer risks and non-cancer hazards calculated for the consumption of Onondaga Lake fish exceeded the upper end of the target risk levels, as follows:
  - The calculated RME cancer risks (ranging from 2.4×10^{-4} to 7.8×10^{-4}) exceeded the high end of the target risk range (10^{-4}), and exceeded the low end of the target cancer risk (10^{-6}) by more than two orders-of-

magnitude. The CT fish ingestion cancer risk (about 4.5×10^{-5} for all recreational receptors) was below the upper end of the target range.

   – The RME non-cancer hazard indices (HIs) (ranging from about 18 to 28) exceeded the target hazard index (HI) (1.0) by a factor of almost 20 or more. The calculated CT non-cancer HIs (4.5 to 7 for adults and children) also exceeded the target.

- RME cancer risks for 21 of the 28 pathways other than fish ingestion equaled or exceeded the low end of the target risk range of 1×10^{-6}, with the highest of these being about 2.6×10^{-4} for older child exposure to Wetland SYW-6 sediments.

- For the CT cancer risk calculations, the low end of the 10^{-6} target range was equaled or exceeded in 8 of the 28 pathways other than fish ingestion, with a maximum CT risk of about 1.4×10^{-5} for older child exposure to Wetland SYW-6 sediments.

- None of the calculated non-cancer hazards (for both RME and CT scenarios) associated with pathways other than fish ingestion exceeded the target threshold of 1.0. The highest RME hazard other than fish ingestion was about 0.54 for young child exposure to southern basin sediments. The calculated non-cancer CT hazards for all pathways other than fish ingestion were all less than 0.1.

Cumulative risks and hazards were calculated for receptors who may be exposed to COPCs in multiple site media – for example, eating contaminated fish and being exposed to contaminated sediments. The receptors evaluated were adult recreators, young child recreators, older child recreators, and construction workers. For all cumulative risk and hazard calculations including fish ingestion, the cumulative risk or hazard was essentially the same as that associated with the fish ingestion pathway alone. Therefore, to assess the cumulative risks associated with pathways other than fish ingestion (i.e., exposure to lake sediment, wetlands sediment, dredge spoils soil, and lake surface water), the cumulative risk for each receptor was also calculated excluding the fish ingestion pathway, as summarized below:

- Cumulative RME cancer risks for adults (excluding fish ingestion) were calculated as 1×10^{-4}.

- Cumulative RME cancer risks (excluding fish ingestion) were calculated as about 3.5×10^{-5} for young children. In addition, the receptor-specific RME HI was calculated as about 0.8 for the young child.

- Cumulative RME cancer risks (excluding fish ingestion) were calculated as about 3.8×10^{-4} for older children. In addition, the calculated value of the cumulative RME HI, excluding fish ingestion, was 0.98 for the older child recreator.

- Cumulative RME cancer risks (excluding fish ingestion) were calculated as 2×10^{-5} for construction workers. In addition, the receptor-specific RME HI was calculated as about 0.8 for construction workers.

It should be noted that these cumulative estimates are probably unrealistically high, especially for the adult and older child recreational receptors, as the cumulative risk calculation assumes RME exposure frequencies summing to 218 days per year to Onondaga Lake sediments, wetlands, and dredge spoils. Cumulative RME HIs calculated in the same manner (excluding fish ingestion) generally did not exceed 1.0, although some approached 1.0, as indicated above.

Chapter 7, Uncertainty Assessment, of the HHRA provides a discussion of the reliability of the input parameters to the quantitative risk calculations, and provides a qualitative and, in some cases, semi-quantitative assessment of the effect of alternative values in risk calculations. As indicated there, actual cancer risks and non-cancer hazards may vary from those presented in the quantitative risk characterization tables.

7.2 Baseline Ecological Risk Assessment

The implementation of the BERA followed the eight-step Superfund ecological risk assessment process specified by USEPA (1997a) to evaluate the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to one or more contaminants or stressors. The specifications of NYSDEC (1994a) were also incorporated into the BERA. The areas evaluated in the BERA include Onondaga Lake, including all pelagic and littoral areas; the mouths of all tributaries to the lake; the area from the lake outlet to the sampling location in the outlet; and Wetlands SYW-6 and SYW-12. In addition to these areas, the BERA included a preliminary evaluation of limited data that were collected in Wetlands SYW-10 and SYW-19 and the dredge spoils area located north of the mouth of Ninemile Creek. Ecological risks associated with these areas will be further evaluated as part of separate sites and, therefore, the risk analysis associated with these areas in the BERA is considered preliminary, pending the finalization of the BERAs associated with these other sites.

Multiple lines of evidence were used to evaluate major components of the Onondaga Lake ecosystem to determine if lake contamination has adversely affected plants and animals around Onondaga Lake. Almost all lines of evidence indicate that the Honeywell-related contaminants and ionic waste in Onondaga Lake have produced adverse ecological effects at all trophic levels examined.

The aquatic macrophytes in the lake have been adversely affected by lake conditions, and the resulting loss of macrophyte habitat that formerly provided valuable feeding and nursery areas has undoubtedly affected the aquatic invertebrates and vertebrates living in Onondaga Lake. In addition to general habitat loss, there has been bioaccumulation of mercury and possibly other chemicals in most organisms serving as a food source in the lake, including phytoplankton, zooplankton, benthic invertebrates, and fish. Exceedances of site-specific sediment probable effect concentrations (PECs) suggest adverse effects to benthic invertebrates will frequently occur (Ingersoll et al., 2000) in most areas of the lake. The greatest number and magnitude of exceedances were found in areas in the southern portion of the lake and near Ninemile Creek (Chapter 8, Figure 8-2).

Comparisons of measured tissue concentrations and modeled doses of chemicals to toxicity reference values (TRVs) show exceedances of hazard quotients (HQs) for site-related chemicals throughout the range of the point estimates of risk. Many of the contaminants in the lake are persistent and, therefore, the risks associated with these contaminants are unlikely to decrease significantly in the absence of remediation. On the basis of these comparisons, it has been determined through the BERA that all receptors of concern are at risk.

8. Preliminary Remedial Action Objectives

Pursuant to USEPA guidance, preliminary remedial action objectives (RAOs) for Onondaga Lake are derived from key conclusions of the RI, including analysis of the nature and extent of contamination, transport and fate of contaminants, and the risk assessments. The key conclusions of the RI for purposes of developing RAOs are that:

- Elevated levels of metals and organic compounds result in adverse impacts (known or modeled) to all trophic levels of the Onondaga Lake ecosystem.
- Consumption of fish drives the potential cancer risks and non-cancer hazards for humans.
- Mercury methylation in the water column is primarily occurring in the anoxic hypolimnion.
- The major external sources of mercury are the tributaries and groundwater from the various Honeywell upland sites. For the remedial actions at Onondaga Lake to be effective, these external sources will need to be remediated under separate programs and are not included in the preliminary RAOs for Onondaga Lake specified below.
- The major internal sources of mercury are the in-lake waste deposit and profundal sediments.
- Groundwater and DNAPL releases from the various Honeywell upland sites are a major external source of organic contaminants.
- The in-lake waste deposit is also an internal source of some organic contaminants.
- Oncolites that formed as a result of ionic waste discharge in the lake have had a significant effect on the ecological structure in the lake.

The preliminary RAOs for Onondaga Lake, which will be addressed pursuant to the FS, are as follows:

- To eliminate or reduce, to the extent practicable, methylation of mercury in the hypolimnion. The process is thought to be primarily biologically mediated under anoxic conditions.

- To eliminate or reduce, to the extent practicable, releases of contaminants from the Honeywell in-lake waste deposit and other littoral areas around the lake. These releases are likely caused by wind-driven erosion and resuspension, although diffusion and porewater advection may also play a role.

- To eliminate or reduce, to the extent practicable, releases of mercury from the profundal sediments. One likely mechanism for the release of mercury from profundal sediments is methane gas ebullition, which causes increases in advective and diffusive migration.

- To eliminate or reduce, to the extent practicable, existing and potential future adverse ecological effects on fish and wildlife resources.

- To achieve surface water quality standards, to the extent practicable, associated with CPOIs.