9. CONCLUSIONS

Chapters 1 through 3 of this Onondaga Lake Remedial Investigation (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 directly 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 oxide, 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 in-lake Honeywell 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 in-lake Honeywell waste deposit. Cadmium contamination in the Ninemile Creek delta and the in-lake Honeywell 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 in-lake Honeywell 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 Metro, 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 at 11,000 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, 1991c) 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 in-lake Honeywell 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.

9.1 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.

9.2 Identification of Potential Applicable or Relevant and Appropriate Requirements and To-Be-Considered Criteria

Section 121(d) of CERCLA requires that remedial actions comply with state and federal applicable or relevant and appropriate requirements (ARARs). Applicable requirements are defined below:

- Any standard, requirement, criterion, or limitation promulgated under federal environmental law that is not implemented by an approved state program.

- Any promulgated standard, requirement, criterion, or limitation under a state environmental or facility siting law that is more stringent than the associated federal standard, requirement, criterion, or limitation.

Relevant and appropriate requirements are those cleanup standards, control standards, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a National Priorities List (NPL) site, address problems or situations sufficiently similar (relevant) to those encountered, and are well-suited (appropriate) to circumstances at the particular site. Requirements must be both relevant and appropriate to be ARARs.

To-be-considered requirements, or TBCs, are non-promulgated criteria, advisories, guidance, and proposed standards issued by federal or state governments. TBCs are not potential ARARs because they are neither promulgated nor enforceable, although it may be necessary to consult TBCs to interpret ARARs, or to determine preliminary remediation goals when ARARs do not exist for particular contaminants or are not sufficiently protective. Compliance with TBCs is not mandatory, as it is for ARARs. The potential ARARs for evaluation in the Onondaga Lake Feasibility Study (FS) in each of the three categories (chemical-specific, location-specific, and action-specific), along with other TBC requirements, are summarized in Tables 9-1 through 9-6 and in Chapter 3, Section 3.4 of the BERA (TAMS, 2002a). These ARARs and TBCs should be further refined during the FS.