S
S CALLAHAN MINE
I 3.4
O 448640

SDMS DocID 448640

# FINAL

# REMEDIAL INVESTIGATION REPORT – EXECUTIVE SUMMARY

# CALLAHAN MINE SUPERFUND SITE
# BROOKSVILLE, MAINE

***Prepared for:***

**Maine Department of Transportation**
**16 State House Station**
**Augusta, ME 04333**

***Prepared by:***

MACTEC

**MACTEC Engineering and Consulting, Inc.**
**511 Congress Street**
**Portland, Maine 04101**

**MACTEC Project 3612062047**

**April 2009**

# EXECUTIVE SUMMARY

MACTEC Engineering and Consulting, Inc. (MACTEC) has been retained by the Maine Department of Transportation (MaineDOT) to conduct a Remedial Investigation (RI) and Feasibility Study (FS) on behalf of the State of Maine, for the Callahan Mine Superfund Site (Site) located in Brooksville, Maine. The Site has undergone characterization activities under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), as amended by the Superfund Amendment and Reauthorization Act (SARA). The United States Environmental Protection Agency (USEPA) is the lead regulatory agency at the Site. The Maine Department of Environmental Protection (MDEP) exercises regulatory oversight and review of the project. Other project stakeholders involved with the review of the RI include: the Technical Assistance Grant (TAG) committee headed by the Marine Environmental Resource Institute (MERI) with assistance from Jacques Whitford; the United States Geological Survey (USGS); the United States Fish and Wildlife Service (USFWS); and the National Oceanic and Atmospheric Administration (NOAA).

The purpose of the RI is to: (1) determine the nature and extent of contamination in soil, sediment, groundwater, air, and surface water both on the Site and in the surrounding areas, (2) evaluate the fate and transport of contaminants, and (3) assess human health and ecological risks. Overall, the RI has determined that contamination is largely the result of the activities associated with the extraction and processing of the ore along with the disposal of the waste rock and tailings. The ore extraction, processing, and waste disposal activities left behind tailings and waste rock that have spread the constituents of the ore (particularly arsenic, cadmium, copper, lead, and zinc) over a large area making them more accessible to human and ecological receptors than prior to mining activities. In addition, certain contaminants associated with the mine operations, including polychlorinated biphenyls (PCBs) and petroleum hydrocarbons, are found at the Site. Migration of contaminants from the waste rock and tailings have resulted in levels of contaminants in soil, groundwater, surface water, and sediments above background and at levels that could pose a threat to public health and the environment. The RI, including the Human Health and Ecological Risk Assessments, also concluded the following:

(1) The sediment contamination in estuarine Goose Pond appears relatively self-contained, with minimal migration of metal-contaminated sediment into marine Goose Cove.

(2) Cancer and non-cancer risks to human health arising from exposure to surface water, sediments, and biota are all within or below USEPA risk management criteria under both current and future site land use assumptions.

(3) Cancer and non-cancer risks to human health were outside the USEPA risk management criteria for (a) soils at 3 residential lots (lead at all three and thallium at one) under both current and future land use assumptions; (b) soil/waste rock in the former Mine Operations Area (PCB's) under both current and future land use assumptions; (c) soil/waste rock/tailings throughout the Source Area (arsenic and lead) under future residential land use assumptions; and (d) in the groundwater (aluminum, arsenic, cadmium, manganese, lead and zinc) under the assumption that the groundwater may be used as a source of drinking water in the future;

(4) Risk of harm to salt marsh plants, the benthic community, water column invertebrates, fish, insectivorous birds, aquatic piscivorous birds, aquatic predatory birds, semi-aquatic mammals, and rare, threatened, and endangered species is unlikely for those areas outside of sediment/salt marsh hot spots;

(5) Risk of harm to the benthic community, water column invertebrates, fish, insectivorous birds, and aquatic piscivorous birds was identified as a concern in the area defined as the sediment/salt marsh hot spots;

(6) Risk of harm to terrestrial plants, terrestrial invertebrates, bird and mammal communities is unlikely in the so-called Halo Area;

(7) Risk of harm to terrestrial plants, terrestrial invertebrates, bird and mammal communities is possible in the Source Area, although there is little growth medium for plants there, and, because it is poor habitat for terrestrial invertebrates, it is an unlikely foraging site for potential receptors.

The RI is organized in the following volumes. Volume 1A contains the text of the RI. Volume 1B of this report contains tables. Figures follow in Volume 1C. Appendices are attached in Volume 1D. The Human Health Risk Assessment (HHRA) is presented in Volume 2. Volume 3 contains the Baseline Ecological Risk Assessment (BERA).

In 2005, a draft Project Work Plan (MACTEC, 2005a) was prepared that specified the data collection activities and sample methods for the RI. The 2005 RI field work focused on field investigations that would support the development of a draft BERA and Preliminary HHRA. Field investigations conducted in 2005 included surface soil, surface water, sediment and biota sampling and testing. The results of the 2005 RI data collection activities are summarized in the Draft Phase 1A RI Report (MACTEC, 2006a) and the draft BERA (MACTEC, 2006b). The Final Project Work Plan (MACTEC, 2006c) was issued in July 2006. The remaining elements outlined in the Final Project Work Plan (e.g., subsurface soils, seeps, air, and groundwater characterization), with the exception of the seep-storm event sampling, were completed in 2006. The Phase 1B Work Plan

(MACTEC, 2007a) presented the results of the 2006 RI activities completed at the Site and provided detailed data collection activities designed to fill data needs.

## INTRODUCTION

The Callahan Mine Superfund Site is located on the northwestern side of Cape Rosier on Penobscot Bay in Brooksville, Maine. The Site proper is an elongated 120 acre property oriented north-south along the east side of Goose Falls Road. The Site also includes the Goose Pond estuary (approximately 75 acres) and private properties that abut the Site proper to the north, west, and south. The Site is situated at 44° 21' 05.9" north latitude and 68° 48' 35.5" west longitude. Goose Pond and Holbrook Island Sanctuary State Park are located immediately east of the Site. A number of private residences and seasonal homes are located adjacent to the Site on Goose Falls Road, Cape Rosier Road, and Old Mine Lane. Privately held properties border the Site to the east and the south (Figure ES-1).

The Site currently consists of a submerged open pit, a former industrial operations area, a series of waste rock piles, and a tailings impoundment. Waste rock piles and operational areas are for the most part unvegetated and barren. Portions of the Site that include waste rock, tailings, access roads, ore, or mine operations remnants encompass approximately 75 acres. The Goose Pond estuary is located immediately adjacent to the developed areas of the Site.

The Callahan Mining Corporation developed a massive sulfide ore body located beneath a bedrock peninsula that extended into Goose Pond. To gain access to the ore, the mouth of the estuary was dammed, and Goose Pond was drained. An open pit mine approximately 600 feet in diameter and 320 feet deep was excavated to access the ore. The trend of the mineralized zone was northeast-southwest, and underground workings to supplement the ore available from the pit were extended from the face of the open pit approximately 500 feet on two levels (adits) to the southwest. These adits are located approximately 120 feet below the current surface of Goose Pond. Open pit mining generally involves the removal of up to 3 times the amount of material to access one part ore. As a result large volumes of waste rock were generated at the Site and deposited in the form of waste rock piles and fill areas.

During early mine operation, groundwater seepage into the pit was pumped to an outfall in Goose Cove. This effluent most likely contained fine grained drilling and blasting waste. This practice was later modified by pumping these waters to a settling basin constructed in Dyer Cove prior to discharge to Goose Cove via pipe. In addition, berms were constructed across portions of Goose Pond to separate surface water flows from mine operating areas and provide a sedimentation basin for overflow and decant discharge from the Tailings Impoundment. As a result of these operations, deposits of light gray, talcose sediment (termed mine waste) accumulated in portions of Goose Cove, Dyer Cove, and South Goose Pond. Areas of mapped mine waste are coincident with areas used as effluent settling ponds, effluent discharge locations, and sumps (Figure ES-2).

During mining operations the Tailings Pile discharged effluent through the decant structures and possibly direct runoff via spillway drainage ditches. The effluent discharge was contained in a settling pond (the area now referred to as South Goose Pond) where water was re-circulated back to the Mine Operations area via a pumping station located at the circular sump on Dyer Point.

During closure of the mine, the dam was breached, and the pit and estuary were re-flooded, restoring a limited tidal exchange in Goose Pond. Although some rock and overburden debris were pushed or blasted into the pit at the time of mine closure, the pit remains mostly unfilled except for a relatively thin mantle of accumulated sediment that drapes the former roads and pit bottom.

As a result of mining activities, a major portion of upland areas at the Site are occupied by mine waste materials including the Tailings Impoundment, three waste rock piles, the Ore Pad, and Mine Operations Area and former haul roads which are predominantly covered with waste rock from mining operations. Much of the rock removed during development of the open pit was not mineralized and consisted of agglomerates, rhyolite, and andesite/dirorite that comprised overburden rock on the hanging wall (upper side) of the mineralized zone. Some of these rock types, in particular Dyer Point Agglomerate and the black rhyolite, contain several percent fine grained pyrite that is typically not readily exposed to oxidizing conditions and occurs as fresh, unweathered pyrite. The mineralized zone at the mine was an approximate 100-foot wide strata-form zone of sheared and brecciated rock that contained lenses of high grade massive sulfide and stringers of massive sulfide within talc-carbonate rock, interspersed with lenses and zones of massive pyrite, with lesser amounts of economically important metal sulfides. Thus, the mineralized zone contained material that was of sufficient grade to be processed as ore and other

sub-ore grade waste rock that was mineralized with iron sulfide, but contained lesser amounts of copper, lead, and zinc bearing minerals. These materials were disposed on-site as waste rock. This material is referred to as mineralized waste rock.

## REMEDIAL INVESTIGATION SUMMARY

Over a 4-year investigation period, air, soil, sediment, groundwater, biota, and waste materials have been sampled and characterized. Characterization events and the number samples collected are summarized below in Table ES-1.

**Table ES-1**
**Summary of Investigations**

| Year of Investigation | Principal Investigator | Investigation Description | Sampling Summary |
|---|---|---|---|
| 2004 | USEPA - TRC | Initial Remedial Investigation | 30 surface soil samples |
| | | | 12 surface water samples |
| | | | 1 seep sample |
| | | | 23 sediment samples |
| | | | Bathymetry survey of Goose Cove and Goose Pond |
| | | | Geophysical surveys to map bedrock |
| 2005 | Maine DOT - MACTEC | Phase 1A 2005 Remedial Investigation | 189 surface soil samples |
| | | | 15 surface water samples |
| | | | 13 seep samples |
| | | | 564 sediment samples |
| | | | 41 ecological sample locations |
| 2006 | Maine DOT - MACTEC | Phase 1A 2006 Remedial Investigation | 22 soil borings |
| | | | 16 piezocone penetrations |
| | | | 5 piezometers |
| | | | 14 overburden monitoring wells |
| | | | 10 bedrock monitoring wells |
| | | | 1 round residential drinking water sampling |
| | | | 2 rounds groundwater sampling |
| | | | 2 synoptic groundwater level surveys |
| | | | 4 air monitoring stations |
| | | | Electromagnetic surveys |
| | | | 15 seep samples |
| | | | 7surface water samples |

**Table ES-1**
**Summary of Investigations**

| Year of Investigation | Principal Investigator | Investigation Description | Sampling Summary |
|---|---|---|---|
| 2007 | Maine DOT - MACTEC | Phase 1B 2007 Remedial Investigation | 12 soil borings |
| | | | 10 piezometers |
| | | | 9 overburden monitoring wells |
| | | | 4 bedrock monitoring wells |
| | | | 44 test pit excavations |
| | | | 1 round residential drinking water sampling |
| | | | 1 round groundwater sampling |
| | | | 1 synoptic groundwater level survey |
| | | | 9-month water elevation monitoring |
| | | | 5 seep samples |
| | | | 325 surface soil samples |
| | | | 103 sediment samples |
| | | | 55 subsurface soil samples |
| | | | 6 surface water samples |
| 2008 | Maine DOT - MACTEC | Clam Tissue/Sediment Bioavailability Study | 22 clam tissue samples |
| | | | 22 sediment samples |

The upland portion of the Site comprises nine primary contaminant source areas: the Tailings Pile, the three Waste Rock Piles (WRPs), the Ore Pad, the former Mine Operations Area, Dyer Point, the perimeter of Dyer Cove, and Access Roads (Figure ES-3).

In general, Site surface soil samples in these areas contain antimony, arsenic, cadmium, chromium, copper, lead, manganese, mercury, thallium, and zinc in excess of screening criteria. Leaching data suggests that cadmium, lead and zinc may pose a risk to groundwater. Other metals that may leach include aluminum, antimony, copper, and molybdenum. Acid base accounting data indicates that waste rock materials are primarily net neutralizing.

In addition, there are five areas at the Site that may have been affected by past operations and/or the defined source areas. These include Halo Area Soils, the Salt Marsh Floodplain, Goose Pond, Goose Cove, and Marsh Creek/Weir Cove (Figure ES-4).

The following paragraphs provide an overview of the history, hydrogeology, and nature and extent of contamination at each of the primary and secondary contaminant source areas at the Site.

**Tailings Pile**

The Tailings Pile is located in the southern portion of the property, adjacent to Goose Pond. The Tailings Pile covers an area of approximately 21 acres, including the rock berm (13.2 acres within the limits of the rock berm). It contains an estimated volume of over 716,000 cubic yards of tailings and waste rock. Analysis of historic photographs, previous reports (FM Beck, 1986), and site visit observations indicate the Tailings Pile was constructed in a series of berm lifts. Historical records indicate that as the Tailings Pile was constructed, additional waste rock was placed around the edge of the Tailings Pile to act as a dam for the placement of additional tailings. This procedure led to a layering at the edge of the Tailings Pile, where the waste rock used to elevate the berm, is likely situated over earlier accumulations of tailings. Waste rock berm materials were packed or chinked with till soil or clay materials. Reportedly, the Tailings Pile had an engineered structure to remove water from inside the impoundment and discharge it under the berm and/or to be re-used as process water. A drainage pipe was found at the western edge of the Tailings Pile. Based on geophysical surveys and dye tracer testing the pipe was determined to discharge at a previously mapped seep (SP-511) buried at the base of the Tailings Pile berm. The pipe currently drains impounded surface water from the Tailings Pile when surface water elevations rise as a result of precipitation and/or snowmelt events. In addition, surface water from the Site drains out the north end through a spillway drainage ditch between the Tailings Pile and WRP-3.

Groundwater within the tailings impoundment is considered leachate. Aluminum, arsenic, lead, sodium, and manganese were detected in excess of maximum contaminant levels (MCL) and Maine Exposure Guidelines (MEG) in tailings impoundment leachate. Sulfate and chloride concentrations were also elevated. Bedrock groundwater contains sodium and manganese in excess of MEGs. Lead was detected in excess of the MEG in the upgradient bedrock borehole.

**Waste Rock Piles**

Open pit mining methods result in removal of large volumes of non-ore bearing rock to gain access to the ore. The Callahan ore deposit was a Kuroko-style volcanogenic massive sulfide ore body that was strata form in nature and consisted of large lenses or massive pods of zinc, copper, lead, and iron sulfide minerals in an approximate one hundred foot thick sequence of talc and calcite bearing rocks (mineralized zone). The same sulfide minerals present in the ore are common in rock

surrounding the ore, although at lower concentrations. The mineralized zone also contained thinner stringers of zinc, copper, and lead sulfides and disseminated to massive iron sulfide (pyrite) and varying amounts of other secondary minerals including metal sulfates and carbonates. The mineralized zone was bounded by diorite (andesite) intrusive rocks, and rhyolite pyroclastic volcanic rocks, which both constituted a waste rock material during the open pit mining of the ore. To gain access to the valuable ore, the waste rock was removed by blasting, then loaded onto trucks, hauled out of the pit and placed onto the WRPs. The high grade massive sulfide ore and to a lesser extent the lower grade zinc, copper and lead mineralization, were removed by truck and placed on the ore pad for sorting and crushing for subsequent processing. Pyritic waste rock, talc and calcite bearing waste rock from the mineralized zone, were also placed on the WRPs and in the Ore Pad area.

The WRPs are not lined or covered (Figures ES-5 and ES-6). They contain sulfide minerals that can leach metals as the sulfide minerals oxidize. The sulfide minerals (principally pyrite) exposed in rock surfaces are oxidized by the presence of atmospheric oxygen and water (infiltrating precipitation) to release sulfate, dissolved ferrous iron and acidity (H+). The concentration of dissolved ferric iron increases as the pH decreases. The dissolved ferric iron is a strong oxidizer and continues to oxidize the pyrite and other metal sulfides producing ferrous iron, sulfate, acidity, and other dissolved / hydrolyzed metal species. The resulting dissolved ferrous iron, in the presence of oxygen and iron oxidizing bacteria (such as thiobacillus ferroxidans), can be rapidly converted back to ferric iron. The ferric iron, depending on surrounding conditions (pH, presence of oxygen, water) may continue to oxidize more pyrite or hydrolyze, and deprotonate, creating iron hydroxide precipitates and additional acidity. This description of sulfide oxidation is known as Acid Rock Drainage (ARD).

**Waste Rock Pile 1**

WRP-1 (Figure ES-3) covers an area of approximately 14.1 acres and contains an estimated volume of almost 1,250,000 cubic yards or waste rock. It was constructed as an arcuate berm structure paralleling an exposed bedrock hill leading down to Dyer Point during the early phases of Site preparation. The area between the hill and the arcuate berm structure was to be filled with waste rock from the open pit. During the first year of mining, the berm separating Stink Cove from the mine pit failed and sediments from Stink Cove partially filled the open pit with silt and clay.

These materials were dredged and deposited in WRP-1 (approximately 4.3 acre area). Dredged materials took up considerable volume, estimated at almost 290,000 cubic yards. Waste rock disposal at WRP-1 was curtailed or ceased and waste rock was then discarded along Dyer Cove, Dyer Point, WRP-2, and WRP-3.

Groundwater under WRP-1 resides in bedrock. Leachate is perched upon the glacial till underlying waste rock. Vertical gradients are downward at all locations monitored except to the north at MW-609, where they are slightly upward, supporting the expectation that bedrock groundwater will ultimately discharge to Dyer Cove and Goose Pond. Groundwater flow from WRP-1 is somewhat radial to the northwest, north, and east. Groundwater discharges to the estuary. A groundwater divide is thought to exist from the bedrock ridge between MW-608 and MW-607, to a point slightly east of MW-606.

Water quality in leachate and underlying bedrock groundwater is similar. Bedrock groundwater to the east is impacted by zinc, cadmium, and manganese at concentrations above the federal maximum contaminant level (MCL) for drinking water or the Maine Exposure Guidelines for groundwater (MEG) (Figure ES-7). Bedrock groundwater to the north has elevated chloride and sodium, and to a lesser extent lead, indicating impacts from Stink Cove sediments placed on the WRP.

Seeps discharging from the east side of WRP-1 contain zinc and copper at concentrations above the acute ambient water quality criteria (AWQC) criterion, and nickel and cadmium above the chronic criterion.

**Waste Rock Pile 2**

WRP-2 (Figure ES-3) is located between the Ore Pad and Dyer Cove and covers an area of approximately 2.2 acres and contains an estimated volume of over 22,000 cubic yards of waste rock. The access road leading from the former open pit to the ore pad is within WRP-2. This access road is cut into bedrock and the talus slope on the downslope (east) side of that road is comprised of the same bedrock types exposed in the road cut. The base of the road is bedrock with varying degrees of a veneer of waste rock cover which includes small amounts of mineralized rock, which may have fallen from ore trucks that traversed this road.

The demarcation of WRP-2 and the Ore Pad is somewhat subjective, being based primarily on the geologic classification and relative quantity of rock present. The surface of the eastern slope of WRP-2 contains a relatively benign appearing mixture of rhyolite volcanic rocks, some diorite (andesite), some talc carbonate rock, and very few fragments of low grade mineralized rock. Moving west toward the Ore Pad, and up slope of the Ore Pad, the abundance of mineralized waste rock increases markedly, and massive sulfide ore is present along the western most side of the Ore Pad. It appears that the majority of WRP-2 may consist of material that is different from the waste rock found in WRP-1 and WRP-3. The waste rock fill is thin, ranging from four to six feet thick where drilled. The waste rock is underlain by four to eight feet of till. Bedrock was encountered between eight and fifteen feet bgs. Prior seismic and GPR data indicated that the depth to bedrock is up to 20 feet bgs.

The overburden well installed in the WRP-2 has been dry. Overburden groundwater may only exist for short periods following heavy rain events. Groundwater is encountered in bedrock, at elevations approximately equal to the bedrock surface. The interpreted direction of bedrock groundwater flow from WRP-2 is east toward Dyer Cove. Bedrock hydraulic conductivity was measured to be 3.0 E-04 cm/sec.

Three rounds of groundwater samples were collected and analyzed from the bedrock well MW-617R, and detected cadmium and manganese at concentrations above the respective MEGs (Figure ES-7).

Based on past use, available Site test data and visual observations, WRP-2 is a potential, though perhaps minor source of metals in surface soils, surface water run-off, and groundwater.

**Waste Rock Pile 3**

WRP-3 (Figure ES-3) is located between WRP-1 and the Tailings Pile. This waste rock pile covers approximately 6.6 acres and contains an estimated volume of over 216,000 cubic yards of waste rock. WRP-3 has abundant sulfide waste rock with conspicuous iron staining (limonite) along its top and eastern slope. WRP-3 is referred to in some historic records as a "prior tailings pile", though no tailings were encountered during drilling of this area. Dead and stressed vegetation

occurs along the base of WRP-3 and near to an area where a copper-rich, blue-green seep discharges to Goose Pond. The USGS collected samples of the gray to light brown and blue-green precipitates from SP-509 and has determined the presence of gypsum ($CaSO_4*2H_2O$) and glaucocerinite, a hydrated copper aluminum sulfate ($Cu_4Al_2(SO_4)(OH)_{12}*3H_2O$), in addition to other detrital minerals including quartz and chlorite. Analytical data confirm that seeps from WRP-3, along the western bank slope of Middle Goose Pond are a source of metals in the environment.

The borings installed in WRP-3 encountered 40 feet of waste rock in the southern end and 19 feet in the northern end. Up to 11 feet of till is present over bedrock which was encountered at 51 feet bgs. Prior seismic and GPR data indicated that depth to bedrock is up to 60 feet bgs. Waste rock core within the top twenty feet contained pyritic rhyolite and abundant limonite staining and strongly weathered rock fragments.

Analysis of waste rock leachate from MW-612 detected aluminum, tin, arsenic, cadmium, chromium, lead, manganese, sodium, and zinc at concentrations greater than MCLs/MEGs. Sulfate was detected at 2,000 mg/L.

Seeps emanating from the eastern side of WRP-3 were monitored at five locations. The highest metal concentrations measured in seeps at the Callahan site are from WRP-3. The seep waters contain zinc, cadmium, copper, lead, and nickel at concentrations that exceed AWQCs. Zinc accounts for approximately 98 to 99 percent of the metals loading (for those metals above an AWQC) from all seeps sampled in October 2006, and a majority of seeps sampled in April 2005. Copper accounted for 24 percent of the metals loading from SP-504 in spring of 2005, 11 percent of metals loading from SP-507 in spring 2005, and 12 percent of loading from SP-508 in spring 2005. In October 2006, zinc dominated these seeps, suggesting that there may be some seasonality affects for leaching of certain metals.

**Ore Pad**

The Ore Pad is where the mine stockpiled the ore on the ground prior to crushing and milling. The Ore Pad covers approximately 2.1 acres and contains an estimated volume of over 15,000 cubic yards of waste rock. The primary crushers were located down slope from the Ore Pad. The Ore

Pad was not lined. Today, fragments of ore and mineralized rock are visible over much of the Ore Pad. The surface soil in the area is conspicuously limonite-stained imparting a yellow brown to orange brown, and brownish black color and coating on soil and rock surfaces that stretches from the top of the exposed slope downhill to the Mine Operations Area. In addition to zinc, copper, and lead sulfide ore fragments, the soils in this area also have a considerable number of blue and blue-green mineral fragments and rarer whitish mineral coating that may have been supergene ore minerals (copper, lead, and zinc carbonates and sulfates), or hydrated copper sulfates and soluble sulfate salts produced from more recent weathering of material remaining on the Ore Pad.

The thickness of waste rock fill at the Ore Pad is thin, consisting of 2 to 3 feet of waste rock, that is mixed together with the till at the till contact. The till varies in thickness up to 11 feet. Bedrock was encountered at depths ranging from 9 to 15 feet bgs.

The vertical hydraulic gradient between the overburden leachate and bedrock groundwater is downward (0.48 ft/ft) and the horizontal gradient from MW-515R to MW-517R was approximately 0.12 ft/ft. Hydraulic conductivity of bedrock was estimated to be $2.2E^{-04}$ cm/sec. Groundwater flows from the Ore Pad to the east and southeast, eventually discharging to Dyer Cove.

Both waste rock leachate and bedrock groundwater were sampled and analyzed from a well pair in the center of a depression within the Ore Pad. Overburden leachate was present in the November sample round, and aluminum, tin, cadmium, chromium, lead, manganese, nickel, sodium, and zinc were detected at concentrations greater than the MCL/MEG. The highest concentrations of cadmium were found in the groundwater below the ore pad which identifies this area as one of the major source areas for groundwater.

Bedrock groundwater contained aluminum, cadmium, copper, manganese and zinc at concentrations above the MCL/MEG (Figure ES-7). Bedrock groundwater is also impacted by sulfate, indicating ARD impacts from overlying waste materials.

**Mine Operations Area**

The Mine Operations Area is the former location of the machinery that was used to mill and process the ore that was staged in the Ore Pad. The Mine Operations Area covers approximately

5.2 acres and contains an estimated volume of almost 44,000 cubic yards of waste rock. At least two underground fuel storage tanks were located in this area (2,000 and 4,000 gallons); they were purportedly removed in 1987. The Operations Area included a machine shop, and assay laboratory, the two rock crushers, and the concentrator building. All of these structures have been removed from the Site, except for some of the building foundations and breached walls of the concentrator building. There may be storm drain structures beneath Mine Operations area.

The Mine Operations Area is underlain by variable thicknesses of waste rock fill and native soil consisting of clay and silt overlying glacial till. The overburden thickness varies greatly from 12.5 feet to as much as 82 feet. In general, a thin layer (2-3 feet) of sandy and gravelly fill overlies the fine grained stratified clay and silt. In absence of the clay and silt, the gravelly, sandy fill extends to bedrock (12.5 feet) near the former floatation building (near SB-614). The clay and silt varies in thickness from 10 to 31 feet across the Site. Up to 72 feet of till was encountered at SB-610, indicating the presence of a narrow and deep channel between the northern and southern ridges that dominated the pre-mine topography of the Site. Bedrock varies from andesite flows to the east, to mineralized talc-carbonate rocks to the west at SB-610. The mineralized rock at this location is on geologic strike with the main ore zone that was mined. The position of the talc carbonate sequence in contact with diorite (andesite) is the same as described for the ore zone in the former pit. The diorite (andesite) exposed on the WRP-2 haul road and at the base of WRP-1 may be the same diorite (andesite) sill described as bordering the ore zone. If so, these zones may be structurally offset by a fault located between WRP-2 and the open pit.

Groundwater in the Mine Operations Area occurs as saturated overburden and bedrock groundwater. In the vicinity of MW-610R, gradients are upward (ranging from 0.029 to 0.049 ft/ft), as groundwater discharges to the small stream drainage near that location. Elsewhere measured gradients are downward (MW-614/614R). Both overburden and bedrock groundwater flows toward Dyer Cove. Horizontal gradients range from 0.025 to 0.028 ft/ft. Hydraulic conductivities range from 1.5 E-04 cm/sec in bedrock to 1.1 E-05 cm/sec in overburden.

The Mine Operations Area contains polychlorinated biphenyls (PCB) contamination in surface soils and subsurface soils. PCBs were detected at concentrations in excess of Toxic Substances Control Act (TSCA) criteria in the area of the former Lab and Crusher buildings. Low levels of

PCBs were detected in subsurface soils associated with a tank grave next to the former Maintenance Garage. The area of PCB contamination is shown in Figure ES-8.

Oil stained subsurface soils are associated with the tank grave located adjacent to the former Maintenance Building. Visually stained soils were observed in TP-7124 and TP-7119 extending from 3 to 9 feet bgs. Diesel range organics (DRO) and gasoline range organics (GRO) contamination was detected in excess of screening criteria. Figure ES-8 shows the area of oil-contaminated soil. Downgradient overburden groundwater was non-detect for DRO and GRO. GRO was detected at a concentration below the MEG in downgradient bedrock groundwater (34 µg/L). Based on the Maine Decision Tree for Petroleum Sites, the Mine Operations Area is classified as a "Stringent site" requiring cleanup of all free product, the removal or remediation of soils containing concentrations in excess of 5 ppm GRO and 10 ppm DRO and the remediation of groundwater containing greater than 50 µg/L GRO or DRO, 35 µg/L methyltertbutylether (MTBE), or 5 µg/L benzene under Maine regulations.

Overburden groundwater has not been severely impacted by mine operations except in the vicinity of the flotation building where concentrates were processed and stored. Both overburden and bedrock groundwater in this area (MW-614/614R) contain cadmium, manganese, sodium, and zinc at concentrations above MCLs/MEGs. Sulfate concentrations are also elevated. The upgradient bedrock well (MW-610R) contains lead at a concentration above the MCL/MEG, but this well is screened in mineralized rock containing quartz veins with lead, zinc, copper, and iron sulfides (Figure ES-4). Bedrock well MW-614R is located downgradient of the former tank grave where DRO/GRO and low levels of PCBs (specify concentration) were detected in subsurface soils. GRO was detected in bedrock groundwater at concentrations below the MEG.

The surface waters and seeps that originate from the combined Mine Operations Area and Ore Pad discharge to Dyer Cove. The dominant seep is SP-501 and contains between 7,300 and 14,500 µg/L of zinc. Surface water run-off that forms during the spring melt and rainfall events also contain elevated concentrations of metals. This run-off ultimately discharges to Dyer Cove.

**Dyer Point and Dyer Cove Perimeter**

Dyer Point and the perimeter of Dyer Cove contain appreciable amounts of waste rock with trace to abundant amounts of mineralized waste rock. These combined areas cover approximately 12 acres and contains an estimated volume of approximately 164,000 cubic yards of waste rock. Test pits revealed the presence of mineralized waste rock up to depths ranging from 6 feet to greater than 12 feet bgs. Large boulders line the perimeter of Dyer Cove. This waste rock is in direct contact with the surface waters of Dyer Cove. Test pits on Dyer Point show that groundwater is in contact with waste rock.

**Access Roads**

Site access roads are constructed of gravel aggregate and waste rock materials. The Ore Pad haul road and access road to WRP-3 cover approximately 4.4 acres and contain an estimated volume of almost 69,000 cubic yards of waste rock.

Surface soil samples collected from access roads show that antimony, arsenic, cadmium, chromium, copper, lead, manganese, and zinc are present at concentrations in excess of screening levels. Concentrations of these elements are high along Old Mine Road and roads adjacent to the former pit, and adjacent to, WRP-2, Mine Operations Area, Dyer Point, and onto WRP-3. Road bed materials are for the most part acid neutralizing. SPLP data suggest that cadmium and lead may leach to groundwater at concentrations that exceed MCLs or MEGs. Other metals that may leach include aluminum, copper, molybdenum, and zinc.

**Halo Area Soils**

Off-site migration and deposition of dust from the active mining operations and current source areas has occurred. Wind and/or blasting operations appear to have resulted in near surface soils displaying slightly elevated concentrations of metal. This halo area is limited to a relatively discrete zone of wood land positioned immediately adjacent to the source. Approximately 5.7 acres of woodland along the western boundary of the Ore Pad and the Mine Operations area show elevated metal concentrations in surface soils.

Based on the surface soil samples collected in 2005, soils are typically affected within 200 feet of the source areas. The elements arsenic, cadmium, chromium, copper, lead, and zinc occur at concentrations above screening levels.

The Halo Area is generally forested and undeveloped. However, some of the residential properties located on the west side of Goose Pond have been affected by the placement of waste rock as fill in the access road, resulting in elevated concentrations of lead in soil.

**Salt Marsh Floodplain**

The Salt Marsh (Figure ES-4) includes the wetland areas between Goose Pond and the source areas, and between Marsh Creek and the adjacent upland forested areas. Elevated concentrations of metals were detected in approximately 6.9 acres of salt marsh. The Salt Marsh contains grasses and vegetation with small areas of standing water and small channels that convey water throughout the flats during tidal movements. Sampling of salt marsh sediments shows that the area proximal to WRP-3 and the Tailings Pile have concentrations of arsenic, copper, lead, and zinc in excess of screening levels.

Three areas of stressed/dead vegetation were observed (i.e., areas of readily apparent harm) in the Salt Marsh near WRP-3 seeps.

**Goose Pond**

Goose Pond sediments contain a widespread distribution of metals at concentrations above risk screening values and background. Highly contaminated sediments in Goose Pond are typically associated with the presence of talcose mine waste related materials.

Ecological characterizations indicate that while the concentration of metals in sediment is elevated, the acid volatile sulfide/simultaneously extracted metals (AVS/SEM) data indicate metals are likely to be less bio-available to ecological receptors via direct contact with sediment pore water than would be predicted based on a review of the concentration data alone. However, pore water concentrations are sometimes in conflict with the AVS/SEM values. Additionally, biota tissue from clams, crabs, worms and fish contains elevated metals at concentrations suggesting that some

degree of uptake is occurring. While the overall benthic community structure does not appear to be degraded when compared to reference sites, sediment toxicity tests indicate there are areas of sediment where ecologically significant reductions in survival and/or growth of test species were observed. The same areas of sediment and the adjacent salt marsh area were identified as having the potential to cause adverse impacts to insect-eating birds and fish-eating birds. An area in the southern portion of Goose Pond has been identified as a mine waste hot spot due to the presence of mine waste and high concentrations of copper, lead, and zinc.

The horizontal distribution of metals appears to be fairly well defined. In the irregularly flooded area of Goose Pond, above the earthen dam, the concentrations of contaminants are highest near the surface (e.g., 0 to 0.5 feet below ground surface (bgs)) and decline with depth in a majority of samples. However, at locations east of WRP-3 and just downstream of the old earthen dam, the highest concentration of metals in the samples is at 0.5 to 1.5 feet bgs. In this area, below the 1.5 foot depth, the concentrations decline significantly. In a few locations (SD-5112, SD-5115, SD-5116) east of WRP-1, sediment metals concentrations decline then increase with depth in samples in the 5 to 10 foot bgs range.

The Middle Goose Pond sediments adjacent to, and south and east of the former pit have concentrations of copper, lead, and zinc an order of magnitude lower than those observed in South Goose Pond and the irregularly flooded portions of Goose Pond.

Dyer Cove sediments have some of the highest concentrations of metals at the Site. This area was used as a settling pond during the mine operations. X-Ray fluorescence (XRF) screening data showed some notable trends in the vertical distribution of metals in sediment. At the south end of Dyer Cove the highest concentrations were reported at a depth of 4 feet to 6 feet.

The former mine pit area of the Site is a unique environment as water depths approach 280 feet deep. Bathymetry and sub-bottom profiling confirm reports that berms constructed around the pit were either pushed or blasted into the pit following cessation of mining. Data also indicate that sediment has accumulated in the pit. Arsenic, copper, lead, manganese, and zinc were detected in samples from the former pit. Lead was the only element detected at concentrations slightly exceeding screening values. Surface sediment samples in the pit contained concentration of inorganic analytes associated with the mining operation (e.g., arsenic, copper, lead, zinc). The

highest concentrations detected included: arsenic (28.7 mg/kg), cadmium (21.6 mg/kg), lead (388 mg/kg) and zinc (3,250 mg/kg). Samples collected below the surface had declining concentrations with depth.

Elevated metals concentrations also exist in Stink Cove; however, concentrations were significantly lower than South Goose Pond, Dyer Cove and Goose Cove. The most contaminated sediment was generally at the surface (0 to 0.5 feet) and in close proximity to a former sump located along the northeastern periphery of the open pit.

North Goose Pond, located north of the former mine pit, is subject to fairly high water velocities and scouring forces during tidal fluctuations. Concentrations of cadmium, copper, lead, and zinc were elevated in a majority of the samples collected from North Goose Pond.

Surface water in Goose Pond and Goose Cove is adversely affected by the Site. Leaching of metals from exposed bedrock, waste rock and earthworks in contact with surface water in the pond, seeps, and overland flow of surface water all likely contribute to some degree to surface water metal concentrations in excess of marine surface water quality criteria.

**Goose Cove**

Goose Cove receives drainage from Goose Pond. During the mining operation Goose Cove received direct discharge from the mine pit dewatering system. Some of highest concentrations of metals reported in Site sediments were detected in Goose Cove close to the reversing falls. The lateral extent of contamination appears to be limited to the cove area, as more distal sediments did not have significantly elevated concentrations of metals.

**Marsh Creek/Weir Cove**

Three sediment samples were submitted for off-site analysis from Marsh Creek. Metal concentrations were generally consistent with background with the exception of copper that was 3 times background in one sample. Based on the available data collected from the creek, sediments do not appear to have been significantly impacted from past Site operations. Weir Cove, located at the downstream end of Marsh Creek, may have received some discharge from the Site when the

earthen dam was in place. Field XRF analysis of sediments from Weir Cove showed concentrations of copper, lead, and zinc close to background. Concentrations reported were within 20 percent of the maximum background data set concentration. Three sediment samples were collected from Weir Cove and submitted to an off-site laboratory for analysis. The concentrations of cadmium, copper, lead, and zinc reported in these samples did not exceed screening values for these analytes. Based on the available data, it does not appear that the sediments in the cove have been affected by the former mine operations.

Analytical results showed aluminum, iron, and manganese were detected at concentrations above the freshwater screening values in all samples from Marsh Stream. However, concentrations of metals in surface waters from Marsh Creek and from background locations in Orcutt Stream are very similar. Similar water chemistry at these locations indicates that Marsh Creek surface water has not been impacted by mining activities or current conditions at the Site. Surface water data was not collected in Weir Cove.

**Penobscot Bay**

Sediment samples were collected from the end of Holbrook Island north to Nautilus Island and Indian Bar. Field XRF analysis data indicate that sediment in these areas of Penobscot Bay have not been adversely affected by the Site. Sediment contamination appears to be confined to the Goose Cove area.

**Former Pit**

Conductivity and temperature profiles completed by WHG and pit profile testing by the USGS indicate that water in the pit changes characteristics at approximately 10 meters (32 feet). Profile data collected by the USGS indicates that significant mixing of mine pit water below 10 meters is unlikely to occur. Model simulations by WHG indicate mixing to a depth of approximately 10 meters. Fred Beck (personal communication) reported that as part of the feasibility study for aquaculture conductivity profiling of the Pit was completed from time to time, and the pit was not observed to turn over.

**Background Locations**

Background sampling locations were established in areas determined to be unaffected by the Site. The purpose of establishing background sampling locations was to provide a data set to which source area media and media affected by former Site operations could be compared. Background samples were collected for surface soils, sediment, surface water (fresh and marine), and groundwater (overburden and bedrock). Biota samples were collected from established reference area locations for comparison to samples collected at paired Site exposure areas.

**Conceptual Site Model Summary**

During early mine operation, groundwater seepage into the pit and entrained rock dust were pumped to an outfall in Goose Cove. Because of concerns about sediment accumulation in Goose Cove, an embayment within Goose Pond (Dyer Cove) was dammed off and used as a settling pond for de-watering the open pit. Following settling, water in Dyer Cove was pumped to the mine water sump, where it was then pumped through a pipe that discharged into Goose Cove. In addition, berms were constructed across portions of Goose Pond to separate surface water flows from mine operating areas and provide a sedimentation basin for overflow and decant discharge from the Tailings Impoundment.

During closure of the mine, the Goose Falls dam was breached, restoring limited tidal exchange in Goose Pond, the Marsh Creek dam was breached, and the pit and estuary were re-flooded. Although some rock and overburden debris were pushed or blasted into the pit at the time of mine closure, the pit remains mostly open except for a relatively thin mantle of accumulated sediment that drapes the former roads and pit bottom.

Contaminated media at the Site include upland soil, groundwater, Goose Pond and Goose Cove sediment, and Goose Pond surface water. Major portions of the upland areas at the Site are contaminated with metals, especially arsenic, copper, lead, and zinc. The presence and widespread distribution of these metals is attributed to spillage during transport, storage, and handling of ore and ore concentrate; disposal of tailings, disposal of waste rock, and contaminated wind blown dust. Although much of the waste rock removed during development of the open pit was not mineralized, other sub-ore grade waste rock was mineralized with iron sulfide and lesser amounts

of copper-, lead-, and zinc-bearing minerals. Use of waste rock to construct containment berms and site roads and surface work areas contributed to site contamination. The following areas contain the highest percentages of mineralized waste rock:

- Ore Pad
- Waste Rock Pile #3
- Portions of Dyer Point/Shoreline

In addition, there is a relatively small area of PCB contamination attributed to historical transformer leakage as well as a relatively small area of DRO/GRO contamination attributed to leaking underground storage tanks removed in 1987. Both these areas are located within the Mine Operations Area. PCBs were detected at a concentration up to 7,900 mg/kg. DRO and GRO were reported in two soil samples at concentration up to 13,000 and 390 mg/kg, respectively, well above the Maine Remediation Goal for "Stringent Sites" of 10 mg/kg for DRO and 5 mg/kg for GRO. Soil at four seasonal residential lots along the mine entrance road connecting the Site to Goose Falls Road is contaminated with arsenic and lead.

Estimated waste rock and tailings dimensions and volumes located within the upland portions of the Site are listed below in Table ES-2.

**Table ES-2**
**Estimated Dimensions and Volumes of Waste Rock and Tailings**

| Site Areas | Estimated Dimensions and Volumes | | | |
|---|---|---|---|---|
| | Average Thickness, ft | Area, sq feet | Area, acres | Volume, yards$^3$ |
| **Waste Rock and Tailings** | | | | |
| Dyer Cove Perimeter | 10.0 | 340,000 | 7.8 | 126,000 |
| Dyer Point | 5.7 | 181,000 | 4.2 | 38,000 |
| Halo Area - West Property Boundary | 1.0 | 249,000 | 5.7 | 9,000 |
| Mine Operations | 5.2 | 227,000 | 5.2 | 44,000 |
| Ore Pad | 4.8 | 90,000 | 2.1 | 16,000 |
| Ore Pad Haul Road | 2.8 | 80,000 | 1.8 | 8,000 |
| Residential Area | 2.0 | 72,000 | 1.7 | 5,000 |
| Road to Waste Rock Pile 3 | 14.6 | 111,000 | 2.6 | 60,000 |
| Tailings Impoundment (footprint including rock berm) | 21.1 | 916,000 | 21.0 | 716,000 |
| Stink Cove Sediment at Waste Rock Pile 1 | 41.7 | 188,000 | 4.3 | 290,000 |
| Waste Rock Pile 1 (including berm) * | 42.7 | 613,000 | 14.1 | 969,000 |
| Waste Rock Pile 2 | 6.5 | 94,000 | 2.2 | 23,000 |
| Waste Rock Pile 3 | 20.5 | 286,000 | 6.6 | 216,000 |
| **Total Waste Rock and Tailings** | | | 79 | **2,521,000** |
| **Tailings Impoundment Surface Inside of Berm** | - | 576,000 | 13.2 | - |
| **Pit Volume 0-310'** | 310 | 467,000 | 11 | 2,035,000 |

**Notes:**
* Waste Rock Pile 1 values exclusive of Stink Cove sediment

Overburden groundwater, where it exists, and bedrock groundwater are also contaminated beneath much of the Site, and concentrations of aluminum, antimony, arsenic, cadmium, chromium, copper, lead, manganese, nickel, sodium, and zinc often exceed MCLs and/or MEGs. Concentrations in excess of MCLs and/or MEGs are most frequent and typically greatest at the Ore Pad, followed by the Mine Operations Area, Waste Rock Pile 1, and Waste Rock Pile 3. The Tailings Impoundment and Waste Rock Pile 2 have the lowest number of metals detected in excess of regulatory criteria. The presence of these metals in groundwater is attributed predominantly to release from mineralized rock as a result of leaching by acid rock drainage. An exception may be sodium whose presence may also be associated with use of salt water during ore concentration and with drainage from Stink Cove sediments impounded at Waste Rock Pile 1. GRO was detected in one bedrock monitoring well (MW-614R) at a concentration less than the MEG and the Maine Remediation Goal for "Stringent Sites". The presence of GRO in bedrock groundwater is attributed to soil

contamination observed in upgradient soils. DRO and PCBs were not detected in groundwater samples.

Goose Pond and Goose Cove sediments are contaminated with metals, especially copper, lead, and zinc. The highest concentrations of metal in sediment are located in the following areas:

- an approximate 10 acre, 2,400-foot reach of southern Goose Pond extending from the southern site boundary northward past the tailings impoundment and Waste Rock Pile 3;
- Dyer Cove;
- a relatively small area east of the mine pit near the mouth of Stink Cove;
- an approximately 6.5 acre area of salt marsh sediments between the tailings impoundment and Goose Pond; and
- an approximate 1.5 acre area in Goose Cove coinciding with mine waste deposits similar to those in Goose Pond.

PCBs and SVOCs have not been detected in Goose Pond or Goose Cove sediments.

The primary source of contamination to Goose Pond and Goose Cove sediments is interpreted to be historical mine operations. The area of highest contaminant concentration in Goose Cove corresponds to an area of mapped mine waste thought to result from mine pit dewatering. Four of the five high concentration areas in Goose Pond also correspond to areas of mapped mine waste. The largest area, adjacent to the tailings impoundment and Waste Rock Pile 3, has mine waste deposits up to 3 feet thick. Based on historical information, the primary source of these deposits is overflow from the tailing impoundment – either through the decant pipe or via overflow ditches at the northwest and southwest corners. Overflow from the northwest corner was also a likely major source of salt marsh contamination. In addition, discharge of contaminated groundwater through seeps and weathering of waste rock via acid rock drainage, followed by surface water transport of suspended and dissolved material, likely contributed to sediment contamination. It is unlikely, however, that precipitation from groundwater discharge (i.e., seeps and submerged groundwater discharge) could have created the 3 foot thick deposits documented during the RI. Overflow from the tailings impoundment and groundwater/seep discharge continue today. At Waste Rock Pile 3, weathering of waste rock via acid rock drainage followed by groundwater/seep and surface water

transport of suspended and dissolved material also appear to be historical and potentially ongoing contributors to the Goose Pond estuary contamination.

The primary source of contamination to Dyer Cove sediments is interpreted to be use of the cove as a settling pond to remove suspended solids from mine pit water after sedimentation of Goose Cove became a concern. In addition, contaminated surface water runoff during and after mine operations as well as the discharge of contaminated groundwater are interpreted as historical and ongoing contributors to Dyer Cove sediment contamination.

Goose Pond surface water shows elevated concentrations of several metals, especially copper and zinc which exceed AWQC. Surface water is continually flushed through Goose Pond as a result of tidal exchange, surface water and groundwater discharge, and precipitation. The presence of elevated concentration of metals may be the result of the ongoing discharge of contaminated surface water and groundwater/seeps from the Site, although dissolution of metals from sediment precipitates may also contribute. It is also possible that weathering of exposed mineralized rock in the pit is contributing metals to Goose Pond surface water.

Acid rock drainage from mineralized rock in select upland areas of the Site and tailings at the tailings impoundment is expected to result in leaching of metals, including copper, lead, and zinc, and may result in contamination of groundwater and surface water runoff with unquantifiable amounts of dissolved-phase metals. Acidic conditions are buffered by the presence of carbonates and other minerals within the source material, essentially neutralizing acidic drainage. Groundwater and surface water runoff emanating from these discrete areas of the Site will transport these metals to discharge locations in Goose Pond. Surface water will also erode friable material and transport suspended material to Goose Pond. Transport by windblown dust, thought to have been a concern during mine operations, is now minor. Because of the volume of mine waste material at the Site, these release and transport mechanisms are expected to persist. Figure ES-9 depicts these transport mechanisms.

PCBs have relatively low water solubility and tend to adhere to soil particles. The PCBs at the Mine Operations Area are expected to remain sorbed to soil and degrade only slowly, with minimal migration in groundwater. DRO also have relatively low water solubility and tend to sorb to soil particles. However, the shorter and more water soluble carbon-chain molecules within DRO are

more amenable to aerobic degradation than longer carbon-chain molecules, and, considering the age of the Site, may have already degraded leaving a relatively immobile and stable higher molecular weight fraction behind. GRO consist of a more water soluble, and more biodegradable molecules than DRO. It is expected that the GRO at the source (i.e., residual contamination at the UST grave) will continue to dissolve and migrate to groundwater. However, as the source is depleted, concentrations are expected to decrease. As long as groundwater remains aerobic, biodegradation is expected, and long distance migration is not expected.

Copper, lead, and zinc in Goose Pond and Goose Cove sediments are expected to exist primarily as sulfide precipitates (where sediments are organic and anaerobic) or carbonate or hydroxide precipitates where sediments are aerobic. They may also sorb onto iron and manganese oxyhydrides in shallow aerobic sediments. Although equilibrium exists between precipitated and dissolved metals, the tendency will be for copper, lead, and zinc to remain as sulfide/carbonate/hydroxide precipitates as long as redox conditions do not change substantially. In that case, there may be dissolution/reprecipitation reactions among sulfide/carbonate/hydroxide species as redox conditions shift between anaerobic and aerobic conditions and back. Sediments, however, are expected to remain a relative sink for copper, lead, and zinc.

Goose Pond is a low-energy environment, and, based on hydrodynamic modeling, mechanical suspension of shallow sediments by wave action and currents and longitudinal transport is expected to be minimal. Goose Cove is a higher energy environment, but potential for suspension of shallow sediments by wave action and currents and longitudinal transport, while greater than in Goose Pond, remains low. Sediment re-suspension by watercraft is more likely in Goose Cove than in Goose Pond.

Estimated sediment accumulation rates in Goose Pond and Goose Cove are low (0.5 to 1 mm/year) and burying of contaminated sediment by accretion of uncontaminated sediment to the 6 to 12 inch depth needed to protect biological receptors could take hundreds of years. Vertical mixing of contaminated sediment with accreting sediment through bioturbation would be expected to keep surface contamination concentration high.

The Site is currently abandoned and unoccupied, although it is used for recreation (e.g., hiking, rock collecting, and ATV riding). There is no use of, or exposure to, site groundwater. There are

no plans to redevelop the site or neighboring upland area to the west. There are four seasonal residential lots along the mine entrance road connecting the Site to Goose Falls Road. Recreational uses of Goose Cove and Goose Pond, including boating, also occur; however, the shallow depth of water at Goose Falls prevents passage between Goose Pond and Goose Cove by larger watercraft. Commercial and recreational lobstering occurs in Penobscot Bay. These activities have not been observed in Goose Cove or Goose Pond. Commercial fishing is not known to occur in Goose Cove or Goose Pond. Recreational fishing occurs in Goose Cove, and may occur in Goose Pond.

The shellfish beds in Goose Cove have been closed by the State, and no shellfishing is known to occur in that area. The shellfish beds of Goose Pond are also closed.

Hydrodynamic model simulations of Goose Pond indicate that contaminated sediment in Goose Pond is not likely to be transported out into Goose Cove and beyond, even under extreme hydrological events. Physical measurements and model simulations also suggest mixing of water occurs primarily within the upper 10 meter (32 foot) profile of the former pit.

## HUMAN HEALTH RISK ASSESSMENT SUMMARY

A baseline human health risk assessment (HHRA) has been performed as part of the RI. Work associated with this effort is described in Volume II of this document. The purpose of the HHRA is to quantify the human health risks associated with potential exposures to site-related contaminants under current and reasonably foreseeable future land use conditions, in the absence of any remedial actions.

The applicable legal context for the HHRA is CERCLA. The applicable regulatory requirement is the National Contingency Plan (NCP), 40 CFR Part 300. The HHRA was performed using United States Environmental Protection Agency (USEPA) national and Region 1 CERCLA guidance for risk assessment, as described in the *Risk Assessment Guidance for Superfund* document series.

The HHRA evaluated cancer and non-cancer health risks associated with potential exposures to media that have been potentially affected by Site-related contamination, including soil, surface water, sediment, groundwater, and biota. The land uses evaluated in the HHRA included:

- Current residential use. This land use included evaluation of child and adult residents who may potentially be exposed to surface soil located at each of four private residential lots located along Old Mine Lane.
- Current and continuing future recreational use. This land use included evaluation of child, older child, and adult recreational visitors who may potentially be exposed to soil at the Source Areas and Halo Area, groundwater seeps at the Source Areas, as well as at the water bodies associated with the Site (Goose Cove, Goose Pond, Goose Pond Irregularly Flooded Area, Salt Marsh, and Marsh Creek) during activities such as swimming, wading, or boating.
- Current and future recreational angling. Under current land use, this included evaluation of recreational anglers who may contact surface water while pulling and placing traps for lobsters and crabs, and who may be exposed to contaminants that have accumulated in crab or lobster tissue by consuming their catch of lobster and crabs. Under future land use, this included evaluation of recreational anglers who may dig for clams or mussels and be exposed to surface water and sediment, and who may be exposed to contaminants that have accumulated in clam or mussel tissue, by consuming their catch of clams or mussels.
- Current and future commercial angling. Under current land use, this included evaluation of commercial anglers who may contact surface water while pulling and placing traps for lobsters, and who eat a portion of their catch of lobster. Under future land use, this included evaluation of commercial anglers who may contact surface water while pulling and placing traps for crabs, who may dig for clams or mussels and be exposed to surface water and sediment, and who may be exposed to contaminants that have accumulated in biota tissue, by consuming a portion of their catch of crabs, clams, or mussels.
- Future residential use. An assessment was performed assuming that the Site was developed for residential purposes. This included evaluation of child and adult residents who may potentially be exposed to soil at the Source Areas and Halo Area if the areas were to be developed for residential use in the future, and to groundwater under the assumption that drinking water supply wells were to be installed in the overburden and bedrock aquifers where Site-related contamination has been identified. In addition, this land use included evaluation of construction workers who may potentially be exposed to soil at the Halo Area and Source Areas during re-development activities.

Current area residents, as well as future residents, could also visit other areas of the Site (e.g., surface water bodies) as recreational visitors, or shellfish as recreational anglers. The risk characterization accounted for these potential multi-media exposures.

Health risks were calculated for the chemicals of potential concern (COPCs) in each of the exposure media. COPCs were identified using a concentration-toxicity screen performed in accordance with USEPA risk assessment guidance. The primary COPCs identified in all media were metals, including arsenic, cadmium, copper, lead, manganese, and zinc. Polychlorinated Biphenyls (PCBs) were also retained as COPCs in Source Area soils, due to PCB contamination identified in soils in the vicinity of the ore pad.

For each COPC in each medium and exposure point evaluated in the HHRA, a representative exposure concentration (termed the exposure point concentration [EPC]) was calculated as the lesser of the maximum detected concentration or the 95% upper confidence limit (UCL) of the arithmetic mean concentration. For groundwater, the maximum detected concentrations were used as the EPCs.

Health risks were calculated and evaluated by three metrics:

- Excess lifetime cancer risks (ELCR) were calculated for potentially carcinogenic COPCs using cancer slope factors and unit risk values obtained from USEPA-approved sources. At this Site, the potentially carcinogenic COPCs include arsenic and PCBs. Cancer risk estimates were compared to an ELCR range of $10^{-6}$ (one in a million) to $10^{-4}$ (one in ten-thousand) as stipulated in the NCP.
- Non-cancer hazard index (HI) values were calculated for all COPCs using reference dose and reference concentration values obtained from USEPA-approved sources. Non-cancer hazards were compared to a hazard index value of 1, which corresponds to levels of exposure that people (including sensitive individuals such as children) could experience without expected adverse effects.
- Risks associated with potential exposures to lead were evaluated using lead uptake models developed by USEPA, which provide estimates of blood lead levels that may result from exposures to lead in environmental media. The estimated blood lead levels are compared to a threshold blood lead level of 10 micrograms per deciliter (µg/dl), which is a multi-Agency goal that has been designated by the US Centers for Disease Control (CDC) and the Agency for Toxic Substances and Disease Registry (ATSDR) as a level of concern to protect sensitive populations, including neonates, infants, and children. USEPA indicates that 95% of the exposed population should have a blood lead level that does not exceed 10 µg/dl.

## CONCLUSIONS

Table ES-3 provides a summary of the HHRA results, which are discussed below.

### Soil

Cancer and non-cancer exposure risks are within or below the USEPA risk management criteria (ELCR range of $10^{-6}$ to $10^{-4}$, HI of 1, and 95% or more of exposed population with a geometric mean blood lead level of 10 µg/dl or less) at the following areas:

- Residential Lot B soil (current residential land use);
- Source Area subsurface soil (future residential use); and
- Halo Area soil (current and future recreational use and future residential use).

Cancer and non-cancer exposure risks are in excess of USEPA risk management criteria (ELCR range of $10^{-6}$ to $10^{-4}$, HI of 1, and/or 5% or more of exposed population with a geometric mean blood lead level 10 µg/dl or more) at the following areas:

- Residential Lot A soil (current residential land use) due to lead;
- Residential Lot C soil (current residential land use) due to lead;
- Residential Lot D soil (current residential land use) due to lead and thallium; and
- Source Area soil (current and future recreational use due to PCBs; future residential use due to PCBs and lead).

**Groundwater and Groundwater Seeps**

Cancer and non-cancer exposure risks are in excess of USEPA risk management criteria (ELCR range of $10^{-6}$ to $10^{-4}$, HI of 1, and/or 5% or more of exposed population with a geometric mean blood lead level 10 µg/dl or more) at the following areas:

- Overburden groundwater (future use as potable water) due to aluminum, arsenic, cadmium, chromium, lead, manganese, and zinc.
- Bedrock groundwater (future use as potable water) due to cadmium, copper, manganese, and zinc.

**Surface Water and Sediment**

Cancer and non-cancer exposure risks are within or below the USEPA risk management criteria (ELCR range of $10^{-6}$ to $10^{-4}$, HI of 1, and 95% or more of exposed population with a geometric mean blood lead level of 10 µg/dl or less) at all exposure points evaluated in the HHRA, for potential exposures by recreational visitors who may wade, swim, or boat, and recreational and commercial anglers who may fish for lobsters or crabs, or dig for clams and mussels. In addition, the conclusions of the risk characterization results for residential exposures to soil would not be

altered when additive risks are considered for potential exposures to surface water/sediment at any of the water bodies.

Cancer and non-cancer risks are below the USEPA risk management criteria (ELCR range of $10^{-6}$ to $10^{-4}$, HI of 1) for potential exposure to seeps.

**Biota**

Cancer and non-cancer exposure risks are within or below USEPA risk management criteria (ELCR range of $10^{-6}$ to $10^{-4}$, HI of 1, and/or 95% or more of exposed population with a geometric mean blood lead level 10 μg/dl or less) for the following biota evaluated in the HHRA:

- Goose Cove mussels; and
- Goose Pond clams.

Cancer and non-cancer exposure risks associated with the remainder of the biota evaluated in the HHRA (Goose Cove lobster, crabs, clams; Goose Pond crabs; and Weir Cove clams) are within or below USEPA risk management criteria (ELCR range of $10^{-6}$ to $10^{-4}$, HI of 1, and/or 95% or more of exposed population with a geometric mean blood lead level 10 μg/dl or less) when incremental risks are considered. In other words, for these biota, the risks associated with biota collected from the Site that are over and above the risks that are associated with biota collected from background locations are within USEPA risk management criteria. In addition, for these biota the principal contributor to calculated risks is arsenic. However, arsenic in biota does not appear to be related to arsenic release from the Site, as evidenced by a lack of association between sediment arsenic EPCs and tissue EPCs, similarity in arsenic tissue EPCs among all biota from Site and background areas, and biota data sets with limited sizes that result in use of maximum detected concentrations as EPCs. The clam tissue in portions of Goose Pond contains lead at concentrations in excess of the level that would be considered acceptable for regular consumption of the clams. The human health risk assessment assumed a frequency of clam consumption (ranging from 3-5 clam meals per year from Goose Pond) based on field verification of the degree of difficulty to obtain a meal size portion of clams.

**Table ES-3**
**Human Health Risk Assessment Summary**

| Exposure Point | Current Resident | | | Future Resident | | | Current/Future Recreational Visitor | | | Future Recreational Angler | | | Future Commercial Angler | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ELCR | HI | $Pb_{BLD}$ | ELCR | HI | $Pb_{BLD}$ | ELCR | HI | $Pb_{BLD}$ | ELCR | HI | $Pb_{BLD}$ | ELCR | HI | $Pb_{BLD}$ |
| Lot A Surface Soil | 5E-05 | 1 [a] | > 10 | | | | | | | | | | | | |
| Lot B Surface Soil | 4E-05 | 0.7 | < 10 | | | | | | | | | | | | |
| Lot C Surface Soil | 3E-05 | 1 | > 10 | | | | | | | | | | | | |
| Lot D Surface Soil | 4E-05 | 2 | > 10 | | | | | | | | | | | | |
| Source Area Surface Soil | | | | 3E-03 | 58 | > 10 | 1E-03 | 167 | < 10 | | | | | | |
| Source Area Subsurface Soil | | | | 3E-07 | 0.07 | | | | | | | | | | |
| Halo Area Surface Soil | | | | 2E-05 | 1 | < 10 | 7E-06 | 0.2 | < 10 | | | | | | |
| Freshwater Seeps | | | | | | | 1E-08 | 0.1 | | | | | | | |
| Overburden Groundwater | | | | 1E-03 | 235 | > 10 | | | | | | | | | |
| Bedrock Groundwater | | | | 1E-04 | 86 | < 10 | | | | | | | | | |
| Goose Cove Surface Water | | | | | | | 5E-09 | 0.001 | | 9E-09 | 0.002 | | 6E-08 | 0.01 | |
| Goose Cove Crustaceans (Crabs) [b] | | | | | | | | | | 3E-04 | 4 | < 10 | 3E-04 | 4 | |
| Goose Cove Crustaceans (Lobster) [b,c] | | | | | | | | | | 2E-04 | 2 | < 10 | 2E-04 | 3 | |
| Goose Cove Bivalves (Clams) [c] | | | | | | | | | | 9E-05 | 3 | < 10 | 7E-05 | 2 | |
| Goose Cove Bivalves (Mussels) | | | | | | | | | | 1E-04 | 1 [a] | < 10 | 1E-04 | 1 [a] | |
| Goose Pond Surface Water | | | | | | | 5E-09 | 0.001 | | 9E-09 | 0.002 | | 6E-08 | 0.01 | |
| Goose Pond Sediment | | | | | | | 3E-07 | 0.003 | | 2E-06 | 0.03 | < 10 | | | |
| Goose Pond (Irregularly Flooded) Sediment | | | | | | | 2E-05 | 0.6 | < 10 | 3E-06 | 0.03 | < 10 | | | |
| Goose Pond Crustaceans (Crabs) [c] | | | | | | | | | | 1E-04 | 3 | < 10 | 1E-04 | 4 | |
| Goose Pond Bivalves (Clams) | | | | | | | | | | 2E-05 | 0.6 | < 10 | | | |
| Salt Marsh Sediment | | | | | | | 1E-05 | 1 | < 10 | | | | | | |
| Marsh Creek Surface Water | | | | | | | 1E-07 | 0.003 | | | | | | | |
| Marsh Creek Sediment | | | | | | | 1E-07 | 0.001 | | | | | | | |
| Weir Cove Bivalves (Clams) [b] | | | | | | | | | | 2E-04 | 1 [a] | < 10 | 1E-04 | 1 [a] | |

Green shading indicates ELCR less than 1E-06, HI less than 1, or $Pb_{BLD}$ 10 µg/dL or less for 95% or more of the population.
Blue shading indicates ELCR between 1E-06 and 1E-04.
Red shading indicates ELCR greater than 1E-04, HI greater than 1, or $Pb_{BLD}$ greater than 10 µg/dL for more than 5% of the population.
Yellow shading indicates incremental risks are below a cancer risk of 1E-04 and a HI of 1.

[a] Based on target organ hazard index.
[b] Risks are due to arsenic; arsenic in biota tissue does not appear to be related to the Site. Incremental risks are below a cancer risk of 1E-04 and a hazard index of 1.
[c] Target organ hazard index does not exceed 1.

ELCR - Excess Lifetime Cancer Risk
HI - Hazard Index
$Pb_{BLD}$ - Geometric mean blood lead level

Prepared by / Date: KJC 03/10/08
Checked by / Date: JHP 03/10/08
Revised by / Date: KJC 10/23/08

## ECOLOGICAL RISK ASSESSMENT SUMMARY

A baseline ecological risk assessment (BERA) was performed as part of the RI. The objective of this BERA is to evaluate the risk of ecological harm associated with Site-related contaminants which consist primarily of metals.

The ecological risk assessment process at the Callahan Mine Superfund Site follows the United States Environmental Protection Agency (USEPA) *Ecological Risk Assessment Guidance For Superfund, Process for Designing and Conducting Ecological Risk Assessments, 1997*, herein referred to as the Process Document.

The BERA considered nine assessment endpoints to evaluate risk in aquatic exposure areas, and six assessment endpoints to evaluate risk in terrestrial exposure areas.

### Exposure Assessment and Effects Assessment

Assessment and measurement endpoints were evaluated for the six aquatic exposure areas and two terrestrial areas. The specific methods used to assess each measurement endpoint generally included:

- Comparison of COPC exposure point concentrations (EPCs) in surface water, sediment, surface soil, and tissue to screening and effects benchmarks; most benchmarks were derived from the scientific literature though some were derived based on site-specific factors;
- Evaluation of AVS SEM data;
- Sediment toxicity tests (chronic 10-day survival and growth for *L. plumulosus* and 28-day survival and growth for *N. arenaceodanta*) , with statistical analysis of co-located sediment and porewater data to try to identify a dose-response relationship to observed effects;
- Fish condition factors;
- Quantitative benthic and terrestrial invertebrate surveys;
- Quantitative salt marsh and terrestrial vegetation surveys; and
- Food chain modeling for terrestrial and semi-aquatic birds and mammals by which modeled doses were compared to toxicity reference values (TRVs) based on no-observable-adverse-effects-levels (NOAELs) and lowest-observable-adverse-effects levels (LOAELs).

Assessment populations evaluated in aquatic exposure area food chain models included:

- Spotted sandpiper, representing insectivorous birds;
- Great blue heron, representing piscivorous birds;
- Osprey, representing predatory birds (bald eagle was used as surrogate for osprey, with emphasis on population-level effects rather than effects on individuals);
- River otter, representing semi-aquatic mammals; and
- Bald eagle, representing rare, threatened, and endangered species. Due to special status, bald eagles were evaluated for individual effects rather than population effects.

Assessment populations evaluated in terrestrial exposure area food chain models included:

- Robin, representing omnivorous song birds;
- Red-tailed hawk, representing predatory birds;
- White-footed mouse, representing omnivorous small terrestrial mammals; and
- Short-tailed shrew, representing worm-eating small terrestrial mammals.

Reference locations were identified and paired with exposure areas based on important habitat characteristics including salinity, community characteristics, and tidal patterns for aquatic reference areas, and surrounding land use and natural community composition for terrestrial areas.

Both reasonable maximum exposures (RME) and central tendency exposures (CTE) were considered when assessing and characterizing risk. RME exposure point concentrations (EPCs) were calculated as the lower of the 95 percent upper confidence limit or the maximum concentration. CTE EPCs were based on the average (arithmetic mean) concentration using one-half the sample quantitation limit (SQL) for non-detects. RME EPCs for reference areas were selected as the maximum detected concentrations due to generally smaller data sets; reference CTE EPCs were also based on the average (arithmetic mean) concentration using one-half the SQL for non-detects.

Pathways that were evaluated included direct contact with surface soil for terrestrial plants and invertebrates, direct contact with surface water and sediment for aquatic life (invertebrates and

fish), and ingestion of surface water, incidental ingestion of soil or sediment, and ingestion of prey items for wildlife receptors.

**Risk Characterization**

Risk characterization involves the integration of exposure and effects data to determine the likelihood of adverse effects. A weight of evidence approach was used to make conclusions regarding risk of harm for assessment endpoints with more than one measurement endpoint. Measurement endpoints were each assigned an inference weight, based upon how closely they represent the assessment endpoint. Conclusions regarding risks to an assessment endpoint were reached by considering the inference weight for each measurement endpoint, i.e., the overall weight of evidence.

Measurement endpoints involving food chain models and comparison of media concentrations to benchmarks were assessed using a hazard quotient (HQ). When HQs were calculated as part of the Effects Assessment, the likelihood of adverse population level effects was first determined using a Four-Way Interpretative Risk Matrix that incorporated all four outcomes from RME and CTE EPC and NOAEL and LOAEL TRV (or screening and effects benchmark) combinations.

**Table ES-4**
**Four-Way Interpretative Ecological Risk Matrix**

| RME/NOAEL HQ | RME/LOAEL HQ | CTE/NOAEL HQ | CTE/LOAEL HQ | Risk Conclusion: Adverse population-level effects: | Confidence Level |
|---|---|---|---|---|---|
| ≤ 1 | ≤ 1 | ≤ 1 | ≤ 1 | Unlikely | High |
| > 1 | ≤1 | ≤ 1 | ≤ 1 | Unlikely | High |
| > 1 | > 1 | ≤ 1 | ≤ 1 | Unlikely | Moderate |
| > 1 | ≤ 1 | > 1 | ≤ 1 | Possible | Low |
| > 1 | > 1 | ≥ 1 | ≤ 1 | Possible | Moderate |
| > 1 | > 1 | > 1 | > 1 | Possible | High (increases with higher HQs) |

In the case of measurement endpoints 1B (Salt Marsh plants), 3A (water column invertebrates), and 4A (fish) which compared surface water or sediment concentrations to benchmarks, the terms "screening benchmark" and "effects benchmark" were used in place of "NOAEL" and "LOAEL ."

HQs calculated for fish, benthic invertebrates, *Spartina,* and soil invertebrate tissue were based only on tissue effects benchmarks combined with the RME and CTE scenarios; only two sets of HQ conditions were calculated. In such cases, the Two-Way Interpretative Risk Matrix was used as a guide to address the range of risk conclusions and confidence levels:

**Table ES-5**
**Two-Way Interpretative Risk Matrix**

| RME/Effects Benchmark HQ | CTE/Effects Benchmark HQ | Risk Conclusion: Adverse population-level effects: | Confidence Level |
|---|---|---|---|
| ≤ 1 | ≤ 1 | Unlikely | High |
| > 1 and <10 | ≤ 1 | Unlikely | Moderate |
| > 1 and >10 | ≤ 1 | Possible | Low |
| > 1 | > 1 | Possible | High (increases with higher HQs) |

When possible, the risk matrices relied on incremental risk HQs which accounted for the background contribution to Site risk.

The Four-Way and Two-Way risk matrices were the first steps to estimate and characterize risk. Then, underlying assumptions and uncertainties such as bioavailability were considered to derive *final* risk conclusions.

Other assessment endpoints which were not based on HQ includes: quantitative benthic and terrestrial invertebrate community surveys, fish condition factors, quantitative salt marsh and terrestrial plant surveys, and sediment toxicity tests were compared to conditions in reference areas. AVS SEM data were compared to threshold concentrations established by USEPA (USEPA, 2005*1*).

**Conclusions**

Risks are summarized in Table ES-6 (aquatic exposure areas) and Table ES-7 (terrestrial exposure areas) and presented in the following text.

Salt Marsh Plants

There is a high risk to salt marsh plants in areas of readily apparent harm (RAH), where vegetation is absent or stunted, located at the upland fringe of the Salt Marsh exposure area; however,

multivariate statistical analyses could not identify a significant dose-response relationship with site COPCs. No statistically significant dose-response relationship could be identified, though benchmark comparisons suggest copper and cadmium as possibly contributing to adverse population level effects. In other areas of Salt Marsh outside of RAH, the weight of evidence suggested that the risk of harm is unlikely; areas of RAH comprise less than 0.5% salt marsh habitat in Goose Pond.

The cause of the RAH is not known; it could be due to an episodic event from a seep discharge, chronic exposure to Site seeps or sediments, or other naturally occurring environmental stressors. The *Spartina* sampled in the Salt Marsh is subject to periods of prolonged inundation and prolonged emergence and is generally growing in a higher intertidal level. A reduction of tidal flow may also causes changes in soil chemistry. Sea water naturally contains large quantities of sulfur, which is reduced by soil bacteria into sulfide in the normally anoxic marsh soil conditions.

**Table ES-6**
**Ecological Risk Summary Matrix - Aquatic Exposure Areas**

| | Receptor Group | Assessment Endpoint | Measurement Endpoints | Inference Weight* | Uncertainty | Goose Cove | Goose Pond Permanently Flooded | Goose Pond Irregularly Flooded | Salt Marsh | Marsh Creek | Weir Cove |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AQUATIC HABITAT | | | | | | | | | | | |
| 1 | Salt Marsh Plants | Maintenance of plant communities in the Salt Marsh exposure area that were potentially affected by past mining activities at the Site similar to those communities found at the reference site. | 1A: Compare Site salt marsh sediment metal concentrations to published sediment benchmarks protective of vascular plants (*Spartina*) and to reference sediment concentrations. | L | Bulk sediment concentrations may overestimate bioavailable fraction. | Not evaluated | Not evaluated | Not evaluated | Adverse population level effects possible from cadmium and copper. HQs are low (1.1 to 2.8 based on RME/CTE and NOAEL/LOAEL combinations. | Not evaluated | Not evaluated |
| | | | 1B: Compare concentrations in Salt Marsh plant tissue (*Spartina*) to literature-based effects thresholds and to reference locations | L/M | Assumes tissue concentrations greater than reference result in adverse effects and therefore overestimates risk. | Not evaluated | Not evaluated | Not evaluated | Adverse population level effects possible for cadmium, copper, and zinc. HQs are low (1.7 to 5.3) based on RME/CTE combinations). | Not evaluated | Not evaluated |
| | | | 1C: Perform field surveys to determine if the Salt Marsh *Spartina* population is significantly different from reference populations. | M/H | Assumes that physical parameters (flooding regime, salinity range, natural sulfuric acid production, etc.) are consistent between study and reference areas. | Not evaluated | Not evaluated | Not evaluated | Salt marsh plants in locations of readily available harm (RAH) located at the upland fringe of the salt marsh are significantly different from reference salt marsh. There is likely a high risk of harm to the salt marsh plant community in areas of RAH. | Not evaluated | Not evaluated |
| | | | **Assessment Endpoint 1 Weight of Evidence Conclusion** | - | - | Not evaluated | Not evaluated | Not evaluated | There is a high risk to salt marsh plants in areas of RAH. The cause of the RAH is not known; it could be due to an episodic event from a seep discharge, chronic exposure to Site seeps or sediment hot spots, or other natural non-chemical stressors. In other areas of the salt marsh, risk of harm is unlikely. Areas of RAH affects less than 0.5% of Salt Marsh habitat. Benchmark comparisons may overestimate risk. | Not evaluated | Not evaluated |
| 2 | Benthic Invertebrates | Maintenance of benthic invertebrate communities at the Site similar to those found at the reference site. | 2A: Compare Site sediment AVS SEM concentrations to toxicity thresholds and reference locations. | M | AVS SEM data are better at predicting lack of toxicity than predicting toxicity. Less than 5% of AVS SEM data are above the uncertainty thresholds (>130 uMols/g) for lack of toxicity. | Divalent metals not likely to be toxic and are not bioavailable. Risk to the benthic macroinvertebrate community unlikely. | Divalent metals not likely to be toxic and are not bioavailable. Risk to the benthic macroinvertebrate community unlikely. | Divalent metals not likely to be toxic. Risk to the benthic macroinvertebrate community unlikely. | Not evaluated | Divalent metals not likely to be toxic and are not bioavailable. Risk to the benthic macroinvertebrate community unlikely. | Divalent metals not likely to be toxic. Risk to the benthic macroinvertebrate community unlikely. |
| | | | 2B: Perform laboratory toxicity tests to measure survival and growth of two marine/estuarine benthic invertebrates (the amphipod *Leptocheirus plumulosus* and the polychaete *Neanthes arenaceodanta*) exposed to sediments collected from Site exposure areas and | M/H | Predators found in some replicates; tests performed at salinity concentrations of 27 parts per thousand (ppt) while field conditions in some exposure areas may be lower, only one reference sample was collected for each exposure area; lab conditions not truly representative of field conditions where biota have had the opportunity to acclimate to ambient conditions. | No effect on *Neanthes* growth, or *Leptocheirus* growth and survival. Ecologically significant effects to *Neanthes arenaceodanta* growth at GC-05. Analysis of dose-response scatter plots for copper, lead, and zinc did not identify a potential effects driver. Sediment COPC concentrations at GC-05 were lower than GC-04 and GC-06 which did not exhibit ecologically significant effects; risk likely overestimated. | Ecologically significant effects to survival and growth. Integrating results of statistical analyses of sediment and pore water concentration data with dose-response scatter plots suggests that arsenic, cadmium, and copper may occur in hotspots at GP-22 and GP-12. Pore water evaluation suggests that copper and zinc may be contributing to the toxicity at locations GP-22 and GP-12. Ecologically significant effects were observed for *Leptocheirus* survival at GP-07 and *Leptocheirus* growth at GP-13; sediment COPC concentrations at GP-07 and GP-13 were lower than other locations which did not exhibit adverse ecological effects. | Possibility of risk to benthic invertebrates due to tissue residual levels for clams in the hot spot area containing mine waste and elevated copper, lead, and zinc hot spot concentrations. Risk to benthic macroinvertebrates in the remainder of the Goose Pond Irregularly Flooded exposure area benthic macroinvertebrate community is unlikely. | Not evaluated | Not evaluated | Not evaluated |
| | | | 2C: Compare tissue residue levels in benthic invertebrates collected from Site exposure areas and reference exposure areas to published tissue benchmarks. | L/M | Benchmark comparisons may overestimate risk; benchmarks not available for between 4 and 5 COPCs (cadmium, copper, plead, nickel, zinc), depending on tissue type. | Adverse population level effects to the benthic macroinvertebrate community are unlikely. | Adverse population level risks to benthic macroinvertebrate community unlikely. Possible adverse population level risks to clams from lead does not signify a community level risk considering other tissue types evaluated in this measurement endpoint. | Adverse population level effects to the benthic macroinvertebrate community possible from lead and zinc based on two clam tissue samples located in the hot spot area. | Not evaluated | Not evaluated | Adverse population level effects are not expected. Risk to benthic macroinvertebrate community unlikely. |
| | | | 2D: Compare the diversity and community structure of benthic invertebrates in sediments from Site exposure areas to reference locations. | M | Assumes that study area conditions worse than reference exhibit adverse effects even though they may actually fall within natural variability. | Based on CSI, diversity and structure of benthic macroinvertebrate community is consistent with reference. Risk to the benthic macroinvertebrate community unlikely. | Based on CSI, diversity and structure of benthic macroinvertebrate community is consistent with reference. Risk to the benthic macroinvertebrate community unlikely | Based on CSI, diversity and structure of benthic macroinvertebrate community is consistent with reference. Risk to the benthic macroinvertebrate community unlikely. | Not evaluated | Not evaluated | Not evaluated |
| | | | **Assessment Endpoint 2 Weight of Evidence Conclusion** | - | - | Overall unlikely risk to the Goose Cove benthic macroinvertebrate community. Effects to *Neanthes* growth did not correlate with sediment COPC concentrations. | Toxicity tests suggest that a hotspot area may occur in the vicinity of GP-22 and GP-12 for arsenic, cadmium, and copper. Pore water evaluation also suggests that copper and zinc may be contributing to the toxicity at locations GP-22 and G-12. The remainder of the Goose Pond Permanently Flooded area did not show impairment to the benthic macroinvertebrate community.The potential for risk to the benthic community in the remainder of the Goose Pond Permanently Flooded is unlikely. | Possibility of risk to benthic invertebrates due to tissue residual levels for clams in the hot spot area containing mine waste and elevated copper, lead, and zinc concentrations. Risk to benthic macroinvertebrates in the remainder of the Goose Pond Irregularly Flooded exposure area benthic macroinvertebrate community is unlikely. | Not evaluated | Risk to the Marsh Creek benthic macroinvertebrate community unlikely. | Risk to the Weir Cove benthic macroinvertebrate community unlikely. |
| 3 | Water Column Invertebrates | Maintenance of water column invertebrate (zooplankton) communities in Site surface waters similar to those found in the reference site | 3A: Compare total and dissolved metal concentrations in Site surface water to published surface water benchmarks and reference locations. | M | Benchmark comparisons may overestimate risk; total concentrations not available in reference samples; benchmarks available for only cadmium, copper, lead, nickel and zinc. | Possible adverse population level effects possible from copper and zinc. Low confidence in conclusions. Only 1 surface water sample evaluated. | Possible adverse population level effects from copper and zinc. Low confidence in conclusions. | Possible adverse population level effects from cadmium, copper, nickel, and zinc. Low confidence in conclusions. Only 1 surface water sample evaluated. | Not evaluated | Risk to the water column invertebrate community unlikely. HQs<1. | Not evaluated |
| | | | **Assessment Endpoint 3 Weight of Evidence Conclusion** | - | - | High uncertainty and low confidence that adverse population level effects are possible in Goose Cove. | High uncertainty and low confidence that adverse population level effects are possible in the Goose Pond Permanently Flooded exposure area. | High uncertainty and low confidence that adverse population level effects are possible in the Goose Pond Irregularly Flooded exposure area. | Not evaluated | Risk to the Marsh Creek water column invertebrate community unlikely. | Not evaluated |
| 4 | Fish | Maintenance of fish communities in aquatic Site exposure areas similar to those found in reference locations. | 4A: Compare total and dissolved metal concentrations in Site surface water to published surface water benchmarks and reference locations. | M | Benchmark comparisons may overestimate risk; total concentrations not available in reference samples; benchmarks not available for all COPCs. | Possible adverse population level effects possible from copper and zinc. Low confidence in conclusions. Only 1 surface water sample evaluated. | Possible adverse population level effects from copper and zinc. Low confidence in conclusions. | Possible adverse population level effects from cadmium, copper, nickel, and zinc. Low confidence in conclusions. Only 1 surface water sample evaluated. | Not evaluated | Risk to fish unlikely. HQs <1. | Not evaluated |
| | | | 4B: Compare tissue residue levels measured in whole fish collected from the Site exposure areas to published benchmarks and reference locations. | L/M | Benchmark comparisons may overestimate risk; benchmarks available for Cd, Cu, and Zn. | Risk unlikely. HQs<1. | Risk unlikely. HQs<1. | Possible adverse population level effects from copper. | Not evaluated | Risk to fish unlikely. HQs<1. | Not evaluated |
| | | | 4C: Calculate fish condition factors and compare to reference locations. | L | Fish data biased to largest specimens to meet tissue sample requirements, however bias applied equally across all exposure areas and reference locations | Fish condition consistent with reference. Risk unlikely. | Fish condition consistent with reference. Risk unlikely. | Fish condition consistent with reference. Unlikely risk. | Not evaluated | Fish condition consistent with reference. Unlikely risk. | Not evaluated |
| | | | **Assessment Endpoint 4 Weight of Evidence Conclusion** | - | - | Risk to fish in Goose Cove unlikely. | Risk to fish in the Goose Pond Permanently Flooded exposure area unlikely, however, it is possible there maybe some risk to fish in areas that exceed water quality criteria. | Risk to fish in the Goose Pond Irregularly Flooded exposure area unlikely, however, it is possible there maybe some risk to fish in areas that exceed water quality criteria. | Not evaluated | Risk to fish in Marsh Creek unlikely. | Not evaluated |

**Table ES-6**
**Ecological Risk Summary Matrix - Aquatic Exposure Areas**

| | Receptor "Guild" | Assessment Endpoint | Measurement Endpoints | Inference Weight* | Uncertainty | Goose Cove | Goose Pond Permanently Flooded | Goose Pond Irregularly Flooded | Salt Marsh | Marsh Creek | Weir Cove |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | Insectivorous Birds (estuarine) | Maintenance of insectivorous populations at the Site similar to those found in the reference site. | 5A: Compare estimated daily dose for insectivorous bird species (spotted sandpiper) based on ingestion of prey in Site exposure areas to published avian Toxicity Reference Values (TRVs) and to reference locations. | M | TRVs assume 100% of COPCs are bioavailable, likely resulting in an overestimate of risk. Forage habitat would normally be limited to sediment under two inches of standing water do to their leg length; food chain model overestimates ingestion from locations deeper than a few inches which would not be accessible. | Adverse population level effects unlikely. | Adverse population level effects unlikely. | Possible adverse population level effects from copper (high confidence) and lead (low confidence). | Possible adverse population level effects from copper. | Adverse population level effectsunlikely. | Adverse population level effects unlikely. |
| | | | Assessment Endpoint 5 Weight of Evidence Conclusion | - | - | Risk to insectivorous birds in Goose Cove unlikely. | Risk to insectivorous birds in the Goose Pond Permanently Flooded exposure area unlikely for those areas outside of sediment hot spots. | Adverse population level effects from copper and lead to insectivorous birds are possible in the Goose Pond Irregularly Flooded exposure area sediment hot spots. The contaminants associated with this risk are copper (high confidence) and lead (low confidence). | Adverse population level effects are possible to insectivorous birds in the Salt Marsh. The contaminant associated with this risk is copper (high confidence). | Risk to insectivorous birds in Marsh Creek unlikely. | Risk to insectivorous birds in Weir Cove unlikely. |
| 6 | Semi-Aquatic Piscivorous Birds | Maintenance of piscivorous populations at the Site similar to those found in the reference site. | 6A: Compare estimated daily dose for piscivorous bird species (great blue heron) based on ingestion of prey in Site exposure areas to published avian Toxicity Reference Values (TRVs) and to reference locations. | M | TRVs assume 100% of COPCs are bioavailable, likely resulting in an overestimate of risk. Forage habitat would normally be limited to sediment under two inches of standing water do to their leg length; food chain model overestimates ingestion from locations deeper than a few inches which would not be accessible. | Adverse population level effects unlikely. | Adverse population level effects unlikely for those areas outside of sediment hot spots. | Possible adverse population level effects from zinc (low confidence). | Possible adverse population level effects from copper (high confidence) and zinc (low confidence). | Adverse population level effectsunlikely. | Possible adverse population level effects from chromium (moderate confidence) and zinc (low confidence). |
| | | | Assessment Endpoint 6 Weight of Evidence Conclusion | - | - | Risk to piscivorous birds in Goose Cove unlikely. | Risk to piscivorous birds in the Goose Pond Permanently Flooded exposure area unlikely. | Adverse population level effects from zinc to piscivorous birds are possible in the Goose Pond Irregularly Flooded exposure area.The contaminants associated with this risk is zinc (low confidence). | Adverse population level effects from copper and lead to insectivorous birds are possible in the Salt Marsh exposure area. The contaminants associated with this risk are copper (high confidence) and zinc (low confidence). | Negligible risk to piscivorous birds in Marsh Creek | Low to moderate possibility of adverse population level effects to piscivorous birds in Weir Cove. |
| 7 | Semi-Aquatic Predatory Birds | Maintenance of predatory bird populations at the Site similar to those found in the reference site. | 7A: Compare estimated daily dose for predatory bird species (osprey) based on ingestion of prey in Site exposure areas to published avian Toxicity Reference Values (TRVs) and to reference locations. Use exposure and risk estimates for bald eagle (Assessment Endpoint #9) as surrogate for predatory birds, with emphasis on population-level effects rathe | M | TRVs assume 100% of COPCs are bioavailable, likely resulting in an overestimate of risk. | Adverse population level effects unlikely. | Adverse population level effects unlikely. | Adverse population level effects unlikely. | Adverse population level effects unlikely. | Adverse population level effects unlikely. | Adverse population level effects unlikely. |
| | | | Assessment Endpoint 7 Weight of Evidence Conclusion | - | - | Risk to predatory birds in Goose Cove unlikely. | Negligible Risk to predatory birds in the Goose Pond Permanently Flooded exposure area unlikely. | Risk to predatory birds in the Goose Pond Irregularly Flooded exposure area unlikely. | Risk to predatory birds in the Salt Marsh exposure area unlikely. | Risk to predatory birds in the Marsh Creek exposure area unlikely. | Risk to predatory birds in the Weir Cove exposure area unlikely.. |
| 8 | Semi-Aquatic Mammals | Maintenance of semi-aquatic mammal populations at the Site similar to those found in the reference site. | 8A: Compare estimated daily dose for semi-aquatic mammal (river otter) based on ingestion of prey in Site exposure areas to published mammalian Toxicity Reference Values (TRVs) and to reference locations. | M | TRVs assume 100% of COPCs are bioavailable, likely resulting in an overestimate of risk. | Adverse population level effects unlikely. | Adverse population level effects unlikely. | Adverse population level effects unlikely. | Adverse population level effects unlikely. | Adverse population level effects unlikely. | Adverse population level effects unlikely. |
| | | | Assessment Endpoint 8 Weight of Evidence Conclusion | - | - | Risk to semi-aquatic mammals in Goose Cove unlikely. | Risk to semi-aquatic mammals in the Goose Pond Permanently Flooded exposure area unlikely. | Risk to semi-aquatic mammals in the Goose Pond Irregularly Flooded exposure area unlikely. | Risk to semi-aquatic mammals in the Salt Marsh exposure area unlikely. | Risk to semi-aquatic mammals in the Marsh Creek exposure area unlikely. | Risk to semi-aquatic mammals in the Weir Cove exposure area unlikely. |
| 9 | Rare, Threatened, and Endangered species | Protection of individual bald eagles foraging in aquatic habitats at the Site similar to those found in the reference site. | 9A: Compare estimated daily dose for predatory bird species (bald eagle) based on ingestion of prey in Site exposure areas to published avian Toxicity Reference Values (TRVs) and to reference locations. | L/M | TRVs assume 100% of COPCs are bioavailable, likely resulting in an overestimate of risk. | Adverse population level effects unlikely. | Adverse population level effects unlikely. | Adverse population level effects unlikely. | Adverse population level effects unlikely. | Adverse population level effects unlikely. | Adverse population level effects unlikely. |
| | | | Assessment Endpoint 9 Weight of Evidence Conclusion | - | - | Risk to bald eagles in Goose Cove unlikely. | Risk to bald eagles in the Goose Pond Permanently Flooded exposure area unlikely. | Risk to bald eagles in the Goose Pond Irregularly Flooded exposure area unlikely. | Risk to bald eagles in the Salt Marsh exposure area unlikely. | Risk to bald eagles in the Marsh Creek exposure area unlikely. | Risk to bald eagles in the Weir Cove exposure area unlikely. |

Prepared by: AMR, 3/25/08
Checked by: BJR, 3/25/08

NOTES:
* Measurement endpoints are assigned an inference weight for each of the attributes that account for strength of association between the assessment and measurement endpoints, data quality, and study design and execution. The relative importance is indicated by an attribute weighting factor following guidance provided by *Mrt al.* (1996).
AVS/SEM - acid volatile sulfide/simultaneously extracted metals
COPC- chemical of potential concern
EPC- exposure point concentration
LOAEL- lowest observed adverse effects level
TOC - total organic carbon
TRV-toxicological reference value
CSI - community site index

**Table ES-7**
**Ecological Risk Summary Matrix - Terrestrial Exposure Areas**

| | Receptor Group | Assessment Endpoint | Measurement Endpoints | Inference Weight* | Uncertainty | Source | Halo |
|---|---|---|---|---|---|---|---|
| | | | **TERRESTRIAL HABITAT** | | | | |
| 10 | Terrestrial Plants | Maintenance of plant communities in terrestrial habitats at the Site similar to those found in a reference site. | 10A: Compare Site soil concentrations to benchmarks protective of terrestrial plants and to reference locations. | L | Benchmark comparisons may overestimate risk; benchmarks not available for the 3 VOC and SVOC COPCs. | High confidence of possible adverse population level effects from aluminum, arsenic, cadmium, copper, lead, mercury, selenium, silver, thallium, zinc, and PCBs. | Possible adverse population level effects from cadmium, copper, lead, and zinc. Benchmark comparisons likely overestimate risk. |
| | | | 10B: Perform field surveys to determine if terrestrial plant communities on-Site are significantly different from terrestrial plant communities at reference locations. | M | Assumes that study area conditions that are worse than reference conditions are indicative of adverse effects, even though they may actually fall within natural variability therefore overestimating risk. | High risk though most of the Source area lacks a suitable growth medium to support plant growth. | Terrestrial plant communities are consistent with reference. |
| | | | **Assessment Endpoint 10 Weight of Evidence Conclusion** | - | - | High risk of harm to the plant community at the Source area from several metal and PCB COPCs. | Risk to Halo area plant community unlikely based on field surveys which were given a higher weight than benchmark comparisons. |
| 11 | Soil Invertebrates | Maintenance of a soil invertebrate community in the terrestrial habitats at the Site similar to those found nearby in a reference site. | 11A: Compare Site soil concentrations to benchmarks protective of soil invertebrates and to reference. | L | Benchmark comparisons may overestimate risk; benchmarks not available for the 5 VOC, SVOC, and PCB COPCs. | Possible adverse population level effects from copper, lead, mercury, and zinc (high confidence). | High confidence of possible adverse population level effects from copper, mercury, and zinc. Benchmark comparisons likely overestimate risk |
| | | | 11B: Compare tissue residue levels in terrestrial invertebrates from the Site to published tissue benchmarks and to reference locations. | L/M | Effects benchmarks not available. | Not evaluated | Not evaluated |
| | | | 11C: Compare forest litter community data from the Site to reference locations. | M | Assumes that study area conditions that are worse than reference conditions are indicative of adverse effects, even though they may actually fall within natural variability therefore overestimating risk. | Not evaluated | Soil invertebrate communities are consistent with reference. |
| | | | **Assessment Endpoint 11 Weight of Evidence Conclusion** | - | - | Adverse population level effects are possible from copper, lead, mercury, and zinc (high confidence). | Risk to Halo area soil invertebrates unlikely based on field surveys which were given a higher weight than benchmark comparisons. |
| 12 | Terrestrial Insectivorous Birds | Maintenance of omnivorous populations of songbirds at the Site similar to those found at a reference site. | 12A: Compare estimated daily dose for omnivorous song bird species (robin) based on ingestion of prey in Site exposure areas to published avian Toxicity Reference Values (TRVs) and to reference locations. | M | TRVs assume 100% of COPCs are bioavailable, likely resulting in an overestimate of risk. | Possible adverse population level effects from copper, zinc, and PCBs (high confidence), cadmium and lead (moderate confidence), and antimony and selenium (low confidence). | Possible adverse population level effects from chromium, copper, lead, selenium, and zinc (low to moderate confidence). Confidence decrease with decreasing HQ values, which are low, ranging from 1.1 to 4.0 in the CTE/LOAEL scenario. |
| | | | **Assessment Endpoint 12 Weight of Evidence Conclusion** | - | - | Adverse population level effects possible. Omnivorous songbirds not likely to forage in the Source area due to poor habitat for prey species. | Possibility of adverse population level effects to omnivorous songbirds in the Halo area is uncertain given that all CTE/LOAEL HQs <1. Food chain models likely overestimate risk since TRVs assume 100% of COPCs are bioavailable. |
| 13 | Terrestrial Predatory Birds | Maintenance of predatory bird populations at the Site similar to those found at a reference site | 13A: Compare estimated daily dose for predatory bird species (red-tailed hawk) based on ingestion of prey in Site exposure areas to published avian Toxicity Reference Values (TRVs) and to reference locations. | M | TRVs assume 100% of COPCs are bioavailable, likely resulting in an overestimate of risk. | Possible adverse population level effects from zinc and PCBs (moderate to high confidence). | Adverse population level effects unlikely |
| | | | **Assessment Endpoint 13 Weight of Evidence Conclusion** | - | - | Moderate to high confidence of adverse population level effects possible from zinc and PCBs. Predatory birds not likely to forage in the Source area due to poor habitat for prey species. | Risk to predatory birds in the Halo area unlikely. |
| 14 | Terrestrial Small Omnivorous Mammals | Maintenance of terrestrial mammal populations at the Site similar to those found in a reference area. | 14A: Compare estimated daily dose for small omnivorous mammal species (white-footed mouse) based on ingestion of prey in Site exposure areas to published mammalian Toxicity Reference Values (TRVs) and to reference locations. | M | TRVs assume 100% of COPCs are bioavailable, likely resulting in an overestimate of risk. | Possible adverse population level effects from arsenic, copper, selenium, vanadium, zinc, and PCBs (high confidence), and antimony, cadmium, lead, manganese, and thallium (moderate confidence). | Possible adverse population level effects from arsenic, chromium, and copper (low confidence). Confidence decreases with decreasing HQ values, which are all <8 in the CTE/NOAEL scenario and are all <1 in the CTE/LOAEL scenario. |
| | | | **Assessment Endpoint14 Weight of Evidence Conclusion** | - | - | Adverse population level effects possible. Omnivorous mammals not likely to forage at the site due to poor habitat and sparse vegetation. | Possibility of adverse population level effects to omnivorous mammal in the Halo area from arsenic, chromium, and copper is uncertain given low CTE/LOAEL HQs. Food chain models likely overestimate risk since TRVs assume 100% of COPCs are bioavailable. Food chain models likely overestimate risk since TRVs assume 100% of COPCs are bioavailable. |
| 15 | Terrestrial Small Worm-Eating Mammals | Maintenance of terrestrial mammal populations at the Site similar to those found in a reference area. | 15A: Compare estimated daily dose for small worm-eating mammal species (short-tailed shrew) based on ingestion of prey in Site exposure areas to published mammalian Toxicity Reference Values (TRVs) and to reference locations. | M | TRVs assume 100% of COPCs are bioavailable, likely resulting in an overestimate of risk. | Possible adverse population level effects from arsenic, cadmium, copper, lead, manganese, selenium, thallium, vanadium, zinc, and PCBs (high confidence), and antimony and mercury (moderate confidence). | Low confidence in adverse population level effects form arsenic, chromium, and copper to small worm-eating mammals in the Halo area. |
| | | | **Assessment Endpoint 15 Weight of Evidence Conclusion** | - | - | Adverse population level effects possible. Worm-eating mammals not likely to forage at the site due to poor habitat and sparse vegetation. | Moderate to high confidence that adverse population level effects to small worm-eating mammals are unlikely. |

NOTES:
* Measurement endpoints are assigned an inference weight for each of the attributes that account for strength of association between the assessment and measurement endpoints, data quality, and study design and execution. The relative importance is indicated by an attribute weighting factor following guidance provided by Menzie et al. (1996).

Prepared by: AMR, 3/25/08
Checked by: BJR, 3/25/08

COPC- chemical of potential concern
LOAEL- lowest observed adverse effects level
NOAEL- no observed adverse effects level
TRV-toxicological reference value

Benthic Invertebrates

Risk to the benthic invertebrate community varies with location. Sediment toxicity tests demonstrated ecologically significant effects to benthic invertebrates in Goose Cove at location GC-05 with respect to the *N. arenaceodanta* growth endpoint. However, no adverse ecologically significant effects were observed for the two other Goose Cove toxicity locations, where sediment concentrations were higher.

The weight of evidence from AVS/SEM data and quantitative benthic community surveys compared to reference suggested that few areas of the sediment should present a high risk. However, the sediment toxicity test data suggest that at least portions of the mine waste hot spot area, represented by locations GP-22 and GP-12, are acutely toxic. Pore water data for that area also suggests the potential for adverse impacts despite the high AVS. Although GP-07 and GP-13 respectively exhibited ecologically significant risk for *L. plumulosus* survival and growth, sediment and pore water concentrations at GP-07 and GP-13 were frequently lower than other locations which did not demonstrate significant risk. Risk at GP-07 is likely overestimated and unlikely to result in adverse population-level effects based on relatively low sediment and pore water contaminant concentrations. Risk at GP-13 is likely overestimated and therefore not likely to result in adverse population level effects, as evidenced by toxicity limited to the growth endpoint for *L. plumulosus* and relatively low metals availability based on pore water chemistry.

The toxicity test for the Goose Pond Irregularly Flooded sediment was ambiguous as one sample indicated potential toxicity and the other did not. Other samples from the Goose Pond Irregularly Flooded sediment outside the mine waste hot spot did not show toxicity. It should be noted that dramatic fluctuations in temperature, dissolved oxygen concentrations, and salinity concentrations observed in the Goose Pond Irregularly Flooded sediment area do not provide a stable environment for most freshwater or marine species. Sediment toxicity tests were not conducted for the Salt Marsh, Marsh Creek, or Weir Cove exposure areas, in accordance with the Phase IB Workplan.

Water Column Invertebrates

Risk to water column invertebrates ranged from unlikely to possible, however, there is high uncertainty associated with this conclusion.

Fish

Adverse population level effects to fish in all aquatic exposure areas is unlikely given fish condition factors that were consistent with background and fish tissue concentrations that resulted in HQs less than 1. Risk to fish based on comparison of surface water concentrations to benchmarks suggested risk ranged from unlikely to possible, however, there is high uncertainty associated with this conclusion. Note that dramatic fluctuations in temperature, dissolved oxygen concentrations, and salinity concentrations observed in South Goose Pond and in the Irregularly Flooded area do not provide a stable environment for most freshwater or marine species.

Aquatic Insectivorous Birds

Adverse population level effects to insectivorous birds (spotted sandpiper) are possible in the Goose Pond Irregularly Flooded exposure area due to copper (high confidence) and lead (low confidence), and in the Salt Marsh due to copper (high confidence). Adverse population level effects to insectivorous birds (spotted sandpiper) from COPCs in other areas of the Site were generally unlikely.

Aquatic Piscivorous Birds

Adverse population level effects to piscivorous birds (great blue heron) are possible in the Goose Pond Irregularly Flooded exposure area due to zinc (low confidence), in the Salt Marsh due to copper (high confidence) and zinc (low confidence), and in Weir Cove due to chromium (moderate confidence) and zinc (low confidence). Adverse population level effects to piscivorous birds (great blue heron) from COPCs in other areas of the Site were generally unlikely.

Aquatic Predatory Birds, Semi-Aquatic Mammals, and Rare, Threatened, & Endangered Species

The risk assessment concluded that in all six aquatic exposure areas, risk of harm to Predatory Bird (osprey), Semi-Aquatic Mammal (river otter), and Threatened, & Endangered Species (bald eagle) is unlikely regardless of exposure scenario.

Terrestrial Plants and Soil Invertebrates, Terrestrial Insectivorous Birds, Terrestrial Predatory Birds Terrestrial Small Omnivorous Mammals, and Terrestrial Small Worm-Eating Mammals

Based on the weight of evidence and confidence and uncertainties in the data, adverse population level impacts to terrestrial plants, terrestrial invertebrates, birds (robin, hawk), and mammals (white-footed mouse and short-tailed shrew) in the Source area may be possible from metals including cadmium,

copper, lead, and zinc, and PCBs. The high incremental risk HQs support the high confidence in this conclusion. Much of the former mine operations area contains no vegetation or very sparse vegetation. This is likely because soils were grubbed and then left bare during mining operations, or because the soils consist of material left from mining operations. These materials provide little or no growth medium for plants because of their texture, and they also provide poor habitat for terrestrial invertebrates which serve as food sources for robin. Receptors are therefore not likely to frequently forage at the Source area.

Based on the weight of evidence and confidence and uncertainties in the data, risk of harm to terrestrial plant, terrestrial invertebrate, bird and mammal communities in the Halo area from most COPCs is unlikely. The risk assessment concluded that confidence for adverse population level effects to occur terrestrial insectivorous birds (robin) and small worm-eating mammals (shrew) in the Halo area due to arsenic, copper, chromium, lead, selenium, and/or zinc was low due to low HQs and assumptions in the food chain models that tend to overestimate risk. Furthermore, risk in the Halo Area was driven principally by two samples located at the Source Area boundary (SS-5148 and TH-5).

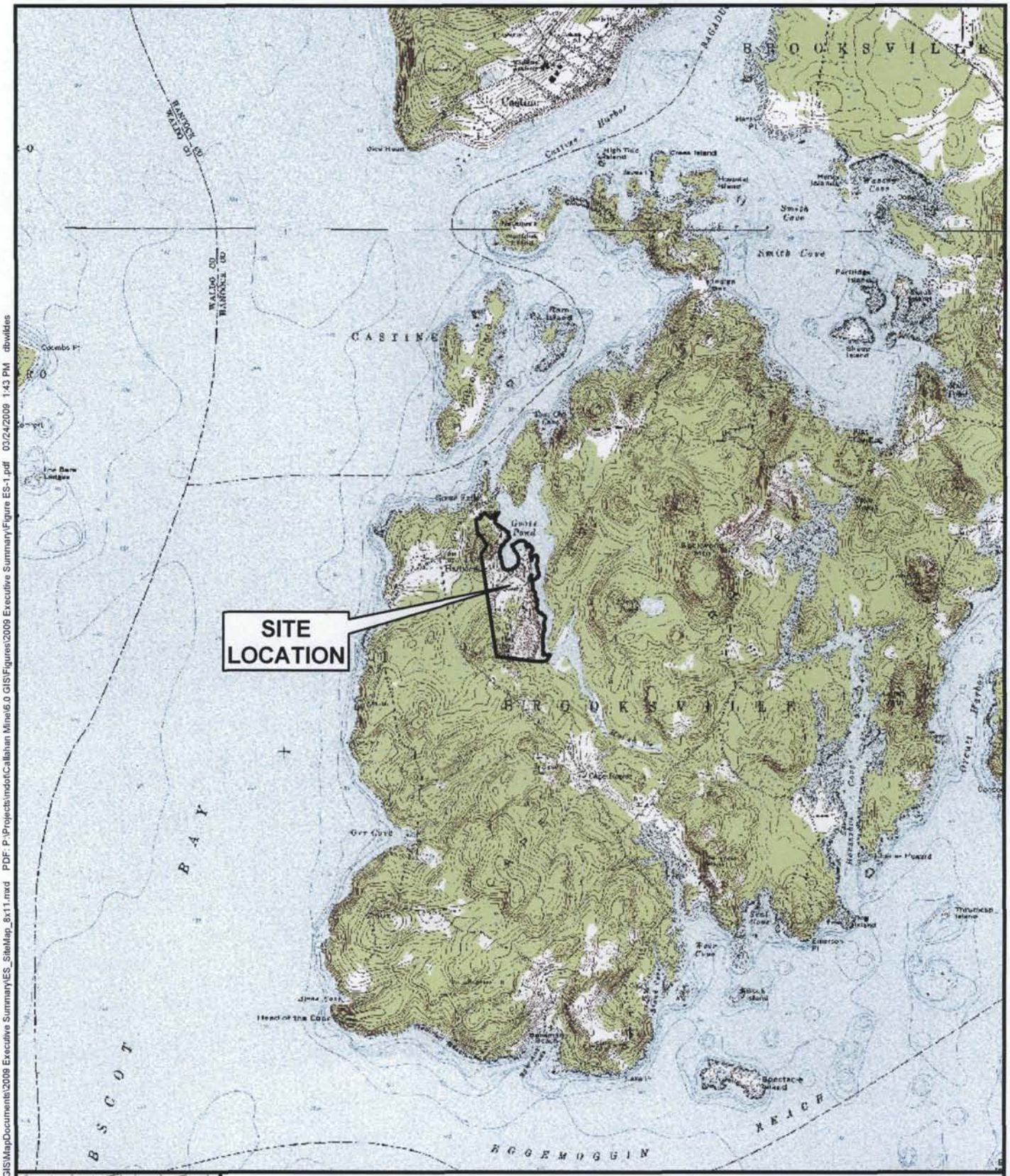
Recommendation

Given the nature of the transport pathways, the concentrations of metals, and the risks to human health and the environment, a feasibility study should be prepared to determine the best approach to address the contaminants of concern. Among the alternatives, the Feasibility Study should consider (a) no action; (b) precisely targeted actions such as (1) cleanup of residential lead-contaminated soils and Source Area PCB's; (2) institutional controls prohibiting withdrawal of groundwater; (3) possible remediation of sediment and salt marsh "hot spots"; (4) reduction of impacts at major seep locations; and (5) possible soil cover or cap over selected Source Areas.

FIGURES

# EXECUTIVE SUMMARY

# FIGURES



1:24,000 scale digital topographic map obtained from Maine Office of GIS at http://apollo.ogis.state.me.us/catalog

N

0 2,000 4,000 Feet

Prepared/Date: DBW 03/24/09 | Checked/Date: SFC 03/24/09

Figure ES-1
Site Location Map

Remedial Investigation Report
Callahan Mine Superfund Site
Brooksville, Maine
MACTEC, Inc.

Document: P:\Projects\mdot\Callahan Mine\6.0 GIS\MapDocuments\2009 Executive Summary\ES_SiteMap_8x11.mxd PDF: P:\Projects\mdot\Callahan Mine\6.0 GIS\Figures\2009 Executive Summary\Figure ES-1.pdf 03/24/2009 1:43 PM dbwildes

**Legend**

- Mine Shaft
- Purported Lateral Mine Shafts The "920" and the "860"
- Operations Piping
- Water
- Intermittent Water
- Pre-Mine Shoreline Excavated

N

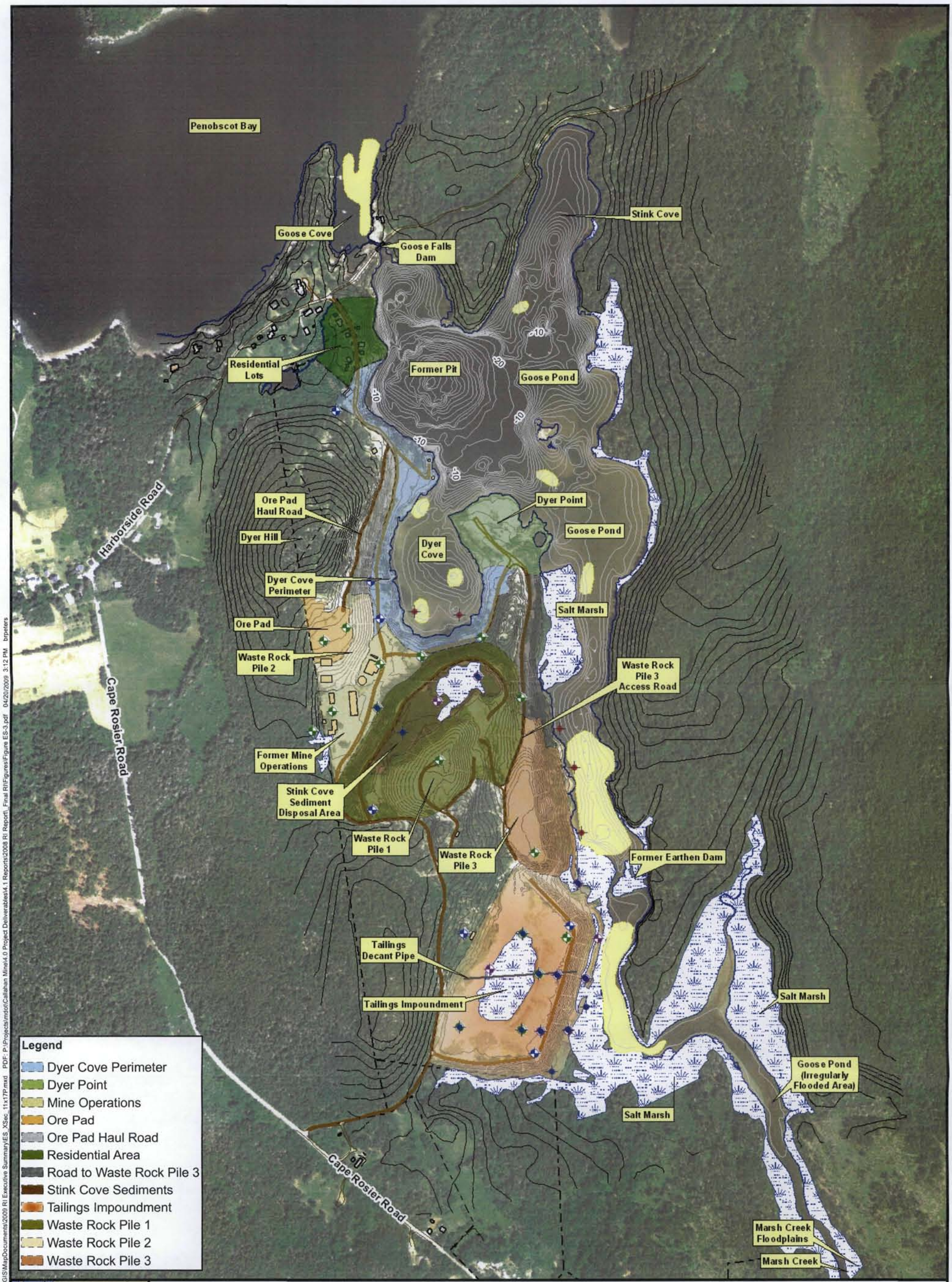
0 250 500 Feet

Prepared/Date: BRP 03/30/09 | Checked/Date: PSB 03/30/09

Figure ES-2
Site Plan with Historic Features

Remedial Investigation Report
Callahan Mine Superfund Site
Brooksville, Maine
MACTEC, Inc.

Document: P:\Projects\mdot\Callahan Mine\6.0 GIS\MapDocuments\2009 RI Executive Summary\ES_HistoricFeatures_11x17P.mxd PDF: P:\Projects\mdot\Callahan Mine\6.0 GIS\Figures\2009 Executive Summary\Figure ES-2.pdf 03/30/2009 10:19 AM brpeters



**Legend**

- Pore Water Sample
- Piezometer
- Overburden Monitoring Well
- Overburden Hydraulic Control Monitoring Well
- Bedrock Monitoring Well
- Decant Pipe
- Bathymetric Contour
- Mine Waste in Sediment
- Delineated Wetlands

N

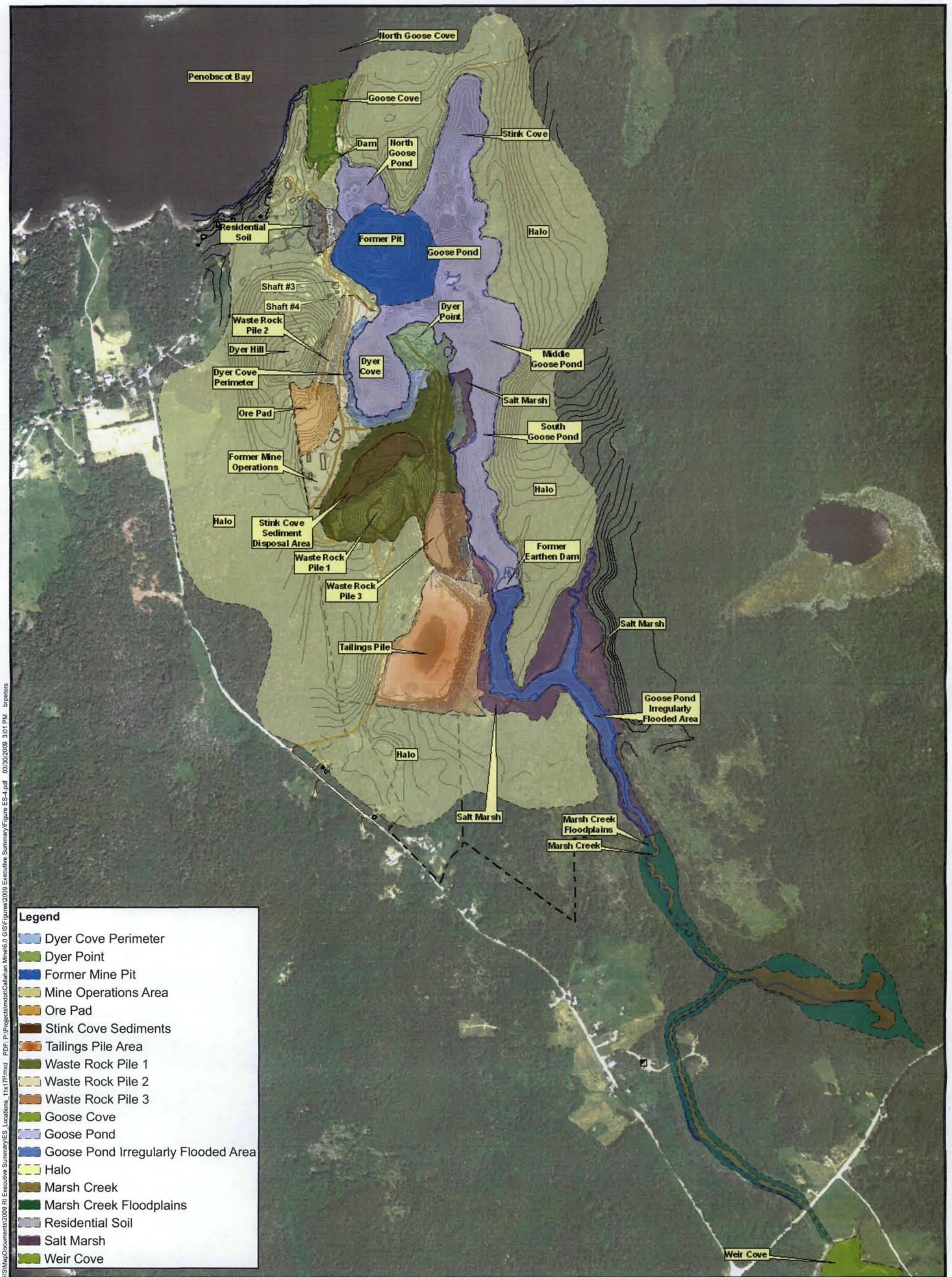
0 275 550 Feet

Prepared/Date: BRP 04/20/09 | Checked/Date: PSB 04/20/09

Figure ES-3
Potential Source Areas

Remedial Investigation Report
Callahan Mine Superfund Site
Brooksville, Maine
MACTEC, Inc.

Document: P:\Projects\mdot\Callahan Mine\6.0 GIS\MapDocuments\2009 RI Executive Summary\ES_XSec_11x17P.mxd PDF: P:\Projects\mdot\Callahan Mine\4.0 Project Deliverables\4.1 Reports\2008 RI Report_Final RI\Figures\Figure ES-3.pdf 04/20/2009 3:12 PM brpeters



Note:
Contour intervals vary.
Off-site topo 10 foot
On-site topo 5 foot
Bathymetry 1 foot
Pit Bathymetry 20 foot

N

0 410 820 Feet

**Legend**

- Abandoned Mine Shaft
- Bathymetric Contour
- Property Line

Prepared/Date: BRP 03/30/09 | Checked/Date: PSB 03/30/09

Figure ES-4
Additional Areas of Study

Remedial Investigation Report
Callahan Mine Superfund Site
Brooksville, Maine
MACTEC, Inc.

Document: P:\Projects\mdot\Callahan Mine\6.0 GIS\MapDocuments\2009 RI Executive Summary\ES_Locations_11x17P.mxd PDF: P:\Projects\mdot\Callahan Mine\6.0 GIS\Figures\2009 Executive Summary\Figure ES-4.pdf 03/30/2009 3:01 PM brpeters

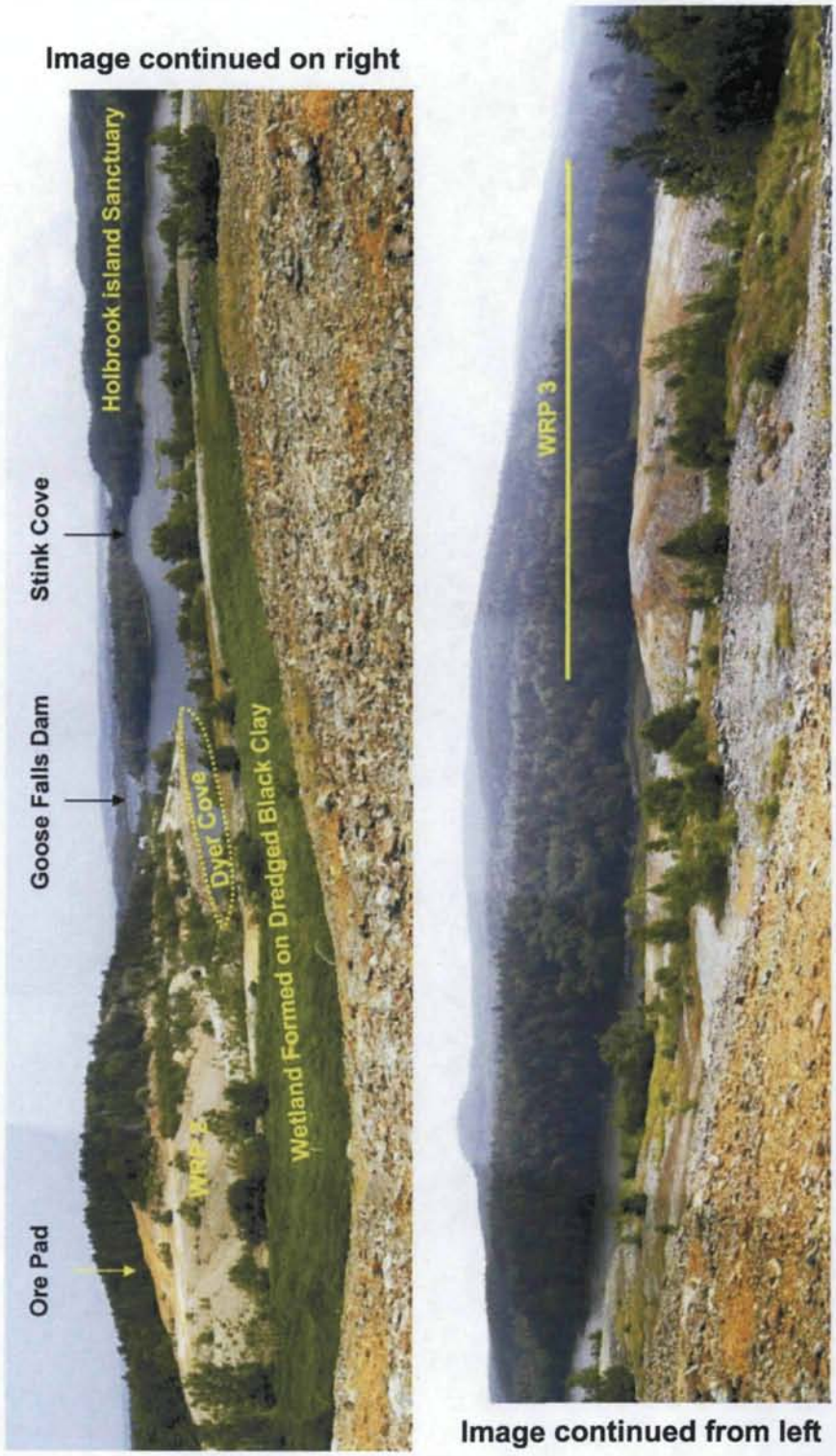



Figure ES-5
Photo of Site from Top of WRP 1

Remedial Investigation Report
Callahan Mining Superfund Site
Brooksville, Maine

Prepared by JPH | Checked By SFC

MACTEC, Inc.

PORT2009014.cdr

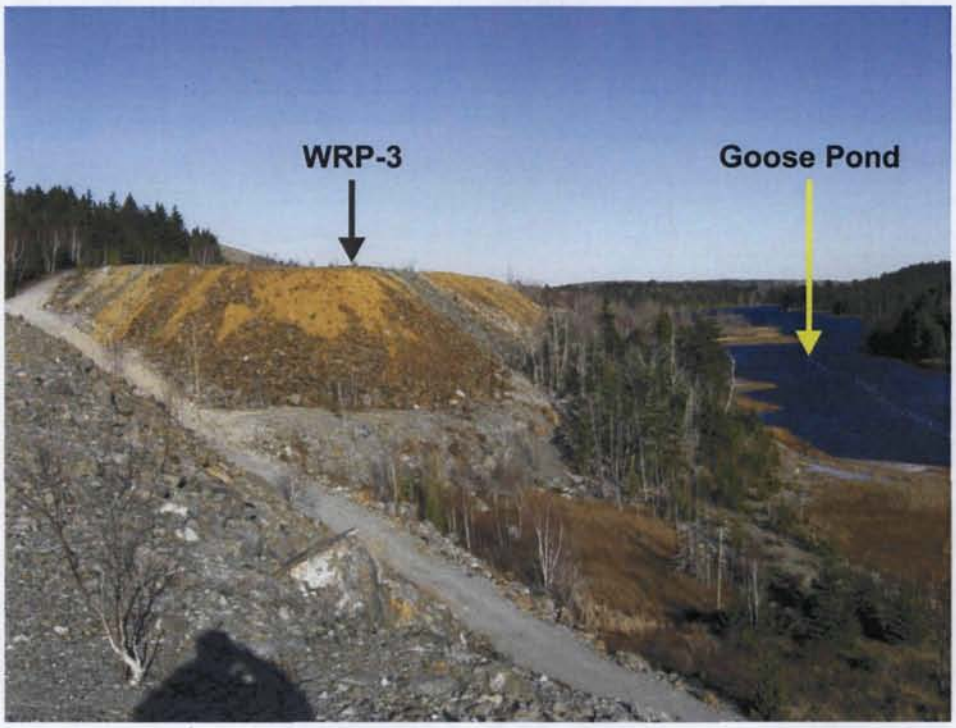


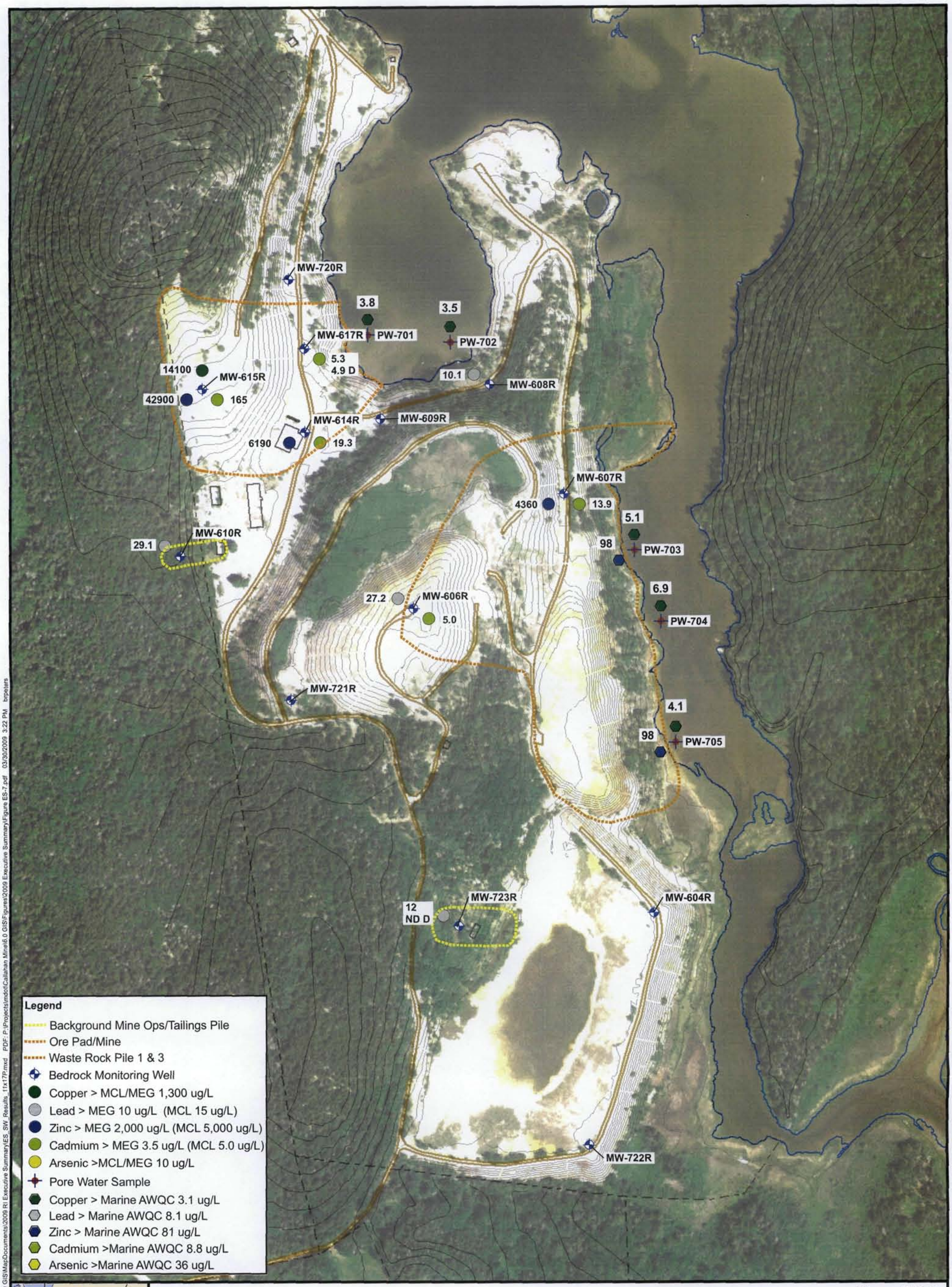
Figure ES-6
Photos of WRP-3 and Tailings Pile

Remedial Investigation Report
Callahan Mining Superfund Site
Brooksville, Maine

Prepared by JPH | Checked By SFC

MACTEC, Inc.

PORT2009014.cdr



N

0 150 300 Feet

Prepared/Date: BRP 03/30/09 | Checked/Date: PSB 03/30/09

Figure ES-7
Extent of Bedrock Groundwater Contamination

Remedial Investigation Report
Callahan Mine Superfund Site
Brooksville, Maine
MACTEC, Inc.

Document: P:\Projects\mdot\Callahan Mine\6.0 GIS\MapDocuments\2009 RI Executive Summary\ES_SW_Results_11x17P.mxd PDF: P:\Projects\mdot\Callahan Mine\6.0 GIS\Figures\2009 Executive Summary\Figure ES-7.pdf 03/30/2009 3:22 PM brpeters

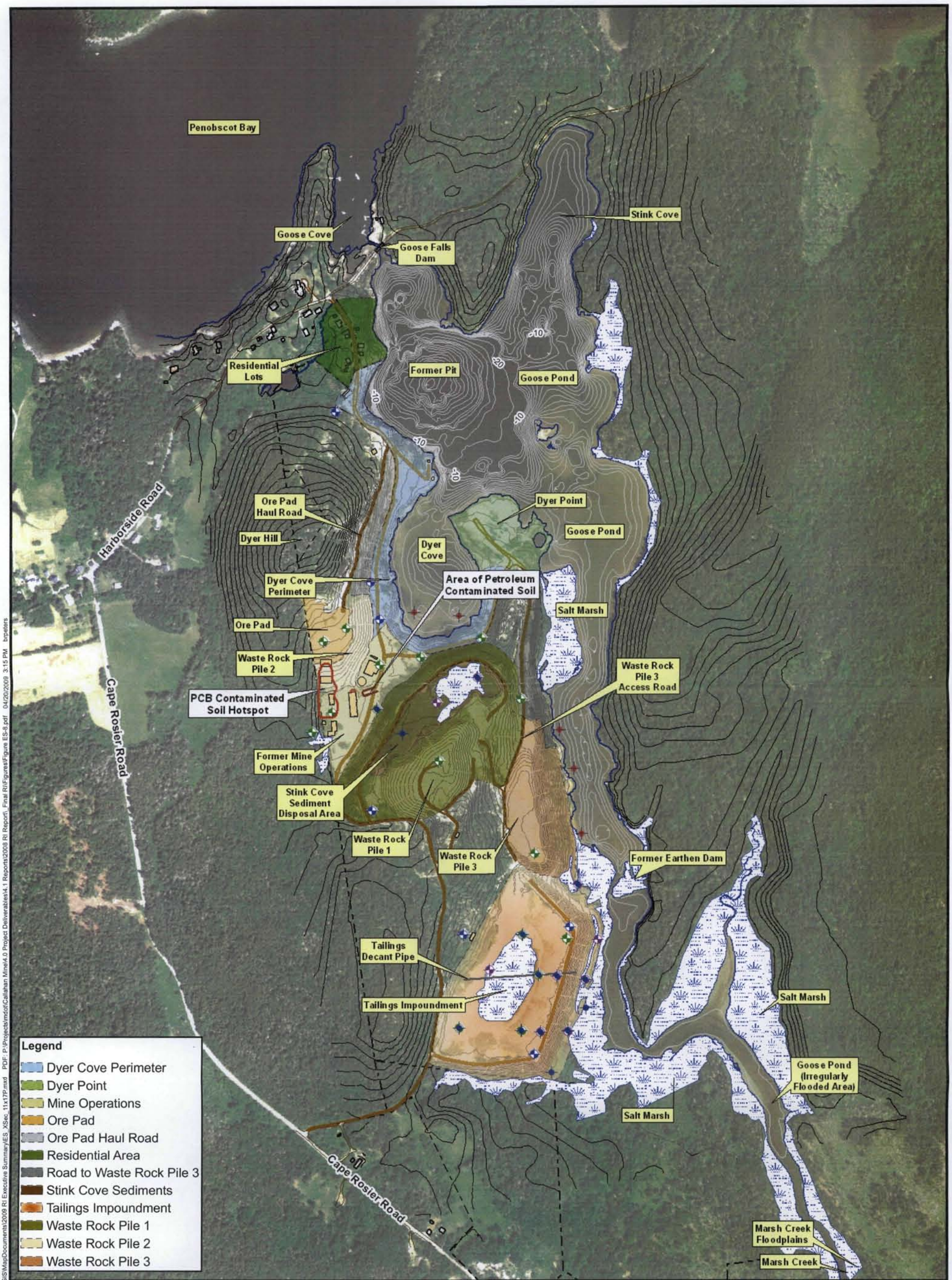


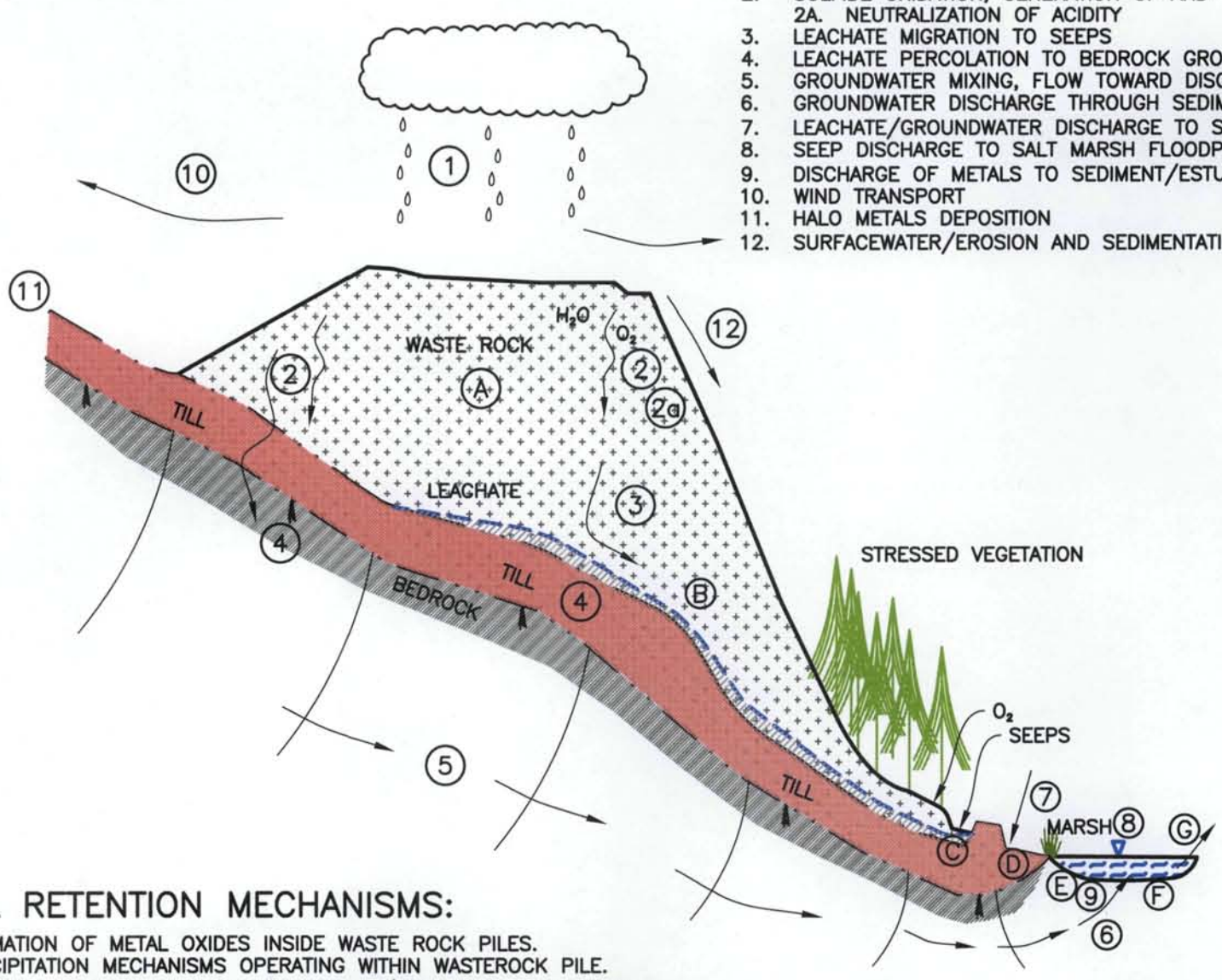

Figure ES-8
PCBs/Petroleum in Soils

Remedial Investigation Report
Callahan Mine Superfund Site
Brooksville, Maine
MACTEC, Inc.

## WASTE ROCK PILES AND ORE PAD

### TRANSPORT PROCESSES:

1. PRECIPITATION
2. SULFIDE OXIDATION, GENERATION OF ARD
   2A. NEUTRALIZATION OF ACIDITY
3. LEACHATE MIGRATION TO SEEPS
4. LEACHATE PERCOLATION TO BEDROCK GROUNDWATER
5. GROUNDWATER MIXING, FLOW TOWARD DISCHARGE
6. GROUNDWATER DISCHARGE THROUGH SEDIMENT TO SURFACE WATER
7. LEACHATE/GROUNDWATER DISCHARGE TO SEEPS AND SURFACE WATER
8. SEEP DISCHARGE TO SALT MARSH FLOODPLAIN SOILS
9. DISCHARGE OF METALS TO SEDIMENT/ESTUARY COLUMN
10. WIND TRANSPORT
11. HALO METALS DEPOSITION
12. SURFACEWATER/EROSION AND SEDIMENTATION



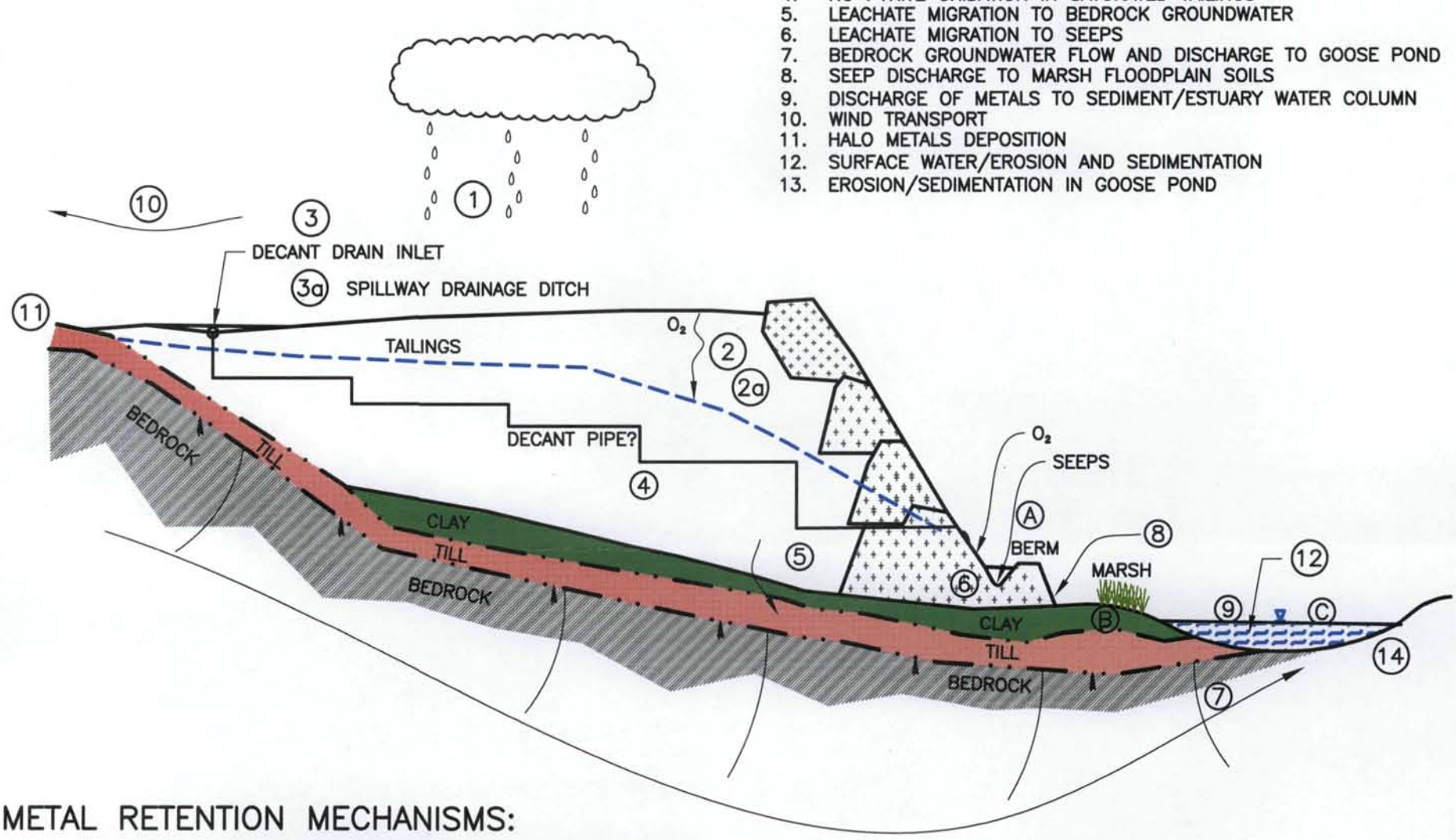

### METAL RETENTION MECHANISMS:

A. FORMATION OF METAL OXIDES INSIDE WASTE ROCK PILES.
B. PRECIPITATION MECHANISMS OPERATING WITHIN WASTEROCK PILE.
C. MINERAL PRECIPITATES IN SURFACEWATERS/SEEP DISCHARGE AREAS.
D. SORPTION/RETENTION OF METALS IN SALT MARSH SEDIMENTS.
E. METALS IN GROUNDWATER; DISCHARGED TO AND RETAINED BY SEDIMENTS.
F. METALS RETAINED IN "MINE WASTE" LAYER IN SEDIMENT.
G. AREAS OF EROSION AND SEDIMENTATION IN GOOSE POND.

## TAILINGS PILE

### TRANSPORT PROCESSES:

1. PRECIPITATION
2. SULFIDE OXIDATION, GENERATION OF ARD ABOVE WATERTABLE
   2A. NEUTRALIZATION OF ACIDITY
3. SURFACE WATER RUN-OFF TO VERTICAL CAST IRON DRAIN PIPE
   3A. SURFACE WATER RUN-OFF TO DRAINAGE DITCH
4. NO PYRITE OXIDATION IN SATURATED TAILINGS
5. LEACHATE MIGRATION TO BEDROCK GROUNDWATER
6. LEACHATE MIGRATION TO SEEPS
7. BEDROCK GROUNDWATER FLOW AND DISCHARGE TO GOOSE POND
8. SEEP DISCHARGE TO MARSH FLOODPLAIN SOILS
9. DISCHARGE OF METALS TO SEDIMENT/ESTUARY WATER COLUMN
10. WIND TRANSPORT
11. HALO METALS DEPOSITION
12. SURFACE WATER/EROSION AND SEDIMENTATION
13. EROSION/SEDIMENTATION IN GOOSE POND




### METAL RETENTION MECHANISMS:

A. SEDIMENTATION IN DITCH BETWEEN TAILINGS IMPOUNDMENT AND SMALL BERM.
B. SORPTION AND EXTENT OF METALS IN MARSH FLOOD PLAIN SOILS.
C. METALS RETAINED IN "MINE WASTE" LAYER IN SEDIMENT.

Prepared/Date: MRS 03/24/09
Checked/Date: SC 03/24/09

Project 3612-06-2047.30

MACTEC

Figure ES-9
SITE CONCEPTUAL MODEL
REMEDIAL INVESTIGATION REPORT
CALLAHAN MINE SUPERFUND SITE
BROOKSVILLE, MAINE