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## The Mineral

Reference 33

# ACANTHITE/ARGENTITE

- **Chemistry:** Ag<sub>2</sub>S, Silver Sulfide
- **Class:** Sulfides
- **Uses:** An ore of silver and as mineral specimens.
- **Specimens**

Acanthite is the most important silver ore next to **galena**. Actually there is an argument to be made that acanthite could be **the** most important silver ore. Galena is a lead ore that often contains enough silver (usually about 1%) that when it is processed for its lead content the *by-product* silver supplies the majority of the world's needs. But most, if not all the silver in *argentiferous galena* is thought to actually be microscopic inclusions of acanthite crystals.

Acanthite is often confused with the name argentite and it is no wonder. Several mineral guides interchange the names or combine the names as is done here. But the proper mineral name when referring to Ag<sub>2</sub>S at room temperatures is acanthite. Argentite is a name applied to one polymorph (meaning many shapes) of Ag<sub>2</sub>S. Acanthite and argentite have the same chemistry, Ag<sub>2</sub>S, but different structures. Argentite has an isometric structure and is only stable at temperatures above 173 degrees Celsius and if cooling from a melt, will form isometric crystals such as cubes, octahedrons and dodecahedrons. Upon cooling to below 173 degrees Celsius, argentite transforms from its isometric structure to the monoclinic structure of acanthite. The transformation often distorts the crystals to unrecognizable shapes, but some will still have an overall isometric crystal shape. These crystals are called pseudomorphs (false shapes) as they are actually acanthite's crystals in the shape of argentite's crystals. Argentite has been historically used when referring to these crystals, but the acknowledgment of the true identity of the mineral requires the naming of these crystals (at lower temperatures) as acanthite.

Acanthite, in addition to the crystals discussed above, forms interesting groupings of crystals. The crystals themselves are often distorted, but they group together into some intricate arborescent (branching) structures.

Argentite comes from the Latin word for silver, *argentum*, from which the chemical symbol for silver, Ag, is also derived. Acanthite comes from the Greek word for thorn, *acantha*, in allusion to its typical crystal habits.

Acanthite is generally easily identified although it may appear like galena and other silver sulfide minerals. The crystal habits discussed above are usually diagnostic enough, however the sectility test may be needed in some cases. Acanthite is sectile which means that it can be cut into by a knife just like **lead**. Acanthite is generally a very valuable mineral specimen, due mostly to the high silver content and the rarity of good crystals. It is a pleasure to own fine acanthite specimens once they are finally procured.

**PHYSICAL CHARACTERISTICS:**

- **Color** is lead gray to black.
- **Luster** is metallic.
- **Transparency:** Crystals are opaque.
- **Crystal System:** Monoclinic; 2/m below 173 degrees Celsius (acanthite) and isometric; 4/m bar 3 2/m above (argentite).
- **Crystal Habits** include rarely well formed pseudo: cubes, octahedrons and dodecahedrons. Non-argentite crystals (those that formed below 173 degrees Celsius) of acanthite tend to be of a slender prismatic habit. More commonly found massive and as coatings or as arborescent (branching) and reticulated groups.
- **Cleavage** is absent.
- **Fracture** is conchoidal.
- **Hardness** is 2.5 - 3
- **Specific Gravity** is approximately 5.5 - 5.8 (slightly heavy even for metallic minerals).
- **Streak** is a shiny black.
- **Other Characteristics:** Sectile, meaning it can be cut with a knife like **lead** and fresh shiny surfaces will eventually form a dull coating after prolonged exposure to light (can be removed by ultrasonic treatment).
- **Associated Minerals** include **silver, quartz, bornite, gold, galena, proustite, pyrargyrite, stephanite** and other silver sulfide minerals.
- **Notable Occurrences** include Guanajuato, Mexico; Freiberg and Saxony, Germany; Cobalt, Ontario, Canada; Comstock Lode, Nevada and Butte, Montana, USA; Cornwall, England; Chile; Peru; Bolivia and especially Kongsberg, Norway.
- **Best Field Indicators** are crystal habit, density, softness, sectility, association with other silver sulfosalts and color.

Quantifying Point-source Trace Metal Contamination in  
Coastal Maine as a Result of Past Zinc and Copper Mining

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Abstract

Sediment samples from areas adjacent to and downstream from two abandoned Zn and Cu mines in the Blue Hill/Cape Rosier region of Mid-Coastal Maine were analyzed for Zn, Cu, Pb, Cd, and Fe concentrations. Selected samples of sediments and mine ores were also analyzed for common Pb isotopic composition. Results of the concentration analyses reveal distinct regions of metal contamination which exhibit metal levels 3 to 90 times that of regional background concentrations. The spatial distribution of metal concentrations demonstrates the highly variable character of trace metal species in freshwater and marine sediments. The processes of sedimentation, aquatic vegetation, water chemistry, and anthropogenic activities exclusive of mining each contribute to a spatial variability which may exceed 100 % over short distances (less than 20 feet in some cases). These studies also demonstrate the enhanced ability of freshwater environments to capture mine contamination in comparison to near-shore marine environments. High metal concentrations are retained over a distance more than 24 times that of the corresponding retention distance in the marine system. This behavior leads to contamination in the near-shore marine system which is highly localized to mine outfalls and is not distributed to any significant distance. In contrast, the freshwater system is highly perturbed and demonstrates elevated metal concentrations as far as its discharge into open marine conditions (~ 12 km).

Pb isotopic analyses of ~ 65 selected sediment samples and 5 galena (PbS) samples allow the characterization of a two-endmember isotopic mixing line. The point-source endmember of these mixing lines is defined by the Pb isotopic compositions of the mine minerals themselves ( $^{206}\text{Pb}/^{207}\text{Pb}$  ratios of 1.16). The regional background endmember of these lines is defined by distant or "ancient" sediment samples ( $^{206}\text{Pb}/^{207}\text{Pb}$  ratios of 1.20 - 1.23). These analyses allow point-source Pb contamination to be distinguished isotopically in samples which show less than 50 % metal enrichment relative to background. This point-source distinction cannot be made by concentration studies alone because the natural environmental variability of metal concentrations often exceeds 50 %.

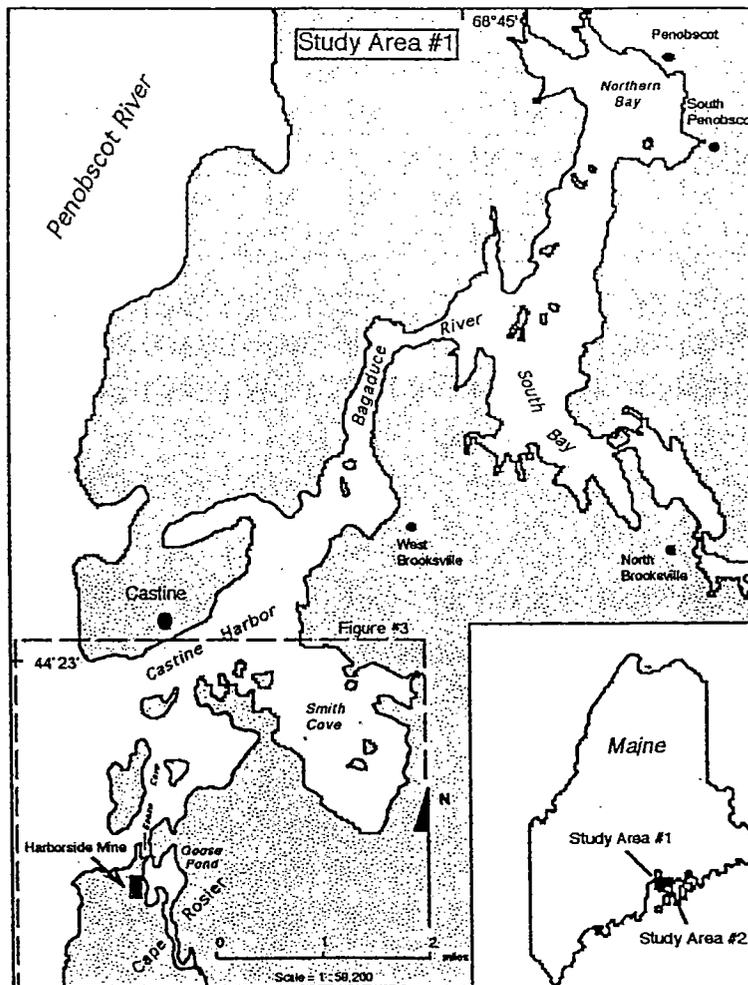
Introduction

Study Area

Areas in Mid-Coastal Maine have been mined for Cu and Zn since the later part of the 1800's. Two of the larger developments, now abandoned, were the Kerramerican (Black Hawk) and Callahan (Harborside) mines. Located in the Blue Hill/Cape Rosier region (see figures #1 and #2), both mines were extensive operations which processed ore on-site. As a result, large quantities of tailings and mine discharge were introduced to the adjacent environments.

The Harborside Mine (Cu/Zn), during the time of its operation from 1968 to 1972, may have been the only intertidal open pit mine in the world (see figure #1). Although dammed and drained during the mining operation, the pit (located in Goose Pond), tunnels, and tailings are now subject to daily tidal exchange. Surveys prior to mining identified a diverse marine fauna in Goose Pond, while studies after mining revealed a large influx of mine sludge and tailings and a nearly abiotic condition (Dow and Hurst, 1972). A later investigation by Hurst (Hurst et al. 1976) identified mine contamination in areas directly adjacent to mine outfalls, but the effect of this mining on the local biota was inconclusive.

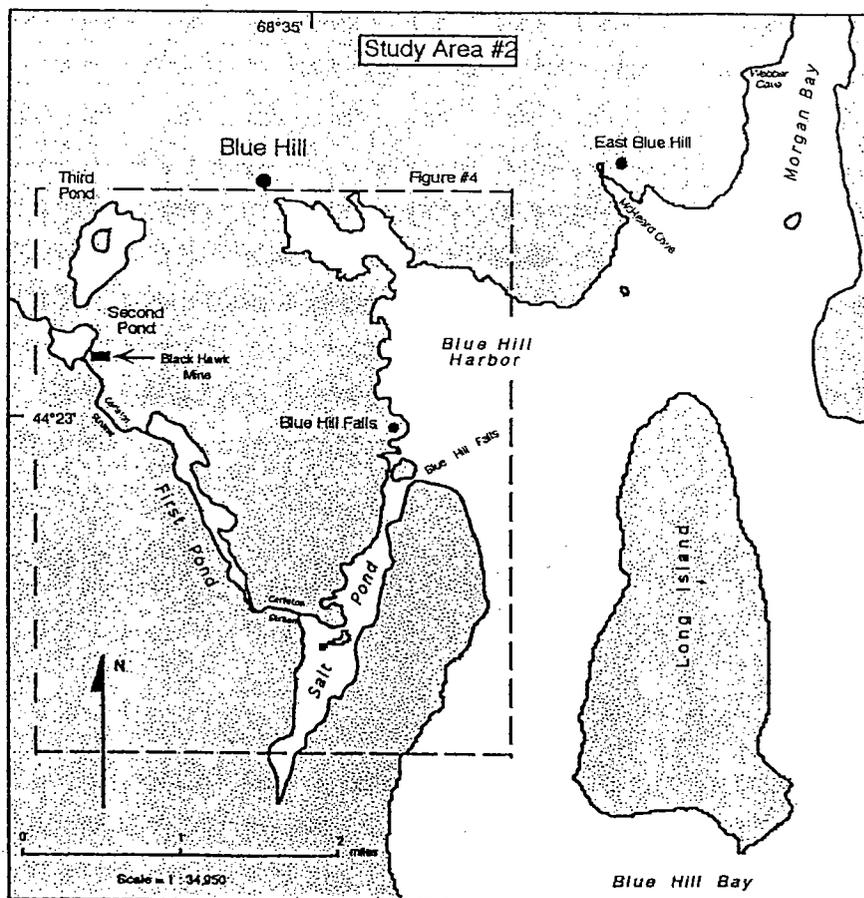
Figure #1 - Study Area #1: Cape Rosier/Castine



The sulfide deposits of the Black Hawk Mine were first discovered in 1876. This led to the development of the Douglas Mine and smelter which produced 2 million pounds of copper between

1880 and 1884. The Black Hawk Mine (see figure #2) was operated intermittently from 1964 to 1978 as a subsurface (shaft) Cu, Zn, and Pb mine. Freshwater from adjacent Second Pond was utilized for milling and separation, the effluent then being discharged into Carleton Stream. Drainage of this stream carries any mine discharge first into First Pond (freshwater), then into Salt Pond (tidal), and finally into Blue Hill Bay (see figure #2). The Hurst study (Hurst et al. 1976) reported elevated levels of copper and lead at the outfall of Carleton Stream into Salt Pond but found most sites in Salt Pond and Blue Hill Bay to be close to background levels. The authors concluded that the Black Hawk mine had less of an environmental impact than the Callahan Mine, but acknowledged that several kilometers of transport through the freshwater environment must claim a significant portion of the metal load.

Figure #2 - Study Area #2: Blue Hill



## Pb Geochemistry

Lead (Pb) occurs in all surficial environments as a natural trace metal and as an artifact of anthropogenic activity. The increase of Pb in atmospheric and marine environments as a result of anthropogenic input is well established and is shown to span a period of time extending back to 605 BC, when silver coinage was discovered and used for the first time (Chow and Patterson 1962; Patterson 1972). In particular, it has been demonstrated that man's activity over the last century has resulted in a dramatic increase of Pb contamination in terrestrial, marine, and atmospheric environments. Pb is introduced to the environment through the combustion of tetraethyl Pb additives in gasoline (the primary source), the smelting of Pb and other metals, the combustion of oil and coal, and Pb's use in many industrial and commercial products such as batteries and paint. Because Pb is toxic even at low concentrations, its modern artificial sources represent significant environmental and health threats. The identification and quantification of such sources of Pb and other trace metal contaminants are therefore primary concerns in environmental studies.

Stable Pb in the natural environment has four isotopes,  $^{204}\text{Pb}$ ,  $^{206}\text{Pb}$ ,  $^{207}\text{Pb}$ , and  $^{208}\text{Pb}$ . The isotopes  $^{206}\text{Pb}$ ,  $^{207}\text{Pb}$ , and  $^{208}\text{Pb}$  form from the radioactive decay of uranium (U) and thorium (Th) and are therefore called the "radiogenic" isotopes of Pb. The isotope  $^{204}\text{Pb}$  does not form as the result of any decay process, but has existed as an isotope of unchanging concentration since the formation of the universe. It is therefore called the "primordial" isotope of Pb. Because of these properties, U and Th bearing rocks have  $^{206}\text{Pb}/^{204}\text{Pb}$ ,  $^{207}\text{Pb}/^{204}\text{Pb}$ , and  $^{208}\text{Pb}/^{204}\text{Pb}$  ratios that increase with age as more radiogenic Pb is produced (from the decay of the U and Th).

Pb is also incorporated in minerals and ores which exclude U and Th, such as galena. This Pb has ratios of  $^{206}\text{Pb}/^{204}\text{Pb}$ ,  $^{207}\text{Pb}/^{204}\text{Pb}$ , and  $^{208}\text{Pb}/^{204}\text{Pb}$  which are dependent on the age and geologic environment of the ore-forming fluids. These ratios remain unchanged after mineralization because there is no U or Th within the mineral or ore. Therefore, ores which formed at different times in geologic history have isotopic signatures unique to that age. In fact, most ore leads have Pb isotopic ratios (as  $^{206}\text{Pb}/^{204}\text{Pb}$ ,  $^{207}\text{Pb}/^{204}\text{Pb}$ ,  $^{208}\text{Pb}/^{204}\text{Pb}$ ) measurably less than ratios in typical soils and sediments (both continental and marine). This relationship enables one to isotopically distinguish ore Pb from "natural" Pb. Such ore bodies (clearly the larger ones) are the single source for industrial Pb, and our use of industrial Pb inevitably results in its introduction into the environment as a trace metal contaminant. Because the source of the pollution may be characterized by a specific isotopic composition, we may use it as a tracer to determine the pollutant source (Faure 1986).

The use of common Pb isotopes to identify sources of trace metal contamination has been applied to a variety of environments with much success. Pb has also been used by some investigators (Flegal et al. 1989) to identify the source of Pb within upwelling waters of the

northeast Pacific as Asian industrial Pb which was introduced at the waters presumed point of origin in coastal Asia. Similar studies, at smaller scale, have been successfully completed by Flegal et al. (1989) and Stukas and Wong (1981). The Pb isotope approach has also been used to identify specific "point source" contaminants in Monterey Bay, California (Flegal et al. 1987). H.E. Gaudette has used Pb isotopes to quantify the historical inputs of non-point source contamination in Casco Bay, Coastal Maine (Gaudette 1994). These studies demonstrate the usefulness of using Pb isotopic composition to discern the sources of both point and non-point source trace-metal contamination.

### Objective

The objectives of this investigation are twofold. The first and primary is to spatially distinguish and characterize the input and accumulation of Pb and other trace-metals to the environment by isotopic methods. Specifically, can point-source contaminants (as represented by previous mining activity) be identified isotopically? If so, what is the resolution and spatial extent of this distinction? The second objective is to provide insight into the effects of recent mining in a range of distinctly different environments. In the case of the Blue Hill mine, effluent is drained first into a fluvial environment then into a lacustrine, estuarine, and finally a marine environment. The Callahan mine pit and effluent, on the other hand, are directly exposed to tidal influences and may exhibit a different mixing influence and a greater leaching effect due to interaction with marine waters. This provides a unique opportunity to investigate the behavior of trace metals and Pb isotopic mixing during transportation through these different systems.

### Methods

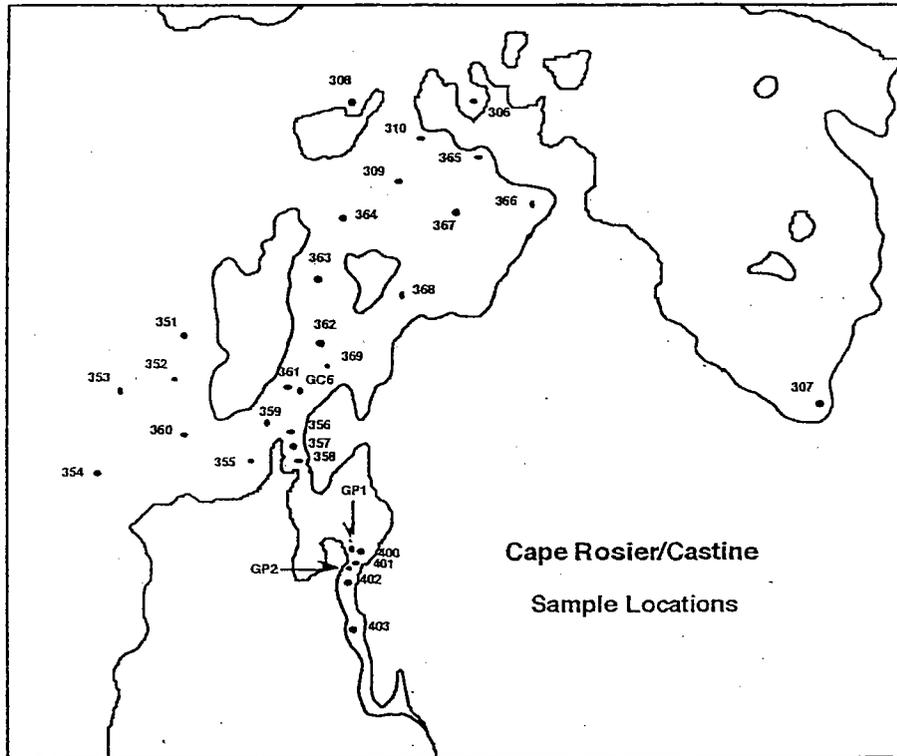
#### Sampling

Sediment samples were obtained during the summer, fall, and winter of 1994. Grab-sample collection was done using a stainless-steel grab-sampler (design by H.E.Gaudette). This sampler obtains ~ 2 to 3 kg of coherent surface sediments, from which 0.5 to 1 kg of the upper oxidized sediment layer was collected and placed in twice sealed ziploc bags. This large sample size minimizes possible Pb contamination. In addition, all sampling equipment is acid-cleaned prior to collection. A total of ~ 60 grab-samples of fine marine and lacustrine mud and ~ 10 samples of coarser marine and stream sediments were collected (see figures #3 and #4). In addition, 9 sediment cores (20 cm to 1.5 m in length) were collected by gravity-core and by hand using acid cleaned polyurethane core-liners. From these cores, each cm was subsampled to a depth of 50 cm after which every 5 cm section was sampled.

Galena (PbS) and ore were collected from tailing piles at both the Harborside and Black Hawk mines. From these samples ~ 0.1 - 0.2 g of pure galena was identified and separated by

microscopic examination. This galena was placed in acid-cleaned teflon vials and directly processed by dissolution in ultra-pure HCl acid for later isotopic determinations.

Figure #3 - Study Area #1: Sample Locations

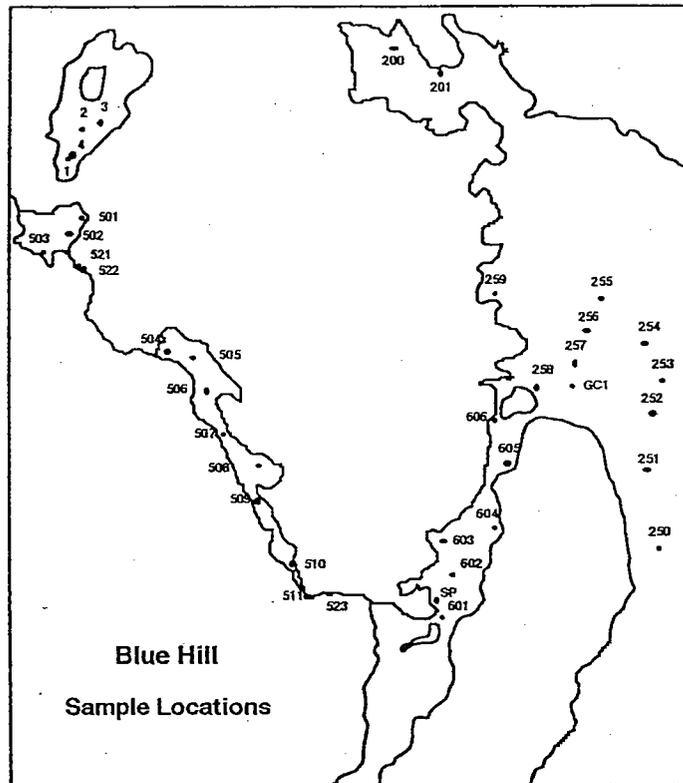


### Analytical Methods

*Sample Processing* : After homogenizing samples within individual sample bags, ~ 50 - 75 g was placed in petri dishes and oven-dried at 70 °C. This dried sample was then disassembled by mortar and pestle and placed in acid-cleaned polyethylene vials. Three grams of each sample was then removed, weighed, and placed in 10 ml of ultra-pure, 3.1 N HNO<sub>3</sub>. This acid-sediment slurry was allowed to sit for 24 hours at room temperature with periodic stirring. This extraction time (24 hours) was calibrated with an initial time-series procedure which determined that all extractable metals were removed within ~ 12 hours at this normality and temperature. The fraction obtained by this extraction represents that portion of the environmentally “available” metals which is available for various exchange processes in the natural environment (Ng and Patterson 1981). The extractions were then filtered through quantitative filter paper, rinsed and diluted to 50 ml with trace analysis grade H<sub>2</sub>O (Milli-pore H<sub>2</sub>O, once distilled in a vycor quartz still), and stored in duplicate, acid-cleaned polyethylene vials. Contamination is monitored using blank analysis.

*Concentration Analysis* : Sample extractions were analyzed for Cu, Zn, Pb, and Cd by inductively-coupled plasma, atomic-absorption spectrometry (ICP-AES) using batch standard calibration. The analytical detection limits are 1.0 ppm Pb, 0.5 ppm Zn, 0.1 ppm Cu, and 0.001 ppm Cd. Analytical uncertainties, as determined from replicate analysis, are ~ 10 %. Fe analysis

Figure #4 - Study Area #2: Grab-sample Locations



was done by colorimetry using the Ferrozine method (Murray 1978). All blanks analyzed were below machine detection limits. Pipette grain-size analysis (GSA) for sediment size distribution was done on all grab samples following a modification of the Folk method (Folk 1960?). Metal concentrations were then normalized to the percent fines (fraction below silt size, or < 65 microns) determined by GSA.

*Isotopic Analysis* : Approximately 3 ml of extraction was placed in ultra-clean teflon beakers and evaporated to dryness in a laminar airflow hood. This fraction was then reacidified and Pb separates were obtained by cation exchange column chromatography. All acids used in this procedure were ultra-pure grade and all work was done under clean room conditions (HEPA filtered air). Contamination was monitored using blank analysis and was below 0.1 ppb Pb. This

represents at most 0.17 % of Pb in any sample, and more typical blank values represent less than 0.01 % of average sample concentrations. Samples were analyzed for Pb isotopic concentration by thermal-ionization mass-spectrometry (TIMS) on a 60° sector, 9-inch radius, Nier design mass-spectrometer. Internal machine variability is monitored using NIST standard NBS-981 - common Pb standard and is typically below 0.3 %. Each of the sample ratios  $^{208}\text{Pb}/^{206}\text{Pb}$ ,  $^{207}\text{Pb}/^{206}\text{Pb}$ , and  $^{204}\text{Pb}/^{206}\text{Pb}$  represent the average of at least 100 individual ratio measurements (each representing 5 peak readings). The average uncertainty of these ratios is 0.1 %, 0.1 %, and 0.2% respectively.

## Results

### *Grab-samples Cu, Zn, Pb, and Cd concentrations*

The results of the AES trace metal analyses are summarized in table #1. This table shows concentration averages over distinct geographic domains within the study area. The actual values for each sample site can be found in Appendix #1. The percent relative standard deviation (% RSD) of this average (as the deviation within the individual domains) is also given. The high % RSD of contaminated domains, such as First Pond and Second Pond, reflect the significant variability of metal retention within short distances. It should be noted that this variability is generally less in samples of low concentration.

Table #1 - Pb, Cu, Zn, and Cd Concentrations: Grab-sample summary

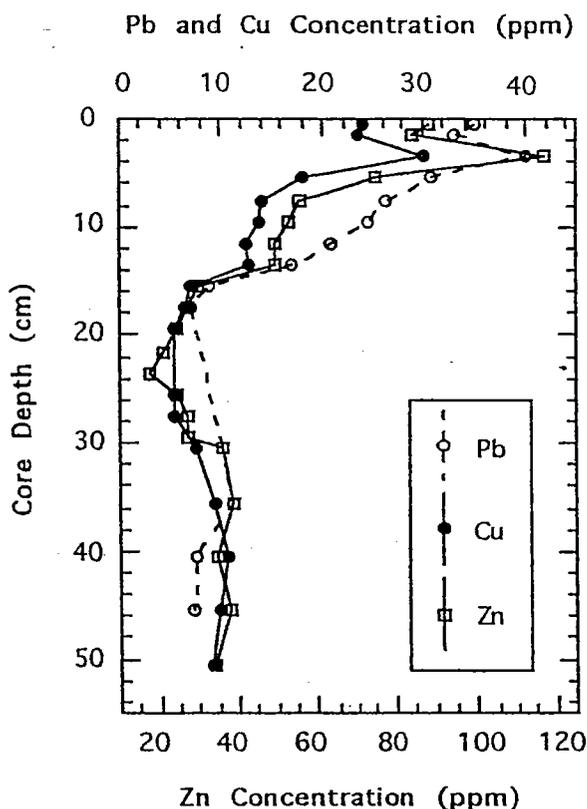
Locations	Pb (ppm)	% RSD	Cu (ppm)	% RSD	Zn (ppm)	% RSD	Cd (ppm)	% RSD
<b>Study Area #1</b>								
Goose Pond	515	72.4	1210	41.2	4380	71.4	11.8	87.5
Goose Cove	297	19.2	731	42.2	3246	22.2	13.4	23.5
Cape Rosier	35.0	21.7	12.9	32.5	64.3	24.8	0.763	28.6
Bagaduce River	33.8	19.9	9.69	12.6	55.2	17.2	0.606	30.4
<b>Study Area #2</b>								
Third Pond	44.2	33.2	34.6	28.5	103	20.4	1.43	24.7
Second Pond	120	129	781	79.0	1088	67.8	5.47	41.2
First Pond	64.9	40.3	1027	61.9	2241	65.2	11.0	59.9
Salt Pond	37.7	76.1	481	232	837	193	3.60	150
Blue Hill Falls	33.8	15.9	12.4	34.6	64.5	35.6	0.816	37.1
Blue Hill Harbor	56.4	4.70	19.9	52.1	83.5	10.3	1.28	13.9
East Blue Hill	39.5	101	14.3	106	46.9	73.7	0.840	71.0
<b>Controls</b>								
Core bottoms	9.33	19.4	9.49	25.6	37.1	15.6	0.756	26.3
Core Tops	17.6	9.02	19.8	45.2	60.0	19.7	0.465	59.0
Background	24.1	30.9	7.62	41.3	36.9	25.8	0.437	51.4

Background or control concentrations for both study areas have been determined from distant sample sites in Northern Bay and Bagaduce River (see figure #1) and from sites in Morgan Bay and South Blue Hill (see figure #2). In addition, the lower portions of sediment cores (determined by  $^{210}\text{Pb}$  methods to be older than 100 years in age) were also used in background calculations. This comparison of "ancient" sediments with recent "clean" background samples allows an additional modern (non-point source) trace metal trend to be identified. The results of these background calculations are summarized in table #1.

*Gravity Core Cu, Zn, Pb, and Cd concentrations*

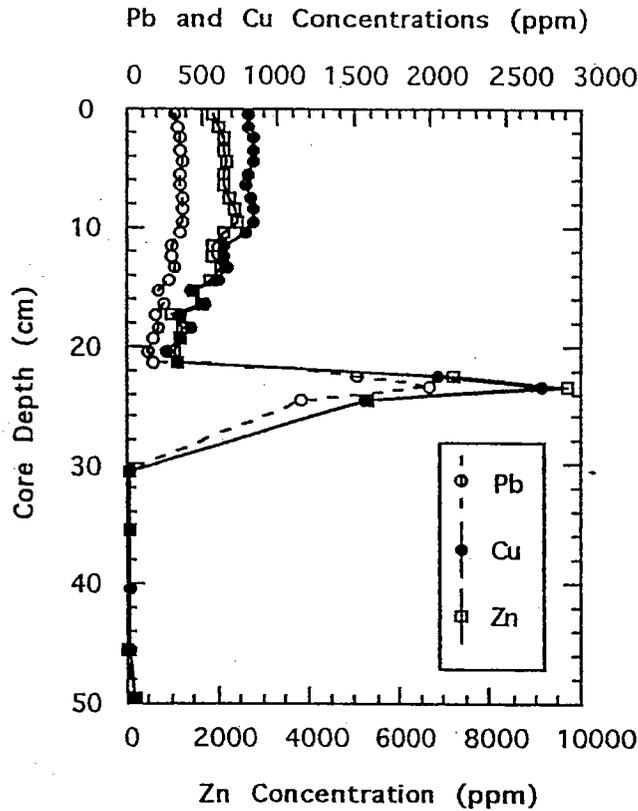
The down-core profiles of two sediment cores from study area #1 (GC6, GP2) and one core from study area #2 (GC1) are shown in figures #5, #6, and #7. The locations of these cores are shown in figures #3 and #4. It should be noted that the cadmium concentrations exhibit the same trend as the Cu, Pb, and Zn data but are not shown on these core plots because the Cd concentration range is much less than the metals plotted above. The Cd ranges for each core are: GC6 = 0.60 - 1.1 ppm, GP2 = 1.4 - 52 ppm, and GC1 = 0.37 - 0.63 ppm (refer to Appendix #1 for the complete Cd data set).

Figure #5 - GC6 Cu, Pb, and Zn Concentration Profiles



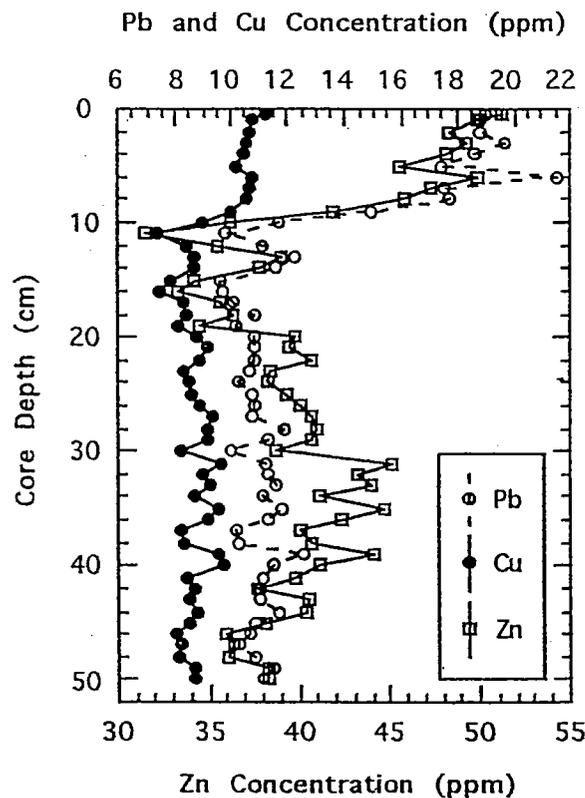
The upper 10 cm of GC6 shows increases of 350 % in Cu and Zn concentrations, and 400 % in Pb concentrations in comparison to those concentrations within the lower portions of the core (cm's 15 - 50).  $^{210}\text{Pb}$  data from this core indicate undisturbed conditions of deposition and yield a sedimentation rate of 0.1 cm/yr. When the core depths are corrected for compaction, the time horizon of the peak concentrations is the period 1965 - 1975, a range equivalent (within analytical error) to the period of active mining at the Harborside Mine. However, these sedimentation rates also indicate initial perturbations beginning around 1945 (the first substantial increases in metal concentrations at ~ cm 7). Because this data is a full 20 years before any major development of the Harborside deposits, an additional correction seems necessary before this age assignment can be considered anything but a first approximation. Initial exploration of this area by the US Bureau of Mines in the late 1940's may have perturbed the system enough to introduce a flux of metals into the environment, but this is unclear from any published records.

Figure #6 - Goose Pond (GP2) Cu, Pb and Zn Concentration Profiles



The results of the GP2 core analyses are dramatically different from the results of the GC6 core. Metal trends in this core show increases (when compared to regional background concentrations) on the order of 2700 % Zn, 2600 % Cd, 2300 % Cu, and 1000 % Pb. In addition, the present day metal values show no increases or decreases over the top 10 cm. This constant profile would seem to indicate that one of two conditions is present: 1) The estuary has reached an approximate steady-state condition following the period of mining (here represented by the maximum concentrations). If this is the case, the new present day metal levels of this environment have experienced increases of 600 % Cu, 550 % Zn, 350 % Cd, and 160 % Pb. 2) The top 10 cm are disturbed such that any original depositional horizons have been eliminated. If this has occurred, any evidence of past metal fluxes would be destroyed and the concentration profiles would appear to reach a steady-state condition. However, even if mixing has occurred we should still be able to discern any previous metal fluxes by noting the magnitude of the mixed average (the constant upper 10 cm of the profile). Because the magnitude of this constant interval (0 - 10 cm) is at least as high as the concentrations within the 20 - 10 cm interval, significant metal decreases could not have occurred during the deposition of the top 10 cm. This observation allows us to make the same conclusions as above under condition #1.

Figure #7 - GC1 Cu, Pb, and Zn Concentration Profiles



The results of core GC1 demonstrate much smaller modern metal trends than seen in the previous two cores. In fact, because the distance from GC1 to the Black Hawk Mine (~ 10 km) is much greater than the distances from GC6 and GP2 to the Harborside Mine (0.6 and 0.1 km respectively), and because any mine outflows have traveled through three distinct geochemical environments before deposition at this core site, it is unclear whether the increases seen in the upper portions of this core are due to past mining activity or may be instead attributed to modern, non point-source contamination.

*Grab-sample Pb isotopic compositions*

Table #2 gives the results of Pb isotopic analysis on ~ 30 grab-samples from both study areas. The ratios  $^{208}\text{Pb}/^{206}\text{Pb}$ ,  $^{207}\text{Pb}/^{206}\text{Pb}$ , and  $^{204}\text{Pb}/^{206}\text{Pb}$  are reported as measured directly by TIMS. Figures #8 and #9 show the isotopic mixing lines formed by these data. The ratios used in these plots are the  $^{206}\text{Pb}/^{207}\text{Pb}$  and  $^{206}\text{Pb}/^{204}\text{Pb}$  values calculated from the above machine measurements. This choice of these isotopes, neglecting the  $^{208}\text{Pb}$  values, eliminates inconsistencies in results due to mineral variations in Pb sources such as bedrock (recall that  $^{208}\text{Pb}$  is derived from Th-bearing minerals, whereas  $^{206}\text{Pb}$  and  $^{207}\text{Pb}$  are both derived from U-bearing minerals). The  $^{206}\text{Pb}/^{207}\text{Pb}$  is considered the “master” common Pb ratio, primarily because it has the smallest measurement error. It is used instead of its inverse, the actual measured ratio, because the whole number values of  $^{206}\text{Pb}/^{207}\text{Pb}$  (values of 1.15 -1.23) are more intuitively understood

Table #2 - Grab Sample Pb Isotopic Compositions

<i>Study Area #1</i>				
<b>Location</b>	<b>Sample #</b>	<b>204/206Pb</b>	<b>207/206Pb</b>	<b>208/206Pb</b>
<i>Bagaduce River</i>	301	0.05325	0.8308	2.047
	303	0.05340	0.8324	2.049
<i>Goose Cove</i>	356	0.05519	0.8594	2.087
	357	0.05551	0.8612	2.087
	358	0.05531	0.8608	2.085
<i>Cape Rosier</i>	351	0.05338	0.8320	2.051
	355	0.05280	0.8348	2.057
	359	0.05346	0.8369	2.055
	360	0.05340	0.8338	2.051
	361	0.05344	0.8399	2.069
	362	0.05341	0.8366	2.055
	364	0.05315	0.8352	2.051
	366	0.05314	0.8361	2.056
	367	0.05336	0.8338	2.048
	368	0.05338	0.8362	2.065

<i>Study Area #2</i>				
<i>Location</i>	<i>Sample #</i>	<i>204/206Pb</i>	<i>207/206Pb</i>	<i>208/206Pb</i>
<i>Blue Hill Falls</i>	251	0.05269	0.8305	2.046
	257	0.05316	0.8308	2.047
<i>Blue Hill Harbor</i>	200	0.05304	0.8273	2.038
	203	0.05211	0.8163	2.017
<i>Morgan Bay</i>	205	0.05296	0.8267	2.039
<i>Third Pond</i>	1	0.05333	0.8352	2.055
	3	0.05262	0.8321	2.056
<i>Second Pond</i>	501	0.05513	0.8627	2.095
<i>First Pond</i>	504	0.05439	0.8490	2.077
	506	0.05412	0.8483	2.071
	508	0.05417	0.8451	2.065
	509	0.05426	0.8456	2.066
	510	0.05420	0.8445	2.065
	511	0.05422	0.8472	2.072
<i>Salt Pond</i>	523	0.05387	0.8432	2.063
	601	0.05304	0.8298	2.041
	602	0.05426	0.8490	2.077

than  $^{207}\text{Pb}/^{206}\text{Pb}$  ratios (values of 0.870 - 0.813). Mean deviations on machine measurements are given in Appendix #2 and are shown as error bars in figures #8 and #9.

Corresponding equations for the plotted mixing lines were calculated using a standard linear regression in Microsoft Excel's Analysis Tools. This regression resulted in the following linear equations and correlation coefficients:

$$\text{study area \#1 (Cape Rosier) - } ^{206}\text{Pb}/^{207}\text{Pb} = 0.0542 (^{206}\text{Pb}/^{204}\text{Pb}) + 0.1824 \quad (R^2 = 0.966)$$

$$\text{study area \#2 (Blue Hill) - } ^{206}\text{Pb}/^{207}\text{Pb} = 0.0578 (^{206}\text{Pb}/^{204}\text{Pb}) + 0.1124 \quad (R^2 = 0.985)$$

The excellent linearity and similar slopes (within 6.3 % error) suggest the validity of a two-endmember mixing interpretation for both study areas. The endmembers of this mixing model for both areas are calculated as:

$$\text{background } ^{206}\text{Pb}/^{207}\text{Pb} = 1.20 - 1.22 \quad (+/- 0.001)$$

$$\text{point-source } ^{206}\text{Pb}/^{207}\text{Pb} = 1.158 \quad (+/- 0.001)$$

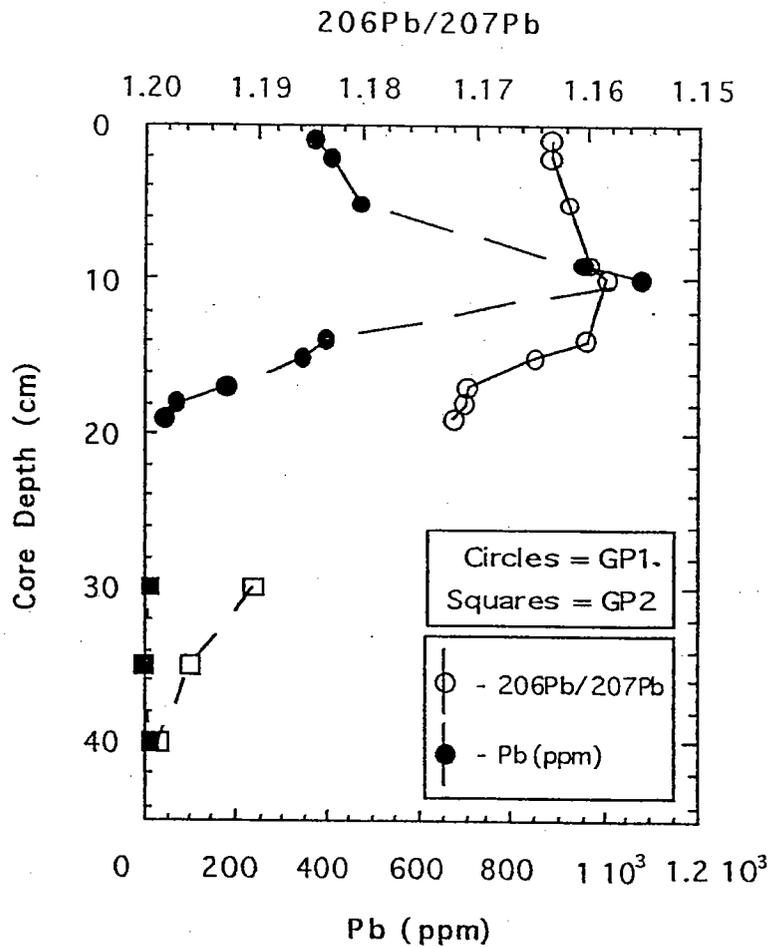
Although the background ratios do have a larger natural variation than the point-source endmember, it is always found within both study areas as 1.20 or greater. This result is supported by the work of Gaudette (1994), whose isotopic survey of surficial sediments in the Portland and Boothbay regions showed average  $^{206}\text{Pb}/^{207}\text{Pb}$  ratios of 1.204 (+/-0.004), and the work of Hamelin et al (1990) whose average  $^{206}\text{Pb}/^{207}\text{Pb}$  values in sediments from the Hatteras Abyssal Plain and offshore southern New England (the "Mud Patch") were 1.20 (+/- 0.002).



*Core Pb isotopic compositions*

Figure #10 shows the results of Pb isotopic analysis of portions of two cores from Goose Pond (Study Area #1). Because there are no sedimentation rates available for these cores, we cannot assume the depths of the cores are correlated in age. Therefore, the trend lines of the data are not connected. The lower three horizons (30, 35, and 40 cm) of the GP2 core are included in the plot to demonstrate that pre-mining common Pb ratios and concentrations in Goose Pond were equal to the typical background levels stated earlier in the paper. Although this composite profile cannot be considered an actual depositional record of Goose Pond, it does record the significant change in Pb composition and concentration due to past mining.

Figure #10 - Goose Pond Core Composite  $^{206}\text{Pb}/^{207}\text{Pb}$  and Pb Concentration Profile

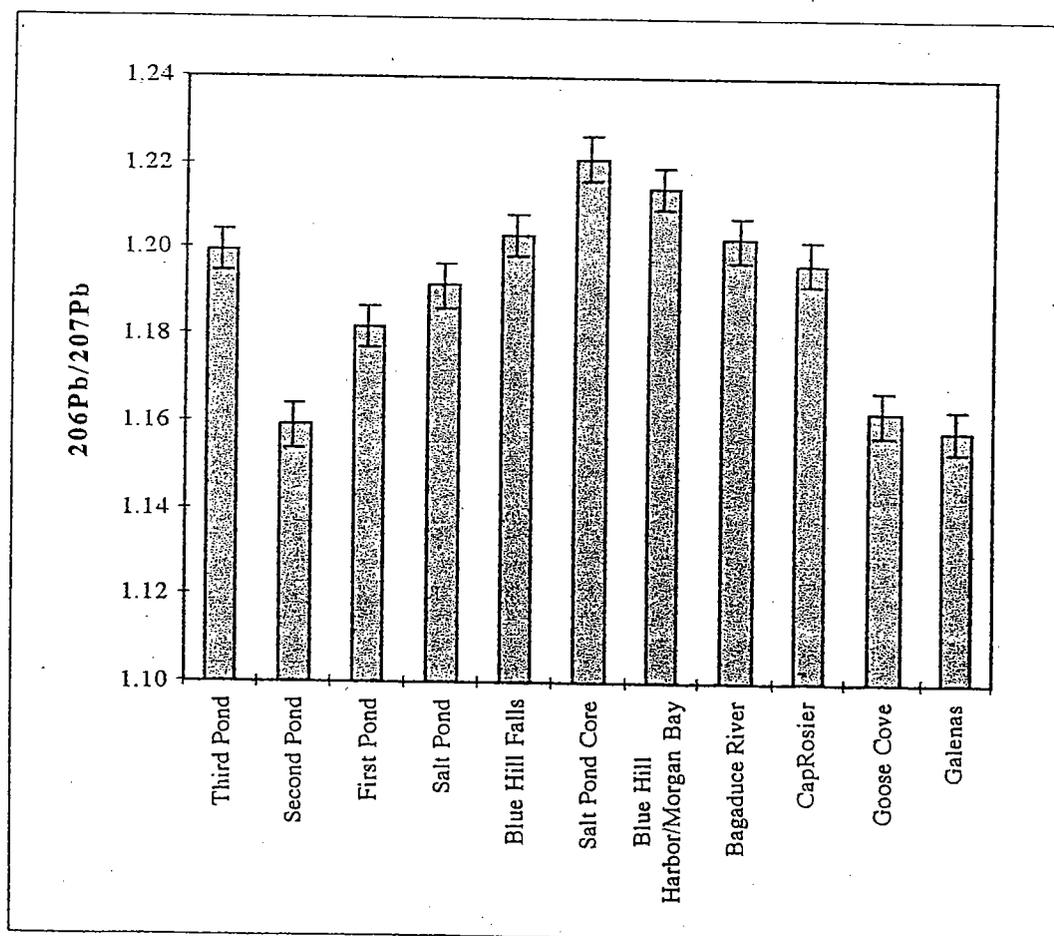


## Discussion

### Isotopic Compositions

A summary comparison of  $^{206}\text{Pb}/^{207}\text{Pb}$  ratios for each the study areas is shown in figure #11. This distribution shows the clear distinction between areas characterized by background ratios, with  $^{206}\text{Pb}/^{207}\text{Pb} > 1.20$ , and those affected by some point-source influence, with  $^{206}\text{Pb}/^{207}\text{Pb} < 1.20$ . Based on this criteria we can assign a "point-source affected" status to five sample areas: Second Pond, First Pond, Salt Pond, Cape Rosier, and Goose Cove. This status would indicate the presence of some measurable amount of point-source mine lead but does not require high sample contamination. In some cases the measurable amount is actually very small.

Figure #11 -  $^{206}\text{Pb}/^{207}\text{Pb}$  Location Averages



This distinction is made even clearer when considering individual sample sites. For instance, the Cape Rosier area has a sample  $^{206}\text{Pb}/^{207}\text{Pb}$  average of  $1.197 \pm 0.003$ . Although

this average is below the calculated background level, the error associated with this calculation places the mean within background levels. By considering individual sample sites, whose errors are less than half that of the area mean error, we can discern point-source influences or isotopic differences which signify less than 0.1 % of the background isotopic values. Table #3 shows three examples which demonstrate the isotopic distinction of contaminant (point-source) Pb in samples which are enriched in concentration only 60-30 % relative to background.

If the natural variability of trace metal concentrations is between 40 and 100 %, as is suggested by this study, then we cannot use concentration fluctuations of less than 100 % to discern or quantify point-source contamination. An isotopic distinction, even though as small as 0.06 %, would then seem to be an important tool in evaluating and quantifying point-source contaminants in moderately polluted areas.

Table #3 - Isotopic Point-source Resolution

Sample #	206Pb/207Pb	+/-	Pb (ppm)	% Pb Enrichment	% Point-source IC Enrichment
364	1.1973	0.0009	31.6	31.1	0.23
366	1.1960	0.0006	38.0	57.7	0.33
367	1.1993	0.0003	34.4	42.7	0.06

Note : IC = isotopic composition

Table #4 - 206Pb/207Pb Location Averages

Locations	206/207	+/-	Total Metals (ppm)
Third Pond	1.200	0.003	183
Second Pond	1.159	0.001	1994
First Pond	1.182	0.003	3344
Salt Pond	1.191	0.019	1359
Blue Hill Falls	1.203	0.001	112
Salt Pond Core	1.221	0.009	85.0
Blue Hill Harbor/Morgan Bay	1.214	0.009	131
Bagaduce River	1.203	0.002	99.3
Cape Rosier	1.197	0.003	113
Goose Cove	1.162	0.001	4287
Galenas	1.158	0.001	na

### Concentrations

The sample area concentration averages are again summarized in table #4 with the additional calculation of enrichment factors for each of these areas. The total metal (Cu+Pb+Zn+Cd ppm) enrichment factor (EF) is calculated as:  $(EF) = \text{sample ppm} / \text{background ppm}$

These enrichment factors exhibit the tremendous contamination of some sample areas and suggest that both study area #1 and study area #2 have distinctly different metal-retention characteristics. For instance both study areas have large enrichments directly adjacent to mine outfalls, Goose Cove (study area #1) EF = 62 and Second Pond (study area #2) EF = 29. However, within 0.5 km of the discharge of Goose Pond this enrichment factor has decreased to ~ 1.6, a value too small even to be attributed directly to mine contamination. In contrast, enrichment factors in study area #2 are still as high as 20 through Salt Pond, a distance of over 10 km.

Table #5 - Sample Area Enrichment Factors

Location	Pb	Cu	Zn	Cd	Total Metals	Enrichment Factors
Third Pond	44.2	34.6	103	1.43	183	2.7
Second Pond	120	781	1088	5.47	1994	29
First Pond	64.9	1027	2241	11.0	3344	48
Salt Pond	37.7	481	837	3.60	1360	20
Blue Hill Falls	33.8	12.4	64.5	0.816	111	1.6
Blue Hill Harbor	56.4	19.9	83.5	1.28	161	2.3
East Blue Hill	39.5	14.3	46.9	0.840	102	1.5
Goose Pond	515	1210	4380	11.8	6117	89
Goose Cove	297	731	3246	13.4	4287	62
Cape Rosier	35.0	12.9	64.3	0.763	113	1.6
Bagaduce River	33.8	9.69	55.2	0.606	99.3	1.4
Core bottoms	9.33	9.49	37.1	0.756	56.7	0.8
Core Tops	17.6	19.8	60.0	0.465	97.8	1.4
Background	24.1	7.62	36.9	0.437	69.0	1.0

It should also be noted that enrichment factors greater than 1 cannot be specifically attributed to point-source contaminants. For example, Blue Hill Harbor and Third Pond have enrichment factors of 2.3 and 2.7 respectively, but  $^{206}\text{Pb}/^{207}\text{Pb}$  ratios of 1.209 and 1.202 respectively. Because these ratios are greater than 1.20 (the calculated background ratio), it is suggested that modern non-point-source contamination (due to fuel combustion, industrial waste, etc.) can introduce enrichment factors as high as 2 to 3 times the background signal while retaining "background" Pb isotopic ratios. This result also demonstrates the usefulness of an isotopic distinction in an environment with non-point source influences. In this case, a contamination study alone may have concluded that Blue Hill Harbor and Third Pond were in some way affected by mining activity.

Based on these results, the only areas which seem to exhibit definite point-source signals, with EF > 3, are Second Pond, First Pond, Salt Pond, Goose Cove, and Goose Pond. The magnitude of these enrichments, Goose Pond EF = 89 and First Pond EF = 48, are nonetheless extreme, and demonstrate the distinct and persistent effect of mining activity which ceased ~ 20

years ago. It is also interesting to note the EF calculated from gravity core bottoms (GC1 and GC6) is less than 1 (0.8), again indicating the modern non-point source contamination present in surficial marine sediments..

Figure #12 - Sample Area  $^{206}\text{Pb}/^{207}\text{Pb}$  and Total Metal Concentrations

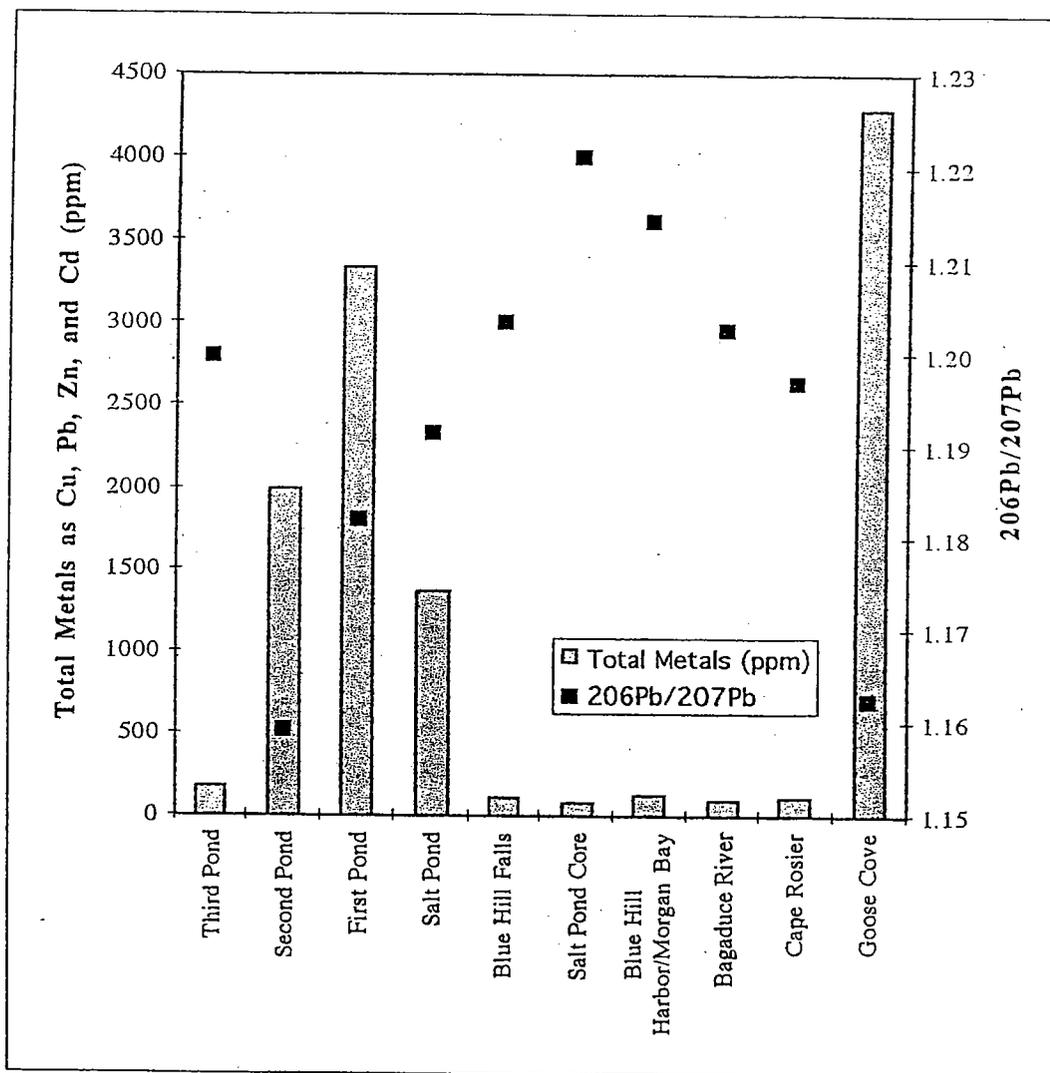


Figure #12 summarizes the relationships between sample area concentration and  $^{206}\text{Pb}/^{207}\text{Pb}$  ratio as seen in some of the sample areas. It is clear from these results that Pb isotopic composition can be used to quantify point-source contamination as a result of past mining activity.

## Conclusions

1) The Pb isotopic systematics of both study areas are defined by a point-source  $^{206}\text{Pb}/^{207}\text{Pb}$  endmember of 1.158 ( $\pm 0.001$ ) and a background  $^{206}\text{Pb}/^{207}\text{Pb}$  endmember of 1.20 - 1.23 ( $\pm 0.001$ ). The mixing lines defined by these endmembers for each of the study areas are:

study area #1 (Cape Rosier) -  $^{206}\text{Pb}/^{207}\text{Pb} = 0.0542 (^{206}\text{Pb}/^{204}\text{Pb}) + 0.1824$  ( $R^2 = 0.966$ )

study area #2 (Blue Hill) -  $^{206}\text{Pb}/^{207}\text{Pb} = 0.0578 (^{206}\text{Pb}/^{204}\text{Pb}) + 0.1124$  ( $R^2 = 0.985$ )

This isotopic distinction allows the discrimination of point-source Pb in samples contaminated by the addition of only an additional ~35 % metals (relative to background samples). Because the natural variability of trace metals within aqueous systems can exceed 100% over very short distances, this isotopic distinction significantly increases the resolution of point-source contamination.

2) The effects of past mining activity in the Blue Hill/Cape Rosier areas of Mid-coastal Maine are variable but distinct. The results of this study suggest that freshwater environments downstream of mine outfalls have much greater metal retention abilities than similar outfalls into near-shore marine systems. The Cape Rosier area is highly affected directly adjacent to the location of the old Harborside mine, with total metal enrichment factors within Goose Pond and Goose Cove of 89 and 62 respectively. However, this contamination rapidly falls off to enrichment factors of below 2 in under 0.5 km from the outfall of Goose Pond. Conversely, the Blue Hill study area is highly affected adjacent to the Blackhawk mine and to distances greater than 12 km, with enrichment factors varying between 29, 48, and 20 from Second Pond to First Pond to Salt Pond.

## References

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- Flegal, A. R., Nriagu, J. O., Niemeyer, S., and Coale, K. H. (1989), Isotopic Tracers of Lead Contamination in the Great Lakes: *Nature*, 339, pp. 455-458.
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- Hurst, J. W., Jr., Kahl, J. S., Patry, E., and Nelson, D. (1979). Bioaccumulation of Trace Elements in Selected Marine Organisms; An Examination of Mined and Unmined Areas in Mid-Coastal Maine. Maine Monitoring Program report (#R802656).
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- Stukas, V. J., and Wong, C. S. (1981), Stable Lead Isotopes as a Tracer in Coastal Waters: *Science*, 211, pp. 1424-1427.





## PROJECT NOTE

To: Callahan Mine Hazard Ranking System Project File

From: Thomas A. Campbell, Roy F. Weston, Inc., Region I START 2000

Date: November 10, 2000

RE: GIS Distance Measurements for the Surface Water Pathway section, Callahan Mine, Brooksville, Maine  
TDD No. 00-06-0020, PCS No. 1150-30

### Method

Distances used in the surface water pathway section of the Callahan Mine HRS package were calculated using ArcView 3.1 Global Information System (GIS) software and Callahan Mine coverages provided to START by the Maine Department of Environmental Protection. The measurement tool in the GIS software was used to determine the following:

Distance from most downstream probable point of entry (PPE) in Goose Pond to Goose Cove:  
1,000 feet (dashed line)

Distance from most upstream PPE to sediment sample 99-SD-39:  
3,960 feet (solid line)

Distance from most upstream PPE to Holbrook Island Sanctuary:  
200 feet (dotted line)

Wetland frontage between the most upstream PPE to sediment sample 99-SD-39:  
0.77 miles (indicated with labels)

A figure of the Callahan Mine site is included as Attachment A of this Project Note.

**Attachment A**

Callahan Mine site figure

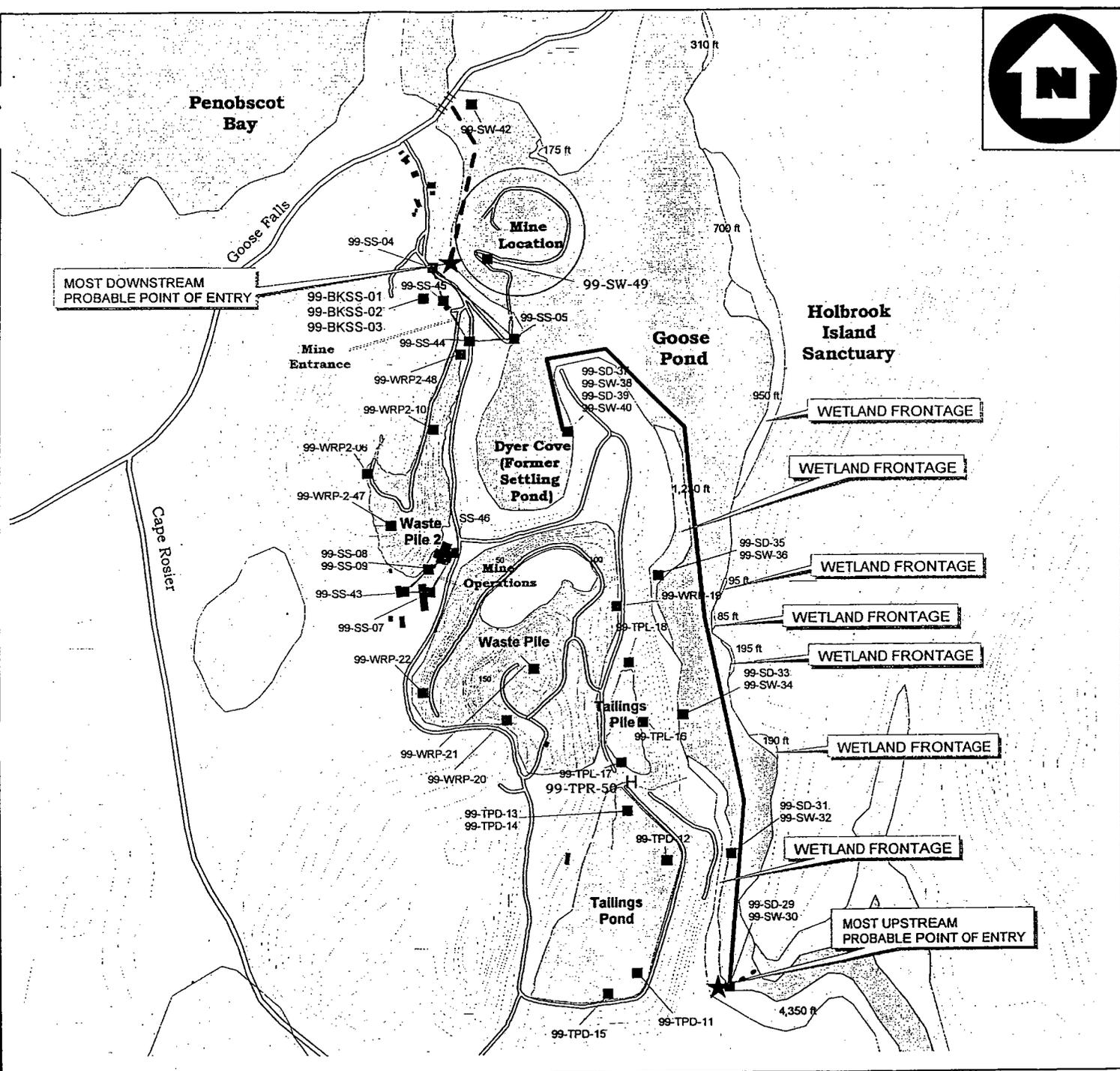
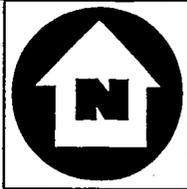


FIGURE ADAPTED FROM MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION, CALLAHAN FIGURE, JUNE 1999

★ : PROBABLE POINT OF ENTRY (PPE)

- WETLAND FRONTAGE : WETLAND FRONTAGE BETWEEN THE MOST UPSTREAM PPE TO SEDIMENT SAMPLE 99-SD-39
- : DISTANCE FROM MOST UPSTREAM PPE TO SEDIMENT SAMPLE 99-SD-39
- : DISTANCE FROM MOST DOWNSTREAM PPE IN GOOSE POND TO GOOSE COVE
- : DISTANCE FROM MOST UPSTREAM PPE TO HOLBROOK ISLAND SANCTUARY

**PROJECT NOTE FIGURE**

**CALLAHAN MINE  
HARBORVIEW  
BROOKSVILLE, MAINE**



REGION I SUPERFUND TECHNICAL ASSESSMENT AND RESPONSE TEAM

TDD #	DRAWN BY:	DATE
00-06-0020	CAMPBELL	09/28/00
FILE NAME:		FIGURE 1
E:\ARC_APRS\START2\CALLAHAN.APR		



Reference 37

Tom Campbell

Originator

PHONE CONVERSATION RECORD

Conversation with:

Name Jean Firth

Company Environmental Specialist

Address ME DEP

Phone (207) 287-7716

Subject Sample depth of background soil samples: 99-BKSS-01, -02, -03

Date 9 / 17 / 00

Time 10:33 AM/PM

Originator Placed Call

Originator Received Call

W.O. No.

Notes:

Ms. Firth confirmed that the depth the background soil samples (99-BKSS-01, 99-BKSS-02, and 99-BKSS-03) were collected was 0 to 6 inches.

File Callahan Mine

Tickle File

Follow-Up By:

Copy/Route To:

Follow-Up-Action:

Originator's Initials Tom A. Campbell



## PROJECT NOTE

To: Callahan Mine Hazard Ranking System Project File

From: Thomas A. Campbell, Roy F. Weston, Inc., Region I START 2000

Date: 31 August 2000

RE: 15-mile downstream pathway arc methodology, Callahan Mine, Brooksville, Maine  
TDD No. 00-06-0020, PCS No. 1150-30

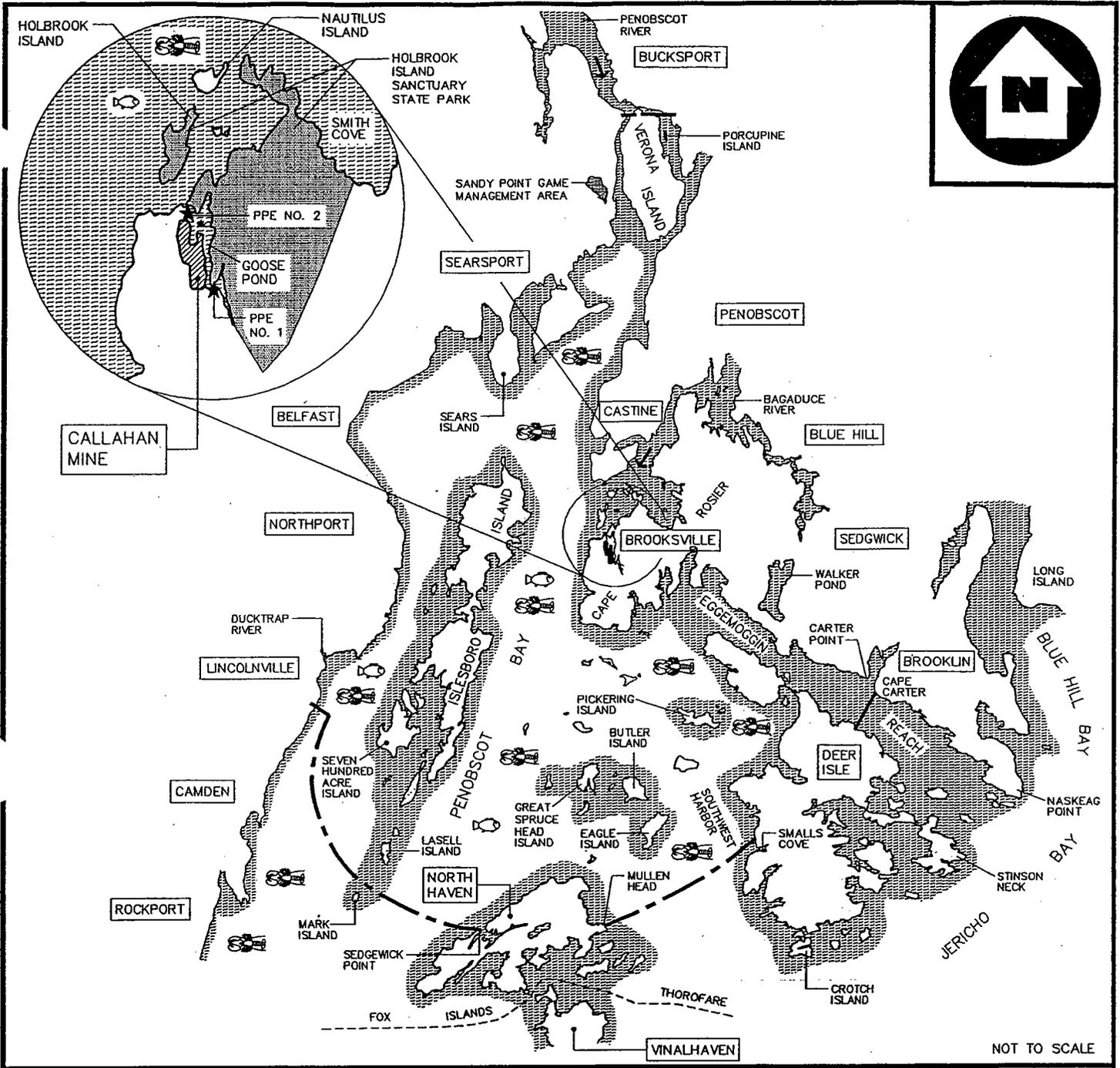
### Method

The 15-mile downstream pathway termini were determined by the following methods. The northern terminus was located by measuring the straight line distance from the most downstream probable point of entry (PPE) in Goose Cove to Verona Island, Maine. The southerly terminus was located by first measuring from the most downstream PPE in Goose Pond to Goose Cove to the northwest corner of Cape Rosier. From this point four radii were measured to determine the southerly 15-mile downstream arc. The first radius was extended northwest to the northern end of Islesboro Island and then southwest to Ducktrap River, in Lincolnville, Maine. The second radius was extended to southwest to the southern end of Islesboro Island and then southwestwest to the 15-mile limit. The third radius was extended southeast to Deer Island. The fourth radius was extended east towards Cape Carter, in Brooklin, Maine. The first and second radii were extended in order to wrap around the Islesboro Island.

The surface water pathway sketch is included as Attachment A of this Project Note.

**Attachment A**

Surface Water Pathway Sketch



**LEGEND**

- WETLANDS
- PROBABLE POINT OF ENTRY TO SURFACE WATER PATHWAY
- FLOW DIRECTION
- 15-MILE DOWNSTREAM SURFACE WATER PATHWAY TERMINUS
- SURFACE WATER
- FISHERIES**
- SHELLFISH FISHERY
- FINFISH FISHERY

SOURCE: U.S.G.S 7.5 MINUTE SERIES QUADRANGLE(S):-  
 BROOKLIN, MAINE 1981  
 BUCKSPORT, MAINE 1982  
 CAPE ROSIER, MAINE 1973 (PHOTOREVISED 1979)  
 CAMDEN, MAINE 1955 (PHOTOREVISED 1973)  
 DEER ISLE, MAINE 1983  
 ISLESBORO, MAINE 1973  
 LINCOLNVILLE, MAINE 1960 (PHOTOREVISED 1973)  
 NORTH HAVEN EAST, MAINE 1982  
 NORTH HAVEN WEST, MAINE 1983  
 SARGENTVILLE, MAINE 1981  
 STENSON NECK, MAINE 1983  
 SEARSPORT, MAINE 1973

**SURFACE WATER PATHWAY SKETCH**

CALLAHAN MINE  
 HARBORSIDE  
 BROOKSVILLE, MAINE

**WESTON**  
 MANAGERS DESIGNERS/CONSULTANTS

REGION I SUPERFUND TECHNICAL ASSESSMENT AND RESPONSE TEAM

TDD # 00-06-0020	DRAWN BY: W. SHAW	DATE 7/26/00
FILE NAME: S:\00060020\FIG4.DWG		FIGURE 4

# Aguilarite Mineral Data Pronunciation Guide



Dealers in Fine Mineral Specimens (Since 1988)  
 Please Click Here to View Our Current Specimen Stock  
 Element ID services for Mineral Identification

## General Information

Reference 39

- ☑ **Chemical Formula:**  $\text{Ag}_4\text{SeS}$
- ☑ **Composition:** Molecular Weight = 542.50 gm)
 

Silver	79.53 %	Ag
Selenium	14.55 %	Se
Sulfur	5.91 %	S
- ☑ **Empirical Formula:**  $\text{Ag}_4\text{SeS}$
- ☑ **Environment:** Low temperature silver mineral in deposits rich in selenium.
- ☑ **Locality:** TL: Mexico, Guanajuato, San Carlos mine.
- ☑ **Name Origin:** Named for Ponciano Aguilar (1853-1935), superintendent of the San Carlos mine, Guanajuato, where the mineral was found.

## Classification

- ☑ **Dana Class:** 2.4.1.3 (2)Sulfides - Including Selenides and Tellurides (2.4)where  $\text{Am Bn Xp}$ , with  $(m+n):p=2:1$  (2.4.1)Dana Group
- ☑ **Strunz Class:** II/B.05-50 II - Sulfides and sulphosalts  
 II/B - Sulfides with metal: sulfur, selenium and tellurium > 1:1, Sulfides, Selenides and Tellurides with predominant Copper and Silver/Gold  
 II/B.05 - Achantite - Empresite series

## Crystallography

- ☑ **Axial Ratios:** a:b:c = 0.6107:1:1.0944
- ☑ **Cell Dimensions:** a = 4.33, b = 7.09, c = 7.76, Z = 2; V = 238.23 Den(Calc) = 7.56
- ☑ **Crystal System:** Orthorhombic - Disphenoidal H-M Symbol (2 2 2) Space Group: P212121
- ☑ **X Ray Diffraction:** By Intensity(I/I<sub>0</sub>): 2.43(1) 2.88(0.5) 1.48(0.4)

## Physical Properties

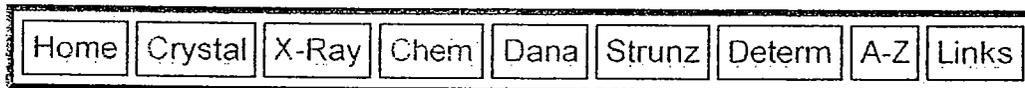
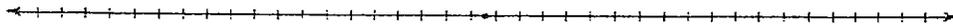
- ☑ **Cleavage:** None
- ☑ **Color:** gray, iron gray, or black.
- ☑ **Density:** 7.4 - 7.56, Average = 7.48
- ☑ **Diaphaniety:** Opaque
- ☑ **Habits:** Massive - Uniformly indistinguishable crystals forming large masses., ,
- ☑ **Hardness:** 2-3 - Gypsum-Calcite
- ☑ **Luminescence:** Non-fluorescent.
- ☑ **Luster:** Adamantine - Metallic
- ☑ **Streak:** grayish black

### Other Information

- ☑ **References:** NAME( Dana8) PHYS. PROP.(Dana8)
- ☑ **See Also:**

Google

1 -Athena Mineralogy 2 - EUROMin Project 3 -  
MinDat.org Location Data 4 -MinMax 5 -École des Mines  
de Paris



**PHONE CONVERSATION RECORD**

**Conversation with:**

Name Mercuria Combl-Microbiologist  
Company Maine Department of Marine Resources  
Address \_\_\_\_\_

Date 1 / 24 / 01  
Time 1030 **(AM/PM)**

Phone 207-667-5654

- Originator Placed Call
- Originator Received Call

W.O. No. 20102-001-001-1150 TDD No. 001-06-0020

Subject Lobster Fishery and Callahan Mine Site

**Notes:**

Ms. Combl stated that the lobster fishery in  
the Callahan Mine area was not affected by  
the shellfish fishery closure. This is because  
lobsters are not filter feeders and are not  
sessile

- File Callahan Mine
- Tickle File \_\_\_\_\_
- Follow-Up By: \_\_\_\_\_
- Copy/Route To: \_\_\_\_\_

Follow-Up-Action: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Originator's Initials Tom Campbell



## PROJECT NOTE

To: Callahan Mine Hazard Ranking System Project File

From: Thomas A. Campbell, Roy F. Weston, Inc., Region I START 2000

Date: January 24, 2001

RE: GIS Distance Measurement for the Soil Exposure Pathway, Callahan Mine, Brooksville,  
Maine  
TDD No. 00-06-0020, PCS No. 1150-30

### Method

Distance to nearest resident used in the soil exposure pathway discussion of the Callahan Mine HRS package was calculated using ArcView 3.1 Global Information System (GIS) software and Callahan Mine coverages provided to START by the Maine Department of Environmental Protection. The measurement tool in the GIS software was used to determine the following:

Distance from the mine entrance to the nearest resident :  
316 feet (dotted line)

A figure of the Callahan Mine site is included as Attachment A of this Project Note.

**Attachment A**

Callahan Mine site figure

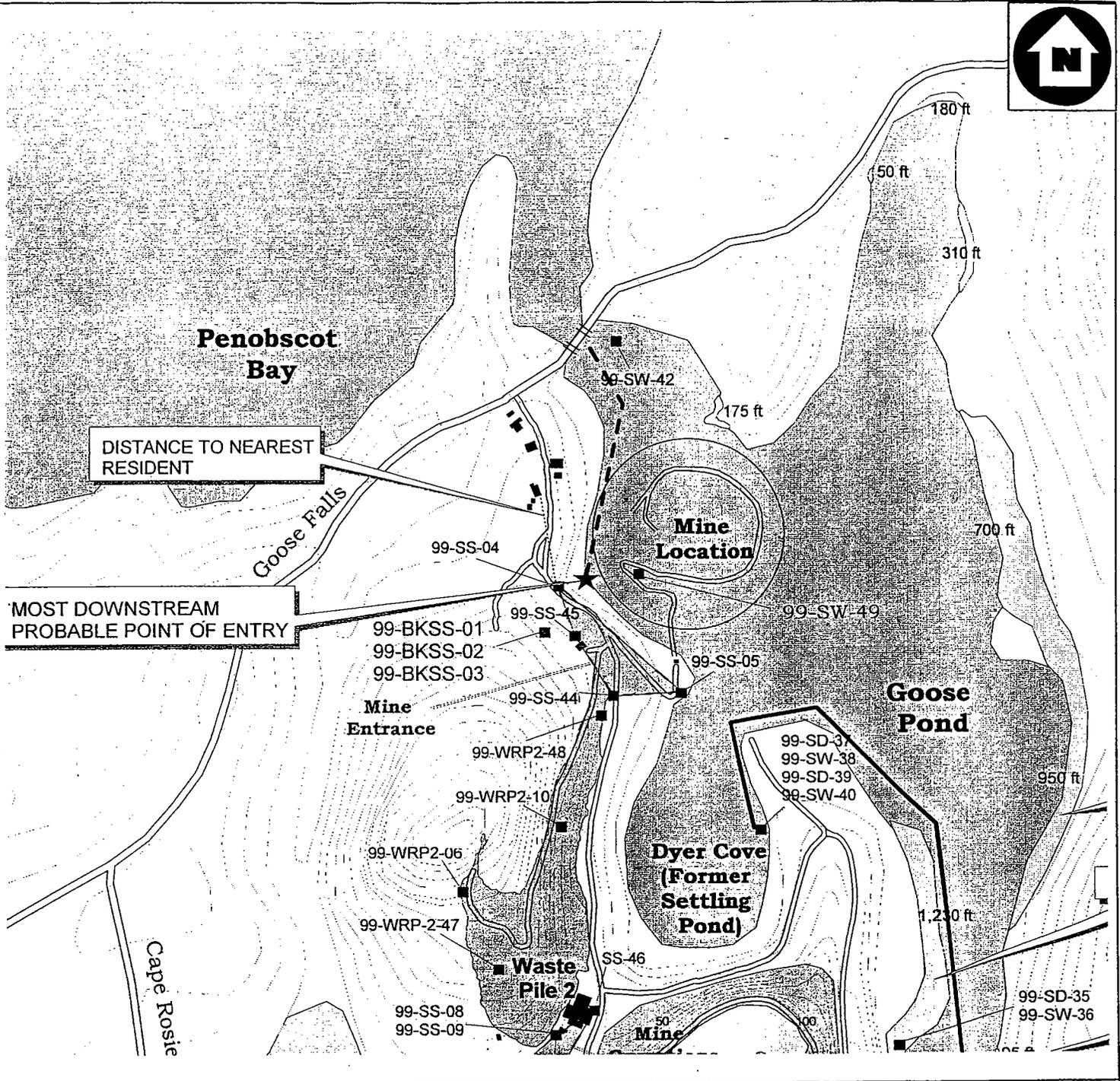


FIGURE ADAPTED FROM MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION, CALLAHAN FIGURE, JUNE 1999

..... : DISTANCE TO NEAREST RESIDENT

**PROJECT NOTE FIGURE**  
**CALLAHAN MINE**  
**HARBORVIEW**  
**BROOKSVILLE, MAINE**



REGION I SUPERFUND TECHNICAL ASSESSMENT AND RESPONSE TEAM

TDD #	DRAWN BY:	DATE:
00-06-0020	CAMPBELL	01/24/01
FILE NAME: E:\ARC_APRS\START2\CALLAHAN.APR		FIGURE 1

**FILE COPY**

**MARINE MONITORING BASELINE DATA**

**FINAL REPORT**

**JUNE 1993**

**Coastal Zone Management Act  
Award # NA17OZO312-01**

**to Maine Marine Environmental  
Monitoring Program**

## Introduction

In 1988, the Maine Marine Environmental Monitoring Program was established by the Legislature to assess the extent and effects of chemical contamination along the Maine coast. The overall goal was to provide scientifically grounded information on coastal contamination to enable resource managers and policy makers to make informed decisions.

Coastal contamination by toxic chemicals has long been a key issue of concern but one which is frequently misunderstood. Many contaminants are naturally occurring elements and compounds essential to biological processes. At sufficiently elevated levels, however, these same chemicals may have toxic effects. Between extremes of nutritional deficiency and toxicity, the issue becomes confusing. Unfortunately, this confusion can lead to public over-reaction, under-reaction, market damage, and unjustified decisions costing private and/or public money. In too many cases, these reactions are unnecessary as well as unfortunate. For example, a report of arsenic or chromium in seafood may result in and has resulted in regional market losses due to consumer ignorance founded fear. Such reaction is uncontrolled and independent of actual risk to public health. Because managers do not have access to information on coastal contamination into which chemical contamination can be placed in perspective, managers have little ability to qualify risk with confidence. A similar scenario can be painted regarding ecological risk with the difference being that environmental management priorities are inappropriately assigned at program expense. At both management and policy making levels, knowing the biological implications of the different contaminant levels is critical to efficient and effective management and public confidence.

As first step to build a base of knowledge, the Marine Environmental Monitoring Program chose to define "normal" for heavy metals along the Maine coast and simultaneously screen the coast for elevated levels in areas suspected as being contaminated. A "Musselwatch" approach similar to that of the National Status and Trends Program of NOAA was selected as both meeting our needs and affordable. A workplan was developed and presented in *Maine's Marine Environment, a Report to the 113th Legislature* in 1989 and funded for the one year. Due to statewide budget shortfalls, however the final 11 sites proposed in the workplan were not sampled. This CZMA Award "Marine Monitoring Baseline Data" enable the Marine Environmental

Monitoring Program to complete its original workplan.

## **Maine Musselwatch**

Modeled after the federal program of the same name conducted by the U.S. Environmental Protection Agency in the late 1970s and now by the National Oceanic and Atmospheric Administration, Maine's Musselwatch Project is intended to provide information on water quality conditions in Maine's near-coastal waters. Information obtained from this project will provide environmental managers with the ability to assess the natural variability of contaminants in mussel tissues and thus determine extent and degree of pollution. It also supplements NOAA's program by providing additional data points for a larger and more comprehensive data base from which a more complete national picture of coastal environmental health may emerge. More recently, Maine's Musselwatch joined with the new international Gulf of Maine Environmental Monitoring Program of the Gulf of Maine Project. Together, these three programs will provide a systems approach to water quality evaluation and a defensible basis for water quality management.

## **Methods**

The original Musselwatch goal was to sample twenty six (26) stations representative of clean reference to establish "background" levels of contamination and screen other areas of concern. After an original round of sampling, key stations would be selected and sampled on a five year rotation for trend determination. Supplementing Musselwatch would be special projects of greater intensity designed to provide more detailed assessments over smaller areas. Four areas have been studied in this manner; the Piscataqua River estuary, Casco Bay, Boothbay Harbor, and Machias Bay.

## **Station Selection Criteria**

Stations were selected based on six factors.

- 1.) **Natural variability** - Since many pollutants are naturally occurring elements and compounds, their presence does not necessarily signify pollution. An understanding of natural processes and concentrations in biota is critical to the interpretation of pollution monitoring data. Primary to the program is the inclusion of

stations along the coast which are located in areas thought to be free of "pollution." While the coast of Maine is hardly pristine, there are areas which have been identified as "background" based on a presumption that they have been spared the impacts associated with either present day or historical industrial or commercial development. These areas are in relatively undeveloped sections of the coast and are intended to provide the basis on which the other stations are compared.

- 2.) **Sources of pollution** - In areas of known discharges (point and non-point), stations have been set up to determine the degree of impact associated with the discharge. Through monitoring these stations over time, as well as comparing them to background stations, trends may be discerned which may be used to evaluate the effectiveness of environmental management practices such as advanced wastewater treatment and "Best Management Practices" for non-point source pollution control.
- 3.) **Spatial distribution** - Because Maine's coast covers a large geographic area and therefore includes many different environments, an attempt has been made to evenly distribute stations along the coastline.
- 4.) **Physiographic and hydrographic condition** - Maine's coast is highly variable ranging from rocky bold deep water to shallow closed embayment mud flats. Human activity and natural processes affect water quality in very different ways depending on flushing, sediment type, land and water use.
- 5.) **Inter-program calibration** - In order to expand the utility of Maine's database, it is necessary to know the degree to which Maine's program compares with work done by others. Included in the Maine Mussel Watch Program are four NOAA Mussel Watch sites. Inclusion of these sites will assist with quality assurance as well as enable us to compare our data with the national database.
- 6.) **Potential to assist other research** - Stations may also be located where there is a potential to compliment other work. For example, a station is being added in Penobscot Bay to supplement a marine mammal PCB biomarker project at Columbia University.

## **Stations**

Fifteen stations were funded by this grant to complete the original workplan:

Billings Cove, Sedgwick; Blue Hill Falls, Blue Hill; Cobscook State Park (Broad Cove), Edmunds; Cape Neddick Hbr., York; Dennys River, Dennysville; Friendship Hbr., Friendship; Goosefare Bk., Saco; Kennebunk R., Kennebunkport; Narraguagus R., Milbridge; Perkins Cove, Ogunquit; Round Pond, Round Pond; Saco R., Saco; Scarborough R., Scarborough; Union R., Surry/ Ellsworth; and Whiting Cove, Whiting.

### Sample Collection

Because body burdens change with the season and reproductive state of the animal, collections are made at the same time of year each year of collection. Unlike NOAA which concentrates its collection efforts in early spring just prior to spawning, Maine's collection is done during the month of August; early at the western end of Maine and later downeast.

Station collection zones range from 100 to 200 meters long and are bounded by identifiable geographic features to facilitate repeat sampling over time. Fifteen (15) blue mussels (*Mytilus edulis*) of approximately the same size (5-6 cm length) were collected from just below mean low water at evenly spaced intervals along the prescribed shoreline. Mussels were composited and placed in clean glass bottles (baked at 550°C). Mussels were depurated of sediment for twenty four hours by filling their containers with offshore sea water 4 times (ca. 6 hrs./change). Each mussel from a station composite were cleaned of algae, sediment and byssal threads. Whole drained mussels were weighed and their shells measured for length, width, and height. Soft tissues were removed, individually weighed and stored frozen as composite samples.

### Laboratory Analysis

Samples were analyzed for 8 total heavy metals; mercury (Hg), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), silver (Ag), and zinc (Zn). In addition, iron (Fe), aluminum (Al) and percent solids were analyzed for quality control purposes. Composites were thawed and blended in an acid washed glass blender equipped with stainless steel blades. A 10 gram aliquot was digested in 8N HNO<sub>3</sub>, dried and muffled at 450°C. The digestion was repeated until all white residue dissolved in 5% HNO<sub>3</sub>. Excepting mercury, furnace atomic absorption spectrophotometry was used to analyze the all mussel digestions (AOPC, 1980). Mercury analyses were according to EPA (1983) methods. U.S.E.P.A. standard trace metals in fish was used for a recovery standard in a tissue matrix.

## Results

Because this grant enabled us to complete a long term project, data from this project is presented as part of the total data set (Table 1). Locations with an \* indicate those supported by this award. A full description of all locations will be available in Sowles and Murray now in preparation.

**Table 1.**  
Summary of statewide master list of heavy metal concentrations  
in *Mytilus edulis* tissue expressed in  $\mu\text{g/g}$  (ppm) dry weight.

**Reference Locations to Define "Normal"**  
(locations and values exceeding "normal" in bold, uc = out of control)

Location	Ag	Cd	Cr	Cu	Pb	Hg	Ni	Zn
Broad Cove	-	0.8	0.8	3.9	2.4	0.14	1.7	83
Thoroughfare	-	1.6	1.4	6.9	4.3	0.18	1.7	80
Little River	-	1.3	0.9	5.6	2.8	0.06	1.3	75
Jewell Is.	-	2	1.05	6.65	0.9	0.095	1.1	86.5
Shag/Pierson	-	2.1	1	5.4	3.5	0.12	2	85
Gray's Beach	-	2.1	1	6.2	2.8	0.09	1.6	105
Collins Branch	-	2.4	2.8	6.8	4.5	0.16	2.4	81
Johnson/ Marston	-	2.2	2	6.7	4.3	0.1	1.9	84
Duck to Sewall Pt	-	2.2	1.9	7.8	3.1	0.09	1.9	89
Sewal to Cow Pt	-	1.6	1.5	7.9	2.2	0.08	1.7	81
Great Cove	-	1.5	2.4	7.1	3.2	0.08	2.3	75
Look Head/Look Pt	-	2.2	2.4	7.8	3.8	0.01	2.3	110
Dunn Island	-	1.7	2.2	9.5	2.9	0.02	2.1	97
Damariscotta	0.18	2	0.74	7.1	2.1	0.05	1.6	61
Brave Boat Harbor	0.29	1.7	1.3	6.9	2.8	0.18	1.9	90
Pickering Is.	0.084	2.5	1.1	8.1	1.8	0.06	1.3	110
Billings Cove*	0.205	1.3	uc	uc	1.05	0.1	uc	100
Cobscook Pk.*	0.05	0.87	uc	uc	1	0.2	uc	85
Cape Neddick*	0.1	1.6	uc	uc	2	0.1	uc	130
Round Pond*	0.02	1.4	uc	uc	1	0.1	uc	92
Whiting Cove*	0.065	1.6	uc	uc	1.5	0.6	uc	71
Average	0.1243	1.75	1.53	6.9	2.57	0.125	1.8	89.1
Std. Dev. (s)	0.092	0.46	0.66	1.28	1.13	0.12	0.38	15.5
N	8	21	16	16	21	21	16	21
Mean + 3s	0.4001	3.14	3.51	10.7	5.96	0.484	2.93	136

Because "normal" is a relative concept, it is somewhat artificial. Normal must be defined in relation to the experience of the observer. As we designed the Musselwatch project, we consciously defined normal as it is represented by late

summer tissue concentrations in depurated mussels from along the entire coast of Maine composed of variable geochemistry. More specific regional, seasonal, or methodological definitions may be developed later if needed. Reference stations were chosen based more on a lack of knowledge of human contamination rather than actual knowledge that contamination is not present. The assumption, then, is that these reference stations in fact represent background conditions; a possibly erroneous assumption.

Mean concentrations and standard deviations from the mean for all metal concentrations from the population of reference station mussels are presented at the bottom of Table 1. Assuming a normal distribution of concentrations for each metal, we arbitrarily defined "normal" as any concentration within three (3) standard deviations from the mean. Although it is possible to have normal values outside this range, the probability is quite rare, in fact less than 0.27%, and considered anomalous. One location, Whiting Cove in Washington County had elevated mercury levels. Since no human sources of mercury are known to exist for sources, we have chosen to retain this value in the data set as indicative of a possible wide natural variation. We intend, however, to resample this location in 1993 to confirm this higher than normal concentration as well as investigate possible human sources of contamination.

In Table 2 below, concentrations of metals in mussels from locations of concern are presented.

Table 2.  
Summary of statewide master list of heavy metal concentrations  
in *Mytilus edulis* tissue expressed in  $\mu\text{g/g}$  (ppm) dry weight.

**Locations of Concern**  
(locations and values exceeding "normal" in bold, uc = out of control)

Location	Ag	Cd	Cr	Cu	Pb	Hg	Ni	Zn
C.E. to Spring Point	-	2.2	2	7.1	6.9	0.3	1.7	120
Outer Harbor	-	0.69	1.99	10.4	<b>8.09</b>	<b>0.51</b>	0.07	78.1
Town Cove	-	0.95	1.24	10.6	<b>22.7</b>	0.29	1.5	146
Mill Cove	-	0.84	1.2	<b>14.7</b>	<b>12</b>	0.28	2.5	<b>148</b>
West Harbor	-	0.98	2.03	11.4	<b>14.7</b>	0.4	2	86.5
Outer Fore R.	-	1.6	1.8	8.6	<b>25</b>	0.3	1.5	<b>200</b>
Central Fore River	-	1.7	1.6	8.6	<b>7.6</b>	0.24	1.5	<b>140</b>
Inner Fore River	-	2.4	1.6	7.5	3.2	0.26	1.6	<b>140</b>
East End	-	1.4	1.4	6.8	<b>7.3</b>	0.25	1	<b>140</b>
Back Cove	-	1.5	2.5	6.7	<b>14</b>	0.32	1.7	110
Presumpscot	-	1.2	2.3	6.8	<b>6.7</b>	<b>0.5</b>	1.2	87
Falmouth Flats	-	0.7	0.7	5.7	3.4	0.11	1.1	75
Mill Creek	-	0.6	0.6	4.6	2.9	0.1	1.1	64
Falmouth Anchg.	-	1.4	0.9	5.5	5.4	0.15	1.7	75
Royal	-	1.3	1.4	5.5	2.1	0.11	1.1	75
Harrasekett	-	2	1.5	7.1	4.5	0.25	2.2	100
Harpswell	-	1.8	0.9	5.8	1.8	0.05	1.3	81
Long Is.	-	2.8	1.6	5.5	5.6	0.19	1.8	120
Great Diamond	-	1.3	2.1	6.4	<b>8.1</b>	0.31	1.6	100
Cocktail Cove	-	2	1.4	5.8	4.2	0.29	1.6	78
Kittery Control	-	2	1.8	8.5	2.6	0.45	2.2	100
Pepperell Cove	-	2.5	<b>3.9</b>	9.1	<b>11</b>	<b>0.57</b>	2.3	110
Spruce Creek	-	1.5	2.6	7.9	5.9	0.39	1.3	110
Back Channel	-	2.4	<b>3.8</b>	8.9	<b>12</b>	<b>0.58</b>	2.2	<b>150</b>
I-95 to Power Line	-	3	<b>4.8</b>	<b>13</b>	5.9	<b>0.74</b>	2.2	100
Thomaston	0.01	2.3	1.4	9.2	2.3	0.06	2.3	69
Waldoboro	0.068	2.9	1.2	9.9	1.7	0.07	1.7	100
Sheepscot	0.04	2.9	2.6	7.4	2.2	0.47	2.2	84
Sandy Point	0.03	<b>3.8</b>	5	8.8	3.2	<b>0.65</b>	3	84
Rockland	0.13	1.5	3.3	8.6	5.8	0.06	1.9	110
Sears Is.	1.4	<b>4.9</b>	1	8	1.4	0.13	1.1	67
Belfast	0.015	1.8	1.2	8.2	2.7	0.26	1.6	79
→ Goose Cove	0.5	<b>9.1</b>	1.3	8.9	<b>6.3</b>	0.06	0.95	<b>180</b>
→ Blue Hill Falls*	0.055	1.2	uc	uc	1	0.1	uc	140
Dennys R.*	0.045	1.7	uc	uc	1.8	0.3	uc	76
Friendship*	0.03	1.1	uc	uc	2	0.2	uc	83
Goosefare Bk.*	0.06	1.4	uc	uc	0.6	0.1	uc	72
Kennebunk R.*	0.01	1.8	uc	uc	2.7	0.4	uc	98
Narraguagus R.*	0.035	1.9	uc	uc	1	0.25	uc	56.5
Perkins Cove*	0.01	1.5	uc	uc	2.9	0.1	uc	140
Saco R.*	0.09	1.4	uc	uc	0.8	0.3	uc	66
Scarboro R.*	0.18	1.2	uc	uc	1	0.1	uc	140
Union R.*	0.085	2.3	uc	uc	1.5	0.3	uc	68

Of the 43 locations of concern tested under this protocol, 26 had at least one element which exceeded the normal range (6 locations with 1 element, 8 with 2, and 6 with 3). Lead, zinc and mercury outside normal in 13, 11, and 6 cases respectively while cadmium, chromium and copper were anomalous in 3 cases. Silver and nickel each were anomalous once.

Based on a combination of toxicity of the metal(s) and concentration(s), the 43 locations may now be reduced to 15 locations of concern. (We also consider Whiting Cove from the reference population to warrant concern.) Further investigation would be necessary before one may ascribe cause(s) of the elevated values, however, the information does provide managers with an object means of refining priorities and targeting future monitoring.

### Discussion

The results of this project are significant in that the most toxic metals, and hence those generally targeted by management (esp. Pb and Hg), are the very metals that exceed the normal range most frequently. For virtually all metals exceeding the normal range, spatial patterns suggest association with either industrial development and/or urbanization.

Of perhaps greater value is the fact that 17 locations initially chosen as suspected of contamination were entirely within the normal range. Prior to this data set, the public and special interest groups have been pressuring managers to correct "problems" which we can now say do not exist. While metal contamination is only a subset of contamination, the information gained here enables managers to better target their effort in areas where problems exist. Many of the areas of concern were chosen specifically because of a concern over metals. For those areas, concern and focus may be relaxed. For those areas with other types of concerns, an approach similar to that used here may be used to efficiently assess severity.

The other implication found here is that the metal contamination appears to be confined to localized areas of the coast and for the most part, Maine's coastal waters appear to be free of elevated levels of metals. Such knowledge may enable policy to justifiably focus on perhaps other threats to coastal water such as pesticides, petroleum, nutrient enrichment, habitat loss, over-harvest, and other issues of concern.

## **Future Monitoring Recommendations**

With a preliminary definition of "normal" metal concentrations to base comparisons and the initial coast wide screening for metals complete, we propose that the Marine Environmental Monitoring Program continue monitoring mussels over time to track trends as originally proposed in its workplan. Some modifications are suggested, however.

For the initial screen, most samples represent single composites of 15 individual mussels making it impossible to assign levels of confidence around the values. We suggest that 4 composites be collected at each location in the future so that temporal changes may be detected.

Since the original budget did not enable analyses for organic contaminants, it is recommended that future workplans provide for organic analyses to complete the coastal toxic contamination picture. This may be accomplished by either increasing the budget or targeting fewer locations. The latter is feasible given that areas of concern which are most likely to show temporal trends have now been identified.

Two ongoing programs complement Maine's Musselwatch Project. They are National Status and Trends and the Gulf of Maine Gulfwatch Projects. Effort should be made to continue co-locating stations as has been done so that there is a basis for comparison between programs. Ideally, protocols should be brought closer together where practical.

Finally, Maine Musselwatch has over the last few years amassed a large data set which deserves further analysis. Patterns appear to exist which should be explored for use as predictive tools. Such predictive tools would enable managers to avoid problems in the future rather than react to them as they develop.

## **Coastal Program Core Law Implications**

In addition to discerning "unacceptable" levels of contamination as described above, this project was also to evaluate the effectiveness of State regulations in protecting marine habitat and recommend needed changes to Coastal Program core law authorities. Through the process of data evaluation, several issues arose which may be

addressed through core laws.

- 1.) The need for documentation of ambient concentrations of contaminants in biota and sediments below likely sources was illustrated in this study. The cause of anomalous tissue concentrations of metals could not be established because most areas sampled had no documentation of contamination levels prior to discharge or development.

Changes should be made in both *Protection and Improvement of Waters*, the *Site Location of Development* and *Hazardous Materials Storage Facility Licensing*. Criteria need to be developed that fairly discriminate between those sources such as coastal discharges and land development which are indeed likely sources. As part of this change, standard procedures of collection, analysis, and reporting need to be established. For activities already permitted, where renewals and/or permit changes are issued, monitoring should be considered.

- 2.) One of the findings of the Marine Policy Committee of the Land and Water Resources Council was that there is room for improved coordination and cooperation between agencies operating in Maine coastal waters. As related to this project, this too has made it difficult to interpret the data due to the multiple protocols in use. While work done here conformed largely to that of NOAA's Status and Trends Program and is comparable, other work done by the DEP and DMR is not.

Institutional arrangements should be made to foster scientific coordination in a more complimentary way.

- 3.) As sites for this project were chosen, it became evident that two conflicting standards of classifying coastal waters exist. The Water Classification Program of the Department of Environmental Protection and the Shellfish Sanitation Program of Department of Marine Resources. In some instances, waters classified as SB are also classified as non-redeemable. As such, it would be legal to introduce a new licensed discharge to a shellfish area not yet having a discharge. This would *de facto* permanently establish this area as non-redeemable thus fulfilling its prophesy. While this study did not address pathogen contamination, toxic contamination of shellfish areas now closed due to pathogens would become a

factor if the new permitted discharge contributed a toxic component.

Classifications of both systems should be compared and revised to reflect proactive management goals rather than defaulting to first use.

- 4.) Finally, the Water Classification Program classifies coastal waters according to biological criteria and habitat. This project has contributed to this aspect of classification by defining "abnormal" level of contamination in biological tissues. Presence of contamination, however, does not necessarily translate into a biological effect. To date, virtually no effort has been invested in fulfilling the mandates of biological classification in marine waters. Without such an investment to develop a biological measurement tool, successful protection of coastal waters can not be known.

It is recommended that rules or a statute be passed that dedicates an annual base funding level of \$95,000 per year to support development of marine biological criteria. Funding sources should be targeted to those activities and programs affecting coastal water quality. Included on this list would be Maine Environmental Protection Fund, Surface Oil Cleanup Fund, Hazardous Waste Fund, and federal Section 106 General Operating Fund, and Construction Grant Program.

#### Budget

	State	309 Funds
Personnel	\$13,185	\$0
Supplies	\$360	\$0
Travel	\$629	\$0
Laboratory	\$0	\$12,600
<b>Project Total</b>	<b>\$14,174</b>	<b>\$12,600</b>

#### Acknowledgments

We are very grateful for the support of the Maine State Planning Office and its Coastal Program for financial support of this project. We would especially like to

thank the Maine Department of Human Services Health and Environmental Testing Laboratory staff who provided responsive service and quality analyses. Susan Murray and Lawrence L'Italien also deserve special acknowledgment for field and laboratory assistance.



## PROJECT NOTE

To: Callahan Mine Hazard Ranking System Project File

From: Thomas A. Campbell, Roy F. Weston, Inc., Region I START 2000

Date: June 19, 2001

RE: GIS Distance Measurements for the Surface Water Pathway section, Callahan Mine,  
Brooksville, Maine  
TDD No. 00-06-0020, PCS No. 1150-30

### Method

Distances used in the surface water pathway section of the Callahan Mine HRS package were calculated using ArcView 3.1 Global Information System (GIS) software and Callahan Mine coverages provided to START by the Maine Department of Environmental Protection. The measurement tool in the GIS software was used to determine the following:

Distance from most upstream PPE to sediment sample 99-SD-39/37:  
3,960 feet (solid line)

Distance from most upstream PPE to sediment sample 99-SD-35:  
2,208 feet (solid line)

Distance from most upstream PPE to sediment sample 99-SD-33:  
1,475 feet (solid line)

Distance from most upstream PPE to sediment sample 99-SD-31:  
700 feet (solid line)

Distance from most upstream PPE to sediment sample 99-SD-29:  
0 feet (solid line)

A figure of the Callahan Mine site is included as Attachment A of this Project Note.

**Attachment A**

Callahan Mine site figure

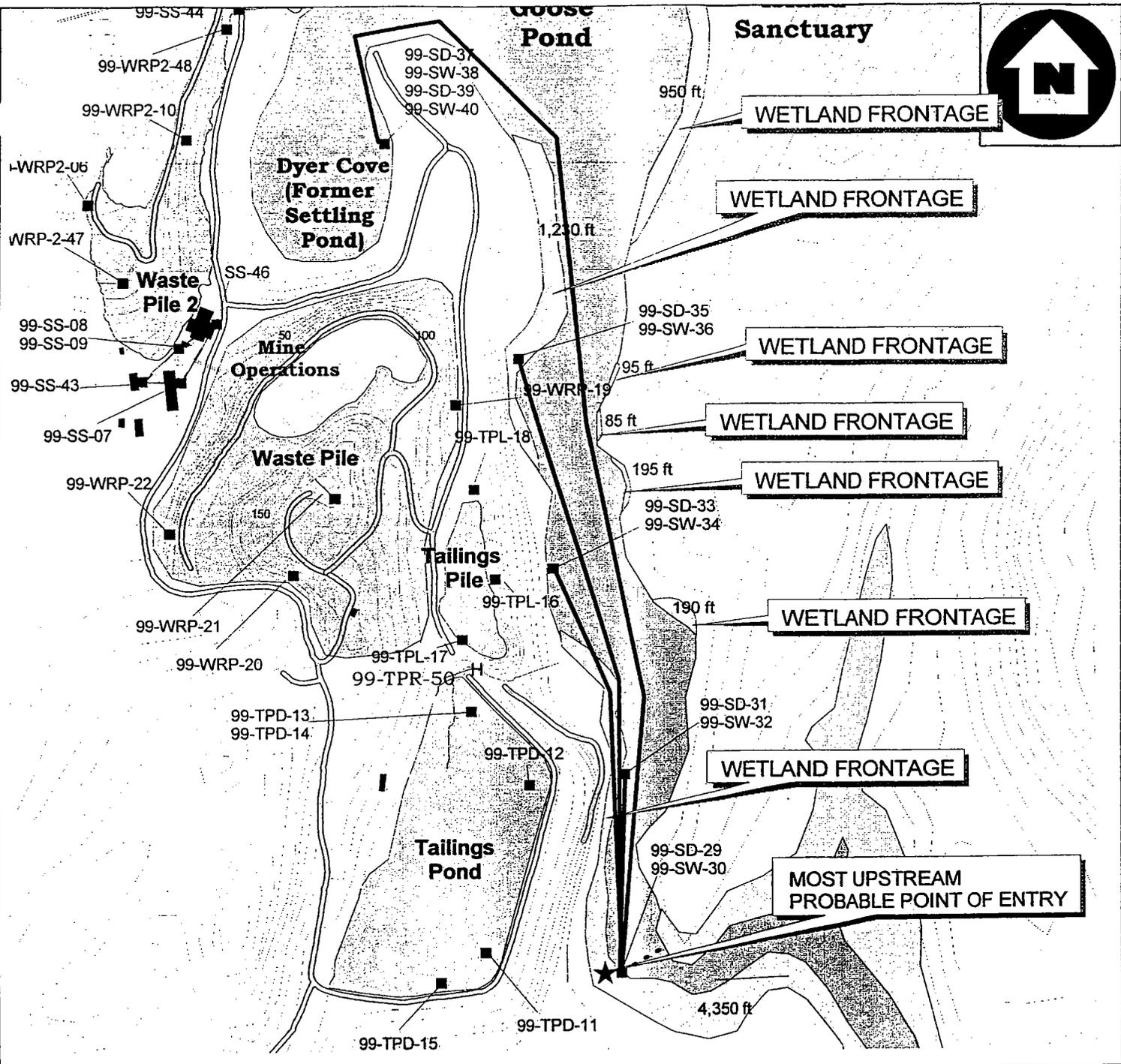


FIGURE ADAPTED FROM MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION, CALLAHAN FIGURE, JUNE 1999

★ : PROBABLE POINT OF ENTRY (PPE)

WETLAND FRONTAGE

: WETLAND FRONTAGE BETWEEN THE MOST UPSTREAM PPE TO SEDIMENT SAMPLE 99-SD-39

: DISTANCE FROM MOST UPSTREAM PPE TO SEDIMENT SAMPLES 99-SD-39/37, 99-SD-35, 99-SD-33, 99-SD-31, and 99-SD-29

..... : DISTANCE FROM MOST UPSTREAM PPE TO HOLBROOK ISLAND SANCTUARY

**PROJECT NOTE FIGURE**

**CALLAHAN MINE  
HARBORVIEW  
BROOKSVILLE, MAINE**



REGION I SUPERFUND TECHNICAL ASSESSMENT AND RESPONSE TEAM

TOD #	DRAWN BY:	DATE
00-06-0020	CAMPBELL	09/28/00
FILE NAME:		FIGURE 1
E:\ARC_APRS\START2\CALLAHAN.APR		

## THE MINERAL CLAUSTHALITE

- **Chemistry:** PbSe, Lead Selenide
- **Class:** Sulfides
- **Subclass:** Selenides
- **Group:** Galena
- **Uses:** As a very minor ore of lead and selenium and as mineral specimens.
- **Specimens**

Clausthalite is a member of the **Galena Group** of minerals. Its properties are very similar to galena as it shares basically the same structure. However it can be distinguished from the far more common galena by its greater density and lack of good crystals. The two minerals are in a series in which the sulfur and selenium ions substitute for each other.

Clausthalite and the mineral **crookesite**, a copper thallium selenide are the two most common selenium minerals. However they are not ores of selenium due to their rarity and the fact that selenium is mostly acquired through the processing of copper sulfide ores. The selenium is found as a trace in many copper sulfide minerals especially **pyrite** and in coal. Some other **selenide** minerals that contain a significant amount of selenium include:

- **Berzelianite** (*Copper Selenide*)
- **Eucairite** (*Silver Copper Selenide*)
- **Hakite** (*Copper Mercury Silver Antimony Selenium Sulfide*)
- **Klockmannite** (*Copper Selenide*)
- **Naumannite** (*Silver Selenide*)
- **Penroseite** (*Nickel Selenide*)
- **Palladseite** (*Palladium Selenide*)
- **Tiemannite** (*Mercury Selenide*)
- **Umangite** (*Copper Selenide*)

The element **selenium** is used in the production of photoelectric cells, resistors, photographic chemicals, pigments and many other industrial uses.

### PHYSICAL CHARACTERISTICS:

- **Color** is a bright lead gray, blue gray to gray black.
- **Luster** is metallic.
- **Transparency:** Crystals are opaque.
- **Crystal System:** Isometric;  $4/m\bar{3}2/m$ .
- **Crystal Habits** include rare cubic and octahedral crystals; much more commonly found in massive and granular forms.
- **Cleavage:** perfect in three directions forming cubes.
- **Fracture:** Uneven.
- **Hardness** is 2.5.
- **Specific Gravity** is 8.1 - 8.3 (much heavier than average for metallic minerals)
- **Streak** is black.
- **Associated Minerals** include **gold, pyrite, calcite, epidote, selenium, sphalerite, tiemannite, naumannite, penroseite, galena** and other sulfides.
- **Notable Occurrences** include the type locality of the Lorenz Mine, Clausthal, **Harz**, Germany as well as Corvusite Mine, Montrose County, Colorado and San Miguel County, New Mexico, USA; Slavkovice, Central Moravia, Czech Republic; Falun, Sweden and Lake Athabasca, Saskatchewan, Canada.
- **Best Field Indicators** are crystal habit, perfect cubic cleavage, associations and density.



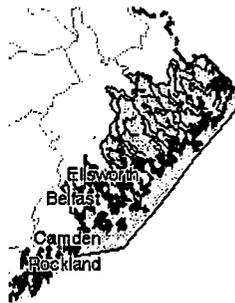
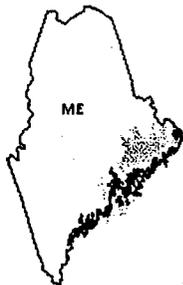
Locate Your Watershed  
JOIN DISCUSSIONS  
ADD INFORMATION  
SEARCH INFORMATION

Atlas

News Flashes:

## Maine Coastal

USGS Cataloging Unit: 01050002



Places Involving this Watershed

States:

- [Maine](#)

Counties:

• [Belknap](#)

## Environmental Profile

*Find general information integrated for this specific watershed*

### Assessments of Watershed Health

[Index of Watershed Indicators](#) (provided by EPA)

[Unified Watershed Assessments \(UWA\)](#) (provided by States and Tribes)

- Penobscot
- Knox
- Penobscot
- Waldo
- Washington

**Metropolitan Areas:**

- Bangor
- None

**Other Watersheds:**

upstream

- Lower Penobscot
- St. George-Sheepscoot

downstream

- St. Croix

**Tribes**

- None Known

**Large Ecosystems:**

- Gulf of

1998 Impaired Water (provided by EPA / State partnership)

**Environmental Information**

River Corridors and Wetlands Restoration Efforts

Environmental Web Sites:

- Real Time

Facilities regulated by EPA (provided by Envirofacts)

- Toxic releases (Source: TRI - Toxic Release Inventory)
- Hazardous Wastes (Source: RCRA - Resource Conservation Recovery Act)
- Superfund Sites (Source: CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act)

EnviroMapper for Watersheds- (interactive mapping tool)

## Water

*Find information focused on water for this specific watershed*

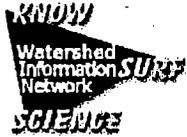
Rivers and Streams in this Watershed: 72 (provided by EPA's first River Reach File)

Lakes in the watershed: 599 Total number of watershed acres: 105693.5

River and stream miles:

- o 3015.5 total river miles
- o 2652.5 perennial river miles

Maine  
Program  
• EMAP  
Northeastern  
Lake  
Assessment



- o No data available :% of total rivers and streams have been surveyed
- o No data available :miles meet all designated uses

The following aquifer's are in this huc:  
(Source: USGS Principal Aquifers of the 48 Contiguous United States 1998)

Aquifer	Square Miles	Rock Type
No Principal Aquifer	3519	N/A

Facilities regulated by EPA (provided by Envirofacts)

- o Community Water Sources (Source: SDWIS Safe Drinking Water Information System)
- o Water Dischargers (Source: PCS - Permit Compliance System)

Information provided by the United States Geological Survey (USGS): ~~EMAP~~

- o Stream Flow (Source: USGS)
- o Science in Your Watershed
- o Historical Water Data
- o Water use (1990): Information about the amount of water used and how it is used
- o Selected USGS Abstracts

## Land

*Find watershed information focused on land characteristics*

Area: 5402.49 sq mi; perimeter: 434.39 mi  
Habitat:

- Forest Riparian Habitat
- Agricultural/Urban Riparian Habitat

## People

*Find out about local actions in this watershed:*

Citizen-based Groups at work in this Watershed

(Provided by Adopt Your Watershed)

Join now (Adopt Your Watershed)

National Watershed Network (provided by

Conservation Technology Information Center)



## Air

*Find information focused on air for this watershed:*

Facilities regulated by EPA (provided by

Envirofacts)

- o Air (Source: AIRS)