



**PEBBLE PROJECT
ENVIRONMENTAL BASELINE DOCUMENT
2004 through 2008**

**CHAPTER 34.
OCEANOGRAPHY AND
MARINE WATER QUALITY
Cook Inlet Drainages**

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ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
EPA	United States Environmental Protection Agency
IIE	Iniskin/Iliamna Estuary
µg/L	micrograms per liter
mph	miles per hour
ng/L	nanograms per liter
NIC	National Ice Center
NTU	nephelometric turbidity unit(s)
OCSEAP	Outer Continental Shelf Environmental Assessment Program
ppt	parts per thousand
PVC	polyvinyl chloride
RRO	residual range organics
SQuiRT	Screening Quick Reference Tables
TSS	total suspended solids
UAF	University of Alaska, Fairbanks

34. OCEANOGRAPHY AND MARINE WATER QUALITY

34.1 Physical Oceanography

34.1.1 Introduction

Iniskin Bay and Iliamna Bay are shallow estuaries on the west side of lower Cook Inlet, north of Kamishak Bay (Figure 34-1). Collectively, the area of these two bays is termed the Iniskin/Iliamna Estuary (IIE; Figure 34-2).

This section presents general findings from both a literature search and observations from the 2004 through 2008 field studies of the physical oceanography in the marine study area for the Pebble Project. The literature search and field studies consisted of investigations and observations of the shape and depth of the IIE, the tidal range and currents, the wave and ice-scour action in the vicinity, and a brief analysis of some of the inputs to, and outputs from the bays. Additional information regarding Cook Inlet is included to provide a regional context and a setting for local observations.

34.1.1 Study Objective

The study objective was to document, based on available information and on-site observations, the physical oceanography of the IIE study area. This information provides a physical context for observed biological conditions (as described in Chapters 42 through 44) in the marine study area.

34.1.2 Study Area

The study area included all marine waters and shorelines of Iniskin and Iliamna bays (Figure 34-2), except for the inner portions of Iniskin Bay and Cottonwood Bay. These portions were not included because they are outside of the project area. A general description of Cook Inlet, focusing primarily on the lower west side, is included to provide a regional context.

34.1.3 Previous Studies

Little scientific investigation of the west side of lower Cook Inlet or the IIE area had occurred prior to the the National Oceanic and Atmospheric Administration's Outer Continental Shelf Environmental Assessment Program (OCSEAP) in the mid-1970s. Under OCSEAP, a substantial body of data was collected during the 1970s and early 1980s. Additional primary information on the inlet's physical and biological conditions has been gathered by the Cook Inlet Regional Citizens Advisory Council and the National Park Service. Oil company-funded studies on the deeper portions of the lower inlet (e.g., Lees, 1976; Houghton et al., 1980) were also reviewed.

34.1.4 Scope of Work

Characterization of physical oceanography in the study area drew primarily on existing information about IIE and western Cook Inlet. That information was supplemented by the personal experience of the investigators and observations made during marine biological field work conducted from 2004 through 2008.

34.1.5 Methods

A thorough literature search related to the natural environment of Cook Inlet was performed. The search emphasized the lower and the west side of the Inlet because they would be indicative of the proposed project area. Additional telephone interviews were conducted with experts in regional physical oceanography. Observations of oceanographic features and events were recorded in field notebooks and documented with photographs. In August 2004, Dr. Jon Houghton of Pentec Environmental and Dr. Stephen Jewett of University of Alaska, Fairbanks (UAF) performed a reconnaissance flight up Iniskin Bay and down Iliamna Bay. From August 2004 through November 2008, a field crew led by Dr. Houghton and/or Mr. Jim Starkes sampled nearshore fish and invertebrates at irregular monthly intervals during the ice-free months. In 2004, 2005, and 2008, the crew also characterized benthic assemblages in the intertidal and subtidal zones. They observed local physical conditions with a particular emphasis on the interactions of the physical environment with observed marine species distributions.

34.1.6 Results and Discussion

34.1.6.1 Physical Description

Cook Inlet

Cook Inlet is a long (370 kilometers), broad (70 to 90 kilometers), and shallow (mean depth approximately 60 meters) embayment extending north-northeast from the Gulf of Alaska (Muench et al., 1978). It has a maximum depth of 200 meters, and it is 139 kilometers wide at its mouth. Lower Cook Inlet is defined as the area north of Kennedy and Stevenson entrances and Shelikof Strait and south of the "Forelands," a constriction north of Kalgin Island (Figure 34-1). For purposes of this report, Kamishak Bay is defined as the portion of southwest Cook Inlet south and west of a line from Cape Douglas, around Augustine Island to Ursus Cove (Figure 34-1).

Britch (pers. comm., 2004 through 2006) classified Cook Inlet as a tide-dominated estuary that has high tidal ranges, low to moderate wave action, and moderate to high fresh water input from multiple rivers. Muench et al. (1978) described the physical behavior of Cook Inlet, especially the lower inlet, as similar to that of a large bay because of vigorous non-estuarine flow across its mouth and limited fresh water input in winter.

IIE

Iliamna and Iniskin bays are shallow inlets on the west side of lower Cook Inlet (Figures 34-1 and 34-2). Both bays were likely formed as glacial troughs that have become filled with sediment over recent geologic time (Detterman and Harstock, 1966). The outer portion of Iniskin Bay from the deepest part of the bay near the head through the Right Arm (a small arm of the bay along the east side) are part of the

Bruin Bay fault system. The current landforms are influenced by this regional-scale complex (Wilson et al., 2009). Both bays generally average less than 5 meters in depth, with deeper troughs leading into the bays and extensive mudflats in the upper bays. Detailed descriptions of intertidal and subtidal habitats in the IIE are provided in Chapter 36.

Iniskin Bay. Iniskin Bay has a relatively deep trough along its western shoreline (maximum depth 24 meters). This trough quickly rises up to mudflats on its western and northern perimeters (Figure 34-2). The eastern side of the trough steps up to a broad shelf that extends to the eastern shore of the bay.

A number of small islands and reefs guard the eastern portion of the entrance to Iniskin Bay. This group includes Scott Island—the largest of the group—Vert Island, Iniskin Island, the Mushroom Islets, and Iniskin Shoal (Figure 34-2). This pattern of islands and reefs extends up the eastern shore of the bay to include the Toadstools and Fossil Reef, which rise out of the eastern shelf. The inner portion of Iniskin Bay is dominated by extensive mudflats. The Iniskin River enters the northernmost point of the bay. The river creates a small shallow channel that extends from the mouth of the river to the deeper trough along the western shore. Approximately one-third of the way up the eastern shore of Iniskin Bay from the mouth of the river, a small bay called Right Arm extends to the east. Several small creeks, including Portage Creek, flow into the Right Arm.

Iliamna Bay. Iliamna Bay is smaller and generally shallower than Iniskin Bay (Figure 34-2). The uppermost portion of Iliamna Bay splits into two smaller arms. Williamsport is at the head of the smaller, western arm. Williams Creek enters Iliamna Bay at Williamsport. Approximately half way down the western shore of Iliamna Bay from Williams Creek, another bay called Cottonwood Bay extends to the west. Diamond Point is the central point of land that separates the upper portions of Iliamna Bay from Cottonwood Bay (Figure 34-2).

The upper portions of Iliamna and Cottonwood bays are occupied by extensive mudflats. The mudflats in both bays are exposed at lower tides with the exception that a marked, dredged channel leads up Iliamna Bay into Williamsport. Cottonwood Bay has a large number of boulders scattered across its mudflats, while central Iliamna Bay is generally a mud bottom with a limited number of intertidal reefs and subtidal hard bottom areas.

Turtle Reef partially blocks the entrance to Iliamna Bay off South Head, and White Gull Island is located just south of the center of the entrance to the bay. The only deeper water in Iliamna Bay is on either side of White Gull Island, with average depths of approximately 10 meters and a maximum depth of 12 meters.

Knoll Head to North Head. Relatively deeper water (approximately twice as deep) and extensive rocky reefs characterize the body of water that separates Iniskin and Iliamna bays. The two portions of Black Reef partially shelter the entrance to the Y Valley. Much of the adjacent waters contain additional offshore rocks and shoals. A small lagoon occurs at the mouth of the Y Valley where a stream comes down from the Back Range (Figure 34-2).

34.1.6.2 Tidal Range, Currents, and Mixing

Cook Inlet

The tidal range is 3.6 meters near the entrance to Cook Inlet at Port Chatham and increases northward. It reaches approximately 4.6 meters in the IIE area, and exceeds 12.2 meters near Anchorage (Brower et al., 1988). On a lateral transect of Cook Inlet, the tidal range on the eastern side of the inlet is 0.6 to 1.2 meters greater than on the western side of the inlet (Sobey, 1979).

The Alaska Coastal Current is deflected westward after passing through the Kennedy Entrance, which causes localized upwelling. A small amount of the Alaska Coastal Current water is enriched by the upwelling. It moves up the east side of the inlet and eventually crosses west near Kalgin Island and replaces water entrained in the southward outflow along the west side of the inlet (Poole and Hufford, 1982). Currents along the west side of lower Cook Inlet are mostly of moderate velocity (100 to 150 centimeters per second) although velocities can exceed this, especially in mid-inlet, in deeper channels, and during extreme tides (Brower et al., 1988).

Tidal rips are present across the lower inlet with differing oceanographic conditions apparent on opposite sides of the rips. Typically, these rips result from shear between water flows in deeper channels and adjacent shallow areas. Oceanic waters are typically found in the deep channels whereas the water in shallower areas tends to be more estuarine (less saline and more turbid). Three defined rip zones exist in the lower inlet below the Forelands. Debris accumulates in the mid-channel and western rips (Burbank, 1977).

Tidal currents within lower Cook Inlet are classically estuarine. The currents flow counterclockwise; that is, north along the eastern shore and south along the western shore. Currents in northern Kamishak Bay near the entrance to the IIE are southeasterly with the ebb tide and northwesterly to westerly with flood tides at speeds of 50 centimeters per second or less. A drogoue track produced by a satellite-tracked drifting buoy in the western portion of lower Cook Inlet shows that the general flow off the mouth of the IIE is southwesterly; small tidal loops result from daily ebb and flood flows (Figure 34-3a; Johnson, pers. comm., 2006). The current intensifies off Cape Douglas, where Muench et al. (1978) reported a strong (approximately 50 centimeters per second) southerly flow at 7 meters depth over a 10-day period. Muench et al. (1978) previously noted a northerly flow at this position. Near-surface velocities of 250 centimeters per second were noted in the general Cape Douglas area during one unusual and extreme winter event (Britch, pers. comm., 2004). Currents are sufficiently strong to thoroughly mix the water column and move coarse sediment along the bottom in some areas (Hampton, 1980). Burbank (1977) described the surface circulation in the area, including a small anticyclonic eddy off the mouths of Iniskin and Iliamna bays (Figure 34-3b). Because of technical challenges with much of the early work in this area, including problems with local magnetic anomalies, generalizations regarding currents in lower Cook Inlet must be interpreted cautiously (Britch, pers. comm., 2004 through 2006).

IIE

Tides and Currents. The IIE has an extreme tidal range of approximately 7.6 meters, with a mean tide range of about 3.75 meters (Brower et al., 1988). Basic tidal data for Iniskin Bay are presented in Table 34-1. No tidal data were available for Iliamna Bay. Researchers have not observed any indications that tidal ranges within Iliamna Bay and along the shoreline adjacent to the Y Valley are different in

magnitude or timing. The magnitude and timing of the tides throughout the study area tend toward similarity, which would be expected given their proximity and somewhat similar configuration of the mouths and shapes (but not the sizes) of the bays.

No direct current measurements were taken during the marine field work. Maximum surface currents are estimated at approximately 300 centimeters per second (5.8 knots) based on observed wind-driven ice movement during the previously described April 2006 marine sampling event and data from Kamishak Bay. Average maximum ebb current in Iniskin Bay is approximately 62 centimeters per second (1.2 knots), and average maximum flood current is 46 centimeters per second (0.9 knots; Nobeltec, 2004).

Small eddies have been observed in the lee of several points of land and behind islands, shoals, and other obstructions. These eddies provide refuge for smaller fish and areas of calmer water during the height of the tidal currents. A few tidal rips have been observed within the bays during marine field sampling events that result from strong wave and tidal action. The largest tidal rip in the bays observed in these studies was located off stations MPS1 and MPS2 (Figure 34-4) during the ebb of one of the larger tidal cycles in April 2008.

Inputs, Mixing, and Waves. The small watersheds that drain into the IIE deliver a relatively minor amount of fresh water into the bays on an annual basis; therefore, nutrient inputs directly from adjacent terrestrial sources are relatively minimal. Seasonal snowmelt or heavy rainfall increase local freshwater runoff. When this runoff is at a maximum, a fresh surface layer of water develops. Even then, nutrient inputs from these events still may not be substantial in relation to other areas of Cook Inlet that are dominated by large river or glacial inputs, such as Knik River and Susitna River.

Tidal fluctuations and wind forcing are the primary drivers of mixing in both bays of the IIE. Minimal lateral mixing in the estuaries has been observed, particularly in Iniskin Bay. The majority of the flow patterns follow tidal currents up and down the length of the bays. Salinity was measured in the water column at a few widely dispersed sites in the IIE (Tables 34-4 and 34-5). These results indicate that the water in the bays is relatively well-mixed with minimal stratification. Occasional temporal and local stratification does occur, for example, during high runoff events.

Sea swell, wind waves, and tidally-generated waves affect exposed shorelines from Knoll Head to North Head and beaches within the bays that face the bay entrances. Wind data for the IIE are reported in EBD Chapter 26. Swell has been observed in both bays, depending on the regional weather patterns and wind direction. Pentec staff biologists observed that strong local wind patterns create waves that either complement or counteract the swells.

Because the orientations of the entrances to Iniskin and Iliamna bays are roughly perpendicular to one another, swell does not generally affect the interior of both bays at the same time. Depending on prevailing weather patterns, larger swells affecting the bays may originate in the Gulf of Alaska, enter Cook Inlet through the Kennedy Entrance, and travel northwest past Augustine Island. The interior of the bays also have some protection from swell for two reasons: the characteristic shallow nature of the bays and because of the extensive reefs and islands that partially block portions of the entrances.

34.1.6.3 Ice Conditions

Cook Inlet

In a typical year, Cook Inlet has varying quantities of ice cover from early November through early April. The extent of ice cover depends on many factors such as earliest inception of sub-freezing temperatures, cloud cover, wind forcing, and freezing precipitation (LaBelle et al., 1983). The maximum extent of ice cover typically occurs between late January and late February (National Ice Center [NIC], 2009). Figure 34-5a displays the maximum extent of the ice pack in Cook Inlet observed by the NIC for 2001 through 2008. Dates for the maximum ice extent ranged from January 19 through February 22. In years with minimal ice, the ice may not extend south of the Forelands (e.g., 2001; Figure 34-5a), but in years with a substantial ice pack, it can extend north from Ninilchik on the east side and cover the entire west side of the inlet, including all of Kamishak Bay (e.g. 2007 and 2008, Figure 34-5a). The overall percentage of ice cover varies considerably. Only portions of Knik Arm, Turnagain Arm, and several side bays regularly (annually) have shore-fast ice, i.e., stationary ice that does not move with currents and wind. Maximum ice extent in 2001 through 2003 was noticeably less than that in 2004 through 2008 (NIC, 2009).

Figures 34-5b through 34-5e show the extent of ice in Cook Inlet for the first week of each month from January through April, respectively, for 2001 through 2008. In each of these years, ice was established in Cook Inlet by January and, in all but 2005, remained into April. The ice edge remained roughly constant for long periods starting as early as January, with only varying percentages of ice cover after that point, until the final spring breakup. This approximately similar ice edge extends south of the Forelands and is presented on Figures 34-5b, 34-5c, and 34-5d for January, February, and March, respectively.

Ice often accumulates in Kamishak Bay during spring breakup. Ice floes have been observed at up to 320 meters across. Thicker floes that form in the intertidal areas of upper Cook Inlet are traps for suspended sediment and display dark horizontal banding (Britch, pers. comm., 2004 through 2006).

IIE

Within the confines of the bays of the IIE, and with a few exceptions, ice was typically present from January through March (Figures 34-5b through 34-5d), often lingering into April (Figure 34-5e). At the time of maximum ice extent (Figure 34-5a), the inner bay ice coverage ranged from 40 to 100 percent (NIC, 2009). Often, the local ice pack extends around North Head, becomes continuous between the two bays, occasionally connects with the larger ice pack in southwestern Cook Inlet, and becomes even with the continuous ice pack in upper Cook Inlet during more severe ice years.

First-hand accounts of mid-winter conditions from the survivors of the *Farallon* wreck in 1910 indicate a relatively rapid and regular freezing and melting of the bays, with slush-ice quickly forming and disappearing. True ice in 1910 appeared to be limited mostly to the upper and side bays or had a limited lifespan, with icebergs drifting through the outer bays and adjoining water adjacent to the Y Valley (Lloyd, 2000). These observations are partially supported by recent data from the NIC (2009), which show ice present and absent in the bays during successive weeks.

During the marine sampling events in mid-March 2008, Pentec staff biologists observed relatively continuous floating masses of ice in the outer portions of the bay. At times, these masses cut off access to certain portions of the bays, but they were constantly moving with tidal and wind fluctuations. During

subsequent field visits in April 2009 and April 2010, biologists observed small amounts of the remaining ice passing back and forth through the bays with the tide cycle. More extensive amounts of ice were present, but not continuous, in the inner portions of both bays. Biologists believe that the local ice pack is routinely extensive enough to provide annual scouring of the intertidal zone (Chapters 36 and 42).

34.1.6.4 Physical Oceanography Summary

Iliamna and Iniskin bays are shallow embayments that are generally well mixed by tidal currents as a result of their shallow nature and the minimal fresh water input during most of the year. An exception may occur during periods of high seasonal snowmelt runoff when a fresh water surface layer temporarily develops. The bays are characterized by extensive mudflats in their upper reaches with deeper channels extending out into the outer bay entrances, adjacent to Black Reef, and into Cook Inlet. Extensive reefs, shoals, offshore rocks, and islands dot the entrances to both bays and the waters in between. The bays have an observed mean tidal range of approximately 3.75 meters with moderate currents. Seasonal ice is present from January through March in most years and tends to scour the intertidal zone (Chapter 42).

34.2 Marine Water Quality

34.2.1 Introduction

This section presents data on ambient marine water quality, including both field-measured parameters (salinity, temperature, and turbidity) and laboratory analyses of sampled marine water. These data provide a representative overview of the ambient water-quality characteristics and the levels of trace metals and organic compounds in waters of the IIE. These data were intended to provide a baseline documentation of general water quality. Data on levels of trace metals and organic compounds in sediment and tissues are provided in Section 35.4.

34.2.2 Study Objectives

The objectives of this study were to gather, analyze, and present marine water quality data and to discuss trends in those data. This analysis was done to characterize the existing baseline water quality of the IIE marine environment.

34.2.3 Study Area

The IIE study area includes all marine waters and shorelines of Iniskin and Iliamna bays, except for the inner portions of Iniskin Bay and Cottonwood Bay. These areas were not included because they are outside of the project area (Figure 34-2). An analysis of available water quality data in Cook Inlet, focusing primarily on the west side, is presented in this report to provide a regional context.

34.2.4 Previous Studies

Despite an extensive literature search, Pentec biologists were not able to locate any previous studies reporting either physical or chemical marine water quality data specifically in the IIE. However, some data exist from greater Kamishak Bay and Cook Inlet in general. Muench et al. (1978) measured oceanographic conditions in lower Cook Inlet in the spring and summer of 1973. Surface salinity was

lowest on the west side of Cook Inlet, and isohalines generally paralleled the coastline there. Salinities in lower Cook Inlet decreased from a range of 30.4 to 31.4 parts per thousand (ppt) in late May 1973 to a range of 26.0 to 30.5 ppt by early September 1973. The highest salinity on the west side of the inlet (greater than 30.2 ppt) was measured in September 1973 in southwestern Kamishak Bay. Decreasing salinity through the summer is attributed to river runoff. Between 70 to 80 percent of runoff came from the Susitna, Knik, and Matanuska rivers into the upper inlet (Hein et al., 1979).

Water temperatures tended to be highest in southwestern Kamishak Bay from spring through summer, relative to other lower inlet sites, reaching greater than 11°C in late summer (Muench et al., 1978). Seawater temperature, salinity, and density distributions varied seasonally and were strongly influenced by variations in fresh water inflow to the inlet and by wind direction and intensity (Sobey, 1979).

Earlier work on trace metals and hydrocarbons in media other than marine waters in lower Cook Inlet and in Kamishak Bay is described in Chapter 35. Saupe et al. (2005) reported mean total ammonia concentrations of 12 µg-N/liter in surface water and 24 µg-N/liter in bottom water. These values were derived from more than 50 observations in each stratum collected throughout coastal waters of southcentral Alaska in 2002.

34.2.5 Scope of Work

Marine water quality parameters included in this study are various chemical constituents and field parameters (salinity, temperature, and turbidity). Field parameters were measured in conjunction with the marine habitat assessments of the IIE from August 2004 through November 2008. Water samples were collected in August and September 2004 and May, July, and September 2008. The samples were analyzed for trace metals, inorganic, and organic constituents.

34.2.6 Methods

34.2.6.1 Field Parameters

Water temperature and salinity were measured to define field water conditions at the time of most beach seine sets and at approximately half of the trawl sampling events from August 2004 through November 2008 as well as during the majority of the gill/trammel sampling events in 2008. Analysis for turbidity was added to the sampling program in 2005 and was typically measured during the sampling events from then through 2008. These field measurements were also recorded during the three water chemistry sampling events in 2008. Water quality sampling locations are shown on Figure 34-4.

A YSI Model 85 multiparameter probe was used to measure temperature and salinity. A LaMotte portable Model 2020 turbidity meter was used to measure turbidity. Parameters were measured at approximately 0.3 meters below the surface of the water and recorded on field data sheets associated with the specific sampling event.

34.2.6.2 Chemical Parameters

Data were collected in accordance with the consolidated study program for Pebble Project (Appendix E of the EBD), the Field Sampling Plan (FSP; Appendix F of the EBD), and the Quality Assurance Project

Plan (QAPP; Appendix G of the EBD). Analytes measured in the 2004 and 2008 marine water quality sampling events are presented in Table 34-2.

In 2004, samples were collected to analyze for both organic compounds and inorganic constituents. The organic compounds were successfully measured. However, analytical data for the inorganic constituents were unavailable because of laboratory problems (Appendix A). Therefore, samples collected in 2008 water sampling were only analyzed for inorganic constituents.

In 2004, the University of Alaska, Fairbanks (UAF) staff members collected water samples off each of four stations (MPS1 through MPS4, Figure 34-4). Tidal stage was not recorded during the 2004 sampling events. In 2008, Pentec staff collected water samples at stations MPS1 and MPS4 and the deeper water site MOPPI, an opportunistic sampling location between Iliamna Bay and Iniskin Bay (Figure 34-4). Samples were collected during high tide at all three stations during all of the sampling events in 2008. An additional sampling event was conducted at low slack water in September at stations MPS1 and MPS4.

In 2004, water samples were collected at an estimated 2 meters above the seafloor with a decontaminated Van Dorn sampler. In 2008, marine water was collected with a 30-liter polyvinyl chloride (PVC) Niskin sampler at two depths: 2 meters below the water surface and 2 meters above the seafloor. The researchers collecting samples were careful during all sampling events to make sure that the sampling device did not disturb the sediment. Sample containers were filled directly from the water sampler.

All samples remained in the custody of the field crew until turned over to a courier in Homer, Alaska, or to Shaw personnel in Anchorage, Alaska. Chain-of-custody was documented at each exchange. Upon receiving the samples, Shaw personnel prepared the samples for transport and shipping to the analytical laboratories.

34.2.6.3 Data Reduction and Interpretation

Only primary sample data were included in data interpretation described in the following section. Results of analyses of field-split samples collected for quality assurance and quality control functions were not used for data interpretation.

Analytical results below the limit of detection were treated as follows. Where laboratory results were reported with a value of zero, these analyses were included for the data set at one-half the method detection limits. Other laboratory results that were reported below the limits of detection were also included in the data base at one-half the method reporting limits. These concentration values were then used in general statistical analysis for calculation of mean values. As a result, some calculated values may comprise all detected concentrations, a mix of detected concentrations and concentrations below the limit of detection, or all concentrations below the limit of detection.

In 2004, inorganic analytical results were rejected and dropped from the data set because inappropriate analytical procedure was used (see Appendix A for detailed explanation). The following constituents had rejected data (number of values in parentheses): beryllium (1), cadmium (1), chromium (2), copper (1), selenium (1), and zinc (4). The rejected data included samples that were spread over time and location, but they were all for filtered (dissolved) samples.

Because of confusion in sample labeling, some results from July 2008 also were dropped from the data base. These omissions include aluminum, antimony, barium, boron, cadmium, iron, lead, manganese, tin, vanadium, and zinc from the filtered samples at station MPS1. Also, no selenium analyses for the July 2008 sampling were successfully performed by the laboratory.

Data from the sampling events were pooled and mean values were used to express the central tendency representative of each station. If only individual samples were available, the data were reported separately.

Concentrations of constituents were evaluated in two ways. The primary approach was to compare the results from the Pebble Project sampling program to thresholds of biological response, as reflected in water quality criteria. In a few instances constituent concentrations have been measured in previous studies from southcentral Alaska. These constituent results have been used for purposes of discussion where available as a second set of concentrations for comparison. The biological response criteria were compiled in Screening Quick Reference Tables (SQuiRT) by a branch of the National Oceanic and Atmospheric Administration from a variety of sources in ecological literature for performing preliminary evaluations of marine and other kinds of habitat (Buchman, 2008). In most cases, these values are Criterion Continuous Concentrations from the National Recommended Water Quality Criteria promulgated by the U.S. Environmental Protection Agency (U.S. EPA, 2009). In other cases, they are criteria proposed by U.S. EPA. Lastly, they may be criteria used by other governments for various purposes. For use in the present report, the most stringent SQuiRT value was selected for each constituent available. These criteria have no present regulatory application in IIE.

Statistics summarizing the marine field parameter data are presented by sampling event in Table 34-3 and by sampling station in Tables 34-4 (Iliamna Bay) and 34-5 (Iniskin Bay). Chemical analyses performed on samples of marine water are provided in Tables 34-2, and results are presented in Tables 34-6 and 34-7. Station locations are shown on Figure 34-4. Where data from the three stations are presented, the order of presentation is west to east, either top to bottom or left to right.

The secondary approach to data interpretation investigated potential trends in the chemical concentrations of constituents. Data were pooled into aggregations and the results plotted on one graph for seasonal, geographical, depth, and tidal variations. Matching data subsets were extracted from the overall database (nonfiltered water samples only). One of the data sets was used to evaluate seasonal, geographical, and depth variations. For these analyses, to keep water depths consistent, the data set was refined to include only the high-tide data. Another data set was used to examine tidal variations. For these analyses, the data set was refined to include only the data from the September collection event (high-tide and low-tide collections). Then, the data were averaged for each constituent in the particular factor of interest (each collection period for seasonal variation, each station for geographical variations, each depth interval for depth variations, and each tide for tidal variations). Lastly, a mean concentration for each constituent in the data subset was computed and concentrations of the respective constituents in each of the relevant portions of the data subset (collection periods, stations, depth intervals, or tides) were divided by this data-subset mean concentration, termed “mean-adjusted concentration.” This technique enabled all results to be plotted on one graph while preserving quantitative relationships among the data subset portions of interest.

34.2.7 Results and Discussion

34.2.7.1 Field Parameters

Water Temperature

During the period from 2004 to 2008, 327 individual measurements of temperature were recorded. Monthly mean water temperatures in the IIE were observed to increase from lows in late winter/early spring (March) to late summer (July or August) and then begin to decline (Figure 34-6). Monthly mean temperatures ranged from 0.2 °C in March 2008 to 18.0 °C in August 2004 (Table 34-3). The lowest single event water temperature of -1.8 °C was recorded during the March 2008 biological sampling event when floating ice was present in the bays. The study-wide maximum single event temperature was 27.4 °C in August 2004 at Station MPSE in inner Iliamna Bay. After August 2004, the next highest monthly mean temperature occurred in July 2005 (Figure 34-6).

When stations that were measured less than six times during the 5-year study period are removed from the data set (Figure 34-7), there is an indication of higher temperatures in inner Iliamna Bay than in the outer bay. For example, high sun exposure in summer and low insolation in winter have a greater influence on the temperature of shallow inner bay waters than on deeper outer bay waters. Exceptions can likely be attributed to local physical characteristics, such as colder localized freshwater inputs reducing local temperatures. Overall, water temperatures are affected by complex variables that include freshwater input, rate of water exchange, and cardinal orientation of the bays.

The three tidal lagoon stations in Iliamna Bay (MACL, MCWL, and MCWSL) had mean spring/summer temperatures that were relatively warm, compared with the observations recorded in the rest of the bay (Table 34-4). These three stations also had three of the four highest summer maximum temperatures as would be expected, given their shallow nature and limited circulation. Stations MCWL and MCWSL were sampled primarily in late spring and in summer months when temperatures were likely to be at maxima. These trends suggest that the three lagoons are significantly influenced by solar radiation in late spring and summer due to their small sizes and shallow depths relative to the remainder of the bay. Lack of winter data precludes direct observation of temperature trends during colder conditions yet the AC Point Lagoon, at least, was observed to freeze before the adjacent bay (November 2008).

Because all of the sampling stations in Iniskin Bay were in the outer portion of the bay and relatively close together (Figure 34-4), no reliable temperature trend can be inferred using the collected data relative to the inner and outer portions of Iniskin Bay.

The data in Table 34-5 imply that the water on the beaches of Iniskin Bay, as recorded at the frequently sampled beach seine stations (MBB, MPS1, MPS1A, MPS1B, MPS1C), is generally warmer (higher mean temperatures) relative to offshore waters, as recorded at the frequently sampled trawl stations (MPS1T, MPS2T, MPS2TA, MPS2TB). Four of the five lowest mean temperatures were recorded at the trawl stations. These data suggest that water temperature in outer Iniskin Bay, especially during the late spring through early fall period, may be driven by a balance between tidal exchange with cooler Cook Inlet waters and nearshore waters exposed to solar heating over mudflats. A similar pattern is evident in Iliamna Bay where two of the consistently sampled trawl stations (MTR1 and MTR2) (Figure 34-4) had lower mean annual temperatures than did the consistently sampled beach seine stations. Trawl station

MTR3 is in very shallow (intertidal) water in inner Iliamna Bay and had a mean temperature comparable to that of nearby beach seine stations (MBSA1, MPS3, MPSE1; Table 34-4).

Winter low temperatures reported in these tables are biased by the fact that during the March 2008 and April (2006 and 2008), as well as during some late fall work, ice excluded us from approaching or sampling many shoreline areas so proportionally more of those data points are from offshore trawl stations.

Salinity

In general, during the period from 2004 to 2008, monthly mean salinity tended to decrease from spring through late summer and started to increase again in the fall months (Figure 34-8). This pattern is not typical for regions that experience significant snowpack and have minimal glacially-fed freshwater inputs. It is not typical because a relative minimum of salinity would be expected during May and June, which are the months of greatest local snowmelt. The minimum average salinity occurred in September 2008 at 23.2 ppt, with August 2004, September 2007, and June and July 2008 having the next lowest values.

These data suggest that salinities may not be greatly influenced by the relative amount of local freshwater inputs such as snow melt or rainfall events. Instead, salinities in the IIE may be determined by broader regional influences combined with tidal and estuarine mixing. Salinities in other portions of Cook Inlet, particularly Knik Arm, have shown similar seasonal variation, with lowest average salinities recorded in mid- to late summer and highest average salinities recorded in spring (Pentec, 2005; Muench et al., 1978). Conditions in the upper portions of Cook Inlet likely influence conditions in the IIE. For example, the lower salinity water from upper Cook Inlet travels in the observed counterclockwise circulation pattern down the west side of the inlet and enters the IIE. Freshwater inputs to the bays should not be completely discounted and are likely important on a localized scale within the bays. One interesting exception to this overall trend came in August 2008 when the average salinity was much higher than either July or September 2008. The reason for this anomaly is unknown.

When stations that were measured less than six times during the study period are removed from the data set, mean salinity was observed to decrease from the outer stations of Iliamna Bay to the inner stations (Figure 34-9). This decrease was likely a result of freshwater inputs at the head of Iliamna Bay. Local stratification was observed during both the spring snowmelt season and in warmer summer months. Stratification was particularly evident during calmer weather and in more sheltered portions of the bays. Snowmelt or significant rain events occasionally created a freshwater surface lens in areas adjacent to freshwater inputs. These lenses were never observed to be greater than 1 or 2 inches deep and can be expected to rapidly diminish as a result of tidal and wind-driven mixing.

Salinities in two of the three tidal lagoon stations were generally lower than at the stations in Iliamna Bay. Both stations MACL and MCWSL have direct freshwater inputs. In contrast, station MCWL which has no apparent fresh surface water inflow, has a relatively unrestricted tidal opening within Cottonwood Bay, and therefore has comparable salinity with other observed stations in Iliamna Bay (Table 34-4).

The proximity of sampling stations in Iniskin Bay does not lend itself to drawing conclusions regarding the spatial distribution of salinity in that area. All stations exhibited comparable salinity values during sampling events (Table 34-5).

Turbidity

Overall turbidity was relatively moderate in both Iliamna Bay and Iniskin Bay. The measured mean was 15.3 nephelometric turbidity units (NTU), and the maximum measurement was 216 NTU (Table 34-3). Comparison of monthly mean turbidities (Figures 34-10a and 34-10b) showed that in most months, Iliamna Bay was generally more turbid than Iniskin Bay.

Available data reflect the dependency of turbidity on wind (and ice) conditions in the IIE. Accordingly, turbidity tended to be highest in the late summer and early fall in Iliamna Bay and slightly elevated in early spring and in late fall for Iniskin Bay. Open water months showing particularly high turbidity, correspond to months in which generally windy conditions prevailed during the field survey period (see Chapter 26 for site wind data). Overall, though, monthly mean, turbidity among all sites in both bays remained relatively constant over the study period. The exceptions were August 2005 and November 2008, when the monthly mean turbidity for both bays combined was approximately twice as high as most other months (31.6 NTU and 47.1 NTU respectively)(Table 34-3). , Wind speeds during these sampling events (August 16 – 18, 2005 and November 11-13, 2008) reached up to 24 miles per hour (mph) and 35 mph respectively which may have contributed to the higher turbidity values (Chapter 2, Appendices 2C, 2F, 2G, and 2H). Another exception was September 2007, when the monthly mean was 26.1 NTU and the largest single turbidity reading of 216 NTU was measured. When this outlier was removed, the average turbidity for that month dropped to 12.5 NTU, which was more in line with the remaining months. In all years of this study, the highest annual monthly means occurred between August and November.

When stations that were measured less than six times during the study period were removed from the data set, average turbidity increased from outer Iliamna Bay to inner Iliamna Bay (Figure 34-11). Increased turbidity is likely due to tide and wave resuspension of the sediments increasing fine-grain sediment levels in the inner bay. The somewhat reduced turbidity levels of station MBS4 (cf. MPSE) in Iliamna Bay may have reflected cleaner water entering the bay from the freshwater stream at Williamsport supplying clearer water to mix with the more turbid inner bay water.

Turbidity in tidal lagoons tended to be relatively low and followed the similar trend as illuminated by the salinity data. More specifically, the two stations in relatively enclosed systems with fresh water inputs (MACL and MCWSL) both had lower than average turbidities while station MCWL was more on par with the other Iliamna stations (Table 34-4). Again, this trend was likely due to the physical configuration of these lagoons and the amount of mixing occurring between the lagoons and the adjacent water in Iliamna Bay or Cottonwood Bay.

In summary, local turbidity appears to reflect the combined influences of the turbulent suspension of fine-grained sediments driven by wind and tidal disturbances, inputs of clearer fresh water, and suspended particulates or clearer water (depending on season) transported in on flood-tide water from Cook Inlet. The lack of appreciable input from glacial melting, with the exception of small glaciers in the Iniskin River watershed, was a contributing reason for low to moderate turbidity in IIE waters.

34.2.7.2 Chemical Analysis

Chemical analysis of marine waters in the IIE showed it to be a high-quality habitat with only minor indications of anthropogenic pollution sources. None of the measured inorganic constituents were above the corresponding National Recommended Water Quality Criteria (U.S. EPA, 2009). More specifically,

concentrations of the inorganic constituents were not above the maximum Criteria Continuous Concentration, which is the most restrictive concentration for water quality criteria for marine habitats and also known as SQuiRT values (Table 34-6). Most concentrations were below both criteria values by one or more orders of magnitude. The full results of chemical analyses are available in Appendix B.

Boron, iron, and tin were the only the measured concentrations that were above the SQuiRT values. These constituents require some clarification in interpretation and the application of their SQuiRT values in this baseline document. Tin was measured below the limit of detection in all samples. Therefore, the values in the table represent averages based on the reporting limits and the method detection limits. These values were not a direct measure of concentration. In addition, the SQuiRT value for tin was based on tributyltin (TBT). TBT has been used in antifouling paints and is a potent biocide. The chance that the tin in IIE was all or even mostly in the form of TBT is extremely low. However, because TBT was not measured directly, it cannot be ruled out.

The SQuiRT value for iron could not be verified. The Ministry of the Environment for British Columbia, Canada, concluded their technical report on iron in water quality guidelines as follows:

“Due to the relatively high mean pH of marine waters (approximately pH 8.2), very little iron would remain in solution, and it is not anticipated that iron toxicity would therefore be a concern. If, in the future, studies are conducted which suggest that iron toxicity in the marine environment may be a concern, a guideline for marine iron levels may be considered at that time” (Phippen et al., 2008).

The most recent edition of the technical report for iron from the Province of British Columbia (Phippen et al., 2008) does not contain a recommended value for iron in marine waters as the SQuiRT compendium attributes.

The value of 1,200 µg/L for boron arose from a water quality document produced by the Ministry of Environment for the Province of British Columbia, Canada. It is based on the application of a 0.1 safety factor to an LC₅₀ of 12,200 µg/liter for a species of salmon (Moss and Nagpal, 2011). This report gives concentrations of boron in coastal Canadian waters as ranging between 3,700 and 4,300 µg/L. Typical oceanic concentrations for boron are in the range of 4,000 to 5,000 µg/L (Culkin, 1965; Williams and Strack, 1966; Marscigrp.org, 2010). The screening value has clear limitations for establishing a threshold of biological response given that natural marine waters exceed its magnitude by factors of three to four.

SQuiRT values help to quickly compare chemical analyses of water and other environmental media and give conservative levels for biological response. However, some SQuiRT values require discussion of their background and applicability before they can be used to interpret ecological conditions. Based on the concentrations in Table 34-6 and the foregoing discussion, all constituents in marine water were considered to be less than their respective SQuiRT values.

Organic constituents in marine water were only analyzed in 2004 (Table 34-7). The majority of organic constituents were not detected. For example, benzene, toluene, ethylbenzene, xylenes, gasoline-range organics, and diesel-range organics were not detected. Residual range organics (RRO) were detected at concentrations ranging between 83 and 258 µg/L. The test for RRO is relatively broad and includes naturally occurring organic compounds with a range of carbon atoms between C₂₅ and C₃₆.

The available data on distribution of all constituents in marine waters of IIE are generally too sparse to substantiate trends. However, a brief analysis of the data set was conducted to look at variations in time, geography, depth, and tidal elevation (Figures 34-12 through 34-15). Some limited observations may be made on the temporal variation of constituents; the other factors did not provide any conclusive patterns.

Analysis of the available water chemistry data from seasonal (May, July, September) sampling in 2008 suggests some relationships with seasonal events in the IIE. The concentrations of total suspended solids (TSS) were substantially higher in the spring than during the summer, a likely result of increased snowmelt during the spring months (orange triangles in Figure 34-12; Table 34-6) although the higher TSS did not parallel a particularly high turbidity during the May 2008 sample period (Table 34.3). Some evidence suggests that concentrations of many inorganic constituents followed a similar although less extreme seasonal pattern as TSS (Figure 34-12). Concentrations of many constituents generally decrease from the May water collection to the July collection. In comparing the July and September concentrations, the results were less consistent.

One additional observed seasonal correlation was the variation in measured concentrations of total ammonia (nitrogen, Ammonia as N in Table 34-6) in non-filtered samples. Total ammonia was measured below detection limits at all stations during the spring, detected at one station in early summer, and measured at all three stations in late summer. A likely explanation for this observation is that planktonic algae used up the ammonia during the spring bloom. As another nutrient or light became the limiting factor to algal production, the ammonia concentrations returned to measurable levels. Saupe et al. (2005) reported mean ammonia concentrations of 12 $\mu\text{g-N/liter}$ in surface water and 24 $\mu\text{g-N/liter}$ in bottom water. These values were derived from more than 50 observations in each stratum collected throughout coastal waters of southcentral Alaska in 2002. The values agree with the IIE data, allowing for the substantial biological influences on the distribution of this nutrient.

Potential depth variation in the concentration of inorganic constituents was examined. Most constituents show only a modest variation over depth, a circumstance consistent with well-mixed water and the absence of a strong thermocline (Figure 34-13). Although the extreme concentration shifts in lead and selenium on this figure stood out, neither of these features is particularly meaningful. The high value for the mean-adjusted concentration of lead in the surface portion of the data—and correspondingly the low value for the bottom portion—derived from one particularly high concentration measured in a surface sample. One data point does not support a trend. Selenium was measured below detection in all samples, so no trend with ecological meaning can be interpreted from those data.

Results of the analysis of potential geographic variation are presented in Figure 34-14. Factoring out the information for lead and selenium for reasons previously stated, the geographical distribution is quite uniform.

Results of the analysis of potential tidal variation are presented in Figure 34-15. In this case, the extreme variation in selenium is based on the single detected concentration measured at the low tidal elevation, which raised the mean-adjusted concentration in the low tidal elevation and depressed it at high tide. Total ammonia was also higher during low tide sampling. Otherwise, no variation in concentration based on tidal stage is apparent.

34.2.7.3 Water Quality Summary

Water quality in the IIE during the period from 2004 to 2008 was influenced by tidal exchange with Cook Inlet and Kamishak Bay. Local fresh water inputs created minor, localized effects at the heads of the bays. Observed gradients in salinity occurred between the inner and outer portions of Iliamna Bay.

Temperatures were driven by insolation and seasonal variations. Ice was generally present through the winter months, a warming trend occurred during the spring and summer, and temperatures declined again in the fall. Temperatures were also driven by water depth, reinforcing the role of insolation as a factor in temperature trends. Salinity decreased from spring to late summer, increased again in the fall, and appeared to be an additional indicator of the influence of regional water on the bays. Turbidity was generally moderate, except near the shoreline during windy periods, and did not exhibit any obvious trends that indicate point-source inputs.

Analyses of hydrocarbon concentration in marine water from IIE in 2004 and of metal and trace element concentrations in 2008 showed little to no effect from anthropogenic sources. Concentrations of all inorganic constituents were less than the Criteria Continuous Concentration water quality criteria for marine habitats, also known as SQUIRT values; many concentrations were lower by orders of magnitude. Data analyses showed the marine waters of IIE to be high-quality habitat for marine biota. These data suggest a relationship between increased concentrations of many inorganic constituents with TSS, but demonstrate no strong patterns with respect to depth in the water column to geography, or to tide stage.

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34.4 Glossary

Anticyclonic—a system of movements or a local circulation pattern that is opposed to the earth's rotation and is clockwise in the Northern Hemisphere.

Cardinal Orientation—orientation with respect to one of the four principal compass points north, south, east, and west.

Drogue track—a track depicting the movements of an unmanned drogue, a buoy, or other device moved primarily by tidal circulation.

Embayment—a bay-like feature often not associated with fresh water inputs where flushing and other oceanographic features are tidally or weather dominated.

Estuary—a semi-enclosed, tidal, coastal body with open connection to the sea; characterized as a mixing environment between saline seawater and fresh water inputs.

Insolation—a measure of solar radiation energy received on a given surface area in a given time.

Isohalines—lines of equal or constant salinity. A line on a chart connecting all points of equal salinity.

Katabatic forces—density-driven forces resulting in wind local wind patterns. In relation to williwaws, these result from denser cold air forming adjacent to snow or ice fields and descending down mountain slopes.

Niskin sampler—a device to sample surface water from depth. It consists of a wide tube made of PVC with stoppers at both ends. The stoppers are tied together with a strong band (generally latex) and closed by receiving the pulse of a messenger attached to and dropped down the sampling line. This type of sampler has a narrower aspect than a Van Dorn sampler and is generally deployed only vertically.

Shore-Fast Ice—sea ice that has frozen along coasts (“fastened” to them), along the shoals, or to the sea floor over shallow parts of the continental shelf, and extends out from land into sea. Fast ice does not move with currents and wind.

Tidal rip—zone of agitated water caused by shear processes resulting from the close proximity of two opposing currents or a strong current in close proximity to a stationary object.

Van Dorn sampler—a device to sample surface water from depth. It consists of a wide tube made of acrylic or PVC with stoppers at both ends. The stoppers are tied together with a strong band (generally latex) and closed by receiving the pulse of a messenger attached to and dropped down the sampling line. This type of sampler has a wider aspect than a Niskin sampler and is frequently deployed horizontally.

Williwaws— a sudden violent gust of cold land air common along mountainous coasts of high latitudes.

TABLES

TABLE 34-1
Tidal Data for Iniskin Bay (59° 40.8', 153° 23.8')

	Elevation ^a (meters)
Highest estimated tide	6.1
Mean higher high water	4.4
Mean high water	4.2
Mean sea level	2.3
Mean low water	0.4
Mean lower low water	0.0
Lowest estimated tide	-1.5

Note:

a. All elevations are relative to mean lower low water.

Source: Brower et al., 1988.

TABLE 34-2
Analytical Constituents for Marine Water Quality Samples

Analyte	Year		Analytical Methods	Detection Limits		Reporting Limits		Units
	2004	2008		Min	Max	Min	Max	
Aluminum		•	E200.7, E200.8, SW6010B	20	624	50	2000	µg/liter
Antimony		•	E200.8	0.1	6.16	1	16	µg/liter
Arsenic		•	E200.8	0.01	20	0.5	40	µg/liter
Barium		•	E200.7, E200.8, SW6010B	0.7	7.52	5	24	µg/liter
Benzene	•		SW8260B	0.11	0.12	0.4	0.5	µg/liter
Beryllium		•	E200.8	0.0004	1.2	0.02	2.4	µg/liter
Bismuth			E200.8	120	120	400	400	µg/liter
Boron		•	E200.7, E200.8, SW6010B	2.1	31	6	100	µg/liter
Cadmium		•	E200.8	0.001	2.48	0.02	8	µg/liter
Chromium		•	E200.8	0.01	8	0.2	16	µg/liter
Cobalt		•	E200.8	0.001	2.48	0.02	8	µg/liter
Copper		•	E200.8	0.003	4.96	0.1	16	µg/liter
Diesel Range Organics	•		AK102	0.031	0.0698	0.313	0.8	mg/liter
Ethylbenzene	•		SW8260B	0.13	0.31	0.5	1	µg/liter
Gasoline Range Organics	•		AK101	0.01	0.01	0.09	0.09	mg/liter
Iron		•	E200.7, E200.8	2	496	20	1600	µg/liter
Lead		•	E200.8	0.001	8	0.02	16	µg/liter
Manganese		•	E200.7, E200.8, SW6010B	0.3	40	2	80	µg/liter
Mercury	•	•	E1631	0.00005	157	0.001	500	µg/liter
Molybdenum			E200.8, SW6010B	5	24.8	10	80	µg/liter
Nickel		•	E200.8	0.01	4.96	0.2	16	µg/liter
Nitrogen, Total Ammonia (as N)	•	•	A4500AD, A4500NG, A4500NH, E350.1	6	40	40	100	µg/liter
o-Xylene	•		SW8260B	0.079	0.31	0.5	1	µg/liter
Residual Range Organics	•		AK103	0.054	0.0698	0.5	0.581	mg/liter
Selenium		•	E200.8, SW7742	0.2	24.8	1	80	µg/liter
Silver		•	E200.8	0.0003	0.496	0.02	2	µg/liter
Thallium		•	E200.8	0.0004	2	0.02	4	µg/liter
Tin		•	E200.8	0.14	24.8	2	80	µg/liter
Toluene	•		SW8260B	0.098	0.31	0.5	1	µg/liter

Total Suspended Solids	•	•	A2540D, E160.2	0.3	5	1	5	mg/liter
Vanadium		•	E200.7, E200.8, SW6010B	0.44	20	2	32	µg/liter
Xylene, Isomers m & p	•		SW8260B	0.22	0.62	0.5	2	µg/liter
Zinc		•	E200.8	0.03	37.6	0.5	120	µg/liter

Note:

Some analyses were performed on only a small number of samples.

TABLE 34-3

Summary Marine Water Quality Statistics by Month and Year, 2004-2008, at all IIE Stations Sampled (see Figure 34-4)

		All Months	2004	2005				2006			2007		2008								
			Aug	May	Jun	Jul	Aug	Apr	May	Sep	Sep	Oct	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Temp (°C)	Mean	8.9	18.0	9.1	11.9	15.2	14.7	3.4	7.3	10.2	11.8	6.0	0.2	1.6	7.4	10.5	12.3	13.6	10.1	5.3	2.0
	Max	27.4	27.4	13.4	18.3	17.6	15.7	4.2	11.4	10.6	12.3	7.4	1.7	2.7	8.9	18.3	22.1	14.5	10.9	7.5	3.4
	Min	-1.8	13.2	6.4	9.3	13.1	13.8	2.8	5.2	10.0	10.4	4.4	-1.8	0.2	4.9	6.2	10.3	12.5	6.8	0.8	-0.7
	n	327	3	14	23	11	10	14	18	12	15	20	8	13	27	31	27	27	20	16	19
Salinity (ppt)	Mean	26.3	23.6	26.4	26.0	25.4	25.1	29.3	28.7	25.4	23.4	27.2	29.9	30.4	26.8	25.2	23.8	27.4	23.2	26.1	28.3
	Max	31.1	28.3	29.1	29.4	28.2	28.2	30.0	30.0	27.4	28.4	28.7	30.5	31.1	30.0	30.0	30.0	29.3	27.1	28.6	29.1
	Min	1.3	15.3	9.4	8.0	18.6	13.3	27.9	24.8	22.3	8.3	23.8	28.6	29.0	4.1	9.4	1.3	16.5	1.4	15.3	26.1
	n	327	3	15	23	11	10	14	18	12	15	20	8	13	27	31	27	27	20	16	19
Turbidity (NTU)	Mean	15.3	N/A	15.0	13.6	12.9	31.6	10.0	10.5	18.2	26.1	5.7	16.8	5.0	11.0	10.2	11.2	4.8	16.2	17.2	47.1
	Max	216.0	N/A	36.0	44.0	37.5	105.0	24.0	70.0	55.9	216.0	13.0	34.0	13.0	11.0	60.0	35.4	40.0	70.0	37.0	170.0
	Min	0.3	N/A	3.8	2.6	3.0	2.4	5.1	4.0	6.4	1.5	1.2	10.0	2.7	11.0	0.3	2.8	1.2	2.8	6.2	11.0
	n	273	N/A	13	23	8	8	13	18	10	15	20	8	10	1	27	20	26	20	16	19

Notes: n = number of measurements

Max = maximum; Min = minimum; ppt = parts per thousand; NTU = nephelometric turbidity units.

Data shown represent statistics from all sets, all stations in a given month.

TABLE 34-4
Summary Marine Water Quality Statistics for Iliamna Bay by Sampling Station, 2004-2008

		Station																		
		MTR2	MPS4- Offshore	MPS4	MTR1	MBS1	MPS3	MBSA1	MTR3	MBS3	MPSE1	MPSE2	MPSE	MBS4	MUI1	MUI2	MACL ^a	MCWL ^a	MCWSL ^a	
Temperature (°C)	Mean	6.9	9.9	8.5	6.4	8.9	7.5	9.3	9.3	10.0	9.5	8.7	12.1	9.7	7.8	6.6	10.1	12.6	11.9	
	Max	13.0	11.9	13.2	12.3	15.1	13.7	14.8	13.4	17.1	16.1	13.6	27.4	16.9	7.8	6.6	18.3	22.1	18.0	
	Min	-0.1	7.3	0.8	-1.0	2.7	0.2	3.7	5.3	0.1	-0.1	0.7	-0.7	-0.5	7.8	6.6	0.8	3.2	6.2	
	n	11	4	22	11	18	11	19	5	23	11	7	17	15	1	1	7	5	3	
Salinity (ppt)	Mean	28.6	27.2	28.1	28.2	26.6	27.0	27.3	25.4	25.7	25.4	24.1	23.7	17.1	24.4	15.6	14.3	23.4	19.9	
	Max	30.8	29.3	30.3	30.5	29.8	31.1	29.6	28.0	29.4	28.7	28.0	27.9	30.6	24.4	15.6	24.7	27.2	24.8	
	Min	24.8	25.3	22.6	26.0	8.3	23.2	23.3	16.5	11.9	20.1	16.8	15.0	1.3	24.4	15.6	4.1	12.2	11.2	
	n	11	4	22	11	18	11	19	5	23	11	7	17	15	1	1	7	5	3	
Turbidity (NTU)	Mean	6.9	6.6	11.7	6.9	11.0	10.0	15.4	6.4	19.7	22.5	28.2	52.0	38.6			5.3	25.4	7.9	
	Max	16.0	8.9	38.0	16.0	31.0	26.0	105.0	8.5	150.0	47.2	82.0	170.0	216.0			10.4	60.0	9.4	
	Min	1.5	2.8	0.3	1.5	1.5	3.4	1.6	5.2	3.5	6.8	6.4	6.8	1.9			1.2	9.8	6.5	
	n	10	3	18	9	17	10	17	4	22	10	6	13	15	0	0	6	4	2	

Notes: Offshore' stations are water and sediment quality stations; Station names including a "T" are trawl stations; all others are beach seine stations (see Figure 34-4)

a. These tidal lagoon stations are discussed separately from the other stations in Iliamna Bay.

Trawl stations are color coded green for easier identification.

n = number of measurements

Max = maximum

Min = minimum

ppt = parts per thousand

NTU = nephelometric turbidity units

TABLE 34-5
Summary Marine Water Quality Statistics for Iniskin Bay by Sampling Station, 2004-2008

		Station														
		MOPP1 - Offshore	MYVCM	MYVL	MPS1A	MPS1	MPS1T	MPS1- Offshore	MPS1B	MPS1C	MBB	MPS2T	MPS2TA	MPS2TB	MTR4	MSLF
Temperature (°C)	Mean	9.5	10.5	6.5	10.2	7.8	7.2	10.0	8.5	8.5	10.1	6.3	7.1	7.5	11.6	11.6
	Max	10.3	12.9	6.5	15.7	13.5	13.6	11.2	13.9	14.0	14.1	14.1	14.1	14.4	11.6	11.6
	Min	8.2	8.6	6.5	2.6	0.5	-1.8	7.8	0.1	0.4	3.3	1.6	0.6	0.9	11.6	11.6
	n	3	4	1	14	12	12	4	21	19	14	9	13	8	1	1
Salinity (ppt)	Mean	28.5	26.8	30.0	28.4	28.6	27.9	27.2	28.4	27.7	28.4	29.0	27.9	27.5	25.1	24.3
	Max	30.0	28.6	30.0	30.0	30.5	30.5	29.5	30.4	30.4	30.0	30.6	30.4	30.6	25.1	24.3
	Min	25.6	22.1	30.0	25.9	26.5	25.0	24.7	25.3	22.8	26.5	27.0	25.7	25.8	25.1	24.3
	n	3	4	1	14	12	12	4	21	19	14	9	13	8	1	1
Turbidity (NTU)	Mean	3.1	4.0		6.2	13.0	9.1	8.6	9.5	12.7	12.1	9.2	6.4	7.3	8.8	17.6
	Max	3.1	5.4		17.1	30.0	28.0	14.0	28.0	35.6	38.0	34.0	17.0	18.0	8.8	17.6
	Min	3.1	1.3		1.2	2.1	1.9	4.1	1.4	3.1	1.7	1.9	1.8	2.6	8.8	17.6
	n	1	3	0	11	9	11	3	15	14	12	8	11	7	1	1

Note: 'Offshore' stations are water and sediment quality stations; station names including a "T" are trawl stations; all others are beach seine stations (see Figure 34-4).

Trawl stations are color coded green for easier identification.

n = number of measurements.

Max = maximum;

Min = minimum;

ppt = parts per thousand;

NTU = nephelometric turbidity units.

TABLE 34-6A
Results of Analyses of Marine Water Quality Samples, 2008

Constituent (µg/L; except TSS, mg/L)	Nonfiltered Samples Sample Station			Filtered Samples Sample Station			SQuiRT value
	MPS4	MOPP1	MPS1	MPS4	MOPP1	MPS1	
Aluminum	252	159	350	25	23	23	NC
Antimony	0.25	0.35	0.24	0.23	0.25	0.24	500 ^a
Arsenic	1.4	1.4	1.4	1.4	1.4	1.4	36
Barium	6.9	5.9	7.4	5.7	5.1	5.6	200 ^a
Beryllium	0.0056	0.0075	0.0067	0.0029	0.0084	0.0052	100 ^a
Boron	3,001	3,038	3,045	3,023	3,043	2,994	1,200 ^a
Cadmium	0.054	0.056	0.059	0.055	0.053	0.053	8.8
Chromium	0.62	0.34	0.59	0.26	0.17	0.17	50
Cobalt	0.204	0.121	0.249	0.074	0.043	0.062	1.0 ^a
Copper	1.25	1.05	1.31	0.70	0.63	0.61	3.1
Iron	402	243	539	47	35	37	50 ^a
Lead	0.420	0.238	0.301	0.110	0.066	0.075	8.1
Manganese	14.6	8.3	16.8	5.6	2.7	4.5	100 ^a
Mercury	0.00085	0.00059	0.00139	N	N	N	0.94
Nickel	0.82	0.68	0.95	0.62	0.52	0.55	8.2
Nitrogen, Total Ammonia (as N)	23	26	27	N	N	N	795
Selenium	0.17	0.20	1.10	0.10	0.10	0.10	71
Silver	0.0059	0.0066	0.0071	0.0076	0.0065	0.0066	0.95 ^a
Thallium	0.015	0.013	0.015	0.012	0.012	0.010	17
Tin	0.19	0.22	0.19	0.19	0.22	0.17	0.0074 ^a
Total Suspended Solids	37	29	31	N	N	N	NC
Vanadium	4.0	4.3	3.0	3.6	3.8	4.1	50 ^a
Zinc	3.0	2.5	2.8	2.2	1.4	1.8	81

Notes: tabular values are mean concentrations representing varying numbers of detected concentrations and results below the limit of detection entered at one-half the detection limit.

a. SQuiRT value from other than National Recommended Water Quality Criteria (U.S. EPA, 2009).

TSS = total suspended solids

SQuiRT value = Screening Quick Reference Table value (Buchman, 2008).

N = only nonfiltered samples analyzed

NC = no SQuiRT value available

µg/liter = microgram per liter

mg/liter = milligram per liter

TABLE 34-6B
Results of Analyses of Marine Water Quality Samples, 2008

Constituent ($\mu\text{g/L}$; except TSS, mg/L)	Sampling Event	Sample Station			SQuiRT Value
		MPS4	MOPP1	MPS1	
Nitrogen, Total Ammonia (as N)	May-08	25	25	25	795
	Jul-08	4	23	4	795
	Sep-08	33	30	33	795
Total Suspended Solids	May-08	59	58	62	NC
	Jul-08	19	14	16	NC
	Sep-08	16	16	25	NC

Notes: tabular values are mean concentrations of results for surface and bottom water samples.

Bold Results = Parameter undetected by test; value shown is 1/2 method detection limit or 1/2 method reporting limit.

(For the ammonia results, all of the samples collected in May 2008 were measured below the method reporting limit (the value of 25 $\mu\text{g/liter}$ represents one-half the method reporting limit). For ammonia analyses of water samples collected in July the results at stations MPS4 and MPS1 were below the limit of detection (the value of 4 $\mu\text{g/liter}$ represents one-half the method detection limit).

For the ammonia results, either both the surface and bottom water samples measured detected concentrations or they both measured below the limit of detection (and at the same value for each sample pair).

SQuiRT value = Screening Quick Reference Table value (Buchman, 2008).

Only nonfiltered samples were used in preparation of this table.

NC = no SQuiRT value available

$\mu\text{g/liter}$ = microgram per liter

mg/liter = milligram per liter

TABLE 34-7
Analyses of Organic Compounds in Marine Bottom Water Quality Samples, 2004

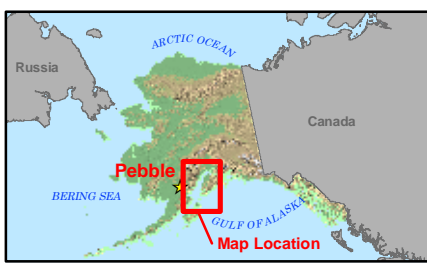
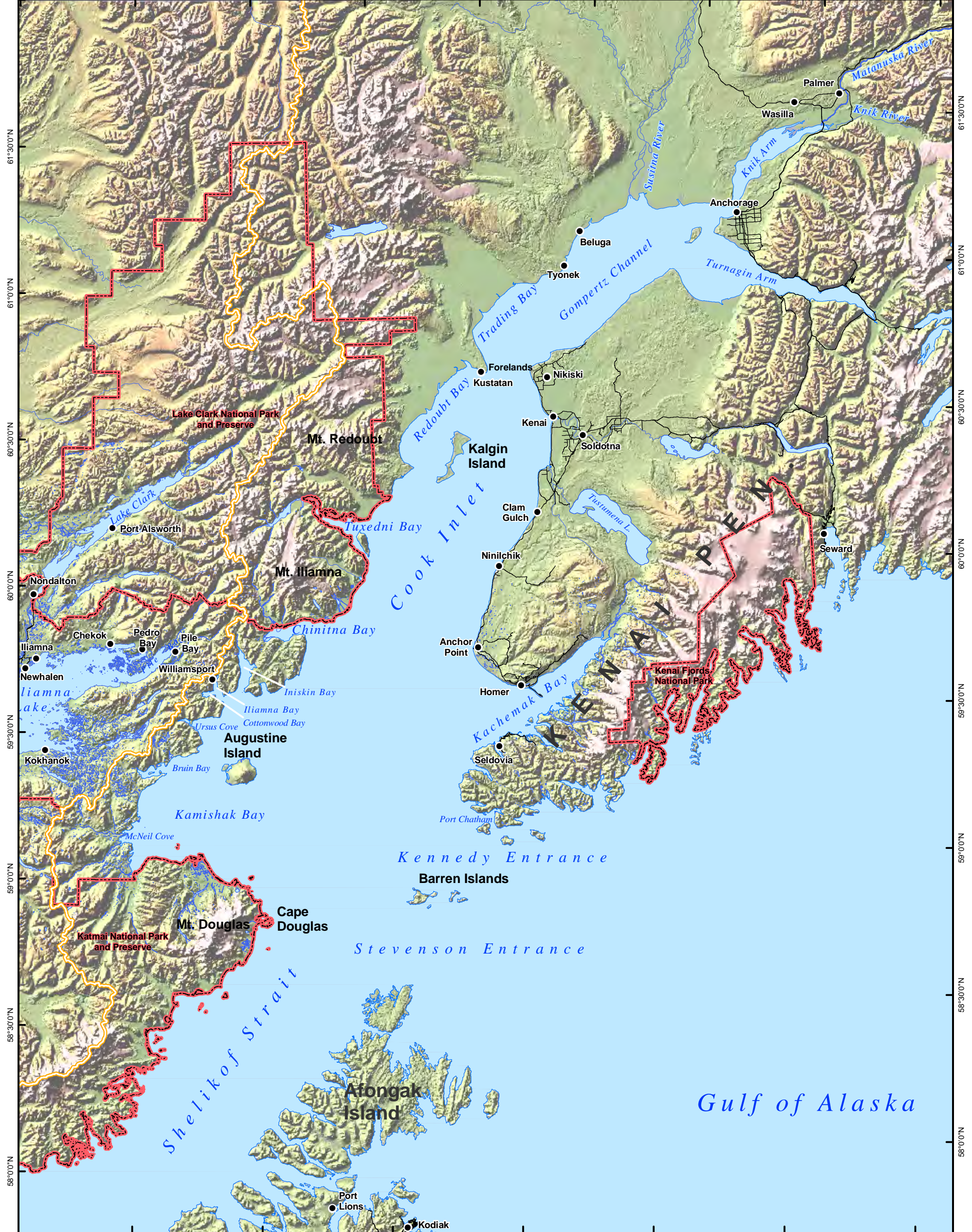
Constituent (µg/L)	Station			
	MPS3	MPS4	MPS1	MPS2
Benzene	0.06	0.06	0.06	0.06
Toluene	0.16	0.16	0.16	0.16
Ethylbenzene	0.16	0.16	0.16	0.16
Xylene, Isomers m & p	0.31	0.31	0.31	0.31
o-Xylene	0.16	0.16	0.16	0.16
Gasoline Range Organics	45	45	45	45
Diesel Range Organics	167	175	157	157
Residual Range Organics	141	83	258	103

Notes: **Bold Results** = Parameter undetected by test; value shown is 1/2 method detection limit or 1/2 method reporting limit.

µg/liter = microgram per liter;

FIGURES

155°0'0"W 154°10'0"W 153°20'0"W 152°30'0"W 151°40'0"W 150°50'0"W 150°0'0"W 149°10'0"W 148°20'0"W






0 10 20 30 40 Miles
0 10 20 30 40 50 Kilometers

Scale 1:1,400,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

Legend

-  Bristol Bay/Cook Inlet Drainages Boundary
-  National Park or Preserve
-  Communities



**Figure 34-1
Cook Inlet and Vicinity**

File: RDI_Pen_Cook_Fig34-1_11x17P_1of1_D04.mxd

Date: July 5, 2011

Version: 4

Author: RDI-LS

153°44'0"W 153°40'0"W 153°36'0"W 153°32'0"W 153°28'0"W 153°24'0"W 153°20'0"W 153°16'0"W



Figure 34-2
Physical Oceanography
and Marine Water Quality Study Area,
Iniskin/Iliamna Bay Estuary,
Cook Inlet, 2004-2008

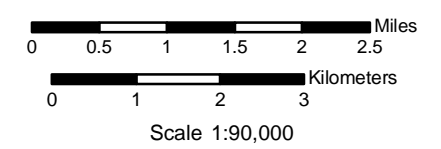
Legend

- IIE Study Area
- Existing Community



59°45'0"N
59°42'0"N
59°39'0"N
59°36'0"N

153°44'0"W 153°40'0"W 153°36'0"W 153°32'0"W 153°28'0"W 153°24'0"W 153°20'0"W 153°16'0"W



Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: RDI_SA_Fig34-2_11X17L_1of1_D08.mxd	Date: July 26, 2011
Version: 8	Author: RDI-LS

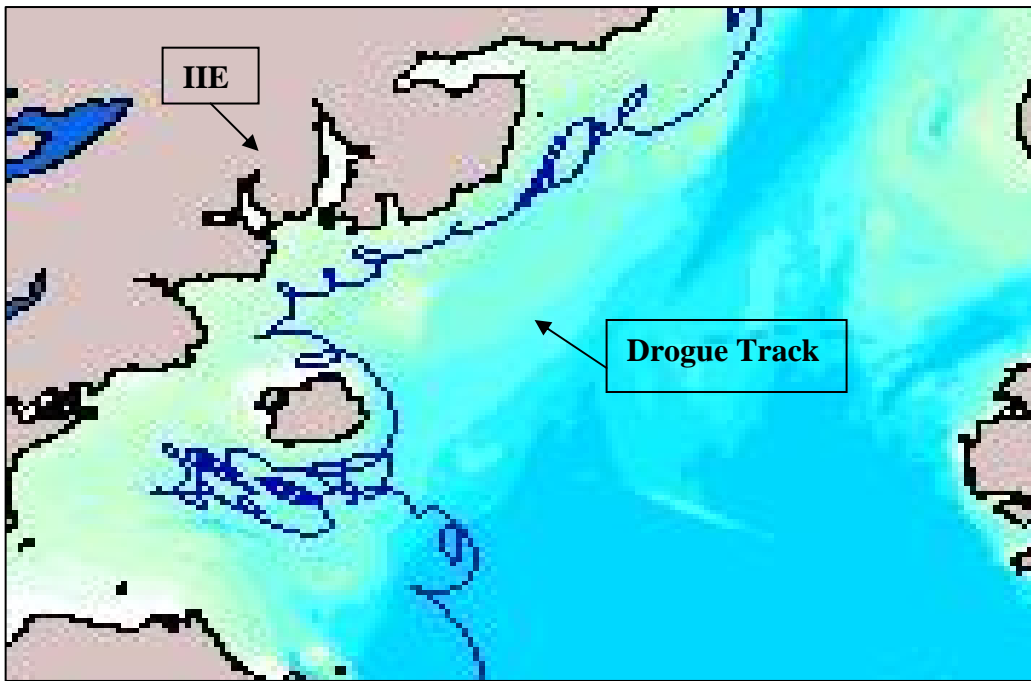


Figure 34-3a
Drogue Track near Iniskin/Iliamna Estuary

Source: Mark Johnson (pers. comm., 2006), supported by Minerals Management Service through Coastal Marine Institute at University of Alaska Fairbanks.

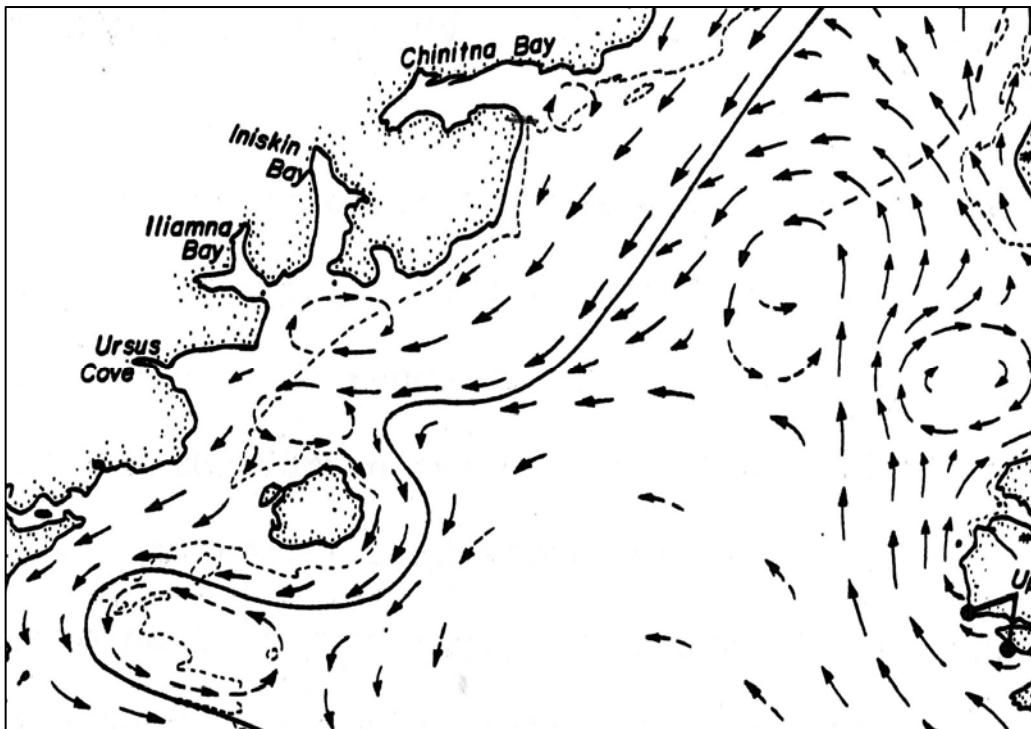
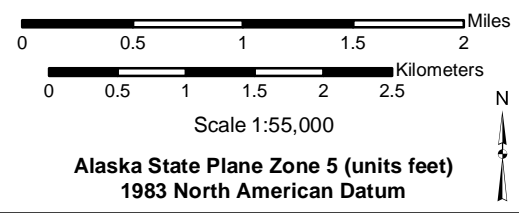
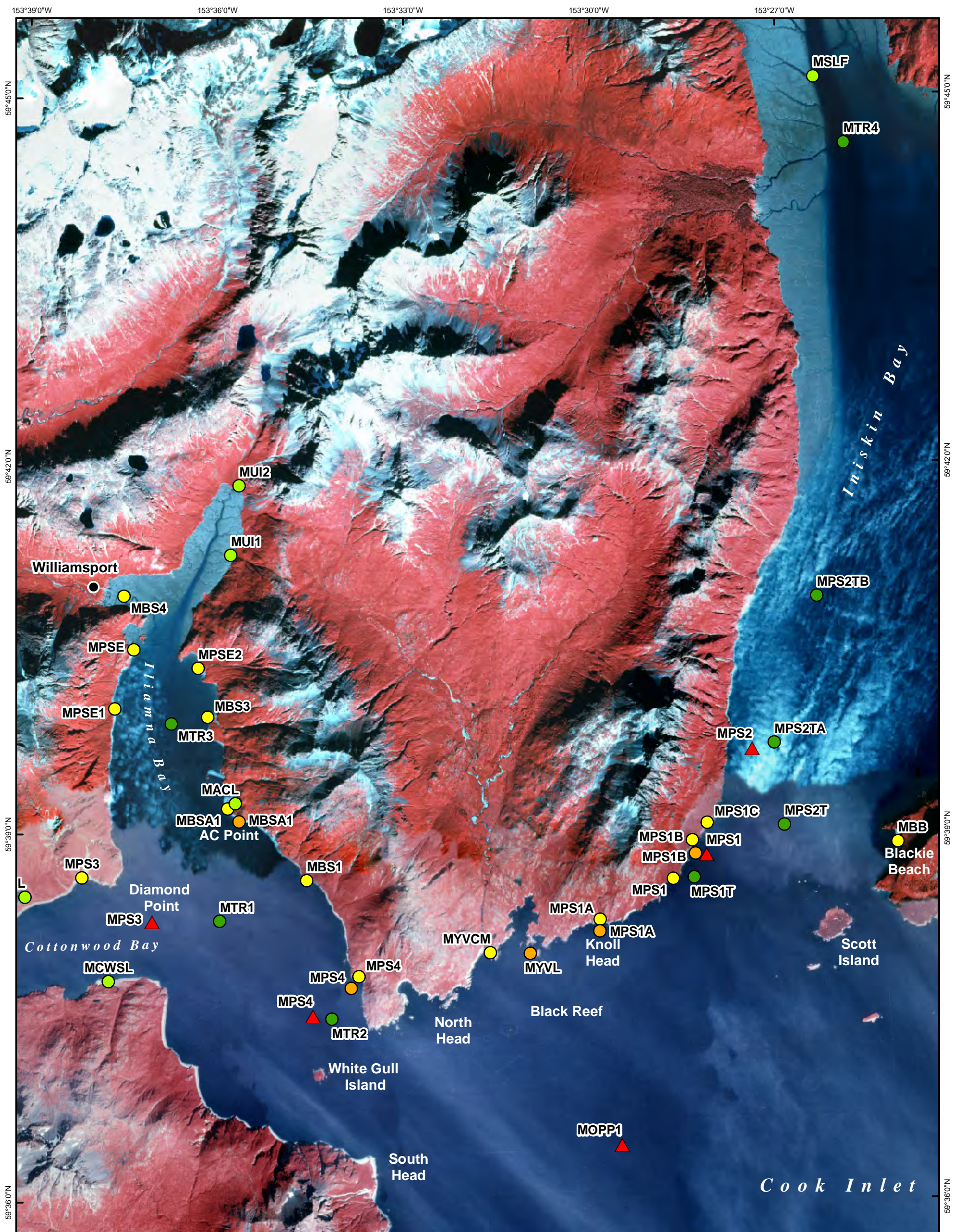


Figure 34-3b
Observed Current Circulation Patterns near the Iliamna/Iniskin Estuary

Source: Burbank, 1977.



Legend

Sampling Locations

- 120-ft Beach Seine
- 30-ft Beach Seine
- Gill/Trammel Net
- Trawl
- ▲ Water Chemistry

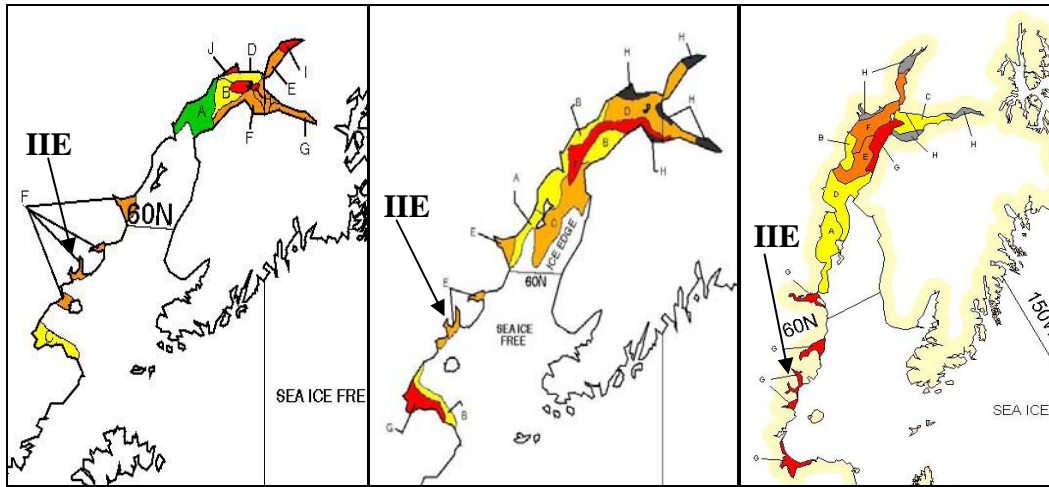
MTS4 Station Identification Label Example

- Existing Community



Figure 34-4
Water Quality Station Locations,
Marine Waters,
Cook Inlet,
2004-2008

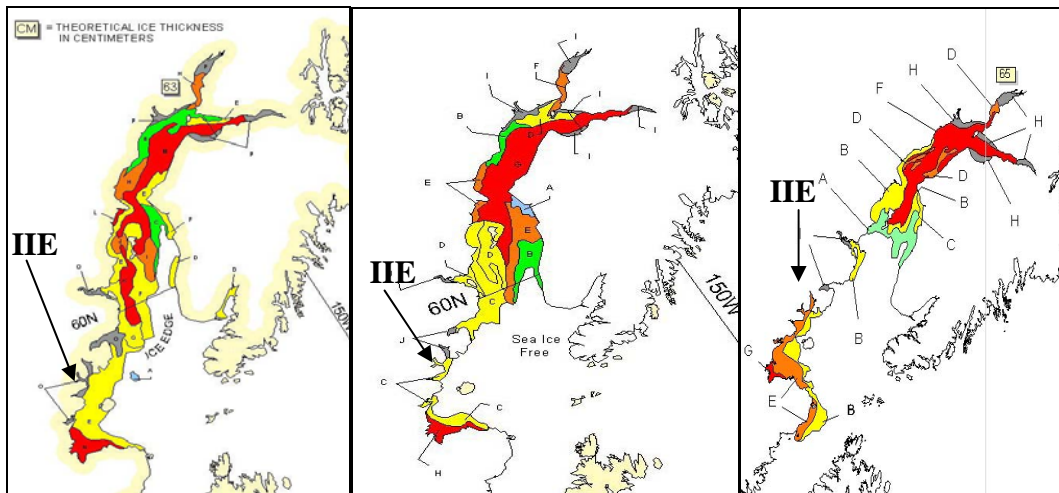
File: RDL_Pen_Seine_Trawl_Fig34-4_11X17P_1of1_D06.mxd	Date: July 8, 2011
Version: 6	Author: RDI - LS



January 19, 2001

February 22, 2002

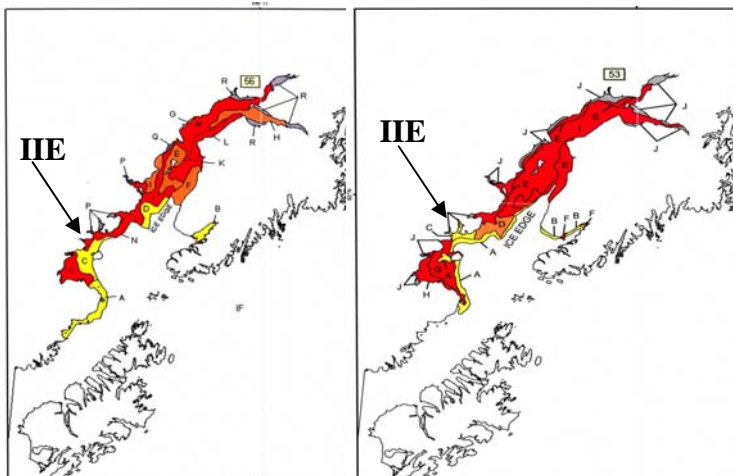
January 24, 2003



February 6, 2004

February 7, 2005

February 3, 2006



January 19, 2007

February 4, 2008

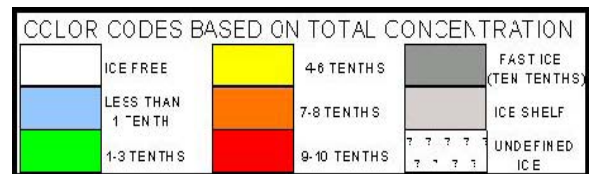
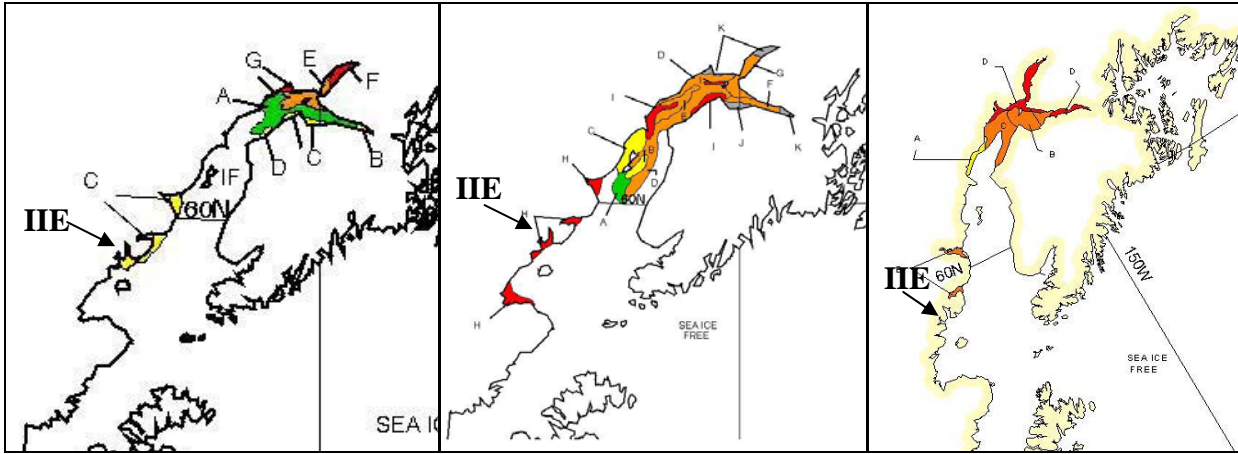


Figure 34-5a, Maximum Extent of Ice Pack in Cook Inlet, 2001-2008

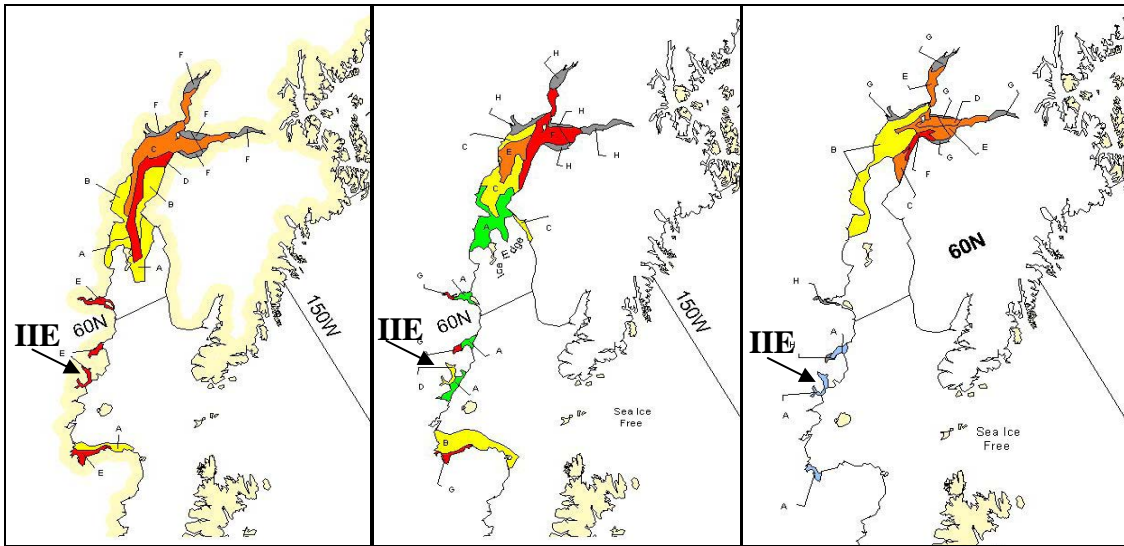
Notes: Not to scale; color codes depict percent ice cover of water surface.
 Source: NIC, 2009.



January 2001

January 2002

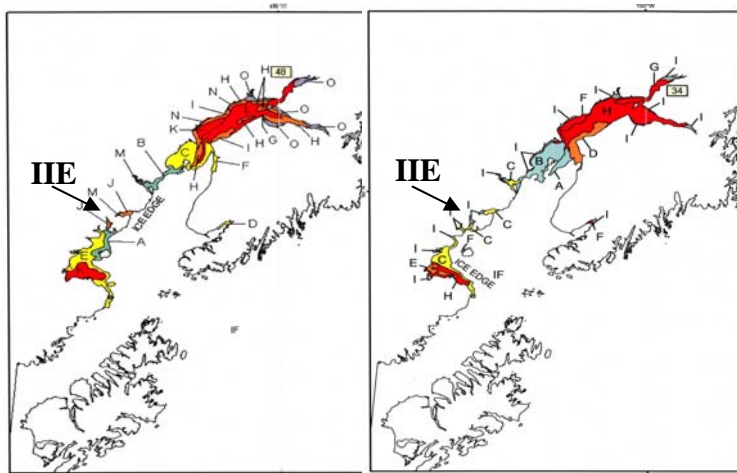
January 2003



January 2004

January 2005

January 2006



January 2007

January 2008

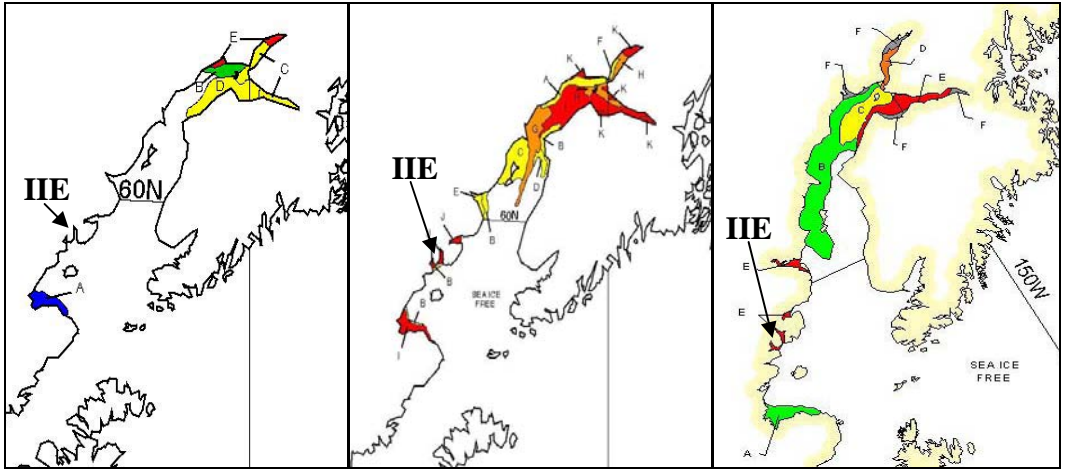


Figure 34-5b, Extent of Ice Pack in Cook Inlet, 1st Week of January 2001-2008

Notes: Not to scale; color codes depict percent ice cover of water surface.

Source: NIC, 2009.

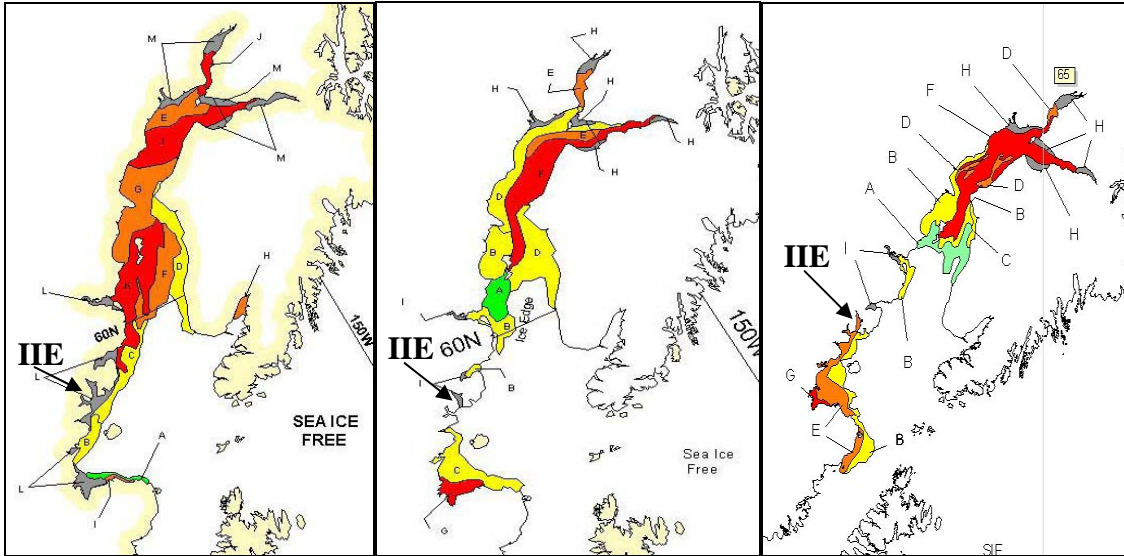
IIE: Iniskin/Iliamna Estuary



February 2001

February 2002

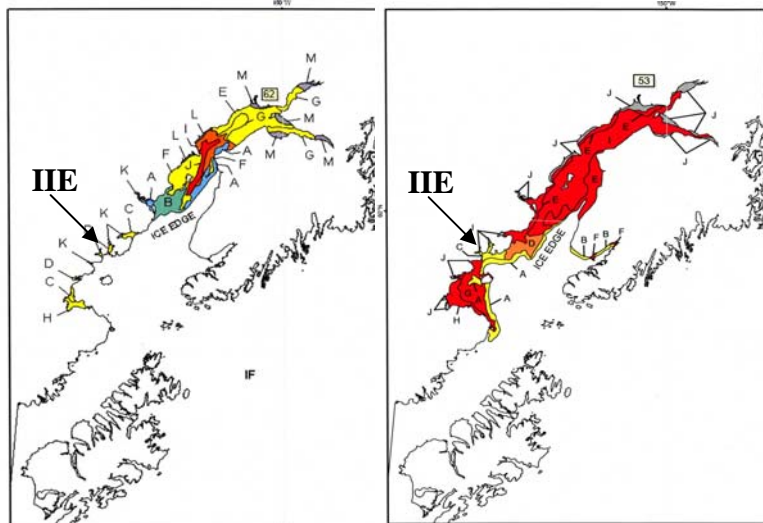
February 2003



February 2004

February 2005

February 2006



February 2007

February 2008

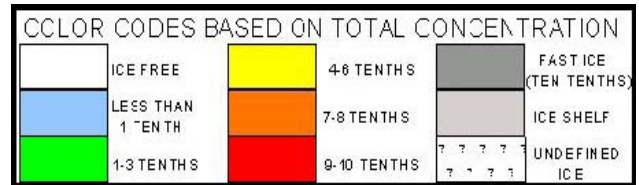
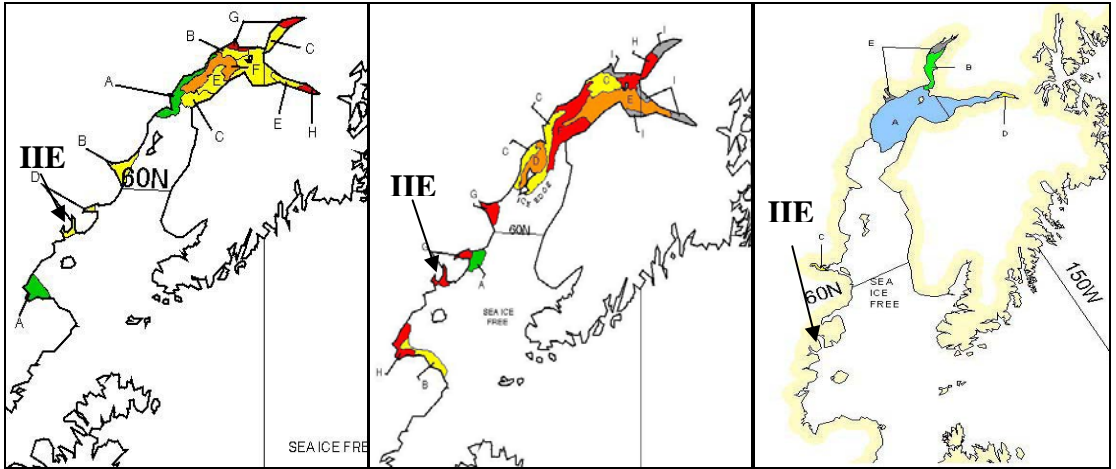


Figure 34-5c, Extent of Ice Pack in Cook Inlet, 1st Week of February 2001-2008

Notes: Not to scale; color codes depict percent ice cover of water surface.
 Source: NIC, 2009.

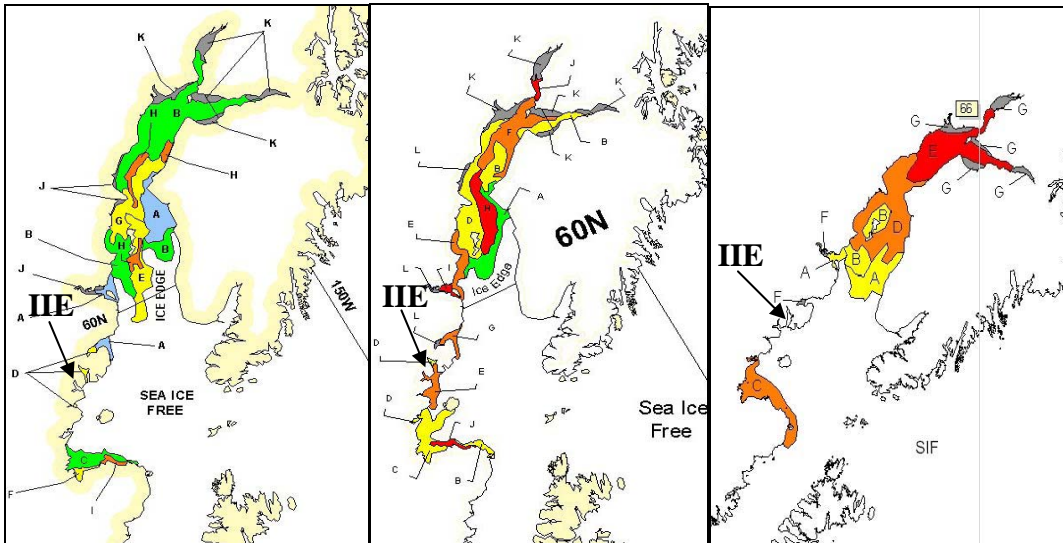
IIE: Iniskin/Iliamna Estuary



March 2001

March 2002

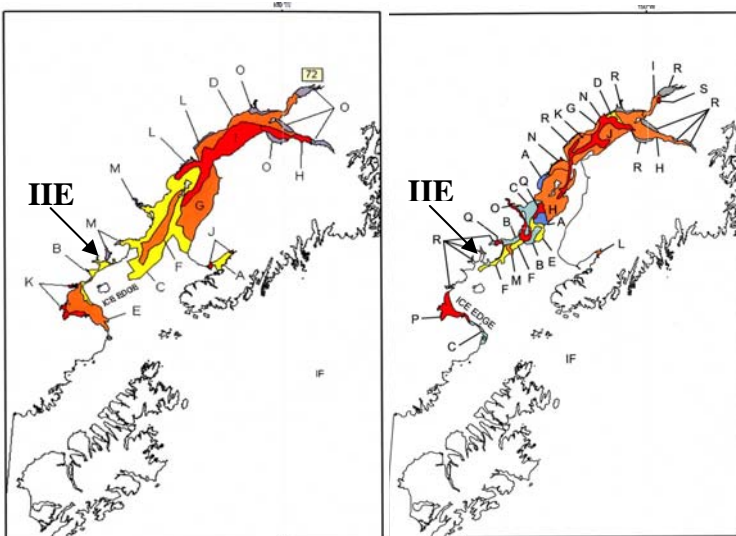
March 2003



March 2004

March 2005

March 2006



March 2007

March 2008

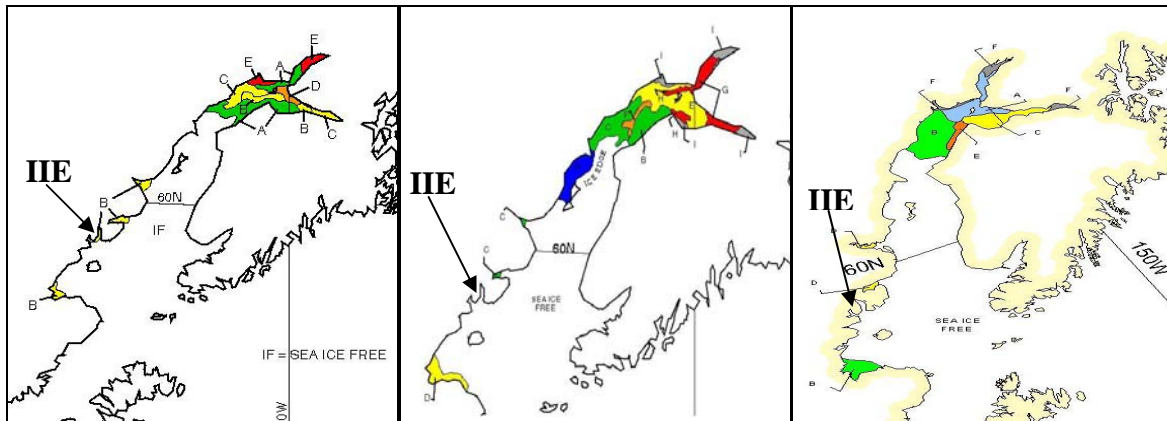
COLOR CODES BASED ON TOTAL CONCENTRATION			
ICE FREE	4-6 TENTHS	FAST ICE (TEN TENTHS)	
LESS THAN 1 TENTH	7-8 TENTHS	ICE SHELF	?
1-3 TENTHS	9-10 TENTHS	UNDEFINED ICE	?

Figure 34-5d, Extent of Ice Pack in Cook Inlet, 1st Week of March 2001-2008

Notes: Not to scale; color codes depict percent ice cover of water surface.

Source: NIC, 2009.

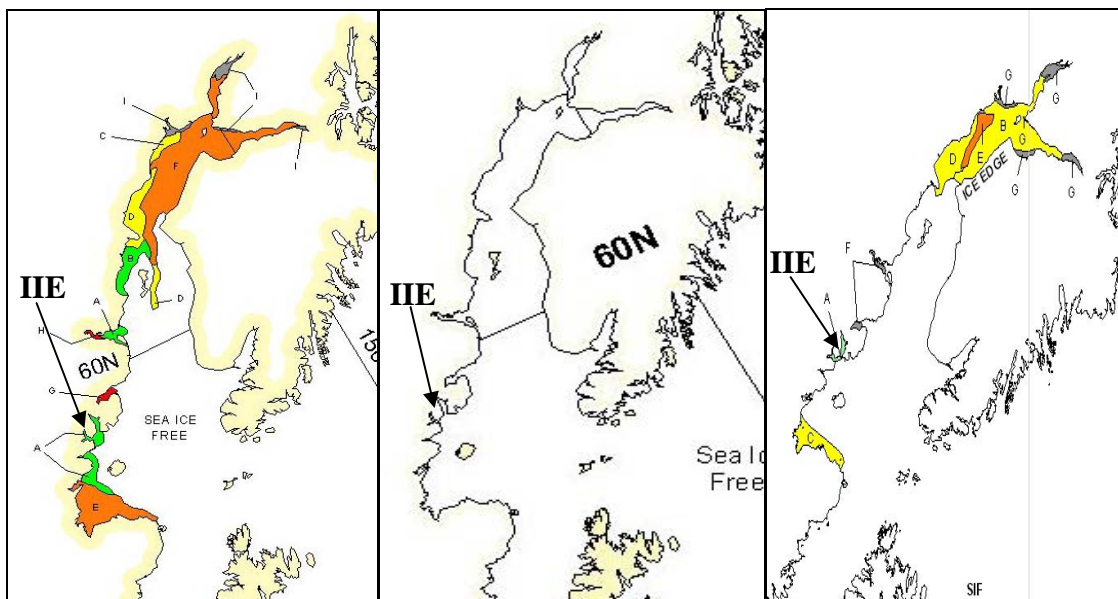
IIE: Iniskin/Iliamna Estuary



April 2001

April 2002

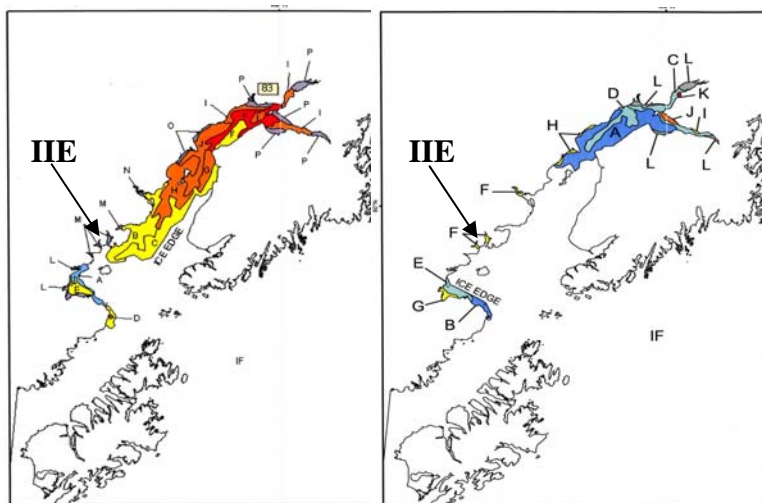
April 2003



April 2004

April 2005

April 2006



April 2007

April 2008

COLOR CODES BASED ON TOTAL CONCENTRATION					
ICE FREE	4-6 TENTHS	FAST ICE (TEN TENTHS)			
LESS THAN 1 TENTH	7-8 TENTHS	ICE SHELF			
1-3 TENTHS	9-10 TENTHS	UNDEFINED ICE			

Figure 34-5e, Extent of Ice Pack in Cook Inlet, 1st Week of April 2001-2008

Notes: Not to scale; color codes depict percent ice cover of water surface.

Source: NIC, 2009.

IIE: Iniskin/Iliamna Estuary

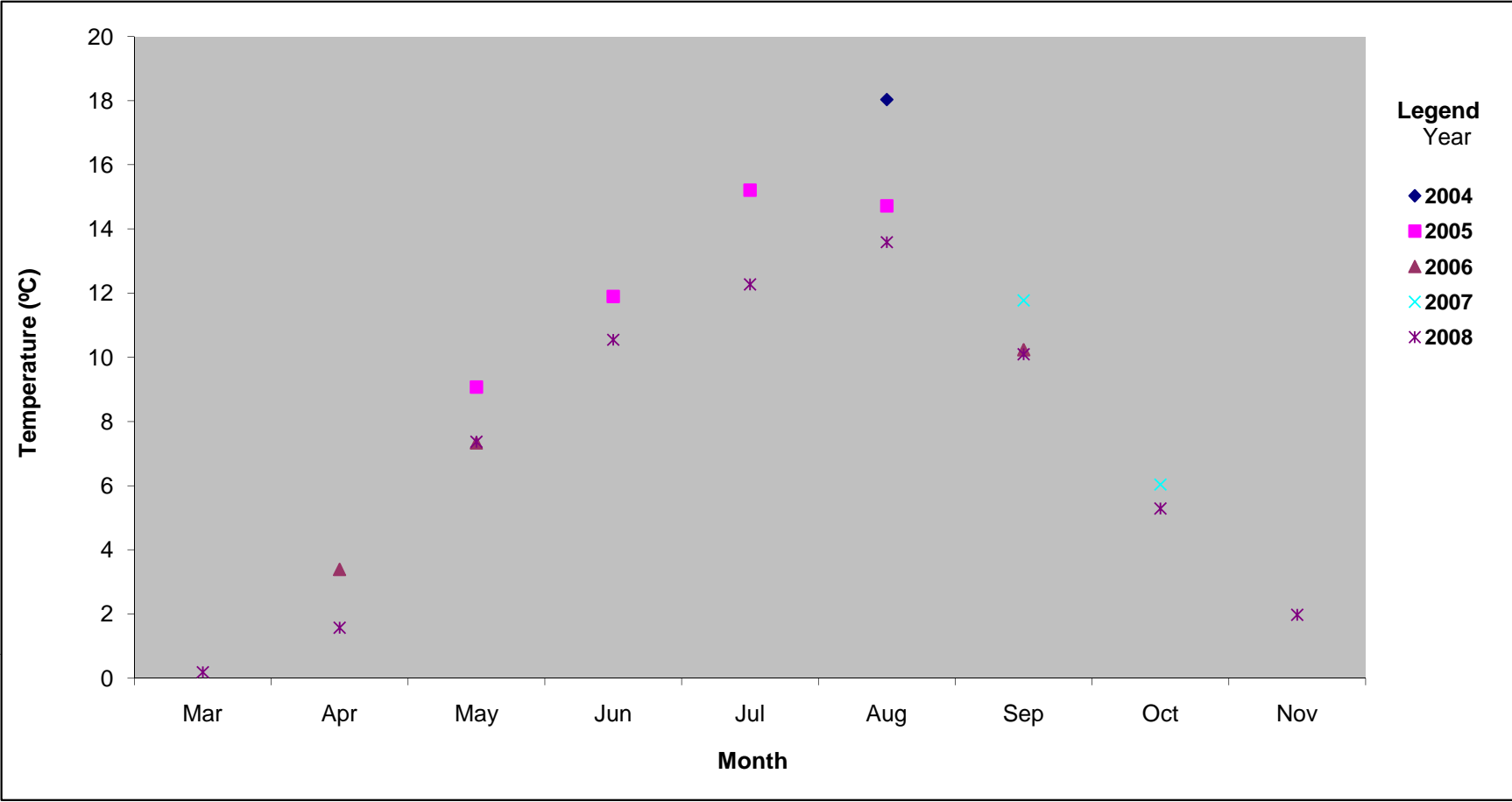


FIGURE 34-6
Monthly Mean Marine Water Quality Temperatures in Iliamna and Iniskin Bays Combined, 2004-2008

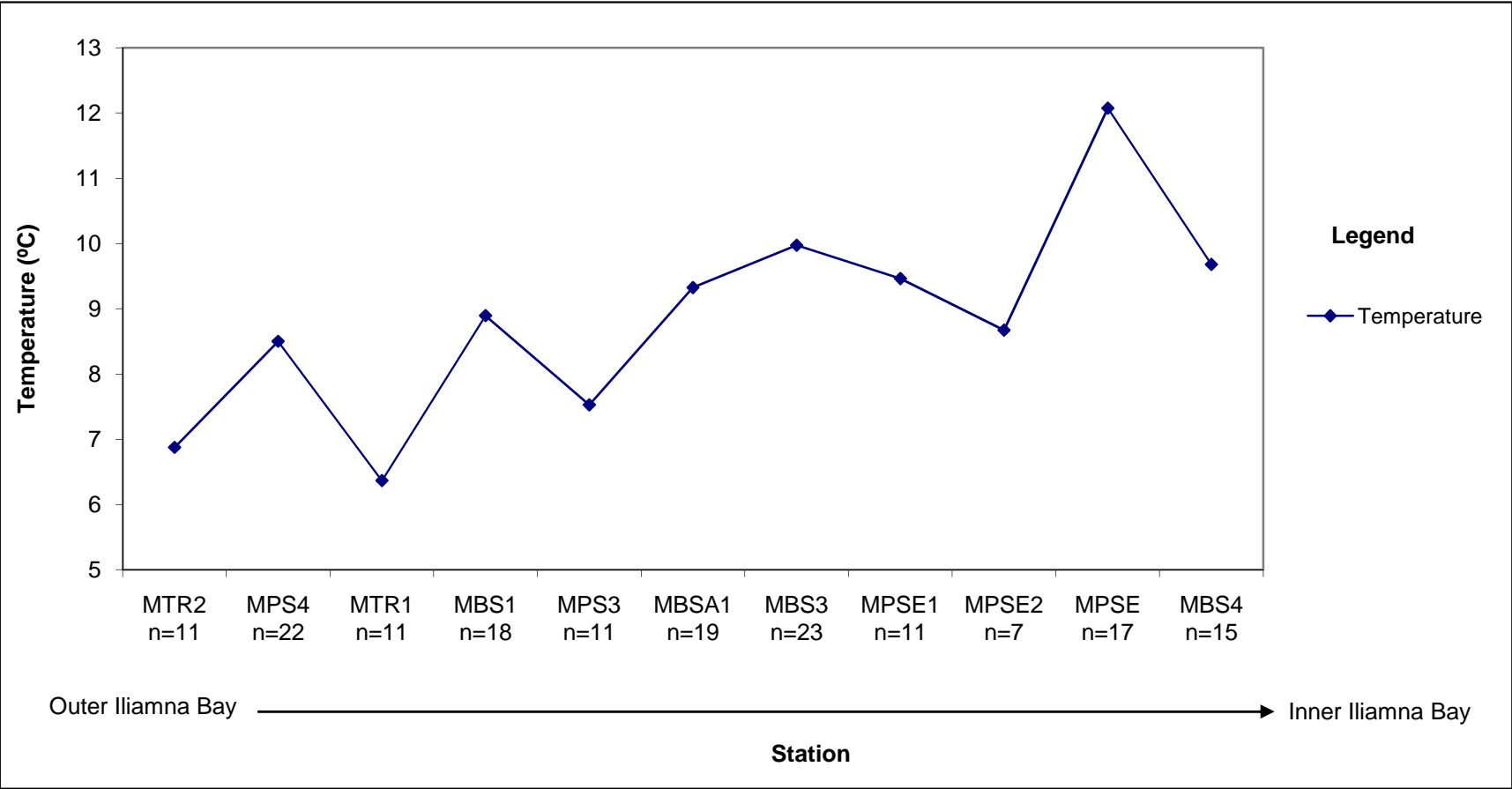


FIGURE 34-7

Mean Marine Water Temperatures in Iliamna Bay For Stations with Six or More Temperature Readings, 2004-2008

Notes: n = number of observations; °C = degrees Celsius; example of station identification label: MTR2.

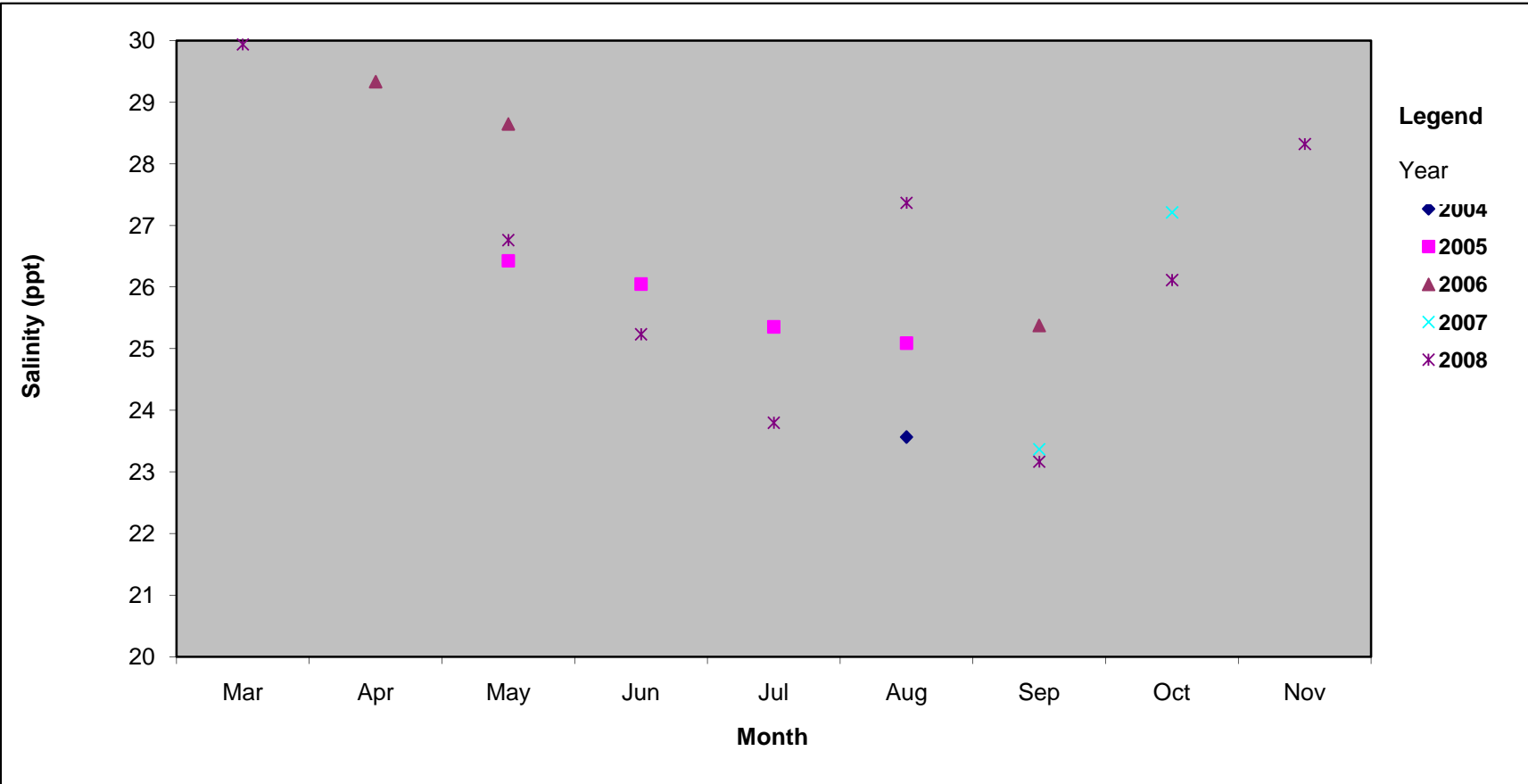


FIGURE 34-8
Monthly Mean Marine Water Salinity in Iliamna and Iniskin Bays Combined, 2004-2008
Note: ppt = parts per thousand.

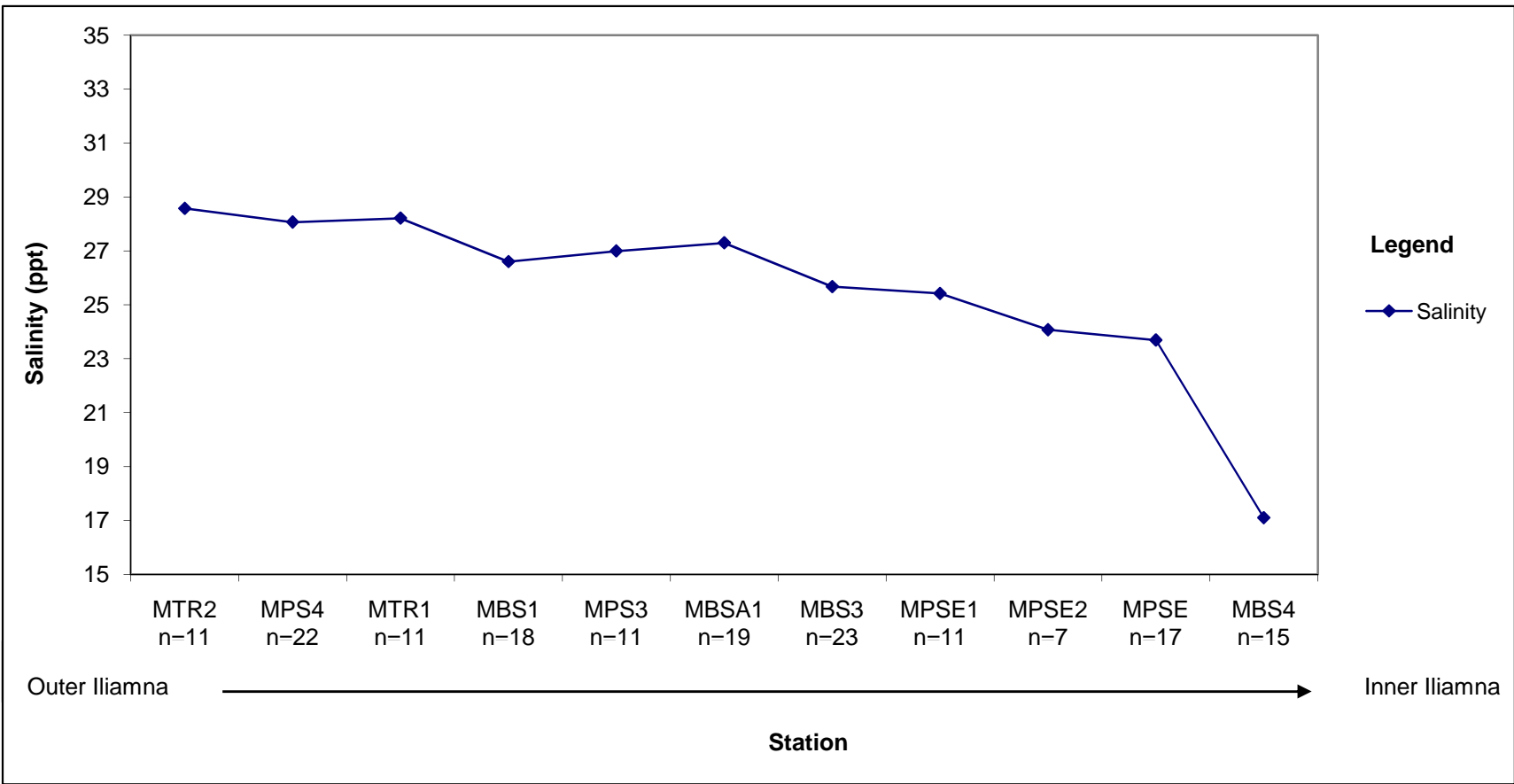


FIGURE 34-9
Mean Marine Water Salinity in Iliamna Bay for Stations with Six or More Measurements, 2004-2008

Notes: Stations presented by location in order of outer Iliamna Bay to inner Iliamna Bay.
ppt = parts per thousand; n = number of observations; sample station identification label: MTR2.
blue dot line ties mean salinity values together.

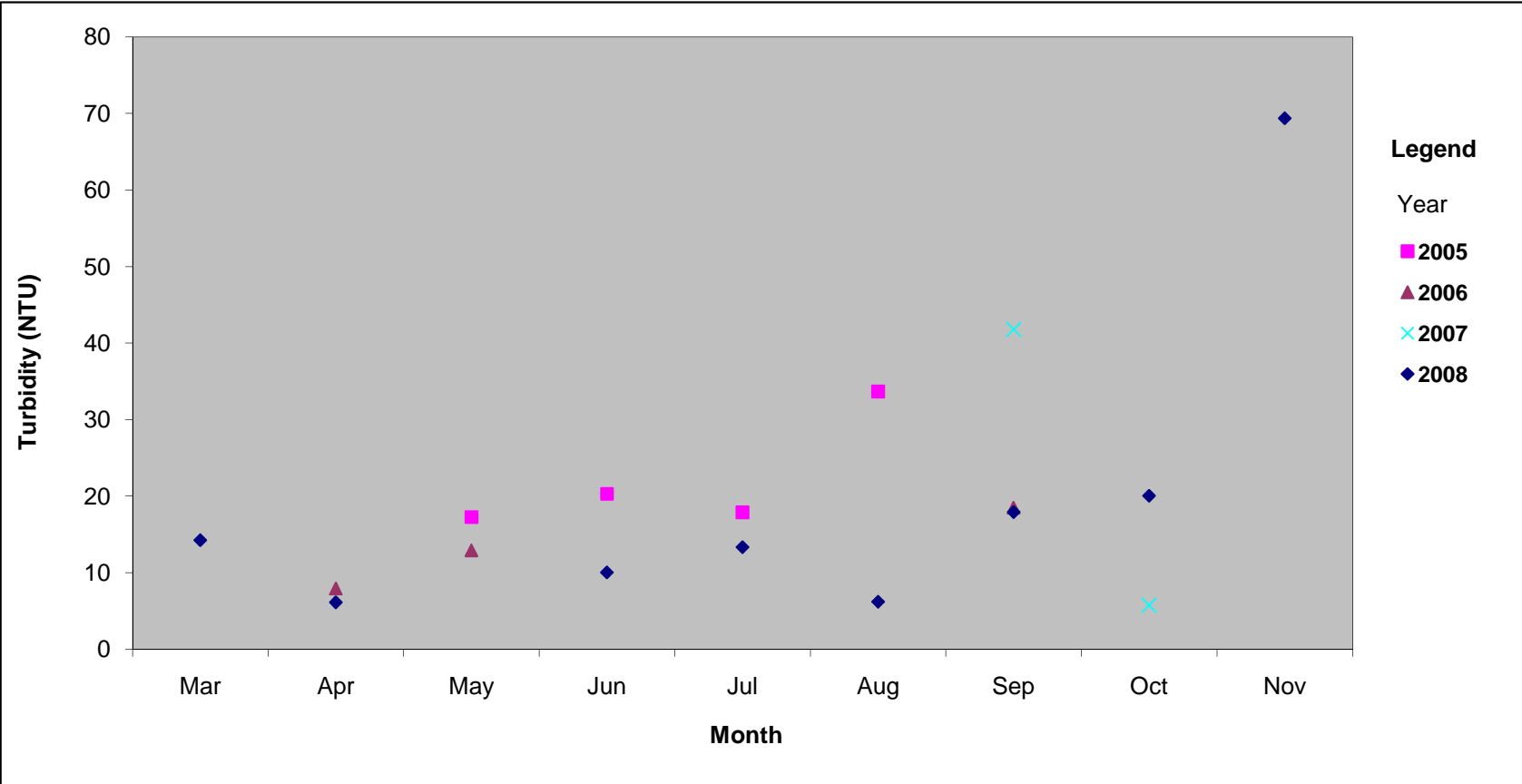


FIGURE 34-10a
Monthly Mean Marine Water Turbidity for Iliamna Bay, 2005-2008
Note: NTU = nephelometric turbidity units.

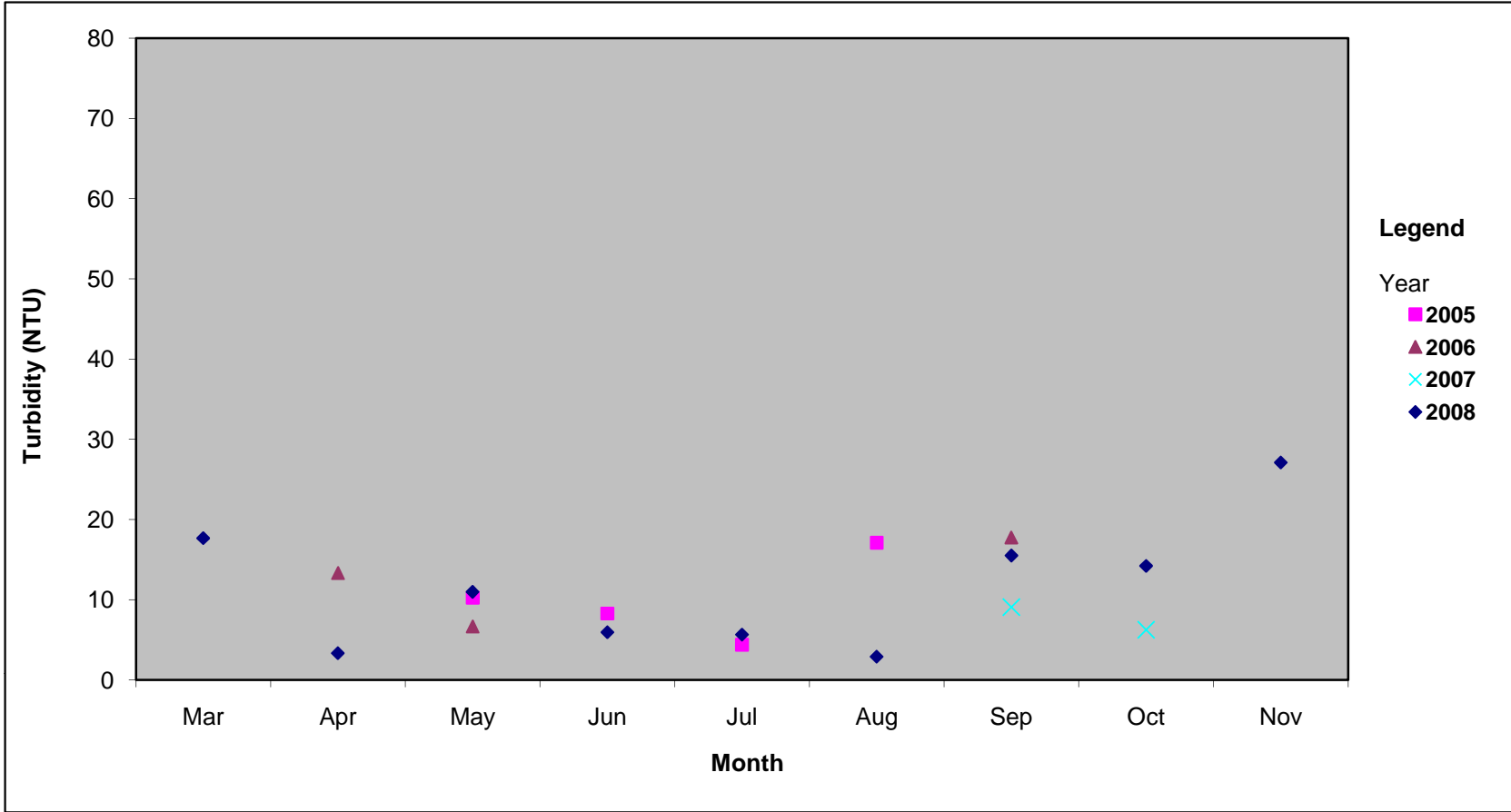


FIGURE 34-10b
Monthly Mean Marine Water Turbidity for Iniskin Bay, 2005-2008
Note: NTU = nephelometric turbidity units.

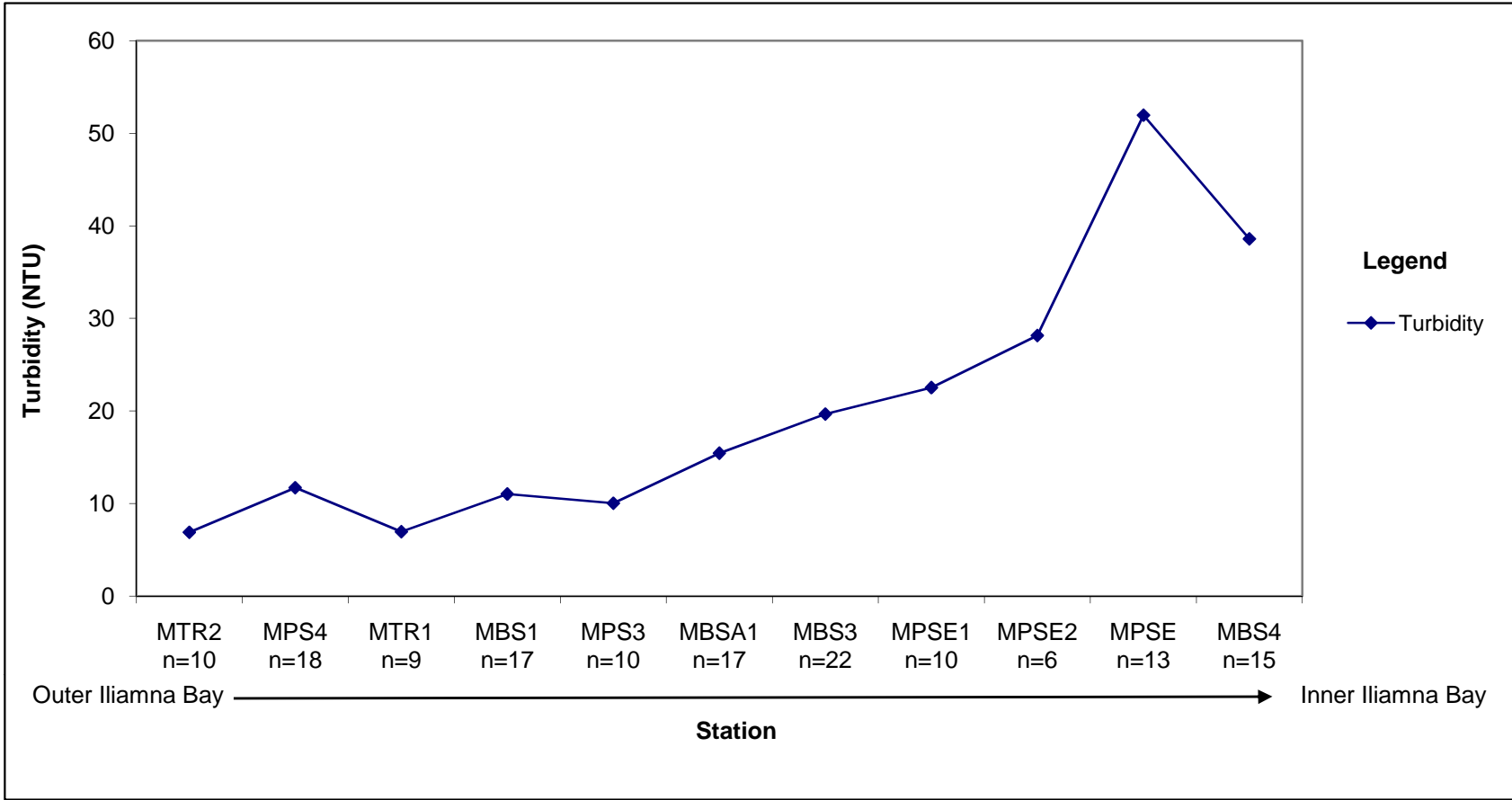


FIGURE 34-11

Mean Marine Water Turbidity in Iliamna Bay for Stations with Six or More Measurements, 2004-2008

Notes: Stations presented by location in order of outer Iliamna Bay to inner Iliamna Bay.

NTU = nephelometric turbidity units; n = number of observations; sample station identification label: MTR2.

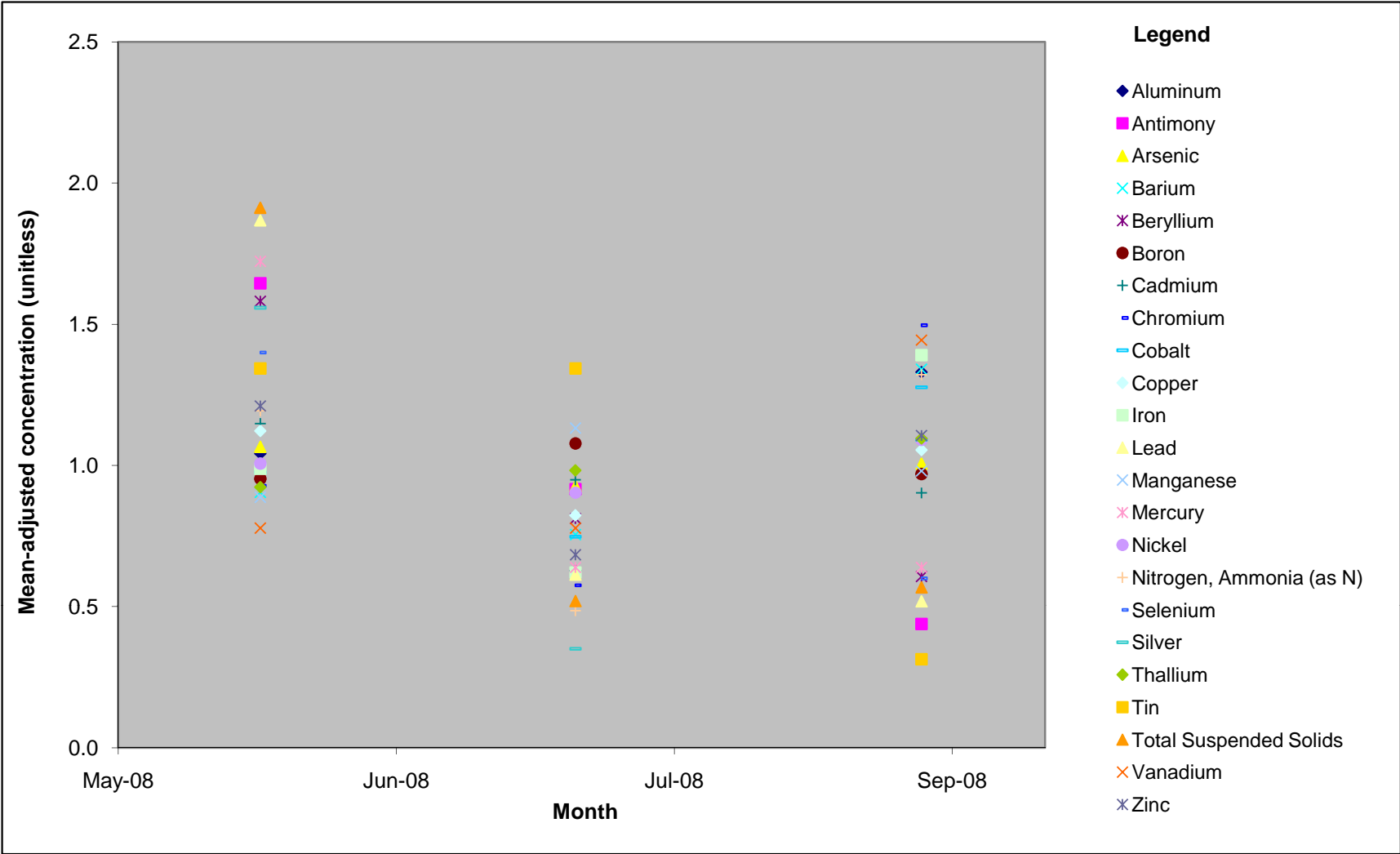


FIGURE 34-12
Seasonal Variation in Inorganic Constituents in Marine Water, Iliamna and Iniskin Bays Combined, 2008

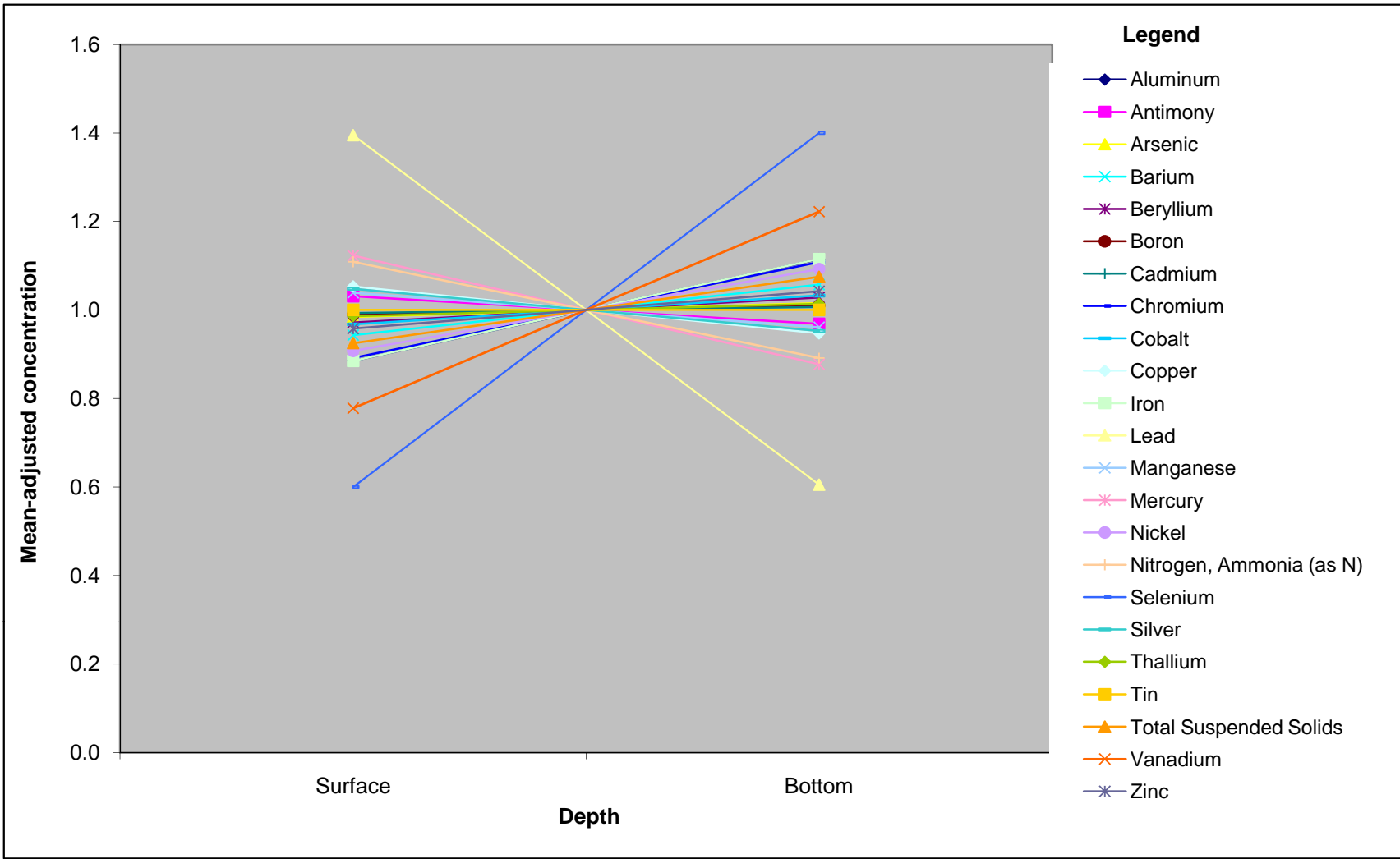


FIGURE 34-13
Depth Variation in Inorganic Constituents in Marine Water, Iliamna and Iniskin Bays Combined, May, July, and September 2008
Note: Lines included only as an aid to locate points; they have no quantitative meaning.

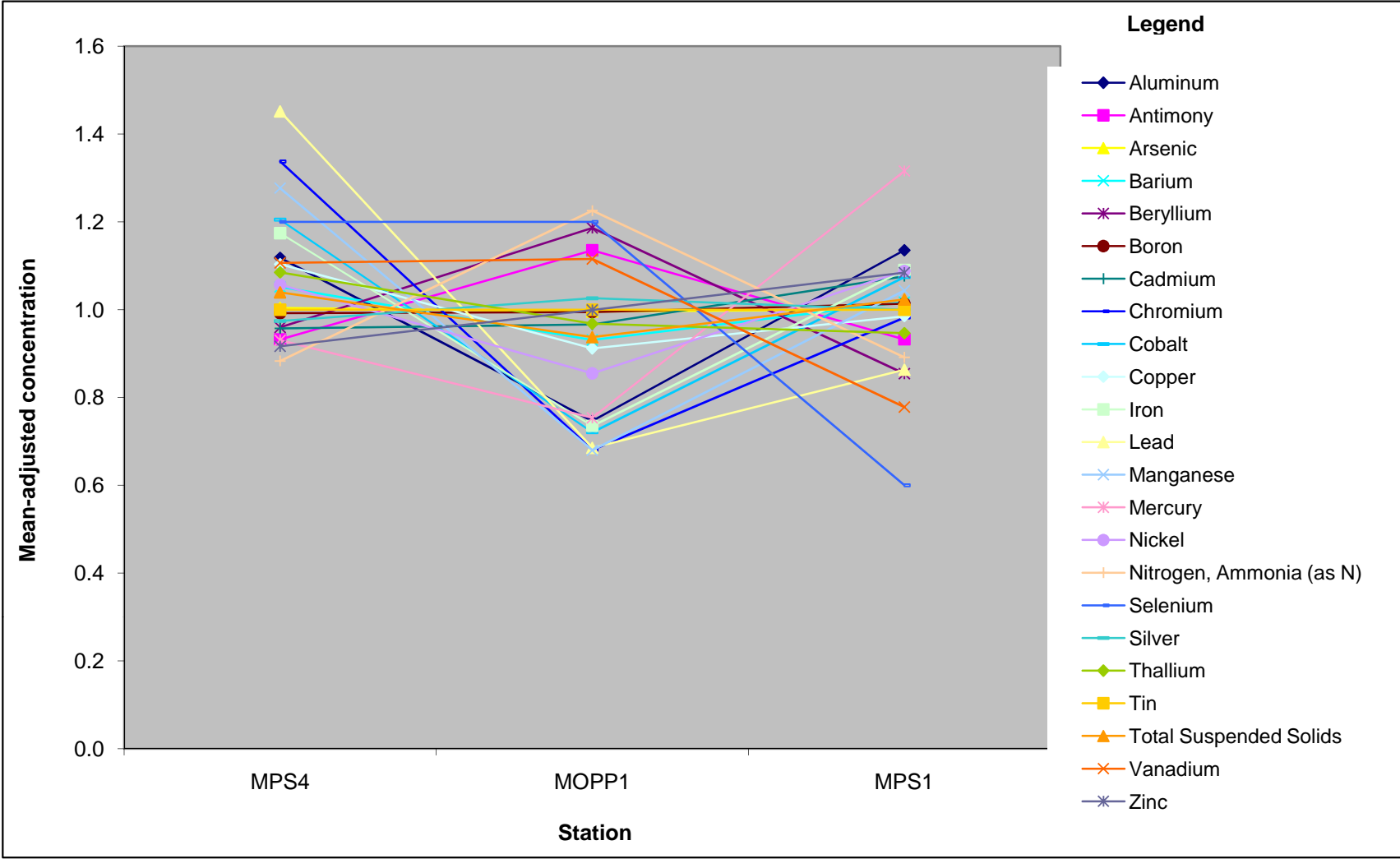


FIGURE 34-14
Geographical Variation of Inorganic Constituents in Marine Water, Combined over Depth and Time, 2008

Note: Lines included only as an aid to locate points; they have no quantitative meaning.

Sample station identification label: MPS4.

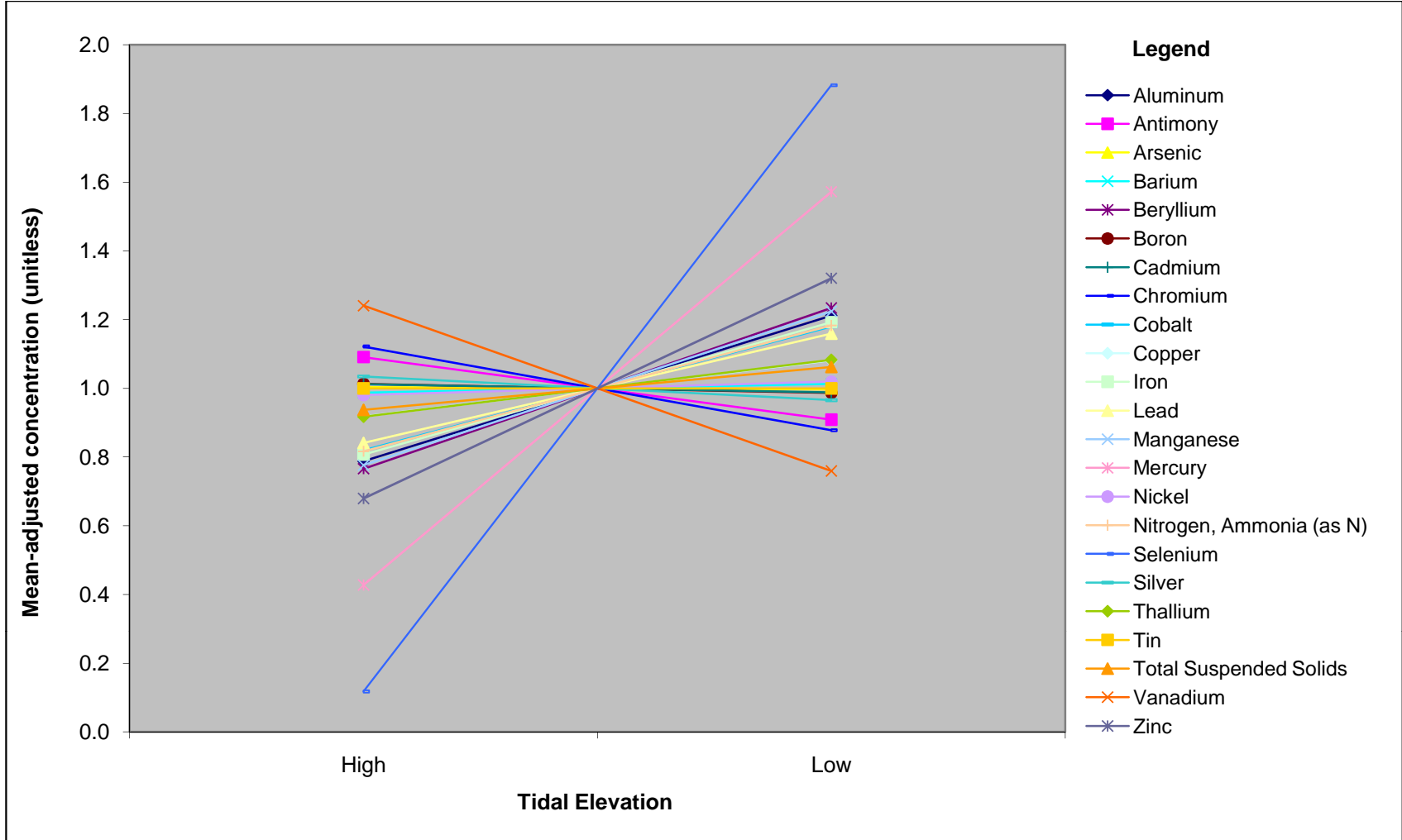


FIGURE 34-15
Tidal Variation of Inorganic Constituents in Marine Water, Iliamna and Iniskin Bays Combined, May, July and September 2008

APPENDIX A

Laboratory Statement on Marine Surface Water Analyses

Appendix A

Laboratory Statement on Marine Surface Water Analyses

Bruce Rummel

From: Crupi, Steve (Anchorage) [Steve.Crupi@sgs.com]
Sent: Sunday, 20 August 2006 17:52
To: Whitsett, Jane; Homestead, Charles (Anchorage)
Cc: Mapes, Sandy; Ella Ede, Jon Houghton; Bruce Rummel; Hall, Heather (Anchorage); Waak, Karen (Anchorage); Wesley, William (Anchorage)
Subject: Pebble Project: 2004 Marine Water Quality Data

SGS utilized EPA Methods 200.2 and 200.8 for sample preparation and analysis, respectively.

At the start of the 2004 sampling season for the project, SGS implemented a couple of changes to the preparation technique parameters intended for all project water samples in an effort to improve overall method sensitivity, thus lowering the reporting limits. The changes included using a 250 mL initial sample volume and a 25 mL final digestate volume. The main difference was the new initial volume amount as 50 mL was the routine. This change increased the microgram (µg) amount of metals present in the digestate being analyzed on the ICPMS. However, increasing the initial volume also raised the possible amount of potential analytical interferences in the digestate such as the salt metals (Ca, K, Na, Mg), dissolved solids, chloride, and sulfate.

Past experiences with testing sea water raised concern at SGS when the 2004 Marine Sampling Program was scheduled. A decision was made to reduce the initial sample volume to 50 mL for the water samples from this program in an effort to reduce the µg amount of interferences in the digestate. The salt metals, sodium, potassium, magnesium, and calcium are known to be high in concentration in sea water. The concentrations are such that if analyzed without dilution, they would saturate the instrument components, resulting in carryover to other samples, and requiring significant down time for maintenance and cleaning. The reduction in initial volume from 250 mL, a parameter established specifically for the overall project, essentially incorporated a 5-fold dilution factor. Additional dilution steps were used at the instrument to further mitigate the salt and other interferent content of the samples.

Comparison of the primary lab (SGS) data to the QA lab (CAS) data suggests that the primary lab data is biased high for select metals. The example elements of arsenic, copper, nickel, thallium, and selenium are summarized in the table in Sandy Mapes' 8/01/06 email attachment and arsenic, copper, nickel, and selenium in Jane Whitsett's 8/09/06 email. Review of the data from SDG 1065704 (marine water samples) demonstrates that essentially along with the salt metals, these are the only elements consistently exhibiting a significant level of detection in the water samples. The other elements are essentially not detected in the samples. Reviewing the metals consistently detected in the water samples (arsenic, copper, nickel, selenium, calcium, magnesium potassium, and selenium) and also chloride and sulfate, I made a comparison of SGS data between a primary sample and field duplicate set (see below).

RPD	Parameter	units	Primary Sample Result	Field Duplicate Result	
	Arsenic	µg/L	38.9	58.6	40
	Calcium	µg/L	249000	263000	5
	Copper	µg/L	16.9	21.6	24
	Magnesium	µg/L	893000	1020000	13
	Sodium	µg/L	7520000	8500000	12
	Nickel	µg/L	32.9	35.3	7
	Potassium	µg/L	243000	262000	7
	Selenium	µg/L	154	186	19
	Chloride	mg/L	18700	14000	29
	Sulfate	mg/L	4110	3780	8

Of these detected metals, the RPD comparison of the primary sample and the field duplicate shows only two of the metals outside of the method prescribed RPD criterion (20%).

I also reviewed SGS matrix spike (MS) and matrix spike duplicate (MSD) recovery and precision data, which are laboratory generated quality control (QC) samples. Recovery outliers occurred mostly with the salts (sodium, magnesium,

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potassium, calcium) while RPD outliers appear to affect more of the metals. The corrective action step performed in response to the outliers, a post digestion spike analysis, consistently yielded recoveries within the method prescribed QC limits.

The data suggest sample nonhomogeneity with respect to the salt content of the sample with the high chloride content as an interferent affecting data precision. The non-salt metals, for example copper, nickel, and selenium demonstrate acceptable quality results for recovery and precision. The data further suggest that matrix related effects on the data are somewhat mitigated by use of dilution, prep and analytical, but not completely. This data, combined with other internal quality control parameters (e.g. blanks, control spikes, post digestion spike analysis), also suggest that the method worked in terms of performance as it was employed. However, as discussed below, it may not have best characterized the samples.

The QA lab (CAS) describes their preparation and analysis procedures for the Marine Water Quality Sample as follows –

In a marine water, isobaric interferences result in false positive concentrations. These isobaric interferences cannot be remedied via dilution. The procedure CAS used for the metals analysis in the marine water was the reductive precipitation technique. The procedure incorporates a chemical separation to remove interfering matrix components so final analysis can be performed using inductively coupled plasma-mass spectroscopy (ICP-MS). The separation utilizes reduction of certain target analytes to the elemental state and precipitation of others as the boride depending on reduction potentials and/or boride solubility. The precipitation is facilitated using elemental palladium and iron boride as carriers. Once separated from the seawater matrix via centrifugation, the precipitate is re-dissolved and analyzed using ICP-MS. Selenium is typically analyzed using GFAAS because of uncorrectable isobaric interferences when using ICP-MS (even with reductive precipitation preparation).

The agreement of the QA lab's (CAS) data to the referenced guideline "Recommended guidelines for Measuring Metals in Puget Sound Marine Water, Sediment and Tissue Samples" may suggest their described preparation and analysis scenario provides a means that effectively and more completely mitigates marine water matrix interferences and accurately characterizes the sample. Indeed, development work SGS conducted in November of 2004 demonstrated improved performance. If the Puget Sound research data best describes sea water the world round, one can then draw the conclusion the techniques employed by the QA lab is a better choice for characterizing the marine water samples for the Pebble Project. Based on history, the comparison of the SGS and CAS data and the development SGS conducted later on, it seems to make sense that all future data generated for the marine water program be done by the technique, or something similar, that CAS employed. Still, some reservation remains in my mind, since the subject samples were not collected from Puget Sound, this discussion and prior discussions are based on data gleaned from analyzing a very small pool of four (4) samples, and intuitively it seems there are influences unique to sea water in and around Alaska (e.g. glacial silt), I have to fall short of making any definitive statements regarding whether one scenario is better than the other. Admittedly, I do not have expertise in the testing of sea water, but I still draw hesitation regarding making decision based on data gathered from four sampling locations.

Steve

Steven R. Crupi
Project Manager
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From: Whitsett, Jane [mailto:Jane.Whitsett@shawgrp.com]
Sent: Wednesday, August 09, 2006 3:00 PM
To: Crupi, Steve (Anchorage); Homestead, Charles (Anchorage)
Cc: Mapes, Sandy; Ella Ede; Jon Houghton; Bruce Rummel; Whitsett, Jane
Subject: 2004 Marine Water Quality Data
Importance: High

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Steve,

Shaw and Pentec have conducted reviews of the 2004 marine water quality data for the Pebble Project (summary table is attached). Our findings indicate discrepancies between the primary (SGS) lab's analyses of the water samples and the QA (CAS) lab's for trace elements. Further, the primary lab's results appear to be substantially higher than the QA lab's for a number of trace elements (examples would be arsenic, copper, nickel, and selenium). Also, the QA lab's results were in the range of literature values for open-ocean water for the four examples above, while the primary lab's results were one to two orders of magnitude higher.

See the reference "Recommended Guidelines for Measuring Metals in Puget Sound Marine Water, Sediment and Tissue Samples" at www.psat.wa.gov/Publications/protocols/protocol_pdfs/metals.pdf

In this guideline see Table 3 for ambient concentrations. You will find that the QA lab (CAS) has comparable numbers with ambient concentrations. For the marine waters by primary lab (SGS) the results are over a magnitude greater.

These discrepancies may be due to the different methodologies employed for trace elements in sea water to reduce interference due to the salt matrix. CAS uses a reductive precipitation method based on Puget Sound protocols whereas SGS used a 20 times sample dilution.

We are requesting SGS to prepare a memorandum to Shaw discussing the trace element results in light of the differing methodologies employed for the primary and QA samples.

Please include the following information:

- What techniques of preparation or analysis were used for these samples?
- What is the level of confidence in each technique?
- A brief narrative statement on why the analysis does not compare to QA or literature values for sea water
- A brief narrative statement on the recoverability of data.

We anticipate a table and two to three paragraphs to address this information, but if more is supplied that's fine. SGS has been responsive to our observations on this data to which I very much appreciated.

We look forward to receiving your memorandum within a week from today and resolving this matter soon.

Best Regards,

Jane Whitsett
Sr. Environmental Scientist
Shaw Alaska, Inc.
2000 W. International Airport Road, Suite C-1
Anchorage, Alaska 99502
907-249-6333 direct line
907-223-0393 cell
907-249-6301 fax
www.shawgrp.com

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APPENDIX B

Laboratory Data Summary for Trace Elements in

Marine Water (2004, 2008)

**2004-2008 Pebble Project Marine Study
Ocean Water Laboratory Results Summary**

Parameters	Hardness	Total Suspended Solids		Chloride	Sulfate	Total Cyanide	Total Ammonia	Aluminum		Antimony		Arsenic		Barium		Beryllium		Bismuth		Boron		Cadmium	
		Total/Dissolved	mg/L					mg/L	mg/L	mg/L	mg/L	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Station: MOPP1																							
Sample A: Surface																							
Sample Date																							
05/28/08		56					0.025	150	25	0.5	0.5	1.45	1.43	4.8	4.3	0.01	0.01			2920	2960	0.06	0.06
07/18/08		10					0.027	55	15	0.42	0.41	1.35	1.32	4.5	4.3	0.01	0.02105			3220	3280	0.055	0.05
09/16/08		12					0.039	171	15	0.1	0.1	1.41	1.36	7.3	6.9	0.002	0.0005			2860	2880	0.051	0.047
Mean		26					0.030	125	18	0.34	0.34	1.40	1.37	5.5	5.2	0.007	0.011			3000	3040	0.06	0.05
Median		12					0.027	150	15	0.42	0.41	1.41	1.36	4.8	4.3	0.01	0.01			2920	2960	0.055	0.05
St. Deviation		26					0.008	62	6	0.21	0.21	0.05	0.06	1.5	1.5	0.005	0.010			193	212	0.00	0.01
# of values	0	3	0	0	0		3	3	3	3	3	3	3	3	3	3	3	0	0	3	3	3	3
Minimum		10					0.025	55	15	0.1	0.1	1.35	1.32	4.5	4.3	0.002	0.0005			2860	2880	0.051	0.047
Maximum		56					0.039	171	25	0.5	0.5	1.45	1.43	7.3	6.9	0.01	0.02105			3220	3280	0.06	0.06
% of values undetected							33%		100%	67%	67%					67%	100%						
# of values between MDL and MRL							2			1	1			2	2	1							
NOAA SQuiRT Criteria Limit							0.795			500	500	36	36	200	200	100	100			1200	1200	8.8	8.8

Station: MOPP1																							
Sample C: Near Bottom																							
Sample Date																							
05/28/08		60					0.025	163	51	0.5	0.2	1.53	1.48	5.3	4.1	0.01	0.01			2960	2930	0.06	0.059
07/18/08		18					0.018	141	15	0.45	0.2	1.28	1.36	4.9	4.1	0.01				3250	3190	0.056	0.049
09/16/08		19					0.020	274	15	0.1	0.1	1.49	1.45	8.6	6.9	0.003	0.0005			3020	3020	0.052	0.052
Mean		32					0.021	193	27	0.35	0.17	1.43	1.43	6.3	5.0	0.008	0.005			3077	3047	0.06	0.05
Median		19					0.02	163	15	0.45	0.2	1.49	1.45	5.3	4.1	0.01	0.00525			3020	3020	0.056	0.052
St. Deviation		24					0.004	71	21	0.22	0.06	0.13	0.06	2.0	1.6	0.004	0.007			153	132	0.00	0.01
# of values	0	3	0	0	0		3	3	3	3	3	3	3	3	3	3	2	0	0	3	3	3	3
Minimum		18					0.018	141	15	0.1	0.1	1.28	1.36	4.9	4.1	0.003	0.0005			2960	2930	0.052	0.049
Maximum		60					0.025	274	51	0.5	0.2	1.53	1.48	8.6	6.9	0.01	0.01			3250	3190	0.06	0.059
% of values undetected							33%		67%	67%	100%					67%	100%						
# of values between MDL and MRL							2			1				1	2	1							
NOAA SQuiRT Criteria Limit							0.795			500	500	36	36	200	200	100	100			1200	1200	8.8	8.8

Station: MPS1																							
Sample A: Surface																							
Sample Date																							
05/25/08		59					0.025	202	15	0.5	0.5	1.49	1.41	5.6	4.5	0.01	0.01			2880	2900	0.073	0.068
07/14/08		13					0.004	101	38	0.2	0.2	1.29	1.22	4.2	4.4	0.0012	0.0002			3320	3340	0.054	0.053
09/15/08		19					0.031	324	15	0.2	0.2	1.34	1.49	8.5	6.8	0.004	0.0005			3020	3030	0.056	0.052
Mean		30					0.020	209	23	0.30	0.30	1.37	1.37	6.1	5.2	0.005	0.004			3073	3090	0.06	0.06
Median		19					0.025	202	15	0.2	0.2	1.34	1.41	5.6	4.5	0.004	0.0005			3020	3030	0.056	0.053
St. Deviation		25					0.014	112	13	0.17	0.17	0.10	0.14	2.2	1.4	0.004	0.006			225	226	0.01	0.01
# of values	0	3	0	0	0		3	3	3	3	3	3	3	3	3	3	3	0	0	3	3	3	3
Minimum		13					0.004	101	15	0.2	0.2	1.29	1.22	4.2	4.4	0.0012	0.0002			2880	2900	0.054	0.052
Maximum		59					0.031	324	38	0.5	0.5	1.49	1.49	8.5	6.8	0.01	0.01			3320	3340	0.073	0.068
% of values undetected							67%		67%	67%	67%					33%	100%						
# of values between MDL and MRL							1		1	1	1			1	2	2							
NOAA SQuiRT Criteria Limit							0.795			500	500	36	36	200	200	100	100			1200	1200	8.8	8.8

**2004-2008 Pebble Project Marine Study
Ocean Water Laboratory Results Summary**

Parameters Total/Dissolved Units	Calcium		Chromium		Cobalt		Copper		Iron		Lead		Magnesium		Manganese		Mercury	Molybdenum		Nickel	
	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	
Station: MOPP1																					
Sample A: Surface																					
Sample Date																					
05/28/08			0.4	0.1	0.11	0.043	0.96	0.49	207	35.6	0.222	0.073			8.8	5.3	0.00104			0.68	0.55
07/18/08			0.3	0.21	0.075	0.021	1.06	0.69	122	31.7	0.221	0.086			6.3	2.1	0.0005			0.61	0.49
09/16/08			0.37	0.22	0.162	0.067	1.01	0.666	263	35.3	0.279	0.068			8.4	3.3	0.0005			0.65	0.48
Mean			0.36	0.18	0.116	0.044	1.01	0.62	197	34	0.241	0.076			7.8	3.6	0.00068			0.65	0.51
Median			0.37	0.21	0.11	0.043	1.01	0.666	207	35.3	0.222	0.073			8.4	3.3	0.0005			0.65	0.49
St. Deviation			0.05	0.07	0.044	0.023	0.05	0.11	71	2	0.033	0.009			1.3	1.6	0.00031			0.04	0.04
# of values	0	0	3	3	3	3	3	3	3	3	3	3	0	0	3	3	3	0	0	3	3
Minimum			0.3	0.1	0.075	0.021	0.96	0.49	122	31.7	0.221	0.068			6.3	2.1	0.0005			0.61	0.48
Maximum			0.4	0.22	0.162	0.067	1.06	0.69	263	35.6	0.279	0.086			8.8	5.3	0.00104			0.68	0.55
% of values undetected				67%		33%											67%				
% of values between MDL and MRL																2					
NOAA SQuiRT Criteria Limit			50	50	1	1	3.1	3.1	50	50	8.1	8.1			100	100	0.94			8.2	8.2

Station: MOPP1																					
Sample C: Near Bottom																					
Sample Date																					
05/28/08			0.32	0.1	0.108	0.035	1.1	0.56	204	36.5	0.41	0.095			6.8	2.5	0.0005			0.87	0.5
07/18/08			0.21	0.1	0.073	0.051	1	0.73	221	34.4	0.174	0.05			8.2	1.9	0.0005			0.49	0.58
09/16/08			0.41	0.27	0.195	0.043	1.19	0.658	442	34.4	0.124	0.026			11	1.1	0.0005			0.77	0.52
Mean			0.31	0.16	0.125	0.043	1.10	0.65	289	35	0.236	0.057			8.7	1.8	0.00050			0.71	0.53
Median			0.32	0.1	0.108	0.043	1.1	0.658	221	34.4	0.174	0.05			8.2	1.9	0.0005			0.77	0.52
St. Deviation			0.10	0.10	0.063	0.008	0.10	0.09	133	1	0.153	0.035			2.1	0.7	0.00000			0.20	0.04
# of values	0	0	3	3	3	3	3	3	3	3	3	3	0	0	3	3	3	0	0	3	3
Minimum			0.21	0.1	0.073	0.035	1	0.56	204	34.4	0.124	0.026			6.8	1.1	0.0005			0.49	0.5
Maximum			0.41	0.27	0.195	0.051	1.19	0.73	442	36.5	0.41	0.095			11	2.5	0.0005			0.87	0.58
% of values undetected				67%												33%	100%				
% of values between MDL and MRL																2					
NOAA SQuiRT Criteria Limit			50	50	1	1	3.1	3.1	50	50	8.1	8.1			100	100	0.94			8.2	8.2

Station: MPS1																					
Sample A: Surface																					
Sample Date																					
05/25/08			0.42	0.1	0.165	0.062	1.45	0.86	311	39.1	0.58	0.203			13	7.1	0.00265			0.76	0.59
07/14/08			0.24	0.1	0.127	0.084	0.82	0.48	158	37.8	0.364	0.081			16	11	0.0005			0.57	0.49
09/15/08			0.78		0.238	0.052	1.33	0.765	501	43.5	0.227	0.045			12	1.5	0.0005			0.92	0.67
Mean			0.48	0.10	0.177	0.066	1.20	0.70	323	40	0.390	0.110			13.7	6.5	0.00122			0.75	0.58
Median			0.42	0.1	0.165	0.062	1.33	0.765	311	39.1	0.364	0.081			13	7.1	0.0005			0.76	0.59
St. Deviation			0.27	0.00	0.056	0.016	0.33	0.20	172	3	0.178	0.083			2.1	4.8	0.00124			0.18	0.09
# of values	0	0	3	2	3	3	3	3	3	3	3	3	0	0	3	3	3	0	0	3	3
Minimum			0.24	0.1	0.127	0.052	0.82	0.48	158	37.8	0.227	0.045			12	1.5	0.0005			0.57	0.49
Maximum			0.78	0.1	0.238	0.084	1.45	0.86	501	43.5	0.58	0.203			16	11	0.00265			0.92	0.67
% of values undetected				100%													67%				
% of values between MDL and MRL																1					
NOAA SQuiRT Criteria Limit			50	50	1	1	3.1	3.1	50	50	8.1	8.1			100	100	0.94			8.2	8.2

**2004-2008 Pebble Project Marine Study
Ocean Water Laboratory Results Summary**

Parameters Total/Dissolved Units	Potassium		Selenium		Silicon	Silver		Sodium		Thallium		Tin		Vanadium		Zinc	
	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L
Station: MOPP1																	
Sample A: Surface																	
Sample Date																	
05/28/08			0.1	0.1		0.01	0.01			0.01	0.01	0.3	0.3	3	3	1.64	1.38
07/18/08						0.007	0.005			0.0209	0.02105	0.3	0.3	3	3	1.73	1.75
09/16/08			0.1	0.1		0.006	0.002			0.012	0.01	0.07	0.07	3	8	2.12	1.08
Mean			0.1	0.1		0.008	0.006			0.014	0.014	0.22	0.22	3	4.7	1.83	1.40
Median			0.1	0.1		0.007	0.005			0.012	0.01	0.3	0.3	3	3	1.73	1.38
St. Deviation			0	0		0.002	0.004			0.006	0.006	0.13	0.13	0	2.9	0.26	0.34
# of values	0	0	2	2	0	3	3	0	0	3	3	3	3	3	3	3	3
Minimum			0.1	0.1		0.006	0.002			0.01	0.01	0.07	0.07	3	3	1.64	1.08
Maximum			0.1	0.1		0.01	0.01			0.0209	0.02105	0.3	0.3	3	8	2.12	1.75
% of values undetected			100%	100%		33%	67%			33%	100%	100%	100%	100%	67%		
# of values between MDL and MRL						2	1			1					1		
NOAA SQuiRT Criteria Limit			71	71		0.95	0.95			17	17			50	50	81	81
Station: MOPP1																	
Sample C: Near Bottom																	
Sample Date																	
05/28/08			0.5	0.1		0.01	0.01			0.01	0.01	0.3	0.3	3	3	1.6	2.07
07/18/08						0.0005	0.002			0.01	0.01015	0.3	0.3	3	3	1.48	1.26
09/16/08			0.1	0.1		0.006	0.01			0.014	0.01	0.07	0.07	10.8	3	6.62	0.92
Mean			0.30	0.1		0.006	0.007			0.011	0.010	0.22	0.22	5.6	3.0	3.23	1.42
Median			0.3	0.1		0.006	0.01			0.01	0.01	0.3	0.3	3	3	1.6	1.26
St. Deviation			0.28	0		0.005	0.005			0.002	0.000	0.13	0.13	4.5	0.0	2.93	0.59
# of values	0	0	2	2	0	3	3	0	0	3	3	3	3	3	3	3	3
Minimum			0.1	0.1		0.0005	0.002			0.01	0.01	0.07	0.07	3	3	1.48	0.92
Maximum			0.5	0.1		0.01	0.01			0.014	0.01015	0.3	0.3	10.8	3	6.62	2.07
% of values undetected			100%	100%		67%	67%			67%	100%	100%	100%	67%	100%		
# of values between MDL and MRL						1	1			1							
NOAA SQuiRT Criteria Limit			71	71		0.95	0.95			17	17			50	50	81	81
Station: MPS1																	
Sample A: Surface																	
Sample Date																	
05/25/08			0.1	0.1		0.01	0.01			0.01	0.01	0.3	0.3	3	3	4.6	3.62
07/14/08						0.0005	0.0005			0.0109	0.0094	0.3	0.3	3	3	1.97	1.77
09/15/08			0.1	0.1		0.007	0.01			0.017	0.01	0.07	0.07	3	3	2.73	1.59
Mean			0.10	0.1		0.006	0.007			0.013	0.010	0.22	0.22	3	3.0	3.10	2.33
Median			0.1	0.1		0.007	0.01			0.0109	0.01	0.3	0.3	3	3	2.73	1.77
St. Deviation			0.00	0		0.005	0.005			0.004	0.000	0.13	0.13	0.0	0.0	1.35	1.12
# of values	0	0	2	2	0	3	3	0	0	3	3	3	3	3	3	3	3
Minimum			0.1	0.1		0.0005	0.0005			0.01	0.0094	0.07	0.07	3	3	1.97	1.59
Maximum			0.1	0.1		0.01	0.01			0.017	0.01	0.3	0.3	3	3	4.6	3.62
% of values undetected			100%	100%		67%	100%			33%	67%	100%	100%	100%	100%		
# of values between MDL and MRL						1				2	1						
NOAA SQuiRT Criteria Limit			71	71		0.95	0.95			17	17			50	50	81	81

**2004-2008 Pebble Project Marine Study
Ocean Water Laboratory Results Summary**

Parameters Total/Dissolved Units	Hardness mg/L	Total Suspended Solids mg/L	Chloride mg/L	Sulfate mg/L	Total Cyanide mg/L	Total Ammonia mg/L	Aluminum		Antimony		Arsenic		Barium		Beryllium		Bismuth		Boron		Cadmium	
							Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L
Station: MPS1																						
Sample C: Near Bottom																						
Sample Date																						
08/31/04	4300	29.6	18700	4110	0.00125	0.05	312	312	3.08	3.08			11.2	13.5	0.6	0.6	60	60	3230	3660	1.24	1.24
05/25/08		64				0.025	369	25	0.5	0.5	1.65	1.46	6.7	3.5	0.01	0.01			2950	2940	0.08	
07/14/08		18				0.004	151		0.2		1.32	1.23	4.9		0.0022	0.00025			3400		0.056	0.049
09/15/08		18				0.023	304	35	0.1	0.1	1.46	1.5	8.8	7	0.005	0.01			3020	3000	0.053	0.052
Mean	4300	32	18700	4110	0.00125	0.026	284	124	0.97	1.23	1.48	1.40	7.9	8.0	0.154	0.155	60	60	3150	3200	0.36	0.45
Median	4300	23.8	18700	4110	0.00125	0.024	308	35	0.35	0.5	1.46	1.46	7.75	7	0.0075	0.01	60	60	3125	3000	0.068	0.052
St. Deviation	NA	22	NA	NA	NA	0.019	93	163	1.42	1.62	0.17	0.15	2.7	5.1	0.297	0.297	NA	NA	205	399	0.59	0.69
# of values	1	4	1	1	1	4	4	3	4	3	3	3	4	3	4	4	1	1	4	3	4	3
Minimum	4300	18	18700	4110	0.00125	0.004	151	25	0.1	0.1	1.32	1.23	4.9	3.5	0.0022	0.00025	60	60	2950	2940	0.053	0.049
Maximum	4300	64	18700	4110	0.00125	0.05	369	312	3.08	3.08	1.65	1.5	11.2	13.5	0.6	0.6	60	60	3400	3660	1.24	1.24
% of values undetected					100%	75%	25%	67%	100%	100%					50%	100%	100%	100%			25%	33%
% of values between MDL and MRL						1		1						2	2	2						
NOAA SQuiRT Criteria Limit						0.795			500	500	36	36	200	200	100	100			1200	1200	8.8	8.8
Station: MPS1																						
Sample A: Surface																						
Tide: Low																						
Sample Date																						
09/15/08		22				0.049	532	15	0.1	0.1	1.4	1.35	9.1	6.1	0.01	0.01			2770	2750	0.049	0.048
NOAA SQuiRT Criteria Limit						0.795			500	500	36	36	200	200	100	100			1200	1200	8.8	8.8
Station: MPS1																						
Sample C: Near Bottom																						
Tide: Low																						
Sample Date																						
09/15/08		39				0.028	814	15	0.1	0.1	1.53	1.46	11.5	6.9	0.011	0.0005			3000	3000	0.052	0.051
NOAA SQuiRT Criteria Limit						0.795			500	500	36	36	200	200	100	100			1200	1200	8.8	8.8
Station: MPS2																						
Sample C: Near Bottom																						
Sample Date																						
09/01/04	4810	89	16900	2450	0.00125	0.0155	1280	312	3.08	3.08			22	12.3	0.6	0.6	60	60	3650	3490	1.24	1.24
NOAA SQuiRT Criteria Limit						0.795			500	500	36	36	200	200	100	100			1200	1200	8.8	8.8
Station: MPS3																						
Sample C: Near Bottom																						
Sample Date																						
09/01/04	4780	21.8	18400	3450	0.00125	0.05	312	312	3.08	3.08			14.1	11.3	0.6	0.6	60	60	3370	3830	1.24	1.24
NOAA SQuiRT Criteria Limit						0.795			500	500	36	36	200	200	100	100			1200	1200	8.8	8.8
Station: MPS4																						
Sample A: Surface																						
Sample Date																						
05/26/08		54				0.025	210	25	0.5	0.5	1.49	1.41	5.6	4.1	0.01	0.01			2870	2870	0.063	0.076
07/13/08		23				0.004	252	32	0.2	0.2	1.36	1.22	5.4	4.7	0.0051	0.0006			3230	3310	0.053	0.047
09/16/08		13				0.029	232	15	0.2	0.1	1.44	1.5	7.9	7.4	0.003	0.0005			2910	2940	0.05	0.048
Mean		30				0.019	231	24	0.30	0.27	1.43	1.38	6.3	5.4	0.006	0.004			3003	3040	0.06	0.06
Median		23				0.025	232	25	0.2	0.2	1.44	1.41	5.6	4.7	0.0051	0.0006			2910	2940	0.053	0.048
St. Deviation		21				0.013	21	9	0.17	0.21	0.07	0.14	1.4	1.8	0.004	0.005			197	236	0.01	0.02

**2004-2008 Pebble Project Marine Study
Ocean Water Laboratory Results Summary**

Parameters Total/Dissolved Units	Calcium		Chromium		Cobalt		Copper		Iron		Lead		Magnesium		Manganese		Mercury	Molybdenum		Nickel	
	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	
Station: MPS1																					
Sample C: Near Bottom																					
Sample Date																					
08/31/04	249000	273000	4	4	1.24	1.24			248	248	4	4	893000	1070000	20	20	0.0005	12.4	12.4		
05/25/08			0.61	0.1	0.228	0.04	1.19	0.5	543	36.7	0.382	0.13			13	2.5	0.00153			0.88	0.54
07/14/08			0.32	0.115	0.118	0.046	0.85	0.51	208		0.1	0.0115			11		0.0005			1.28	0.41
09/15/08			0.53	0.27	0.202	0.041	1.19	0.596	443	30.6	0.148				11	1	0.0005			0.77	0.6
Mean	249000	273000	1.37	1.12	0.447	0.342	1.08	0.54	361	105	1.158	1.381	893000	1070000	13.8	7.8	0.00076	12.4	12.4	0.98	0.52
Median	249000	273000	0.57	0.1925	0.215	0.0435	1.19	0.51	345.5	36.7	0.265	0.13	893000	1070000	12	2.5	0.0005	12.4	12.4	0.88	0.54
St. Deviation	NA	NA	1.76	1.92	0.531	0.599	0.20	0.05	159	124	1.899	2.269	NA	NA	4.3	10.6	0.00052	NA	NA	0.27	0.10
# of values	1	1	4	4	4	4	3	3	4	3	4	3	1	1	4	3	4	1	1	3	3
Minimum	249000	273000	0.32	0.1	0.118	0.04	0.85	0.5	208	30.6	0.1	0.0115	893000	1070000	11	1	0.0005	12.4	12.4	0.77	0.41
Maximum	249000	273000	4	4	1.24	1.24	1.19	0.596	543	248	4	4	893000	1070000	20	20	0.00153	12.4	12.4	1.28	0.6
% of values undetected			25%	75%	25%	25%			25%	33%	25%	67%			25%	67%	75%	100%	100%		
% of values between MDL and MRL																1					
NOAA SQuiRT Criteria Limit			50	50	1	1	3.1	3.1	50	50	8.1	8.1			100	100	0.94			8.2	8.2
Station: MPS1																					
Sample A: Surface																					
Tide: Low																					
Sample Date																					
09/15/08			0.81	0.22	0.412	0.119	1.56	0.569	857	41.1	0.286	0.027			26	7	0.00145			1.08	0.55
NOAA SQuiRT Criteria Limit			50	50	1	1	3.1	3.1	50	50	8.1	8.1			100	100	0.94			8.2	8.2
Station: MPS1																					
Sample C: Near Bottom																					
Tide: Low																					
Sample Date																					
09/15/08			1.01	0.25	0.498	0.05	2.08	0.591	1290	32.9	0.32	0.026			32	1.2	0.00347			1.32	0.54
NOAA SQuiRT Criteria Limit			50	50	1	1	3.1	3.1	50	50	8.1	8.1			100	100	0.94			8.2	8.2
Station: MPS2																					
Sample C: Near Bottom																					
Sample Date																					
09/01/04	260000	260000	4	4	2.82	1.24			2220	248	4	4	1010000	1020000	47.1	20	0.0012	12.4	12.4		
NOAA SQuiRT Criteria Limit			50	50	1	1	3.1	3.1	50	50	8.1	8.1			100	100	0.94			8.2	8.2
Station: MPS3																					
Sample C: Near Bottom																					
Sample Date																					
09/01/04	267000	266000	4	4	1.24	1.24			498	248	4	4	999000	1040000	20	20	0.0073	12.4	12.4		
NOAA SQuiRT Criteria Limit			50	50	1	1	3.1	3.1	50	50	8.1	8.1			100	100	0.94			8.2	8.2
Station: MPS4																					
Sample A: Surface																					
Sample Date																					
05/26/08			0.5	0.1	0.17	0.077	2.01	1.17	313	39.7	2.06	0.558			12	6.7	0.00122			0.78	0.57
07/13/08			0.39	0.1	0.231	0.106	1.19		368	37.9	0.279	0.101			26	14	0.0005			0.77	0.47
09/16/08			0.55	0.34	0.178	0.064	1.12	0.664	391	43.6	0.134	0.028			11	2.7	0.0005			0.74	0.84
Mean			0.48	0.18	0.193	0.082	1.44	0.92	357	40	0.824	0.229			16.3	7.8	0.00074			0.76	0.63
Median			0.5	0.1	0.178	0.077	1.19	0.917	368	39.7	0.279	0.101			12	6.7	0.0005			0.77	0.57
St. Deviation			0.08	0.14	0.033	0.022	0.49	0.36	40	3	1.073	0.287			8.4	5.7	0.00042			0.02	0.19

**2004-2008 Pebble Project Marine Study
Ocean Water Laboratory Results Summary**

Parameters	Potassium		Selenium		Silicon	Silver		Sodium		Thallium		Tin		Vanadium		Zinc	
	Total/Dissolved Units	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L
Station: MPS1																	
Sample C: Near Bottom																	
Sample Date																	
08/31/04	243000	269000			750	0.248	0.248	7520000	8820000	1	1	12.4	12.4	10	10	18.8	18.8
05/25/08			0.1	0.1		0.01	0.01			0.01	0.01	0.3	0.3	3	3	3.79	2.85
07/14/08						0.003	0.0005			0.0133	0.0122	0.3		3		1.23	0.81
09/15/08			0.1	0.1		0.008	0.01			0.014	0.01	0.07	0.07	3	3	2.16	
Mean	243000	269000	0.10	0.1	750	0.067	0.067	7520000	8820000	0.259	0.258	3.27	4.26	4.75	5.3	6.50	7.49
Median	243000	269000	0.1	0.1	750	0.009	0.01	7520000	8820000	0.01365	0.0111	0.3	0.3	3	3	2.975	2.85
St. Deviation	NA	NA	0.00	0	NA	0.121	0.121	NA	NA	0.494	0.495	6.09	7.05	3.5	4.0	8.27	9.85
# of values	1	1	2	2	1	4	4	1	1	4	4	4	3	4	3	4	3
Minimum	243000	269000	0.1	0.1	750	0.003	0.0005	7520000	8820000	0.01	0.01	0.07	0.07	3	3	1.23	0.81
Maximum	243000	269000	0.1	0.1	750	0.248	0.248	7520000	8820000	1	1	12.4	12.4	10	10	18.8	18.8
% of values undetected			100%	100%	100%	50%	100%			50%	75%	100%	100%	100%	100%	25%	33%
% of values between MDL and MRL						2				2	1						
NOAA SQuiRT Criteria Limit			71	71		0.95	0.95			17	17			50	50	81	81
Station: MPS1																	
Sample A: Surface																	
Tide: Low																	
Sample Date																	
09/15/08			6.1	0.1		0.009	0.01			0.019	0.01	0.07	0.07	3	6.8	2.59	1.08
NOAA SQuiRT Criteria Limit			71	71		0.95	0.95			17	17			50	50	81	81
Station: MPS1																	
Sample C: Near Bottom																	
Tide: Low																	
Sample Date																	
09/15/08			0.1	0.1		0.009	0.002			0.023	0.01	0.07	0.07	3	7.2	3.4	0.67
NOAA SQuiRT Criteria Limit			71	71		0.95	0.95			17	17			50	50	81	81
Station: MPS2																	
Sample C: Near Bottom																	
Sample Date																	
09/01/04	259000	259000			750	0.248	0.248	8610000	8370000	1	1	12.4	12.4	10	10	18.8	18.8
NOAA SQuiRT Criteria Limit			71	71		0.95	0.95			17	17			50	50	81	81
Station: MPS3																	
Sample C: Near Bottom																	
Sample Date																	
09/01/04	262000	266000			750	0.248	0.248	8290000	8840000	1	3.74	12.4	12.4	10	10	18.8	18.8
NOAA SQuiRT Criteria Limit			71	71		0.95	0.95			17	17			50	50	81	81
Station: MPS4																	
Sample A: Surface																	
Sample Date																	
05/26/08			0.1	0.1		0.01	0.01			0.01	0.01	0.3	0.3	3	3	4.12	3.5
07/13/08						0.002	0.0005			0.0117	0.0095	0.3	0.3	3	3	1.61	
09/16/08			0.1	0.1		0.008	0.01			0.015	0.01	0.07	0.07	3	3	1.32	
Mean			0.10	0.1		0.007	0.007			0.012	0.010	0.22	0.22	3	3.0	2.35	3.50
Median			0.1	0.1		0.008	0.01			0.0117	0.01	0.3	0.3	3	3	1.61	3.5
St. Deviation			0.00	0		0.004	0.005			0.003	0.000	0.13	0.13	0.0	0.0	1.54	NA

**2004-2008 Pebble Project Marine Study
Ocean Water Laboratory Results Summary**

Parameters	Hardness	Total Suspended Solids	Chloride	Sulfate	Total Cyanide	Total Ammonia	Aluminum		Antimony		Arsenic		Barium		Beryllium		Bismuth		Boron		Cadmium	
							Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
Total/Dissolved Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
# of values	0	3	0	0	0	3	3	3	3	3	3	3	3	3	3	0	0	3	3	3	3	
Minimum		13				0.004	210	15	0.2	0.1	1.36	1.22	5.4	4.1	0.003	0.0005			2870	2870	0.05	0.047
Maximum		54				0.029	252	32	0.5	0.5	1.49	1.5	7.9	7.4	0.01	0.01			3230	3310	0.063	0.076
% of values undetected						67%		67%	67%	100%					33%	67%						
# of values between MDL and MRL						1		1	1					2	2	1						
NOAA SQuiRT Criteria Limit						0.795			500	500	36	36	200	200	100	100			1200	1200	8.8	8.8

**2004-2008 Pebble Project Marine Study
Ocean Water Laboratory Results Summary**

Parameters	Calcium		Chromium		Cobalt		Copper		Iron		Lead		Magnesium		Manganese		Mercury	Molybdenum		Nickel	
	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L		
Total/Dissolved Units	0	0	3	3	3	3	3	2	3	3	3	3	0	0	3	3	3	0	0	3	3
# of values																					
Minimum			0.39	0.1	0.17	0.064	1.12	0.664	313	37.9	0.134	0.028			11	2.7	0.0005			0.74	0.47
Maximum			0.55	0.34	0.231	0.106	2.01	1.17	391	43.6	2.06	0.558			26	14	0.00122			0.78	0.84
% of values undetected				67%													67%				
% of values between MDL and MRL																1					
NOAA SQuiRT Criteria Limit			50	50	1	1	3.1	3.1	50	50	8.1	8.1			100	100	0.94			8.2	8.2

**2004-2008 Pebble Project Marine Study
Ocean Water Laboratory Results Summary**

Parameters	Potassium		Selenium		Silicon	Silver		Sodium		Thallium		Tin		Vanadium		Zinc	
	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L
Total/Dissolved Units	0	0	2	2	0	3	3	0	0	3	3	3	3	3	3	3	1
# of values																	
Minimum			0.1	0.1		0.002	0.0005			0.01	0.0095	0.07	0.07	3	3	1.32	3.5
Maximum			0.1	0.1		0.01	0.01			0.015	0.01	0.3	0.3	3	3	4.12	3.5
% of values undetected			100%	100%		33%	100%			33%	67%	100%	100%	100%	100%		
% of values between MDL and MRL						2				2	1						
NOAA SQuiRT Criteria Limit			71	71		0.95	0.95			17	17			50	50	81	81

**2004-2008 Pebble Project Marine Study
Ocean Water Laboratory Results Summary**

Parameters Total/Dissolved Units	Hardness mg/L	Total Suspended Solids mg/L	Chloride mg/L	Sulfate mg/L	Total Cyanide mg/L	Total Ammonia mg/L	Aluminum		Antimony		Arsenic		Barium		Beryllium		Bismuth		Boron		Cadmium		
							Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L
Station: MPS4																							
Sample C: Near Bottom																							
Sample Date																							
08/31/04	4870	28.6	19000	2840	0.00125	0.0155	312	312	3.08	3.08				11.8	12.8	0.6	0.6	60	60	3240	3780	1.24	1.24
05/26/08		64				0.025	238	25	0.5	0.5	1.5	1.46	6.4	4.5	0.01					2890	2890	0.061	0.062
07/13/08		15				0.004	101	59	0.2	0.2	1.33	1.24	4.8	4.3	0.0023	0.0002				3340	3360	0.054	0.054
09/16/08		25				0.024	396	15	0.1	0.1	1.46	1.42	9.9	7.3	0.006	0.0005				2950	3020	0.05	0.05
Mean	4870	33	19000	2840	0.00125	0.017	262	103	0.97	0.97	1.43	1.37	8.2	7.2	0.155	0.153	60	60	3105	3263	0.35	0.35	
Median	4870	26.8	19000	2840	0.00125	0.01975	275	42	0.35	0.35	1.46	1.42	8.15	5.9	0.008	0.00525	60	60	3095	3190	0.0575	0.058	
St. Deviation	NA	21	NA	NA	NA	0.010	125	141	1.42	1.42	0.09	0.12	3.2	4.0	0.297	0.298	NA	NA	219	398	0.59	0.59	
# of values	1	4	1	1	1	4	4	4	4	4	3	3	4	4	4	4	1	1	4	4	4	4	
Minimum	4870	15	19000	2840	0.00125	0.004	101	15	0.1	0.1	1.33	1.24	4.8	4.3	0.0023	0.0002	60	60	2890	2890	0.05	0.05	
Maximum	4870	64	19000	2840	0.00125	0.025	396	312	3.08	3.08	1.5	1.46	11.8	12.8	0.6	0.6	60	60	3340	3780	1.24	1.24	
% of values undetected					100%	75%	25%	75%	100%	100%					50%	100%	100%	100%			25%	25%	
% of values between MDL and MRL						1								2	3	2							
NOAA SQuiRT Criteria Limit						0.795			500	500	36	36	200	200	100	100			1200	1200	8.8	8.8	
Station: MPS4																							
Sample A: Surface																							
Tide: Low																							
Sample Date																							
09/16/08		12				0.038	277	15	0.1	0.1	1.35	1.43	7.6	6.4	0.005	0.0005			2860	2830	0.05	0.052	
NOAA SQuiRT Criteria Limit						0.795			500	500	36	36	200	200	100	100			1200	1200	8.8	8.8	
Station: MPS4																							
Sample C: Near Bottom																							
Tide: Low																							
Sample Date																							
09/16/08		12				0.040	308	15	0.2	0.1	1.38	1.5	7.8	6.9	0.003	0.0005			2960	2960	0.053	0.051	
NOAA SQuiRT Criteria Limit						0.795			500	500	36	36	200	200	100	100			1200	1200	8.8	8.8	

Key: All sampling was done at high tide except as noted.
Bold Results = Parameter undetected by test, value shown is 1/2 MDL or 1/2 MRL.
 If result was not detected at the lab MDL, the value shown is 1/2 MDL.
 If result was validation flagged U or UJ, the value shown is 1/2 MRL.
Green Results = Estimated result reported by laboratory below reporting limit (MRL).
Red Results = Result exceed applicable NOAA SQuiRT Limits.
 MDL = Method Detection Limit.
 MRL = Method Reporting Limit.
 NA = Not Applicable.
 NOAA SQuiRT = National Oceanic and Atmospheric Administration Screening Quick Reference Tables
 mg/L = Milligrams per Litre (Parts per Billion)
 µg/L = Micrograms per Litre (Parts per Billion)

**2004-2008 Pebble Project Marine Study
Ocean Water Laboratory Results Summary**

Parameters Total/Dissolved Units	Calcium		Chromium		Cobalt		Copper		Iron		Lead		Magnesium		Manganese		Mercury	Molybdenum		Nickel	
	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	
Station: MPS4																					
Sample C: Near Bottom																					
Sample Date																					
08/31/04	245000	264000	4	4	1.24	1.24			248	248	4	4	1030000	1050000	20	20	0.0021	12.4	12.4		
05/26/08			0.49	0.45	0.198	0.065	1.07	0.53	383	57.8	0.244	0.063			11	2.5	0.00115			0.82	0.61
07/13/08			0.24	0.1	0.126	0.083	0.79	0.55	155	37.7	0.141	0.059			15	10	0.0005			0.58	0.54
09/16/08			1.78	0.48	0.306	0.054	1.47	0.653	720	52.7	0.171	0.03			18	2.6	0.0005			1.34	0.63
Mean	245000	264000	1.63	1.26	0.468	0.361	1.11	0.58	377	99	1.139	1.038	1030000	1050000	16.0	8.8	0.00106	12.4	12.4	0.91	0.59
Median	245000	264000	1.135	0.465	0.252	0.074	1.07	0.55	315.5	55.25	0.2075	0.061	1030000	1050000	16.5	6.3	0.000825	12.4	12.4	0.82	0.61
St. Deviation	NA	NA	1.72	1.84	0.520	0.586	0.34	0.07	247	100	1.908	1.975	NA	NA	3.9	8.3	0.00076	NA	NA	0.39	0.05
# of values	1	1	4	4	4	4	3	3	4	4	4	4	1	1	4	4	4	1	1	3	3
Minimum	245000	264000	0.24	0.1	0.126	0.054	0.79	0.53	155	37.7	0.141	0.03	1030000	1050000	11	2.5	0.0005	12.4	12.4	0.58	0.54
Maximum	245000	264000	4	4	1.24	1.24	1.47	0.653	720	248	4	4	1030000	1050000	20	20	0.0021	12.4	12.4	1.34	0.63
% of values undetected			25%	50%	25%	25%			25%	25%	25%	25%			25%	50%	50%	100%	100%		
% of values between MDL and MRL																1					
NOAA SQuiRT Criteria Limit			50	50	1	1	3.1	3.1	50	50	8.1	8.1			100	100	0.94			8.2	8.2
Station: MPS4																					
Sample A: Surface																					
Tide: Low																					
Sample Date																					
09/16/08			0.57		0.226	0.084	1.24	0.65	434	48.6	0.16	0.01			12	3.8	0.00193			0.8	0.75
NOAA SQuiRT Criteria Limit			50	50	1	1	3.1	3.1	50	50	8.1	8.1			100	100	0.94			8.2	8.2
Station: MPS4																					
Sample C: Near Bottom																					
Tide: Low																					
Sample Date																					
09/16/08			0.46	0.22	0.194	0.06	1.14	0.65	454	61.9	0.171	0.03			12	2.6	0.0005			0.72	0.54
NOAA SQuiRT Criteria Limit			50	50	1	1	3.1	3.1	50	50	8.1	8.1			100	100	0.94			8.2	8.2

**2004-2008 Pebble Project Marine Study
Ocean Water Laboratory Results Summary**

Parameters Total/Dissolved Units	Potassium		Selenium		Silicon	Silver		Sodium		Thallium		Tin		Vanadium		Zinc	
	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L	Total µg/L	Dissolved µg/L
Station: MPS4																	
Sample C: Near Bottom																	
Sample Date																	
08/31/04	246000	263000			750	0.248	0.248	8670000	8770000	1	1	12.4	12.4	10	10	18.8	18.8
05/26/08			0.5			0.01	0.01			0.0233	0.0252	0.3	0.3	3	3	2.65	2.22
07/13/08						0.0005	0.0005			0.0112	0.0094	0.3	0.3	3	3	2.37	2.18
09/16/08			0.1	0.1		0.007	0.01			0.015	0.01	0.07	0.07	10.6	8	1.86	
Mean	246000	263000	0.30	0.1	750	0.066	0.067	8670000	8770000	0.262	0.261	3.27	3.27	6.65	6.0	6.42	7.73
Median	246000	263000	0.3	0.1	750	0.0085	0.01	8670000	8770000	0.01915	0.0176	0.3	0.3	6.5	5.5	2.51	2.22
St. Deviation	NA	NA	0.28	NA	NA	0.121	0.121	NA	NA	0.492	0.493	6.09	6.09	4.2	3.6	8.26	9.58
# of values	1	1	2	1	1	4	4	1	1	4	4	4	4	4	4	4	3
Minimum	246000	263000	0.1	0.1	750	0.0005	0.0005	8670000	8770000	0.0112	0.0094	0.07	0.07	3	3	1.86	2.18
Maximum	246000	263000	0.5	0.1	750	0.248	0.248	8670000	8770000	1	1	12.4	12.4	10.6	10	18.8	18.8
% of values undetected			100%	100%	100%	75%	100%			25%	50%	100%	100%	75%	75%	25%	33%
% of values between MDL and MRL						1				2	1				1		
NOAA SQuiRT Criteria Limit			71	71		0.95	0.95			17	17			50	50	81	81
Station: MPS4																	
Sample A: Surface																	
Tide: Low																	
Sample Date																	
09/16/08			0.1	0.1		0.006	0.01			0.014	0.01	0.07	0.07	3	3	7.88	1.12
NOAA SQuiRT Criteria Limit			71	71		0.95	0.95			17	17			50	50	81	81
Station: MPS4																	
Sample C: Near Bottom																	
Tide: Low																	
Sample Date																	
09/16/08			0.1	0.1		0.004	0.01			0.016	0.01	0.07	0.07	3	3	1.81	2.13
NOAA SQuiRT Criteria Limit			71	71		0.95	0.95			17	17			50	50	81	81