Screening-Level Risk Evaluation

Small Commercial Passenger Vessels Wastewater Discharge Impacts on the Marine Environment and Human Health

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Table of Contents

6 Risk Characterization

7 Summary & Recommendations

8 References

Appendices

Appendix A: COPC Toxicity Profiles
Appendix B: CARDINAL Modeling Approach
Appendix C: Data Used for Modeling Purposes
Appendix D: Bathymetric Maps of Areas of Concern

1

Introduction

In 1999, due to potential environmental and human health concerns regarding wastewater discharges from commercial passenger vessels into Alaska's marine waters, environmentalists, government agencies, the cruise ship industry, and other stakeholders formed the Alaska Cruise Ship Initiative. In 2000, as a result of this Initiative, a voluntary wastewater effluent sampling program was established for large cruise ships (e.g., more than 250-passenger capacity) that regularly discharge into Alaskan waters.

Subsequently, in June 2001, the Alaska legislature passed law AS 46.03.460 – 490. This law, which affected commercial passenger vessels with 50 or more lower berths, extended the compliance time for effluent discharge standards directed at smaller commercial vessels. However, these vessels were required to provide vessel-specific sampling plans and wastewater discharge logs and samples. The law also required the Alaska Department of Environmental Conservation (ADEC) to prepare a report to the governor discussing the environmental impacts of effluent discharges from small ships. As such, the present document provides a screening-level evaluation of the potential for effects on ecological and human receptors from small ship discharges in portions of southeast Alaska.

1.1 Study Objectives

The overall objective of this screening evaluation is to identify and quantify those discharge constituents that may be occurring within the marine ecosystem at concentrations that present acute or chronic risks to the health and viability of ecological and human populations.

To accomplish this objective, E & E worked closely with ADEC personnel to identify and collate analytical sampling data from small vessels during years 2001 and 2002. Primarily for modeling purposes, except for free chlorine, data represented those collected during 2001. Free chlorine data for 2002 was used because it represented highest concentrations and thus a worst-case exposure potential. These data included conventional, priority pollutant, and whole effluent toxicity (WET) information, which were provided in spreadsheet format. The data were then evaluated in terms of usability and data gaps were identified.

Generally, the data provided for use in the modeling effort was sufficient for its intended purpose. In some instances, analyses for volatile and semi-volatile organic compounds were listed in laboratory data packs, but in most cases these constituents were either not measured or found at concentrations below detection limits. Fecal coliform data were reported in MPN/100 mL but modeled as MPN/m^3 and, although this is a standard unit of measurement for in situ discharge concentrations, it made comparison to benchmarks difficult as water quality standards (WQS) are reported in colonies/100 mL.

Results of the WET program were presented by the Science Advisory Panel for ADEC in July 2002 (http://www.state.ak.us/dec/press/cruise/documents/wetfinal.html) and generally reported that if a small cruise ship was moored, drifting, or anchored – when dilution benefits are greatly reduced – then a potential for toxicity from excess chlorine in graywater exists.

After the data were evaluated, and upon consultation with ADEC, a decision was made on the chemicals of interest (COIs). COIs were deemed to be those constituents found in standard discharges from on-board wastewater treatment systems (Table 1). The list of COIs consisted of conventional pollutants and organic compounds, along with a short list of metal compounds. Although various priority pollutant organics were identified infrequently within wastewater streams, no consistent discharge of these compounds was documented and, as such, they were not considered COIs.

After COIs were selected through this process, a literature review of scientific databases was conducted to determine appropriate and relevant toxicological benchmarks. The overall goal of this task was to identify levels-of-effects that could be used to compare with modeled contaminant concentration distributions. Two effect levels, No Observed Adverse Effect Levels (NOAEL) and/or Lowest Observed Adverse Effect Levels (LOAEL), were selected for both ecological and human health risk concerns, although it was understood that toxicological benchmarks would not be available for all COIs considered in the ecological risk screen.

Table 1. COPC Determination for Small Cruise Ship Discharges within SE Alaska Waters[1]

Chemical of Interest (COI)	Maximum Concentration (mg/L unless indicated)	Benchmark Values		Analyte Retained as COPC?	Justification
		Ecological[2]	Human Health[3]		
Total Chlorine	40	NA	2	Yes	A
Fecal Coliform	1.60E+11 (MPN/ m^3) or 1.60 E+7 MPN/100 ml)	NA	14 (col/100 ml)	Yes	B
PH	[range]5.39-8.78	6.5-8.5	6.5-8.5	No	C
COD (mg/L)	5,690	NA	NA	Yes	B
BOD (mg/L)	1,010	NA	NA	Yes	B
Conductivity	NA	NA	NA	No	C
Free Chlorine	25	2.0	NA	Yes	A
Total Suspended Solids	880	NA	NA	Yes	B
Ammonia – N	55	NA	2.5	Yes	A
Total – N	48	35	10,000	Yes	A
Phosphorous	5.19	0.1	NA	Yes	A
Antimony (ug/L)	1.37 (d)	500 (t)	6 (t)	No	D
Arsenic (ug/L)	53.2 (d)	36 (d)	0.018 (d)	Yes	A
Chromium (ug/L)	17.4 (d)	50 (Cr^6, d)	100 (t)	No	D
Copper (ug/L)	319 (d)	2.9 (d)	1,000 (d)	Yes	A
Lead (ug/L)	16.6 (d)	8.1 (d)	15 (t)	Yes	A
Nickel (ug/L)	36.1 (d)	8.2 (d)	610 (d)	Yes	A
Selenium (ug/L)	233 (d)	0.23 (d)	50 (d)	Yes	A

Table 1. COPC Determination for Small Cruise Ship Discharges within SE Alaska Waters[1]

Chemical of Interest (COI)	Maximum Concentration (mg/L unless indicated)	Benchmark Values		Analyte Retained as COPC?	Justification
		Ecological[2]	Human Health[3]		
Zinc (ug/L)	1,350 (d)	81 (d)	5,000 (d)	Yes	A

NOTES:
COPC = Contaminant of Potential Concern
1=DATA REPRESENTS CONCENTRATIONS FROM SINGLE SHIP
2=BENCHMARKS FROM TABLE 3.
3=BENCHMARKS FROM TABLE 4.
A = EITHER SCREENING BENCHMARK EXCEEDED.
B = COI IS STANDARD WWTP DISCHARGE AND POTENTIAL EFFECTS EXIST FROM EXPOSURE.
C = CANNOT BE MODEL AND THEREFORE IS NOT RETAINED.
D = MAX CONCENTRATION DID NOT EXCEED BENCHMARK(S).

From the environmental information collected for the area and from a basic understanding of the toxicological properties of the designated COIs, conceptual site models (CSMs) were developed for both ecological and human health exposure pathways. Subsequent development of CSM assessment and indicator species (i.e., ecological) was based on guidance provided in ADEC's ecological risk assessment document (ADEC 1998); EPA's *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* , (EPA 1997; http://www.epa.gov/superfund/programs/risk/ecorisk/ecorisk.htm; and EPA's *Risk Assessment Guidance for Superfund (RAGS) Part A* (EPA 1989; http://www.epa.gov/superfund/programs/risk/ragsa/index.htm.

1.2 Study Approach

The approach to assessing the preliminary risk posed to ecological and human receptors at or near small-ship wastewater discharge points was conducted in a step-wise manner. First ADEC provided E & E with small ship wastewater discharge information collected during 2001 and 2002. Next, the contractor evaluated the data for sampling consistency and collated yearly data for each ship per documented discharge point. Discharge points were identified at either docking sites or static locations within open waters where the ship spent more than 4 hours. (An early approach for mapping discharges continuously along a ship's transit pathway was eliminated when it was determined that the ship's standard log only provided the location where it stopped, and thus subsequent predicted pathways many times crossed over land, making discharge rate prediction between listed points difficult.) At the discharge points identified, a hydrodynamics-based fate and transport model was used to predict contaminant concentration gradients, proceeding away from the discharge point, as a result of discharge volume and concentration. The model used in this effort (see Section 1.3) considered dilution, water temperature, pH, and wind effects, among other variables. At those locations where discharges were identified and scheduled for subsequent modeling efforts, sensitive ecological and human resources and/or activities were identified and mapped. Finally, modeled maximum concentrations for pollutants were compared to Alaska water quality standards and other ecological or human health benchmarks to determine if identified receptors may be at risk from discharge constituents. The exposure scenario for ecological receptors conservatively assumed that selected organisms/receptors reside/exist in a "contaminated" area for 100% of their life cycle (or exposure period). It also assumed that the most sensitive life stage(s) for the receptor was present, and bioaccumulation and biomagnification were taken into account.

1.3 Modeling Approach

Distribution isopleths for selected contaminants identified for the wastewater discharges were calculated using the CARDINAL® software package (Klevanny et al. 1994). CARDINAL® is a 3-dimensional (3D) modeling system for simulation of currents, water levels, dispersion of pollutants, and transport of bottom sediments in arbitrary water domains (http://www.webcenter.ru/~klevanny). An in-depth discussion of CARDINAL®, along with a justification for its use in this project, is presented in Appendix B.

2

Environmental Setting

The environmental setting within which the small cruise ships operate includes the open water and coastline of southeast Alaska. This coastline includes a large number of small islands and fjords that reach inland along the eastern Gulf of Alaska coast (see Figure 1). The habitat is variable, including biologically rich bays and estuaries, lowland deltas, beaches, forested mountains rising from the water, and glaciers draining and calving into the ocean.

Elevation within the sub-region lies between sea level and 500 meters. The terrain varies from low-lying coastal estuaries and river deltas to steep, forested seaside mountains. The coastline is underlain by Mesozoic volcanic and intrusive rocks and Mesozoic and Paleozoic sedimentary rocks. Soils within this sub-region are highly variable and may be shallow or deep, with a wide range of materials, from rock and gravel at the foot of the seaside mountains and cliffs to sand, silt, alluvium, loess, and clay along beaches and at the mouths of streams and rivers.

The climate of the coast is maritime, dominated by the effects of the Gulf of Alaska. Winds are persistent and strong, frequently from the south or southeast. The severity of the winter is moderated by the maritime influence, and very little ice forms over the ocean water. Average daily temperatures vary from –3°C during winter to 18°C in summer. Precipitation occurs throughout the year and is highly variable, depending on elevation and distance inland. Annual averages vary from 135 to 390 cm, with an annual average snowfall of 80 to 100 cm.

The type and abundance of vegetation in the coastline community depend largely on the type of soil. Other factors include the exposure to prevailing winds, wave action, and salinity. Sandy beaches may be colonized by grasses such as beach rye and other species such as honckenya, beach plea, and groundsel. Seaside mountains and hills are usually forested with needleleaf tree species, including western hemlock and Sitka spruce.

2.1 Ecological Attributes

This sub-region provides important biological functions, including resting, nesting, feeding, rearing, and/or migration staging grounds for fish (especially salmon and steelhead); waterfowl; seabirds; and shorebirds (Shannon and Wilson, Inc. 1999). The waters in this region are extremely productive. Eelgrass is an important aquatic plant for many fish and wildlife resources. Brackish grasses may include ditch grass, horned pondweed, alkali grasses, honckenya, fivefinger, maritime arrow grass, and reed grass. Phytoplankton (nannoplankton) and algae are also found in marine and estuarine areas. Marine algae species play an important role in the food chain of bird and fish species inhabiting the islands and nearshore areas. The algae are present at various depths and associated with various bottom substrates (i.e., rocks, sand, or silt). There may be more than 100 species of algae within at least three taxonomic groups, including *Chlorophycophyta*, *Phaeophycophyta*, and *Rhodophycophyta* (Lebednik and Palmisano, 1977 as cited by Shannon and Wilson, Inc. 1999).

Shellfish potentially found in the estuarine climate of the bays and nearshore areas include king crab, tanner crabs, razor clams, and shrimp. Barnacles, snails, limpets, and starfish also are common. Other species present include representatives of the taxa Porifera (sponges); Cnidaria (hydrozoans); Ctenophora (comb jellies); Platyhelminthes (flatworms); Nemertea (ribbon worms); Mollusca (gastropods, bivalves, and cephalopods); Annelida (segmented worms); Sipuncula (peanut worms); Arthropoda (barnacles, shrimp, and crabs); Bryozoa (moss animals); Brachiopoda (lamp shells); Phoronida (phoronids); Echinodermata (echinoids, crinoids, etc.); and Chordata (thaliaceans and allies) (Barr and Barr, 1983 as cited by Shannon and Wilson, Inc. 1999).

Birds commonly inhabiting the coastline community include both migratory and resident species, including raptors, seabirds, shorebirds, and waterfowl. Seabirds, shorebirds, and waterfowl may nest along the shoreline. However, the majority use this sub-region as staging grounds and pass through to the north (spring) or south (fall) to preferred breeding or wintering habitat, respectively. Seabirds include fulmar, shearwaters, storm-petrels, cormorants, loons, grebes, gulls, terns, kittiwakes, murres, guillemots, murrelets, auklets, and puffins. Waterfowl are present along the coastline, especially in the estuaries of the sub-region. Canada geese, northern pintail, scaup, teal, mallards, wigeon, harlequins, goldeneye, bufflehead, scoters, and mergansers are common. Shorebirds are also numerous, including sandpipers, plovers, godwits, and curlew. Nesting and rearing occur in May and June, respectively, and the migratory birds depart for warmer climates by late October. Raptors such as eagles, sharp-shinned hawks, and kestrels are common in the forests of the coastline. Crows and ravens also are present (Shannon and Wilson, Inc. 1999). The Stikine and Mendenhall river deltas and Yakutat and Bering Glacier forelands areas are particularly important staging areas for birds. Major seabird breeding colonies are located on St. Lazaria, Forrester, and Hazy Islands (Southeast SCP 1997).

Aquatic mammals use the coastline in various ways. Mink may remain within a small area such as an estuary when food and cover are plentiful, but sea otters and seals range over wide areas and may use a particular feeding or resting area for short periods. Whales such as beluga, gray, and orca whales may briefly inhabit the nearshore areas of the coastline as they migrate north or south (Shannon and Wilson, Inc. 1999). Harbor seals, Steller sea lions, sea otters, killer whales, and porpoises are present throughout the year. Several species of baleen whales, including large numbers of gray and humpback whales, migrate through southeast Alaska and feed during the spring and summer. Sea lion rookeries are located on Forrester and Hazy Islands and several haulouts are scattered along the coast and the protected, inside waters. Harbor seals are particularly abundant in Glacier, Icy, and Yakutat Bays (Southeast SCP 1997).

The entire Alexander Archipelago is a fish-rich area. Fish of the sub-region include all major salmon species, steelhead, ling cod, halibut, rockfish, herring, and eulachon. Many of these species are migratory, some returning to rivers to spawn and others retreating seasonally to deeper or warmer ocean waters. Other species may include perch, sablefish, pollock, sole, flounder, lampreys, sharks, skates, smelts, lightfishes, viperfishes, lances, grenadier, sandfishes, ronquils, pricklebacks, and poachers (Simenstad et al. 1977 as cited by Shannon and Wilson, Inc. 1999).

2.2 Human Use Attributes

Many of the major population centers, local communities, and smaller villages found within the study area rely on natural resources for subsistence, commerce, and recreation. As such, abundance and diversity of the environmental resources play an important role in maintaining the integrity and viability of these communities.

Major population centers in southeast Alaska include Juneau, Skagway, Sitka, Ketchikan, and Petersburg (see Figure 1). Villages where at least 50% of residents are Native Alaskans include Hoonah, Angoon, Kake, Kasaan, Klawaock, Hydaburg, Saxman, Metlakatla, Tanana, Klukwan, and Yakutat (ADFG 2001a). The following briefly describes selected villages found within southeast Alaska and associated subsistence characteristics.

Angoon is located north of Petersburg and is accessible only by floatplane and boat, although it is serviced by the state’s ferry system. Alaska Natives comprise more than 80% of the population and more than 90% of the households harvest fish and other marine life (ADFG 2001a). Subsistence residents rely on salmon, halibut, and shellfish (ADFG 2001a). The economy is based on commercial fishing.

Craig is located on Prince of Wales Island, west of Ketchikan, and is accessible via floatplane, boat, and state ferry. This village is predominantly a commercial fishing village where fewer than 25% of the residents are Native Alaskan (ADFG 2001a). Various recreation activities are popular in the vicinity of Craig and several fisheries are present. In addition, more than 90% of the households harvest fish and other marine life (ADFG 2001a).

Haines and Skagway are located above the Chilkoot Inlet and are accessible via floatplane, plane, boat, state ferry and cruise ship, and car. Skagway is also accessible by rail. Because of their accessibility, these villages are major trans-shipment points. Haines is a commercial fishing area and a popular tourist destination. Fewer than 20% of Haines residents are Native Alaskan and more than 90% of households harvest marine life (ADFG 2001a). Fewer than 6% of Skagway residents are Native Alaskan and 68% of households harvest marine life for subsistence use (ADFG 2001a).

Hoonah is found on Chichagof Island and is accessible by air, ferry, and boat. About 68% of the residents are Native Alaskan and more than 94% of the households are involved in harvesting marine life (ADFG 2001a). Commercial fishing and fish processing are major industries of Hoonah (NMFS 2002).

Juneau, the state capital, is accessible via boat, state ferry, airplane, floatplane, and car. The major industries are government administration, fish processing, and tourism. Salmon fishers are operated in the vicinity of Juneau (NMFS 2002).

Kake is accessible by floatplane, boat, state ferry, and airplane. The commercial fishing industry, including processing and storage, employs a large number of the residents (NMFS 2002). About 73% of the residents are Native Alaskans and about 85% of the households harvest marine life such as salmon, halibut, and shellfish (ADFG 2001a).

Ketchikan is accessible by floatplane, boat, state ferry, airplane, and automobile. About 18% of the residents are Native Americans; the city is not considered to have a large subsistence population (ADFG 2001a). The fishing industry has only a small presence in Ketchikan (less than 5% of population), with 25% of the residents working in the government sector and much of the remaining employment consisting of the service and professional sectors (Census 2000).

Sitka is accessible via airplane, floatplane, helicopter, boat, and ferry. Native Alaskans comprise 21% of the population and 83% of the households harvest marine life for subsistence use (ADFG 2001a). Sitka's economy is based on commercial fishing, fish processing, and tourism (NMFS 2002).

Subsistence use of aquatic natural resources in southeast Alaska involves the harvest of fish, shellfish, marine mammals, and other marine life for food, fuel, clothing, transportation, home goods, trade, ceremony, and arts and crafts. Many of the marine life components identified in Section 2.1 are consumed by area residents. In addition, areas that are considered spawning, nesting, and feedings grounds may also be important for subsistence harvesting. Subsistence harvests species consist primarily of salmon, halibut, and shellfish but may also include marine mammals and seaweed and kelp (ADFG 2001a).

The many recreation areas found along the coastlines include national, state, and local parks. The following are major recreation areas found in the southeast region of Alaska that are used for kayaking, boating, fishing, wildlife viewing, scuba diving and picnicking:

- Glacier Bay National Park: Bartlett Cove, Berg Bay, Beardlee Islands, Hugh Miller/Scidmore/Charpentier Inlets, Adams Inlet, Marble Islands, Dundas Bay, Dry Bay/Alsek River;
- Point Bridget State Park;
- Refuge Cove State Recreational Site;
- Settlers Cove State Recreational Site;
- Chilkoot State Park;
- Dall Bay State Marine Park;
- Thom's Place State Marine Park;
- Beecher Pass State Marine Park

- Security Bay State Marine Park;
- Joe Mace Island State Marine Park
- Taku Harbor State Marine Park
- Funter Bay State Marine Park; and
- Shelter Island State Marine Park.

Marine sport fishing in southeast Alaska represents one of the most popular recreational activities. Harvest of marine life for personal use is allowed year-round for shrimp, Dungeness crab, brown king crab, red and blue king crab, tanner crab, clams, abalone, herring, bottomfish, salmon, and smelt, and the halibut season is open most of the year. However, fishing is more common during the warmer summer months when waters are calm and fish are found closer to shore.

The commercial fishing industry capitalizes on the abundance and diversity of natural resources in the area. Commercial fishing includes all varieties of salmon, shrimp, crab, clam, halibut, smelt, and herring. Commercial fishing seasons are noted in Table 2 below. Salmon, herring, and groundfish are caught by handline and/or net. Shrimp are harvested using beam trawl and pots; crab are harvested in pots; and geoducks, urchins, and sea cucumbers are harvested exclusively by scuba divers. In 2002, commercial fishers in the southeast region caught approximately 241,907,000 pounds of salmon (ADFG 2002a), 10,988 tons of herring roe (ADFG 2003), 790,000 pounds of king crab (ADFG 2002b), and 2,570,000 pounds of shrimp (ADFG 2002b). Salmon hatcheries are present in southeast Alaska in the vicinity of Ketchikan, Sitka, Craig, Kake, Skagway, Juneau, and Metlakatla.

Table 2. Commercial Fishing Season in Southeast Alaska (ADFG 2000)

Month	Commercial Fish
January	Chinook salmon, herring, red and blue king crab, Dungeness crab, shrimp, geoducks, red urchins, sea cucumber, rockfish
February	Chinook salmon, herring, golden king crab, Tanner crab, Dungeness crab, shrimp, geoducks, red urchins, sea cucumber, rockfish
March	Chinook salmon, herring sac roe and roe on kelp, golden king crab, Tanner crab, geoducks, red urchins, sea cucumber, rockfish
April	Chinook salmon, herring sac roe and roe on kelp, golden king crab, Tanner crab, geoducks, red urchins
May	Chinook salmon, herring sac roe and roe on kelp, golden king crab, shrimp, geoducks,

Table 2. Commercial Fishing Season in Southeast Alaska (ADFG 2000)

Month	Commercial Fish
	red urchins, lingcod
June	Chinook, coho, pink, and sockeye salmon, golden king crab, Dungeness crab, shrimp, geoducks, red urchins, sablefish, lingcod
July	Chinook, coho, pink, sockeye, and chum salmon, Dungeness crab, shrimp, geoducks, red urchins, sablefish, lingcod
August	Chinook, coho, pink, sockeye, and chum salmon, Dungeness crab, shrimp, geoducks, red urchins, sablefish, lingcod
September	Chinook, coho, sockeye, and chum salmon, shrimp, geoducks, red urchins, sablefish, lingcod
October	Chinook and chum salmon, herring, Dungeness crab, shrimp, geoducks, red urchins, sea cucumber, sablefish, lingcod
November	Chinook salmon, herring, red and blue king crab, Dungeness crab, shrimp, geoducks, red urchins, sea cucumber, rockfish, sablefish, lingcod
December	Chinook salmon, herring, red and blue king crab, Dungeness crab, shrimp, geoducks, red urchins, sea cucumber, rockfish

2.3 Conceptual Site Models (CSMs)

Conceptual site models (CSMs) in any risk assessment are a result of information produced during the problem formulation phase of a project (Suter 1996). They include the hypothesized sources of contaminants, routes of transport and exposure, media of concern, and endpoint receptors. They are typically presented in the form of a flow chart and descriptive narrative. CSMs should represent current concerns but should also consider future scenarios that could result in increased risk (Suter 1996).

Ecological and human health CSMs were developed (see Figures 2 and 3, respectively) based on ADEC guidance documents, correspondence with ADEC personnel, advisory committee members and developed information which has been presented in the previous sections. The CSMs were useful for determining the appropriate receptor species and/or exposure parameters considered within the subsequent risk evaluation.

2.3.1 Ecological Conceptual Site Model

A simplified ecological CSM (Figure 2) was developed to help identify specific receptors that might be directly or indirectly exposed to contaminants and to identify exposure pathways. The CSM identifies the primary source, release and transport mechanisms, exposure pathways, and a food web for guilds of receptor species. A guild is defined as a group of wildlife species that have a similar diet (i.e., are at the same trophic level and use the same resources in a similar fashion); food webs show interlocking patterns of food chains. A food chain is a direct connection (e.g., straight-line on CSM) from a food source (e.g., plants) to a series of organisms feeding on the source or other organisms feeding on the source. A food web depicts how energy, and in this case contaminants, may be transferred within an ecosystem. In Figure 2, the upper tier boxes represent general feeding guilds within an Alaskan southeast coastal marine ecosystem. The arrows indicate potential exposure pathways as a guild is exposed to contaminated media or through trophic transfer mechanisms. This food web is simplified for clarity and brevity and it must be understood that species' interactions are much more complex than indicated. Although guilds may be linked, species in one guild may not necessarily consume species in another guild on a regular basis.

For each food guild displayed in Figure 2, candidate receptor species were chosen in accordance with ADEC (1999) guidance. The following provides brief descriptions of candidate receptor species displayed in the ecological CSM. A conservative assumption predicts that each of these species may be present at or near the ecologically sensitive resource areas that have been identified near the modeled small ship discharge points.

Pigeon Guillemot

The primary habitat of the pigeon guillemot (*Cepphus columba*) is a coastal cliff or cave or rocky islands. The pigeon guillemot nests in colonies. The pigeon guillemot's diet consists of crustaceans and mollusks; chicks feed mostly on fish (Ehrlich et al. 1988).

Salmon

Salmon species that migrate through the Gulf of Alaska include the chinook salmon (*Oncorhynchus tshawytscha*), the pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*Oncorhynchus keta*), sockeye salmon (*Oncorhynchus nerka*), and coho salmon (*Oncorhynchus kisutch*). All of the species are anadromous and are important sources of food for both human and wildlife. Pink and chum salmon do not have a period of freshwater residence after emergence of the fry, as chinook, coho, and sockeye salmon do (ADFG 2002a). Pacific salmon migrate from freshwater rearing habitats to the marine environment, where they spend one to six years before returning to their natal rivers to spawn (Alaska Fisheries Science Center [AFSC] 2003a). Salmon populations in the Gulf of Alaska have been highly productive in recent decades, which may be the result of fluctuating climate and community changes in the Gulf of Alaska (AFSC 2003b). Icy Strait in the northern region of southeast Alaska is the principal seaward corridor used by juvenile salmon, such as pink and chum salmon, migrating to the Gulf of Alaska from inside water of the region. Juvenile salmon are most abundant in June and July; declining abundance in August coincides with declining zooplankton biomass. Annual and seasonal differences in biophysical parameters were related to early marine growth of salmon. Lower temperatures result in lower zooplankton biomass, which translates into lower growth during June and July for pink and chum salmon in straight habitats. Lower growth of juvenile salmon may lead to increased mortality by decreasing the ability to compete or by increasing vulnerability to size-selective predation (AFSC 2003a).

Killer Whale

The killer whale (*Orcinus orca*) is the largest member of the group of marine mammals known as dolphins (family Delphinidae). Adult killer whales may weigh as much as 10 tons. Killer whales in southeast Alaska live in groups called pods. Resident pods feed primarily on a wide variety of fish such as salmon, herring, halibut, and cod. Transient pods feed primarily on any available species of marine mammal, such as harbor seals or sea lions (ADFG 2002b).

Humpback Whale

The humpback whale (*Megaptera novaengliae*) is distinguished from other whales by its extremely long flippers, which may reach 25 to 30 percent of its entire length. Female adults average 42 feet in length and male adults average 40.5 feet in length. Humpback whales feed primarily on herring, other small schooling fish, and on swarms of euphausiids (krill). The humpback whale summers in Southeast Alaska and spends the rest of the year in tropical areas of the Pacific Ocean. Recent studies indicate that more than 500 humpback whales may be found in Southeast Alaska during the summer. A Federal Recovery Plan was formulated for the humpback whale in 1991 (ADFG 2002e).

Pacific Harbor Seal

Pacific harbor seals (*Phoea vitulina richardsi*) inhabit coastal and estuarine waters off Baja California, north along the western coast of North America to Cape Newenham in the Bering Sea (Pacific Marine Fisheries Management). Harbor seals use nearshore rocks, reefs, sand bar beaches, and drifting glacial ice for rookery and haulout sites. They feed in marine, estuarine, and occasionally fresh waters. They frequent logs and floating structures, shallow bays and tidal flats near abundant food sources (Pacific Marine Fisheries Management). Harbor seals can be found along the Pacific coast on a year-round basis. Harbor seals' diet varies seasonally and includes bottom-dwelling fishes (e.g., flounder, sole, eelpout), invertebrates (e.g., octopus), and other species (e.g., herring, lance, squid). Recently weaned pups tend to feed on prey that are more easily captured than fish such as shrimp or other crustaceans (EPA 1993).

Black Oystercatcher

The primary habitat of the black oystercatcher (*Haematopus bachmani*) is rocky coasts and islands. The back oystercatcher eats various marine invertebrates (e.g., mussels, worms, echinoderms), fish, crustaceans, barnacles, and limpets. It nests above the high tide line in weedy turf, beach gravel, or rock depressions (Ehrlich et al. 1988).

Semipalmated Plover

The semipalmated plover (*Charadrius semipalmatus)* breeds in northern Canada and Alaska and on parts of the east coast of Canada, in particular Newfoundland and Nova Scotia. It winters along the east and west coasts of the United States and Mexico, south of Virginia in the east, and south of central California in the west. The semipalmated plover feeds mainly on crustaceans but will also eat insects and seeds regularly. The diet may be supplemented with small molluscs and aquatic worms (Hebert, P.D.N, 2002).

Sea Otter

Sea otters are members of the weasel family (Mustelidae) and are related to mink and river otters. An adult male's average weight is 70 to 90 pounds (32 to 41 kilograms); females average 40 to 60 pounds (18 to 27 kilograms). Otters daily food intake can equal one-quarter of its body weight (ADFG 2002c). The primary habitat of the sea otter (*Enhydra lutris*) is kelp beds and rocky shores. Its diet consists of abalones, sea urchins, and other marine mammals. Its range is from the Aleutian Islands of Alaska to California (Burt 1976).

2.3.2 Human Health Conceptual Site Model

Figure 3 presents a CSM for human receptors. The CSM provides the primary source, release and transport mechanisms, exposure pathways, and receptors for identified COIs. Closed circles indicate significant complete exposure pathways, open circles indicate insignificant or potentially complete exposure pathways, and broken lines represent incomplete exposure pathways.

As shown in Figure 3, small vessels may discharge effluent while moored in port or while stationary offshore. Constituents of the sewage effluent include coliform bacteria, chlorine, ammonia, and other substances (see Section 1.1 above and Section 2.4 below). Detailed information on small ship wastewater effluent constituents can be accessed by going to http://www.state.ak.us/dec/press/cruise/documents/impact/smallvessels.htm on the web. These COIs mix with ambient water and are transported throughout the port or offshore waters. Humans may be exposed to COIs found in surface water, aquatic plants, sediment, fish, marine mammals, and shellfish. Human receptors of concern include adult and child subsistence hunters and gatherers, children who swim and play in the water, commercial divers, commercial fishers, and recreational shellfish gatherers. Although other people such as recreational fishermen, kyakers, and boaters may also have contact with contaminated media, the receptors of concern are assumed to have a higher potential for contact and therefore a greater potential for exposure and health risks.

The adult and child residents who use Alaska waters for collection of subsistence foods may be exposed to COIs in vessel effluent through ingestion of aquatic plants, represented by seaweed and kelp; ingestion of fish, shellfish, mammals, and other marine life such as salmon, halibut, rockfish, clams, crabs, octopus, shrimp, and seal; and incidental ingestion of, and dermal contact with, sediment and surface water at both port and offshore locations.

Two recreational receptors are also considered. A child who swims at the port or offshore may be exposed to COIs in vessel effluent through incidental ingestion of surface water and sediment and through dermal contact with surface water and sediment. In addition, a recreational user may collect and consume shellfish, such as crabs, at an offshore location. This recreational user is potentially exposed to COIs in vessel effluent through incidental ingestion of sediment and surface water and also may be exposed through ingestion of shellfish.

Two occupational receptors include a commercial diver and commercial fisherman. The diver is assumed to conduct subsurface construction work or may collect seafood. The commercial fisherman also is assumed to collect shellfish and fish. Thus, both occupational receptors may be exposed to COIs in vessel effluent through ingestion of fish and shellfish and incidental ingestion of and dermal contact with surface water at port and offshore locations. Contact with sediment by the occupational receptors of concern is considered a potentially complete or insignificant pathway only.

Although the model for this study did not provide a measure of loading to sediments due to effluent discharges, the potential for exposure to human receptors from this medium is considered low and deemed negligible in light of the study's objectives.

2.4 Selection of Chemicals of Potential Concern

The Contaminants of Interest (COIs) identified in Section 1.1 (see Table 1) were evaluated for inclusion as chemicals of potential concern (COPCs). If a maximum COI concentration from a single ship exceeded screening benchmark values it was included in the modeling process. If no benchmark was available (e.g., most conventional pollutants) and the COI was a standard discharge constituent for wastewater treatment facilities, it was also considered a COPC. If the COI in question was found at extremely low levels or found intermittently and was not typical of wastewater discharges, it was not considered a COPC. From this approach, only COPCs that were standard contaminants in effluent and were at concentrations above identified benchmarks were included in the dispersion modeling process.

COPCs were initially selected through a comparison of the maximum detected concentration with available water quality criteria (standards) or other appropriate screening values established for protection of aquatic biota or human health (Tables 3 and 4, respectively). When human health criteria were not available for a chemical, ecological screening values were used. Screening levels included EPA's National Recommended Water Quality Criteria (2002a) for marine water and State of Alaska Water Quality Standards (18 AAC 70.020). EPA's marine water quality criteria for protection of humans who consume aquatic life and criteria for protection of organoleptic (taste and odor) effects were both included in the COPC screening process. In addition, water quality criteria from other states were included in the screening when EPA and ADEC criteria were not available. While criteria are available for water that is consumed as drinking water, few criteria are available for protection of marine water that is used for recreation and harvesting seafood.

No COPCs had octanol-water partitioning coefficients (K_{ow}) greater than 3.5; therefore, none were considered bioaccumulative and risk from this perspective was not considered relevant. The following COIs (or chemical attributes) either exceeded screening levels or were considered important wastewater components and were retained as COPCs and modeled for potential dispersion effects: fecal coliform, chemical oxygen demand (COD), biochemical oxygen demand (BOD), nitrogenous oxygen demand (NBOD), total suspended solids (TSS), ammonia-N, total N, free chlorine, phosphorous and copper. To avoid repetition, certain COIs were selected at individual ports to illustrate the nature of contaminant migration through water quality modeling. Due to lack of site-specific data on the properties of the COIs, it was not necessary to run the models with each of the COIs at each of the ports. For example, for metals, only copper was selected at Ketchikan port to illustrate the distribution nature of a dissolved metal under a given hydrodynamic condition. Since the partitioning of metals into dissolved and suspended phase can not be made without site-specific data on partitioning coefficients (K_d) and total suspended solids (TSS), settling velocity or degradation coefficient, all metals were considered as a conservative dissolved substance with zero settling velocity. Consequently, the modeling results with copper will provide information on the nature of distribution for all metals with similar properties. Only the absolute values of the concentration isopleths will vary depending on the concentration of the respective metals in the effluents from the cruise ships.

3

Toxicological Profile and Effects Evaluation

Information on the toxicity of the modeled contaminants of potential concern (COPCs), based on the selection process described in section 2.4, is provided in Appendix A. The toxicity assessments provide information regarding the nature of adverse effects that COPCs in vessel effluent could pose to both ecological and human receptors.

3.1 Fate and Transport

Fate-transport assessment evaluates the ability of chemical constituents to become mobile or to change in the environment, based on their chemical and physical properties and on processes that govern the interaction of constituents with environmental media. A discussion of fate and transport of contaminants helps to identify potential receptors that may be affected by constituent movement in the environment.

Properties Affecting Fate and Transport

Numerous chemical and physical properties, of both the chemical constituents and the surrounding media, are used to evaluate fate-transport mechanisms. In an aquatic environment, sediment transport and aqueous solubility of an analyte are the primary mechanisms. Chemical and physical properties of constituents such as vapor pressure, density, solubility, Henrys law constant, half-life or decay coefficient, organic carbon/water partitioning coefficient, and molecular weight, are used to evaluate fate and transport (Table 3). Compounds with similar chemical and physical properties display similar fate-transport behavior. These characteristics facilitate the general grouping of contaminants, based on chemical and physical properties, into these categories: conventional pollutants, semivolatile organic compounds (SVOCs) and inorganics.

Table 3. Chemical Characteristics Based on Chemical and Physical Properties

Property	Critical Value	High (>)	Low (<)
Vapor Pressure	10^{-3} mm Hg	Volatile	Nonvolatile
Density[a]	1.0 g/cm^3	Sinks/falls	Floats/rises
Solubility[a]	0 to 100 mg/L	Leaches from sediment; mobile in water; does not readily volatilize from water	Sorbs to sediment; immobile in water; volatilizes from water
Henry's Law Constant	$5x10^{-6}$ to $5x10^{-3}$ atm-m^3/mole	Resistance to mass transfer in the aqueous phase	Resistance to mass transfer in the gas phase
Half-life ($T_{1/2}$)	Biologically dependent	Does not degrade readily	Degrades readily
Organic Carbon/Water Partitioning Coefficient[a] (K_{oc})	10 to 10,000 kg_{oc}/L_{water}	Tends to sorb to organic material in sediment; immobile in the sediment matrix	Tends not to sorb to organic material in sediment; mobile in the sediment matrix
Molecular Weight	400 g/mole	Characteristics listed above may not hold true; more detailed evaluation necessary	All of the above generally hold true

Notes:
a = Determinations of the Critical Values were based on literature review and professional judgment.
MmHg = millimeters of mercury
g/cm^3 = grams per cubic centimeter
atm-m^3/mole = atmospheres per cubic meter per mole
g/mole = grams per mole

Conventional Pollutants

The properties of the COPCs used in the respective models are discussed in section 5 describing the models and the results.

Inorganics

Solubility has the greatest influence on the fate and transport of inorganics. Inorganics, for this discussion, are limited to metals. Typical fate-transport characteristics are as follows.

- Metals tend to sorb to sediment particles.
- Metals are not degradable, but may be assimilated by biota.
- Metals tend to have moderate to low mobility; however, in environments where pH is less than 5 (i.e., acidic conditions), metals can become mobile.

Site-specific conditions (tannic acid, humus, etc.) can significantly modify pH. These conditions may result in suspension or precipitation of metals within the water column and thus an increased or decreased potential for deposition into sediment. Overall, metals are anticipated to be immobile and to remain sorbed to sediment particles, not readily diffusing into overlying waters.

Media Properties Affecting Fate and Transport

The properties of environmental media used to evaluate fate and transport are total organic carbon (TOC), normalized partition coefficient (K_d), cation exchange capacity (CEC), oxidation/reduction (redox) conditions, pH and TSS.

Total Organic Carbon

TOC indicates the sediment's sorptive capabilities. The higher the TOC, the higher the potential for a chemical, particularly an organic compound, to sorb to sediment particles.

Normalized Partition Coefficient (K_d)

K_d is used to predict the capacity for a constituent to partition between sediment and water; it is a function of both the constituent and the sediment. To estimate K_d, the constituent's organic carbon/water partitioning coefficient (K_{oc}) is adjusted by the sediment's TOC: $K_d = K_{oc} \times f_{oc}$, where f_{oc} = organic carbon content fraction of the sediment. Sediments with higher K_ds have a higher potential to sorb organic compounds.

Cation Exchange Capacity (CEC)

CEC reflects the sediment's capacity to adsorb ions, neutralizing ionic deficiencies on the surfaces of its particles. Generally, trivalent ions are preferentially adsorbed to sediment over divalent ions, and divalent ions are preferentially adsorbed over monovalent ions. Although this relationship generally holds true, the process also depends on sediment pH. Sediment with high CEC values has the potential to adsorb inorganic ions, although organic compounds with dipole moments also are affected by CEC.

Oxidation/Reduction Conditions

Redox is the process that includes oxidation (the loss of electrons) and reduction (the gain of electrons). The resultant change in valence generates products that are different from the parent reactants in their solubilities, toxicities, reactivities, and mobilities. Extreme redox conditions tend to mobilize chemicals, especially transition metals.

pH

The pH value is a measure of the negative inverse logarithm of the hydrogen ion concentration in water, indicating the acidity or alkalinity of the medium. Chemicals react differently as pH changes. Low pH conditions tend to mobilize most metals and facilitate substitution in organic compounds. High pH conditions may cause metals to precipitate and organic molecules to degrade.

Total Suspended Solids (TSS)

The terms "sediment" and "silt" are often used to refer to suspended solids. Suspended solids consist of an inorganic fraction (silts, clays, etc.) and an organic fraction (algae, zooplankton, bacteria, and detritus) that are carried along by water as it runs off the land. The inorganic portion is usually considerably higher than the organic. Both contribute to turbidity, or cloudiness of the water.

Suspended solids can clog fish gills, either killing them or reducing their growth rate. They also reduce light penetration. This reduces the ability of algae to produce food and oxygen.

Indirectly, suspended solids can affect other parameters such as temperature and dissolved oxygen. Because of the greater heat absorbency of the particulate matter, the surface water becomes warmer and this tends to stabilize the stratification (layering) in embayments. This, in turn, interferes with mixing, decreasing the dispersion of oxygen and nutrients to deeper layers.

A positive effect of the presence of suspended solids in water is that toxic chemicals such as pesticides and metals tend to adsorb to them or become complexed with them which makes the toxics less available to be absorbed by living organisms.

4

Exposure Assessment

An exposure assessment considers the concentration of a pollutant at which a receptor is exposed (exposure point concentration [EPC]), in addition to the duration of time at which that receptor may be exposed. In the case of human exposure this may entail the pollutant concentration found in a body of water to which a person is exposed on a temporary or intermittent basis, or it may relate to exposure through ingestion of contaminated food items. In this case, the time intervals at which a human is exposed to water-borne contaminants, or the amount and number of times a person consumes contaminated food (based on the concentration found within the food item), will ultimately provide a measure of exposure to the contaminant.

Ecological receptors differ in that they are continually exposed to a contaminant if it is found within the medium in which they normally exist (e.g., water). In the case of ecological receptors in Alaskan waters, exposure mechanisms will include exposure via skin or gill uptake from aqueous-borne contaminants, in addition to exposure through food items (which are also exposed continually) that they consume on a regular basis within the body of water [if the contaminant can be bioaccumulated or biomagnified through the food web].

For this study, the occurrence of resources (i.e., areas that support receptors in some fashion) that are proximal to ship docking, berthing, or mooring sites and that thus provide a measure of exposure to either human or ecological receptors, were considered “sensitive resources.” Sensitive resources were identified near the areas (docking, berthing, or mooring sites) considered in the modeling process, and contaminant concentrations that posed a risk to these areas, based on the effects-based benchmarks considered (Ecological Benchmarks; Table 4 and Human Health Benchmarks; Table 5) were noted.

The following sections provide information on sensitive resources within the study area that have been identified near modeled discharge points (i.e., Areas of Concern [AOCs]) selected as docking, berthing, or mooring sites.

4.1 Designated Areas of Concern

The following provides a brief discussion of the designated *Areas of Concern* (AOC) that were addressed by this risk evaluation. Generally, the sites represent ports where ships dock; mooring sites near port cities; or areas within scenic bodies of water where ships remain stationary for more than 4 hours. As stated previously, although effluent discharge occurs along transit pathways between AOCs, a greater likelihood of cumulative effects is predicted at locations where ships aggregate. Five AOCs were considered in this risk evaluation:

- Juneau;
- Sitka;
- Skagway;
- Haines; and
- Ketchikan.

Table 4. ADEC Cruise Ship Risk Evaluation; Comparison of Saltwater Water Standards/Criteria based on Human Health Protection

Contaminants of Concern (COCs)	EPA (1999) National Recommended Water Quality Criteria[a] (µg/L)	EPA (1999) National Recommended Water Quality Criteria - Organoleptic Effects (µg/L)	EPA (2000) Maximum Contaminant Levels - Freshwater (µg/L)	WA-Ecology Ambient Saltwater Quality Criteria[c] (µg/L)	ADEC (1999) Water Quality Standards 18 AAC 70.020(b) (µg/L)	Miscellaneous Saltwater Criteria For Protection of Human Health/Consumption of Aquatic Life (µg/L)
Conventional Pollutants (mg/L)						
Alkalinity						
Ammonia						2.5[d]
Biological Oxygen Demand-5 Day						
Chemical Oxygen Demand						
Fecal Coliform Bacteria			0		20 col/100 mL	14 col/100 mL[e]
Free Cl residual						
Oil & Grease						15[f]
Nitrate as N			10000			
TKN	10000					
PH			6.5 - 8.5		6.5 - 8.5	
Phosphorous, Total						
Total Cl, residual			4000		2	2[g]
Total Nitrate & Nitrite as N			10000			
Total Organic Carbon						
Total Settleable Solids						
Total Suspended Solids						
Priority Pollutant Metals (µg/L)						
Antimony, Total Recoverable	14		6	4,300		
Arsenic, Dissolved	0.018		5	0.14		
Arsenic, Total Recoverable						
Cadmium, Dissolved			5			2.7[h]
Cadmium, Total Recoverable						

Table 4. ADEC Cruise Ship Risk Evaluation; Comparison of Saltwater Water Standards/Criteria based on Human Health Protection

Contaminants of Concern (COCs)	EPA (1999) National Recommended Water Quality Criteria[a] (µg/L)	EPA (1999) National Recommended Water Quality Criteria - Organoleptic Effects (µg/L)	EPA (2000) Maximum Contaminant Levels - Freshwater (µg/L)	WA-Ecology Ambient Saltwater Quality Criteria[c] (µg/L)	ADEC (1999) Water Quality Standards 18 AAC 70.020(b) (µg/L)	Miscellaneous Saltwater Criteria For Protection of Human Health/Consumption of Aquatic Life (µg/L)
Chromium, Dissolved						
Chromium, Total Recoverable			100			
Copper, Dissolved	1300	1000	1300			
Copper, Total Recoverable						
Lead, Dissolved						
Lead, Total Recoverable			15			
Nickel, Dissolved	610			4600		
Nickel, Total Recoverable						
Selenium, Dissolved	170		50	11000		
Selenium, Total Recoverable						
Silver, Dissolved						5700[i]
Silver, Total Recoverable						
Thallium, Dissolved	1.7		2	6.3		
Thallium, Total Recoverable						
Zinc, Dissolved	9100	5000				
Zinc, Total Recoverable						
Base, Neutrals, and Acids (µg/L)						
Benzoic Acid						
Benzyl Alcohol						
Bis(2-Ethylhexyl)Phthalate	1.8			6		
3&4-Methylphenol						
Diethylphthalate	23,000			120,000		
Di-n-Butylphthalate	2,700			12,000		2100[i]

Table 4. ADEC Cruise Ship Risk Evaluation; Comparison of Saltwater Water Standards/Criteria based on Human Health Protection

Contaminants of Concern (COCs)	EPA (1999) National Recommended Water Quality Criteria[a] (µg/L)	EPA (1999) National Recommended Water Quality Criteria - Organoleptic Effects (µg/L)	EPA (2000) Maximum Contaminant Levels - Freshwater (µg/L)	WA-Ecology Ambient Saltwater Quality Criteria[c] (µg/L)	ADEC (1999) Water Quality Standards 18 AAC 70.020(b) (µg/L)	Miscellaneous Saltwater Criteria For Protection of Human Health/Consumption of Aquatic Life (µg/L)
Phenol	21,000	300		4,600,000		
Priority Pollutants Volatile Organics (µg/L)						
1,2,4-Trimethylbenzene						
1,3,5-Trimethylbenzene						
2-Butanone						
4-Isopropyltoluene						
Acetone						
Benzene	1		5	71		
Bromochloromethane						
Bromodicloromethane			80[b]			46[j]
Bromoform	4.3		80[b]	360		
Bromomethane (Methyl bromide)	48			4,000		
Carbon Disulfide						
Chloroethane (Ethyl chloride)						
Chloroform	5.7		80[b]			
Chloromethane (Methyl chloride)						
Dibromochloromethane			80[b]			
Dibromomethane						
Ethylbenzene	3,100		700	29000		
Iodomethane						
m&P Xylenes			10,000			
Naphthalene						
tert-Butyl Methyl Ether		20				

Table 4. ADEC Cruise Ship Risk Evaluation; Comparison of Saltwater Water Standards/Criteria based on Human Health Protection

Contaminants of Concern (COCs)	EPA (1999) National Recommended Water Quality Criteria[a] (µg/L)	EPA (1999) National Recommended Water Quality Criteria - Organoleptic Effects (µg/L)	EPA (2000) Maximum Contaminant Levels - Freshwater (µg/L)	WA-Ecology Ambient Saltwater Quality Criteria[c] (µg/L)	ADEC (1999) Water Quality Standards 18 AAC 70.020(b) (µg/L)	Miscellaneous Saltwater Criteria For Protection of Human Health/Consumption of Aquatic Life (µg/L)
Toleune	6,800		1,000	200,000		

Footnotes:
a = Standard for human consumption of water + organism
b = 1998 Final Rule for Disinfectants and Disinfection Byproducts: The total for trihalomethanes is 80 ug/L.
c = Values from National Toxics Rule, 40 CFR 131 and 173-201A WAC, Water Quality Standards for Surface Waters of the State of Washington
d = British Columbia, Warrington 1997
e = Washington State - 173-201A WAC
f = ANZECC 1992
g = British Columbia, Swain & Holms 1985
h = NY Department of Environmental Conservation 1998
i = Delaware Department of Natural Resources and Environmental Conservation 1993
j = New Hampshire Department of Environmental Services

Table 5. ADEC Cruise Ship Risk Evaluation; Salt Water Standards/Criteria based on Effects to Marine Aquatic Life

Analytes	EPA (2002a) National Recommended Water Quality Criteria/ Saltwater CCC	EPA (2002a) National Recommended Water Quality Criteria/ Saltwater CMC	NOAA (1999) SQuiRTs Table/ Saltwater CCC	NOAA (1999) SQuiRTs Table/ Saltwater CMC	ADEC (2002) Division of Air and Water Quality Saltwater Aquatic Life Proposed Criteria/Chronic	ADEC (2002) Division of Air and Water Quality Saltwater Aquatic Life Proposed Criteria/Acute	EPA (2002b) Region 4 Waste Management Division Saltwater Surface Water Screening Values/Chronic
Conventional Pollutants (mg/L)							
Alkalinity	- -	- -	- -	- -	- -	- -	- -
Ammonia (total)	Formula	- -	- -	- -	Formula	Formula	- -
Ammonia (unionized)	- -	- -	- -	- -	0.035	0.233	- -
Biological Oxygen Demand-5 Day	- -	- -	- -	- -	- -	- -	- -
Chemical Oxygen Demand	- -	- -	- -	- -	- -	- -	- -
Fecal Coliform Bacteria	- -	- -	- -	- -	- -	- -	- -
Free Chlorine, residual[a]	- -	- -	- -	- -	0.002 (for salmonid fish) or 0.01 (for other organisms)	- -	- -
Chlorine	0.0075	0.013	- -	- -	0.0075	0.013	0.0075
Oil & Grease	- -	- -	- -	- -	- -	- -	- -
Nitrate as N	- -	- -	- -	- -	- -	- -	- -
Total Kjeldhal Nitrogen	- -	- -	- -	- -	- -	- -	- -
Phosphorous, Total	0.0001	- -	0.0001	- -	0.0001	- -	- -
Total Chloride, residual	- -	- -	- -	- -	- -	- -	- -
Total Nitrate & Nitrite as N	- -	- -	- -	- -	- -	- -	- -
Total Organic Carbon	- -	- -	- -	- -	- -	- -	- -
Total Settable Solids	- -	- -	- -	- -	- -	- -	- -
Total Suspended Solids	- -	- -	- -	- -	- -	- -	- -
Priority Pollutant Metals (µg/L)							
Antimony, Total Recoverable	- -	- -	500	1,500	- -	- -	- -

Table 5. ADEC Cruise Ship Risk Evaluation; Salt Water Standards/Criteria based on Effects to Marine Aquatic Life

Analytes	EPA (2002a) National Recommended Water Quality Criteria/ Saltwater CCC	EPA (2002a) National Recommended Water Quality Criteria/ Saltwater CMC	NOAA (1999) SQuiRTs Table/ Saltwater CCC	NOAA (1999) SQuiRTs Table/ Saltwater CMC	ADEC (2002) Division of Air and Water Quality Saltwater Aquatic Life Proposed Criteria/Chronic	ADEC (2002) Division of Air and Water Quality Saltwater Aquatic Life Proposed Criteria/Acute	EPA (2002b) Region 4 Waste Management Division Saltwater Surface Water Screening Values/Chronic
Arsenic, Dissolved[b]	36	69	36	69	36	69	36
Arsenic, Total Recoverable	36	69	- -	- -	- -	- -	- -
Cadmium, Dissolved	8.8	40	9.3	42	8.8	43	9.3
Cadmium, Total Recoverable	8.9	40	- -	- -	- -	- -	- -
Chromium (VI), Dissolved	50	1,100	50	1,100	50	1,100	50
Chromium (VI), Total Recoverable	50	1,108	- -	- -	- -	- -	- -
Copper, Dissolved	3.1	4.8	3.1	4.8	3.1	2.9	2.9
Copper, Total Recoverable	3.7	5.8	- -	- -	- -	- -	- -
Lead, Dissolved	8.1	210	8.1	210	8.1	220	8.5
Lead, Total Recoverable	8.5	221	- -	- -	- -	- -	- -
Nickel, Dissolved	8.2	74	8.2	74	8.2	75	8.3
Nickel, Total Recoverable	8.3	75	- -	- -	- -	- -	- -
Selenium, Dissolved	71	290	71	290	71	300	71
Selenium, Total Recoverable	71	291	- -	- -	- -	- -	- -
Silver, Dissolved	- -	1.9	- -	- -	1.9	2.3	0.23
Silver, Total Recoverable	- -	- -	- -	- -	- -	- -	- -
Thallium, Dissolved	- -	- -	- -	2,130	- -	213	21.3
Thallium, Total Recoverable	- -	- -	- -	- -	- -	- -	- -
Zinc, Dissolved	81	90	81	90	81	95	86
Zinc, Total Recoverable	86	- -	- -	- -	- -	- -	- -
Base, Neutrals, and Acids (µg/L)							
Benzoic Acid	- -	- -	- -	- -	- -	- -	- -
Benzyl Alcohol	- -	- -	- -	- -	- -	- -	- -

Table 5. ADEC Cruise Ship Risk Evaluation; Salt Water Standards/Criteria based on Effects to Marine Aquatic Life

Analytes	EPA (2002a) National Recommended Water Quality Criteria/ Saltwater CCC	EPA (2002a) National Recommended Water Quality Criteria/ Saltwater CMC	NOAA (1999) SQuiRTs Table/ Saltwater CCC	NOAA (1999) SQuiRTs Table/ Saltwater CMC	ADEC (2002) Division of Air and Water Quality Saltwater Aquatic Life Proposed Criteria/Chronic	ADEC (2002) Division of Air and Water Quality Saltwater Aquatic Life Proposed Criteria/Acute	EPA (2002b) Region 4 Waste Management Division Saltwater Surface Water Screening Values/Chronic
Bis(2-Ethylhexyl)Phthalate	- -	- -	- -	- -	- -	- -	- -
3&4-Methylphenol	- -	- -	- -	- -	- -	- -	- -
Diethylphthalate	- -	- -	- -	- -	- -	- -	75.9
Di-n-Butylphthalate	- -	- -	- -	- -	- -	- -	3.4
Phenol	- -	- -	- -	- -	- -	- -	58
Priority Pollutants Volatile Organics (µg/L)							
1,2,4-Trimethylbenzene	- -	- -	- -	- -	- -	- -	- -
1,3,5-Trimethylbenzene	- -	- -	- -	- -	- -	- -	- -
2-Butanone	- -	- -	- -	- -	- -	- -	- -
4-Isopropyltoluene	- -	- -	- -	- -	- -	- -	- -
Acetone	- -	- -	- -	- -	- -	- -	- -
Benzene	- -	- -	700	5,100	- -	- -	109
Bromochloromethane	- -	- -	- -	- -	- -	- -	- -
Bromodicloromethane	- -	- -	6,400	12,000	- -	- -	- -
Bromoform	- -	- -	- -	- -	- -	- -	640
Bromomethane (Methyl bromide)	- -	- -	- -	- -	- -	- -	120
Carbon Disulfide	- -	- -	- -	- -	- -	- -	- -
Chloroethane (Ethyl chloride)	- -	- -	- -	- -	- -	- -	- -
Chloromethane (Methyl chloride)	- -	- -	- -	- -	- -	- -	2,700
Dibromochloromethane	- -	- -	6,400	12,000	- -	- -	- -
Ethylbenzene	- -	- -	- -	430	- -	- -	4.3
Iodomethane	- -	- -	- -	- -	- -	- -	- -

Table 5. ADEC Cruise Ship Risk Evaluation; Salt Water Standards/Criteria based on Effects to Marine Aquatic Life

Analytes	EPA (2002a) National Recommended Water Quality Criteria/ Saltwater CCC	EPA (2002a) National Recommended Water Quality Criteria/ Saltwater CMC	NOAA (1999) SQuiRTs Table/ Saltwater CCC	NOAA (1999) SQuiRTs Table/ Saltwater CMC	ADEC (2002) Division of Air and Water Quality Saltwater Aquatic Life Proposed Criteria/Chronic	ADEC (2002) Division of Air and Water Quality Saltwater Aquatic Life Proposed Criteria/Acute	EPA (2002b) Region 4 Waste Management Division Saltwater Surface Water Screening Values/Chronic
m&P Xylenes	- -	- -	- -	- -	- -	- -	- -
Naphthalene	- -	- -	- -	2,350	- -	- -	23.5
tert-Butyl Methyl Ether	- -	- -	- -	- -	- -	- -	- -
Toluene	- -	- -	5,000	6,300	- -	- -	37

Footnotes:
ADEC = Alaska Department of Environmental Conservation.
CCC = Criterion Continuous Concentration, which is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect.
CMC = Criteria Maximum Concentration, which is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect.
EPA = United States Environmental Protection Agency.
ug/L = Micrograms per liter.
mg/L = Milligrams per liter.
NOAA = National Oceanic and Atmospheric Administration.
– – indicates that surface water quality criteria are not provided for listed analyte.
[a] ADEC (1999) Water Quality Standard for residual chlorine based on marine water use of growth and propagation of fish, shellfish, other aquatic life, and wildlife.
[b]Water quality criterion was derived from data for arsenic (III), but is applied to total arsenic, which might imply that arsenic (III) and arsenic (V) are equally toxic to aquatic life and that their toxicities are additive.

4.2 Sensitive Resources – Human Health

Sensitive resources for humans are those that are important for cultural, recreational, or subsistence practices. Because many of the villagers in the southeast region maintain a subsistence lifestyle and/or are employed by the fishing industry, the sensitive areas for ecological receptors described in Section 2.1 also are also important for human populations and thus represent an exposure potential. This also includes areas where aquatic farms are located, i.e., salmon hatcheries, oyster and mussel farms, and kelp farms. Most of these farms are located between Ketchikan and Petersburg. The recreational areas listed in Section 2.2 are those that are valued for wildlife viewing, fishing, diving, and other recreational uses. Sensitive resources proximal to each selected AOC are provided on maps that have been developed showing contaminant distribution isopleths (see Section 5.0).

4.3 Sensitive Resources - Ecological

This section presents brief descriptions of environmentally sensitive areas in the southeast region that are close to the small cruise ship routes. These sensitive areas (Table 6) were identified from information provided from ADEC, EPA, and the U.S. Coast Guard (USCG 1997) in the Southeast Sub-area Contingency Plan and the Draft Geographic Response Strategies (GRS) for Southeast Alaska (Southeast GRS Workgroup 2003). Although these environmentally sensitive areas are highlighted in this discussion, it is important to note that the region is generally considered biologically rich. Sensitive resources proximal to selected AOCs are provided on maps that have been developed showing contaminant distribution isopleths (see Section 5).

Table 6. Ecologically Sensitive Resource Areas Near Small Cruise Ship Discharge Points

Sensitive Area Identification	Sensitive Area Attributes	Closest Small Cruise Point Discharge Location
Chilkoot River Flats	• Salmon concentrations • Eulachon spawning • Waterfowl and shorebird spring and fall staging and winter concentrations • Bald eagle feeding concentrations	Haines
Taiya River	• Harbor seal concentration	Skagway

Table 6. Ecologically Sensitive Resource Areas Near Small Cruise Ship Discharge Points

Sensitive Area Identification	Sensitive Area Attributes	Closest Small Cruise Point Discharge Location
	• Eulachon spawning • Salmon spawning • Marsh • Sheltered tidal flats • Waterfowl and shorebird concentration (Spring & Fall) • Sheltered rocky shore	
Mendenhall Wetlands	• Salmon concentrations • Eulachon spawning • Waterfowl and shorebird spring and fall staging and winter concentrations • Seabird colonies (>100 birds) • Mendenhall Wetlands State Game Refuge	Juneau
Auke Bay West	• Waterfowl and shorebird concentration area (Winter) • Clam bed • Marsh • Kelp or eelgrass beds	Juneau
Middle Island	• Marine mammals • Tidal mud flats • Marine invertebrates	Sitka
Sandy Cove	• Marsh • Eelgrass Inter-tidal	Sitka
Pirate Cove	• Herring spawning areas • Kelp beds and eelgrass • Inter-tidal	Sitka
Indian River	• Salmon concentrations • Herring spawning areas • Juvenile fish habitat • Waterfowl and shorebird migration, molting and winter habitat	Sitka
Sources: ADEC, EPA, and USCG (1997) and Southeast Alaska Geographic Response Strategies Workgroup (2003)		

The use of an area by a federal- or state-listed threatened, endangered or sensitive species must, by definition, be considered during any discussion of sensitive resources. Table 7 lists rare, endangered, and threatened species of the open water and coastline of southeast Alaska, as listed by Shannon & Wilson, Inc. (1999), and by ADEC, EPA, and USCG (1997).

Table 7. Rare, Threatened and Endangered Species of the Alaskan Southeast Ecoregion

Occurrence	Common Name	Latin Name	Status	Subregion	Preferred Habitat
BIRDS					
SU	Kittlitz's murrelet	*Brachyramphus brevirostris*	SSSC	Coastline	Open water and beach bluffs
RU	Marbled murrelet	*Brachyramphus marmoratus*	SSSC	Coastline and coastal western hemlock-Sitka spruce forests	Open water and nests in coastal forests
SU	Peale's peregrine falcon	*Falco peregrinus pealei*	USFS-S	Coastal western hemlock-Sitka spruce forests	Coastal nesting habitat
SU	Short-tailed albatross	*Diomedea albatrus*	FE	Coastline	Open water and beach bluffs
SU	Osprey	*Pandion haliaetus*	USFS-S	Coastal western hemlock-Sitka spruce forests	Near lakes, rivers, and coast
MAMMALS					
SU	Bowhead whale	*Balaena mysticetus*	FE, SSSC	Pacific Ocean	Open water
SU	Sei whale	*Balaenoptera borealis*	FE	Pacific Ocean	Open water
SU	Blue whale	*Balaenoptera musculus*	FE, SE	Pacific Ocean	Open water
SU	Fin whale	*Balaenoptera physalus*	FE	Pacific Ocean	Open water
SU	Northern fur seal	*Callorhinus ursinus*	NMFS-D	Coastline	Shorelines
SU	Northern right whale	*Eubalaena glacialis*	FE, SE	Pacific Ocean	Open water
SU	Steller sea lion	*Eumetopias jubatus*	FT, SSSC	Coastline	Remote shorelines
SU	Humpback whale	*Megaptera novaeangliae*	FE, SE	Pacific Ocean	Open water
RU	Harbor seal	*Phoca vitulina richardsi*	SSSC	Coastline	Shorelines
SU	Sperm whale	*Physeter marcrocephalus*	FE	Pacific Ocean	Open water

Notes:

RU – Resident, Uncommon; SC – Seasonal, Common; SU – Seasonal, Uncommon; NR – Not Reported

FE - Federal Endangered; FT - Federal Threatened; FP - Federal Proposed Species; USFS-S - U.S. Forest Service Sensitive Species

NMFS-D - National Marine Fisheries Depleted Species; SE- State Endangered; SSSC - State Species of Special Concern

Sources: Shannon & Wilson, Inc. (1999) and ADEC, EPA, and USCG (1997)

5

Fate and Transport: Water Quality Modeling

5.1. General Considerations

The southeastern coastal zone of Alaska is shown in Figure 1. Modeling fate and transport of contaminants from moving sources in such a large water body is a highly complex and time-consuming process. Therefore, several strategies were taken so that the process could be simplified yet still capture the essential features of pollutant migration in this environment. These are enumerated below.

5.1.1. Localized Models

The water bodies of the entire southeastern coast of Alaska cover a large geographic area. A highly complex curvilinear grid covering the entire coastal water was first constructed (Figure 4) for the development of pollutant fate and transport model using CARDINAL software (see Appendix B). Theoretically, hydrodynamic and pollutant transport modeling can be carried on this large grid. However, it was found that due to the large geographical extent compared to the localized discharge events, such a model would not yield any significant insight on the nature of pollutant transport in this environment. Furthermore, sufficient hydraulic and meteorological data (such as tides, wind, etc.) are not available to cover this entire area. Consequently, a selected number of areas (see Figure 1) were chosen for fate and contaminant transport modeling. However, the initial small-scale model was still used as a guide to determine the regional flow patterns and water level fluctuations for the selected 24-hour (h) period of July 14, 2001 modeled in the present investigation. The five selected areas represent four types of water systems that constitute the southeastern coastal zone of Alaska under consideration. These include: bays; estuaries; straits; and coastal channels.

5.1.2. Locations of the Cruise Ships

In practice, discharge of treated wastewater from the cruise ships into the coastal waters occurs when both the ships are traveling and when they are anchored at the ports or near a cove. Although incorporation of moving sources of discharge is possible in the CARDINAL modeling system, due to the localized areas that were selected, the appropriate strategy was to select certain ships at certain ports for a definite duration of discharge during a given day. A date during the summer of 2001, around which most of the sampling of the discharged wastewater was conducted, was selected as the 'model date'. This date is July 14, 2001, and all fate and transport models are based on the 24-hour period of this date.

5.2 Input Data

5.2.1. Bathymetric Data

Bathymetric maps covering the entire water bodies in the southeastern coastal zone of Alaska were purchased. These maps were scanned and input into the CARDINAL software system so that depth values at a sufficient number of points within a water body could be graphically input into the model. From these scattered point values, an interpolation program within CARDINAL, was run to assign depth values at each of the nodes of the curvilinear grid covering a particular water system. The following admiralty maps (scale 1: 250000) were used.

- Admiralty Map No. 62796. Ministry of Defense, Russia, 1995. Juneau Area.

- Admiralty Map No. 62793. Ministry of Defense, Russia, 1995. Sitka Area.
- Admiralty Map No. 62795. Ministry of Defense, Russia, 1995. Ketchikan Area.
- Admiralty Map No. 62792. Ministry of Defense, Russia, 1995. Skagway Area.
- Admiralty Map No. 62792. Ministry of Defense, Russia, 1995. Haines Area.

The maps are included in Appendix D for reference purpose. These maps were also used to develop the small-scale models shown as Figure 4.

5.2.2. Tidal Data

Tidal data are required to define the open boundary conditions (time history of the water levels at open boundaries of the water bodies). These data were obtained from the NOAA website [http://co-ops.nos.noaa.gov/data_res.html] for 14 July 2001 (day with minimum tide). Data could be obtained from four sites; Skagway, Juneau, Sitka, and Ketchikan. Figure 5 (A-B) shows the tidal data used in the models.

5.2.3. Wind data

Wind data are used to define the surface boundary conditions. Wind data (direction, speed, and atmospheric pressure) were taken from the NOAA site http://www.ndbc.noaa.gov/Maps/alaska_hist.html for the 'model date'. Figure 6 shows the wind-rose diagrams for the two localities where data were available. These two localities are Five Finger (Station No. FFIA2) and Cape Edgecumbe Buoy (Station No. 46084).

5.2.4. Chemical Data

Analyses of treated wastewater were carried out during the summer of 2001. In certain cases, samples were taken on more than one occasion (maximum 3 samples during this year from a given ship) and in those cases the analytical results were averaged to obtain a representative analysis for the 2001 sampling round. Most samples and analysis were conducted between July and September. However, the analyses were considered to be representative of the water quality of the treated wastewater that was discharged during the 24-hour period of July 14, 2001. The duration of discharge from a particular ship at a given port was obtained by the Alaska Department of Environmental Conservation. Table 8 presents the summary of the data.

5.3. Model Parameters

As illustrated in Appendix B, there are several hydraulic and chemical parameters that are required for modeling. Ideally, such model parameters are initially selected from a range of plausible values that have been either experimentally or empirically derived from numerous studies and have been published in scientific/technical literature. These initially selected values of the various model parameters are subsequently refined for site-specific cases with model calibration that involves comparison of the water quality parameters observed in the field to those predicted by the models. However, in the present study no field-based observations are available. Therefore, the initially selected values are the ones that are used in all of the models throughout. Table 9 shows the model parameters and their values used in the subsequent models.

For all computations, the initial concentrations of the pollutants in the water bodies were assigned to zero due to lack of available ambient water quality data. This does not introduce any error in the interpretation of the results as long as relative magnitude and extent of pollutant transport is of primary concern. However, the added assumption in this approach is that there is no reaction between a discharged pollutant and any of the pollutants present in the ambient water.

Water levels at the boundary conditions were assigned from the tidal data at 00:00:00 h on July 14, 2001. The time step for computation of the 24-hour transport models was 1 to 3 seconds(s). A second-order advection term was considered in each model, and tangential velocities at the open boundaries were set to zero.

5.4. Areas of Concern (AOCs): Localized Hydrodynamics and Pollutant Models

5.4.1. The Ketchikan Area

The Area of Concern (AOC) that is considered for this model is bounded to the north by latitude

55°41′55.8″N, to the south by 55°12′18.4″N, to the west by longitude 131°43’’0.7″ W, and to the east by 130°59′54″W. In this model the water body is a strait located to the south of Ketchikan (Figure 7). The grid size of the model is 121 × 355 × 1 = 42955 points and the grid steps are about 20 m across the strait and about 60 m along its longitudinal direction.

In the models, three ships, namely *Spirit of Discovery*, *Spirit of 98*, and *Matanuska*, discharged treated wastewater for different durations during a 24 h period on July 14, 2001 (Table 8). The *Spirit of Discovery* discharged from 4 AM till 12 Noon, *Spirit of 98* discharged from 2 PM till 10 PM, and *Matanuska* discharged from 10 PM till 12 midnight.

Figure 8 (A-T) shows the velocity patterns and distribution of fecal coliform for the 24 h period, at two hours interval starting two hours after *Spirit of Discovery* started discharging. The flow patterns exhibited by the strait and the passages to the northeast and south west of Pennok Island are characterized by unidirectional flow from northwest to the southeast. However circulation occurs to southeast of Pennok Island.

During the discharge event of *Spirit of Discovery*, the maximum fecal concentration 1.45 × 10^5 MPN/m^3 is found after six hours of discharge (Fig. 8F). During the initial phase of discharge, the depth-averaged contaminant plume is elongated in shape with longitudinal dimension far greater than the transverse dimension. Areas with high concentrations persist as long as the ship discharges (Fig. 8J). The length of the concentrated plume achieves its maximum value two hours after discharge stopped (Fig. 8J). At this time the length of the plume is 8.4 km and width is 200 m. At the time discharge stopped (Fig. 8H), the length of the plume is 7.2 km and width is 400 m. Note that the plume propagated about 10 km to the southeast through the eastern passage around the Pennok Island. With time, its length gradually increased.

The locations of *Spirit of 98* and *Matanuska* are the same so the pollutant plumes generated from the discharge from these two ships interfere. The resultant plume exhibits the same characteristics as the plume from *Spirit of Discovery* with the exception of the absolute vales of concentrations at different parts of the plume. The maximum fecal concentration of 2.1 × 10^5 MPN/m^3 is observed at 8:00 PM. The plume geometry for the time period 8:00 PM to

Table 8. Cruise Ships Locations during July 14, 2001, Duration of Treated Wastewater Discharge, and the Water Quality Parameters

Vessel	Date	Time	Discharge Flow Rate (m^3/sec)	Total Chlorine (mg/m^3)	Fecals (MPN/m^3)	pH	COD (mg/m^3)	BOD (mg/m^3)	Cond.	Free Chlorine (mg/m^3)	TSS (mg/m^3)	Ammonia as Nitrogen (mg/m^3)	Total Nitrogen (TKN) (mg/m^3)	Phos-phorous (mg/m^3)
Kennicott	12/4/2001	16:00-20:00	0.00074884	3500	5.00E+04	7.1	500000	3500	NA	3000	43000	4170	28700	110
Kennicott	7/10/02 Mixed BW&GW	16:00-20:00	0.00074884	40000	10,000	8.1	870000	500	31200	25000	22500	80	28700	110
Spirit of Columbia	9/5/2001 BW only	00:00-24:00	0.00017473	14000	1.00E+04	7.23	569000	32100	NA	3500	518000	10704	10500	365
Spirit of Endeavor	08/25/01 AVG BW&GW	8:00-20:00	0.00011036	0	4.00E+09	7.99	816000	234500	NA	50	252300	42680	10500	5190
Clipper Odyssey	08/04/01 AVG BW&GW	8:00-20:00	0.00014189	0	5.66E+08	NA	351160	200000	NA	50	47000	2060	3050	1593
Taku	(AVG 2001) AVG BW&GW	16:00-20:00	7.09E-05	1750	1.00E+09	7.31	800000	165000	12502	500	164000	3200	48000	4920
Spirit of Oceanus	08/27/01 GW	18:00-24:00	0.0001072	0	1.60E+11	5.39	860000	1010000	NA	50	269000	39750	1400	4540
Spirit of Discovery	08/30/01 BW	4:00-12:00	0.00022071	0	9.00E+10	7.72	697000	88200	NA	50	142000	2100	365	
Spirit of 98	08/18/01 BW	14:00-22:00	0.00022071	0	1.60E+11	7.5	1240000	585000	NA	50	880000	10500	5190	
Matanuska	04/09/01, 12/18/01 Mixed BW/GW	20:00-24:00	0.00074884	3100	1.10E+07	7.3	608000	130000	35900	50	71500	17600	2380	
Malaspina	07/02/01 Mixed BW&GW	16:00-20:00	0.00074884	0	7.00E+04	7.9	470000	20000	34800	50	40000	800	345	

Table 9. Hydrodynamic Parameters used in the Fate and Transport Models

Parameters	Values
Horizontal Eddy Viscosity Coefficient (*A*)	20 m^2 s^{-1}
Bottom Friction Coefficient, *f(n,h)* (where *n* is Manning's *n*)	$f = 9.81\sqrt{\frac{n}{\sqrt[3]{h}}}$
N	0.025
Equivalent grain size of bottom sediments	0.5 mm
Grain Density	2.65 g cm^{-3}
Density of sediments	2600 kg m^{-3}
Turbulence Model	Prandtl or Prandtl-Montgomery method
Wind drag coefficient	$C_D = a + b\lvert\vec{W}\rvert$ where, a = 0.000630 and b = 0.0000660
Sedimentation	Model off
Wall sliding	None
Ice Cover	None
Horizontal Diffusion Coefficient, *K*	$K = 10^{-6} e^{(1.15\ln(100L))}$, where L is the grid length
Sinking velocity, v_s	0.0 (unless specified in the text)
BOD decay rate (first order reaction), $_1$	0.3 day^{-1}
Nitrification/NH_3 oxidation rate (first order reaction), λ_2	0.1 day^{-1}
Degradable COD oxidation rate (first order reaction), λ_3	0.3 day^{-1}

10:00 PM, due to the combined discharge of two ships (Fig. 8R) show that the concentrated plume is 6.25 km long and 125 m in its maximum width. After 4 hours of discharge from *Matanuska*, the zone of maximum concentration for fecal coliform is 3.2 km long, with a maximum width of 133 m (Fig. 8T).

During the 24 h modeling period the plume was restricted within the passage to the northeast of Pennok Island. However, it should be pointed out that if such discharge events are continued for a longer period of time, then the plume has the potential to migrate toward the ecologically sensitive area; Bostwick Inlet (see Fig. 7).

Three points are noteworthy from the above models.

- In a water body with the geometry of a strait and flow velocity patterns dominated by a unidirectional flow with negligible transverse components, the contaminant plume is elongated with its longitudinal dimension far greater than its transverse dimension.

- The pollutant plume contains zonal distributions of contaminant concentrations. The concentrated parts of the plume exist as long as the discharge continues. The plume becomes diluted within a short interval after discharge discontinues. In other words, the mixing zones are restricted around the point of discharge and are elongated in shape for this type of water geometry. Thus, the length of the mixing zone is a function of the coastal current and duration of discharge.

- The overall plume geometry presented above is applicable to all other pollutants that can be considered as conservative substances. In other words, the distribution of the fecal concentration was modeled by assuming that the first order decay coefficient (l in equation 3, Appendix A) is zero. For other pollutants such as dissolved metals, if this approximation is made then their relative patterns of distribution will be the same as those presented in Figure 8 (A-T). Only the absolute values of the contaminant concentration will vary. The absolute values can be calculated simply by taking the ratio of the pollutant load that has been modeled (e.g. the fecal bacteria used above) and the load of the pollutant for which absolute values in the various zones need to be calculated.

Another model set with ammonia nitrogen (NH_3-N) has been computed (Figure 9; A-J). In this case, the pollutant does not behave as a conservative substance. The first order decay coefficient for NH_3-N is taken as 0.1 day^{-1} (Thomann and Mueller, 1987). In this instance too, the pollutant plume is characterized by a long elongate/lenticular shape, with its longitudinal dimension far exceeding the transverse dimension. The only difference in plume configuration from the case with fecal coliform [that was considered as a conservative substance] is that the areal extent of the concentrated portion of the plume is much smaller. The maximum concentration of NH_3-N is calculated as 0.09 mg/m^3 [i.e., 9.0 E-05 mg/L] after 6 h of discharge from *Spirit of Discovery* (Fig. 9C).

To illustrate the nature of migration for a dissolved metal, one model set was calculated for treated wastewater discharge for which data on copper concentrations were available. Copper concentration in the treated wastewater discharge from the ship *Matanuska* at Ketchikan port is highest amongst the measured copper concentrations in all wastewater samples (see Table 1). However, there is no metal data on the wastewater samples from the other two ships that are included in Ketchikan port. Discharge from *Matanuska* creates an extremely dilute plume with maximum copper concentration of 7.1×10^{-4} mg/m^3 [i.e., 7.1 E-07 mg/L] after two hours of discharge (Fig. 10 A-D). With progression in time, the mixing zone elongates in the direction of flow and progressively becomes further diluted. It should be noted that in these models, no partitioning of the metal into dissolved and adsorbed phases was made due to lack of site specific data on K_d (partition coefficient). Furthermore, the dissolved metal was considered as a conservative substance.

5.4.2. The Sitka Area

The model domain is bounded to the east by latitude 135°26′15.0″ W to the north by longitude 57°4′29.5″ N and to the south by 56°56′30.0″ N (Figure 11-A). The grid size of the model is 193 × 97 × 1 (18721 points) with grid step of about 30-50 m (Figure 11-A). In contrast to the geometry of a strait (e.g. Ketchikan area), the water body of the Sitka area is a bay. Consequently, the velocity field (current pattern) in this area is characterized by localized circulation (vortex formation) as well as ebb and tide (Figure 11-B and C).

In the models, two ships, namely *Spirit of Columbia* and *Kennicott*, discharged treated wastewater for different durations during a 24 h period on July 14, 2001 (Table 8). The *Spirit of Columbia* discharged continually for the entire 24 h period while *Kennicott* discharged from 4 to 8 PM.

Figure 12 (A-T) shows the velocity patterns and distribution of fecal coliform for the 24 h period, at two hours interval starting two hours after *Spirit of Columbia* started discharging. The flow patterns exhibited by the bay are characterized by multidirectional flows and vortex (circulation) formation. Consequently, there is no single well-defined plume of the pollutant. The contaminant spreads and circulates around the point of discharge. Note that in this case, a zone with maximum fecal coliform concentration of 4×10^{-5} to 5×10^{-5} MPN/m^3 persist throughout the modeling period. This zone is surrounded by successive zones with progressively lower concentrations of coliform bacteria. The overall pattern of distribution of the pollutant is a swirling and spreading dilute mixing zone.

A pollutant that has potentially high toxicity is free residual chlorine. However, modeling fate and transport of free residual chlorine is not straightforward without site-specific data on the environmental chemistry of residual chlorine. Thus, before presenting approximate fate and transport model of free residual chlorine, the uncertainties are briefly reviewed.

Residual free chlorine in the treated wastewater was measured at all of the ports that were modeled. The highest concentration (3 ppm [mg/L]) was observed from the *Kennicott* ship at Sitka. The next highest concentration was 0.5 ppm from the ship *Taku* at Skagway. In all other cases concentration of free residual chlorine was very low (0.05 ppm). However, in order to assess the behavior of free residual chlorine, the chemical data collected during the second round of sampling in the year 2002 were used, as these represent a worst-case scenario. As provided in Appendix C, the 2002 data show that the residual chlorine concentration in the discharge from the ship *Kennicott* was as high as 25 mg/L. This value, along with the 3.5 mg/L free chlorine as measured in the discharge water from the ship *Spirit of Columbia,* were used in modeling the fate and transport of free residual chlorine at Sitka.

Free chlorine in the wastewater originates during disinfection by chlorination. When Cl_2 (g) is dissolved in water then the two aqueous species of chlorine are HOCl (hypochlorous acid) and OCl^- (hypochlorate ion). Toxicity of HOCl is far greater (in the order of 100-1000 times) than OCl^-. However, the fraction of HOCl increases with decreasing pH. At a near neutral pH value (~ 7.0) and a temperature of 0°C, 90% of free residual chlorine is HOCl. At the same pH but temperature of 20°C, the percentage of HOCl decreases to 80%. Furthermore, if the discharge water contains dissolved ammonia then free chlorine residual reacts extremely fast with ammonia to form chloramines. In any event, both HOCl and OCl^- are highly unstable. Under all pH-pe (electron activity or oxidation-reduction potential) conditions of natural water, Cl^- is the most stable form. This is due to the strong oxidizing property of chlorine. Free chlorine in the form of HOCl and OCl^- has the oxidation state of (+1). It oxidizes water (and the dissolved ions in it such as ammonia) and itself is reduced to chloride in which its oxidation state is (-1). Consequently, the rate of decay of free chlorine or the rate of conversion of Cl(+1) to Cl(-1) is extremely fast. Furthermore, the rate also depends on salinity, temperature, and pH. Thus, the aquatic chemistry of dissolved chlorine is highly complex. For this reason, no good estimate of the rate of decay of free chlorine is available in the literature. This is normally assessed from a study of the specific system under consideration. Without such data, modeling the fate and transport of free chlorine residual into a water body is not quite meaningful. The US EPA (1984) notes that "The complexity of the reactions of chlorine in fresh and salt water makes it important that studies of the effects of chlorine on aquatic organisms be appropriately designed and that concentrations of TRC (total residual chlorine) or CPO (chlorine-produced oxidants) be adequately measured. Because the half-lives of TRC and CPO are short in most waters, usually tests must be flow-through and the concentrations must be measured often enough to demonstrate that substantial reduction in concentration is not occurring. Also, the measurements must usually be performed using a method (e.g. amperometric, idometric, or potentiometric titration, or DPD) that measures TRC or CPO and not just one or more components, such as free, but not combined chlorine."

With the uncertainties explained above, free chlorine was modeled as a conservative substance (similar to fecal coliform). This gives a highly conservative estimate of the pollutant distribution. However, the effect may be partly compensated by the depth-averaged values obtained in the models.

Figure 13 (A-K) shows the distribution of free residual chlorine for the 24 h period, at two hours interval starting two hours after *Spirit of Columbia* started discharging. The contaminant spreads and circulates around the point of discharge. Due to the assumption of conservative character of free chlorine, the pattern of migration of free chlorine is identical to that of fecal coliform. However, in the case of free chlorine, the concentration in the discharge water was significantly higher when *Kennicott* started discharging. As a result, the free chlorine concentration in the concentrated zone of the pollutant plume attained concentrations in the range of 0.00057- 0.00071 mg/m^3 (Φg/L). Successive zones with progressively lower concentrations of free chlorine surround this zone. The most dilute portions of the swirling plumes have free chlorine concentrations in the range of 0.00014-0.00028 mg/m^3.

In order to model fate and transport of BOD and COD an approach was adopted that is more significant for the direct effect of these pollutants on the water quality. In this respect, dissolved oxygen (DO) is the critical water quality parameter that controls sustainability of aquatic life. On the other hand, DO is controlled by carbonaceous and nitrogenous biochemical oxygen demand which constitute portions of chemical oxygen demand (COD). For this reason, the measured value of chemical oxygen demand (COD) was divided into two parts, namely the degradable (DCOD) and the non-degradable (NCOD) portions according to the following scheme:

$$DCOD = CBOD + NBOD \text{ and } NCOD = COD - DCOD$$

Where, CBOD = carbonaceous biochemical oxygen demand and NBOD = nitrogenous biochemical oxygen demand.

$$NBOD = 4.57 \times NH_3\text{-N (measured)}\ ;\ \ CBOD = BOD \text{ (measured)}$$

Figure 14 (A-L) shows the distribution of the degradable portions of chemical oxygen demand (DCOD), at intervals of two hours, resulting from discharge of treated wastewater from *Spirit of Columbia* and *Kennicott* at Sitka during the 24 h period on June 14, 2001. In this case, the pollutant is not a conservative substance. The decay coefficient for DCOD is taken as 0.3 day^{-1} (Thomann and Mueller, 1987). In contrast to the distribution pattern of fecal coliform (treated as a conservative substance), the migration of DCOD occurs in a better-defined pattern. During the initial stages of the discharge event, the plume geometry is lobe-shaped with the tapered end of the lobe emanating from the point of discharge. In time, the plume geometry changes through elongation and curvature. The concentrated part of the plume remains restricted near the points of discharge but the diluted parts of the plume spreads by formation of further lobes that are controlled by the circulation of coastal currents. The maximum concentration of DCOD is calculated as 0.14 mg/m^3 [i.e., 1.4 E-04 mg/L] after 8 h of discharge from *Spirit of Columbia* (Fig. 14D).

Figure 15 (A-L) shows the distribution of non-degradable portions of chemical oxygen demand (NCOD), at intervals of two hours, resulting from discharge of treated wastewater from *Spirit of Columbia* and *Kennicott* at Sitka during the 24-h period on June 14, 2001. In this case, the pollutant is treated as a conservative substance. The initial pattern of migration of NCOD is similar to that of DCOD (compare Figures 12 A-H with Figures 14 A-H) except that the size of the plume in case of NCOD is slightly larger than that of DCOD. However, after 4:00 PM, the differences in these patterns become more pronounced. In the case of NCOD plumes, the concentrated portions of the plumes spread further as elongated and bifurcated lobes. The maximum concentration of NCOD is calculated as 0.99 mg/m^3 [i.e., 9.9 E-04 mg/L] after 20 h of discharge from *Spirit of Columbia* (Fig. 14D).

The salient points from these model calculations can be summarized as follows:

- In a coastal water body with the geometry of a bay, the contaminants spread in circular or oval shaped plumes with branches and lobes, the pattern being controlled by the circulatory currents, ebbs and tides.
- If the pollutant is a conservative substance then it spreads further as diluted plumes having swirling lobes and branches.
- If the pollutant is a non-conservative substance then its migration is relatively restricted close to the source. However, the absolute value of the decay coefficient does influence the geometric pattern of the plumes.

5.4.3. The Skagway Area

The boundaries of the model domain (i.e., AOC) are latitudes 59°31′1.2″N to the north, 59°25′6.5″N to the south and longitudes 135°26′6.4″W to the west and 135°18′40″W to the east (Figure 16). The grid size of the model is 81 × 249 × 1 (20169 points) with grid step of about 10-30 m (Figure 17 A). The geometry of the water body is that of a wide and deep in-land estuary (Figure 17B).

In the models, two ships, namely *Spirit of Oceanus* and *Taku*, discharged treated wastewater for different durations during the 24 h period of July 14, 2001 (Table 8). The *Taku* discharged from 4 to 8 PM while *Spirit of Oceanus* discharged from 6 PM to 12 midnight. Therefore, the model was run without any pollutant being discharged from midnight to 4 PM.

Figure 18 (A-P) shows the velocity patterns and distribution of phosphorous for the 8-h period, at one-hour intervals beginning after *Taku* started discharging. The flow patterns exhibited within this estuarine water body are characterized by reversal of flow directions from north to south and south to north. However, the flow is dominantly from north to south during the period of pollutant discharge. In these models, phosphorous acts as a conservative substance and hence represents all other conservative substances in their patterns of migration in this water body. The plume geometry is characterized by oval shaped pattern with concentric zonal distribution of the pollutant. The highest concentration is around the points of discharge. The maximum concentration of P is 0.11 mg/m^3 [i.e., 1.1 E-04 mg/L], observed about two hours after discharge ceased (Figure. 17 L). The maximum length of the plume is 300 m and width is 150 m (Fig. 18 H, P).

Figure 19 (A-H) shows the distribution of BOD for the 8-h period, at one-hour intervals beginning after *Taku* started discharging. In these models, BOD acts as a non-conservative substance with first-order decay coefficient of 0.3 day^{-1} (Thomann and Mueller, 1987). The plume geometry is characterized by oval shaped pattern with concentric zonal distribution of the pollutant. The highest concentration is around the points of discharge. The maximum BOD concentration 24 mg/m^3 [i.e., 2.4 E-02 mg/L] is observed about two hours after discharge ceased (Figure. 18 F). The maximum length of the plume is 200 m and width is 150 m (Fig. 19 F, H).

Figure 20 (A-H) shows the distribution of NH_3-N for the 8-h period, at one hour intervals beginning after *Taku* started discharging. In these models, NH_3-N acts as a non-conservative substance with first-order decay coefficient of 0.1 day^{-1} (Thomann and Mueller, 1987). The plume geometry is characterized by an oval shaped pattern with a concentric zonal distribution of the pollutant. The highest concentration is around the point of discharge. The maximum concentration of NH_3-N is 0.96 mg/m^3 [i.e., 9.6 E-04 mg/L], observed about two hours after discharge ceased (Fig. 20 F). This is equivalent to 4.39 mg/m^3 [i.e., 4.4 E-03 mg/L] NBOD. The maximum length of the plume is 368 m and width is 191 m four hours after the discharge ceases (Fig. 19 H).

A distinction can be drawn between the plume geometry observed in the case of a narrow strait (e.g. Ketchikan) and that in the case of a wide and deep estuary. In the case of the former, the contaminant plume is elongated with length of the plume several order of magnitude greater than the width of the plume. In the latter case however, the plume is oval shaped with longitudinal dimension slightly exceeding the transverse direction. In both cases, magnitude and extent of the concentrated plume depends on the conservativity coefficient of the pollutant. The plume geometry due to release of P and NH_3-N appear similar in spite of the fact that in the case of P, the decay coefficient is 0^{-day} whereas in the case of NH_3-N the decay coefficient is 0.1^{-day}. However, the pollutant plume resulting from BOD has shorter longitudinal dimension than those resulting from P and NH_3-N due to a larger decay coefficient (0.3^{-day}).

5.4.4. The Juneau Area

The model domain is bounded to the west by latitude 134°35′0.0″ W to the north by longitude 58°44′53.4″ N and to the south by 58°22′0.0″ N (Figure 21). The grid size of the model is 99 × 315 × 1 (31185 points) with grid steps of about 10 m in the direction across the strait, and 100 m along its longitudinal direction. The geometry of the water body is that of a deep and straight channel. However, geographically it can also be classified as a strait. The tidal effects (reversal of current direction) are pronounced in this AOC.

In the models, two ships, namely *Spirit of Endeavor* and *Clipper Odyssey*, discharged treated wastewater from 8 AM to 8 PM during the 24 h period of the model date (Table 8). Therefore, the model was run without pollutant discharge from midnight to 8 AM on June 14, 2001. The locations of these two ships at Juneau port are very close to each other (< 10 m apart).

Figure 22 (A-P) shows the velocity patterns and distribution of fecal coliform for the 16 h period, at two-hour intervals starting two hours after both the ships started discharging. The flow patterns exhibited by the strait are characterized by flows from northwest to the southeast and vice versa. As a result of these counter currents, a single plume originally generated by simultaneous discharge of treated wastewater from two ships, is broken down into two parts giving the appearance of two plumes juxtaposed to each other (Figures 22B, D, H). However, the concentrated portions of the fecal coliform plumes are not divided into two parts due to these velocity reversals.

During the discharge event, the maximum fecal concentration 11.6×10^3 MPN/m^3 is observed after eight hours of discharge (Fig. 22H). During the initial phase of discharge, the depth-averaged contaminant plume is elongated in shape with the longitudinal dimension greater than the transverse dimension. Within the modeling period, the length of the plume achieves its maximum at 12:00 midnight, or four hours after discharge stops (Fig. 22P). At this time, the length of the plume is 4.4 km and maximum width is 200 m. At the time discharge stopped (Fig. 8H), the length of the plume is 3.6 km and width is 360 m. Note that the plume propagated about 3.2 km to the southeast. With progress in time, its length gradually increased and there were formations of two concentrated parts along the length of the entire plume (Figure 22P). Areas with high concentrations (concentrated plumes) persisted even after discharge ceased (Fig. 22 N, P).

For the reasons discussed with Sitka models, CBOD and NBOD were used in the Juneau models to assess the effect of discharge on DO in this water system. Figure 23 (A-H) shows the distribution of the carbonaceous biochemical oxygen demand (CBOD), at intervals of two hours, resulting from discharge of treated wastewater from *Spirit of Endeavor* and *Clipper Odyssey* at Juneau during the 16 h period on June 14, 2001. In this case, the pollutant is not a conservative substance. The decay coefficient for CBOD is taken as 0.3 day^{-1} (Thomann and Mueller, 1987). In contrast to the geometry of the pollutant plume resulting from fecal coliform (treated as a conservative substance), the concentrated part of the CBOD plume breaks into two juxtaposed portions due to the counter current directions discussed above. However, as time progresses, the two parts tend to merge into one long, elongated plume. Similar to the situation for the fecal coliform plume, at the end of the simulation period there are two concentrated parts along the entire length of the plume (Figure 23H). The maximum concentration of CBOD is calculated as 0.65 mg/m^3 [i.e., 6.5 E-04 mg/L] after 6 h of discharge from *Spirit of Endeavor* and *Clipper Odyssey* (Fig. 23D).

Figure 24 (A-H) shows the distribution of nitrogenous biochemical oxygen demand (NBOD), at intervals of two hours, resulting from discharge of treated wastewater from *Spirit of Endeavor* and *Clipper Odyssey* at Juneau during the 16 h period on June 14, 2001. In this case too, the pollutant is treated as a non-conservative substance with the decay coefficient taken as 0.1 day^{-1} (Thomann and Mueller, 1987). In the case of NBOD, the combination of the decay coefficient and velocity reversals tend to negate each other's effect, resulting in a single elliptical plume as opposed to the divided plumes observed with fecal coliform and CBOD. However, after the cease of treated wastewater discharge, the plume geometry changes to an elongated shape with two separated regions of concentration along the longitudinal direction. The maximum concentration of NBOD is calculated as 0.71 mg/m^3 [i.e., 7.1 E-04 mg/L] after 6 h of discharge from *Spirit of Endeavor* and *Clipper Odyssey* (Fig. 24D).

Two points are noteworthy from the above models:

- In a water body with the geometry of a channel and hydrodynamics characterized by countercurrents resulting from tidal cycles, the contaminant plume can be divided into two parts by reversal of flow direction. The nature and extent of the break-up of the plumes into two transverse parts is not only a function of reversals of flow directions but also of the magnitude of the decay coefficient and location of the discharge points.

- The pollutant plume contains zonal distributions of contaminant concentrations. During the initial stages of the discharge event the shape of the plume tends to be elliptical, but with progression in time the plume becomes elongated with its longitudinal dimension far greater than the transverse dimension. However, there can be more than one zone of concentrated plume along the longitudinal direction of the entire plume. The overall plume can be shifted with time due to advection only.

5.4.5. The Haines Area

The boundaries of the model domain are latitudes 59°28′51.1″N to the north, 59°10′16.1″N to the south and longitudes 135°20′1.9″W to the west and 135°18′40″W to the east (Figure 17). The grid size of the model is 65 × 99 × 1 (6435 points) with grid step about 10-30 m. The geometry of the water body is that of a wide and deep estuary; downstream of the confluence of two other estuaries.

At Haines port, only one ship, *Malaspina*, discharged treated wastewater from 4 to 8 PM on June 14, 2001.

Figure 25 shows the hourly velocity distribution around the Haines AOC on June 14, 2001. In general, the flow was always seaward in a south-southeasterly direction. However, due to the confluence of two estuaries to the north-northwest of Haines, flow was also toward the Haines shoreline and occasionally northwest along the northwestern part of the estuary (Figures 25 CC, EE).

At Haines, fecal coliform was modeled as a non-conservative substance with a very large decay coefficient of 37 day^{-1} (Thomann and Mueller, 1987). As long as the flow is to the southeast, the shape of the fecal coliform plume is elliptical (Figures 25- R, T, V, X, Z, and BB). The size of the elliptical plume increases as discharge progresses with time. When the current is directed toward the shoreline, the concentrated part of the plume reaches the shoreline (Figures 25 DD and FF). As discussed earlier, this is an ecologically sensitive area (the opposite side of Chilkoot River flat). The maximum fecal concentration is calculated as 10^{-2} MPN/m^3 after 4 h of discharge.

Phosphorous was used as an example of migration of conservative pollutant at Haines. In this case, the initial pollutant plume is elliptical in shape (Fig 25 A-B). However, from 7 PM (three hours after discharge started), the plume geometry changed to pear-shaped (Figures 26 C, D, E) and eventually to an elongated and lens-shaped (Figures 26 E, F, G, H) patterns. Note that the original elliptical plume that developed around the source shifted 1 km southward and the diluted portion of the plume approached the shoreline. The highest concentration of P within the concentrated plume was calculated as 0.81×10^{-4} mg/m^3 [8.1 E-08 mg/L] at 6:00 PM; two hours after the discharge started (Fig. 26 B). The maximum length (4.48 km) of the plume was achieved at 12:00 midnight (Fig. 26 H). However, the maximum width (1.5 km) was achieved at 10:00 PM (Fig. 26 F).

Fate and transport of total suspended solid (TSS) was modeled at Haines by considering a settling velocity value of 2.74 cm/year. In this case, the grid size of the model is $65 \times 99 \times 15$ (96525 points). The overall pattern of migration of this pollutant is similar to that of phosphorous (Figure 27 A-F). However, in this case due to incorporation of the settling velocity in the model, the plumes represent the concentrations near the water surface as opposed to the depth-averaged values obtained in all of the other models discussed. The maximum concentration is calculated as 0.09 mg/m^3 [9.0 E-05 mg/L] at 5:00 PM; one hour after the discharge began (Figure 27A). Figure 28 (A-B) shows the vertical distribution of TSS along the cross sectional lines shown in the inset figures. Note that in spite of introducing a settling velocity for this pollutant, concentrations are higher in the surface layers, and the pollutant practically does not penetrate to the bottom layers of the water body. Figure 29 (A-B) shows the vertical distribution of TSS, velocities, and vertical eddy viscosity near the source (point of discharge).

5.5. Sources of Uncertainties

Any water quality model should first be built on certain basic observations made in the field, and subsequently calibrated against observations on water quality parameters collected from the field. The present investigation lacks these two aspects, and as a result, the models presented here provide the approximate nature of the fate and transport of the pollutants investigated along with inherent uncertainties. These sources of uncertainties that should be eliminated during any future investigation are briefly discussed below.

Open boundary conditions

In general, open boundary conditions are some of the most important attributes within the hydrodynamic component of the simulations presented above. In coastal waters, hydrodynamics strongly control the fate and transport of the contaminants. For example, Figure 30 illustrates how the coastal currents can create a highly complex flow regime within a relatively restricted geographic area.

As an example of the importance of open boundary conditions in the fate and transport modeling, attention is directed to the Ketchikan models. Initially the time history of water level at two open boundaries (see Fig.7 for their locations) was taken as predicted by NOAA for 14-15 July 2001 (day with minimum tide) for Ketchikan port (see Fig. 5B). In other words, the same time-dependent conditions existed for both the open boundaries. With this condition, it was found that due to shallowness opposite to Ketchikan, assignment of simultaneous oscillations on both of the open boundaries produced a wave anti-node near Ketchikan. In this area, periodic divergence or convergence of currents had occurred. Figure 31 (A) shows an example of current pattern near Ketchikan for the moment of convergence. Progressive-vector diagrams of velocities at different points in the Tongass Narrows Strait, when the same water level was assigned to the two open boundaries, are shown in Figure 31 (B). It can be seen that currents in the north and south are directed first opposite to each other and then towards each other.

In the Juneau model, where two open boundaries also exist for the strait, depths decrease from south to north. In this case, assignment of simultaneous oscillations on both open boundaries lead to a one-directional current from south to north. Thus, as can be concluded in the Ketchikan model, the influence of phase-shift on water oscillations for the two open boundaries should be taken into account.

Therefore, simulation of dynamics with the small-scale Alaska model (see Fig. 4) was made and water level oscillations on Ketchikan open boundaries were recorded. It was found that water level difference between north and south edges was approximately about 10 cm, and more often, water level at the northern edge was even higher. This result was incorporated in the Ketchikan model. Therefore, on the south open boundary, water level was assigned as predicted by NOAA, but on the northern boundary 10 cm was added to all values.

In the examples given above (Skagway-Haines, Ketchikan, and Juneau), only one set of data on the tidal harmonics were available from NOAA (see Figure 5 A-D). For the area, use of one set of observations at multiple open boundaries often lead to erroneous fluid mechanics for the water systems. The example illustrates that further studies, based on field observations, are necessary for more accurate setting of the open boundary conditions that control the water movements, and which in turn is the ultimate governing factor in the transport of pollutants in an aquatic environment.

Model Parameters

The model parameters can be divided into two categories; substance-specific and water system-specific. Substance-specific parameters include the decay coefficient and settling velocity. Water system-specific parameters include the eddy viscosity coefficient, bottom friction coefficient, and other physical attributes associated with the water body (see Table 9). The sensitivity of the fate and transport of a particular pollutant in a given water system to these parameters can be evaluated by varying these parameter values within a range that is applicable to the system under consideration. The applicable range can be obtained through modeling, provided sufficient amount of water quality data from a given area are available. Owing to the total absence of site-specific studies, no sensitivity analysis was conducted in the present investigation.

As shown with the examples of water quality modeling using both conservative (non-degradable) and non-conservative (degradable) substances in the same water body, the magnitude of the decay coefficient has a strong influence on the fate and transport of the pollutants. In general, values of decay coefficients depend on multiple factors, of which the overall chemical make-up of the water body and reactions between substances are the most dominant. Consequently, for this study, further studies would be necessary to evaluate the magnitudes of these parameters.

Of the physical parameters, settling velocity has a discernable influence on the model results. Values of settling velocities for various pollutants can only be ascertained from careful field measurements. Due to the lack of such data, the pollutant plumes calculated in all cases, with the exception of Haines TSS models, represent depth-averaged values. But, as shown with the Haines TSS models, within a 24 h period, the pollutants mostly remain near the surface of the water body. Thus, for the depth-averaged models, the actual magnitudes of the concentrated zones of the pollutant plumes are greater than those calculated in the models. In other words, the nature of migration of the pollutants predicted in these models are valid in their general characteristics, but their fates are not accurately predicted by grossly averaging their presence throughout the water column under consideration. In reality, most of the pollutants occur within the surface layers of the water bodies.

5.6 Summary of Observations on Pollutant Transport

Fate and transport of pollutants resulting from discharge of treated wastewater have been modeled by taking five (5) different geographic varieties of water bodies and the representative contaminants. The geometry of the water bodies includes that of a bay (Sitka), a strait (Ketchikan), a deep in-land estuary (Skagway), a coastal channel (Juneau), and a deep and wide estuary downstream of the confluence of two in-land estuaries (Haines). These water bodies represent the types of water systems present in the southeastern coastal zone of Alaska. The pollutants that were used in the model include; fecal coliform, degradable and non-degradable parts of COD, ammonia-nitrogen, CBOD, NBOD, phosphorous, free chlorine, and total suspended solids [due to analytical uncertainties, total nitrogen was not included in the model calculations]. Each of these are common pollutants found in treated wastewater. Furthermore, these pollutants cover the essential characteristics of all other pollutants. Therefore, the nature of migration of any other pollutant can be understood from the study of the nature of migration of the pollutants used in these models. In addition, copper, as the representative heavy metal pollutant, was also included in the models. The model calculations provide important insights into the fate and transport of pollutants discharged from treated wastewater in the southeastern coastal zone of Alaska from small passenger vessels (cruise ships).

The models show that:

1) Pollutant plumes are generated within the coastal waters of southeastern Alaska around the points of discharge of treated wastewater from the anchored cruise ships. Within a 24 h period, plume sizes can reach tens of square kilometers. The geometric shape of the plumes depends on the geographic type of the water bodies and hydrodynamics (velocity fields, tidal cycles etc.) of the water systems. In the case of a strait, the plume shape is long and elongated; within a bay the plumes are lobed to swirling branches; within an estuary, the plumes are oval to elliptical; and within a coastal water body having the geometry of a long open channel, the plumes are lenticular in shape. Thus, within an estuary the geographic extent of the plumes are smaller than those plumes within straits, bays, and channels. The implication of these geometric shapes is that pollutants can migrate from the points of discharge to ecologically sensitive areas depending on the nature of the water bodies.

2) Owing to the dependence of plume shape and size on the geography and hydrodynamics of the water body, variation of concentration over time at a certain point is also highly variable depending on those factors. Figure 32 (A-B) provides two examples. In the case of Sitka (Figure 32-A), where the plume geometry is not well defined, the pattern of variation of a pollutant concentration over time at different points are highly variable and erratic due to circulatory motion of the currents, ebbs and tides (Figure 32A). In the case of Skagway (Figure 32-B), where the pollutant plume has a well defined geometric shape, the variation of concentration near the source (point of discharge) is predictable. In this instance, the concentration increases, as discharge progresses and then declines as discharge stops and the plume migrates away with the flow of the water.

3) Due to strong control of the hydrodynamics on the plume shape and size, ebbs and tides affect both extension and restriction of a plume within a water system. In general, within the 24 h modeling period, plumes do not leave the boundary of

a water system. However, the extent of the plume also depends upon the duration of the discharge. In the models, the duration of discharge from each of the cruise ships is a discrete time period less than 24 h. If discharge continues for a longer period, the possibility exists for plumes to migrate beyond the boundaries of the model domains used in the present study.

4) A pollutant plume generated through discharge of a conservative (non-degradable) substance can migrate to great distances from the initial point of discharge and affect various areas. An example is provided in Figure 33. Figure 33A shows the locations of the point of discharge and the pollutant plume 5 hours later after discharge from the vessel *Spirit of 98* [Ketchikan] has ceased. Note that the plume has propagated about 10 km to the southeast through the eastern passage around the Pennok Island. Its length has increased about 2 times. The details of the isopleths within this plume at this hour are captured in Figure 33B. The concentration-time history at the point of discharge shown in Figure 33A, has been recorded in Figure 33C. Note that at the point of discharge, the concentration of the pollutant drops to an almost undetected levels after discharge ceased. But this does not imply that the pollutant plume has vanished from the water. It has simply been advected at another place.

5) As illustrated above, pollutant plumes can migrate several kilometers from the source and can persist in the water for a long period of time after the discharge ceases. This indicates that mixing zones of varying dimensions and concentrations exist within many portions of coastal southeast Alaskan waters due to discharge of treated wastewater from small passenger vessels. Dilution of these mixing zones takes a long time and can be inhibited by further or continued discharge.

6) In general, a pollutant plume exhibits relatively concentrated portions (shown in red and maroon), surrounded by very dilute portions (shown in green, blue, and black). A combination of factors such as the treated nature of the discharged wastewater, great volumes of the receiving water bodies, strong currents, etc., exert considerable influence on the dilution of the pollutants within the receiving waters. The models presented show that concentration levels for all the pollutants used are extremely low, even within the relatively more concentrated portions of the plumes. As modeled in this study, none of the calculated concentrations appear to pose a serious threat to receptors found within the aquatic environment.

7) A single plume can be divided into two or more parts due to the action of tidal actions and counter currents. This causes further spread and migration of the plume, a result of the complex function of the hydrodynamics of the water systems.

8) The present model calculations show that, in general, the concentration of the

pollutants, even in the concentrated parts of the plumes, are very low. However, before interpreting these dilute concentrations as a confirmation that no resources are at stake from the nature of the pollutant plumes, the numerous sources of uncertainties in the model results should also be considered. Most, if not all, of these uncertainties stem from the lack of site-specific chemical, water quality, and hydraulic data (see section 5.5). For example, for all pollutants except for TSS, the settling velocity is considered to be zero. As a result, for all these pollutants the depth-averaged values are obtained in the model. But as shown with the TSS model (see section 5.4.5), even a pollutant that is considered to be sinking, the concentrated parts remain mostly near the water surface. Thus, depth-averaging reduces the concentrations that are actually present near the surface layers. In other words, in realty, the concentrations of pollutants in various parts of the plumes should be considered higher than those calculated in the models.

9) From the discussions presented above it can be concluded that the general patterns of migration of the pollutants (transport of contaminants) predicted by the model calculations are valid. However, the magnitude of pollution (fate of the contaminants) predicted by the models has considerable uncertainties and should not be used as an absolute indication of the level of contamination that can result from discharge of treated wastewater from the numerous cruise ships found at many locations for substantially longer durations than those addressed by the model calculations.

10) Accurate estimation of model parameters is necessary for better interpretation of the model results. To illustrate the importance of these factors such as the decay coefficient, settling velocity, etc., Figure 34 (A-E) shows the fecal coliform model with decay coefficient 0 day^{-1} and settling velocity 0 cm/day. In this case, the maximum fecal coliform concentration is calculated as 0.21 MPN/m^3 after 2 h of discharge from *Malaspina*. This is in contrast to the models previously presented (see Fig. 24) where a large decay coefficient (37 day^{-1}) was used. In that case, the maximum fecal concentration was calculated as 0.99×10^{-2} MPN/m^3. This example also shows that if a pollutant behaves as a conservative substance then not only is its concentration increased in the water body, but its persistence is also increased around the point(s) of discharge.

5.7 Modeling Recommendations

The models used in the present investigation have one serious limitation; they lack validation. Models can be validated only when they are calibrated with site-specific data. Given the large geographic extent of the area under consideration, the amount and types of data required for modeling with acceptable levels of uncertainties, and the many passenger vessels involved in the study, it is recommended that ADEC should select a few areas that cover the variety of water systems present in the study area shown in Figure 1. Once a small number of such areas/locations are selected, the hydrologic and meteorological data should be collected from these sites. The model parameters should then be evaluated from careful field measurements. The models calculated on the basis of these data should be further verified/calibrated for their fullest potential as forecasting/ decision making tools, as based on water quality data obtained from the field.

6

Risk Characterization

Results of the modeling efforts for COPC distributions in selected water bodies of southeast Alaska revealed that for the ‘model date’ used, most discharge concentrations were not at levels considered to be harmful to ecological or human receptors.

Although fecal coliform was modeled for most ports, a comparison of modeled volumetric concentrations to established levels of concern could not be made. Standard criteria for fecal coliform in Alaska and other states provide a measure directed at colonies per water volume, based on incubation techniques. Although an attempt was made to correlate volumetric data to laboratory determined colony concentrations, this was unsuccessful. Therefore, at present, only a relative evaluation of the modeled concentrations at the various ports can be made. It appears that discharged fecal coliform concentrations at Ketchikan warrant the most concern. The port is located on a strait, and the hydrodynamic modeling (see section 5.4.1) indicates that flow patterns and the water body’s configuration may reduce overall mixing effects and extend contaminant exposure periods. As such, an increase in the number of ships within this system, coupled with extended mooring or anchoring periods, could result in fecal coliform levels that could be significant to human (swimmers or shellfish collectors) or ecological receptors (shellfish) near or within the plume's boundary.

For phosphorous, although the maximum modeled concentration at Haines (8.1 E-08 mg/L) was several orders of magnitude below the ecological screening value (0.1 μg/L) presented in Table 5, the maximum concentration near Skagway (1.1 E-04 mg/L) was very near the screening value. For copper, the maximum concentration modeled at Ketchikan (7.1 E-04 μg/L) was approximately four orders of magnitude lower than the ADEC criterion (2.9 μg/L) presented in Table 5.

For free chlorine, the highest estimated concentration (~0.00071 mg/m^3; equal to Φg/L), near the port of Sitka, was several orders of magnitude less than the state's water quality criterion of 2 Φg/L. Even with a very conservative assumption that the fate of free chlorine in marine waters will act similarly to a conservative substance such as fecal coliform, the magnitude of concentrations observed were well below levels indicative of effects to marine biota.

Only ammonia-N concentrations, from the *Spirit of 98* near the port of Ketchikan, were above the ADEC chronic criterion for unionized ammonia of 0.035 mg/L, as presented in Table 5. Modeled concentrations (See Figure 9) exceeded the criterion throughout the discharge period (e.g., 20 hours). The exceedance of this criterion is important because source influx of nitrogen to marine systems can have significant affects to primary production and long term sustainability of an ecosystem. Generally speaking, nitrogen is considered the primary limiting nutrient in marine systems (Smith 1984). Although there is some debate on whether nitrogen (N) or phosphorous (P) is most limiting, McComb et al. (1981) and D'Elia et al. (1986) have proposed that both are important, with P limitation during spring and N limitation during the summer. But, for this study, a conservative approach would dictate that the additional N inputs resulting from ship discharges could potentially increase phytoplankton primary production, resulting in plankton blooms and related negative effects. Again, an increase in the number of ships within a system, coupled with extended mooring or anchoring periods, could result in long term nitrogen loading which might impact more confined water bodies.

Due to a lack of criteria or screening values, no comparison of modeled concentrations for BOD and COD could be made. Most significant is the fact that the nitrogenous component of COD, which is the conservative, non-degradable portion, will persist within a water body at a higher spatial coverage and longer period of time. This fate condition may thus increase its ability to impact sensitive receptors through effects on oxygen availability and utilization, especially within upper portions of the water column.

The most important aspect of the modeling efforts directed at TSS at Haines is the finding that this constituent appears to remain at the surface, despite the incorporation of a settling velocity parameter within the model. This is an important issue because limiting light penetration, due to increased TSS over time, may be an important factor when primary production within a system is considered. Cloern (1999) suggests that "among some coastal ecosystems, light availability appears to be an equally good predictor of phytoplankton primary production as nutrient loading".

7

Summary & Recommendations

The results of modeling efforts for small cruise ship waste water discharges, within the five water bodies addressed, indicate that no serious threat to either human or ecological receptors exist. A lack of screening values for some constituents makes definitive conclusions impossible, and the fate aspects of many of the parameters considered may indicate long term changes to the environment over time that cannot be determined through 'point-in-time' measurements. But at this stage, these implications are only theoretical. It is recommended that a more comprehensive evaluation of the annual inputs into some of the more hydraulically-restricted water bodies be conducted, with field verification of model parameters conducted for validation of the model's results.

8

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A

COPC Toxicity Profiles

Metals

Arsenic

In surface water, soluble inorganic arsenic (As5+) predominates under normal conditions and is more stable than arsenate. Soluble forms of arsenic remain dissolved in the water column or absorb onto sediments. Exposure routes for aquatic organisms include gill uptake, ingestion of arsenic suspended on particles in the water column or deposited in sediment, and ingestion of plant matter and lower trophic level aquatic species. Arsenic bioconcentration in aquatic organisms is low. Fish and shellfish rapidly metabolize arsenic to non-toxic forms. Biomagnification does not readily occur in the food chain (EPA 2002a).

Exposure to arsenic has been shown to lead to cancer-causing and mutation-causing effects in aquatic organisms, with effects including behavioral impairments, growth reduction, appetite loss, and metabolic failure. Bottom feeders are more susceptible to arsenic. Arsenic is a carcinogen (cancer-causing), teratogen, and possible mutagen (causing mutations in genes/DNA) in mammals. Chronic exposure can result in fatigue, gastrointestinal distress, anemia, neuropathy, and skin lesions that can develop into skin cancer in animals (EPA 2002a). The EPA lists a Chronic Continuous Concentration (CCC) of 36 µg/L of dissolved arsenic in saltwater (EPA 2002b) based on effects to aquatic life.

In humans, ingestion of arsenic in drinking water has been shown to cause blackfoot disease and increased incidence of keratosis, hyperpigmentation, and cancer of the liver, lung, bladder, and kidney (EPA 1998). EPA's criterion for arsenic for human consumption of seafood is 0.14 µg/L.

Copper

Copper is highly toxic in aquatic environments. Copper will bioconcentrate in many different organs in fish and mollusks. Copper is an effective algaecide. The copper free ions are the lethal agent. Single cell and filamentous algae and cyanobacteria are more susceptible to the acute effects, which include reductions in photosynthesis and growth, loss of photosynthetic pigments, disruption of potassium regulation, and mortality. Mammals are not as sensitive as aquatic organisms. The predominant mammalian effects include hepatic and renal toxicity, and fetal mortality (EPA 2002a). The EPA (2002b) lists a CCC of 3.1 µg/L of dissolved copper (3.7 µg/L of total recoverable copper) in saltwater based on effects to aquatic life.

Low levels of copper are essential for humans; however, exposure to high levels of copper can be toxic. Exposure to high levels of copper may cause mouth and eye irritation and may induce vomiting, nausea, and intestinal pain (ATSDR 2002).

Lead

Fish exposed to high levels of lead exhibit a wide-range of effects including muscular and neurological degeneration and destruction, growth inhibition, mortality, reproductive problems, and paralysis. At elevated levels lead can cause reduced growth, photosynthesis, mitosis, and water absorption. Lead adversely affects algal growth, invertebrate reproduction, and fish survival. Birds and mammals suffer effects from lead poisoning such as damage to the nervous system, kidneys, liver, sterility, growth inhibition, developmental retardation, and detrimental effects in blood (EPA 2002a). The EPA (2002b) lists a CCC of 8.1 µg/L of dissolved lead (8.5 µg/L of total recoverable lead) in saltwater based on effects to aquatic life.

Children are the most sensitive to lead exposure, exhibiting adverse effects on the central nervous system, blood, and organs (ATSDR 1999b). While less toxic to adults, higher doses of lead may result in similar effects as those seen in children and may also damage the reproductive system and cause birth defects (ATSDR 1999b). The EPA has not developed measures of toxicity because there does not appear to be a threshold for lead toxicity (IRIS 2002).

Nickel

Observed effects of nickel (a carcinogen and mutagen) in aquatic environments include tissue damage, genotoxicity, and growth reduction. Mollusks and crustaceans are more sensitive than other organisms (EPA 2002a). The EPA (2002b) lists a CCC of 8.2 µg/L of dissolved nickel (8.3 µg/L of total recoverable nickel) in saltwater based on effects to aquatic life.

Nickel is an allergen for some people, causing an asthmatic reaction or skin rash when exposed to nickel in jewelry or other products (ATSDR 1997a). Nickel causes intestinal discomfort when ingested at very high doses only (ATSDR 1997a). EPA's water criterion for consumption of seafood is 4,600 µg/L (2002b).

Selenium

Selenium undergoes bioconcentration, bioaccumulation, and biomagnification as trophic levels increase. It can enter the food web through both sediments and surface water. Elevated levels cause growth reduction in green algae. In other aquatic organisms, the following adverse effects have been observed: loss of equilibrium and other neurological disorders, liver damage, reproductive failure, reduced growth, reduced movement rate, chromosomal aberrations, reduced hemoglobin and increased blood count, and necrosis of the ovaries (EPA 2002a). The EPA (2002b) lists a CCC of 71 µg/L of dissolved selenium (71 µg/L of total recoverable selenium) in saltwater based on effects to aquatic life.

Like copper, selenium is an essential metal for humans. At high doses, selenium may cause brittle hair, deformed nails, dizziness, respiratory illness, and loss of control of the extremities (ATSDR [illegible]7a). EPA's water quality criterion for consumption of seafood is 4,200 µg/L (2002b).

Zinc

In many types of aquatic plants and animals, growth, survival, and reproduction can all be adversely affected by elevated zinc levels. Zinc in aquatic systems tends to be partitioned into sediment and less frequently dissolved as hydrated zinc ions and organic and inorganic complexes (EPA 2002a). The EPA (2002b) lists a CCC of 81 µg/L of dissolved zinc (86 µg/L of total recoverable zinc) in saltwater based on effects to aquatic life.

Zinc is essential for human development; although, high levels of zinc may cause indigestion, damage to the pancreas, and anemia (ATSDR [illegible]5c). EPA's water quality criteria for consumption of seafood is 26,000 µg/L and an alternate criteria set for organoleptic effects is 5,000 µg/L (2002b).

Conventional Pollutants

Fecal Chloroform

Fecal chloroform bacteria are formed in the guts of warm-blooded vertebrate animals, and indicate the presence of pathogens. Several pathogens (*Clostridium perfringens*, *E. coli*, *Cryptosporidim, Giardia*, etc.) have no published water quality standards (EPA 2001). Fecal chloroform bacteria are found when fecal (intestinal) contamination is present. The presence of fecal coliforms usually indicates the presence of pathogens.

In the environment, fecal coliform bacteria may be an indicator of the presence of nutrients from fecal waste, such as nitrogen. This pollution then may cause an increase in algal growth. Shellfish concentrate fecal coliform bacteria and other pathogens that may be present with coliform bacteria (Ecology 2002). For this reason, shellfish beds are closed to harvesting when fecal coliform bacteria are present at levels exceeding 14 colonies per 100 milliliters of water.

Testing for disease-causing bacteria is difficult in open waters because they are present in low numbers, are difficult to isolate and detect, and because there are so many different types of bacteria to test. Due to these difficulties, fecal coliform bacteria are used as indicators for organisms that are typically found in fecal pollution. While most fecal coliform bacteria are harmless to humans, exposure to some may cause short-term adverse effects, including rash, ear infections, gastrointestinal pain, nausea, diarrhea, vomiting, and fever (Ecology 2002).

The State of Alaska has established several criteria for fecal coliform, depending on the intended use of the water (ADEC 1999). For open waters used in aquaculture and where harvested seafood will not be cooked, the geometric mean of samples taken in a 30-day period may not exceed 20 colonies per 100 milliliters of water (2E+5 colonies per cubic meter, 2E+5 col/m^3). For recreational waters, the geometric mean of samples collected over a 30-day period may not exceed 1E+10 col/m^3. When mollusks will be harvested and eaten raw, the criteria for fecal coliform is 1.4E+9 col/m^3. EPA’s national recommended water quality standard for fecal coliform is 2E+10 col/m^3 (EPA 2002a)

Ammonia

Ammonia is present in two forms in saltwater: un-ionized ammonia (NH_3) and the ammonium ion (NH_4+). The un-ionized ammonia form has been demonstrated to be the more toxic form of ammonia. Water quality parameters, particularly pH and temperature, but also salinity, affects the proportion of un-ionized ammonia. Data available on the acute toxicity of ammonia to 21 saltwater animals in 18 genera showed a LC50 concentration ranging from 0.23 to 43 milligrams per liter (mg/L) of un-ionized ammonia. Fishes and crustaceans are well represented among both the more sensitive and more resistant species. Mollusks are generally resistant. Available data on the toxicity of un-ionized ammonia to plants suggests significant effects may occur in benthic diatoms exposed to concentrations only slightly greater than those lethal to salt-water animals. Ammonia at concentrations slightly less than those chronically toxic to animals may stimulate growth and reduce reproduction of a red macroalgal species (EPA 1989).

The State of Alaska Department of Conservation (ADEC 2002) has developed tables to display chronic and acute criterion for total ammonia, based on varying salinity, temperature, and pH, to account for hydrolysis of ammonium ions.

Inhalation of ammonia vapors is the most common route of exposure in humans and there is relatively little information about toxicity via other routes of exposure. Exposure to high concentrations of ammonia in water may cause burns, irritation, and drying of the skin and mucous membrane (HSDB 2002). Currently, EPA does not provide a quantitative estimate of the toxicity of ammonia for dermal exposures (EPA 2002c). Case studies indicate that ammonia exposures at 5,000 to 10,000 parts per million (ppm) are fatal (HSDB 2002).

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Chloride, Free and Residual

Free residual chlorine is described as the portion of the chlorine injected into water, that remains as molecular chlorine, hypochlorous acid, or hypochlorite ions after the solution has reached a state of equilibrium. Combined residual chlorine is described as the portion of chlorine injected into water that remains combined with ammonia or nitrogenous compounds after the equilibrium has been reached. Chlorine-produced oxidants are described as the sum of free chlorine, combined chlorine, and combined bromine oxidative products found in saltwater (EPA 1991). Anthropogenic sources of chloride are unlikely to pose a threat to ecological species in marine waters (EPA 1988). Free and residual chlorine have a very short half-life in marine waters; therefore, it is difficult to assess the effects of chlorine on aquatic life (EPA 1985). The EPA (2002) does not list saltwater criteria for chloride. The EPA (2002) saltwater criteria for chlorine are 13 µg/L (acute criterion) and 7.5 µg/L (chronic criterion). ADEC's water quality standard for residual chlorine is 2 µg/L (1999).

In humans, ingestion of large doses of chlorine may cause gastrointestinal irritation, including vomiting and nausea (HSDB 2002). If dehydration occurs, body temperature increases and circulatory and central nervous system damage may result (HSDB 2002). Exposure of the eyes to sodium chloride may cause stinging while exposure to other forms of chlorine, including free and residual chlorine, may cause stinging or irritation of the skin (HSDB 2002).

Nitrate as N

The nitrogen-containing compounds nitrate, nitrite, and ammonia, are interrelated through the process of nitrification. Ammonia is converted into nitrate through a two-step process with nitrite produced as an intermediate product. Nitrite is toxic through the conversion of hemoglobin to methemoglobin, a form incapable of carrying oxygen, resulting in anoxia. Exposure of fish to acutely toxic concentrations of ammonia causes increased gill ventilation, hyperexcitability, convulsions, and death. Toxic effects of nitrate on warm-blooded animals may be related to in vivo conversion of nitrate to nitrite. Neonatal stages and newborn individuals are especially susceptible because nitrate may be converted to nitrite under anaerobic conditions in the gut (Scott and Crunkilton 2000).

Ecological screening levels and surface water quality standards are not available for nitrate. A literature review of the ecological toxicity of nitrates and nitrites to ecological receptors was performed to obtain toxicological reference values. Scott and Crunkilton (2000) studied the acute and chronic toxicity of nitrate to three freshwater aquatic species: *Ceriodaphnia dubia* (water flea), *Daphnia magna* (water flea), and *Pimephales promelas* (flathead minnow). *C. dubia*, a freshwater invertebrate which is an important link in the aquatic food chain, was the most sensitive species with a no-observed-effect concentration (NOEC) and a lowest-observed-effect concentration (LOEC) for neonate production of 21.3 NO_3-N and 42.6 mg/L NO_3-N, respectively.

Nitrate is also a nutrient that may stimulate algal production and biomass accumulation in coastal systems. There is a great deal of uncertainty about the mechanisms through which nutrient enrichment can disrupt biological systems. The availability of light greatly effects the stimulation of algal production (Cloern 1999).

The toxicity of nitrates in humans varies depending on the chemical formulation. For example, absorbed potassium nitrate is rapidly excreted and induces adverse health effects only at very high doses (HSDB 2002). Exposure to high doses of nitrates may result in headache, vertigo, nausea, and vomiting (HSDB 2002). Nitrate may be converted to nitrite by intestinal bacteria when conditions are favorable. Iron in hemoglobin that is oxidized by nitrite cannot bind oxygen. When a significant amount of nitrate is converted to nitrite, methemoglobinemia and coma and/or death due to circulatory collapse may result. Methemoglobinemia is more likely to occur in infants and young children.

EPA's water quality criteria for nitrates that is protective of consumption of sea life is 10,000 µg/L (2002a).

Phosphorous

The EPA (2002) sets a chronic criterion of 0.1 µg/L of elemental phosphorus for marine and estuarine water; an acute criterion is not listed. Phosphorus in the elemental form is particularly toxic and is subject to bioaccumulation. The predominant effects from phosphorous poisoning to salmon are external redness, hemolysis, and reduced hematocrits. Phosphorus as phosphate is one of the major nutrients required for plant growth. Phosphates are used by algae and higher aquatic plants and may be stored in excess of use within the plant cell. With decomposition of the plant cell, some phosphorus may be released immediately through bacterial action for recycling with the biotic community, while the remainder may be deposited in sediments. The criterion of 0.1 µg/L elemental phosphorous for marine or estuarine waters is 0.1 of demonstrated lethal levels to important marine organisms and of levels that have been found to result in significant bioaccumulation (EPA 1986). This criterion is not intended to prevent the stimulation of algal production. No water quality criterion were found for exposure of phosphorus in water to humans.

Phosphorous is also a nutrient that may stimulate algal production and biomass accumulation in coastal systems. There is a great deal of uncertainty about the mechanisms through which nutrient enrichment can disrupt biological systems. The availability of light greatly effects the stimulation of algal production (Cloern 1999).

In humans, the toxicity of phosphorous depends on the chemical formulation, but generally it is not considered a concern for human health. Because of the low toxicity in humans, phosphorous is suitable for use in fertilizers and provides valuable nutrients to plants and bacteria. Ingestion of large doses of phosphorous (as potassium sulphate) may cause irritation of the intestinal tract (HSDB 2002).

Biological and Chemical Oxygen Demand

Dissolved oxygen content is the most important parameter for protecting fish and aquatic biota. The dissolved oxygen balance is an important water quality consideration for estuaries. Biological oxygen demand (BOD) and chemical oxygen demand (COD) are the content of biodegradable organics in waste discharges. When waste discharges containing biodegradable organics are introduced into receiving waters, decomposers (e.g., bacteria and fungi) begin immediately to decompose the biodegradable organic matter and then convert it to carbon dioxide (alkalinity), water, and mineral and organic nonbiodegradable residues. Dissolved oxygen is used in the bioxidation-decomposition process. BOD and COD in waste discharges may decrease dissolved oxygen to levels that are harmful to fish and other aquatic species (Novotny and Olem 1994). The EPA has recently published saltwater criteria for dissolved oxygen (5 mg/L) for the Virginian Province of the Atlantic Coast (from southern Cape Cod to Cape Hatteras) because hypoxia is a significant problem for certain coastal waters that receive runoff containing nutrients (e.g., nitrogen and phosphorous) and oxygen demanding biological wastes (EPA 2002). For many fish and shellfish, extended periods of dissolved oxygen below 5 mg/L can cause adverse effects to larval life stages (EPA 2002). There is no saltwater dissolved oxygen criterion for southeast Alaska.

Total Suspended Solids

Shallow coastal environments are particle-rich relative to the open ocean. Suspended particles absorb and scatter light, so shallow coastal environments are turbid environments in which phytoplankton growth can be limited by the availability of sunlight to sustain photosynthesis (Cloern 1996).

B

CARDINAL Modeling Approach

Overview of the CARDINAL modelling system

CARDINAL is a user-friendly computer program for the simulation of long wave dynamics and dispersion of pollutants in any complicated area. The program solves numerically the depth-averaged shallow water equations for 2D conditions and 3D equations by taking a hydrostatic approach. The system is an MS Window-based application and has a standard graphical user interface (GUI). Its GUI includes convenient methods of input of a water body with arbitrary geometry, bathymetry, open boundaries, and wind fields; possibility to translate user-defined input-texts into analytical expressions for model coefficients; wide graphic support and other features. The program creates computer models of different water systems, by simulating non-steady water dynamics and transport of pollutants, for presentation in a wide variety of graphical forms. The underlying theory and the salient features of the model are summarized below.

The governing equations

The CARDINAL software solves the equations of motion (conservation of mass and momentum equations given as the Navier-Stokes equations with hydrostatic assumption and adoption of some theory on turbulence exchange). The stipulation in the water dynamics equations is that the waves are long waves and the acceleration in the vertical direction is neglected (note that the velocity in the vertical direction is not neglected and not constant). The hydrodynamic solutions of these equations are then used to solve the advection-dispersion and the first order reaction equation of mass transport to model the migration of pollutants from any number of sources.

In a 3D case the system of equations that are solved in CARDINAL is given as:

Navier-Stokes Equations with hydrostatic pressure gradient

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{\rho_s}{\rho_w}g\frac{\partial \varsigma}{\partial x}-\frac{g}{\rho_w}\int_z^{\varsigma}\frac{\partial \rho}{\partial x}dz-\frac{1}{\rho_w}\frac{\partial P_a}{\partial x}+fv+K\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)+\frac{\partial}{\partial z}k\frac{\partial u}{\partial z} \tag{1}$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}=-\frac{\rho_s}{\rho_w}g\frac{\partial \varsigma}{\partial y}-\frac{g}{\rho_w}\int_z^{\varsigma}\frac{\partial \rho}{\partial y}dz-\frac{1}{\rho_w}\frac{\partial P_a}{\partial y}-fu+K\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)+\frac{\partial}{\partial z}k\frac{\partial v}{\partial z} \tag{2}$$

with bottom and surface boundary conditions

$$\begin{aligned} k\frac{\partial u}{\partial z}\Big|_{z=-h} &= -f_b u\,|\vec{\mathrm{v}}|\,\Big|_{z=-h} \\ k\frac{\partial v}{\partial z}\Big|_{z=-h} &= -f_b v\,|\vec{\mathrm{v}}|\,\Big|_{z=-h}, \end{aligned} \tag{3}$$

$$k\frac{\partial u}{\partial z}\Big|_{z=\varsigma} = \rho_a C_D w_{(x)}\,|\vec{W}|$$
$$k\frac{\partial v}{\partial z}\Big|_{z=\varsigma} = \rho_a C_D w_{(y)}\,|\vec{W}|, \tag{4}$$

Mass conservation Equation for uncompressed liquids in the differential form

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=\forall \tag{5}$$

which in the *integral form* is given as

$$\frac{\partial \varsigma}{\partial t}+\frac{\partial \mathrm{U}}{\partial \mathrm{x}}+\frac{\partial V}{\partial y}=\forall_s \tag{6}$$

Advection-diffusion Equatioin for pollutants

$$\frac{\partial C}{\partial t}+\frac{\partial (uC)}{\partial x}+\frac{\partial (vC)}{\partial y}+\frac{\partial [C(w-w_0)]}{\partial z}=\forall C_s-\lambda C+K_c\left(\frac{\partial^2 C}{\partial x^2}+\frac{\partial^2 C}{\partial y^2}\right)+\frac{\partial}{\partial z}k_c\frac{\partial C}{\partial z} \tag{7}$$

where,

u, v, w are the x-, y-, and z- components of the velocity vector in the Cartesian co-ordinate system with orthogonal axes, x, y, and z representing the three spatial directions, $\zeta(x, y, t)$ is the water level, g is the gravitational acceleration, ρ_w is the density of water, ρ_s is the density of water at the surface, K and k are the coefficients of turbulent eddy viscosity in the horizontal and vertical directions respectively, $P_a(x, y, t)$ is the atmospheric pressure, $f(y) = 2\Omega\sin\phi$ is the Coriolis parameter (Ω is the frequency of rotation of the earth and ϕ is the latitude), f_b is the bottom friction coefficient, C_D is the wind drag coefficient, ρ_a is the air density, $\vec{W}(x,y,t)$ is the wind velocity vector with components $w_{(x)}$ and $w_{(y)}$, $U(x,y,t)$ and $V(x,y,t)$ are the Cartesian components of the flux (velocity) $\vec{V}$ per unit width: $U=\int_{-h}^{\varsigma}udz$, $V=\int_{-h}^{\varsigma}vdz$; $H = h + \zeta$, $h(x, y)$ is the undisturbed water depth, $\forall(x,y,z,t)$ is water volume, which comes from internal sources into one unit of volume per unit time, $\forall_s(x,y,t)=\int_{-h}^{\varsigma}\forall dz$ is water volume, which comes from internal sources into one unit of square of water column per unit time, $C(x,y,z,t)$ is the concentration of the pollutant species, λ is decay coefficient of the pollutant species, and w_o is the vertical velocity due to buoyancy force, K_c and k_c are the coefficients of turbulent diffusion in the horizontal and vertical directions respectively.

In 2D conditions the shallow water equations that are solved in CARDINAL take the following forms:

$$\frac{\partial U}{\partial t}+\frac{\partial}{\partial x}\left(\frac{U^2}{H}\right)+\frac{\partial}{\partial y}\left(\frac{UV}{H}\right)= fV-gH\frac{\partial \varsigma}{\partial x}-\frac{H}{\rho_w}\frac{\partial P_a}{\partial x}+K\left(\frac{\partial^2 U}{\partial x^2}+\frac{\partial^2 U}{\partial y^2}\right)+C_D\frac{\rho_a}{\rho_w}w_{(x)}\left|\vec{W}\right|-f_b\frac{U\left|\vec{V}\right|}{H^2} \tag{8}$$

$$\frac{\partial V}{\partial t}+\frac{\partial}{\partial x}\left(\frac{UV}{H}\right)+\frac{\partial}{\partial y}\left(\frac{V^2}{H}\right)=-fU-gH\frac{\partial \varsigma}{\partial y}-\frac{H}{\rho_w}\frac{\partial P_a}{\partial y}+K\left(\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}\right)+C_D\frac{\rho_a}{\rho_w}w_{(y)}\left|\vec{W}\right|-f_b\frac{V\left|\vec{V}\right|}{H^2} \tag{9}$$

$$\frac{\partial \varsigma}{\partial t}+\frac{\partial \mathrm{U}}{\partial \mathrm{x}}+\frac{\partial V}{\partial y}=\forall_s \tag{10}$$

$$\frac{\partial (HC)}{\partial t}+\frac{\partial (UC)}{\partial x}+\frac{\partial (VC)}{\partial y}=\forall_s C_s-\lambda(CH)+K_c H\left(\frac{\partial^2 C}{\partial x^2}+\frac{\partial^2 C}{\partial y^2}\right)-f_s \tag{11}$$

where,
f_s is changes in concentrations due to bottom and surface vertical fluxes. *C(x,y,t)* here is the depth averaged concentration.

For solving these equations numerically, in an arbitrary water domain by the method of finite difference approximation, a transformation to curvilinear boundary-fitted co-ordinates $\xi=\xi(x,y), \quad \eta=\eta(x,y), \sigma(x,y,z,t)=\frac{z+h}{H}$ is made. Along the lateral boundaries one of the co-ordinates ξ,η is fixed and other is distributed arbitrarily, but monotonously. Transformation to curvilinear co-ordinates makes it possible to increase considerably the accuracy of computations (Klevanny et al., 1994). The computational domain is mapped on a rectangle or on a system of rectangles. The curvilinear grid generated by solving a set of elliptical equations. A deficiency of using the Cartesian velocity components in curvilinear co-ordinates is the interpretation of zero normal component of velocity vector at solid lateral boundaries, which leads to a cumbersome averaging procedure. For the simplification of boundary conditions the contravariant components of velocity vector instead Cartesian ones are introduced. The transformed equations are solved with a semi-implicit numerical method (Klevanny, 1999) with a non restrictive stability condition. It should be noted that the numerical scheme used in the model becomes unstable when water velocities are close to the super critical values.

The GUI and Input of CARDINAL

The GUI of CARDINAL modelling system is divided into separate windows/menus for input of various attributes and variables of the system under consideration. These windows and the input that goes under each of these windows are summarized below.

The '***Project***' window serves for selection of names of data files and saving them.

The '***Area***' window serves to define boundaries of an area of computation and to generate the curvilinear grid for the area. Tables of data in ASCII format can be used to generate the geometry of the system of water bodies that are modeled.

The '***Depth***' window is used for input of bathymetric data. Bathymetric data are incorporated in one of the four ways. 1) Depth values in arbitrarily located points within the water body are assigned with further interpolation of depth values to the nodes of the curvilinear grid. 2) A rectangular grid is set up for depth data input also with further interpolation to the nodes of the curvilinear grid. 3) Depth values are assigned directly to the nodes of the curvilinear grid. 4) Depth expressed as an analytical function of space coordinates. Depth and domain boundary data may also be assimilated in the program from ASCII files.

The '***Vertical***' window is used in 3D problems only. It is used to define the number of grid points in vertical direction, the selection of their distribution and selection of relation for the vertical eddy viscosity coefficient. The turbulence in the layers can be modeled according to various methods such as the Prandtl method, Prandtl-Montgomery method etc.

The '***Open Boundaries***' window allows: 1) to define the locations of open boundaries with the prescribed time histories of discharges (*rivers*) and concentrations of pollutants along these open boundaries; 2) to define the locations of open boundaries with the prescribed time histories of water levels (such as *tides*) and concentrations of pollutants; 3) to define the locations of open boundaries through which disturbances may exit the area of computation. Three types of 'open boundaries' are used. These are (1) discharge type (i.e. flux boundary or Neuman boundary condition); (2) level type (prescribed boundary or Dirichlet boundary condition); and (3) Free exit type (radiation boundary condition). For a water body with open boundary toward the ocean along which tidal data are available, the boundary type is the level type where the water levels as a function of time is prescribed.

In the '***Atmosphere***' window wind and pressure data may be defined either in the form of the time series in arbitrary located weather stations, or in the form of an analytical expression of co-ordinates and time, or in the form of gridded ASCII files of fields produced as output from an atmospheric model (e.g. the GRIB, gridded binary format used in the World Meteorological Organisation). The time series weather station data include wind direction, speed, and atmospheric pressure. The relationship between the wind drag coefficient, C_D, and wind velocity, $\vec{W}$ is given as: 1) $C_D = a + b\left|\vec{W}\right|$ where a and b are site-specific empirical constants that can be used as input to the model; 2) C_D is determined with the modern wind over waves coupling theory (*Makin, 2002*).

The '***Dynamics***' window allows to input some empirical coefficients (such as horizontal eddy viscosity coefficient) and select the regime of computation, assign initial fields of flow and surface levels using analytical expressions or data values stored in files. Two regimes of computations can be used. These are either 'dynamic' (time-dependent solutions) or steady state (invariant in time). It is possible to compute first the dynamic configuration of the hydrodynamics of the system and once the steady state is achieved, the results to be used for computation of advection-dispersion-decay of a pollutant.

The '***Concentration***' window serves to define locations and loading factor (powers) of any number of point pollution sources and an initial pollution field. Values of concentration (kg m^{-3}) and discharge (m^3 s^{-1}) are used as input for a source. Sources are placed either graphically or from a table giving their locations, date and time duration of discharge, flow rate and concentration. In addition, dispersion (m^2 s^{-1}) and decay (s^{-1}) coefficients for a pollutant are defined under this menu. Apart from chemical species, temperature and salinity can also be modeled.

The '***Bottom***' window is used for 1) definition of an analytical expression for the bottom friction coefficient and 2) definition of variable bottom roughness, grain sizes and grain densities in different parts of the area of computation. The bottom friction coefficient f_b can be expressed through the Manning's n familiar in the case of open channel or overland flow.

In the '***Device***' window it is possible to select a number of points and regions for which time histories of surface levels, velocities, concentrations, volumes of pollution and discharges will be recorded during computations.

The '***Tools***' window allows the user to import and export input values or results into text formats, background maps as images.

The '***Time***' window is for input of the time variables used in the model. This includes, the computational time steps, the start and ending time in calendar days, and save results at discrete time steps. The program advises the time step necessary for numerical stability of computation.

The '***Print***' window allows the user to print the screen picture or to save it in graphical (bmp) file in colour or in black-white mode.

The '***Run***' menu is for start and stop of the computation.

The '***Result***' window allows the view and export to files of output of various parameters.

Advantages of CARDINAL

The CARDINAL software system has several advantages over other models that could be used in water quality modeling in coastal zones. Its main advantages include GUI; boundary-fitted curvilinear co-ordinates (BFC); pre-processor, post-processor and the solver integrated in one executable form; import and export ASCII files for compatibility with other software; GRIB decoder inside for easy possibility to import wind and atmospheric pressure fields from local atmospheric models; zoom capabilities; possibility to assign arbitrary analytical expressions for empirical coefficients and initial fields; possibility to make animations; and ease of use.

BFC together with σ-transformation in the vertical direction provides the possibility to receive a fine grid resolution in important regions and more accurate solutions than using rectilinear grids.

The equation for dispersion of pollutants is solved by the combined third and first order implicit up-stream conservative finite-differences. This solution method gives high accuracy of results.

The input information is prepared conveniently in a graphical regime inside the program or may be imported. Input information for this project included: geometry and bathymetry of the discharge areas of concern, locations of the open boundaries and open boundary conditions, loading of pollutants, time/space variable wind and atmospheric pressure fields, bottom roughness field, relations for empirical coefficients and initial conditions.

Output information is presented in graphical form inside the program and for publication purposes, and includes velocity and flux vector fields, isopleths, and bird's eye views of water surface, depths and concentrations, time histories of all variables on selected locations, spectrum characteristics of water surface oscillations, vertical distribution of all variables on selected cross-sections and locations.

Comparisons with other models

Currently, there are a few water quality models available for dealing with coastal water bodies.

One of the earliest models is CE-QUAL-ICM v. 1.0 (Cerco and Cole, 1995). This is a 3D water quality model that has been applied to eutrophication problems in bays (e.g. Chesapeake Bay case, Cerco and Cole, 1994). This model takes into account the interactions of various water quality parameters, sediment-water interactions, and nutrient fluxes. However, the model does not compute hydrodynamics. Flows, diffusion coefficients, and volumes must be specified externally and read into the model. Hydrodynamics are usually obtained from a separate hydrodynamics model. It is a DOS-based program with no GUI capability.

Another model available in the public domain, is the CE-QUAL-W2 (Cole and Buchak, 1995; Wells and Cole, 2002). It is a Window-based application that has been developed by the U. S. Army Corps of Engineers Waterways Experiment Station (WES) with the latest enhancements made by the workers at Portland State University. CE-QUAL-W2 is a two-dimensional (longitudinal and vertical) water-quality and hydrodynamic code that can model temperature and 21 water quality parameters, including DO, pH, and nutrients in addition to hydraulic parameters such as horizontal and vertical velocities and water surface elevation (its hydraulic routine is quite rigorous). Since the water quality parameters are averaged in the transverse direction, this code is best suited for relatively long and narrow water bodies exhibiting longitudinal and vertical water quality gradients or where the lateral variation of water quality and hydrodynamics can safely be averaged. It has limited GUI for data input with no post processing capability.

The CORMIX model (http://www.cormix.info/) is fluid mechanics model designed to configure the mixing zone that results from discharge of a turbulent buoyant jet from a stationary outfall into a channel or any other water body. In principle, this is an applicable model. However, this is truly not a water quality model. Its hydrodynamics is designed to address the mixing behavior of a jet due to boundary interactions. Consequently, variables such as wind, tides etc., that are important in controlling the hydrodynamics of a coastal zone environment, are ignored in the

CORMIX model. Similarly, chemical specific dispersion, decay, and settling are ignored in CORMIX. Furthermore, there is a subtle distinction between a mixing zone and a contaminant plume.

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C

Data Used for Modeling Purposes

Pollutant/COPC – Year 2001						
Vessel Name	Code Sample Dte	Location Assigned and Time	Vessel Location		Volumetric Discharge Rate (m^3/s)	Total Chlorine Concentration (mg/m^3)
			Longitude	Latitude		
Spirit of Discovery 8/30/01	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	0
Spirit of Discovery 8/30/01	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	0
Spirit of Oceanus 8/27/01	SOO	Auke Bay 0:00-18:00	-134.679667	58.381750	0.000709425	0
Columbia 8/14/01	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	1230
Kennicott (12/4/01)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	3500
Kennicott (12/4/01)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	3500
Malaspina (7/2/01)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	0
Taku (AVG 2001)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	1750
Sea Bird (AVG 8/4& 8/18/01)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	114000
Sea Bird AVG 8/4& 8/18)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	114000
Sea Lion (8/5&8/19/)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	3430
Spirit of Endeavor (8/25/01)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	0
Spirit of Columbia (9/5/01)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	14000
Spirit of Alaska (8/9&8/23)	SOA	Petersburg 8:00-12:00	-132.961667	56.810000	0.000180247	700
Spirit of Alaska (8/9&8/23)	SOA	Wrangell 13:00-17:00	-132.421883	56.474250	0.000180247	700

Clipper Odyssey (8/4/01)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	0
Spirit of 98 (8/18/01)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	0
Spirit of 98 (8/18/01)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	0
Yorktown Clipper (9/5&9/8/01)	YOR	Sawyer Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	700
Yorktown Clipper (9/5&9/8/01)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775	700
Wilderness Adventurer (8/9/01)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	800
Wilderness Adventurer (8/9/01)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	800
Wilderness Adventurer (8/9/01)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	800
Wilderness Discoverer (8/23&9/17)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	0
Wilderness Discoverer (8/23&9/17)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	0
Spirit of Oceanus (8/27/01)	SOO	Skagway 18:00-24:00	-135.324917	59.448717	0.000107202	0
Matanuska (4/9&12/18)	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	3100
Matanuska (4/9&12/18)	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	3100
Matanuska (4/9&12/18)	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	3100
Pollutant/COPC – Year 2001						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	Fecal Concentration (MPN/m^3)
			Long	Lat		

Spirit of Discovery 8/30/01	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	9×10^{10}
Spirit of Discovery 8/30/01	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	9×10^{10}
Spirit of Oceanus 8/27/01	SOO	Auke Bay 0:00-18:00	-134.679667	58.381750	0.000709425	16×10^{10}
Columbia 8/14/01	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	9670000
Kennicott (12/4/01)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	50000
Kennicott (12/4/01)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	50000
Malaspina (7/2/01)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	70000
Taku (AVG 2001)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	10×10^{8}
Sea Bird (AVG 8/4& 8/18/01)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	450000
Sea Bird AVG 8/4& 8/18)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	450000
Sea Lion (8/5&8/19/)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	8.1×10^{9}
Spirit of Endeavor (8/25/01)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	4×10^{9}
Spirit of Columbia (9/5/01)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	1×10^{4}
Spirit of Alaska (8/9&8/23)	SOA	Petersburg 8:00-12:00	-132.961667	56.810000	0.000180247	1.7×10^{9}
Spirit of Alaska (8/9&8/23)	SOA	Wrangell 13:00-17:00	-132.421883	56.474250	0.000180247	1.7×10^{9}
Clipper Odyssey (8/4/01)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	566000000

Spirit of 98 (8/18/01)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	1.6x10^{11}
Spirit of 98 (8/18/01)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	1.6x10^{11}
Yorktown Clipper (9/5&9/8/01)	YOR	Sawyer Glacier/Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	575000
Yorktown Clipper (9/5&9/8/01)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	575000
Wilderness Adventurer (8/9/01)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	9x10^{7}
Wilderness Adventurer (8/9/01)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	9x10^{7}
Wilderness Adventurer (8/9/01)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	9x10^{7}
Wilderness Discoverer (8/23&9/17)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	1.6x10^{11}
Wilderness Discoverer (8/23&9/17)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	1.6x10^{11}
Spirit of Oceanus (8/27/01)	SGB	Skagway 18:00-24:00	-135.324917	59.448717	0.000107202	1.6x10^{11}
Matanuska (4/9&12/18)	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	1.1x10^{7}
Matanuska (4/9&12/18)	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	1.1x10^{7}
Matanuska (4/9&12/18)	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	1.1x10^{7}
Pollutant/COPC – Year 2001						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	PH
			Long	Lat		

Spirit of Discovery 8/30/01	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	7.72
Spirit of Discovery 8/30/01	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	7.72
Spirit of Oceanus 8/27/01	SOO	Auke Bay 0:00-18:00	-134.679667	58.381750	0.000709425	5.39
Columbia 8/14/01	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	7.5
Kennicott (12/4/01)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	7.1
Kennicott (12/4/01)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	7.1
Malaspina (7/2/01)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	7.9
Taku (AVG 2001)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	7.31
Sea Bird (AVG 8/4& 8/18/01)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	8.0
Sea Bird AVG 8/4& 8/18)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	8.0
Sea Lion (8/5&8/19/)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	7.33
Spirit of Endeavor (8/25/01)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	7.99
Spirit of Columbia (9/5/01)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	7.23
Spirit of Alaska (8/9&8/23)	SOA	Petersburg 8:00-12:00	-132.961667	56.810000	0.000180247	7.63
Spirit of Alaska (8/9&8/23)	SOA	Wrangell 13:00-17:00	-132.421883	56.474250	0.000180247	7.63
Clipper Odyssey (8/4/01)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	Not tested

Spirit of 98 (8/18/01)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	7.5
Spirit of 98 (8/18/01)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	7.5
Yorktown Clipper (9/5&9/8/01)	YOR	Sawyer Glacier/Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	7.89
Yorktown Clipper (9/5&9/8/01)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	7.89
Wilderness Adventurer (8/9/01)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	7.2
Wilderness Adventurer (8/9/01)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	7.2
Wilderness Adventurer (8/9/01)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	7.2
Wilderness Discoverer (8/23&9/17)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	5.9
Wilderness Discoverer (8/23&9/17)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	5.9
Spirit of Oceanus (8/27/01)	SGB	Skagway 18:00-24:00	-135.324917	59.448717	0.000107202	5.39
Matanuska (4/9&12/18)	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	7.3
Matanuska (4/9&12/18)	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	7.3
Matanuska (4/9&12/18)	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	7.3
Pollutant/COPC – Year 2001						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	COD Concentration (mg/m^3)
			Long	Lat		

Spirit of Discovery 8/30/01	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	697000
Spirit of Discovery 8/30/01	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	697000
Spirit of Oceanus 8/27/01	SOO	Auke Bay 0:00-18:00	-134.679667	58.381750	0.000709425	860000
Columbia 8/14/01	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	790700
Kennicott (12/4/01)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	500000
Kennicott (12/4/01)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	500000
Malaspina (7/2/01)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	470000
Taku (AVG 2001)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	800000
Sea Bird (AVG 8/4& 8/18/01)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	903000
Sea Bird AVG 8/4& 8/18)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	903000
Sea Lion (8/5&8/19/)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	955300
Spirit of Endeavor (8/25/01)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	816000
Spirit of Columbia (9/5/01)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	569000
Spirit of Alaska (8/9&8/23)	SOA	Petersburg 8:00-12:00	-132.961667	56.810000	0.000180247	807600
Spirit of Alaska (8/9&8/23)	SOA	Wrangell 13:00-17:00	-132.421883	56.474250	0.000180247	807600
Clipper Odyssey (8/4/01)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	351160

Spirit of 98 (8/18/01)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	1240000
Spirit of 98 (8/18/01)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	1240000
Yorktown Clipper (9/5&9/8/01)	YOR	Sawyer Glacier/Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	351160
Yorktown Clipper (9/5&9/8/01)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	351160
Wilderness Adventurer (8/9/01)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	1340000
Wilderness Adventurer (8/9/01)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	1340000
Wilderness Adventurer (8/9/01)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	1340000
Wilderness Discoverer (8/23&9/17)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	2350000
Wilderness Discoverer (8/23&9/17)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	2350000
Spirit of Oceanus (8/27/01)	SGB	Skagway 18:00-24:00	-135.324917	59.448717	0.000107202	860000
Matanuska (4/9&12/18)	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	608000
Matanuska (4/9&12/18)	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	608000
Matanuska (4/9&12/18)	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	608000
Pollutant/COPC – Year 2001						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	BOD Concentration (mg/m^3)
			Long	Lat		

Spirit of Discovery 8/30/01	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	88200
Spirit of Discovery 8/30/01	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	88200
Spirit of Oceanus 8/27/01	SOO	Auke Bay 0:00-18:00	-134.679667	58.381750	0.000709425	1010000
Columbia 8/14/01	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	84700
Kennicott (12/4/01)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	3500
Kennicott (12/4/01)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	3500
Malaspina (7/2/01)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	20000
Taku (AVG 2001)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	165000
Sea Bird (AVG 8/4& 8/18/01)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	113780
Sea Bird AVG 8/4& 8/18)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	113780
Sea Lion (8/5&8/19/)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	347600
Spirit of Endeavor (8/25/01)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	234500
Spirit of Columbia (9/5/01)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	32100
Spirit of Alaska (8/9&8/23)	SOA	Petersburg 8:00-12:00	-132.961667	56.810000	0.000180247	133800
Spirit of Alaska (8/9&8/23)	SOA	Wrangell 13:00-17:00	-132.421883	56.474250	0.000180247	133800
Clipper Odyssey (6/6/01)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	200000

Spirit of 98 (8/18/01)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	585000
Spirit of 98 (8/18/01)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	585000
Yorktown Clipper (9/5&9/8/01)	YOR	Sawyer Glacier/Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	67780
Yorktown Clipper (9/5&9/8/01)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	67780
Wilderness Adventurer (8/9/01)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	580000
Wilderness Adventurer (8/9/01)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	580000
Wilderness Adventurer (8/9/01)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	580000
Wilderness Discoverer (8/23&9/17)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	1695000
Wilderness Discoverer (8/23&9/17)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	1695000
Spirit of Oceanus (8/27/01)	SGB	Skagway 18:00-24:00	-135.324917	59.448717	0.000107202	1010000
Matanuska (4/9&12/18)	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	130000
Matanuska (4/9&12/18)	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	130000
Matanuska (4/9&12/18)	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	130000

Pollutant/COPC – Year 2001

Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	Conductivity
			Long	Lat		

Spirit of Discovery 8/30/01	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	Not tested
Spirit of Discovery 8/30/01	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	Not tested
Spirit of Oceanus 8/27/01	SOO	Auke Bay 0:00-18:00	-134.679667	58.381750	0.000709425	Not tested
Columbia 8/14/01	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	34600
Kennicott (12/4/01)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	Not tested
Kennicott (12/4/01)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	Not tested
Malaspina (7/2/01)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	34800
Taku (AVG 2001)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	12502
Sea Bird (AVG 8/4& 8/18/01)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	Not tested
Sea Bird AVG 8/4& 8/18)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	Not tested
Sea Lion (8/5&8/19/)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	Not tested
Spirit of Endeavor (8/25/01)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	Not tested
Spirit of Columbia (9/5/01)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	Not tested
Spirit of Alaska (8/9&8/23)	SOA	Petersburg 8:00-12:00	-132.961667	56.810000	0.000180247	Not tested
Spirit of Alaska (8/9&8/23)	SOA	Wrangell 13:00-17:00	-132.421883	56.474250	0.000180247	Not tested
Clipper Odyssey	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	Not tested
Spirit of 98 (8/18/01)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	Not tested

Spirit of 98 (8/18/01)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	Not tested
Yorktown Clipper (9/5&9/8/01)	YOR	Sawyer Glacier/Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	Not tested
Yorktown Clipper (9/5&9/8/01)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	Not tested
Wilderness Adventurer (8/9/01)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	Not tested
Wilderness Adventurer (8/9/01)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	Not tested
Wilderness Adventurer (8/9/01)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	Not tested
Wilderness Discoverer (8/23&9/17)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	Not tested
Wilderness Discoverer (8/23&9/17)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	Not tested
Spirit of Oceanus (8/27/01)	SGB	Skagway 18:00-24:00	-135.324917	59.448717	0.000107202	Not tested
Matanuska (4/9&12/18)	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	35900
Matanuska (4/9&12/18)	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	35900
Matanuska (4/9&12/18)	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	35900

Pollutant/COPC – Year 2001

Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	Free Chlorine Concentration (mg/m^3)
			Long	Lat		
Spirit of Discovery 8/30/01	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	50
Spirit of Discovery 8/30/01	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	50

Spirit of Oceanus 8/27/01	SOO	Auke Bay 0:00-18:00	-134.679667	58.381750	0.000709425	50
Columbia 8/14/01	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	600
Kennicott (12/4/01)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	3000
Kennicott (12/4/01)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	3000
Malaspina (7/2/01)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	50
Taku (AVG 2001)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	500
Sea Bird (AVG 8/4& 8/18/01)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	82825
Sea Bird AVG 8/4& 8/18)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	82825
Sea Lion (8/5&8/19/)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	2530
Spirit of Endeavor (8/25/01)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	50
Spirit of Columbia (9/5/01)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	3500
Spirit of Alaska (8/9&8/23)	SOA	Petersburg 8:00-12:00	-132.961667	56.810000	0.000180247	266
Spirit of Alaska (8/9&8/23)	SOA	Wrangell 13:00-17:00	-132.421883	56.474250	0.000180247	266
Clipper Odyssey (8/4/01)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	50
Spirit of 98 (8/18/01)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	50
Spirit of 98 (8/18/01)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	50

Yorktown Clipper (9/5&9/8/01)	YOR	Sawyer Glacier/Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	50
Yorktown Clipper (9/5&9/8/01)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	50
Wilderness Adventurer (8/9/01)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	100
Wilderness Adventurer (8/9/01)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	100
Wilderness Adventurer (8/9/01)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	100
Wilderness Discoverer (8/23&9/17)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	50
Wilderness Discoverer (8/23&9/17)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	50
Spirit of Oceanus (8/27/01)	SGB	Skagway 18:00-24:00	-135.324917	59.448717	0.000107202	50
Matanuska (4/9&12/18)	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	50
Matanuska (4/9&12/18)	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	50
Matanuska (4/9&12/18)	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	50

Pollutant/COPC – Year 2001						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	TSS Concentration (mg/m^3)
			Long	Lat		
Spirit of Discovery 8/30/01	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	142000
Spirit of Discovery 8/30/01	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	142000

Spirit of Oceanus 8/27/01	SOO	Auke Bay 0:00-18:00	-134.679667	58.381750	0.000709425	269000
Columbia 8/14/01	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	111300
Kennicott (12/4/01)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	43000
Kennicott (12/4/01)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	43000
Malaspina (7/2/01)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	40000
Taku (AVG 2001)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	164000
Sea Bird (AVG 8/4& 8/18/01)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	190650
Sea Bird AVG 8/4& 8/18)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	190650
Sea Lion (8/5&8/19/)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	282900
Spirit of Endeavor (8/25/01)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	252300
Spirit of Columbia (9/5/01)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	518000
Spirit of Alaska (8/9&8/23)	SOA	Petersburg 8:00-12:00	-132.961667	56.810000	0.000180247	101600
Spirit of Alaska (8/9&8/23)	SOA	Wrangell 13:00-17:00	-132.421883	56.474250	0.000180247	101600
Clipper Odyssey (8/4/01)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	47000
Spirit of 98 (8/18/01)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	880000
Spirit of 98 (8/18/01)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	880000

Yorktown Clipper (9/5&9/8/01)	YOR	Sawyer Glacier/Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	27760
Yorktown Clipper (9/5&9/8/01)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	27760
Wilderness Adventurer (8/9/01)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	1030000
Wilderness Adventurer (8/9/01)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	1030000
Wilderness Adventurer (8/9/01)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	1030000
Wilderness Discoverer (8/23&9/17)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	673000
Wilderness Discoverer (8/23&9/17)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	673000
Spirit of Oceanus (8/27/01)	SGB	Skagway 18:00-24:00	-135.324917	59.448717	0.000107202	269000
Matanuska (4/9&12/18)	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	71500
Matanuska (4/9&12/18)	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	71500
Matanuska (4/9&12/18)	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	71500

Pollutant/COPC – Year 2001						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	Ammonia as Nitrogen Concentration (mg/m^3)
			Long	Lat		
Spirit of Discovery 8/30/01	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	55000
Spirit of Discovery 8/30/01	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	55000

Spirit of Oceanus 8/27/01	SOO	Auke Bay 0:00-18:00	-134.679667	58.381750	0.000709425	39750
Columbia 8/14/01	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	37530
Kennicott (12/4/01)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	4170
Kennicott (12/4/01)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	4170
Malaspina (7/2/01)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	6370
Taku (AVG 2001)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	3200
Sea Bird (AVG 8/4& 8/18/01)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	546
Sea Bird AVG 8/4& 8/18)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	546
Sea Lion (8/5&8/19/)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	9770
Spirit of Endeavor (8/25/01)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	42680
Spirit of Columbia (9/5/01)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	10704
Spirit of Alaska (8/9&8/23)	SOA	Petersburg 8:00-12:00	-132.961667	56.810000	0.000180247	2050
Spirit of Alaska (8/9&8/23)	SOA	Wrangell 13:00-17:00	-132.421883	56.474250	0.000180247	2050
Clipper Odyssey (8/4/01)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	2060
Spirit of 98 (8/18/01)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	51398
Spirit of 98 (8/18/01)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	51398

Yorktown Clipper (9/5&9/8/01)	YOR	Sawyer Glacier/Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	2060
Yorktown Clipper (9/5&9/8/01)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	2060
Wilderness Adventurer (8/9/01)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	40800
Wilderness Adventurer (8/9/01)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	40800
Wilderness Adventurer (8/9/01)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	40800
Wilderness Discoverer (8/23&9/17)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	9160
Wilderness Discoverer (8/23&9/17)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	9160
Spirit of Oceanus (8/27/01)	SGB	Skagway 18:00-24:00	-135.324917	59.448717	0.000107202	39750
Matanuska (4/9&12/18)	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	13900
Matanuska (4/9&12/18)	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	13900
Matanuska (4/9&12/18)	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	13900
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	Ammonia as Nitrogen Concentration (mg/m^3)
			Long	Lat		
Spirit of Discovery 8/30/01	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	0
Spirit of Discovery 8/30/01	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	0
Spirit of Oceanus 8/27/01	SOO	Auke Bay 0:00-18:00	-134.679667	58.381750	0.000709425	39750

Columbia 8/14/01	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	37530
Kennicott (12/4/01)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	4170
Kennicott (12/4/01)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	4170
Malaspina (7/2/01)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	6370
Taku (AVG 2001)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	6750
Sea Bird (AVG 8/4& 8/18/01)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	12240
Sea Bird AVG 8/4& 8/18)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	12240
Sea Lion (8/5&8/19/)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	9770
Spirit of Endeavor (8/25/01)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	42680
Spirit of Columbia (9/5/01)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	10704
Spirit of Alaska (8/9&8/23)	SOA	Petersburg 8:00-12:00	-132.961667	56.810000	0.000180247	0
Spirit of Alaska (8/9&8/23)	SOA	Wrangell 13:00-17:00	-132.421883	56.474250	0.000180247	0
Clipper Odyssey (8/4/01)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	2060
Spirit of 98 (8/18/01)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	51398
Spirit of 98 (8/18/01)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	51398
Yorktown Clipper (9/5&9/8/01)	YOR	Sawyer Glacier/Trac y Arm 14:00-18:00	-133.121183	57.856500	0.000394125	2060

Yorktown Clipper (9/5&9/8/01)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	2060
Wilderness Adventurer (8/9/01)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	40800
Wilderness Adventurer (8/9/01)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	40800
Wilderness Adventurer (8/9/01)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	40800
Wilderness Discoverer (8/23&9/17)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	43400
Wilderness Discoverer (8/23&9/17)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	43400
Spirit of Oceanus (8/27/01)	SGB	Skagway 18:00-24:00	-135.324917	59.448717	0.000107202	0
Matanuska (4/9&12/18)	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	13900
Matanuska (4/9&12/18)	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	13900
Matanuska (4/9&12/18)	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	13900
Pollutant/COPC – Year 2001(not taken in 2001 used 2002)						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	Total Nitrogen Concentration (mg/m^3)
			Long	Lat		
Spirit of Discovery (SOC-BW)	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	2100
Spirit of Discovery (SOC-BW)	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	2100
Spirit of Oceanus (7/9/02)	SOO	Auke Bay 0:00-18:00	-134.679667	58.381750	0.000709425	1400
Columbia (7/9/02)	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	42400
Kennicott (7/10/02)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	28700

Kennicott (7/10/02)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	28700
Malaspina (7/9/02)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	800
Taku (8/22/02)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	48000
Sea Bird (SOE)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	10500
Sea Bird (SOE)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	10500
Sea Lion (SOE)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	10500
Spirit of Endeavor (8/22/02)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	10500
Spirit of Columbia (9/4/02)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	10500
Spirit of Alaska (SOC)	SOA	Petersburg 8:00-12:00	-132.961667	56.810000	0.000180247	2100
Spirit of Alaska (SOC)	SOA	Wrangell 13:00-17:00	-132.421883	56.474250	0.000180247	2100
Clipper Odyssey (YCL)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	3050
Spirit of 98 (SOE)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	10500
Spirit of 98 (SOE)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	10500
Yorktown Clipper (7/13/02)	YOR	Sawyer Glacier/Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	3050
Yorktown Clipper (7/13/02)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	3050
Wilderness Adventurer (WDI)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	36800

Wilderness Adventurer (WDI)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	36800
Wilderness Adventurer (WDI)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	36800
Wilderness Discoverer (7/15)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	36800
Wilderness Discoverer (7/15)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	36800
Spirit of Oceanus (7/9/02)	SOO	Skagway 18:00-24:00	-135.324917	59.448717	0.000107202	1400
Matanuska (7/20)	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	17600
Matanuska (7/20)	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	17600
Matanuska (7/20)	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	17600
Pollutant/COPC – Year 2001						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	Phosphorous Concentration (mg/m^3)
			Long	Lat		
Spirit of Discovery (SOC-BW)	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	365
Spirit of Discovery (SOC-BW)	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	365
Spirit of Oceanus (7/9/02)	SOO	Auke Bay 0:00-18:00	-134.679667	58.381750	0.000709425	4540
Columbia (7/9/02)	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	5650
Kennicott (7/10/02)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	110
Kennicott (7/10/02)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	110
Malaspina (7/9/02)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	345
Taku (8/22/02)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	4920

Sea Bird (SOE)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	5190
Sea Bird (SOE)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	5190
Sea Lion (SOE)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	5190
Spirit of Endeavor (8/22/02)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	5190
Spirit of Columbia (9/4/02)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	365
Spirit of Alaska (SOC)	SOA	Petersburg 8:00-12:00	-132.961667	56.810000	0.000180247	365
Spirit of Alaska (SOC)	SOA	Wrangell 13:00-17:00	-132.421883	56.474250	0.000180247	365
Clipper Odyssey (YCL)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	1593
Spirit of 98 (SOE)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	5190
Spirit of 98 (SOE)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	5190
Yorktown Clipper (7/13/02)	YOR	Sawyer Glacier/Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	1593
Yorktown Clipper (7/13/02)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	1593
Wilderness Adventurer (WDI)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	15500
Wilderness Adventurer (WDI)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	15500
Wilderness Adventurer (WDI)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	15500

Wilderness Discoverer (7/15)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	15500
Wilderness Discoverer (7/15)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	15500
Spirit of Oceanus (7/9/02)	SGB	Skagway 18:00-24:00	-135.324917	59.448717	0.000107202	4540
Matanuska (7/20)	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	2380
Matanuska (7/20)	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	2380
Matanuska (7/20)	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	2380

- This table contains all ship data from 2001.
- NOTE: Total Cl, Fecal, COD, BOD, Free Cl and TSS were converted from mg/L to mg/m^3. Conductivity and pH are listed without units.
- Total Nitrogen (TKN) and Phosphorous were taken from the ADEC sample data.
- If concentration is undetected, then assign ½ Minimum Detection Limit.
- TKN and phosphorus were sampled only in 2002 for a few of the ships. Sample data from the Yorktown Clipper will be used for the Clipper Odyssey. Wilderness Discovered will be used for the Wilderness Adventurer. Spirit of Endeavour will be used for the Spirit of 98, Spirit of Glacier Bay, Sea Lion and Sea Bird. The Spirit of Columbia results will be used for the Spirit of Alaska and Spirit of Discovery. This 2002 will be used for 2001 as well.

Pollutant/COPC – Year 2002						
Vessel Name(Sample Date)	Code	Location Assigned and time	Vessel Location		Volumetric Discharge Rate (m^3/s)	Total Chloride Concentration (mg/m^3)
			Long	Lat		
Spirit of Discovery (8/15)	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	50
Spirit of Discovery (8/15)	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	50

Spirit of Oceanus (7/9,7/17 & 8/6)	SOO	Auke Bay 0:00-18:00	-134.679667	58.381750	0.000709425	50
Columbia (7/22,8/12, 9/3)	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	6700
Kennicott (7/10)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	40000
Kennicott (7/10)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	40000
Malaspina (7/9)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	3500
Taku (8/22)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	15000
Sea Bird (6/28,8/17)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	1675
Sea Bird (6/28,8/17)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	1675
Sea Lion (7/21,8/4)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	62.5
Spirit of Endeavor (7/11,8/22)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	400
Spirit of Columbia (Use 2001)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	14000
Clipper Odyssey (6/25,7/5)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	566
Spirit of 98 (7/6)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	350
Spirit of 98 (7/6)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	350
Yorktown Clipper (7/6, 7/27)	YOR	Sawyer Glacier/Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	587.5
Yorktown Clipper (7/6, 7/27)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775	587.5

Wilderness Adventurer (7/1,8/19)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	800
Wilderness Adventurer (7/1,8/19)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	800
Wilderness Adventurer (7/1,8/19)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	800
Wilderness Discoverer (7/15)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	500
Wilderness Discoverer (7/15)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	500
Spirit of Oceanus 7/9,7/17,7/17	SOO	Skagway 18:00-24:00	-135.324917	59.448717	0.000107202	50
Matanuska 7/20	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	25000
Matanuska 7/20	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	25000
Matanuska 7/20	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	25000
Pollutant/COPC – Year 2002						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	Fecal Concentration (MPN/m^3)
			Long	Lat		
Spirit of Discovery (8/15)	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	1.3×10^8
Spirit of Discovery (8/15)	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	1.3×10^8
Spirit of Oceanus (7/9,7/17 & 8/6)	SOO	Auke Bay 0:00-18:00	-134.679667	58.381750	0.000709425	3.67×10^{10}
Columbia (7/22,8/12, 9/3)	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	2.5×10^{10}
Kennicott (7/10)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	10000

Kennicott (7/10)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	10000
Malaspina (7/9)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	10000
Taku (8/22)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	$5x10^7$
Sea Bird (6/28,8/17)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	$4.25x10^7$
Sea Bird (6/28,8/17)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	$4.25x10^7$
Sea Lion (7/21,8/4)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	$7.5x10^{10}$
Spirit of Endeavor (7/11,8/22)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	$4.75x10^{10}$
Spirit of Columbia (Use 2001)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	10000
Clipper Odyssey (6/25,7/5)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	$4.0\ x10^9$
Spirit of 98 (7/6)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	$1.33\ x10^9$
Spirit of 98 (7/6)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	$1.33\ x10^9$
Yorktown Clipper (7/6, 7/27)	YOR	Sawyer Glacier/Trac y Arm 14:00-18:00	-133.121183	57.856500	0.000394125	$4.80\ x10^6$
Yorktown Clipper (7/6, 7/27)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	$4.80\ x10^6$
Wilderness Adventurer (7/1,8/19)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	$4.10\ x10^{10}$
Wilderness Adventurer (7/1,8/19)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	$4.10\ x10^{10}$
Wilderness Adventurer (7/1,8/19)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	$4.10\ x10^{10}$

Wilderness Discoverer (7/15)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	10000
Wilderness Discoverer (7/15)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	10000
Spirit of Oceanus 7/9,7/17,7/17	SGB	Skagway 18:00-24:00	-135.324917	59.448717	0.000107202	3.67×10^{10}
Matanuska 7/20	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	10000
Matanuska 7/20	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	10000
Matanuska 7/20	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	10000
Pollutant/COPC – Year 2002						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	PH
			Long	Lat		
Spirit of Discovery (8/15)	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	7.5
Spirit of Discovery (8/15)	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	7.5
Spirit of Oceanus (7/9,7/17 & 8/6)	SOO	Auke Bay 6:00-24:00	-134.679667	58.381750	0.000709425	6.00
Columbia (7/22,8/12, 9/3)	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	7.56
Kennicott (7/10)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	8.1
Kennicott (7/10)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	8.1
Malaspina (7/9)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	7.91
Taku (8/22)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	8.33
Sea Bird (6/28,8/17)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	6.89

Sea Bird (6/28,8/17)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	6.89
Sea Lion (7/21,8/4)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	6.95
Spirit of Endeavor (7/11,8/22)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	8.78
Spirit of Columbia (Use 2001)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	7.23
Clipper Odyssey (6/25,7/5)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	7.725
Spirit of 98 (7/6)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	7.41
Spirit of 98 (7/6)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	7.41
Yorktown Clipper (7/6, 7/27)	YOR	Sawyer Glacier/Trac y Arm 14:00-18:00	-133.121183	57.856500	0.000394125	7.75
Yorktown Clipper (7/6, 7/27)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	7.75
Wilderness Adventurer (7/1,8/19)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	8.2
Wilderness Adventurer (7/1,8/19)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	8.2
Wilderness Adventurer (7/1,8/19)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	8.2
Wilderness Discoverer (7/15)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	6.54
Wilderness Discoverer (7/15)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	6.54
Spirit of Oceanus 7/9,7/17,7/17	SGB	Skagway 8:00-20:00	-135.324917	59.448717	0.000107202	6.00

Matanuska 7/20	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	6.88
Matanuska 7/20	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	6.88
Matanuska 7/20	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	6.88
Pollutant/COPC – Year 2002						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	COD Concentration (mg/m^3)
			Long	Lat		
Spirit of Discovery (8/15)	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	600000
Spirit of Discovery (8/15)	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	600000
Spirit of Oceanus (7/9,7/17 & 8/6)	SOO	Auke Bay 6:00-24:00	-134.679667	58.381750	0.000709425	1350000
Columbia (7/22,8/12, 9/3)	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	500000
Kennicott (7/10)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	870000
Kennicott (7/10)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	870000
Malaspina (7/9)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	514000
Taku (8/22)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	780000
Sea Bird (6/28,8/17)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	673250
Sea Bird (6/28,8/17)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	673250
Sea Lion (7/21,8/4)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	912750
Spirit of Endeavor (7/11,8/22)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	1015500

Spirit of Columbia (Use 2001)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	5690000
Clipper Odyssey (6/25,7/5)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	725000
Spirit of 98 (7/6)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	500000
Spirit of 98 (7/6)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	500000
Yorktown Clipper (7/6, 7/27)	YOR	Sawyer Glacier/Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	465000
Yorktown Clipper (7/6, 7/27)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	465000
Wilderness Adventurer (7/1,8/19)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	775000
Wilderness Adventurer (7/1,8/19)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	775000
Wilderness Adventurer (7/1,8/19)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	775000
Wilderness Discoverer (7/15)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	1290000
Wilderness Discoverer (7/15)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	1290000
Spirit of Oceanus 7/9,7/17,7/17	SGB	Skagway 8:00-20:00	-135.324917	59.448717	0.000107202	1350000
Matanuska 7/20	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	451000
Matanuska 7/20	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	451000
Matanuska 7/20	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	451000

Pollutant/COPC – Year 2002						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	BOD Concentration (mg/m^3)
			Long	Lat		
Spirit of Discovery (8/15)	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	78500
Spirit of Discovery (8/15)	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	78500
Spirit of Oceanus (7/9,7/17 & 8/6)	SOO	Auke Bay 6:00-24:00	-134.679667	58.381750	0.000709425	750000
Columbia (7/22,8/12, 9/3)	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	170000
Kennicott (7/10)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	500
Kennicott (7/10)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	500
Malaspina (7/9)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	500
Taku (8/22)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	177000
Sea Bird (6/28,8/17)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	225000
Sea Bird (6/28,8/17)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	225000
Sea Lion (7/21,8/4)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	382000
Spirit of Endeavor (7/11,8/22)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	350000
Spirit of Columbia (Use 2001)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	32100
Clipper Odyssey (6/25,7/5)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	132000

Spirit of 98 (7/6)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	85000
Spirit of 98 (7/6)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	85000
Yorktown Clipper (7/6, 7/27)	YOR	Sawyer Glacier/Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	45000
Yorktown Clipper (7/6, 7/27)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	45000
Wilderness Adventurer (7/1,8/19)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	175000
Wilderness Adventurer (7/1,8/19)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	175000
Wilderness Adventurer (7/1,8/19)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	175000
Wilderness Discoverer (7/15)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	3070
Wilderness Discoverer (7/15)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	3070
Spirit of Oceanus 7/9,7/17,7/17	SGB	Skagway 8:00-20:00	-135.324917	59.448717	0.000107202	750000
Matanuska 7/20	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	134000
Matanuska 7/20	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	134000
Matanuska 7/20	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	134000
Pollutant/COPC – Year 2002						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	Conductivity
			Long	Lat		

Spirit of Discovery (8/15)	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	Not tested
Spirit of Discovery (8/15)	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	Not tested
Spirit of Oceanus (7/9,7/17 & 8/6)	SOO	Auke Bay 6:00-24:00	-134.679667	58.381750	0.000709425	1860
Columbia (7/22,8/12, 9/3)	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	22800
Kennicott (7/10)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	31200
Kennicott (7/10)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	31200
Malaspina (7/9)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	23800
Taku (8/22)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	28200
Sea Bird (6/28,8/17)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	Not tested
Sea Bird (6/28,8/17)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	Not tested
Sea Lion (7/21,8/4)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	Not tested
Spirit of Endeavor (7/11,8/22)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	Not tested
Spirit of Columbia (Use 2001)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	Not tested
Clipper Odyssey (6/25,7/5)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	Not tested
Spirit of 98 (7/6)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	Not tested
Spirit of 98 (7/6)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	Not tested

Yorktown Clipper (7/6, 7/27)	YOR	Sawyer Glacier/Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	17435
Yorktown Clipper (7/6, 7/27)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	17435
Wilderness Adventurer (7/1,8/19)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	Not tested
Wilderness Adventurer (7/1,8/19)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	Not tested
Wilderness Adventurer (7/1,8/19)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	Not tested
Wilderness Discoverer (7/15)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	11400
Wilderness Discoverer (7/15)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	11400
Spirit of Oceanus 7/9,7/17,7/17	SGB	Skagway 8:00-20:00	-135.324917	59.448717	0.000107202	1860
Matanuska 7/20	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	23000
Matanuska 7/20	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	23000
Matanuska 7/20	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	23000

Pollutant/COPC – Year 2002						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	Free Chloride Concentration (mg/m^3)
			Long	Lat		
Spirit of Discovery (8/15)	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	50
Spirit of Discovery (8/15)	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	50

Spirit of Oceanus (7/9,7/17 & 8/6)	SOO	Auke Bay 6:00-24:00	-134.679667	58.381750	0.000709425	100
Columbia (7/22,8/12, 9/3)	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	4000
Kennicott (7/10)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	25000
Kennicott (7/10)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	25000
Malaspina (7/9)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	2500
Taku (8/22)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	10000
Sea Bird (6/28,8/17)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	1000
Sea Bird (6/28,8/17)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	1000
Sea Lion (7/21,8/4)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	50
Spirit of Endeavor (7/11,8/22)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	50
Spirit of Columbia (Use 2001)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	3500
Clipper Odyssey (6/25,7/5)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	300
Spirit of 98 (7/6)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	50
Spirit of 98 (7/6)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	50
Yorktown Clipper (7/6, 7/27)	YOR	Sawyer Glacier/Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	137.5
Yorktown Clipper (7/6, 7/27)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	137.5

Wilderness Adventurer (7/1,8/19)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	600
Wilderness Adventurer (7/1,8/19)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	600
Wilderness Adventurer (7/1,8/19)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	600
Wilderness Discoverer (7/15)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	50
Wilderness Discoverer (7/15)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	50
Spirit of Oceanus 7/9,7/17,7/17	SGB	Skagway 8:00-20:00	-135.324917	59.448717	0.000107202	100
Matanuska 7/20	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	10000
Matanuska 7/20	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	10000
Matanuska 7/20	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	10000
Pollutant/COPC – Year 2002						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	TSS Concentration (mg/m^3)
			Long	Lat		
Spirit of Discovery (8/15)	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	110000
Spirit of Discovery (8/15)	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	110000
Spirit of Oceanus (7/9,7/17 & 8/6)	SOO	Auke Bay 6:00-24:00	-134.679667	58.381750	0.000709425	207000
Columbia (7/22,8/12, 9/3)	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	64000
Kennicott (7/10)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	650

Kennicott (7/10)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	650
Malaspina (7/9)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	650
Taku (8/22)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	311000
Sea Bird (6/28,8/17)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	155000
Sea Bird (6/28,8/17)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	155000
Sea Lion (7/21,8/4)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	400000
Spirit of Endeavor (7/11,8/22)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	300000
Spirit of Columbia (Use 2001)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	518000
Clipper Odyssey (6/25,7/5)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	37400
Spirit of 98 (7/6)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	75000
Spirit of 98 (7/6)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	75000
Yorktown Clipper (7/6, 7/27)	YOR	Sawyer Glacier/Tracy Arm 14:00-18:00	-133.121183	57.856500	0.000394125	21500
Yorktown Clipper (7/6, 7/27)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	21500
Wilderness Adventurer (7/1,8/19)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	200000
Wilderness Adventurer (7/1,8/19)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	200000
Wilderness Adventurer (7/1,8/19)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	200000

Wilderness Discoverer (7/15)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	278000
Wilderness Discoverer (7/15)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	278000
Spirit of Oceanus 7/9,7/17,7/17	SGB	Skagway 8:00-20:00	-135.324917	59.448717	0.000107202	207000
Matanuska 7/20	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	75200
Matanuska 7/20	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	75200
Matanuska 7/20	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	75200
Pollutant/COPC – Year 2002						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	Ammonia as Nitrogen Concentration (mg/m^3)
			Long	Lat		
Spirit of Discovery (8/15)	SOD	Ketchikan 4:00-12:00	-131.646111	55.342222	0.00022071	40000
Spirit of Discovery (8/15)	SOD	Metlakatla 14:00-20:00	-131.578333	55.131333	0.00022071	40000
Spirit of Oceanus (7/9,7/17 & 8/6)	SOO	Auke Bay 6:00-24:00	-134.679667	58.381750	0.000709425	43000
Columbia (7/22,8/12, 9/3)	COL	Auke Bay 00:00-04:00	-134.685933	58.381600	0.000670013	37500
Kennicott (7/10)	KEN	Auke Bay 00:00-04:00	-134.687567	58.381750	0.000748838	8
Kennicott (7/10)	KEN	Sitka 16:00-20:00	-135.381750	57.129383	0.000748838	8
Malaspina (7/9)	MAL	Haines 16:00-20:00	-134.685933	58.381600	0.000748838	121
Taku (8/22)	TAK	Skagway 16:00-20:00	-135.325683	59.449050	7.09425E-05	10700
Sea Bird (6/28,8/17)	SBD	Margerie Glacier 6:00-10:00	-137.044633	59.042683	0.000231746	7000

Sea Bird (6/28,8/17)	SBD	Bartlett Cove 19:00-23:00	-135.887117	58.455200	0.000231746	7000
Sea Lion (7/21,8/4)	SLN	Idaho Inlet 6:00-12:00	-136.159167	58.082283	0.000241205	10000
Spirit of Endeavor (7/11,8/22)	SOE	Juneau 8:00-20:00	-134.409367	58.298767	0.000110355	21000
Spirit of Columbia (Use 2001)	SOC	Sitka 00:00-24:00	-135.349433	57.054867	0.000174729	10704
Clipper Odyssey (6/25,7/5)	CLO	Juneau 8:00-20:00	-134.411000	58.298767	0.000141885	1400
Spirit of 98 (7/6)	S98	Rudyerd Bay 8:00-12:00	-130.746933	55.590633	0.00022071	30000
Spirit of 98 (7/6)	S98	Ketchikan 14:00-22:00	-131.694100	55.354067	0.00022071	30000
Yorktown Clipper (7/6, 7/27)	YOR	Sawyer Glacier/Trac y Arm 14:00-18:00	-133.121183	57.856500	0.000394125	2060
Yorktown Clipper (7/6, 7/27)	YOR	Juneau 00:00-12:00	-134.681033	58.384667	0.000551775 (Juneau)	2060
Wilderness Adventurer (7/1,8/19)	WAD	Gambier 8:00-14:00	-134.064867	57.467833	0.000149768	56700
Wilderness Adventurer (7/1,8/19)	WAD	Excursion Inlet 00:00-6:00	-135.496183	58.492683	0.000149768	56700
Wilderness Adventurer (7/1,8/19)	WAD	Sanford Cove/TA 16:00-24:00	-133.482050	57.678017	0.000149768	56700
Wilderness Discoverer (7/15)	WDI	Warm Springs Bay 6:00-12:00	-134.813250	57.090717	0.000149768	53500
Wilderness Discoverer (7/15)	WDI	Red Bay Bluff 14:00-20:00	-134.785867	56.867883	0.000149768	53500
Spirit of Oceanus 7/9,7/17,7/17	SGB	Skagway 8:00-20:00	-135.324917	59.448717	0.000107202	43000

Matanuska 7/20	MAT	Ketchikan 20:00-24:00	-131.694100	55.354067	0.000748838	1270
Matanuska 7/20	MAT	Petersburg 8:00-12:00	-132.977433	56.808283	0.000748838	1270
Matanuska 7/20	MAT	Wrangell 13:00-17:00	-132.391883	56.474250	0.000748838	1270
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	Ammonia as Nitrogen Concentration (mg/m^3)
			Long	Lat		
Spirit of Discovery	SOD	Ketchikan	-131.646111	55.342222	0.00022071	0
Spirit of Discovery	SOD	Metlakatla	-131.571944	55.128889	0.00022071	0
Spirit of Oceanus	SOO	Auke Bay	-134.659722	58.383333	0.000709425	39750
Columbia	COL	Auke Bay	-134.659722	58.383333	0.000670013	37530
Kennicott	KEN	Auke Bay	-134.659722	58.383333	0.000748838	4170
Kennicott	KEN	Sitka	-135.330000	57.052778	0.000748838	4170
Malaspina	MAL	Haines	-135.445000	59.235556	0.000748838	6370
Taku	TAK	Skagway	-135.313611	59.313611	7.09425E-05	6750
Sea Bird	SBD	Margerie Glacier	-137.357500	58.914722	0.000231746	12240
Sea Bird	SBD	Bartlett Cove	-135.899167	58.456389	0.000231746	12240
Sea Lion	SLN	Idaho Inlet	-136.196667	58.151944	0.000241205	9770
Spirit of Endeavor	SOE	Juneau	-134.419722	58.301944	0.000110355	42680
Spirit of Columbia	SOC	Sitka	-135.330000	57.052778	0.000174729	10704
Spirit of Alaska	SOA	Petersburg	-132.955278	56.812500	0.000180247	0
Spirit of Alaska	SOA	Wrangell	-132.376389	56.470556	0.000180247	0
Clipper Odyssey	CLO	Juneau	-134.419722	58.301944	0.000141885	2060
Spirit of 98	S98	Rudyerd Bay	-130.745833	55.589722	0.00022071	51398
Spirit of 98	S98	Ketchikan	-131.646111	55.342222	0.00022071	51398
Yorktown Clipper	YOR	Tracy Arm	-133.402222	57.911389	0.000394125	2060
Yorktown Clipper	YOR	Juneau	-134.419722	58.301944	0.000551775	2060

Wilderness Adventurer	WAD	Gambier	-134.023056	57.480278	0.000149768	40800
Wilderness Adventurer	WAD	Excursion Inlet	-135.464167	58.439722	0.000149768	40800
Wilderness Adventurer	WAD	Tracy Arm	-133.402222	57.911389	0.000149768	40800
Wilderness Discoverer	WDI	Warm Springs Bay	-134.803333	57.083056	0.000149768	43400
Wilderness Discoverer	WDI	Red Bay Bluff	-134.803333	57.083056	0.000149768	43400
Spirit of Glacier Bay	SGB	Skagway	-135.313611	59.313611	0.000107202	0
Matanuska	MAT	Ketchikan	-131.646111	55.342222	0.000748838	13900
Matanuska	MAT	Petersburg	-132.955278	56.812500	0.000748838	13900
Matanuska	MAT	Wrangell	-132.376389	56.470556	0.000748838	13900
Pollutant/COPC – Year 2001						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	Total Nitrogen Concentration (mg/m^3)
			Long	Lat		
Spirit of Discovery	SOD	Ketchikan	-131.646111	55.342222	0.00022071	0
Spirit of Discovery	SOD	Metlakatla	-131.571944	55.128889	0.00022071	0
Spirit of Oceanus	SOO	Auke Bay	-134.659722	58.383333	0.000709425	0
Columbia	COL	Auke Bay	-134.659722	58.383333	0.000670013	42400
Kennicott	KEN	Auke Bay	-134.659722	58.383333	0.000748838	28700
Kennicott	KEN	Sitka	-135.330000	57.052778	0.000748838	28700
Malaspina	MAL	Haines	-135.445000	59.235556	0.000748838	800
Taku	TAK	Skagway	-135.313611	59.313611	7.09425E-05	48000
Sea Bird	SBD	Margerie Glacier	-137.357500	58.914722	0.000231746	0
Sea Bird	SBD	Bartlett Cove	-135.899167	58.456389	0.000231746	0
Sea Lion	SLN	Idaho Inlet	-136.196667	58.151944	0.000241205	0
Spirit of Endeavor	SOE	Juneau	-134.419722	58.301944	0.000110355	0
Spirit of Columbia	SOC	Sitka	-135.330000	57.052778	0.000174729	0
Spirit of Alaska	SOA	Petersburg	-132.955278	56.812500	0.000180247	0
Spirit of Alaska	SOA	Wrangell	-132.376389	56.470556	0.000180247	0

Clipper Odyssey	CLO	Juneau	-134.419722	58.301944	0.000141885	0
Spirit of 98	S98	Rudyerd Bay	-130.745833	55.589722	0.00022071	0
Spirit of 98	S98	Ketchikan	-131.646111	55.342222	0.00022071	0
Yorktown Clipper	YOR	Tracy Arm	-133.402222	57.911389	0.000394125	3050
Yorktown Clipper	YOR	Juneau	-134.419722	58.301944	0.000551775	3050
Wilderness Adventurer	WAD	Gambier	-134.023056	57.480278	0.000149768	0
Wilderness Adventurer	WAD	Excursion Inlet	-135.464167	58.439722	0.000149768	0
Wilderness Adventurer	WAD	Tracy Arm	-133.402222	57.911389	0.000149768	0
Wilderness Discoverer	WDI	Warm Springs Bay	-134.803333	57.083056	0.000149768	0
Wilderness Discoverer	WDI	Red Bay Bluff	-134.803333	57.083056	0.000149768	0
Spirit of Glacier Bay	SGB	Skagway	-135.313611	59.313611	0.000107202	0
Matanuska	MAT	Ketchikan	-131.646111	55.342222	0.000748838	17600
Matanuska	MAT	Petersburg	-132.955278	56.812500	0.000748838	17600
Matanuska	MAT	Wrangell	-132.376389	56.470556	0.000748838	17600
Pollutant/COPC – Year 2001						
Vessel Name	Code	Location Assigned	Vessel Location		Volumetric Discharge Rate (m^3/s)	Phosphorous Concentration (mg/m^3)
			Long	Lat		
Spirit of Discovery	SOD	Ketchikan	-131.646111	55.342222	0.00022071	0
Spirit of Discovery	SOD	Metlakatla	-131.571944	55.128889	0.00022071	0
Spirit of Oceanus	SOO	Auke Bay	-134.659722	58.383333	0.000709425	0
Columbia	COL	Auke Bay	-134.659722	58.383333	0.000670013	5650
Kennicott	KEN	Auke Bay	-134.659722	58.383333	0.000748838	110
Kennicott	KEN	Sitka	-135.330000	57.052778	0.000748838	110
Malaspina	MAL	Haines	-135.445000	59.235556	0.000748838	345
Taku	TAK	Skagway	-135.313611	59.313611	7.09425E-05	4920
Sea Bird	SBD	Margerie Glacier	-137.357500	58.914722	0.000231746	0
Sea Bird	SBD	Bartlett Cove	-135.899167	58.456389	0.000231746	0

Sea Lion	SLN	Idaho Inlet	-136.196667	58.151944	0.000241205	0
Spirit of Endeavor	SOE	Juneau	-134.419722	58.301944	0.000110355	0
Spirit of Columbia	SOC	Sitka	-135.330000	57.052778	0.000174729	0
Spirit of Alaska	SOA	Petersburg	-132.955278	56.812500	0.000180247	0
Spirit of Alaska	SOA	Wrangell	-132.376389	56.470556	0.000180247	0
Clipper Odyssey	CLO	Juneau	-134.419722	58.301944	0.000141885	0
Spirit of 98	S98	Rudyerd Bay	-130.745833	55.589722	0.00022071	0
Spirit of 98	S98	Ketchikan	-131.646111	55.342222	0.00022071	0
Yorktown Clipper	YOR	Tracy Arm	-133.402222	57.911389	0.000394125	1593
Yorktown Clipper	YOR	Juneau	-134.419722	58.301944	0.000551775	1593
Wilderness Adventurer	WAD	Gambier	-134.023056	57.480278	0.000149768	0
Wilderness Adventurer	WAD	Excursion Inlet	-135.464167	58.439722	0.000149768	0
Wilderness Adventurer	WAD	Tracy Arm	-133.402222	57.911389	0.000149768	0
Wilderness Discoverer	WDI	Warm Springs Bay	-134.803333	57.083056	0.000149768	0
Wilderness Discoverer	WDI	Red Bay Bluff	-134.803333	57.083056	0.000149768	0
Spirit of Glacier Bay	SGB	Skagway	-135.313611	59.313611	0.000107202	0
Matanuska	MAT	Ketchikan	-131.646111	55.342222	0.000748838	2380
Matanuska	MAT	Petersburg	-132.955278	56.812500	0.000748838	2380
Matanuska	MAT	Wrangell	-132.376389	56.470556	0.000748838	2380

- This table should contain all ships in the 2002 list.
- NOTE: Total Cl, COD, BOD, Free Cl and TSS were converted from mg/L to mg/m^3. Fecal coliform was converted to MPN/cubic meters. Conductivity and pH are listed without units.
- If concentration is Undetected assign ½ the Minimum Detection Limit (MDL) to it.

D

Bathymetric Maps of Areas of Concern

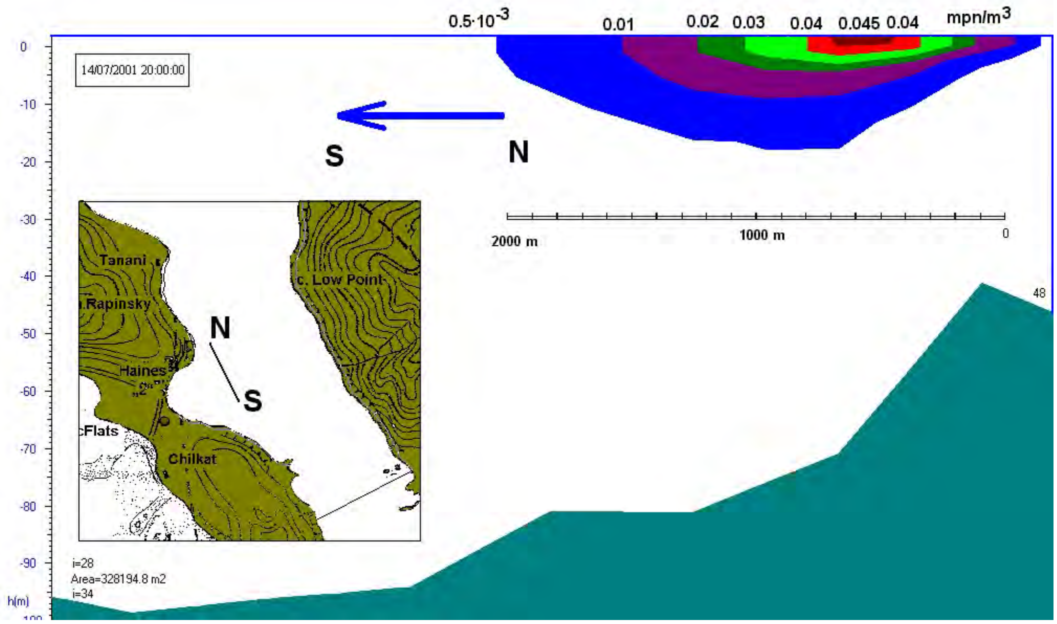


Figure 34D
Isopleths of fecal concentrations after 4 hours of discharge from '*Malaspina*' on the cross- section N-S**.**

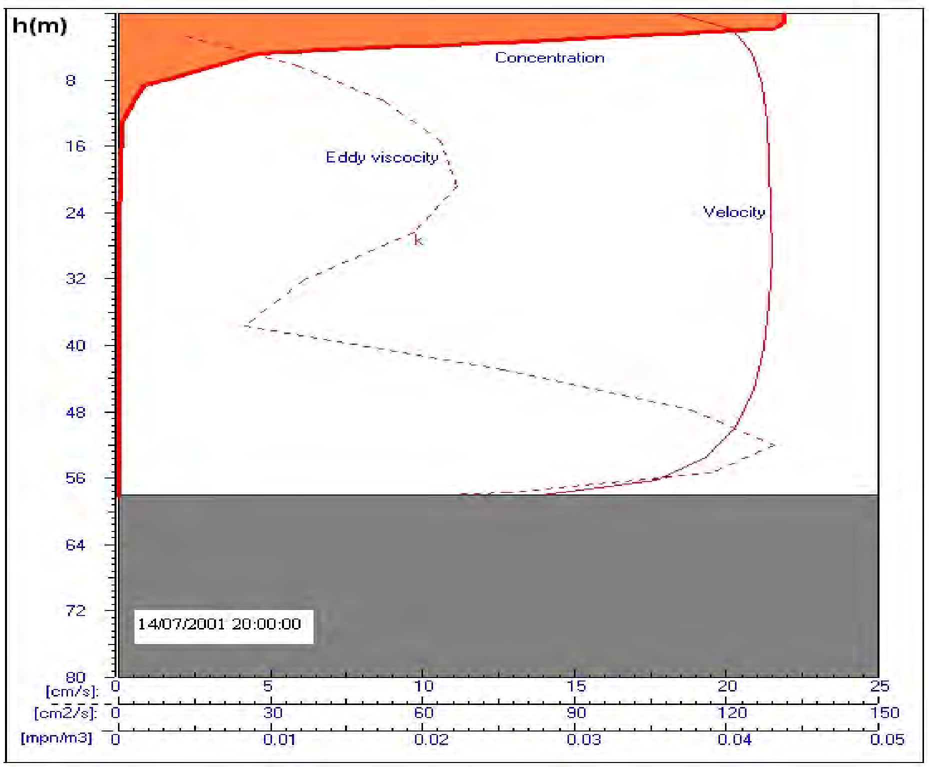
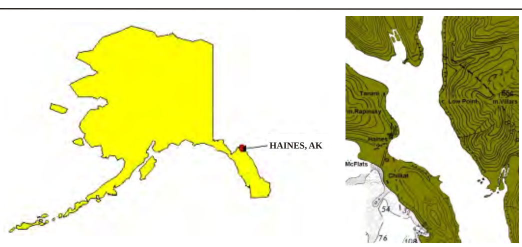


Figure 34E
The vertical distribution of izopleths of fecal concentrations, velocities and vertical eddy viscosity coefficient near the source at the moment 20h (4 hours of discharge from '*Malaspina*')**.**



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001332AU11_34A.CDR

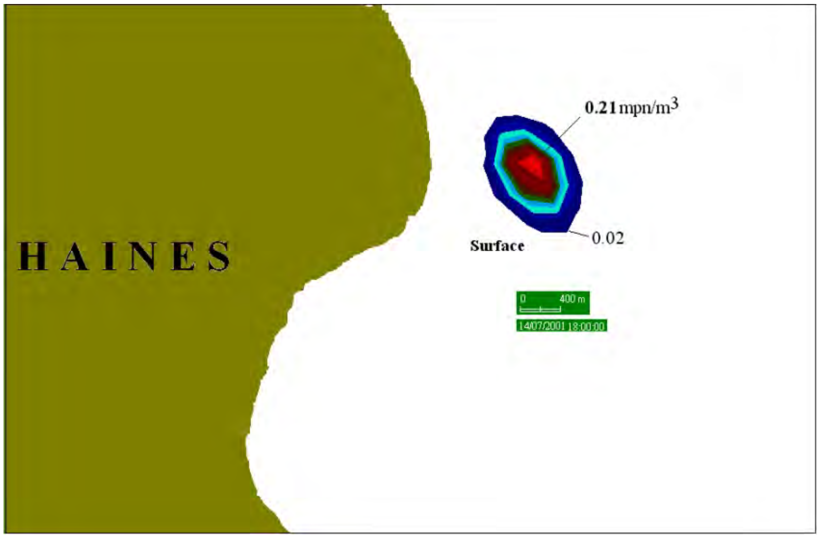


Figure 34A
Zoomed view of isopleths of fecal concentrations near surface after 2 hours of discharge from '*Malaspina'***.**
Chemical parameters: = 0 day^{-1}; v_s = 0 cm/day.

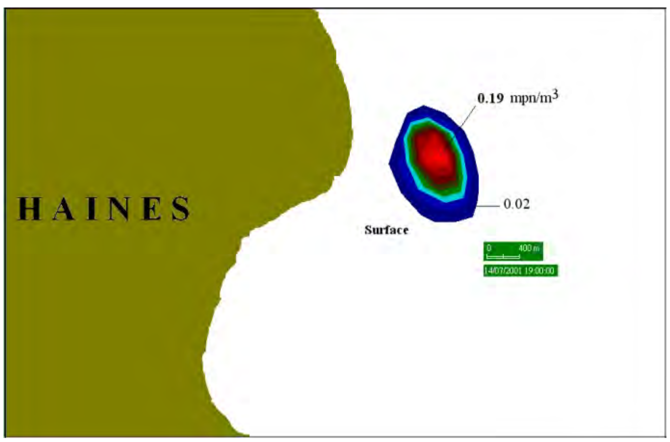


Figure 34B
Zoomed view of isopleths of fecal concentrations near surface after 3 hours of discharge from '*Malaspina'***.**
Chemical parameters: = 0 day^{-1}; v_s = 0 cm/day.

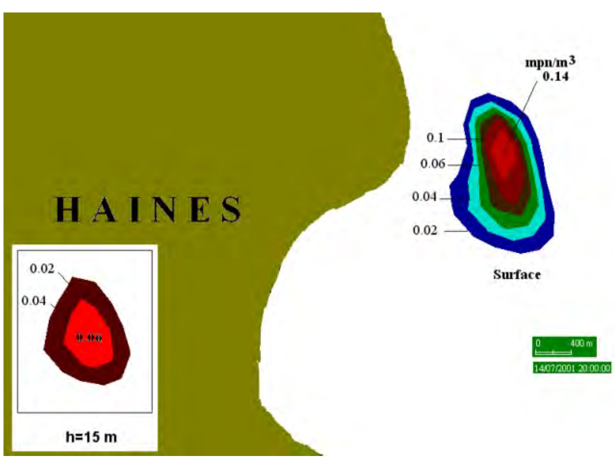
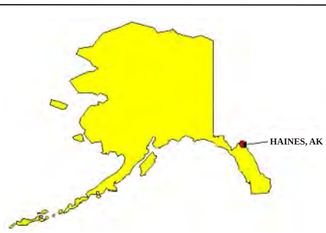


Figure 34C
Zoomed view of isopleths of fecal concentrations near surface and at 15-20 m depth after 4 hours of discharge from '*Malaspina'***.**
Chemical parameters: = 0 day^{-1}; v_s = 0 cm/day.



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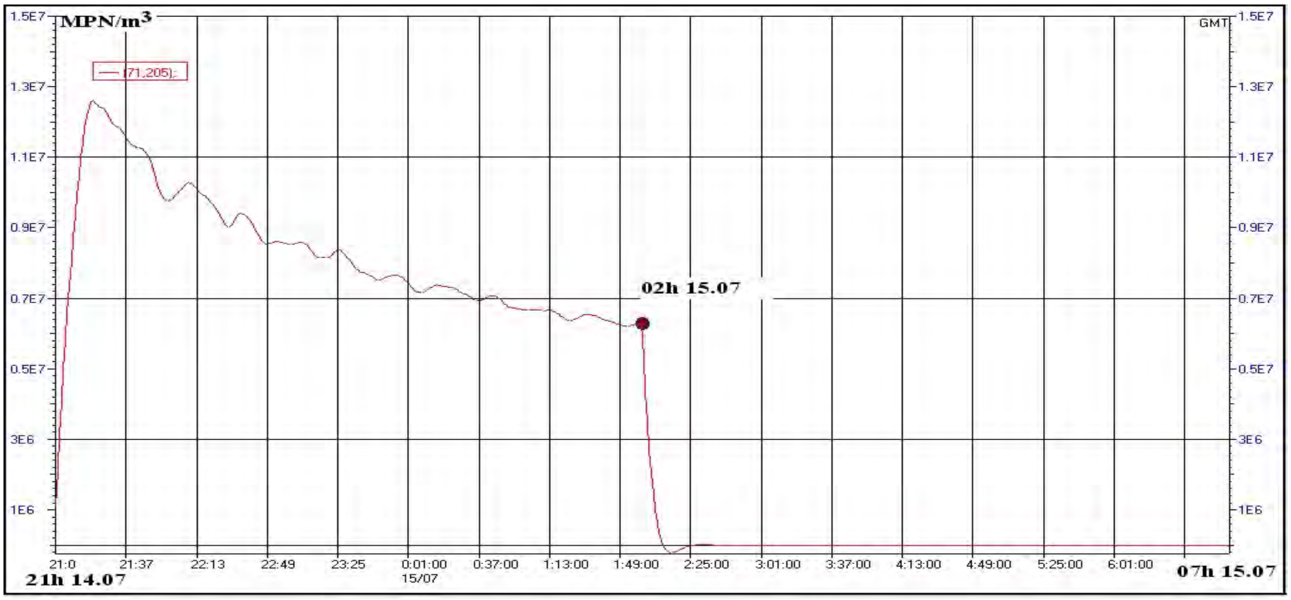
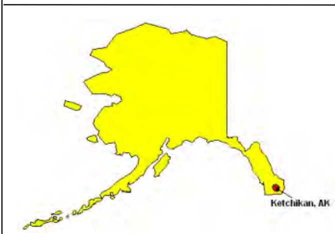


Figure 33C
The time history of fecal concentrations in the source point during 5 h of discharge from the *Spirit of 98* located in grid point (71, 205) as shown in (A) at 5 hours after stop of discharge.



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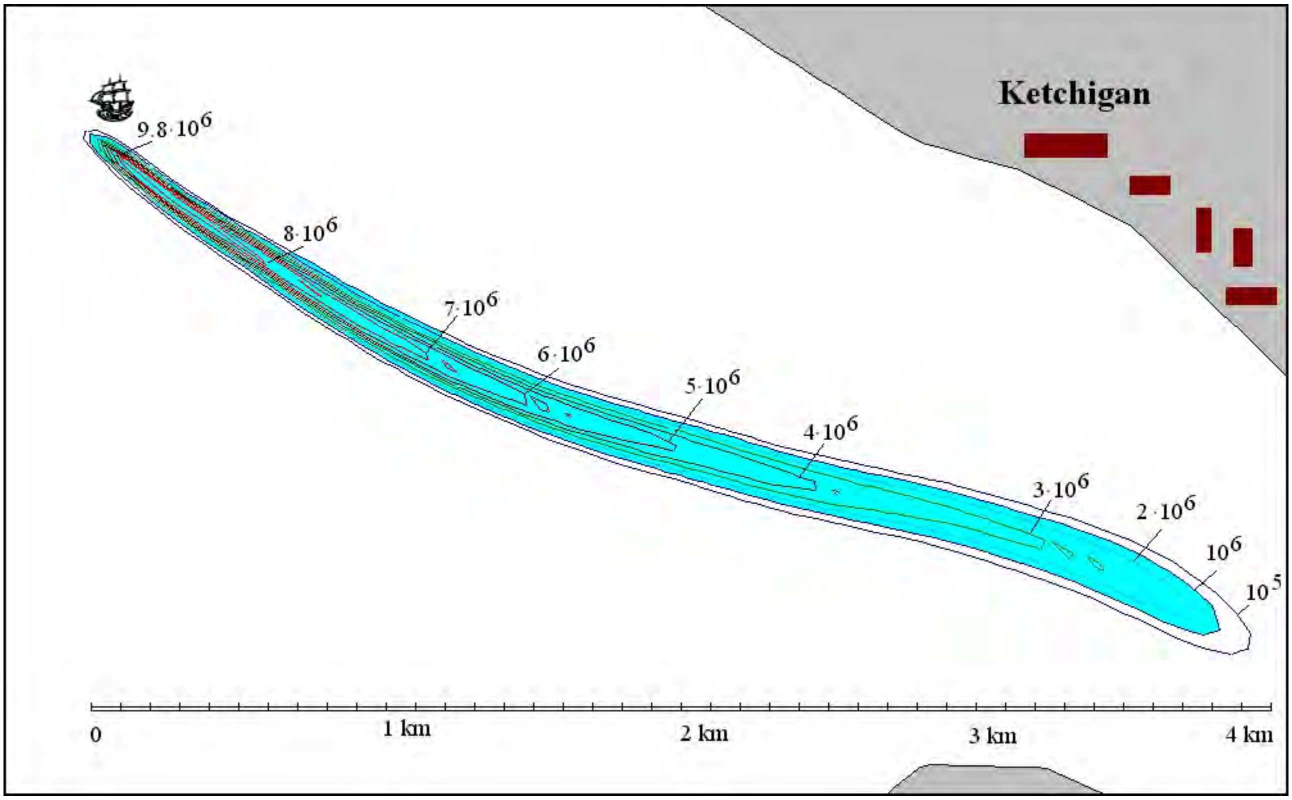
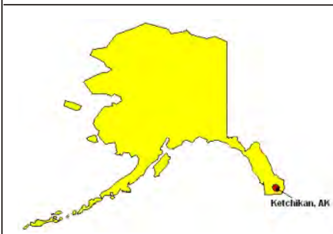


Figure 33B
Zoomed view of isolines of depth-averaged fecal concentration (MPN/m^3) at the moment discharge stopped.



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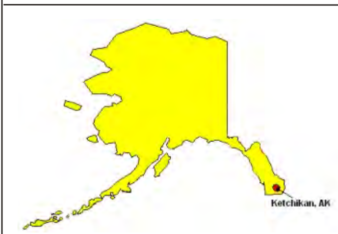
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Figure 33A
Location of the source and the plume
5 hours later after discharge ceased.



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PROJECT No. 001332.AU11.01 **JUNE 2003**

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

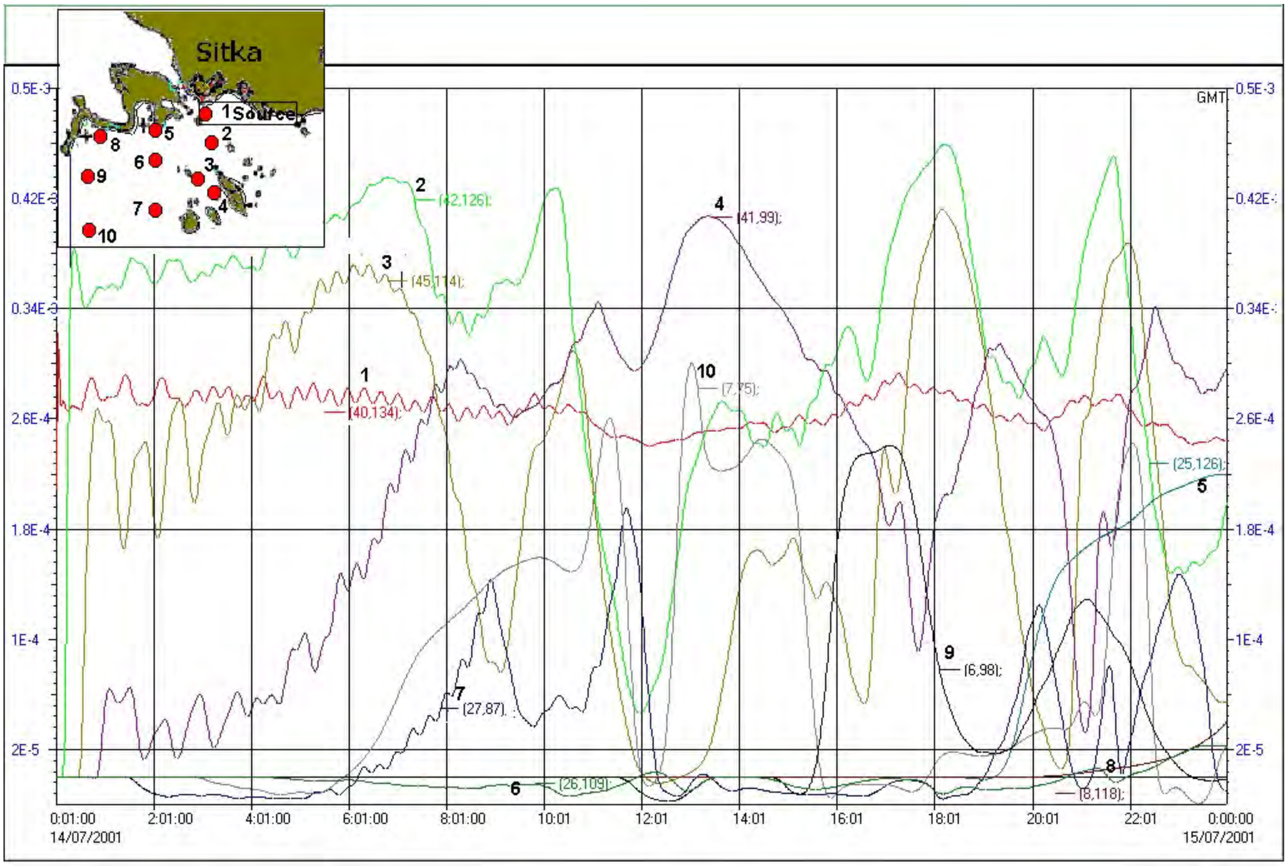


Figure 32A
Time history of fecal concentrations (MPN/m^3) at different points near Sitka during 24h of wastewater discharge.

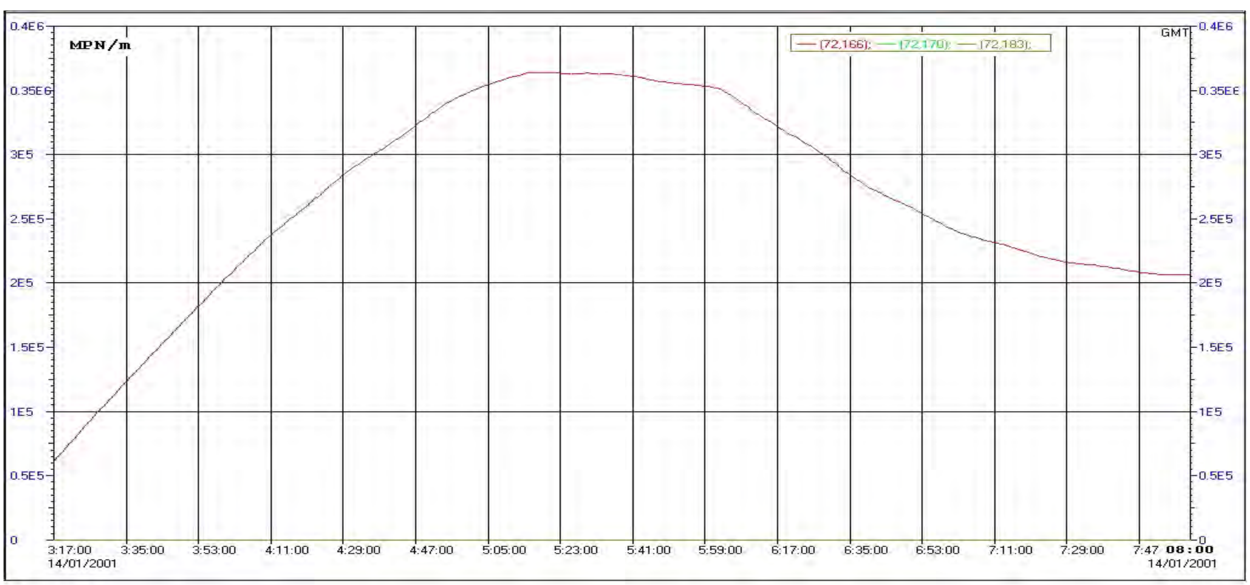
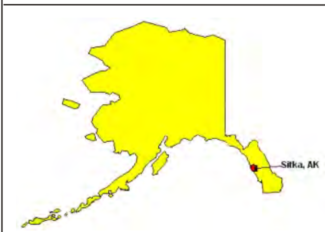


Figure 32B
The time history of fecal concentrations in Tajasanka Bay near Skagway at the point where pollution source was located during 5 h of discharge.



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PROJECT No. 001332.AU11.01 **JUNE 2003**

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

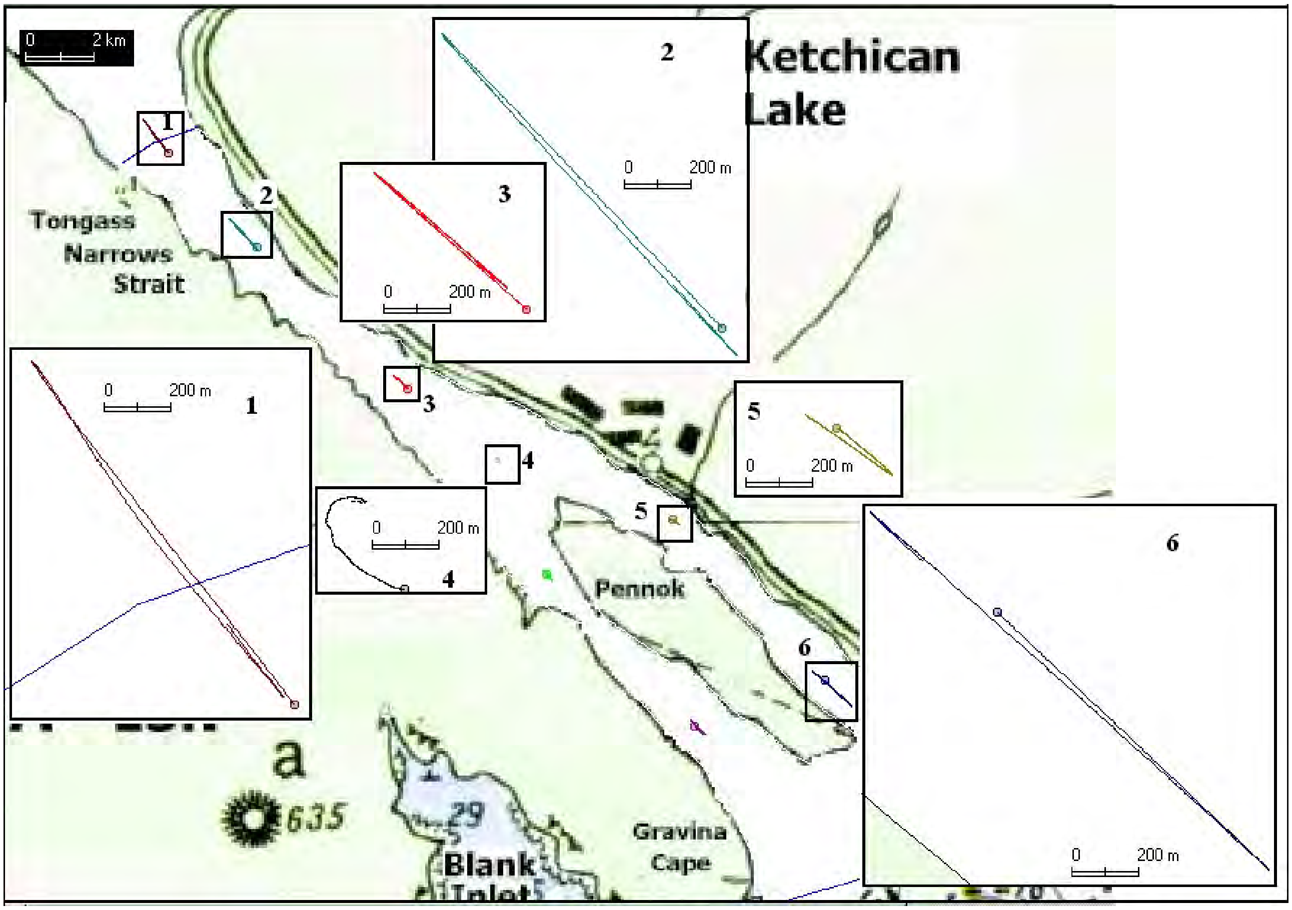
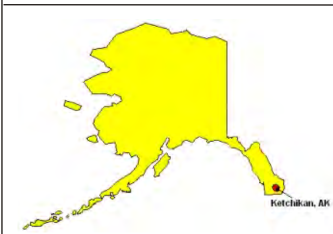


Figure 31B
Progressive vector diagrams of velocities in different points in the Tongass Narrows Strait when same water levels was assigned at the two open boundaries.



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PROJECT No. 001332.AU11.01 **JUNE 2003**

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

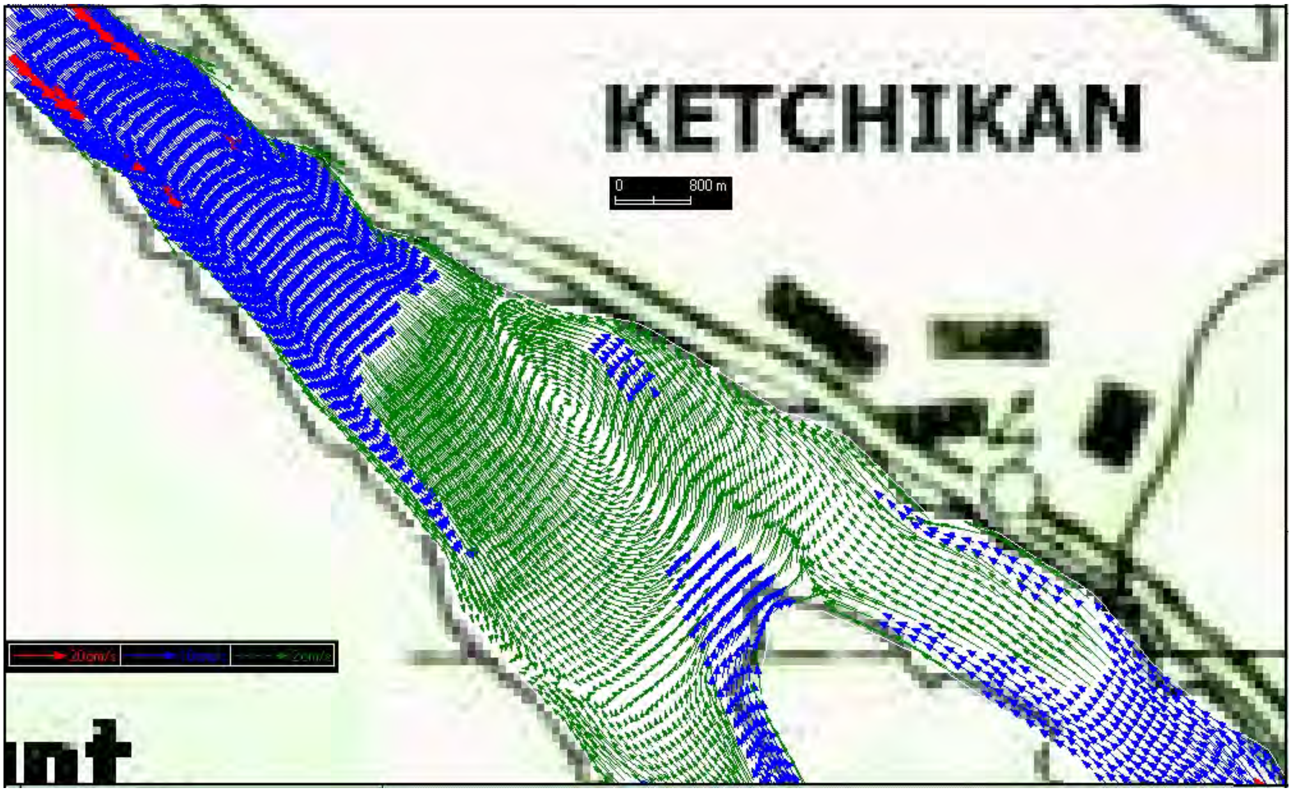
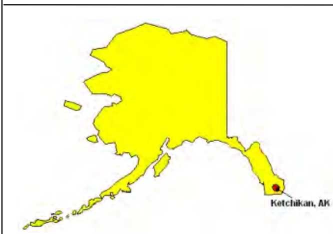


Figure 31A
Velocity field at the moment on convergence of currents opposite to Ketchikan port. This is due to assignment of same water level oscillations (tidal cycles) at two open boundaries.



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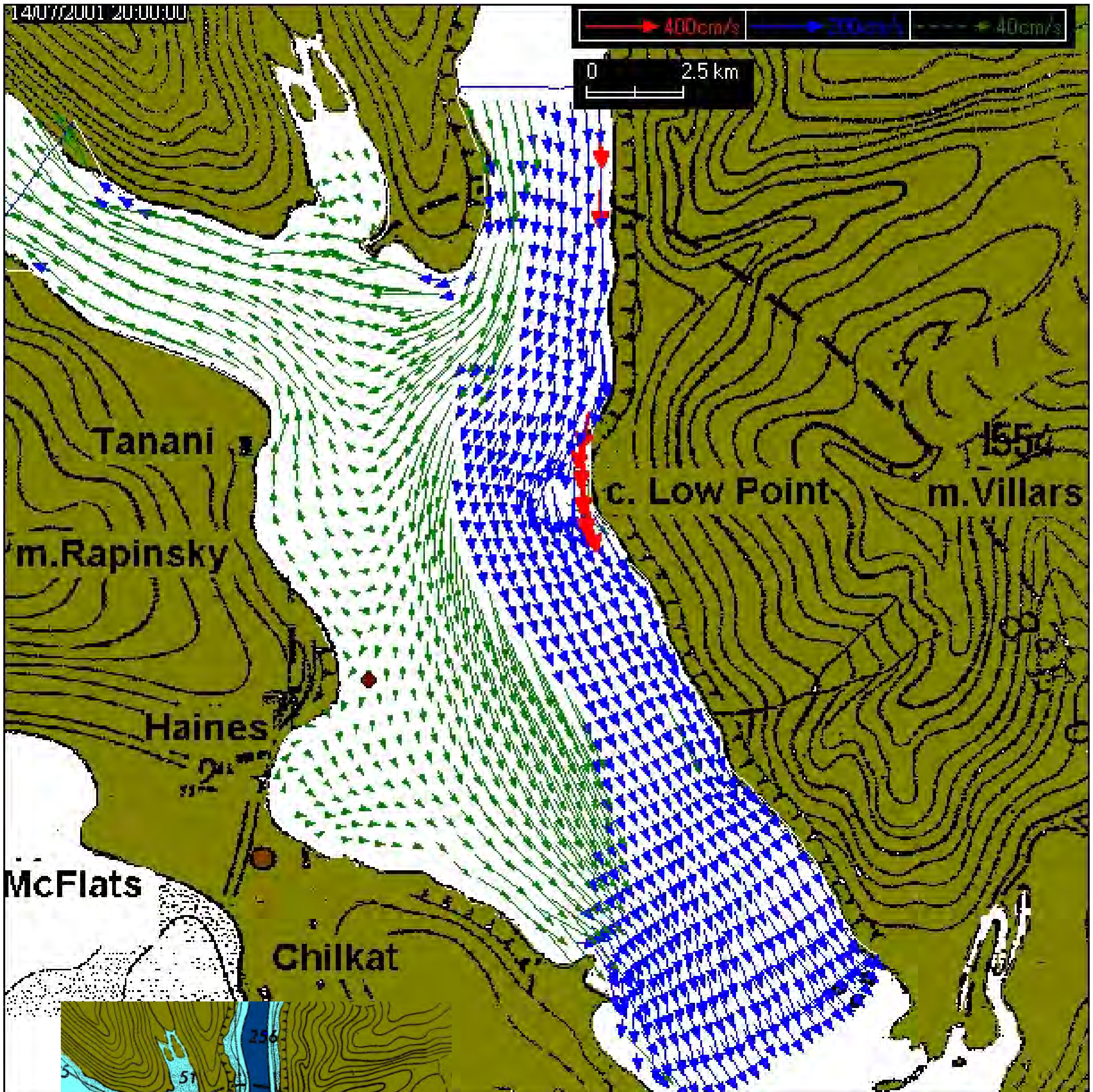
PROJECT No. 001332.AU11.01	JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION



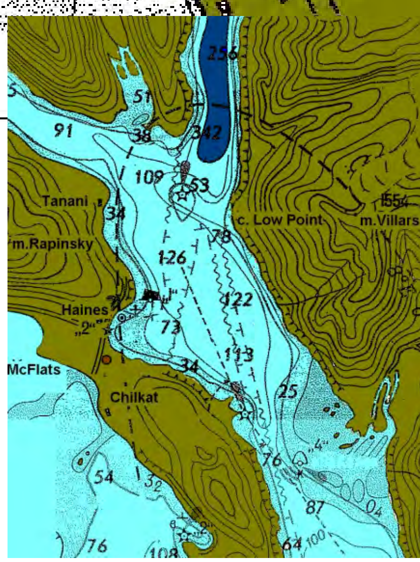
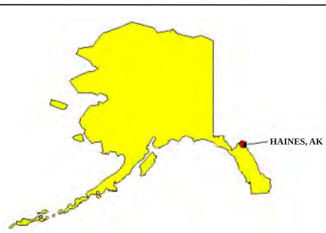


Figure 30
Velocity Pattern at 20:00 h on July 14, 2001
at Haines area.



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PROJECT No. 001332.AU11.01 **JUNE 2003**

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

001332AU11_29.CDR

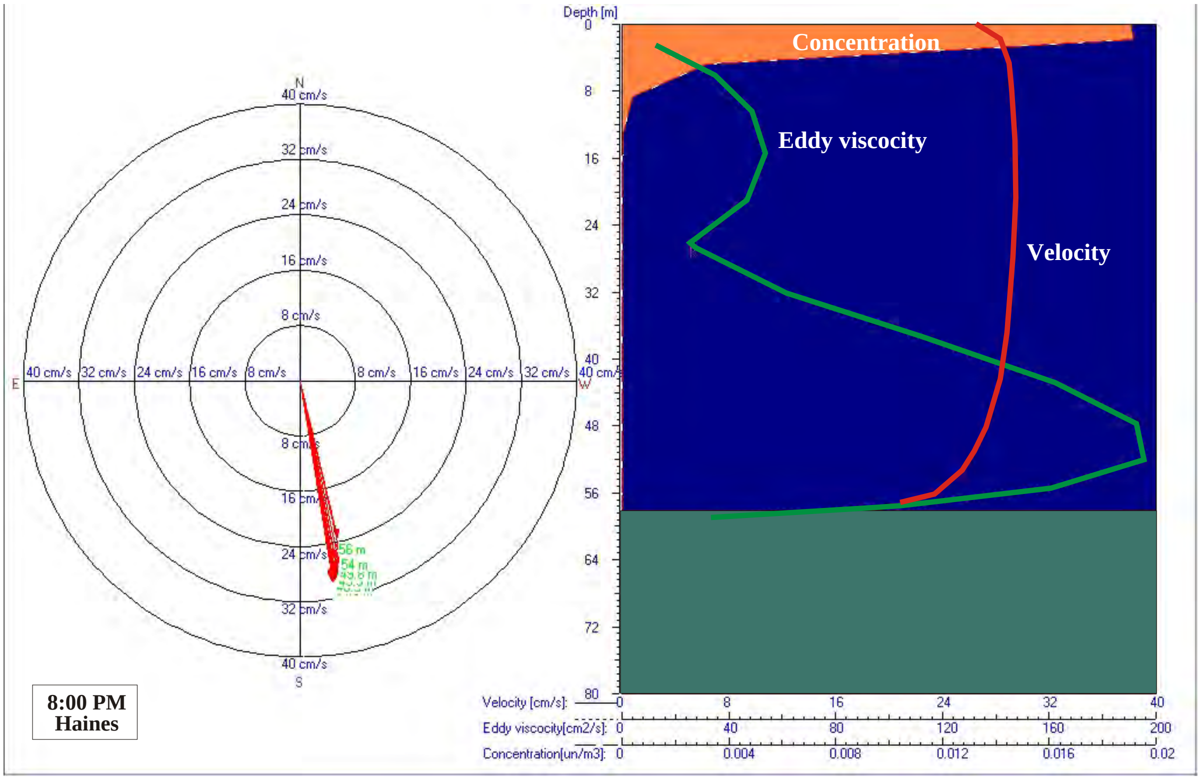


Figure 29A

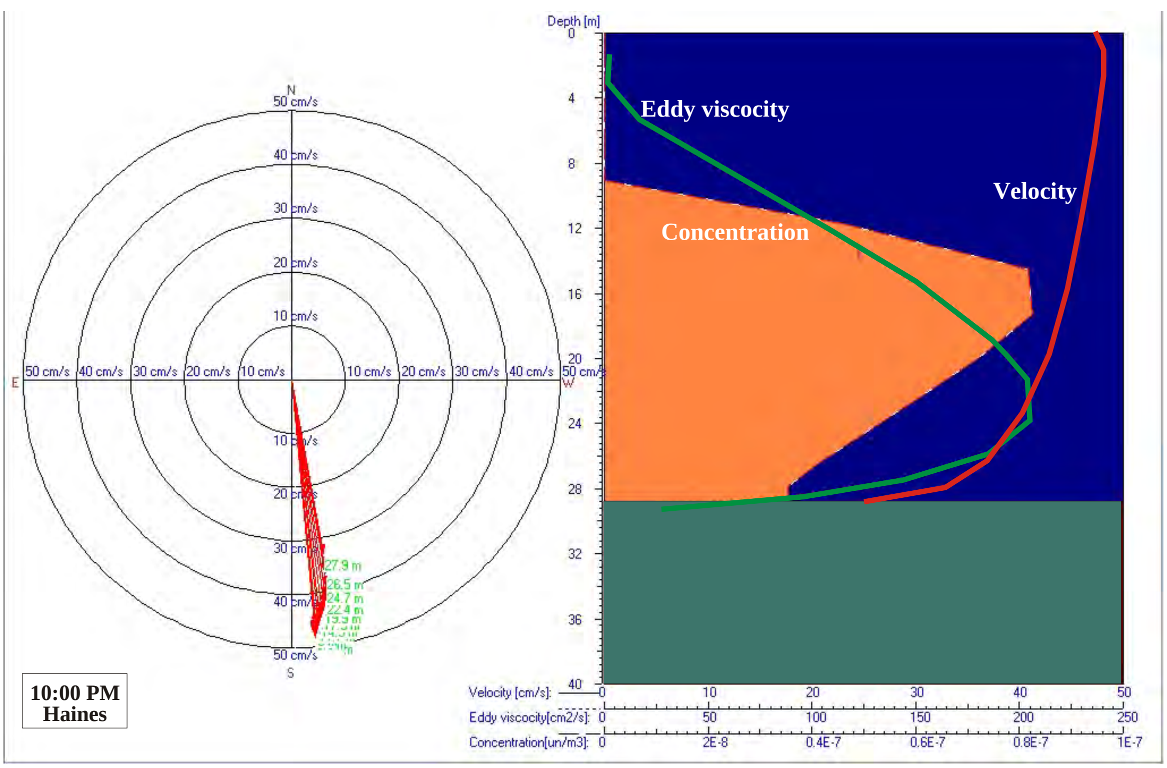
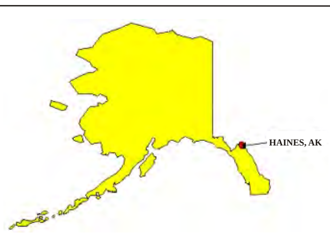


Figure 29B



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THE VERTICAL DISTRIBUTION OF VELOCITIES, CONCENTRATIONS AND EDDY VISCOSITY COEFFICIENT AT 8:00 PM (END OF DISCHARGE) AND 10:00 PM (TWO HOURS AFTER DISCHARGE) AT HAINES, AT THE POINT OF DISCHARGE (*MALASPINA*).

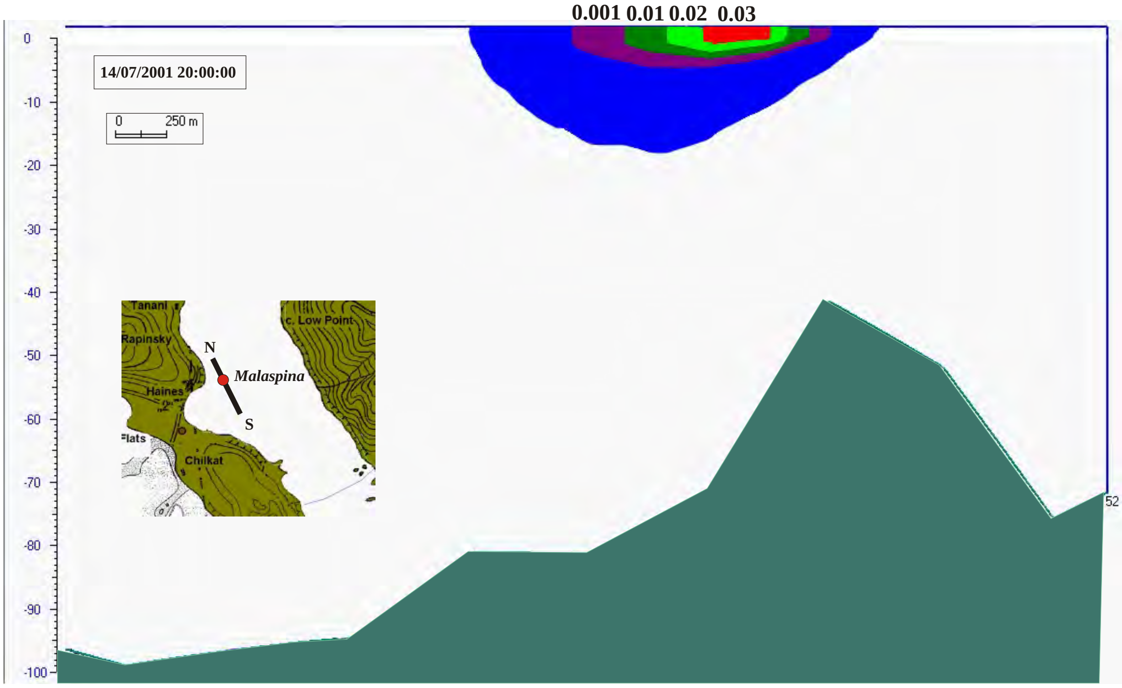


Figure 28A

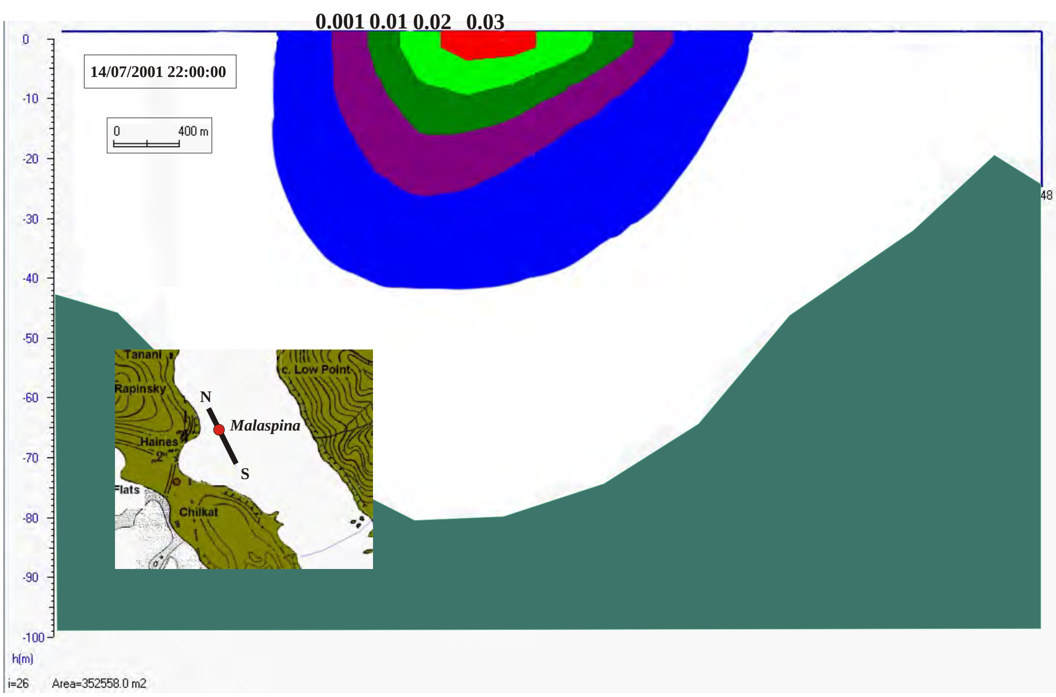
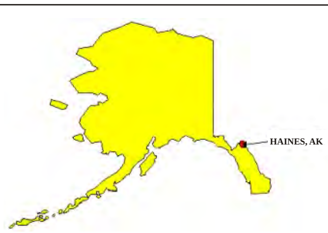


Figure 28B



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VERTICAL DISTRIBUTION OF TSS ALONG THE CROSS-SECTIONAL LINE N-S NEAR HAINES AT 8:00 PM AND 10:00 PM.

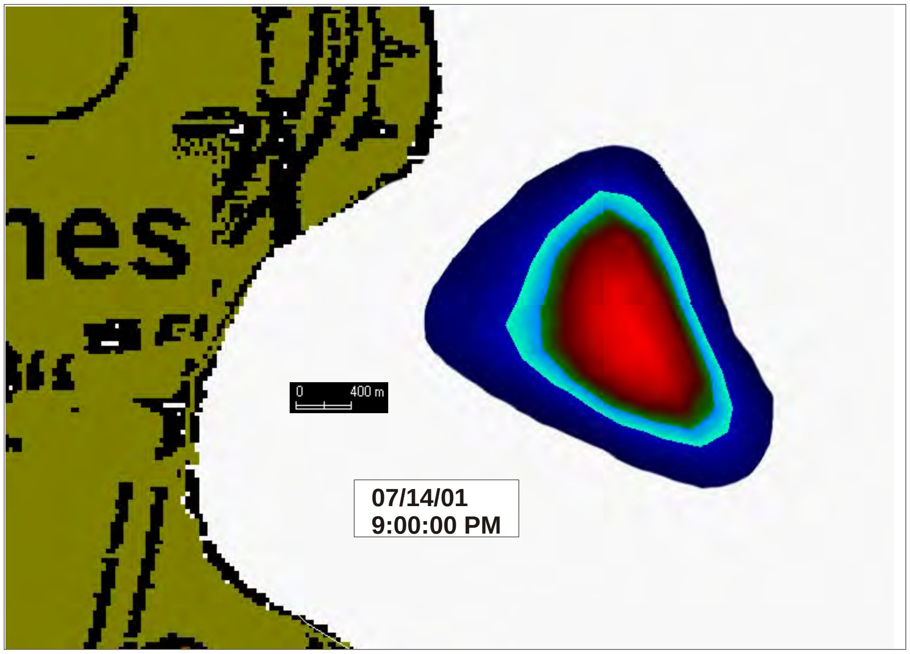


FIGURE 27E
Total Suspended Solids concentration (mg/m^3) near water surface after one hour of stop of discharge from *Malaspina* at Haines port.

CONCENTRATION LEGEND

Red	0.03 - 0.02
Dark red	0.02 - 0.01
Green	0.01 - 0.83E-2
Blue	0.82E-2 - 0.66E-2
Cyan	0.65E-2 - 0.59E-2
Navy	0.58E-2 - 0.97E-4

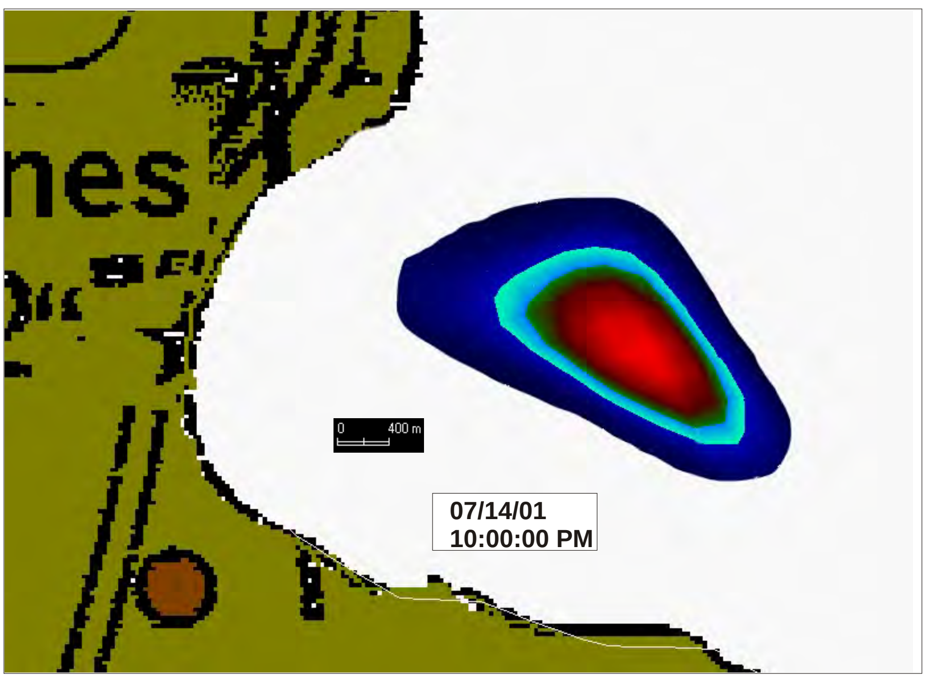
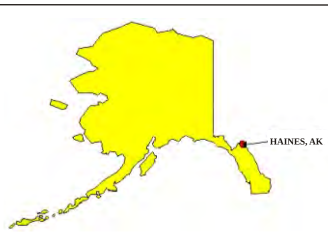


FIGURE 27F
Total Suspended Solids concentration (mg/m^3) near water surface after two hours of stop of discharge from *Malaspina* at Haines port.

CONCENTRATION LEGEND

Red	0.02 - 0.01
Dark red	0.01 - 0.92E-2
Green	0.91E-2 - 0.79E-2
Blue	0.78E-2 - 0.61E-2
Cyan	0.60E-2 - 0.43E-2
Navy	0.42E-2 - -0.59E-3



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PROJECT No. 001332.AU11.01 JUNE 2003

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ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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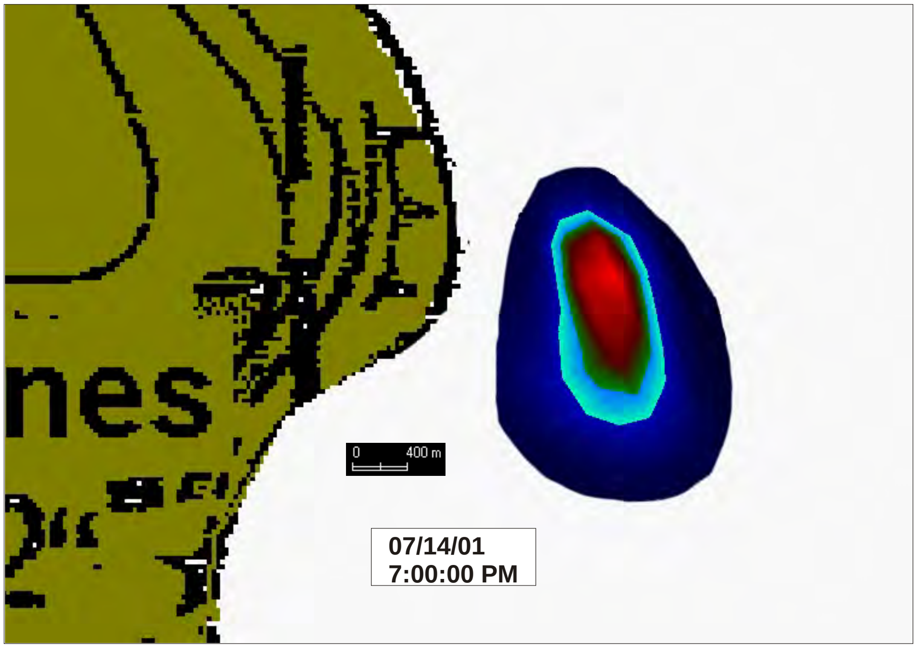


FIGURE 27C
Total Suspended Solids concentration (mg/m^3) near water surface after three hours of discharge from *Malaspina* at Haines port.

CONCENTRATION LEGEND

Red	0.07 - 0.06
Dark brown	0.05 - 0.04
Green	0.04 - 0.03
Blue	0.03 - 0.02
Aqua	0.02 - 0.01
Navy	0.01 - 0.77E-4

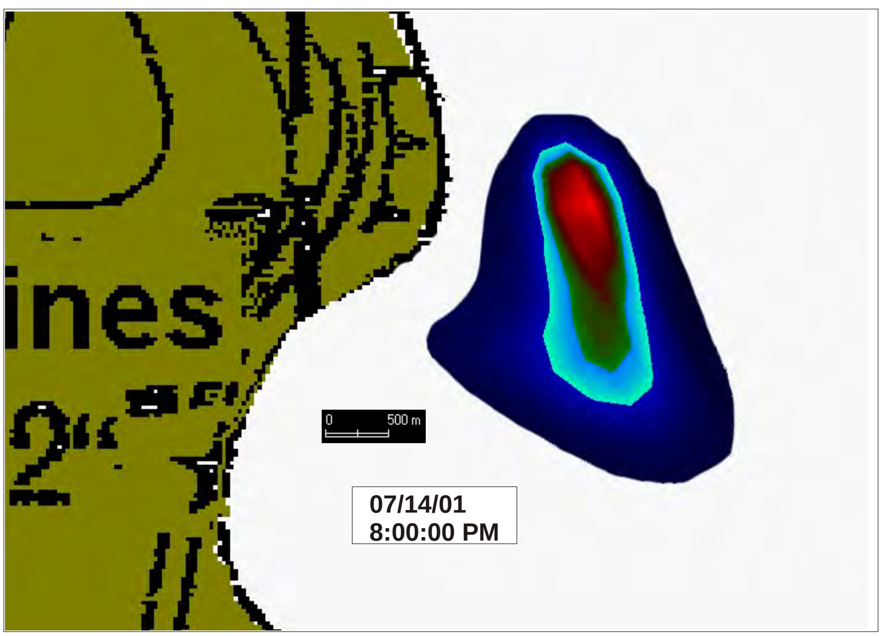
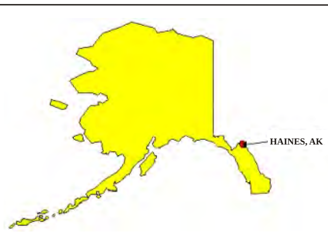


FIGURE 27D
Total Suspended Solids concentration (mg/m^3) near water surface after four hours of discharge from *Malaspina* at Haines port.

CONCENTRATION LEGEND

Red	0.06 - 0.05
Dark brown	0.05 - 0.04
Green	0.04 - 0.03
Blue	0.03 - 0.02
Aqua	0.02 - 0.01
Navy	0.01 - 0.57E-4



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PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

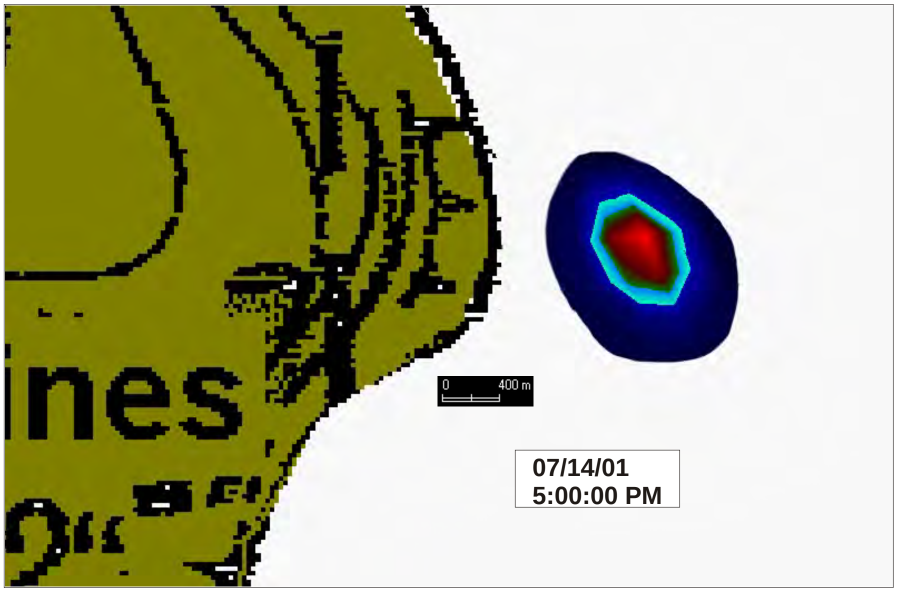


FIGURE 27A
Total Suspended Solids concentration (mg/m^3) near water surface after one hour of discharge from *Malaspina* at Haines port.

CONCENTRATION LEGEND

- 0.09 - 0.07
- 0.06 - 0.05
- 0.05 - 0.04
- 0.03 - 0.02
- 0.02 - 0.01
- 0.01 - 0.38E-4

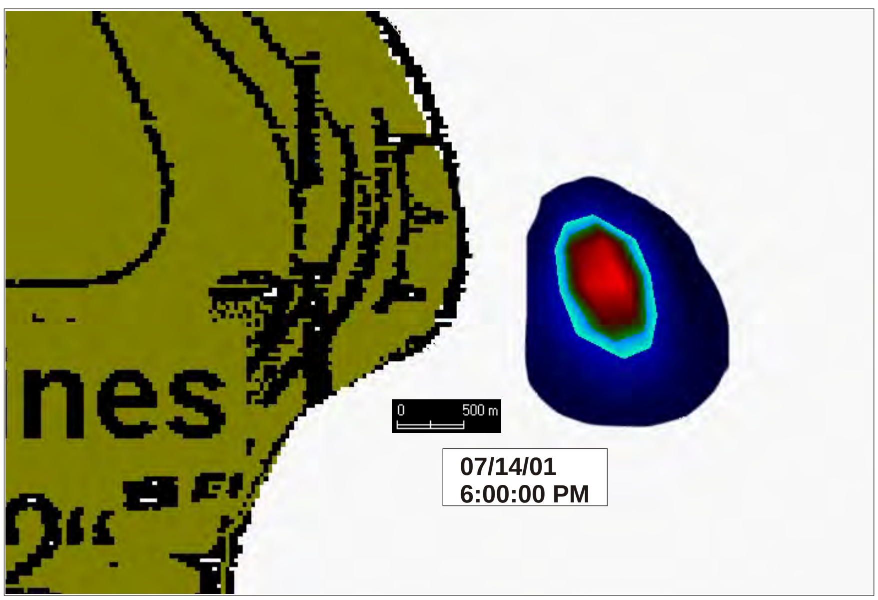
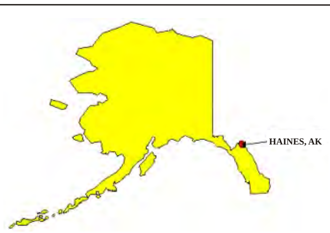


FIGURE 27B
Total Suspended Solids concentration (mg/m^3) near water surface after two hours of discharge from *Malaspina* at Haines port.

CONCENTRATION LEGEND

- 0.08 - 0.07
- 0.06 - 0.05
- 0.05 - 0.04
- 0.03 - 0.02
- 0.02 - 0.01
- 0.01 - 0.40E-4



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PROJECT No. 001332.AU11.01 JUNE 2003

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ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

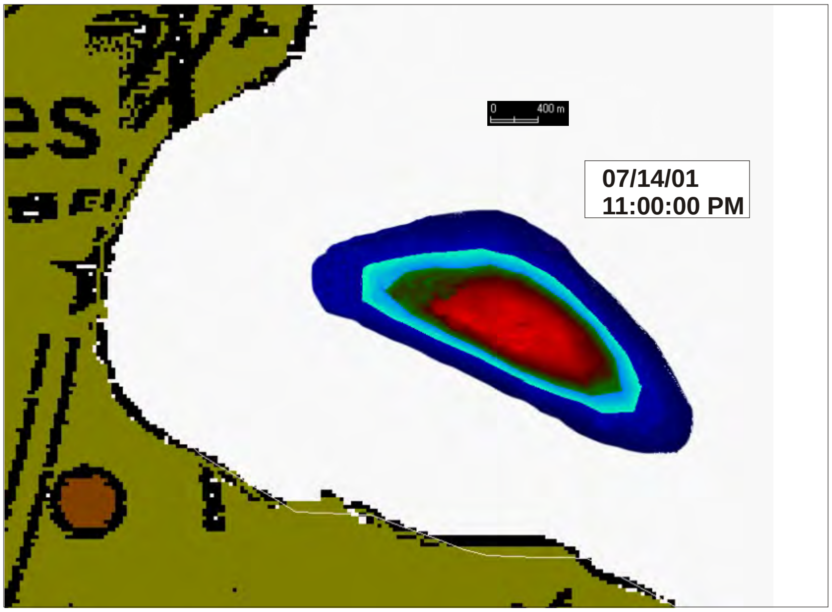


FIGURE 26G
Depth averaged *phosphorous* concentration (mg/m^3) after three hours of stop of discharge from *Malaspina* at Haines port.

CONCENTRATION LEGEND

0.47E-4 - 0.39E-4
0.38E-4 - 3.11E-5
3.10E-5 - 2.32E-5
2.31E-5 - 1.44E-5
1.43E-5 - 0.65E-5
0.64E-5 - -1.23E-8

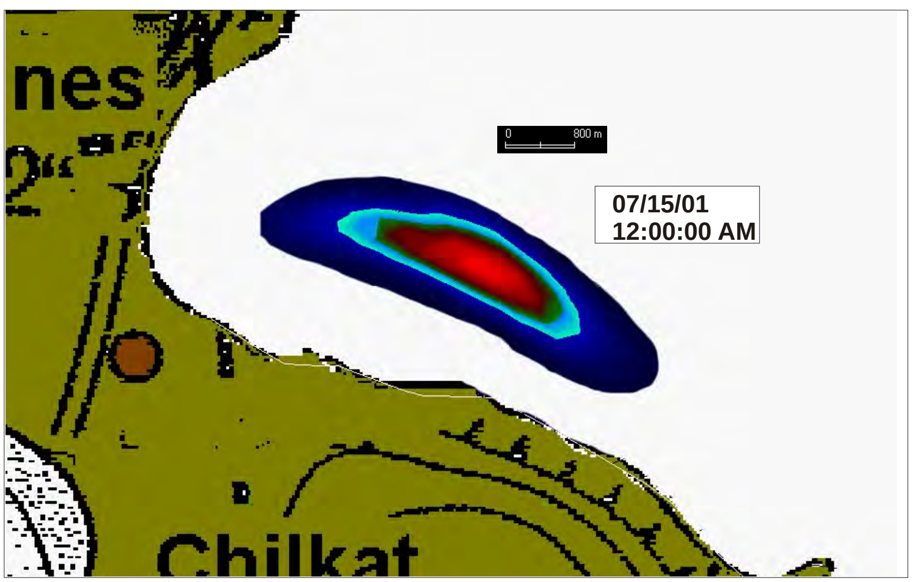
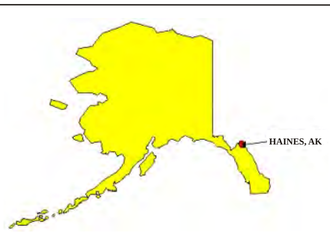


FIGURE 26H
Depth averaged *phosphorous* concentration (mg/m^3) after four hours of stop of discharge from *Malaspina* at Haines port.

CONCENTRATION LEGEND

0.47E-4 - 0.39E-4
0.38E-4 - 3.11E-5
3.10E-5 - 2.32E-5
2.31E-5 - 1.44E-5
1.43E-5 - 0.65E-5
0.64E-5 - -1.23E-8



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PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

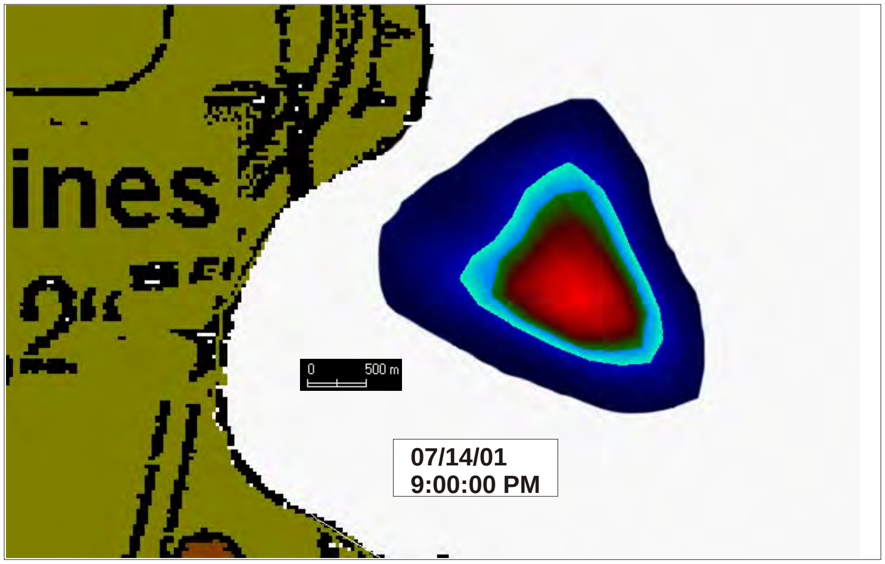


FIGURE 26E
Depth averaged *phosphorous* concentration (mg/m^3) after one hour of stop of discharge from *Malaspina* at Haines port.

CONCENTRATION LEGEND

Red	0.54E-4 - 0.46E-4
Dark red	0.45E-4 - 0.39E-4
Green	0.38E-4 - 2.68E-5
Blue	2.67E-5 - 1.56E-5
Cyan	1.55E-5 - 0.98E-5
Dark blue	0.97E-5 - -1.12E-8

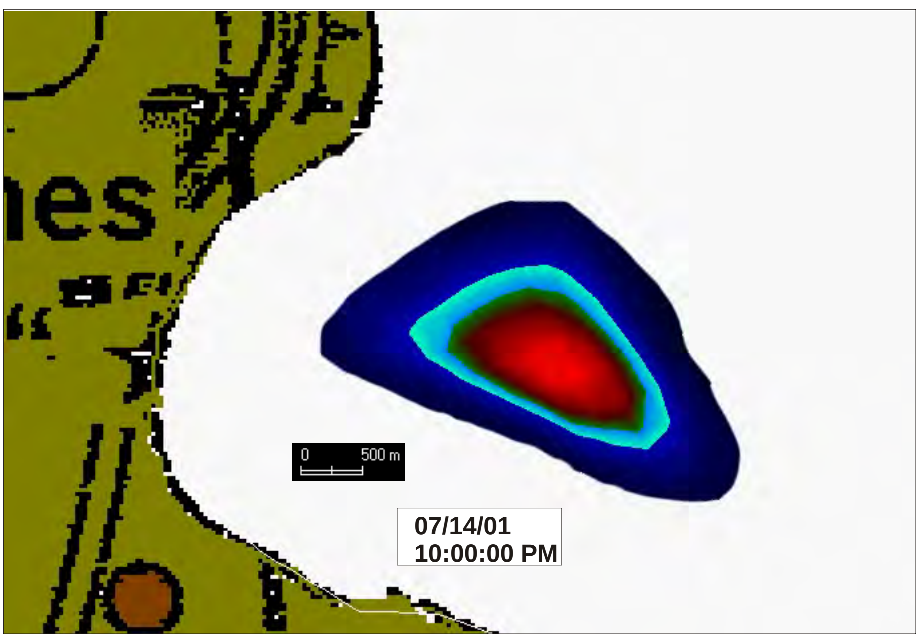
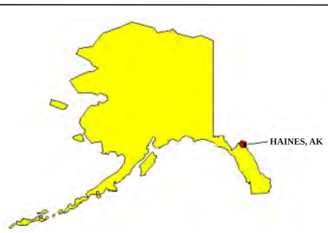


FIGURE 26F
Depth averaged *phosphorous* concentration (mg/m^3) after two hours of stop of discharge from *Malaspina* at Haines port.

CONCENTRATION LEGEND

Red	0.50E-4 - 0.41E-4
Dark red	0.40E-4 - 0.33E-4
Green	0.32E-4 - 2.62E-5
Blue	2.61E-5 - 1.80E-5
Cyan	1.79E-5 - 0.59E-5
Dark blue	0.58E-5 - -0.79E-8



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PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

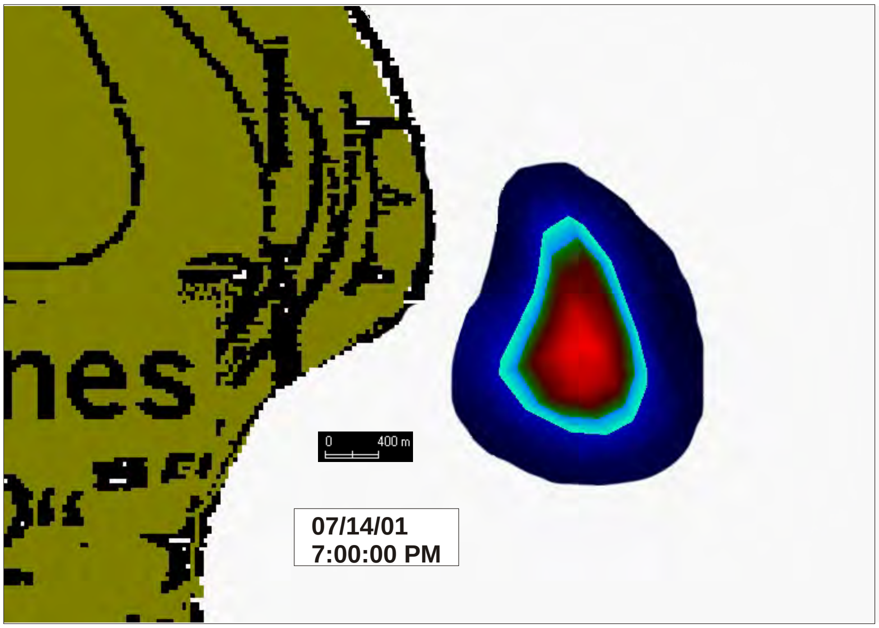


FIGURE 26C
Depth averaged *phosphorous* concentration (mg/m^3) after three hours of discharge from *Malaspina* at Haines port.

CONCENTRATION LEGEND

Red	0.68E-4 - 0.55E-4
Dark red	0.54E-4 - 0.46E-4
Green	0.45E-4 - 2.90E-5
Blue	2.89E-5 - 2.07E-5
Aqua	2.06E-5 - 0.84E-5
Dark blue	0.83E-5 - -0.87E-8

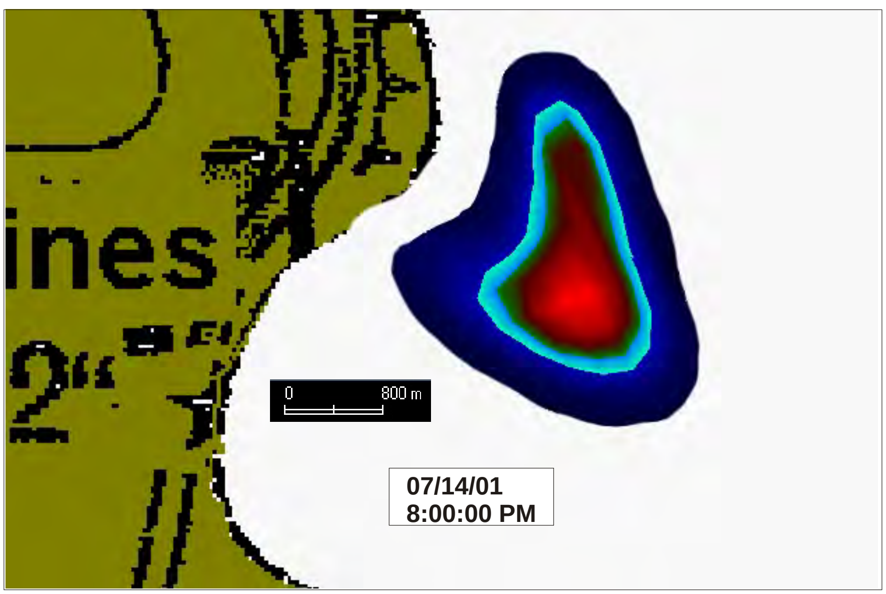
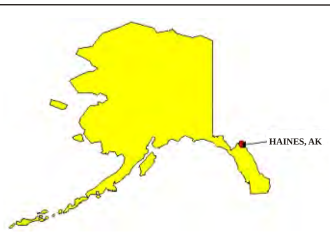


FIGURE 26D
Depth averaged *phosphorous* concentration (mg/m^3) after four hours of discharge from *Malaspina* at Haines port.

CONCENTRATION LEGEND

Red	0.57E-4 - 0.50E-4
Dark red	0.49E-4 - 0.35E-4
Green	0.34E-4 - 2.77E-5
Blue	2.76E-5 - 1.79E-5
Aqua	1.78E-5 - 1.12E-5
Dark blue	1.11E-5 - -2.38E-8



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PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

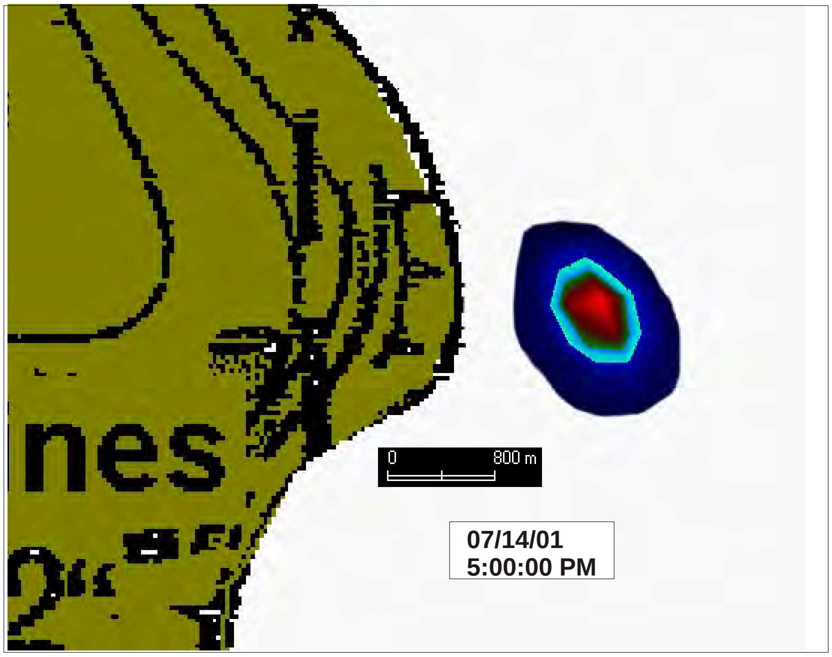


FIGURE 26A
Depth averaged *phosphorous* concentration (mg/m^3) after one hour of discharge from *Malaspina* at Haines port.

CONCENTRATION LEGEND

0.76E-4 - 0.57E-4
0.56E-4 - 0.40E-4
0.39E-4 - 2.51E-5
2.50E-5 - 0.49E-5
0.48E-5 - 0.94E-6
0.94E-6 - -0.45E-6

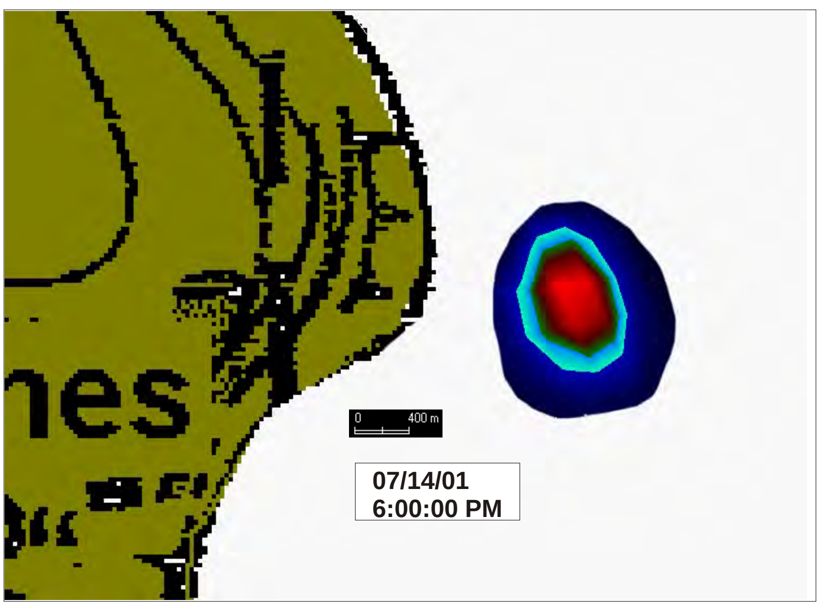
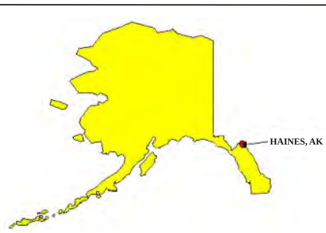


FIGURE 26B
Depth averaged *phosphorous* concentration (mg/m^3) after two hours of discharge from *Malaspina* at Haines port.

CONCENTRATION LEGEND

0.81E-4 - 0.73E-4
0.72E-4 - 0.62E-4
0.61E-4 - 0.44E-4
0.43E-4 - 0.33E-4
0.32E-4 - 0.42E-5
0.41E-5 - -0.78E-7



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PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

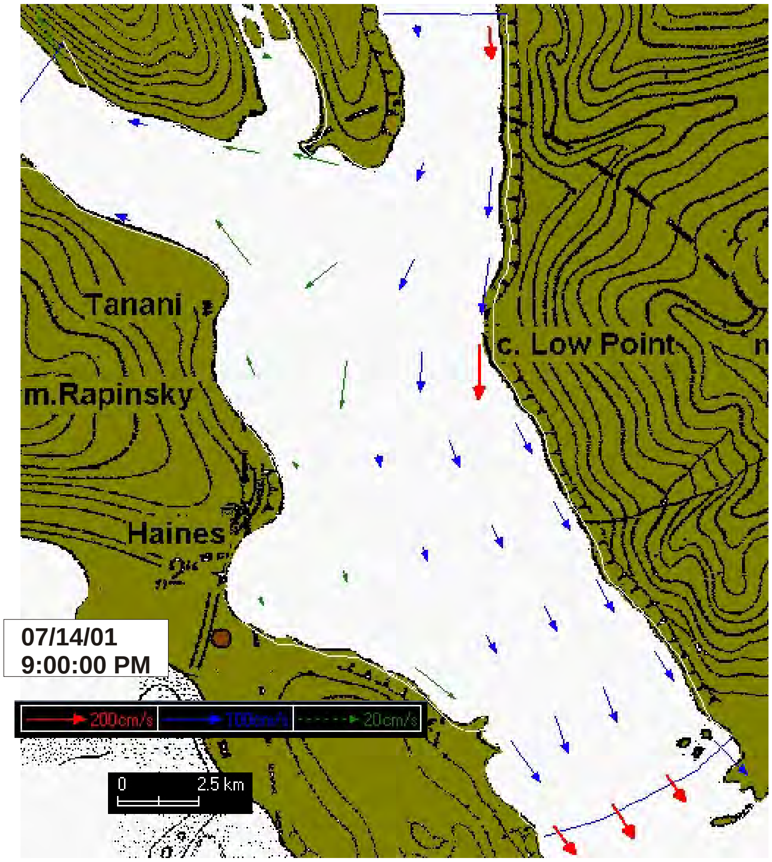
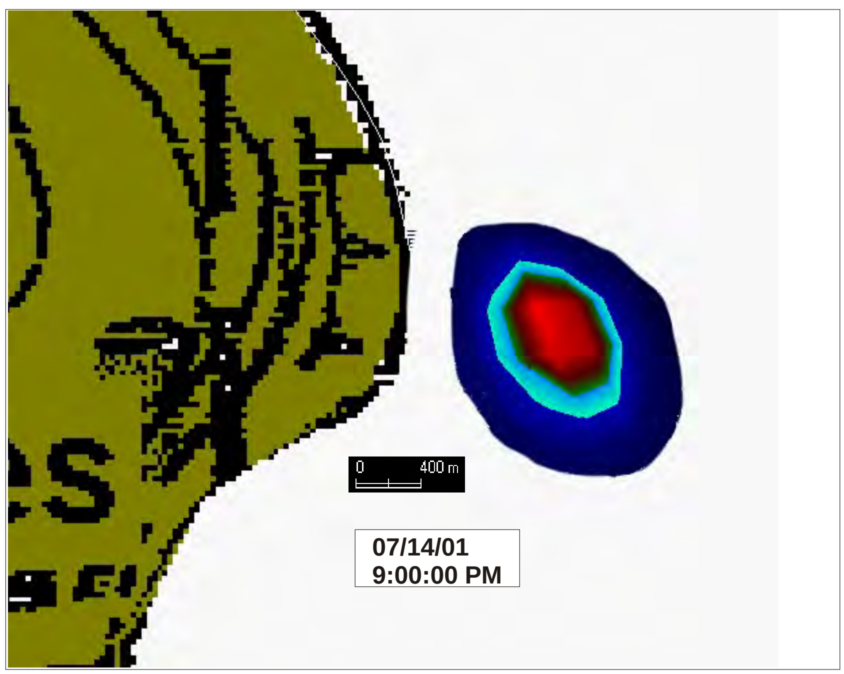


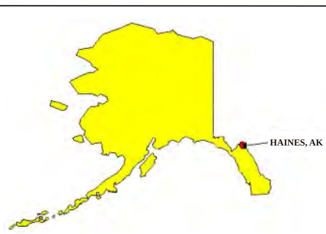
FIGURE 25Y
Velocity pattern after one hour of stop of discharge from the *Malaspina* at Haines port.

FIGURE 25Z
Depth averaged *fecal coliform* concentration (MPN/m^3) after one hours of stop of discharge from the *Malaspina*.

CONCENTRATION LEGEND

(red)	0.58E-3 - 1.49E-3
(dark brown)	1.48E-3 - 0.72E-3
(green)	0.71E-3 - 0.66E-3
(blue)	0.65E-3 - 0.57E-3
(cyan)	0.56E-3 - 2.77E-4
(dark blue)	2.76E-4 - 1.86E-6





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ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

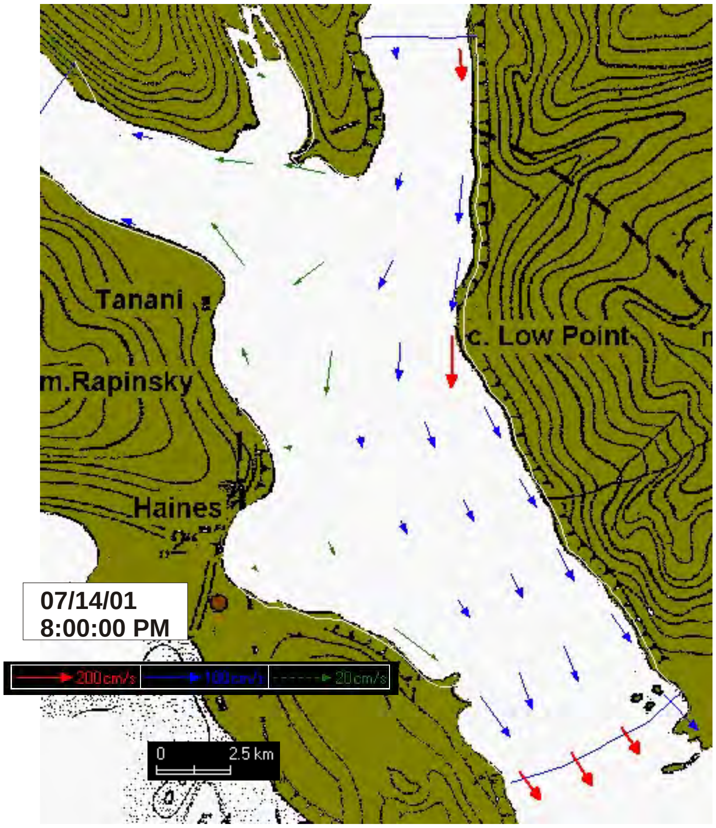


FIGURE 25W
Velocity pattern after four hours of start of discharge from the *Malaspina* at Haines port.

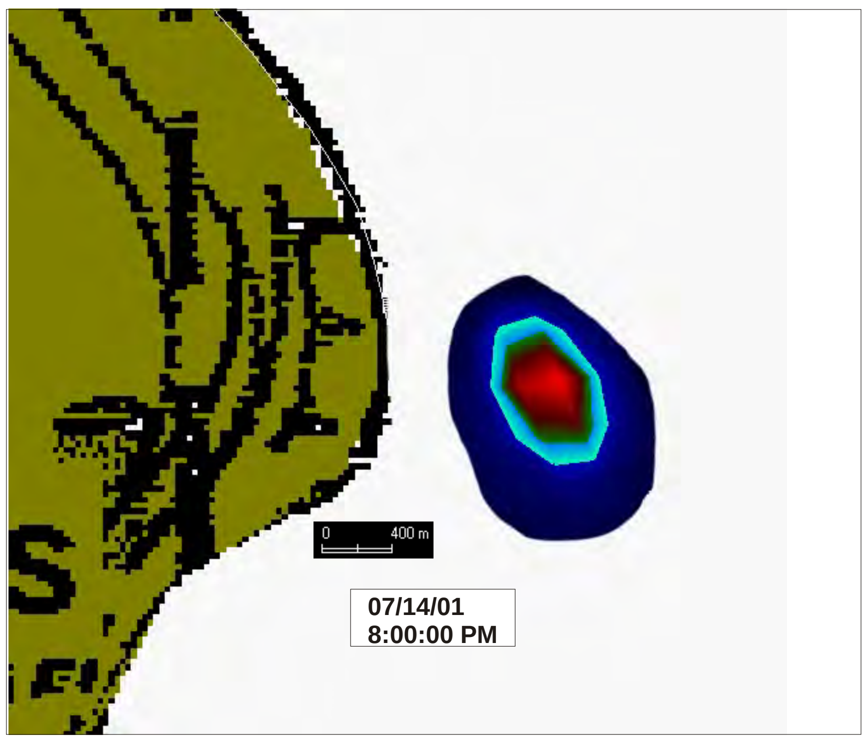
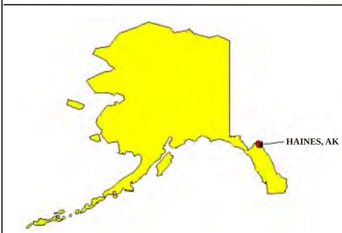


FIGURE 25X
Depth averaged *fecal coliform* concentration (MPN/m^3) after four hours of discharge from the *Malaspina*.

CONCENTRATION LEGEND

Red	0.94E-2 - 0.79E-2
Dark brown	0.78E-2 - 0.52E-2
Green	0.51E-2 - 0.39E-2
Blue	0.38E-2 - 2.82E-3
Cyan	2.81E-3 - 1.38E-3
Navy	1.37E-3 - 0.32E-5



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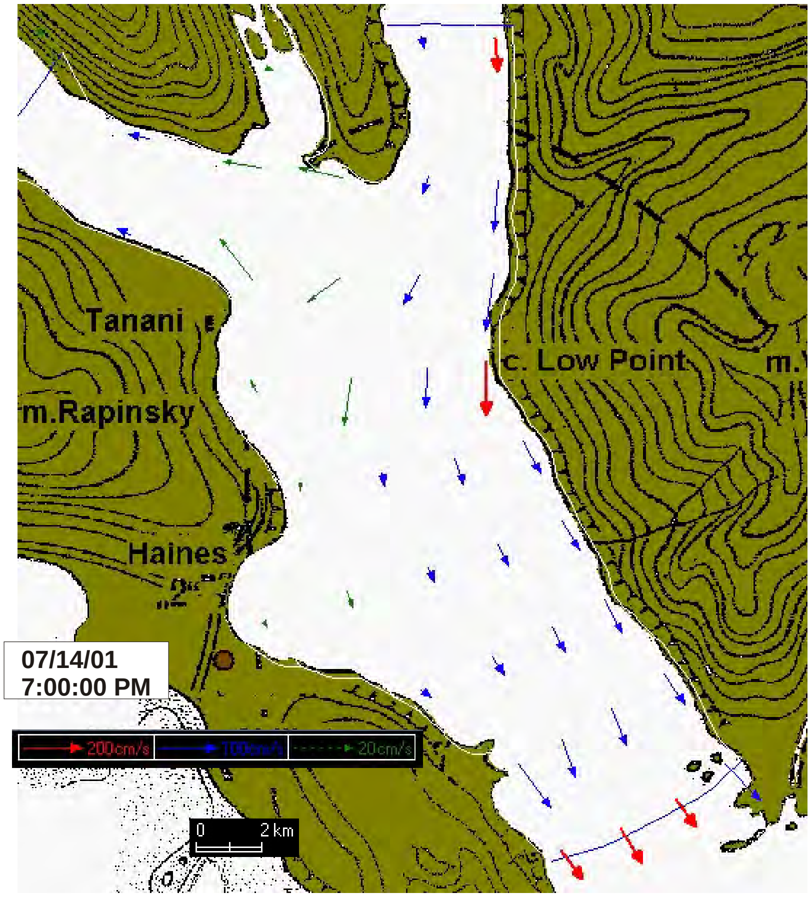
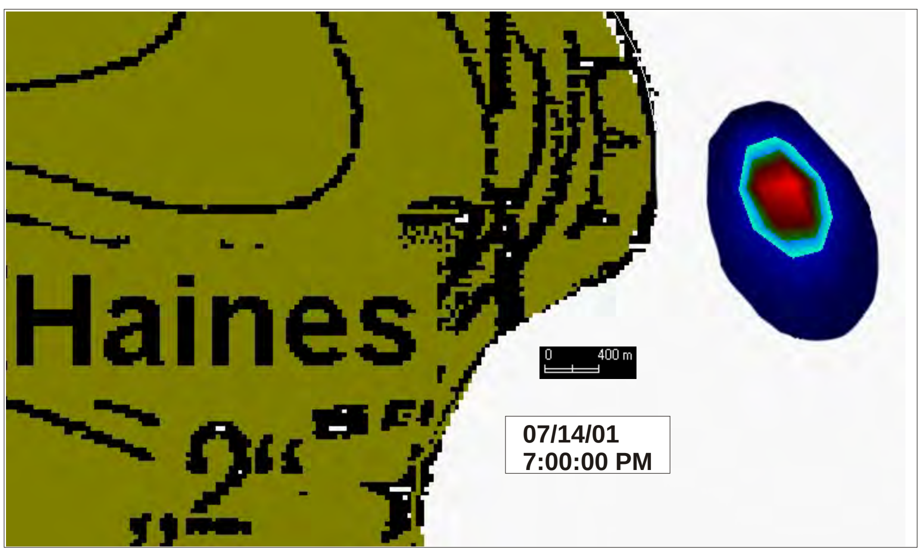
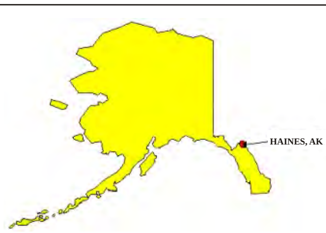


FIGURE 25U
Velocity pattern after three hours of start of discharge from the *Malaspina* at Haines port.

FIGURE 25V
Depth averaged *fecal coliform* concentration (MPN/m³) after three hours of discharge from the *Malaspina*.

CONCENTRATION LEGEND	
(red)	0.83E-2 - 0.70E-2
(dark brown)	0.69E-2 - 0.53E-2
(green)	0.52E-2 - 2.77E-3
(blue)	2.76E-3 - 2.50E-3
(cyan)	2.49E-3 - 1.03E-3
(dark blue)	1.02E-3 - 0.33E-5





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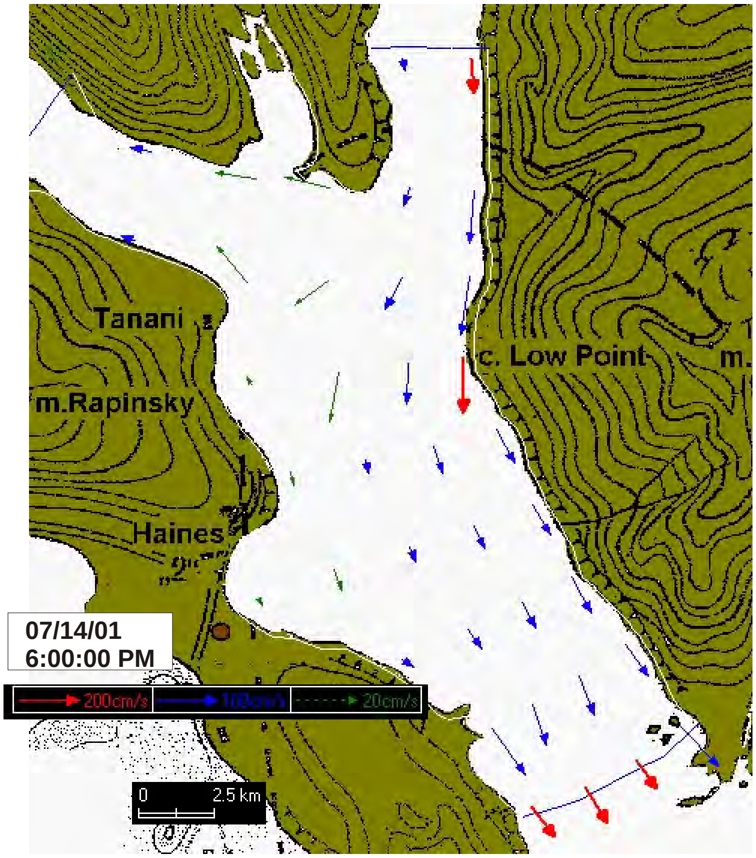


FIGURE 25S
Velocity pattern after two hours of start of discharge from the *Malaspina* at Haines port.

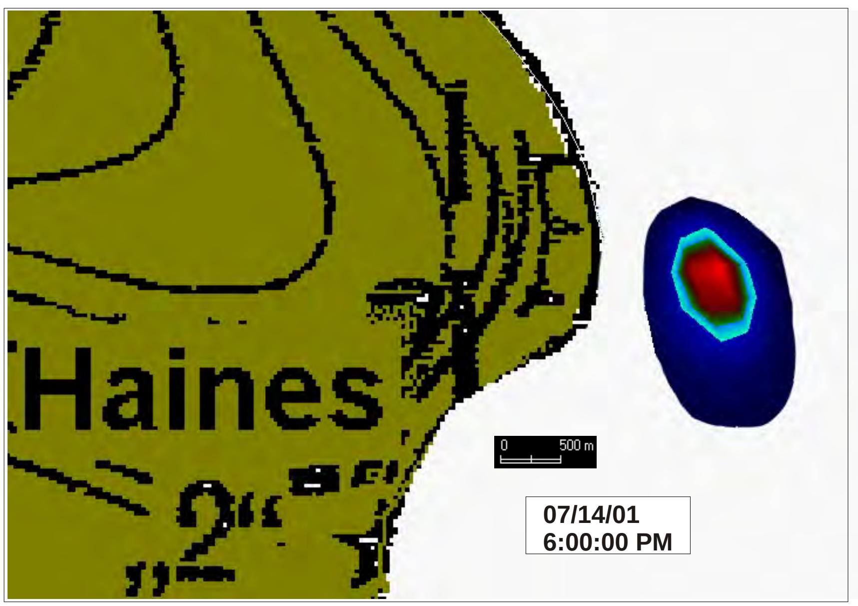
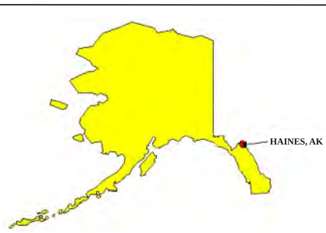


FIGURE 25T
Depth averaged *fecal coliform* concentration (MPN/m³) after two hours of discharge from the *Malaspina*.

CONCENTRATION LEGEND

Red	0.73E-2 - 0.62E-2
Dark brown	0.61E-2 - 0.53E-2
Green	0.52E-2 - 2.05E-3
Blue	2.04E-3 - 1.66E-3
Cyan	1.65E-3 - 0.93E-3
Navy	0.92E-3 - 0.32E-5



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PROJECT No. 001332.AU11.01 JUNE 2003

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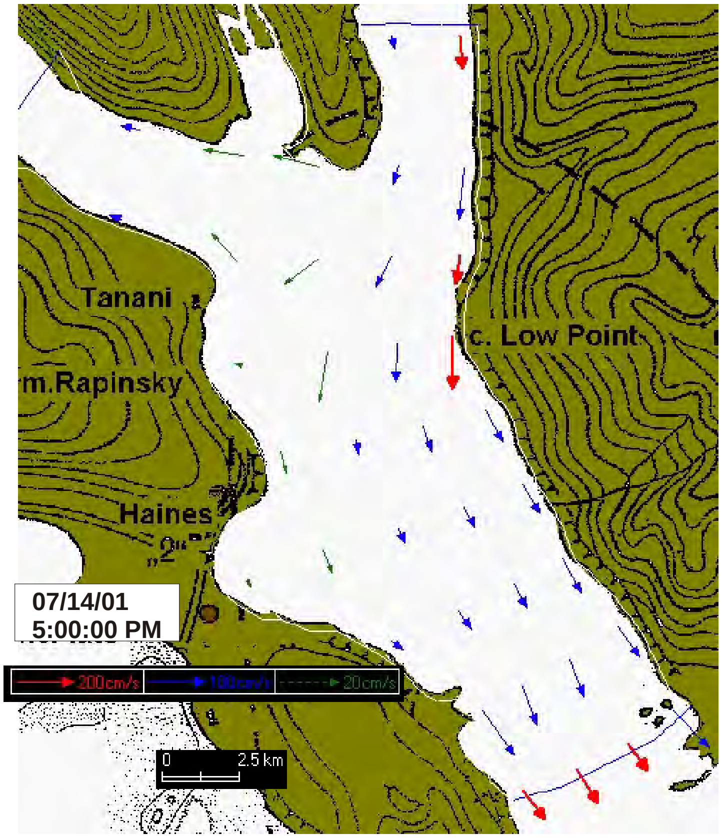


FIGURE 25Q
Velocity pattern after one hour of start of discharge from the *Malaspina* at Haines port.

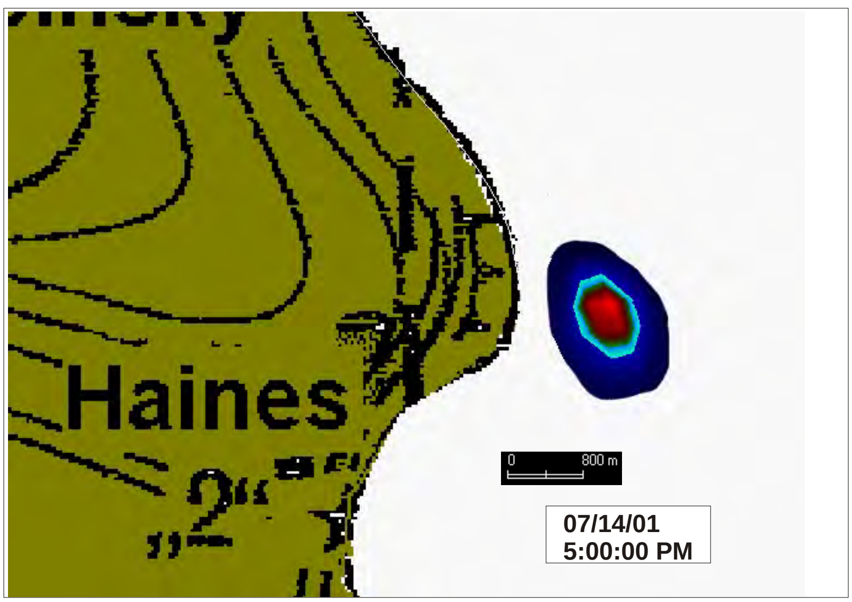
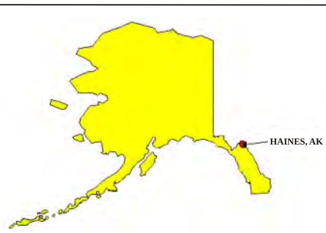


FIGURE 25R
Depth averaged *fecal coliform* concentration (MPN/m^3) after one hour of discharge from the *Malaspina*.

CONCENTRATION LEGEND

Red	0.64E-2 - 0.54E-2
Dark brown	0.53E-2 - 0.46E-2
Green	0.45E-2 - 2.24E-3
Blue	2.23E-3 - 1.70E-3
Cyan	1.69E-3 - 1.40E-3
Navy	1.39E-3 - 2.83E-6



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PROJECT No. 001332.AU11.01 **JUNE 2003**

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ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

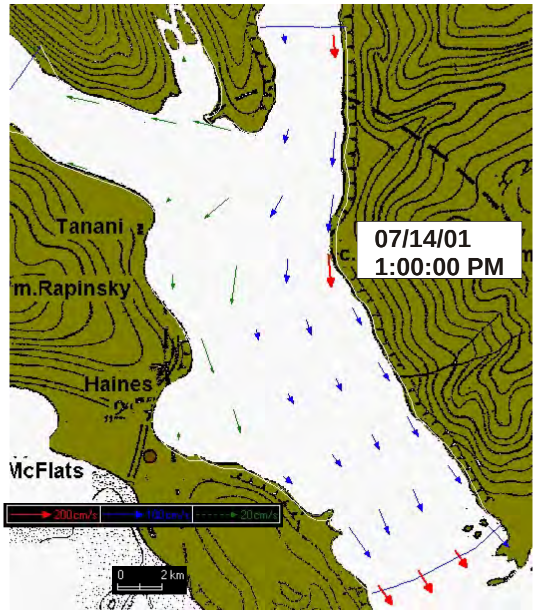


FIGURE 25M
Velocity pattern before start of discharge from the *Malaspina* at Haines port.

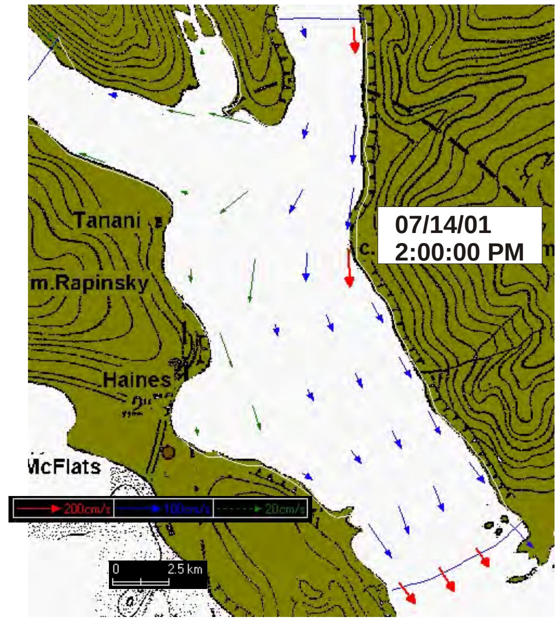


FIGURE 25N
Velocity pattern before start of discharge from the *Malaspina* at Haines port.

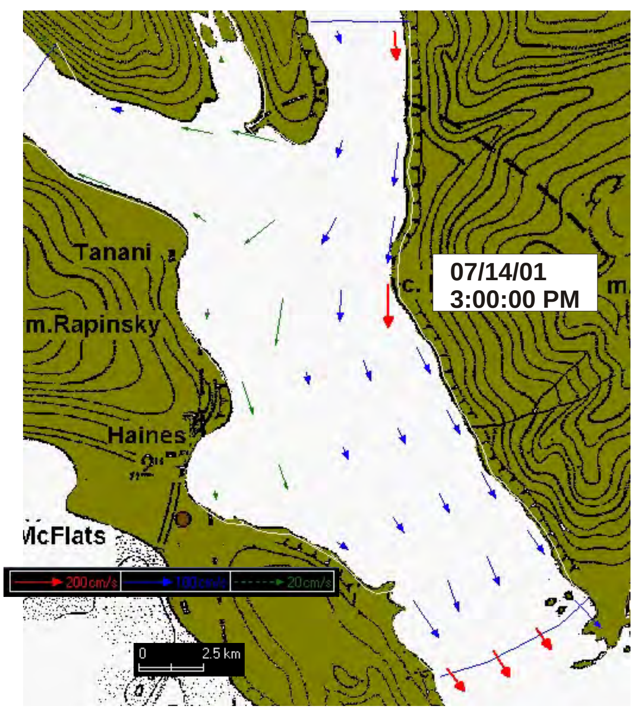


FIGURE 25O
Velocity pattern before start of discharge from the *Malaspina* at Haines port.

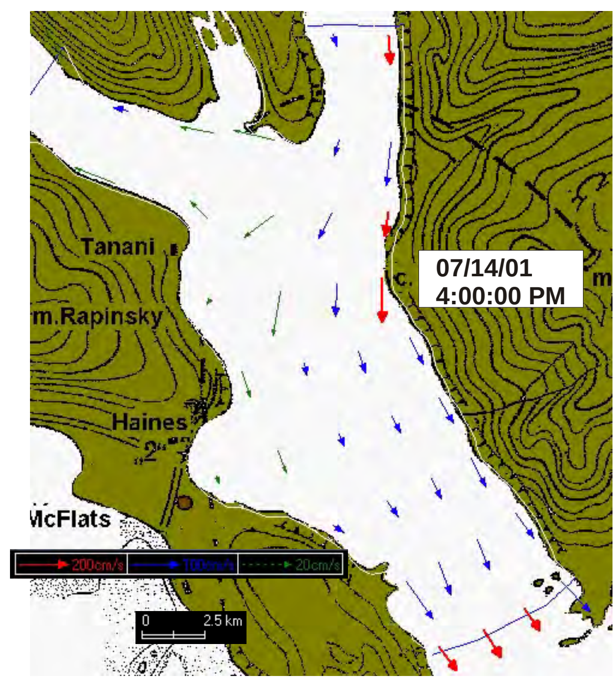
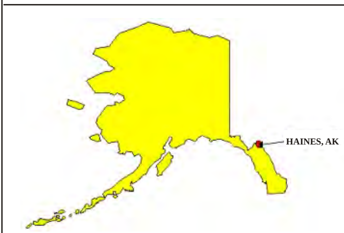


FIGURE 25P
Velocity pattern before start of discharge from the *Malaspina* at Haines port.



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PROJECT No. 001332.AU11.01 **JUNE 2003**

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

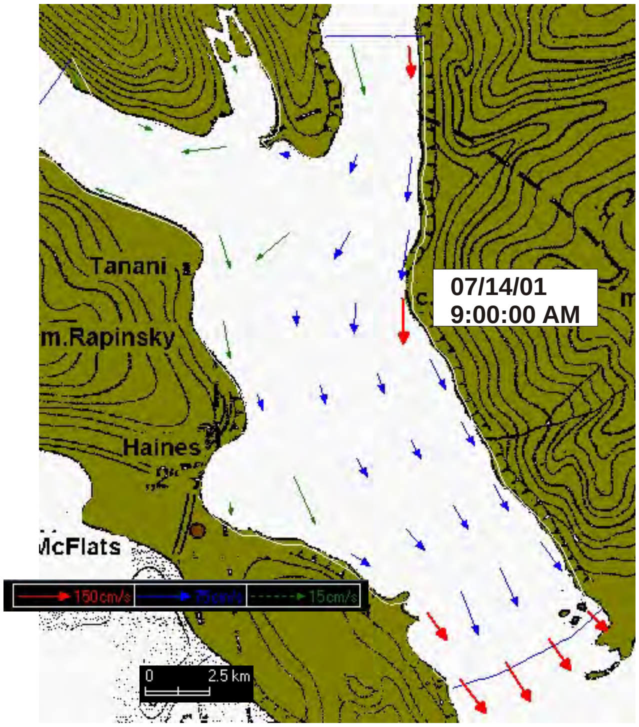

FIGURE 25I
Velocity pattern before start of discharge from the *Malaspina* at Haines port.

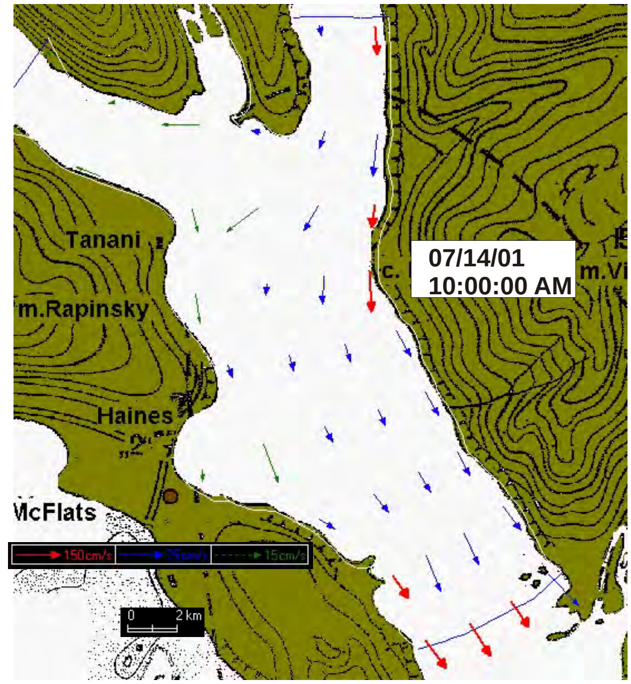

FIGURE 25J
Velocity pattern before start of discharge from the *Malaspina* at Haines port.

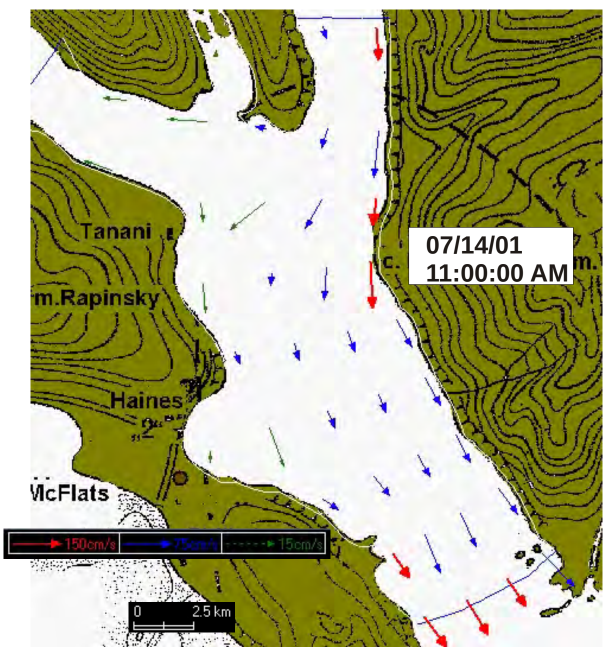

FIGURE 25K
Velocity pattern before start of discharge from the *Malaspina* at Haines port.

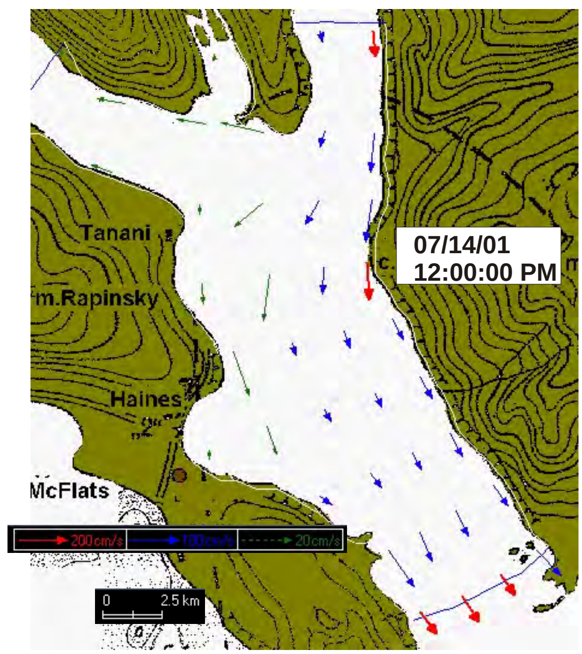

FIGURE 25L
Velocity pattern before start of discharge from the *Malaspina* at Haines port.

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PROJECT No. 001332.AU11.01 **JUNE 2003**

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

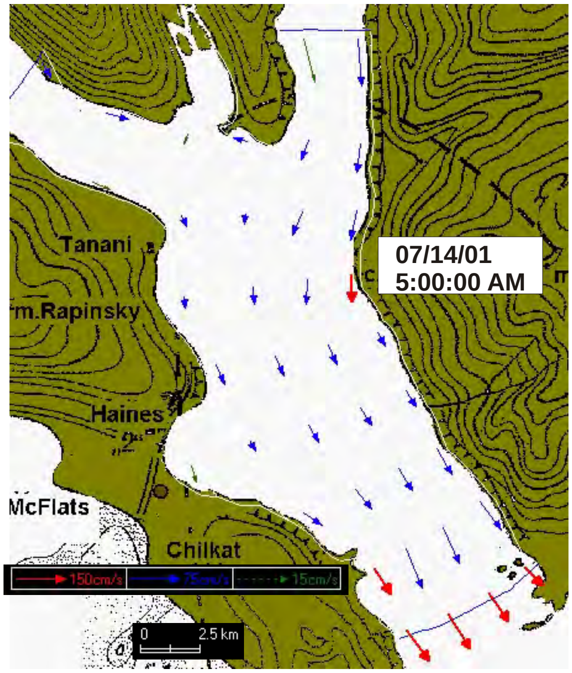

FIGURE 25E
Velocity pattern before start of discharge from the *Malaspina* at Haines port.

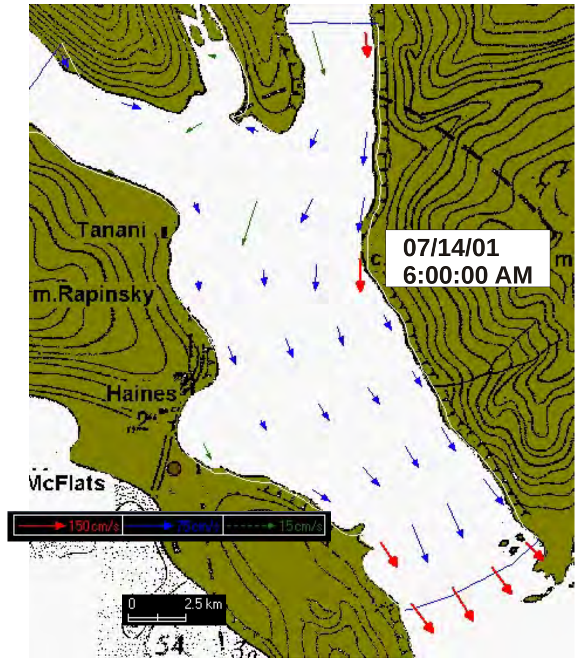

FIGURE 25F
Velocity pattern before start of discharge from the *Malaspina* at Haines port.

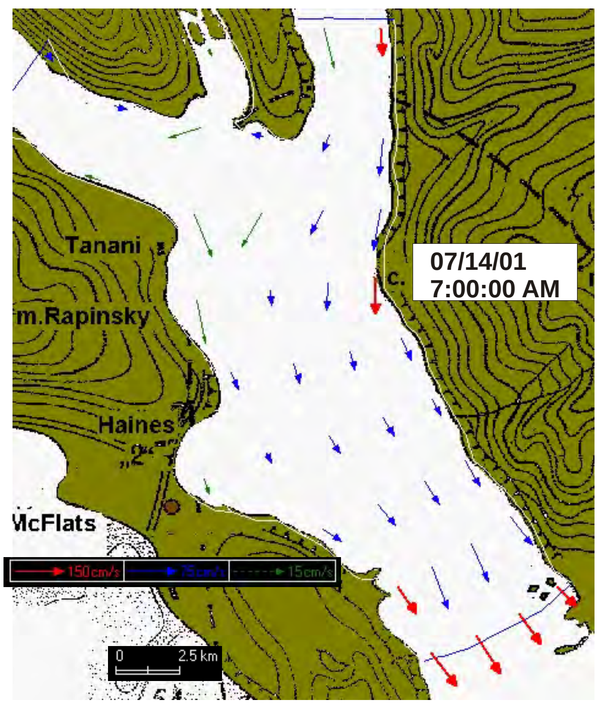

FIGURE 25G
Velocity pattern before start of discharge from the *Malaspina* at Haines port.

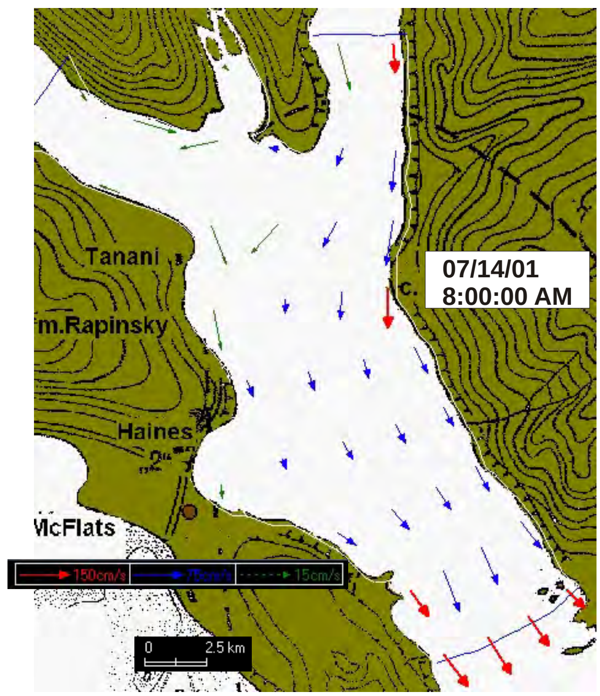

FIGURE 25H
Velocity pattern before start of discharge from the *Malaspina* at Haines port.

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PROJECT No. 001332.AU11.01 **JUNE 2003**

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

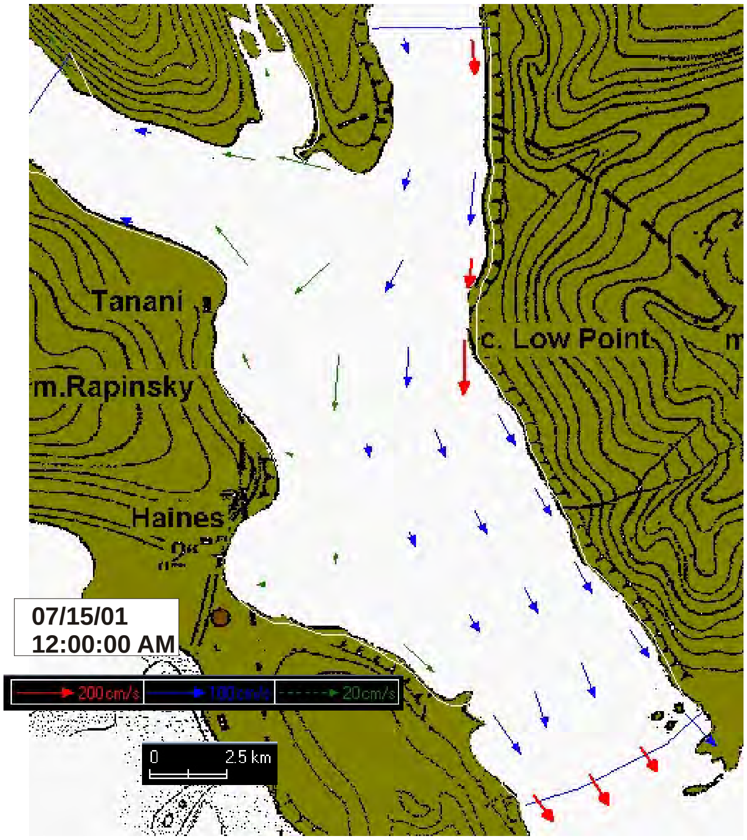


FIGURE 25EE
Velocity pattern after four hours of stop of discharge from the *Malaspina* at Haines port.

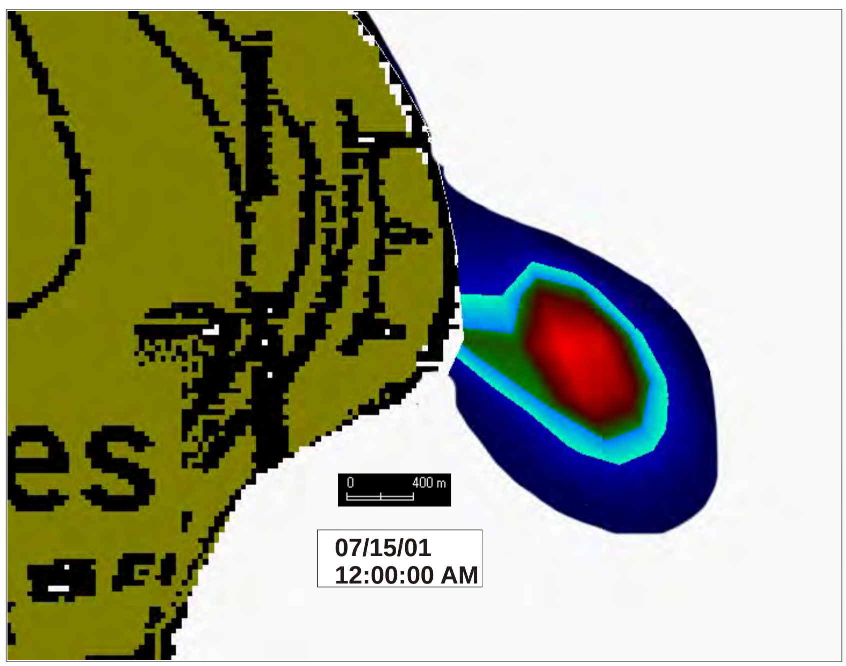
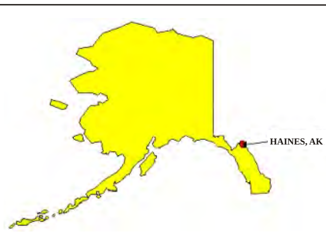


FIGURE 25FF
Depth averaged *fecal coliform* concentration (MPN/m^3) after four hours of stop of discharge from the *Malaspina*.

CONCENTRATION LEGEND

(red)	1.30E-5-1.12E-5
(dark brown)	1.11E-5-1.05E-5
(green)	1.04E-5-0.70E-5
(blue)	0.69E-5-0.40E-5
(cyan)	0.39E-5-0.34E-5
(navy)	0.33E-5-2.87E-8



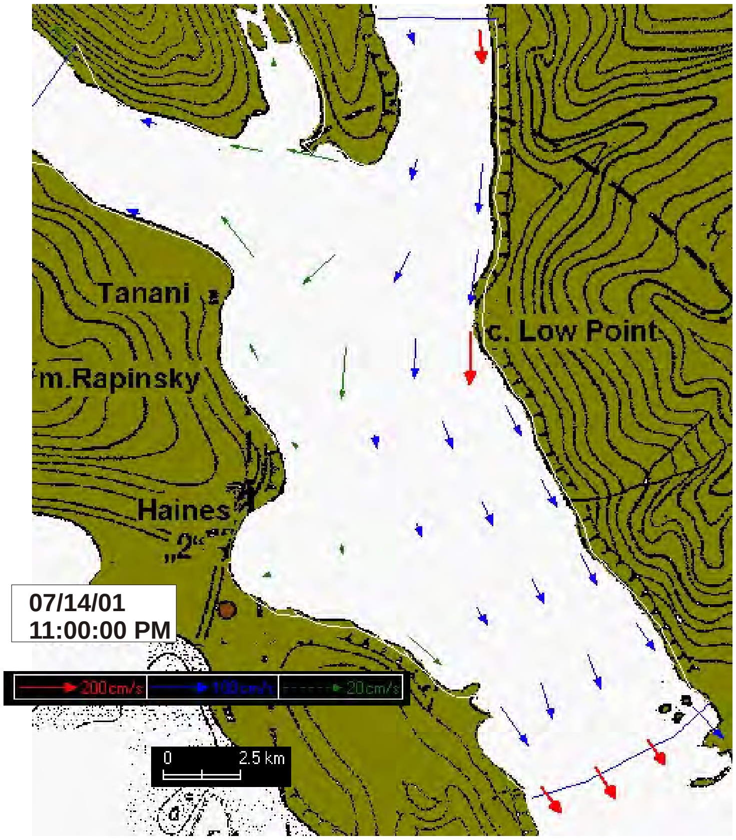


FIGURE 25CC
Velocity pattern after three hours of stop of discharge from the *Malaspina* at Haines port.

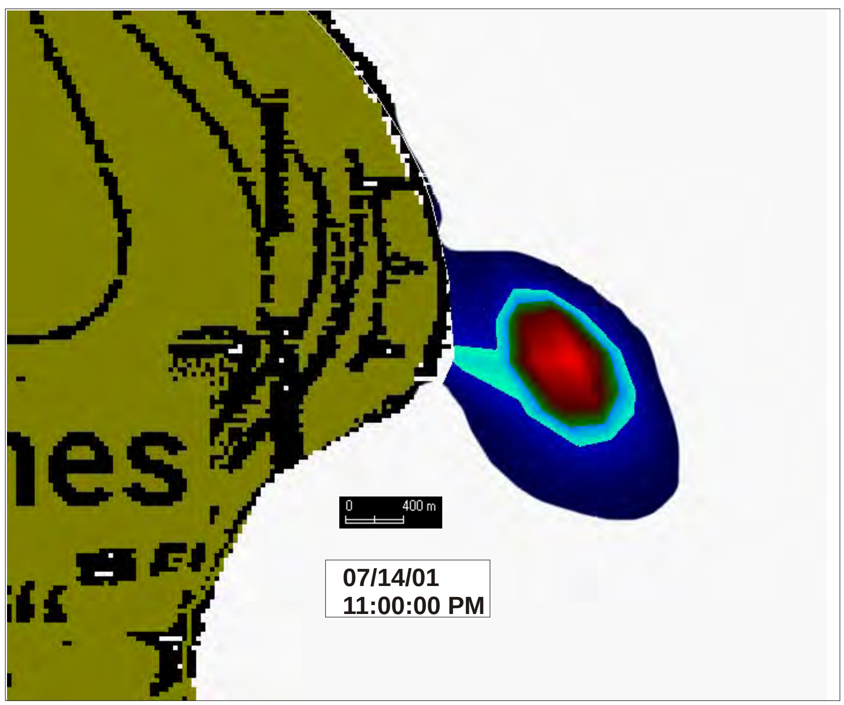
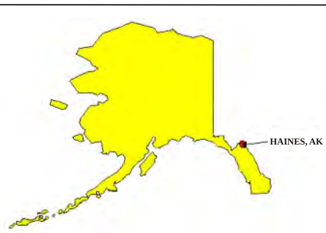


FIGURE 25DD
Depth averaged *fecal coliform* concentration (MPN/m^3) after three hours of stop of discharge from the *Malaspina*.

CONCENTRATION LEGEND

(red)	0.67E-4 - 0.58E-4
(dark brown)	0.57E-4 - 0.44E-4
(green)	0.43E-4 - 0.35E-4
(blue)	0.34E-4 - 1.85E-5
(cyan)	1.84E-5 - 1.25E-5
(navy)	1.24E-5 - 1.79E-7



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PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

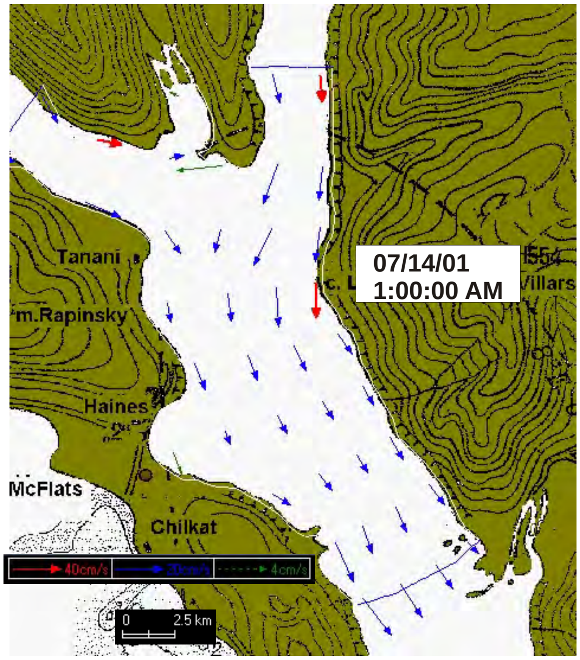


FIGURE 25A
Velocity pattern before start of discharge from the *Malaspina* at Haines port.

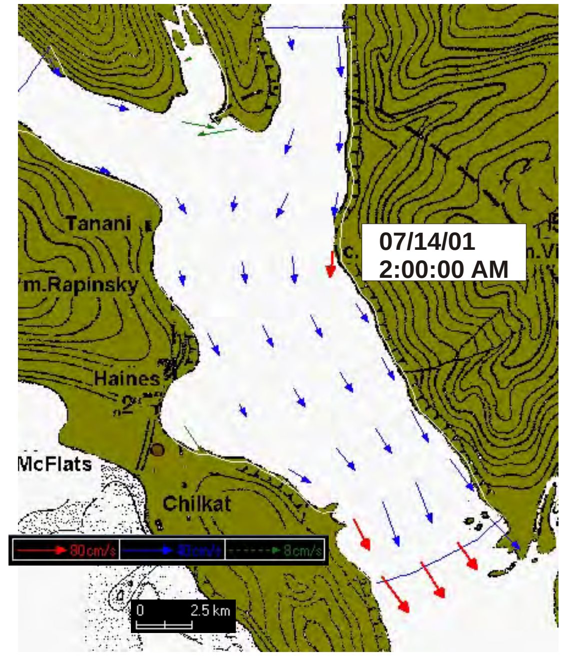


FIGURE 25B
Velocity pattern before start of discharge from the *Malaspina* at Haines port.

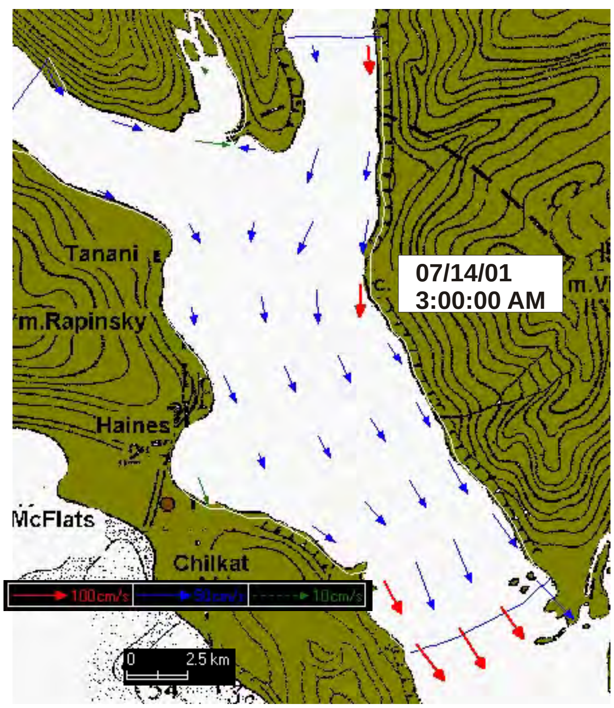


FIGURE 25C
Velocity pattern before start of discharge from the *Malaspina* at Haines port.

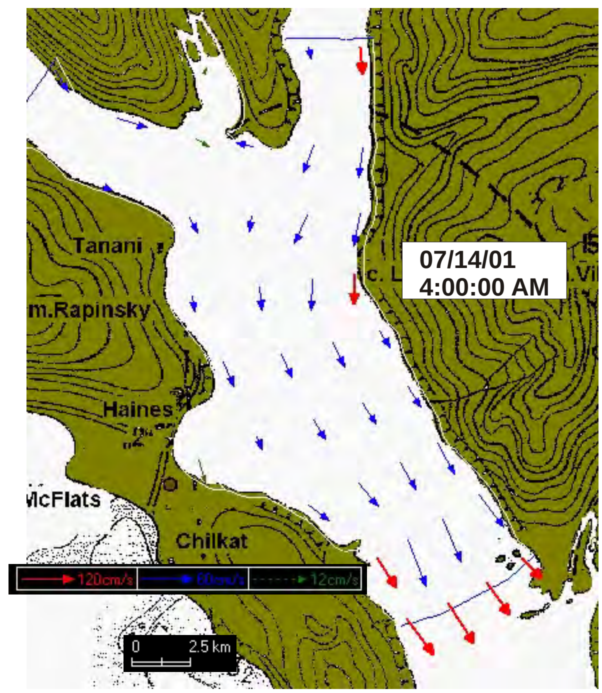
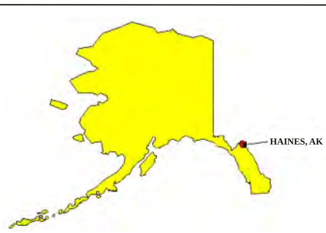


FIGURE 25D
Velocity pattern before start of discharge from the *Malaspina* at Haines port.



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PROJECT No. 001332.AU11.01 **JUNE 2003**

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

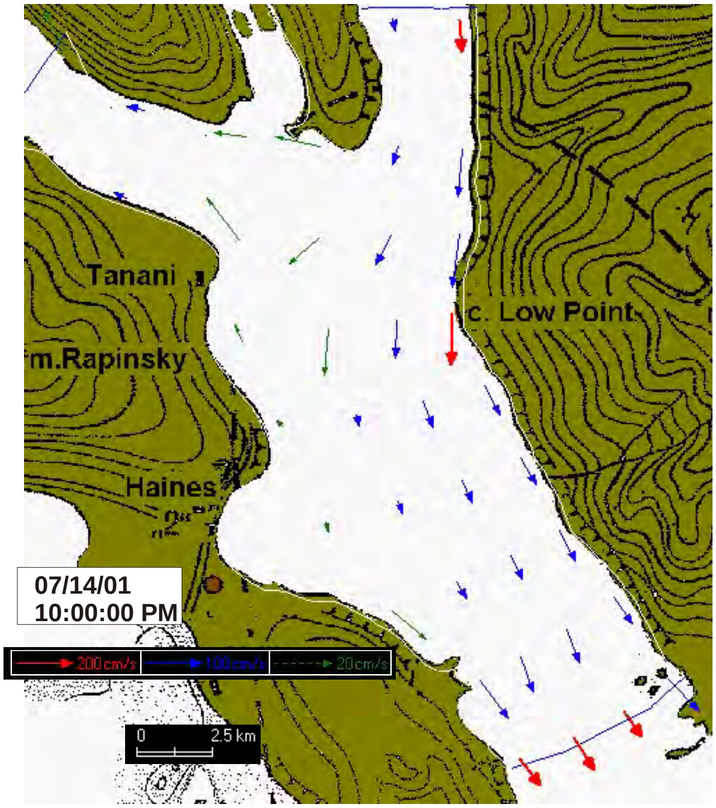


FIGURE 25AA
Velocity pattern after two hours of stop of discharge from the *Malaspina* at Haines port.

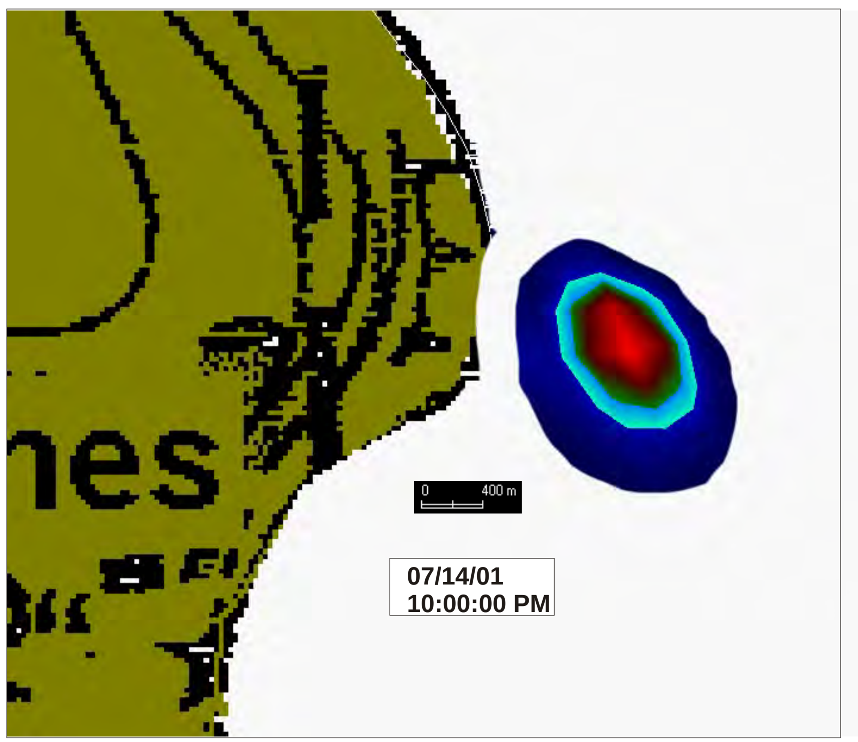
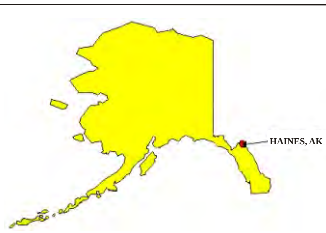


FIGURE 25BB
Depth averaged *fecal coliform* concentration (MPN/m^3) after two hours of stop of discharge from the *Malaspina*.

CONCENTRATION LEGEND

(red)	0.33E-3 - 2.90E-4
(dark brown)	2.89E-4 - 2.26E-4
(green)	2.25E-4 - 1.43E-4
(blue)	1.42E-4 - 0.61E-4
(cyan)	0.60E-4 - 0.45E-4
(navy)	0.44E-4 - 0.77E-6



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PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

FIGURE 24G
Distribution of Nitrogenous Biochemical Oxygen Demand (NBOD) after fourteen hours of discharge from *Spirit of Endeavor* and *Clipper Odyssey* at Juneau port.

CONCENTRATION mg/m3 LEGEND	
Red	0.37 - 0.28
Dark red	0.27 - 0.19
Green	0.18 - 0.16
Blue	0.15 - 0.10
Cyan	0.09 - 0.06
Dark blue	0.05 - 0.03
Black	0.02 - 0.72E-4

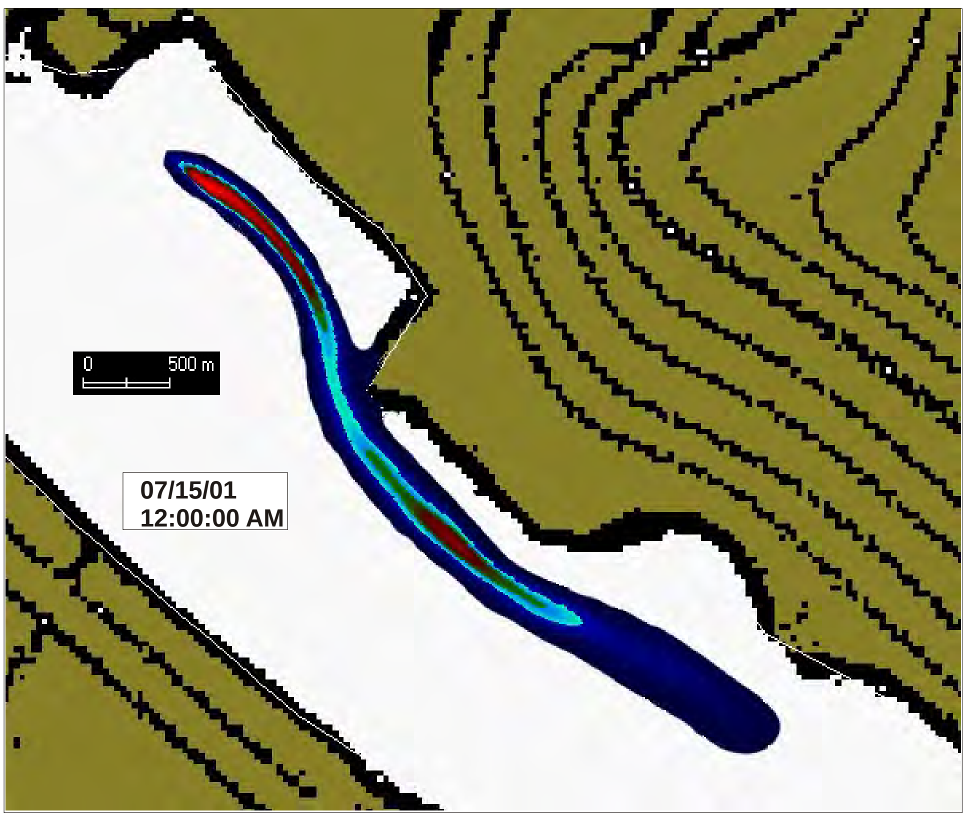

FIGURE 24H
Distribution of Nitrogenous Biochemical Oxygen Demand (NBOD) after sixteen hours of discharge from *Spirit of Endeavor* and *Clipper Odyssey* at Juneau port.

CONCENTRATION mg/m3 LEGEND	
Red	0.36 - 0.30
Dark red	0.29 - 0.20
Green	0.19 - 0.16
Blue	0.15 - 0.10
Cyan	0.09 - 0.07
Dark blue	0.06 - 0.02
Black	0.01 - 0.54E-4

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PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

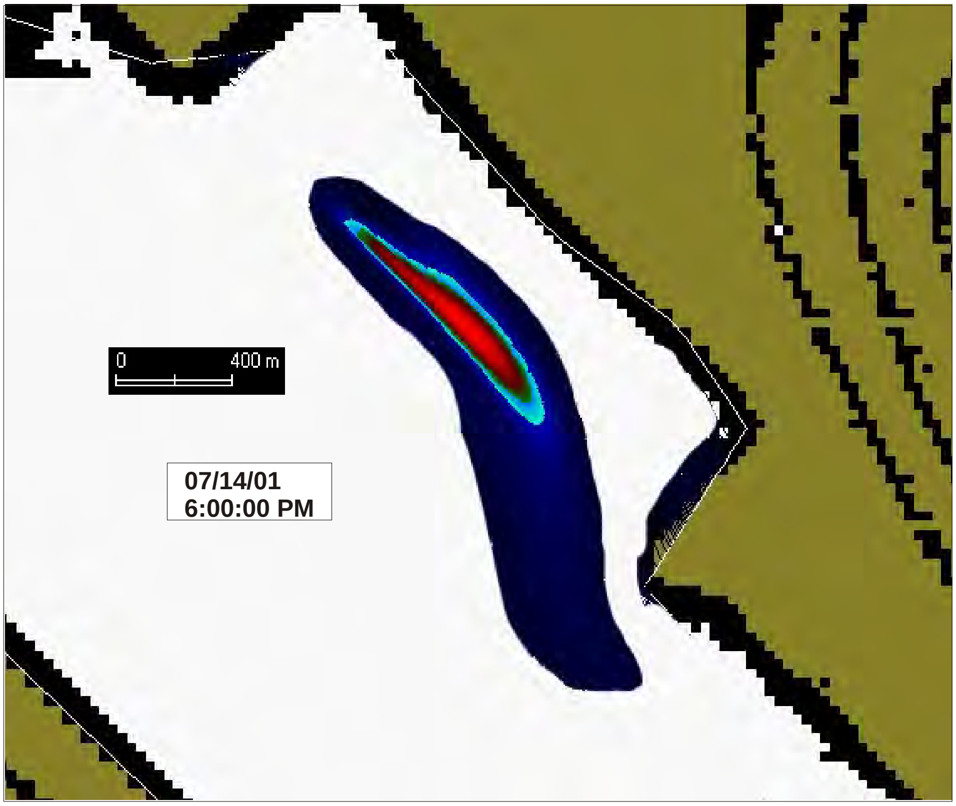

FIGURE 24E
Distribution of Nitrogenous Biochemical Oxygen Demand (NBOD) after ten hours of discharge from *Spirit of Endeavor* and *Clipper Odyssey* at Juneau port.

CONCENTRATION mg/m3 LEGEND
0.61 - 0.56
0.55 - 0.35
0.34 - 0.29
0.28 - 0.19
0.18 - 0.16
0.15 - 0.02
0.01 - -0.87E-4

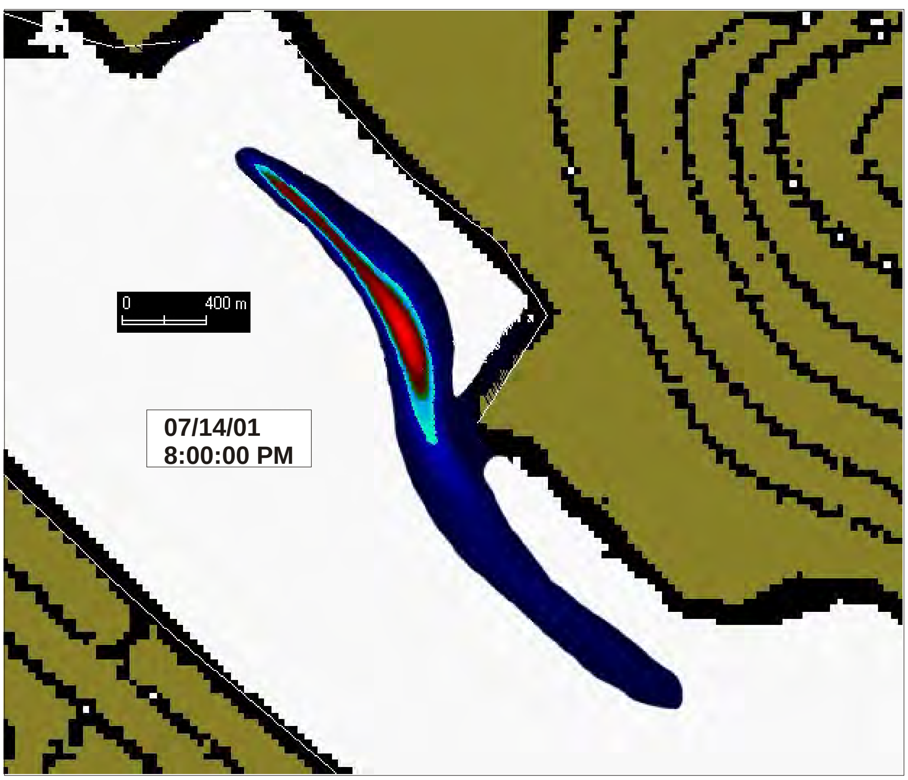

FIGURE 24F
Distribution of Nitrogenous Biochemical Oxygen Demand (NBOD) after twelve hours of discharge from *Spirit of Endeavor* and *Clipper Odyssey* at Juneau port.

CONCENTRATION mg/m3 LEGEND
0.52 - 0.46
0.45 - 0.35
0.34 - 0.26
0.25 - 0.16
0.15 - 0.09
0.08 - 0.03
0.02 - -0.63E-4

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PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

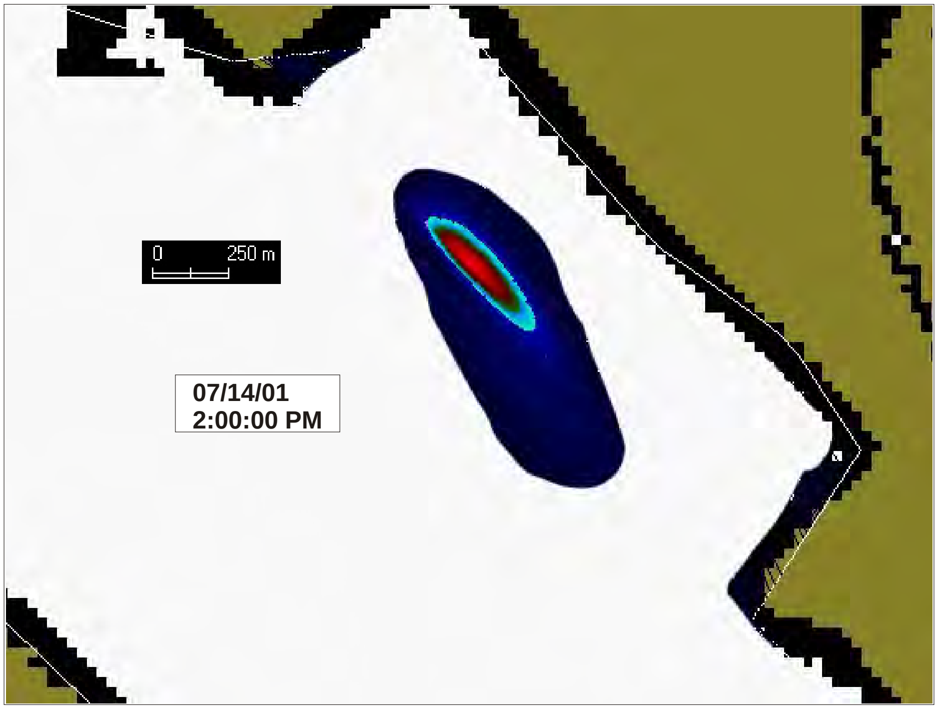

FIGURE 24C
Distribution of Nitrogenous Biochemical Oxygen Demand (NBOD) after six hours of discharge from *Spirit of Endeavor* and *Clipper Odyssey* at Juneau port.

CONCENTRATION mg/m3 LEGEND

Red	0.71 - 0.58
Dark maroon	0.57 - 0.39
Green	0.38 - 0.32
Blue	0.31 - 0.24
Cyan	0.23 - 0.18
Dark blue	0.17 - 0.05
Black	0.04 - -0.95E-4

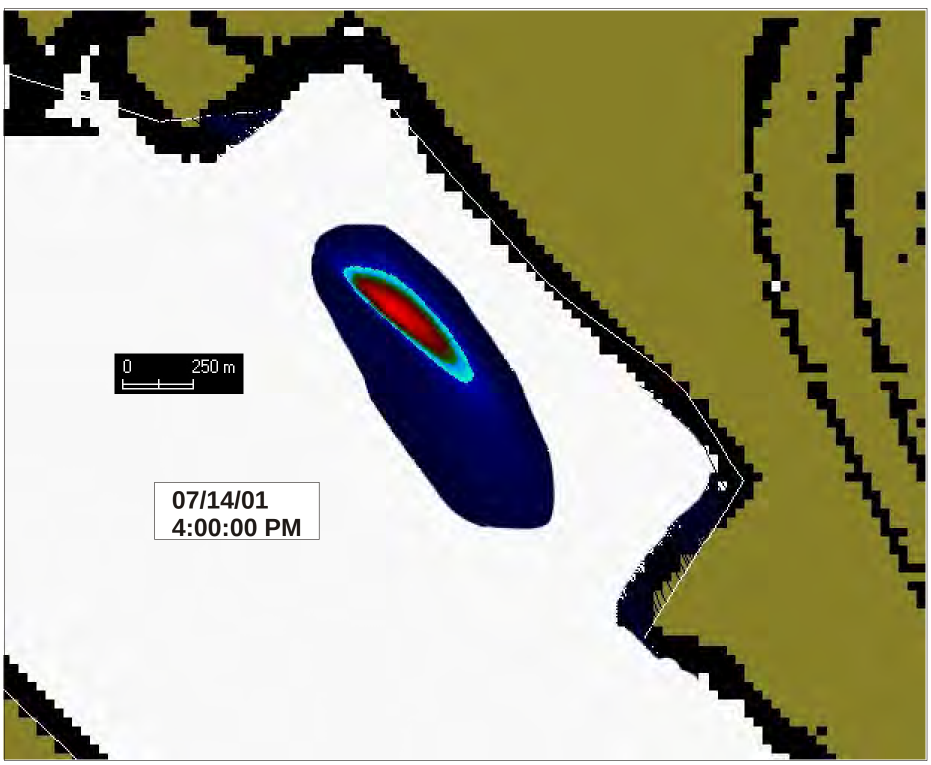

FIGURE 24D
Distribution of Nitrogenous Biochemical Oxygen Demand (NBOD) after eight hours of discharge from *Spirit of Endeavor* and *Clipper Odyssey* at Juneau port.

CONCENTRATION mg/m3 LEGEND

Red	0.71 - 0.60
Dark maroon	0.59 - 0.38
Green	0.37 - 0.32
Blue	0.31 - 0.23
Cyan	0.22 - 0.19
Dark blue	0.18 - 0.06
Black	0.05 - -2.01E-4

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PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

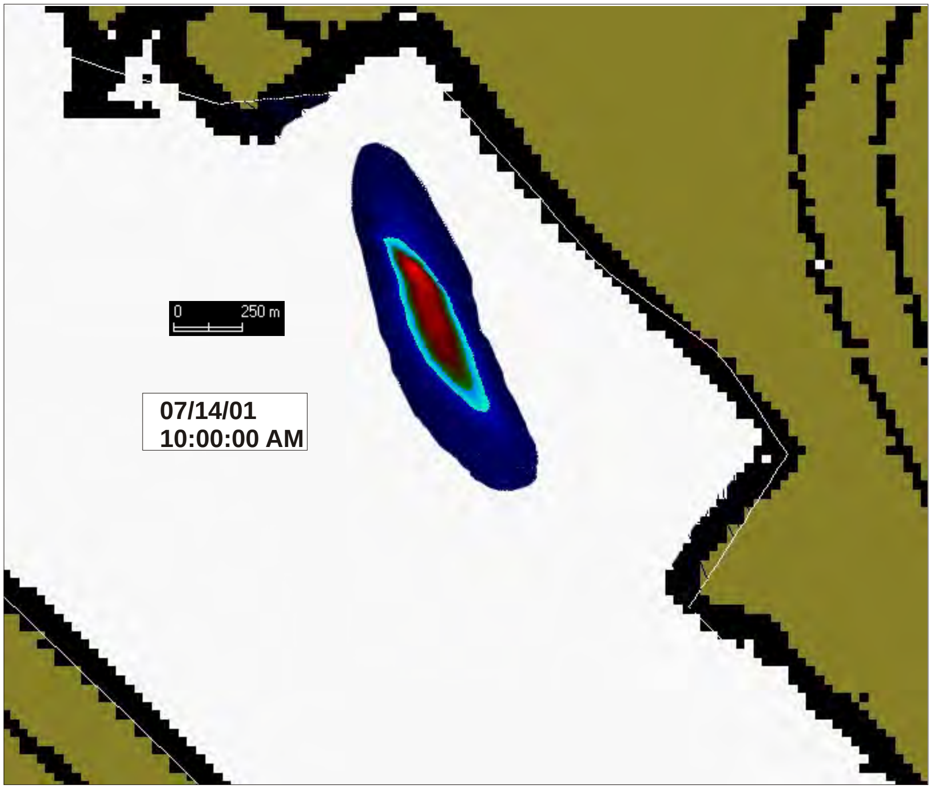

FIGURE 24A
Distribution of Nitrogenous Biochemical Oxygen Demand (NBOD) after two hours of discharge from *Spirit of Endeavor* and *Clipper Odyssey* at Juneau port.

CONCENTRATION mg/m3 LEGEND

- 0.16 - 0.13
- 0.12 - 0.10
- 0.09 - 0.08
- 0.07 - 0.06
- 0.05 - 0.04
- 0.03 - 0.02
- 0.01 - -2.81E-5

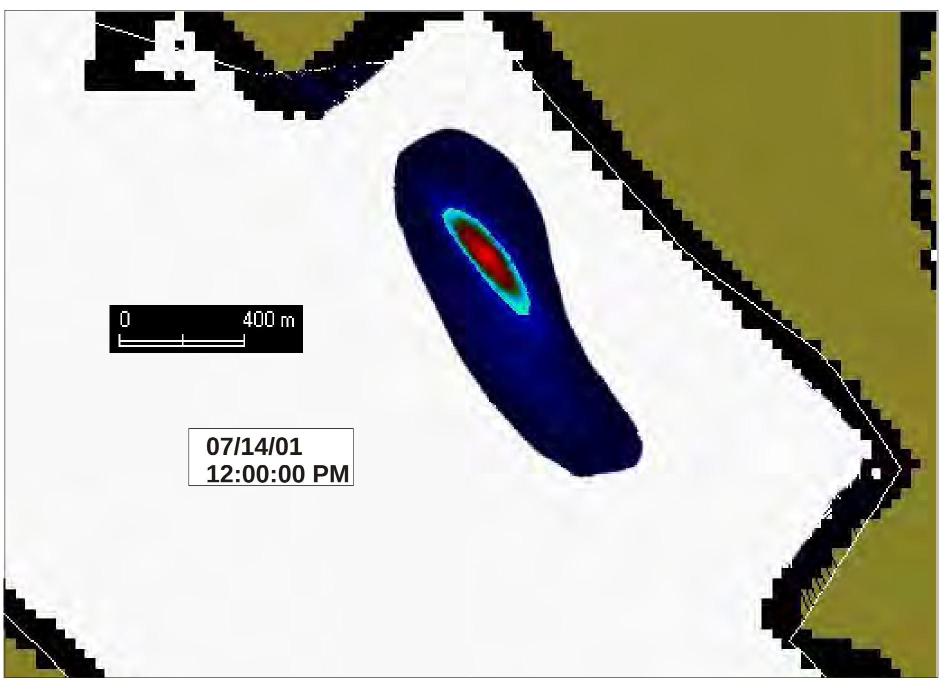

FIGURE 24B
Distribution of Nitrogenous Biochemical Oxygen Demand (NBOD) after four hours of discharge from *Spirit of Endeavor* and *Clipper Odyssey* at Juneau port.

CONCENTRATION mg/m3 LEGEND

- 0.50 - 0.37
- 0.36 - 0.25
- 0.24 - 0.22
- 0.21 - 0.19
- 0.18 - 0.12
- 0.11 - 0.05
- 0.04 - 0.76E-3

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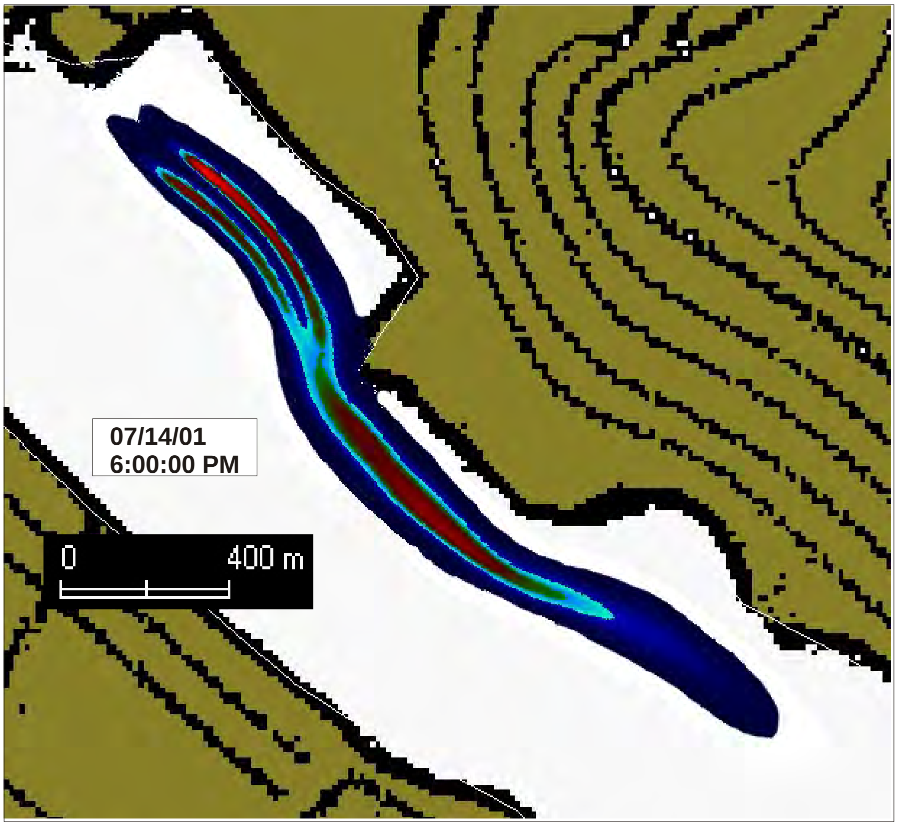

FIGURE 23G
Distribution of Carbonaceous Biochemical Oxygen Demand (CBOD) after fourteen hours of discharge from *Spirit of Endeavor* and *Clipper Odyssey* at Juneau port.

CONCENTRATION mg/m3 LEGEND
0.42 - 0.39
0.38 - 0.28
0.27 - 0.19
0.18 - 0.13
0.12 - 0.07
0.06 - 0.04
0.03 - -2.59E-4

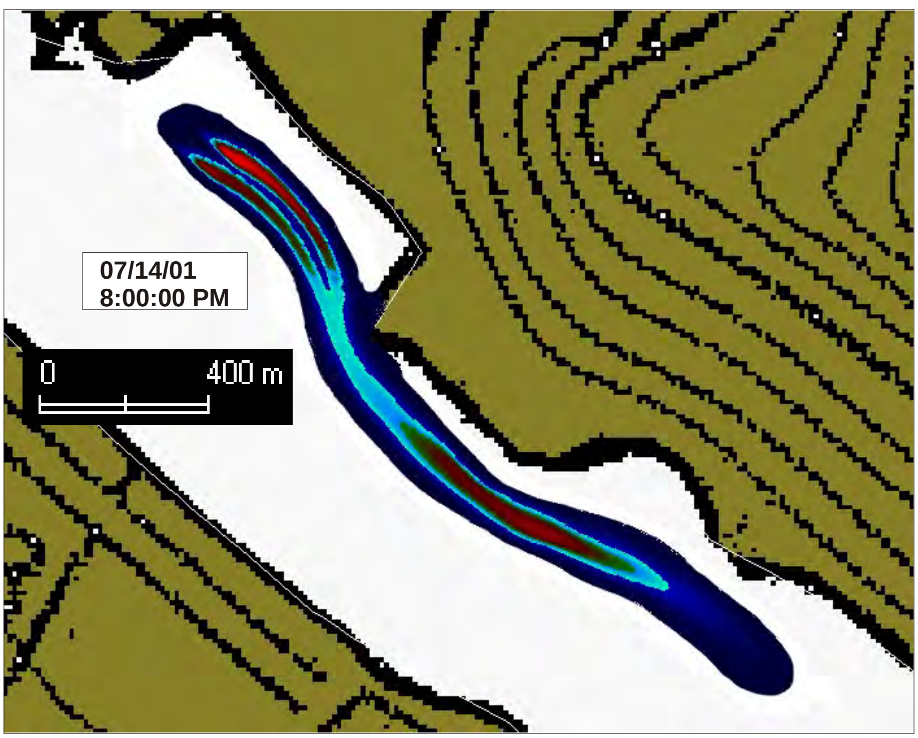

FIGURE 23H
Distribution of Carbonaceous Biochemical Oxygen Demand (CBOD) after sixteen hours of discharge from *Spirit of Endeavor* and *Clipper Odyssey* at Juneau port.

CONCENTRATION mg/m3 LEGEND
0.42 - 0.39
0.38 - 0.28
0.27 - 0.19
0.18 - 0.13
0.12 - 0.07
0.06 - 0.04
0.03 - -2.59E-4

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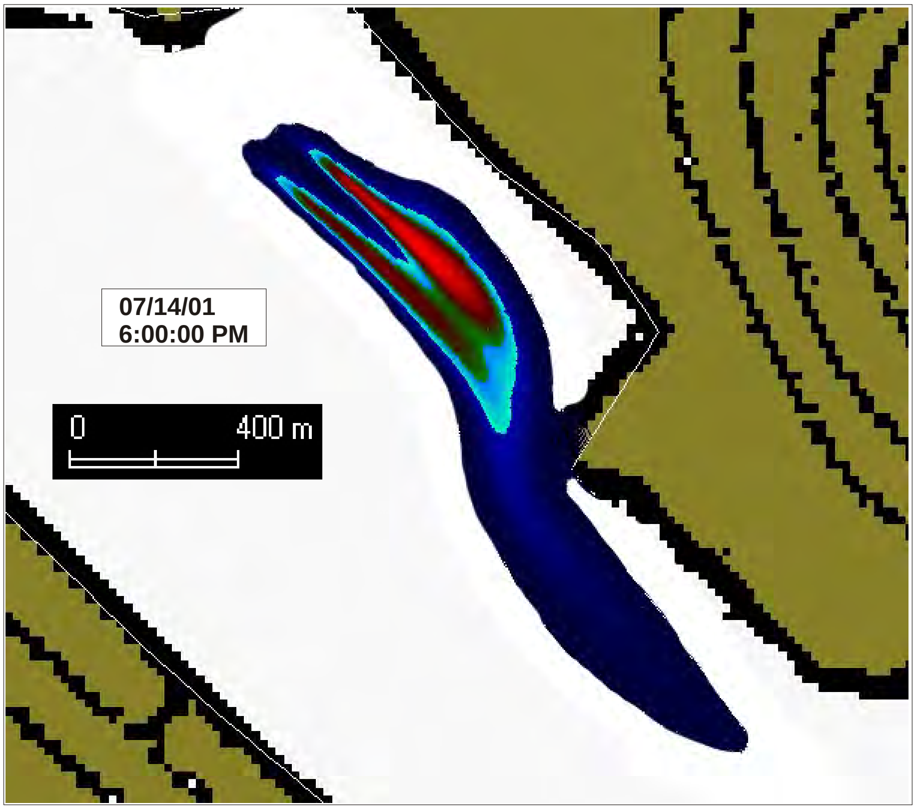

FIGURE 23E
Distribution of Carbonaceous Biochemical Oxygen Demand (CBOD) after ten hours of discharge from *Spirit of Endeavor* and *Clipper Odyssey* at Juneau port.

CONCENTRATION mg/m3 LEGEND
0.60 - 0.55
0.54 - 0.47
0.46 - 0.34
0.33 - 0.21
0.20 - 0.12
0.11 - 0.03
0.02 - -1.44E-4

FIGURE 23F
Distribution of Carbonaceous Biochemical Oxygen Demand (CBOD) after twelve hours of discharge from *Spirit of Endeavor* and *Clipper Odyssey* at Juneau port.

CONCENTRATION mg/m3 LEGEND
0.54 - 0.46
0.45 - 0.33
0.32 - 0.25
0.24 - 0.17
0.16 - 0.09
0.08 - 0.04
0.03 - -0.85E-4

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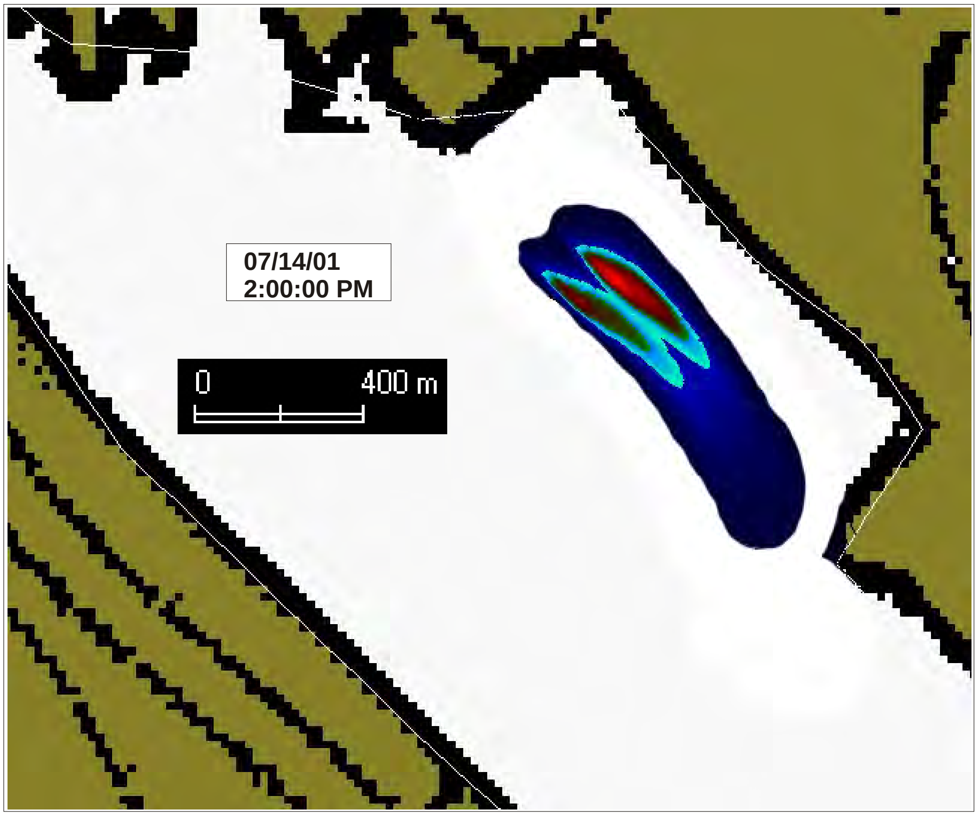

FIGURE 23C
Distribution of Carbonaceous Biochemical Oxygen Demand (CBOD) after six hours of discharge from *Spirit of Endeavor* and *Clipper Odyssey* at Juneau port.

CONCENTRATION mg/m3 LEGEND

red	0.57 - 0.49
dark maroon	0.48 - 0.39
green	0.38 - 0.27
blue	0.26 - 0.20
cyan	0.19 - 0.14
dark blue	0.13 - 0.04
black	0.03 - -1.32E-4

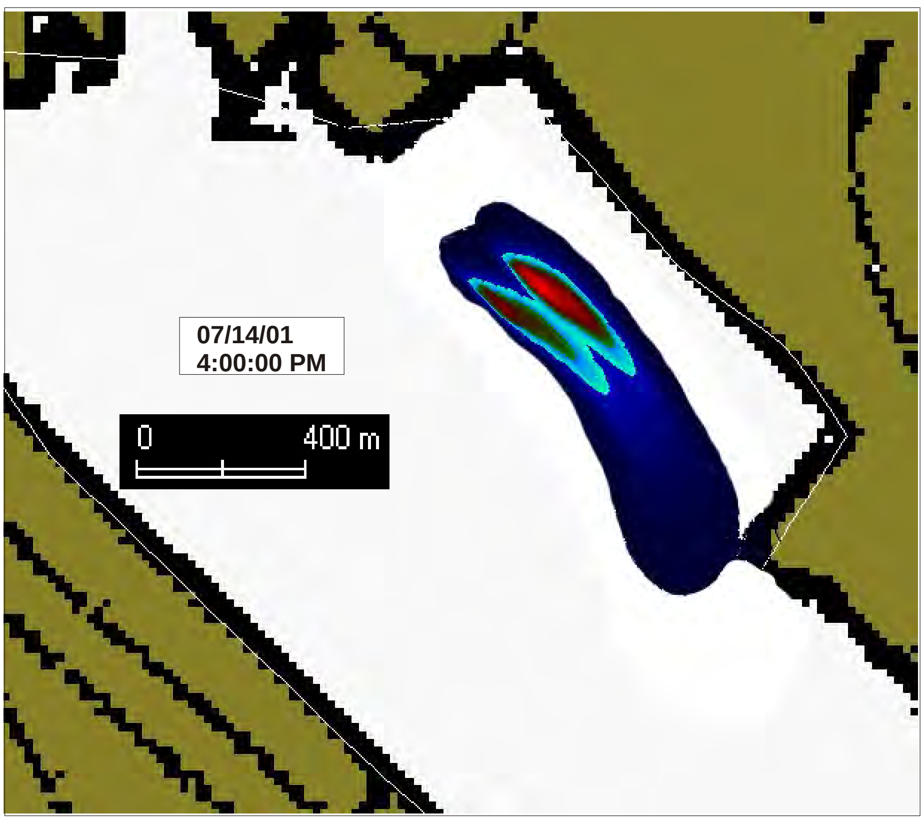

FIGURE 23D
Distribution of Carbonaceous Biochemical Oxygen Demand (CBOD) after eight hours of discharge from *Spirit of Endeavor* and *Clipper Odyssey* at Juneau port.

CONCENTRATION mg/m3 LEGEND

red	0.65 - 0.57
dark maroon	0.56 - 0.47
green	0.46 - 0.32
blue	0.31 - 0.25
cyan	0.24 - 0.15
dark blue	0.14 - 0.03
black	0.02 - -0.97E-4

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PROJECT No. 001332.AU11.01 **JUNE 2003**

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ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

FIGURE 23A
Distribution of Carbonaceous
Biochemical Oxygen Demand (CBOD)
after two hours of discharge from
Spirit of Endeavor and *Clipper Odyssey*
at Juneau port.

CONCENTRATION mg/m3 LEGEND
0.34 - 0.28
0.27 - 0.20
0.19 - 0.16
0.15 - 0.13
0.12 - 0.07
0.06 - 0.03
0.02 - -3.03E-4

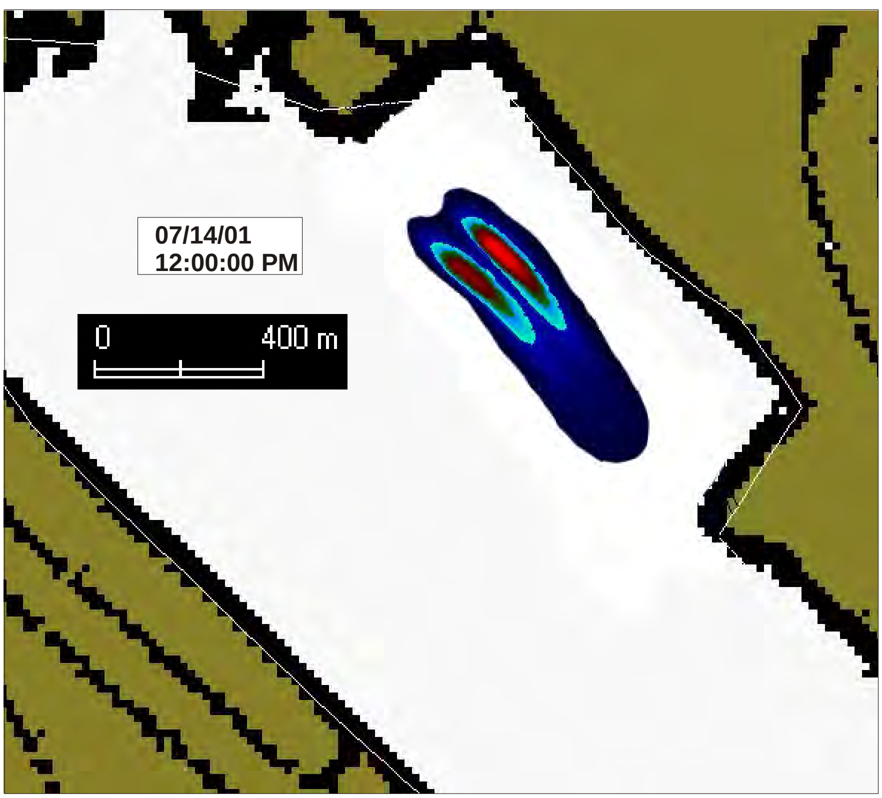

FIGURE 23B
Distribution of Carbonaceous
Biochemical Oxygen Demand (CBOD)
after four hours of discharge from
Spirit of Endeavor and *Clipper Odyssey*
at Juneau port.

CONCENTRATION mg/m3 LEGEND
0.54 - 0.40
0.39 - 0.32
0.31 - 0.26
0.25 - 0.19
0.18 - 0.12
0.11 - 0.03
0.02 - -1.07E-4

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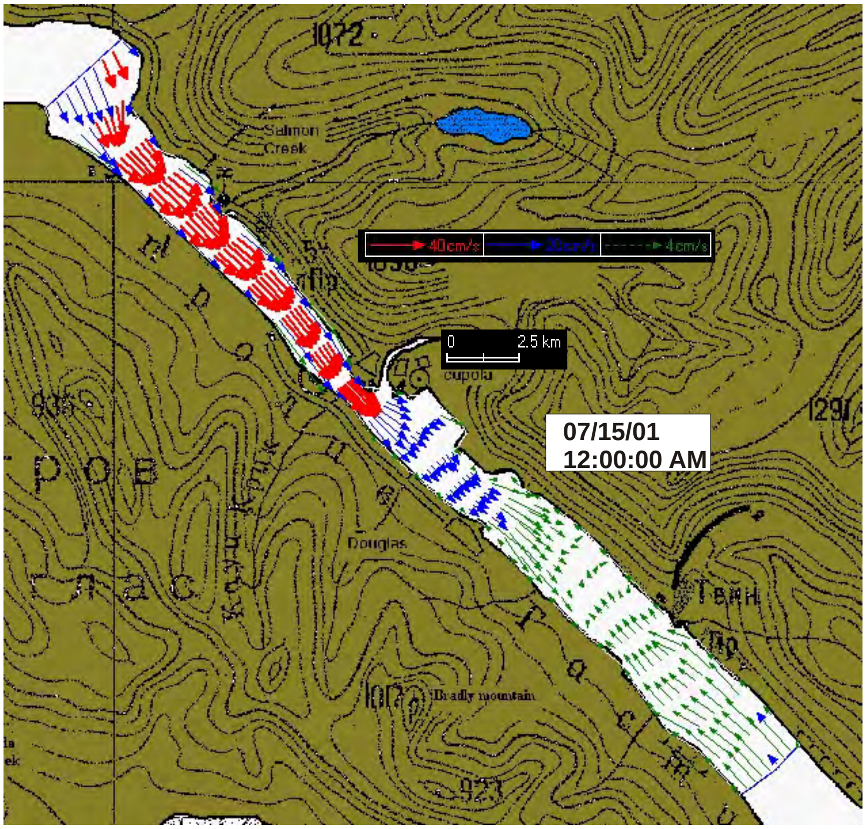
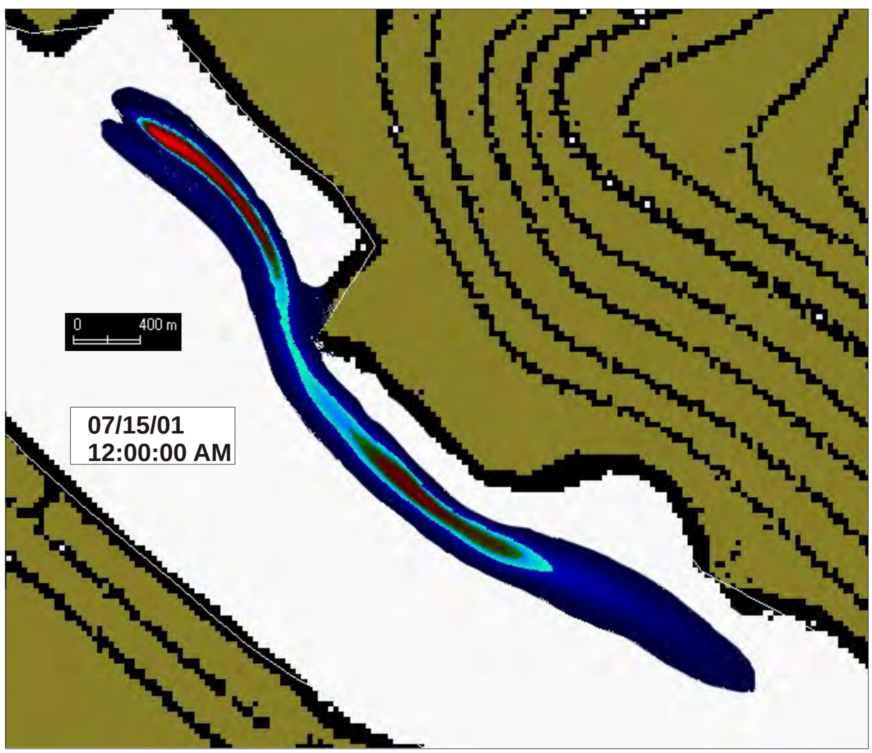


FIGURE 22O
Velocity pattern after sixteen hours of start of discharge from *Spirit of Endeavor* and *Clipper Odyssye* at Juneau port.

FIGURE 22P
Depth averaged *fecal coliform* concentration (MPN/m^3) after sixteen hours of discharge from *Spirit of Endeavor* and *Clipper Odyssye*.

CONCENTRATION LEGEND

Red	7,394 - 6,001
Dark brown	6,000 - 5,164
Dark green	5,163 - 3,193
Blue	3,192 - 2,263
Cyan	2,262 - 1,371
Dark blue	1,370 - -0.75



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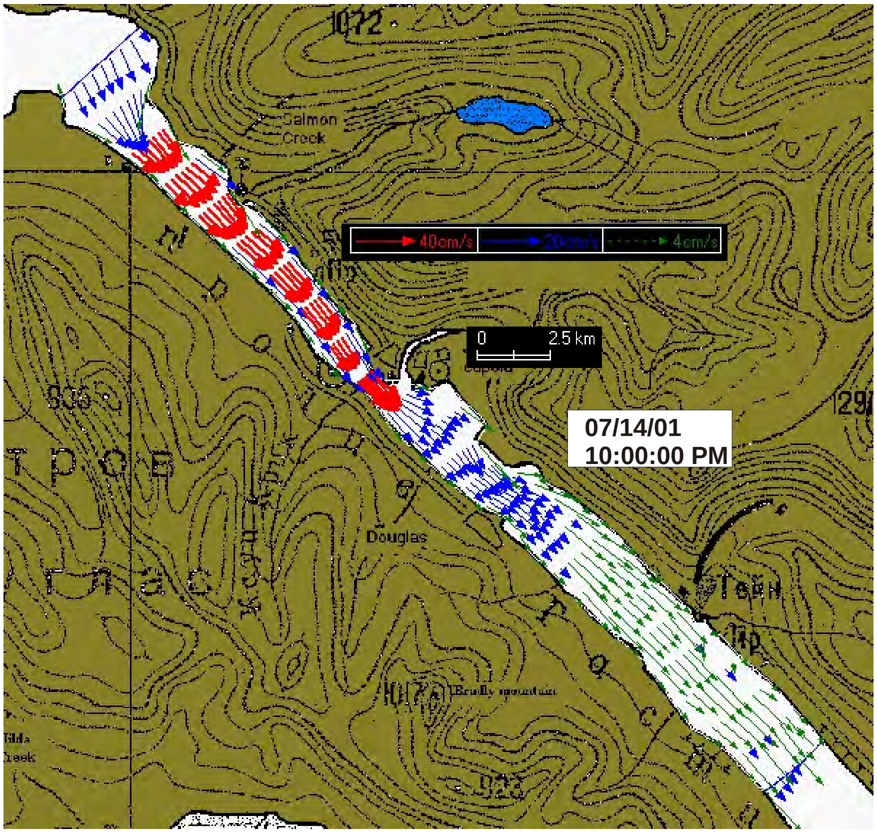
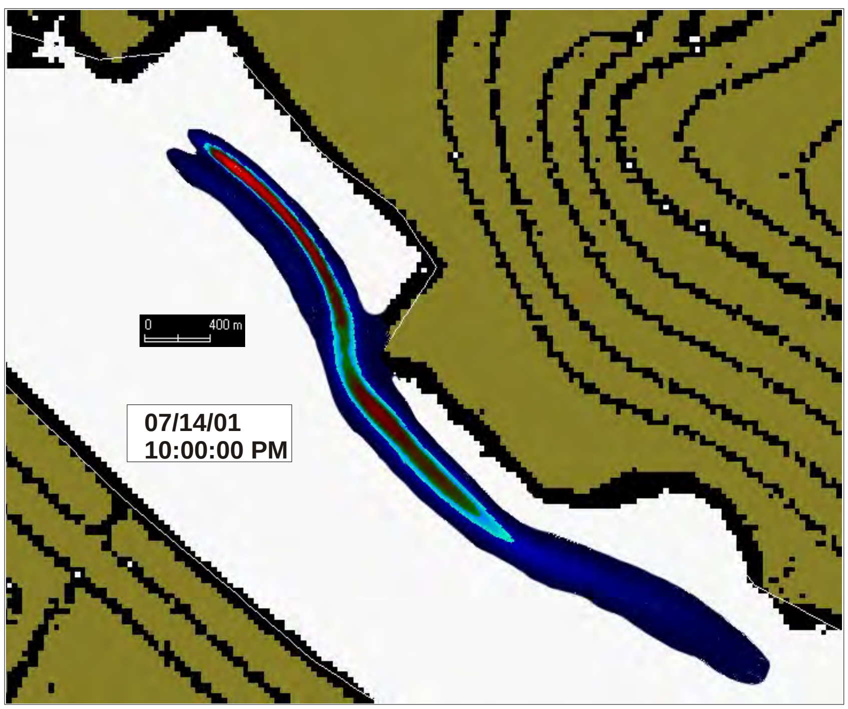


FIGURE 22M
Velocity pattern after fourteen hours of start of discharge from *Spirit of Endeavor* and *Clipper Odyssye* at Juneau port.

FIGURE 22N
Depth averaged *fecal coliform* concentration (MPN/m^3) after fourteen hours of discharge from *Spirit of Endeavor* and *Clipper Odyssye*.

CONCENTRATION LEGEND	
red	7,614 - 6,579
dark brown	6,578 - 5,876
green	5,876 - 3,191
blue	3,190 - 1,528
cyan	1,527 - 1,104
navy	1,103 - -24.6



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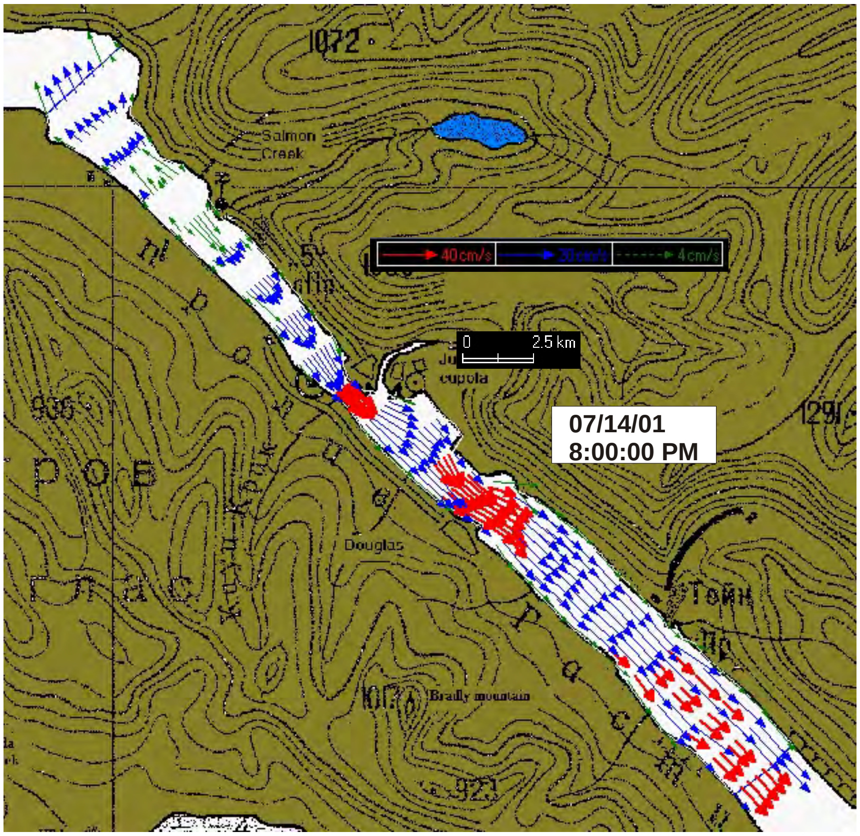

FIGURE 22K
Velocity pattern after twelve hours of start of discharge from *Spirit of Endeavor* and *Clipper Odyssye* at Juneau port.

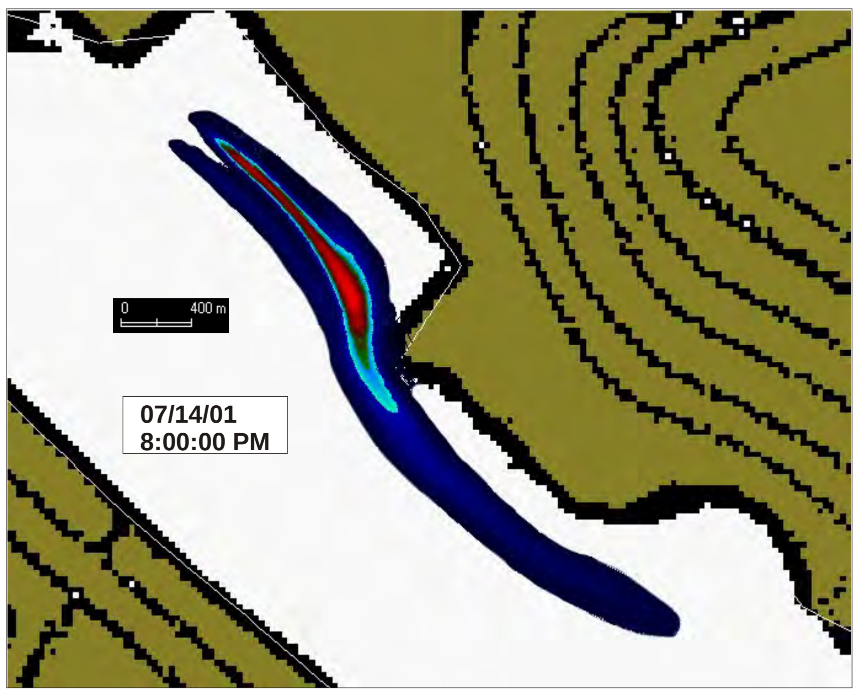

FIGURE 22L
Depth averaged *fecal coliform* concentration (MPN/m^3) after twelve hours of discharge from *Spirit of Endeavor* and *Clipper Odyssye*.

CONCENTRATION LEGEND

Red	9,036 - 7,734
Dark brown	7,733 - 5,380
Green	5,379 - 4,400
Blue	4,399 - 3,052
Turquoise	3,051 - 1,978
Navy	1,977 - 1.8

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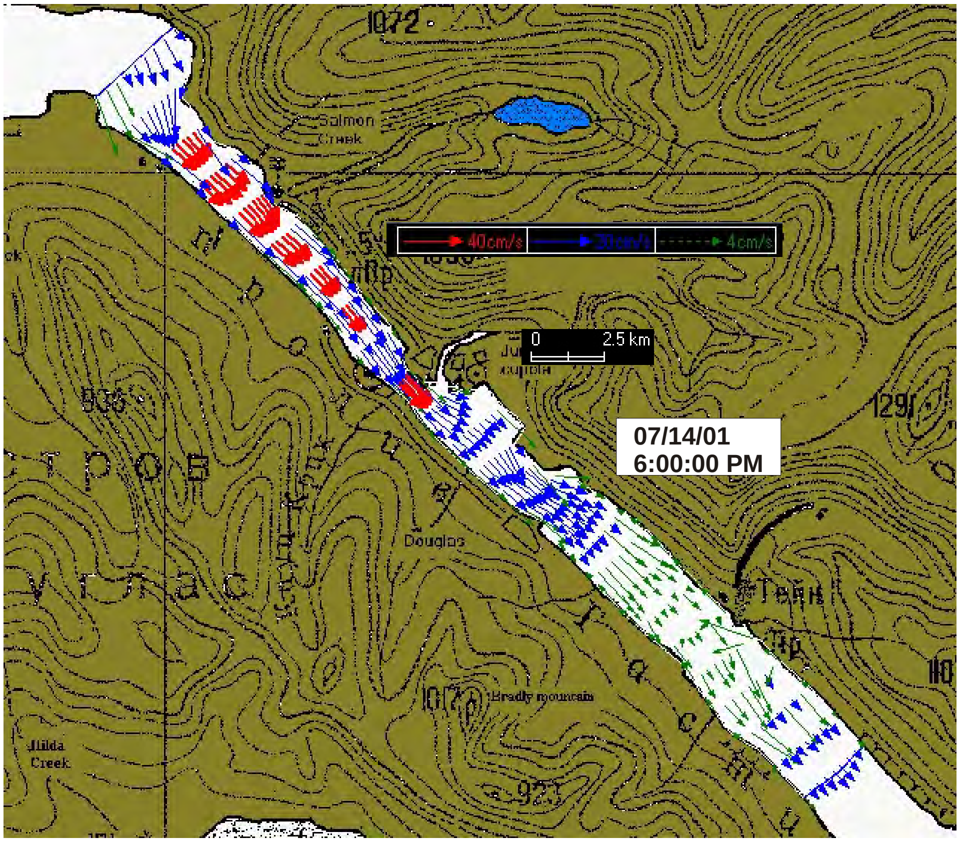
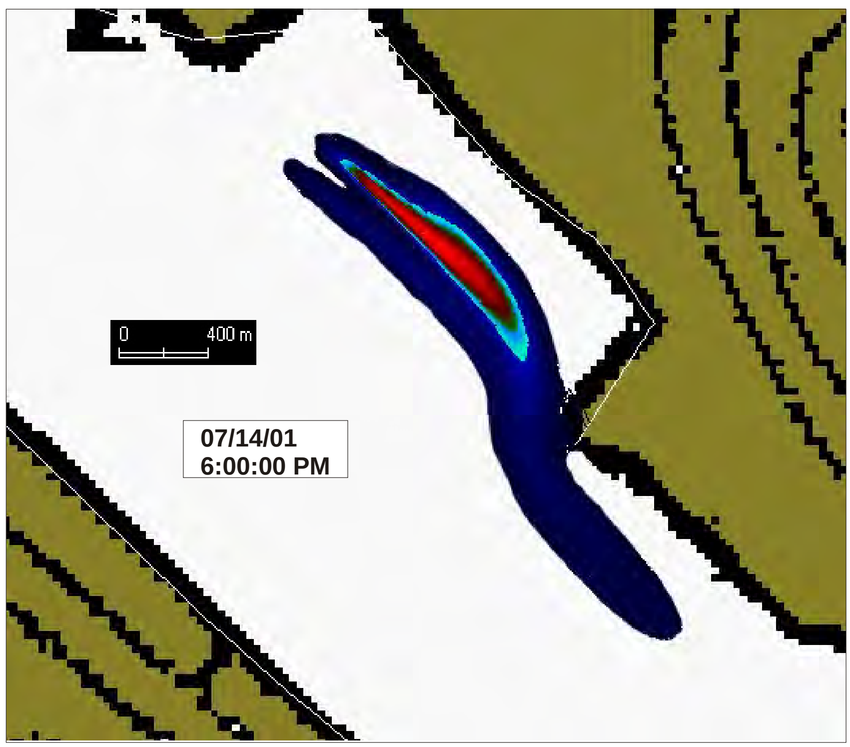


FIGURE 22I
Velocity pattern after ten hours of start of discharge from *Spirit of Endeavor* and *Clipper Odyssye* at Juneau port.

FIGURE 22J
Depth averaged *fecal coliform* concentration (MPN/m^3) after ten hours of discharge from *Spirit of Endeavor* and *Clipper Odyssye*.

CONCENTRATION LEGEND

Red	10,052 - 7,850
Dark brown	7,849 - 5,856
Green	5,855 - 5,000
Blue	4,999 - 2,986
Cyan	2,985 - 2,030
Navy	2,029 - -3.4



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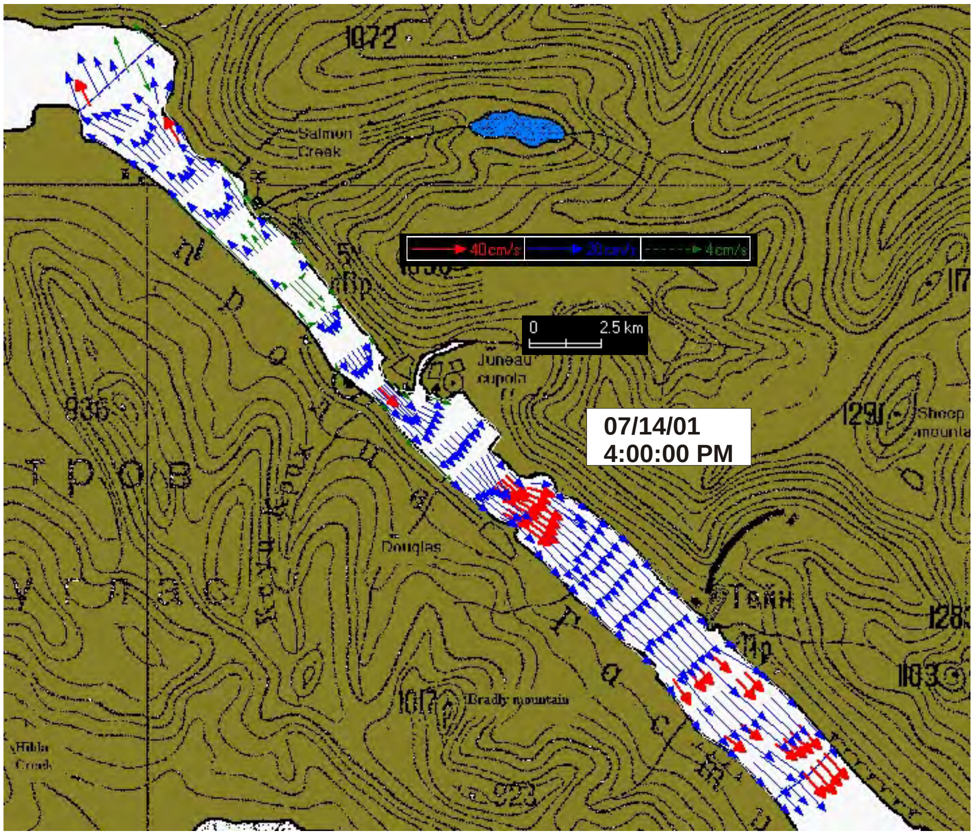
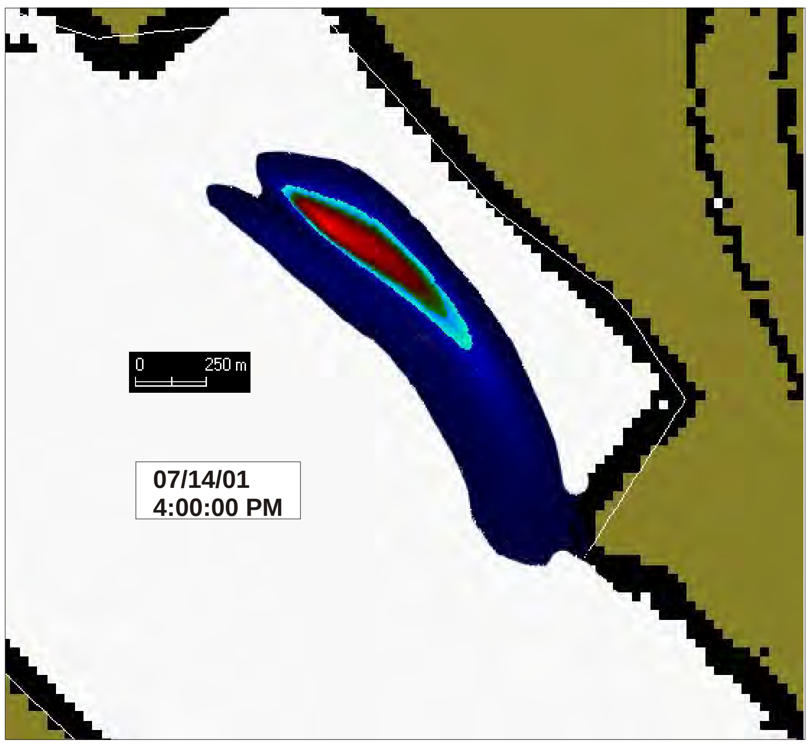


FIGURE 22G
Velocity pattern after eight hours of start of discharge from *Spirit of Endeavor* and *Clipper Odyssye* at Juneau port.

FIGURE 22H
Depth averaged *fecal coliform* concentration (MPN/m^3) after eight hours of discharge from *Spirit of Endeavor* and *Clipper Odyssye*.

CONCENTRATION LEGEND

(red)	11,693 - 8,380
(dark brown)	8,379 - 7,032
(green)	7,031 - 5,511
(blue)	5,510 - 3,691
(cyan)	3,690 - 2,590
(navy)	2,589 - -2.9



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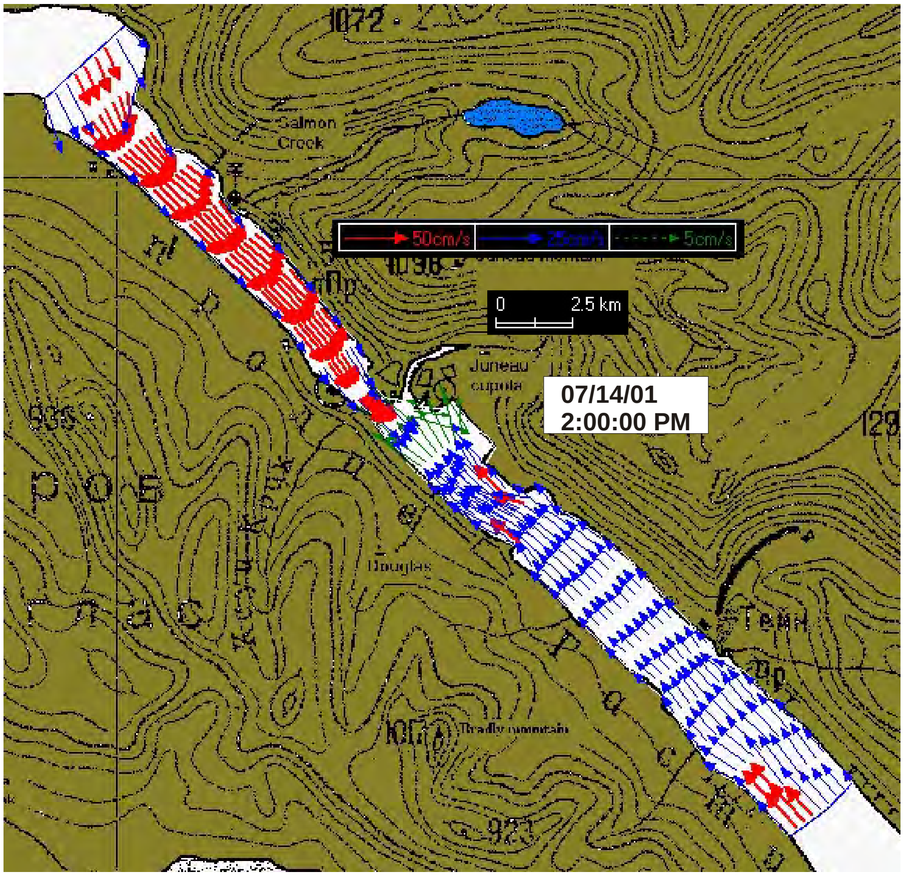
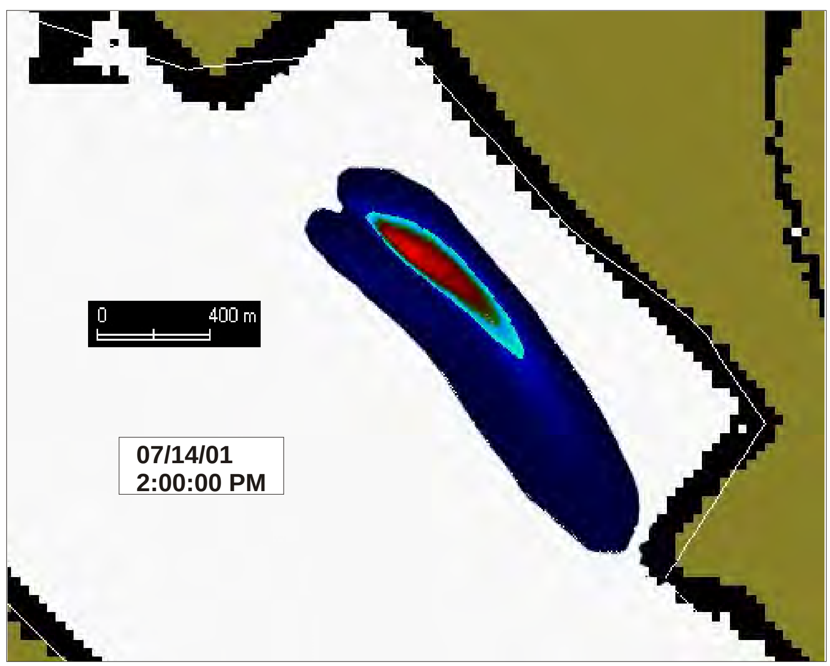


FIGURE 22E
Velocity pattern after six hours of start of discharge from *Spirit of Endeavor* and *Clipper Odyssye* at Juneau port.

FIGURE 22F
Depth averaged *fecal coliform* concentration (MPN/m^3) after six hours of discharge from *Spirit of Endeavor* and *Clipper Odyssye*.

CONCENTRATION LEGEND

Red	11,160 - 8,419
Dark brown	8,418 - 6,714
Green	6,713 - 5,211
Blue	5,210 - 3,391
Cyan	3,390 - 2,398
Dark blue	2,397 - -2.2



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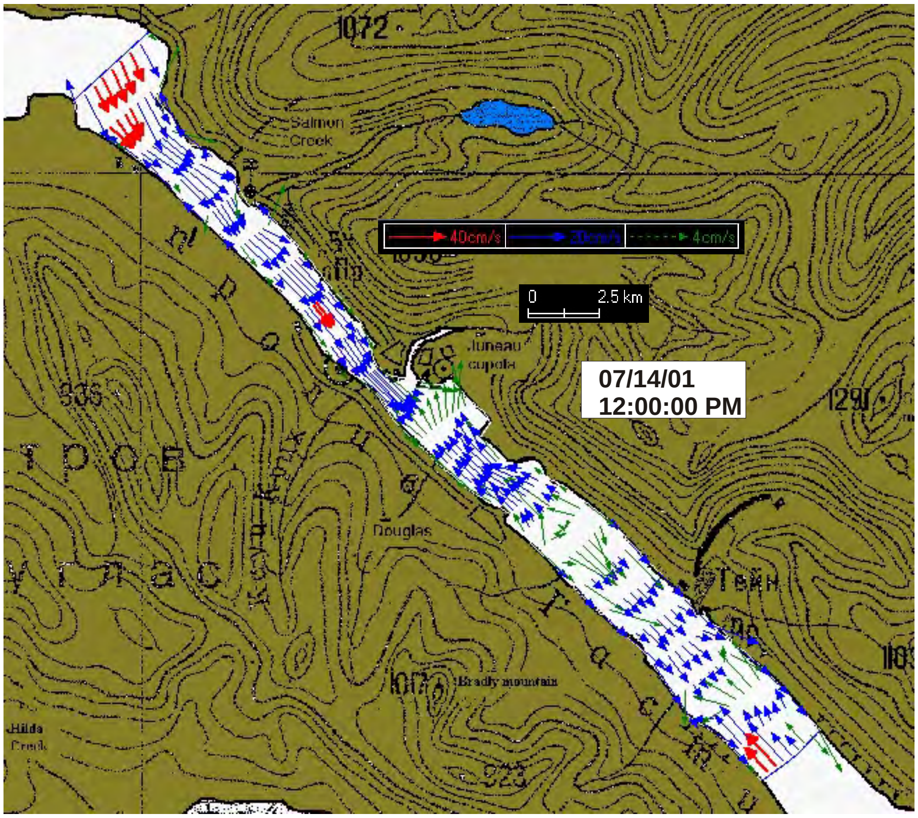
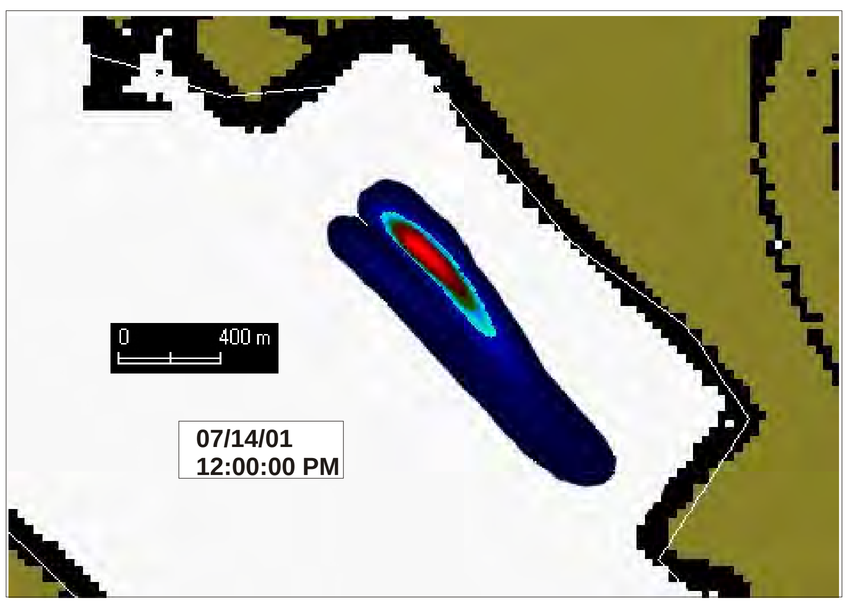


FIGURE 22C
Velocity pattern after four hours of start of discharge from *Spirit of Endeavor* and *Clipper Odyssye* at Juneau port.

FIGURE 22D
Depth averaged *fecal coliform* concentration (MPN/m³) after fours hour of discharge from *Spirit of Endeavor* and *Clipper Odyssye*.

CONCENTRATION LEGEND

red	9,196 - 6,871
dark brown	6,870 - 5,404
green	5,403 - 4,494
blue	4,493 - 3,493
cyan	3,492 - 1,169
navy	1,168 - 1



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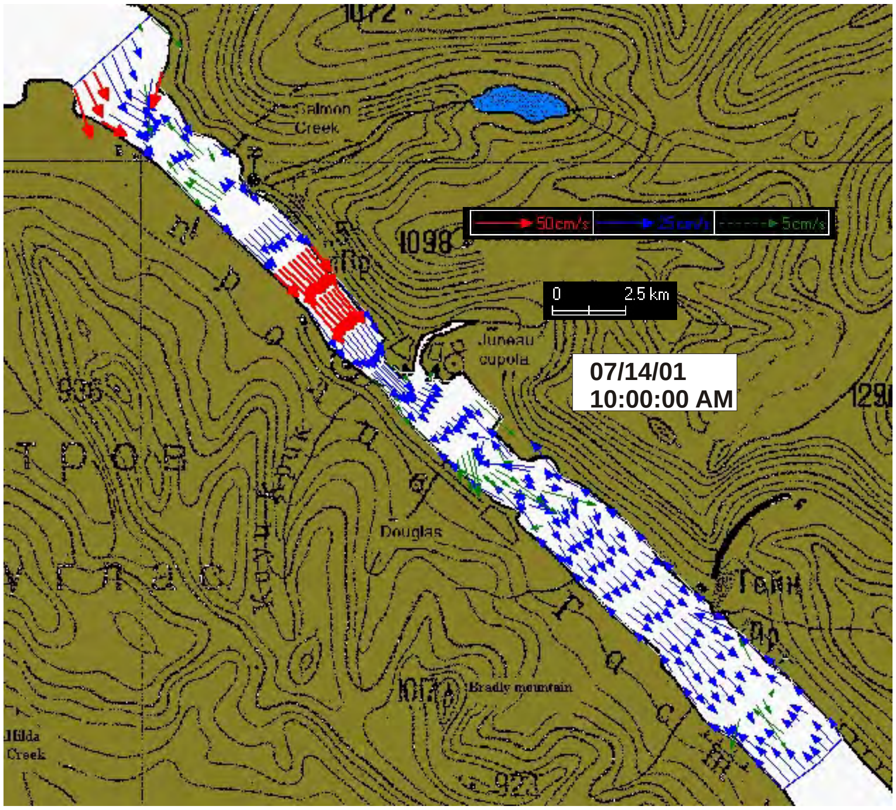
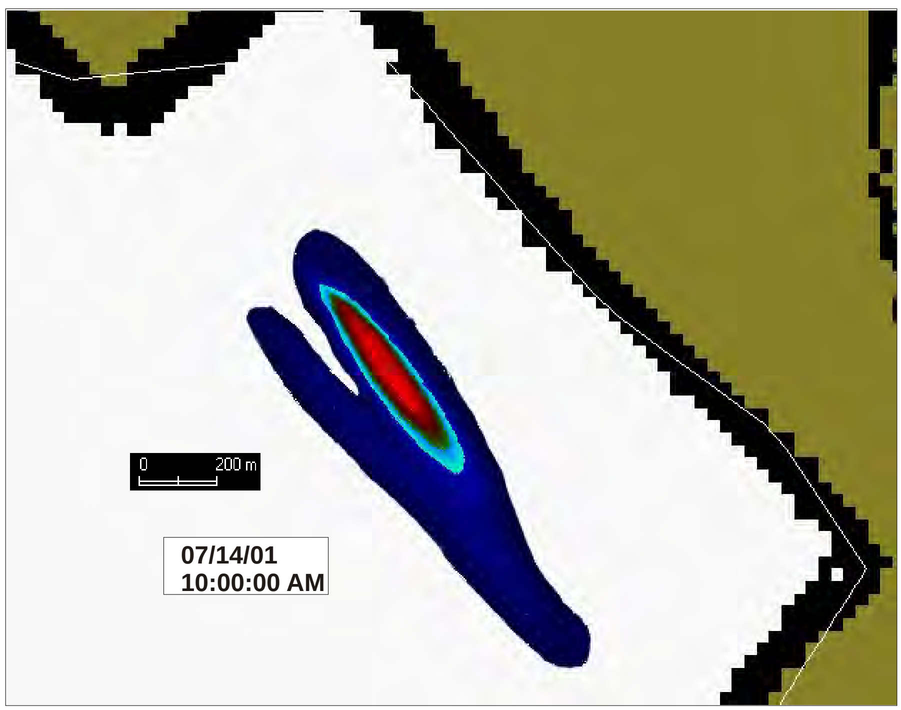


FIGURE 22A
Velocity pattern after two hours of start of discharge from *Spirit of Endeavor* and *Clipper Odyssye* at Juneau port.

FIGURE 22B
Depth averaged *fecal coliform* concentration (MPN/m^3) after two hours of discharge from *Spirit of Endeavor* and *Clipper Odyssye*.

CONCENTRATION LEGEND

Red	5,914 - 5,027
Dark brown	5,026 - 3,351
Green	3,350 - 3,013
Blue	3,012 - 2,335
Aqua	2,334 - 1,073
Dark blue	1,072 - 0.69



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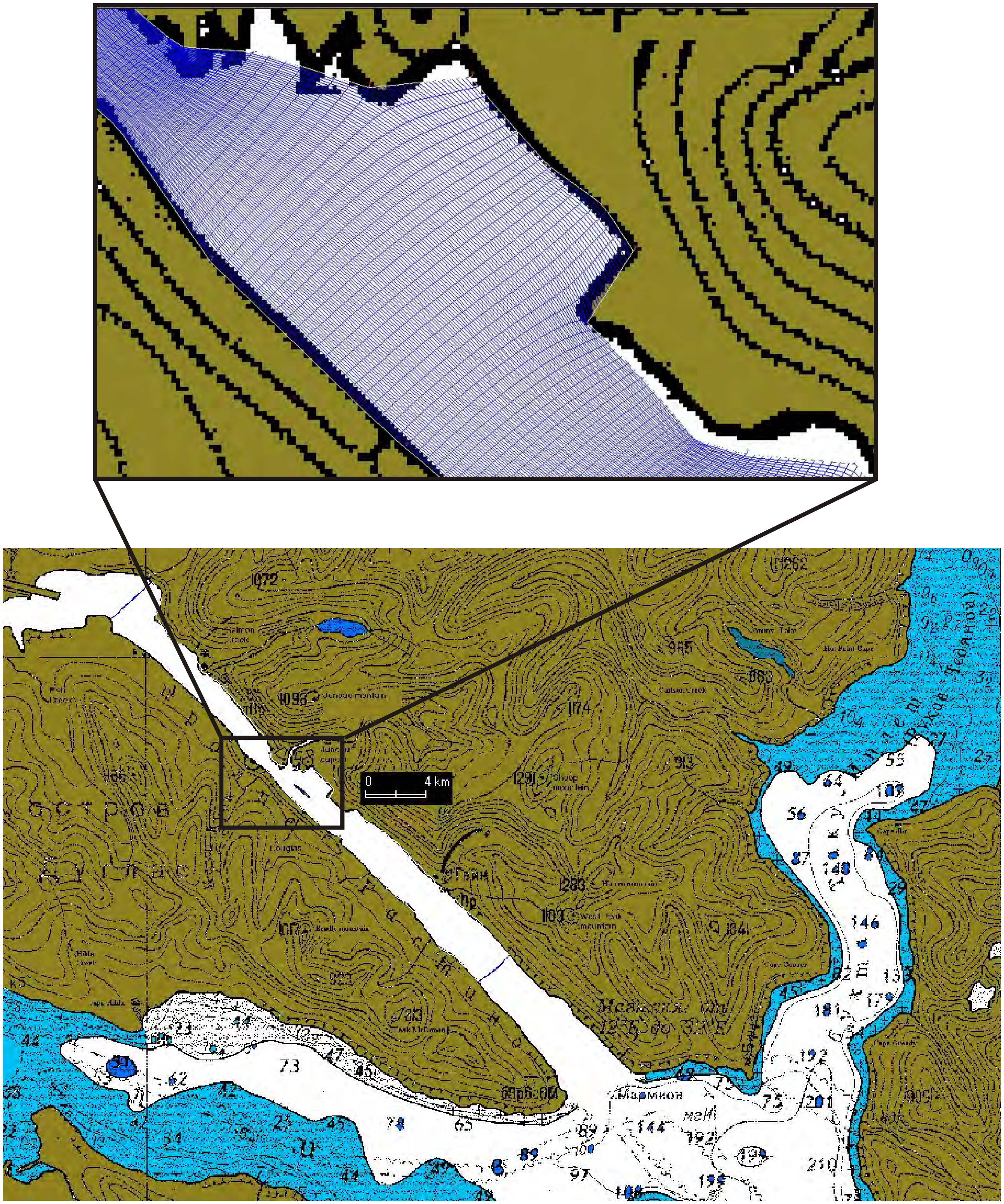

FIGURE 21

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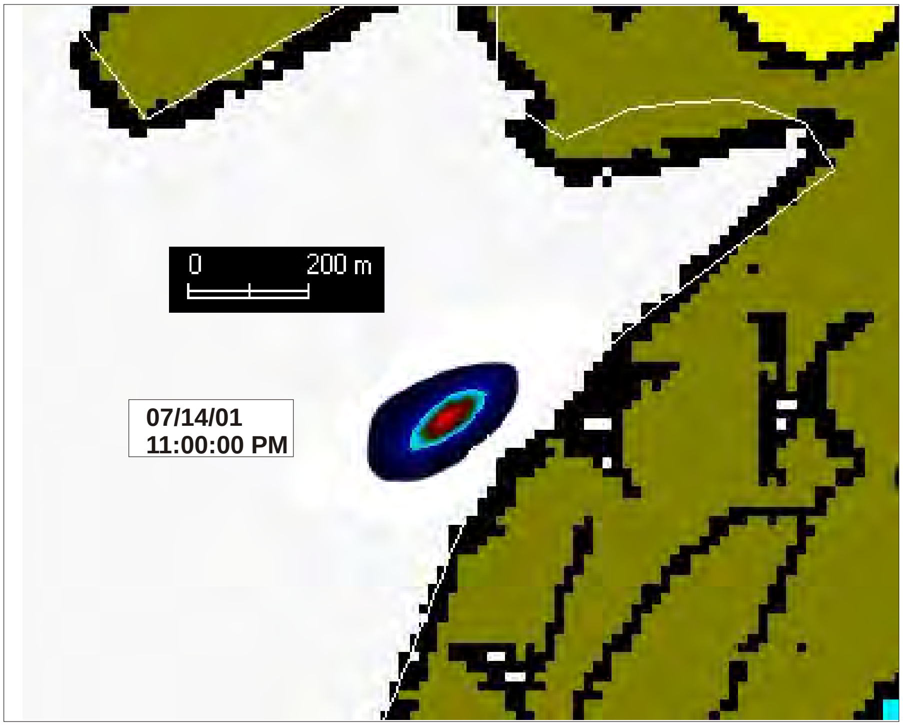


FIGURE 20G
Distribution of Ammonia Nitrogen (NH3-N) after three hours of stop of discharge from *Taku* at Skagway port and five hours of discharge from *Spirit of Oceanus*.

CONCENTRATION mg/m3 LEGEND

- 0.88 - 0.63
- 0.62 - 0.59
- 0.58 - 0.49
- 0.48 - 0.30
- 0.29 - 0.13
- 0.12 - 0.03
- 0.02 - -1.49E-4

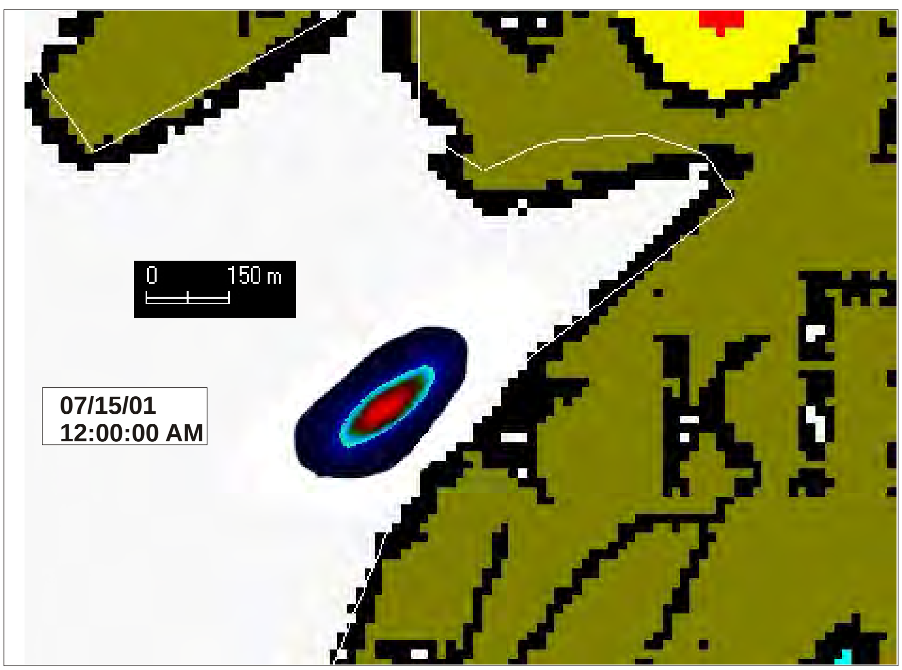
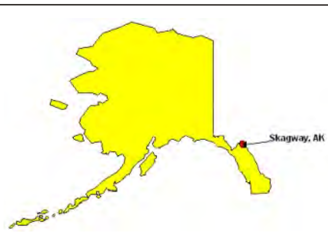


FIGURE 20H
Distribution of Ammonia Nitrogen (NH3-N) after four hours of stop of discharge from *Taku* at Skagway port and six hours of discharge from *Spirit of Oceanus*.

CONCENTRATION mg/m3 LEGEND

- 0.62 - 0.50
- 0.49 - 0.42
- 0.41 - 0.33
- 0.32 - 0.25
- 0.24 - 0.12
- 0.11 - 0.02
- 0.01 - 0.7E-4



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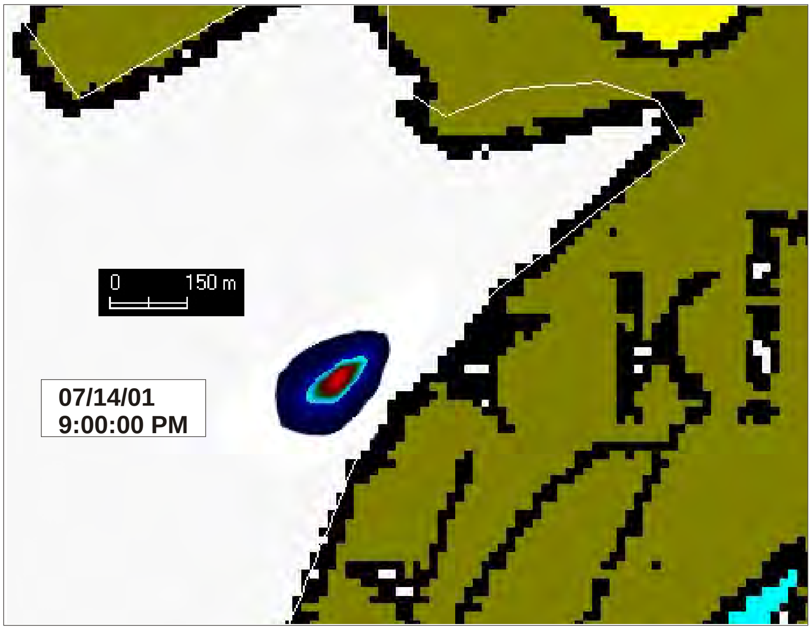


FIGURE 20E
Distribution of Ammonia Nitrogen (NH3-N) after one hour of stop of discharge from *Taku* at Skagway port and three hours of discharge from *Spirit of Oceanus*.

CONCENTRATION mg/m3 LEGEND
0.69 - 0.61
0.60 - 0.37
0.36 - 0.31
0.30 - 0.16
0.15 - 0.08
0.07 - 0.02
0.01 - -1.68E-4

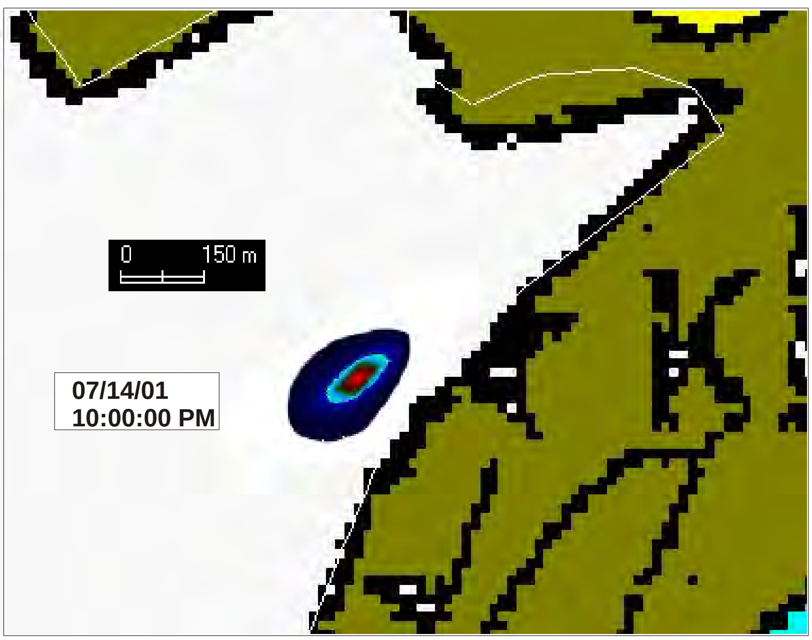
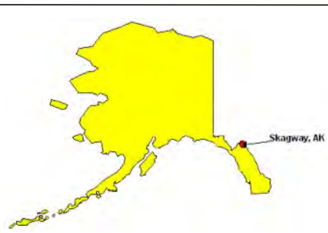


FIGURE 20F
Distribution of Ammonia Nitrogen (NH3-N) after two hours of stop of discharge from *Taku* at Skagway port and four hours of discharge from *Spirit of Oceanus*.

CONCENTRATION mg/m3 LEGEND
0.96 - 0.57
0.56 - 0.48
0.47 - 0.44
0.43 - 0.30
0.29 - 0.26
0.25 - 0.02
0.01 - -1.73E-4



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PROJECT No. 001332.AU11.01 JUNE 2003

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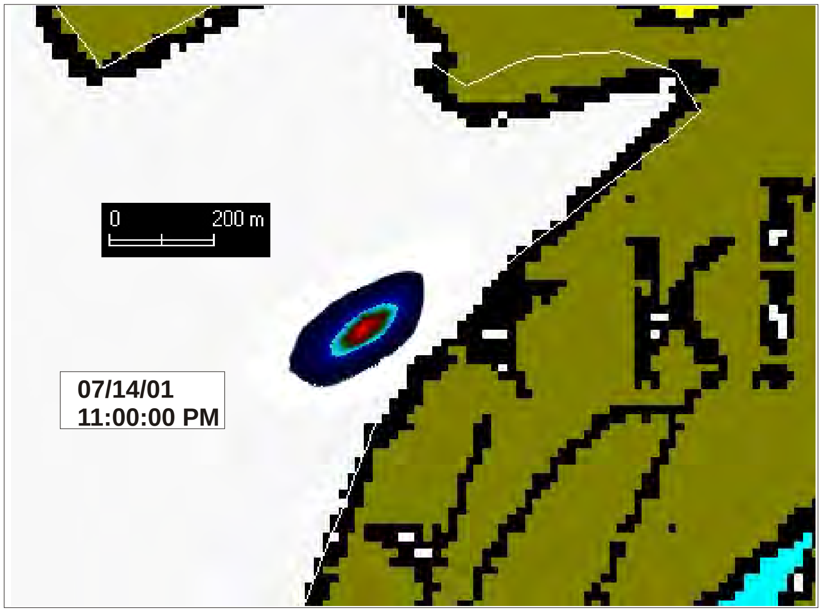


FIGURE 19G
Distribution of
Biochemical Oxygen Demand (BOD)
after three hours of stop of discharge
from *Taku* at Skagway port and
five hours of discharge
from *Spirit of Oceanus*.

CONCENTRATION LEGEND

Red	22 - 15.6
Dark brown	15.5 - 12.7
Green	12.6 - 9.2
Blue	9.1 - 7.5
Cyan	7.4 - 3.6
Navy	3.5 - 2.9
White	2.8 - -2.45E-3

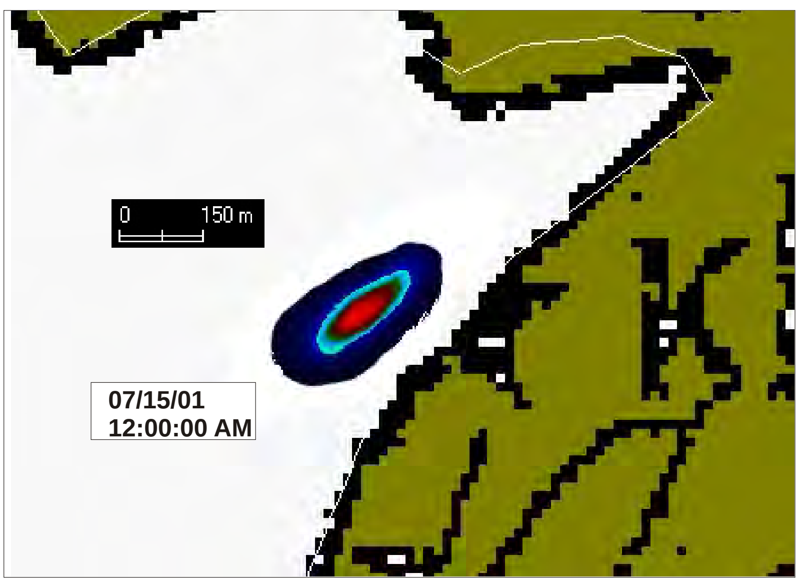
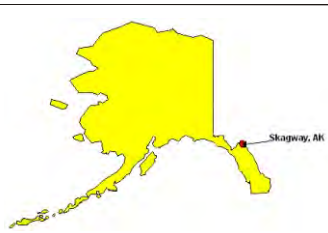
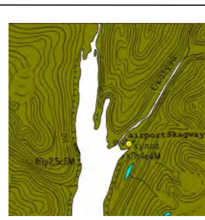


FIGURE 19H
Distribution of
Biochemical Oxygen Demand (BOD)
after four hours of stop of discharge
from *Taku* at Skagway port and
six hours of discharge
from *Spirit of Oceanus*.

CONCENTRATION LEGEND

Red	15.5 - 14.8
Dark brown	14.7 - 8.3
Green	8.2 - 7.9
Blue	7.8 - 6.2
Cyan	6.1 - 5.8
Navy	5.7 - 1.7
White	1.6 - -2.06E-3





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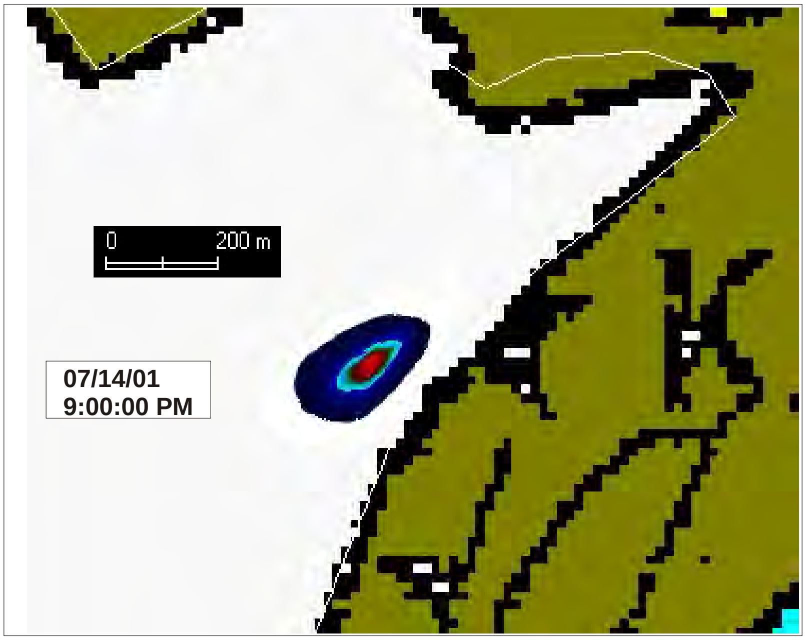


FIGURE 19E
Distribution of
Biochemical Oxygen Demand (BOD)
after one hour of stop of discharge
from *Taku* at Skagway port and
three hours of discharge
from *Spirit of Oceanus*.

CONCENTRATION LEGEND	
Red	17.6 - 15.2
Dark brown	15.1 - 9.4
Green	9.3 - 7.9
Blue	7.8 - 6.5
Cyan	6.4 - 5.6
Navy	5.5 - 0.44

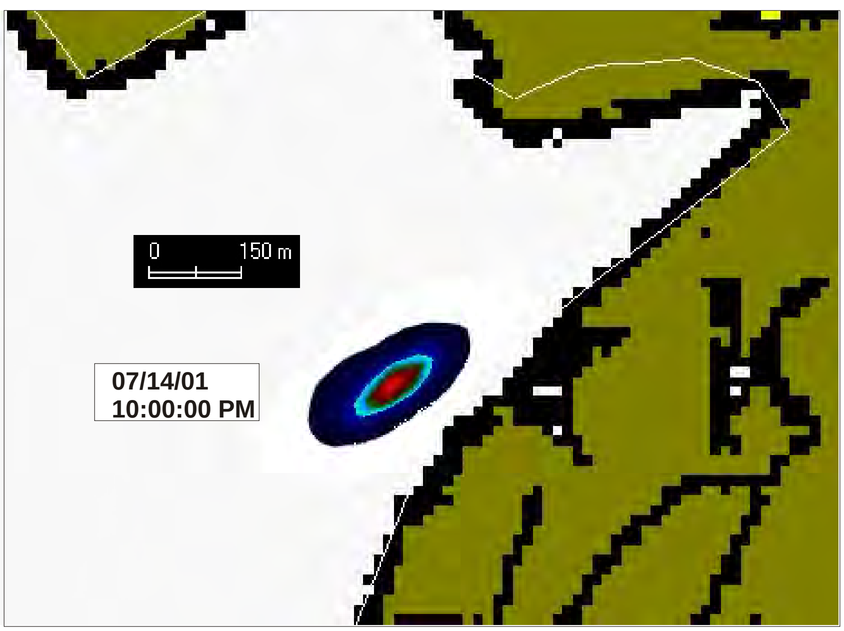
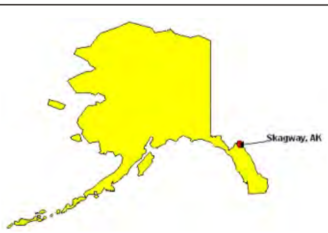
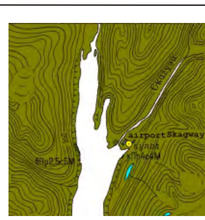


FIGURE 19F
Distribution of
Biochemical Oxygen Demand (BOD)
after two hours of stop of discharge
from *Taku* at Skagway port and
four hours of discharge
from *Spirit of Oceanus*.

CONCENTRATION LEGEND	
Red	24 - 14.2
Dark brown	14.1 - 13.7
Green	13.6 - 11.9
Blue	11.8 - 7.8
Cyan	7.7 - 6.4
Navy	6.3 - 2.3





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ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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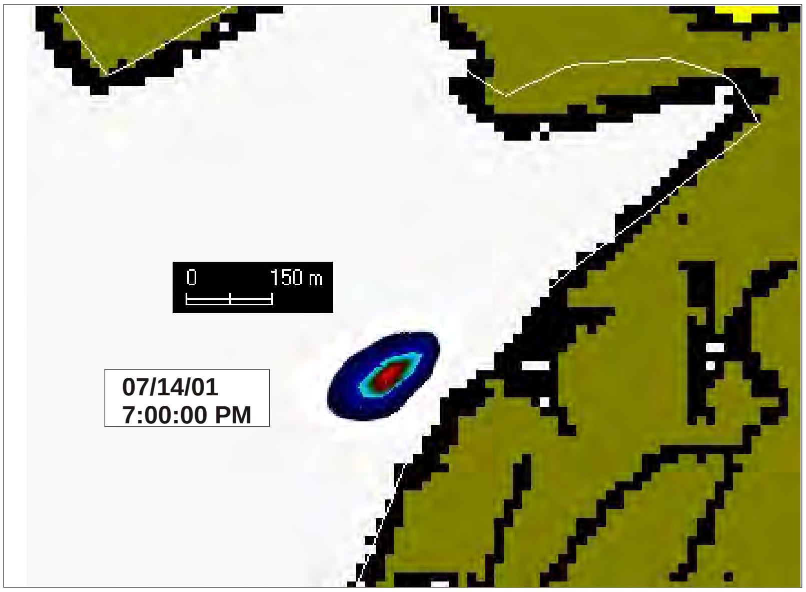


FIGURE 19C
Distribution of
Biochemical Oxygen Demand (BOD)
after three hours of discharge from
***Taku* at Skagway port and**
one hour of discharge
from *Spirit of Oceanus*.

CONCENTRATION LEGEND

Red	7.5 - 5.9
Dark brown	5.8 - 5.7
Green	5.6 - 3.7
Blue	3.6 - 1.9
Cyan	1.8 - 1.6
Dark blue	1.5 - 0.02

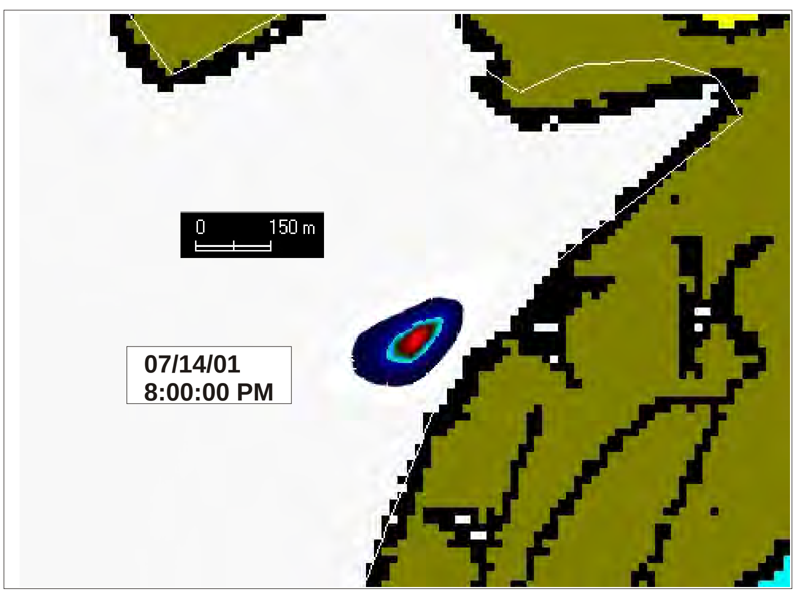
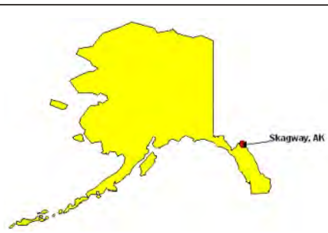
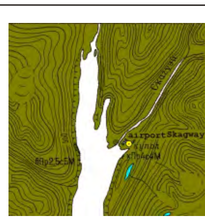


FIGURE 19D
Distribution of
Biochemical Oxygen Demand (BOD)
after four hours of discharge from
***Taku* at Skagway port and**
two hours of discharge
from *Spirit of Oceanus*.

CONCENTRATION LEGEND

Red	11.7 - 11.5
Dark brown	11.4 - 6.3
Green	6.2 - 5.4
Blue	5.3 - 2.7
Cyan	2.6 - 1.8
Dark blue	1.7 - .04





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ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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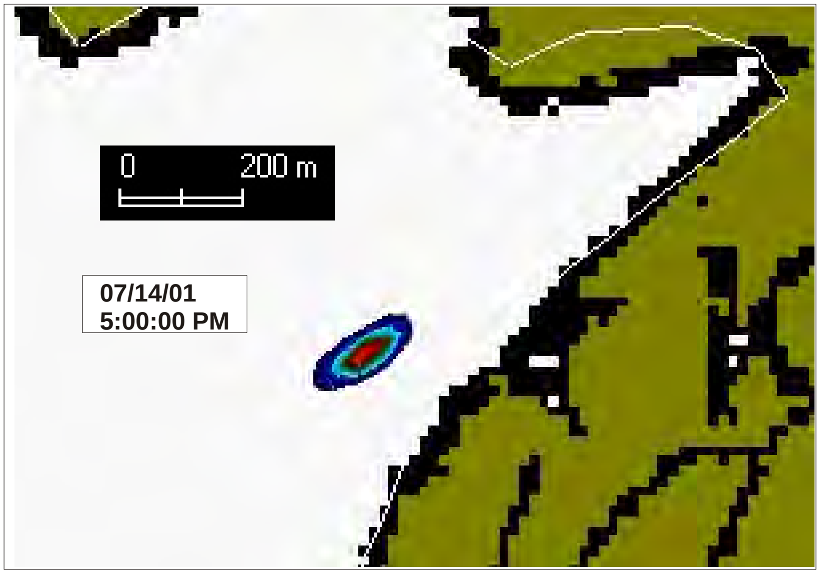


FIGURE 19A
Distribution of
Biochemical Oxygen Demand (BOD)
after one hour of discharge from
***Taku* at Skagway port.**

CONCENTRATION LEGEND

Red	0.4 - 0.25
Dark brown	0.24 - 0.22
Green	0.21 - 0.20
Blue	0.19 - 0.18
Turquoise	0.18 - 0.17
Navy	0.16 - 0.1

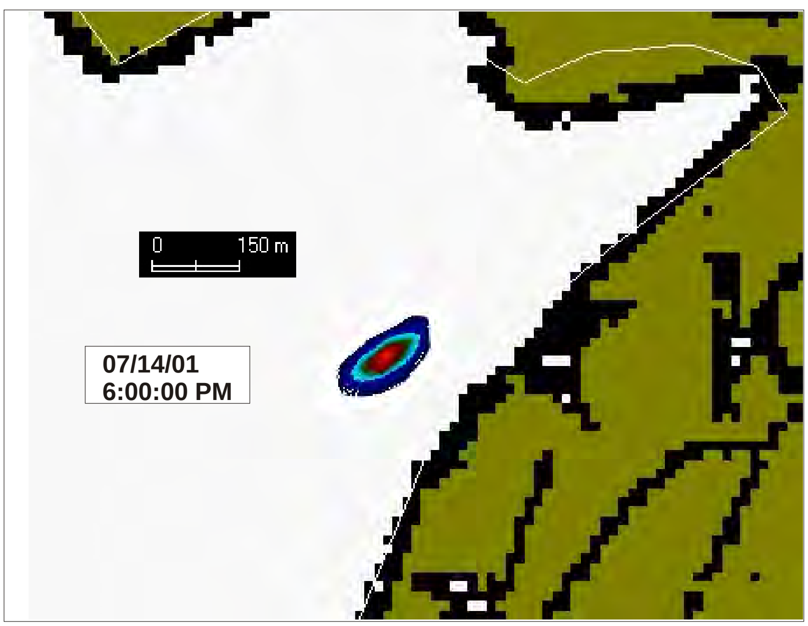
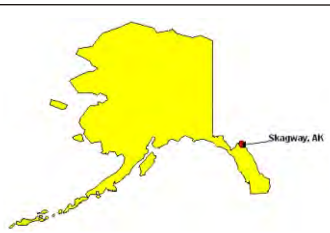
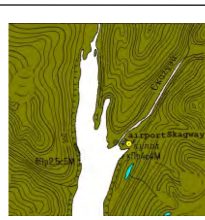


FIGURE 19B
Distribution of
Biochemical Oxygen Demand (BOD)
after two hours of discharge from
***Taku* at Skagway port.**
***Spirit of Oceanus* starts discharging.**

CONCENTRATION LEGEND

Red	0.68 - 0.57
Dark brown	0.56 - 0.38
Green	0.37 - 0.30
Blue	0.29 - 0.28
Turquoise	0.27 - 0.16
Navy	0.15 - 0.1





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PROJECT No. 001332.AU11.01 **JUNE 2003**

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ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

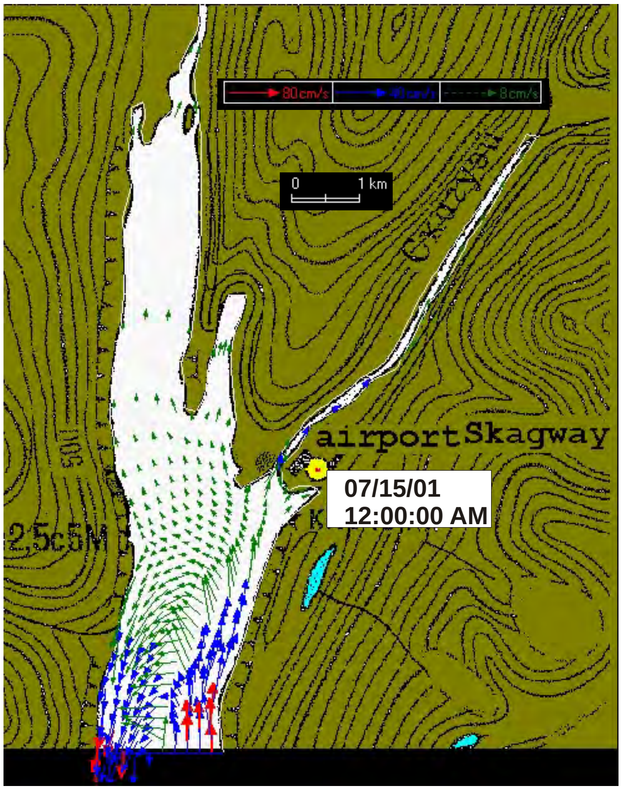


FIGURE 18O
Velocity pattern after four hours of stop of discharge from *Taku* at Skagway port and six hours of discharge from *Spirit of Oceanus*.

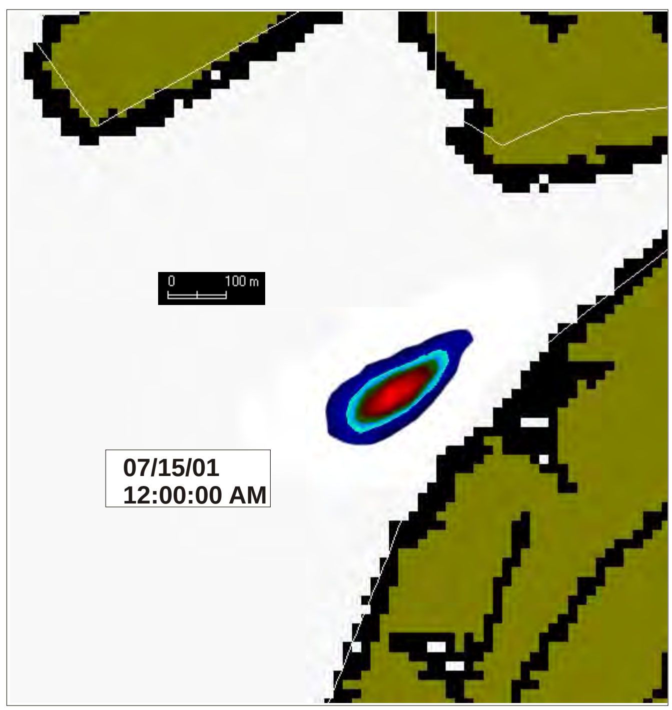
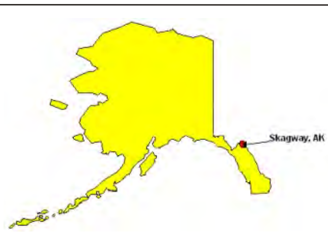


FIGURE 18P
Depth averaged *phosphorous* concentration (mg/m^3) after four hours of stop of discharge from *Taku* and six hours discharge from *Spirit of Oceanus*.

CONCENTRATION LEGEND

(red)	0.08 - 0.07
(dark brown)	0.07 - 0.06
(green)	0.05 - 0.04
(blue)	0.04 - 0.03
(aqua)	0.03 - 0.02
(navy)	0.01 - -1.44E-4



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ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

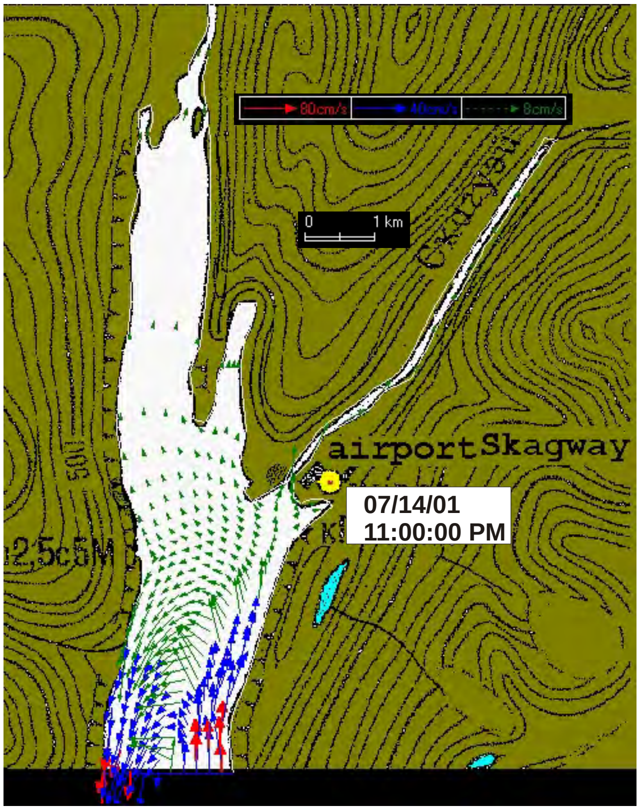


FIGURE 18M
Velocity pattern after three hours of stop of discharge from *Taku* at Skagway port and five hours of discharge from *Spirit of Oceanus*.

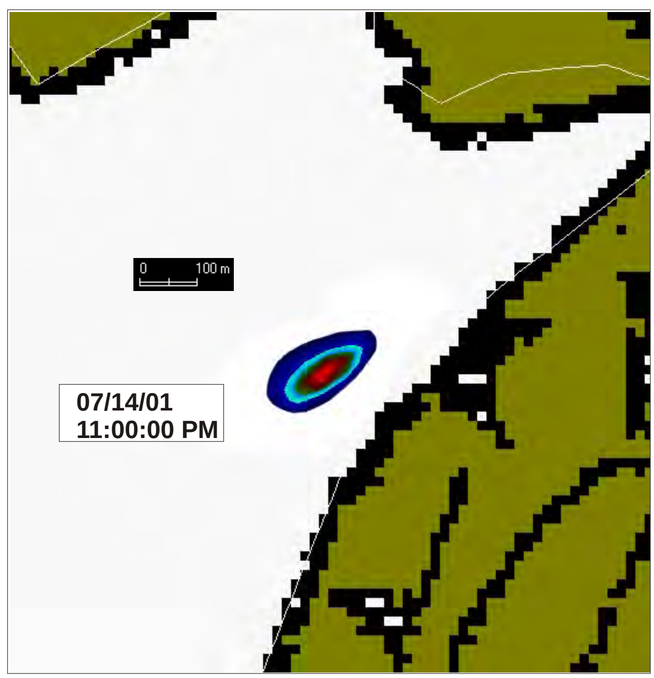
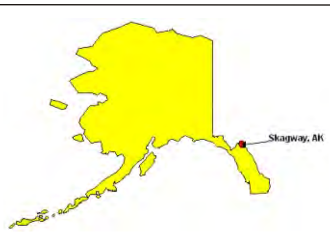


FIGURE 18N
Depth averaged *phosphorous* concentration (mg/m³) after three hours of stop of discharge from *Taku* and five hours discharge from *Spirit of Oceanus*.

CONCENTRATION LEGEND

- 0.11 - 0.08
- 0.07 - 0.06
- 0.06 - 0.05
- 0.05 - 0.03
- 0.02 - 0.01
- 0.01 - -0.64E-4



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ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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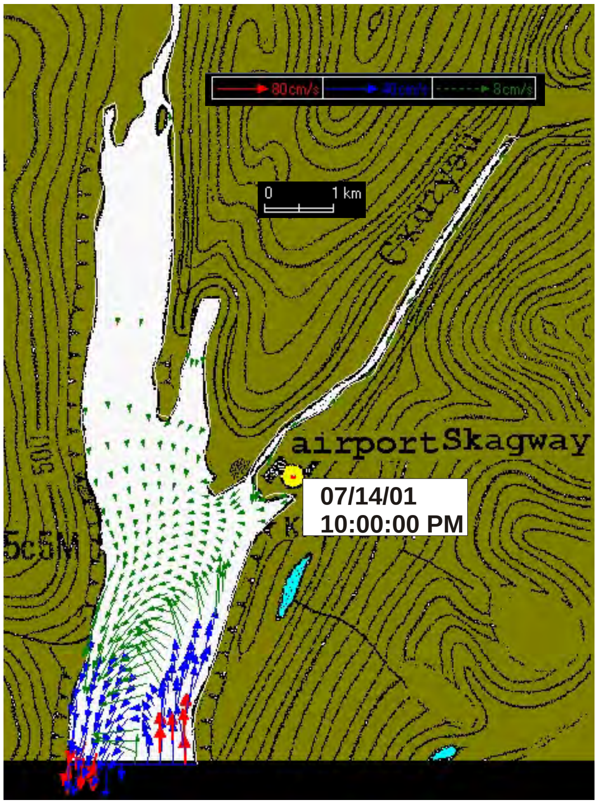


FIGURE 18K
Velocity pattern after two hours of stop of discharge from *Taku* at Skagway port and four hours of discharge from *Spirit of Oceanus*.

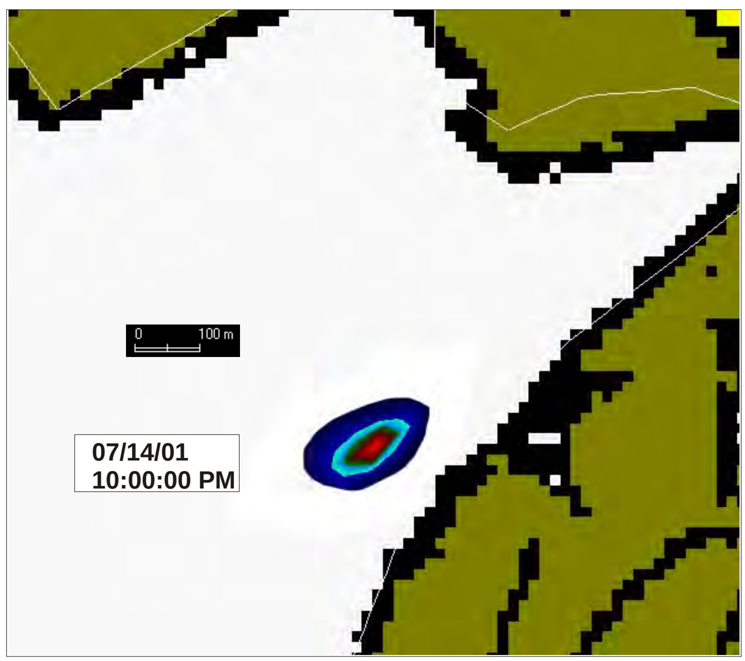
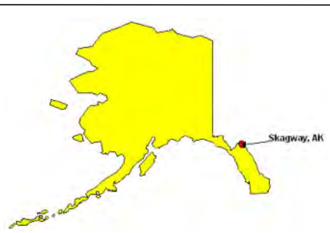


FIGURE 18L
Depth averaged *phosphorous* concentration (mg/m^3) after two hours of stop of discharge from *Taku* and four hours discharge from *Spirit of Oceanus*.

CONCENTRATION LEGEND

- 0.11 - 0.08
- 0.07 - 0.06
- 0.06 - 0.05
- 0.05 - 0.03
- 0.02 - 0.01
- 0.01 - -0.64E-4



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PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

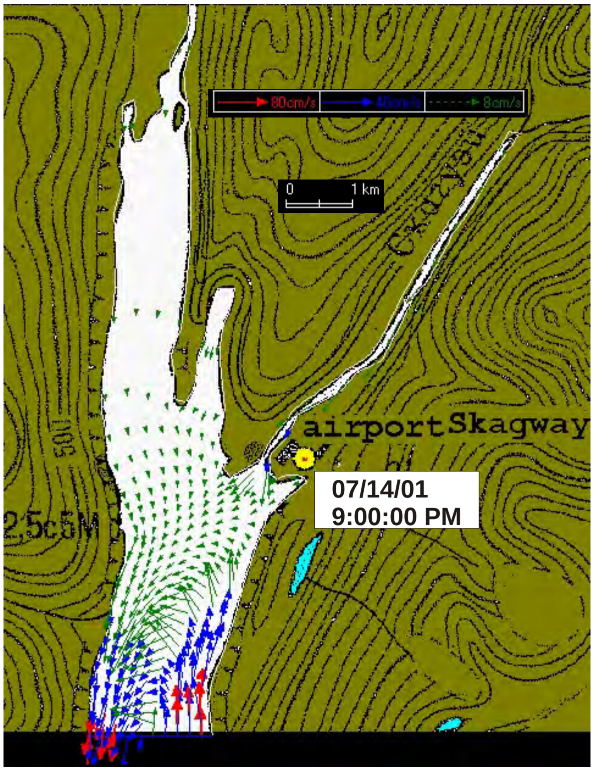


FIGURE 18I
Velocity pattern after one hour of stop of discharge from *Taku* at Skagway port and three hours of discharge from *Spirit of Oceanus*.

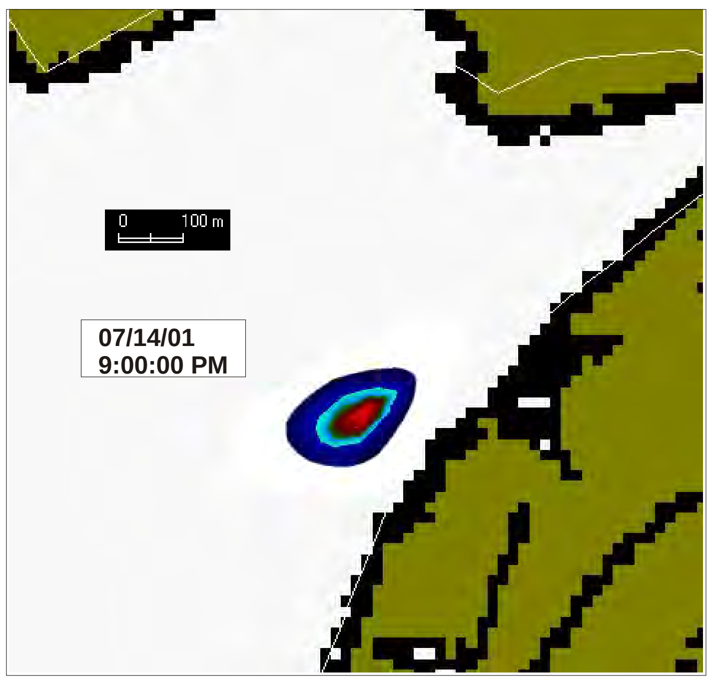
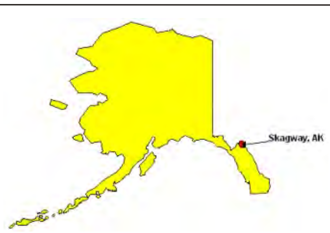


FIGURE 18J
Depth averaged *phosphorous* concentration (mg/m³) after one hour of stop of discharge from *Taku* and three hours discharge from *Spirit of Oceanus*.

CONCENTRATION LEGEND

Red	0.09 - 0.08
Dark brown	0.07 - 0.05
Green	0.04 - 0.03
Blue	0.03 - 0.02
Aqua	0.02 - 0.01
Dark blue	0.01 - -2.23E-5



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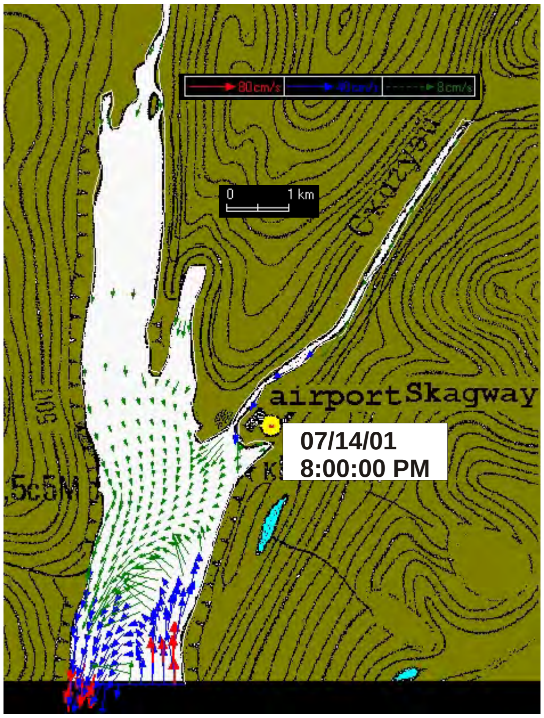
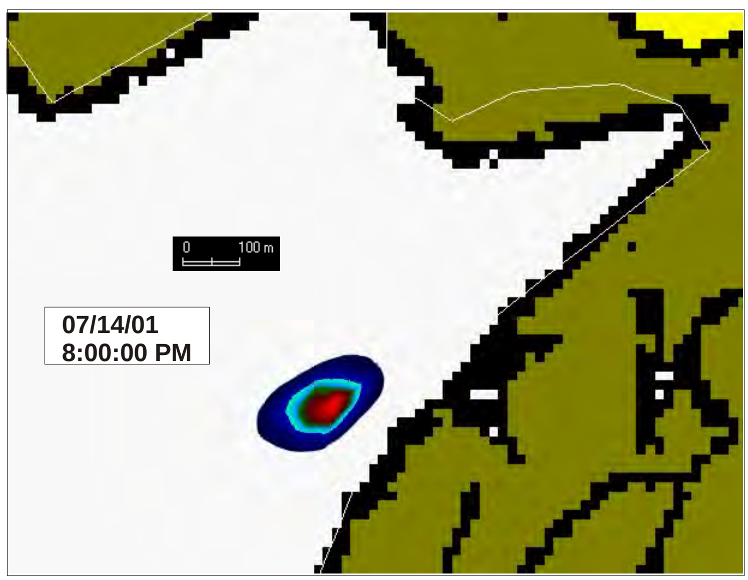


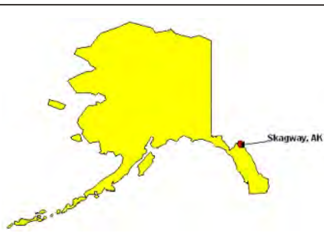
FIGURE 18G
Velocity pattern after four hours of start of discharge from *Taku* at Skagway port and two hours of discharge from *Spirit of Oceanus*.

FIGURE 18H
Depth averaged *phosphorous* concentration (mg/m^3) after four hours of discharge from *Taku* and two hours discharge from *Spirit of Oceanus*.

CONCENTRATION LEGEND

- 0.06 - 0.05
- 0.04 - 0.03
- 0.03 - 0.02
- 0.02 - 0.01
- 0.01 - 0.98E-2
- 0.97E-2 - -0.59E-4





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ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

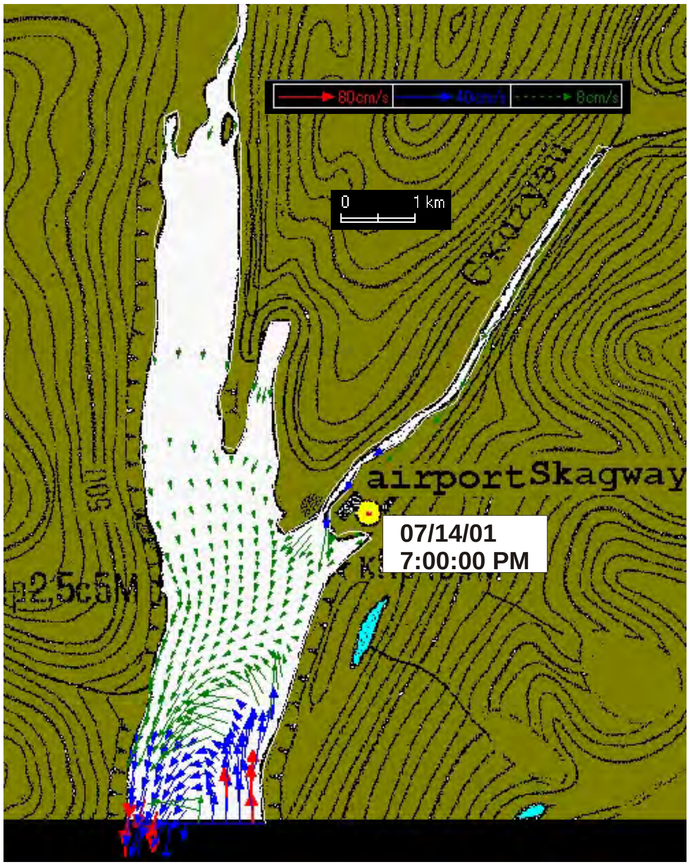
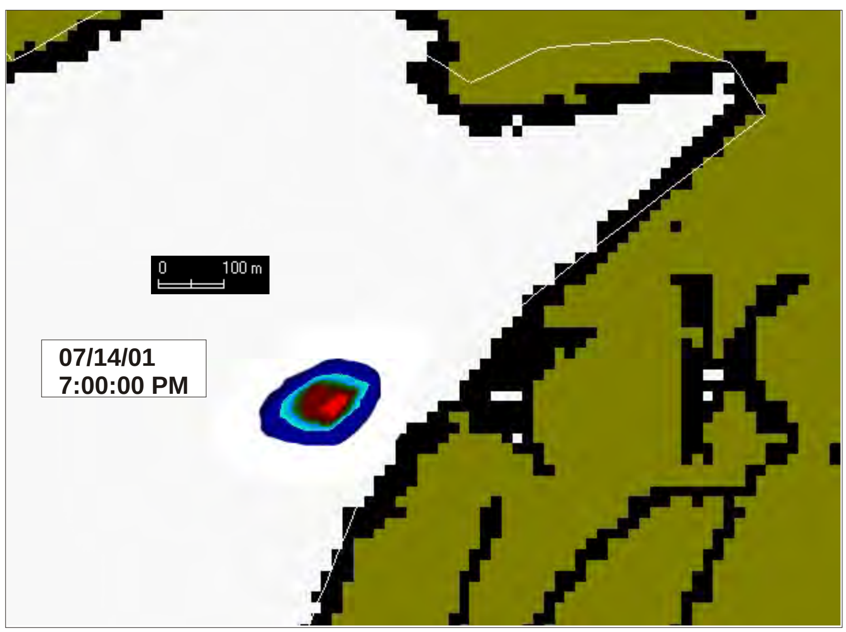
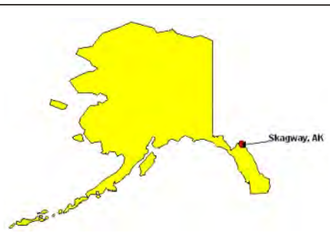


FIGURE 18E
Velocity pattern after three hours of start of discharge from *Taku* at Skagway port and one hour of discharge from *Spirit of Oceanus*.

FIGURE 18F
Depth averaged *phosphorous* concentration (mg/m^3) after three hours of discharge from *Taku* and one hour discharge from *Spirit of Oceanus*.

CONCENTRATION LEGEND	
(red)	0.04 - 0.03
(dark brown)	0.03 - 0.02
(dark green)	0.02 - 0.01
(blue)	0.01 - 0.99E-2
(aqua)	0.98E-2 - 0.71E-2
(dark blue)	0.70E-2 - -0.76E-5





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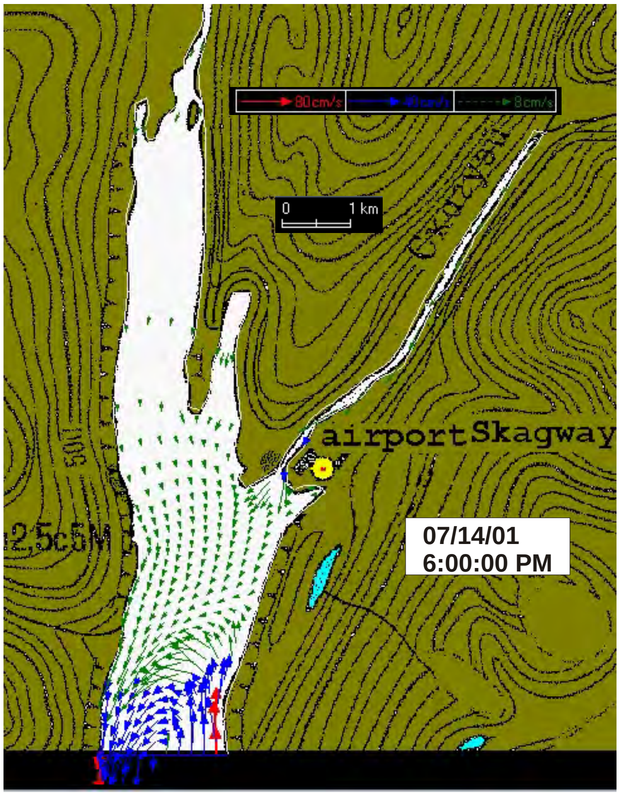


FIGURE 18C
Velocity pattern after two hours of start of discharge from *Taku* at Skagway port. *Spirit of Oceanus* starts discharging.

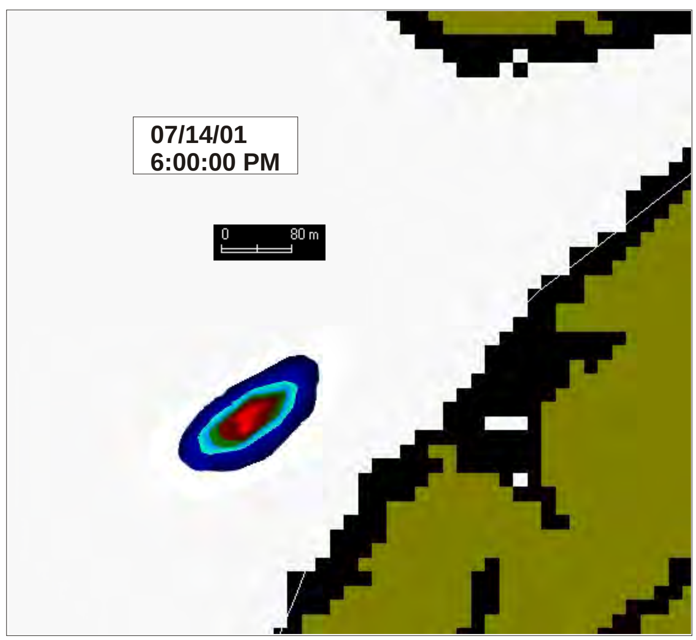
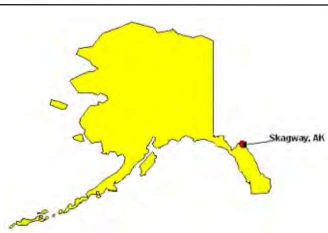


FIGURE 18D
Depth averaged *phosphorous* concentration (mg/m³) after two hours of discharge from *Taku*.

CONCENTRATION LEGEND

red	0.02 - 0.01
dark brown	0.01 - 0.99E-2
green	0.98E-2 - 0.87E-2
blue	0.88E-2 - 0.51E-2
aqua	0.50E-2 - 0.39E-2
navy	0.38E-2 - 1.65E-4



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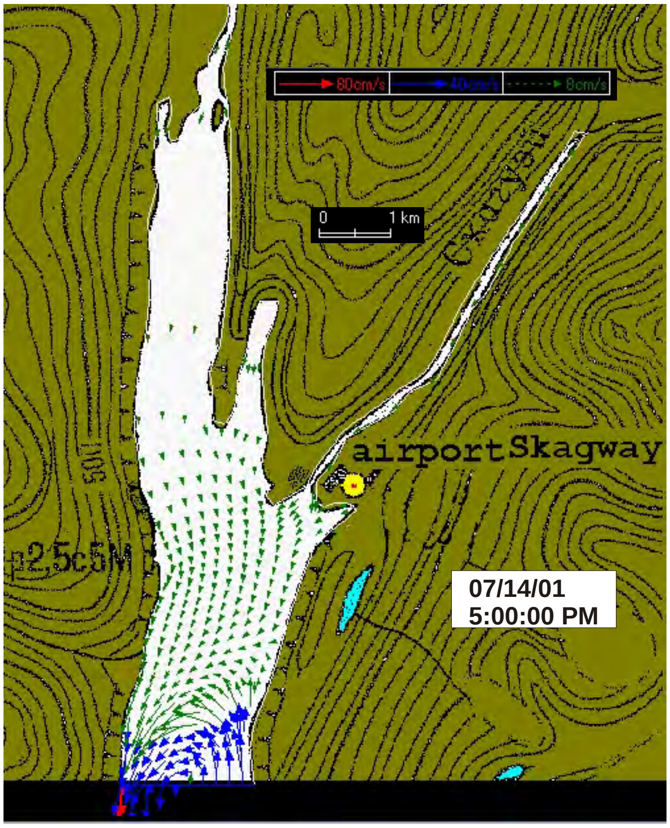


FIGURE 18A
Velocity pattern after one hour of start of discharge from *Taku* at Skagway port.

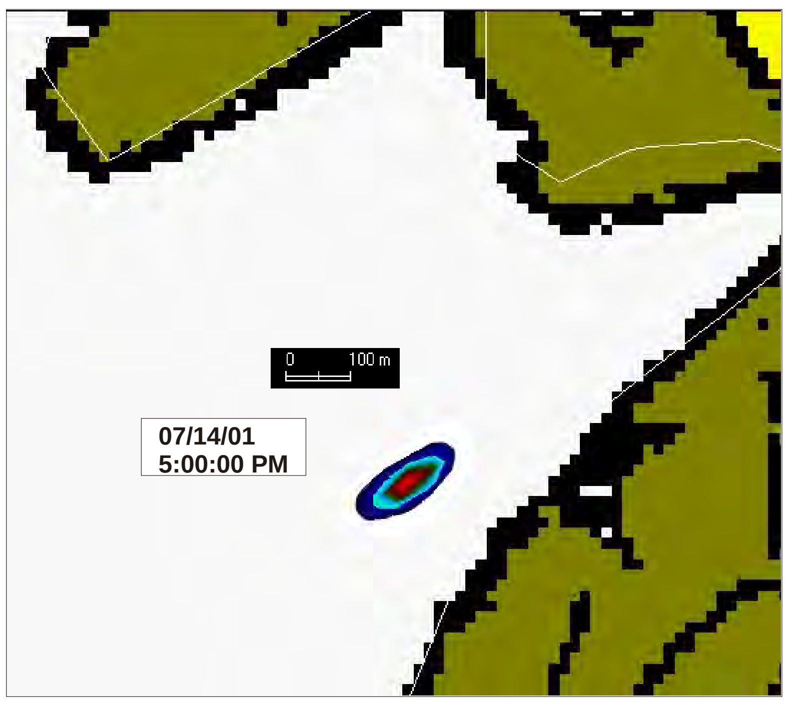
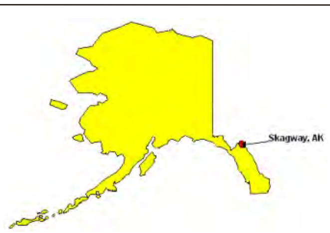


FIGURE 18B
Depth averaged *phosphorous* concentration (mg/m^3) after one hour of discharge from *Taku*.

CONCENTRATION LEGEND

(red)	0.01 - 0.74E-2
(dark brown)	0.73E-2 - 0.64E-2
(green)	0.63E-2 - 0.55E-2
(blue)	0.54E-2 - 0.37E-2
(aqua)	0.36E-2 - 3.05E-3
(navy)	3.04E-3 - -3.05E-6



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PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

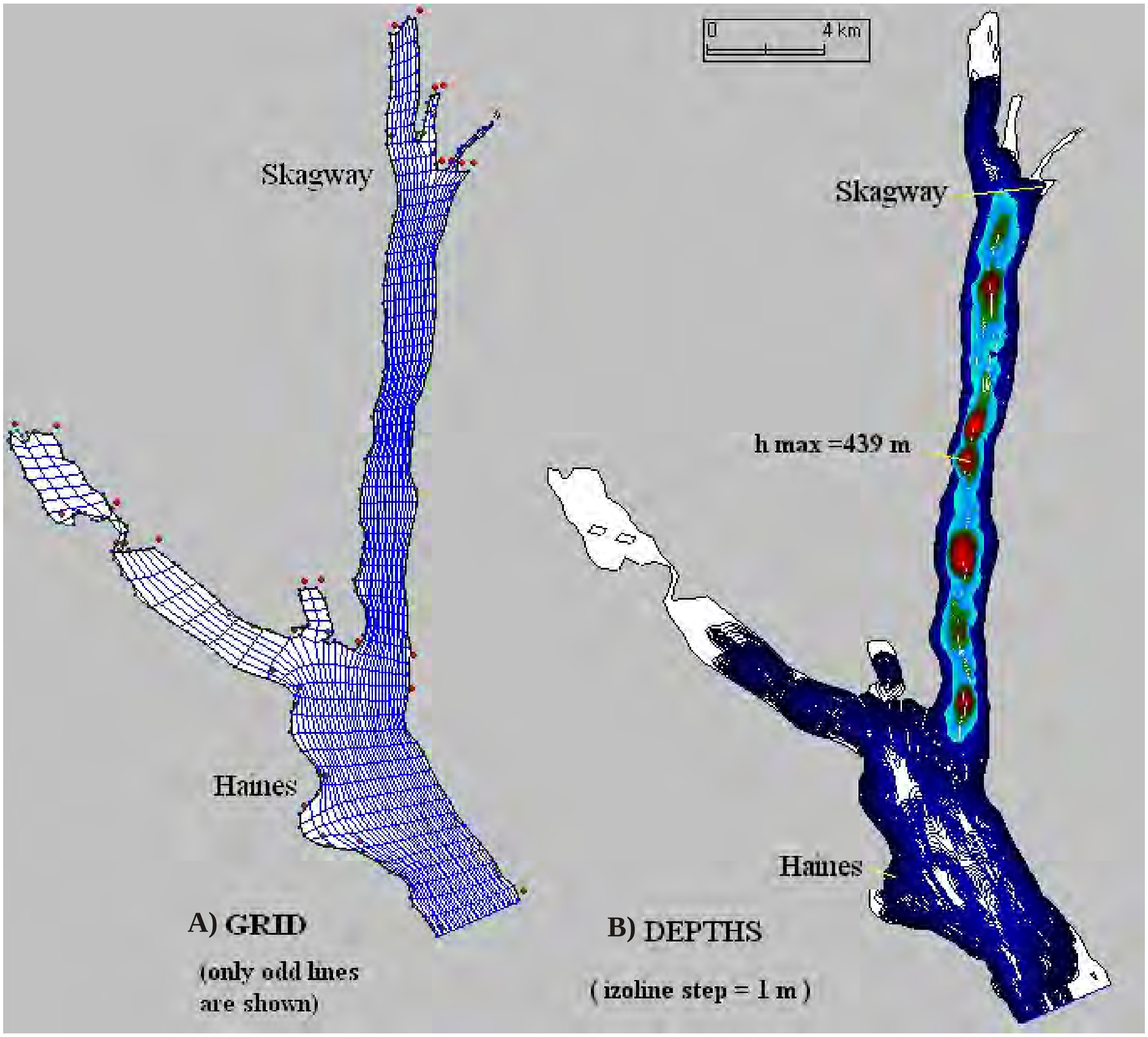
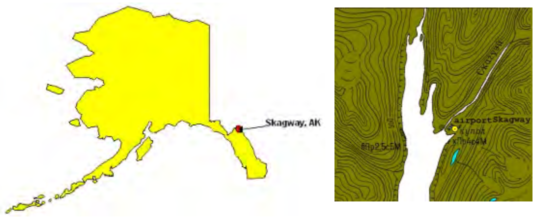


Figure 17
Computational grid and water depth in the Skagway-Haines model domain.



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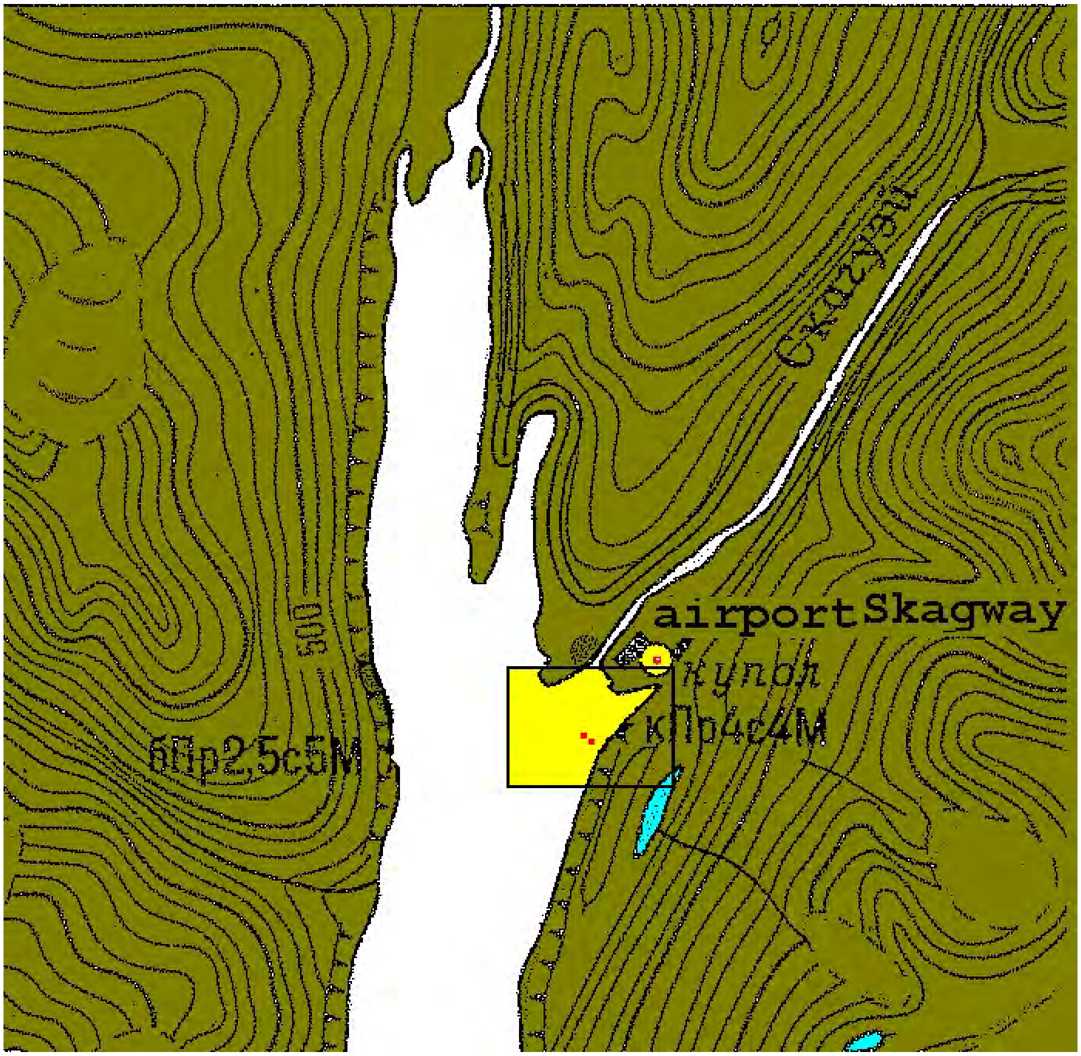
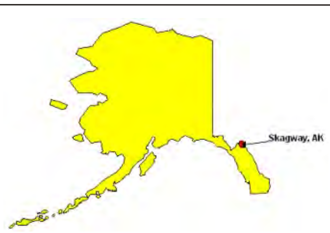
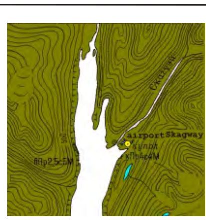


Figure 16
Computational area and location of ships
***Taku* and *Spirit of Oceanus* in Skagway.**





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PROJECT No. 001332.AU11.01 **JUNE 2003**

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

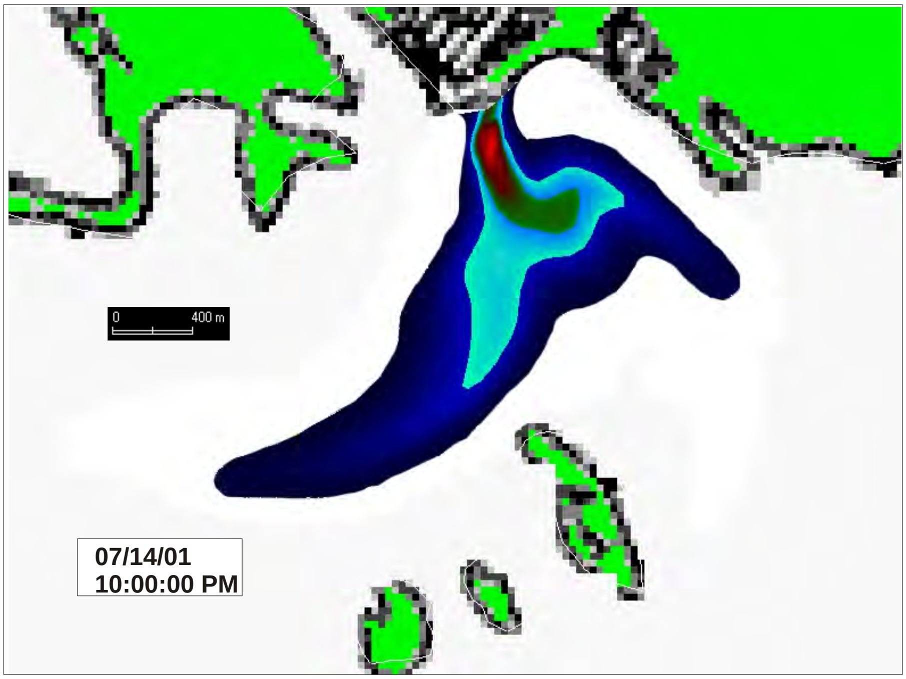


FIGURE 15K
Distribution of non degradable part of Chemical Oxygen Demand (NCOD) after twenty two hours of discharge from *Spirit of Columbia* at Sitka port and six hours of discharge from *Kennicott*.

CONCENTRATION mg/m3 LEGEND

- 0.99 - 0.73
- 0.72 - 0.63
- 0.62 - 0.50
- 0.49 - 0.39
- 0.38 - 0.29
- 0.28 - 0.02
- 0.01 - -3.15E-4

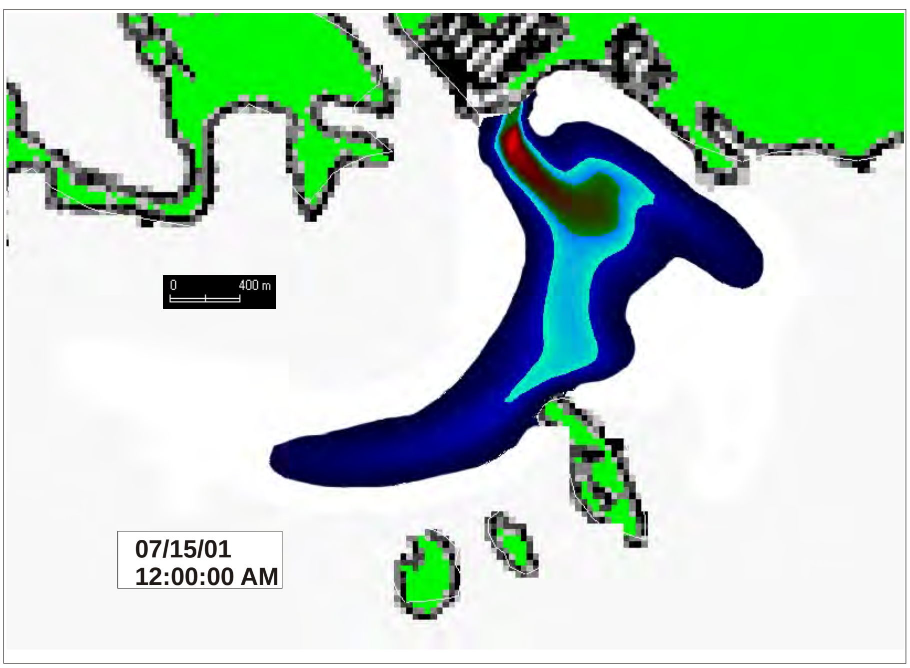
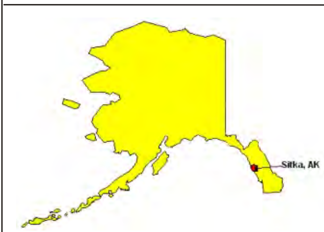


FIGURE 15L
Distribution of non degradable part of Chemical Oxygen Demand (NCOD) after twenty four hours of discharge from *Spirit of Columbia* at Sitka port and eight hours of discharge from *Kennicott*.

CONCENTRATION mg/m3 LEGEND

- 0.90 - 0.71
- 0.70 - 0.55
- 0.54 - 0.46
- 0.45 - 0.34
- 0.33 - 0.28
- 0.27 - 0.02
- 0.01 - -2.17E-4



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GRAPHICAL REPRESENTATION OF MODEL RESULTS
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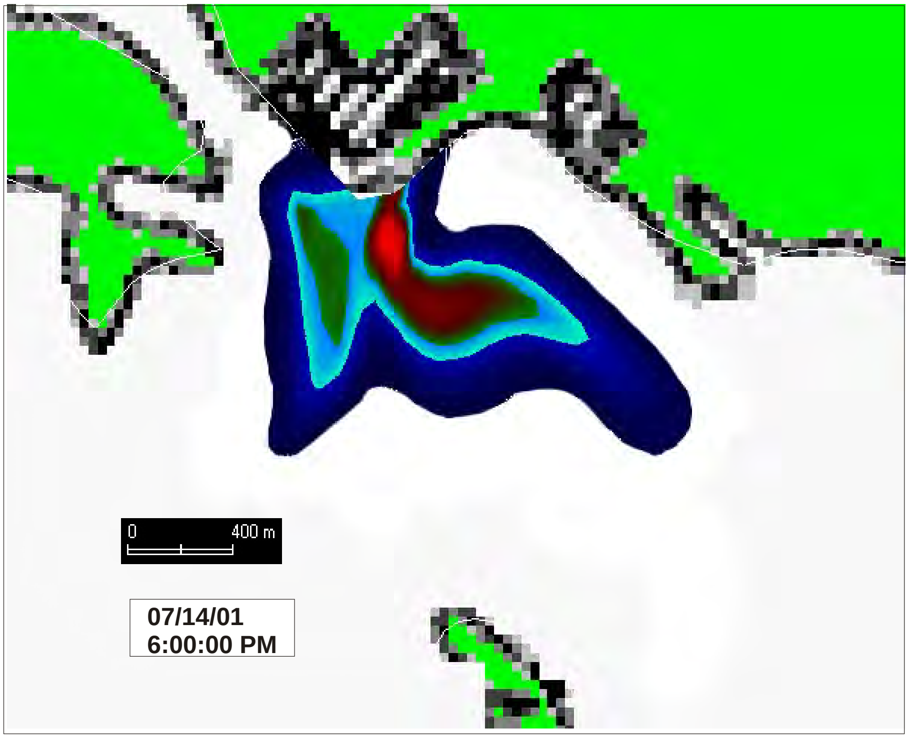


FIGURE 15I
Distribution of non degradable part of Chemical Oxygen Demand (NCOD) after eighteen hours of discharge from *Spirit of Columbia* at Sitka port and two hours of discharge from *Kennicott*.

CONCENTRATION mg/m3 LEGEND

- 0.77 - 0.55
- 0.54 - 0.46
- 0.45 - 0.37
- 0.38 - 0.27
- 0.28 - 0.18
- 0.17 - 0.02
- 0.01 - -2.12E-4

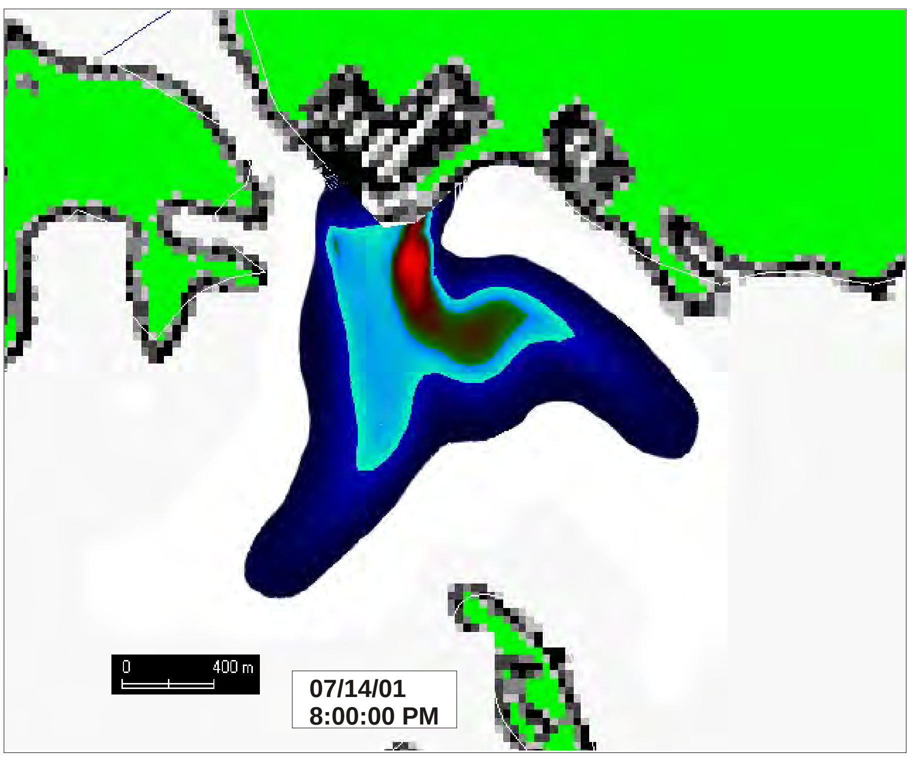
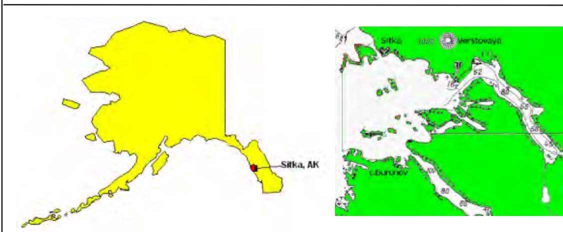


FIGURE 15J
Distribution of non degradable part of Chemical Oxygen Demand (NCOD) after twenty hours of discharge from *Spirit of Columbia* at Sitka port and four hours of discharge from *Kennicott*.

CONCENTRATION mg/m3 LEGEND

- 0.88 - 0.74
- 0.75 - 0.53
- 0.52 - 0.46
- 0.45 - 0.36
- 0.35 - 0.29
- 0.28 - 0.03
- 0.02 - -2.35E-4



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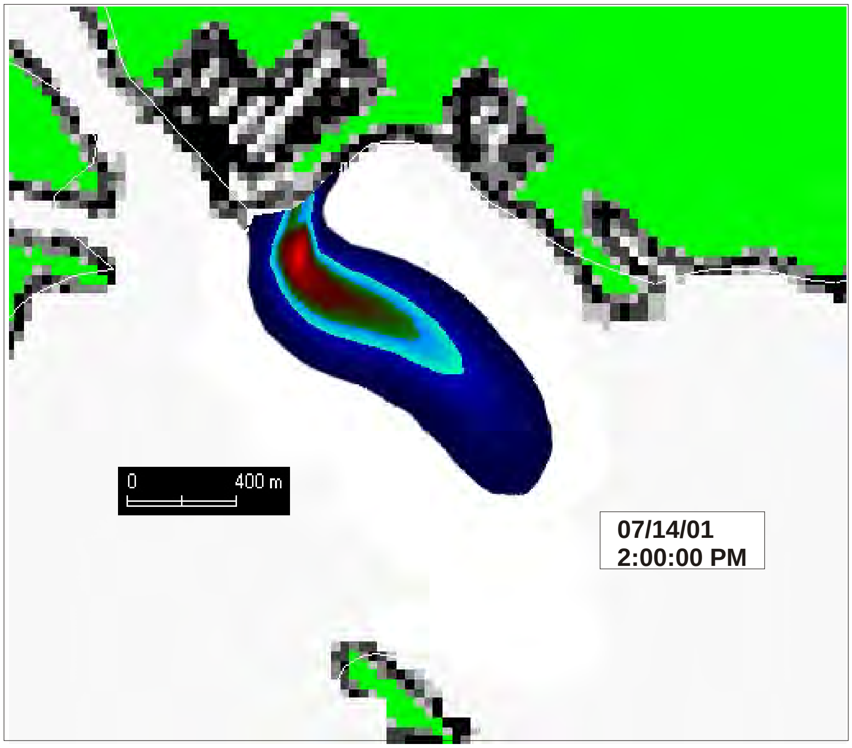


FIGURE 15G
Distribution of non degradable part of Chemical Oxygen Demand (NCOD) after fourteen hours of discharge from *Spirit of Columbia* at Sitka port.

CONCENTRATION mg/m3 LEGEND

- 0.87 - 0.62
- 0.61 - 0.53
- 0.52 - 0.44
- 0.43 - 0.34
- 0.33 - 0.27
- 0.26 - 0.04
- 0.03 - -1.22E-4

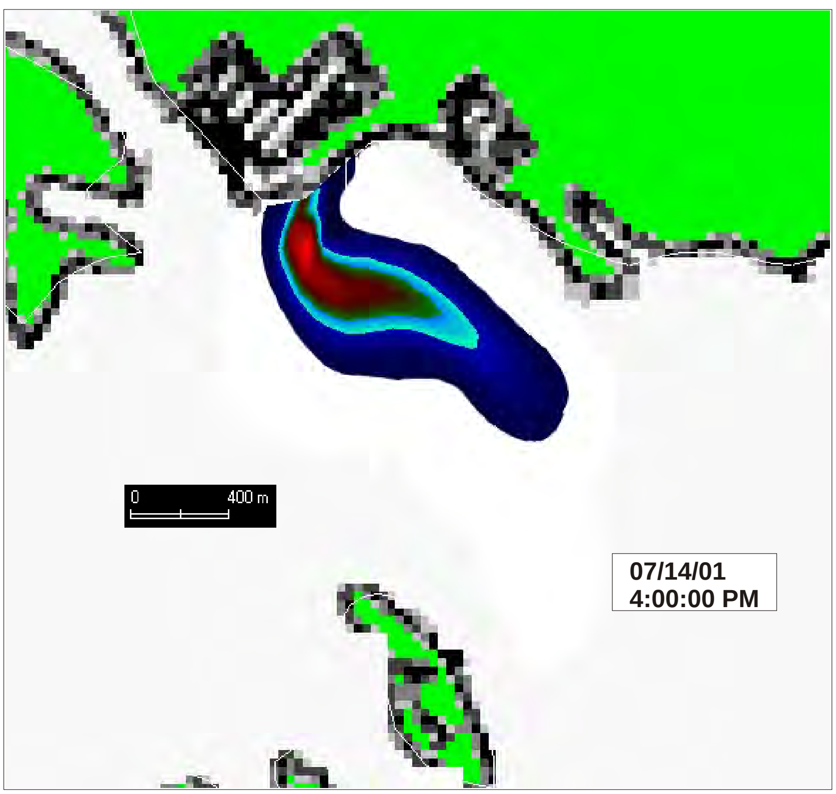
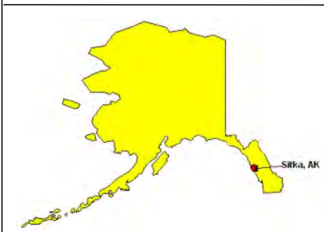


FIGURE 15H
Distribution of non degradable part of Chemical Oxygen Demand (NCOD) after sixteen hours of discharge from *Spirit of Columbia* at Sitka port. *Kennicott* starts discharging.

CONCENTRATION mg/m3 LEGEND

- 0.78 - 0.59
- 0.58 - 0.46
- 0.44 - 0.37
- 0.36 - 0.26
- 0.25 - 0.19
- 0.18 - 0.03
- 0.02 - -2.19E-4



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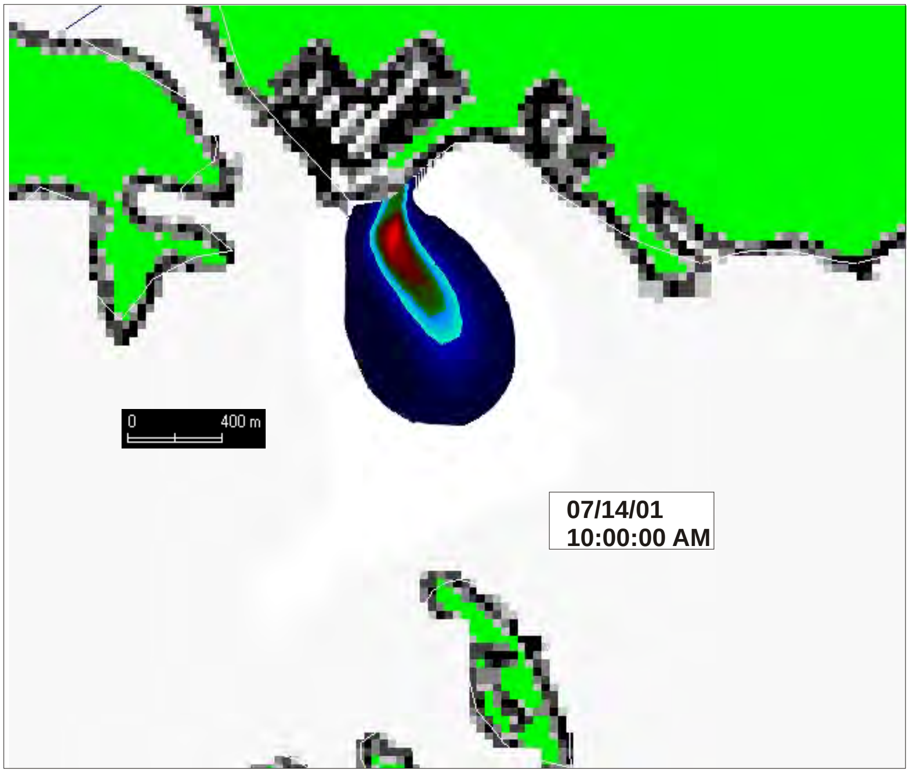


FIGURE 15E
Distribution of non degradable part of Chemical Oxygen Demand (NCOD) after ten hours of discharge from *Spirit of Columbia* at Sitka port.

CONCENTRATION mg/m3 LEGEND

Red	0.86 - 0.62
Dark maroon	0.61 - 0.53
Dark green	0.52 - 0.43
Blue	0.42 - 0.34
Cyan	0.33 - 0.29
Navy	0.28 - 0.06
Black	0.05 - -2.11E-4

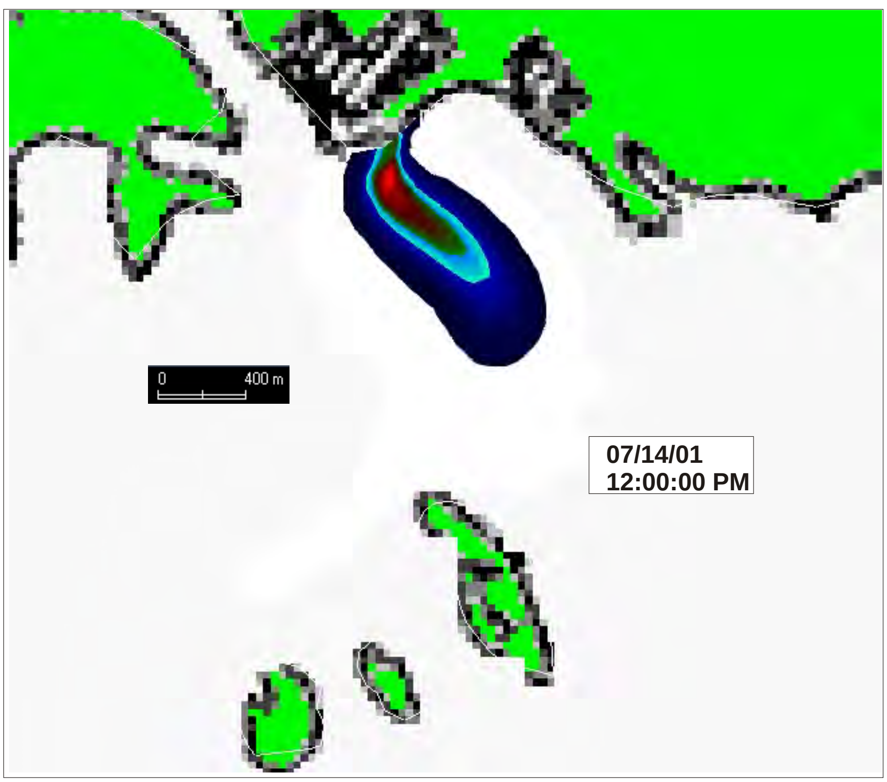
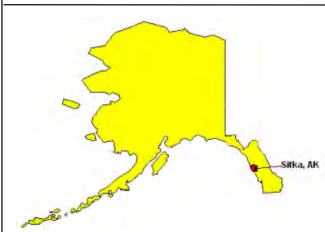


FIGURE 15F
Distribution of non degradable part of Chemical Oxygen Demand (NCOD) after twelve hours of discharge from *Spirit of Columbia* at Sitka port.

CONCENTRATION mg/m3 LEGEND

Red	0.83 - 0.59
Dark maroon	0.58 - 0.48
Dark green	0.47 - 0.40
Blue	0.39 - 0.33
Cyan	0.32 - 0.22
Navy	0.21 - 0.02
Black	0.01 - -2.1E-4



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PROJECT No. 001332.AU11.01 — JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

FIGURE 15C
Distribution of non degradable part of Chemical Oxygen Demand (NCOD) after six hours of discharge from *Spirit of Columbia* at Sitka port.

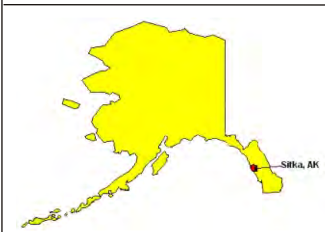
CONCENTRATION mg/m3 LEGEND

Red	0.81 - 0.74
Dark maroon	0.73 - 0.49
Dark green	0.48 - 0.35
Blue	0.34 - 0.28
Turquoise	0.27 - 0.26
Navy	0.25 - 0.04
Black	0.03 - -1.18E-4

FIGURE 15D
Distribution of non degradable part of Chemical Oxygen Demand (NCOD) after eight hours of discharge from *Spirit of Columbia* at Sitka port.

CONCENTRATION mg/m3 LEGEND

Red	0.87 - 0.64
Dark maroon	0.63 - 0.44
Dark green	0.45 - 0.39
Blue	0.38 - 0.30
Turquoise	0.29 - 0.27
Navy	0.26 - 0.04
Black	0.03 - -1.31E-4



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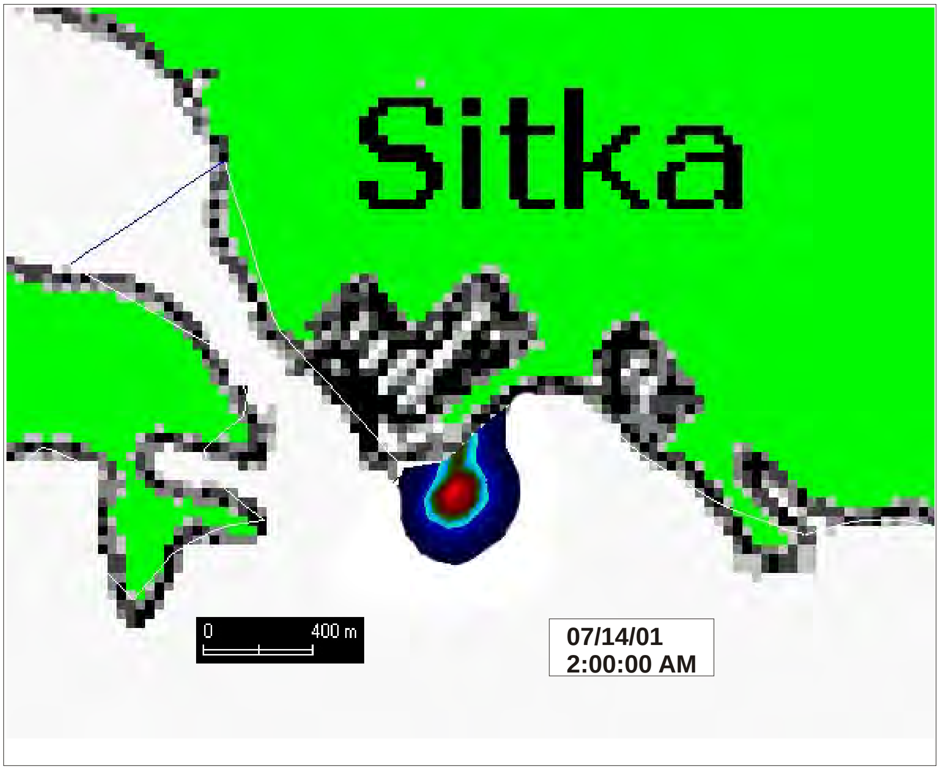
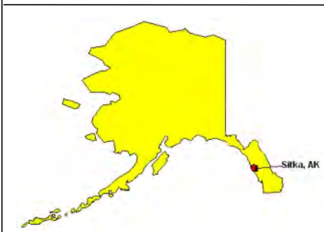


FIGURE 15A
Distribution of non degradable part of Chemical Oxygen Demand (NCOD) after two hours of discharge from *Spirit of Columbia* at Sitka port.

CONCENTRATION mg/m3 LEGEND	
Red	0.44 - 0.36
Dark brown	0.35 - 0.20
Dark green	0.19 - 0.17
Blue	0.16 - 0.15
Cyan	0.14 - 0.10
Navy	0.09 - 0.03
Black	0.02 - -1.3E-3

FIGURE 15B
Distribution of non degradable part of Chemical Oxygen Demand (NCOD) after four hours of discharge from *Spirit of Columbia* at Sitka port.

CONCENTRATION mg/m3 LEGEND	
Red	0.66 - 0.50
Dark brown	0.49 - 0.40
Dark green	0.39 - 0.25
Blue	0.24 - 0.23
Cyan	0.22 - 0.18
Navy	0.17 - 0.03
Black	0.02 - -1.01E-4



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ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

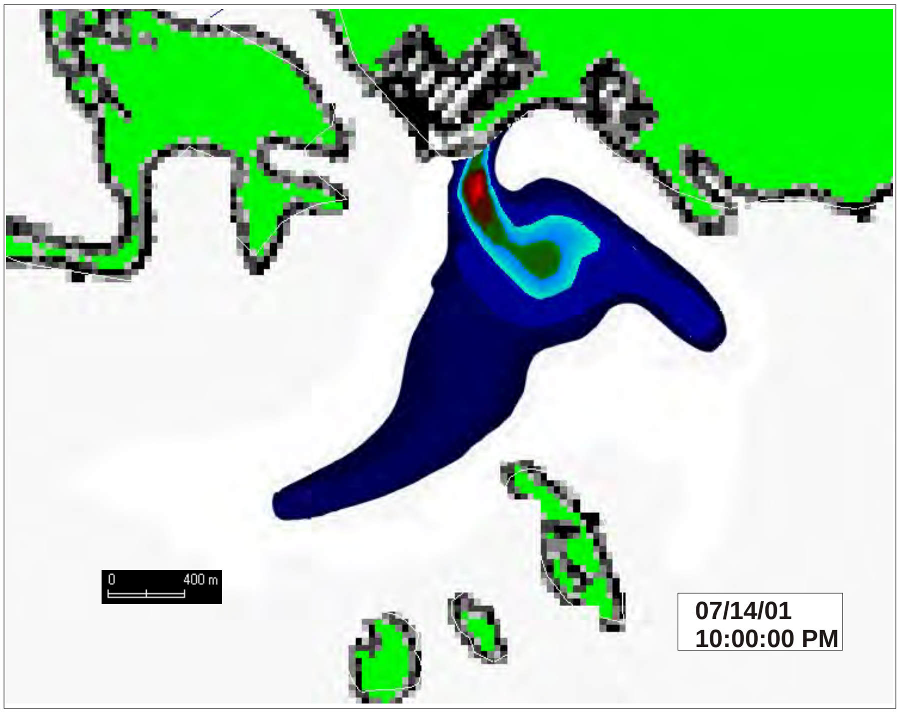


FIGURE 14K
Distribution of degradable part of Chemical Oxygen Demand (DCOD) after twenty two hours of discharge from *Spirit of Columbia* at Sitka port and six hours of discharge from *Kennicott*.

CONCENTRATION mg/m3 LEGEND
0.14 - 0.12
0.12 - 0.10
0.10 - 0.08
0.08 - 0.06
0.06 - 0.04
0.04 - 0.01
0.01 - 0.001

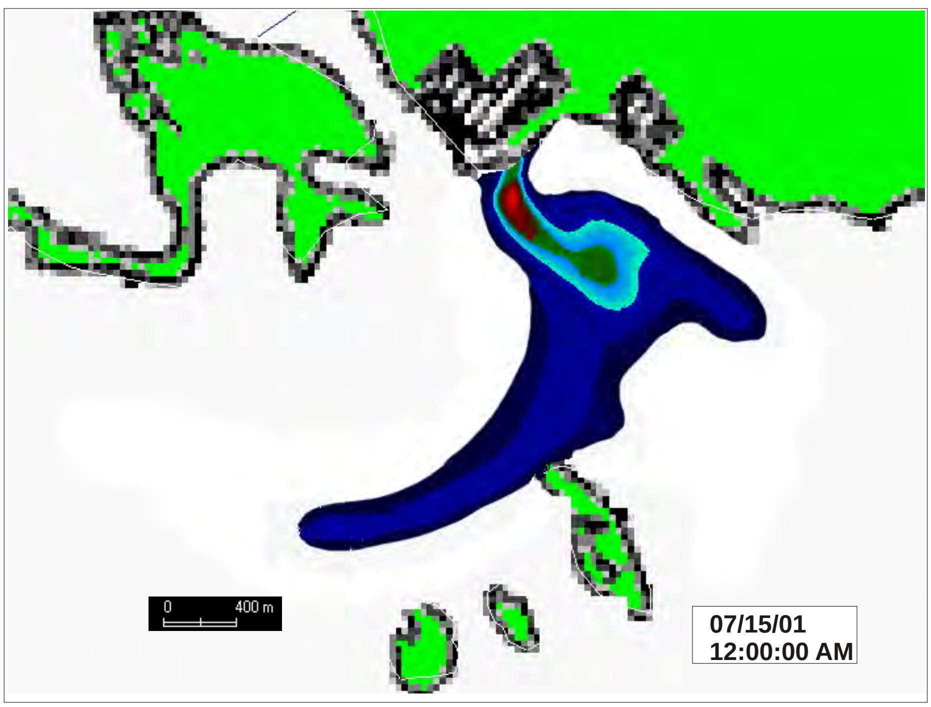
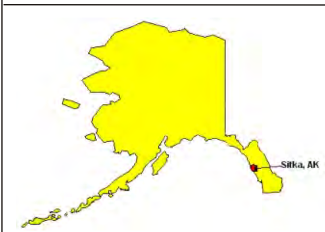


FIGURE 14L
Distribution of degradable part of Chemical Oxygen Demand (DCOD) after twenty four hours of discharge from *Spirit of Columbia* at Sitka port and eight hours of discharge from *Kennicott*.

CONCENTRATION mg/m3 LEGEND
0.14 - 0.12
0.12 - 0.10
0.10 - 0.08
0.08 - 0.06
0.06 - 0.04
0.04 - 0.01
0.01 - 0.001



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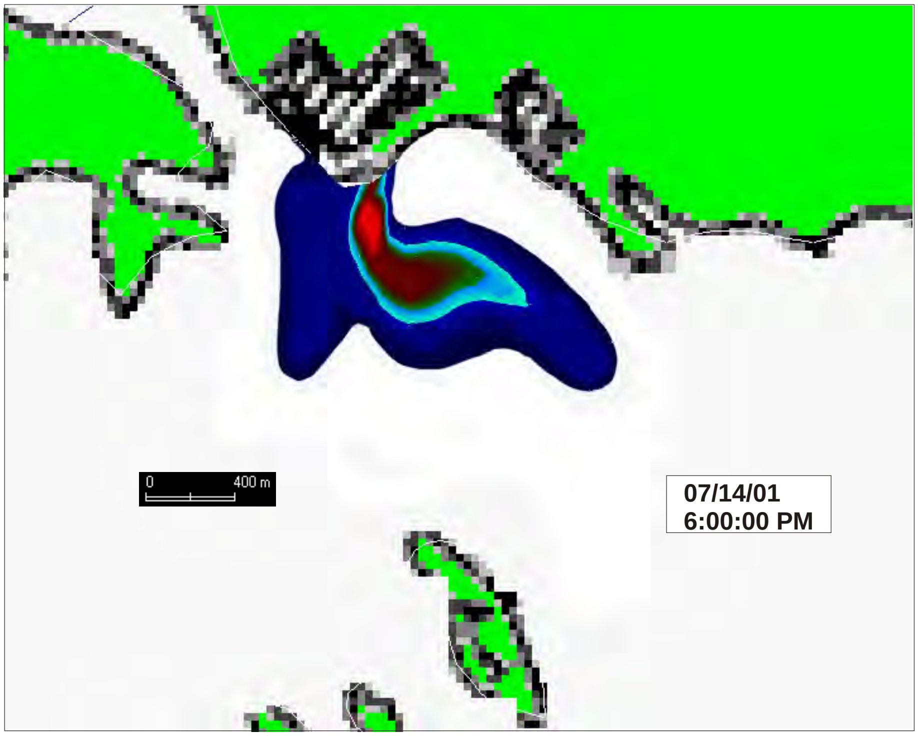


FIGURE 14I
Distribution of degradable part of Chemical Oxygen Demand (DCOD) after eighteen hours of discharge from *Spirit of Columbia* at Sitka port and two hours of discharge from *Kennicott*.

CONCENTRATION mg/m3 LEGEND

- 0.12 - 0.10
- 0.10 - 0.08
- 0.08 - 0.06
- 0.06 - 0.05
- 0.05 - 0.03
- 0.03 - 0.01
- 0.01 - 0.001

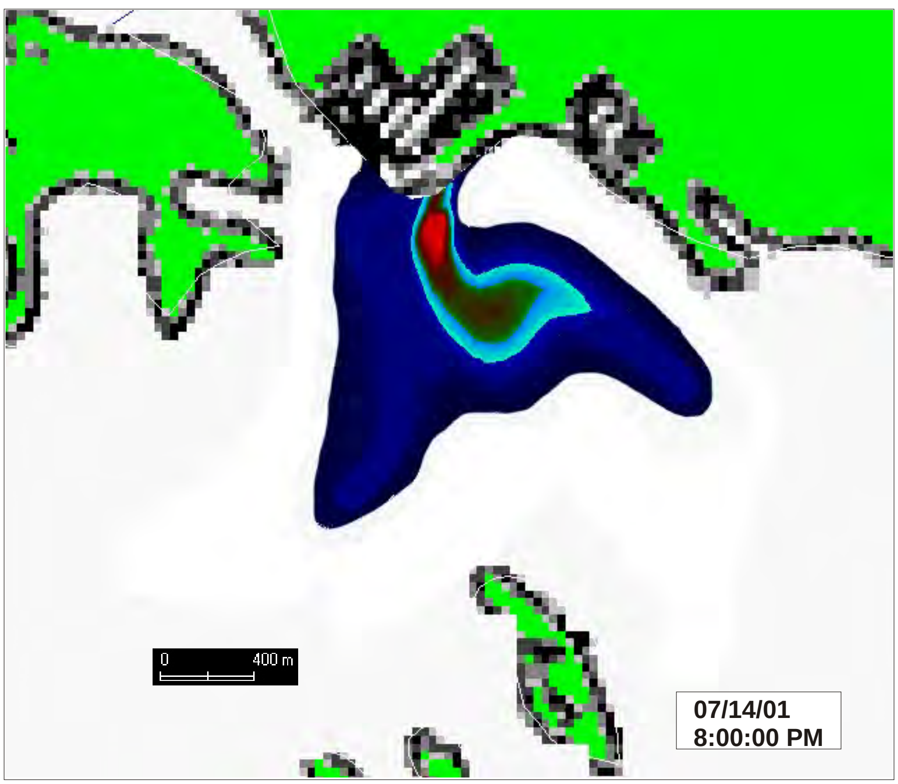
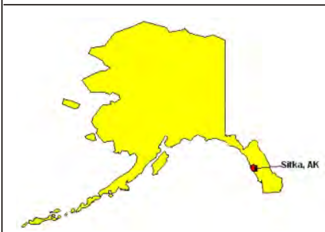


FIGURE 14J
Distribution of degradable part of Chemical Oxygen Demand (DCOD) after twenty hours of discharge from *Spirit of Columbia* at Sitka port and four hours of discharge from *Kennicott*.

CONCENTRATION mg/m3 LEGEND

- 0.13 - 0.10
- 0.10 - 0.08
- 0.08 - 0.06
- 0.06 - 0.05
- 0.05 - 0.03
- 0.03 - 0.01
- 0.01 - 0.001



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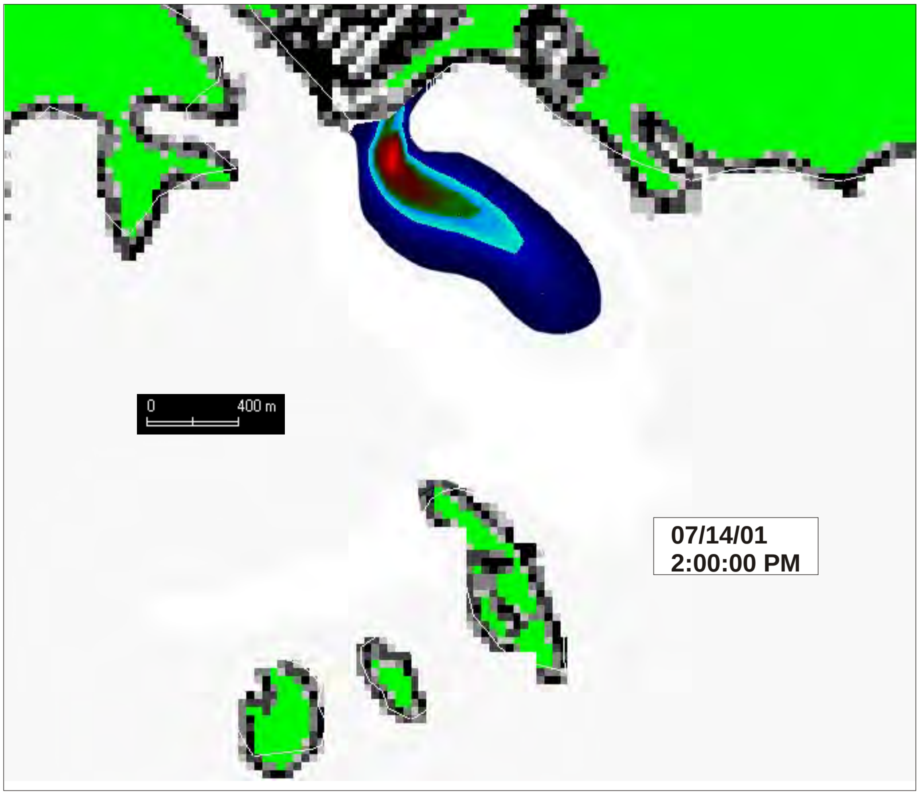


FIGURE 14G
Distribution of degradable part of Chemical Oxygen Demand (DCOD) after fourteen hours of discharge from *Spirit of Columbia* at Sitka port.

CONCENTRATION mg/m3 LEGEND

Red	0.14 - 0.11
Dark red	0.11 - 0.10
Dark green	0.10 - 0.07
Blue	0.07 - 0.05
Cyan	0.05 - 0.03
Dark blue	0.03 - 0.01
Black	0.01 - 0.001

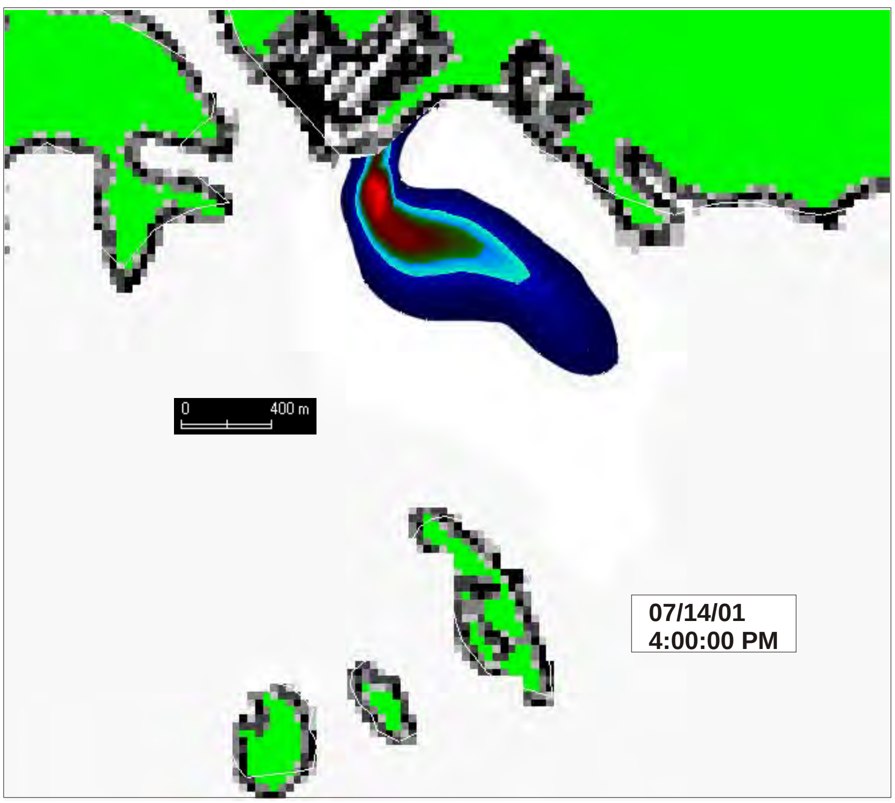
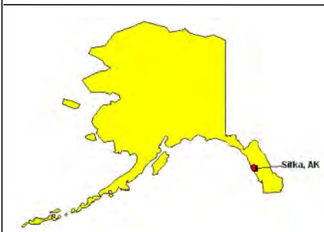
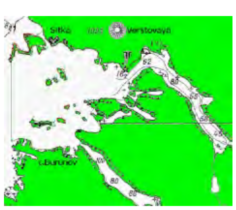


FIGURE 14H
Distribution of degradable part of Chemical Oxygen Demand (DCOD) after sixteen hours of discharge from *Spirit of Columbia* at Sitka port. *Kennicott* starts discharging.

CONCENTRATION mg/m3 LEGEND

Red	0.12 - 0.10
Dark red	0.10 - 0.07
Dark green	0.07 - 0.06
Blue	0.06 - 0.05
Cyan	0.05 - 0.04
Dark blue	0.04 - 0.01
Black	0.01 - 0.001





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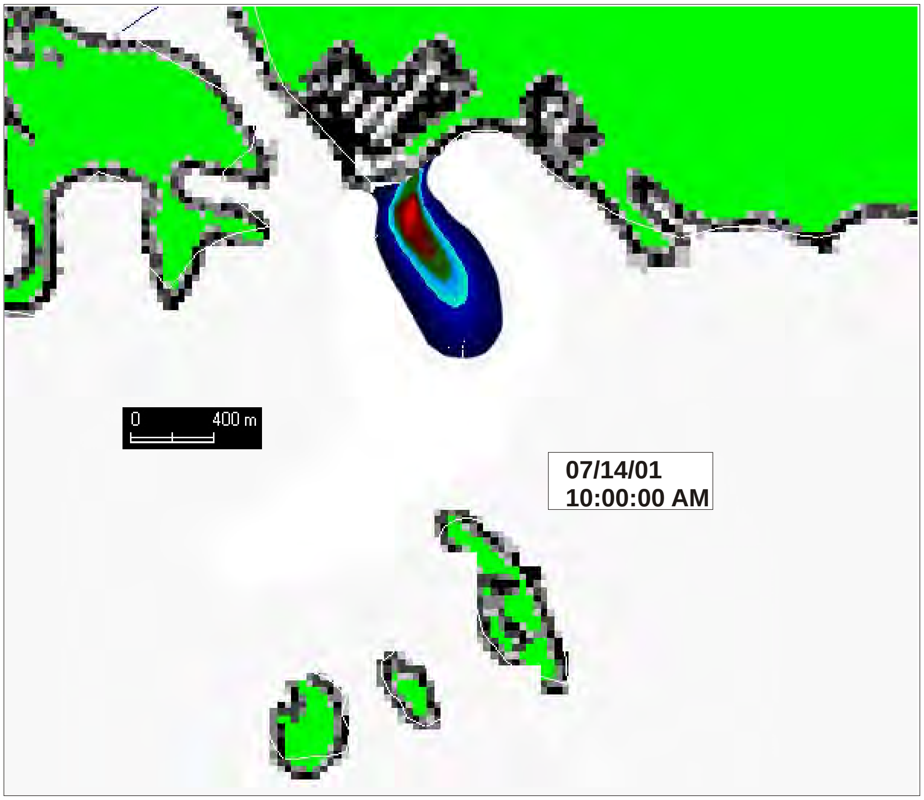


FIGURE 14E
Distribution of degradable part of Chemical Oxygen Demand (DCOD) after ten hours of discharge from *Spirit of Columbia* at Sitka port.

CONCENTRATION mg/m3 LEGEND

- 0.14 - 0.13
- 0.13 - 0.10
- 0.10 - 0.07
- 0.07 - 0.06
- 0.06 - 0.05
- 0.05 - 0.01
- 0.01 - 0.001

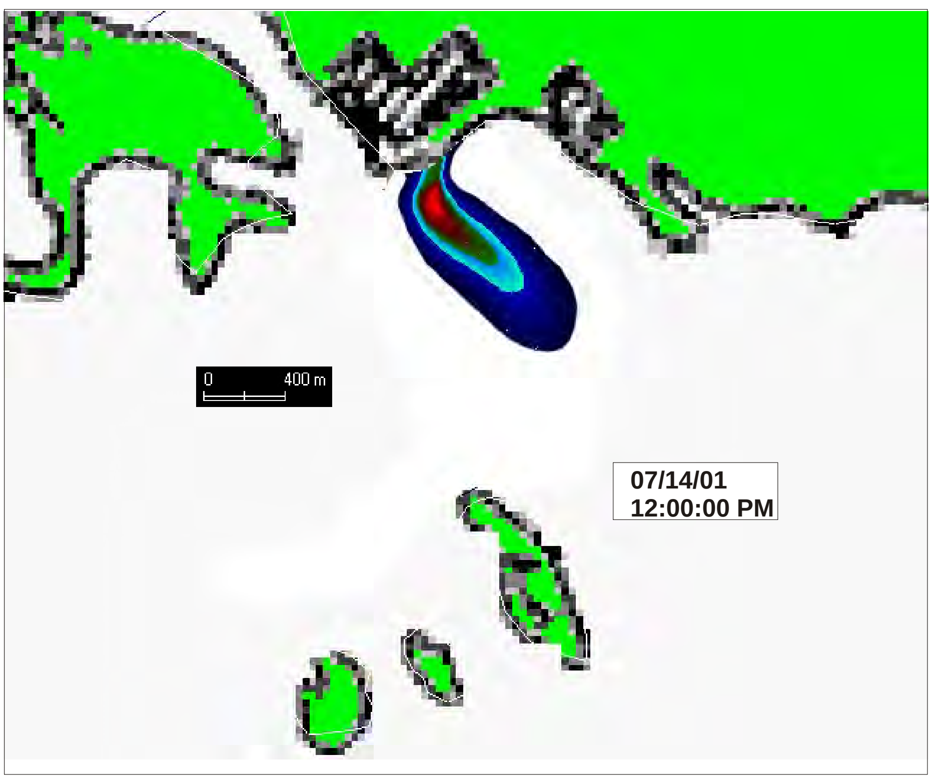
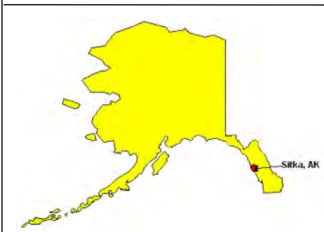


FIGURE 14F
Distribution of degradable part of Chemical Oxygen Demand (DCOD) after twelve hours of discharge from *Spirit of Columbia* at Sitka port.

CONCENTRATION mg/m3 LEGEND

- 0.13
- 0.13 - 0.10
- 0.10 - 0.07
- 0.07 - 0.05
- 5.06 - 0.03
- 0.03 - 0.01
- 0.01 - 0.001



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ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

FIGURE 14C
Distribution of degradable part of Chemical Oxygen Demand (DCOD) after six hours of discharge from *Spirit of Columbia* at Sitka port.

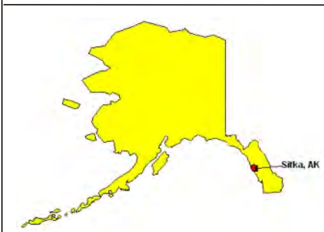
CONCENTRATION mg/m3 LEGEND

- 0.14 - 0.13
- 0.13 - 0.10
- 0.10 - 0.07
- 0.07 - 0.06
- 0.06 - 0.05
- 0.05 - 0.01
- 0.01 - 0.001

FIGURE 14D
Distribution of degradable part of Chemical Oxygen Demand (DCOD) after eight hours of discharge from *Spirit of Columbia* at Sitka port.

CONCENTRATION mg/m3 LEGEND

- 0.14 - 0.13
- 0.13 - 0.10
- 0.10 - 0.07
- 0.07 - 0.06
- 0.06 - 0.05
- 0.05 - 0.01
- 0.01 - 0.001



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PROJECT No. 001332.AU11.01 JUNE 2003

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ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

FIGURE 14A
Distribution of degradable part
of Chemical Oxygen Demand (DCOD)
after two hours of discharge from
Spirit of Columbia at Sitka port.

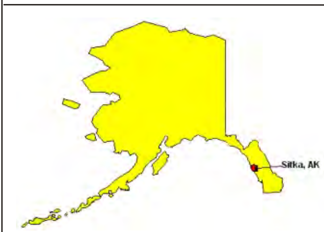
CONCENTRATION mg/m3 LEGEND

Red	0.07 - 0.5
Dark red	0.1 - 0.07
Dark green	0.05 - 0.03
Blue	0.06 - 0.05
Cyan	0.05 - 0.04
Navy	0.03 - 0.01
Black	0.01 - 0.001

FIGURE 14B
Distribution of degradable part
of Chemical Oxygen Demand (DCOD)
after four hours of discharge from
Spirit of Columbia at Sitka port.

CONCENTRATION mg/m3 LEGEND

Red	0.11 - 0.1
Dark red	0.1 - 0.07
Dark green	0.07 - 0.06
Blue	0.06 - 0.05
Cyan	0.05 - 0.04
Navy	0.04 - 0.01
Black	0.01 - 0.001



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PROJECT No. 001332.AU11.01 JUNE 2003

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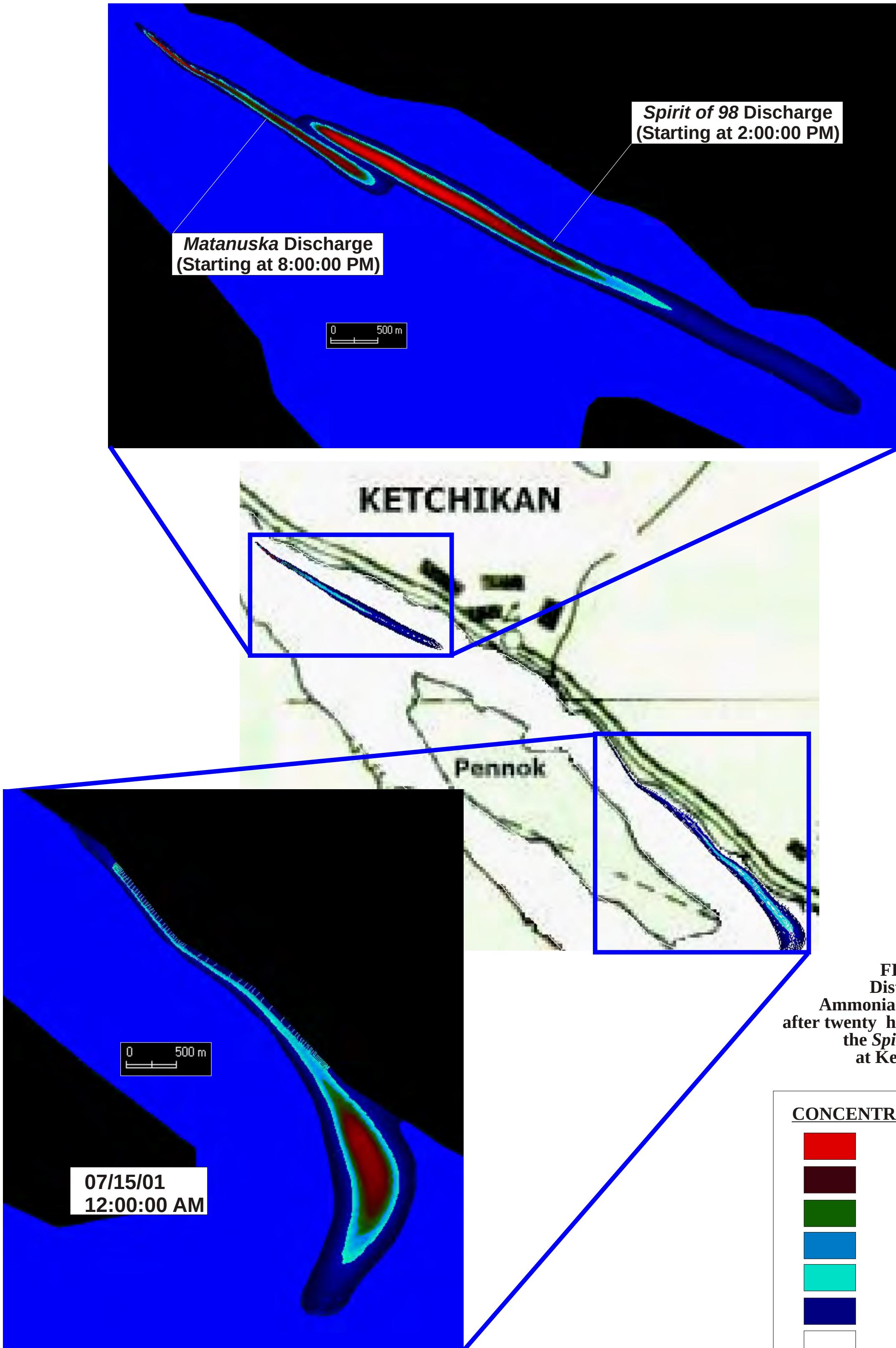


FIGURE 9J
Distribution of
Ammonia Nitrogen (NH3-N)
after twenty hours of discharge from
the *Spirit of Discovery*
at Ketchikan port.

CONCENTRATION mg/m3 LEGEND

0.05 - 0.04

0.04 - 0.03

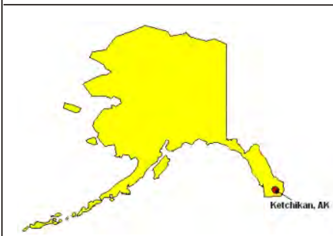
0.03 - 0.02

0.02 - 0.01

0.01 - 0.99E-2

0.98E-2 - 2.10E-3

2.09E-3 - 0.35E-5



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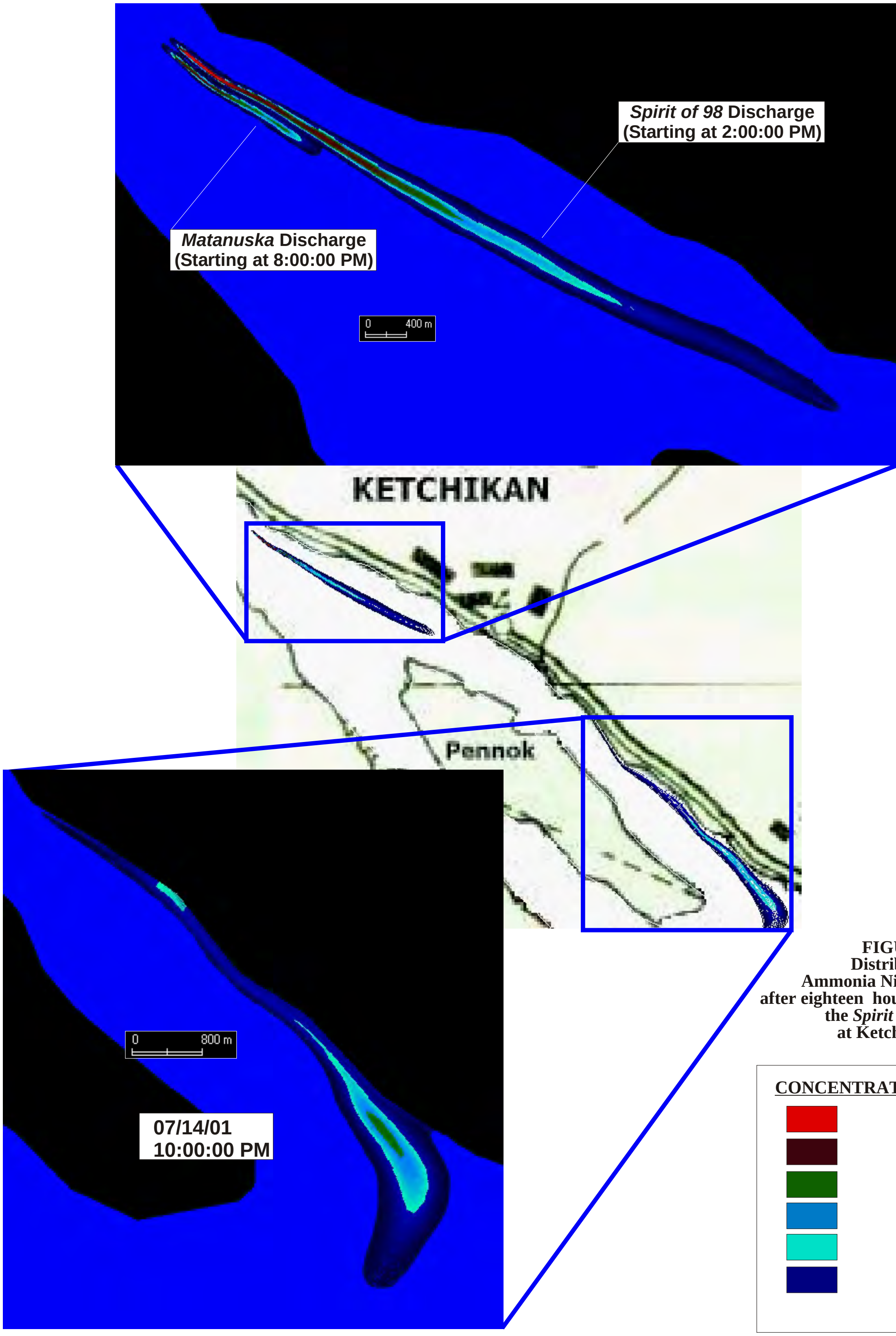
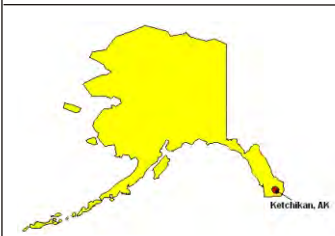


FIGURE 9I
Distribution of
Ammonia Nitrogen (NH_3-N)
after eighteen hours of discharge from
the *Spirit of Discovery*
at Ketchikan port.

CONCENTRATION mg/m3 LEGEND

Red	0.05 - 0.04
Dark brown	0.04 - 0.03
Dark green	0.03 - 0.02
Blue	0.02 - 0.01
Cyan	0.01 - 0.79E-2
Navy	0.78E-2 - -0.33E-4



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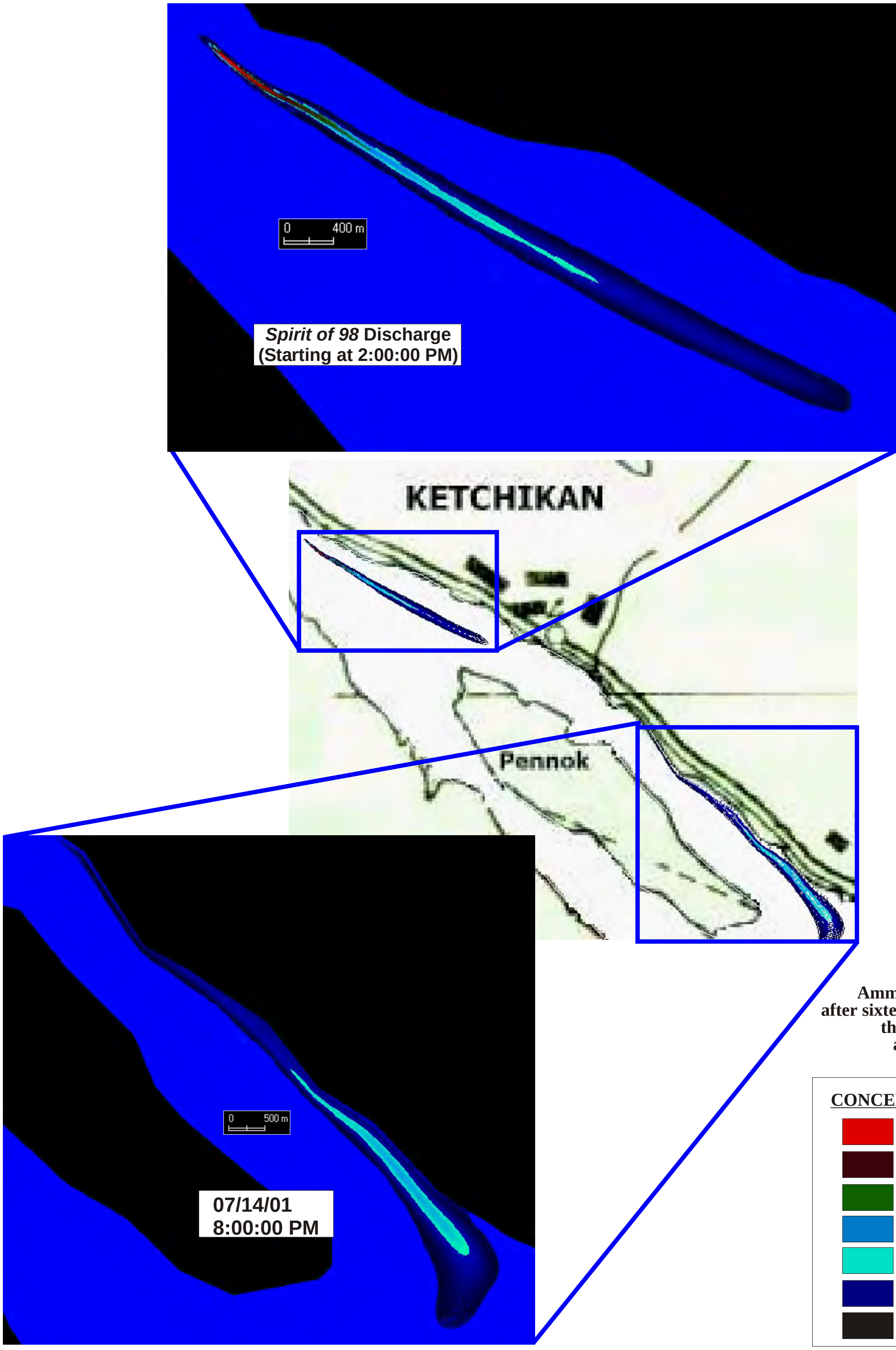
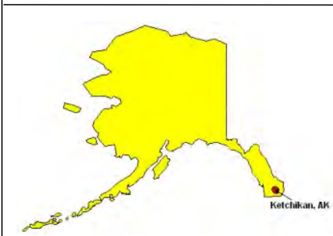


FIGURE 9H
Distribution of
Ammonia Nitrogen (NH3-N)
after sixteen hours of discharge from
the *Spirit of Discovery*
at Ketchikan port.

CONCENTRATION mg/m3 LEGEND

- 0.07 - 0.06
- 0.06 - 0.05
- 0.05 - 0.04
- 0.04 - 0.03
- 0.03 - 0.02
- 0.01 - 0.07E-2
- 0.06E-2 - -0.08E-5



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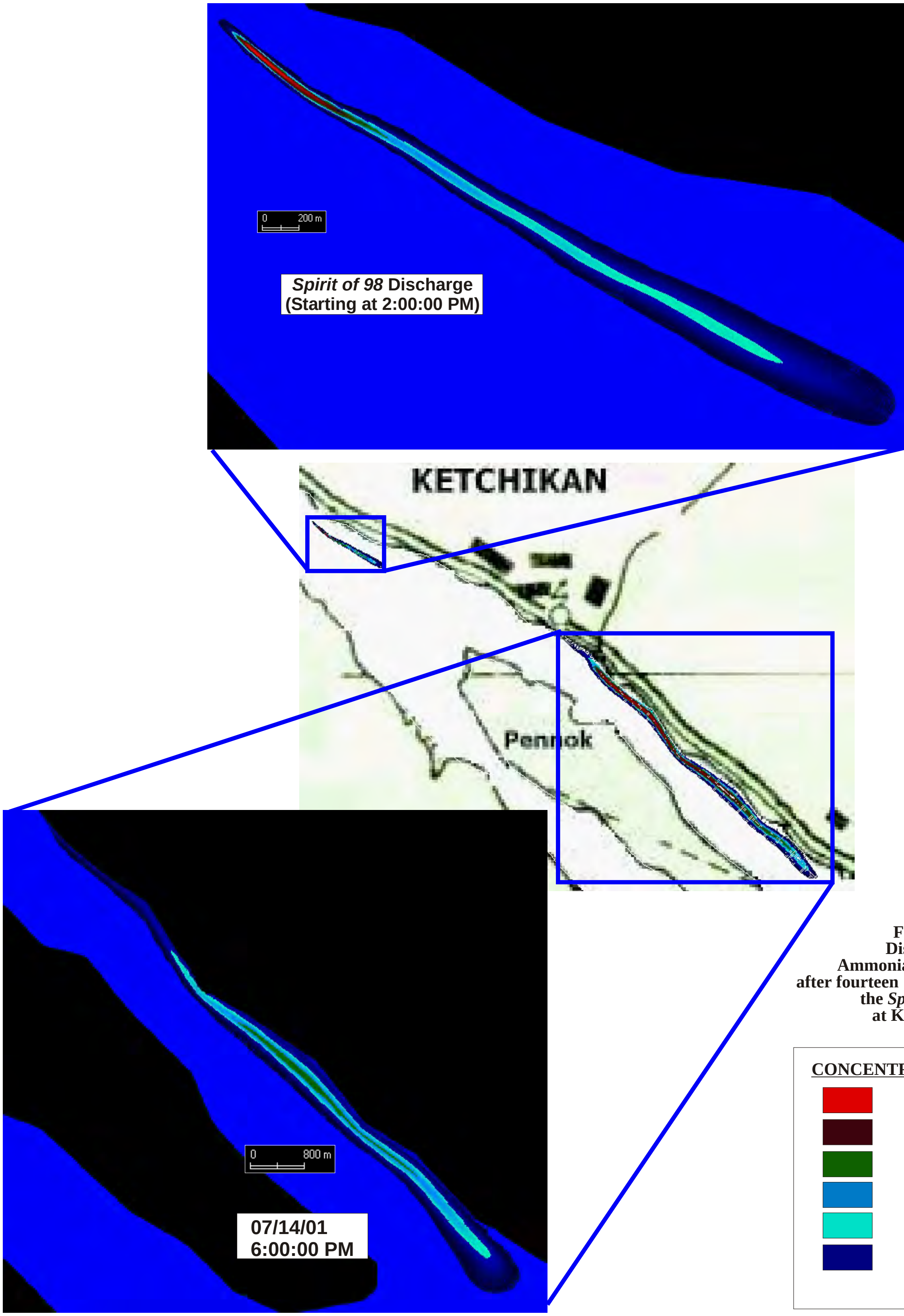
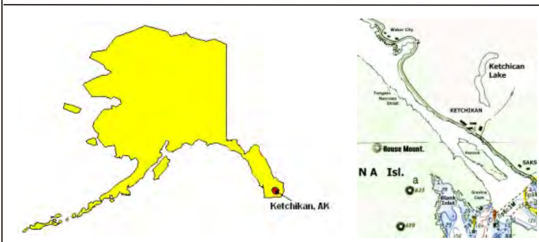


FIGURE 9G
Distribution of
Ammonia Nitrogen (NH3-N)
after fourteen hours of discharge from
the *Spirit of Discovery*
at Ketchikan port.

<u>CONCENTRATION mg/m3 LEGEND</u>

red	0.06 - 0.05
dark brown	0.04 - 0.03
green	0.03 - 0.02
blue	0.02 - 0.01
cyan	0.01 - 0.35E-2
navy	0.34E-2 - -0.35E-3



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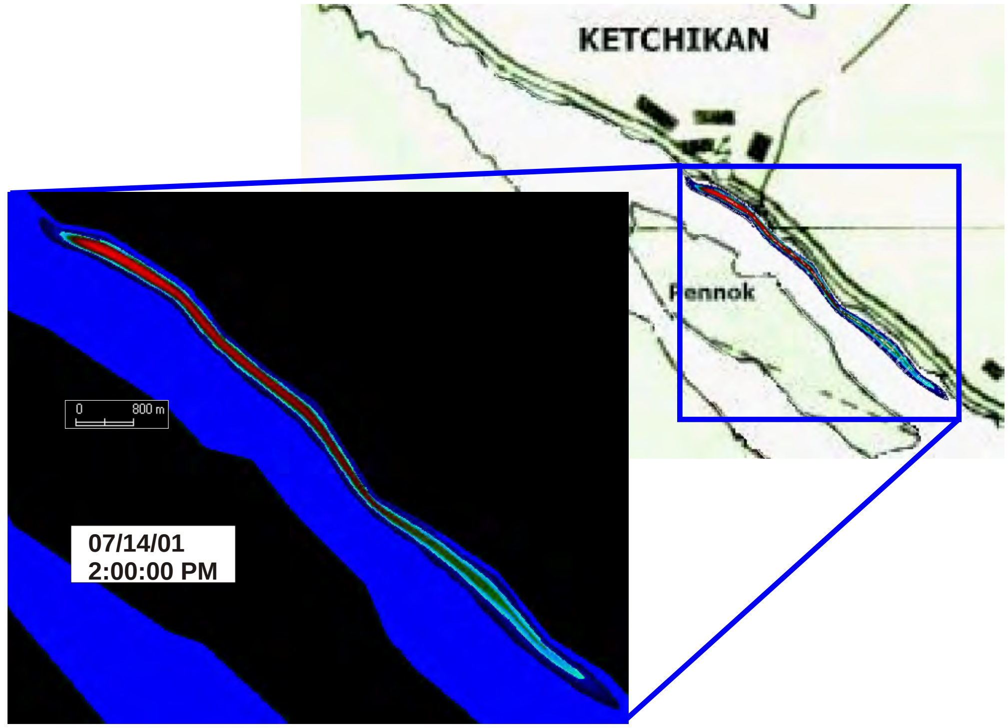


FIGURE 9E
Distribution of
Ammonia Nitrogen (NH3-N)
after ten hours of discharge from
the *Spirit of Discovery*
at Ketchikan port.

CONCENTRATION mg/m3 LEGEND	
	0.05 - 0.04
	0.04 - 0.03
	0.03 - 0.02
	0.02 - 0.01
	0.01 - 0.96E-2
	0.95E-2 - 0.66E-2
	0.65E-2 - 3.04E-4

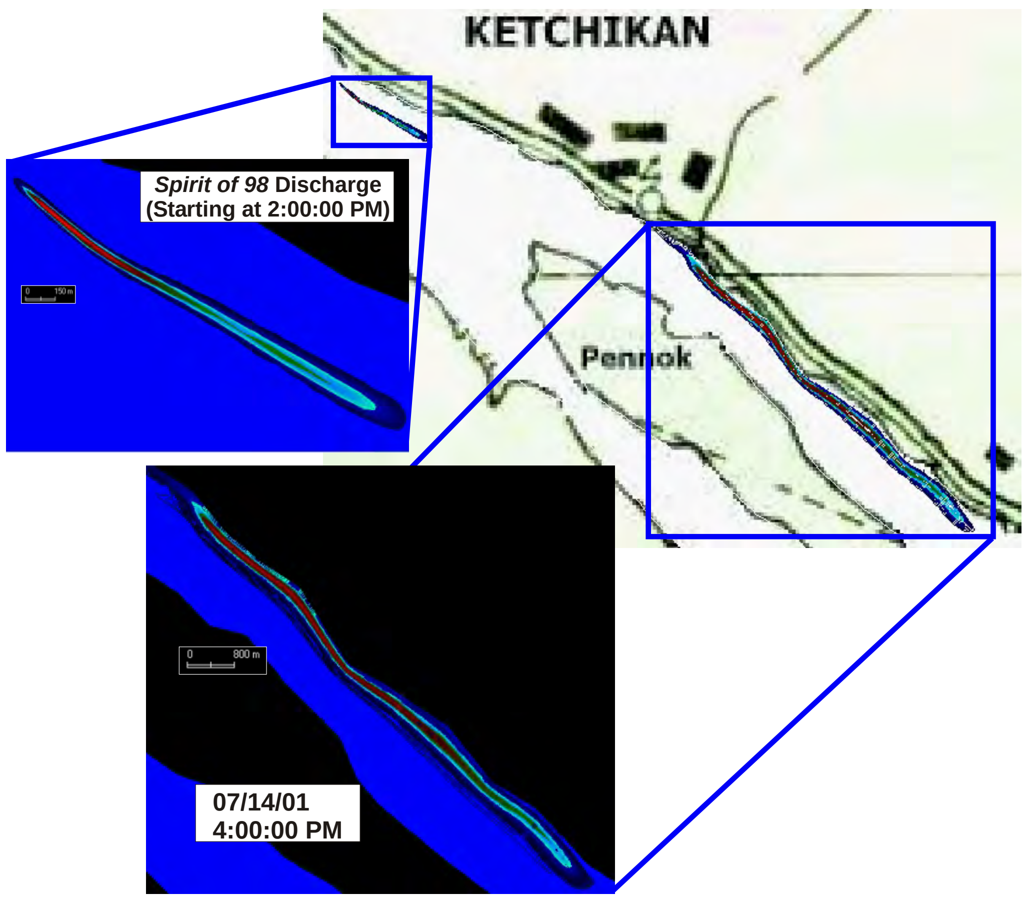
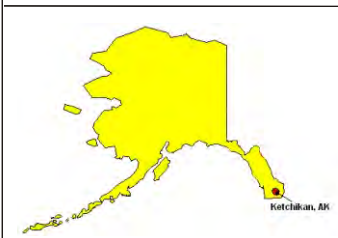


FIGURE 9F
Distribution of
Ammonia Nitrogen (NH3-N)
after twelve hours of discharge from
the *Spirit of Discovery*
at Ketchikan port.

CONCENTRATION mg/m3 LEGEND	
	0.05 - 0.04
	0.04 - 0.03
	0.03 - 0.02
	0.02 - 0.01
	0.01 - 0.96E-2
	0.95E-2 - 0.66E-2
	0.65E-2 - 3.04E-4



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GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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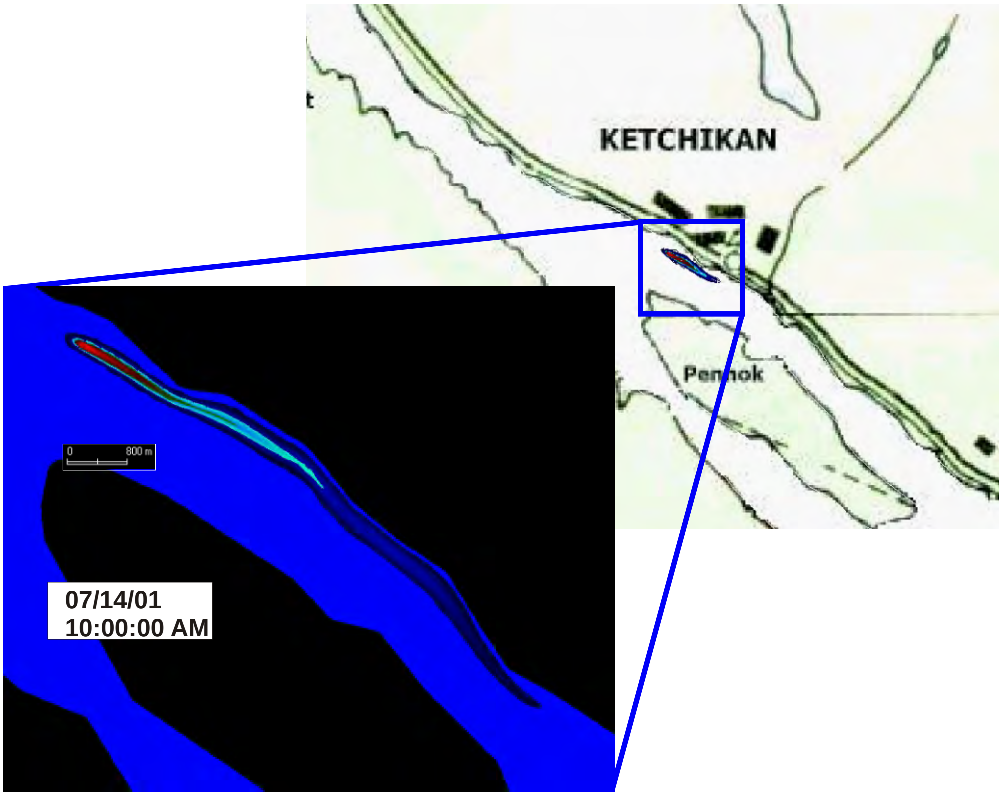

FIGURE 9C
Distribution of
Ammonia Nitrogen (NH3-N)
after six hours of discharge from
the *Spirit of Discovery*
at Ketchikan port.

CONCENTRATION mg/m3 LEGEND
0.09 - 0.07
0.06 - 0.05
0.05 - 0.04
0.04 - 0.03
0.03 - 0.02
0.02 - 0.01
0.01 - 1.77E-5

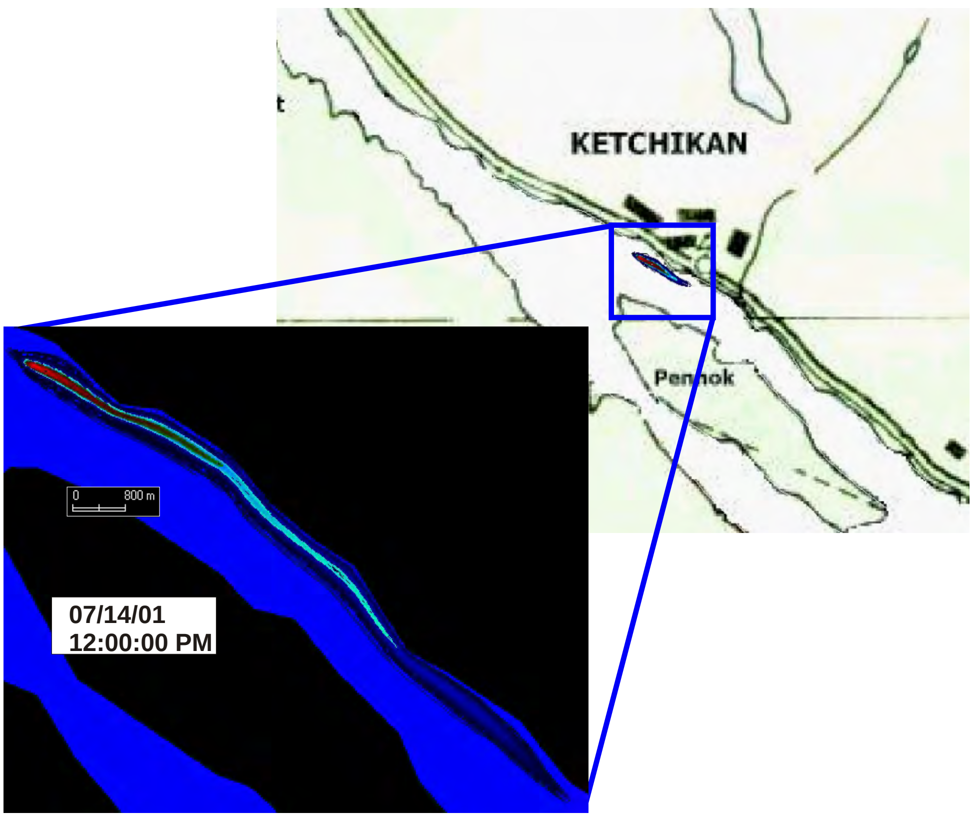

FIGURE 9D
Distribution of
Ammonia Nitrogen (NH3-N)
after eight hours of discharge from
the *Spirit of Discovery*
at Ketchikan port.

CONCENTRATION mg/m3 LEGEND
0.08 - 0.07
0.06 - 0.04
0.03 - 0.02
0.02 - 0.01
0.01 - 0.78E-2
0.77E-2 - 2.34E-3
2.33E-3 - 1.13E-5

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PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

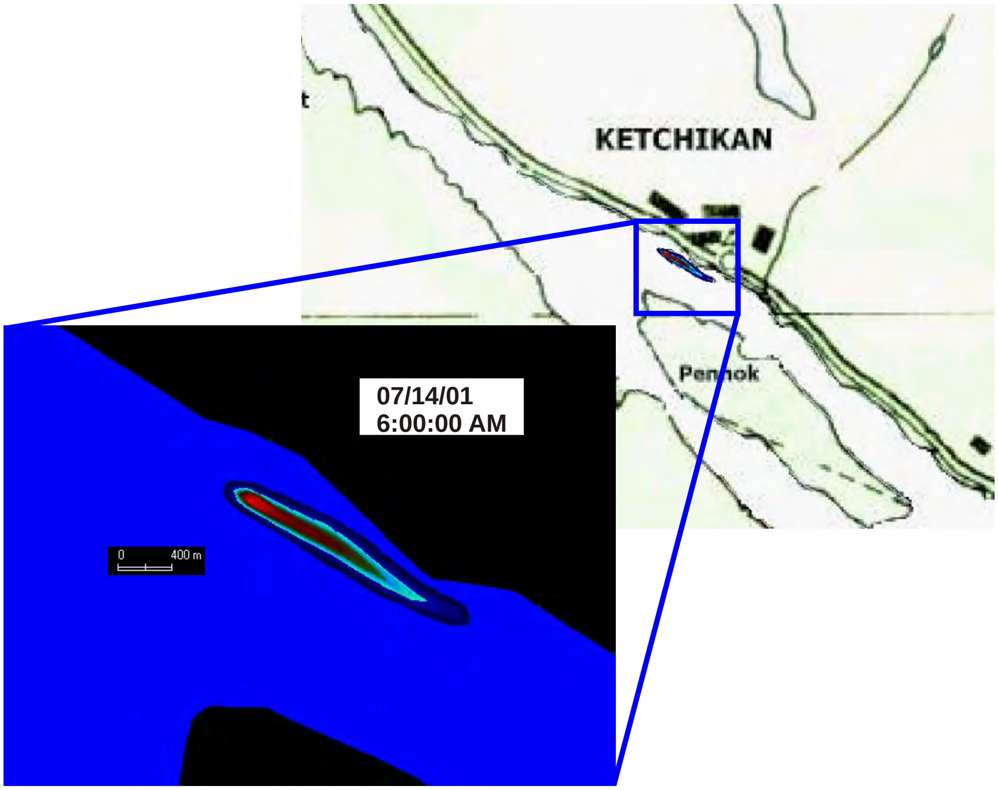


FIGURE 9A
Distribution of
Ammonia Nitrogen (NH3-N)
after two hours of discharge from
the *Spirit of Discovery*
at Ketchikan port.

CONCENTRATION mg/m3 LEGEND	
Red	0.06 - 0.05
Dark red	0.05 - 0.04
Green	0.04 - 0.03
Blue	0.03 - 0.02
Cyan	0.02 - 0.01
Navy	0.01 - 0.39E-2
Black	0.38E-2 - 0.98E-5

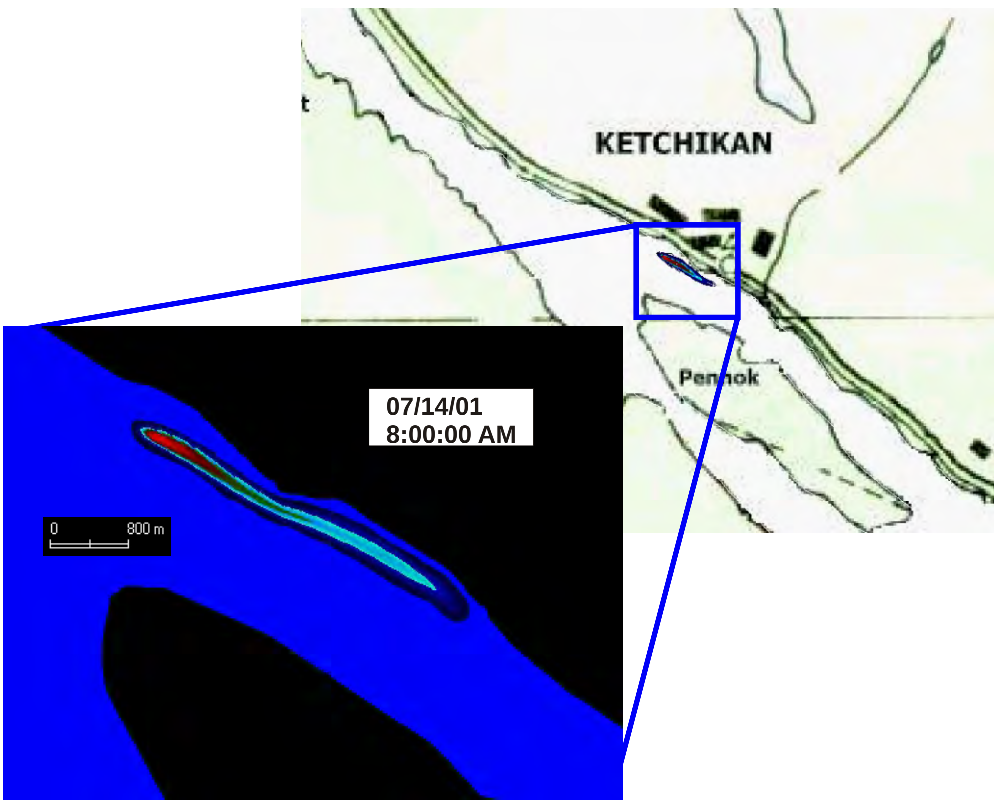
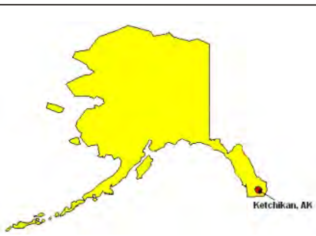


FIGURE 9B
Distribution of
Ammonia Nitrogen (NH3-N)
after four hours of discharge from
the *Spirit of Discovery*
at Ketchikan port.

CONCENTRATION mg/m3 LEGEND	
Red	0.08 - 0.07
Dark red	0.06 - 0.05
Green	0.05 - 0.04
Blue	0.04 - 0.03
Cyan	0.03 - 0.02
Navy	0.02 - 0.01
Black	0.01 - -1.12E-4



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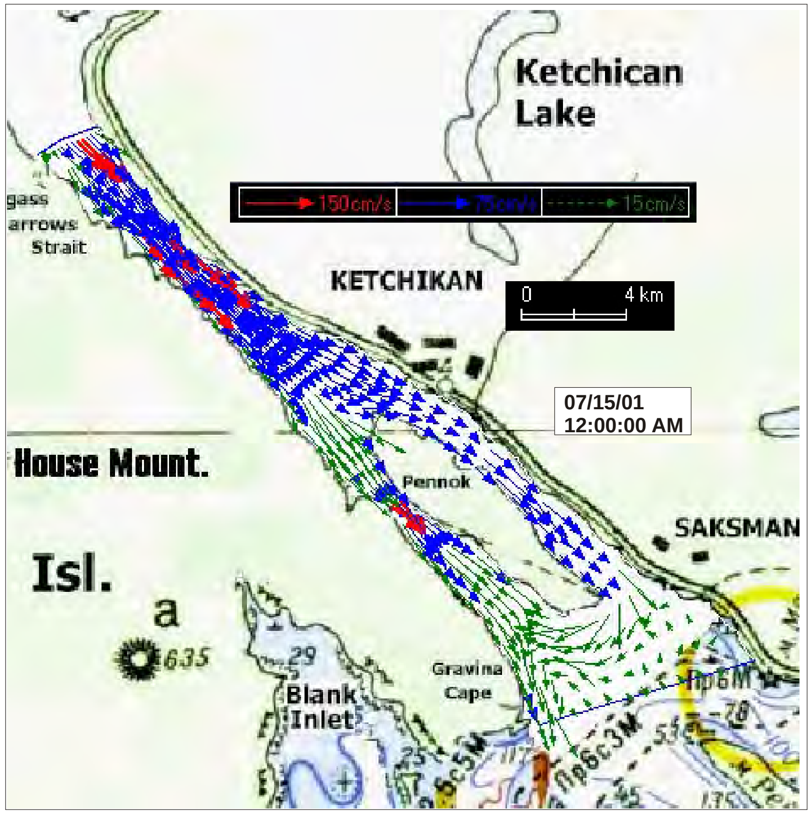
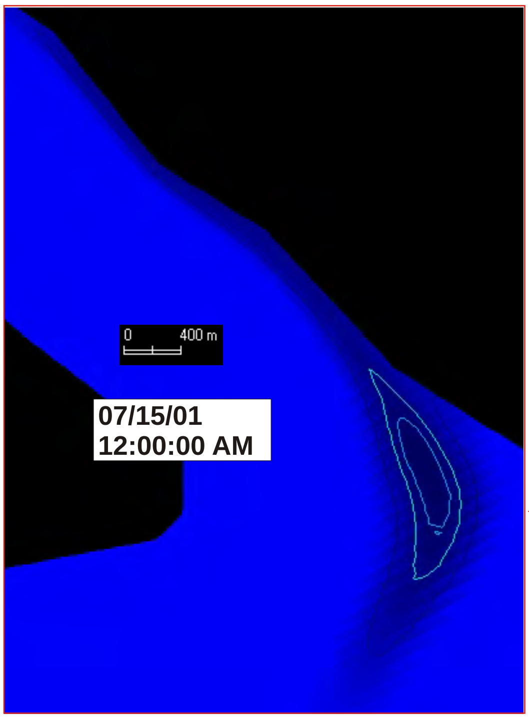
PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

FIGURE 8S
Velocity pattern after twenty hours of start of discharge from the *Spirit of Discovery* at Ketchikan port.





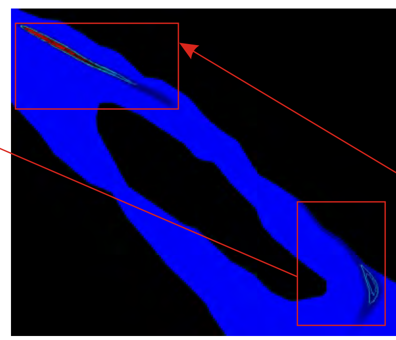
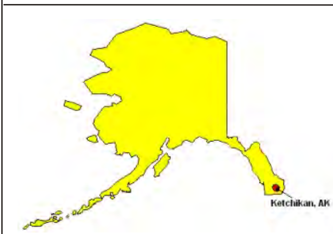


FIGURE 8T
Depth averaged *fecal coliform* concentration (MPN/m^3) after twenty hours of discharge from the *Spirit of Discovery*.

CONCENTRATION LEGEND

red	106,000 - 100,000
dark brown	100,000 - 70,000
green	70,000 - 50,000
blue	50,000 - 40,000
cyan	40,000 - 30,000
navy	30,000 - 36



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PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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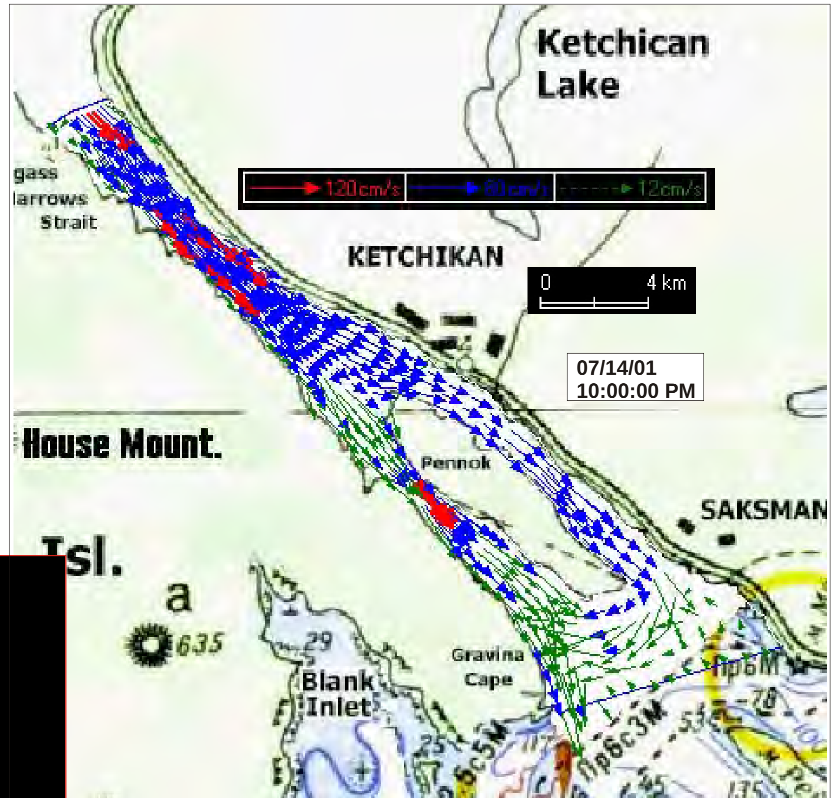
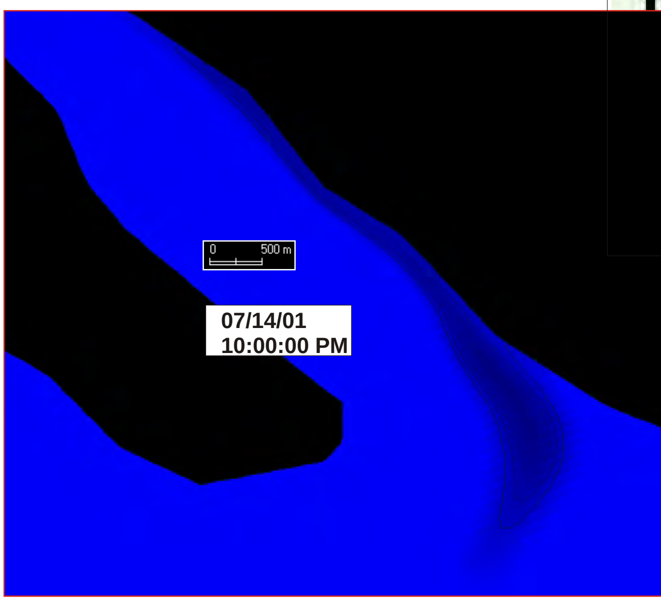
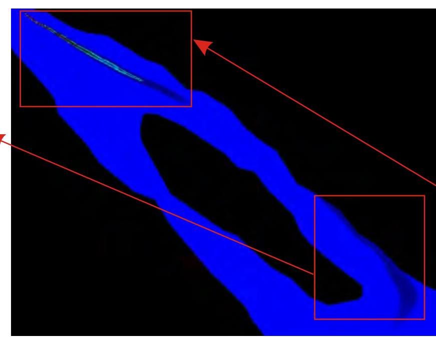
FIGURE 8Q
Velocity pattern after eighteen hours of start of discharge from the *Spirit of Discovery* at Ketchikan port.







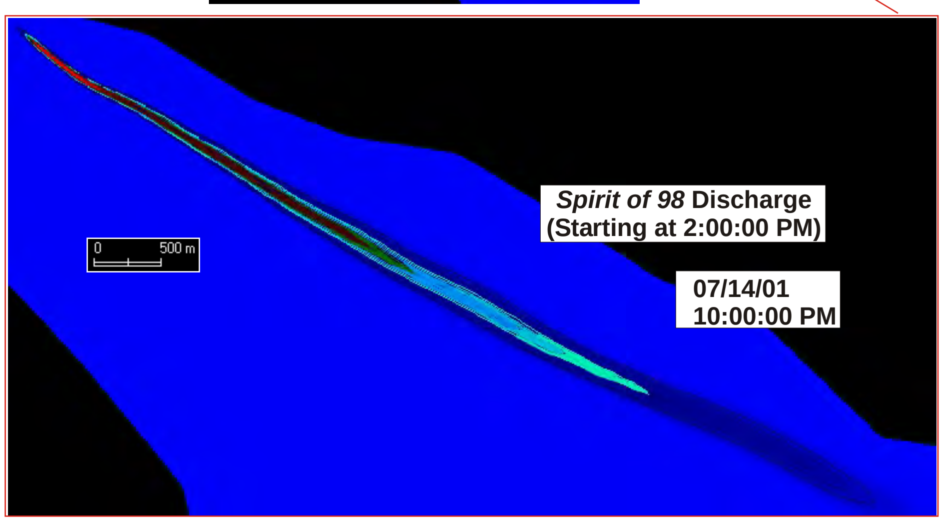
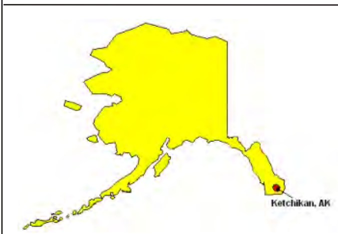


FIGURE 8R
Depth averaged *fecal coliform* concentration (MPN/m^3) after eighteen hours of discharge from the *Spirit of Discovery*.

CONCENTRATION LEGEND	
(red)	167,000 - 140,000
(dark brown)	140,000 - 127,000
(green)	127,000 - 80,000
(blue)	80,000 - 70,000
(turquoise)	70,000 - 50,000
(navy)	50,000 - 300



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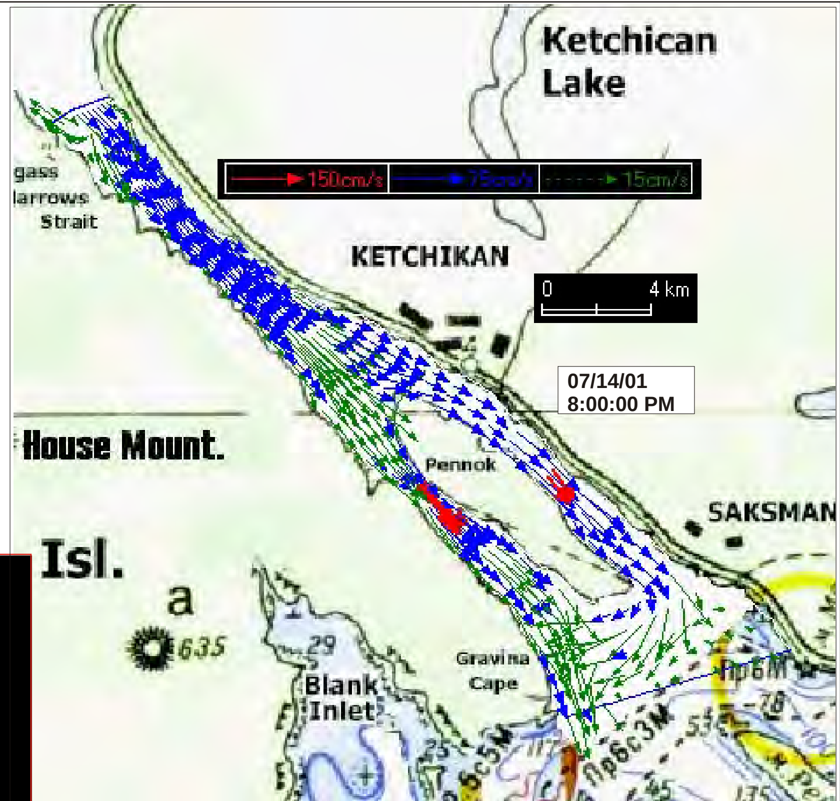
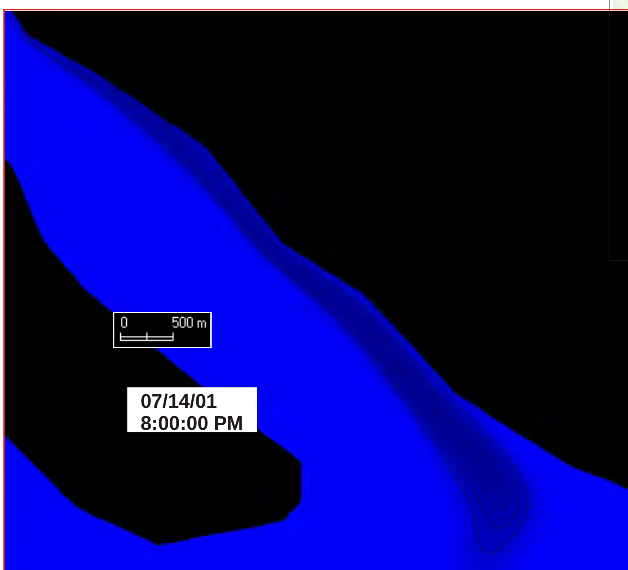
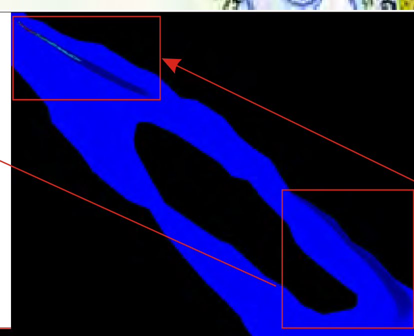
PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

FIGURE 8O
Velocity pattern after sixteen hours of start of discharge from the *Spirit of Discovery* at Ketchikan port.







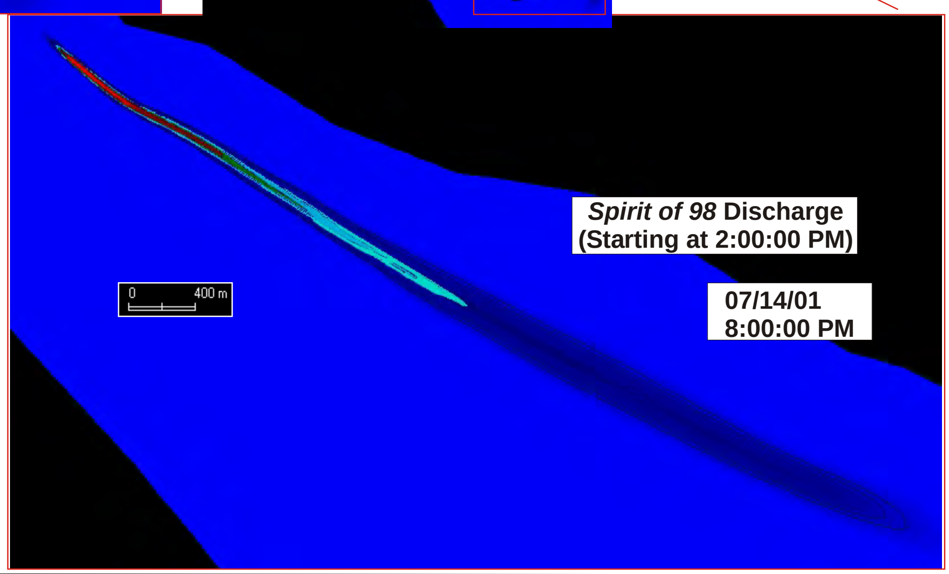
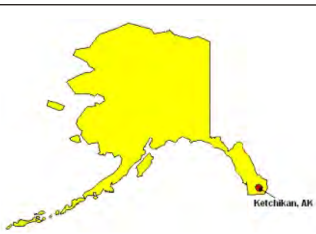


FIGURE 8P
Depth averaged *fecal coliform* concentration (MPN/m^3) after sixteen hours of discharge from the *Spirit of Discovery*.

CONCENTRATION LEGEND

(red)	210,000 - 202,000
(dark brown)	202,000 - 122,000
(green)	122,000 - 97,000
(blue)	97,000 - 70,000
(cyan)	70,000 - 50,000
(navy)	50,000 - 120



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PROJECT No. 001332.AU11.01 JUNE 2003

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ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

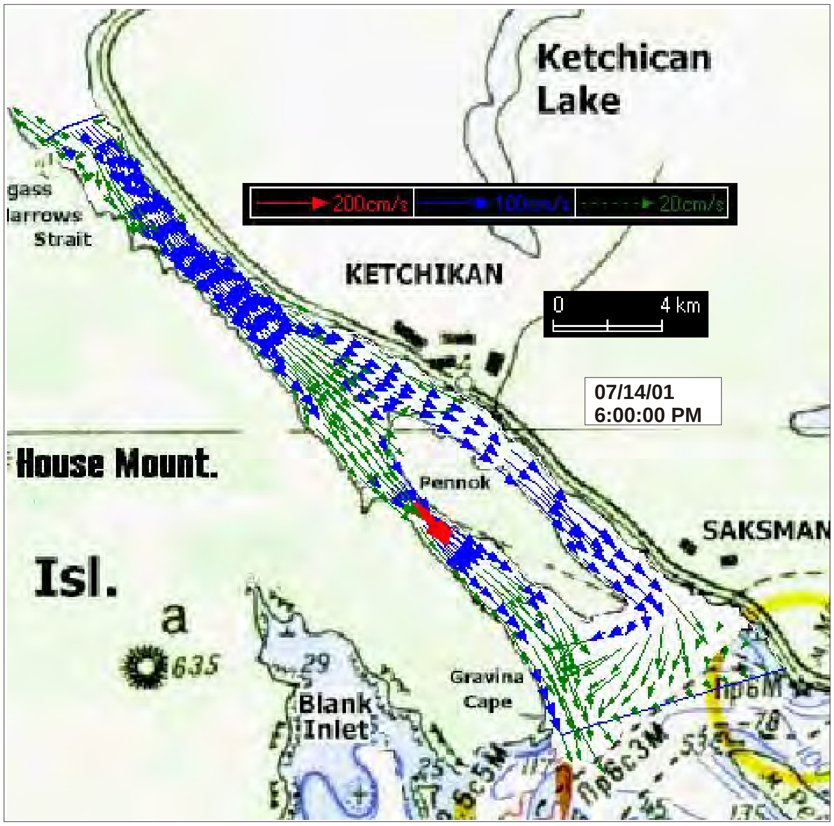
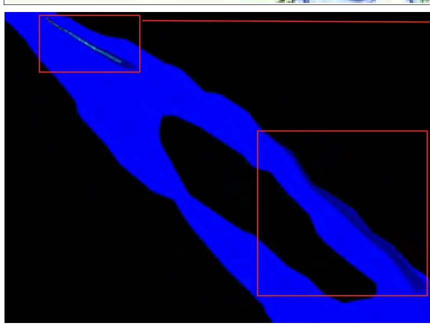
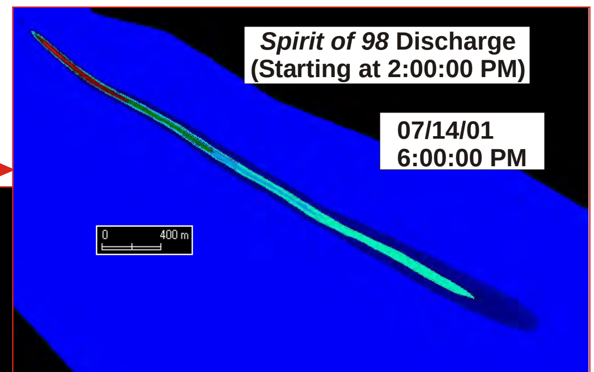


FIGURE 8M
Velocity pattern after fourteen
hours of start of discharge
from the *Spirit of Discovery*
at Ketchikan port.





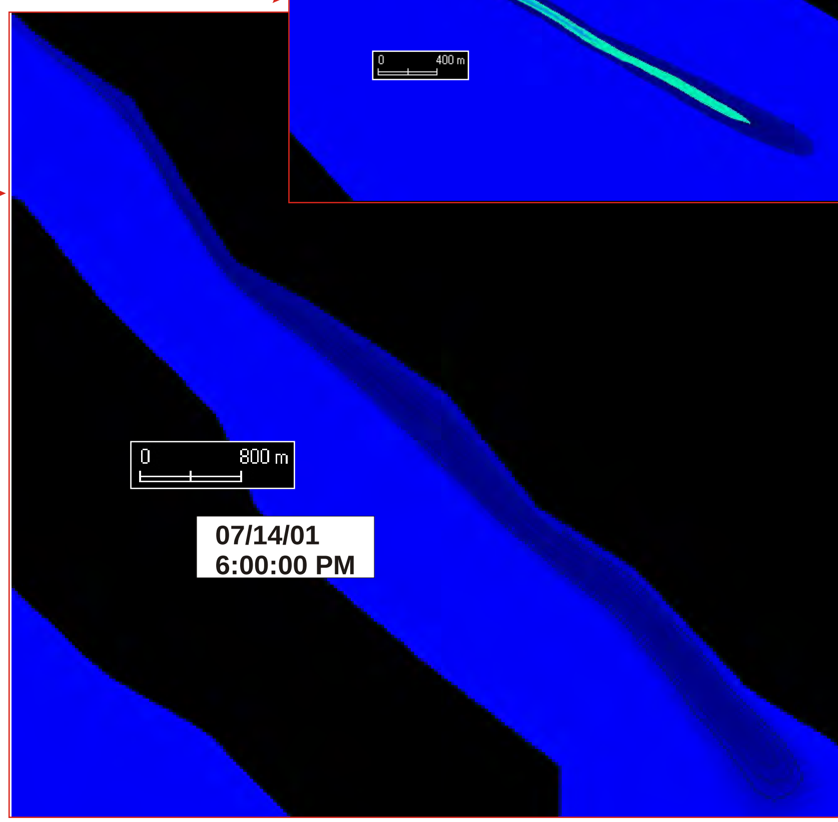
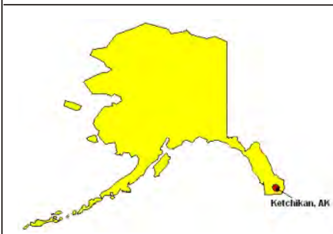


FIGURE 8N
Depth averaged *fecal coliform*
concentration (MPN/m^3) after
fourteen hours of discharge from
the *Spirit of Discovery*.

CONCENTRATION LEGEND

red	184,000 - 108,000
dark brown	108,000 - 88,000
green	88,000 - 75,000
blue	75,000 - 70,000
cyan	70,000 - 60,000
navy	60,000 - 300/75



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GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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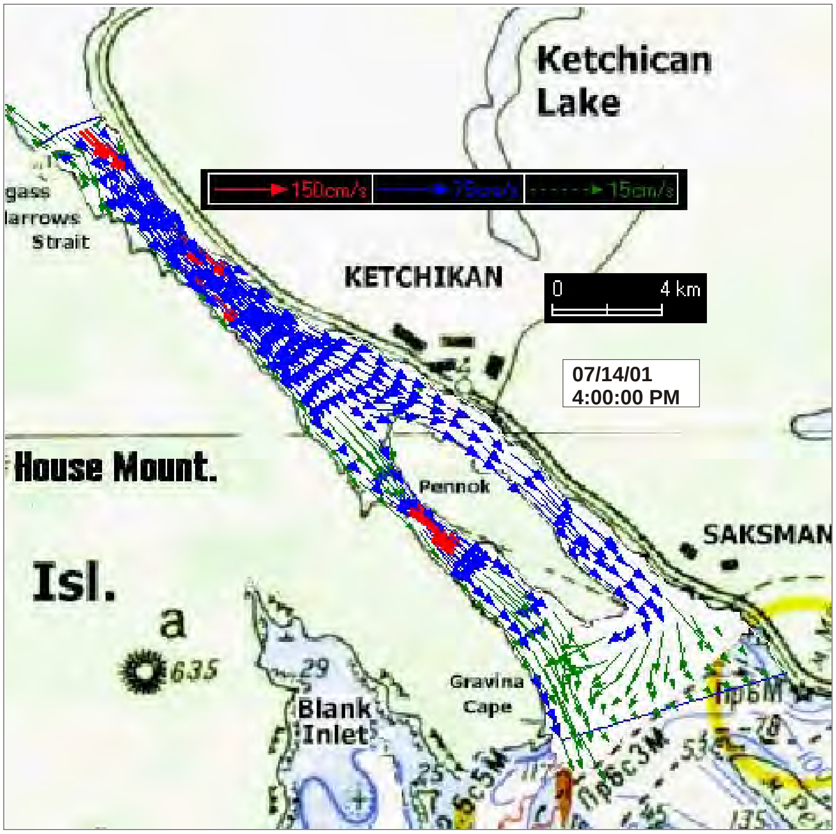
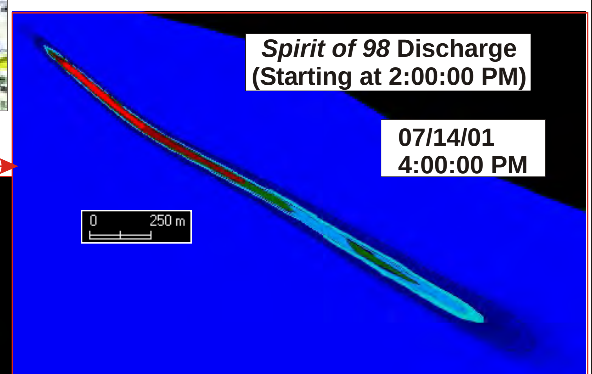


FIGURE 8K
Velocity pattern after twelve hours of start of discharge from the *Spirit of Discovery* at Ketchikan port.



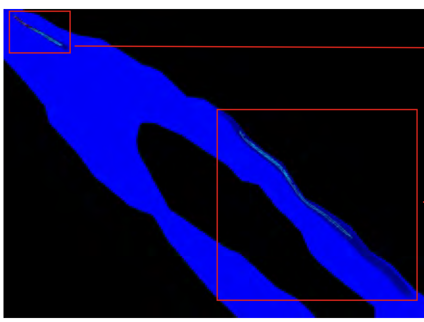
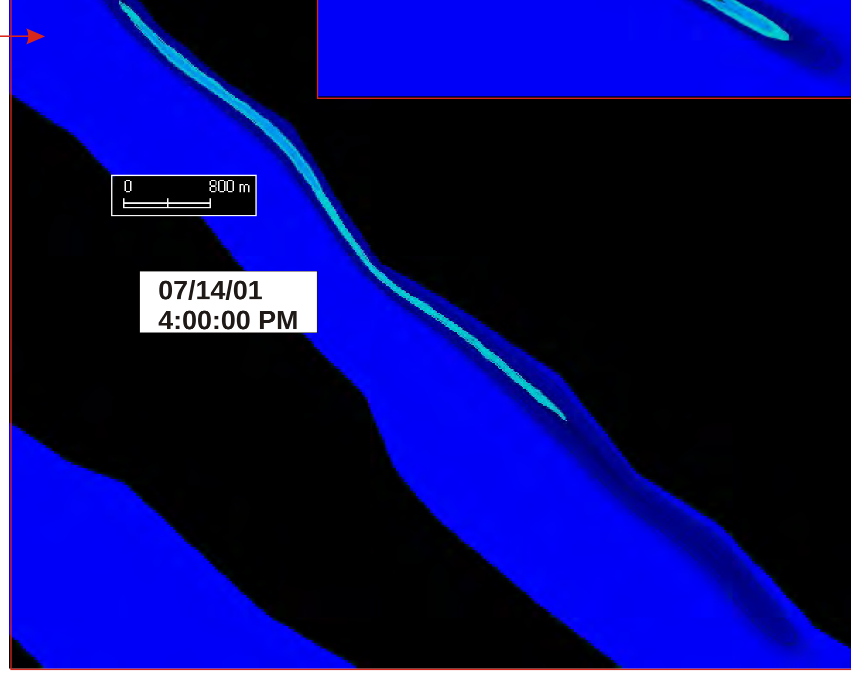
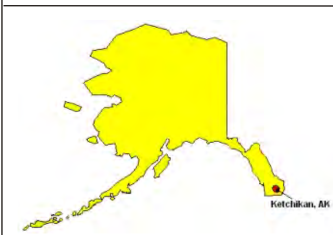


FIGURE 8L
Depth averaged *fecal coliform* concentration (MPN/m^3) after twelve hours of discharge from the *Spirit of Discovery*.



CONCENTRATION LEGEND

(red)	103,000 - 98,000
(dark brown)	98,000 - 90,000
(green)	90,000 - 70,000
(blue)	70,000 - 60,000
(cyan)	60,000 - 50,000
(navy)	50,000 - 100



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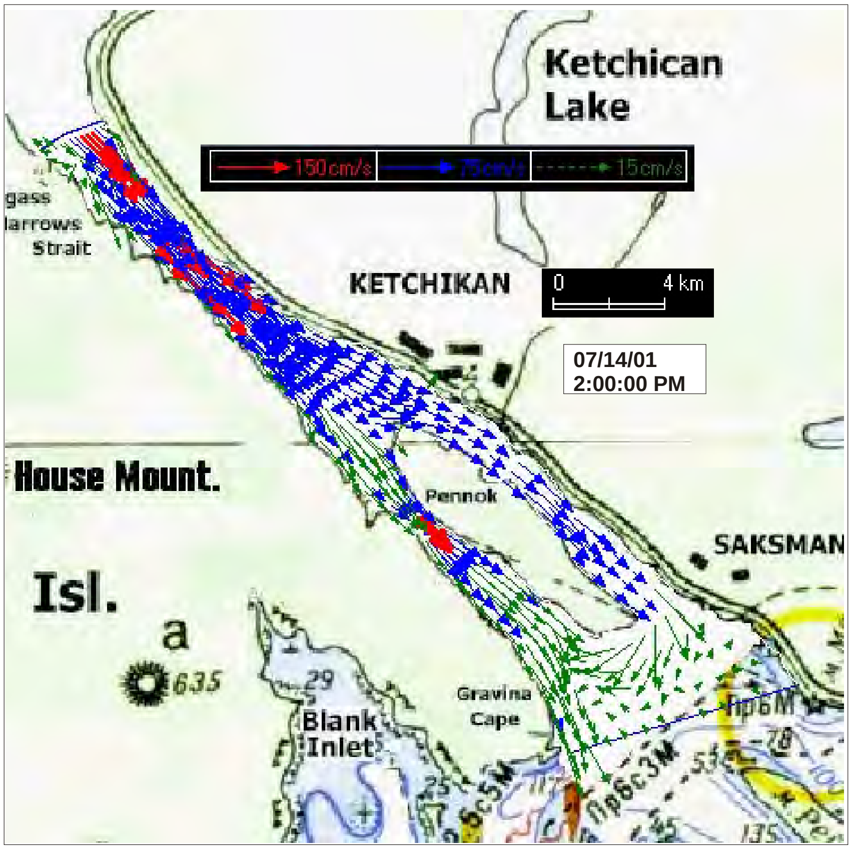


FIGURE 8I
Velocity pattern after ten hours of start of discharge from the *Spirit of Discovery* at Ketchikan port.

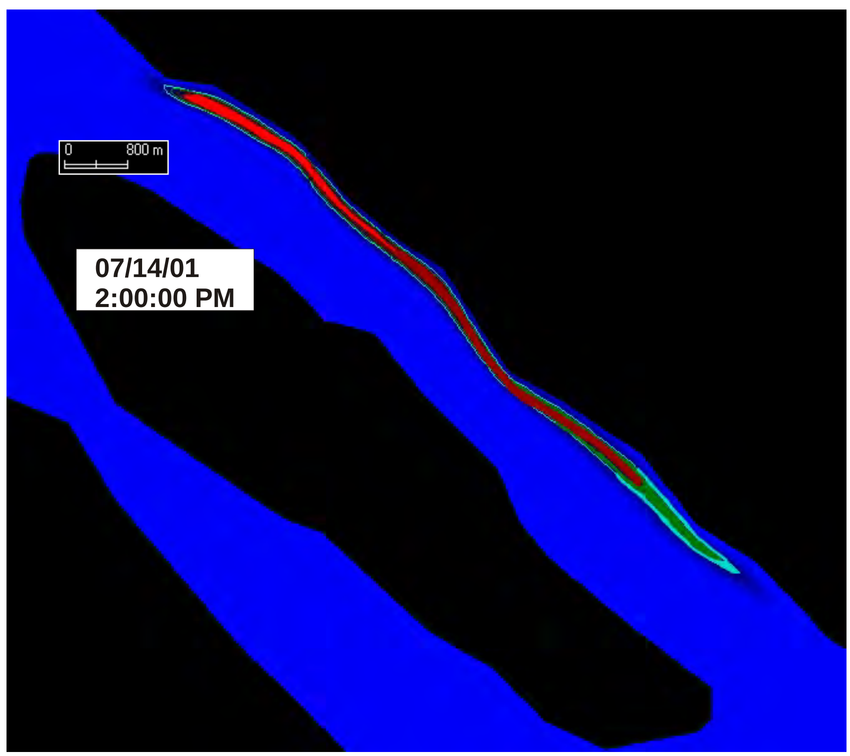
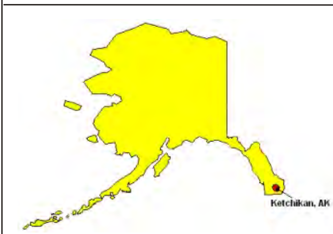


FIGURE 8J
Depth averaged *fecal coliform* concentration (MPN/m^3) after ten hours of discharge from the *Spirit of Discovery*.

CONCENTRATION LEGEND

Red	76,000 - 70,000
Dark brown	70,000 - 50,000
Green	50,000 - 30,000
Cyan	30,000 - 20,000
Dark blue	20,000 - 200



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ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

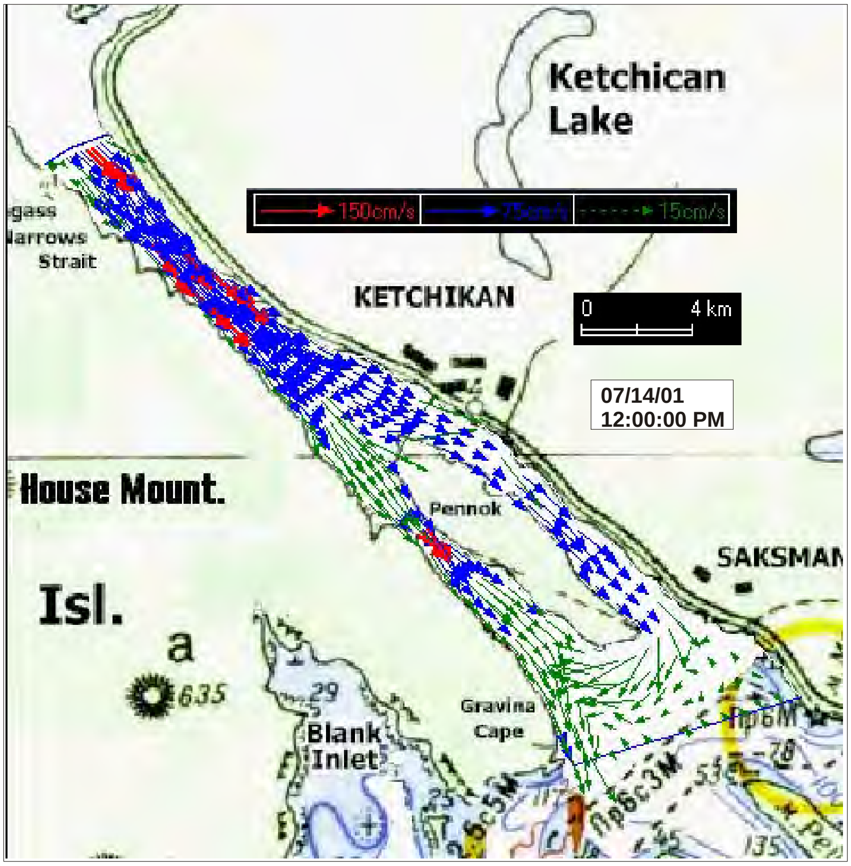
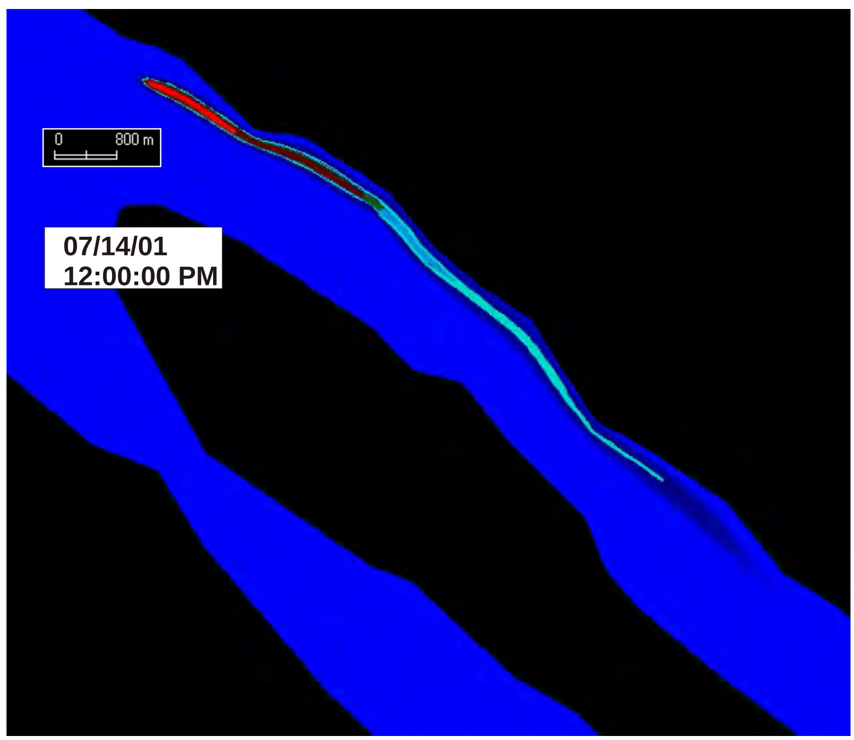


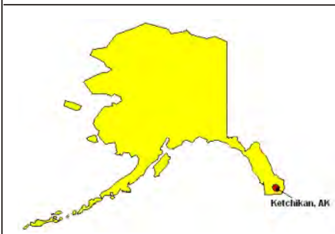
FIGURE 8G
Velocity pattern after eight hours of start of discharge from the *Spirit of Discovery* at Ketchikan port.

FIGURE 8H
Depth averaged *fecal coliform* concentration (MPN/m^3) after eight hours of discharge from the *Spirit of Discovery*.

CONCENTRATION LEGEND

red	130,000 - 114,000
dark red	114,000 - 90,000
green	90,000 - 70,000
blue	70,000 - 50,000
cyan	50,000 - 40,000
navy	40,000 - 140





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PROJECT No. 001332.AU11.01 **JUNE 2003**

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

FIGURE 8E
Velocity pattern after six hours of start of discharge from the *Spirit of Discovery* at Ketchikan port.

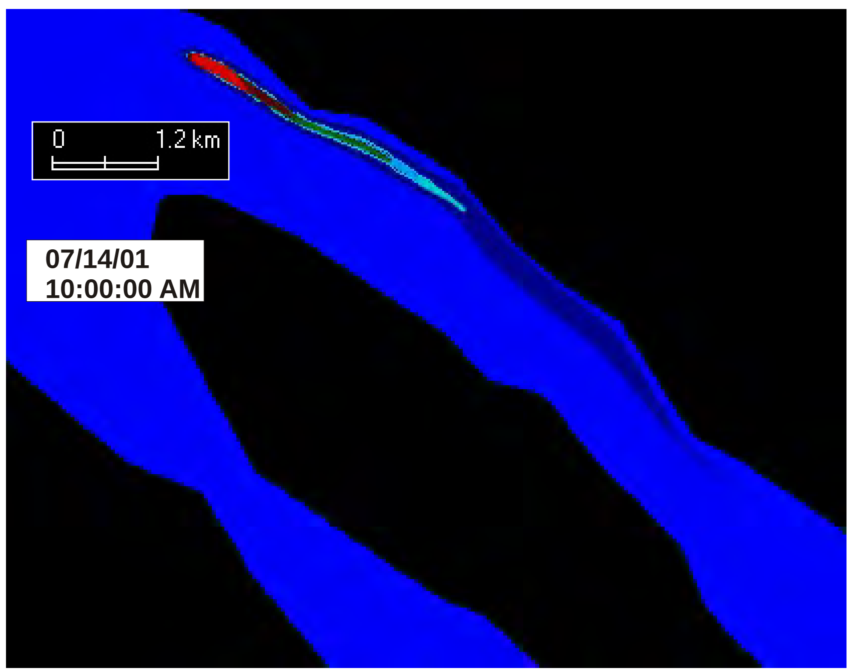
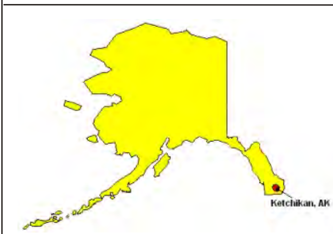


FIGURE 8F
Depth averaged *fecal coliform* concentration (MPN/m^3) after six hours of discharge from the *Spirit of Discovery*.

CONCENTRATION LEGEND

- 145,000 - 120,000
- 120,000 - 100,000
- 100,000 - 70,000
- 70,000 - 60,000
- 60,000 - 50,000
- 50,000 - 15



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GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

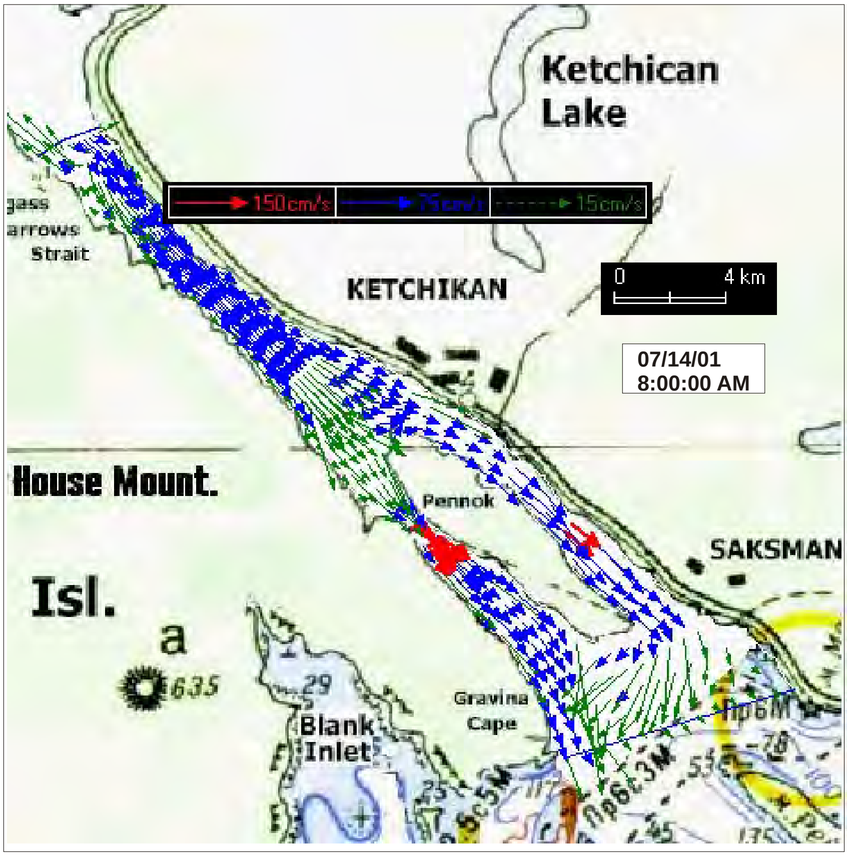


FIGURE 8C
Velocity pattern after four hours of start of discharge from the *Spirit of Discovery* at Ketchikan port.

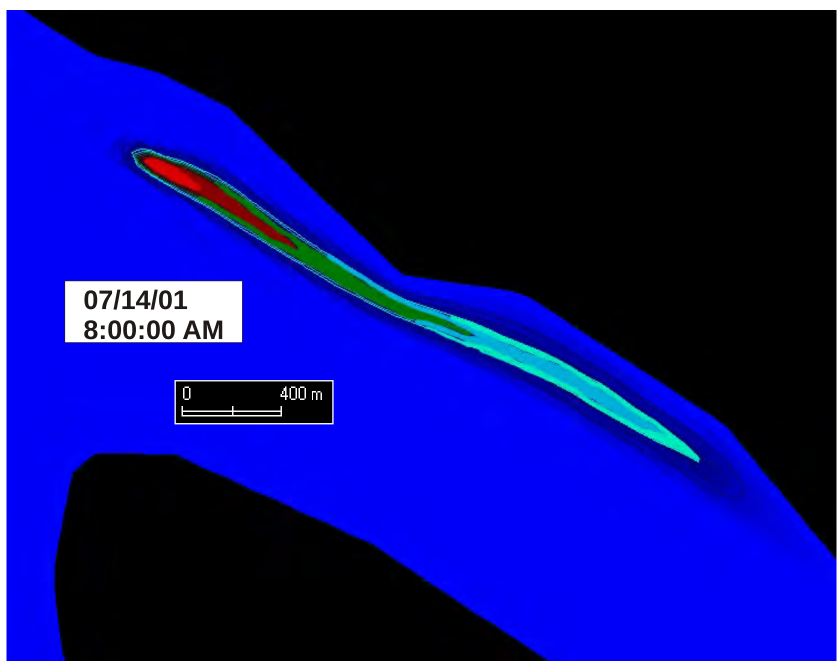
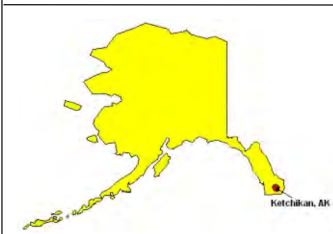


FIGURE 8D
Depth averaged *fecal coliform* concentration (MPN/m^3) after four hour of discharge from the *Spirit of Discovery*.

CONCENTRATION LEGEND

(red)	131,000 - 104,000
(dark brown)	104,000 - 98,000
(green)	98,000 - 60,000
(blue)	60,000 - 50,000
(cyan)	50,000 - 40,000
(navy)	40,000 - 10



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PROJECT No. 001332.AU11.01 **JUNE 2003**

GRAPHICAL REPRESENTATION OF MODEL RESULTS
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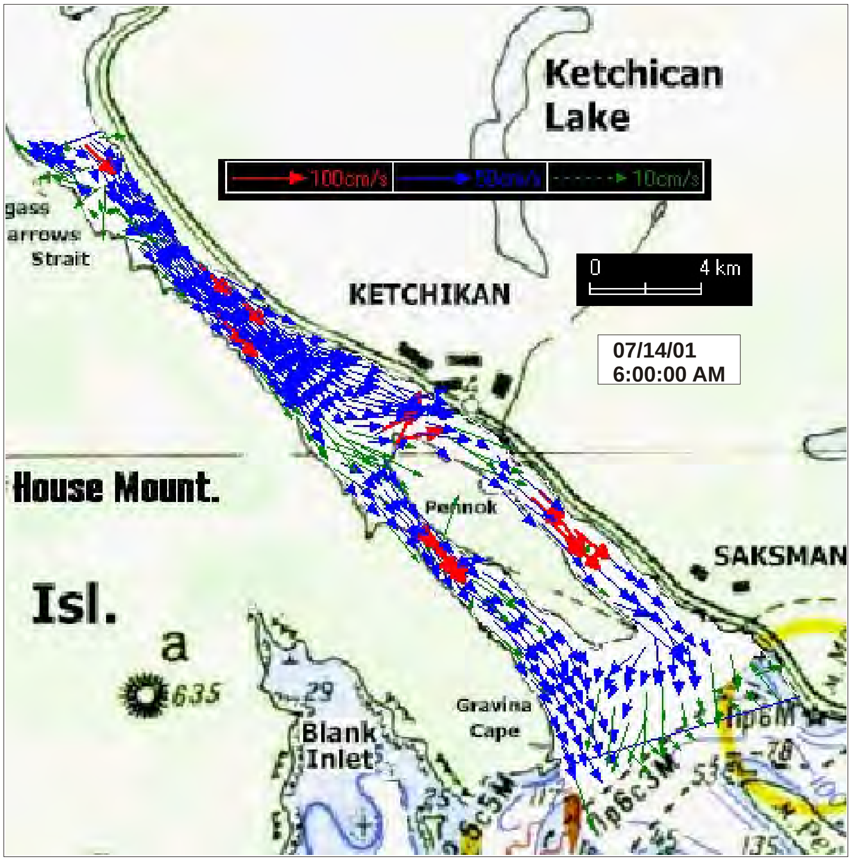


FIGURE 8A
Velocity pattern after two hours of start of discharge from the *Spirit of Discovery* at Ketchikan port.

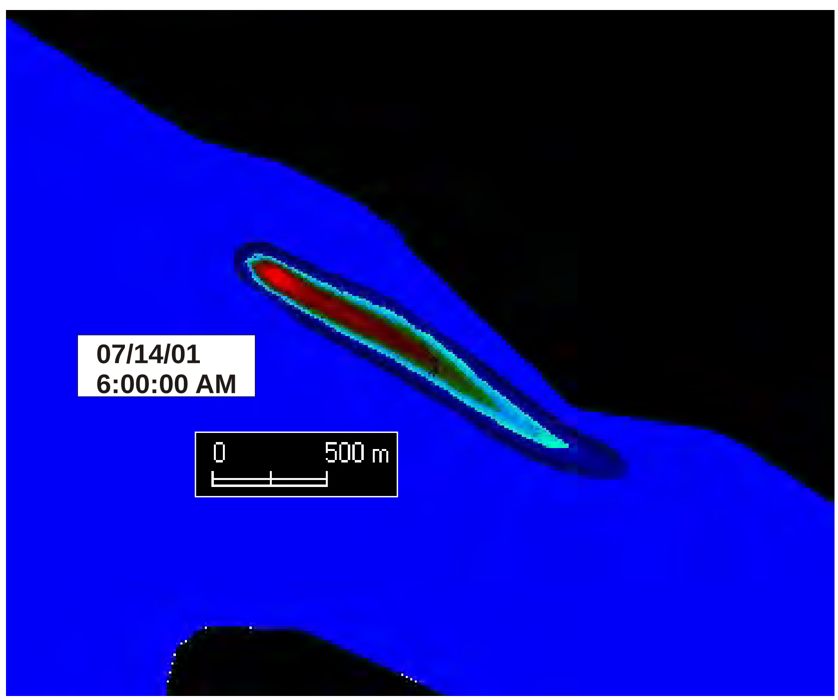
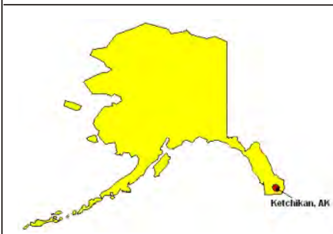


FIGURE 8B
Depth averaged *fecal coliform* concentration (MPN/m^3) after two hour of discharge from the *Spirit of Discovery*.

CONCENTRATION LEGEND

(red)	114,000 - 85,000
(dark brown)	85,000 - 80,000
(green)	80,000 - 50,000
(blue)	50,000 - 40,000
(cyan)	40,000 - 20,000
(navy)	20,000 - 1,000



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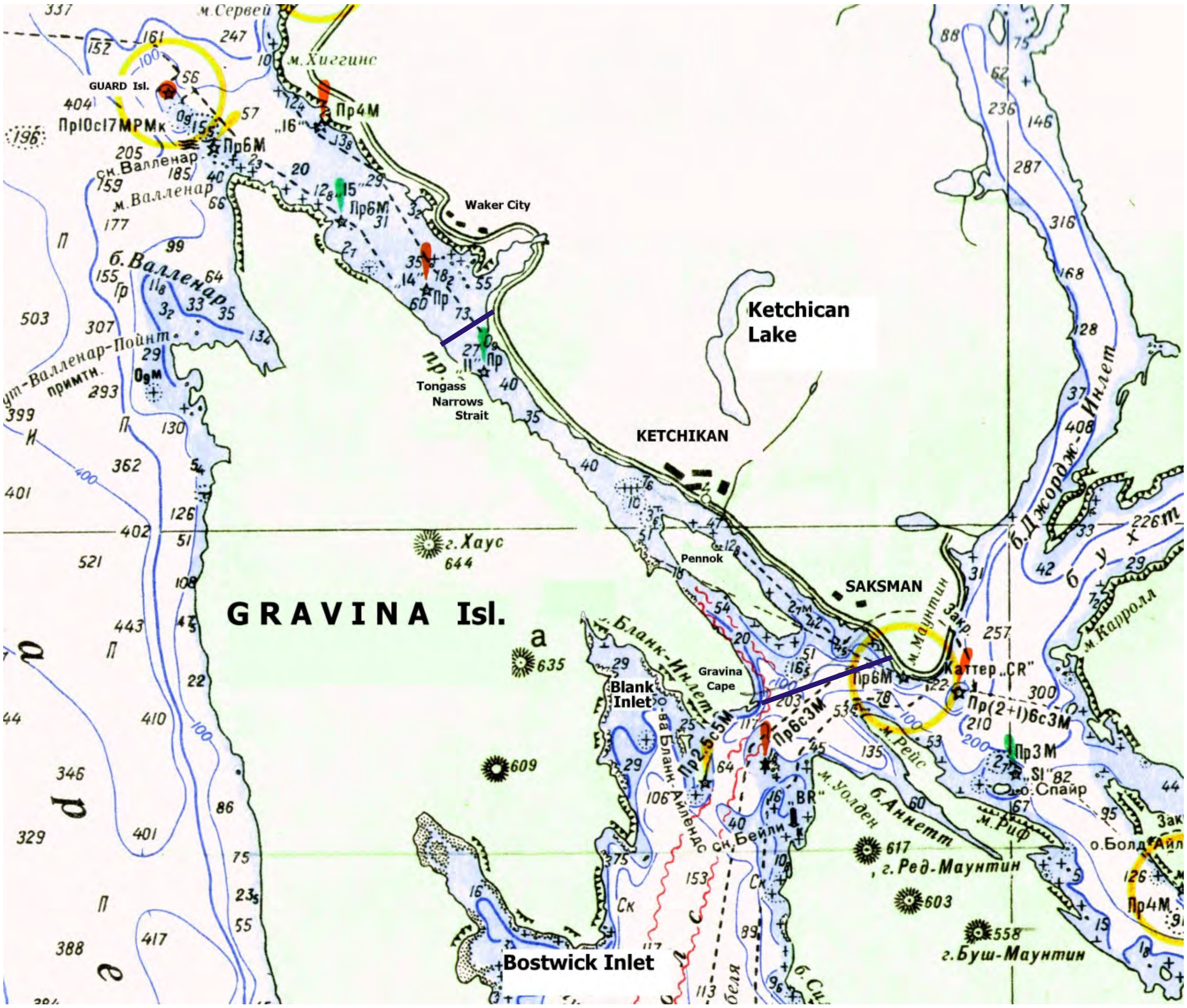
PROJECT No. 001332.AU11.01 **JUNE 2003**

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION



- OPEN BOUNDARIES

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FIGURE 7
GENERAL MAP OF KETCHIKAN AREA (FROM ADMIRALTY MAP NO 72795) SHOWING THE LOCATIONS OF OPEN BOUNDARIES USED IN THE WATER QUALITY MODELS. POTENTIAL ECOLOGICALLY SENSITIVE AREA IS LOCATED NEAR BOSTWICK INLET.
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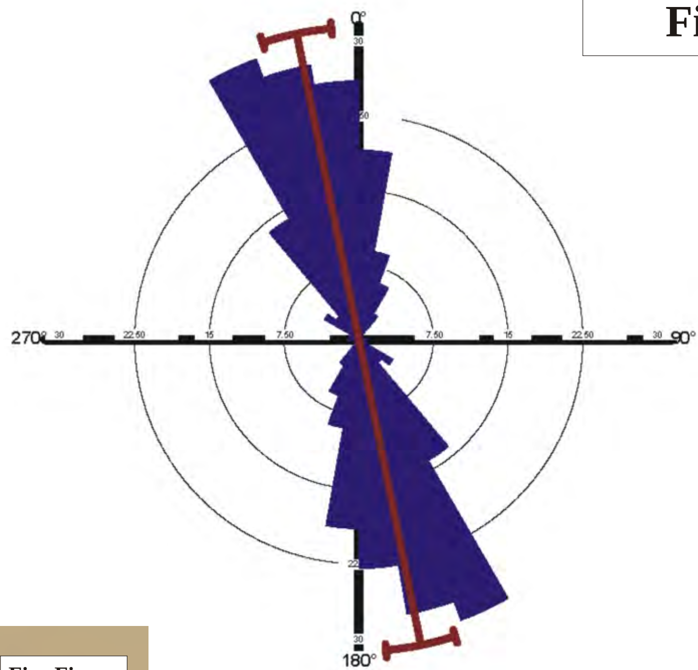
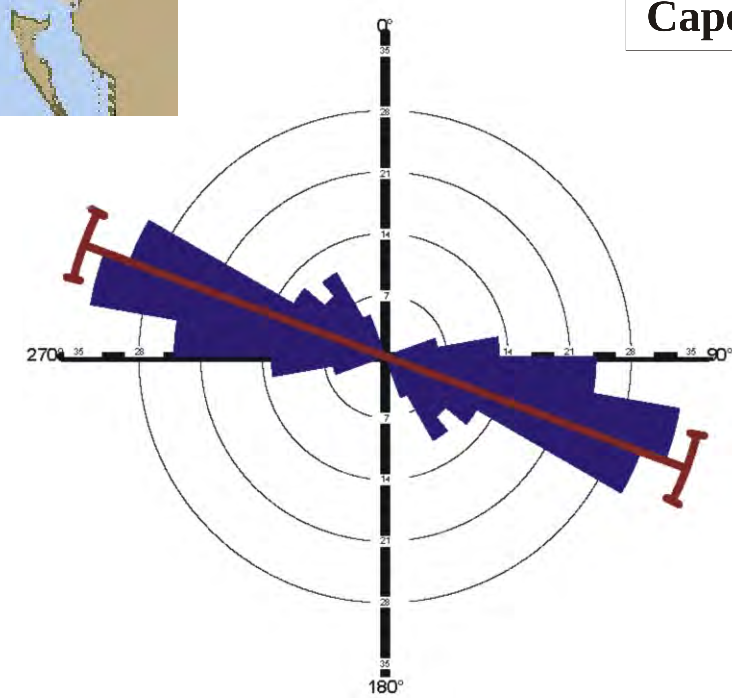
Five Finger



Cape Edgecumbe



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JUNE 2003

FIGURE 6
HISTORIC WIND DATA PRESENTED AS ROSE DIAGRAMS
WHERE WIDTH OF AN ARROW IS PROPORTIONAL TO THE WIND SPEED.
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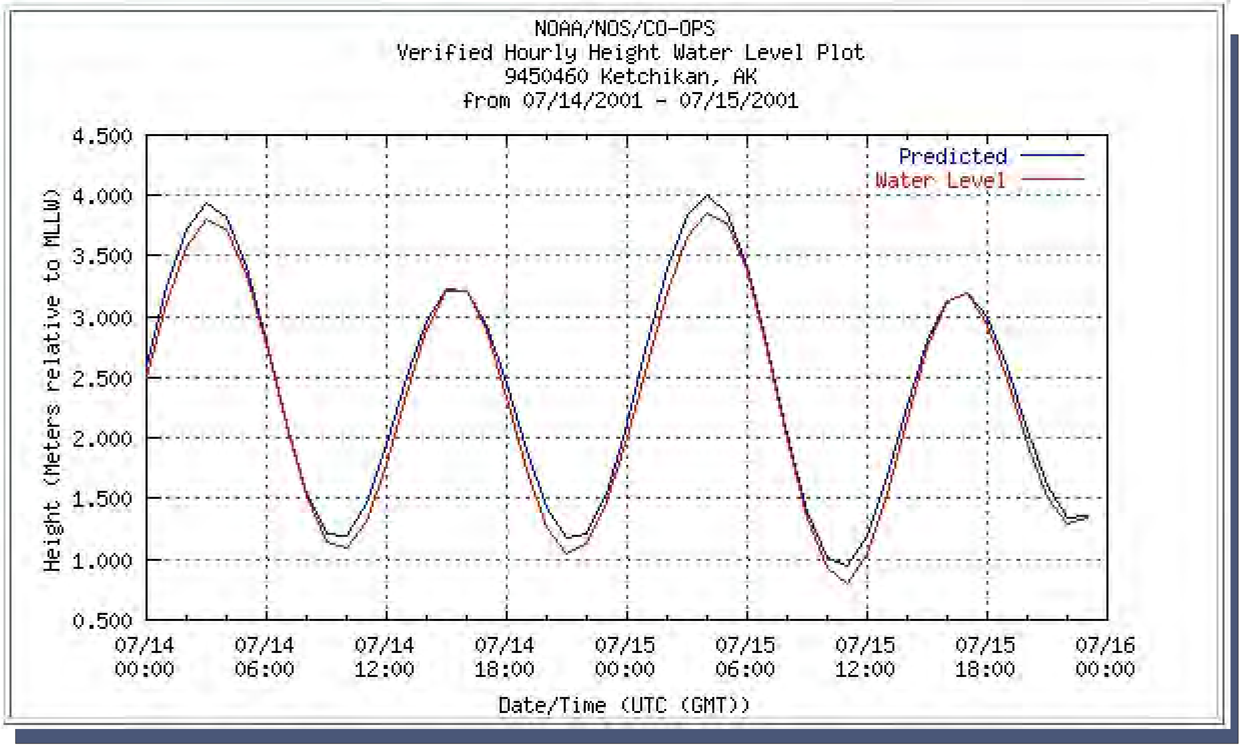

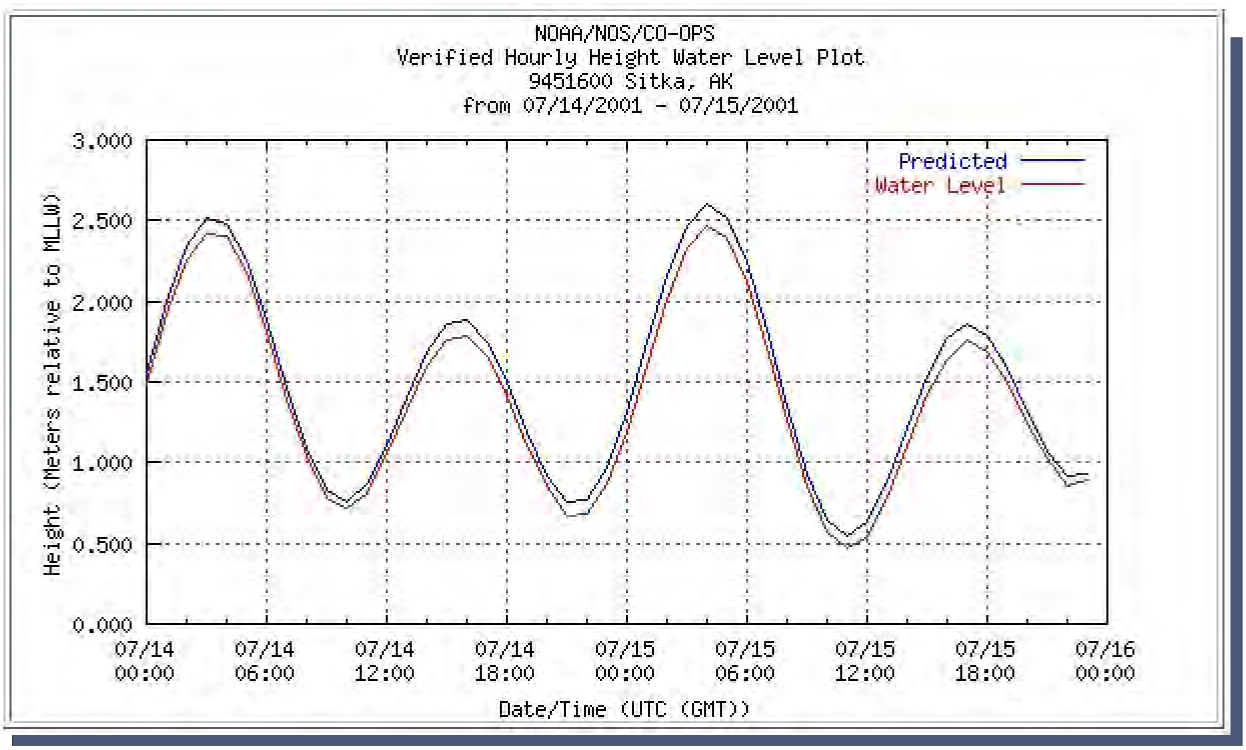

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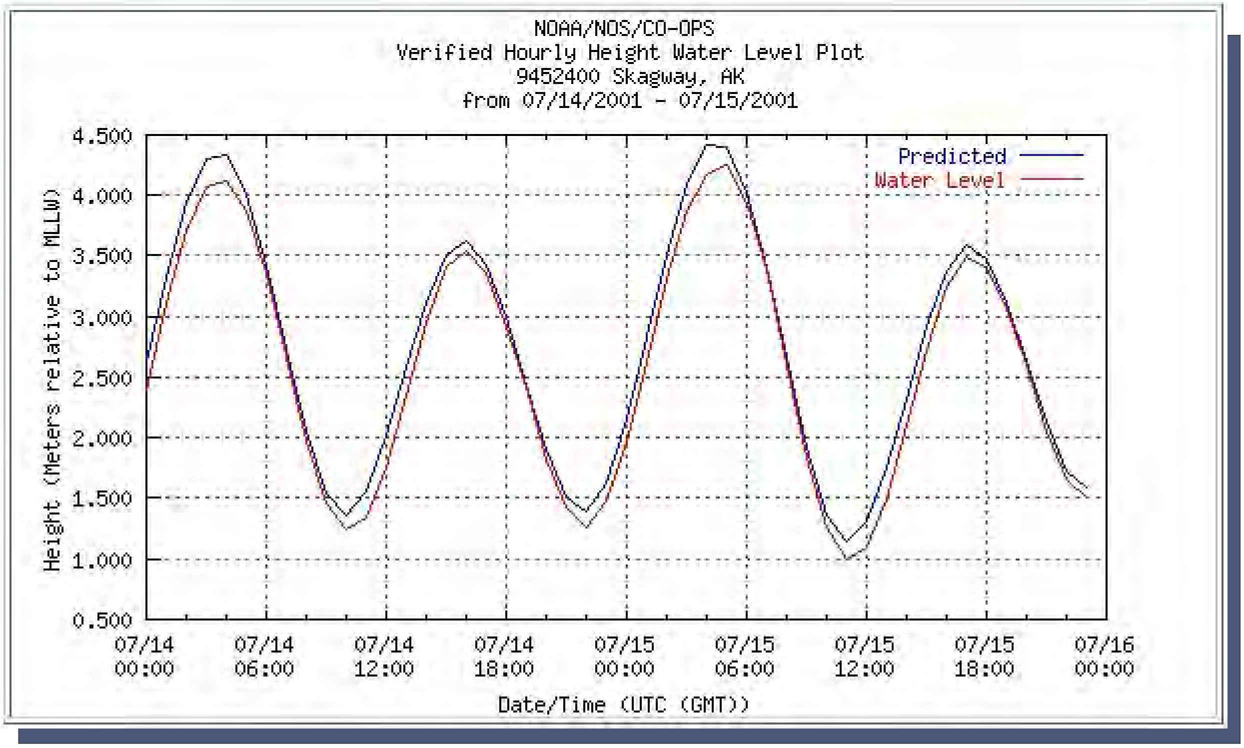
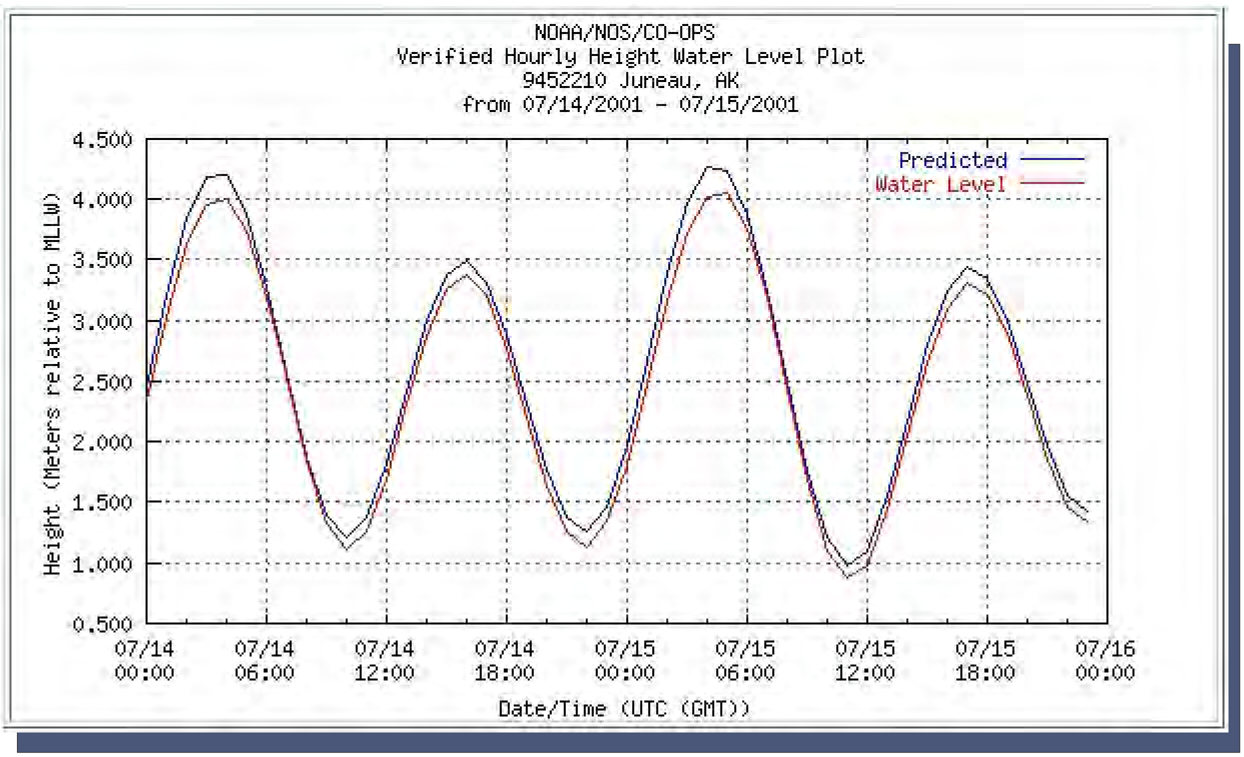
FIGURE 5B
HISTORIC WATER LEVEL DATA (TIDES)
FOR KETCHIKAN AND SITKA, ALASKA
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION





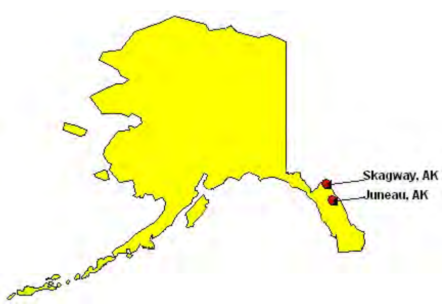


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FIGURE 5A
HISTORIC WATER LEVEL DATA (TIDES)
FOR SKAGWAY AND JUNEAU, ALASKA
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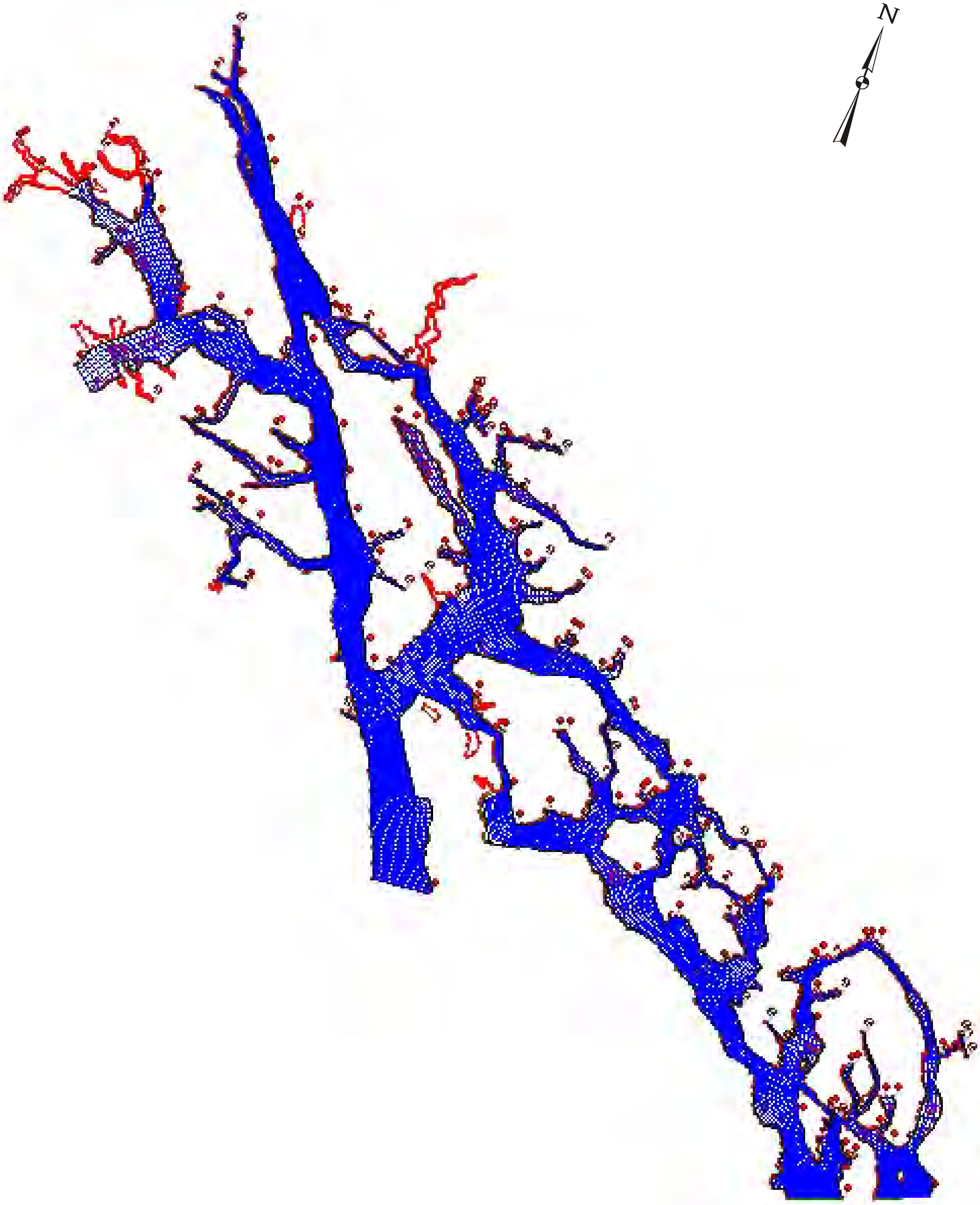
001332AU11_4.CDR



APPROXIMATE SCALE IN KILOMETERS

0 100 200 300

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JUNE 2003

FIGURE 4
CURVILINEAR COMPUTATIONAL GRID SYSTEM ENCOMPASSING THE WATER BODIES SHOWN IN FIGURE 1. RED DOTS ARE BOUNDARY NODES.
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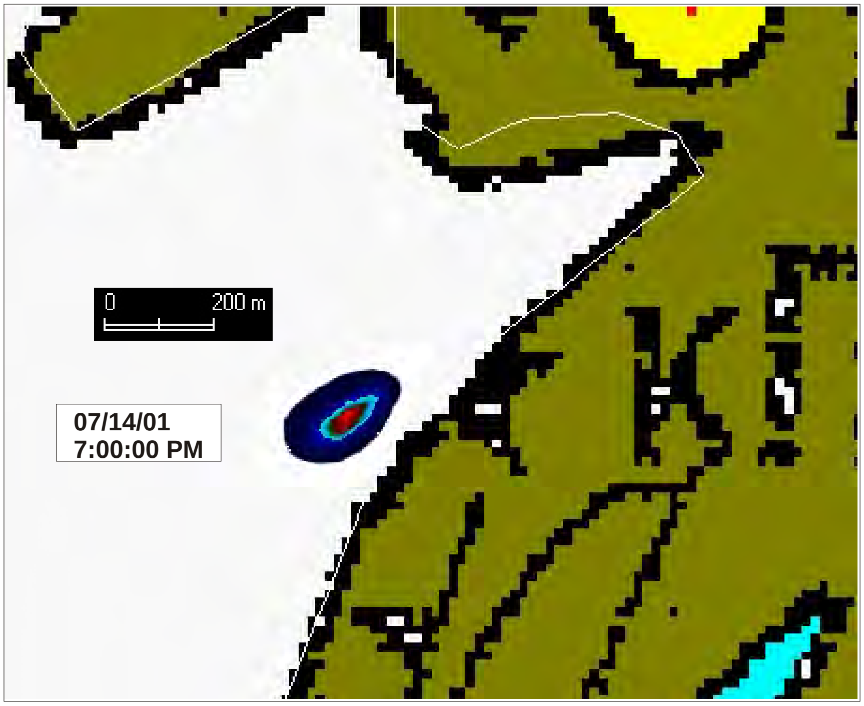


FIGURE 20C
Distribution of Ammonia Nitrogen (NH3-N)
after three hours of discharge from
Taku at Skagway port and
one hour of discharge
from *Spirit of Oceanus*.

CONCENTRATION mg/m3 LEGEND	
Red	0.29 - 0.24
Dark maroon	0.23 - 0.15
Green	0.14 - 0.12
Blue	0.11 - 0.09
Turquoise	0.08 - 0.07
Dark blue	0.06 - 0.02
Black	0.01 - -0.41E-4

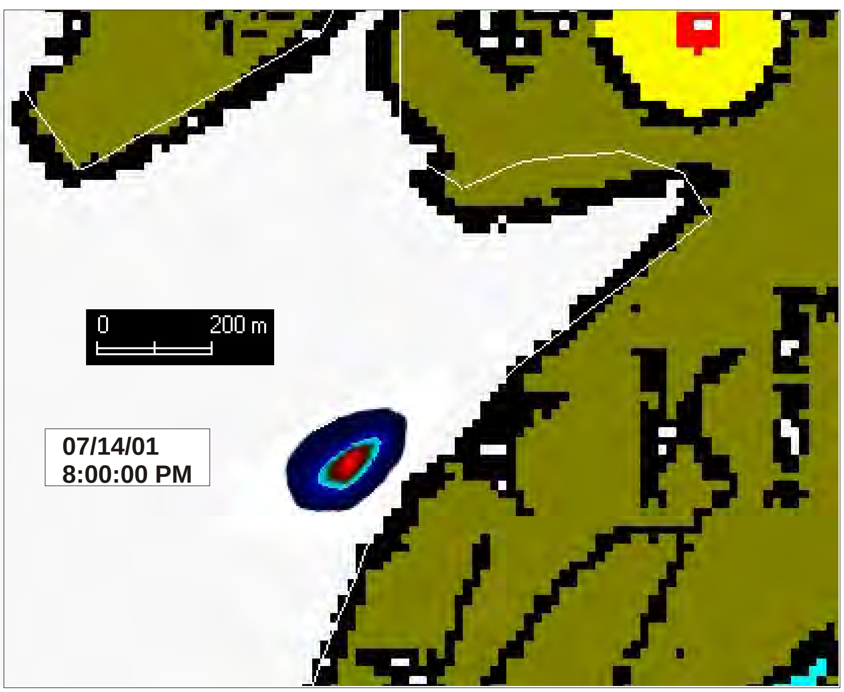
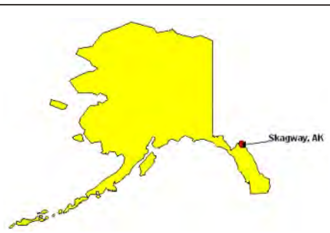


FIGURE 20D
Distribution of Ammonia Nitrogen (NH3-N)
after four hours of discharge from
Taku at Skagway port and
two hours of discharge
from *Spirit of Oceanus*.

CONCENTRATION mg/m3 LEGEND	
Red	0.46 - 0.24
Dark maroon	0.23 - 0.22
Green	0.21 - 0.20
Blue	0.19 - 0.18
Turquoise	0.17 - 0.09
Dark blue	0.08 - 0.02
Black	0.01 - -0.6E-4



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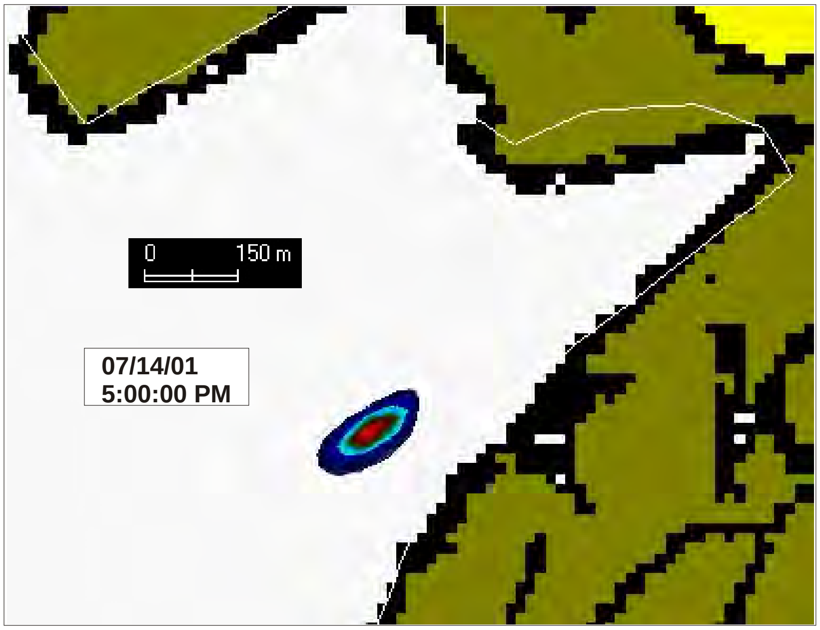


FIGURE 20A
Distribution of Ammonia Nitrogen (NH3-N) after one hour of discharge from *Taku* at Skagway port.

CONCENTRATION mg/m3 LEGEND	
Red	0.77E-2 - 0.42E-2
Dark maroon	0.41E-2 - 0.38E-2
Green	0.37E-2 - 0.36E-2
Blue	0.35E-2 - 0.34E-2
Cyan	0.33E-2 - 1.23E-4
Navy	1.22E-4 - 1.16E-4
Black	1.15E-4 - -1.82E-6

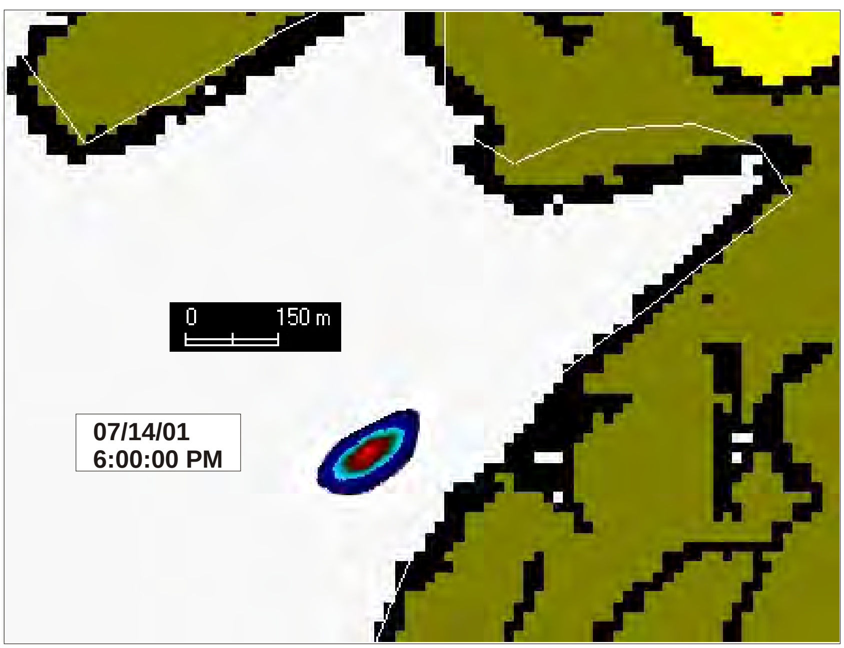
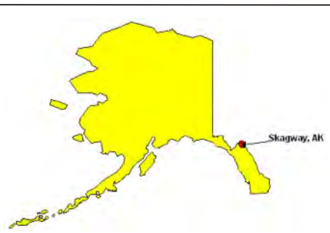


FIGURE 20B
Distribution of Ammonia Nitrogen (NH3-N) after two hours of discharge from *Taku* at Skagway port. *Spirit of Oceanus* starts discharging.

CONCENTRATION mg/m3 LEGEND	
Red	0.01 - 0.73E-2
Dark maroon	0.72E-2 - 0.58E-2
Green	0.57E-2 - 0.56E-2
Blue	0.55E-2 - 0.33E-2
Cyan	0.32E-2 - 0.73E-3
Navy	0.72E-3 - 0.44E-3
Black	0.43E-3 - -0.57E-5



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PROJECT No. 001332.AU11.01 JUNE 2003

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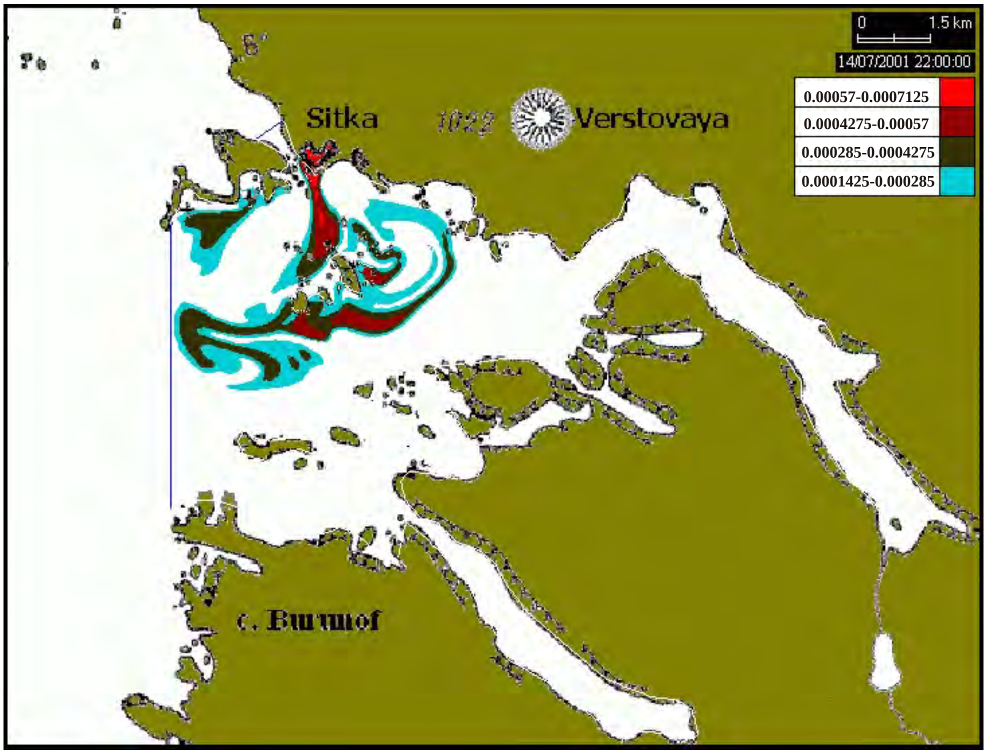
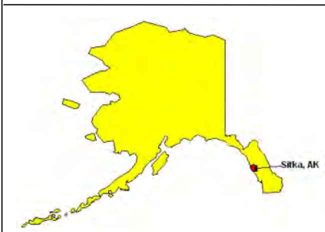


FIGURE 13K
Depth averaged *Free Chlorine* concentration (mg/m^3) after twenty four hours of discharge from the *Spirit of Columbia*.



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PROJECT No. 001332.AU11.01	**JUNE 2003**

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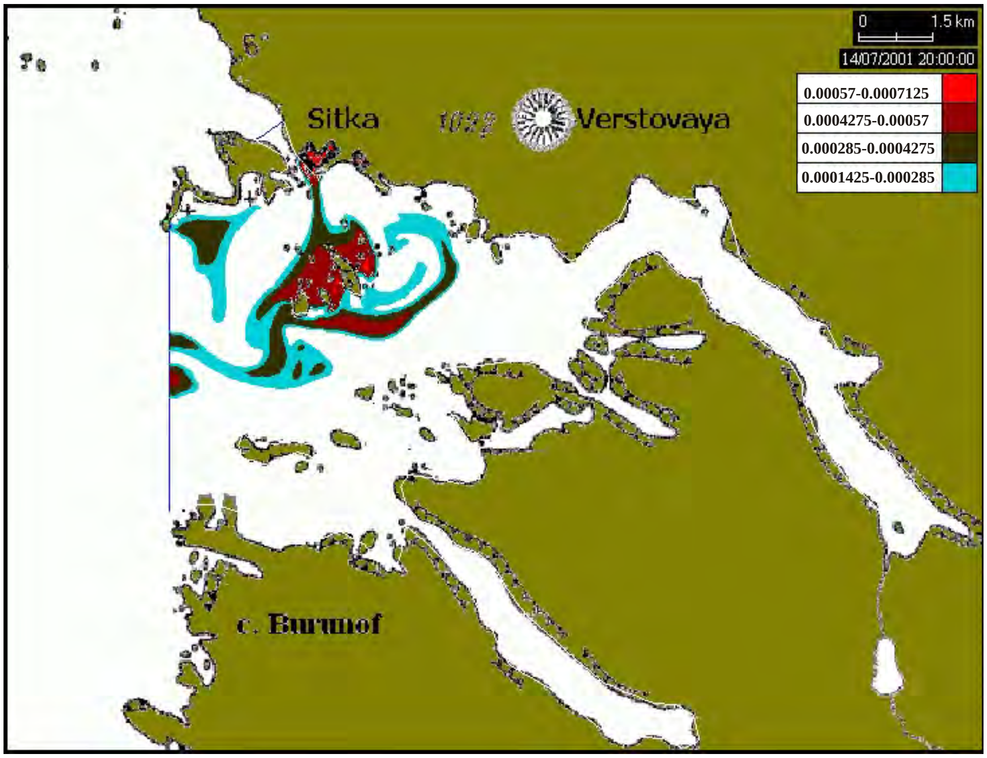


FIGURE 13I
Depth averaged *Free Chlorine* concentration (mg/m^3) after twenty hours of discharge from the *Spirit of Columbia*.

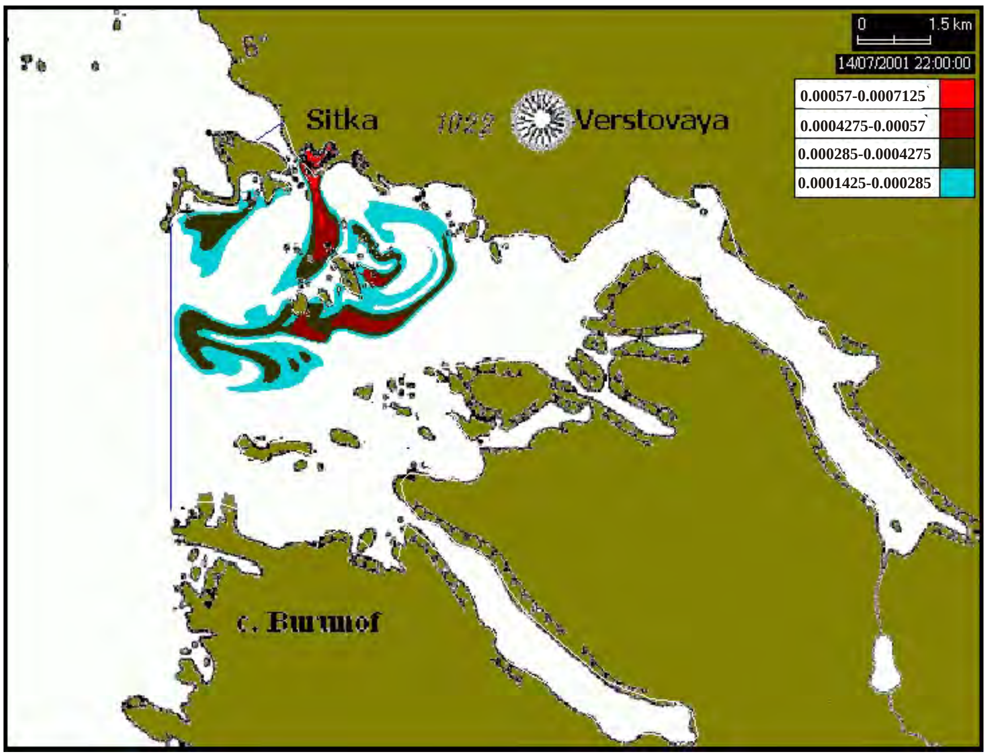
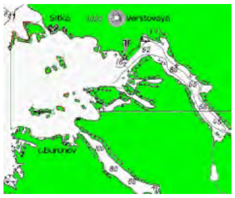


FIGURE 13J
Depth averaged *Free Chlorine* concentration (mg/m^3) after twenty two hours of discharge from the *Spirit of Columbia*.



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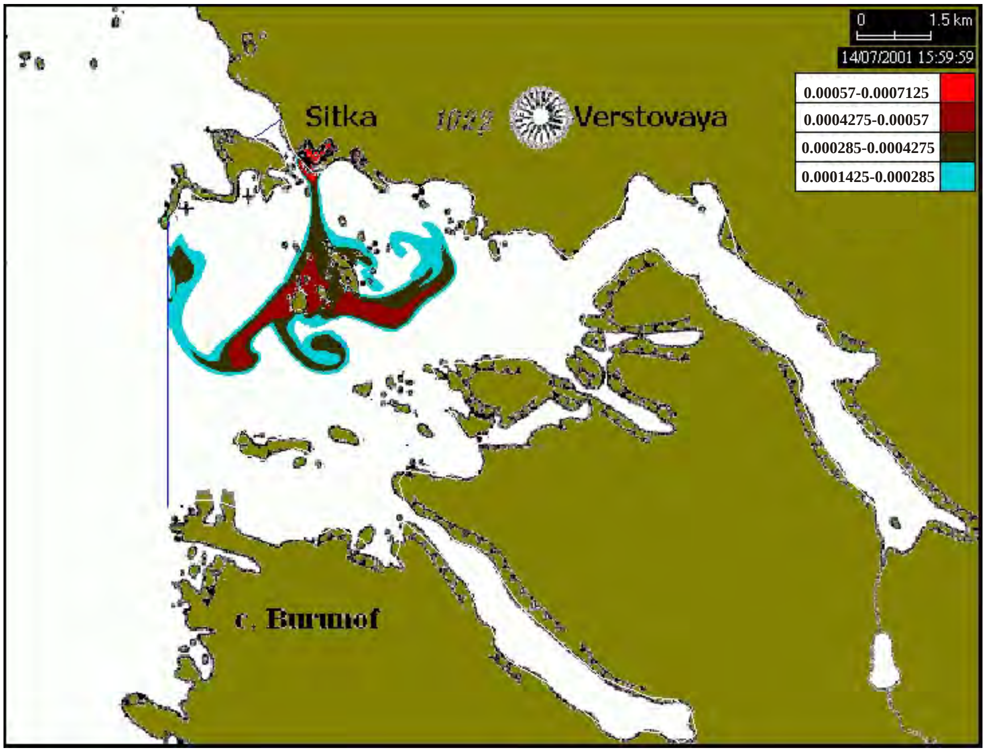


FIGURE 13G
Depth averaged *Free Chlorine* concentration (mg/m^3) after sixteen hours of discharge from the *Spirit of Columbia*.

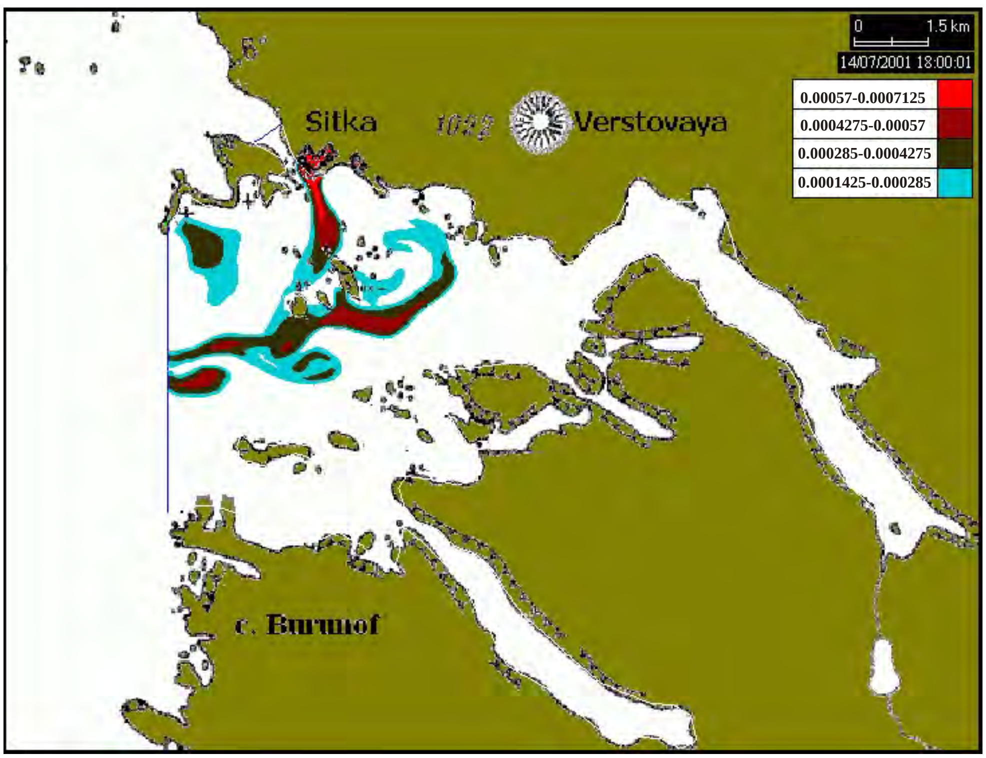
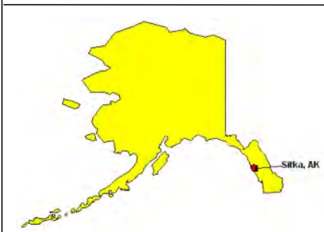


FIGURE 13H
Depth averaged *Free Chlorine* concentration (mg/m^3) after eighteen hours of discharge from the *Spirit of Columbia*.



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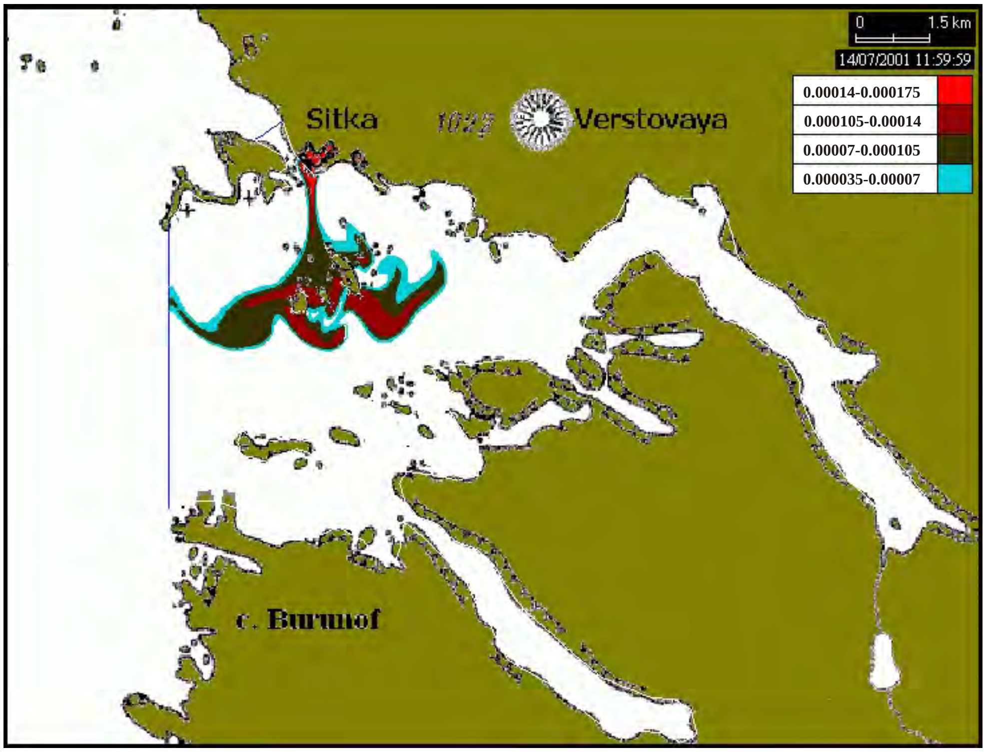


FIGURE 13E
Depth averaged *Free Chlorine* concentration (mg/m^3) after twelve hours of discharge from the *Spirit of Columbia*.

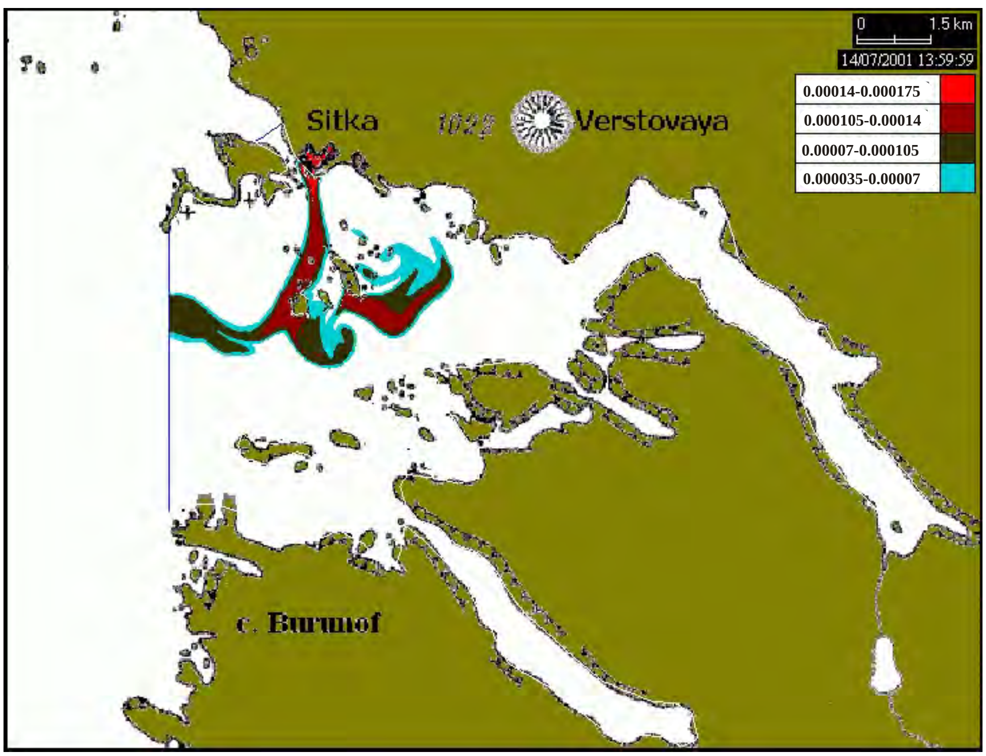
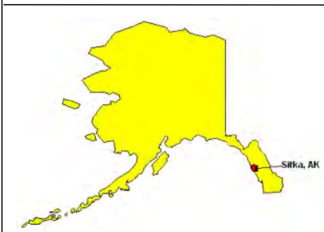
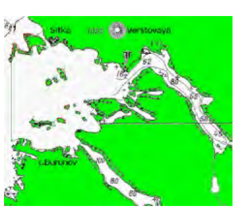


FIGURE 13F
Depth averaged *Free Chlorine* concentration (mg/m^3) after fourteen hours of discharge from the *Spirit of Columbia*.





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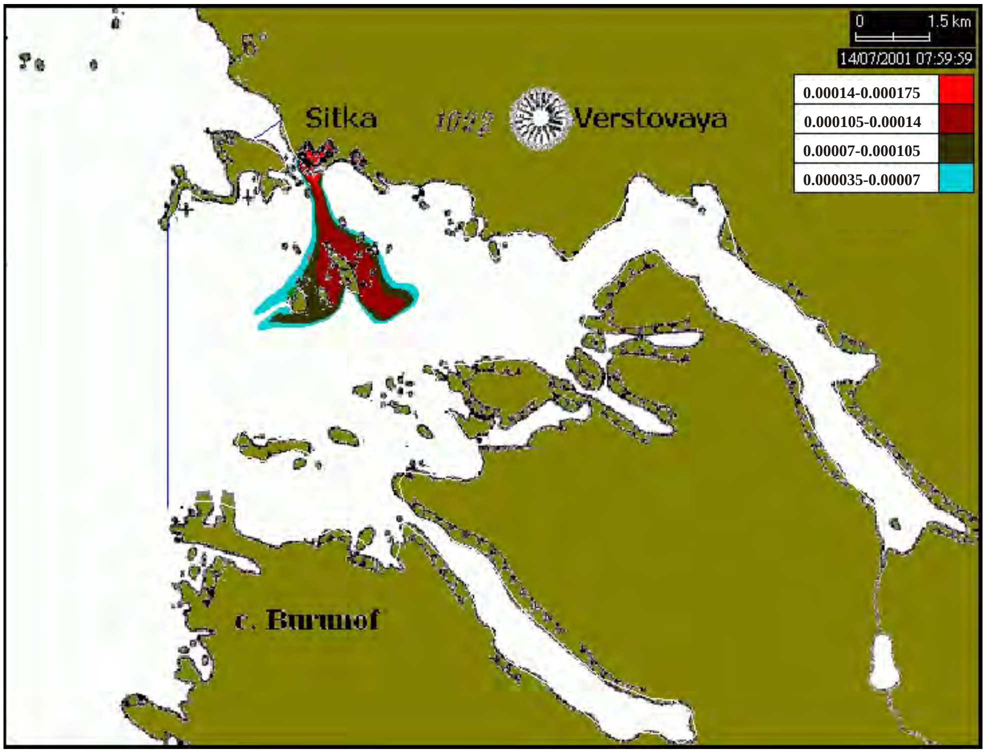


FIGURE 13C
Depth averaged *Free Chlorine* concentration (mg/m^3) after eight hours of discharge from the *Spirit of Columbia*.

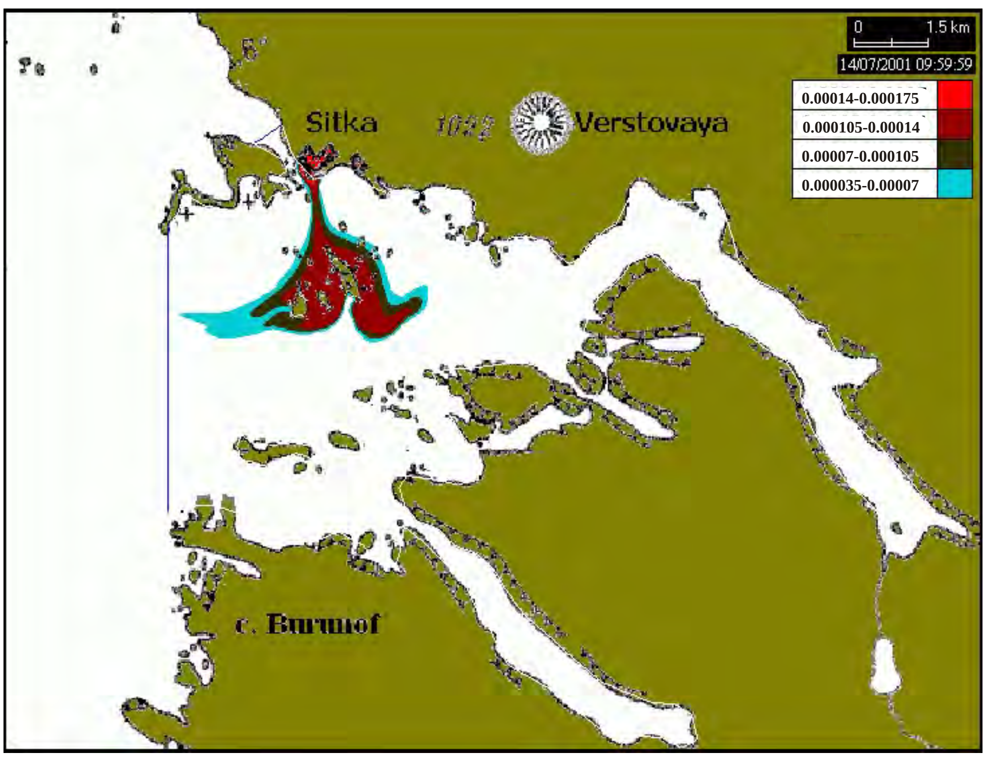
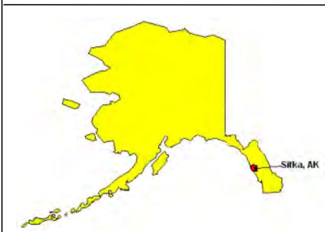
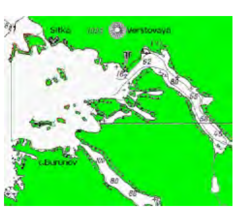


FIGURE 13D
Depth averaged *Free Chlorine* concentration (mg/m^3) after ten hours of discharge from the *Spirit of Columbia*.





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PROJECT No. 001332.AU11.01 **JUNE 2003**

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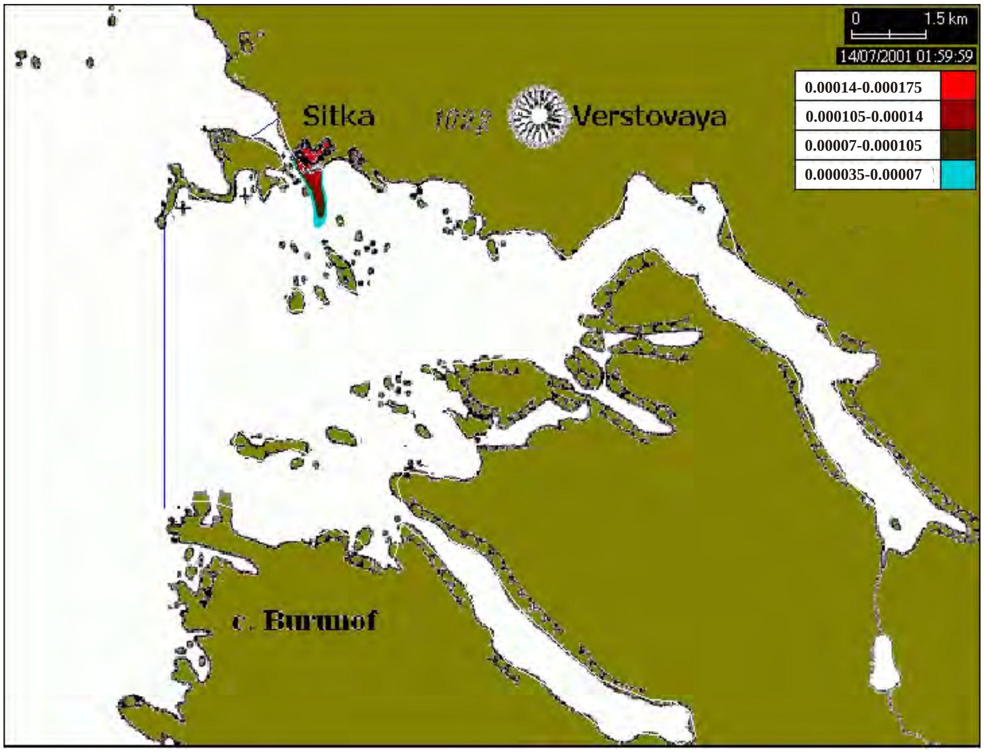


FIGURE 13A
Depth averaged *Free Chlorine* concentration (mg/m^3) after two hours of discharge from the *Spirit of Columbia*.

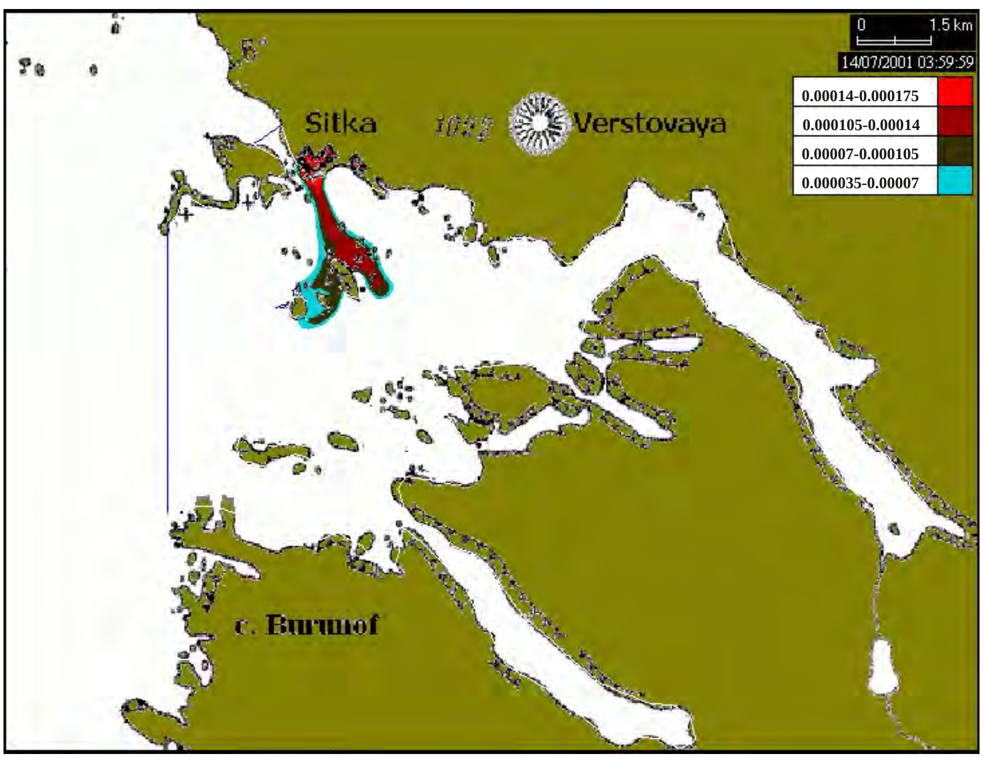
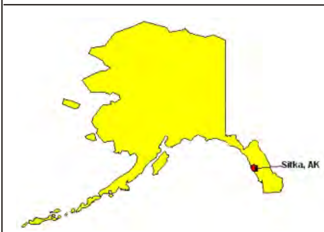


FIGURE 13B
Depth averaged *Free Chlorine* concentration (mg/m^3) after four hours of discharge from the *Spirit of Columbia*.



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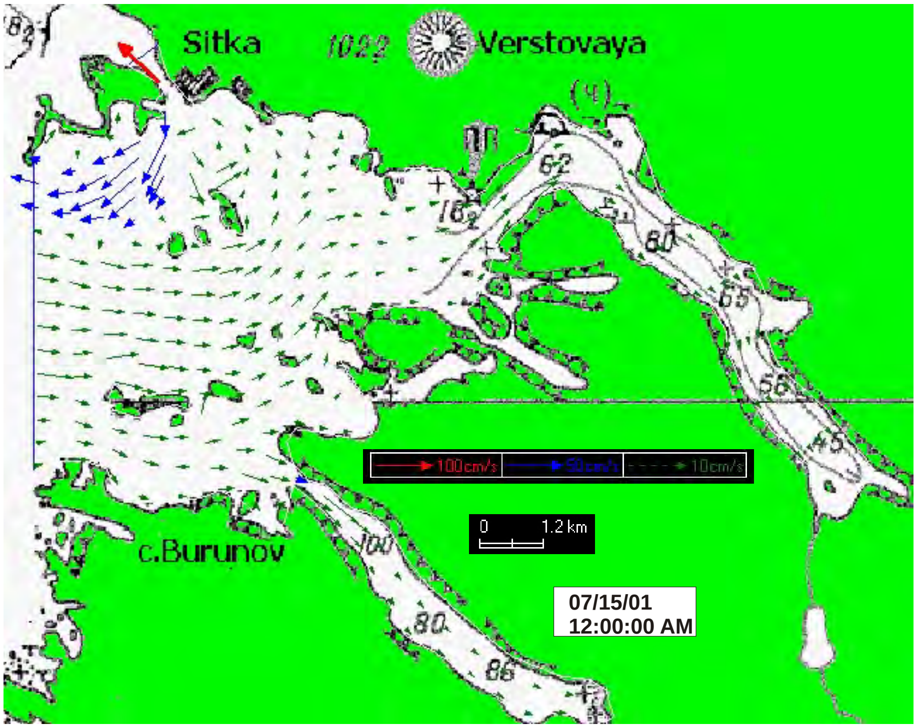


FIGURE 12U
Velocity pattern after twenty four hours of start of discharge from the *Spirit of Columbia* at Sitka port and eight hours of discharge from *Kennicott*.

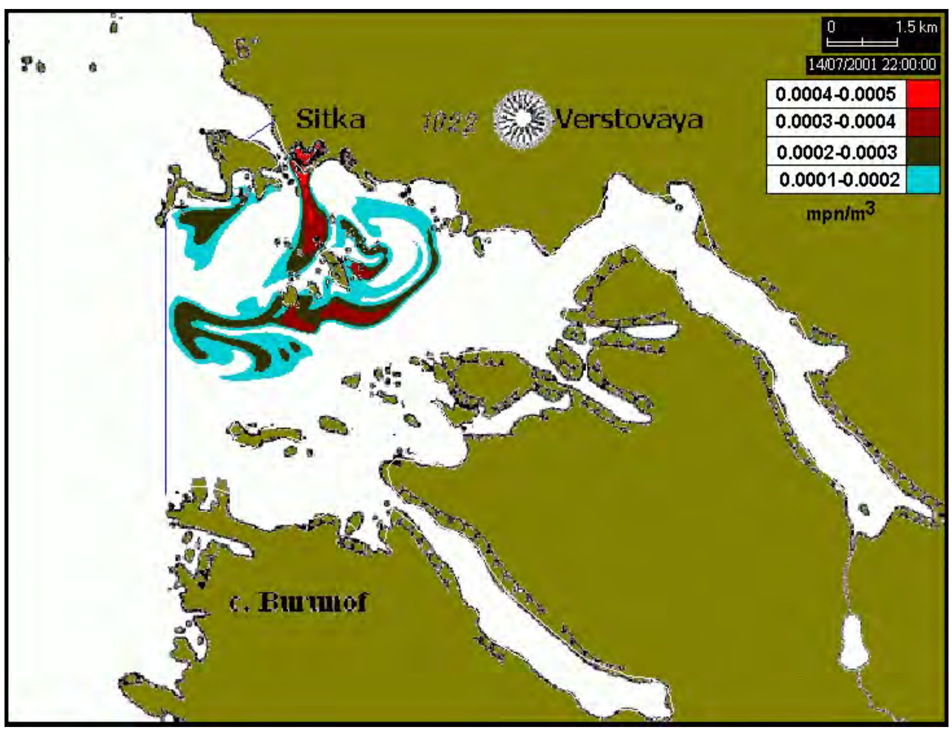
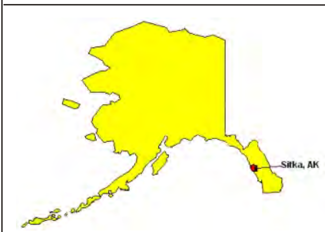


FIGURE 12V
Depth averaged *fecal coliform* concentration (MPN/m^3) after twenty four hours of discharge from the *Spirit of Columbia* and eight hours of discharge from *Kennicott*.



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PROJECT No. 001332.AU11.01 **JUNE 2003**

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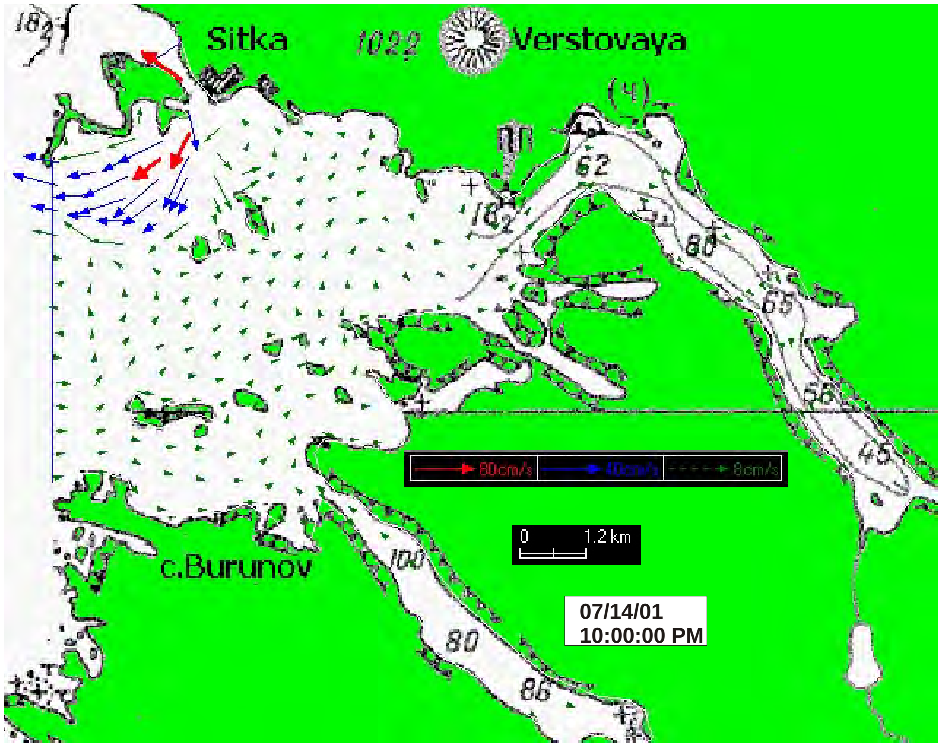


FIGURE 12S
Velocity pattern after twenty two hours of start of discharge from the *Spirit of Columbia* at Sitka port and six hours of discharge from *Kennicott*.

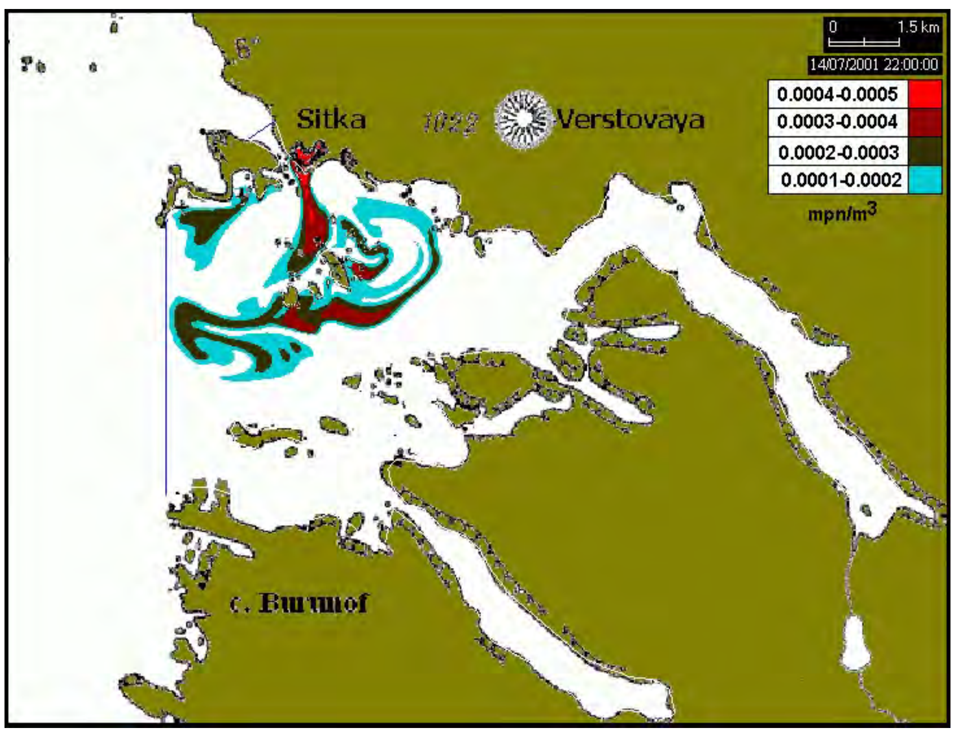
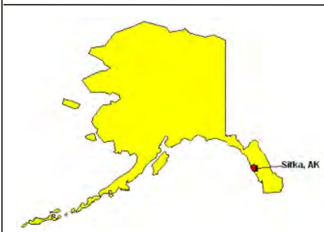


FIGURE 12T
Depth averaged *fecal coliform* concentration (MPN/m^3) after twenty two hours of discharge from the *Spirit of Columbia* and six hours of discharge from *Kennicott*.



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PROJECT No. 001332.AU11.01 JUNE 2003

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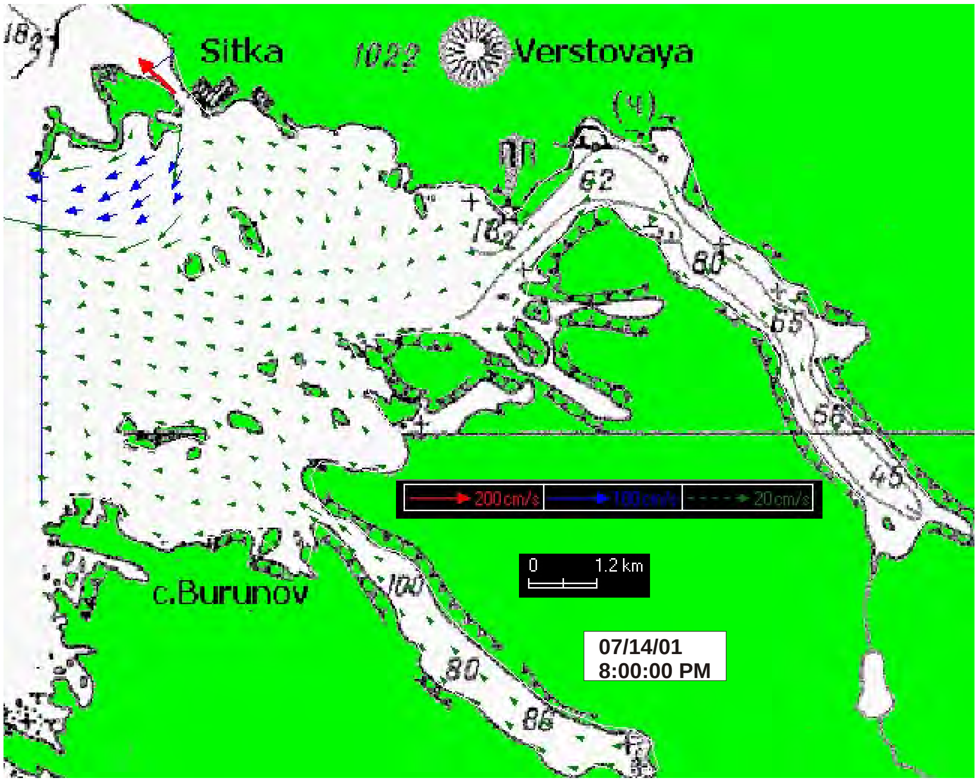


FIGURE 12Q
Velocity pattern after twenty hours of start of discharge from the *Spirit of Columbia* at Sitka port and four hours of discharge from *Kennicott*.

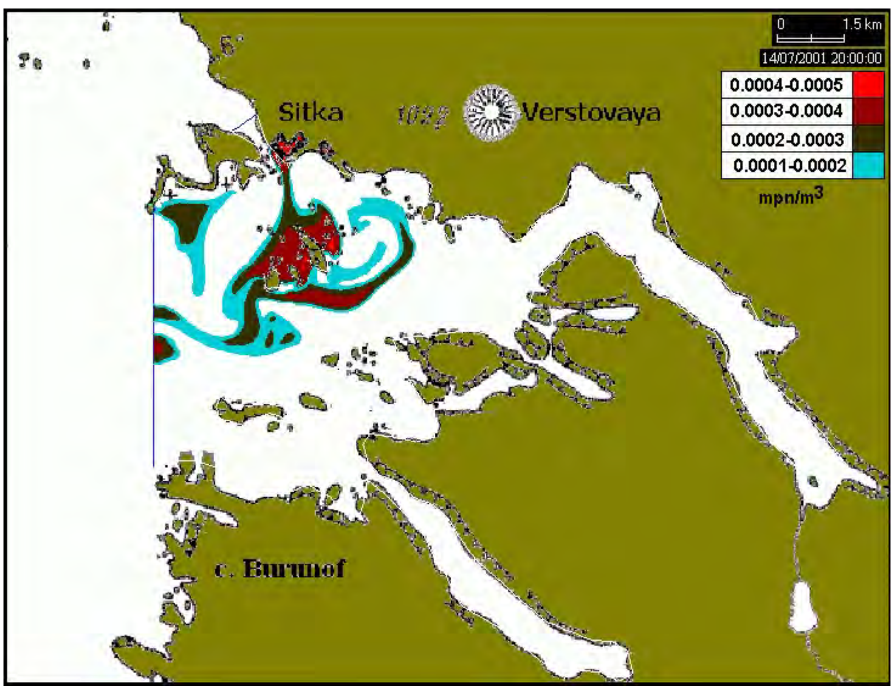
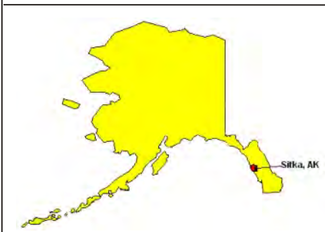


FIGURE 12R
Depth averaged *fecal coliform* concentration (MPN/m^3) after twenty hours of discharge from the *Spirit of Columbia* and four hours of discharge from *Kennicott*.



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PROJECT No. 001332.AU11.01 **JUNE 2003**

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

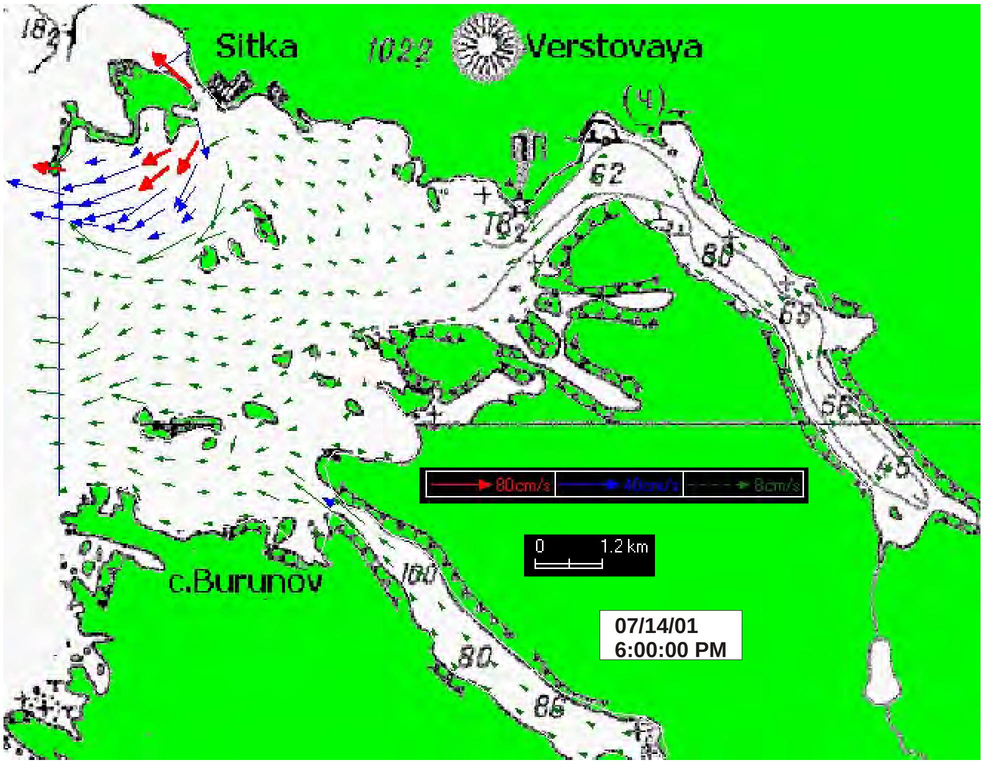


FIGURE 12O
Velocity pattern after eighteen hours of start of discharge from the *Spirit of Columbia* at Sitka port and two hours of discharge from *Kennicott*.

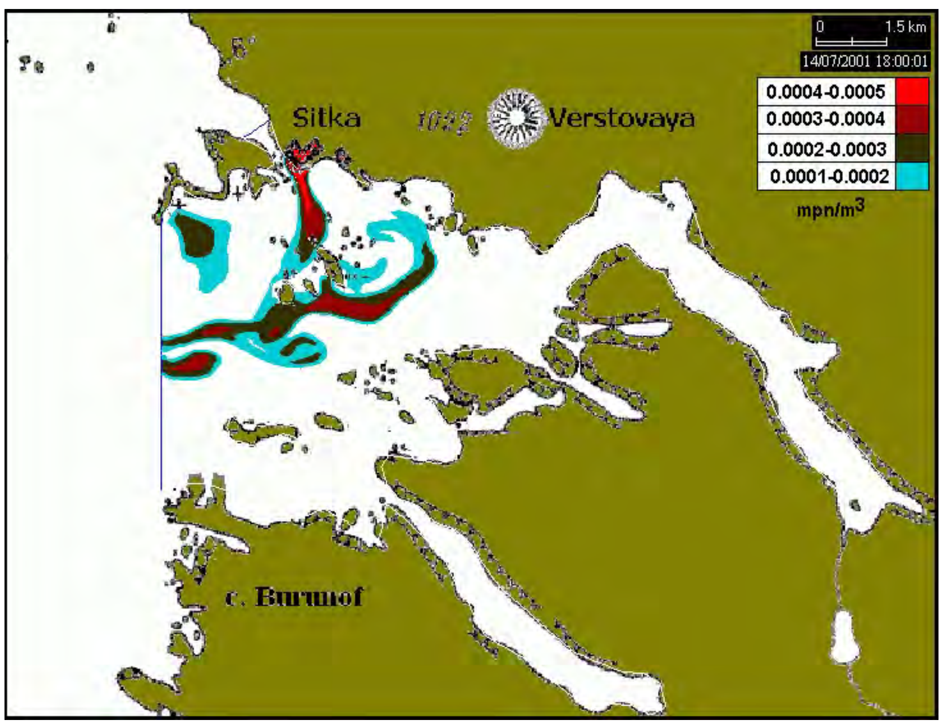
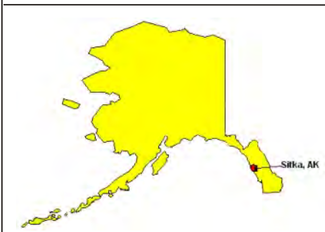


FIGURE 12P
Depth averaged *fecal coliform* concentration (MPN/m^3) after eighteen hours of discharge from the *Spirit of Columbia* and two hours of discharge from *Kennicott*.



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PROJECT No. 001332.AU11.01	**JUNE 2003**

GRAPHICAL REPRESENTATION OF MODEL RESULTS
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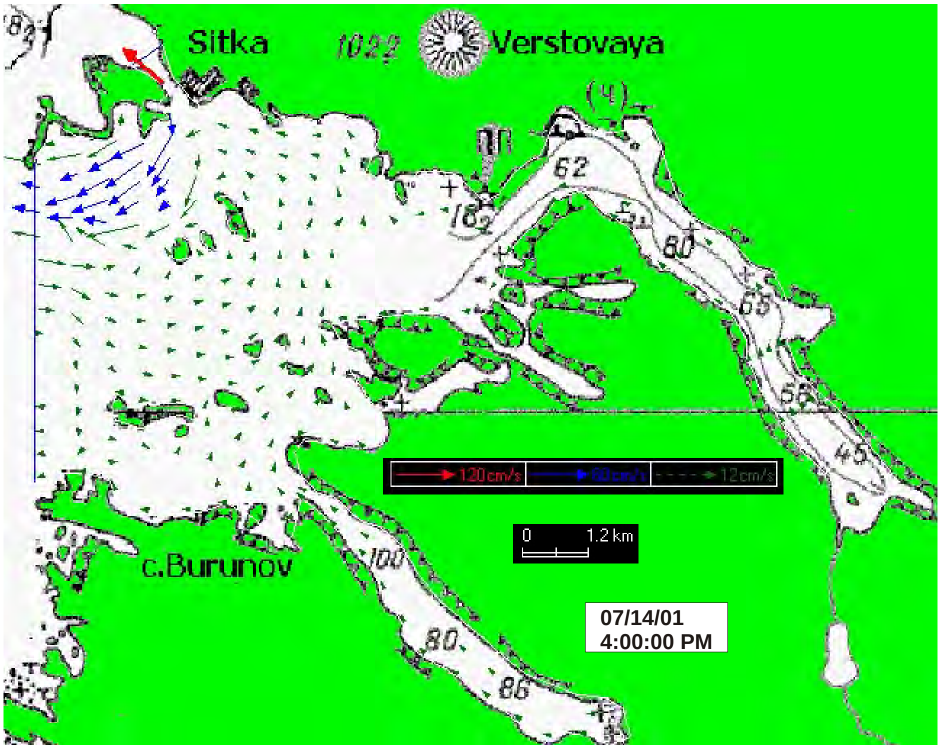


FIGURE 12M
Velocity pattern after sixteen hours of start of discharge from the *Spirit of Columbia* at Sitka port. *Kennicott* starts discharging.

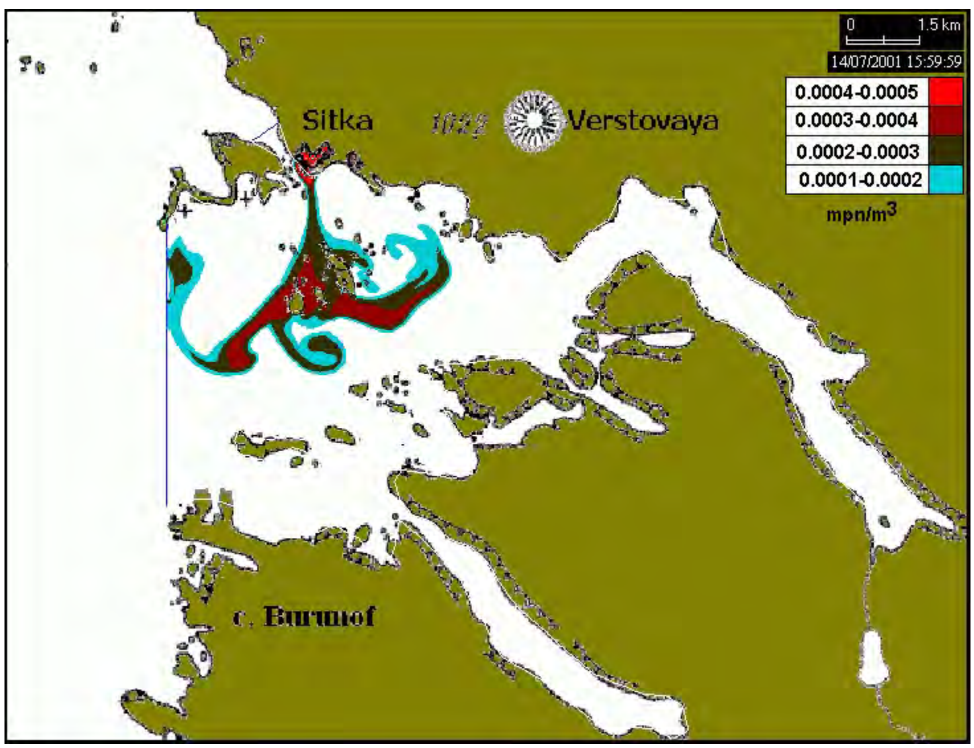
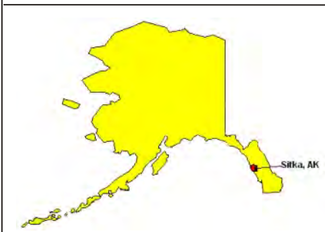


FIGURE 12N
Depth averaged *fecal coliform* concentration (MPN/m^3) after sixteen hours of discharge from the *Spirit of Columbia*.



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PROJECT No. 001332.AU11.01 JUNE 2003

GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

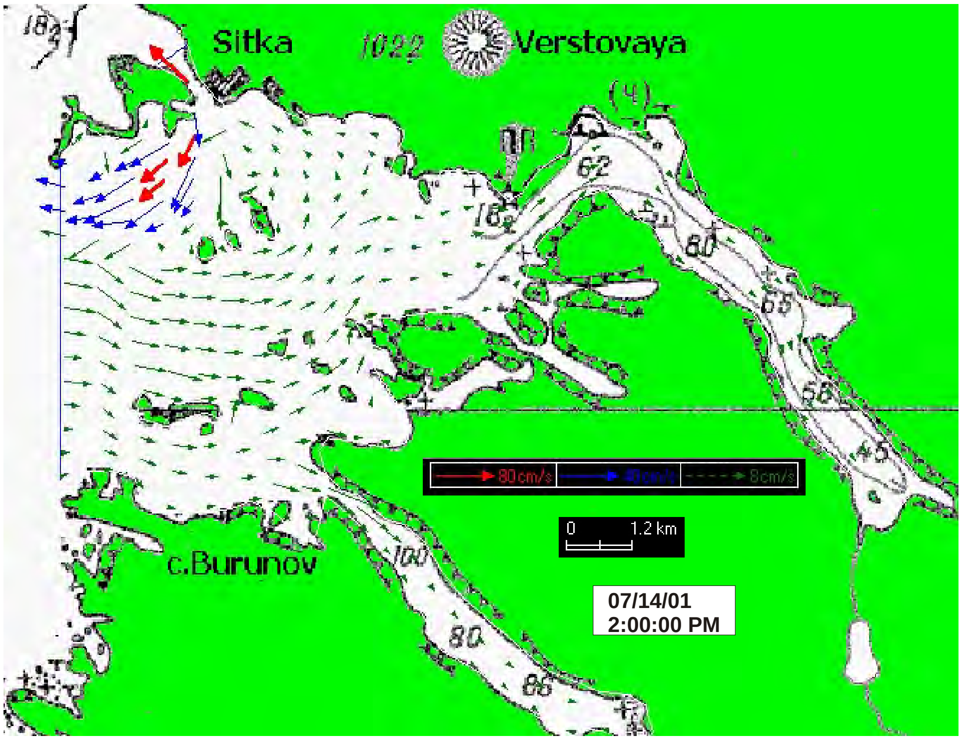


FIGURE 12K
Velocity pattern after fourteen hours of start of discharge from the *Spirit of Columbia* at Sitka port.

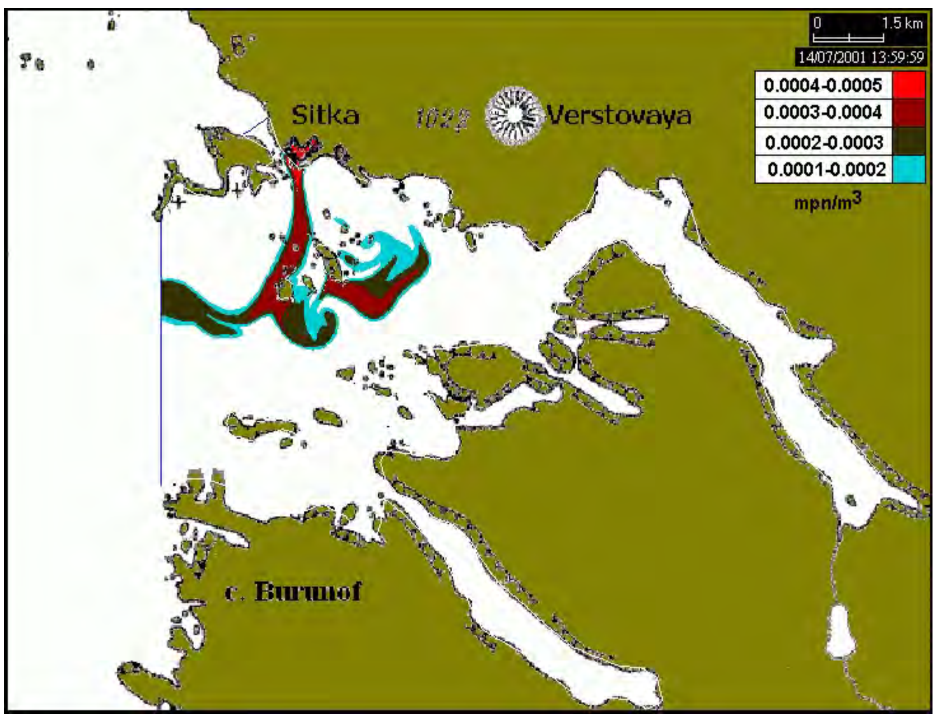
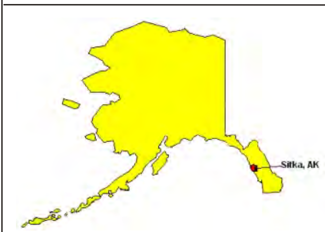


FIGURE 12L
Depth averaged *fecal coliform* concentration (MPN/m^3) after fourteen hours of discharge from the *Spirit of Columbia*.



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GRAPHICAL REPRESENTATION OF MODEL RESULTS
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

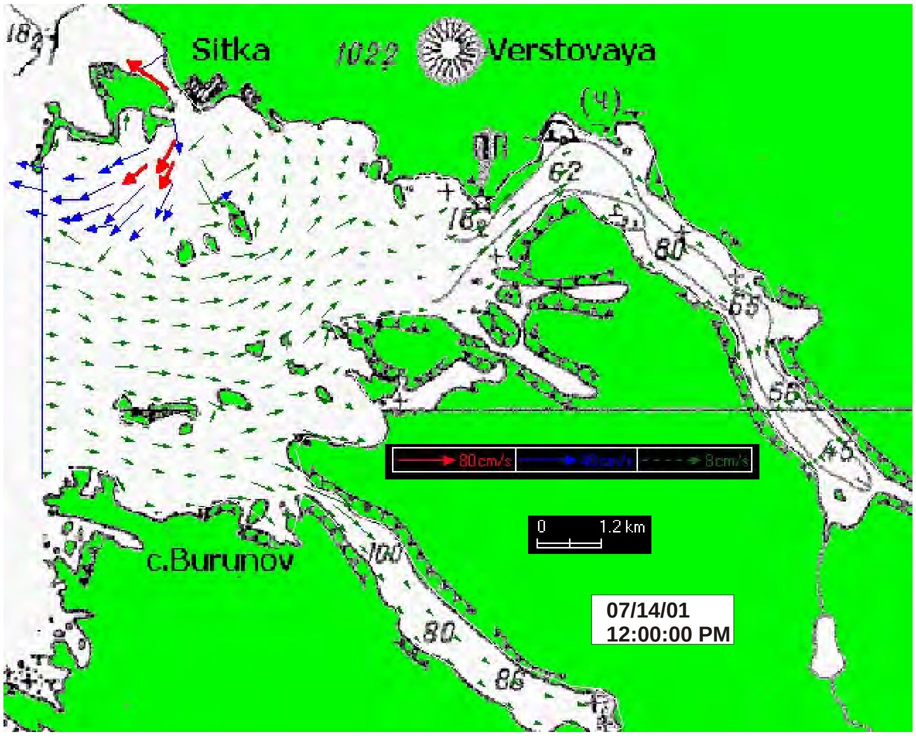


FIGURE 12I
Velocity pattern after twelve hours of start of discharge from the *Spirit of Columbia* at Sitka port.

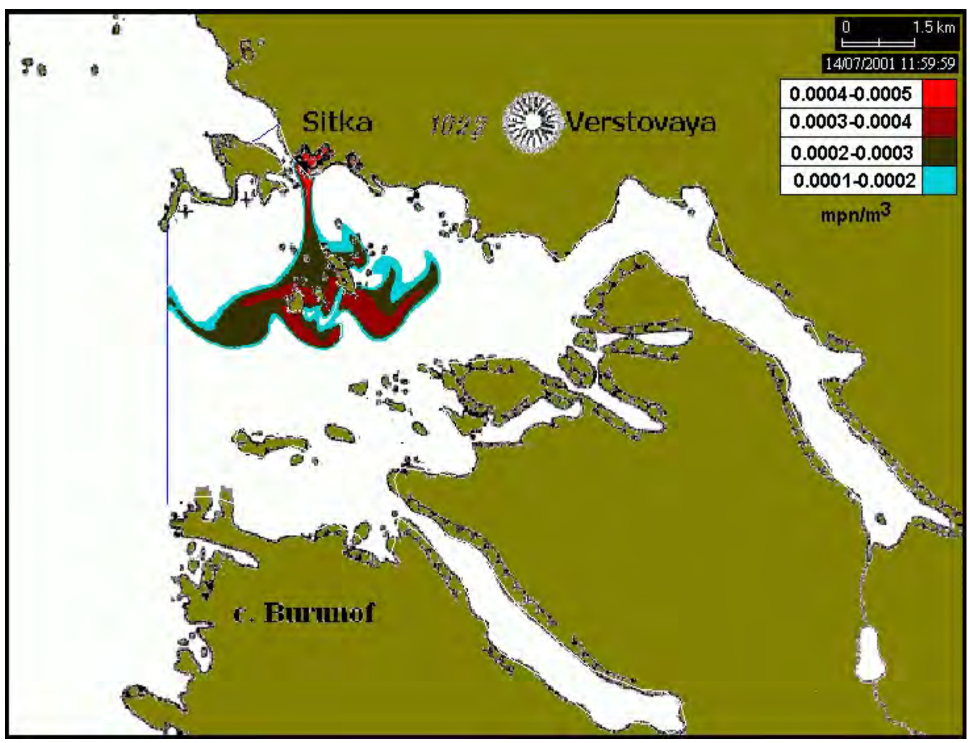
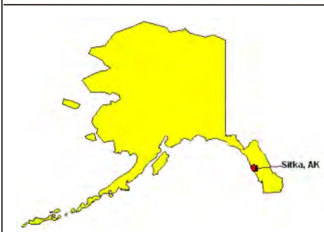


FIGURE 12J
Depth averaged *fecal coliform* concentration (MPN/m^3) after twelve hours of discharge from the *Spirit of Columbia*.



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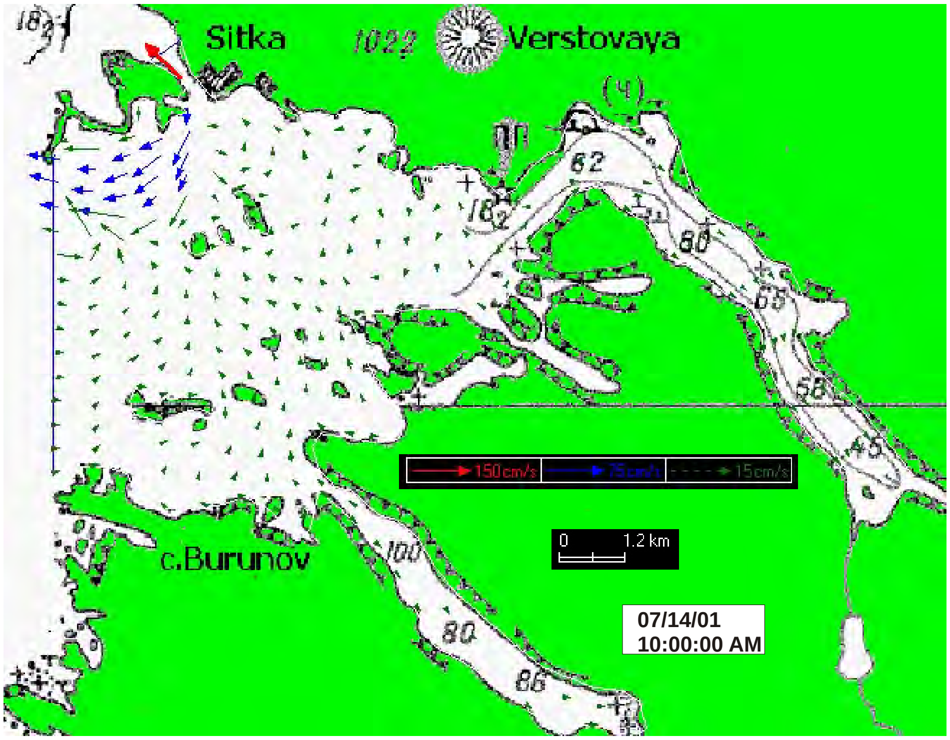


FIGURE 12G
Velocity pattern after ten hours of start of discharge from the *Spirit of Columbia* at Sitka port.

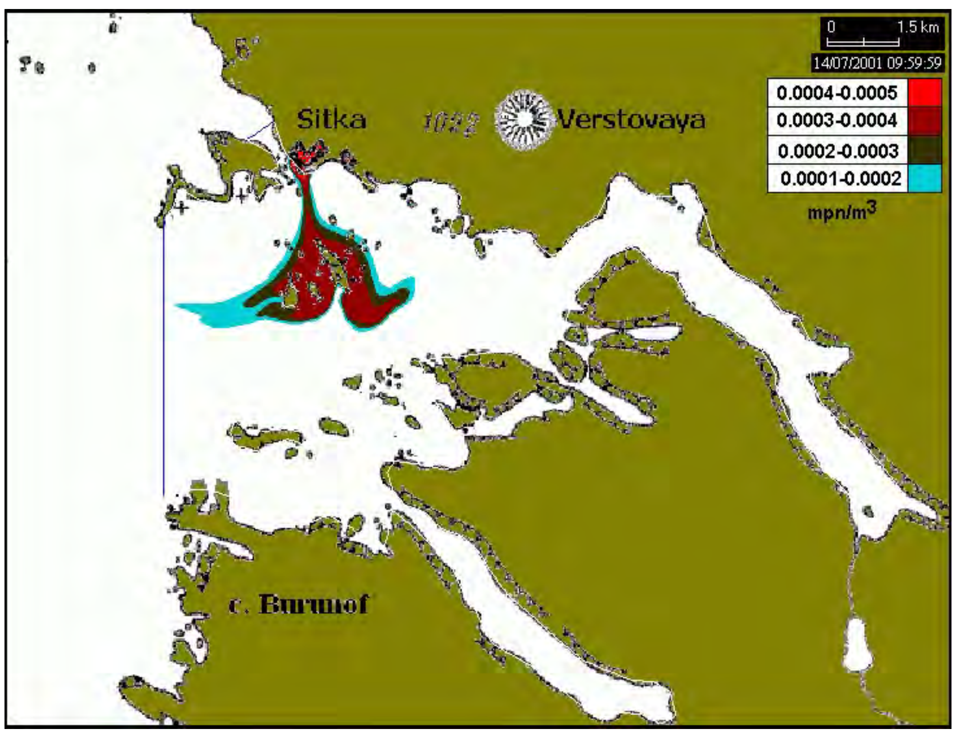
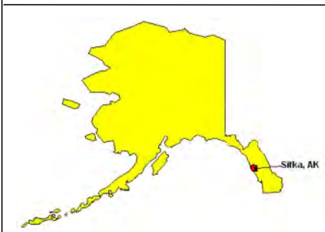


FIGURE 12H
Depth averaged *fecal coliform* concentration (MPN/m^3) after ten hours of discharge from the *Spirit of Columbia*.



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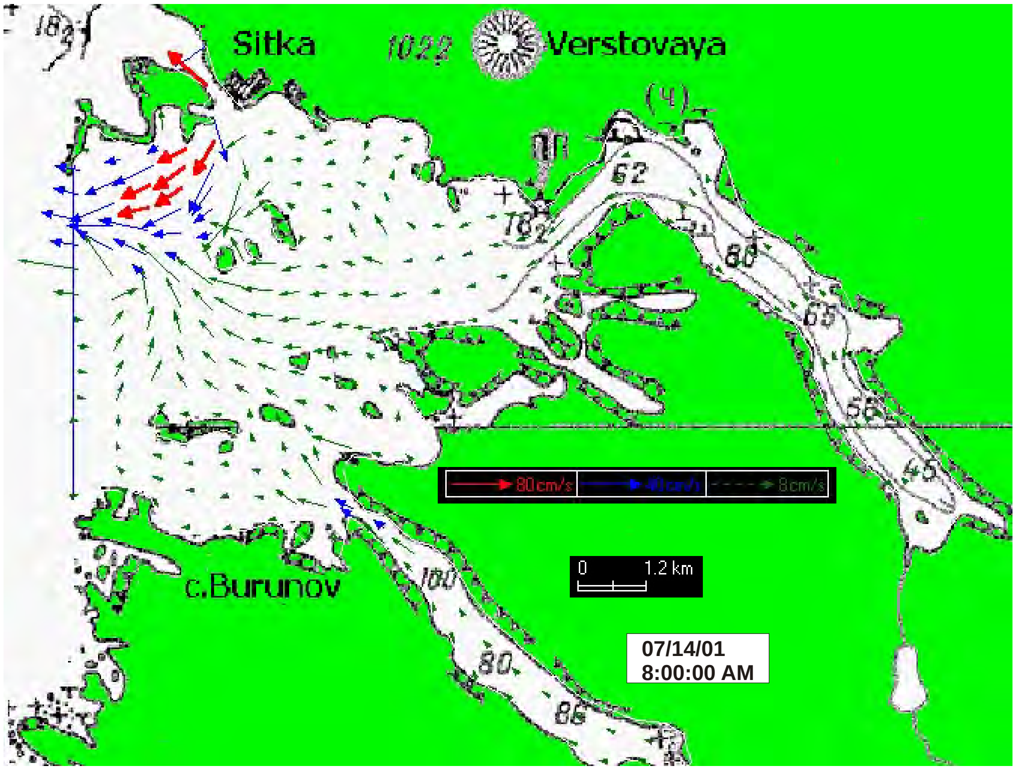
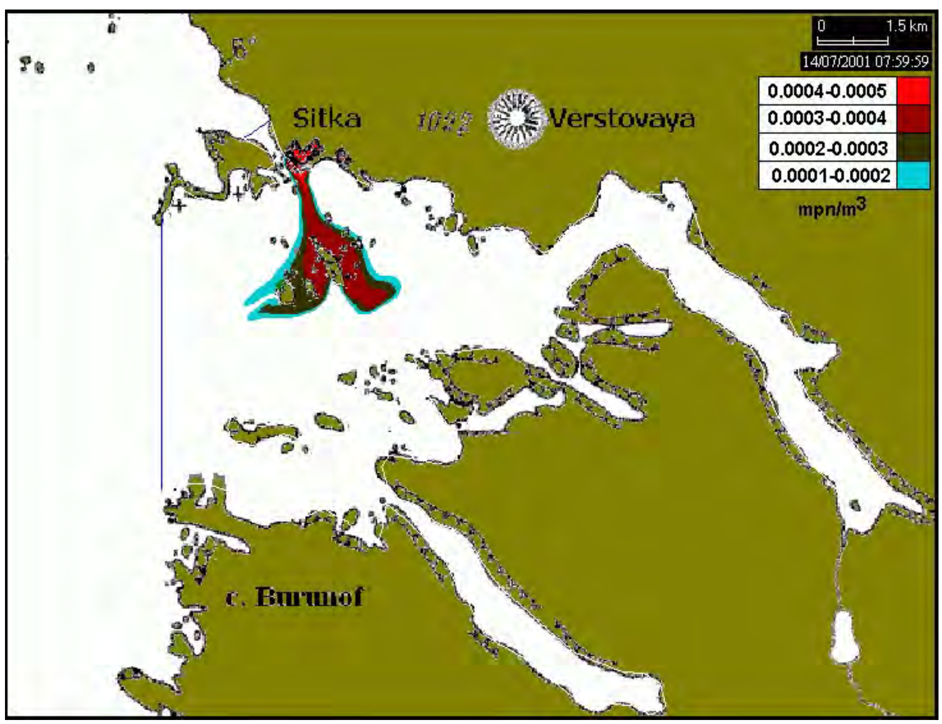
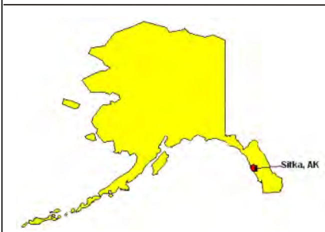


FIGURE 12E
Velocity pattern after eight hours of start of discharge from the *Spirit of Columbia* at Sitka port.

FIGURE 12F
Depth averaged *fecal coliform* concentration (MPN/m^3) after eight hours of discharge from the *Spirit of Columbia*.





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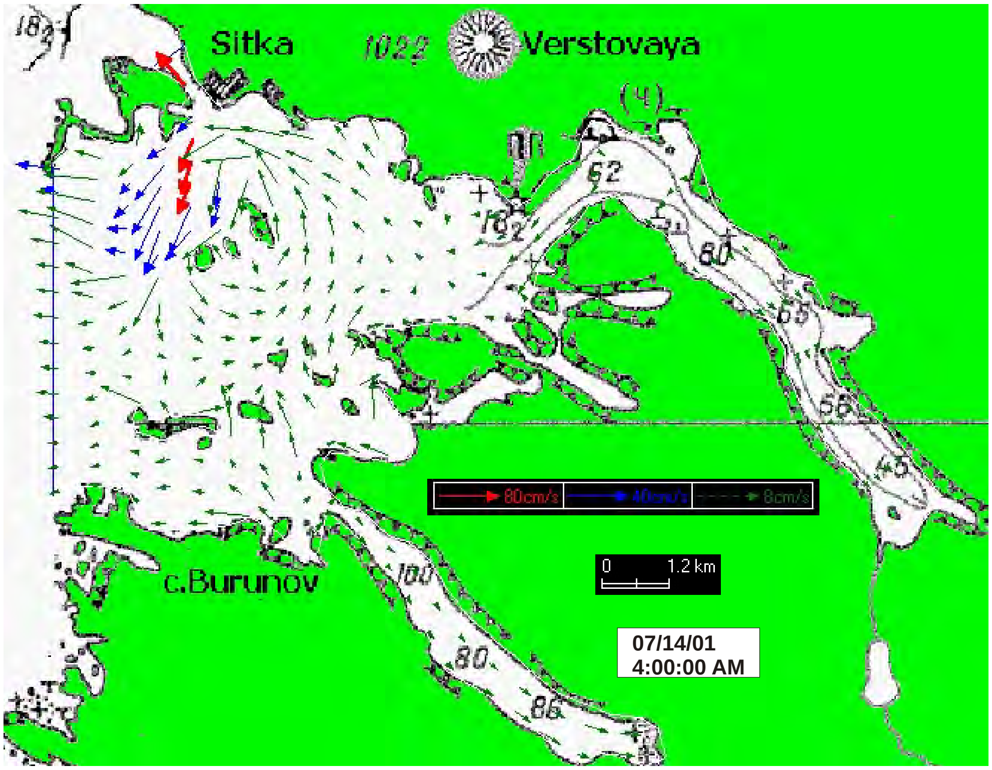


FIGURE 12C
Velocity pattern after four hours of start of discharge from the *Spirit of Columbia* at Sitka port.

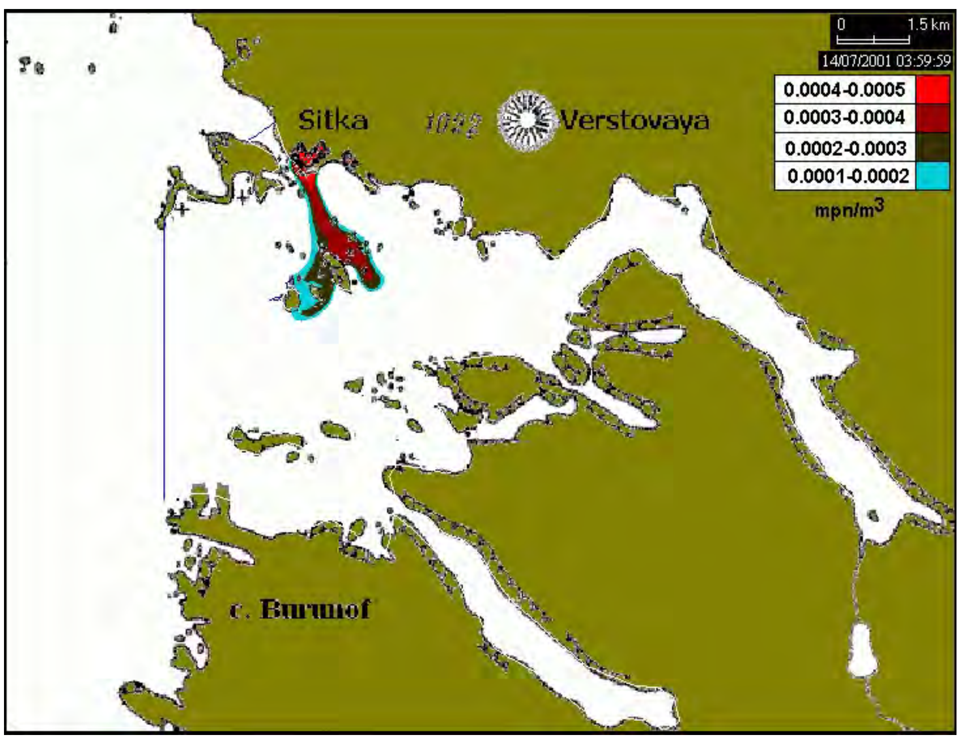
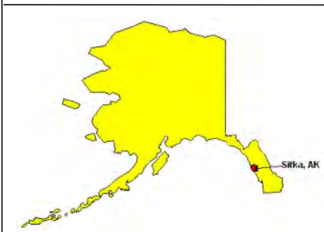


FIGURE 12D
Depth averaged *fecal coliform* concentration (MPN/m^3) after four hours of discharge from the *Spirit of Columbia*.



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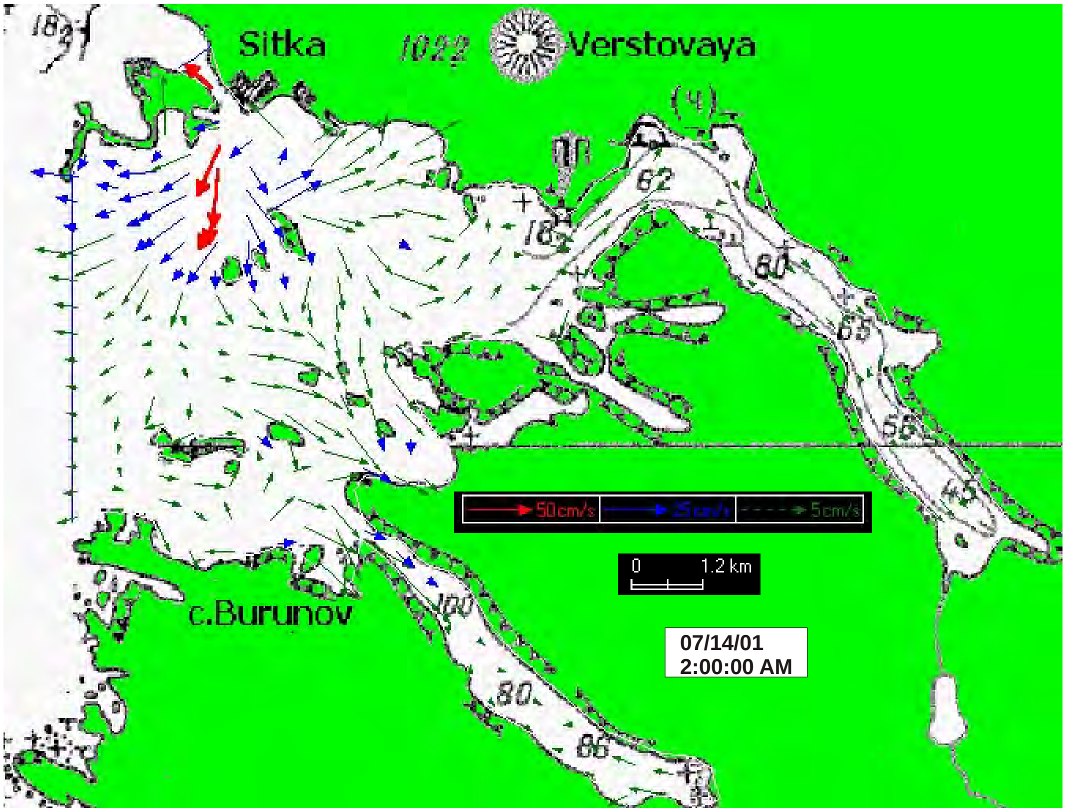


FIGURE 12A
Velocity pattern after two hours of start of discharge from the *Spirit of Columbia* at Sitka port.

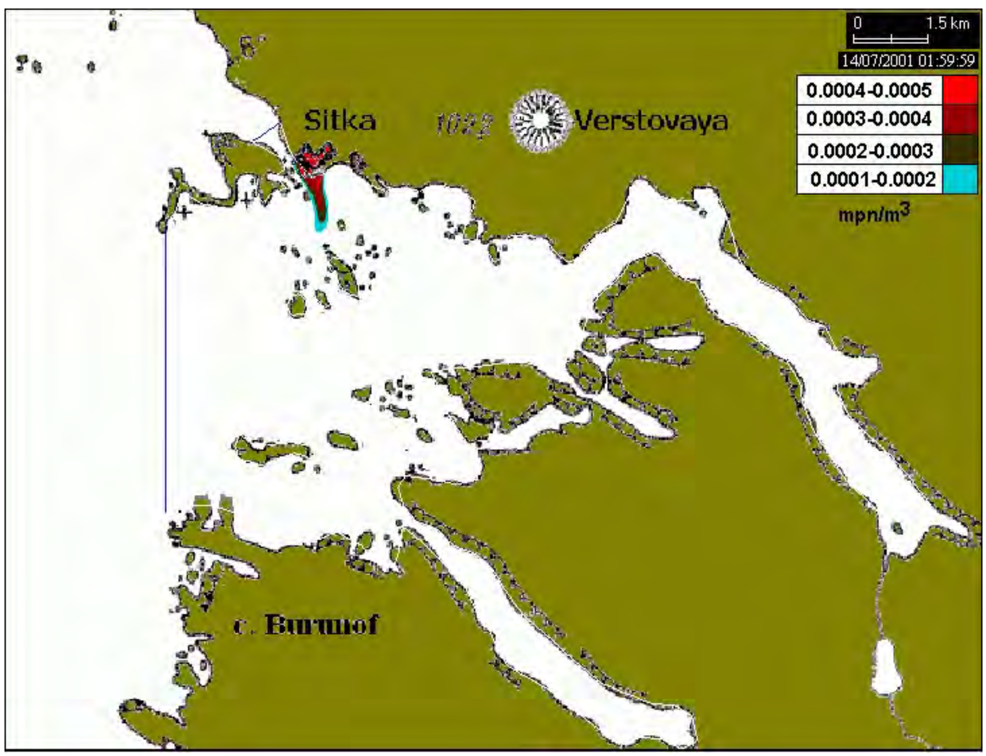
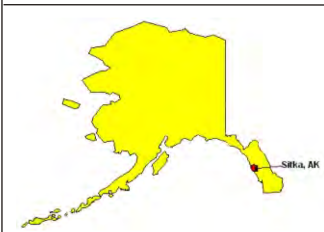


FIGURE 12B
Depth averaged *fecal coliform* concentration (MPN/m^3) after two hours of discharge from the *Spirit of Columbia*.



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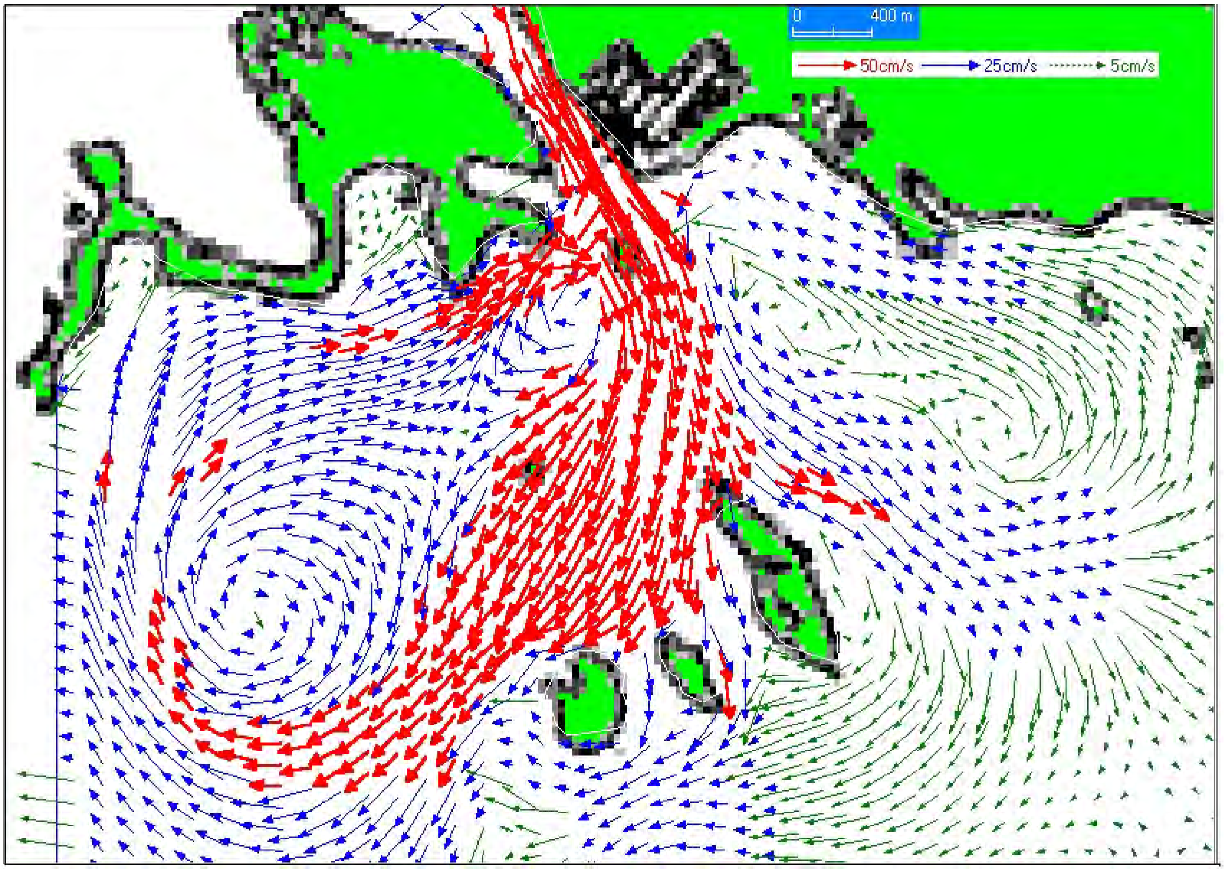
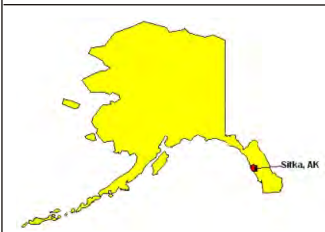


Figure 11C
15:00 hrs
Zoomed distribution of depth averaged velocities
at 15:00 h on July 14, 2001, at Sitka Bay.



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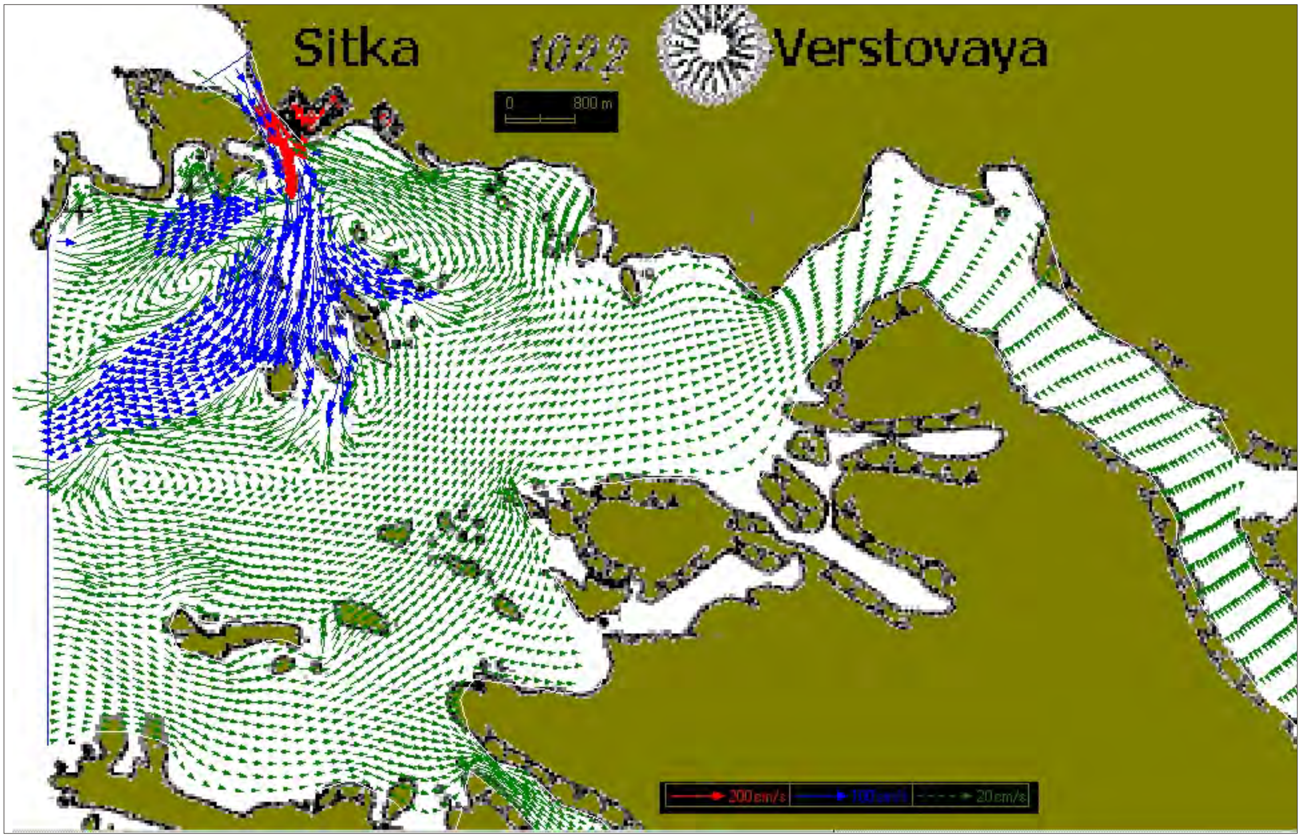
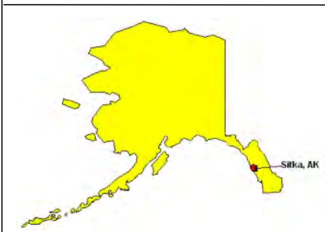


Figure 11B
24:00 hrs
Depth averaged velocities at the moment of the end of simulation (24 h 14 July 2001) at Sitka Bay.



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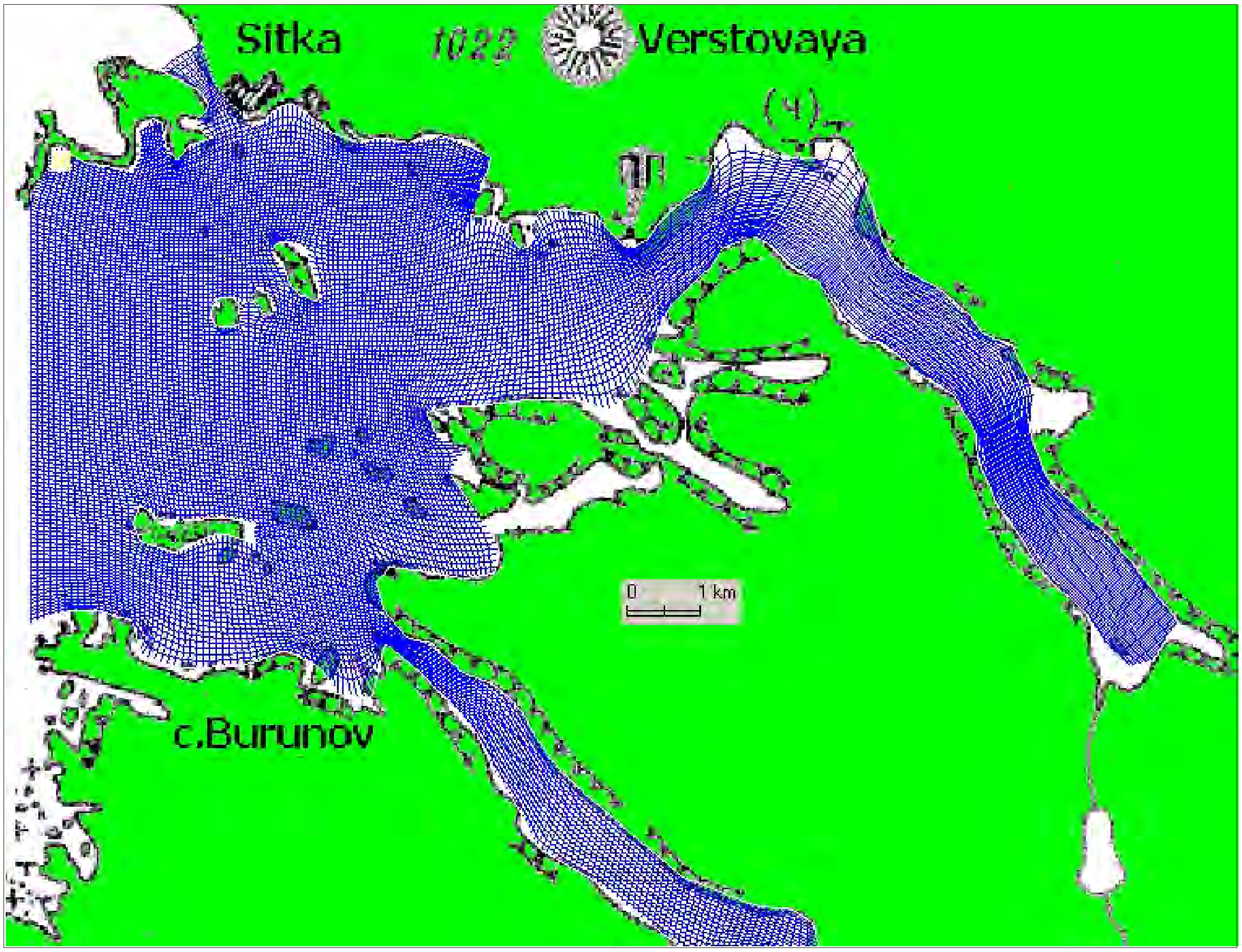
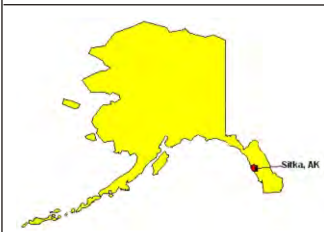
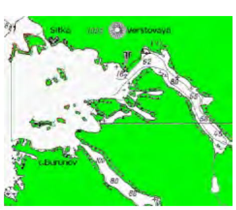


Figure 11A
Water body at Sitka Bay and the curvilinear grid used in hydrodynamics-water quality modeling.





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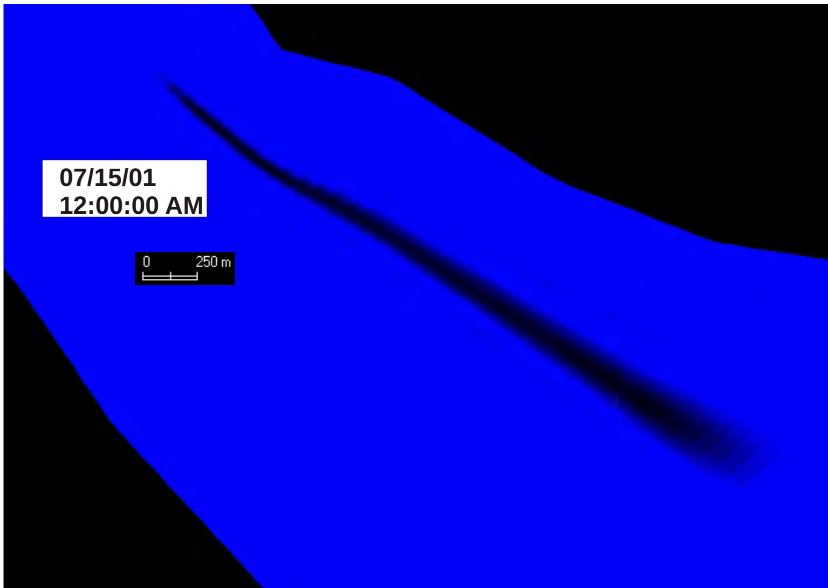
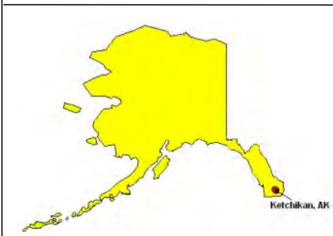


CONCENTRATION mg/m3 LEGEND

0.57E-3 - 1.44E-7

FIGURE 10E
Distribution of Copper
after four hours of discharge from
***Matanuska* at Ketchikan port.**



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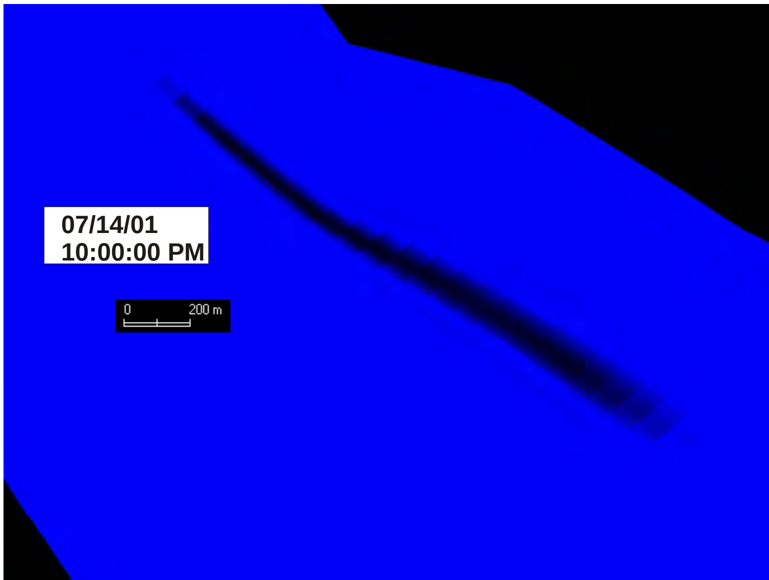


CONCENTRATION mg/m3 LEGEND

0.71E-6 - 1.24E-10

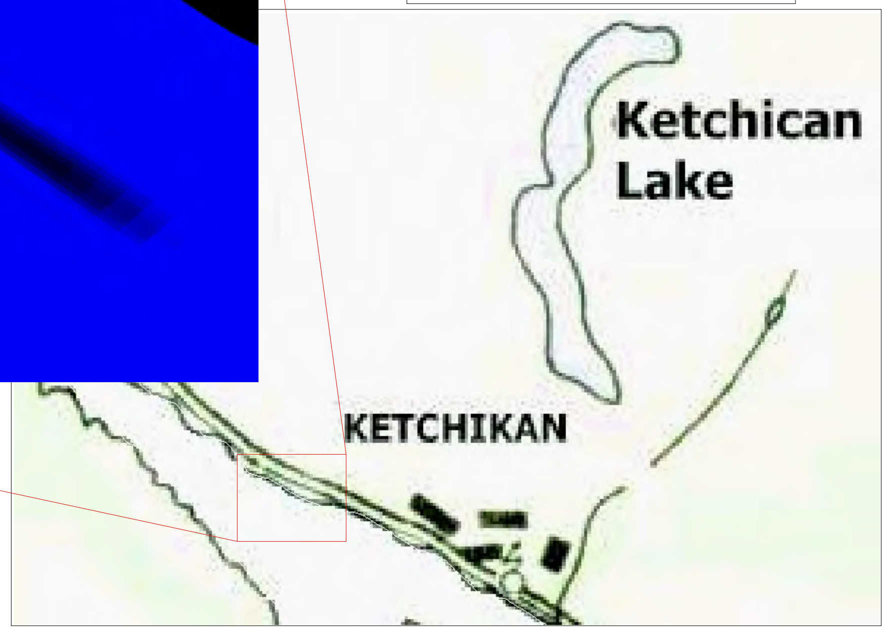
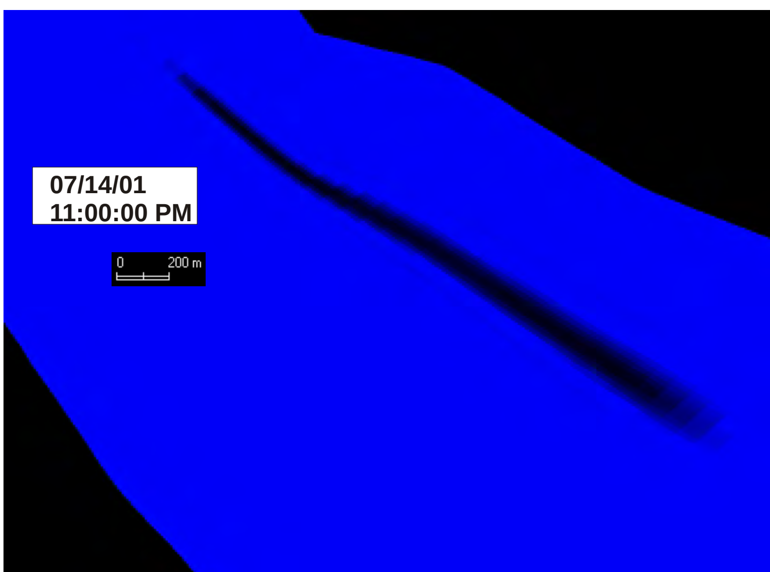


FIGURE 10C
Distribution of Copper
after two hours of discharge from
***Matanuska* at Ketchikan port.**



CONCENTRATION mg/m3 LEGEND

0.63E-3 - 2.43E-10

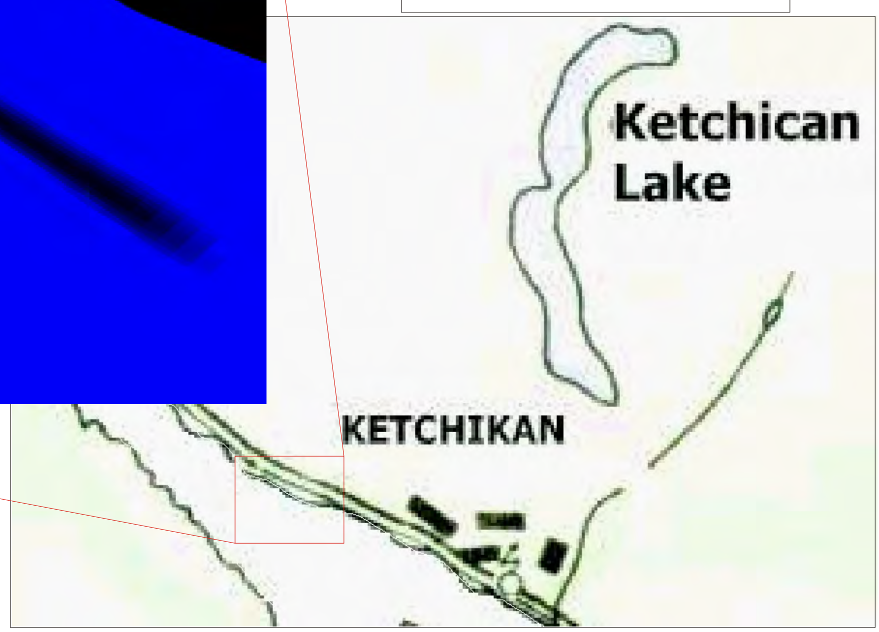
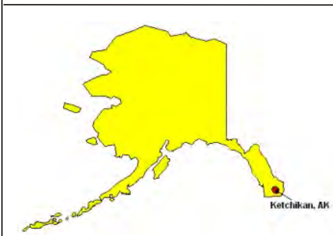


FIGURE 10D
Distribution of Copper
after three hours of discharge from
***Matanuska* at Ketchikan port.**



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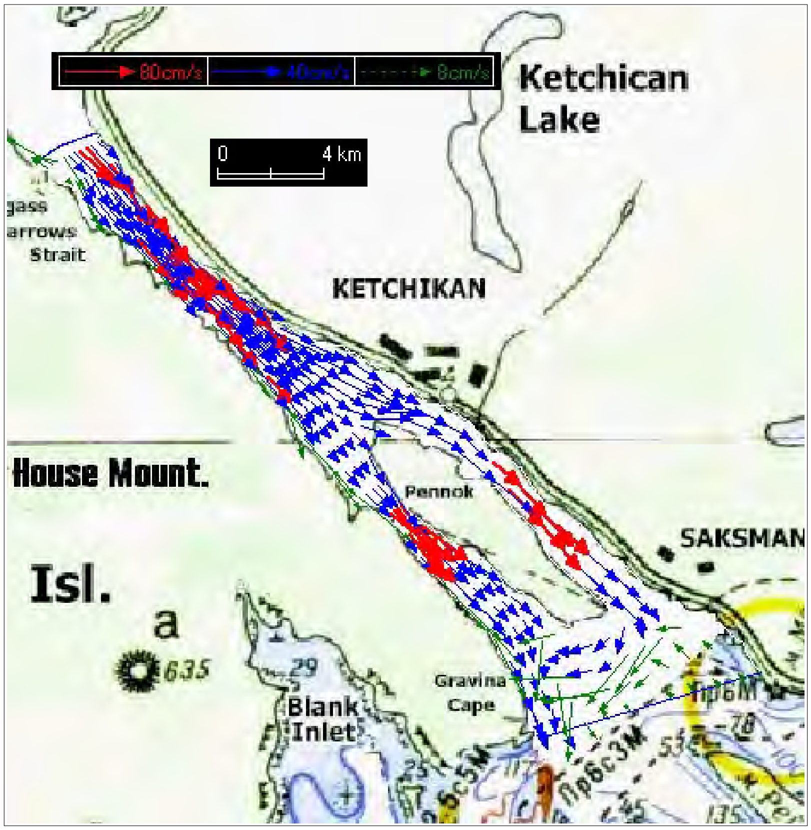


FIGURE 10A
Distribution of Velocity Field at 9PM
(one hour of discharge from
Matanuska at Ketchikan port).

CONCENTRATION mg/m3 LEGEND

■	0.57E-3 - 2.65E-7

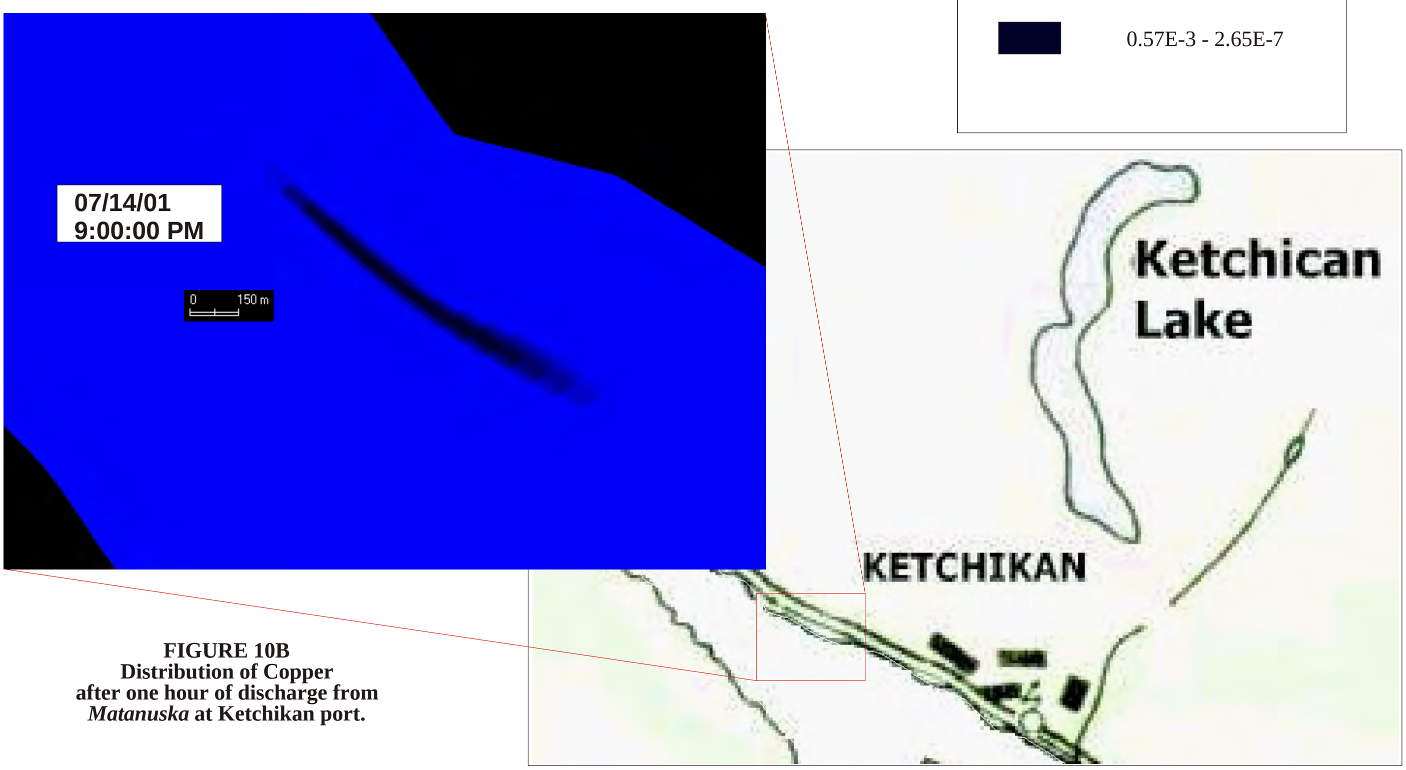
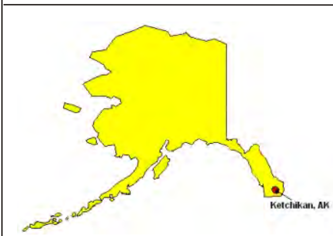


FIGURE 10B
Distribution of Copper
after one hour of discharge from
Matanuska at Ketchikan port.



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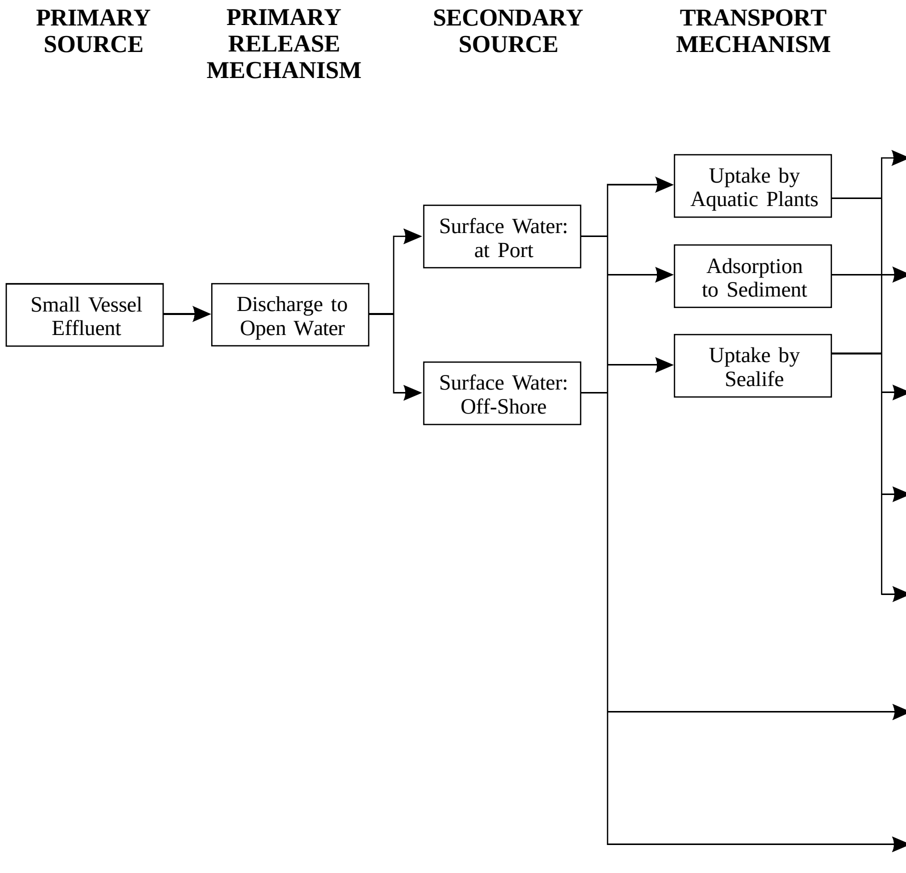

RECEPTORS

EXPOSURE MEDIA	EXPOSURE ROUTE	Subsistence Adult/Child	Child Swimmer	Commercial Diver	Commercial Fisher	Recreational Shellfish Gatherer
Aquatic Plants	Ingestion	●	— —	— —	— —	— —
Sediment at Port and Off-Shore	Incidental Ingestion	●	●	○	○	●
	Dermal Contact	●	●	○	○	●
Fish	Ingestion	●	— —	●	●	— —
Marine Mammals	Ingestion	●	— —	— —	— —	— —
Shellfish	Ingestion	●	— —	●	●	●
Surface Water: at Port	Incidental Ingestion	●	●	●	●	— —
	Dermal Contact	●	●	●	●	— —
Surface Water: Off-Shore	Incidental Ingestion	●	●	●	●	●
	Dermal Contact	●	●	●	●	●

Key:

- ○ Potentially Complete Pathway; Not Quantified
- ● Complete Pathway
- — — Incomplete Pathway

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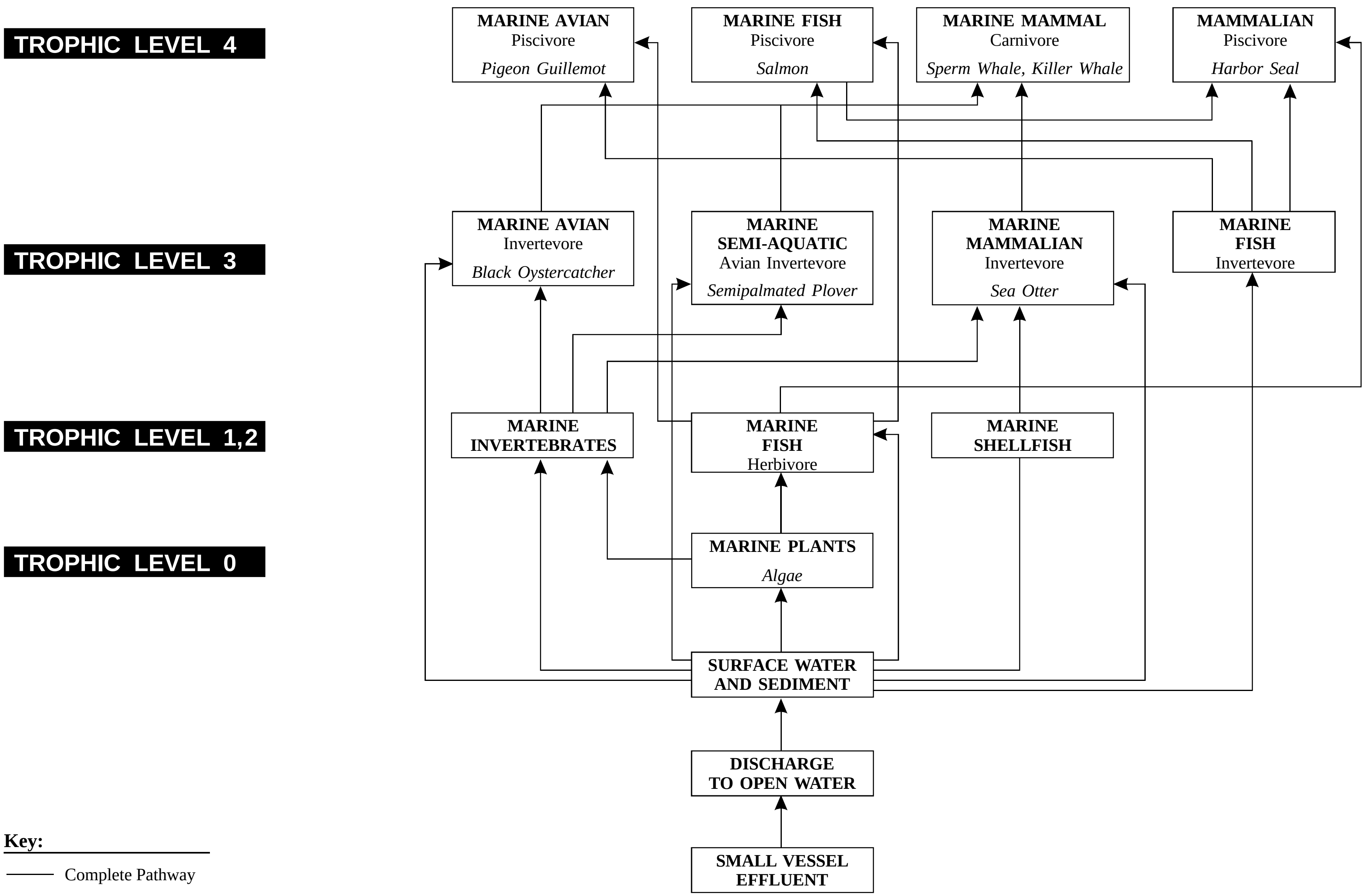
Anchorage, Alaska

SMALL VESSEL DISCHARGE
Inside Passage, Alaska

Figure 3

HUMAN HEALTH CONCEPTUAL SITE MODEL

Date:	Drawn by:	
2/24/03	AES	10:001332AU1101\fig 3



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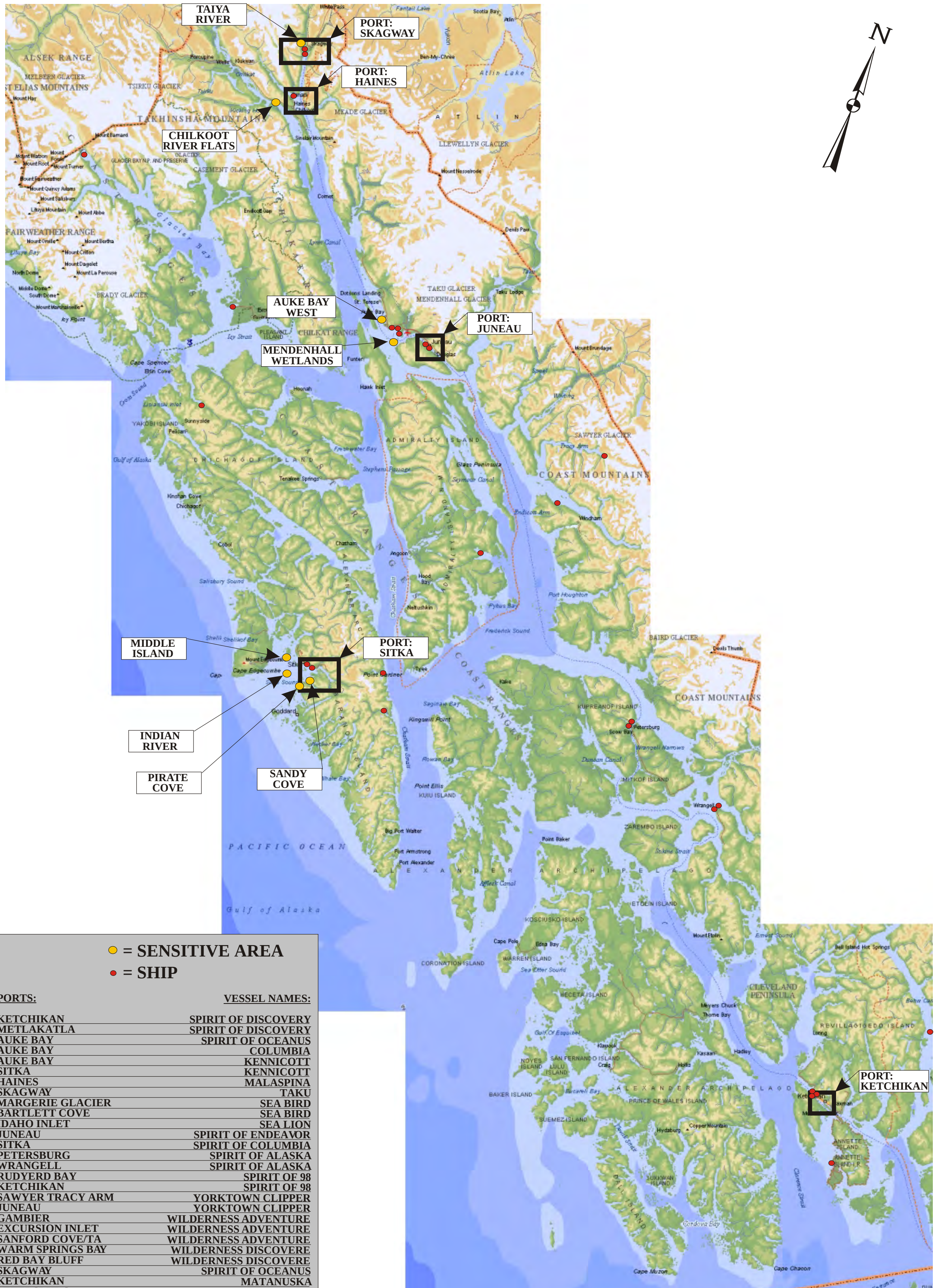
SMALL VESSEL DISCHARGE
Inside Passage, Alaska

Figure 2

ECOLOGICAL CONCEPTUAL SITE MODEL

Date:	Drawn by:	
2/24/03	AES	10:001332AU1101\fig 2

001332AU11_1.CDR



PORTS:	VESSEL NAMES:
KETCHIKAN	SPIRIT OF DISCOVERY
METLAKATLA	SPIRIT OF DISCOVERY
AUKE BAY	SPIRIT OF OCEANUS
AUKE BAY	COLUMBIA
AUKE BAY	KENNICOTT
SITKA	KENNICOTT
HAINES	MALASPINA
SKAGWAY	TAKU
MARGERIE GLACIER	SEA BIRD
BARTLETT COVE	SEA BIRD
IDAHO INLET	SEA LION
JUNEAU	SPIRIT OF ENDEAVOR
SITKA	SPIRIT OF COLUMBIA
PETERSBURG	SPIRIT OF ALASKA
WRANGELL	SPIRIT OF ALASKA
RUDYERD BAY	SPIRIT OF 98
KETCHIKAN	SPIRIT OF 98
SAWYER TRACY ARM	YORKTOWN CLIPPER
JUNEAU	YORKTOWN CLIPPER
GAMBIER	WILDERNESS ADVENTURE
EXCURSION INLET	WILDERNESS ADVENTURE
SANFORD COVE/TA	WILDERNESS ADVENTURE
WARM SPRINGS BAY	WILDERNESS DISCOVERE
RED BAY BLUFF	WILDERNESS DISCOVERE
SKAGWAY	SPIRIT OF OCEANUS
KETCHIKAN	MATANUSKA
PETERSBURG	MATANUSKA
WRANGELL	MATANUSKA

APPROXIMATE SCALE IN KILOMETERS

0 100 200 300

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PROJECT No. 001332.AU11.01 JUNE 2003

FIGURE 1
SOUTHEASTERN COASTAL ZONE OF ALASKA, PORTS AND WATER BODIES WHERE SMALL PASSENGER VESSELS ARE ANCHORED AND DISCHARGING TREATED WASTE WATER ON JULY 14, 2001. THE FIVE PORTS THAT ARE INCORPORATED INTO HYDRODYNAMIC BASED POLLUTANT TRANSPORT MODELING ARE IDENTIFIED WITHIN BOXES.
ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION