Exxon Valdez Oil Spill
Restoration Project Final Report

Chenega Shoreline Restoration

Restoration Project 98291
Final Report

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Study History: Restoration Project 97291 involved treating five beaches in the vicinity of Chenega Bay in Prince William Sound to reduce levels of residual surface and subsurface *Exxon Valdez* oil. The treatment process used was demonstrated on a beach segment in the Chenega area in 1993 (Tumeo, M.A., J. Braddock, T. Venator, S. Rog, and D. Owens. 1994. Effectiveness of a Biosurfactant in Removing Weathered Crude Oil from Subsurface Beach Material. Spill Science and Technology Bulletin, Vol. 1 No. 1.). A workshop was held in 1995 to discuss the benefits of additional shoreline treatment, appropriate treatment methods, acceptable levels of treatment, and the environmental costs of treatment. (Loeffler, R.M., E. Piper and D. Munson. 1996. Workshop Report: Residual Shoreline Oiling. Exxon Valdez Oil spill Restoration Project 95266 Final Report. Alaska Department of Environmental Conservation.) The project was guided by a Restoration Plan incorporating workshop results (Stephl Engineers, CH2M Hill, Inc. and Stephen R. Rog and Associates. 1996. Chenega Beach Restoration Project, Draft Report).

Abstract: Five cobble-boulder armored shoreline segments in the vicinity of the village of Chenega Bay in Prince William Sound were treated in the summer of 1997 to reduce levels of residual oil from the 1989 *Exxon Valdez* spill. The treatment involves injecting a d-limonene based cleaning agent (PES-51[7]) into beach substrates using an air knife to free residual oil, followed by ambient temperature seawater flushing and collecting the oil and cleaning agent mixture with standard oil spill recovery techniques. Treatment was completed over a 33-day period. 9,490 square meters were treated producing a total of 20,007 pounds of oiled sorbent materials. Visual observations and physical measurements show removal of 50% of the surface oil in 1997. However, rearrangement of boulders by winter storms thoroughly altered the parts of the beach where oil was uncovered and available for either sampling or cleaning. This implies that much less than 50% of the total oil entrained in these beaches was removed. No obvious catastrophic effect on the biota of the beaches involved was detected. Beach mussels took up significant levels of oil and d-limonene, and mussels moored in the water column outside cleaning operations took up traces, but all mussels had depurated them by September, 1997. Almost no measurable oil or surfactant escaped into the surrounding water column. Any physical damage to intertidal biota was too subtle to be observed against natural variability.

Key Words: Beach restoration, biosurfactant, Chenega, *Exxon Valdez,* oil spill, PES-51®, Prince William Sound, residual oil, shoreline treatment, surfactant.

Project Data: *Description of data* - "Shoreline Cleanup" data sets produced as part of project documentation include a photo documentation log, video tape of beach environments and treatment activities, and daily progress summary reports. *Format* - The photo documentation log consists of approximately 150 pages of 4-inch by 6-inch, color prints mounted two per page on laminated 8.5- by 11-inch paper. Photographs are keyed to a seven-page index describing date, time, location, direction of view, and subject. The video documentation consists of 150 minutes of unedited, narrated video on two 8 millimeter cassette tapes. Daily progress summary reports consist of 35, one-page, *8.5- by* 11-inch summaries of daily activities beginning June 15 and ending July 19, 1997. Summaries include entries for tides, weather, PES-51® use, square meters treated, wildlife observations, etc., as well as a short narrative description of the day's work effort. *Custodian* - Contact Dan Easton at the Alaska Department of Environmental Conservation, 410 Willoughby Avenue, Suite 105, Juneau, Alaska 99801; phone (907) 465-5048; e-mail **deaston@envircon.state.ak.us** - *Availability* - Copies are available for the price of reproduction.

Description of Monitoring data – Data sets produced include collection and analysis records for the following: quatities of oil in 227 test beach samples, total polycyclic aromatic hydrocarbons (TPAH) in 17 test beach samples, TPAH in 53 mussel and 17 chiton tissues (40 in beach mussels and 13 moored cage mussels), and 12 TPAH in MLLW sediment samples, as well as counts of biota present in 360 quadrats and echinoderms present in 75 50-m beach sections. All oil sampling and biota counting were recorded photographically, as were many other aspects of the monitoring process. *Format* – All the oil sample data is available in either Excel or Lotus 1-2-3. Biota counts are available as photocopies. Photos are available as reprints or photocopies. *Custodian* – Contact Christine Brodersen at the Auke Bay Fisheries Laboratory, 11305 Galcier Highway, Juneau, AK, 99801; phone (907) 789-6098; e-mail chris.brodersen@noaa.gov *Availability* – Copies are available for the price of reproduction.

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Executive Summary

The Chenega Shoreline Restoration project was developed in response to concerns raised by citizens of Chenega Bay that residual *Exxon Valdez* oil contained in beach sediments continues to affect local use and perception of area shorelines. On the basis of their value to area residents and the extent of oil present, three beach segments were treated on the north end of LaTouche Island and two on the northeast end of Evans Island, all near Chenega Bay, in southwestern Prince William Sound. The selected shorelines were all moderate to high energy environments consisting mainly of boulders or cobbles overlying gravel sediments.

The treatment process was to meet three objectives: 1) a significant reduction in observable oil residue in surface and subsurface sediment; 2) a 50 percent decrease in the levels of measurable petroleum hydrocarbons in the surface and subsurface sediment; and 3) no significant environmental impact on biota and no evidence of petroleum hydrocarbons being introduced into the water column. The selected treatment process was successfully demonstrated in a 1993 pilot test on LaTouche Island. It involves injecting a cleaning agent (d-limonene-based surfactant trade name PES-51®) into beach sediments using an air knife (a high pressure air injection tool) to release oil trapped in the beach sediments. The surfactant-oil mixture is forced to the surface where it is washed down the beach using ambient temperature seawater, and collected using standard oil spill recovery techniques.

The shoreline treatment project was overseen by the Alaska Department of Environmental Conservation. The work was conducted by the Chenega area native corporation subsidiary, ESC, Inc., with beach treatment crews comprised primarily of local shareholders. Scientific monitoring to determine reductions in oil levels, and impacts of the process on biota and water quality was conducted by the National Oceanic and Atmospheric Administration, National Marine Fisheries Service Auke Bay Laboratory. Treatment took place over the 33-day period from June 17 through July 19, 1997. Approximately 9,500 square meters of beach were treated and 20,000 pounds of oiled sorbent material were generated.

Measurements by Auke Bay Laboratory (NMFS) personnel show the cleaning process to have removed half of the surface oil being monitored. Fifty-four specific sample sites were selected, each consisting of three carefully located 25 cm^2 quadrats, and all of the oil below one quadrant at each site was excavated and collected before the cleaning work, the oil below the second was excavated just after the cleaning, and the third a year later, in May of 1998. Nine additional reference sites, not associated with the cleaning, were similarly measured. Oil at the sample sites in the cleaned areas were reduced to half as much oil as the amounts remaining in the reference sample sites, as was originally hoped. However, the amounts of oil in the reference sites did fall somewhat even without purposeful cleaning. An explanation was clear in the spring of 1998. Rocks, cobbles and even meter-long boulders, were moved and rearranged to a remarkable degree by winter weather. Surface oil that had been available for cleaning and for sampling in 1997 was covered over, and new areas of oil were uncovered. Much of the oil on the surface any given summer has probably been sealed under rocks much of the time since it was originally deposited. When uncovered it is much less weathered than one would expect after so many years, and more prone to be naturally washed out as well. Consequently, the cleaning work only reduced beach oil in those portions of the beach which were accessible to cleaning.

No obvious catastrophic effect on the biota of the beaches involved was detected. The quantities of intertidal invertebrates and algae were little different at cleaned and reference sites. Mussels near the work took up significant tissue burdens of polycyclic aromatic hydrocarbons and of d-limonene, but de-purated the material again within approximately a month. Chitons took in no measurable oil. Mussels maintained in cages just outside the cleaning operations took up traces of hydrocarbons, and de-purated them again. Cleaning may not have removed as much oil as originally hoped, but did improve the condition of the beaches without any unexpected ill effects.

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Introduction

The 1989 *Exxon Valdez* oil spill released approximately eleven million gallons of North Slope crude oil into Prince William Sound, Alaska. In 1997, *the Exxon Valdez* oil spill Trustee Council authorized *Exxon Valdez* oil spill restoration funds for treatment of shorelines near the village of Chenega Bay that still exhibited significant surface oiling.

The shoreline treatment project was overseen by the Alaska Department of Environmental Conservation. The work was conducted by the Chenega area native corporation, ESC, Inc., with beach treatment crews comprised primarily of local shareholders. Treatment took place over the 33-day period from June 17 through July 19, 1997. Approximately 9,500 square meters of beach were treated.

Scientific monitoring of the treatment project was done by the NMFS Auke Bay Laboratory. The chief objectives of the monitoring were to measure how much available oil was removed from the work areas and to determine whether intertidal biota were seriously damaged or the surrounding water column was contaminated.

This report describes the evolution, implementation and results of the Chenega Shoreline Cleanup project, as well as the outcome of the Auke Bay Laboratory monitoring work.

1. Introduction

The 1989 *Exxon Valdez* oil spill released approximately eleven million gallons of North Slope crude oil into Prince William Sound, Alaska. That spill ultimately spread to contaminate portions of shorelines from Prince William Sound to the Alaska Peninsula. In 1997, the *Exxon Valdez* Oil Spill Trustee Council authorized *Exxon Valdez* oil spill restoration funds for additional treatment of Prince William Sound shorelines in the vicinity of the village of Chenega Bay that still exhibited significant surface oiling. This report describes the evolution, implementation and some of the results of the Chenega Shoreline Restoration project.

Part I - Shoreline Cleanup
1.a Project Development

Exxon Valdez Trustee Council. In 1991, the U.S. District Court approved a plea agreement that resolved various criminal charges against Exxon as well as a civil settlement for recovery of natural resources damages resulting from the oil spill. As part of that agreement, Exxon agreed to pay $900 million over a 10-year period. The agreement required that the funds be used first to reimburse the federal and state governments for the cost of cleanup, damage assessment and litigation. The remaining funds were designated for restoration purposes. The *Exxon Valdez* Oil Spill Trustee Council was formed to guide the use of the civil settlement funds and consists of three state and three federal trustees.

Residual Shoreline Oil. Despite shoreline cleanup efforts from 1989 through 1992, beach areas with residual surface and subsurface oil persist. Quoting from an Environmental Assessment prepared by the Alaska Department of Environmental Conservation for the U.S. Department of Agriculture, Forest Service for the Chenega Shoreline Restoration project (USFS, 1997):

"The 1993 assessment, conducted by the Alaska Department of Environmental Conservation for the *Exxon Valdez* Oil Spill Trustee Council, identified 225 locations at 45 ground survey sites in Prince William Sound with surface oil. The average oiled location with surface oil residue, asphalt, or mousse was 160 square meters in size and had about a 23 percent oil coverage. The survey identified 109 locations with subsurface oil. A comparison of comparable sites between 1991 and 1993 indicated the amount of subsurface oiling had decreased by about half. However, the survey showed that the remaining surface oil had become very stable. In fact, there was no measurable reduction in the remaining surface oil from 1991 to 1993. Much of the most significant oil remaining was shown to be located within close proximity to the village of Chenega Bay."

Throughout the period following the end of initial shoreline treatment efforts, Chenega Bay residents voiced concern over the impacts of the oil remaining on those shorelines traditionally used by villagers for subsistence and other purposes. Representatives working with Alaska Department of Environmental Conservation (DEC) staff identified seven beach segments on LaTouche, Elrington and Evans Islands as most in need of further evaluation and possibly additional treatment.

1993 Shoreline Restoration Demonstration Project. In 1993, Tesoro Alaska and the State Hazardous Substance Spill Technology Review Council sponsored a demonstration of a relatively new beach restoration treatment process - the PES Shoreline Treatment Process - on a section of beach on the north end of LaTouche Island (designated segment LA 019A). The PES treatment process involves injecting a d-limonene-based cleaning agent, PES-51®, into beach substrates with an air knife. The surfactant releases subsurface oils from the substrate, and injection pressure forces the residual to the beach surface where it is flushed with ambient temperature seawater to a point where the surfactant and oil mixture can be collected with a skimmer or sorbent materials.

The demonstration received favorable reviews. Tumeo et al. (1994) found an average 70 percent reduction in semivolatile petroleum hydrocarbons in sediment material, with no inhibition of microbial activity, and no indication that oil was transported offshore during the treatment process.

Pursuant to encouraging reviews of the process, DEC contracted with Petroleum Environmental Services, Inc. for the preparation of a report (PES, 1995b) describing how the PES Shoreline Treatment Process could be applied to the seven (later increased to eight) oiled beach segments in the vicinity of Chenega Bay, and estimating the associated costs. That report would provide some of the specifics needed to help focus further deliberation about potential merits, impacts and costs of additional beach treatment.

1995 Residual Shoreline Oiling Workshop. Significant debate surrounded the question of whether the *Exxon Valdez Trustee* Council should authorize funding for further treatment of shoreline areas, and a workshop on the issue was held in 1995. The Environmental Assessment characterized the impetus for, and purpose of the workshop as follows (USFS, 1997):

"The question of whether to remove residual oil was a difficult one for the Trustee Council. Scientists had indicated that treatment may not aid the resources, and may in fact set back recovery of intertidal areas. In addition, total removal of the oil is technically and financially infeasible, and it was unclear whether partial removal would satisfy those concerned about the presence of oil. As a result, the Trustee Council sponsored a workshop on Remaining Shoreline Oil in November of 1995 to attempt to answer the technical, social, and policy questions that surround this issue. The workshop addressed the benefits of additional shoreline treatment, appropriate treatment techniques, acceptable level of treatment, and the environmental cost of treatment. The workshop was designed to allow experts in the field of oil spill response and assessment, natural resource scientists, citizens of Chenega Bay, and other interested persons to discuss these issues and to provide the Trustee Council with information to allow them to decide whether or not to fund additional treatment."

The report prepared by Petroleum Environmental Services on the application and costs of the PES Shoreline Treatment System was presented at the workshop and discussed as one of the more promising treatment alternatives.

Workshop proceedings - as well as subsequent efforts by DEC pursuant to input received at the workshop - were captured in a report that would later provide the basis for the Restoration Plan that would guide the Chenega Shoreline Restoration project. The workshop report (Loeffler et al., 1996) suggested that if additional shoreline treatment were to be undertaken, the PES Shoreline Treatment Process would be a "useful treatment method and ... probably appropriate for many locations identified by Chenega Bay residents." The report cautioned, however, that the process would not necessarily be appropriate for every location and that each beach would have to be considered separately to determine whether further treatment would be appropriate. The report also reflected many of the workshop participants' sentiments that the entire scope of a limited program needed to be set out before the *Exxon Valdez Oil Spill* Trustee Council could be asked to decide whether to approve funding.

Subsequent to the workshop, DEC staff and Chenega Bay residents met to refine information and understanding of beach oiling characteristics, uses and priorities. Five treatment alternatives were developed ranging from no additional treatment, to treating the highest priority shorelines, to more extensive and complex treatment alternatives. What evolved from the workshop and subsequent discussions with Chenega Bay residents was a proposal for a limited program consisting of PES treatment of eight significantly oiled and locally important beaches in the Chenega area. In June of 1996, the *Exxon Valdez Oil Spill* Trustee Council approved a budget of up to $1.9 million to implement the limited beach treatment program including project management, monitoring and documentation elements (USFS, 1997).

1.b The Shorelines

The eight high priority beaches identified by DEC and Chenega Bay residents included five on LaTouche Island, two on Evans Island, and one on Elrington Island:

LaTouche Island	Evans Island	Elrington Island
LA 015C	EV 037A	ER 020B
LA 019A	EV 039A	
LA 020B		
LA 020C		
LA 021A		

Substantial information on the beach environments and oiling patterns was available. Each of the beaches had been surveyed by DEC at least once between 1992 and 1994. Additional reconnaissance of seven of the eight beaches (all except LA 021A) was conducted in September 1995 by a team including representatives of DEC, the Chenega IRA Council and Petroleum Environmental Services, Inc.

All of the beaches are on the northern ends of the islands, corresponding to the direction from which the oil originally impinged on the beach. The beaches are also all characterized as moderate to high energy environments with substrates consisting mainly of boulder or cobble-boulder armor overlying gravel sediment (USFS, 1997).

The 1995 reconnaissance found residual oil in the upper and middle intertidal zones on all beaches. Residual oil types and patterns "included surface oil residue ranging from heavy to light, mousse and asphaltic pavement. Most often, the residual oil was found on, or adhering to, or below, the boulder and cobble layers, especially in sheltered crevices and other areas that were protected from wave energy. (PES, 1995) The oiled locations were generally in areas with limited flora and fauna (USFS, 1997).

In addition to containing substantial amounts of residual oil, each of the beaches was important to the people of Chenega Bay. The results of the cooperative effort between DEC and representatives of Chenega Bay generated a priority rating for each of 22 area beaches (Loeffler et al., 1996). The eight shoreline segments targeted for treatment were those with significant community concern and a significant area of surface or subsurface oil (see **Appendix A).**

1.c Basic Project Nature and Scope

The scope of the Chenega Shoreline Restoration project included treatment of as many as possible of the eight priority beach segments to reduce residual oil levels. It also included, however, significant monitoring, documentation and community relations components.

The restoration treatment component was by far the largest in terms of level of effort and cost. It involved assembling a workforce comprised of a combination of local labor and treatment and recovery experts, mobilizing equipment and personnel to the vicinity and to the beaches, applying the PES Shoreline Treatment Process at as many of the eight beaches as possible, demobilizing from the area, and disposing of wastes.

The project's monitoring component was designed to determine the effectiveness of the process in reducing residual oil levels, as well as to ascertain the impacts on biota and water quality. The U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service, Auke Bay Laboratory (hereafter referred to as the NOAA Auke Bay Lab) conducted the scientific monitoring program. The monitoring component also included extensive video and photographic documentation of the process, as well as maintaining detailed measurements and records of field activities and observation logs.

The community relations component included using local labor to the extent possible, holding two public meetings for the purpose of discussing project plans and progress, using a project Oversight Committee with local representation for key decision-making, and generally involving and communicating with local residents over the course of the project.

1.d Permitting Process

The proposed locations and scope of work mandated seeking a number of state and federal authorizations. Authorizations in the form of permits or approvals were sought from landowners and state and federal land management agencies, as well as environmental and wildlife management agencies. The specific authorizations required included:

- a finding of consistency with the Alaska Coastal Management Program issued by the Alaska Division of Governmental Coordination (DGC) in concert with the state resource agencies - the Departments of Environmental Conservation, Natural Resources, and Fish and Game;
- a land use permit issued by the Alaska Department of Natural Resources (for use of state-owned tidelands);
- a short-term water quality standard variance issued by the State of Alaska Department of Environmental Conservation (to allow temporary exceedances of state Water Quality Standards during treatment); and
- an uplands access permit for the one beach with federal upland ownership (ER 020B) from the U.S. Department of Agriculture, Forest Service.

In pursuing authorizations, two environmental planning and permitting processes were invoked - one federal and one state. Application for all state authorizations was made through the coordinated permit process whereby the Alaska Division of Governmental Coordination coordinates review of projects by the state resource agencies for consistency with the Alaska Coastal Management Program, as well as coordinating development of individual permits by the agencies. On the federal side, federal agency decision making as members of the *Exxon Valdez* Trustee Council along with the need for a U.S. Department of Agriculture, Forest Service permit at one of the sites triggered the environmental planning process prescribed by the National Environmental Policy Act, and an Environmental Assessment was prepared. The Environmental Assessment process required that the lead agency coordinate with and seek the counsel of other state and federal resource agencies, as well as the public.

Agencies and organizations that had a hand in the preparation of the Environmental Assessment included the U.S. Forest Service as the lead federal agency; DEC as cooperating agency and primary author; the *Exxon Valdez* Oil Spill Trustee Council; NOAA Auke Bay Lab, and two private companies - CH2M Hill, Inc. and Stephl Engineers. Also consulted during the preparation of the Environmental Assessment were:

- the Alaska Department of Fish and Game;
- the Alaska Department of Natural Resources;
- the U.S. Environmental Protection Agency;
- the U.S. Department of the Interior, Geological Survey;
- the State Historic Preservation Officer;
- the U.S. Department of Transportation, Coast Guard;
- the U.S. Department of the Army, Corps of Engineers; and
- the U.S. Department of the Interior, Fish and Wildlife Service.

While support for the project was expressed, a number of issues were raised and addressed during the Environmental Assessment process. Concerns related generally to effects on water quality, intertidal and subtidal plants and animals, fish species, human health and safety, and commercial fishing. Mitigation measures that would later be reflected in the project work plan were developed to address concerns. A detailed monitoring plan was also prepared.

The National Environmental Policy Act process concluded with a "Finding of No Significant Impact" issued by the U.S. Forest Service in April 1997.

1.e Restoration Plan

While the basic project components, objectives and design arose from the project development process, it remained to flesh out the project to the level of detail required for contracting and other implementation purposes. That effort fell to Stephl Engineers who, in association with CH2M Hill, Inc. and Stephen R. Rog and Associates, prepared a comprehensive work plan - or Restoration Plan - for the project (Stephl et al., 1996). Preparation of the Chenega Beach Restoration Plan was the first phase of the project, with the second phase being implementation of the plan involving the actual treatment work. The Restoration Plan set out:

- the treatment method and techniques to be used;
- the project objectives and endpoints;
- the restoration team roles & responsibilities;
- restoration work schedule;
- a monitoring and reporting program;
- the contract documents that would establish the respective roles and obligations of the project managers and restoration treatment contractor; and
- the estimated costs for completing the different aspects of the project.

1.f Contracting Process

In early June 1997, a contract covering the vast majority of the work to implement the second phase of the project was awarded by DEC to the Prince William Sound Economic Development Council, a regional development council as defined in Alaska Statutes at 44.33.026, under the standard procurement code exemption allowed in Alaska Statutes at 36.30.850(30). The only efforts not included in the contract were the monitoring program to be implemented by the NOAA Auke Bay Lab, and direct DEC costs. The Prince William Sound Economic Development Council, in turn, contracted with ESC, Inc. (a subsidiary of the Chenega Native Corporation) for the restoration work, using the contract documents developed as part of the Restoration Plan. The Prince William Sound Economic Development Council was allotted funding for its overall project management and coordination efforts, and contracted with Easton Environmental for contract administration and documentation tasks, as well as final reporting.

The total amount of the contract with Prince William Sound Economic Development Council was $1,286,132 with not-to-exceed budgets for the various aspects of the project as follows:

Project Management (PWSEDC) Overall	$36,400
Restoration Contract Work (ESC, Inc.)	$1,134,811
Restoration Documentation (Easton Environmental)	$50,834
Final Report (Easton Environmental)	$27,704
Contingency	$36,383

In addition to meeting insurance requirements (including environmental remediation coverage in the amount of $5,000,000) imposed by its contract with DEC to protect state interests, the Prince William Sound Economic Development Council was required to a post a performance bond, valid for a period of not less than one year, in the amount of $1,000,000 as a condition of the state land use permit. As a condition of its contract with Prince William Sound Economic Development Council, ESC, Inc. was required to post performance and payment bonds each in the amount equal to the contract price.

2. Objectives

2.a Project Area

Prince William Sound is an island fjord complex formed by glacial retreat and ringed by glaciers. The climate is maritime with an average summer temperature range of 44 to 61 °F, an average winter range of 26 to 40 °F, and temperature extremes from 1 to 88 °F (at LaTouche Island). Average annual precipitation in the Chenega area is 180 inches, 140 inches of which fall as snow. (Selkregg, Undated)

Lower elevations are forested in coastal western hemlock and Sitka spruce. Higher elevations on the islands are alpine tundra. Bedrock geology in the project area consists of middle Tertiary, continental deposits of sandstone, siltstone, conglomerate, claystone, and coal beds. (Selkregg, Undated)

The village of Chenega Bay is located at the mouth of Sawmill Bay on Evans Island in the southwestern portion of Prince William Sound. The original village on the south end of Chenega Island, some 15 miles north of the current location, was destroyed by the 1964 earthquake. The village was subsequently relocated to its current location. (See **Figure 2-1** next page.)

2.b Project Objectives

In its report to DEC on the application and costs of the PES Shoreline Treatment Process, Petroleum Environmental Services, Inc. suggested three short-term, and two long-term goals for a limited beach treatment program (PES, 1995). The short-term goals were refined and stated as project objectives in the Monitoring Plan appended to the project Environmental Assessment (USFS, 1997):

- Objective I: Significant reduction in visually observable oil residue in surface and subsurface sediment.
- Objective II: Significant decrease in the levels of measurable petroleum hydrocarbons in the surface and subsurface sediment.
- Objective III: No significant environmental impact on biota and no evidence of petroleum hydrocarbons being introduced into the water column.

A fourth objective relating to restoration contractor progress and schedule was inherent in the contract between DEC and the Prince William Sound Economic Development Council:

- Treatment within the contract budget and schedule, and to the satisfaction of the project Oversight Committee, of at least the top five priority beaches of the total of eight identified for treatment.

2.c Project Constraints

Objectives were to be met within constraints imposed for safety reasons and to protect local resources. Specific constraints were derived from the project description and mitigation measures set out in the Environmental Assessment, as well as conditions stipulated in agency permits and contract documents. While the complete list of contract and permit conditions is long, some of the key constraints with most potential to significantly affect project design, operations and results included:

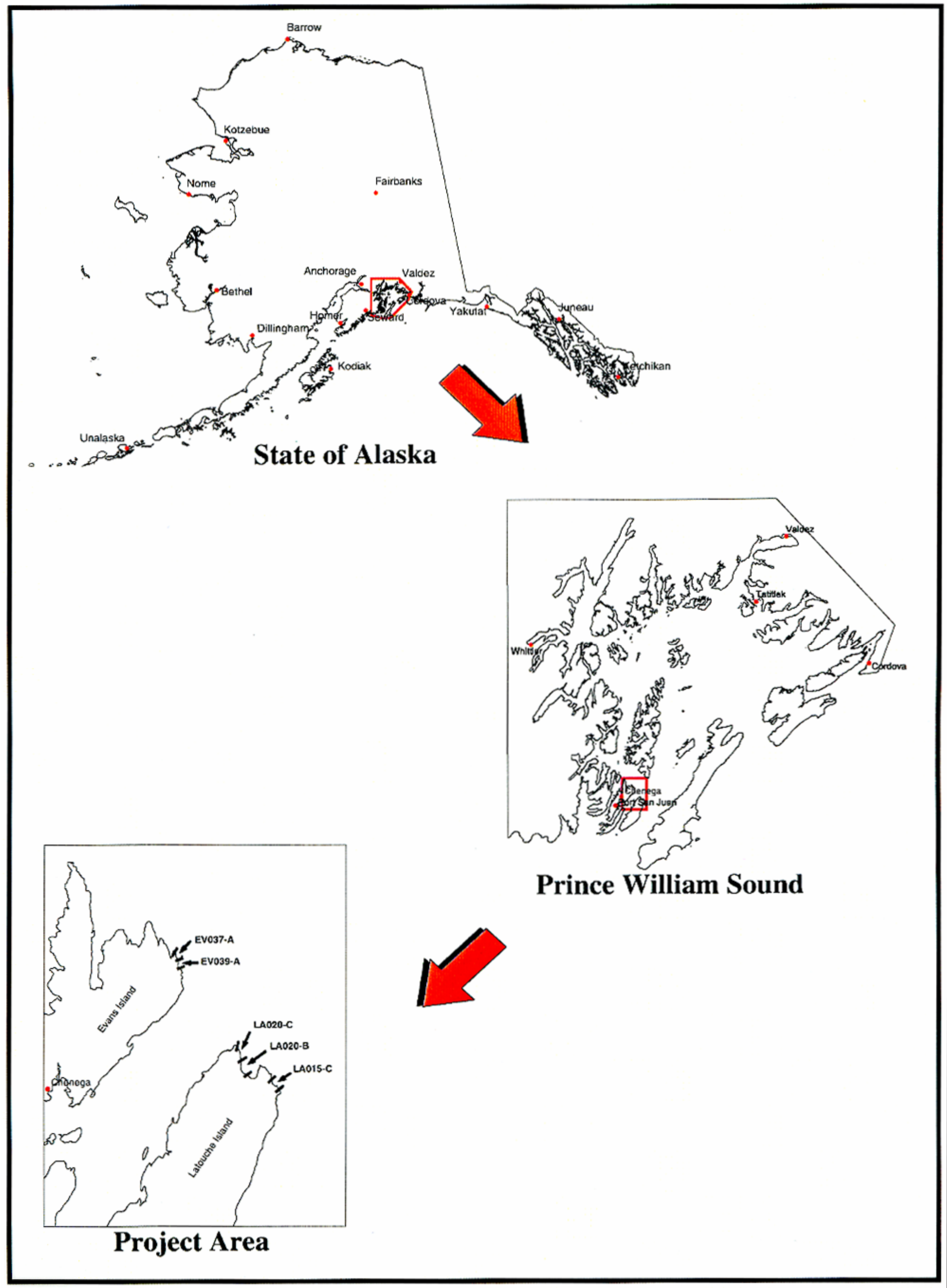


Figure 2-1
Vicinity Map

Containment

- Double containment boom was to be deployed before treatment, and was to remain in place and be maintained during treatment, washing, and oil collection.
- All treatment work was to be stopped if any materials escaped the containment area, and all efforts directed to recovering escaped materials.
-
- Sorbent boom was to be maintained around the treatment areas until no sheening was observed for two days after treatment in the near shore area.

Surfactant Usage

- Application of PES-51® was to be limited to a single application per beach segment.
- The application rate of PES-51® was restricted to no more than one gallon for each 250 square feet of treatment area.

Scheduling

- Restoration treatment work was to be completed prior to the opening of a local commercial fishery projected to begin July 18, 1997.
- The was to be no surfactant injection during portions of the tidal cycle when the lower intertidal zone was exposed.
- All work for each day was to end by 10:00 PM.

Deluge

- The water deluge was to be in operation before beginning treatment, and to remain in operation for a minimum of two hours after treatment was completed.

Waste Management

- All oily wastes were to be collected, packaged and delivered to a permitted facility for disposal.
- Oily waste stockpiles were to be lined with 10 mil polyethylene or other liner material of equal or greater thickness and strength.
- All other (non-oily) wastes were to be collected and disposed of at the Chenega Bay landfill. On-site burning of solid waste was prohibited.

Wildlife Impacts

- Eagle nest trees were to be identified, and no work was to be conducted within 330 feet of an eagle nest tree.
- Any observed impacts on wildlife were to be recorded and reported.

3. Methods

For purposes of describing the methods used, the project can be considered to consist of three programs: a management program, a monitoring program and a treatment program. The methods used to implement each of these programs are described in the following sections.

3.a Management Program

The number and diversity of participating and interested organizations mandated a well-structured management program with clear assignment of responsibility and authority, as well as specific decision-making procedures.

DEC served as lead agency with responsibility for overall project planning and design, as well as procuring and funding services to implement the project. A departmental onsite observer played a key role in project oversight and day-to-day operations management, as well as in the decision-making process as a representative to the project Oversight Committee (the project Oversight Committee is discussed further below).

Implementation of the vast majority of the project fell to the Prince William Sound Economic Development Council under contract to DEC. The council served as general manager. As such, it subcontracted for (and managed) specialty services for restoration treatment, as well as for contract administration and documentation. The council also had a direct role in coordinating the project with local and regional interests. The council sponsored two public meetings in the village of Chenega Bay - one before and one at the conclusion of the treatment work - for the purpose of fostering open discussion of the project and any local concerns.

The management program included a project Oversight Committee consisting of a representative of the Chenega IRA Council, a representative of the DEC, and a representative of the Prince William Sound Economic Development Council. That committee was tasked with responsibility for deciding which specific areas within the shoreline segments to treat, and for deciding when treatment of a particular area was sufficient.

ESC, Inc., served as the restoration treatment subcontractor to the Prince William Sound Economic Development Council. Cleanup crews were assembled from corporation shareholders - many of which were current Chenega Bay residents. A key to the project design was this availability, and ultimate use, of an experienced and conscientious local workforce. Many of the beach crew had prior *Exxon Valdez* beach treatment experience, and all met current U.S. Occupational Safety and Health Administration Hazardous Waste Operations and Emergency Response (HAZWOPER) safety training requirements.

Included on the ESC, Inc. restoration team were three other key organizations. Project management was provided by Stephen R. Rog & Associates, a company with specialized expertise and experience with the PES treatment process. As restoration project managers, Stephen R. Rog & Associates was tasked with planning and directing on behalf of ESC, Inc. all day-to-day restoration treatment operations from mobilization, to treatment operations, to demobilization, to final waste disposal. ESC, Inc. also retained Foss Environmental Services, Inc. who provided professional spill response technicians and specialized equipment. The expertise of the technicians was used to help train and direct the beach labor crews, as well as to configure, operate and maintain equipment. Foss Environmental Services, Inc. also prepared the Site Specific Safety and Health Plan for the project. Finally, the Chenega IRA Council provided local support services such as lodging and meals for project personnel.

In addition to contracting with ESC, Inc. for treatment services, the Prince William Sound Economic Development Council subcontracted for contract administration and project documentation services. Easton Environmental served as "project engineers”, a role that included ensuring that work proceeded in accordance with the contract documents, as well as dealing with day-to-day issues and questions posed by the contractor, and recommending payment of contractor invoices. Easton Environmental was also tasked with project documentation which included photographing and video taping operations and conditions, maintaining records of project progress and effects, and compiling observations and records into a report.

Finally, the scientific expertise of the NOAA Auke Bay Lab was tapped to implement the scientific monitoring program.

3.b Monitoring Program

The system used to monitor progress against objectives was derived from the Monitoring Plan developed as part of the Environmental Assessment (USFS, 1997). The Monitoring Plan set out three objectives, and specified measures to monitor progress towards those objectives.

Objective I: Significant reduction in visually observable [oiling of] surface and subsurface sediment. To monitor progress against this objective, each beach was to be surveyed using standard oil survey forms before, during, and after treatment. The level of oil reduction found by these surveys would be the basis for determining whether treatment objectives had been met, and whether to move on to the next treatment area.. In addition to the surveys, each beach segment was to be extensively photographed and videotaped before, during and after treatment.

Objective II: Significant decrease in the levels of measurable petroleum hydrocarbons in the surface and subsurface Sediment. A target removal efficiency of 50 percent was specified. To assess progress against this objective, sample spots were to be selected where there was enough surface oil to establish three 25 cm^2 quadrats, one to be sampled before cleaning, one soon after cleaning and the third the following spring. Similar reference sample spots were to be established as possible, where there was surface oil that was not cleaned. The sampling was to be done by excavating all material straight down below a quadrant, and extracting the resulting oily mud. Quantities of oil are presented as grams of oil per area of beach. To determine whether treatment caused oil to be moved down the slope of the beach, smaller samples, for GC/MS analysis, were to be collected at intervals along the MLLW line before and after cleaning. Later added to this aspect of the monitoring program was a dry knife test in which sediments were to be sampled before and after treatment using only the air knives and no cleaning agent, and again sampled after application of the surfactant. The sampling program was to be supplemented with observations of beach and oil conditions made by the sampling team.

Objective III: No significant environmental impact on biota and no evidence of petroleum hydrocarbons being introduced into the water column. Progress against this objective was to be assessed primarily through counts and photography of population changes among intertidal invertebrates and algae, and through chemical monitoring for petroleum hydrocarbons in mussels and chitons on the cleaned beaches and in mussels moored in cages below the water surface just outside the booms that corralled oil released in the cleaning process. Counts, photographs, and chemical sampling took place before, just after and one year after beach treatment.

3.c Treatment Program

The treatment program consisted of five systems: a surfactant delivery and injection system; a water deluge and flushing system; a containment and recovery system; an oily waste collection, transport and disposal system; and a support system. A schematic is included on the next page **(Figure 3-1)**. Systems and components are described in the following paragraphs.

Modified airknife use for surfactant injection. Photo by D. Easton

Surfactant Delivery and Injection. Three diesel-driven air compressors powered the surfactant delivery and injection system. The compressors were staged aboard the landing craft and were capable of delivering up to 250 cubic feet per minute of air at 80 to 130 pounds per square inch of pressure to on-shore manifolds. From the manifolds, air was delivered to the air knives and double diaphragm pumps via 0.5-inch hose. The pneumatic double diaphragm pumps transferred PES-51© from storage containers on the beach to the modified air knives via the chemical feed lines. The chemical feed is valved at the air knife so that the barrel of the knife can be loaded with the beach cleaning agent, the chemical feed closed, and the air valve opened injecting the dose of surfactant in the barrel into the substrate under the direct pressure of the air knife.

Water Deluge and Flushing. Three diesel-driven 6inch centrifugal pumps rated up to 1500 gallons per minute each of seawater for deluge and flushing. The pumps were staged aboard the landing craft. Six-inch suction hoses with intake screens were placed overboard to supply the pumps. Six-inch, lay-flat hose delivered water from the pumps to the on shore deluge header and manifolds. The deluge header was placed just above the treatment area and consisted of six-inch plastic hose perforated at intervals along its length to provide a continuous flow of water across the entire length of the treatment area.

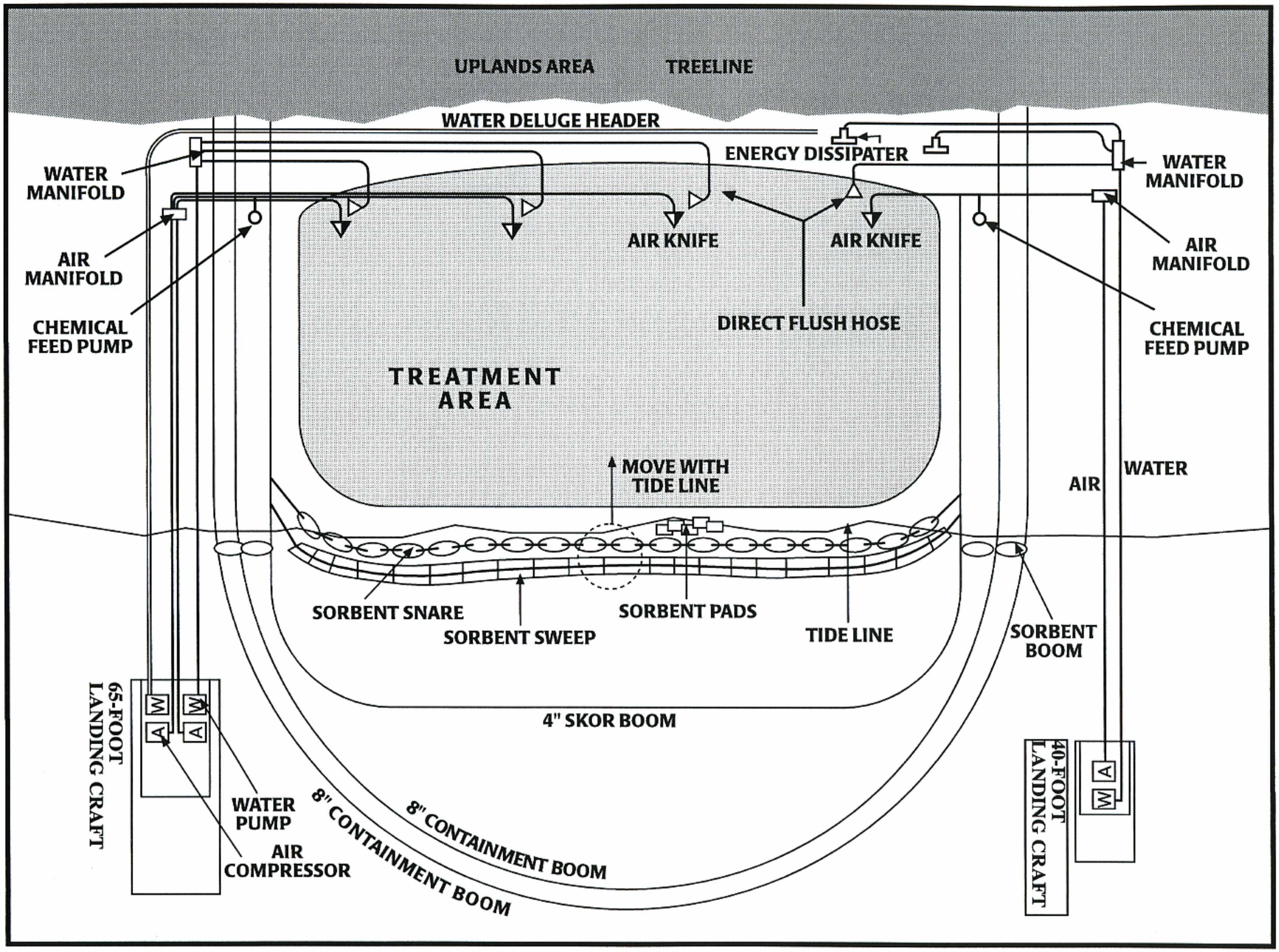


Figure 3-1
System Schematic

The Hose Monster®, an energy dissipater, was used to aid deluge flooding. Photo by D. Easton

Deluge flooding was supplemented with one or two energy dissipaters, trade name Hose Monster®. The Hose Monster© is a device designed for dissipating the energy of a fire hydrant stream during flushing.

The manifolds also fed a varying number of two-inch flat lay hoses with adjustable nozzles used for direct flushing operations. At least one direct flush hose was used with each air knife. Direct flush hoses were also used to direct released oils and surfactant to recovery areas.

Containment and Recovery. Prior to treatment the treatment area was enclosed with two sets of a vinyl-coated containment boom with an 8-inch flotation section and a 12-inch, chain-ballasted curtain. The boom was secured onshore and anchored offshore in a "U" configuration with the inner and outer boom sets separated by approximately 10 feet.

A hybrid sorbent/containment boom was used to establish yet a third containment barrier inside the inner containment boom. SKOR® boom consists of a sorbent flotation section with a weighted vinyl curtain. Four inch SKOR® boom was placed in a shallow "U" configuration spanning from one side of the inner containment boom to the other. Short sections of sorbent boom were strung between the SKOR® boom and inner containment boom, and between the two containment boom sets to keep any oil reaching the areas between the booms from migrating seaward.

In addition to the containment and SKOR® boom sets, a combination of sorbent materials was maintained at the tide line during treatment operations. A row of sorbent sweep (50 to 100-foot sections of flat sorbent material) and a row of sorbent snares, or "pompoms," strung on a line were positioned to span the water's edge from one side of the treatment area to the other.

The most used of the collection materials were sorbent pads, 18-inch squares of oleophilic material. These were used any where below treatment operations where the oil/surfactant mix collected.

The containment and recovery system included a drum skimmer which was not used.

Oily Waste Collection, Transport and Disposal. Oiled sorbent materials were collected in waste bags, transported back to the Chenega staging area at the end of each day, and temporarily stockpiled on a 10-mil liner. As time permitted, sorbent materials were run through a hand wringer to remove excess water. Relatively clean materials were set aside for reuse. All other materials were either bagged, or in the case of sorbent pads, stacked on pallets and shrink wrapped. Pallets and bags were placed in the waste trailer which was double lined with 10mil liner.

Support System. In support of all treatment systems were the two landing craft, which were used to mobilize and demobilize some of the equipment to and from the Chenega Bay area, to provide daily transport of equipment and personnel between the village of Chenega Bay and the beaches, and to house all the heavy equipment during treatment operations. The L/C "Ocean State" is a steel-hulled vessel with an overall length of 65 feet. Aboard were staged two air compressors, two 6-inch centrifugal pumps, and a small construction trailer (ATCO© unit) which served as a storage shed for smaller equipment and tools. Also stored aboard were extra sorbent materials, a 500-gallon holding tank, and fuel for the compressors, pumps, and skiffs.

Typical boom and sorbent deployment. Shown here is LA 015C-1. Photo by J. Ginter

The smaller landing craft, the L/C "Silver Eagle," is an aluminum-hulled vessel with an overall length of 40 feet. Aboard were-staged one compressor, one pump and a portable toilet. The faster of the two landing craft, the Silver Eagle was used to pick up supplies each day prior to departing to the

Two skiffs were used for much of the project. One skiff was devoted to maintaining and tending containment boom and the containment areas. The other was often used to assist with this task, to shuttle equipment and supplies from the landing craft to shore, and to provide local transport such as for pretreatment reconnaissance of the next treatment area. In addition, two larger charter boats were onsite during each day of field transport work crews and visitors, as well as to provide transport or support in the event of a medical emergency or other mishap. Charter vessels were wood or fiberglass-hulled in the size range of 25 to 35 feet.

Oiled pads were stored in lined trailers at the village of Chenega Bay. Photo by J. Ginter

Work Force. The field work force required to carry out the treatment program comprised a total of 30 persons, not including landing craft and charter vessel captains and crew:

Table 3-1
Field Work Force

Positions	Number of Persons
Project Manager	1
Assistant Project Manager	1
Expediter	1
Spill Technicians/Equipment Operators	6
Beach Crew Supervisor	1
Air Knife Operators	6
Direct Flush Operators	6
General Laborers	6
Boom Tenders	2
Total	30

3.d About PES-51®

PES-51® is a National Contingency Plan (NCP) listed miscellaneous oil spill agent manufactured by Petroleum Environmental Services, Inc. of San Antonio, Texas. It is a clear, combustible liquid with a variable light yellowish/brown cast and a strong citrus odor. Specific gravity is 0.84 at 25 °C. (Petroleum Environmental Services, 1995). PES-51® is composed of two major fractions: A carrier fraction consisting of d-limonene, and a second fraction described by the manufacturer as bacterial fermentation by-products consisting of a mixture of exopolysaccharides, proteins and rhamnolipid type compounds. (PES, 1994). Because it contains biological process-derived components and exhibits surfactant properties, PES-51® is referred to by the manufacturer as a "biosurfactant."

While the Material Safety Data Sheet (MSDS - see **Appendix H)** generally indicates that the product is not expected to pose any specific health hazard, it notes that the d-limonene component can be a skin, eye and respiratory tract irritant. D-limonene is not listed as a carcinogen by environmental health or worker safety agencies. Workers are advised to avoid contact with skin, eyes and clothing, and to wear chemically resistant clothing, splash goggles, gloves, and boots. In the event of strong vapors, respirators with organic vapor cartridges are indicated.

Crew works to consolidate waste at Chenega staging area. Photo by J. Ginter

The manufacturer's Technical Product Bulletin describes the composition and mode of action as follows (PES, 1994):

"PES-51® is composed of bacterial fermentation by products that are amphipathic in nature and when put into combination with d-limonene form a unique biological mixture with biosurfactant properties. This mixture complexes with the hydrocarbon and decreases the interfacial tension around the oil molecule without changing the surface chemistry of the hydrocarbon. Therefore, the oil/product mixture is stable and water insoluble. The mixture will not emulsify into the water column. This non-emulsification property reduces the oil/product mixture's toxicity to aquatic organisms by not allowing the water soluble fractions to enter the water column. In addition, PES-51® by itself is virtually insoluble in water (less than 50 ppm)."

3.e Mobilization

Waste and equipment is loaded onto a landing craft at the end of a work day. Photo by J. Ginter

Equipment and supplies were mobilized from Anchorage by truck to Valdez and from Valdez to Chenega by project landing craft, or from Anchorage to Whittier by truck and rail, and from Whittier to Chenega by commercial barge. Personnel were flown in from Anchorage to Chenega by commercial carrier.

Upon arrival at the village of Chenega Bay, project equipment was sorted and staged at Long Beach - a local landing area with a relatively uniform beach slope and some adjacent, open upland area. Larger equipment, such as pumps and compressors, was loaded onto the landing craft where it would stay for the duration of the project. Consumable materials were stored in trailers at Long Beach for later use.

Certain items, such as sorbent materials, air knives, manifolds, safety equipment and PES-51®, were unloaded from the landing craft and moved to the beach at the start of work each day. Upon completion of the day's effort, all oily waste and trash would be loaded onto the landing craft, along with all smaller tools and equipment.

3.f Operational Overview

The protocol summarized below (and more fully described in the following paragraphs) was observed in treating each beach sub-segment.

1. Project Oversight Committee conducts pre-treatment survey.
2. Containment system configured.
3. Vessels, equipment and sorbent lines configured.
4. Deluge started.
5. Surfactant injection, flushing and recovery conducted.
6. Deluge and flushing continued for a minimum of two hours after injection.
7. Project Oversight Committee conducts post-treatment survey and agrees that visual treatment objectives have been met.
8. Equipment mobilized to next beach sub-segment, leaving SKOR© boom in place.
9. Sub-segment observed for post-treatment sheening for a minimum of two days.
10. SKOR© boom removed.

The treatment process for each beach segment began with the pre-treatment survey by the project Oversight Committee. One or two days before treatment was scheduled, the three committee representatives, often accompanied by the ESC, Inc. project manager, would travel to the beach. The beach segment horizontal extremes were located and marked with flagging and survey hubs (2-inch by 2-inch wooden stakes). The DEC representative would conduct a survey of the beach using standard survey forms. At the same time, the other representatives would begin marking specific treatment target areas using a combination of survey hubs, flagging and rock cairns. The Prince William Sound Economic Development Council onsite representative would select and photograph areas with visible surface oiling carefully logging photo vantage points. Boom set placement was planned and the beach segment divided into sub-segments corresponding to each planned boom set and intervening sub-segments. Beach sub-segments were identified by adding a numerical suffix to the segment designation (e.g., LA 015C-1).

The landing craft *Ocean State* and equipment. Photo by J. Ginter

Setup started with the double containment boom. The boom was secured by lines to objects onshore, and using anchors off-shore. With the containment boom set, the treatment area was measured and recorded. The treatment area was defined as the area extending horizontally between each side of the inner containment boom and vertically between the upper and lower treatment limits. The treatment area and allowable surfactant application rate were used to calculate the quantity of surfactant available for use on the sub-segment.

The two landing craft were positioned on either side of the treatment area. Air and water manifolds were set just outside of the treatment area to avoid contamination. The PES-51® supply and chemical feed pumps were located just inside the treatment area so that any spillage would be contained.

Hoses were run from the pumps and compressors on the landing craft to the manifolds on the beach; and deluge, direct flush and air hoses laid out and connected. The SKOR® boom was strung inside the inner containment boom and sorbents positioned at the water's edge.

Treatment would begin when the system was completely set up, and the tidal level high enough to cover the lower intertidal zone. The entire beach area was flooded with ambient seawater by the deluge header and Hose Monsters®. Marked target areas were then treated by injecting the surfactant into the subsurface beach soils using air knives. As the oil and surfactant mixture was forced to the surface, workers would flush the mixture down the beach towards the containment area. Another crew worked downstream of the injection and flushing operation collecting released oil and surfactant with sorbent pads.

Airknife injection and flushing at LA 020B. Photo by J. Ginter

Treatment operations would continue in this manner until the project Oversight Committee was satisfied that visual objectives had been met, or until tidal levels began to drop to within two hours of exposing the lower intertidal zone. In both cases, surfactant injection would stop while maintaining deluge, direct flushing and sorbent recovery. Deluge, flushing and recovery would continue for a minimum of two hours. If after two hours, the area still yielded oil and surfactant runoff, flushing and recovery would continue until the tidal level had dropped to just above the lower intertidal zone. At that point flushing would stop, to be resumed when the lower intertidal was again inundated.

Once flushing was complete, the treatment equipment would begin to be broken down for transport to the next area. The sorbent SKOR® boom would be replaced if oiled, and securely anchored and left in place to contain any residual sheening. The containment boom would be decontaminated by hand wiping using PES-51® on a sorbent pad. In cases where the next treatment area was adjacent to the area just treated, one side of the containment boom was left anchored in place while the other side was swung to encompass the next area. The side remaining in place would then be shifted to overlap the previously treated zone.

After all treatment work had been completed at a sub-segment, a post-treatment survey was conducted, photo documentation points were recovered, and post-treatment conditions photographed.

3.g Documentation Methods

The pre-treatment condition of the beach was documented by the DEC representative during the pre-treatment surveys using the standard oiled shoreline assessment techniques and forms developed during the response to the *Exxon Valdez spill.*

Pre and post-treatment conditions were also photographed using a 35 millimeter camera, and video taped using an 8 millimeter recorder. That process involved selecting points that had visual surface oiling typical of a treatment area. The substrate was photographed and video taped before treatment while carefully recording the photographic target area and photographer vantage point. These areas were again located and photographed and video taped after treatment. Logs were maintained with entries for each photograph and video tape segment.

Project progress was also documented in field notes, in site sketches, and by completing a number of daily logs that included entries for such items as tides, weather, PES-51® use, square meters treated, wildlife observations, etc., as well as a short narrative description of the day's work effort.

3.h **Recovered Oil Estimates**

A batch extraction and gravimetric analytical procedure was used to estimate the amount of oil contained in sorbent materials at the end of the project. The oil estimating protocol involved collecting samples of each of the different types of sorbent materials used, extracting the sorbed oil by washing the materials in a known quantity of solvent (PES-51®), analyzing sub-samples of the solvent extract to determine concentrations of oil and grease; and using those concentrations to estimate the oil contained in each sample and the total oil contained in each type of sorbent material.

Calculations. Quantities of sorbed oil for each type of sorbent material were calculated using the total petroleum hydrocarbon concentrations yielded by laboratory analysis, the weight of each sorbent sample, the weight of solvent used per sample, and the total weight of sorbent material used. Calculations proceeded as follows:

1. Calculate the weight of oil ($W_{oil\text{-}batch}$ in kilograms – kg) yielded from each batch of sorbent samples:

$$W_{oil\text{-}batch}\ (kg) = (C_{oil+PES} - C_{PES})\ (mg/kg) \times W_{PES}\ (kg) \times 10^{-6}\ (kg/mg)$$

where:

$C_{oil+PES}$ = the total oil and grease concentration in milligrams per kilogram (mg/kg) produced by the gravimetric analysis of the PES and oil extract.
C_{PES} = the concentration in mg/kg of oil and grease produced by the gravimetric analysis of PES alone.
W_{PES} = the total weight of the solvent used for the sample batch.

2. Calculate the weight of oil per unit weight of sorbent material ($W_{oil/sorb}$):

$$W_{oil/sorb}\ (kg/kg) = W_{oil\text{-}batch}\ (kg)\ /\ W_{sorb\text{-}sample}\ (kg)$$

where:

$W_{sorb\text{-}sample}$ = the weight of the sorbent material sample before extract.

3. Use the weight of oil per unit sorbent material to estimate the total weight of oil ($W_{oil\text{-}total}$) contained in the total amount of a particular type of sorbent material:

$$W_{oil\text{-}total}\ (kg) = W_{oil/sorb}\ (kg/kg) \times W_{sorb\text{-}total}\ (kg)$$

where:

$W_{sorb\text{-}total}$ = the total weight of a particular type of sorbent material (e.g. sorbent pads or sorbent sweep).

4. Convert kilograms of oil to gallons ($V_{oil\text{-}total}$) using an assumed specific gravity of 0.95 corresponding roughly to weathered crude oil.

$$V_{oil\text{-}total}\ (gal) = W_{oil\text{-}total}\ (kg) \times (0.95 \times 3.79)\text{-}1\ (kg/gal)\text{-}1, \text{ or}$$

$$V_{oil\text{-}total}\ (gal) = 0.28 \times W_{oil\text{-}total}\ (kg)$$

Sampling procedures. Samples comprised a total of 310 sorbent pads, 100 linear feet of sorbent sweep, 50 linear feet of SKOR boom, 50 linear feet of sorbent boom, and 40 individual snares (pompoms) representing a minimum of one percent of the total volume of each sorbent type. An equal number of the individual items (pads and snares) was taken at more-or-less equal intervals (e.g., approximately every 100th pad) from each storage container (pallet or waste bag). The sweep, SKOR and sorbent boom were sampled by cutting open a storage bag and then cutting a length from the first material pulled from the bundle (two feet for sweep, one foot for SKOR and sorbent boom).

Extracting oil from sorbent pads to estimate oil content. Photo by J. Ginter

Individual grab sample of materials were composited into batches and weighed. A measured amount of PES-51® was poured into a container. The sorbent materials were added, soaked until saturated, agitated, and rung. After a batch of material had been through the extraction process, three aliquots of the extract were collected for laboratory analysis. The remaining extract was discarded into a waste drum and the process repeated for the next batch of materials.

Sample Analysis. The extract samples were analyzed by Northern Testing Laboratories, Inc. using a gravimetric process for total petroleum hydrocarbons adapted from U.S. Environmental Protection Agency method 1664. This method involves comparing the before and after weights of an oil and solvent extract heated to drive off the solvent component.

Investigation Derived Wastes. About *165* gallons of extract solution and water were collected in a waste and delivered to a permitted facility for disposal.

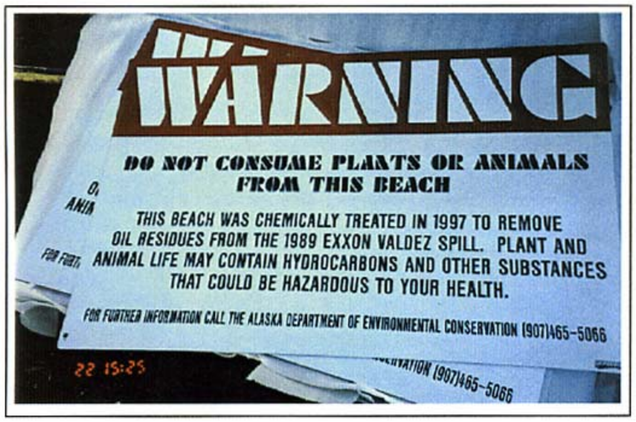
4. Results

This chapter presents the results of the treatment effort in meeting contract terms, budgets and schedules, as well as observations on the effects of the shoreline treatment process. The results of the NOAA Auke Bay Lab monitoring program to determine whether there was a significant decrease in levels of measurable petroleum hydrocarbons, and whether there were impacts on biota and the water column is contained in Part II of this report.

An overview of the project results is provided in the next section. Descriptions of project activities for each of the shoreline segments follow the overview.

4.a Implementation Overview

Restoration treatment took place over the 33-day period from June 17 through July 19, 1997. In that period, the top five priority of the eight target shoreline segments were treated: three on LaTouche Island designated LA 020B, LA 020C, and LA 015C; and two on Evans Island designated EV 039A and EV 037A.



Signs placed on the beaches after treatment warned against subsistence use. Photo by J. Ginter

Schedule. Mobilization of equipment, supplies and personnel to the vicinity was completed on June 15, and a public meeting was held in the village of Chenega Bay that evening. Treatment of the first beach sub-segment (LA 020B-1) began on June 17. Beach treatment activities continued until July 19. Treatment activities did not occur on five days: Two days were taken for crew rest. Stormy weather precluded treatment operations on three other days. A second public meeting was held in Chenega Bay the evening of July 19. All personnel were demobilized from the Chenega Bay area by July 23. The final shipment of equipment and waste left Chenega on July.30. Signs warning against harvesting plants and animals from treated beaches were posted on September 3. (See project calendar, **Appendix B.)**

Budget. The cost of the treatment effort - not including project oversight, documentation or monitoring was $1.1 million. (NOTE: This figure will be updated when final costs are available).

Treatment area. A total of 9,490 square meters of beach substrates were treated using 404 gallons of PES-51®:

Table 4-1
Treatment Areas

Segment	Sub-Segment	Treatment Days	Ana (sq. meters)	PES-51`JUsed (gallons)
LA 020B	1	4	1150	113
	2	1	375	12
	3	1	480	15.5
	4	2	600	21.5
LA 020C	1	1	280	3
	4	2	185	4.5
	6	3	840	31
	7	2	925	36
	9	2	540	20
LA 015C	1	3	840	32
	2	2	750	28
	3	1	650	23
EV 039A	1	2	1025	34.5
EV 037A	1	3	850	30
Totals	14	2	9490	404

Wildlife impacts. No wildlife impacts were observed. U.S. Fish and Wildlife Service and Alaska Department of Natural Resource eagle nest tree mapping reviewed before the field work showed no eagle nest trees in the immediate vicinity of any of the beaches targeted for treatment, and no new eagle nest trees were located during the field work. Workers in transit to, or working on the beaches routinely spotted Steller's sea lion, humpback whale, Orca, Dall porpoise, Sitka black-tailed deer, sea and river otter, seals, bald eagle and a variety of other bird life. A pair of sea ducks surfaced in the containment area of LA 020B-1, though there was no threat of oiling. On two occasions deer were discovered within or near the treatment areas when crews arrived to begin work.

Safety incidents. The uneven, often slippery work areas posed significant risk of injury to beach crews, and personnel safety was emphasized throughout the project. There were three accidents involving personal injury: Slips on two separate occasions resulted in an injured leg and an injured back. One crew member also burned a hand on one of the diesel pump exhausts. All injured crew were transported for treatment, though none of the injuries proved serious.

Other mishaps. On June 27, one of the landing craft had a small (estimated at five gallons or less) diesel fuel leak. The spill was immediately contained and recovered.

Containment system. Overall, the containment system proved effective. There were, however, a few minor incidents of small (less than five square meters) sheen temporarily (less than one hour) breaching containment where the boom was suspended between boulders by the outgoing tide. In all cases, the sheen was contained. In some cases, additional SKOR® boom was positioned to supplement the containment boom. Close attention was paid to containment throughout the project, with a skiff and two-person crew devoted entirely to maintaining boom configuration and integrity.

Recovery and wastes. A total of 20,007 pounds of oily sorbent wastes containing an estimated equivalent of 63 gallons* of weathered crude oil were generated. Oily wastes were tested and incinerated as non-Resource Conservation and Recovery Act (RCRA) waste at the Entech, Inc. facility in Anchorage.

**Our oily mud samples averaged about 58 ml of oil / liter of sample, which implies that 63 gallons of oil would have made 1000 gallons of oily crude.*

4.b Segment LA 020B

Environnent. LA 020B lies within Sleepy Bay on the north end of LaTouche Island **(Figure 4-1).** The segment is approximately 325 meters long and is moderately sloped over much of its length. The beach segment is oriented north-south, with the southern end marked by a "No Fishing" sign. A more productive lower intertidal zone ("green zone") was noted toward the north end of the segment and the stream, while no green zone was exposed at the southern end.

The treatment area of beach LA 020B, looking South. Photo by J. Ginter

The beach is armored with angular boulders and cobble overlying a gravel substrate. The proportion of boulders to cobble increases from south to north. A group of three large (approximately 3-meter diameter) boulders just south of the center of the segment provides an easily recognizable landmark. A small stream crosses the segment near the northern boundary

Residual oil. Oil was present largely as patches of asphalt pavement and surface oil residue in gravels and cobbles between boulders in the upper intertidal. Heavy and moderate subsurface oil was noted toward the center and southern end of the segment. Patches of residual oil were also found in the middle intertidal in the vicinity of a large boulder near the center of the segment. No oil was present in or around the stream bed, or in the lower intertidal.

Treatment efforts. The segment was broken into four sub-segments (LA 020B-1 through LA 020B-4) corresponding to four boom sets with the stream near the north end of the segment falling between sub-segments three and four. Treatment proceeded south to north, beginning with LA 020B-1 on June 17 and ending with completion of LA 020B-4 on June 25. (June 23 was taken as a crew rest day.)

Two areas of LA 020-B had oiling in the form of heavy oil residue that demanded extra attention during treatment. These areas were in the vicinity of the three large boulders in the upper intertidal at LA 020B-2, and the large boulder in the middle intertidal at LA 020B-3.

A total of 2,605 square meters was treated using 162 gallons of PES-51©. Total treatment time (air knife injection and flushing) was 44 hours over eight work days.

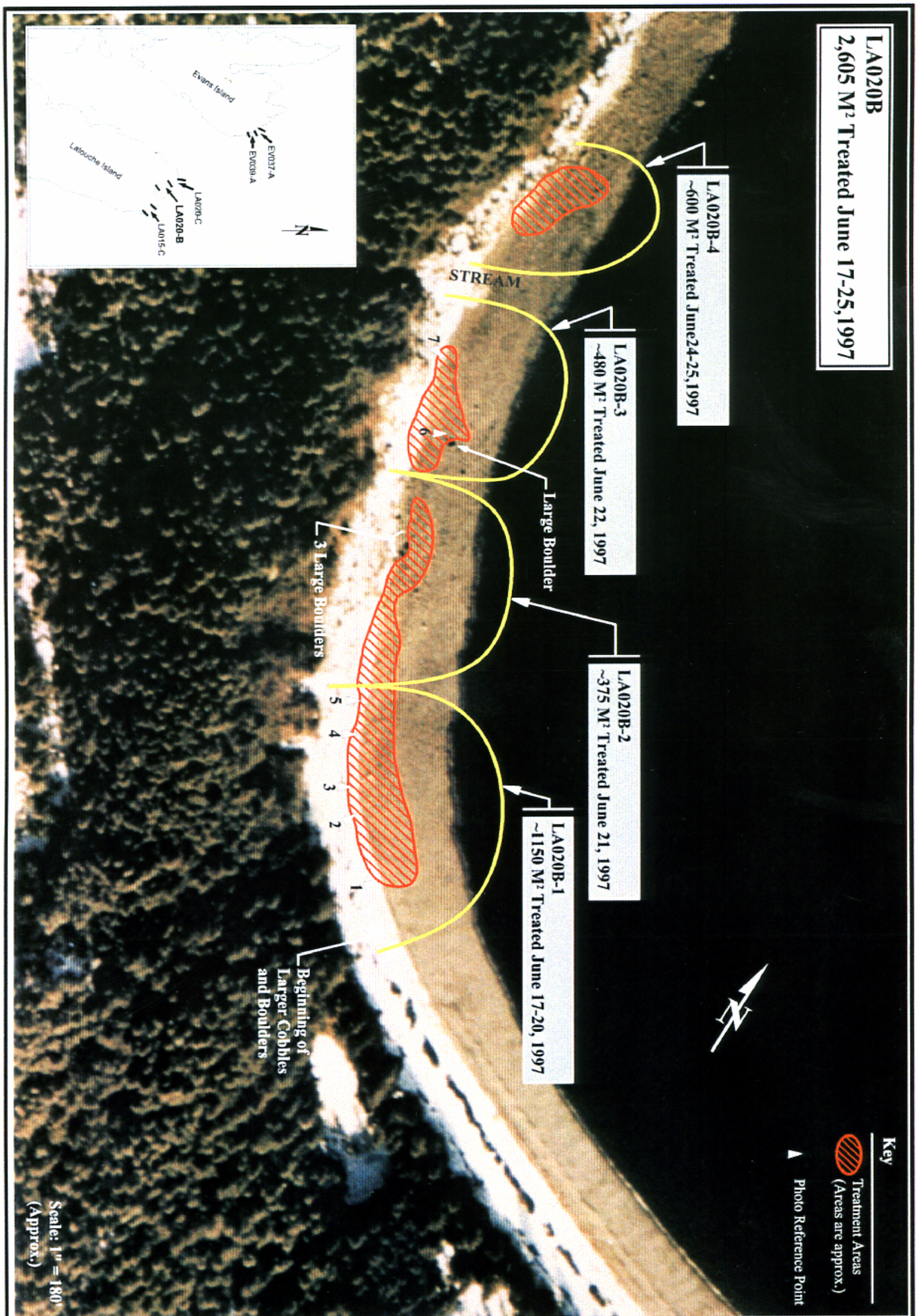
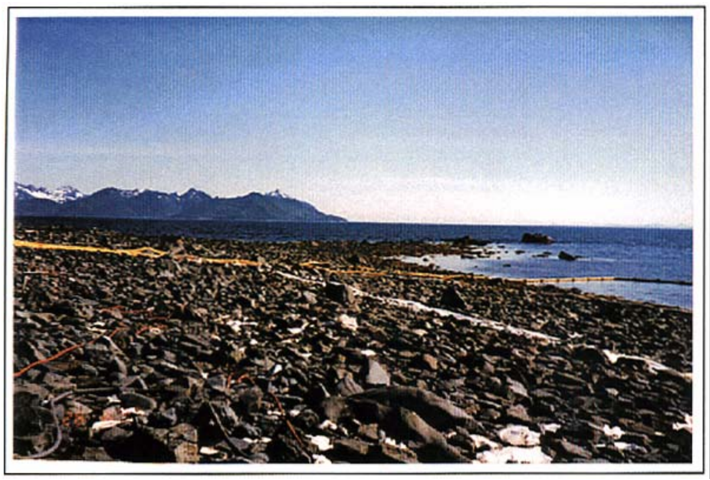


Figure 4-1
Segment LA 020B

4.c Segment LA 020C

Environment. At approximately 1000 meters in length, LA 020C was the largest of the targeted beaches, and is situated immediately north of LA 020B (**Figures 4-2a and 4-2b**). Proceeding from south to north, prominent features include a large, isolated, green-colored boulder in the upper intertidal approximately 250 meters north of the southern segment limit. Some 200 meters farther to the north, a reef, conspicuous at low tide, extends out from the shoreline. Located near the northernmost end of the segment is a shale bedrock outcrop.



The reef point at LA 020C, approaching low tide. Photo by J. Ginter

The area between the southern limit and the reef is covered in boulders and cobble, with size decreasing towards the reef. The area directly above the reef consists of vertically-fractured shale bedrock with very little other coverage. Northwest past the reef, there is another transition from bare shale bedrock to bedrock covered with gravel and small cobble. Some of the cobble appears evenly distributed (reportedly the result of mechanical treatment in 1991). Continuing further northwest, the cobble cover gives way to large outcroppings of exposed bedrock and large angular boulders for the last 200 meters.

The beach slope is shallow on both sides of the reef but gradually increases to a moderate slope at the northwestern end. While a green zone was apparent throughout, it was most pronounced around the reef and the outcrop near the northwestern segment limit.

Residual Oil. South of the reef, oil was found in sporadic patches of surface asphalt and oil residues in the upper intertidal. Oil in the upper intertidal immediately above the reef point was found as surface asphalt in the crevices of the shale bedrock. The oil appeared highly weathered, yet when probed would ooze liquid. Continuing north past the reef, in the area of small cobble, oiling was sporadic although there were areas of patchy surface asphalt and heavy subsurface oil residues below the cobble armor. Further north, pockets of oil residue were found among the larger boulders and bedrock formations. Surface and subsurface oil was present in this area in both the upper and middle intertidal. The upper intertidal area above the shale bedrock point near the north end of the segment contained pockets of asphalt in bedrock recesses. The northernmost 100 meters contained patchy asphalt and surface oil residue amongst very large angular boulders.

Treatment Efforts. The segment was broken into ten sub-segments (LA 020C-1 through LA 020C-10) corresponding to five treatment areas (sub-segments 1, 4, 6, 7 and 9) and five areas not treated (sub-segments 2, 3, 5, 8 and 10). Treatment took place between June 26 and July 6. July 4 was a crew rest day.

The first sub-segment (LA 020C-1) started in the vicinity of the green-colored boulder (approximately 250 meters north of the southern segment limit) and continued north for 75 meters. The thin asphalt layer in this area was treated.

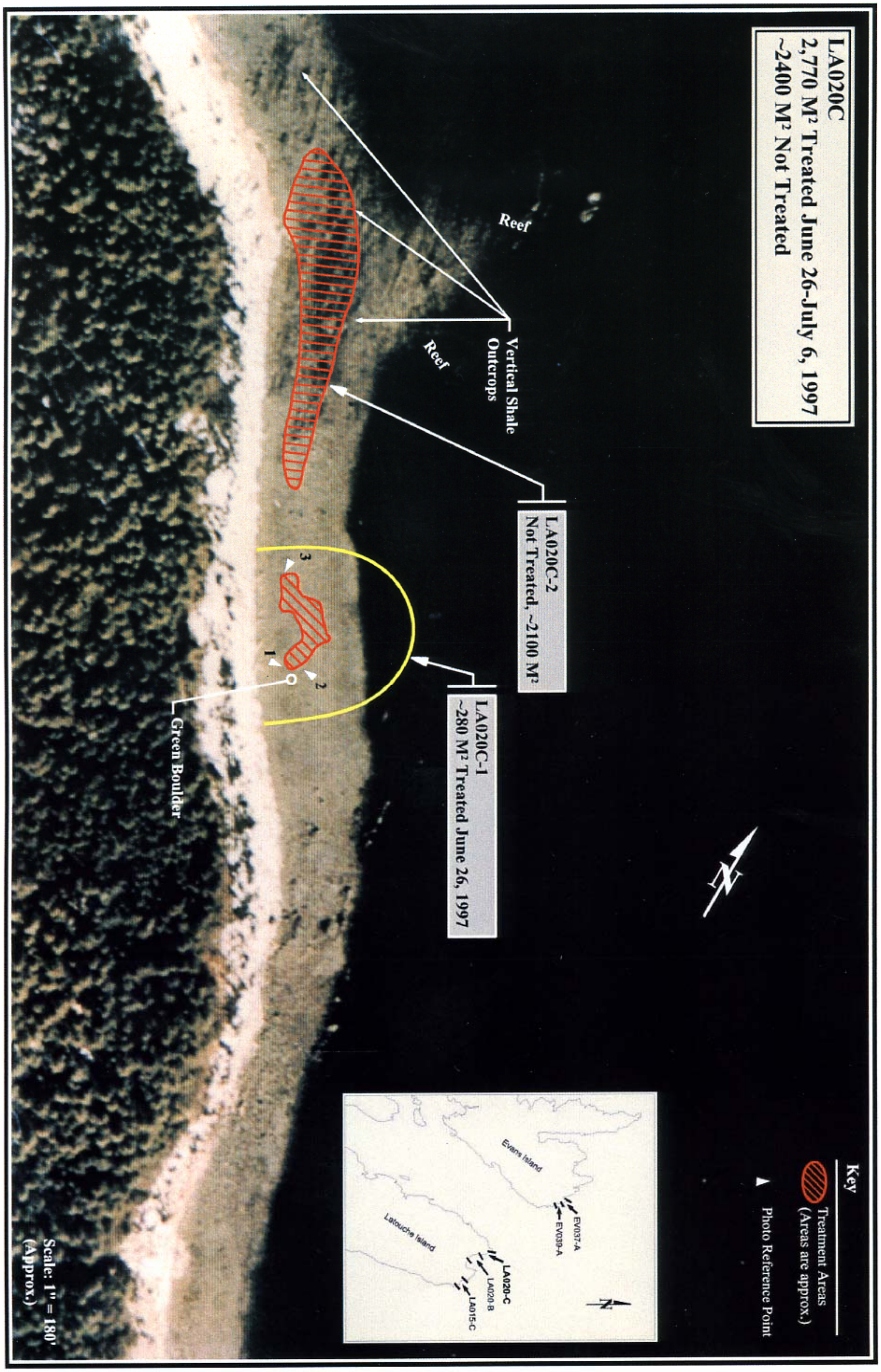


Figure 4-2a
Segment LA 020C

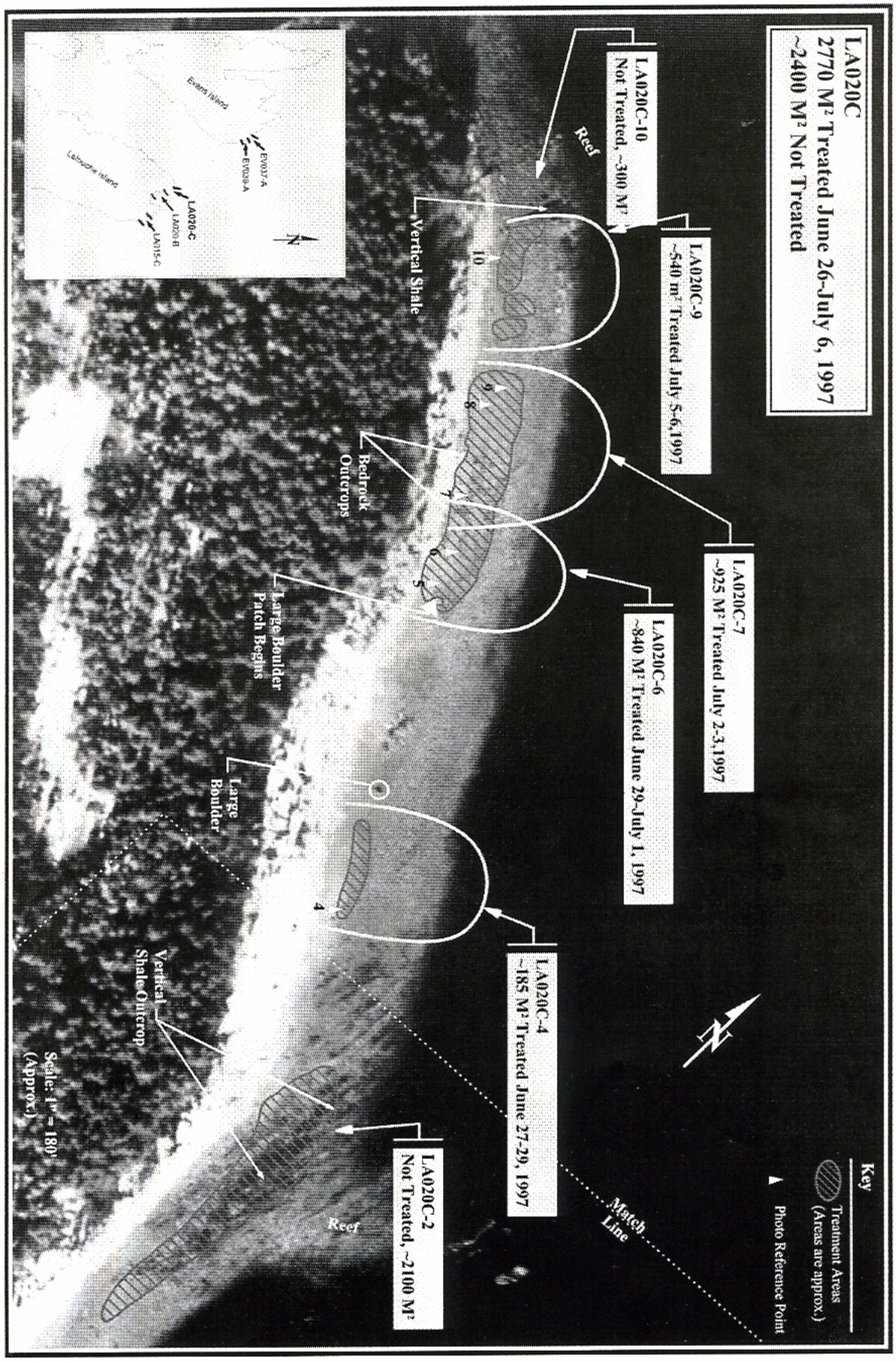


Figure 4-2b
Segment L020C

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The shallow gradient of the next sub-segment (LA 020C-2), combined with the offshore reefs and pinnacles precluded bringing the landing craft close enough to support treatment efforts. Approximately 2,100 square meters of oiled shoreline area above the reef was not treated. LA 020C-3 included only trace amounts of surface asphalt, and was not treated.

The next sub-segment treated was LA 020C-4. LA 020C-5 did not contain oil. The next two sub-segments requiring treatment, LA 020C-6 and LA 020C-7, had large boulders and exposed bedrock, and contained substantial subsurface oil residue. Treatment of these sub-segments generated large amounts of oil and required extensive flushing.

The next small sub-segment (LA 020C-8) did not contain oil. As with LA 020C-6 and 7, LA 020C-9 contained substantial subsurface oil residue and treatment generated considerable amounts of oil, and required extended flushing. LA 020C-10, which contained approximately 300 square meters of patchy surface asphalt and oil residue, was not treated because the landing craft could not be positioned close enough to allow operations.

A total of 2,770 square meters of LA 020C was treated using 94.5 gallons of PES-51®. Total treatment time (air knife injection and flushing) was 34.5 hours over ten work days. A total of about 2,400 square meters of oiled beach could not be treated because offshore obstacles prevented positioning the landing craft close enough to support operations.

4.d Segment LA 015C

Environnent. LA 015C is a pocket beach located at the northeast end of LaTouche Island (**Figure 4-3**). The shoreline segment is oriented northwest-southeast. The southeastern portion includes an anadromous fish stream. The sub-segments targeted for treatment begin approximately 200 meters northwest of the stream and continue for another 145 meters in that direction. The segment is highly to moderately sloped, with the slope decreasing to the southeast.

Northern end of the treatment area at LA 015C. Photo by _j. Ginter

The sub-segments targeted for treatment include a number of bedrock outcrops, some over three meters in height. Much of the area is armored with large angular boulders above bedrock with some gravel substrate. The size of the boulders decreases moving southeast, with increasing cobble. An abundance of plant and invertebrate life was noted in the lower intertidal zone at the northwest end of the treatment area.

Residual oil. Asphalt and viscous mousse were present around and under boulders and within bedrock crevices in both the upper and middle intertidal. The area with the heaviest oiling was in the vicinity of the bedrock outcrop in the center of the treated area continuing offshore to another bedrock outcrop in the middle intertidal. Patches of surface and subsurface asphalt, oil residue, and tar were also found in the cobble area at the southeastern end of the treated area.

Treatment efforts. The segment was divided into three sub-segments, numbered from northwest to southeast as LA 015C-1, 2 and 3. Treatment took place between July 7 and July 14. Operations were precluded by weather on July 11 and 13.

Treatment of the first sub-segment (LA 015C-1) began at a vertical bedrock face at the northwest extent of the targeted treatment area, and continued south. All three sub-segments yielded substantial oil during treatment, requiring extended flushing and containment precautions.

A total of 2,240 square meters was treated at LA 015C using 83 gallons of PES-51®. Total treatment time (air knife injection and flushing) was 27 hours over six work days.

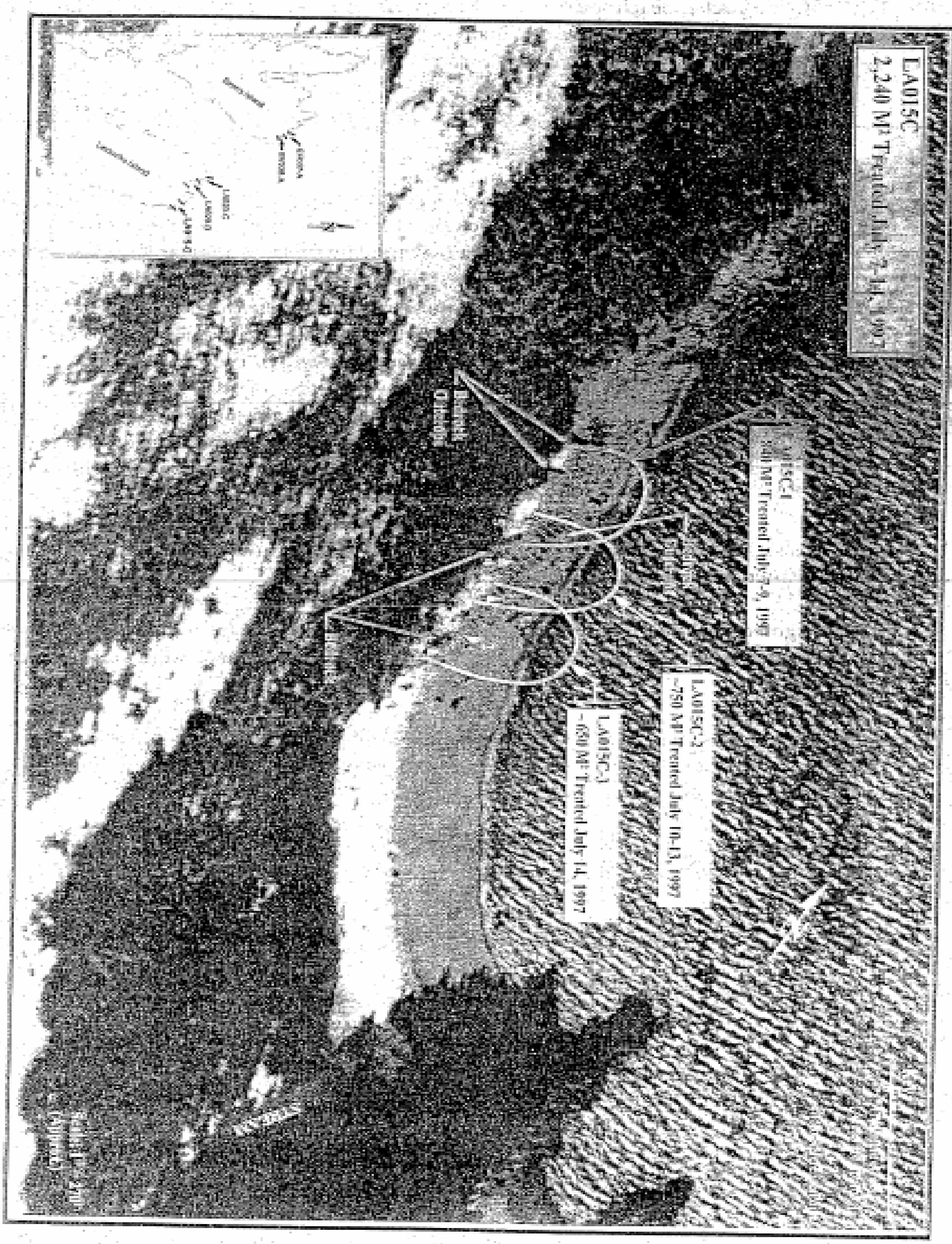

Figure 4-3
Segment LA 015C

4.e Segment EV 039A

Environment. EV 039A is a small, protected bay located on the northeast shore of Evans Island, northwest of Bishop Rock **(Figure 4-4).** The segment is oriented northwest-southeast and is divided by a small stream. A bedrock outcrop further divides the area east of the stream into east and west pockets at high tide. The beach is moderately sloped.

Treatment operations at EV 039A, looking east. Photo by J. Ginter

The area northwest of the stream consists of bedrock with overlying boulders and cobble. A cluster of low, jagged rock extending seaward of this area is exposed at low tide. Southeast of the stream, the substrate consists of cobble, gravels and some sands overlying conglomerate bedrock, with scattered boulders. The pocket southeast of the dividing outcrop contains more sand and finer gravels, while the pocket to the northwest contains more cobble and boulders.

Residual oil. In the area northwest of the stream, oil was found in the middle and upper intertidal as sporadic asphalt, mousse and surface oil residue. Southeast of the stream, oil was present in the middle and upper inter-tidal as patchy to sporadic areas of surface and shallow subsurface asphalt and oil residues.

Treatment efforts. The segment was divided into two sub-segments, one northwest and one southeast of the stream. Only the sub-segment southeast of the stream (EV 039A-1) could be accessed for treatment due to the rocks in front of EV 039A-2. Treatment took place on July 15 and July 16.

Treatment of EV 039A-1 was conducted without complication producing a moderate amount of oil. The southeastern-most pocket of sub-segment EV039A-1, was treated first without, and after sampling, with PES51® as part of the "dry knife" element of the NOAA Auke Bay Lab monitoring program.

A total of 1,025 square meters (including the dry knife area) was treated at EV 039A using 34.5 gallons of PES-51®. Total treatment time (air knife injection and flushing) was seven hours over two work days.

4.f Segment EV 037A

Environment. EV 037A is located on the northeastern shore of Evans Island south of EV 039A, with a rock promontory separating the two **(Figure 4-4**, previous page). The section of the beach targeted for treatment begins at the promontory on the north end of the segment and continues 90 meters south. The segment is oriented north-south with the area targeted for treatment moderately sloped.

This small beach segment is covered in large cobble and boulders overlying coarse gravel and bedrock. Near the rock promontory to the north is a small area of cobble and gravel overlying peat. Further south, the beach extends to an offshore outcrop that can be reached at low tide. A productive lower intertidal zone was evident around the promontory to the north, and the offshore outcrop. There are numerous boulders and outcrops just offshore of this beach preventing vessel access except at the southern end.

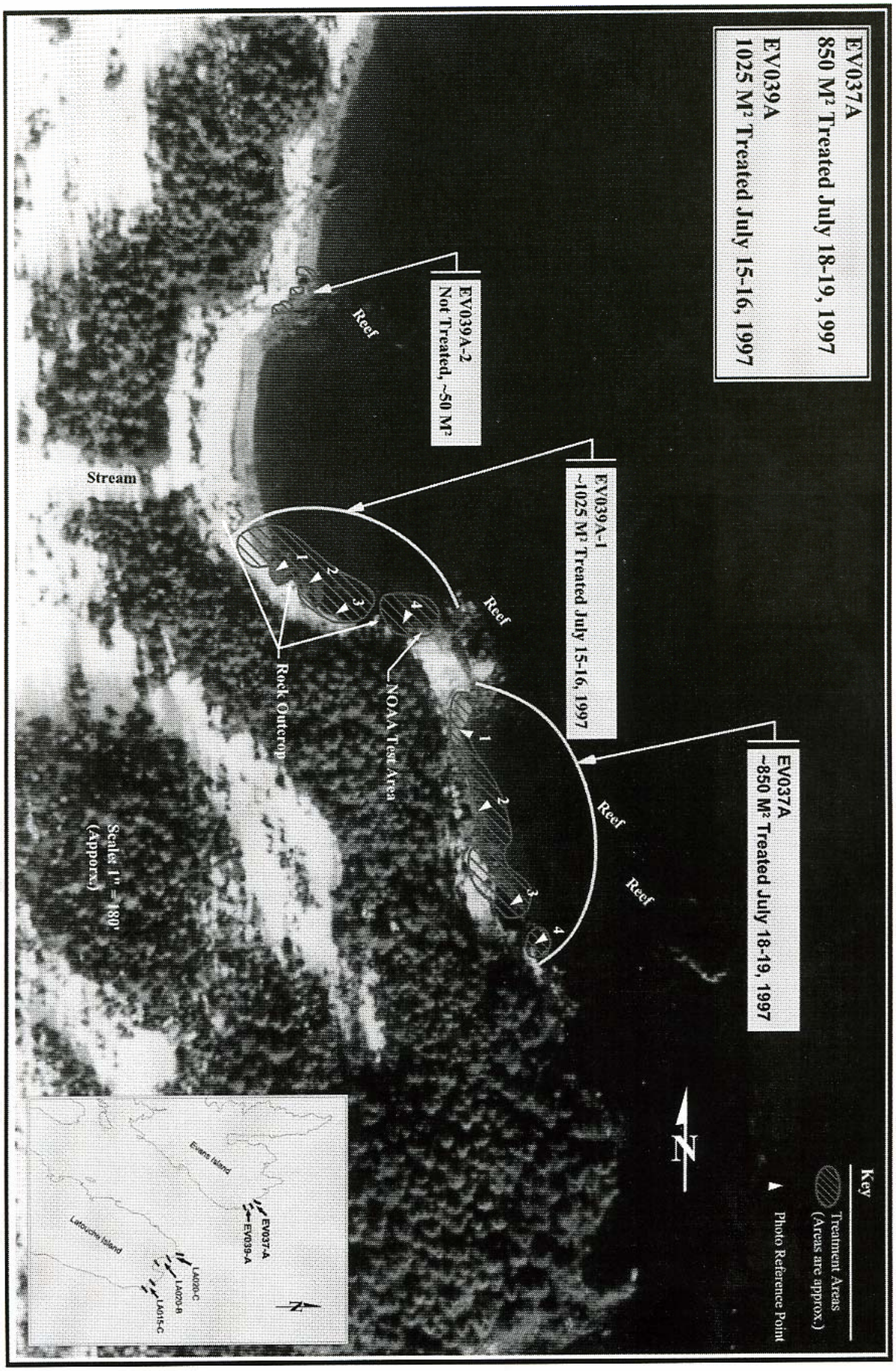

Figure 4-4
Segment EV 039A and 037A

Residual oil. A small area of heavy surface oil residue was present in the upper and middle intertidal just south of the rock promontory, among the boulders. Further south, surface asphalt and oil residue extended to the subsurface in patches in amongst the boulders and cobbles. The heaviest oiling was in the center of the treated area.

Treatment efforts. The treatment area of EV 037A was small enough that it did not need to be divided into sub-segments, and the entire area was encompassed in one boom set. With offshore access available only from the south, only the larger of the two landing craft was used.

Treatment operations at beach EV 037A, Evans Island.
Photo by J. Ginter

Treatment of the area was delayed by inclement weather on July 17. Treatment was conducted July 18 and 19 generating a moderate amount of oil. A total of 850 square meters of EV037A was treated using 30 gallons of PES-51®. Total treatment time (air knife injection and flushing) was 7.5 hours over two work days.

5. Discussion and Conclusions

Visual objectives. Recall that one of the objectives of the treatment process was a significant reduction in observable oil residue in surface and subsurface sediment. We conclude on the basis of observations during pre and post-treatment surveys that there was indeed a significant reduction in oil residue visible at the surface of the beach sediments in the treatment areas. That conclusion was shared by all members of the project Oversight Committee prior to concluding treatment of each area.

Treatment rates. In estimating project costs, Petroleum Environmental Services, Inc. assumed a treatment rate of 200 square meters per day per air knife not including mobilization, demobilization and set-up time (PES, 1995b).

We found that, on average, for each of the 22 days during which PES-51® injection occurred:

- 4.5 air knives were used;
- actual injection occurred for 2.6 hours; and
- 431 square meters of shoreline were treated.

The project results suggest a treatment rate of 96 square meters per air knife per day. The smaller treatment rate is likely a direct result of injection occurring for an average of only a few hours per 12-hour workday when daylight and tidal conditions permitted.

Treatment costs. Contractor costs for treatment
(i.e., not including costs associated with project management, monitoring, documentation, or mobilization/ demobilization) were $955 thousand to treat 9,490 square meters of shoreline for an average of approximately $100 per square meter. (NOTE: These figures will be updated when final cost figures are available.)

Recovered oil. Oil recovery operations originally envisioned using a skimmer that would produce a free mixture of water, PES-51®, and oil; the volumes of which would be measured and recorded. With the change to sorbent recovery, a method for estimating oil as a component of waste sorbent material had to be devised. The batch extraction process described previously was developed as a compromise to keep costs in line with budgets while providing rough figures for the amount of oil contained in sorbent materials. The advantage of the process was that a relatively large amount of sorbent material could be sampled and analyzed for the cost of a limited number of laboratory analyses of the bulk extract. The disadvantage was that it was not a well-tested, approved method with standard procedures and expectations for data quality. For that reason, the estimate of 63 gallons of recovered oil should be considered very approximate.

While the estimate of recovered oil is interesting data, oil recovery was not intended as a specific objective or measure of project success. The project objective of significant reductions in measurable oil concentrations allows for not only physically removing the oil, but for reductions in oil concentrations due to conversion of the oil from more stable to less stable forms subject to reduction through weathering processes.

We can postulate at least one explanation for the low oil recovery. It could be that treatment was effective in releasing the oil from the sediments, but significantly less effective in floating the oil and PES-51© mixture to the surface where it could be recovered. Contributing factors would be that the residual oil has, in all probability, a relatively high specific gravity, and that the allowable PES-51 application rate may not have been sufficient to produce a buoyant mixture.

Crew retrieving oiled sorbent pads during treatment at LA 015C. Photo by J. Ginter

As a final thought on the topic of oil recovery: We speculated about the feasibility of other recovery methods, such as using some type of modified suction skimmer with each air knife to immediately collect the released oil and surfactant as it surfaced from the substrate. It may be that a more direct means of collecting the released oil could be devised.

Photographic and video documentation methods. Photographic and video documentation of surface oil conditions before and after treatment was not particularly successful. (Some before-and-after photographs of beach substrates are included in **Appendix C.)** Several conditions combined to hinder the effectiveness of this particular documentation method. First, substrate surface oiling is often not readily observable from a distance of more than a few meters. Consequently, comparison of pre- and post treatment photographs or video of overall beach sub-segments or even substantial portions of beach sub-segments taken from more than a few meters away would often reveal nothing about changes in surface oiling conditions.

Second, surface oiling conditions often consisted of patches of asphalt pavement or residual oil in small areas between boulders. It is often difficult to distinguish dark oil from wet areas and shadows even in close-up (one to two-meter) photographs and video of the areas down in between the boulders. It is also often difficult to distinguish under any conditions asphaltic pavement from unconsolidated gravels as the difference is not always visually apparent without physically probing the substrate to see if it is bound into an asphaltic matrix.

Finally, despite carefully recording and duplicating both photographic targets and vantage points, we found it difficult to replicate pre- and post-treatment photographs such that the pairs were clearly of the same substrate area. Changes in lighting conditions due to overcast or time of day, minor variations in the direction of view or camera height, differences in the degree to which substrates were wet or dry, and actual movement of beach materials during treatment combined to alter the appearance of many of the beach areas between the pre and post-treatment photographs.

We suggest that while there is a role for photographic and video documentation of any similar projects, that role might be restricted to recording pre- and post-treatment conditions in a few, select areas with favorable conditions for illustrative purposes. Of course, different beach and oiling conditions may also be more conducive to photographic documentation of pre and post-treatment surface oiling conditions. Certainly, there remains a role for photographic documentation of other aspects of the treatment process.

The management program. In designing the management program, representatives of Chenega Bay and DEC recognized, based on their *Exxon Valdez* experience, that two decisions would be difficult: Which specific areas within the beach segments should be treated, and when has an area been sufficiently cleaned to move on? The management program reserved those questions for a consensus-based decision of the Oversight Committee. Despite the potential for disagreement, consensus on those difficult questions came relatively easily. We attribute that to all committee members being directly involved in the treatment process and developing an understanding of its capabilities and limitations. The committee structure provided a strong local voice in the decision-making process as well as a stake in the project results.

Containment system. The containment system, consisting of two sets of 8-inch containment boom with an inner set of SKOR© boom, worked well. We believe that the SKOR® boom, with its ballasted curtain, provided significant protection beyond that which would have been afforded by standard sorbent boom. Operating procedures, however, also contributed to bolstering containment integrity. Those procedures included:

- limiting the amount of oil actually reaching the tidewater containment area by capturing as much of the released oil as possible immediately below injection and flushing operations;
- simultaneously recovering oil as it reached the tidewater containment area;
- never leaving oil in the containment area while unattended;
- conducting operations only when conditions were within the operating range of containment system components; and
- devoting a skiff and two-person crew to maintaining containment configuration and integrity.

Not surprisingly, the containment boom on the boulder and cobble beaches will not prevent lateral escape of oil in the areas above tidewater. It is important that enough buffer be allocated between the horizontal extent of treatment operations and the containment boom to ensure that released oil reaches tidewater before it spreads laterally beyond the containment boom. In addition, the boom often requires attention right at the tide line where it can suspend on high points as the tide falls.

Post-treatment releases. From the outset, post-treatment bleeding of oil was a primary concern. In fact, this phenomenon did not occur to the degree expected. Post-treatment sheening was observed within the containment areas of two shoreline sub-segments, LA 015C-2 and LA 015C-3. In both cases, however, sheening caused by residual oil was also present before treatment. Our observations suggest that, under the conditions encountered in this project (including a limited surfactant application rate), thorough deluge and flushing (sometimes up to a day) following injection was effective in controlling post-treatment sheening. Nevertheless, maintaining a sorbent barrier (for which SKOR© boom seems particularly well suited) around the areas for two days after treatment provided insurance against unexpected releases.

Oiled sorbent materials were incinerated at Entech Inc. in Anchorage. Photo by J Ginter

Surfactant application rate. Posed for further consideration is the impact of the PES-51© application rate restriction on the effectiveness of the shoreline treatment process. Surfactant usage was limited to one gallon per 250 square feet of treatment area. We suspect that treatment would have been even more effective in reducing substrate oil concentrations and recovering released oil with a higher allowable surfactant dose. Should the results of the chemical and biological impact monitoring under way by the NOAA Auke Bay Lab prove favorable, consideration might be given to increasing the allowable application rate for any future projects.

Part II - NMFS Monitoring

Auke Bay Laboratory personnel worked with the managers of the cleaning operations to determine the effectiveness of the oil removal process and whether the water or intertidal biota were seriously contaminated by the process. Six specific objectives were accomplished:

- Determining the proportion of oil removed from treated beach segments.
- Determining potential usefulness of air knives used without surfactant.
- Determining the severity and persistence of receiving water contamination.
- Determining whether lower-intertidal sediments become contaminated.
- Determining the accumulation and persistence of contamination in mussels and chitons.
- Determining major population changes of intertidal fauna.

6. Determining the proportion of oil removed from treated beach segments

One of the key aspects of this monitoring program was to determine how much of the remaining EVO was removed by the cleaning operations. We did this through measuring amounts of oil at specifically selected sample sites. Each site had to be large enough for three samplings: one before cleaning, one after cleaning, and one the following year, after a season of winter storms. An innovative method had to be devised for measuring the oil at the selected sites. The usual measurement, concentrations of specific oil hydrocarbons, are not relevant in this case. It is the physical amount of oil that is of interest. The measurements were made by excavating large samples of sediment straight down from a measured area of beach surface, extracting all oil from the sediment, evaporating the extraction solvent, and reporting the results in terms of mass of oil / area of beach.

Ideally, the entire quantity of oil on the beaches involved would be estimated before and after cleaning. Several factors made this a virtually impossible task. First, there is the extremely uneven distribution of the oil, which is in erratic patches here and there throughout the area. This would make an enormous number of randomly chosen samples necessary to estimate the total quantity of oil there. Second, the beaches are covered with rocks from cobble size to boulder size, which increases the erraticness of oil distribution, and assure that many randomly chosen samples would be almost impossible to collect without heavy machinery. And finally, there was the virtually insurmountable problem that the areas to be cleaned could only be approximated ahead of time. Efficiency, weather, tides and the skill of the work crew, among many other factors, served to adjust the exact areas cleaned. For example, one large and oily area, above the rocky spit in the middle of LA020-C, could not be reached by the cleaning crew at all because the support barges could not get close enough to the potential work area. Given the erratic distribution of oil between and under boulders weighing up to several tons, and the lack of foreknowledge of the areas that would actually get cleaned, our analysis of the degree of oil removal in selected sample sites was the only practical approach to follow.

Methods

Locations: Oil sample sites were selected throughout the areas tentatively designated for cleaning. They were on LA020-B, LA020-C, LAO15-C, EV037-A and EV039-A. All were in badly oiled spots along the upper reaches of these beaches (Figure 6.1). We also selected six control sites on a part of LA017-A that harbored considerable oil but was not designated for cleaning. We attempted to locate as many sample sites as possible, so the sites indicated on Figure 6.1 correlate reasonably well with the maximum surface oil on the target beaches.

Sample Sites: Each sample site consisted of three 25 cm x 25 cm quadrats placed near each other on oily beach surface. Most sets of quadrats were placed within one meters of each other; there were a few exceptions with spacing of three or more meters. Each set was laid out so that from the surface there appeared to be roughly the same degree of oiling in each quadrant (Figure 6.2 A). Originally, two types of oiling were targeted. One was by far the commonest type of oil on these beaches, oil mixed into the dirt and gravel under and between rocks and generally covered with at least a thin layer of asphalt surface. The other type consisted of oil compressed into the grain of shale-like bedrock. Ultimately, however, nearly all the bedrock sites were out of reach of the cleaning crews, and that substrate was dropped from our study.

Once the three quadrats were placed in a given sample site, they were carefully photographed, described in notebooks, and surveyed. Measurements to each quadrant were taken from eye bolts screwed into alder trees along the shoreline. No marks were left on the beach to show where the quadrats belonged; enough data was recorded to precisely locate them again after the cleaning, and again the following year.

Sample collection: The three quadrats that made up each sample site were randomly designated for sampling at each of the three main sample times: in May of 1997 (before cleaning), in July of 1997, (just after cleaning), and in May of 1998, after a stormy winter had followed the cleaning work. Sampling consisted of collecting all sediment straight down from the designated quadrant, to the point where digging was stopped by immovable rock or the hole was deeper than the oil layer (Figure 6.3). The process was usually completed using a trowel and putty knife, sometimes with the addition of hammer and chisel. Oil was scraped from larger rocks into the collection bucket, and smaller rocks were included in the colleted material.

If the collected sample weighed more than about 5.5 kg, it was homogenized (asphalt chunks were broken up and the material was stirred thoroughly by hand and poured back and forth between buckets) and subsampled (by weight) to about 5 kg. Samples were then stored in two gallon plastic buckets with lids for transport to Auke Bay Laboratory for analysis. Roughly 300 kg of these samples were collected and transported on each sampling trip.

Reference sites: This project was not designed as a standard experiment. As much oil was to be removed from the subject beaches as was possible, so there was no initial division between control and treatment beaches. To gain some number of reference sites that were not cleaned, that we could compare to our cleaned sites, we used the six very oily sites on LA017-A (not designated for cleaning) plus three sites that could not be reached for cleaning by the work crews because they were above the rock spit in the middle of LA020-C.

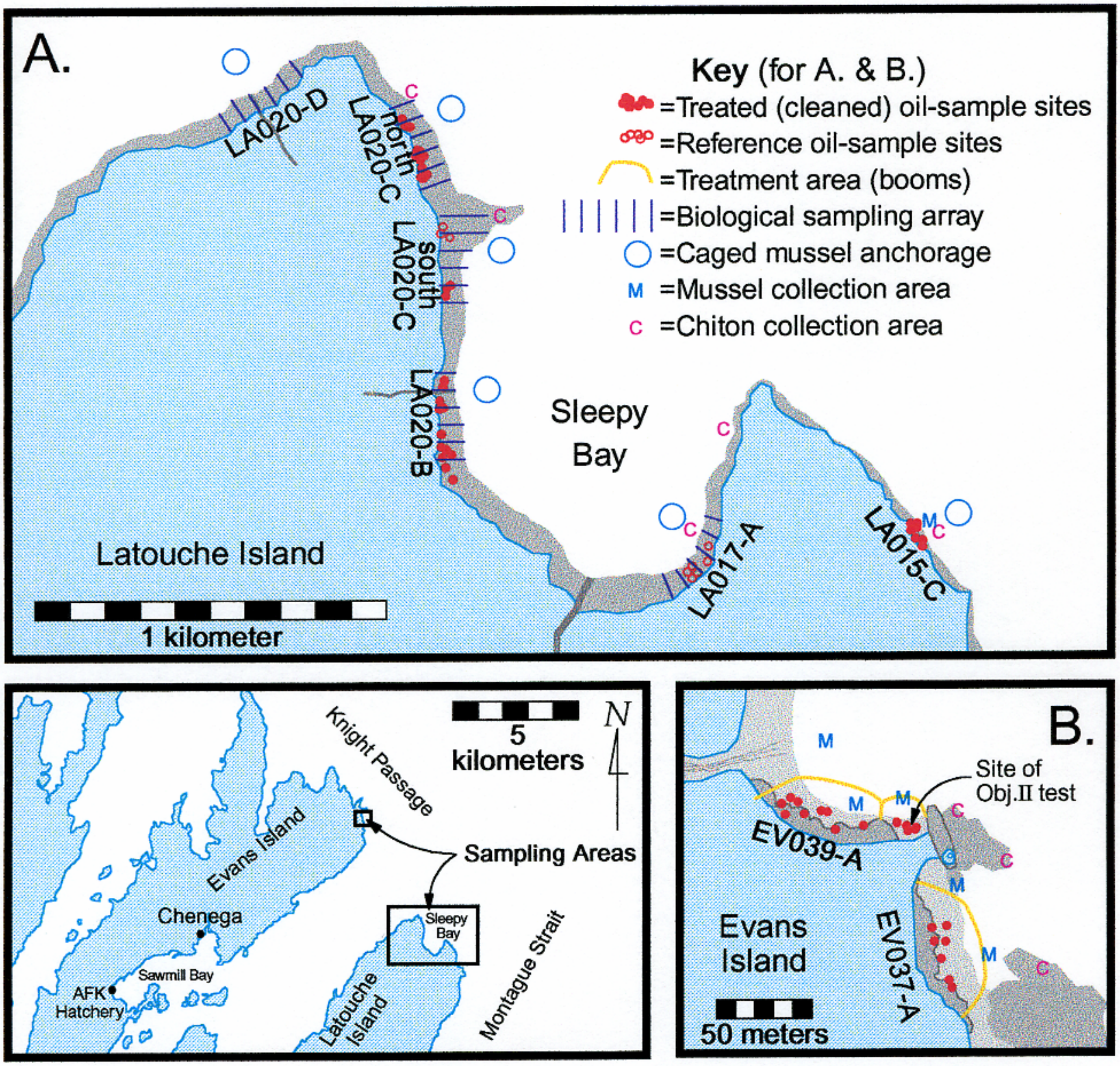

Figure 6-1 Map of study areas

Oil sample site

Figure 6-2 Comparison of substrate at an oil sampling site, on the north end of LA020-C, before the cleanup work, within a month after cleaning, and the following year. All three sample quadrats are shown in A. The dark mud, which is especially clear under the front quadrant, is a compacted mixture of oil, sand and gravel. After the cleaning work (B) the three sample areas are typical cleaned loose fine gravel. A "bathtub ring" of oil shows on the front of the prominent flat topped boulder, typical of recently cleaned areas. When C. was taken the following spring, rocks had been thoroughly rearranged by winter wave action. Note how the prominent flat-topped boulder, about one meter long, was moved relative to the buried boulder. (The quadrats are $^{1}/4$ meter on a side.) Also note that the oiled patches previously on the surface have been completely covered by cobbles.

Oil sampling

Figure 6-3 Methods used for oil sampling. A shows surveying of quadrant locations. B, C & D show excavating below quadrats. E shows a particularly dry sample hole. Note that oil is sticking the gravel together at the top few cm of the hole, allowing it to retain its square shape, but that unoiled gravel in the bottom of the hole has caved in. F shows a particularly wet and oily hole, with plastic glove for scale.

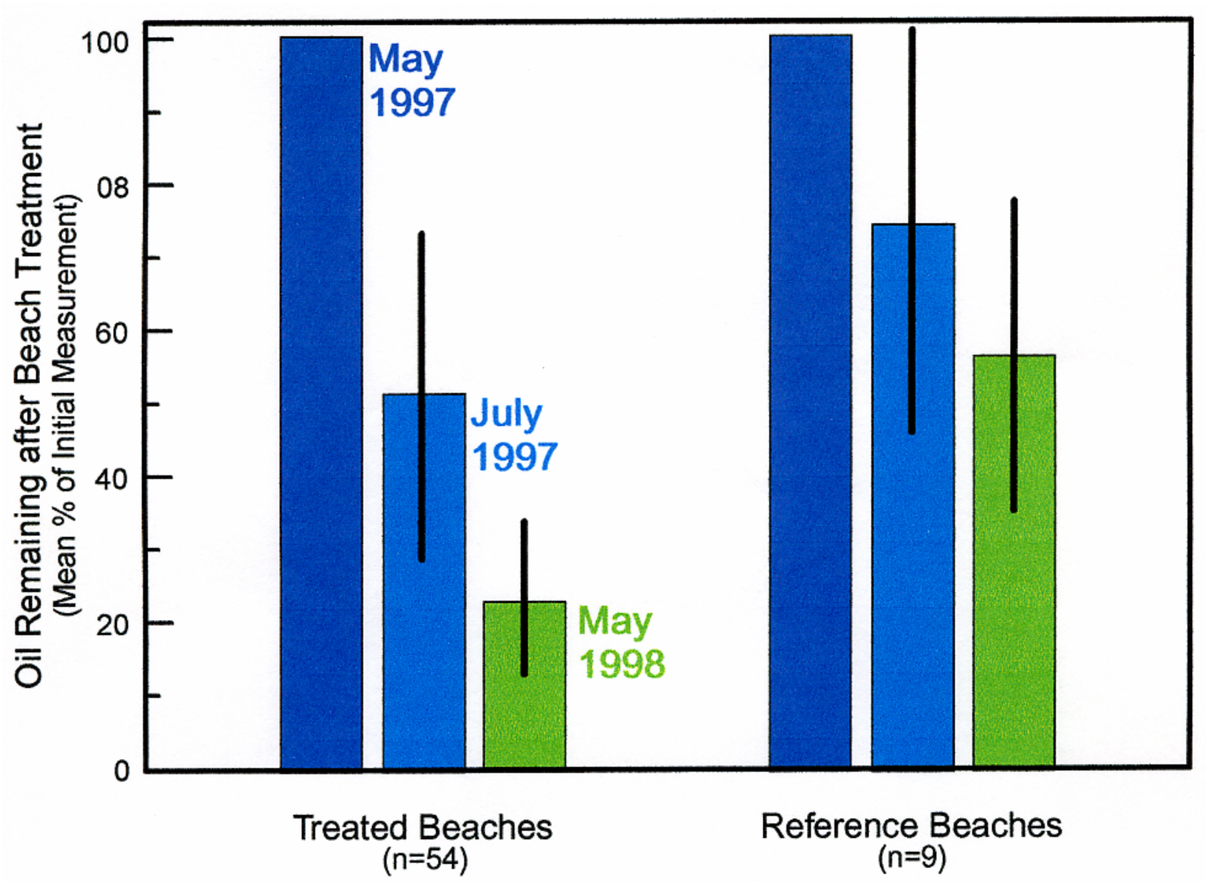

Figure 6-4 Decreases in oil at sample sites over time. Oil is measured in terms of mass per unit area of beach (g of oil / m^2 of beach). The mean initial (before cleaning) amounts of oil are assigned the value of 100%, and the mean amounts of oil just after the cleaning work (July 1997) and a year later (May 1998) are presented relative to the initial amounts. Colors indicate sample dates. Quantities of oil decreased at reference sample sites, but only about half as far as quantities of oil were reduced at cleaned sites.

Sample analysis: In the lab, each sample was extracted by adding 1-1.5 L of dichloromethane to the material, in its transport bucket, and stirred. After 1-2 hr of static extraction, with occasional stirring, the extract was decanted sequentially through a 250 µm sieve containing 100 ml of sodium sulfate, and a 63 µm sieve. Any sample and sodium sulfate left in the sieves were returned to the original sample container for additional extraction and drying. Sample extracts were passed through a glass wool pad in a funnel into 2000 ml Erlenmeyer flasks. The original sample was extracted again, for 2-4 hours, and this extract added to the first extract. A third extraction was completed overnight. The resulting combined extracts were concentrated on a steam bath, and the oil residue weighed. Results are presented as g of oil / m^2 of beach surface. In addition, six oil samples from each collecting trip were further analyzed by GC/MS (see method details under Section 8 below) to determine the relative quantities of 39 polynuclear aromatic hydrocarbons (PAH) they contained, so that the oil source could be conclusively identified.

Statistical analysis: The sampling strategy corresponds to a two-factor randomized block design, where each site is a block and samples within blocks are randomly assigned. Factors include cleaning method and time. To remove variability among sites, we considered proportional changes in oil measured per unit area within each site, calculated as:

$$z_{ijk} = \left(\frac{y_{i1k} - y_{ijk}}{y_{i1k}} \right) 100\% \qquad (1)$$

where *I* indicates the treatment factor (cleaned or not), *j* indicates the sampling time (/ = 1, before cleaning; *j = 2* or 3, just following or 1 year following cleaning), *k* indicates the site, and *Yi1k* indicates the amount of oil measured initially at site *k* within treatment *I*.

The significance of differences between mean proportional change of oil (i.e. averaged over all sites within a treatment) was determined by a randomization test based on the following *t*-statistic:

$$t_{i,j>1} = \frac{\bar{z}_{ij}}{s_{ij}/\sqrt{n}} \quad where \quad s_{ij}^2 = \frac{1}{n-1}\sum_{k=1}^{n}(z_{ijk} - \bar{z}_{ij})^2 \qquad (2)$$

The following randomization test was used to avoid assumptions regarding the distribution of this t-statistic. Under the null hypothesis that oil amounts per unit area did not change between the initial (j = 1) and a later (j = 2 or 3) sampling, the expected value of t remains zero even if the y_{ijk} values are randomly permuted. This permutation corresponds with randomly switching the initial and later observations of oil amounts in eq. 1. Repeated calculation of *t*-statistic values that result from randomly permuting the initial and later samplings among the k sites within a treatment and a particular later sampling time generates a basis for estimating the probability that the observed *t*-statistic would occur due to chance alone. We therefore report significance of the observed *t*-statistic as the proportion, *P*, of occurrences as large or larger calculated from 1000 iterations of random permutation trials. Each trial involved random permutation of the initial and later y_{ijk} data pairs of each site, among all the sites for each treatment and later sampling time. This is analogous with pairwise comparisons among treatments and sampling times based on one-tailed *t*-tests.

This approach was extended to evaluate the significance of differences between treatments just after or at 1 year after the initial measurements. The *t*-statistic used to assess these differences was:

$$t_{j>1} = \frac{\bar{z}_{1j} - \bar{z}_{2j}}{\left(\frac{s_j^2}{n_1} + \frac{s_j^2}{n_2}\right)^{1/2}} \quad \text{where} \quad s_j^2 = \frac{\sum_{k=1}^{n_1}(z_{1jk} - \bar{z}_{1j})^2 + \sum_{k=1}^{n_2}(z_{2jk} - \bar{z}_{2j})^2}{n_1 + n_2 - 2} \tag{3}$$

and where n_l and n_2 are the number of sites included in each treatment at the *j*th sampling. The significance of this *t*-statistic was based on 1000 iterations of random permutation trials as described above, but including sites from both treatments. Note that the significance of this statistic is that the cleaning procedure resulted in greater oil loss than not cleaning at the *j*th later sampling time.

Results & **Discussion**

Beach cleaning did remove at least 50% of the oil at the selected sample sites (Figure 6.4). The mean quantity of oil retrieved from the 54 treatment sites established on LaTouche and Evans Islands in May of 1997 was 2900 g/m^2. The mean retrieved in July, just after the cleaning work, was 1100 g/m^2, and by the following spring, May of 1998, it was only 400 g/m^2. This considerable drop was not entirely due to direct results of the cleaning. Oil retrieved from the nine reference sites also fell over time, from 4400 g/m^2, to 3200 g/m^2, to 2500 g/m^2. However, the reference drops, to 72% and then 56% of initial measurements, were not nearly so great as the treatment drops, to 40% and then 14% of initial measurements. All of these reductions were highly significant ($P < 0.001$).

All of the seventeen samples analyzed by GC/MS matched the model for moderately to well weathered *Exxon Valdez* Oil (EVO) (Short and Heintz. 1997). See Figure 6.5 A.

Considerable oil was evident on beaches in the study area, both before and after cleaning. If one walks these beaches without disturbing the dry oil surface, most if it is not immediately apparent, but wherever one pokes into it, one finds oil in forms anywhere from crumbly asphalt mixed with dirt to wet brown sticky oil (Figure 6.3). Most of it still smells strongly of aromatic hydrocarbons, even after eight or nine years on the beach. Where oil is compacted into fissured shale bedrock, it is possible to dig out rock, break it open, and find oil that has soaked into the rock. Where conglomerate rock sits in oil, as it does on the Evans Island beaches, it is possible to break embedded rocks out of the matrix material and find that oil had penetrated between the rocks and the matrix.

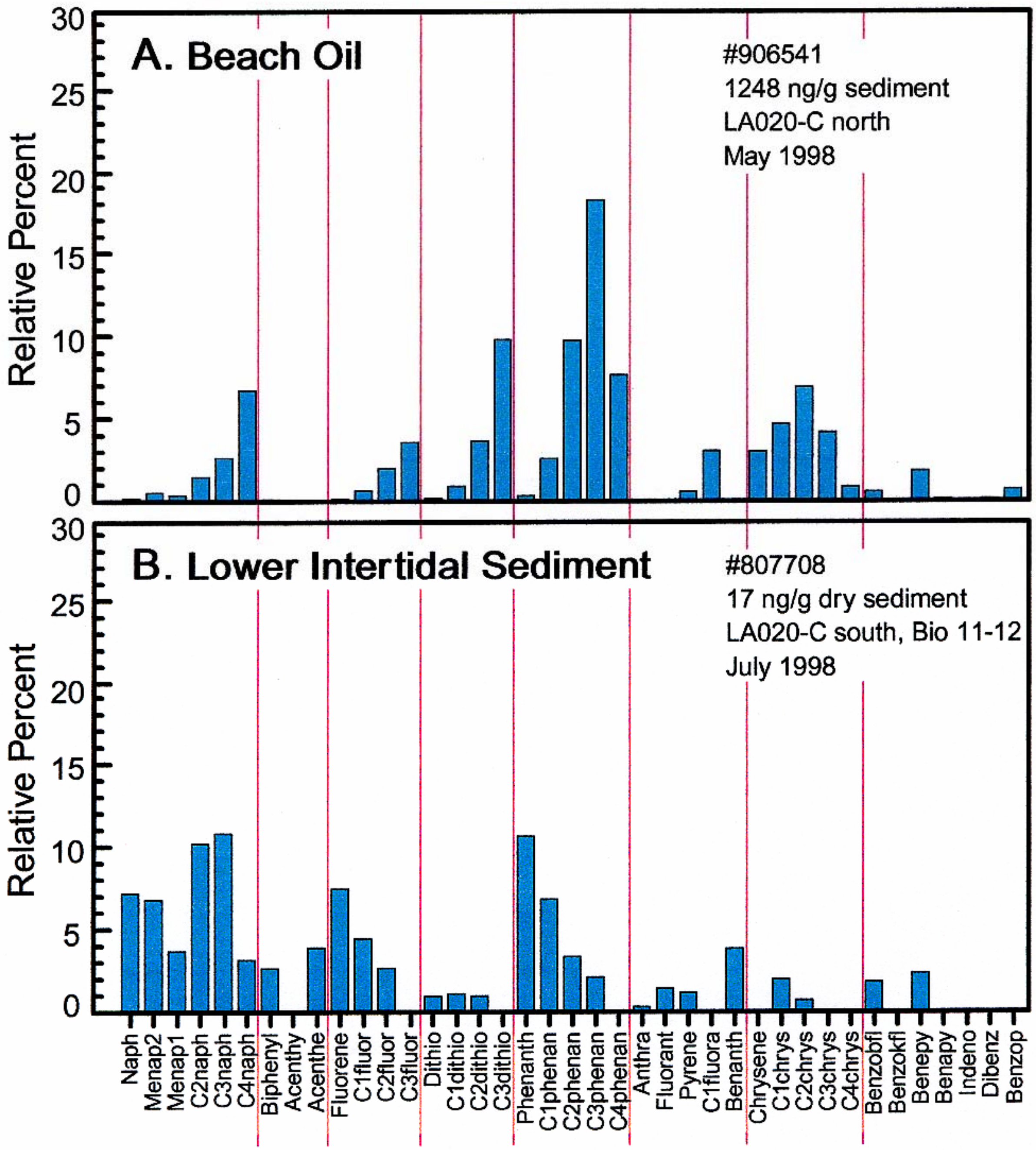

Figure 6-5 Relative concentrations of polycyclic aromatic hydrocarbons (PAH) in oil samples analyzed by GC/MS ("fingerprints"). A represents the oil that covers much of upper Sleepy Bay, typical moderately weathered EVO. B represents the very small quantities of PAH present at the MLLW line, a typical background of traces of coal.

Oil sample site

Figure 6-6 Comparison of substrate at an oil sampling site, just north of the reef in the middle of LA020-C, within a month after cleaning and the following year. Note that the only rock clearly in the same location in both pictures is the meter long boulder that is marked with a yellow flag in B. (For scale, the quadrats are $^1/4$ meter on a side.) The three designated sampling points are obvious in A., although only one is indicated by quadrant location. The oil at all three points is buried in B.

The team collecting samples in 1998 made the key observation that remarkably large rocks had rolled and shifted since the preceding summer (Figures 6.2 & 6.6). The considerable natural reduction in oil over time at control sites is probably because the oil in all of our sample sites was unprotected, and open to weather effects as well as to sample collectors. The same oil may have spent years buried beneath rocks before the summer of 1997, weathering only minimally. The significantly greater loss of oil from cleaned sites between May and June was certainly a direct result of the cleaning. The continued greater-than-reference losses over the winter were probably due to the break-up of compacted and asphalted oil-sediment mixtures by cleaning and made more vulnerable to wave action than the untouched material. The facts that many surface oil patches that were uncovered in 1997 were covered over by rocks in 1998, and that oil that had been covered in 1997 was uncovered in 1998, suggest that while 50% of the sampled surface oil may have been removed by the cleaning operations, a great deal less than 50% of the total oil on the beaches was probably removed. The mobile boulders not only limited the sampling design but limited the effectiveness of the cleaning process as well.

7. **Determining potential usefulness of air knives used without surfactant**

This test was added in order to learn whether the air knife cleaning methods used might be successful without the use of a surfactant. Testing required considerable interference with cleaning operations and the full cooperation of the work crew. We selected the test site based on convenience of logistics, using the small pocket beach at the west end of the EV039 cleaning area (Figure 6.1). The site was sufficiently isolated from the rest of EV039 by a bedrock outcrop that it could be boomed separately and tested while the rest of the beach was cleaned. The oil on the test beach was particularly dry, including very little sticky mousse. It was definitely a location where cleaning without surfactant would work if it was going to work anywhere.

Methods

Treatment and Sampling: Five oil sample sites like the ones described for Objective I were used for this test. The A quadrats of each site were excavated in May of 1997, at the same time all the other oil sites were first sampled, using the methods described above. On July 16 of 1997, while cleaning was underway on the rest of EV039, the small beach containing these five sites was boomed separately from the others, and cleaned in the usual manner, except that none of the surfactant (PES-51) was injected along with the blasts of air used to disrupt the compacted dirt and oil. The areas being treated were flooded with ambient temperature seawater throughout this time. When knife work was finished, the area was flushed with a heavy wash of seawater for 30minutes. The B quadrats of each sample site were located and excavated. Then the area was cleaned again, in the same manner, but including injection of the usual amounts of PES-51. After another 30 minute seawater wash, the C quadrats were located and excavated.

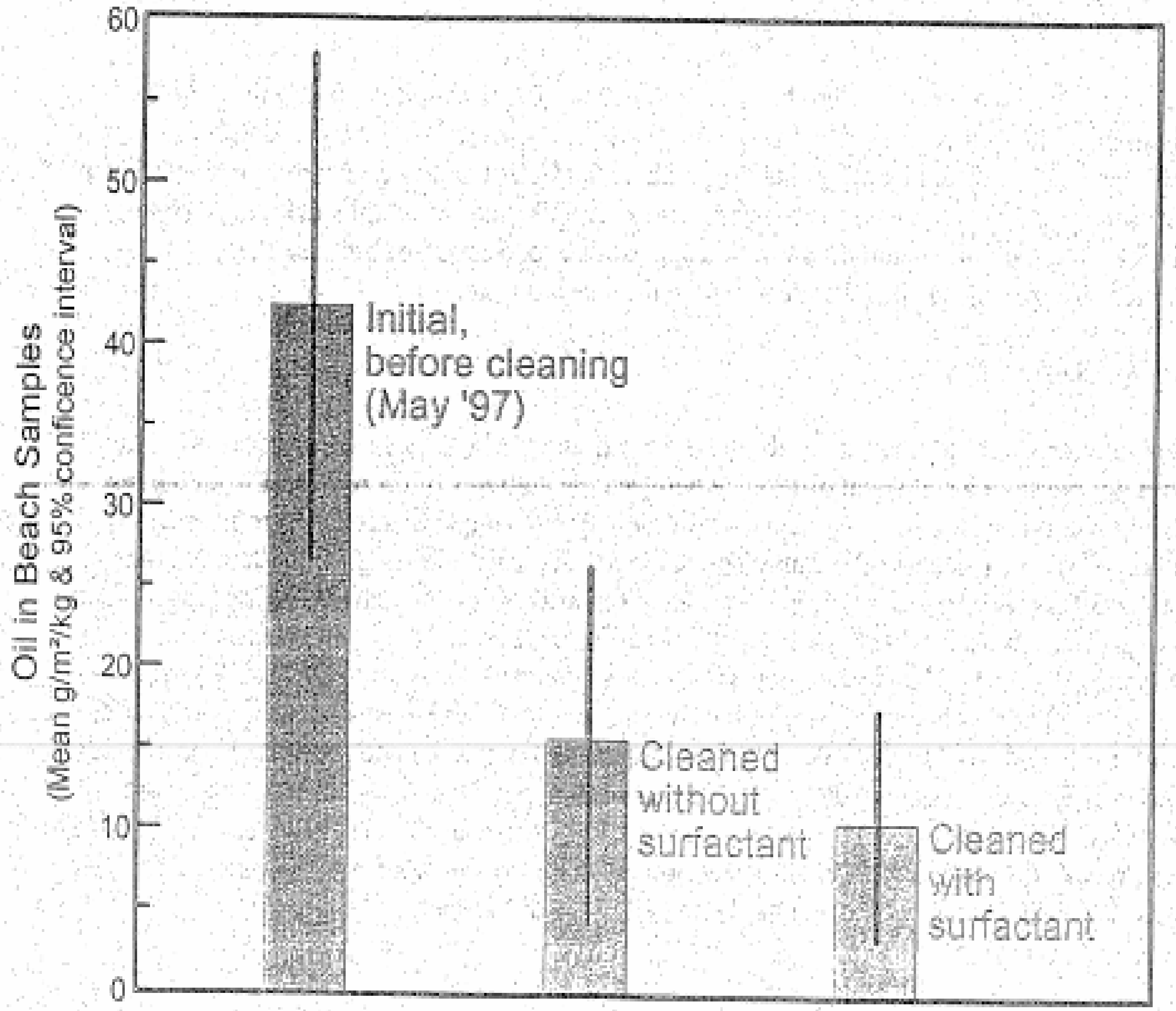

Figure 7-1 Decreases in oil at five sample sites, after cleaning with air knives without surfactant, and then recleaning with surfactant (PES-51). Oil is measured in terms of mass per unit area of beach (g of oil / m^2 of beach) divided by the size of the sample (kg collected). Differences between groups cleaned with and without surfactant were not significantly different, demonstrating that at least in some cases an air knife can be useful even when injecting only air.

Analysis: Collected samples were brought to the Auke Bay Laboratory for analysis of the amount of oil in them, as described above in Section 6. Amounts of oil excavated from each sample site before cleaning, after cleaning without surfactant and after cleaning with surfactant were compared with each other in terms of oil excavated / size of sample, using analysis of variance. We used oil / sample size in this test (unlike for Section 6) because there were only five sites, not enough to compensate for differing sample sizes.

Results & **Discussion**

Although more oily mousse was visible in the wash water when the surfactant was being used, we did not measure a statistical difference between the amounts of oil removed from the test sites with and without surfactant. Masses of oil in the original sample quadrats range from 22-53 g/m^2 /kg of sample (mean = 42). Samples taken after dry knife cleaning (no surfactant) ranged from 7.5-30 g/m^2/kg (mean = 15) and samples taken after cleaning with surfactant ranged from 3.9-16 g/m^2 /kg (mean = 10) (Figure 7-1). The difference between the two groups was not significant; $P = 0.33$. The chief reason for this lack of difference is almost certainly that the oil on this particular beach was relatively shallow and dry, with very little sticky mousse, exactly the type of oiling one would most expect to be disrupted and dispersed adequately without the use of surfactant. Stickier oil is probably removed more efficiently with surfactant use, and more oil may be recovered (not just dispersed) when combined with floating surfactants such as PES-5 1, but our results do indicate that the air knife process itself has considerable cleaning value, because reduced sediment adhesion facilitates oil removal by flowing water.

8. Determining the severity and persistence of receiving water contamination

A serious concern about beach cleaning is the potential for release of oil and cleaning materials into the water column where they could pose a risk to pelagic animals, especially feeding and migrating schools of salmon fry. To test for presence of oil and surfactant in the water column just offshore from the beaches cleaned in Sleepy Bay, we moored local mussels in cages outside of the booms positioned to keep floating oil and cleaning materials corralled. Mussels are a valuable sampling device for low levels of waterborne contaminants because they filter enormous quantities of water, taking any biologically available materials into their tissues. Mussels concentrate contaminants from the water surrounding them and integrate the amounts over time, which makes them more reliable in many ways than direct physical sampling of the water. In addition, we floated oil absorbent pads on the water surface alongside each cage mooring to get an indication of whether much floating oil was released.

Methods

Locations: *Six* biological sampling areas were chosen in and around Sleepy Bay (Figure 6.1). Four were treatment areas, including the cleaned areas on LA020-B, on the north and the south ends of LA020-C and on LA 015-C. The other two were reference areas, including uncleaned but oily LA017-A, and uncleaned, virtually unoiled LA020-D. One mussel cage was moored outside each of these areas. One floating oil absorbent pad, enclosed in a nylon mesh bag, was attached to each mooring.

Moorings: Cages consisted of nylon diving "goody bags". They were suspended on polyester buoy line from plastic floats and anchored with 45 pound longline anchors with 7 m of chain. Each mooring included an additional weight on the line below the cage to keep it below the surface, and small float below that to take up the slack in the line at low tide. Each cage was anchored as close to shore as possible without allowing it either to come within three m of the surface (to prevent contamination with floating material, even in rough weather) or allowing them snag on the bottom. This system was similar to that used by Short and Harris (1996).

Sampling: At least 80 mussels (from LA020-D), measuring 2.0 - 2.5 cm, were placed in each nylon bag on May 24, when the cages were first set out. All moorings were checked and mussels sampled on June 17, as cleaning began in Sleepy Bay. At least 20 mussels were sampled per cage into a hydrocarbon-free glass jar with a Teflon lid liner. Jars were kept cool so that mussels were still alive and their valves tightly closed when placed in a freezer, where they remained until transport (frozen) to the Auke Bay Laboratory for analysis. Mussels were sampled again on July 21, when cleanup work in the vicinity was finished. Mussels were sampled one last time on September 16, 1997, at which time the moorings were retrieved. The surface sampling pads remained floating from June 17 to July 21, when they were retrieved and frozen.

Analysis: Chemical analysis of the aromatic hydrocarbon content of tissues was done as described in Short et al. (1996). Mussels were thawed just enough to remove the tissue. Tissues were ground up and extracted in dichloromethane. Alkane hydrocarbons and polycyclic aromatic hydrocarbons (PAH) were separated by silica gel-alumina chromatography. PAH were further purified by gel permeation high pressure liquid chromatography (HPLC). Gas chromatography with flame ionization detection (GC/FID) was used to measure d-limonene, the chief component of the surfactant PES-51, and gas chromatography with mass spectrometry (GC/MS) was used to detect PAR Thirty-nine PAH (Table 8.1) were included in the total PAH (TPAH) for each sample, by summing the gg/g dry tissue weight for all compounds showing amounts above the method detection limits (MDL). Samples containing only a single PAH above MDL were considered to contain no oil. Samples containing two to six PAH above MDL, up to 0.05 gg/g of TPAH, are reported as containing "traces" of PAH. These may be real traces of petrogenic oil, but in marginally measurable and probably meaningless amounts, or they may be contaminants from other sources. All samples containing enough PAH to be tested were fitted to the model developed to determine whether the oil source was EVO (Short and Heintz. 1997). The oil absorbent surface sampling pads were analyzed by cutting a six cm^2 rectangle from each pad, extracting it in dichloromethane and analyzing the extract by GC/MS, as above.

Table 8.1 Polycyclic aromatic hydrocarbons (PAH) included in total PAH (TPAH):

Naphthalene	dibenzothiophene	benz-a-anthracene
2- methylnaphthalene	C-1 dibenzothiophenes	chrysene
1- methylnaphthalene	C-2 dibenzothiophenes	C-1 chrysenes
C-2 naphthalenes	C-3 dibenzothiophenes	C-2 chrysenes
C-3 naphthalenes	phenanthrene	C-3 chrysenes
C-4 naphthalenes	C-1 phenanthrenes/anthracenes	C-4 chrysenes
biphenyl	C-2 phenanthrenes/anthracenes	benzo-b-fuoranthene
acenaphthylene	C-3 phenanthrenes/anthracenes	benzo-k-fluoranthene
acenaphthene	C-4 phenanthrenes/anthracenes	benzo-e-pyrene
fluorene	anthracene	benzo-a-pyrene
C-1 fluorenes	fluoranthene	indeno-123-cd-pyrene
C-2 fluorenes	pyrene	dibenzo-a,h-anthracene
C-3 fluorenes	C-1 fluoranthenes/pyrenes	benzo-g,h,i-perylene

Results & Discussion

Water column contamination as a result of beach cleaning was minimal and short lived. The caged mussels collected very low levels of PAH during the cleaning work, but no measurable limonene, and they had depurated all contaminates by the end of summer. An initial mussel sample, taken May 24, registered no measurable PAH. The samples collected on June 17, just before commencement of cleaning, contained no more than traces of TPAH. The four samples collected on July 21, shortly after completion of cleaning, contained TPAH ranging from a trace to 0.10 µg/g dry tissue. (Two cages, one from off of the south end of LA020-C and one from off of LA020-D, had broken from the moorings and were lost.) TPAH concentrations had returned to baseline by 16 September, so sampling was terminated. There were very few mortalities at the September endpoint, despite a thick set of young bivalves, mostly mussels.

Total PAH in the surface sampling pads were calculated in terms of $\mu g/cm^2$ of pad. The six samplers registered from 0.56 - 1.35 $\mu g/cm^2$, surprisingly little considering they would have absorbed and retained oil from any source and they spent 2 weeks in the vicinity of heavy boating activity.

9. Determining whether lower-intertidal sediments become contaminated

Nearly all of the obvious oil on the beaches in this study is in the upper intertidal, above the mussel line and up as far as the grass line. One possible outcome of the cleaning work would be for oil stirred up at the top of the beach to find its way to the lower intertidal instead of being collected. To test for this possibility, we collected sediment samples along the mean lower low water line (MLLW) before and after the cleanup activity to check for an increase oil content.

Methods

Locations: Sediment samples from LaTouche Island were taken in conjunction with the biological observations in Sections 8, 10 and 11, in May and July of 1997 and in May of 1998. Three of the biological sampling areas chosen in and around Sleepy Bay (Figure 6.1) were in treatment areas, including the cleaned areas on LA020-B, and the north and south ends of LA020-C. These were sampled at all three sampling periods. Two others were in reference areas, including uncleaned but oily LAO 17-A, and uncleaned, virtually unoiled LA020-D. These were sampled only in 1998. At each of these areas a 250 m sampling grid was laid out for Section 11 measurements. Six transects, each running from grass to water, separated each site into five 50 m long sections of beach.

Sampling: Five samples of sediment, generally very course sand, were taken from each sampling grid, one from between each pair of adjacent transects. Each jar of sediment was collected by pooling sediment from at least eight points along the MLLW line, all along the distance between transects. Sediment was collected with hydrocarbon free stainless steel implements into hydrocarbon free glass jars with Teflon lid liners, and frozen for transport to the Auke Bay Laboratory for analysis.

Analysis: GC/FID analysis of the sediment was used to detect very small quantities of oil. The analysis technique was modified to be faster and cheaper than the methods described above for tissues. Samples were extracted as described above but the extracts were purified by silica gel alumina chromatography without separating alkanes from PAH. No gel permeation HPLC was used. Samples were analyzed by GC/FID using calibration standards of oil and limonene. However, some samples were ultimately analyzed by GC/MS (as well as /FID) to determine the source of oil found.

Results & Discussion

The GC/FID method registered oil in some form in all of the MLLW sediment samples, both before and after the cleaning work. There is no apparent relationship between sample time and quantities of oil. When samples from the reference sites were added in 1998, those sites had higher quantities of unidentified oil components than any of the samples from the cleaning areas. We ran subsamples of four of these samples by GC/MS, two from before cleaning (May 1997) and the same two again just after cleaning (July 1997) and a year later (May 1998). We found that the oil contained only minute traces of TPAH (0.015-0.072 µg/g dry wt), and that these followed the typical background pattern for PWS sediments, mostly consisting of traces of coal (Figure 6.5 B). In short, our samples do not show an increase in EVO, or any other oil, at the lower levels of the cleaned beaches that has any correlation with the cleaning process.

V. Determining the accumulation and persistence of contamination in mussels and chitons

The animals most likely to be exposed to oil and cleaning materials are the intertidal animals within the cleaned areas and just down slope from them. Not much grows on the highest reaches of the beaches treated in this project. The substrate is armored with cobbles and boulders, and it is open to storm waves each winter. In some places there are reasonably dense areas of mussel and *Fucus* growth in the mid-levels of the beaches, most of them on protruding bedrock. Below the mean lower low water line (MLLW) beaches in this vicinity tend to be lushly covered with algae. The cleaning operation was designed to take palce above any *Fucus* or mussel grownth, while the tide was high, with all oil and other waste skimmed from the water surface before it could be stranded on *Fucus* or mussels as the tide fell. This was generally accomplished by the work crews. We collected tissue samples from mussels below the cleaning operations, expecting them to be most likely to show contamination due to their location and their propensity for concentrating materials from their surroundings. We also sampled chitons *(Katharina Tunicata)* from these areas for tissue analysis, because they were collected as food items from most of the beaches in question before the oil spill.

Methods

Locations: Mussel samples from LaTouche Island were taken in conjunction with other biological observations, in May and July of 1997 and May of 1998. Six biological sampling areas were chosen in and around Sleepy Bay (Figure 6.1). Four were in treatment areas, including the cleaned areas on LA020-B, the north and the south ends of LA020-C, and LA 015-C. The other two were in reference areas, including uncleaned but oily LAO 17-A, and uncleaned, virtually unoiled LA020-D. At each of these except LAO15-C, a 250 m sampling grid was laid out for Section 11 measurements. One sample of mussels was taken from each of these five grids, by pooling animals taken from the mussel zone from one end of the grid to the other, wherever they existed. The treatment area on LA015-C was too short and too rocky for a 250 m sampling grid; on that beach one mussel sample was taken from the patches of mussels available on boulders just below the work area. Four additional samples were taken in September of 1997. All were similar to those above but each taken from no more than 50 m of beach. The sample from LA0 15-C was just like those taken at the other sample times, but samples from LA020-B, the north end of LA020-C and from LAO 17-A amounted to subsets of the other samples taken there.

Chitons were collected wherever they could be found on the bedrock and boulders below the treatment and reference sites on LaTouche and below the treated beaches on Evans Island (Figure 6.1).

Sampling: Mussel sampling consisted of placing at least 20 mussels, enough to provide more than 10 g of tissue, into a hydrocarbon-free glass jar with a Teflon lid liner. Jars were kept cool so that mussels were still alive and tightly closed when placed in a freezer, where they remained until transport (frozen) to the Auke Bay Laboratory for analysis. Chiton sampling consisted of placing enough chitons to provide more than 10 g of tissue into a hydrocarbon-free glass jar. This was often a single animal. Chitons were carefully collected without touching them, using hydrocarbon-free screwdrivers, since the tissue to be analyzed is not sealed within a protective shell as it is with mussels.

Analysis: Sample analysis was by GC/MS, as described in Section 8 above. For the chitons, tissue was dissected away from the internal shell plates, and homogenized. GC/MS and GC/FID analysis were used to measure PAHs and d-limonene, the chief component of the surfactant PES-51, as described in Section 8. Samples containing only a single PAH above MDL were considered to contain no oil. Samples containing two to six PAH above MDL, up to 0.05µg/g of total PAH, are reported as containing "traces" of PAH. These may be real traces of petrogenic oil, but in marginally measurable and probably meaningless amounts, or they may be contaminants from other sources. All samples containing enough PAH to be tested were fitted to the model developed to determine whether the oil source was EVO (Short and Heintz.1997).

Results & Discussion

None of the chitons collected either in May or July of 1997 contained more than a trace of TPAH or any d-limonene. All the chitons, situated on bedrock or boulders at the lower reaches of the intertidal, were apparently too far from the cleaning operations to take up measurable oil or surfactant. No further chitons were sampled.

Mussels, however, were widespread just below cleaning operations, and in a few cases actually within the cleaned areas. Moreover, since mussels filter enormous quantities of water and collect any contaminants from that water into their tissues, it is not surprising that some mussels did take up significant amounts of oil and of d-limonene. In the Sleepy Bay area (Figure 6.1), none of the samples taken in May, 1997, before cleaning, showed any oil. However, in July, 1997, just after cleaning was finished, mussels from the sampling sites on LA020-B, LA020-C south, LA020-C north, and LA015-C showed tissue concentrations from 0.083 to 6.3 gg/g dry wt of TPAH respectively, and up to 3.7 µg/g dry wt of d-limonene. Mussels from neither reference site contained more than a trace of TPAH or any d-limonene. TPAH concentrations in mussel tissues above 1 gg/g dry wt of TPAH are substantial, in the range found in mussels living on the oiliest sediments we've tested in PWS. Two of the samples contained enough PAH to test them for source; both showed their sources to be moderately weathered EVO.

However, none of the elevated readings in mussel tissues lasted long. Since cleaning took a month and sampling only required a week, different amounts of time passed between initial uptake and sampling. Samples having had 23 days of depuration time were nearing uncontaminated (Figure 10.1). None of the four samples taken in September showed more than traces of PAH or any d-limonene, and neither did the May 1998 samples. The Sleepy Bay mussels taking up oil during the cleanup work depurated their collected oil promptly, in contrast to PWS mussels living permanently in mussel beds directly on soft highly-oiled sediment.

VI. Determining major population changes of intertidal fauna

Intertidal populations fluctuate widely in short periods of time. Seasonal changes, weather effects (especially temperature, degree of desiccation, and currents that do or don't bring in plankton for feeding), and interactions with other advancing or declining populations combine to turn a "base line" population count into something far more complex than a line. It would take several years of extensive counts to learn what is really normal on any particular beach with any precision. However, it should be possible to document truly devastating changes in populations caused by specific events, even with a minimum number of observations, and that is what we set out to do for this beach work.

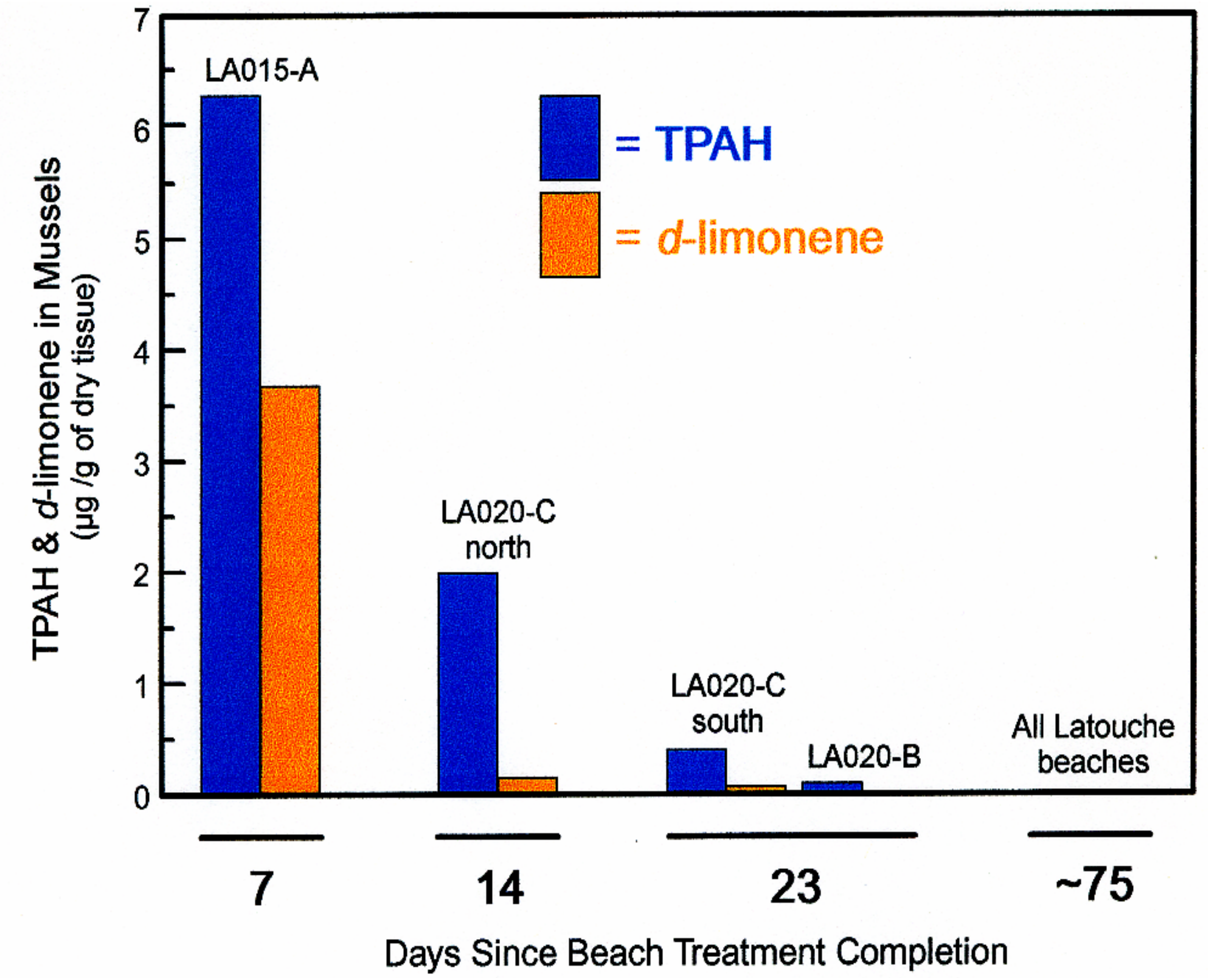

Figure 10-1 Concentrations of oil (total polycyclic aromatic hydrocarbons, TPAH) and of d-limonene (the chief constituent of the surfactant used in cleaning) found in the tissues of mussels collected alive from beaches just below the cleaned areas in the Sleepy Bay vicinity. No oil or limonene was found in mussels from two similarly sampled reference beaches. The cleaning work took a month and the sampling work less than a week, so the time between the end of cleaning and mussel sampling was different at the different beaches. The data shown imply that beach mussels depurated most of the contaminants they had taken up within three or four weeks.

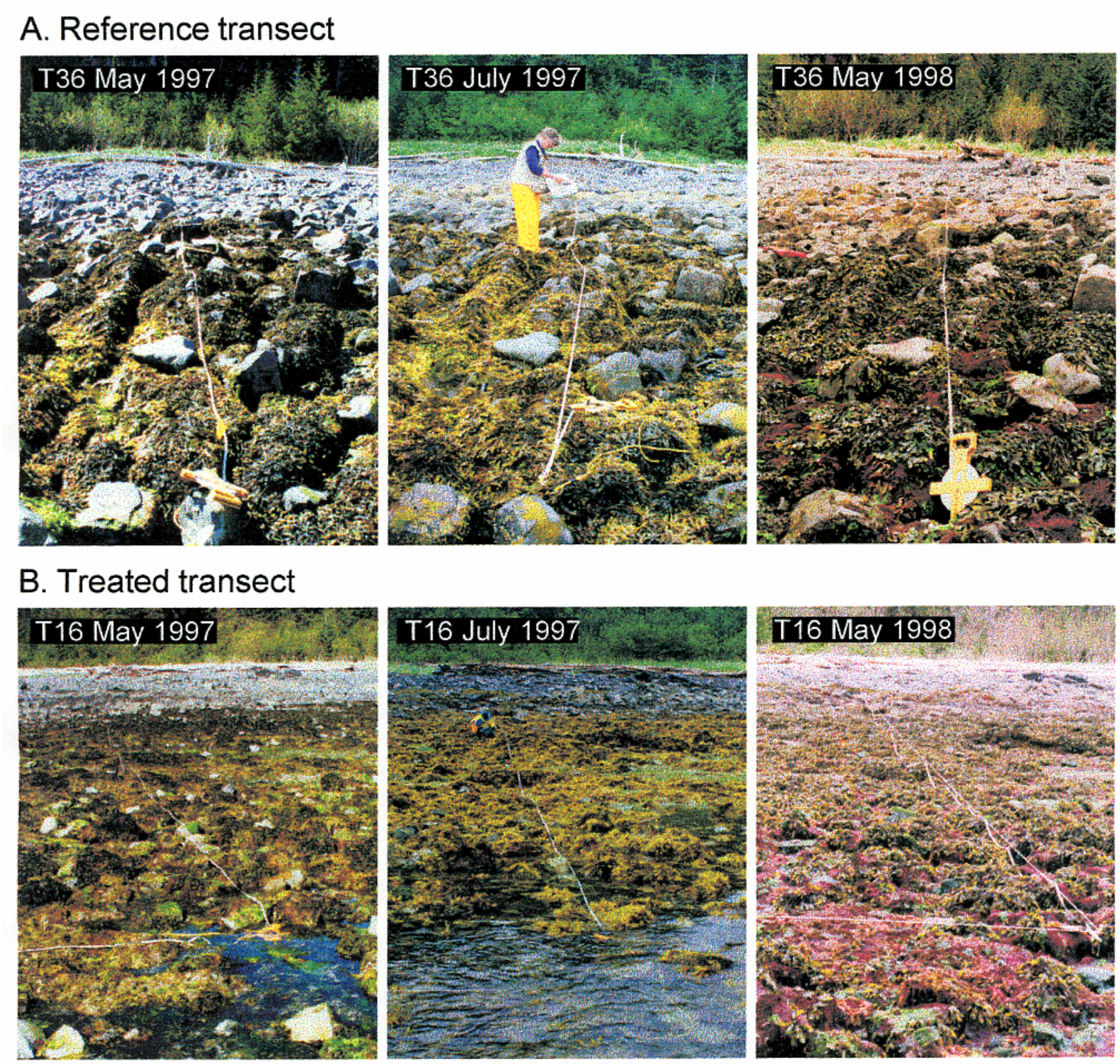

Figure 11-1 Comparison of the algae present at the locations of two beach transects, one a reference quadrant (on LA020-D, away from the cleaning work) and the other a treatment transect (on the south end of LA020-C, directly below where cleaning work took place). The May 1997 photographs were taken before the cleaning, the July 1997 photographs were taken within a month after cleaning, and May 1998 photographs were taken the following year. Visible changes over time are no greater at the treatment site than at the reference site.

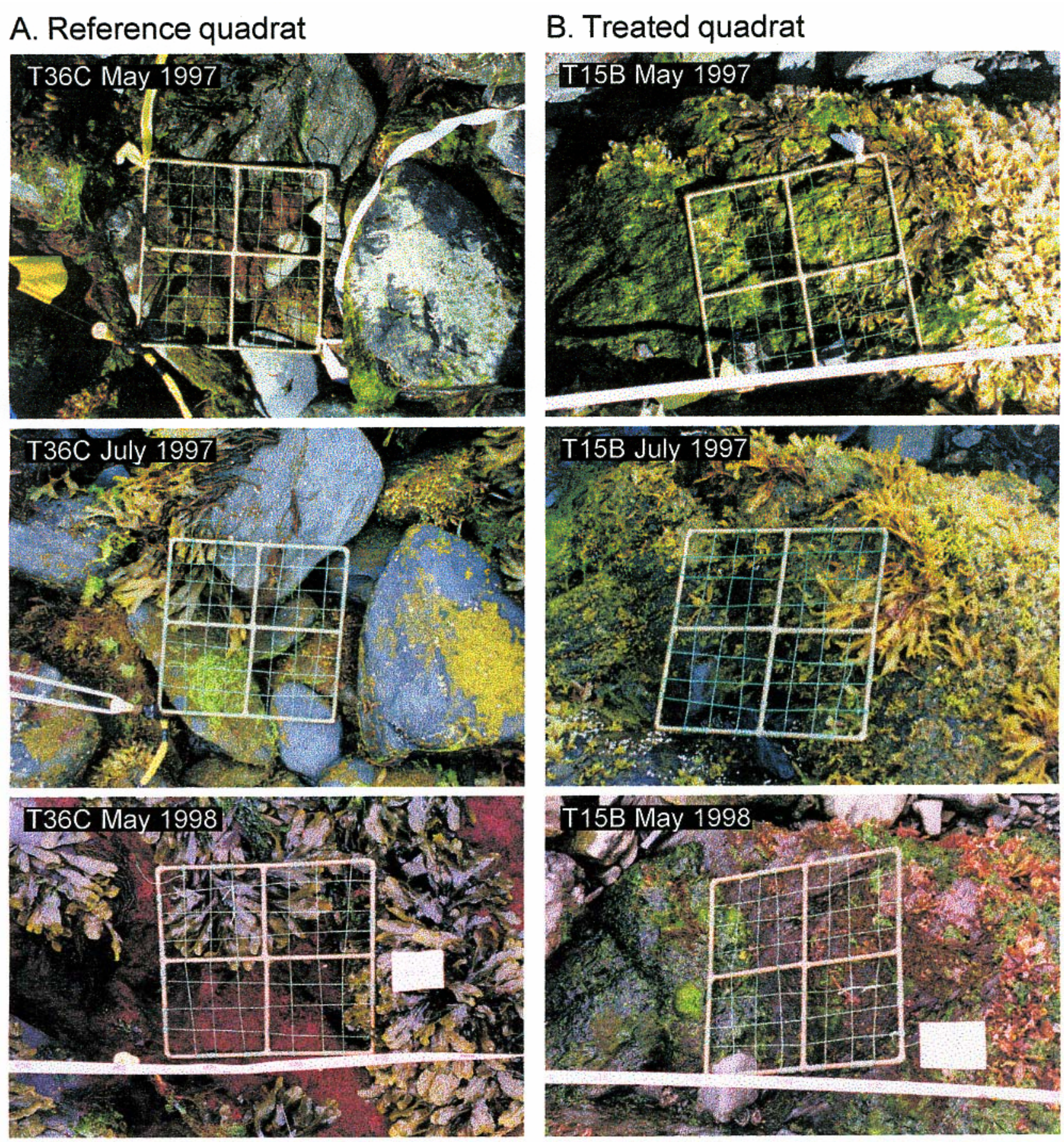

Figure 11-2 Comparison of the algae present at the locations of two 25 cm x 25 cm quadrats, one a reference quadrant (on LA020-D, away from the cleaning work) and the other a treatment quadrant (on the north end of LA020-C, directly below where cleaning work took place). The May 1997 photographs were taken before the cleaning, the July 1997 photographs were taken within a month after cleaning, and May 1998 photographs were taken the following year. Visible changes over time are no greater at the treatment site than at the reference site.

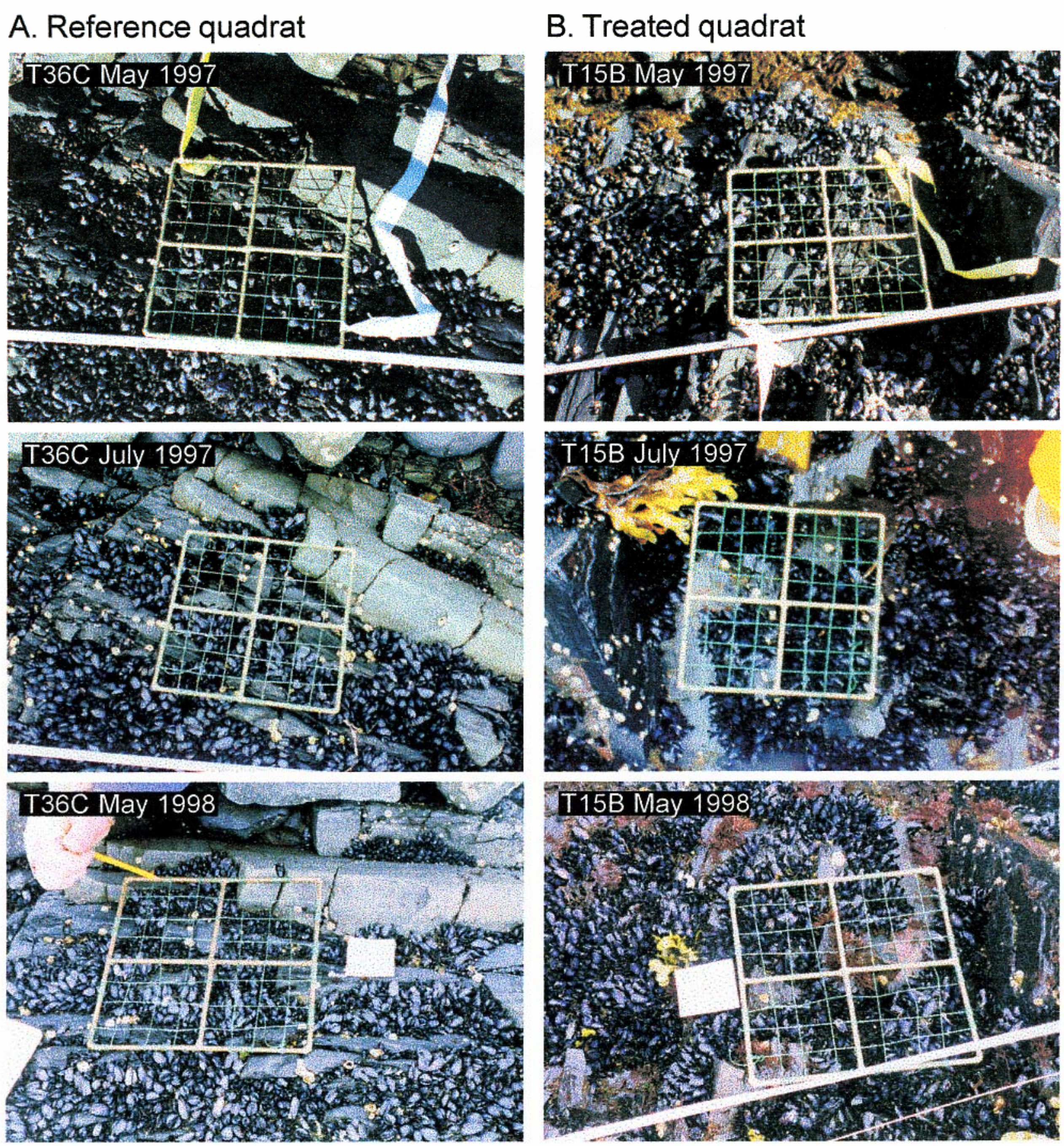

Figure 11-3` Comparison of the mussels present at the locations of two 25 cm x 25 cm quadrats, one a reference quadrant (on LA020-D, away from the cleaning work) and the other a treatment quadrant (on the north end of LA020-C, directly below where cleaning work took place). The May 1997 photographs were taken before the cleaning, the July 1997 photographs were taken within a month after cleaning, and May 1998 photographs were taken the following year. Visible changes over time are no greater at the treatment site than at the reference site.

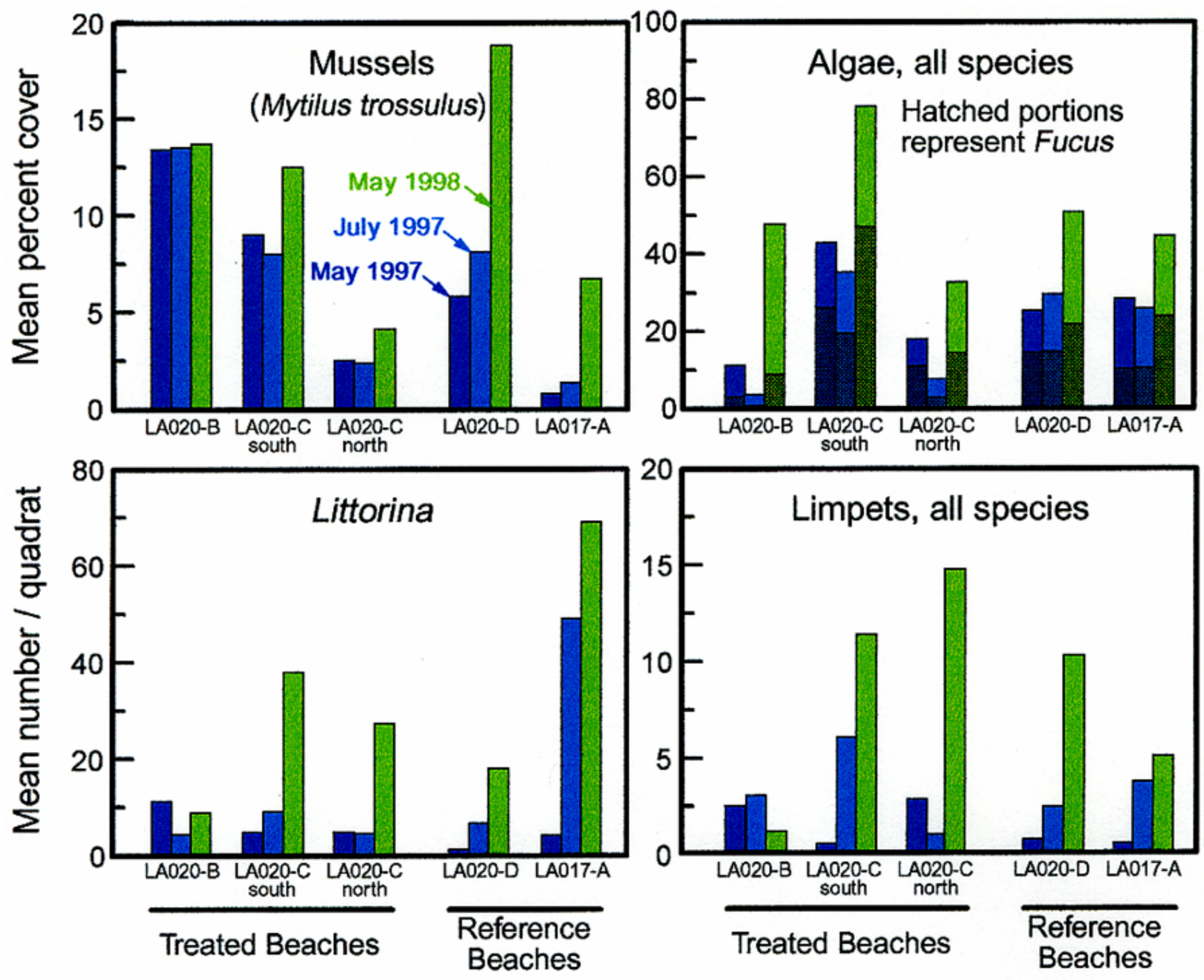

Figure 11-4 Changes over time in quantities of small biota in fixed quadrats on cleaned and reference beaches. Colors indicate sample dates: initial (before cleaning), just after the cleaning work (July 1997) and a year later (May 1998). Changes on different beaches have little relationship to whether the beaches were treated or reference, and no relationship that can logically be tied to the cleaning process. Note, for instance, the large set of *Littorina* on one of the reference beaches in July of 1997, followed the next spring by greatly increased numbers of Littorines on all of the beaches except one.

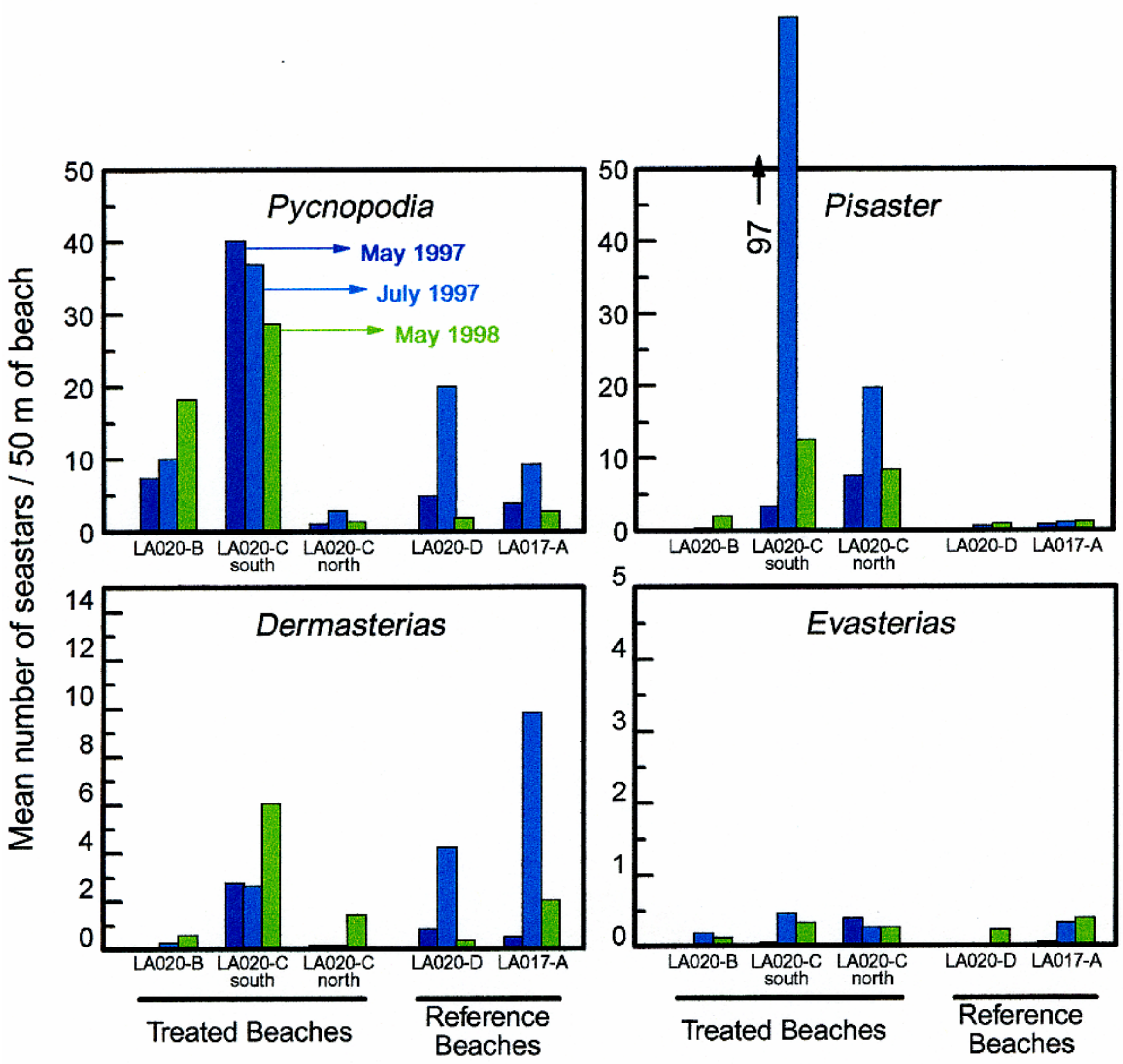

Figure 11-5 Changes over time in quantities of echinoderms in fixed sections on cleaned and reference beaches. Colors indicate sample dates: initial (before cleaning), just after the cleaning work (July 1997) and a year later (May 1998). Changes on different beaches have little relationship to whether the beaches were treated or reference, and no relationship that can logically be tied to the cleaning process. Note, for instance, the gathering in July of *Pisaster ochraceus, on* the spit in the middle of LA020-C.

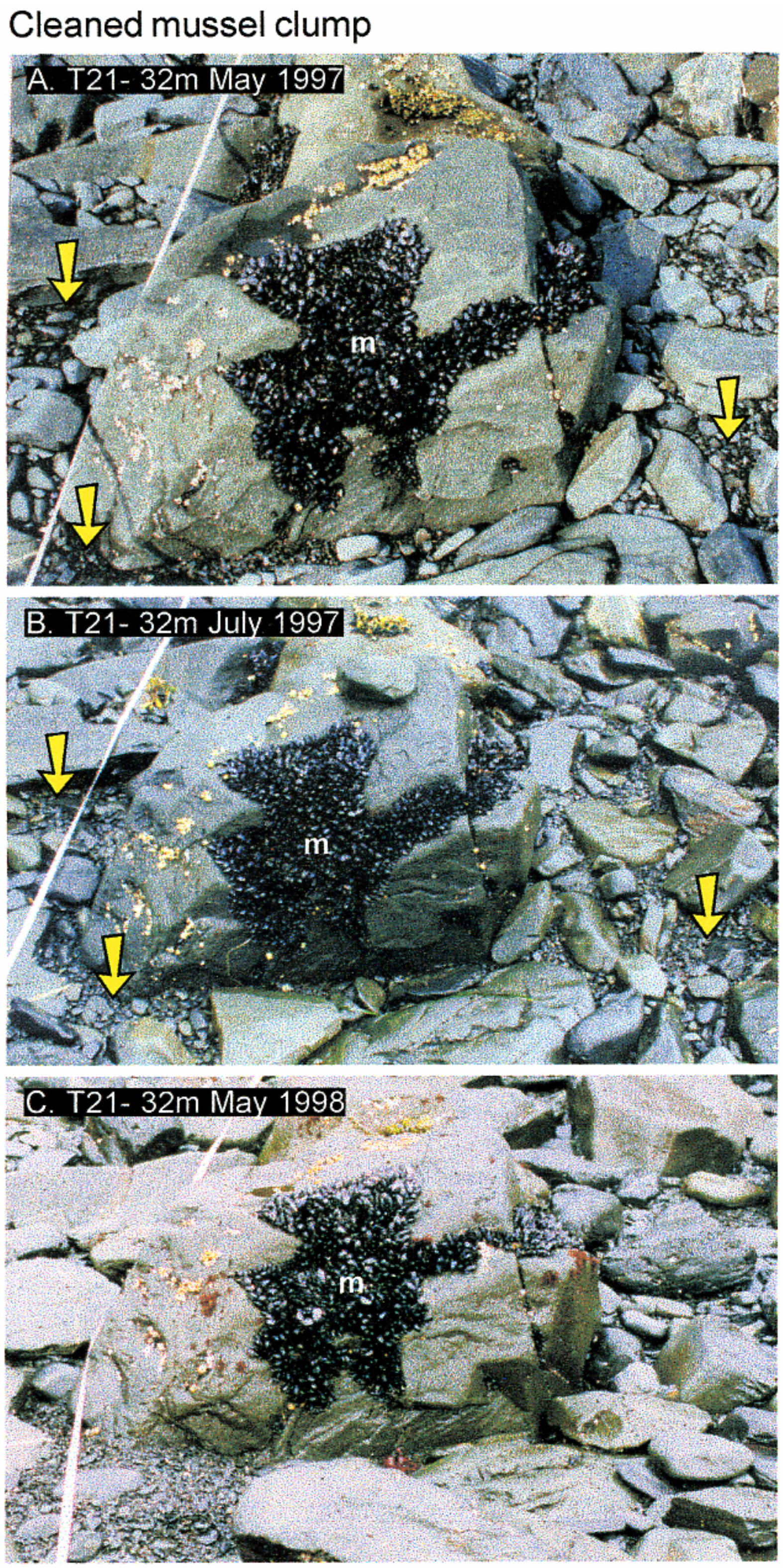

Figure 11-6 Stability of a single clump of mussels (m) photographed before (A), just after (B) and a year after (C) cleaning. The particular significance of this clump is that the substrate immediately around the boulder was thoroughly cleaned, a situation that was generally avoided throughout this project. Compare the black compacted oil between the gravel in A (arrows) with the loose cleaned gravel in B. The mussels appear undamaged, even the following spring (C).

Methods

Monitoring for severe damage to intertidal biota was done through repeated counts of organisms at permanent plots before and after the cleanup work, and through repeated photography at the same places before and after the work.

Locations: Six biological sampling sites were set up on LaTouche Island, in and around Sleepy Bay (Figure 6.1), and biota counted there in May and July of 1997 and May of 1998. Four of the sites were in treatment areas, including the cleaned areas on LA020-B, on the north and the south ends of LA020-C and on LA 015-C. The other two were in reference areas, including uncleaned but oily LA0 17-A, and uncleaned, virtually unoiled LA020-D. At each of these (except short, rocky LA0 15-C) a 250 m sampling grid was laid out for biological sampling. Each grid consisted of six transects laid across the beach from the grass line to mean lower low water (MLLW). The grass line was determined by presence of permanent land plants. MLLW was estimated by measuring 5 m (16 ft) vertical distance from the grass line, appropriate for the tidal differences in western Prince William Sound. (Checking by the tide height at the time when a zero tide height was predicted showed this approximation to be surprisingly accurate on most beaches). Stakes were driven at the top and bottom of each transect so they could be located repeatedly. The length of each transect was divided into five equal sections and a 25 cm x 25 cm quadrant placed at random within each of the lower four sections. The highest section was skipped because this area rarely contained surface biota. The locations of the quadrats were recorded by measurements on the transect and by photography so they could be found repeatedly.

Population Counts: Quadrats were sampled by placing a 25 cm x 25 cm frame, divided into 64 squares (8 x 8), at the right location and counting biota visible from the surface. All macroscopic animals were counted, but only a few were present in more than two or three quadrats. The prevalent littorine snails and limpets (all species) were counted individually. Mussels were counted in terms of percent cover within the quadrant (actually the number of squares out of 64 filled, to the nearest half square). Barnacles were the only other animal present in great numbers, but were not used in analysis, because their differing concentrations were so awkward to record in any reasonable way. *Fucus,* generally the most common alga in the observed areas, and all algae combined, including *Fucus,* were also enumerated in terms of percent cover.

Larger animals, virtually all of them sea stars, were counted between each two transects, from the mussel zone to MLLW. Each biological sampling site included five count areas, each of them 50 meters long and varying in width depending on the steepness of the beach. Three observers counted each section and the mean of their counts was used for analysis, because there is room for considerable error in counting animals between rocks and in algae over a large area. Any dead or injured sea stars were noted.

Photographs were taken of each transect at each of the three observation times (May and July of 1997 and May of 1998), as well as of each quadrant as it was being counted. Other series of photos were taken of locations specifically selected because of their concentrations of and types of biota.

Results & **Discussion**

A look at any of the sets of photographs will demonstrate the impressive difference between life on these beaches at the three main sampling periods (Figures 11.1, 11.2, 11.3), but none of the differences can be correlated in any meaningful way with the cleaning process. The last week of May of 1997 was unusually hot and dry. Algae became desiccated between tides. Conversely, mid July of 1997 was cold, wet, and stormy. The weather was less extreme the last week of May of 1998, but conditions were especially good for many species of spring ephemeral algae, particularly filamentous red *Pterosiphonia,* which were far more extensive than in the previous year. In fact, biologists doing Prince William Sound field work in late May of 1998 noted greater abundances of ephemeral algae than they had seen in several years (Lindeberg, Harris. 1998. personal communication). This was not simply a Sleepy Bay phenomenon, and was extremely unlikely to be related to the cleaning work. (It may well have been due to more than typical stripping and turning of rocks during severe winter weather, which allowed more than average available substrate for colonizing.) These condition differences at the three sample periods completely overshadowed any effects that might potentially be attributed to the cleaning work, and clearly demonstrate that a study of intertidal populations with a single baseline count can only be expected to document truly devastating treatment effects.

Small Species Counts: These beaches are covered with lush algal growth at their lower reaches, but the upper portions are fairly bare. Many of the sample quadrats contained none of the counted biota, and there was little uniformity among the other quadrats. For instance, only 35 out of the 120 quadrats contained mussels. Thirteen ever had more than 10% coverage with mussels, while two (one reference and one treatment) had over 90% coverage (Figure 11.3). In July of 1997, photos from the previous counts were used to be certain that the quadrats were replaced in exactly the same places on exactly the same rocks so that the same sessile animals would be counted again, and at least the exact same habitat would be counted for mobile animals. In May of 1998, however, so many rocks had been moved by winter wave action that for nearly half the quadrats, not a single rock could be recognized to aid in relocation. When this happened, the quadrant was aligned with the transect tape, exactly as it lay. The high mobility of rocks on these beaches is certainly one of the key reasons for the minimum biota established there.

The counts we made are presented here (Figure 11.4) in terms of the average quantity of a species in all the quadrats from one sample array that ever had any of that species observed in it. (For example, of the 24 quadrats on LA020-B, only three contained mussels. The mean percent cover of mussels for those three quadrats is presented for May and July 1997 and for May 1998). These count comparisons show some interesting events. Reference beach LA017-A hosted a major set of littorine snails between May and July of 1997, for instance, that was not duplicated on any of the other observed beaches. Nearly all counted species increased in numbers on nearly all beaches between 1997 and 1998. However, none of the shifts in numbers with time could be associated in any realistic way with the cleaning operations.

Large Species Counts: With the exceptions of three sea urchins and two sand dollars, all the large animals counted were sea stars, with *Pycnopodia* and *Pisaster* making up the majority, followed by *Dermasterias.* Most species were more numerous below the MLLW mark, but were out of our study range. The counts made are presented here much as the small species counts are (Figure 11.5). Each bar represents the mean number of a species counted in each of the five counting spaces in a particular sampling array at a certain time. The most dramatic occurrence observed was the gathering of hundreds of *Pisasters* on the spit in the middle of LA020-C in July of 1997. The numbers of *Pycnopodia* and especially of *Dermasterias* increased considerably between May and July of 1997 on both reference beaches but not on any of the treated beaches. Results such as this could potentially be related to the cleanup operations, but there is simply not enough information to determine whether the cleanup or any number of other variables were involved. The treatment beaches all faced northeast, for instance, which was the direction from which the oil originally came, and they were in the sun during the early morning low tides we observed, while the reference beaches all faced northwest and were still in the shade then. This almost certainly affected sea star behavior, and affected it differently in dry weather than in rain.

Observers recorded all occurrences of dead or abnormal starfish observed. Exactly nine dead or badly injured stars were reported, most of them *Pycnopodia,* exactly three of them during each of the three sampling times, May and July of 1997 and May of 1998. The six observed after the cleaning had taken place were all on the LAO 17-A reference beach. Clearly, they were not a result of the cleaning.

What our small species and large species counts demonstrate is that the cleanup work did not have any obvious catastrophic effect on the biota of the beaches involved. The single observation of post-cleanup conditions that could be identified as abnormal consisted of two extremely lethargic sculpins in a tide pool just outside the cleaned area on EV039-A, seen four days after the cleaning was completed, while containment booms were still in place. Although it is relatively safe to inject limonene, it is hazardous to expose one's gills to it, so this observation is not surprising.

Photographs: Comparisons of photographs taken before cleaning with those taken afterwards reinforce the conclusion that any detrimental effects on the intertidal biota were too subtle to differentiate from the natural variations occurring over this time.

Photos taken of each transect line, taken from just below the MLLW stake at the lower end toward the trees, looked very much alike at the three sampling periods (Figure 11.1). Algae covered the same general part of the lower beach. The May, 1997, photos show desication, the July, 1997, photos show the results of persistent rain, and the May, 1998, photos show a greater variety of ephemeral algae, especially *Pterosiphonia.* Examples of specific quadrant photos show no more variability over time (Figures 11.2, 11.3). Several additional series of photos showed similar lack of effects. Three photos of a particularly dense clump of mussels on a boulder on the north end of LA020-C (Figure 11.6) were particularly significant because most beach mussels were situated some distance down the slope of the beach from cleaning operations, while the gravel around this boulder was clearly well cleaned. Arrows on the photos show places where compacted oil and gravel in May of 1997 have been washed and released by July of 1997. Yet there is little change in the appearance of the clump, even the following spring.

Conclusions

The overall cleaning process was judged to work well on the surface oil available. It appears that a 50% visual reduction in oil was achieved. 96 square meters per air knife per day were treated, at a cost of roughly $100 per square meter. The use of an Oversight Committee, with all members working on the beach and familiar with the process and it's limitations, to determine exactly what areas would be cleaned and when each area was finished, was very successful. The use of booms to corral the oil and sorbent materials to retrieve it also worked very well.

As for objective monitoring by Auke Bay Laboratory personnel, the cleaning process did remove more than 50% of the oil on the beaches that were accessible to cleaning. However, large boulders protect much of the oil underneath them from cleaning, either by people or by nature. Unless nearly every rock on these beaches is moved to remove the oil beneath it, the annual rearrangement of the rocks by winter storms will remain a crucial part of the very slow natural recovery of this area.

Biologically available oil and surfactant were released in the cleaning areas and the immediate vicinity of the cleanup work, and were taken up by resident mussels, but were not measurable in their tissues for long. Almost no measurable oil or surfactant escaped into the surrounding water column. Any physical damage to intertidal biota was too subtle to be observed against natural variability.

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Appendices

A	Beach Characteristics
B	Project Calendar
C	Photographs Before and After Treatment
D	Field Oiling Classification and Survey Terms
E	Pre-Treatment Shoreline Assessment Forms
F	Recovered Oil Estimate
G	Treatment Rate Calculations
H	PES-51® MSDS

Appendix A Beach Characteristics

Location	Site	Environmental Sensistivity	Community Concerns	Substrate Type	Residual Oil	Comments
Elrington Island	ER 020 B	Mussel Bed	Popular picnic area; large sea lion population; whale foraging; land otter dens; chiton harvesting; duck, deer and seal hunting; pre-spill seal pupping area.	Cobble and boulders over gravel sediment.	Surface and subsurface oil residue, sheen in water pools and asphalt pavement in western and eastern pockets.	Subsurface oil appears to be decreasing with time. Site is within eyesight of Chenega Bay. There are two locations at this site with heavy SOR amongst bedrock outcroppings.
Evans Island	EV 037 A	None	Duck and seal hunting.	Large boulders over gravel sediment.	Asphalt pavement, as well as surface and subsurface oil residue, sheen in water pools.	Majority of oil is AP and SOR between and under boulders at the high and supra intertidal zones.
	EV 039 A	None	Duck and seal hunting; land otter dens; octopus harvesting.	Cobble and boulder armor over gravel sediment. Beach divided by stream.	Asphalt pavement, tar patties, as well as surface and subsurface oil residue.	A large area of soft and friable AP is present on the south part of the site. The AP is as much as 25 cm thick. Two other smaller and less concentrated areas of AP and SOR are also present in boulder and bedrock settings.
Latouche Island	LA 015 C	Anadromous Stream	Duck, seal and bear hunting; chiton harvesting.	Boulders over gravel sediment, stream near eastern border.	Mousse on the underside of boulders, sporadic pockets of surface oil residue, tar patties and sheen in water pools.	One area has significant oil remaining. High concentrations of AP and SOR occur interstitially between large immobile boulders and bedrock. No significant subsurface oil remains at this site.
	LA 019 A	None	Duck, seal and bear hunting; chiton harvesting; subsistence bottom fishing; popular wood collecting area; berry picking.	Boulder armor over gravel sediment.	Asphalt pavement, mousse and surface oil residue among the boulders.	The eastern ½ of the subdivision is bordered by a prominent outcrop and large boulders. This natural border separated the site for the PES test. It has a concentrated area of AP/MS amongst boulders and cobbles. Subsurface oil coincides with surface oil.

Source: Loeffler, R. M., E. Piper and D. Munson. 1996. "Workshop Report: Residual Shoreline Oiling." Exxon Valdez Oil spill Restoration Project 95266 Final Report. Alaska Department of Environmental Conservation. As presented in: U.S. Department of Agriculture Forest Service (USFS). 1997. "Environmental Assessment for Chenega-area Shoreline Residual Oiling Reduction."

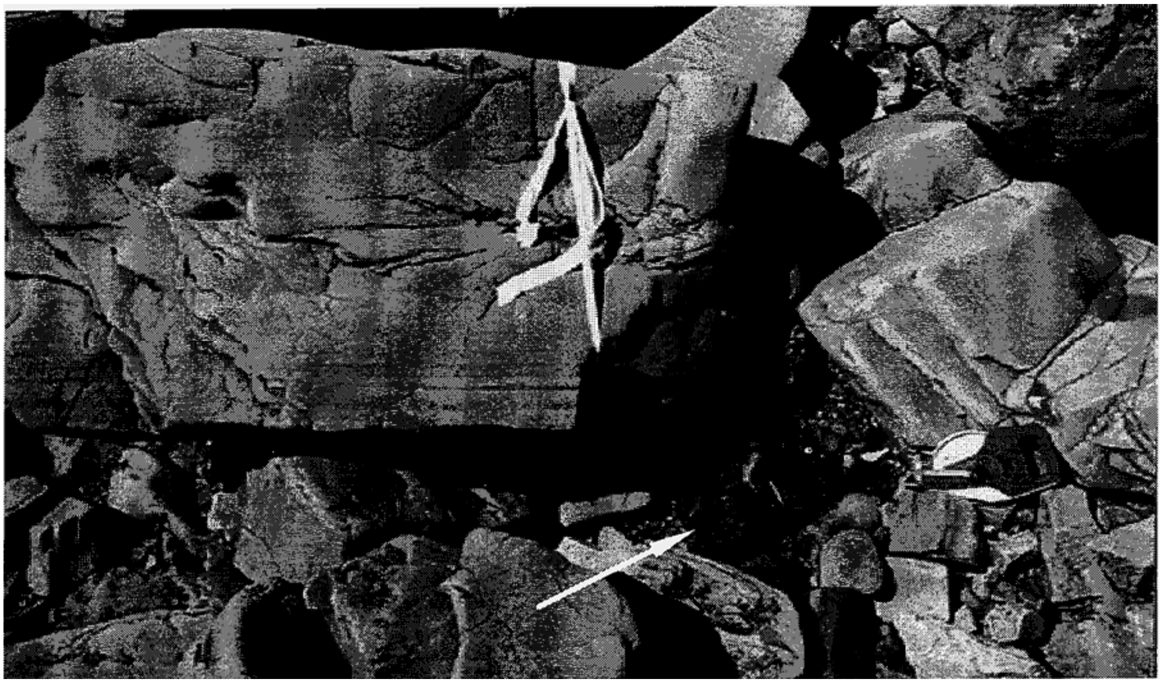
Location	Site	Environmental Sensistivity	Community Concerns	Substrate Type	Residual Oil	Comments
	LA 020 B	None	Duck, seal and bear hunting; chiton harvesting; subsistence bottom fishing; popular wood collecting area; berry picking.	Cobble and boulder armor over gravel sediment, stream near northern border.	Patchy areas of asphalt pavement, as well as surface and subsurface oil residue.	Large boulders with AP and SOR stuck in between.
	LA 020 C	None	Duck, seal and bear hunting; chiton harvesting; subsistence bottom fishing; popular wood collecting area; berry picking.	Boulder armor over vertically aligned shale bedrock and gravel sediment.	Patchy areas of asphalt pavement, as well as surface and subsurface oil residue, sheen in water pools.	Four large areas of significant oiling occur at this site. The oiling is primarily AP and SOR occurring in vertical shale and amongst boulders and cobbles. Subsurface oil is often an extension of surface oil.
	LA 021 A	None	Fresh water; wood gathering; berry picking; chiton harvesting.	Boulder cobble beach overlying shallow bedrock.	Discontinuous light oil residue in subsurface soils.	Oiling occurs as sporadic AP, SOR, CT, ST. Subsurface oil is coincident with surface oil. Unable to locate oil 1994. Treatment should occur at a tide level of 3.0' and lower.

Source: Loeffler, R M., E. Piper and D. Munson. 1996. "Workshop Report: Residual Shoreline Oiling." Exxon Valdez Oil spill Restoration Project 95266 Final Report. Alaska Department of Environmental Conservation. As presented in: U.S. Department of Agriculture Forest Service (USFS). 1997. "Environmental Assessment for Chenega-area Shoreline Residual Oiling Reduction."

Appendix B Project Calendar

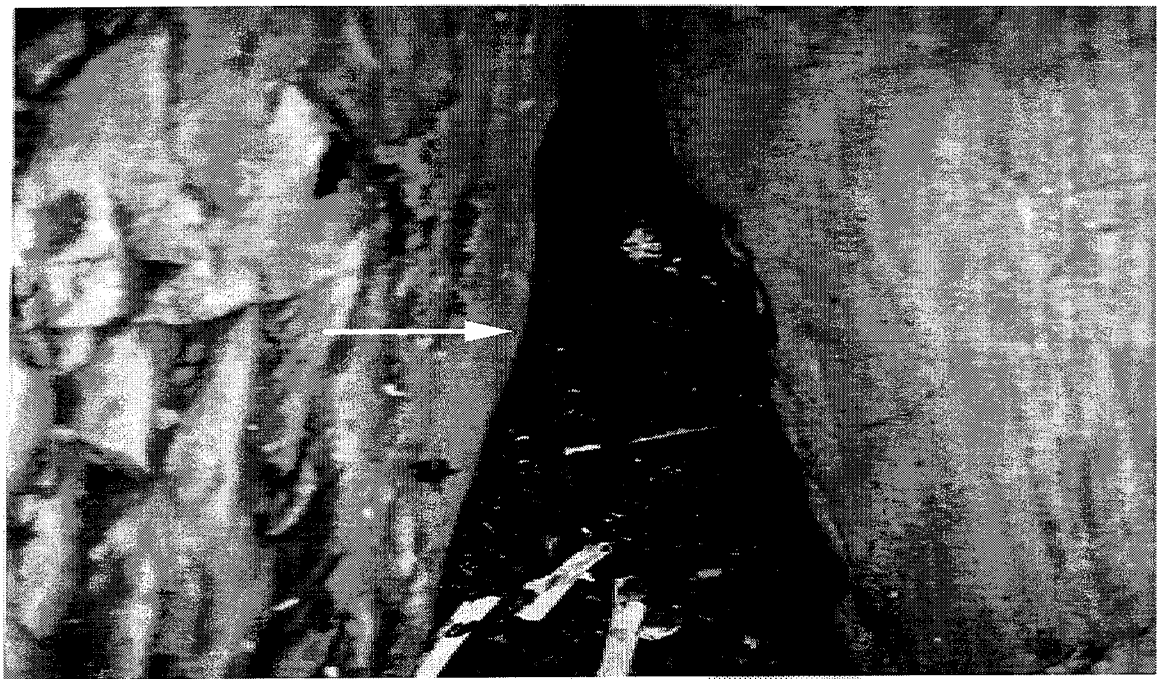
Sun	Mon	Tue	Wed	Thu	Fri	Sat
June 1997						
1	2	3	4	5	6	7
8	9	10	11	12 MOBILIZATION	13 MOBILIZATION	14 MOBILIZATION
15 MOBILIZATION PUBLIC MEETING	16 SET UP	17 LA 020B-1 BEGIN TREATMENT	18 LA 020B-1	19 LA 020B-1	20 LA 020B-1	21 LA 020B-2
22 LA 020B-3 SURVEY LA 020C	23 CREW REST DAY	24 LA 020B-4	25 LA 020B-4	26 LA 020C-1	27 LA 020C-4	28 LA 020C-4
29 LA 020C-6	30 LA 020C-6					
July 1997						
		1 LA 020C-6	2 LA 020C-7 SURVEY LA 015C	3 LA 020C-7	4 CREW REST DAY	5 LA 020C-9
6 LA 020C-9	7 LA 015C-1	8 LA 015C-1	9 LA 015C-1	10 LA 015C-2	11 WEATHER DAY	12 LA 015C-2
13 WEATHER DAY	14 LA 015C-3 SURVEY EV 039A	15 EV 039A-1	16 EV 039-A-1 SURVEY EV 037A	17 WEATHER DAY	18 EV 037A	19 EV 037A COMPLETED TREATMENT PUBLIC MEETING
20 DEMOBILIZATION TEAR DOWN	21 DEMOBILIZATION	22 DEMOBILIZATION	23	24	25	26
27	28	29	30	31		

Appendix C   Photographs Before and After Treatment

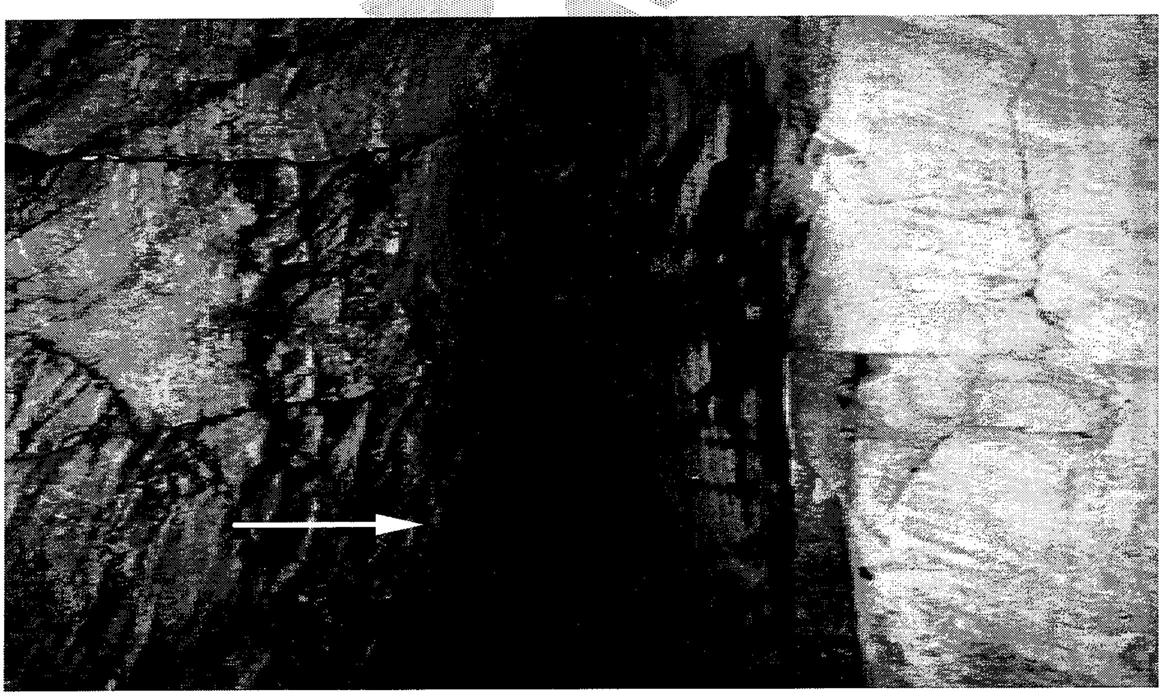


Conditions before treatment, photo reference point 5, LA 020B. Note oily asphalt patch below and right of flagged rock. Photo taken 6/17/97.

Conditions after treatment, photo reference point 5, LA 020B. Note unconsolidated cobble between boulders, center of picture. Photo taken 6/24/97.



Conditions before treatment at photo reference point 7, LA 020C. Note oil and asphalt in rock crevice. Photo taken 6/30/97.



Conditions after treatment, photo reference point 7, LA 020C. Photo taken 7/7/97.

Photo reference point 1, LA 015C, before a between boulders is consolidated asphalt mat. Photo taken 7/6/97.

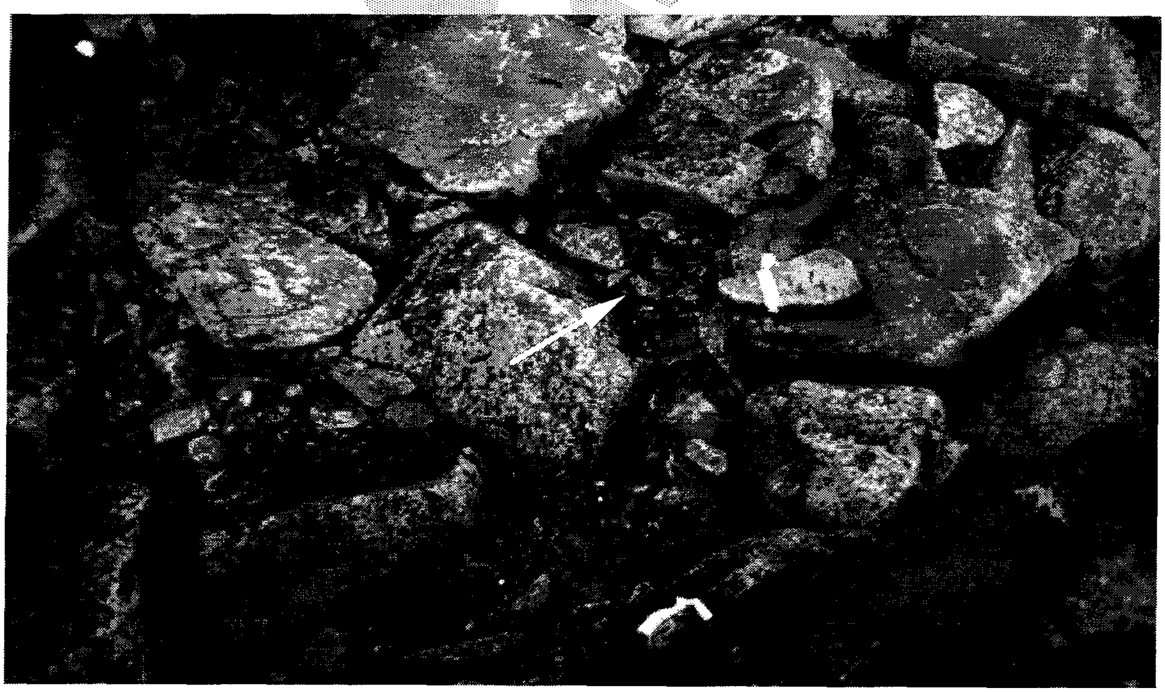
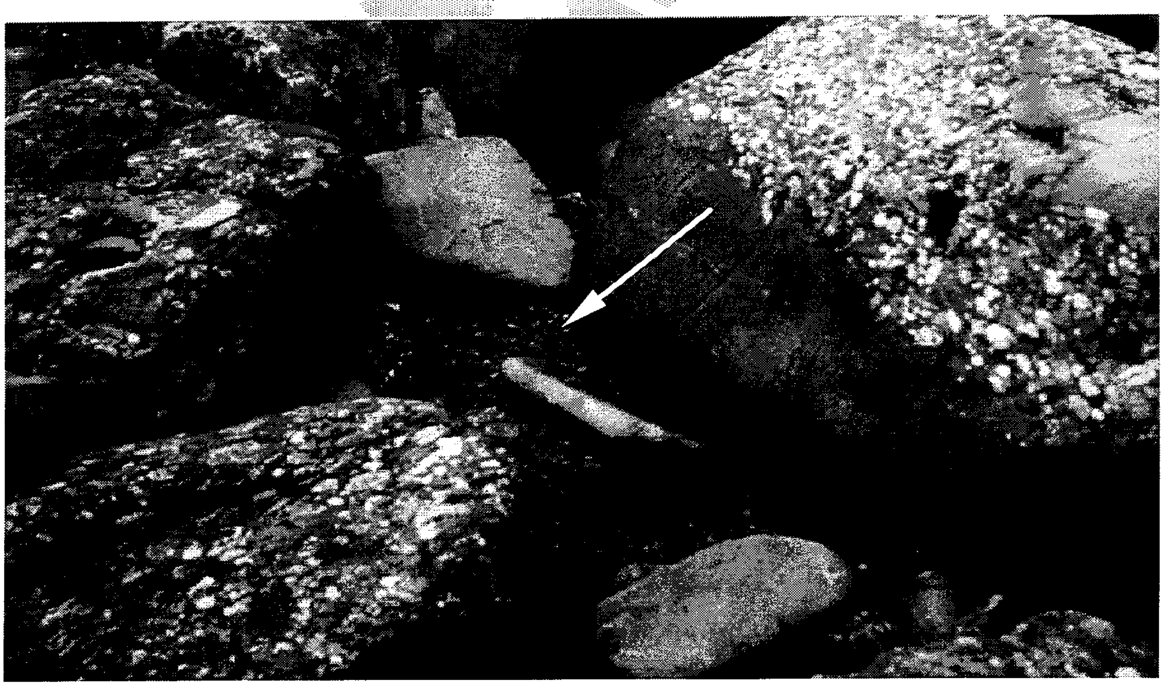


Photo reference point 1 at LA 015C, after treatment. Note loose gravel. Photo taken 7/15/97.

Conditions before treatment, photo reference point 4, EV 039A. Gravel and cobble consolidated in asphalt mat. Photo taken 7/16/97.

Conditions after treatment at photo reference point 4, EV 039A. Gravels are loose an unconsolidated. Photo taken 7/17/97.

Before treatment conditions at photo reference point. EV 037A. Note mousse an asphalt between boulders. Photo taken 7/16/97.



Conditions after treatment, photop reference point 4, EV 037A. Mousse has been removed, gravels are unconsolidated. Photo taken 7/22/97.

Appendix D Field Oiling Classification and Survey Terms

Field Oiling Classification and Survey Terms

Surface Oil Types	Abbreviation	Definition
asphalt/pavement	AP	Heavily oiled beach sediments held cohesively together.
mousse/pooled oil	MS	Any oil/water emulsion with a thickness of more than 1 cm.
tar balls/tar patties	TB	Small, distinct oil deposits lying on top of the beach surface; possibly binding debris but typically not sediments.
surface oil residue	SOR	Significantly oil coated beach sediments in the top 5 cm; sediments do not form a cohesive layer; may be described as heavy or light.
cover	CV	Oil more than 1 mm to 1 cm thick.
coat	CT	Oil more than 0.1 mm to less than or equal to 1 mm thick; can be easily scratched off with fingernail.
stain	ST	Oil less than or equal to 0.1 mm thick; cannot be easily scratched off with fingernail.
film or sheen	FL	Transparent or translucent film or sheen.
oiled debris	DB	Any oiled debris or cleanup material stranded on a shore.

Surface Oil - Distribution Classes	Abbreviation	Definition
continuous	C	Area or band with 91 % to 100% oil coverage.
broken	B	Area or band with 51 % to 90% coverage.
patchy	P	Area or band with 11 % to 50% coverage.
sporadic	S	Area or band with 1 % to 10% coverage.
trace	T	Area or band with less than 1 % coverage.

Subsurface Oil Types	Abbreviation	Definition
oil pore	OP	Pore space are completely filled with oil resulting in oil oozing out of sediments-water cannot penetrate OP zone.
heavy oil residue	HOR	Pore spaces partially filled with oil residue but not generally flowing out of sediments.
medium oil residue	MOR	Heavily coated sediments; pore spaces are not filled with oil - pore spaces may be filled with water.
light oil residue	LOR	Sediments lightly coated with oil.
oil film	OF	Continuous layer of sheen or film on sediments - water may bead on sediments.
trace	TR	Discontinuous film; spots of oil on sediments; an odor or tackiness with no visible evidence of oil.
Surface and Subsurface Sediment Types	**Abbreviation**	**Definition**
bedrock	R	
boulder	B	Greater than 256 millimeters.
cobble	C	64 to 256 millimeters.
pebble	P	4 to 64 millimeters.
granule	G	2 to 4 millimeters
sand	S	0.06 to 2 millimeters
mud/silt	M	Less than 0.06 millimeters.
Tidal Zones	**Abbreviation**	**Definition**
supratidal	SU	Above the upper intertidal zone.
upper intertidal	U1TZ	Upper 1/3 of active intertidal zone.
middle intertidal	MITZ	Middle 1/3 of active intertidal.
lower intertidal	LITZ	Lower 1/3 of active intertidal zone.

Appendix E   Pre-Treatment Shoreline Assessment Forms

1997 Chenega-area Oil Reduction Project
Pre-Treatment Shoreline Assessment Oiling Summary

Team Members: D. Munson (ADEC)
D. Easton & J. Ginter, (Easton Environmental)
C. Robertson, (Chenega Corporation)

Segment: LA020
Subdivision: B
Date: 6 / 16 /97

Energy Level: L ☐ M ■ H ☐

Surveyed from: ■ Foot ☐ Boat ☐ Helo

Weather: ■ Sun ■ Clouds ☐ Fog ☐ Rain ☐ Snow

Total Length Shoreline Surveyed: 310 m

Near Shore Sheen: ☐ BR ☐ RB ☐ SL ■ NONE

LOC	SURFACE OIL CHARACTER (use , C, B, P, S, or T See Below) AP	MS	TB	SOR	CV	CT	ST	FL	DB	NO	SURFACE SEDIMENT TYPE	SHORE SLOPE V H M L	AREA WIDTH m	AREA LENGTH m	ZONE S	UI	MI	LI	NOTES
A	P			P								H-M	4	140		X			
B	P			P								H-M	5	50			X		
C	P			P								M	6	13		X			
D	S			S								M	10	30		X			
E	S			S								H-M	10	60		X			
F	S			S								H	5	40		X			This location not treated

R=Bedrock, B=Boulder, C=Cobble, P=Pebble, S=Sand, M=Mud/Silt
SURFACE OIL DISTRIBUTION: C = 91-100%; B = 51-90%; P = 11-50%; S = 1-10%; T = <1%;
SLOPE: V = VERTICAL; H = HIGH ANGLE; M = MEDIUM ANGLE; L = LOW ANGLE;

PIT NO.	PIT DEPTH (cm)	SUBSURFACE OIL CHARACTER OP	HOR	MOR	LOR	OF	TR	NO	OILED ZONE cm - cm	CLEAN BELOW Y/N	H2O LEVEL (cm)	SHEEN COLOR B R S N	PIT ZONE S	UI	MI	LI	SURFACE SUBSURFACE SEDIMENTS	NOTES
1	22			X					2 - 10	Y	—	—		X			BcP/PS	under clean pebbles
2	21		X						2 - 8	Y	—	—		X			"	"
3	32			X					0 - 6	Y	—	—		X			"	Extension of
4	18		X						0 - 5	Y	—	—		X			"	surface AP/SOR
5	14		X						0 - 8	Y	—	—		X			"	↓
6	18			X					0 - 9	Y	—	—		X			"	
7	17	X							0 - 6	Y	—	—			X		"	
8	12		X						0 - 7	Y	—	—		X			"	
									-									
									-									
									-									

SHEEN COLOR: B = Brown; R = Rainbow; S = Silver; N = None

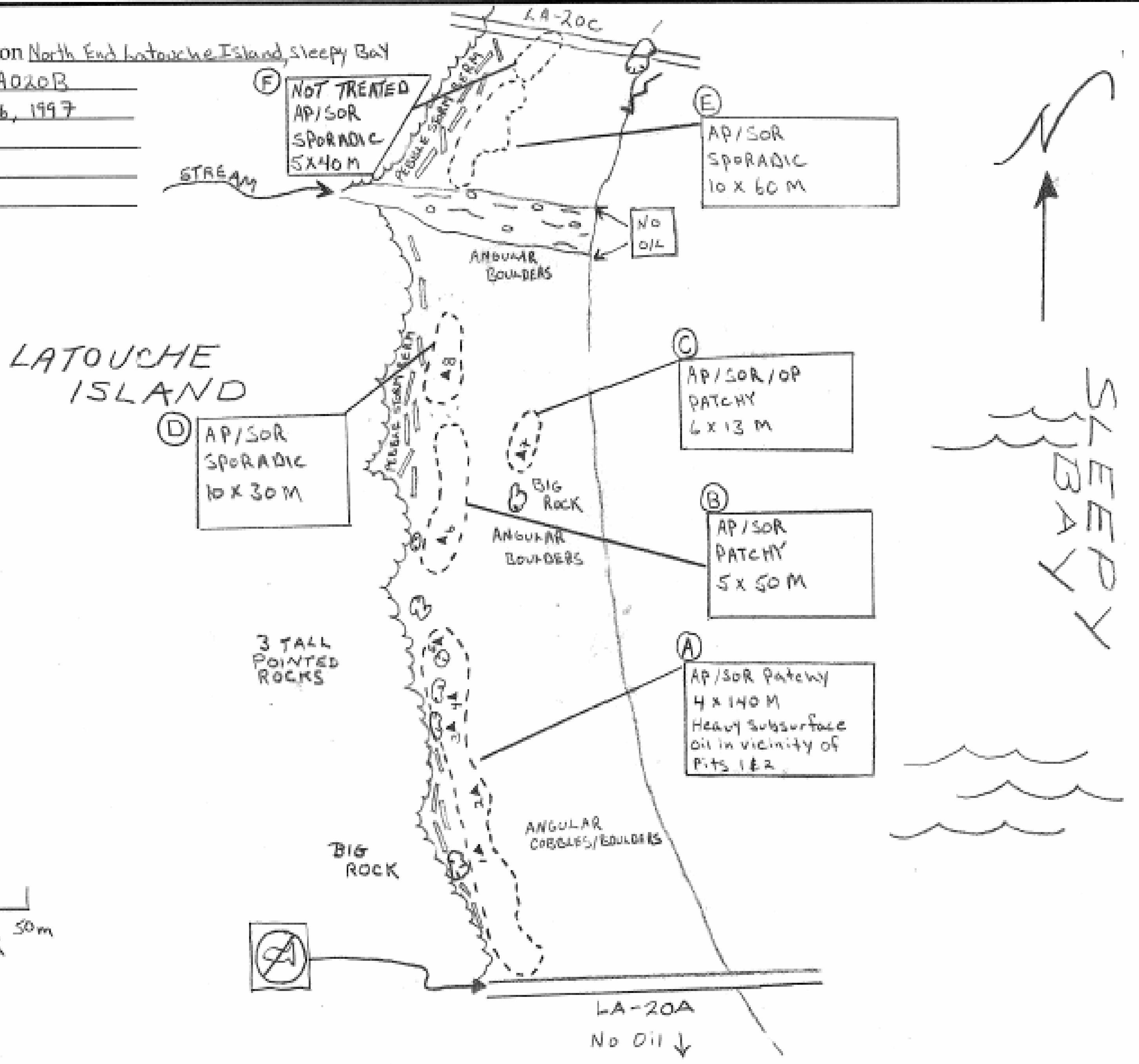
SKETCH MAP

Segment Location North End Latouche Island, Sleepy Bay
Segment No LA020B
Date June 16, 1997
Names

Legend

1 △ Pit Number No Subsurface Oil

2 ▲ Pit Number Susurface Oil



1997 Chenega-area Oil Reduction Project
Pre-Treatment Shoreline Assessment Oiling Summary

Team Members: D. Munson, (ADEC)
J. Ginter, (Easton Environmental)
C. Robertson, (Chenega)

Segment: LA020
Subdivision: G
Date: 6 /24 /97

Energy Level: L ☐ M ☒ H ☒

Surveyed from: ☒ Foot ☐ Boat ☐ Helo

Weather: ☒ Sun ☐ Clouds ☐ Fog ☐ Rain ☐ Snow

Total Length Shoreline Surveyed: 916 m

Near Shore Sheen: ☐ BR ☐ RB ☐ SL ☒ NONE

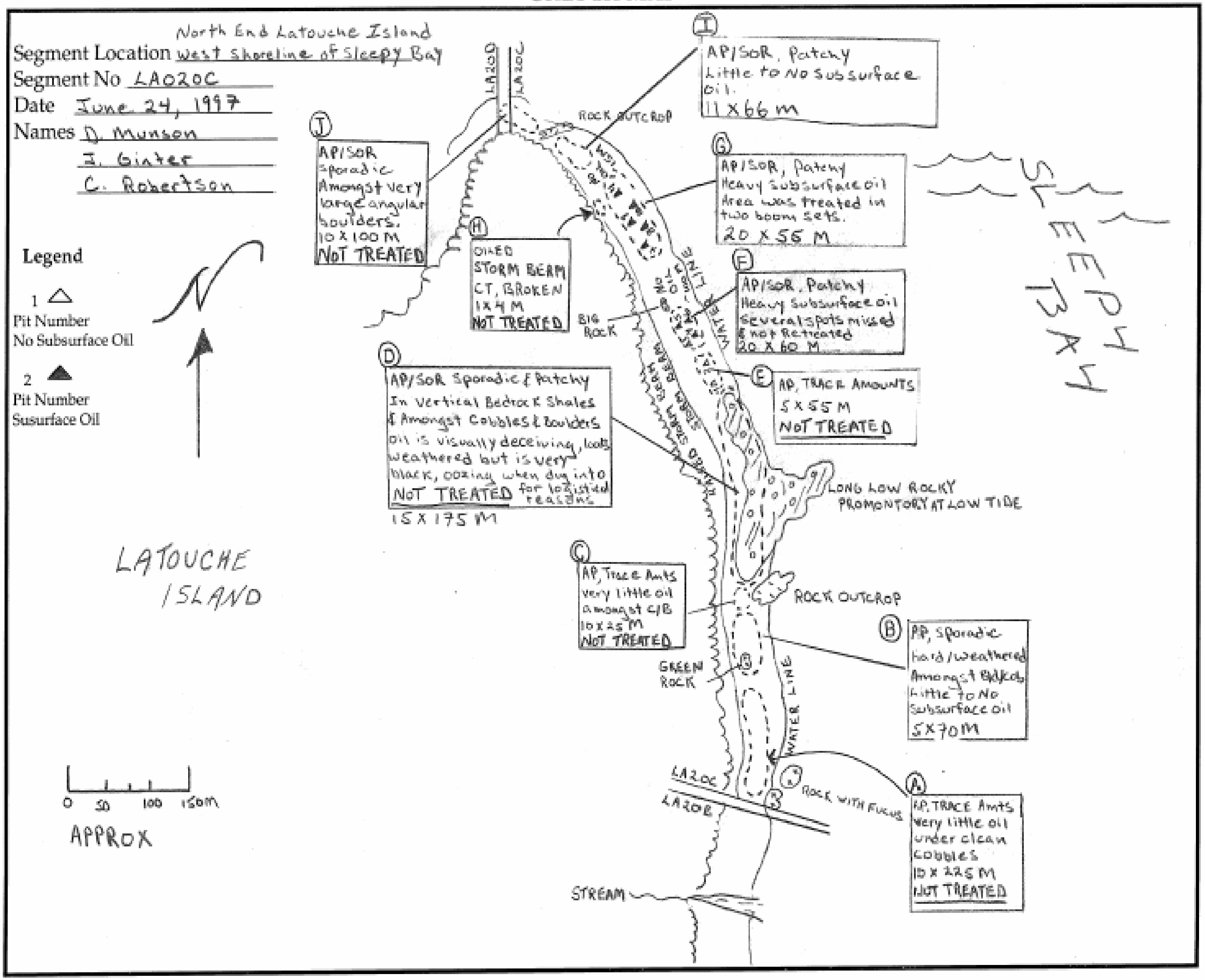
LOC	SURFACE OIL CHARACTER (use , C, B, P, S, or T See Below) AP	MS	TB	SOR	CV	CT	ST	FL	DB	NO	SURFACE SEDIMENT TYPE	SHORE SLOPE V H M L	AREA WIDTH m	AREA LENGTH m	ZONE S	UI	MI	LI	NOTES
A	T										BC	L	10	225		X	X		Small Amounts, NOT TREATED
B	S										BC	L	5	70		X			Primarily Hard & Weathered
C	T										BC	L	10	25		X			Trace Amounts, NOT TREATED
D	P			S							R,B,C,P	L	15	175		X	X		NOT TREATED for logistical reasons
E	P			P							B,C	L	5	55		X	X		Trace Amounts, Not Treated
F	P			P							B,C,P	L	20	60		X	X		Heavy Subsurface oil
G	P			P							B,C,P	L	20	55		X	X		Heavy Subsurface oil
H						B					C,P	H	1	4	X				coated Pebbles at Storm Berm
I	P			P							B,C,P	L-M	11	66		X	X		Little to no Subsurface oil.
J	S			S							R,B,C	M-H	10	100		X	X		NOT TREATED, Extreme Access.

R=Bedrock, B=Boulder, C=Cobble, P=Pebble, S=Sand, M=Mud/Silt
SURFACE OIL DISTRIBUTION: C = 91-100%; B = 51-90%; P = 11-50%; S = 1-10%; T = <1%;
SLOPE: V = VERTICAL; H = HIGH ANGLE; M = MEDIUM ANGLE; L = LOW ANGLE;

PIT NO.	PIT DEPTH (cm)	SUBSURFACE OIL CHARACTER OP	HOR	MOR	LOR	OF	TR	NO	OILED ZONE cm - cm	CLEAN BELOW Y/N	H2O LEVEL (cm)	SHEEN COLOR B R S N	PIT ZONE S	UI	MI	LI	SURFACE SUBSURFACE SEDIMENTS	NOTES
1	28							X	-					X			BCP/CPG	
2	14							X	-					X				
3	19							X	-					X				
4	18		X						0 - 8	Y	—	—			X			AP on surface
5	20		X						14 - 18	Y	—	—		X				
6	23		X						12 - 23	N	—	—			X			Surface is clean
7	17		X						3 - 17	N	—	—		X				" "
8	25			X					2 - 11	Y	—	—			X			" "
9	31				X				15 - 28	Y	—	—		X				Surface is clean
10	26			X					4 - 20	Y	—	—			X			" "
11	24		X						3 - 24	N	—	—		X			↓	" "

SHEEN COLOR: B = Brown; R = Rainbow; S = Silver; N = None

SKETCH MAP


Segment Location North End Latouche Island west shoreline of Sleepy Bay
Segment No LA020C
Date June 24, 1997
Names D. Munson
I. Ginter
C. Robertson
Legend
1 Pit Number No Subsurface Oil
2 Pit Number Susurface Oil
N
LATOUCHE ISLAND
0 50 100 150m
APPROX
SLEEPY BAY
LA020D
LA020C
LA020B
ROCK OUTCROP
BIG ROCK
GREEN ROCK
STREAM
WATER LINE
STORM BERM
LONG LOW ROCKY PROMONTORY AT LOW TIDE
ROCK WITH FUCUS
(A) AP, TRACE Amts very little oil under clean cobbles 10 x 225 M NOT TREATED
(B) AP, Sporadic hard/weathered Amongst Bld/cob Little to No Subsurface oil 5X70M
(C) AP, Trace Amts very little oil amongst C/B 10 x 25 M NOT TREATED
(D) AP/SOR Sporadic & Patchy In Vertical Bedrock Shales & Amongst Cobbles & Boulders oil is visually deceiving, looks weathered but is very black, oozing when dug into NOT TREATED for logistical reasons 15 X 175 M
(E) AP, TRACE AMOUNTS 5 X 55 M NOT TREATED
(F) AP/SOR, Patchy Heavy Subsurface oil several spots missed & not Retreated 20 X 60 M
(G) AP/SOR, Patchy Heavy Subsurface oil Area was treated in two boom sets. 20 X 55 M
(H) OILED STORM BERM CT, BROKEN 1X4 M NOT TREATED
(I) AP/SOR, Patchy Little to No Subsurface oil. 11 X 66 M
(J) AP/SOR sporadic Amongst very large angular boulders. 10 X 100 M NOT TREATED

1997 Chenega-area Oil Reduction Project
Pre-Treatment Shoreline Assessment Oiling Summary

Team Members: D. Munson, (ADEC)
J. Ginter, (Easton Environmental)
C. Robertson, (Chenega)

Segment: LA015
Subdivision: C
Date: 7 / 2 /97

Energy Level: L ☐ M ☐ H ■

Surveyed from: ■ Foot ☐ Boat ☐ Helo

Weather: ■ Sun ■ Clouds ☐ Fog ☐ Rain ☐ Snow

Total Length Shoreline Surveyed: 300 m

Near Shore Sheen: ☐ BR ☐ RB ☐ SL ■ NONE

LOC	SURFACE OIL CHARACTER (use , C, B, P, S, or T See Below)										SURFACE SEDIMENT	SHORE SLOPE	AREA		ZONE				NOTES
	AP	MS	TB	SOR	CV	CT	ST	FL	DB	NO	TYPE	V H M L	WIDTH m	LENGTH m	S	UI	MI	LI	
A	P	P		P							RBCP	H-M	17	185		X	X		
B	S			S							BCP	M				X			
C	S			S							BCP	M				X			
D	S			S							BCP	M				X			

R=Bedrock, B=Boulder, C=Cobble, P=Pebble, S=Sand, M=Mud/Silt
SURFACE OIL DISTRIBUTION: C = 91-100%; B = 51-90%; P = 11-50%; S = 1-10%; T = <1%;
SLOPE: V = VERTICAL; H = HIGH ANGLE; M = MEDIUM ANGLE; L = LOW ANGLE;

PIT NO.	PIT DEPTH (cm)	SUBSURFACE OIL CHARACTER							OILED ZONE	CLEAN BELOW	H2O LEVEL	SHEEN COLOR	PIT ZONE				SURFACE SUBSURFACE SEDIMENTS	NOTES
		OP	HOR	MOR	LOR	OF	TR	NO	cm - cm	Y/N	(cm)	B R S N	S	UI	MI	LI		
1	22							X	-						X		B/C	
2	33							X	-						X		↓	
3	27							X	-						X		↓	
4	38							X	-						X		↓	
5	24							X	-						X		↓	
									-									
									-									
									-									
									-									
									-									
									-									

SHEEN COLOR: B = Brown; R = Rainbow; S = Silver; N = None

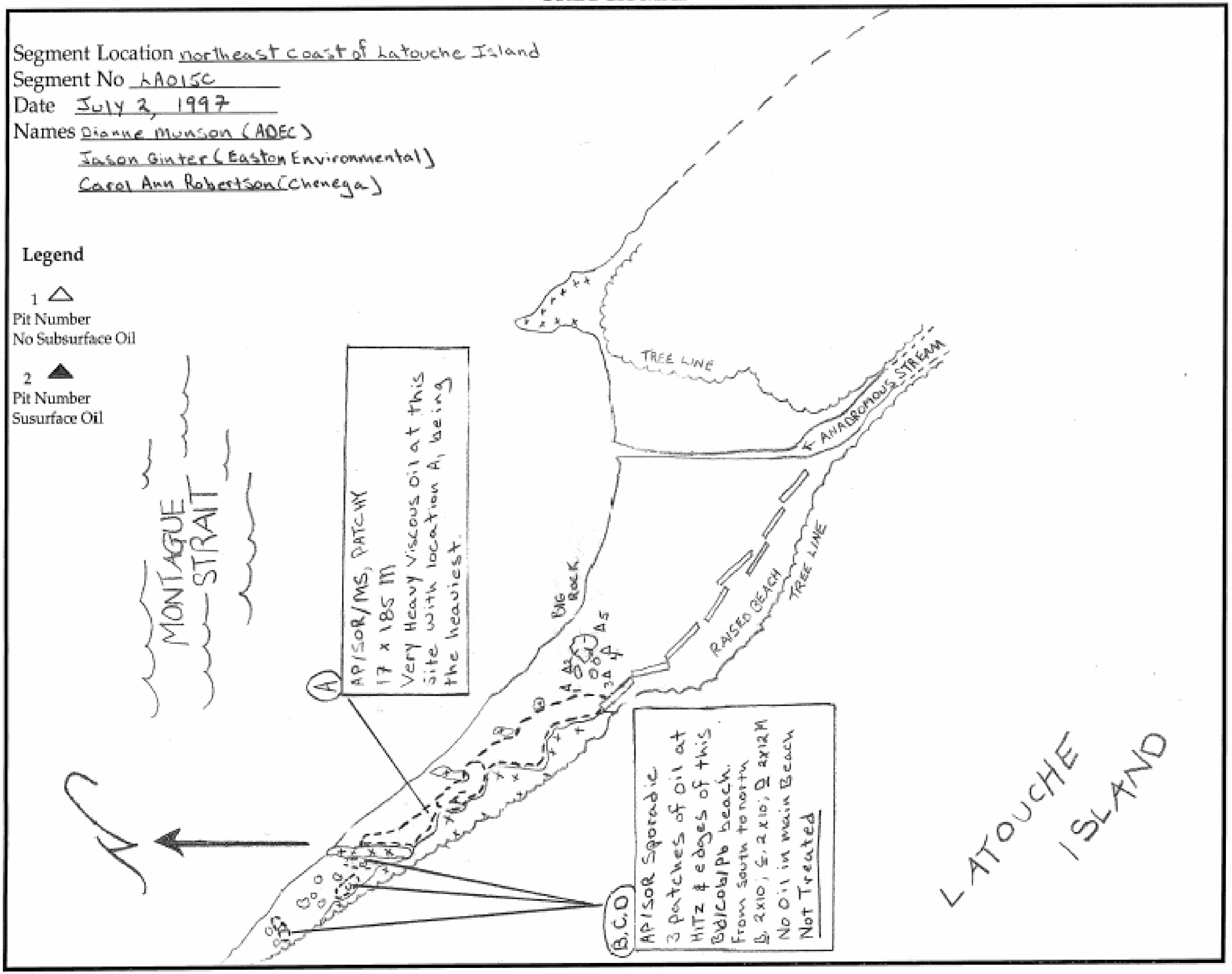
SKETCH MAP

Segment Location northeast coast of Latouche Island
Segment No LA015C
Date July 2, 1997
Names Dianne Munson (ADEC)
Jason Ginter (Easton Environmental)
Carol Ann Robertson (Chenega)

Legend

1 △ Pit Number No Subsurface Oil

2 ▲ Pit Number Susurface Oil



1997 Chenega-area Oil Reduction Project
Pre-Treatment Shoreline Assessment Oiling Summary

Team Members: D. Munson (ADEC)
J. Ginter (Easton Environmental)
L. Evanoff (Chenega)

Segment: EV 039
Subdivision: A
Date: 7 / 14 /97

Energy Level: L ☐ M ☒ H ☐

Surveyed from: ☒ Foot ☐ Boat ☐ Helo

Weather: ☒ Sun ☒ Clouds ☐ Fog ☐ Rain ☐ Snow

Total Length Shoreline Surveyed: ______m

Near Shore Sheen: ☐ BR ☐ RB ☐ SL ☒ NONE

LOC	SURFACE OIL CHARACTER (use, C, B, P, S, or T See Below) AP	MS	TB	SOR	CV	CT	ST	FL	DB	NO	SURFACE SEDIMENT TYPE	SHORE SLOPE V H M L	AREA WIDTH m	AREA LENGTH m	ZONE S	UI	MI	LI	NOTES
A	S	S		S		T	T				RBCP	M	10	5		X	X		Small Amount, Not Treated
																			Difficult to Boom &
																			Contain.
B	S			S		T	T				RBCP	M	20	95		X	X		

R=Bedrock, B=Boulder, C=Cobble, P=Pebble, S=Sand, M=Mud/Silt
SURFACE OIL DISTRIBUTION: C = 91-100%; B = 51-90%; P = 11-50%; S = 1-10%; T = <1%;
SLOPE: V = VERTICAL; H = HIGH ANGLE; M = MEDIUM ANGLE; L = LOW ANGLE;

PIT NO.	PIT DEPTH (cm)	SUBSURFACE OIL CHARACTER OP	HOR	MOR	LOR	OF	TR	NO	OILED ZONE cm - cm	CLEAN BELOW Y/N	H2O LEVEL (cm)	SHEEN COLOR B R S N	PIT ZONE S	UI	MI	LI	SURFACE SUBSURFACE SEDIMENTS	NOTES
									-									
									-									
									-									
									-									
									-									
									-									
									-									
									-									
									-									
									-									
									-									

SHEEN COLOR: B = Brown; R = Rainbow; S = Silver; N = None

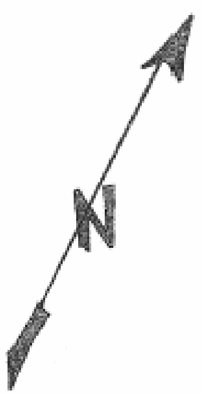
SKETCH MAP

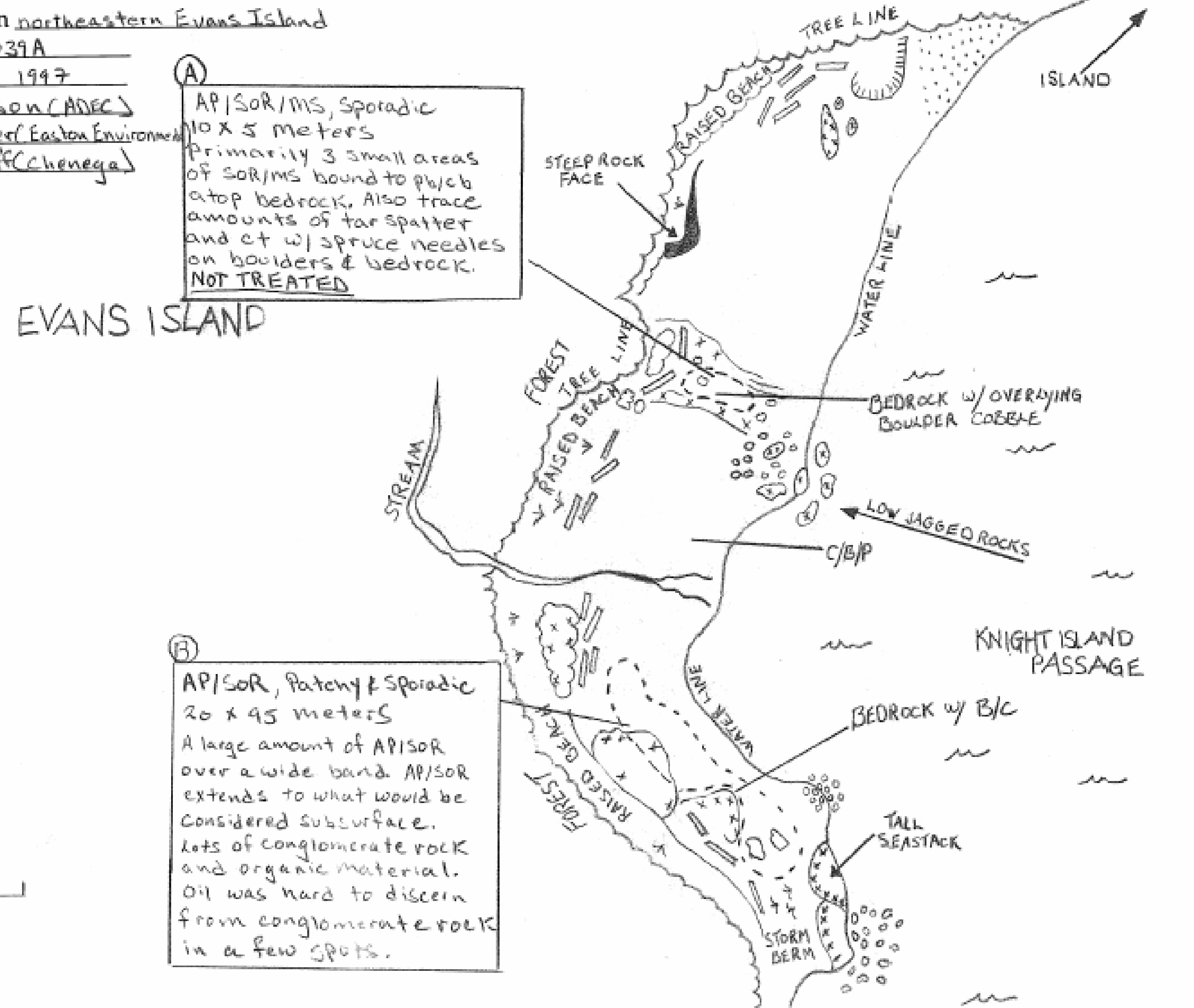
Segment Location northeastern Evans Island
Segment No EV039A
Date July 14, 1997
Names D. Munson (ADEC)
J. Ginter (Easton Environmental)
L. Evanoff (Chenega)

Legend

1 △ Pit Number No Subsurface Oil

2 ▲ Pit Number Susurface Oil





APPROX
65m

1997 Chenega-area Oil Reduction Project
Pre-Treatment Shoreline Assessment Oiling Summary

Team Members: D. Munson (ADEC)
J. Ginter (Easton Environmental)
L. Evanoff (Chenega)
____

Segment: EV037
Subdivision: A
Date: 7 / 14 /97

Energy Level: L ☐ M ☐ H ■

Surveyed from: ■ Foot ☐ Boat ☐ Helo

Weather: ■ Sun ■ Clouds ☐ Fog ☐ Rain ☐ Snow

Total Length Shoreline Surveyed: 238 m

Near Shore Sheen: ☐ BR ☐ RB ☐ SL ■ NONE

LOC	SURFACE OIL CHARACTER (use . C, B, P, S, or T See Below)										SURFACE SEDIMENT TYPE	SHORE SLOPE V H M L	AREA WIDTH m	AREA LENGTH m	ZONE				NOTES
	AP	MS	TB	SOR	CV	CT	ST	FL	DB	NO					S	UI	MI	LI	
A	P	P		P							RBCP	M				X			
B	S					S					BCP	M	2	6	X				
C				S		S	S				BCP	M	12	2		X	X		

R=Bedrock, B=Boulder, C=Cobble, P=Pebble, S=Sand, M=Mud/Silt
SURFACE OIL DISTRIBUTION: C = 91-100%; B = 51-90%; P = 11-50%; S = 1-10%; T = <1%;
SLOPE: V = VERTICAL; H = HIGH ANGLE; M = MEDIUM ANGLE; L = LOW ANGLE;

PIT NO.	PIT DEPTH (cm)	SUBSURFACE OIL CHARACTER							OILED ZONE cm - cm	CLEAN BELOW Y/N	H2O LEVEL (cm)	SHEEN COLOR B R S N	PIT ZONE				SURFACE SUBSURFACE SEDIMENTS	NOTES
		OP	HOR	MOR	LOR	OF	TR	NO					S	UI	MI	LI		
1	12		X						1 - 7	Y	—	—		X			BC/CP	
2	20		X						3 - 17	Y	—	—		X			BC/CP	
3	27		X						17 - 23	Y	—	—		X			BCP/PG	
4	15		X						0 - 12	Y	—	—		X			BCP/PG	
5	14		X						0 - 14	N	—	—		X			BCP/PGS	
6	9	X							0 - 9	N	—	—		X			BCP/PSM	
7	12		X						1 - 12	N	—	—		X			BCP/PGM	
									-									
									-									
									-									
									-									

SHEEN COLOR: B = Brown; R = Rainbow; S = Silver; N = None

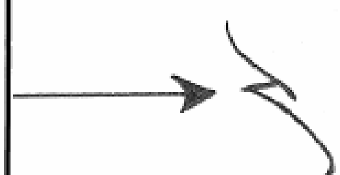
SKETCH MAP

Segment Location northeastern Evans Island
Segment No EVO37A
Date July 14, 1997
Names D. Munson, (ADEC)
J. Ginter (Easton Environmental)
Larry Evanoff (Chenega)

Legend

1 △ Pit Number No Subsurface Oil

2 ▲ Pit Number Susurface Oil



Appendix F Recovered Oil Estimate

Sorbent Material		Batch #	Weight of sample before extraction (kg)l	Lab sample ID#	Weight of PES-51 used for extraction (kg)	Concentration of oil in sample (mg/kg)	Concentration of PES in sample (mg/kg)	Weight of oil in sorbent batch (kg)	Weight of oil in total sorbent material type (kg)	Volume of oil in sorbent type (gallons)	Average Volume of oil in sorbent type (gallons)
Sweep		SW01	7.843	CS003	4.2536	51000	600	0.2144	37.143	10.400	
sample weight (kg):	14.95		7.843	CS004	4.2536	56000	600	0.2356	40.827	11.432	
total weight (kg):	1358.84		7.843	CS005	4.2536	54000	600	0.2271	39.354	11.019	
sample %:	1.100	SW02	7.107	CS006	4.2536	38000	600	0.1591	30.417	8.517	
			7.107	CS007	4.2536	38000	600	0.1591	30.417	8.517	
			7.107	CS008	4.2536	41000	600	0.1718	32.856	9.200	**9.8**
Pads		PD06	5.658	CS009	5.10432	70000	600	0.3542	218.045	61.053	
sample weight (kg):	51.9777		5.658	CS010	5.10432	72000	600	0.3644	224.328	62.812	
total weight (kg):	3482.66		5.658	CS011	5.10432	74000	600	0.3747	230.612	64.571	
sample %:	1.492	PD03	10.971	CS012	8.5072	53000	600	0.4458	141.509	39.622	
			10.971	CS013	8.5072	52000	600	0.4373	138.808	38.866	
			10.971	CS014	8.5072	54000	600	0.4543	144.209	40.379	
		PD04	11.1642	CS015	8.5072	68000	600	0.5734	178.867	50.083	
			11.1642	CS016	8.5072	57000	600	0.4798	149.675	41.909	
			11.1642	CS017	8.5072	56000	600	0.4713	147.021	41.166	
		PD05	11.431	CS018	8.5072	53000	600	0.4458	135.814	38.028	
			11.431	CS019	8.5072	47000	600	0.3947	120.263	33.674	
			11.431	CS020	8.5072	49000	600	0.4117	125.447	35.125	
		PD01	2.8405	CS021	2.97752	21000	600	0.0607	74.473	20.853	
			2.8405	CS022	2.97752	23000	600	0.0667	81.775	22.897	
			2.8405	CS023	_ 2.97752	25000	600	0.0727	89.076	24.941	
		PD02	9.913	CS024	9.35792	30000	600	0.2751	96.657	27.064	
			9.913	CS025	9.35792	31000	600	0.2845	99.944	27.984	
			9.913	CS026	9.35792	35000	600	0.3219	113.095	31.667	**39.0**
Snare		PP01/02									
sample weight (kg):	18.5702		18.5702	CS028	9.35792	69000	600	0.6401	37.799	10.584	
total weight (kg):	1096.64		18.5702	CS029	9.35792	12000	600	0.1067	6.300	1.764	
sample %:	1.693		18.5702	CS030	9.35792	38000	600	0.3500	20.668	5.787	**6.0**
Sorbent boom		SB02	6.578	CS031	5.95504	19000	600	0.1096	24.704	6.917	
sample weight (kg):	14.122		6.578	CS032	5.95504	23000	600	0.1334	30.074	8.421	
total weight (kg):	1483.04		6.578	CS033	5.95504	17000	600	0.0977	22.018	6.165	
sample %:	0.952	SB01	7.544	CS034	5.10432	13000	600	0.0633	12.443	3.484	
			7.544	CS035	5.10432	15000	600	0.0735	14.449	4.046	
			7.544	CS036	5.10432	16000	600	0.0786	15.453	4.327	**5.6**
SKOR boom		SK01	8.786	CS037	1.70144	39000	600	0.0653	12.667	3.547	
sample weight (kg):	18.814		8.786	CS038	1.70144	38000	600	0.0636	12.337	3.454	
total weight (kg):	1703.38		8.786	CS039	1.70144	40000	600	0.0670	12.997	3.639	
sample %:	1.105	SK02	10.028	CSO40	1.70144	20000	600	0.0330	5.607	1.570	
			10.028	CSO41	1.70144	20000	600	0.0330	5.607	1.570	
			10.028	CS042	1.70144	20000	600	0.0330	5.607	1.570	**2.6**
										Total	**63.0**

NORTHERN TESTING LABORATORIES, INC.

3330 INDUSTRIAL AVENUE FAIRBANKS, ALASKA 99701 (907) 456-3116 • FAX 456-3125
8005 SCHOON STREET ANCHORAGE, ALASKA 99518 (907) 349-1000 • FAX 349-1016

September 17, 1997

Jason Ginter
Easton Environmental 418
Harris St. Juneau, AK
99801

Dear Jason:

The samples that were received by Northern Testing Laboratories, Inc. were a mixture of a petroleum product and a solvent, PES-5 1. The analysis for Total Petroleum Hydrocarbons by EPA Method 1664 was not possible due to sample matrix. The sample was soluble in hexane, however, the solvent has a higher boiling point than hexane, therefore, sample preparation and gravimetric determination was not possible.

Since it was determined that the sample extracts were produced by a solvent extraction, it followed that it was necessary to separate the solvent, PES-5 1, from the petroleum product. Laboratory experimentation found that the solvent was volatile at a lower temperature than typical heavy hydrocarbons (140°C). An approximate concentration of petroleum product was determined by heating a tared portion of the sample to 145°C. The mass of this residual was then compared to the sample portion to determine the percentage of the petroleum product. A solvent blank of PES-51 was prepared to determine residual solids for a baseline comparison with sample results. This is consistent with liquid-liquid and liquid-solid extractions followed by gravimetric determination as per EPA Method 1664. However, EPA Method 1664 was modified due to the solvent extraction having been performed in the field. Also, the solvent used was not hexane and the samples were not treated with a silica gel clean-up.

If you have any questions, please feel free to contact me at (907) 349-1000.

Sincerely,
Northern Testing Laboratories, Inc.

Stephanie Cowling
Quality Assurance Manager

NORTHERN TESTING LABORATORIES, INC.

3330 INDUSTRIAL AVENUE FAIRBANKS, ALASKA 99701 (907) 456-3116 • FAX 456-3125
8005 SCHOON STREET ANCHORAGE, ALASKA 99518 (907) 349-1000 • FAX 349-1016

Easton Environmental
418 Harris St.
Juneau, AK 99801
Attn: Jason Ginter

PES-51 Cleanup
Total Petroleum Hydrocarbons Analyzed by EPA Method 1664 (Modified)

Client ID	NTL ID	Matrix	Result	Units	Date Sampled	Time Sampled	Date Arrived	Date Analyzed
CS001	A151363	Solvent	0.06	% by wt.	08/18/97	1530	08/18/97	08/20/97
CS002	A151364	Solvent	1.70	% by wt.	08/18/97	1530	08/18/97	08/20/97
CS003	A151446	Extract	5.10	% by wt.	08/20/97	1510	08/22/97	09/02/97
CS004	A151447	Extract	5.60	% by wt.	08/20/97	1510	08/22/97	09/02/97
CS005	A151448	Extract	5.40	% by wt.	08/20/97	1510	08/22/97	09/02/97
CS006	A151449	Extract	3.80	% by wt.	08/20/97	1535	08/22/97	09/02/97
CS007	A151450	Extract	3.80	% by wt.	08/20/97	1540	08/22/97	09/02/97
CS008	A151451	Extract	4.10	% by wt.	08/20/97	1540	08/22/97	09/02/97
CS009	A151452	Extract	7.00	% by wt.	08/21/97	0920	08/22/97	09/02/97
CS010	A151453	Extract	7.20	% by wt.	08/21/97	0920	08/22/97	09/02/97
CS011	A151454	Extract	7.40	% by wt.	08/21/97	0920	08/22/97	09/02/97
CS012	A151455	Extract	5.30	% by wt.	08/21/97	1030	08/22/97	09/02/97
CS013	A151456	Extract	5.20	% by wt.	08/21/97	1030	08/22/97	09/02/97
CS014	A151457	Extract	5.40	% by wt.	08/21/97	1030	08/22/97	09/02/97
CS015	A151458	Extract	6.80	% by wt.	08/21/97	1145	08/22/97	09/02/97
CS016	A151459	Extract	5.70	% by wt.	08/21/97	1145	08/22/97	09/02/97
CS017	A151460	Extract	5.60	% by wt.	08/21/97	1145	08/22/97	09/02/97
CS018	A151461	Extract	5.30	% by wt.	08/21/97	1230	08/22/97	09/02/97
CS019	A151462	Extract	4.70	% by wt.	08/21/97	1230	08/22/97	09/02/97
CS020	A151463	Extract	4.90	% by wt.	08/21/97	1230	08/22/97	09/02/97
CS021	A151464	Extract	2.10	% by wt.	08/21/97	1350	08/22/97	09/02/97
CS022	A151465	Extract	2.30	% by wt.	08/21/97	1350	08/22/97	09/02/97
CS023	A151466	Extract	2.50	% by wt.	08/21/97	1350	08/22/97	09/02/97
CS024	A151467	Extract	3.00	% by wt.	08/21/97	1530	08/22/97	09/02/97
CS025	A151468	Extract	3.10	% by wt.	08/21/97	1530	08/22/97	09/02/97
CS026	A151469	Extract	3.50	% by wt.	08/21/97	1530	08/22/97	09/02/97
CS027	A151470	Water	0.07	% by wt.	08/22/97	0940	08/22/97	09/02/97
CS028	A151471	Extract	6.90	% by wt.	08/22/97	1005	08/22/97	09/02/97
CS029	A151472	Extract	1.20	% by wt.	08/22/97	1005	08/22/97	09/02/97
CS030	A151473	Extract	3.80	% by wt.	08/22/97	1005	08/22/97	09/02/97
CS031	A151474	Extract	1.90	% by wt.	08/22/97	1050	08/22/97	09/02/97
CS032	A151475	Extract	2.30	% by wt.	08/22/97	1050	08/22/97	09/02/97
CS033	A151476	Extract	1.70	% by wt.	08/22/97	1050	08/22/97	09/02/97
CS034	A151477	Extract	1.30	% by wt.	08/22/97	1140	08/22/97	09/02/97
CS035	A151478	Extract	1.50	% by wt.	08/22/97	1140	08/22/97	09/02/97

Reported By: Daniel J. Bacon
Operations Manager

NORTHERN TESTING LABORATORIES, INC.
3330 INDUSTRIAL AVENUE FAIRBANKS, ALASKA 99701 (907) 456-3116 • FAX 456-3125
8005 SCHOON STREET ANCHORAGE, ALASKA 99518 (907) 349-1000 • FAX 349-1016

Easton Environmental
418 Harris St.
Juneau, AK 99801
Attn: Jason Ginter

PES-51 Cleanup
Hydrocarbons anal zed by EPA 1664 (Modified)

Client ID	NTL ID	Matrix	Result	Units	Date Sampled	Time Sampled	Date Arrived	Date Analyzed
CS036	A151479	Extract	1.60	% by wt.	08/22/97	1140	08/22/97	09/02/97
CS037	A151480	Extract	3.90	% by wt.	08/22/97	1205	08/22/97	09/02/97
CS038	A151481	Extract	3.80	% by wt.	08/22/97	1205	08/22/97	09/02/97
CS039	A151482	Extract	4.00	% by wt.	08/22/97	1205	08/22/97	09/02/97
CS040	A151483	Extract	2.00	% by wt.	08/22/97	1220	08/22/97	09/02/97
CS041	A151484	Extract	2.00	% by wt.	08/22/97	1220	08/22/97	09/02/97
CS042	A151485	Extract	2.00	% by wt.	08/22/97	1220	08/22/97	09/02/97
CS043	A151486	Pads	4.90	% by wt.	08/21/97	1500	08/22/97	09/02/97
CS044	A151484	Pads	5.40	% by wt.	08/21/97	1500	08/22/97	09/02/97

Reported By: Daniel J. Bacon
Operations Manager

Appendix G Treatment Rate Calculations

Date	Location	No. of Airknives	Duration (hrs)	Area sq meters	Rate (m2/ak/hr)		
18-Jun	LA020B-1	1	6.25	800	25.6		
19-Jun	LA020B-1	5	6.251	100	3.2		
20-Jun	LA020B-1	4	2.5	250	25.0		
21-Jun	LA020B-2		4.5	375	13.9		
22-Jun	LA020B-3	5	4	480	24.0		
24-Jun	LA020-B-4	4	4	375	23.4		
25-Jun	LA020B-4	4	2.75	225	20.5		
26-Jun	LA020C-1	3	0.75	280	124.4		
28-Jun	LA020C-4	3	1.5	185	41.1		
29-Jun	LA020C-6	4	0.5	400	200.0		
30-Jun'	LA020C-6	5	2.25	440	39.1		
2-Jul	LA020C-7	5	2.5	650	52.0		
3-Jul	LA020C-7	4	2	275	34.4		
5-Jul	LA020C-9	5	2	540	54.0		
7-Jul	LA015C-1	6	2.25	550	40.7		
8-Jul	LA015C-1	5	2	290	29.0		
10-Jul	LA015C-2	5	1.5	600	80.0		
12-Jul	LA015C-2	4	1	150	37.5 j		
14-Jul	LA015C-3	5	2.25	650	57.8		
15-Jul	EV039A-1	4	0.75	400	133.3		
16-Jul 1	EV039A-1	5	3	625	41.7		
18-Jul	EV037-A	4	3.25	850	65.4		
	means	**4.5**	**2 6**	**431.4**	**53.0**	**Avg sq m/air knife/hr**	
					9490	**total m treated**	
					22.0	**injection days**	
					95.9	**avg sq m/air knife/day**	

Appendix H PES-51® MSDS

Section I – Product Identification

Manufacturer's Name:

ACME Soap, Inc. for Practical Environmental Solutions
1206 Fulton Ave.
San Antonio, Texas 78201
(210) 822-4205

After Hours Emergency Assistance: CHEMTREC (800) 424-9300 (U.S.)

Product Name: PES-51™
Chemical Name: Organic Biocleanser
Chemical Family: Organic
Formula: Organic Chemical Mixture
Revision Date: 05/01/2000

Hazard Rating	(HMIS)	Hazard Rating Scale
Health:	1	0 = Minimal
Flammability:	2	1 = Slight
Reactivity:	0	2 = Moderate
Protective:	G	3,4 = Serious G = Gloves

d-Limonene CAS No.: 5989-27-5 PES Code: 410 Date Issued:03/93

Section II – Physical Data

Appearance and Odor: Clear liquid, variable colorless to light yellowish cast with strong citrus odor
Specific Gravity @25° C: 0.8400
Boiling Point: 325°F (163°C)
Vapor Pressure @ 20° C: 1.9 mm Hg
Vapor Density (Air=1) @20°C: N/1
Solubility in Water: Insoluble
Percent Volatile: 92 + %
Evaporation Rate (ether = 1): Less than 1

Section III – Fire and Explosion Hazard Data

Flash Point (TOC): 124°F (51°C)
Flammable Limits: (@302°F) LEL 0.7%, UEL 6.1%
Extinguishing Media: CO_2 foam and dry chemical
Special Fire Fighting Procedures: SCBA recommended: Smother to exclude air. Do not use water; handle as an oil Fire Class B fire procedures.
Unusual Fire and Explosion Hazards: Combustible liquid; keep away from heat, sparks, and open flames.

Section IV – Health Hazard Data (for d-Limonene component of PES-51™)

Threshold Limit Value (TLV): Undetermined by ACGIH
Permissible Exposure Limit (PEL): Undetermined by OSHA
Following Health Hazard has been Determined: Harmful if swallowed. May be irritating to skin and eyes. Not listed as carcinogen by NTP, OSHA, or LARC. FEMA and FDA list d-Limonene as GRAS, "generally recognized as safe."
Toxicity Testing: RIFM Lists
Acute Oral: LD_{50} (rat)>5g/kg
Acute Dermal: LD50 (rabbit) >5g/kg
Signs and Symptoms of Overexposure: None under conditions of expected use
Medical Conditions Generally Recognized as Being Aggravated by Exposure: None Known
Emergency & First Aid Procedures:
Eyes: Remove contact lenses at once.
Flush with water for at least 15 minutes.
If irritation persists, see a physician.
Skin: Wash with soap and water.
Indigestion: Do not induce vomiting. Get immediate medical attention.
Inhalation: If symptoms of overexposure are experienced, evacuate to fresh air. If symptoms persist, seek medical attention.
Reported Human Effects: Irritation – mildly irritating (none in 10% petrolatum).

Section V – Reactivity Data

Stability: Stable
Conditions to Avoid: Excessive or extreme heat
Incompatible with: Strong oxidizing agents and acidic agents, including clays. Reacts explosively with iodine pentafluroroethylene.
Hazardous Decomposition Products: Smoke may be acrid and fumes irritating. Burning generates CO, CO_2 and smoke. Product is not an oxygen donor.
Conditions to Avoid for Polymerization: Polymerization catalysts such as aluminum chloride

Section VI– Spill, Leak, and Disposal Procedures

Steps to be taken in case material is released or spilled: Soak up on absorbent material. CAUTION: Slippery on floor.
Waste Disposal Method: Incinerate or dispose of in accordance with all local, State, and Federal regulations.

Section VII – Special Protection Information

Respiratory Protection: Not normally required, but if vapor concentration becomes high, use either half or full face respirator mask with organic respirator vapor cartridges. (NIOSH approved)

Ventilation: Local exhaust should be adequate. Mechanical ventilation otherwise recommended, if necessary.

Personal Protective Equipment: Chemical resistant gloves, chemical splash goggles or face shield for eye protection.

Other Protective Equipment: For industrial use, chemically resistant splash proof clothing is recommended.

Appropriate Hygienic Practice: Wash thoroughly with soap and water after handling.

Section VIII – Fire and Explosion Information

Precautions to be Taken in Handling: Usual precautions for combustible liquids.

Handling and Storage Precautions: Keep temperature below 140°F (60°C) for quality control. Avoid acids and oxidizing agents. Store in tightly sealed full containers. Clean up all spills. All handling equipment should be electrically grounded.

Other Precautions: Product may expand slightly in storage causing pressure to build on container. Open container carefully if product appears to be under pressure.

IX – Regulatory Status (for d-Limonene component of PES-51™)

1. FDA lists d-limonene as GRAS – "generally recognized as safe."
2. NTP, OSHA, and IARC do **NOT** list product as carcinogenic to humans.
3. Unused product is **NOT** listed by EPA as hazardous waste (40CFR Part 261).
4. D-limonene is **NOT** listed on California's Prop. 65n toxic substance list.
5. D-limonene is listed on EPA's Chemical Inventory (PL 94-469); however, it is NOT on EPA's CORR (Chemicals of Regulatory Rules) list, which contains those materials which pose a health or environment risk.
6. D-limonene does **NOT** contain lead, cadmium, mercury, or hexavalent chromium or come in contact with these chemicals since it is a citrus derived essential oil produced by steam distillation. Further, d-limonene is packaged in food grade containers with inert liners that do **NOT** contain lead, cadmium, mercury, or hexavalent chromium.
7. D-limonene does **NOT** contain and is **NOT** manufactured with any of the Class I or II ozone-depleting substances listed under the United States Clean Air Act of 1990.
8. Since d-limonene is a combustible liquid, it is hazardous under OSHA 29CFR 1910.120. D-limonene does require MSDS sheets.

Section X – Shipping Classification

Shipping Name:	TERPENE HYDROCARBONS, N.O.S.
Hazard Class:	3 (3.3 for Canada)
ID Number:	UN#2319, NMFC #149980, SUB-1, Class 55
Packaging Group:	III
Highway/Rail:	Per requirements for COMBUSTIBLE LIQUIDS
Air/Ship:	Per requirements for FLAMMABLE LIQUIDS
Emergency Phone Numbers:	**CHEMTREC (800) 424-9300 (U.S.)**

Section XI - Notice

All statements, information and data provided in this material safety data sheet are believed to be accurate and reliable, but are presented without guarantee, or responsibility of any kind, expressed or implied, on our part. Users should make their own investigations to determine the suitability of the information or products for their particular purpose. Nothing contained herein is intended as permission, inducement or recommendation to violate any laws or to practice any invention covered by existing patents.

PES-51™
Oil Release Agent

I. **Name, Brand or Trademark:** PES-51™

II. **Type of Product:** Miscellaneous Oil Spill Control Agent (NCP List: M-12)

Surface Washing Agent
Biological Hydrocarbon Cleanser
Hydrocarbon Stabilizing Agent

III. **Manufacturer:**
Practical Environmental Solutions
117 W. El Prado Drive, Suite 3
San Antonio, Texas 78212
Phone:(210) 822-4205

IV. **Distributors:** *Contact Manufacturer for distributor locations and information.*

V. **Product Statement:**

PES-51™ is a biological hydrocarbon cleanser designed to be used in removing oil from impacted rocks, beaches, concrete, bulkheads, pilings, tanks, oil spill response equipment and other solid surfaces. Once the product is applied by spraying, it forms a product/oil mixture. The product is virtually insoluble in water (less than 50 ppm) and, with a density of 0.84, floats on water. Therefore, the product/oil mixture and any incidental pure product remain on the surface of the water inside the boomed containment area, there to be recovered by traditional methods (skimming, vacuuming, use of absorbent materials, etc). After surface treatment with PES-51™ the product leaves a temporary molecular protein film. This protein film minimizes re-attachment of oil to the treated surface. This product is formulated from 100% naturally occurring components and is completely biodegradable. The product has very specific use instructions and restrictions.

VI. **Mode of Cleansing Action**

PES-51™ is composed of bacterial fermentation by-products that are amphipathic in nature and, when put into combination with d-limonene, form a unique biological mixture with biosurfactant properties. This mixture complexes with the hydrocarbon and decreases the interfacial tension around the oil molecule without changing the surface chemistry of the hydrocarbon. Therefore, the oil/ product mixture is stable and water insoluble. The mixture will not emulsify into the water column.

(Continued)

This non-emulsification property reduces the oil/product mixture's toxicity to aquatic organisms by not allowing the water-soluble fractions to enter the water column. In addition, PES-51™ by itself is virtually insoluble in water (less than 50ppm).

The product leaves a mixed protein type film on all treated surfaces. This film minimizes re-attachment of the hydrocarbon to the treated surface reducing recontamination during the cleanup process. The film is sensitive to nature and begins to degrade within 96 hours.

Because the oil/product mixture does not change the surface chemistry of the hydrocarbon, the mixture is readily adsorbed by oleophyllic/hydrophobic materials (pads, sweeps, snares, booms, etc.) or by conventional skimming or vacuum methods from the water surface.

The d-limonene fraction, a citrus derivative, provides solvent characteristics to the mixture and allows it to penetrate into porous surfaces and extract hydrocarbons. It also acts as a suitable carrier solution and re-odorant for the bacterial by-products.

In summary, PES-51™ technology removes, isolates and maximizes the hydrocarbon recovery from impacted surfaces.

VII. Special Handling and Worker Precautions for Storage and Field Application:

1.Flammability: I24°F (Class 3 - Combustible Liquid)

2.Ventilation: Handle product in a normal well ventilated area. For standard outdoor application procedures, natural ventilation should be adequate. For standard indoor application, local exhaust should be adequate. However, during industrial usage and depending on PES-51™ application technique, mechanical ventilation is recommended where natural ventilation or local exhaust is inadequate or in areas where confined space entry is necessary.

3. Precautionary Measures:

Although PES-51™ is not expected to pose any specific health hazard, the following precautions are recommended due to possible irritation from the citrus and biological derivatives contained in the product. Individual dermal and respiratory sensitivities to the components of PES-51™ will vary. Avoid contact with skin, eyes, and clothing. Use of proper personal protective equipment (PPE) is recommended including chemically resistant clothing, splash goggles, gloves, and boots. Completely decontaminate clothing, shoes or leather goods before re-use or discard. Individual sensitivities and site-specific conditions may warrant the use of a barrier cream in conjunction with PPE selection.

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Avoid prolonged or repeated contact with skin, breathing mist, and do not take internally. Wash thoroughly with soap and water after skin contact. Skin cream may be used to reduce possible irritation. If taken internally, do not induce vomiting. Rinse mouth with water, then drink one glass of water. Contact physician immediately.

Since the Threshold Limit Value (TLV) and Permissible Exposure Limit (PEL) of the d-limonene fraction are undetermined by the ACGIH and OSHA, the use and type of respiratory protection selected will be a Health & Safety officer site specific decision. If vapors become excessive, half or full-face respirators with organic vapor cartridges are recommended. (NIOSH approved)

Keep product away from heat, sparks and flames, and store in a cool, dry, well ventilated place away from incompatible materials. Minimize product exposure to direct sunlight in hot climates.

Vent container in warm weather to relieve pressure.

Do not cut, grind, weld or drill on or near product containers.

Handle empty containers just as you would the full ones.

4. Handling Temperatures:

a. Maximum Storage Temperature: 165°F

b. Minimum Storage Temperature: -142°F

c. Optimum Storage Temperature Range: Not Applicable

d. Temperatures of Phase Separations and Chemical Changes: Not Applicable, however PES-51™ freezes at -142°F.

VIII. PRODUCT CERTIFICATION

PES-51™ is composed of two major fractions: Fraction 1 ("the carrier"-as certified by the manufacturer of the d-limonene) is not listed as a carcinogen by the National Toxicology Program, Occupational Safety and Health Administration, and the International Agency for Research on Cancer. The Federal Emergency Management Agency and Food and Drug Administration list the Product as "generally recognized as safe" (GRAS). Fraction 2 ("the bacterial fermentation by-products") are mixtures of exopolysaccharides, proteins and rhamnolipid type compounds that do not demonstrate any carcinogenic characteristics.

Additionally, since PES-51™ contains bacterial by-products, it is screened to determine that it does not contain overt pathogens and other organisms of concern. PES-51™ meets the guidelines for sanitary

(Continued)

quality as outlined by the United States Department of Agriculture (USDA), which mandates testing for the detection of pathogenic micro-organisms. The Bioremediation Laboratory at the University of Texas at San Antonio (UTSA) conducts quality testing by examining samples utilizing the procedures described in the Standard Methods for the Examination of Water and Wastewater, 17th Edition, 1989. The Bioremediation Laboratory at UTSA is responsible for the following analyses on each sample provided by Practical Environmental Solutions (PES), the manufacturer:

Coliforms	9222D
	9221C (Membrane Filter Method)
Fecal Streptococci	9230C (Membrane Filter Method)
Salmonella	9260B (Qualitative Isolation)
Shigella	9260E (Qualitative Isolation)
Staphylococci	9213B Procedure #3

IX. SHELF LIFE: 6 years (unopened drum), 1 year (opened drum).

X. RECOMMENDED APPLICATION PROCEDURE

1. Application Method:

The following PES-51™ application methods are applicable for the full range of PES-51™ industrial usages, including shoreline and surface treatment, tank cleaning and equipment decontamination. The selection of the method(s) will be dependent on the level and extent of hydrocarbon contamination, type of oil, and its degree of weathering/emulsion and the nature and type of surface to be treated or cleaned. Equipment availability, logistics and manpower requirements should also be considered. Application methods may be combined, if necessary. In addition, for shoreline cleaning, the treatment area will be boomed and contained prior to PES-51™ usage. For equipment decontamination the use of portable decon pools or secondary containment liners are recommended.

PORTABLE EQUIPMENT

A. Hand Held Spraying

Spray PES-51™ on the contaminated area using a Chapin Steel Spray #1729 (or equivalent), 2.5 gallons capacity, or the AU 8000 MicroNair sprayer. After application, allow 3 to 5 minutes for soaking without allowing evaporation of PES-51™ (weather dependent). When saturation is attained, hydrocarbon will be seen running off the impacted surface.

Rinse the treated surface with available water (fresh or sea water) from the pump until no hydrocarbon remains.

(Continued)

The water should be used at ambient temperature. Depending on level and extent of contamination, a pressure washer may also be used for rinsing (ambient may be used).

Collect the effluent hydrocarbons with absorbent booms and pads and squeeze off the oil contaminants from the booms and pads for reuse as process oil.

B. Airless Sprayer

Depending on the level and extent of the hydrocarbon contamination and the nature of the impacted surface, an airless type sprayer may be used for direct product application. Common types of airless sprayers are: Airlessco, Graeco or equivalents. These airless sprayers can have single or multi-hose attachments and can include wand extensions as required. Application rate and pressure will vary depending on equipment type and site-specific conditions.

After spraying with PES-51™, allow to soak for 3 to 5 minutes (weather dependent) avoiding evaporation, rinse/flush surfaces with pumps, fire hoses, deluge headers or pressure washers (ambient).

C. Pressure Washer with Syphon Feed System

Depending on the level and extent of the hydrocarbon contamination and the nature of the impacted surface proposed for treatment, a pressure washer may be used for direct product application. In most applications hot water (greater than 120 °F) is not necessary. Common types of pressure washers are: Hotsy and Lambda, or equivalents. These pressure washers have a variable rate "detergent syphon feed" system for PES-51™ application and can have single or multi-hose attachments which can include wand extensions. Application rate and pressure will vary depending on equipment type and site specific conditions.

After spraying with PES-51™ allow to soak for 3 to 5 minutes (weather dependent) avoiding evaporation, rinse/flush surfaces with pumps, fire hoses, deluge headers or pressure washers (ambient).

D. Air Knife (Modified for PES-51™ Application)

PES has developed a patent-pending modified air knife system for product application. This method was developed primarily for rocky, cobble, bedrock type shorelines with both surface and subsurface oil. The modified air knife delivers the PES-51™ in both a liquid stream (125 psi) or as an aerosol. Compressed air is used to dilate subsurface sediments and allow for distribution of the PES-51™. The air knife method is also applicable for surface treatment of impacted rocks, bulkheads, seawalls, rip-rap jetties, etc.

(Continued)

After spraying with PES-51™, allow to soak for 3 to 5 minutes (weather dependent) avoiding evaporation, rinse/flush surfaces with pumps, fire hoses, deluge headers or pressure washers (ambient). For subsurface treatment, continue flushing with large quantities of low-pressure seawater at ambient temperatures.

MOBILE EQUIPMENT

A. Boat Spraying Procedure

The recommended application rate is 1 to 5 gallons per 200 sq. ft. from a boat with speed of 1 to 3 knots, depending on the sea conditions and oil film thickness on the rocks. For a boat with amounted AU-8110 MicroNair sprayer (or equivalent sprayer) and a spray swath of about 20 feet, travelling at approximately two knots, 25 acres per hour will be treated.

After spraying, rinse PES-51™ off the rocks with a hard, coarse spray of sea water. Standard size pumps with fire hoses or deluge headers may be used. Higher pressure rinses may be required if oil is thick and weathered. The shoreline may also be sprayed from the beach side which will force the oil into the containment boom.

B. Helicopter Deployed Spraying Procedure

Aerial spraying can be utilized for shore treatments and pretreatment with the AU 5000 atomizer (MicroNair), or equivalent sprayer.

The recommended aerial application rate for PES-51™ is 14 to 23 liters per minute. The AU 5000 (or equivalent) can be used with fixed-wing aircraft and helicopter operating at speeds of 90 MPH (145 km per hr) and more. The smaller AU 7000 sprayer (or equivalent) is recommended for use at airspeeds below 90 MPH.

After spraying, the hydrocarbons can then be rinsed off the shore rocks as described above with hand held pumps, deluge headers or boat spraying.

C. Vehicular Spraying

The recommended vehicular spraying is 50 to 150 square feet per gallon depending on climatic conditions. A MicroNair vehicle-mounted sprayer is recommended. This unit is a self contained sprayer kit that combines the AU 8000 spray head (or equivalent) with a powerful 4-stroke engine and a 60 liter chemical tank to give complete product coverage.

(Continued)

After spraying, the hydrocarbons can then be rinsed off the shore rocks as described above with hand held pumps, deluge headers or boat spraying.

2. Concentration/Application Rate:

The product comes already mixed and ready for use.

Product coverage and application method will vary with the level and extent of contamination and type of surface proposed for treatment (rocks, concrete, steel, etc.).

Product coverage will range from approximately 50 to-up-to 200 square feet per gallon.

3. Conditions for Use:

Water temperature (less than 120°F) and salinity do not affect the product performance. PES-51™ is effective against hydrocarbons only, and the age of the hydrocarbon is not relevant.

XI. TOXICITY

MATERIAL TESTED	SPECIES	*LC50 (ppm)
PES-51™	Fundulus heteroclitus Artemia salina	1,425.00 96-hr 665.00 48-hr
No.2 Fuel Oil	Fundulus heteroclitus Artemia salina	5,200.00 96-hr 58.00 48-hr
PES-51™ & No.2 Fuel Oil (1:10)	Fundulus heteroclitus Artemia salina	5,650.00 96-hr 1,542.00 48-hr
Reference Toxicant	Fundulus heteroclitus Artemia salina	7.10 96-hr 5.00 48-hr

*LC50 -Lethal concentration of material that will cause the death of 50% of the test species population.

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XII. PHYSICAL PROPERTIES

1. Flash Point: 124°F(5IOC)
2. Pour Point: -50°F at 30 min. (-58°C)
3. Viscosity: Water thin
4. Specific Gravity: 0.840 at 25°C (77°F)
5. pH: Not applicable
6. Chemical Name and Percentage by Weight of the Total Formulation: *CONFIDENTIAL*
7. Surface Active Agents: *CONFIDENTIAL*
8. Solvents: D-limonene
9. Additives: Biological by-products
10. Solubility: Insoluble

XII. ANALYSIS FOR HEAVY METALS, CYANIDE, AND CHLORINATED HYDROCARBONS

COMPOUND	CONCENTRATION (ppm)	ASTM METHOD
Arsenic	<0.005	7060
Cadmium	<0.01	610
Chromium	<0.05	610
Copper	<0.05	610
Lead	<0.05	610
Mercury	<0.005	7470
Nickel	<0.01	610
Zinc	<0.05	610
Cyanide	<1.00	9010
Chlorinated Hydrocarbons	<0.01	8010