

1.0 Introduction

The Minerals Management Service (MMS) program “Sediment Quality in Depositional Areas of Shelikof Strait and Outermost Cook Inlet,” consisted of a two-year study whose hypotheses and objectives are explored in this report. As part of this study, a scientific crew on board the Research Vessel (R/V) *Alpha Helix*, collected samples for biological, chemical, and toxicological analyses from the program study area during two sampling surveys. The first survey was conducted from July 7 to July 17, 1997 and the second undertaken the following year, from June 27 to July 5, 1998. In this report, the final results including the field sampling and analytical methods are summarized, and the results and interpretation of the chemical, biological, and physical measurements from both the 1997 and 1998 field surveys are presented.

1.1 Background

The purpose of this two-year study was to provide and update environmental information to support future MMS oil- and gas-leasing decisions in the outermost Cook Inlet/Shelikof Strait planning area. Such uses of this information include environmental risk assessments, environmental impact statements, and other pre- and post-leasing decision documents. This study was initiated to establish baseline environmental conditions prior to any oil- and gas-leasing activities. The results of the entire two-year field survey data are described in this report.

The literature on the study area has been reviewed and summarized as part of this program (Boehm *et al.*, 1998) and an excerpt appears below.

1.1.1 Physical Setting

Cook Inlet is a large tidal estuary, 350 km long and ranging from 20 to 90 km wide. The average water depth is approximately 60 m, varying from 100 m near the entrance to less than 20 m near the head of the estuary (Arthur D. Little, 1995). It is bordered on the west and northwest by the Alaska Range, on the northeast by the Talkeetna Mountains, and on the southeast by the Kenai-Chugach Mountains. Cook Inlet can be divided into three distinct regions: the head, consisting of Knik and Turnagain Arms; upper Cook Inlet, extending from the Forelands to Point Woronzof; and lower Cook Inlet, from the Forelands to the Gulf of Alaska. Outermost Cook Inlet, as defined by the area encompassing both the Kachemak and Kamishak Bays, from Cape Douglas to the Barren Islands in the Gulf of Alaska, is the potential depositional area on which this study **focused**.

Shelikof Strait is a marine channel situated between the Kodiak Island archipelago and the Alaska Peninsula. Shelikof Strait is approximately 200 km long and 50 km wide. A central trough extending beyond both ends of Shelikof Strait characterizes the sea floor, which has a gradually southwest-sloping central platform bordered by narrow marginal channels. Currents bring sediment into the northwest end of the strait from Cook Inlet, near Cape Douglas, depositing a covering of well stratified sediment throughout the depositional areas of the strait. The complex oceanography and biology of the outermost Cook Inlet and Shelikof Strait are described in detail in the literature study (Boehm *et al.*, 1998) and summarized briefly below.

1.1.2 Oceanography

Interactions of tides and geostrophic, baroclinic, and wind-induced currents with the topography of outermost Cook Inlet and Shelikof Strait provide a complex hydrographic regime that determines the distribution and eventual deposition of particle-associated contaminants released from offshore production platforms in upper Cook Inlet (Hampton *et al.*, 1987). Vigorous, tidal-induced mixing results in strong initial dilution of contaminant inputs at their sources with naturally derived terrigenous materials. The main sources of these natural sediments are several large, glacially influenced rivers emptying into upper Cook Inlet, while, farther south and east in the Inlet and in Shelikof Strait, the Copper River to the east of the study area is the predominant source of suspended sediments. These suspended sediments are transported by the Kenai Current (the Alaska Coastal Current [ACC]) along the Kenai Peninsula into lower Cook Inlet and Kachemak Bay, as well as Shelikof Strait (Hampton, 1985).

The import of inshore flow to Cook Inlet-Shelikof Strait is through the Kennedy and Stevenson Entrances, while offshore flow occurs through these passages as well as the lower end of Shelikof Strait. With the slackening of prevailing winds during the summer months in the Gulf of Alaska, the strong onshore convergence relaxes. As a consequence, cold, nutrient-rich water is upwelled onto the shelf (Strickland and Sibley, 1984) and can be observed in the general area of the passages on either side of the Barren Islands. This upwelled water supports high gross biological productivity in the study area. A large, clockwise gyre develops in eastern Cook Inlet offshore of Kachemak Bay, although net flow is to the southeast through outermost Cook Inlet.

In Shelikof Strait, net flow is also strongly to the southeast; however, mesoscale eddies have also been documented in the surface waters in the northeast portion of Shelikof Strait (Schumacher *et al.*, 1993; Bogard *et al.*, 1994). The main sediment deposition sites in the study areas are the shallows of Kamishak Bay (for sediments transported down the western side of Cook Inlet), Kachemak Bay (with a strong component of Copper River sediments), and some deeper portions of outermost Cook Inlet and Shelikof Strait (Hampton *et al.*, 1987). Other possible sites of sediment deposition of platform materials from upper Cook Inlet include glacier-incised scars in the Kodiak shelf, the shelf slope, and shallow bays on either side of Shelikof Strait. However, local sources become increasingly important with distance from the upper Cook Inlet, and sills limit the depths from which suspended materials may be imported.

1.1.3 Biology

The northern shelf of the Gulf of Alaska is extremely productive, and annual primary productivity in outermost Cook Inlet is greater than 300 g C m^{-2} (Sambrotto and Lorenzen, 1987). The intrusion of cold, nutrient-rich water brought by the ACC into outermost Cook Inlet in late spring and summer, combined with long days, supports vigorous biological activity in the oceanic regime from phytoplankton growth through baleen whale foraging. The Cook Inlet/Shelikof Strait area contains a great variety of biological habitats. Shallow intertidal and subtidal areas are predominantly unconsolidated sediments containing mainly polychaetes, bivalves, crustaceans, and echinoderms (O'Clair and Zimmerman, 1987; Feder and Jewett, 1987). These habitats also support a rich variety of algae and epibenthic invertebrates, and are frequented by nekton, pelagic fishes, nearshore demersal fishes (Rogers *et al.*, 1986), a variety of seabirds, and several species of marine mammals. Rocky habitat is much less common in Cook Inlet and Shelikof Strait, although it predominates on Kodiak Island. The rocky intertidal habitats are dominated by barnacles, limpets, mussels, and snails, a rich variety of attached

algae, other invertebrates, and associated semidemersal fishes (O'Clair and Zimmerman, 1987). The deeper neritic environments are dominated by typical pelagic and nektonic communities, and overlay important benthic environments in the finer unconsolidated sediments, including those expected to be depositional areas for platform-derived contaminants (Hampton *et al.*, 1987). Here the communities are also dominated by polychaetes, crustaceans, echinoderms, and bivalves with a variety of demersal, semidemersal, and associated pelagic fishes. The peculiarities of sediment transport put the main depositional areas for platform-derived contaminants in both shallow water embayments (e.g., Kamishak Bay) and deeper open waters (deeper portions of outermost Cook Inlet, bottom of Shelikof Strait, and shelf slope).

1.2 Objectives

Due to the need to definitively examine the distribution and environmental risk of anthropogenic chemicals (i.e., metals, petroleum hydrocarbons) in advance of any future oil and gas E&P activities that could potentially affect the lower Cook Inlet and Shelikof Strait, MMS established a multi-disciplinary sediment quality evaluation program for the region. The objectives of the overall MMS program were to evaluate:

- The Shelikof Strait and outermost Cook Inlet depositional areas as traps for oil-industry contaminants.
- Whether the contaminant concentrations in sediment of these areas pose an environmental risk.
- Whether contaminants in these areas have accumulated relative to pre-industry concentrations and to determine whether any increases can be correlated to specific discharge events or activities (e.g., the *Exxon Valdez* spill).

1.2.1 Null Hypotheses

Based on the objectives of the program, four null hypotheses were developed. These null hypotheses were finalized at technical meetings held in May 1997 between the Arthur D. Little team, MMS, industry and regulatory representatives (e.g., UNOCAL, Alaska Department of Fish and Game, and U.S. Environmental Protection Agency [EPA]), and other interested parties (e.g., Cook Inlet Regional Citizens' Advisory Council [CIRCAC]).

The hypotheses which form the scientific framework for the study are as follows:

- Hypothesis 1: The offshore area of outermost Cook Inlet and Shelikof Strait is not a trap for organic and metals pollutants (i.e., there is no indication of **net** deposition).
- Hypothesis 2: Concentrations of organic and metal contaminants in sediment cores do not show increases **since offshore oil exploration and production began in Cook Inlet (circa 1963)**.
- Hypothesis 3: Compositions of organics and metals in sediment cores do not show changes in composition (i.e., cannot be correlated with known sources, such as the *Exxon Valdez* oil spill residues) **since offshore oil exploration and production began in Cook Inlet (circa 1963)**.

- Hypothesis 4: Concentrations of organic and metal contaminants in outermost Cook Inlet and Shelikof Strait do not pose an ecological risk to marine organisms as defined by sediment toxicology measurements (i.e., compared to reference sediments), sediment quality criteria, and fish P-450 response.

The study design centered on the testing of these hypotheses. The first year's effort in 1997 focused on sediment quality across the study area. Potential uptake of contaminants by bottom-dwelling fish and resulting indicators of exposure to contaminants were also evaluated by analyzing fish collected from each zone. Based on these results, a number of recommendations were made to enhance the following year's survey in 1998. These included additional source sampling, expansion of the fish species collected, sampling for hydrocarbon degrading microbes, and extending the sampling region to investigate the potential depositional area to the south of Shelikof Strait. In this report, we evaluate the specific objectives and hypotheses based on the entire field survey data.