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DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
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OPEN-FILE REPORT O-89-12

PRELIMINARY FEASIBILITY STUDY: OREGON PLACER MINERALS

Joint State-Federal
Oregon Placer Minerals Task Force

Funded by the U.S. Department of the Interior,
Minerals Management Service

1990

NOTICE

This report is based on results of a program directed by the joint federal-state Oregon Placer Minerals Technical Task Force, managed by the Oregon Department of Geology and Mineral Industries, and funded by the Minerals Management Service, U.S. Department of the Interior, through Cooperative Agreement. Opinions expressed are those of the authors and do not constitute endorsement by the Task Force.

The Oregon Department of Geology and Mineral Industries is publishing this paper because the subject matter is consistent with the mission of the Department. To facilitate timely distribution of information, camera-ready copy submitted by the authors has not been edited by the staff of the Oregon Department of Geology and Mineral Industries.

PREFACE

In September 1989, the Secretary of the Interior and the Governor of Oregon announced the formation of the joint state-federal Oregon Placer Minerals Task Force. The purpose of the task force is to define the extent of black sand deposits offshore Oregon, evaluate their economic and strategic importance, and examine the environmental aspects of their development. The task force, with members and advisors representing government, academia and industry, has met four times during the period October 1988 to January 1990.

The report contained herein constitutes the preliminary feasibility study of the task force. This feasibility study was conducted to determine whether work on Oregon's marine placer minerals should continue based on perceived economic potential and other constraints. The components of this feasibility study include a summary of placer mineral resource information and models, an economic evaluation, an environmental review, a market definition, an economic and strategic analysis, and a set of recommendations for future study. The geological summary (Section 1) and the environmental review (Section 3) were drafted at the College of Oceanography, Oregon State University. The economic evaluation (Section 2) was conducted by the U.S. Bureau of Mines and the remaining sections (4,5, and 6) were written by task force subgroups. The report sections in draft form were made available for public comment at the October 1989 task force meeting. Responses to public and peer review comments on the drafts have been summarized in the appendix to this report.

In addition to the authors of the report sections, acknowledgement should be made to persons who have supported the development of this document. First, the task force appreciates the participation in this process by the citizens of Oregon. Second, the task force acknowledges the support of the coordinators, Mike Carter, Dennis Olmstead, and Greg McMurray. Funding for the task force was provided by the Department of the Interior, Minerals Management Service, Office of Strategic and International Minerals, through Cooperative Agreement No. 14-12-0001-30462 with the State of Oregon, Department of Geology and Mineral Industries.

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OPEN FILE REPORT 0-89-12

PRELIMINARY EVALUATION OF HEAVY-MINERAL CONTENT OF CONTINENTAL SHELF PLACER DEPOSITS OFF CAPE BLANCO, ROGUE RIVER, AND UMPQUA RIVER

by

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1990

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Summary

In 1988 the Secretary of the Interior and the Governor of Oregon formed a joint State-Federal Placer Task Force to evaluate the possible economic and strategic importance of potential heavy-mineral placer deposits on the southern Oregon continental shelf. High concentrations of heavy minerals in the surface deposits contain variable amounts of chromium-bearing chromite, titanium-bearing ilmenite, zirconium-bearing zircon, garnet, and gold. Three potential offshore placers, Cape Blanco, Rogue River, and Umpqua River, were jointly selected by the College of Oceanography, Oregon State University, and the U.S. Bureau of Mines, Western Field Operations Center, Spokane, WA, for an economic evaluation.

The College of Oceanography provided the following parameters to the Bureau of Mines, who conducted the economic evaluation of the three offshore placers (Wetzel and Stebbins, this volume): (1) dimensions of placer deposit, (2) probable type and grade of the various heavy minerals, (3) sediment overburden, (4) water depths of the deposits, and (5) distance to port from placer deposit.

Two models, the Heavy-Mineral Model and the Magnetic Model, were formulated to provide constraints on the economic evaluation. The former model utilizes the total surface area of heavy-mineral concentrations (halos) present in the surface sediments and should produce the maximum size for the Cape Blanco, Rogue River, and Umpqua River shelf placers. It assumes a 5-m-thick layer of placer material containing an average 2.5 and 5.0 weight percent opaque minerals for halos with 10 to 20 percent and >20 percent heavy minerals, respectively. The latter model utilizes the width and length of magnetic anomalies present over the heavy-mineral halos and should represent the minimum size of the placers for the Cape Blanco and Rogue River. It uses a 5-m-thick layer containing an average of 40 weight percent opaque minerals. The opaque (magnetite, chromite, ilmenite) and nonopaque (zircon and garnet) mineralogy of the shelf surface deposits were used to determine the mineral tonnages present in each placer, with the exception of the Cape Blanco placer, where the garnet content from the onshore Pioneer terrace placer was utilized.

The bulk elemental composition of the opaque minerals (i.e., chrome and titanium) was determined previously by Instrumental Neutron Activation Analysis (Kulm and Peterson, 1988). The opaque-mineral composition (i.e., titanium oxide and chromium oxide) of individual mineral grains was determined by electron microprobe in this study. Nonopaque-mineral contents of zircon and garnet were determined with a petrographic microscope in the surface sediments of the shelf. Off Cape Blanco, the average titanium oxide content of ilmenite grains is 44.62 and 43.42 weight percent for samples taken in waters of 21 and 27 m, respectively. The average chromium oxide content of chromite grains is 35.73 and 29.93 weight percent for the same samples. Off the Rogue River the average titanium oxide content is 47.36 and 41.88 weight percent for samples taken in water depths of 17 m and 70 m, respectively. The average chromium oxide content is 26.91 and 34.46 weight percent for the same samples. Off the Umpqua River the titanium oxide content averages 43.92 weight percent and the chromium oxide 41.61 weight percent .

Using the Heavy-Mineral Model, ilmenite is the dominant tonnage (9,247,000 metric tons; 10,171,700 short tons), followed by garnet (5,519,000; 6,070,900), magnetite (4,325,000; 4,757,500), chromite (1,343,000; 1,477,300, and zircon (895,000; 984,500) in the Cape Blanco placer. In the Rogue River placer, magnetite and ilmenite are characterized by nearly equal tonnages (31,132,000 and 31,911,000 metric tons; 34,245,200 and 35,102,100 short tons, respectively) with about half as much chromite (14,788,000; 16,266,800) and much smaller amounts of garnet (3,892,000; 4,281,200) and zircon (778,000; 855,800). In the Umpqua placer, ilmenite (31,329,000 metric tons; 34,461,900 short tons) is three times as abundant as magnetite (9,494,000; 10,443,400), with essentially co-equal amounts of chromite and garnet (6,646,000 and 6,076,000 metric tons; 7,310,600 and 6,683,600 short tons, respectively) and a much smaller quantity of zircon. Ilmenite (72,487,000 metric tons; 79,735,700 short tons) is three times more

abundant than chromite (22,777,000 metric tons; 25,054,700 short tons) in the three areas combined. Garnet and zircon decrease in abundance from the Umpqua River placer to the Rogue placer. The large total surface area represented by the heavy-mineral halos in the surface sediment probably overestimates the total tonnage of the placers because seasonal storm waves can redistribute the surface sediments on the shelf, scattering the heavy minerals, which may create somewhat larger halos.

Using the Magnetic Model, ilmenite is the dominant tonnage (1,354,000 metric tons; 1,489,400 short tons) with lesser amounts of garnet (808,000; 888,800), magnetite (633,000; 696,300), chromite (197,000; 216,700), and zircon (131,000; 144,100) in the Cape Blanco placer. In the Rogue River placer ilmenite (2,005,000 metric tons; 2,205,500) and magnetite (1,957,000; 2,152,700) are present in nearly equal amounts followed by chromite (929,000; 1,021,900), garnet (245,000; 269,500), and zircon (49,000; 53,900). No data is available for the Umpqua River placer. Mineral tonnages for ilmenite and chromite in the Magnetic Model are a factor of seven and ten less, respectively, than in the Heavy-Mineral Model because of the much smaller surface area. It is difficult to derive a reliable estimate of the total tonnage of the potential placer deposits off the Cape Blanco and Rogue River areas using the Magnetic Model because the offshore magnetic survey tracklines are widely spaced and intermittent. This model probably underestimates the total tonnage of the potential placer deposits.

This report attempts to constrain the upper limit of the tonnages of potential heavy mineral placer deposits on the continental shelf based upon surface and near-surface heavy-mineral data and assumed thickness in the subsurface deposits. These potential placer deposits should be vibra-cored in selected localities on the southern Oregon shelf to determine the three-dimensional character of the placer deposits and to more precisely ascertain their economic value.

Introduction

A joint State-Federal Placer Task Force was formed in October 1988 to evaluate the possible economic and strategic importance of the black-sand placer resources on the Oregon continental shelf. Previous marine studies indicate that these potential placer deposits contain the chromium-bearing chromite, titanium-bearing ilmenite, zirconium-bearing zircon and garnet, and the metal gold.

The College of Oceanography, Oregon State University, was contracted to produce selected parameters for each of three potential placer deposits located on the southern (Rogue River and Cape Blanco areas) and south-central (Umpqua River area) Oregon continental shelf. To provide constraints on these models, the College of Oceanography, Oregon State University, provided a number of parameters to the U.S. Bureau of Mines, Western Field Operations Center, Spokane, WA, who conducted the economic modeling studies. These parameters include: (1) dimensions of placer deposits, (2) probable type and grade of the various heavy minerals, (3) sediment overburden, (4) water depths of the deposits, and (5) distance to port from the placer deposit. The U.S. Bureau of Mines then conducted a preliminary economic appraisal of the potential heavy-mineral placer deposits on the southern Oregon continental shelf (Wetzel and Stebbins, this volume).

The contract period extended from December 27, 1988, to March 17, 1989. This Open-File Report was completed in June 1989 following a review of the Oregon State University and Bureau of Mines preliminary results by the State-Federal Task Force on May 25, 1989.

Preliminary estimates of heavy-mineral tonnages from these potential placer deposits were derived using a combination of offshore and onshore data described in this report. Because of the lack of subsurface data on the continental shelf deposits, high-resolution magnetic surveying and deep vibra-coring of the offshore heavy-mineral concentrations and associated magnetic anomalies are required to establish the thickness and concentration of heavy-mineral placer deposits on the continental shelf and their ultimate economic potential.

This study utilizes both unpublished and published data that were obtained from the College of Oceanography sediment sample and data archives.

Relevant Studies

Beach Placers

Three modern beach deposits were studied for mineral composition in the vicinity of Cape Blanco (42.84° N latitude) including the Port Orford beach placer (42.73° N, >66 percent opaque minerals), the Cape Blanco beach sand (42.84° N, nonplacer deposit) and the Sacci beach placer (43.21° N, >59 percent opaque minerals) (Figure 1). Opaque minerals and nonopaque minerals (zircon and garnet) were examined for relative abundance with the aid of a petrographic microscope (Peterson and Binney, 1988). The relative abundances of the different opaque minerals (magnetite, chromite, and ilmenite) were determined by major element analyses (INAA) and major element partitioning based on preliminary microprobe analysis of beach and terrace opaque minerals (Table 1; Peterson and others, 1987). Since the individual opaque minerals are measured as a percent of the total opaque-mineral fraction, it is convenient to also normalize garnet and zircon to the abundance of the opaque-mineral fraction, even though these relations are not co-linear over wide compositional ranges. The relative abundances of the economic placer minerals in these deposits were averaged to yield representative beach placer compositions, which were used only as a guide to formulate the placer models utilized for the offshore deposits described in this report.

A magnetometer survey was made on a well-defined modern beach placer on the south side of the headland at Otter Rock, central Oregon (44.67° N latitude, Figure 1). Magnetic anomalies ranging

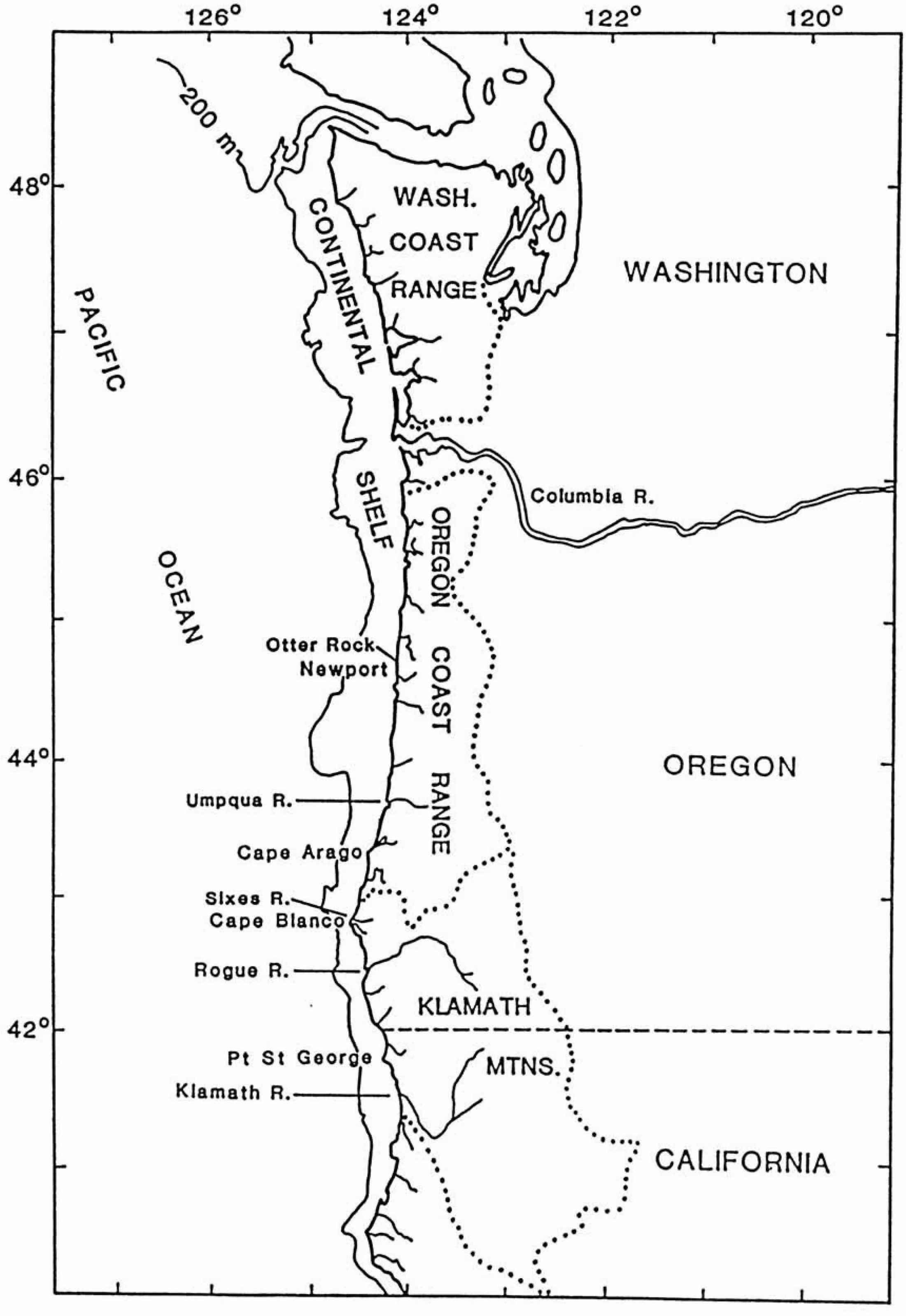


Figure 1. Location map of southern Oregon continental shelf and adjacent coastal region.

Table 1. Beach and Terrace Placer Mineral Composition

Placers	Opaque:total (ratio)	Opaque (% of total)	Magnetite:opaque (ratio)	Magnetite (% of total)	Ilmenite:opaque (ratio)	Ilmenite (% of total)
Top Beach Placer	NA	NA	NA	NA	NA	NA
Bottom Beach Placer	0.65	65	0.24	15.60	0.6	39.00
Top Pioneer Terrace	0.05	5	NA	NA	NA	NA
Bottom Pioneer Terrace	0.85	85	0.28	23.80	0.13	11.05

Placers	Chromite:opaque (ratio)	Chromite (% of total)	Garnet:opaque (ratio)	Garnet (% of total)	Zircon:opaque (ratio)	Zircon (% of total)
Top Beach Placer	NA	NA	NA	NA	NA	NA
Bottom Beach Placer	0.16	10.40	0.13	8.45	0.23	14.95
Top Pioneer Terrace	NA	NA	0.06	0.30	0	0.00
Bottom Pioneer Terrace	0.64	54.40	0.27	22.95	0.07	5.95

from 25 to 125 gammas were associated with the underlying sands enriched in ilmenite and other iron-bearing minerals (Peterson and others, 1986). We have measured the magnetic susceptibility of the opaque-mineral fraction of the beach sands of Oregon and found that it is strongly correlated to the magnetite content of the sands. The Otter Rock placer extends about 1,000 m alongshore and 100 m across shore and ranges from >1.5 m to <0.1 m in thickness from the mid-backshore to the lower foreshore, respectively. This elongate and lens-shaped placer contained approximately 80 x 10^3 m^3 of sediment with >50 percent heavy minerals.

Coastal Terrace Placers

Representative sections of the Eagle-Pioneer placer (Peterson and others, 1987) were used to establish top and bottom mineral compositions from this ancient marine-placer deposit (Figure 2). Samples taken from the northern and southern ends of the exposed mine pit averaged 5 percent opaque minerals at the top of the 5-m-thick section and 85 percent opaque minerals in the basal placer layers at the bottom of the section. The abundances of the nonopaque economic minerals (garnet and zircon) relative to the opaque minerals were determined by petrographic microscopy. The relative abundances of the different opaque minerals (magnetite, chromite, and ilmenite) in the basal layer of the Eagle-Pioneer placer were determined by preliminary microprobe analyses (Peterson and others, 1987). The relative abundances of these different opaque minerals were not established for the top of the Eagle-Pioneer section. The average mineral compositions from the bottom of this ancient placer deposit (Table 1) were used only as a guide to formulate the placer models utilized for the offshore deposits described in this report.

A magnetometer survey was made over the black-sand placer deposits of the uplifted marine terraces on the southern Oregon coast (Stephenson, 1945). Most of the measured magnetic anomalies were less than 50 gammas, but they were invariably correlated with the black-sand placers occurring beneath an overburden ranging from a few meters to about 20 m as identified in drill holes along the survey traverses (Figure 3). Placers with an abrupt edge (compared to a tapered edge) produced a strong magnetic effect even though the rest of the placer had no anomalies. This indicates that the magnetic anomalies may represent less than the actual width of the placer deposit. Sufficient magnetic material was present to generate detectable anomalies, although the amount and composition of the heavy minerals varied somewhat from one traverse to another. Magnetometer surveys are a useful tool in the exploration of black-sand placers in the coastal terrace deposits (Stephenson, 1945).

Continental-Shelf Placers

Recent studies conducted by the College of Oceanography, Oregon State University, of heavy-mineral separates from continental-shelf sediment samples have confirmed earlier indications of potential chromite, ilmenite, zircon, and garnet offshore of southern Oregon (Figure 1; Clifton, 1968; Kulm and others, 1968; Chambers, 1969; Kulm, 1988; Kulm and Peterson, 1988; Peterson and others, 1988). The compositional analyses of bulk opaque-mineral separates from the southern shelf were completed earlier by Kulm and Peterson (1988) using Instrumental Neutron Activation Analysis (INAA). These bulk compositional analyses indicate that significant proportions of the opaque-mineral fractions are comprised of chromite and ilmenite. During the present study, elemental analyses were conducted on specific opaque minerals in each of the three shelf areas (Cape Blanco, Rogue, and Umpqua) with an electron microprobe in the College of Oceanography.

Previously published studies of beach placers and ancient placers mined from onshore marine terraces of southern Oregon (Griggs, 1945; Peterson and others, 1987) suggest that black-sand concentrates from this area should also be enriched in garnet, zircon, trace amounts of gold (Clifton, 1968), and platinum. The terrace deposits enriched in heavy minerals (5 to 100 weight percent) range from 1 m to 10 m in thickness and average about 5 m in thickness over the two largest placer deposits on the Seven Devils and Pioneer terraces (Figure 2).

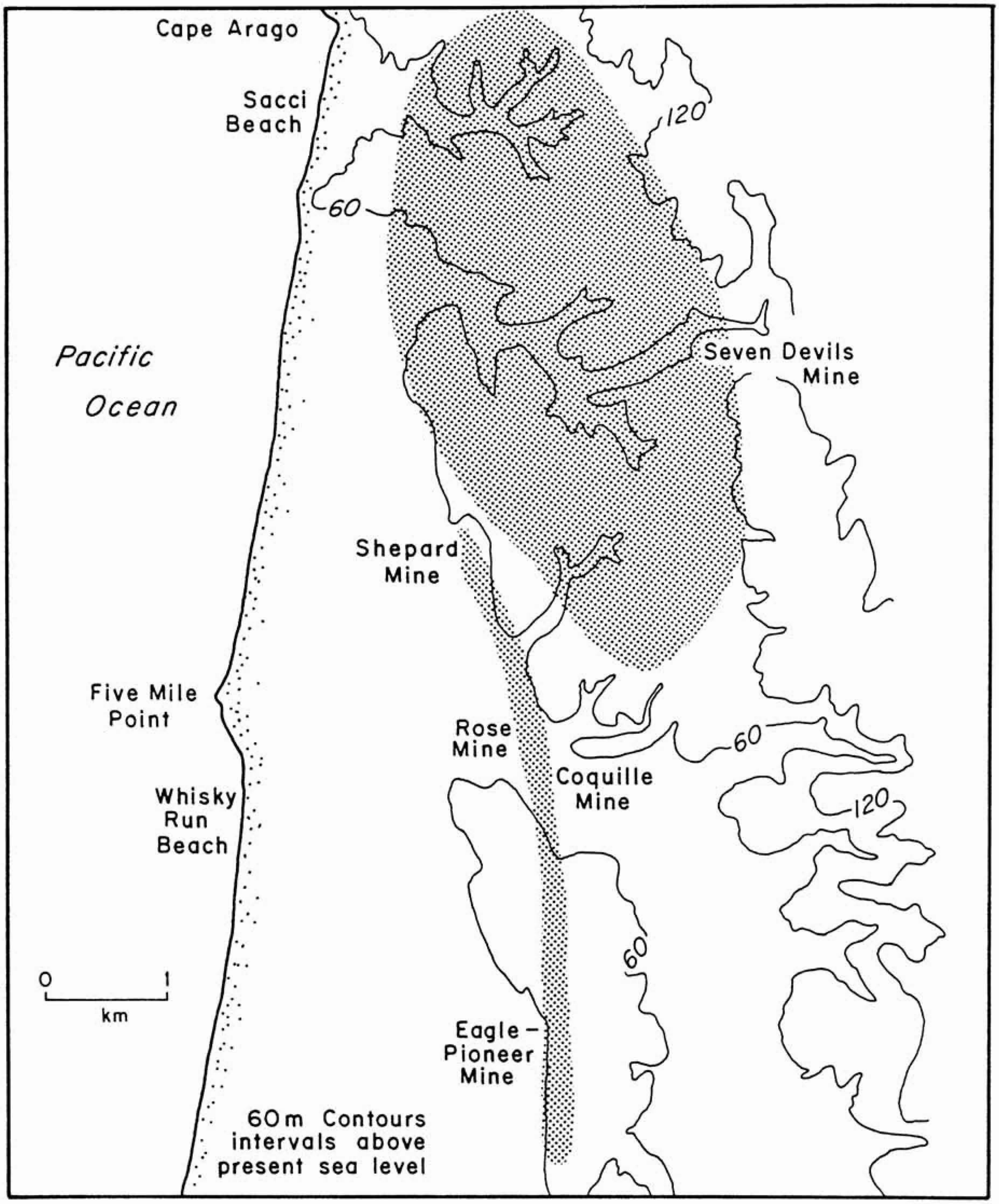


Figure 2. Location of ancient marine placers south of Cape Arago, Oregon (from Peterson and others, 1987). The Seven Devils and Eagle-Pioneer placers are formed on adjacent uplifted terraces of late Pleistocene age. The lower Pioneer placer has been extensively explored and mined for gold.

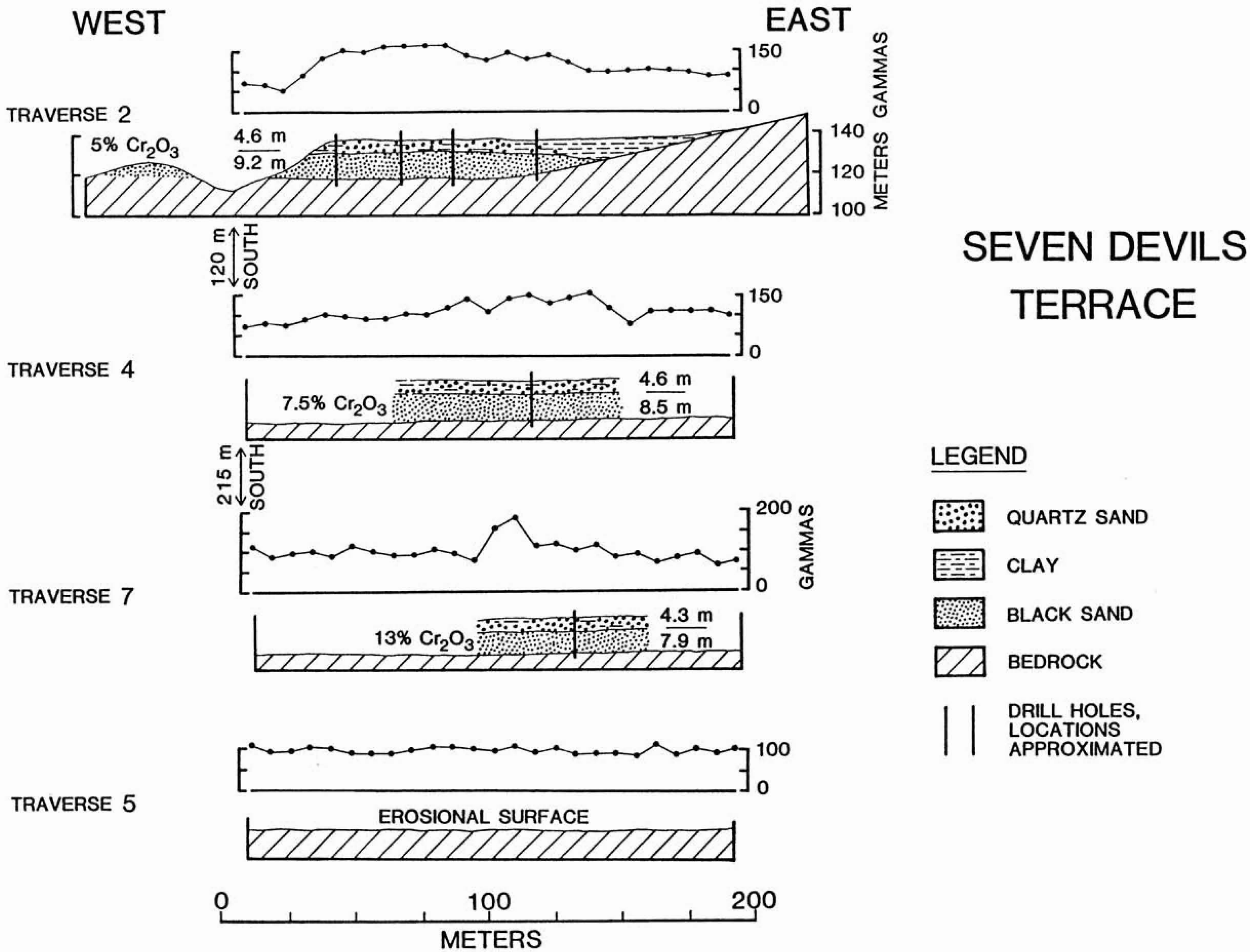


Figure 3. Magnetic survey over selected transects of the marine terrace placers along the southern Oregon coast (drawn from data given in Stephenson, 1945).

Magnetic anomalies associated with zones of high heavy-mineral concentration on the Oregon continental shelf (Kulm, 1988) are now known to be comparable or larger than magnetic anomalies measured over known placer deposits mined from the marine terraces south of Cape Arago (Stephenson, 1945).

Sampling and Physical Characteristics Of Offshore Placer Sites

Three potential offshore placer sites were selected for economic modeling in this study. From south to north, they are located off the Rogue River, Cape Blanco, and Umpqua River areas (Table 2, Figure 4A). The available data for each of these sites is described below.

Seismic Reflection and Magnetic Surveys

A 5000 joule sparker, a 40 cubic inch air gun, and a uniboom seismic system were used to obtain information on the shallow structure and sediment thickness of the continental shelf (Clarke and others, 1985; Kulm, 1988). About 2320 km of these seismic profiles were collected on the southern Oregon shelf. A proton precession magnetometer was towed to measure the magnetic field in the vicinity of selected heavy mineral surface concentrations described later in this report (Kulm, 1988). Several magnetic models were generated with these magnetics data (Kulm, 1988). No sidescan sonar data was collected during these surveys.

Sediment Sampling and Analyses

A variety of equipment (i.e., Smith-McIntyre grab, Shipek sampler, box-corer) was used to obtain samples from the surface and subsurface sediments on the continental shelf off Cape Blanco, Rogue River, and Umpqua River (Kulm, 1988). Box-cores range in length from 10 to 40 cm. All samples were analyzed for their heavy-mineral content (Kulm, 1988) and the majority for their sediment texture. Selected samples were analyzed for their gold content (Clifton, 1968). Textural parameters were determined for the surface and subsurface samples. The sand fraction (>0.062 mm) was analyzed with the Emery (1938) settling tube; the fine fraction (<0.062 mm) was analyzed using a soils hydrometer. Heavy-mineral analyses were made on the sand fraction (>0.062 mm) of the surface and subsurface samples. The heavy-mineral separation was made with tetrabromoethane (specific gravity 2.96). Heavy minerals consist of those minerals of greater than specific gravity 3.0 ($g\ cm^{-3}$) which can be separated by floatation on a liquid such as tetrabromoethane. A colloid solution of tungsten carbide and sodium polytungstate, specific gravity 4.3, was used to isolate the opaque minerals (densities >4.4 $g\ cm^{-3}$). Opaque minerals utilized in this report include chromite, ilmenite, and magnetite; nonopaque minerals are garnet and zircon.

Heavy-Mineral Concentrations

A number of well-defined heavy-mineral concentrations occur in the unconsolidated surface and near-surface sediments on the continental shelf off southern Oregon (Figures 4A, B; Kulm, 1988). Heavy-mineral percentages range from 10 to 56 percent by weight of the total sand fraction. An intermediate sized, relatively high concentration of heavy minerals lies off Cape Blanco and the Sixes River. It is about 13 km long and 6 km wide and occurs in water depths ranging between 18 and 55 m. Concentrations range from 10 percent to a little more than 33 percent in heavy minerals. Farther south, a large-sized, tongue-shaped, relatively high concentration of heavy minerals lies off the Rogue River area from 42° 16' N to 42° 36' N latitude. It is about 37 km long and extends 19 km north and 18 km south of the Rogue River mouth; the concentration is 4 to 17 km wide. Heavy-mineral concentrations range from 10 to 25 percent in heavy minerals. Reasonably well-defined heavy-mineral concentrations also occur in the unconsolidated surface sediments on the continental shelf west of the Umpqua River (Figure 1; Peterson and Binney, 1988). An elongate concentration of heavy minerals lies in an area from 43° 28' N to 43° 49' N latitude (Figure 4A). It is about 40 km long and extends north and south of the Umpqua River mouth; the concentration is 2 to 10 km wide. Heavy-mineral concentrations range from 10 to 20 percent by weight of the total sand fraction.

Table 2. Southern Oregon Continental Shelf Placer Statistics for Heavy-Mineral Model

Shelf Placers	Water depths (meters)	Distance from Coos Bay (naut. miles)	Heavy-mineral concentrations (percent)	Opaque* minerals (percent)	Total area heavy mineral (square km)	Tonnage** placer (metric tons x 10^3)
Cape Blanco	18 - 55	35	10 - 20	2.50	24.1	202,488
			20 - 33	5.00	23.46	197,064
Rogue River	17 - 90	60	10 - 20	2.50	264.85	2,224,740
			20 - 25	5.00	52.88	444,234
Umpqua River	105 - 160	17	10 - 20	2.50	226.04	1,898,727

* Assumed opaque mineral contents of heavy-mineral model
**Calculated tonnages based upon heavy-mineral model.
To convert metric tons to short tons multiply by factor 1.1 (202,488,000 metric tons x 1.1 = 222,736,800 short tons)

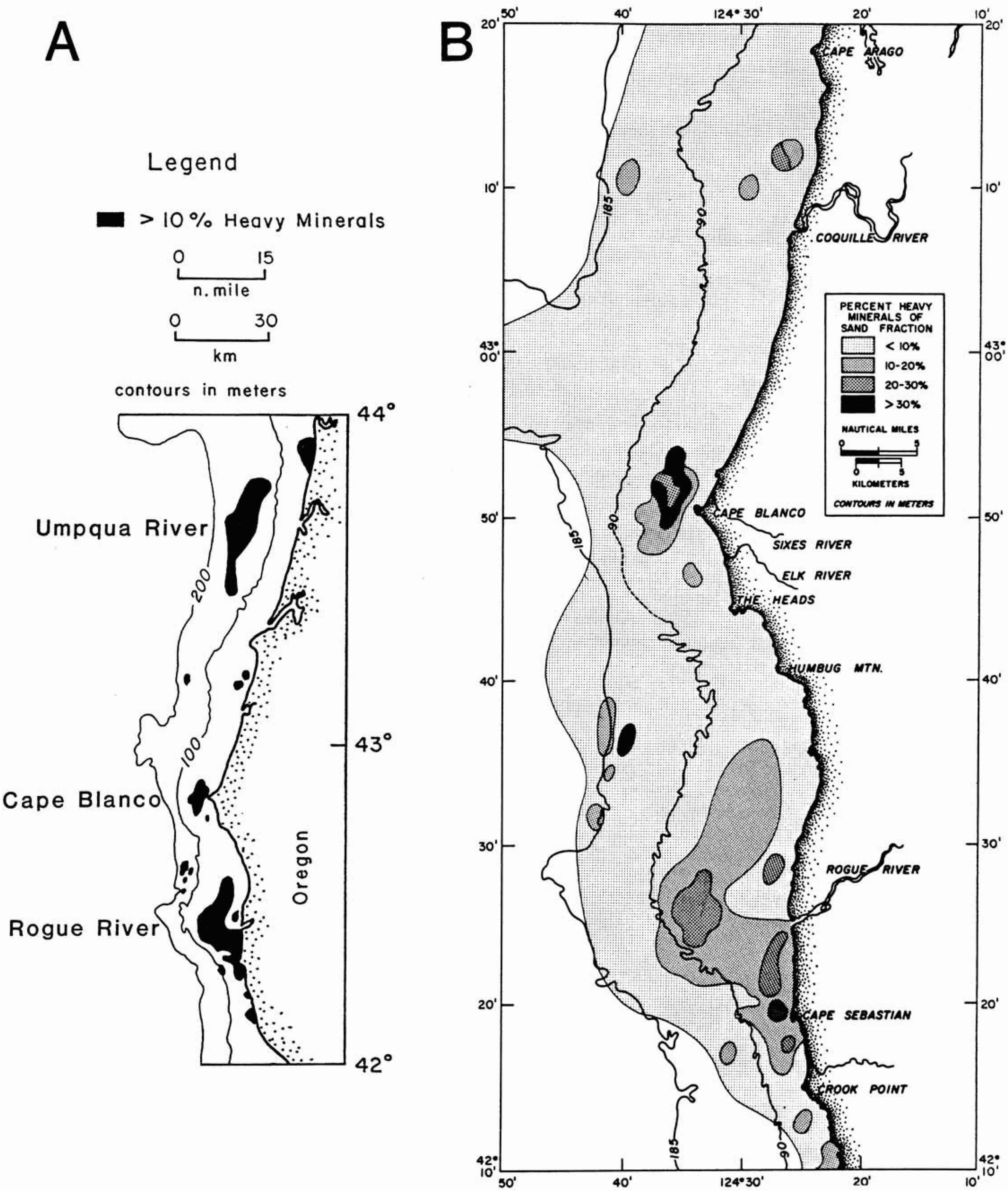


Figure 4A. Heavy-mineral concentrations in the sand fraction of surface sediments of the continental shelf off southern and south-central Oregon; solid pattern indicates heavy-minerals concentrations >10 percent (modified from Peterson and others, 1988).

B. Detailed heavy-mineral concentrations shown in diagram A for Cape Blanco and Rogue River areas off southern Oregon (Kulm, 1988).

Gold Concentrations

A total of 120 surface sediment samples from the shelf off Cape Blanco and the Rogue River were analyzed for their gold content (Clifton, 1968). The samples were collected with grab samplers and box cores. The gold content was derived by analysis of analytical portions preconcentrated from approximately 1000 gram samples of sediment (Clifton and others, 1967, their figure 2). These procedures, which do not include panning, are designed to concentrate all of the gold present in the original sample into the portions that are analyzed by a combination of wet chemical and atomic absorption techniques (with a minimum level of detection of 0.1 to 0.2 parts per million (ppm) gold). The values thus obtained were converted to weight and the combined weight of gold in all the portions was then divided by the weight of the original sample, yielding values in the parts per billion (ppb) range.

Size data for gold on the Oregon shelf (Clifton and others, 1967; Clifton, 1968) and a detailed size analysis is given for gold in an 80-pound sample of sand from a black-sand beach a short distance north of the mouth of the Rogue River (Clifton and others, 1969). These studies indicate that the size distribution of gold in the shelf sand resembles that of gold on the present beaches. The shelf gold ranges in size from about 0.250 to 0.040 mm in diameter and its maximum significant diameter is slightly more than 0.250 mm.

Local concentrations of gold occur in the sandy sediments at water depths shallower than 70 m on the continental shelf. Gold concentrations are extremely low (5 to 150 ppb), but they occur in distinct groups (Clifton, 1968). (For conversion of parts per billion (ppb) to troy ounces, use 300 ppb = 0.00876 troy ounce.) The largest gold concentrations approach 150 ppb and are located off Cape Blanco within the prominent heavy-mineral concentrations (Figure 5A). Local concentrations of gold occur in the sandy sediments at water depths shallower than 40 m on the continental shelf off the Rogue River. Gold concentrations are extremely low (5 to 150 ppb) off the Rogue, but they occur in distinct groups (Figure 5B; Clifton, 1968). Several gold anomalies show a strong linearity with an orientation parallel to the present shoreline and to the ancient beach placers in the coastal marine terraces (Clifton, 1968).

The gold content of the shelf surface sediments was not used in heavy-mineral assessment of the Rogue River, Cape Blanco, and Umpqua River placer deposits because no gold analyses were available for the Umpqua River and only scattered occurrences of gold were detected off the Rogue River area. However, in their preliminary economic appraisal of these southern Oregon placer deposits, Wetzel and Stebbins (this volume) indicate that approximately 0.008 troy ounce of recoverable gold and platinum (i.e., an added value of between $3.00 and $3.50/short ton of dredged materials) is needed to make these shelf placers economically viable (i.e., in addition to chromite, ilmenite, garnet, and zircon). The highest gold concentrations measured by Clifton (1968) in the bulk surface sediment off Cape Blanco contain approximately one-half this amount of gold (i.e., 150 ppb = 0.00438 troy ounce).

Water Depths of the Heavy-Mineral Concentrations

Water depths of the Cape Blanco heavy-mineral surface concentrations on the continental shelf range between 18 m on the inboard side to 55 m on the outboard side (Table 2). Heavy-mineral concentrations off the Rogue River occur in water depths ranging from 17 m to about 90 m. They probably extend to the shoreline, but cores could be collected only to the shallower water depth from the research vessel. Heavy-mineral concentrations of 10 to 20 percent in the Umpqua shelf deposit occur in water depths ranging from 105 m to about 160 m. This represents the deepest water depth for a deposit of this size. The highest heavy-mineral concentrations, 56 percent, were found off the Rogue River at 150 m water depth (Figure 4B), but this concentration covers less than 5 percent of the surface area of the Umpqua deposit and was not included in this study.

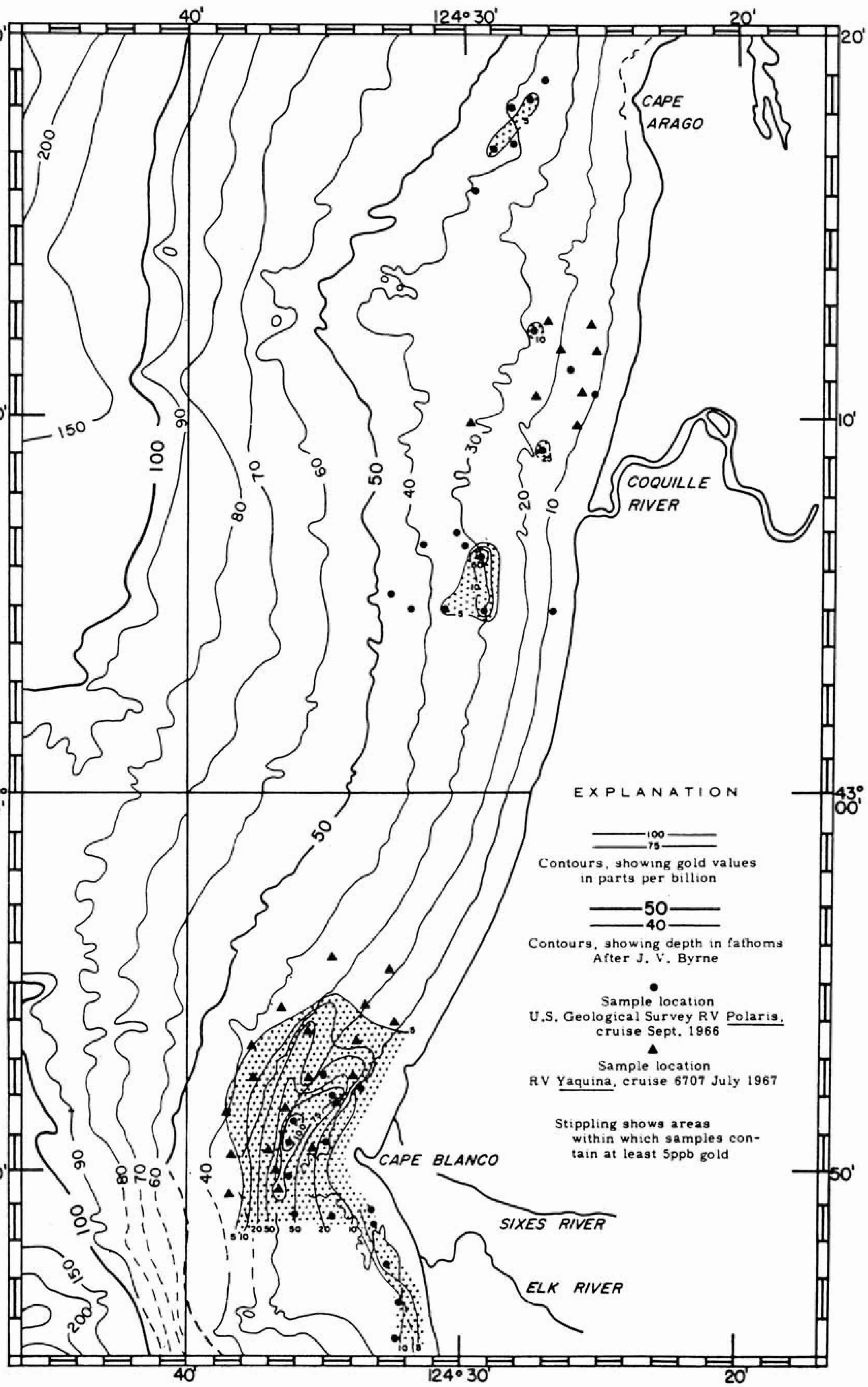


Figure 5A. Gold content (ppb) of surface sediments on the continental shelf off Cape Blanco and Coquille River (From Clifton, 1968).

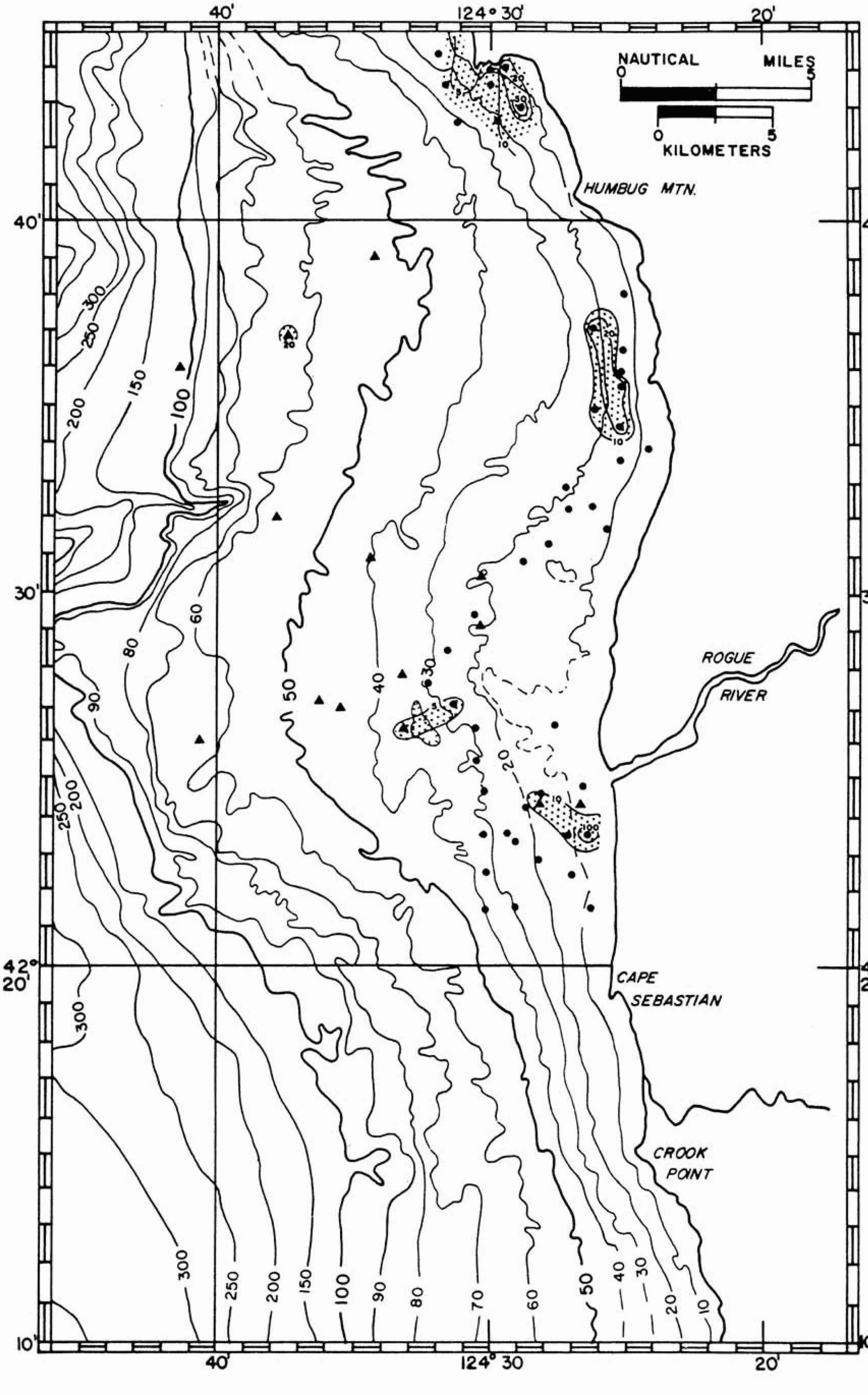


Figure 5B. Gold content (ppb) of surface sediments on the continental shelf off Rogue River and Humbug Mountain (From Clifton, 1968). See figure 5A for explanation.

Distance to Deep-Water Port

Coos Bay, Oregon, is the closest and most suitable deep-water port in the southern Oregon region for transportation of the heavy-mineral concentrates recovered at sea to a potential separation plant on land. The Cape Blanco deposit is located a distance of 35 nautical miles from this port, measured from the mid-point of the heavy-mineral deposit to the entrance (i.e., mouth of the jetty) of Coos Bay (Table 2). The Rogue River deposit is located 60 nautical miles from port, measured from the mid-point of the heavy-mineral deposit to the entrance of Coos Bay. The mid-point of the heavy-mineral deposit off the Umpqua River deposit is situated 17 nautical miles from port.

Sediment Overburden

The distribution of unconsolidated sediment (called overburden) on the southern Oregon shelf was determined from the seismic reflection profiles. It is mapped as four thickness zones: 0-16, 16-25, 25-33, and >33 m thick in addition to rocky areas (Figures 6A, B). To the north of Cape Blanco, there is an apparent smaller amount of unconsolidated sediment on the continental shelf as compared to the region south of the Cape. Most areas north of the Cape have only a thin veneer of sediment (<16 m thick), with a few small isolated pockets of unconsolidated sediment with greater thicknesses. Large areas of sedimentary rock crop out in the nearshore region off Cape Blanco. The bulk of the heavy-mineral concentrations directly off Cape Blanco lie within the 0 to 16 m-thick sediment zone, except in the southwest quadrant, which lies within the 16 to 25 m-thick zone (Figure 6A).

The Rogue River heavy-mineral surface concentrations lie over a lens-shaped sediment accumulation whose axis is essentially parallel to the modern shoreline and which thins toward the inner and outer portion of the shelf (Figure 6A). Rocky areas interrupt the unconsolidated deposits in the vicinity of the Rogue Reef immediately north of the Rogue River mouth and seaward of the mouth. The unconsolidated sediments range essentially from the 0 to 16 m zone to the 25 to 33 m zone. The bulk of the concentrations overlie the 16 to 25 m zone. Therefore, the average thickness of unconsolidated sediment is about 20 m.

The Umpqua River heavy-mineral surface concentrations overlie a sediment accumulation that is >33 m thick to the south and gradually thins to 0 to 16 m-thick interval to the north (Figure 6B). The bulk of the concentrations overlie the 0 to 16 m and 16 to 25 m zones. The average thickness of unconsolidated sediment probably ranges between 16 and 25 m.

Coastal Placer Analogues

Estimates of the potential tonnage of placer accumulations offshore of southern Oregon are severely limited by the lack of deep coring (>1 m) on the continental shelf. While shallow cores (0.25-0.6 m depth subsurface) have identified unusually high concentrations of heavy minerals (10 to 56 weight percent of sand fraction) in the surface sediments of the shelf (Kulm, 1988), the concentration and composition of potential placer sands underlying these surface and near-surface deposits are not known. The best onshore analogues for potential offshore placer deposits are the Pleistocene marine-terrace placers located south of Cape Arago (Figure 2). Compilations of bore-hole logs from the terrace placer bodies (Griggs, 1945; Peterson and others, 1987) provide thickness and surface area constraints on the size of these ancient coastal placers (see also Figure 3). Representative placer thicknesses (5 m) of the onshore placer sections can be used as a first-order approximation of an average thickness of potential placer deposits offshore. The surface areas of the two largest terrace placers are 11 km^2 (Seven Devils) and 0.9 km^2 (Pioneer). The Seven Devils placer is about one-fourth the size of the heavy-mineral deposit modeled on the shelf off Cape Blanco.

Field investigations of modern beach placers and Pleistocene terrace placers have established that the concentration of heavy minerals increase dramatically with depth in the marine sections (Peterson and others, 1987; Peterson and Binney, 1988). For example, heavy minerals (>3.0 g

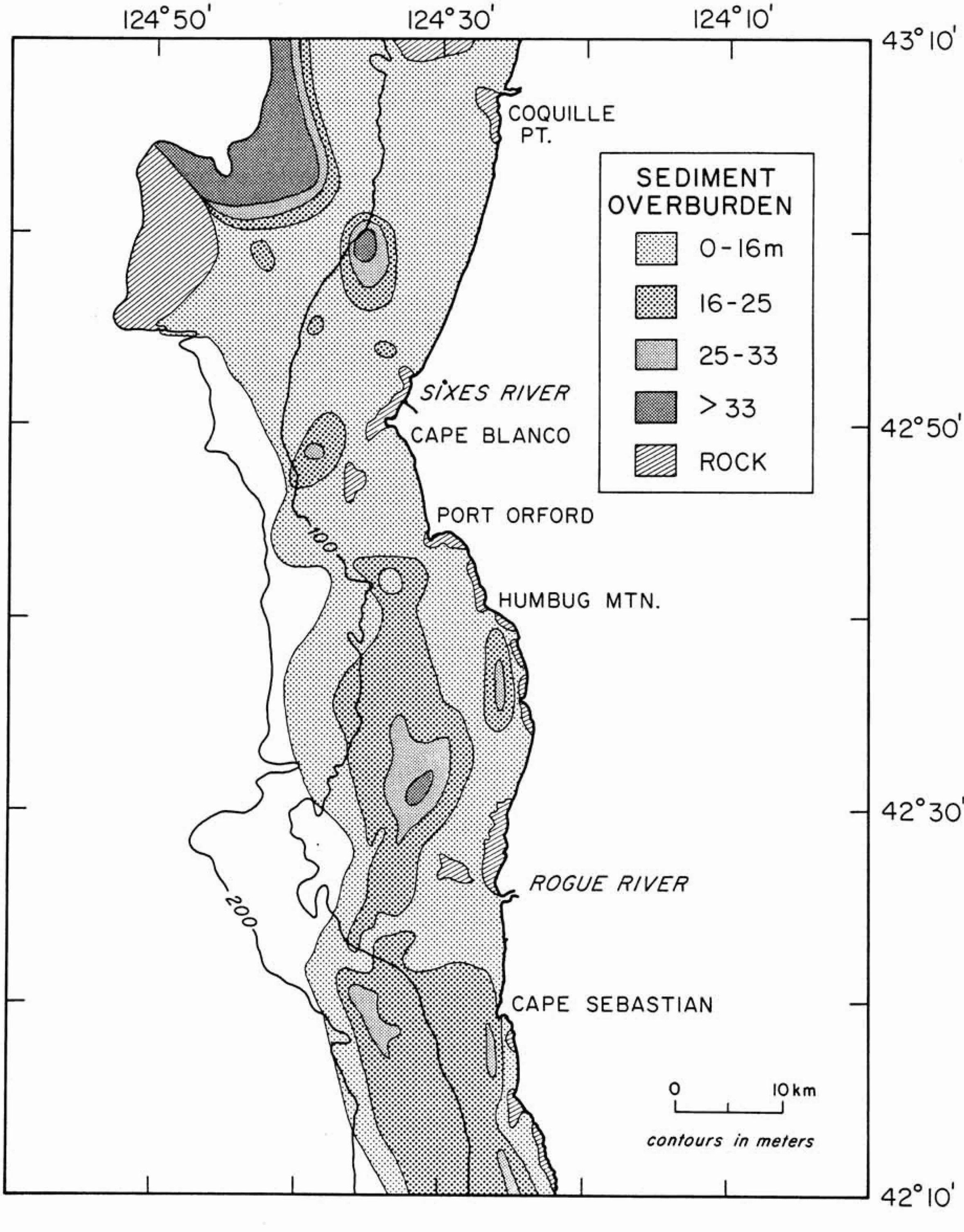


Figure 6A. Map of unconsolidated sediment thickness zones of the continental shelf off southern Oregon (revised from Kulm, 1988).

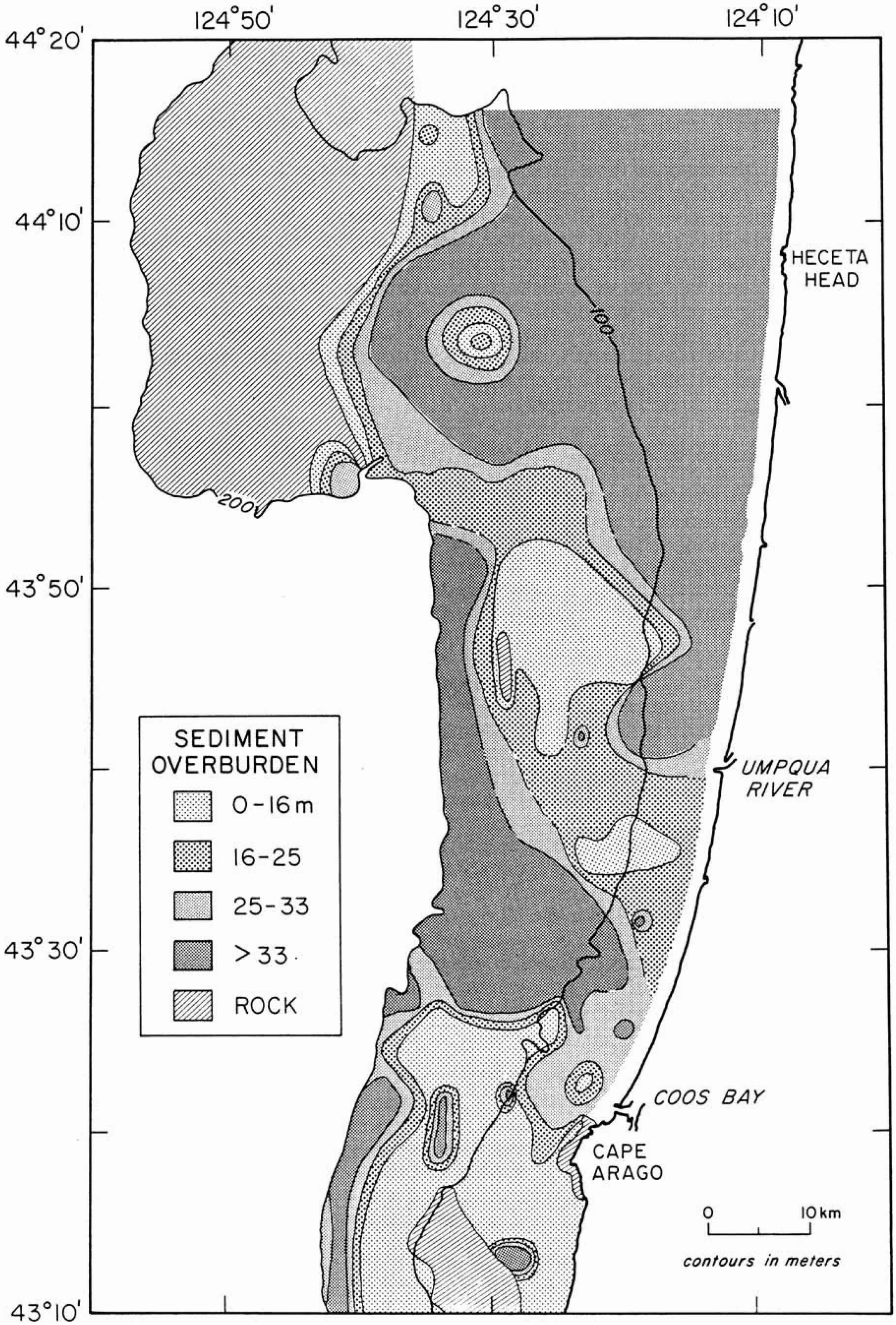


Figure 6B. Map of unconsolidated sediment thickness zones of the continental shelf off south-central Oregon (unpublished map). Note rocky areas (submarine reefs and banks) indicated by lined pattern.

cm^{-3}) in both modern beach placers and in ancient terrace placers can increase from several percent to greater than 90 weight percent over a depth of 2 m. Furthermore, these studies have revealed that the relative abundances of the different heavy minerals change substantially with depth in the placer deposit. Typically, the iron oxides (opaque minerals), garnet, and zircon abundances increase with depth relative to the noneconomic heavy minerals (pyroxene, amphibole, and epidote). It is unrealistic to predict the relative mineral compositions in basal placer deposits by using simple extrapolations from overlying heavy-mineral suites. However, basal placer compositions of potential offshore deposits can be constrained by using direct measures of naturally occurring mineral suites in basal sections of beach and terrace placer deposits. Such extrapolations will be accurate only where the mineral sources of the onshore and offshore deposits are similar. Due to the present uncertainties of the offshore deposit sources in the southern Oregon shelf, we have used only the sample mineralogies of the shelf surface deposits to predict more concentrated placer compositions at depth.

Development of Continental-Shelf Placer Models

Two models, Heavy-Mineral Model and Magnetic Model, were used to estimate the probable maximum and minimum size, respectively, of the potential placer bodies on the continental shelf off Cape Blanco and Rogue River. Only the Heavy-Mineral Model could be used off the Umpqua River because no magnetic survey is available here. With the geological and geophysical data presently available from the continental shelf, these are the only two models that can be used to estimate the distribution of potential placer deposits on the continental shelf.

Model Parameters

The Heavy-Mineral Model utilizes the total surface area represented by the heavy-mineral concentrations (10 to 20 percent and >20 percent) in the surface sediments, and the Magnetic Model relies upon the total surface area represented by the width and length of the magnetic anomalies. In each model a 5 m-thick layer of placer material, which is the estimated average thickness of the Pleistocene terrace placer deposits onshore, was multiplied by the respective surface areas to calculate the volume of each placer deposit. The computed volumes in each model were multiplied by the appropriate dry bulk densities to calculate the tonnages of each placer deposit. The heavy-mineral content of surface sediments of each placer off the Rogue, Cape Blanco and Umpqua was subdivided into the percent opaque (chromite, ilmenite, and magnetite) and nonopaque (garnet and zircon) minerals. The actual opaque and nonopaque mineral content of the shelf surface deposits was used in the Heavy-Mineral Model and Magnetic Model, with the exception of the Cape Blanco placer, where the garnet content from the onshore Pioneer terrace placer (bottom) was utilized. Each mineral content (percent) was multiplied by each placer tonnage to calculate the tonnage of that heavy mineral in the deposit. The assumptions made and the specific data used in each model are discussed in detail below.

Heavy-Mineral Composition

The bulk elemental composition of the opaque minerals (i.e., chrome and titanium) off the Cape Blanco, Rogue River, and Umpqua River areas was determined previously by Instrumental Neutron Activation Analysis (INAA) by Kulm and Peterson (1988). The opaque mineral composition (i.e., titanium oxide and chromium oxide) of individual mineral grains was determined by electron microprobe in selected samples analyzed by INAA (Table 3). Nonopaque mineral contents of zircon and garnet were determined with a petrographic microscope in the surface sediments of the shelf and in the Pioneer terrace placer. In the present study, both the individual opaque-mineral phases and the nonopaque minerals are given as relative values (e.g., normalized to opaque-mineral abundance).

In the case of the Heavy-Mineral Model, the abundance of opaque minerals (relative to the total sand fraction) within the heavy-mineral concentrations of the surface deposits varies, as does the relative abundance of heavy minerals. We used the actual average opaque mineral contents

Table 3. Samples Analyzed For Heavy-Mineral Content

Sample number	OSU sample number	Latitude	Longitude	Water depth	Sand (%)	Heavy mineral (%)	Other analyses
CAPE BLANCO							
S14	6404-402	42°53.0'	124°42.7'	137	NA	5	INAA
S15	6708-70T	42°52.3'	124°36.7'	50	95	20	INAA
S16	6708-74A	42°52.7'	124°34.8'	27	95	28	INAA, microprobe
S17	6708-72	42°51.9'	124°34.2'	21	97	16	INAA, microprobe
S60	6404-393	42°44.0'	124°39.7'	120	NA	3	INAA
S61	6708-57	42°45.4'	124°33.9'	35	97	6	INAA
ROGUE RIVER							
S13	6708-49A	42°33.4'	124°28.7'	50	89	5	INAA
S45	6708C-31A	42°21.4'	124°27.6'	22	NA	21	INAA
S46	6708-15A	42°23.2'	124°33.5'	85	45	12	INAA
S48	6708-48	42°24.2'	124°26.7'	17	97	11	INAA, microprobe
S50	6708-16B	42°25.2'	124°34.8'	75	64	13	INAA
S51	6708-17A	42°25.3'	124°32.2'	70	29	18	INAA, microprobe
UMPQUA RIVER							
S68	6403-268	43°44.0'	124°24.4'	123	64	10	INAA, microprobe

measured in offshore sands having 10 to 20 percent heavy mineral concentrations and >20 percent heavy mineral concentrations. This corresponds to values of 2.5 and 5.0 weight percent opaque minerals in the sands, respectively. The maximum heavy-mineral concentrations that can be effectively separated by onboard spirals from the bulk sediment recovered in the suction dredge operation on the shelf is 5.0 weight percent opaque minerals. The average values for both the opaque (magnetite, ilmenite, and chromite) and nonopaque (garnet and zircon) mineral contents for these heavy-minerals concentrations (i.e., halos) are given in Table 4A along with their total mineral tonnages for each shelf placer.

Mineralogical analyses of the offshore Cape Blanco placer deposits were used to constrain the average placer composition of the Cape Blanco heavy-mineral concentration patterns (10 to 20 percent heavy minerals and >20 percent heavy minerals). Six samples were examined for both opaque (chromite and ilmenite) and nonopaque (garnet and zircon) mineral abundances (Table 3). Microprobe analyses of two of these samples shows the average titanium oxide content is 43.42 and 44.62 weight percent for samples taken in waters of 21 and 27 m, respectively (Table 5). The average chromium oxide content is 29.93 and 35.73 weight percent for the same samples.

Six surface sediment samples offshore of the Rogue River were used to constrain the average placer composition of the Rogue River heavy-mineral concentration patterns (10 to 20 percent heavy minerals and >20 percent heavy minerals). Microprobe analysis of two samples shows the average titanium oxide content is 47.36 and 41.88 weight percent for samples taken in water depths of 17 m and 70 m, respectively (Table 5). The average chromium oxide content is 26.91 and 34.46 weight percent for the same samples. Each Rogue River sample can be subdivided into two populations with higher and lower values of chromium oxide.

Off the Umpqua River, one sample was available from INAA analysis, and the same sample was analyzed with the microprobe to constrain the average placer composition of the single heavy-mineral concentration pattern (10 to 20 percent heavy minerals). Microprobe analysis indicates the titanium oxide content averages 43.92 weight percent, and the chromium oxide 41.61 weight percent (Table 5).

In the case of the magnetic model, we have assumed a basal placer opaque-mineral composition for the shelf that is the average of (1) the nearby Pioneer terrace placer at the Eagle Mine and of (2) the nearby modern beach placers at Sacci and Port Orford beaches. We have used the mid-point between the assumed basal placer composition (percent opaque minerals) and the surface sediment composition (percent opaque minerals) to derive an average composition of 40 weight percent for the 5 m-thick placer beneath these narrow magnetic anomalies (Table 1). We used the same average value of the relative abundance of opaque and nonopaque minerals from surface samples on the shelf to estimate their average abundances in the concentrated subsurface placer beneath the magnetic anomalies (Table 4B), with the exception of the Cape Blanco placer, where the garnet content from the bottom of the onshore Pioneer terrace placer was utilized (Table 1).

Heavy-Mineral Model

In order to determine the dimensions of the potential placer bodies in the Heavy Mineral Model, we assumed that the surface area of the heavy-mineral concentrations of the surface sediments (i.e., halos with 10 to 20 percent heavy minerals and halos with >20 percent heavy minerals) represent actual placer bodies of this same size in the subsurface (Figure 7). The surface area was measured with an AutoCad computer program (Table 2). Off Cape Blanco, the surface area of the 10 to 20 percent heavy-mineral halo is 24.10 km^2 and >20 percent heavy-mineral halo is 23.46 km^2. The total surface area is 47.56 km^2. Off the Rogue River, the surface area of the 10 to 20 percent heavy-mineral halos is 264.85 km^2 and >20 percent heavy-minerals is 52.88 km^2. The total surface area is 317.73 km^2. Off the Umpqua River, the single 10 to 20 percent heavy-mineral halo is represented by a total surface area is 226.04 km^2.

Table 4A. Summary of Shelf Placer Tonnages and Percent Minerals Based Upon Heavy-Mineral Model

Placer size in metric tons ($x10^3$) and weight-percent of minerals

Minerals	Cape Blanco		Rogue River		Umpqua River	
	Tonnage*	Percent	Tonnage	Percent	Tonnage	Percent
Magnetite						
Halo 10-20%	1,468	0.73	22,247	1.00	9,494	0.50
Halo >20%	2,857	1.45	8,885	2.00		
Ilmenite						
Halo 10-20%	3,138	1.55	22,804	1.03	31,329	1.65
Halo >20%	6,109	3.10	9,107	2.05		
Chromite						
Halo 10-20%	456	0.23	10,568	0.48	6,646	0.35
Halo >20%	887	0.45	4,220	0.95		
Garnet						
Halo 10-20%	1,873	0.93	2,781	0.13	6,076	0.32
Halo >20%	3,646	1.85	1,111	0.25		
Zircon						
Halo 10-20%	304	0.15	556	0.03	2,335	0.12
Halo >20%	591	0.30	222	0.05		
Total placer Halos > 10%	21,329		82,501		55,880	

*To convert metric tons to short tons multiply by factor 1.1 (1,468,000 Mt x 1.1 = 1,614,800 St)

Table 4B. Summary of Shelf Placer Tonnages and Percent Minerals Based Upon Magnetic Model

Placer size in metric tons (x10^3) and weight percent of minerals

Minerals	Cape Blanco		Rogue River	
	Tonnage*	Percent**	Tonnage***	Percent**
Magnetite	633	11.60	1,957	16.00
Ilmenite	1,354	24.80	2,005	16.40
Chromite	197	3.60	929	7.60
Garnet	808	14.80	245	2.00
Zircon	131	2.40	49	0.40
Total placer	3,123		5,185	

* Total area of magnetic anomalies is 0.48 km^2, and total size is 5,460,000 metric tons. To convert metric tons to short tons multiply by factor 1.1 (633,000 Mt x 1.1 = 696,300 St)

** Assumed average opaque mineral content of 5-m-thick placer is 40%.

*** Total area of magnetic anomalies is 1.08 km^2, and total tonnage is 12,228,125.

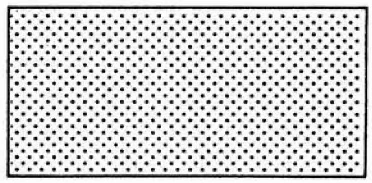
Table 5. Summary of Beach and Shelf Microprobe Analyses

	Titanium Oxide			Chromium Oxide					
SHELF	Mean	Range	Stand. dev.	Mean	Range	Stand. dev.	Cr:Fe ratio	Ti grains	Cr grains
Umpqua 123 m	43.92	34.07 54.61	2.63	41.61	29.20 54.17	5.69	1.43	40	24
Blanco S17 21 m	43.42	34.24 50.27	2.27	29.93	29.78 56.36	5.31	1.07	46	39
Blanco S16 27 m	44.62	35.17 50.52		35.73	18.78 47.99	5.57	1.19	22	21
Rogue S48 17 m	47.36	39.53 57.77	2.67	26.91	9.94 46.00	7.59	0.51	13	25
		Population #1 (>20% Cr)		34.97	29.48 46.00	3.99	0.96	14	
		Population #2 (5-20% Cr)		16.63	9.94 28.37	4.49	0.22	11	
Rogue S51 70 m	41.88	33.33 56.53	3.71	34.46	7.84 58.28	8.86	0.85	17	33
		Population #1 (>20% Cr)		42.09	32.31 58.28	4.57	1.48	22	
		Population #2 (5-20% Cr)		19.17	8.37 27.04	5.18	0.30	11	
BEACHES									
Blanco	41.87	34.92 50.07	2.40	40.43	15.74 54.66	7.36	1.00	14	24
Nesika	44.15	38.31 50.62	2.45	45.26	31.29 52.56	3.90	1.58	16	22

NOTES: Titanium oxide values: Ti content >20%
Chromium oxide values: Cr content >5%

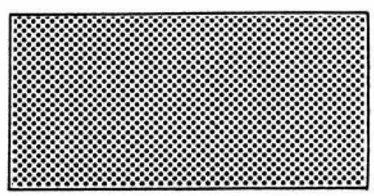
OREGON SHELF-PLACER MODELS

HEAVY-MINERAL MODEL
Heavy-Mineral Surface Concentrations



Layer Thickness: 5 meters
Surficial Opaque Mineral Content:
- 2.5% (10-20% Heavy Mineral Halo)
- 5.0% (>20% Heavy Mineral Halo)

MAGNETIC MODEL
Magnetic Anomalies



Layer Thickness: 5 meters
Average Opaque Mineral Content:
- 40% (10-20% Heavy Mineral Halo)
- 40% (>20% Heavy Mineral Halo)

Figure 7. Models for the placer deposits on the southern Oregon continental shelf.

We further assumed a thickness of 5 m for the placer deposit, which is the estimated average thickness of the onshore placers in the marine terraces (Figure 7). We then calculated the volume of the deposits for each heavy-mineral "halo" (i.e., 10 to 20 percent and >20 percent) for each placer body. The computed volumes for each placer were then multiplied by the corresponding dry bulk density (i.e., 1.68 mt/m^3 for the dilute placer beneath the heavy-mineral concentrations) to estimate total placer tonnages (Table 2).

The total heavy-mineral tonnage represented by the Cape Blanco placer under the heavy-mineral halos (i.e., 10 to 20 percent) is 202,488,000 metric tons (222,736,800 short tons) and the heavy-mineral halos (i.e., >20 percent) 197,064,000 metric tons (216,770,400 short tons). Table 2 lists the placer tonnages for the various heavy-mineral halos present in each of the three areas. The total heavy-mineral tonnage represented by the Rogue River placer under the 10 to 20 percent heavy-mineral halos is 2,224,740,000 metric tons (2,447,214,000 short tons) and under the >20 percent heavy-mineral halos is 444,234,000 (488,657,400). The total heavy-mineral tonnage represented by the Umpqua River placer under the 10 to 20 percent heavy-mineral halo is 1,898,727,000 metric tons (2,088,599,700). There is no >20 percent heavy-minerals halo in the Umpqua placer.

The placer tonnages were then multiplied by the corresponding mineral compositions of the opaque minerals and nonopaque minerals to obtain these mineral tonnages (Table 4A). We used the actual opaque mineral (i.e., chromite, ilmenite, and magnetite) content of these 10 to 20 percent and the >20 percent heavy-mineral halos of each of the three placer deposits (Cape Blanco, Rogue and Umpqua). They average 2.5 and 5.0 weight percent opaque minerals, respectively (Figure 7). We also used the actual nonopaque mineral (garnet and zircon) content of these same halos in the Rogue and Umpqua placer deposits, and the zircon content of these halos and the garnet content of the Pioneer terrace for the Cape Blanco placer deposit to obtain the appropriate mineral tonnages.

Magnetic Model

Magnetic anomalies are associated with heavy-mineral placers in modern beach deposits along the central Oregon coast (Peterson and others, 1986) and with heavy-mineral placers in the ancient marine terrace deposits situated south of Cape Arago along the southern Oregon coast (Stephenson, 1945; Figure 3). These studies demonstrate that magnetic surveys are a useful tool in locating the buried placer deposit and in calculating the approximate size of the placer. Prominent magnetic anomalies also were measured on the continental shelf directly underlying the heavy mineral surface concentrations (Kulm and others, 1968; Kulm, 1988; unpublished magnetics data acquired by L. Kulm). These anomalies range from 10 to 580 gammas in magnitude and are significantly larger than those anomalies measured in the coastal placers. Selected magnetic anomalies on the shelf were modeled from two areas, Cape Blanco and Rogue River, to determine the size (i.e., length and width) of the placer bodies (Kulm, 1988).

Specifically, two small magnetic anomalies (G,H), spaced 4 km apart, occur off Cape Blanco and the Sixes River (Figure 8A). The anomalies occur as doublets along each track line and are located in water depths between 29 and 46 m (Figure 8B). Hypothetical models were constructed to simulate the magnetic anomalies observed at anomaly "G" (Kulm and others, 1968; Kulm, 1988). The closely spaced double anomaly "G" observed off the Sixes River could be produced by two magnetic bodies 10 m thick and 60 m wide. To determine the *minimum* size of the placer body off Cape Blanco, we assumed that anomalies at "G" and "H" represent the actual width of the placer bodies in the subsurface and that the north-south distance between the double pairs on the two tracklines (4 km) is the length of the placer in the subsurface. This scenario produces two placer bodies (i.e., each 60 m wide and 4,000 m long) with a total combined area of 0.48 km^2.

In addition, several large magnetic anomalies (e.g., A-F), occur off the Rogue River (Figure 8A). The anomalies are located in water depths ranging between 37 and 105 m. Hypothetical models were constructed to simulate the magnetic anomaly observed at anomaly "E" (Kulm and others, 1968; Kulm, 1988). It could be produced by two placer bodies each 10 m thick and about 25 m

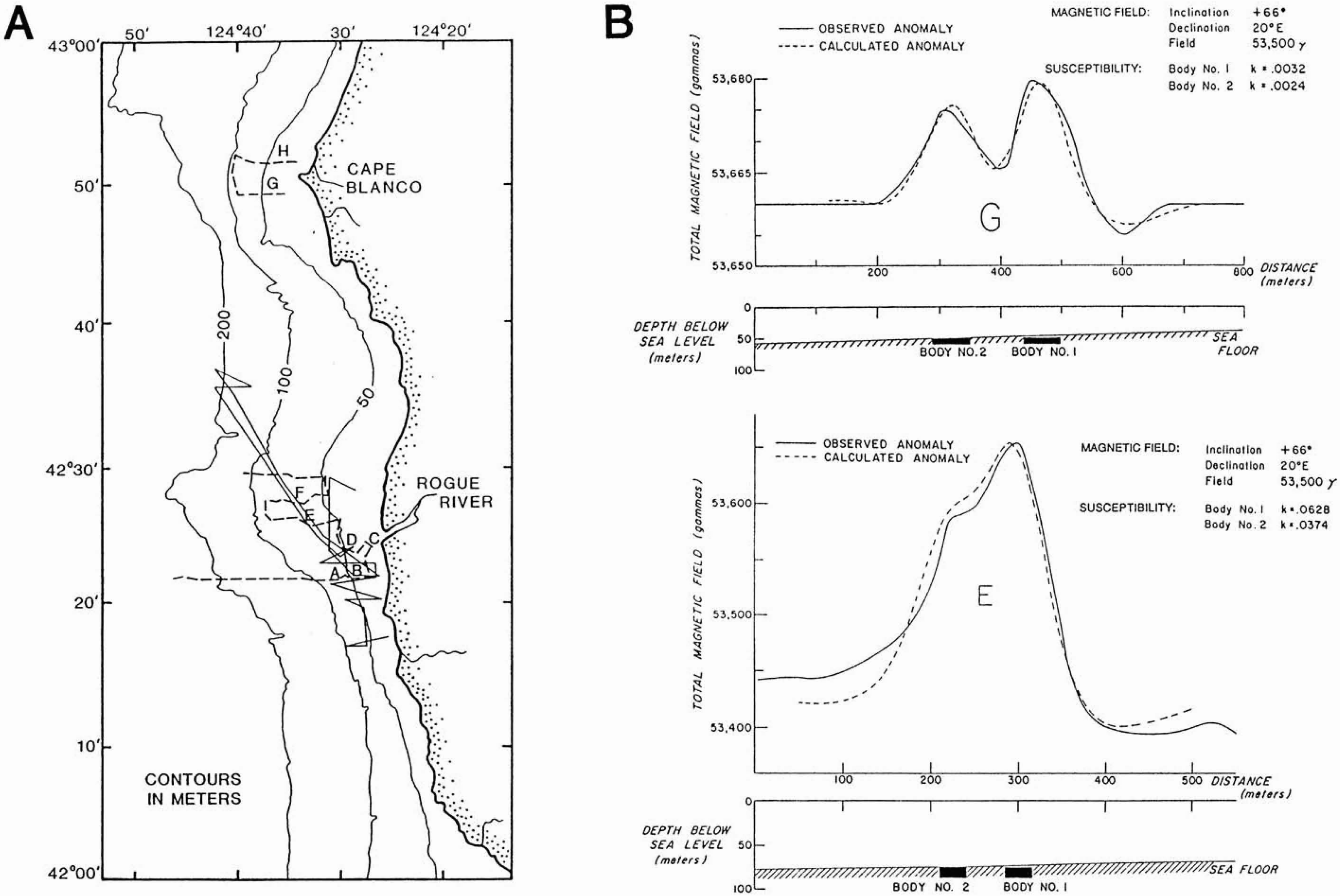


Figure 8. (A) Tracklines of magnetometer survey in the vicinity of heavy-mineral concentrations on the southern Oregon shelf. The most prominent magnetic anomalies are lettered (e.g., A, F). (B) Calculated anomaly for simple model of magnetic anomaly "G" off Cape Blanco. Calculated anomaly for magnetic anomaly "E" off the Rogue River. (After Kulm and others, 1968.)

wide and spaced 45 m apart (Figure 8B). While several other magnetic anomalies are identified off the Rogue River in east-west magnetometer tracklines (Figure 8A, solid lines) made over the heavy-mineral concentrations, none have been modeled as described above. To determine the *minimum* size of the placer bodies off the Rogue River, we used the combined widths (25 m + 25 m = 50 m) of the two placer bodies modeled beneath anomaly "E" for the maximum width of the shelf placer (Figure 8B). We then mapped the locations of all additional magnetic anomalies over their respective heavy-mineral concentrations and projected the anomalies along the length of the concentrations in a north-south direction (i.e., assumes an ancient shoreline parallel to the modern one). The sum of the projected lengths was then multiplied by the 50 m width. This scenario produces several placer bodies with a combined area of only 1.08 km^2.

No magnetics data were available for the Umpqua River placer deposit to calculate the surface area of this placer. Therefore, the Magnetic Model was not used in this case.

We next assumed a thickness of 5 m for the Cape Blanco and Rogue River placers, which is the best estimate of the average thickness of the onshore marine terrace placers, but less than the thickness required to generate the anomalies. The surface areas were multiplied by the placer thickness to determine the volume of the deposit. The computed volumes for each placer were then multiplied by the corresponding dry bulk density (i.e., 2.27 mt/m^3 for the concentrated placer beneath the magnetic anomalies) to calculate total placer tonnages (Table 4B). The total heavy-mineral tonnage of the Cape Blanco placer is calculated at 5,460,000 metric tons (6,006,000 short tons) and the Rogue River placer at 12,228,125 metric tons (13,450,938 short tons).

These placer tonnages were then multiplied by the corresponding mineral compositions of the opaque and nonopaque minerals to obtain tonnage estimates for each of these heavy minerals (Table 4B). An average value of 40 weight percent opaque minerals was used for the 5 m-thick layer (see Heavy-Mineral Composition). The actual nonopaque mineral content of the shelf surface sediments was used, with the exception of the Cape Blanco placer, where the garnet content of the bottom of the Pioneer terrace placer onshore was utilized (Table 1).

The Magnetic Model required the extrapolation of magnetic anomalies between sparse magnetic profiles made across the shelf for the Rogue River placer which makes this tonnage value rather tenuous. It should be noted that several of the magnetic anomalies investigated from the southern Oregon shelf required unrealistically high magnetic susceptibilities to produce the observed anomaly with our given depth constraints. For this reason, vibra coring of the magnetic anomaly beneath the heavy-mineral deposits is required to test the origin (e.g., heavy mineral placers or igneous intrusive bodies with high magnetic susceptibilities) of these observed magnetic anomalies.

Estimates of Shelf Placer Mineral Tonnages

In the Heavy-Mineral Model, the placer tonnages and mineral percentages associated with each heavy-mineral halo were calculated using the parameters described previously (Table 4A). In the Cape Blanco placer, ilmenite is the dominant tonnage (9,247,000 metric tons; 10,171,700 short tons), followed by garnet (5,519,000; 6,070,900), magnetite (4,325,000; 4,757,500), chromite (1,343,000; 1,477,300), and zircon (895,000; 984,500). In the Rogue River placer, magnetite and ilmenite are characterized by nearly equal tonnages (31,132,000 and 31,911,000 metric tons; 34,245,200 and 35,102,100 short tons, respectively) with about half as much chromite (14,788,000; 16,266,800) and much smaller amounts of garnet (3,892,000; 4,281,200) and zircon (778,000; 855,800). In the Umpqua placer, ilmenite (31,329,000 metric tons; 34,461,900 short tons) is three times as abundant as magnetite (9,494,000; 10,443,400), with essentially co-equal amounts of chromite and garnet (6,646,000 and 6,076,000; 7,310,600 and 6,683,600, respectively) and a much smaller quantity of zircon. Combining all three offshore placers, we find that the tonnage of the economic mineral ilmenite is 72,487,000 (79,735,700) and chromite is 22,777,000 metric tons (25,054,700) , which suggests that ilmenite is three times more abundant than chromite off southern Oregon. Garnet and zircon decrease in abundance from the Umpqua River placer to the Rogue placer.

In the Magnetic Model, the placer tonnages and mineral percentages were calculated using the parameters described previously (Table 4B). In the Cape Blanco placer, ilmenite is the dominant tonnage (1,354,000 metric tons; 1,489,400 short tons) with lesser amounts of garnet (808,000; 888,800), magnetite (633,000; 696,300) chromite (197,000; 216,700) and zircon (131,000; 144,100). In the Rogue River placer ilmenite (2,005,000 metric tons; 2,205,500 short tons) and magnetite (1,957,000; 2,152,700) are present in nearly equal amounts followed by chromite (929,000; 1,021,900) garnet (245,000; 269,500) and zircon (49,000; 53,900). No data are available for the Umpqua River placer because no magnetics data were collected in the area.

Comparison of Placer Models

In the Heavy Mineral Model, the surface area of the heavy-mineral "halos" probably overestimates the actual size of the subsurface placer since oscillatory ripple marks occur in shelf surface sediments, indicating wave stirring (Komar and others, 1972) and associated strong unidirectional transport by bottom currents (Smith and Hopkins, 1972) of the sediments to water depths of at least 125 m and probably to 200 m. Seasonal storm waves can redistribute the surface sediments on the shelf, scattering the heavy minerals, which may create somewhat larger halos. On the other hand, the relatively dilute concentrations of heavy minerals (10 to 20 percent and >20 percent heavy minerals) observed in the surface sediments might represent less than the concentrations of heavy-minerals in the basal placer deposits if such placers do underlie the heavy-mineral concentrations. The Heavy Mineral Model, which assumes that substantial subsurface placers lie beneath the halos, must be tested by vibra-coring the heavy-mineral deposits to adequate subsurface depths.

In the Magnetic Model, the mineral tonnages for ilmenite and chromite are a factor of seven and ten less, respectively, than in the Heavy-Mineral Model because the total surface area and, consequently, the total placer tonnage is calculated to be much smaller (compare Tables 4A with 4B) than in the Heavy-Mineral Model. Furthermore, the higher opaque-mineral content (40 percent versus 2.5 to 5.0 percent) used in the Magnetic Model does not adequately compensate for this drastic reduction in placer tonnage. Based upon the magnetic survey over the coastal-terrace placers (Figure 3; Stephenson, 1945), magnetic anomalies represent only a portion of the drilled placers or are absent over other placers. The magnetic anomalies that have been mapped over the placers no doubt underestimate the actual size of the placer. This may explain, in part, the very small surface area and hence very small placer tonnages calculated for the offshore placers in relationship to the much larger placer tonnages for the offshore placers derived from heavy-mineral halos. Because the offshore magnetic survey tracklines are widely spaced and intermittent, it is difficult to correlate the magnetic anomalies between tracklines. For these reasons, we conclude that the Magnetic Model probably underestimates the total tonnage of the potential placer deposits off the Cape Blanco and Rogue River areas. However, the magnetic anomalies should be useful in locating possible placers on the shelf.

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Section 2.0

A PRELIMINARY ECONOMIC APPRAISAL OF POTENTIAL HEAVY MINERAL PLACER DEPOSITS ALONG THE OREGON CONTINENTAL SHELF

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Prepared for

Federal/State of Oregon Black Sands Task Force

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ILLUSTRATIONS

TABLES

LIST OF UNIT OF MEASURE ABBREVIATIONS

d/a	day per year	st	short ton
ft	feet, foot	st/a	short ton per year
gpm	gallon per minute	st/d	short ton per day
h/d	hour per day	st/h	short ton per hour
hp	horsepower	tr oz/st	troy ounce per short ton
in	inch	wt pct	weight percent
lb/h	pound per hour	yd^2	square yard
nmi	nautical mile	yr	year
pct	percent		

INTRODUCTION

Placer deposits of heavy minerals can form in any environment where a mechanism is available to concentrate mineral grains of high specific gravity. Such mechanisms include winnowing by high velocity winds, fluvial transport, and wave action. As a result, placer minerals are found in three primary environments: beach, river, and continental shelf. The continental shelf along the Oregon coast is likely to contain placer deposits, because all three of the mentioned mechanisms have operated on the shelf in the geologic past.

Marine placers enriched in chromite, ilmenite, magnetite, garnet, zircon, and precious metals are known to occur on elevated terraces and beaches along the central and southern Oregon coast. During World War II and the Korean Conflict, chromite concentrates were produced from high-grade deposits on terraces between Cape Arago and Bandon, OR. Recent mineral investigations by the College of Oceanography, Oregon State University (OSU), Corvallis, OR, indicate the likelihood of similar heavy mineral placers on the Oregon Continental Shelf (Kulm, 1988). Sources of the heavy minerals have been traced to metamorphic and ultramafic rocks of the Klamath Mountains of California and Oregon and the southern Oregon Coast Range (Peterson, 1986).

Objective

The Bureau of Mines has been supporting several Exclusive Economic Zone (EEZ) and Outer Continental Shelf (OCS) related task groups by preparing a series of Technical Assistance Reports and by actively participating on various committees. An earlier study by the Bureau provided an economic reconnaissance of potential offshore placer deposits in the U.S. EEZ (Bureau of Mines, 1987; Ritchey, 1988).

The Bureau was requested by the Oregon Black Sands Task Force to provide a preliminary appraisal of the economic feasibility of mining and processing potential offshore placer deposits. Three known deposit areas were evaluated for potential economic development of heavy minerals: off Cape Blanco, and near the mouths of the Umpqua and Rogue Rivers. These sites were selected and agreed upon by task force members and advisors.

Resource estimates were provided by OSU and were used to design appropriate mining and processing scenarios. Capital and operating cost estimates were compared with current market factors for the various commodities to complete a preliminary financial analysis. Evaluation of uncertainties and unknowns in the analysis provides a series of constraints for economic viability of offshore mineral production.

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Resource data was prepared and provided by LaVerne D. Kulm and Curt D. Peterson, College of Oceanography, OSU. For details on sampling techniques employed, see Kulm and Peterson (1988).

Critical reviews were provided by C. T. Hillman, J. L. Ritchey, and N. T. Zilka.

RESOURCE MODELS

Chromite, ilmenite, garnet, zircon, and gold are the potentially marketable commodities present in the placers; however, much uncertainty is associated with their marketability. The apparent derivation of these minerals from multiple sources in the Klamath Mountains and Oregon Coast Ranges (Peterson and Binney, 1988) will significantly affect the average elemental compositions of the chromite and ilmenite, and consequently their marketability. The amount of gold present in the offshore placers is unknown and the presence of platinum group minerals is suspected but unconfirmed.

Cape Blanco Placer

The Cape Blanco placer, centered at approximately 42°50' N. latitude and 124°38' W. longitude (fig. 1), covers an estimated 28 million yd^2. Water depth ranges from 59 ft on the nearshore side to 180 ft on the seaward side. Distance from the center of the deposit to Coos Bay (the most suitable deep water port) is approximately 35 nmi (Kulm and Peterson, 1989). Table 1 shows the estimated resource size and inferred bulk grade for the Cape Blanco placer.[1]

TABLE 1. - Resource Model, Cape Blanco placer

	Mineral content, wt pct	Contained minerals, st
Magnetite...........	1.08	4,757,000
Ilmenite............	2.13	10,175,000
Chromite............	0.34	1,498,000
Garnet..............	1.01	4,449,000
Zircon..............	.07	308,000
All others..........	95.37	419,290,000
Totals.........	100.00	440,477,000

[1]Discrepancies in tabulated numerical data are due to rounding.

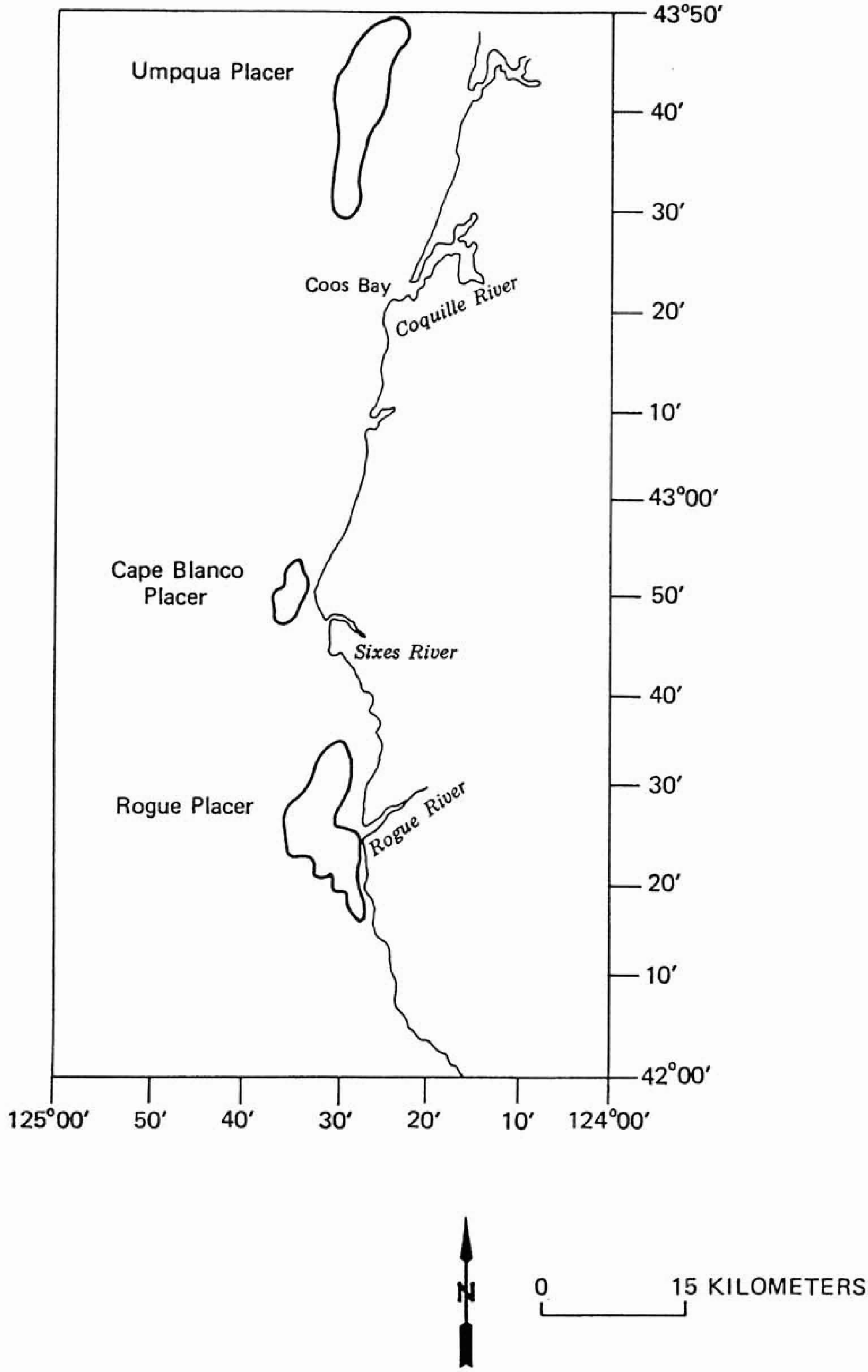

FIGURE 1.— Location map, heavy mineral placers along the southern Oregon Continental Shelf

Rogue River Placer

The Rogue River placer, centered at approximately 42°25'N. latitude and 124°32' W. longitude, encompasses approximately 317 million yd^2. Water depth ranges from 56 ft nearshore to 295 ft seaward. Distance from the center of the deposit to Coos Bay is about 60 nmi (Kulm and Peterson, 1989). Table 2 shows the estimated resource size and inferred bulk grade for the Rogue River placer.

TABLE 2. - Resource model, Rogue River placer

	Mineral content, wt pct	Contained minerals, st
Magnetite.........	1.16	34,390,000
Ilmenite..........	1.19	35,280,000
Chromite..........	0.55	16,606,000
Garnet............	.14	4,151,000
Zircon............	.03	889,000
All others........	96.93	2,873,374,000
Totals.......	100.00	2,964,690,000

Umpqua River Placer

The Umpqua River placer, centered at approximately 43°38'N. latitude and 124°28' W. longitude, covers about 270 million yd^2. Water depth ranges from 344 ft nearshore to 525 ft on the seaward side. Distance from the center of the deposit to Coos Bay is approximately 17 nmi (Kulm and Peterson, 1989). Table 3 shows the estimated resource size and inferred bulk grade for the Umpqua River placer.

TABLE 3. - Resource model, Umpqua River placer

	Mineral content, wt pct	Contained minerals, st
Magnetite............	0.50	10,467,000
Ilmenite.............	1.65	34,541,000
Chromite.............	.35	7,327,000
Garnet...............	.32	6,699,000
Zircon...............	.22	4,606,000
All others...........	96.96	2,028,775,000
Totals..........	100.00	2,093,415,000

COMMODITY DATA

The following commodity summaries are primarily a summation of data presented by the Bureau (1988). Consumption, uses, and net import reliance figures are for 1987.

Chromite

Currently, 90 pct of the chromite products consumed by U.S. companies is in the chemical and metallurgical industries and 10 pct in the refractory industry. End-use consumption of ferrochromium alloys, metal, and other chromium containing materials is estimated to be: stainless and heat-resisting steels, 79 pct; full alloy steel, 8 pct; superalloys, 3 pct; and other alloys, 10 pct. Reported U.S. consumption in 1987 was about 360,000 st. Excluding a small amount of concentrates produced from a California deposit in the 1970's, there has been no domestic production of chromite since termination of the Defense Production Act in 1960. Import sources from 1983 to 1986 were: Republic of South Africa, 61 pct; Turkey, 10 pct; Zimbabwe, 10 pct; Yugoslavia, 5 percent; and others, 14 pct. The domestic depletion allowance for chromite is 22 pct and our net import reliance is 75 pct; the balance is derived from recycling. The current market value for chromite concentrates containing greater than 40 pct chromic oxide is $54.42/st (Industrial Minerals, Jan. 1989).

Garnet

Domestic industrial garnet is used for: abrasives in transport manufacturing, 50 pct; filtration media, 30 pct; wood furniture finishing, 10 pct; electronic components, 7 pct; and ceramics and glass, 3 pct. Domestic production of industrial garnets in 1987 is estimated at 41,900 st and domestic consumption is estimated to be 41,200 st. Australia was the sole foreign source from 1983 to 1986. The domestic depletion allowance is 14 pct and the United States is a net exporter. Depending on size and abrasive quality, the current market value broadly ranges from $25.00 to $2,000/st.

Marketing of garnets produced from Oregon offshore placers, if of suitable abrasive quality, would probably require exportation.

Ilmenite

In 1988, the primary use of ilmenite by U.S. companies was in pigment production. Minor amounts were used in welding rod coatings and well-drilling muds. Reported U.S. consumption of ilmenite concentrates in 1987 was about 1,150,000 st. Domestic production has remained constant during the past few years, with 1988 production estimated to be 1.2 million st. Import sources from 1983 through 1986 were: Australia, 61 pct; Canada, 26 pct; and the Republic of South Africa, 13 pct. The domestic depletion allowance for ilmenite is 22 pct. The current market value (Industrial Minerals, Jan. 1989) is $45.00/st f.o.b. U.S. east coast.

Marketing of West Coast ilmenite for production of pigment would require transport to the east coast, or to Alabama for the production of synthetic rutile.

Magnetite

Most domestic production of magnetite and other iron ores is restricted to the Great Lake states. Value of magnetite concentrates would be on the order of $ 27.00/st ton delivered to lower Great Lake ports. Transportation costs from the Oregon coast would exceed current market value.

Zircon

Zircon in the United States is used for: foundry sands, 35 pct; refractories, 28 pct; ceramics, 20 pct; abrasives, 5 pct; and chemical manufacturing and production of zirconium metal and alloys for nuclear applications, 12 pct. Domestic production has remained constant over the past few years and U.S. reported consumption for 1988 is estimated at 135,000 st.

Import sources for zircon from 1983 to 1986 were: Australia, 63 pct; Republic of South Africa, 27 pct; and other countries, 10 pct. The domestic depletion allowance for zircon is 22 pct. The current market value is $235.00/st f.o.b. east coast (Industrial Minerals, Jan. 1989).

Most zircon is presently consumed on the east coast; however, one plant in Oregon does produce primary zirconium sponge.

SYSTEM DESCRIPTION

Introduction

This study assumes that dredging and processing of shelf sediments along the coast of Oregon would use a twin pipe trailing suction head dredge, on-board rougher spiral concentrating plant, and onshore beneficiation plant using a combination of electrostatic and magnetic separators and gravity equipment to separate the various heavy minerals. The following descriptions are for the Cape Blanco base-case scenario. Process flowsheets, and material balances for the similar Rogue and Umpqua River base case scenarios are contained in appendix A.

Cape Blanco Placer

Dredging and On-Board Processing

Marine sediments are recovered using a twin-pipe trailing suction head dredge. The dredging equipment is mounted on a 9,100-ton-displacement hull with an overall length of 333 ft, a width of 56 ft, and a depth (draft) of 26 ft. Suction pipes are 2.5 ft in diameter and 125 ft long, which allows a maximum dredging depth of approximately 98 ft. Each dredge utilizes a single visor draghead in conjunction with a 1,200-hp submersible pump.

On average, 1,200 st/h of dredged sediments flow directly into a decanting surge bin with a capacity of 1,440 st. Wet sediments are fed to two 66-in-diam, 29-ft-long trommels where the material is scrubbed, and oversize organics and rocks removed. Next, sediments are pumped to a bank of 12-in cyclones where the fines are removed. Cyclone underflow passes to a bank of 900 single-start spiral classifiers where heavy materials are concentrated. For the Cape Blanco scenario, 61.33 st of concentrate are recovered for every 1,200 st of sediment dredged. It is anticipated that 85 pct of the valuable minerals will be recovered by the on-board plant. The spiral portion of the plant is positioned on a wave compensating platform in an effort to obtain reasonable gravity separation recovery rates in the unstable offshore environment. Spiral concentrates flow to a decanting bin, and are then conveyed to a 3,875-ton capacity barge adjacent to the dredge.

Tails from the on-board plant are pumped approximately 200 ft shoreward from the dredge, and deposited back on the seafloor. Tailings placement is facilitated by a 300-hp pump, 250 ft of 3-ft-diam pipe, and a 45-ft dedicated tender. The tailings pipe is mounted on a swivel at the stern of the dredge to accommodate direction reversals at the end of each pass through the deposit. The tender manipulates the tailings pipe through a winch system, thereby controlling discharge placement.

A typical mining cycle consists of the complete excavation of a single 100-ft-wide trench. The dredge passes back and forth through the trench removing subsequent layers of material from the bottom until the maximum mining depth is reached, or the heavy minerals are depleted. The dredge then begins excavating another 100-ft wide trench immediately seaward from the previous one, and the process is repeated. During each cycle, tails are deposited approximately 200 ft shoreward, so that by the third trench the tailings backfill previous workings. In this way, it is hoped that tails will not sluff in on current operations, and that the configuration of the seafloor will be restored.

Fuel, food, and supplies for the dredge are delivered once each week by a 140-ft supply vessel. Port tugs, seagoing tugs, and supply vessels are all contracted. The dredge, barges, and tailing tender are owner operated. Dredging is carried out 24 h/d, 7 days/week, 250 d/a, weather permitting. All dredging, on-board plant, tailings disposal, and maintenance personnel are housed aboard ship. A crew of 56 may be aboard the dredge at any one time, and crews are rotated once every 2 weeks. The dredge is dry-docked during the winter months to facilitate major repairs, overhauls, and maintenance.

Barge Transportation

Loaded barges are towed to port using 70-ft seagoing tugs traveling at approximately 9 knots. Upon reaching port, the barges are secured to a dolphin buoy located just outside Coos Bay. From here, a 51-ft harbor tug picks up the loaded barge and transfers it to the port facilities. The harbor tug trades the loaded barge for an empty one, and then hauls the empty barge back to the dolphin. This empty barge is returned to the dredge by the seagoing tug on its next trip out. In the Cape Blanco scenario, the seagoing tug needs to make only one trip to the dredge every 2.6 days to maintain production. Periodically, tails from the onshore plant are loaded into one of the returning barges and pumped into previously dredged workings.

Beneficiation Plant

At the port, concentrates are removed from the barge using draglines and are conveyed to stockpile storage. After air drying, concentrates are loaded by front-end loader into a 3-ft-diam by 30-ft-long rotary dryer at a rate of 42.59 st/h, 3 shifts/day, 7 days/week, 360 d/a.

Dried concentrates are conveyed to a high-tension separation circuit, where the conductor minerals (magnetite, ilmenite, chromite, and minor amounts of platinum) are separated from the nonconductors (quartz, zircon, garnet, and minor amounts of gold). The rougher high-tension section consists of 12 units operating in parallel. The units are all-start, 6-roll, with a design capacity of 7,200 lb/h. After separation, conductors at 25.48 st/h and nonconductors at 17.11 st/h, are conveyed to separate cleaner high-tension circuits. Middlings from the rougher units are recycled. Conductor retreatment requires 8 units operating in parallel and nonconductor retreatment requires 5 units operating in parallel. These units are 2-start, 6-roll, with a design capacity of 7,200 lb/h. Conductors thrown from nonconductor retreatment are combined with the conductor retreatment feed. Nonconductors pinned from conductor retreatment are combined with nonconductor retreatment feed. Final products from the cleaner high tension section contain an average 26.28 st/h of conductors and 16.31 st/h of nonconductors.

Conductors from the high tension section are conveyed to high-intensity induced-roll magnetic separators. All units in this circuit are 2-roll units with a design capacity of 3,420 lbs/hour. The entire circuit consists of 16 rougher magnetite units, 16 cleaner magnetite units, 10 ilmenite rougher units, 9 ilmenite cleaner units, and 2 ilmenite scavenger units. The final nonmagnetic fraction from the ilmenite scavenger units is a chromite concentrate. Total production from the magnetic separation section averages 9.19 st/h of magnetite concentrate assaying 81.17 pct magnetite, 17.54 pct ilmenite, and 1.29 pct chromite; 14.85 st/h of ilmenite concentrate assaying 98.75 pct ilmenite, 1.02 pct magnetite, and 0.23 pct chromite; and 2.25 st/h of chromite concentrate assaying 99.87 pct chromite, and 0.13 pct ilmenite. The magnetite concentrate is conveyed to a byproduct storage stockpile, while ilmenite and chromite are conveyed to product loadout bins.

Nonconductors from the high-tension section are conveyed to high-intensity induced-roll magnetic separators for removal of garnet. The high-intensity circuit consists of 10 units, 2 rolls each, with a capacity of 3,420 lb/h. The magnetic fraction is conveyed to one of two high- tension units for removal of magnetite, ilmenite and chromite not recovered previously. Nonconductor production totals 7.01 st/h of nearly pure garnet concentrate (99.98 pct garnet), which is conveyed to byproduct stockpile storage. Conductors from the high-tension circuit total 0.21 st/h and are conveyed to a waste dump stockpile.

The garnet-poor, nonmagnetic fraction from the magnetic separation circuit is conveyed to a slurry tank where 9.09 st/h are slurried with 84.76 gpm water to achieve a pulp density of approximately 30 pct solids, which is fed to a bank of spirals. A total of seven spirals are used to make a rougher zircon concentrate. Spiral tailing is delivered to four shaking tables for secondary zircon recovery. Concentrates from the spirals and tables are combined to produce 0.55 st/h of concentrate. Tails from the tables are produced at a rate of 8.54 st/h and consist primarily of quartz. They are thickened and pumped to a tail storage area where they are eventually combined with material from the waste dump stockpile, loaded on the transport barges, and returned to the minesite.

The zircon concentrate is dried in a rotary dryer and passed through a magnetic scalper to remove remaining garnet. The garnet, averaging 0.07 st/h is combined with the garnet from the high-tension circuit and conveyed to stockpile storage. The cleaner zircon concentrate, now totaling 0.48 st/h and averaging 99.85 pct zircon, is calcined in a rotary kiln and conveyed to product loadout bins.

A material balance for both on-board and beneficiation plant processing is shown in table 4. Schematic diagrams illustrating on-board processing, beneficiation plant operations, and generalized materials flow are shown in figures 2, 3, and 4, respectively.

TABLE 4. - Material balance, Cape Blanco placer

On-Board Processing

Item	Units	Weight percent - heavy minerals					Units - st/hour - heavy minerals					Percent Distribution - heavy minerals				
	st/hour	Mag.	Ilm.	Chr.	Gar.	Zir.	Mag.	Ilm.	Chr.	Gar.	Zir.	Mag.	Ilm.	Chr.	Gar.	Zir.
Dredge output	1200.00	1.08%	2.31%	0.34%	1.01%	0.07%	12.96	27.72	4.08	12.12	0.84	100.00%	100.00%	100.00%	100.00%	100.00%
Spiral feed	1200.00	1.08%	2.31%	0.34%	1.01%	0.07%	12.96	27.72	4.08	12.12	0.84	100.00%	100.00%	100.00%	100.00%	100.00%
Spiral conc.	61.33	17.96%	38.42%	5.65%	16.80%	1.16%	11.02	23.56	3.47	10.30	0.71	85.00%	85.00%	85.00%	85.00%	85.00%
Spiral tail	1138.67	0.17%	0.37%	0.05%	0.16%	0.01%	1.94	4.16	0.61	1.82	0.13	15.00%	15.00%	15.00%	15.00%	15.00%

Port Processing Facility

Item	Units	Weight percent - heavy minerals					Units - st/hour - heavy minerals					Percent Distribution - heavy minerals				
	st/hour	Mag.	Ilm.	Chr.	Gar.	Zir.	Mag.	Ilm.	Chr.	Gar.	Zir.	Mag.	Ilm.	Chr.	Gar.	Zir.
Plant Feed	42.59	17.96%	38.42%	5.65%	16.80%	1.16%	7.65	16.36	2.41	7.15	0.50	100.00%	100.00%	100.00%	100.00%	100.00%
Rougher High Tension																
Conductors	25.48	28.52%	61.00%	8.98%	1.40%	0.10%	7.27	15.54	2.29	0.36	0.02	95.00%	95.00%	95.00%	5.00%	5.00%
Nonconductors	17.11	2.24%	4.78%	0.70%	39.73%	2.75%	0.38	0.82	0.12	6.80	0.47	5.00%	5.00%	5.00%	95.00%	95.00%
Cleaner High Tension-rougher pinned																
Conductors	1.31	28.95%	61.93%	9.12%	0.00%	0.00%	0.38	0.81	0.12	0.00	0.00	4.95%	4.95%	4.95%	0.00%	0.00%
Nonconductors	15.80	0.02%	0.05%	0.01%	43.02%	2.98%	0.00	0.01	0.00	6.80	0.47	0.05%	0.05%	0.05%	95.00%	95.00%
Cleaner High Tension-rougher thrown																
Conductors	24.97	28.95%	61.93%	9.12%	0.00%	0.00%	7.23	15.47	2.28	0.00	0.00	94.52%	94.53%	94.52%	0.00%	0.00%
Nonconductors	0.51	7.15%	15.30%	2.25%	70.42%	4.88%	0.04	0.08	0.01	0.36	0.02	0.48%	0.47%	0.48%	5.00%	5.00%
Total high tension products																
Conductors	26.28	28.95%	61.93%	9.12%	0.00%	0.00%	7.61	16.28	2.40	0.00	0.00	99.48%	99.47%	99.48%	0.00%	0.00%
Nonconductors	16.31	0.25%	0.53%	0.08%	43.87%	3.04%	0.04	0.09	0.01	7.15	0.50	0.53%	0.52%	0.53%	100.00%	100.00%

TABLE 4. - Material balance, Cape Blanco placer--Continued
Nonconductors, subsequent processing

Item	Units st/hour	Weight percent - all minerals Quartz	Conductors	Garnet	Zircon	Units - st/hour - all minerals Quartz	Conductors	Garnet	Zircon	Percent Distribution - all minerals Quartz	Conductors	Garnet	Zircon
Feed	16.31	52.24%	0.85%	43.87%	3.04%	8.52	0.14	7.15	0.50	100.00%	0.53%	100.00%	100.00%
Magnetic Separation													
Magnetics	7.22	0.00%	1.90%	98.10%	0.00%	0.00	0.14	7.08	0.00	0.00%	99.00%	99.00%	0.00%
Nonmagnetics	9.09	93.74%	0.02%	0.79%	5.46%	8.52	0.00	0.07	0.50	100.00%	0.01%	1.00%	100.00%
High Tension Separation - Magnetic fraction													
Garnet	7.01	0.00%	0.02%	99.98%	0.00%	0.00	0.00	7.01	0.00	0.00%	0.01%	98.01%	0.00%
Conductors	0.21	0.00%	65.75%	34.25%	0.00%	0.00	0.14	0.07	0.00	0.00%	0.51%	0.99%	0.00%
Spiral Concentration - Nonmagnetic fraction													
Concentrate	0.46	0.00%	0.24%	12.58%	87.18%	0.00	0.00	0.06	0.40	0.00%	0.00%	0.80%	80.00%
Tail	8.63	98.68%	0.00%	0.17%	1.15%	8.52	0.00	0.01	0.10	100.00%	0.00%	0.20%	20.00%
Table Concentration - Spiral tails													
Concentrate	0.09	0.00%	0.24%	12.58%	87.18%	0.00	0.00	0.01	0.08	0.00%	0.00%	0.16%	16.00%
Tail	8.54	99.73%	0.00%	0.03%	0.23%	8.52	0.00	0.00	0.02	100.00%	0.00%	0.04%	4.00%
Gravity circuits - Totals													
Concentrates	0.55	0.00%	0.24%	12.58%	87.18%	0.00	0.00	0.07	0.48	0.00%	0.01%	0.96%	96.00%
Tails	8.54	99.73%	0.00%	0.03%	0.23%	8.52	0.00	0.00	0.02	100.00%	0.00%	0.04%	4.00%
Magnetic Separation - Gravity Circuit Concentrates													
Zircon	0.48	0.00%	0.00%	0.14%	99.85%	0.00	0.00	0.00	0.48	0.00%	0.00%	0.01%	96.00%
Garnet	0.07	0.00%	1.90%	98.10%	0.00%	0.00	0.00	0.07	0.00	0.00%	0.00%	0.95%	0.00%
Nonconductors - Total products													
Zircon	0.48	0.00%	0.00%	0.14%	99.85%	0.00	0.00	0.00	0.48	0.00%	0.00%	0.01%	96.00%
Garnets	7.08	0.00%	0.04%	99.96%	0.00%	0.00	0.00	7.08	0.00	0.00%	0.01%	98.96%	0.00%
Tails	8.75	97.38%	1.55%	0.84%	0.23%	8.52	0.14	0.07	0.02	100.00%	0.51%	1.03%	4.00%

TABLE 4. - Material balance, Cape Blanco placer--Continued
Conductors, subsequent processing

Item	Units	Weight percent - heavy minerals					Units - st/hour - heavy minerals					Percent Distribution - heavy minerals				
	st/hour	Mag.	Ilm.	Chr.	Gar.	Zir.	Mag.	Ilm.	Chr.	Gar.	Zir.	Mag.	Ilm.	Chr.	Gar.	Zir.
Plant Feed	26.28	28.95%	61.93%	9.12%	0.00%	0.00%	7.61	16.28	2.40	0.00	0.00	99.48%	99.47%	99.48%	0.00%	0.00%
Magnetite Rougher Magnetic Scalpers																
Magnetics	26.02	28.95%	61.93%	9.12%	0.00%	0.00%	7.53	16.11	2.37	0.00	0.00	98.48%	98.48%	98.48%	0.00%	0.00%
Nonmagnetics	0.26	28.95%	61.93%	9.12%	0.00%	0.00%	0.08	0.16	0.02	0.00	0.00	0.99%	0.99%	0.99%	0.00%	0.00%
Magnetite Cleaner Magnetic Scalpers																
Magnetics	9.19	81.17%	17.54%	1.29%	0.00%	0.00%	7.46	1.61	0.12	0.00	0.00	97.50%	9.85%	4.92%	0.00%	0.00%
Nonmagnetics	16.83	0.45%	86.17%	13.39%	0.00%	0.00%	0.08	14.50	2.25	0.00	0.00	0.98%	88.63%	93.56%	0.00%	0.00%
Ilmenite Rougher Magnetic Scalpers																
Feed	17.09	0.89%	85.79%	13.32%	0.00%	0.00%	0.15	14.67	2.28	0.00	0.00	1.98%	89.63%	94.55%	0.00%	0.00%
Magnetics	14.90	1.02%	97.46%	1.53%	0.00%	0.00%	0.15	14.52	0.23	0.00	0.00	1.98%	88.73%	9.46%	0.00%	0.00%
Nonmagnetics	2.20	0.00%	6.68%	93.32%	0.00%	0.00%	0.00	0.15	2.05	0.00	0.00	0.00%	0.90%	85.10%	0.00%	0.00%
Ilmenite Cleaner Magnetic Scalpers																
Magnetics	14.53	1.03%	98.89%	0.08%	0.00%	0.00%	0.15	14.37	0.01	0.00	0.00	1.96%	87.84%	0.47%	0.00%	0.00%
Nonmagnetics	0.36	0.42%	39.99%	59.59%	0.00%	0.00%	0.00	0.15	0.22	0.00	0.00	0.02%	0.89%	8.98%	0.00%	0.00%
Ilmenite Scavenger Magneitc Scalpers																
Feed	2.56	0.06%	11.40%	88.54%	0.00%	0.00%	0.00	0.29	2.27	0.00	0.00	0.02%	1.78%	94.08%	0.00%	0.00%
Magnetics	0.31	0.48%	92.28%	7.24%	0.00%	0.00%	0.00	0.29	0.02	0.00	0.00	0.02%	1.77%	0.94%	0.00%	0.00%
Nonmagnetics	2.25	0.00%	0.13%	99.87%	0.00%	0.00%	0.00	0.00	2.24	0.00	0.00	0.00%	0.02%	93.14%	0.00%	0.00%
Conductors - Total Products																
Magnetite	9.19	81.17%	17.54%	1.29%	0.00%	0.00%	7.46	1.61	0.12	0.00	0.00	97.50%	9.85%	4.92%	0.00%	0.00%
Ilmenite	14.85	1.02%	98.75%	0.23%	0.00%	0.00%	0.15	14.66	0.03	0.00	0.00	1.98%	89.61%	1.41%	0.00%	0.00%
Chromite	2.25	0.00%	0.13%	99.87%	0.00%	0.00%	0.00	0.00	2.24	0.00	0.00	0.00%	0.02%	93.14%	0.00%	0.00%

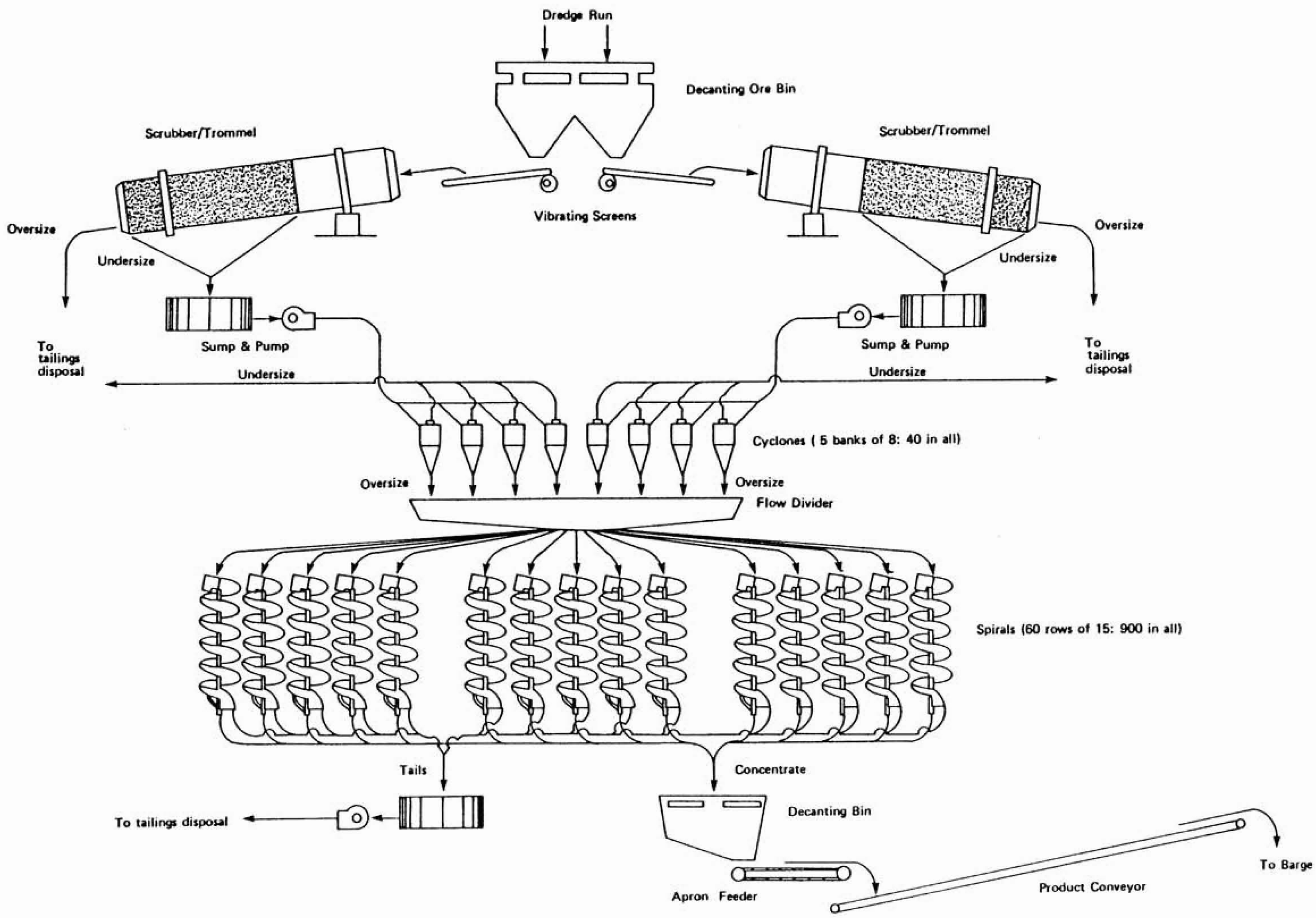

FIGURE 2.– Schematic diagram illustrating on-board processing, Cape Blanco placer

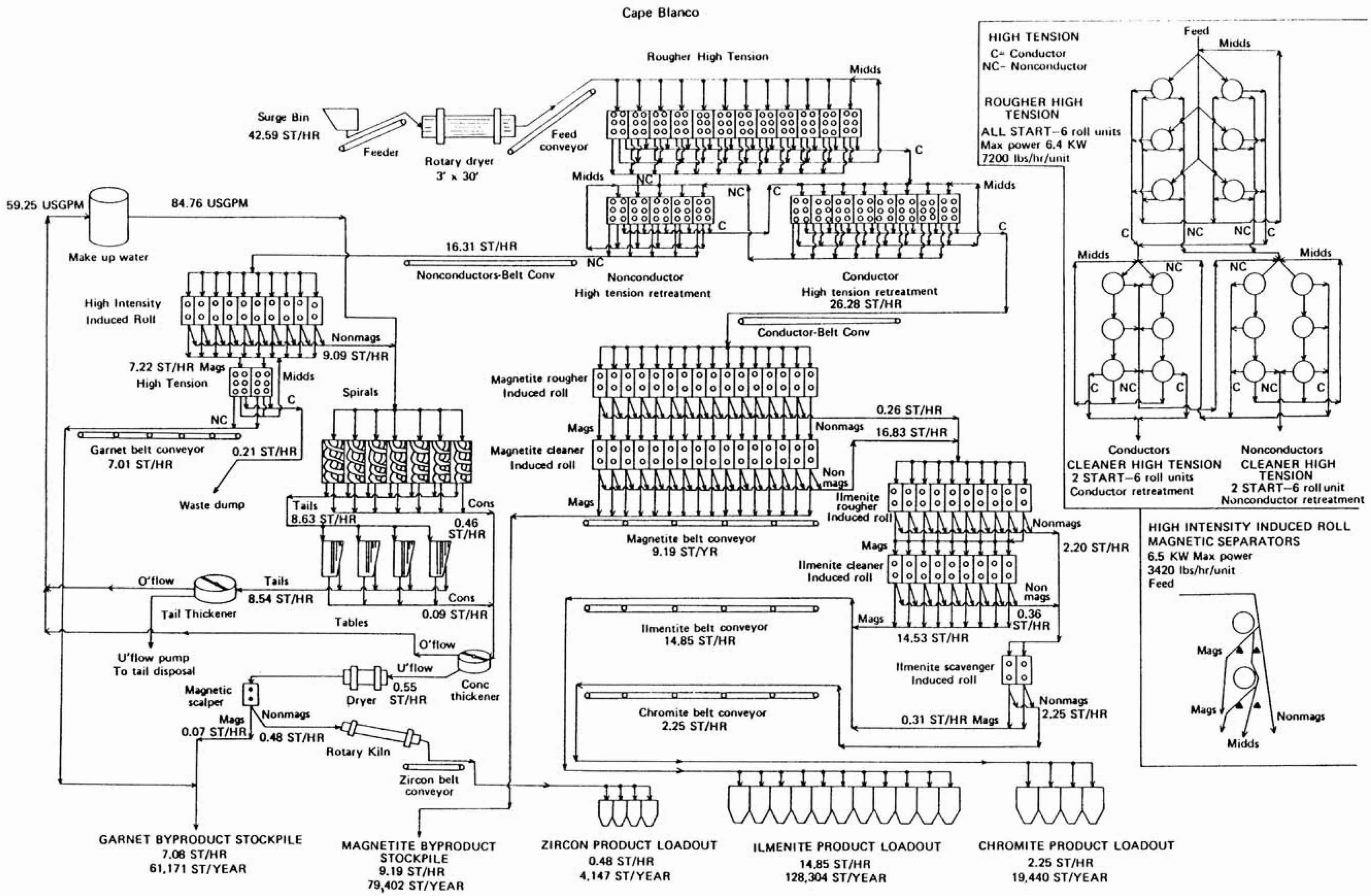

FIGURE 3.- Schematic diagram illustrating onshore beneficiation, Cape Blanco placer

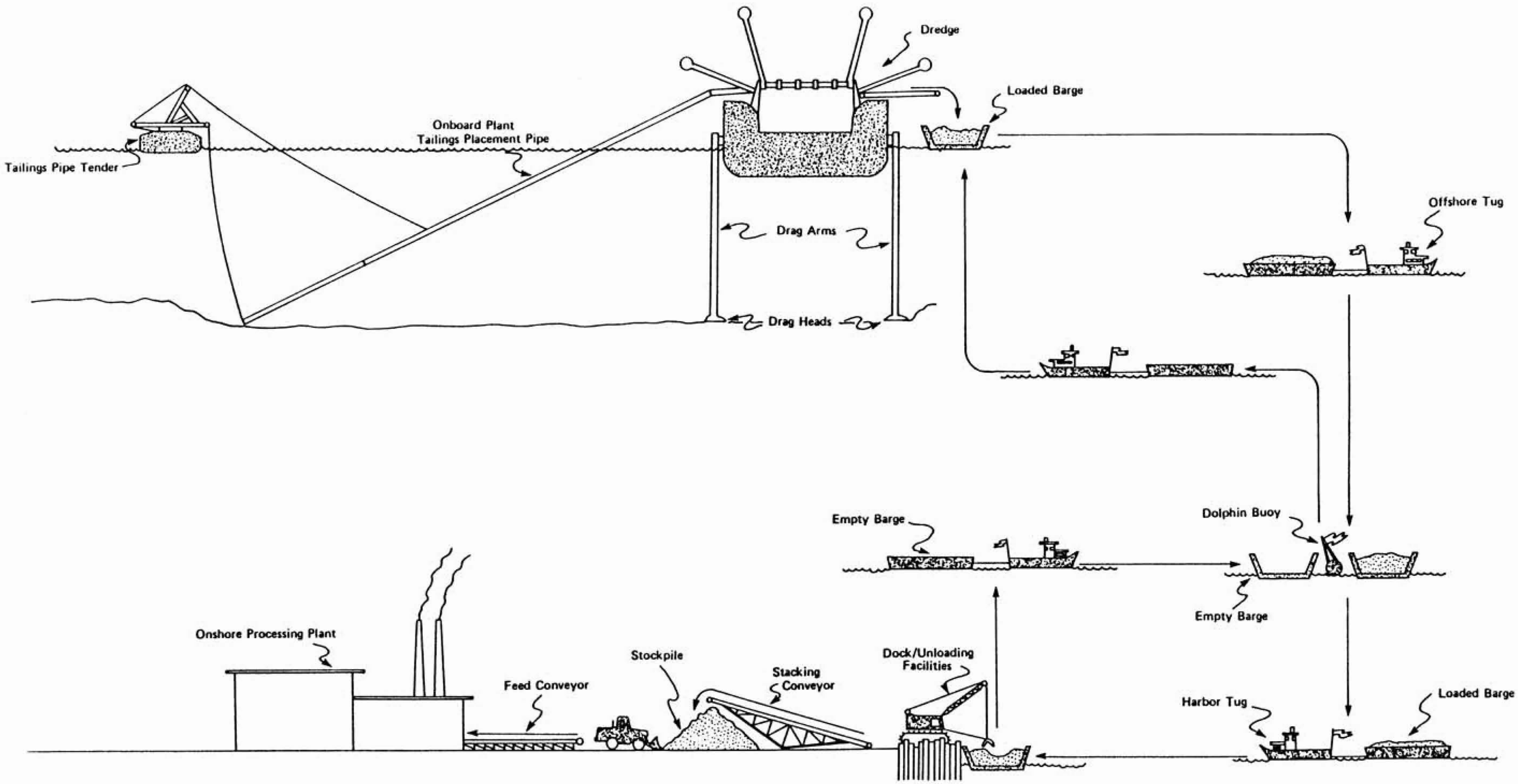

FIGURE 4.-- Schematic diagram illustrating circuit material flow, Cape Blanco placer

COSTS

Methodology

Capital and operating cost data were developed using a variety of information sources and assumptions. Primary considerations affecting cost data are:

- The maximum dredging depth of U.S. dredges in use is 94 ft. This depth would allow a portion of both the Cape Blanco and Rogue River placers to be exploited; however, the shallowest portion of the Umpqua River placer is over 300 ft. It has been assumed that dredging at such depths will require additional pumping stations; however, the technologic feasibility is unknown.

- There has been no process evaluation testing conducted for shelf placers on the Oregon coast. The flowsheets and material balances developed for these deposits are based on average recoveries and separation techniques currently in place in the United States.

- It has been assumed that wave compensation equipment will allow 85 pct recovery of the heavy mineral fraction with the removal of 90 pct of the waste in an on-board spiral concentrating plant.

Capital and operating costs were estimated using the following sources:

- Cost Reference Guide, Dataquest.
- Mining Cost Service, Western Mine Engineering.
- Richardson Rapid System, Richardson Engineering.
- Means Construction Costs, R.S. Means Co.
- Mining and Mineral Processing Equipment Costs and Preliminary Capital Cost Estimations, Canadian Institute of Mining and Metallurgy.
- Offshore mining systems cost, George Gale, Personal Communication.
- Carpco, Inc., Jacksonville, FL.
- Associated Minerals (USA) Inc., Green Cove Springs, FL.

Capital costs include the dredge, complete with on-board processing plant and wave compensators, transport barges, tailings disposal system, onshore beneficiation plant, and dock facility. Also included are exploration costs, research and development expenses, project management expenses and working capital. Exploration for all models was assumed to be $2.5 million and working capital is based on 6 months annual operating costs to cover both the business cycle and startup delays.

Operating costs include dredging, on-board processing, transportation, unloading, and beneficiation plant processing.

Cape Blanco Placer

Capital and operating costs were developed for the Cape Blanco scenario as previously described in this report, i.e., dredging 7.2 million st/a at 28,800 st/d for 250 d/a. Feed to the on-board spiral plant would average an estimated 5 pct heavy minerals (magnetite, chromite, ilmenite, garnet and zircon). Spiral plant production would be 1,472 st/d averaging 80 pct heavy minerals with an 85 pct recovery. Beneficiation of rougher concentrates would produce 1,022 st/d product, byproduct and tail with work continuing 360 d/a.

In addition to the above (base-case) scenario, costs were also developed for two higher grade placers, one containing 10 pct heavy minerals and the other 20 pct. Annual mineral production rates are summarized in table 5. Capital and operating cost estimates for the base-case, 10-pct, and 20-pct models are summarized in table 6. Detailed tables are contained in appendix B; assumptions, calculations, and backup files are contained in appendix C.

TABLE 5. - Annual mineral production, Cape Blanco placer

	Base-case scenario,	Heavy mineral placers,	
	5 pct	10 pct	20 pct
Chromite.............	19,440	38,275	76,464
Garnet...............	61,171	122,342	244,126
Ilmenite.............	128,305	257,126	514,253
Magnetite............	79,402	159,408	318,211
Zircon...............	4,147	8,813	17,626

TABLE 6. - Capital and operating cost estimates, Cape Blanco placer

	Base-case scenario,	Heavy mineral placers,	
	5 pct	10 pct	20 pct
Capital cost.........	$68,958,000	$84,152,000	$112,813,000
Annual operating cost	17,734,000	20,737,000	26,063,000
Cost/st ore[1].........	2.46	2.88	3.62
Cost/st concentrate[2].	48.23	28.12	17.71

[1]Annual tonnage: 7,200,000 st.

[2]Annual tonnage: 368,000 st (5 pct); 737,000 st (10 pct); 1,472,000 st (20 pct).

Rogue River Placer

Like the Cape Blanco placer, capital and operating cost estimates for the Rogue River base-case scenario assume dredging 7.2 million st/a at 28,800 st/d, for 250 days. Feed to the on-board spiral plant would average 3 pct heavy minerals. Spiral plant production would be 939 st/d averaging 80 pct heavy minerals with an 85 pct recovery. Beneficiation of rougher concentrates would produce 652 st/d product, byproduct and tail; operations would continue 360 d/a.

In addition to the base case, costs were developed for two additional scenarios with 6 pct and 12 pct heavy minerals. Annual production rates are summarized in table 7. Capital and operating cost estimates are summarized in table 8. Detailed tables are contained in appendix B; assumptions, calculations, and backup files are contained in appendix C.

TABLE 7. - Annual mineral production, Rogue River placer

	Base-case scenario, 3 pct	Heavy mineral placers, 6 pct	12 pct
Chromite.............	31,363	62,726	125,453
Garnet...............	8,467	17,626	35,165
Ilmenite.............	67,132	133,747	268,013
Magnetite............	78,019	156,038	311,558
Zircon...............	1,728	3,542	7,085

TABLE 8. - Capital and operating cost estimates, Rogue River placer

	Base-case scenario, 3 pct	Heavy mineral placers, 6 pct	12 pct
Capital cost..........	$67,872,000	$71,117,000	$102,227,000
Annual operating cost.	16,902,000	19,094,000	22,824,000
Cost/st ore[1]..........	2.35	2.65	3.17
Cost/st concentrate[2]..	71.90	40.62	24.25

[1]Annual tonnage: 7,200,000 st.
[2]Annual tonnage: 235,000 st (3 pct); 470,000 st (6 pct); 941,000 st (12 pct).

Umpqua River Placer

As before, capital and operating cost estimates for the Umpqua River base scenario are based on dredging 7.2 million st/a at 28,800 st/d, for 250 days. Feed to the on-board spiral plant averages 3 pct heavy minerals as does the Rogue River placer; however, feed composition is markedly different. As indicated in table 9, the Umpqua placer is enriched in ilmenite, garnet and zircon, while the Rogue placer is enriched in chromite and magnetite (table 7).

TABLE 9. - Annual mineral production, Umpqua River placer

	Base-case scenario, 3 pct	Heavy mineral placers, 6 pct	12 pct
Chromite.............	19,958	39,917	79,934
Garnet...............	19,354	38,793	77,587
Ilmenite.............	91,411	182,822	365,558
Magnetite............	40,867	81,648	163,296
Zircon...............	12,960	26,438	52,877

Spiral plant production would be 930 st/d averaging 80 pct heavy minerals with an 85 pct recovery. Beneficiation of rougher concentrates would result in production of 646 st/d product, byproduct, and tail, 360 d/a.

In addition to the base case, costs were also developed for a 6 pct and a 12 pct heavy mineral placer. Capital and operating cost estimates are summarized in table 10. Detailed tables are contained in appendix B; assumptions, calculations, and backup files are contained in appendix C.

TABLE 10.- Capital and operating cost estimates, Umpqua River placer

	Base-case scenario, 3 pct	Heavy mineral placers, 6 pct	12 pct
Capital cost...........	$72,400,000	$81,712,000	$99,704,000
Annual operating cost..	18,508,000	20,660,000	24,498,000
Cost/st ore[1]...........	2.56	2.87	3.40
Cost/st concentrate[2]...	79.58	44.36	26.32

[1]Annual tonnage: 7,200,000 st.

[2]Annual tonnage: 233,000 st (3 pct); 466,000 st (6 pct); 931,000 st (12 pct).

ECONOMIC ANALYSES

Methodology

Financial evaluations were performed using Software for Economic Evaluation (SEE), published by Investment Evaluations Corp., Golden, CO. The software provides standard discounted cash flow after tax evaluations of cost data provided by the user. The following assumptions were used in the analyses:

- Federal corporate income tax rate - 34 pct
- State corporate income tax rate - 6.6 pct
- Property tax rate - 2.646 pct
- Metal recovery:
  - Chromite - 79.2 pct
  - Ilmenite - 76.2 pct
  - Zircon - 81.6 pct
  - Garnet 84.1 pct
- Metal prices:
  - Chromite - $54.42/st
  - Ilmenite - $45.00/st
  - Zircon - $235.00/st
  - Garnet - $25.00/st

Additionally, mine life for all evaluations is set at 20 yr. Although potential deposits would probably last well beyond this, 20 yr is considered the maximum time that financial projections remain reasonably accurate. A 4-yr preproduction research, exploration, and development period is anticipated for these operations.

It is also uncertain whether the garnet is marketable. Accordingly, financial analyses initially were run with garnet revenues included, then rerun without garnet revenues.

Financial analyses using discounted cash flow over a 20-yr mine life show negative rates of return (ROR) for all three placer areas, even if inferred grades are doubled. If a grade of 20 pct recoverable heavy minerals is assumed for the Cape Blanco deposit, a 10 pct ROR is possible only if garnet concentrates can be marketed, which is highly speculative. A similar result (8.6 pct ROR) is obtained for the Umpqua River deposit by assuming a grade of 12 pct recoverable heavy minerals. All analyses assumed that ilmenite and chromite are of marketable quality. If recoverable precious metals are present in the offshore deposits, an added value of between $3.00 and $3.50/st of dredged materials is required to provide a 15 pct ROR. In terms of grade, approximately 0.008 tr oz/st of recoverable gold or platinum would be needed for economic viability.

Cash flow files and sensitivity analyses are contained in appendix D.

CONCLUSIONS AND RECOMMENDATIONS

Resource models developed by OSU indicate more than sufficient quantities of material to support a sustained mining operation. However, at current prices, chromium and titanium grades inferred from shallow near-surface samples could sustain profitable operations only with significant recovery of precious metals, i.e., gold and platinum. Recent sampling of onshore placers in the Rogue, Sixes, and Klamath Rivers near their discharge points into the Pacific Ocean identified concentrations of both gold and platinum. This suggests that these metals are likely to be present in the Cape Blanco and Rogue River offshore placers. Potential quantities and recoverabilities remain to be determined.

This preliminary appraisal of Oregon offshore placers identifies the resource, technology, and economic constraints for potential development. Further refinement of the analysis will require completion of the following recommended investigations: (1) vibracore drilling of heavy mineral anomalies to confirm placer concentrations and determine grades at depth, especially precious metal content; (2) recovery of bulk samples for beneficiation testing and determination of ilmenite and chromite bulk compositions for evaluation of marketability; (3) evaluation of garnet fractions to determine suitability and marketability; and (4) based on beneficiation tests, evaluation of potential value-added processing of concentrates to produce synthetic rutile, titanium sponge, and charge ferrochromium.

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Section 3.0

A PRELIMINARY LITERATURE REVIEW OF POTENTIAL ENVIRONMENTAL AND BIOLOGICAL CONCERNS RELATED TO PLACER MINING ON THE SOUTHERN OREGON COAST

A report prepared for the Oregon Department of Geology and Mineral Industries

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PREFACE

This report reviews the possible environmental and biological effects an offshore placer mining operation may have on the biological resources of the southern Oregon coast. The introduction provides information on the location, geology, and potential mining scenario of the placer deposits based on assessments provided by the authors of other sections included in this volume.

Because little ocean mining is currently taking place at this time, a thorough survey of potential impacts is difficult to complete. The potential generic impacts presented here are based on the available literature which relies heavily on studies concerning channel dredging and sand and gravel mining operations. Few studies directly address the potential impact of offshore mineral mining. The major components of the biological communities found off Oregon are reviewed, and where possible, those living resources known to be important in the nearshore environment off southern Oregon, or those that may be affected by mining are focused on. A review of environmental studies of mining operations or dredging projects that may have application to placer mining off Oregon is also presented. This section includes a brief review of major findings, followed by detailed appendices of the studies.

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A PRELIMINARY LITERATURE REVIEW OF POTENTIAL ENVIRONMENTAL AND BIOLOGICAL CONCERNS RELATED TO PLACER MINING ON THE SOUTHERN OREGON COAST

INTRODUCTION

The mineral resources located on the continental shelf of southern Oregon are currently being evaluated for their possible economic and strategic importance. High concentrations of heavy minerals found in these offshore deposits include chromite, ilmenite, zircon, magnetite, garnet, and gold (Kulm, 1988). Chromite is of particular interest because of its importance as a strategic metal. Knowledge of mineral deposits located onshore provides clues to potential deposits located offshore; however, until more is known about the location, extent, and mineral characteristics of these deposits, the future of ocean mining off Oregon is conjectural.

Historically, heavy minerals have been mined from the beaches and rivers of southwest Oregon. Trace quantities of gold and platinum were mined as early as 1850, and chromite was mined from coastal terrace deposits between Cape Arago and Bandon during World War II (U.S. Department of the Interior, 1987). Today, interest has shifted from onshore deposits to offshore deposits. Recent studies identifying the location and concentrations of heavy mineral deposits of the Oregon beaches show that there is considerable potential for these deposits (Peterson and Binney, 1988; Peterson and others, 1988, 1986; Komar and Wang, 1984). The sources of these heavy minerals are the igneous and sedimentary rocks that comprise the drainage basins of southern Oregon and northern California (Kulm, 1988). These minerals are carried by coastal rivers and streams to the beach, where coastal processes concentrate them into enriched placer deposits. The continental shelf adjacent to these coastal rivers is believed to contain similar placer deposits that were formed during periods of low sea levels (Kulm and others, 1968). By studying onshore marine terrace and beach deposits, characteristics of offshore deposits may be predicted.

Heavy-mineral deposits located on the continental shelf presumably formed by the same processes seen occurring on beaches today. As heavy minerals are deposited on the beach face, they are subject to wave swash, and sediment transport processes sort the heavier minerals from the lighter ones. Because these heavy minerals are fine-grained, high-density particles, they tend to concentrate on the beach face more readily than larger-grained, low-density particles such as quartz and feldspar, which tend to be transported offshore by wave action (Komar and Wang, 1984). Along with the sorting of minerals on the beach face, patterns of longshore-sediment transport are also responsible for the sorting of minerals. High-energy waves from strong southwest winds of winter storms result in the deposition of sand and heavy minerals on the south sides of headlands. During the summer, smaller waves approaching from the northwest move sands back to the south, selectively transporting larger grained particles, thus leaving behind concentrations of heavy-minerals deposits (Peterson and others, 1988).

The locations of several offshore placer deposits have been identified as the result of magnetometer surveys and sediment core samples. The surface and near-surface core samples of these deposits indicate that heavy minerals range from 10 to 56 percent by weight of the total sample, with chromite, ilmenite, and magnetite forming the bulk of the concentration (Kulm, 1988). The most extensive deposits to date are located off the Rogue River, where heavy mineral concentrations range from 20 to 30 percent, and in an area off Cape Blanco and the Sixes River, where heavy mineral concentrations range up to 33 percent (Figure 1). The Rogue River deposit is approximately 37 km long and extends from the nearshore zone to depths of 90 m of water, and covers an area of 48 km^2. The Cape Blanco deposit is about 13 km long and ranges in depth from 18 m to 55 m of water, and covers an area of 318 km^2 (Kulm and Peterson, this volume). It has been suggested that the magnetic

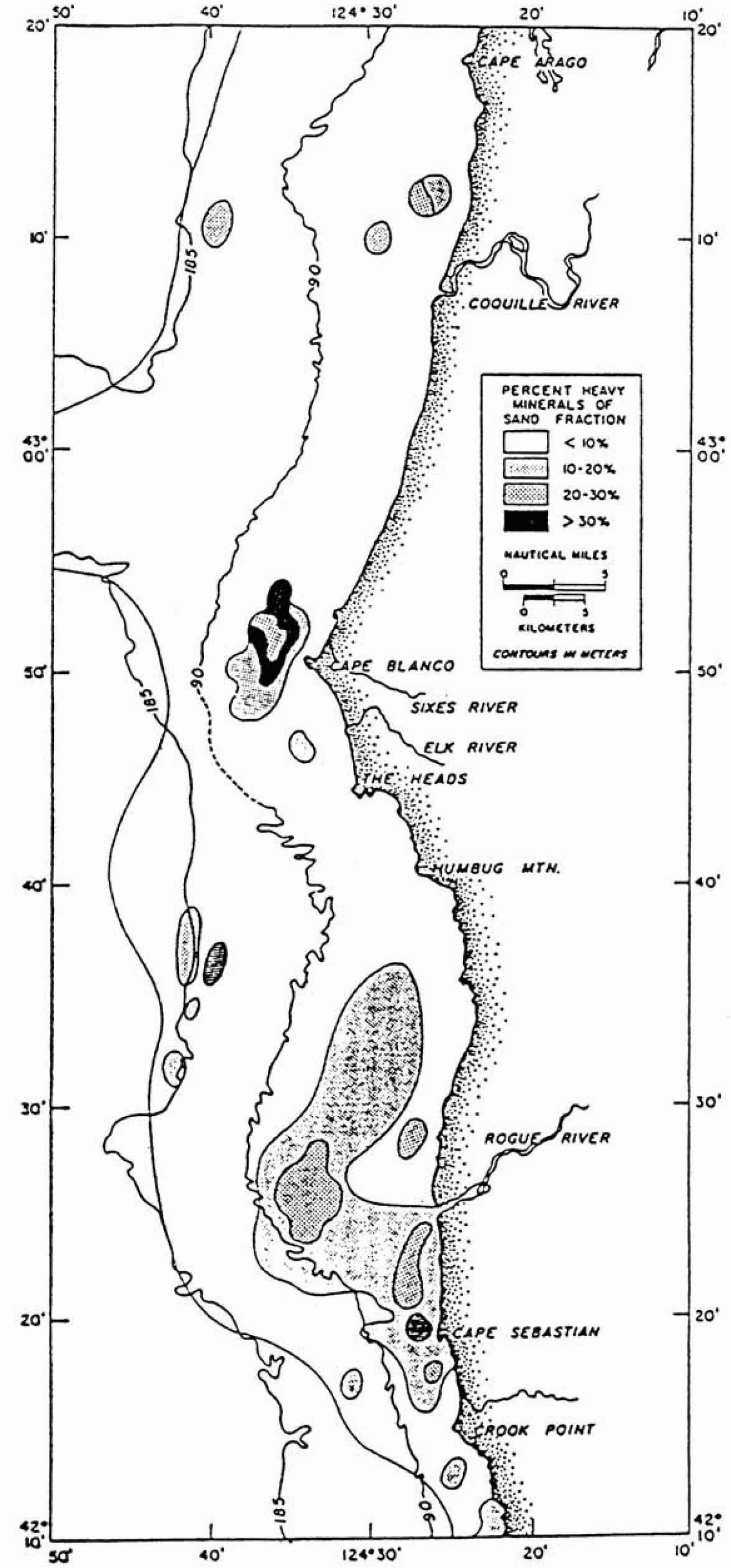


Figure 1. Heavy-mineral concentrations in the sand fraction of surface samples. From Kulm, 1988.

anomalies found off the Rogue and Sixes Rivers are caused by mineral deposits of similar dimensions and mineral characteristics as those deposits located onshore in adjacent beach and terrace deposits (Kulm, 1988; Peterson and others, 1988).

Offshore mineral deposits are unconsolidated sedimentary materials buried below varying depths of overburden (Cruickshank and others, 1987). The most widely used technology applicable to offshore mining is dredging, which consists of excavating the unconsolidated material from the sea floor, raising the dredged material to the surface, and discharging it into a hopper or barge. Waste material or tailings are returned to the water after the desired minerals are removed. Similar dredging technologies are currently used by the U.S. Army Corps of Engineers in routine harbor and channel maintenance operations. Dredging methods were also used to mine the rivers draining the gold fields of southern New Zealand over a century ago. To date, no minerals of any type have been commercially dredged offshore in depths greater than 100 m, and very little has occurred in depths greater than 50 m (Office of Technology Assessment, 1987). Dredging and other ocean mining technologies are described in detail by the Office of Technology Assessment (OTA) (1987) and Cruickshank and others (1987).

A recent assessment of mining technologies applicable to the recovery of heavy minerals off the Oregon coast concluded that a twin-pipe trailing suction head dredge would be the method most likely to be used (Wetzel and Stebbins, this volume). This type of dredge is self propelled and will have a hold or hopper on board to store the dredged material. As the dredge moves along, a slurry of sediment and sea water is suctioned off the seafloor, pumped up through the drag arms, and emptied into the hold. Once on board, the dredged material will be scrubbed and large rocks and organic materials will be removed. The sediments will then undergo some degree of mineral concentration through the use of a spiral classifier (a mechanical gravity separation device). This method takes advantage of the difference in densities of the dredged materials. The heavier, valuable minerals such as ilmenite, chromite, and magnetite will be separated from the lighter sand particles. The spiral concentrates then are moved to a decanting bin, then conveyed to a tending barge adjacent to the dredge where they will be transported to an on-shore facility for further benefication. The unwanted materials, or tailings, from the on-board plant are discarded by pumping them approximately 200 m shoreward from the dredge and depositing them on the seafloor. In this way, the tailings may backfill trenches left by the initial collection process.

Recent research efforts indicate that heavy mineral deposits do indeed exist on the continental shelf, but detailed information describing the exact location and mineral characteristics of Oregon's offshore placer deposits is lacking. Such information is needed in order to assess the feasibility of their development. A study including detailed seismic and magnetic surveys, along with deep core sediment samples and seismic testing would be required in order to define the location and extent of placer deposits and their mineral content. Without such information, economic and mining technology assessments would not be possible, nor would a thorough environmental assessment be possible.

Jurisdiction over resources located within 5.6 km of the shoreline was awarded to the state of Oregon by Congress in the Submerged Lands Act of 1953. Further, the Exclusive Economic Zone (EEZ), established by Presidential proclamation in 1983, is the area extending 371 km seaward from coastal state shorelines. The EEZ guarantees the United States sovereign rights over all seabed resources, living and non-living. The majority of the placer deposits off of Oregon are located within 5.6 km of the shore and subsequently fall under the jurisdiction of state agencies. The agency authorities concerned with the mineral mining and exploration of Oregon's territorial sea have been described by Good and others (1987) and Good and Hildreth (1985). In 1987, the State of Oregon passed legislation to revise existing laws governing mineral leasing on submerged state lands. The Oregon Division of State Lands (DSL) has exclusive authority over both submerged lands and mineral exploration activities. Permits for the exploration of hard minerals on submerged lands are administered by the DSL. Administrative rules for offshore exploration and development of hard minerals are currently being developed by the DSL. Development leases will not be issued until the DSL adopts leasing rules for Oregon's territorial waters. To date, no state or federal exploration permits have been issued for areas off Oregon.

I. POTENTIAL GENERIC IMPACTS OF OFFSHORE PLACER MINING

Marine mining operations may potentially affect various geological, physical, chemical, and biological processes and equilibria in the nearshore zone. An outline of the potential impacts of marine mining is included in Table 1.

PHYSICAL IMPACTS

Coastal Erosion. The mining of offshore mineral deposits will require the removal of large quantities of material from the seafloor. An initial concern over this type of activity is the possibility of coastal erosion. The nearshore zone is in equilibrium between erosional and depositional processes and any disturbance in this balance could result in changes in sediment distribution (Komar, 1976). The removal of bulk quantities of material from the nearshore zone could result in materials from adjacent areas shifting into the excavated area, thereby causing erosion of the coastline (Rees, 1980). Increases in depth at the excavation site could alter wave patterns or tidal current circulation patterns that would affect the rate or direction of the longshore current, the principle agent of sediment transport in the nearshore zone. Any interference in the movement of sediment could result in siltation of harbors or navigation channels, formation of sand spits or bars, or erosion of shorelines, particularly beaches (Owen, 1977).

In the United Kingdom, where sand and gravel extraction operations have been occurring for over 50 years, there has been little actual evidence of coastal erosion resulting from dredging operations (Hess, 1971). However, several erosional problems of questionable origin have been noted at beaches and nearshore sandbars adjacent to long-term dredging operations. Some beaches have been completely denuded of sand, exposing lattice structures originally designed to retain sand on those stretches of shoreline. Dredging operations may have affected processes conducive to the natural replenishment of sand, while the natural erosional processes continued to transport sand away from the beaches (Hess, 1971).

Although little is known about the effects of ocean dredging on coastal erosion, research has shown that significant wave induced sediment transport generally occurs at depths of less than 20 m (Crickmore and others, 1972; Swift and others, 1972) Beyond the zone of breaking waves, the water is sufficiently deep that any changes in bottom contours will not appreciably affect the wave energy expended at the shoreline. Gravel mining below this depth is not likely to cause coastal erosion (Baram and others, 1977). The United Kingdom now grants mining permits almost exclusively to regions beyond the 5.6 km limit where minimum depths range from 30 m to 50 m (Hess, 1971).

United States research on the impacts of sand and gravel mining tends to focus on how nearshore "borrowing" and beach sand replenishment affect benthic communities. Recent studies have shown that potential environmental and biological impacts can be avoided or minimized by thorough assessment of the environment within the proposed area and by careful planning before a dredge and fill operation occurs. Although the environmental impact of this type of dredging operation has been less thoroughly examined, studies concerning nearshore borrowing and beach replenishment may be applicable to offshore mining concerns (Hurme and Pullen, 1988).

Navigational Hazards. Other physical effects of dredging include changes in bottom contours due to the extraction process. A clamshell, bucketline, or any type of stationary dredge will cause large pits or craters to be formed in the seafloor. Stationary dredges currently used in sand extraction

Table 1. Outline of Potential Generic Impacts from Marine Mining

I. Physical Impacts

   A. Coastal erosion
   B. Navigational hazards (craters, swaths, mounds, etc.)

II. Biological Impacts on the Benthic Environment

   A. Destruction of benthic organisms
   B. Alteration of benthic habitat
   C. Benthic recolonization

III. Biological Impacts on the Pelagic Environment

   A. Increased turbidity, rain of fines
      1. Inhibit photosynthesis/primary production
      2. Interfere with feeding efficiency
      3. Disrupt animal behavior, migratory routes

   B. Reintroduction of Substances from the Sediment
      1. Anoxic sediments
      2. Nutrients
      3. Trace metals
      4. Toxic compounds (PCB's, pesticides, etc.)

V. General Disturbance from Mining Operation
      1. Disruption of foraging, resting, breeding areas
      2. Interference with migration patterns, animal distribution

VI. Exploration Techniques and Fuel Spills operations can leave holes in the seafloor up to 20 m deep and 70 m in diameter (Cruickshank and Hess, 1978). Craters of this size may persist for many years and will fill slowly with silt and clays if the water circulation in the area is poor. Under such conditions, these craters may become anaerobic and thus biologically unproductive (Good and others, 1987). One dredge crater was the focus of a study by the Corps of Engineers in the Long Island Sound. A large pit was formed when 334,000 m^3 of sand and gravel was removed from the seafloor. Three years later, bathymetric surveys indicated that only 18,350 m^3 of material had accumulated in the hole. Analysis of grab samples taken within the crater revealed that the refilled material was mainly silt and clays, although the surrounding material was comprised of sand and large-grained sediments (Vesper, 1961). A situation such as this is unlikely to occur in the high-energy, sand environment of the inner shelf off southern Oregon.

Trailing dredges do not leave large craters; instead they leave behind a series of shallow linear tracks as a result of scraping or suctioning off the top layers of sediment (Cruickshank and Hess, 1978). This method of extraction would tend to minimize the effects of altering bottom contours, although a rough surface will be left behind that may reduce the efficiency of bottom trawls used by commercial fishermen (International Council for the Exploration of the Sea, 1975).

After the mined material is brought on board and processed, the unwanted materials will be disposed of at sea. Mounding or shoaling may occur if such disposal is allowed to take place at any one site over an extended period of time. Such mounds in shallow water could create potential navigational hazards if allowed to persist. Mounding is not likely to occur in the proposed south coast mining area due to significant rates of sand transport in the high energy nearshore environment.

The proposed mining dredge for the Oregon south coast will create a single trench approximately 30 m wide. The depth of the trench will depend on the amount of sediment over the deposit and the depth of the deposit itself. At present, it is estimated that the bulk of the recoverable minerals off Cape Blanco are located under 0 to 16 m of sediment overburden, while the average thickness of overburden for the Rogue River deposit is about 20 m (Kulm and Peterson, this volume). The depth of these deposits is currently unknown, therefore it is difficult to calculate the amount of material that will be removed from the seafloor for processing, or the approximate depth of the dredged trenches. Tailings from the on-board processing plant will be pumped down to the seafloor in such a way as to backfill previous trenches thus minimizing the potential for altering the configuration of the seafloor (Wetzel and Stebbins, this volume). The actual mining scenario for the Oregon coast will depend on the nature and location of the offshore deposits.

Benthic Recolonization. Benthic organisms residing in the nearshore zone, tend to be well adapted to this high-energy environment and the natural erosional and depositional cycles associated with seasonal storms and sediment transport. Although an initial decline in species numbers and diversity will be observed immediately following dredging, recovery is rapid once operations have ceased (Jewett and others, 1989). In a study looking at the biological effects of sand mining off Panama City Beach, Florida, Saloman and others (1982) found that although the physical environment had been altered and the benthic communities destroyed, recovery was almost immediate for some motile species, and almost complete within one year for dominant groups including annelids, mollusks, and crustaceans. At several sand and gravel mining sites in the North Sea, observations at post-dredged areas found that benthic recolonization began within months of cessation of dredging, and benthic communities similar to the pre-dredging communities were established after two to three years (de Groot, 1986). Macrofauna tend to recover quickly due to their short life cycles, high reproductive rates, and planktonic larval recruitment from unaffected areas. However, the composition of the new community may differ from the pre-mining community depending on the availability of larvae, suitable conditions for settlement, and mortality (Hurme and Pullen, 1988). The new faunal elements may be less preferred food for other organisms and once established, may be difficult to be displaced by the original community.

In areas that are periodically disturbed, a stable, diverse community may never be attained. Recolonization studies off Nome, Alaska, have shown that after an initial decline in the benthic population due to the removal of organisms, recolonization of sand substrate is apparent after one year, and a stable community is expected in three to four years; however the species composition of the reestablished community may differ from the composition of the community prior to dredging (Jewett and others, 1989).

Hurme and Pullen (1988) concluded that if the composition of the post-mining substrate is similar to the pre-mining substrate composition, the final long-term bottom profile has similar contours to the original profile, and the relative depths have not been changed greatly, then the removal or addition of layers of sediments will probably not have any long-term adverse effects on the marine benthos.

IMPACTS ON THE PELAGIC ENVIRONMENT

Turbidity Plumes

Turbidity plumes will be created as the material is collected off the bottom and as tailings are discarded from the ship. Although sediment plumes may be visibly observed for several kilometers, measurable effects from the resettling of suspended material will occur over much shorter distances from the source (Cruickshank, and others, 1987). Physical factors influence how long particles remain suspended in the water column and therefore how far from the source they will be deposited. This in turn will determine the specific locations and habitats that may be at risk from the adverse effects associated with the resettling of suspended material (Bottom and others, in prep).

The degree of severity of the turbidity plumes will depend on the methods used in both the extraction process and during tailings disposal. The use of a suction-head type dredge will tend to minimize the amount of sediment released into the surrounding water at the site of collection, while piping tailings down to the seafloor will reduce the amount of material released into the water column adjacent to the dredging site (Demlow and others, 1989). It should be noted that conditions of high turbidity occur naturally in the nearshore environment where high rates of sediment transport are common (Komar, 1976).

BIOLOGICAL IMPACTS

During any discussion of potential impacts on marine organisms, one must keep in mind that organisms interact via a complex system of ecological pathways; therefore, changes in one group or trophic level of organisms may affect other groups or trophic levels of organisms. In this way, the potential impacts associated with marine mining may come from secondary or indirect sources, as well as from direct impacts.

IMPACTS ON THE BENTHIC ENVIRONMENT

Potential impacts to the benthic community include entrainment, smothering or burial, loss of substrate, and redistribution of benthic populations due to changes in the sediment qualities (grain size, texture, etc.). Each of these impacts potentially could result in changes in the number of species present, species diversity, and density as well as the productivity of the affected area. These variations may not be significant ecologically, but if an area is slow to recover, it could have a long-term impact on the ecological pathways in the affected area. The severity of disturbance will depend on the size of the area to be mined, composition of the benthic community (presence of unique or commercially valuable species), seasonal timing of the operation, composition of the resulting substrate, and the rate at which the area will recover from the disturbance (Owen, 1977).

Destruction of Organisms. Any type of mining operation will invariably disturb benthic communities located in the path of the dredging device. Motile organisms may be able to avoid the dredging equipment, while less motile species will be collected along with mined material. In addition to the direct loss of benthos through entrainment, the resettlement of bottom sediments released during the mining process may effectively bury or smother organisms within the zone of deposition.

Elimination of Habitat. Resettlement of sediments could have long-term impacts on the benthos, especially if habitats that do not normally experience heavy sediment loads or are inhabited by long-lived species, are located within the zone of deposition. Such areas may be sensitive to disturbance and slow to recover (Bottom and others, in prep). Feeding and spawning grounds may also be particularly vulnerable to changes in sediment characteristics (texture, grain size, organics content, etc.). Sand and gravel mining in the North Sea has raised particular concern over loss of spawning habitat and benthic food sources for commercially important species (International Council for the Exploration of the Sea, 1975). Many species have specific requirements for spawning substrates, and changes in sediment type could result in the loss of preferred spawning ground. Some organisms such as crabs may exhibit short-term avoidance of the disturbed area due to a loss of habitable substrate or food sources; however, they also may be attracted into the mined areas as new benthic food sources become available due to the disturbance of bottom sediments during mining. In areas where the repopulation of benthic communities is slow, organisms may move out of the area due to the displacement of a food source. Other commercial fisheries which target bottom dwelling species may also experience decreased catch rates as benthic feeding species move out of the area due to the displaced food source.

Creation of New Habitat. Conversely, changes in the bottom contours from the mining operation could create new types of habitats. Local mounding or shoaling of tailings and depressions created from mining may cause fish to congregate in these areas of relief, especially if a food source is also available (Rounsefell, 1975). Such effects may be short-lived, as the area will be smoothed out due to the natural migrations of sediment in the high-energy environment.

Primary Productivity. Any increase in the suspended particle load will interfere with the passage of light into the water column (Lee, 1979). Increased turbidity due to sediment plumes created during mining may promote or inhibit photosynthesis depending on the light and nutrient requirements of each phytoplankton species. A reduction in photosynthetic activity due to a decrease in the available light may occur, or on the contrary, primary productivity may increase due to nutrient enrichment of the surrounding water from materials released from bottom sediments disturbed during mining. Either effect could alter the abundance, diversity, and composition of the plankton community. Because photosynthetic phytoplankton comprise the lowest trophic level, variations of the standing stock of plankton could affect higher trophic levels which feed on phytoplankton. However, in all probability, turbidity plumes will have little immediate affect on phytoplankton due to the small area to be mined and the high dilution rate of the nearshore zone.

Food Ingestion and Assimilation. Intense turbidity may limit the availability of acceptable food sources, causing ingestion of non-nutritive particles or clogging of feeding mechanisms of filter-feeding organisms (Cruickshank and others, 1987). A number of laboratory studies have assessed the lethal limits of suspended particles for a variety of organisms. Sensitivity to high turbidity varies between species and life stages, with larval and juvenile forms generally being more vulnerable than adult forms (Brinkhuis, 1980). Such studies often use artificial sediments such as Kaolin clay or glass shards to create conditions of high turbidity and do not allow for the behavioral response of avoidance (Lee, 1978). Although these studies have limited applicability to the conditions likely to occur in a real dredging scenario, their results may be useful in identifying those species that are more sensitive to prolonged exposure of suspended particles.

Behavioral Responses. Exposure of fishes to high suspended sediment loads will occur in the water column where the discharge plume exists and on the seafloor in the zone of deposition. The response of various fishes to the mining operation can be expected to vary, with some species being attracted to the area while others will avoid the area of increased turbidity. Some fishes may be attracted into the area if new sources of food are made available during the mining process. High turbidity could indirectly affect fish species by reducing the plankton and benthic populations that serve as a food source. It is expected that most fish will avoid the area if the suspended sediment load becomes stressful.

Many organisms respond to light intensity by moving vertically within the water column. Migrating species generally move toward the surface during dusk and away from the surface during dawn (Anikouchine and Sternberg, 1981). Changes in light penetration may disrupt the feeding behavior and success of these organisms by altering patterns of diel migration. A decrease in available light from an increase in turbidity could also interfere with the visual feeding of some organisms by inhibiting their ability to locate food. This reduction in obtainable food sources may cause some organisms to leave the area in search of food.

Most studies concluded that the impacts associated with increased turbidity would be minimal due to rapid dilution in open waters, the relatively small area being mined, and the apparent tolerance of many species to high suspended sediment loads that occur naturally in the nearshore environment (Cruickshank and others, 1987; Office of Technology Assessment, 1987; Baram and others, 1977). However, little is known about the long-term effects of a continuous sediment plume. Most research has focused on the short-term effects of increased turbidity in a laboratory setting or from transient dredged material disposal operations. During a commercial mining operation, the sediment plume will be continuously renewed, creating a turbidity gradient down-current from the mining site. Mobile species like fishes may avoid the areas of high turbidity or migrate around them. Complications arise when species that avoid the area are an integral part of the food chain or are of commercial value and no longer congregate in traditional fishing grounds (Owens, 1977). Because of the difficulty of predicting the dispersion pattern of suspended particles, qualitative and observational approaches will be needed to determine the long-term effects of such a sediment plume (Baram and others, 1977).

Reintroduced Substances

The reintroduction of substances from the sediment can affect the water quality in the dredged area. Exposure of anoxic sediments to the oxygenated environment of the overlying water column will initiate a series of chemical reactions resulting in the reduction of dissolved oxygen levels and the production of hydrogen sulphide in the surrounding water. The pH and redox potential of the bottom sediments are particularly sensitive to the dissolved oxygen content and strongly influence the chemical state and bioavailability of nutrients, trace metals, and toxic compounds that may be present in the bottom sediments (Gambrell and others, 1976).

Nutrients. The release of nutrients such as nitrogen and phosphorus into the water column may provide some beneficial effects to the mined area. An increase in the available nutrient supply may stimulate the growth of phytoplankton, which provide a source of food to other trophic levels. On the other hand, some species may be inhibited by these conditions, causing a change in species composition and production levels in the area. High production may also cause a reduction in oxygen levels in bottom waters as the additional cells die and begin to decompose (Lee, 1978).

Trace Metals and Toxins. Trace metals occur in nearshore sediments naturally or as a result of runoff or discharges from industrial or agricultural processes (Baram and others, 1977). Disturbance of such sediments during dredging could cause the release of metals or toxic organic compounds into the water column. Most studies on the effects of reintroduced substances have been done in estuaries or harbors, where sediments tend to be contaminated and high in organics. Impacts on water quality due to the release of substances from the sediment are unlikely due to rapid dispersion rates and buffering abilities of open coastal waters (Baram and others, 1977). Sediment samples from potential mining sites should be examined for possible toxins and trace metals prior to any mining operation. Historic Corps of Engineers dredge disposal sites also should be identified for their proximity to the potential mining sites.

Disturbance from Mining Activity

General Disturbance. General disturbance from the mining operation is likely to cause mobile animals to avoid the area. Noise and movement of dredges, support vessels, and air traffic may cause displacement of marine birds and mammals from established colonies located near the disturbance. Animal responses will depend on the species, reproductive state of the animal, distance from the disturbance, and the type, intensity, and duration of the disturbance (U.S. Department of the Interior, 1988). Low-flying aircraft near colonies of birds often frighten adults off their nests, leaving eggs and juveniles vulnerable to exposure, predation, or accidental displacement. Repeated disturbance could significantly reduce the hatching and fledging success of eggs and juveniles, which could cause a reduction in the local population (Roy Lowe, USFWS, personal communication). Noise from aircraft and vessel traffic also will panic hauled-out seals and sea lions near the source of the disturbance, possibly causing death, injury, or abandonment of pups. If such disturbances occur frequently, preferred areas may be abandoned, resulting in a long-term change in animal distribution.

The possibility of entrainment exists not only for those organisms in the path of the dredge, but also for those organisms near water intakes located at the sides of the vessel. As water is drawn on board for benefication of the mined material, phytoplankton, zooplankton, and pelagic eggs and larvae of fishes and shellfishes may be entrained, although the effects will likely be undetectable on future recruitment.

In order to minimize disturbance to biological resources, buffer zones should be established around those areas frequented by various species. Consideration should also be given to those times of the year when species are breeding at or migrating through a particular area. The size of the buffer zone would be dependent on the sensitivity and behavioral patterns of the species involved or the time of year or life stage of the animal.

Underwater Noise. Sound may play an important role in the behavioral response of many marine fishes and mammal species, such as detection and localization of prey. Marine mammals use sound for communication and echolocation (U.S. Department of the Interior, 1988). Many species may use natural background sounds as cues for locating preferred reproductive and feeding areas or traditional migratory routes. Sensitivities and responses of marine species to loud or prolonged underwater noise are poorly understood. The frequency and intensity of sound will also be factors in determining the degree of potential impact. Underwater noise from exploration or mining activities may alarm some species, including commercially valuable species, causing them to avoid the area or stop feeding (Pearson and others, 1987). Continuous noise or disturbance may interfere with long-range communication or echolocation signals, resulting in altered patterns of migration or species distribution (Ljungblad, 1985).

Exploration Techniques and Fuel Spills

Exploration techniques used in locating and defining offshore deposits, including magnetometers, gravimeters, and spectrometers, all of which are towed along behind the research vessel, would have minimal biological impacts (Office of Technology Assessment, 1987). Vibra-coring and seismic testing will also be used to determine the extent of the placer deposits. Organisms located within the core-sampling site will be collected along with the sediment sample. Seismic exploration techniques will utilize high-resolution devices, air guns, and/or sparkers. Recent research by the Mediation Institute (CA) Eggs and Larvae Committee has shown no demonstrable effect of seismic impulses on Dungeness crab zoea. Pearson and others (1987), examined the effects of sounds from geophysical survey devices used in oil and gas exploration. This information may be useful for hard mineral exploration, although the seismic impulses used in high-resolution reflection requires much smaller quantities of energy than those required for deep reflection in oil and gas exploration. Timing of any seismic testing should be planned in relation to biological life stages and/or migrations.

A commercial dredging operation will require the dredge vessel to operate on a continuous basis. The proposed mining schedule for the Oregon coast calls for dredging to be carried out 24 hours a day, 7 days a week, 250 days per year, weather permitting. Fuel, food, and supplies for the dredge will be delivered on a weekly basis, and crews will be rotated every two weeks. Loaded barges will return to the on-shore processing plant approximately every 2 to 3 days (Wetzel and Stebbins, this volume). At-sea refueling of vessels and the increase in vessel traffic in the area will introduce the possibility of fuel spills and/or accidents during the mining operation.

II. BIOLOGICAL RESOURCE ASSESSMENT

This section describes the major ecological groups of organisms found in the ocean off Oregon, studies specific to the southern Oregon coast, and comments of those species most likely to be affected by mining in this area. Information on the distribution and abundance of marine species, the composition of biological communities, and the identification of important habitats is available from published and unpublished reports, theses, agency reports, and selected databases. Although information specific to the biological resources of the south Oregon coast is limited, a thorough review of studies for the continental shelf from the intertidal region to depths of 900 m for the Oregon and Washington coasts is provided in a forthcoming publication by Bottom and others. Other sources of information pertaining to the biological resources off Oregon include a series of open-file reports identifying the state of scientific information relating to the biology and ecology of the Gorda Ridge study area (Harvey and Stein, 1986; Krasnow, 1986; Ellis and Garber, 1986).

Plankton. Organisms that drift passively with the ocean currents are called plankton. Although many planktonic organisms are capable of some degree of swimming, they spend most or all of their lives subject to the motion of the surrounding waters. Phytoplankton are the single-celled plants that comprise the lowest level of the food chain. Primary productivity is influenced by the quality, intensity, and duration of light as well as nutrient availability in the euphotic zone. Light and nutrients are essential for photosynthesis. Zooplankton are free-floating animals that occupy the first few trophic levels above the primary producers (Davis, 1978). They are an important link in the food chain as they convert plant tissue to animal tissue. Although the food habits of many marine animals are largely unknown, it is highly likely that most organisms feed on zooplankton at some stage of their lives (Parmenter and Bailey, 1985).

Patterns of wind stress affect the primary productivity of the nearshore areas. The northwest winds of the summer create periods of upwelling, when deeper, colder, nutrient-rich water rises to the surface to replace the surface layer which is being driven offshore by Ekman transport (Huyer, 1983). This phenomenon can extend 10 to 30 km offshore but may affect a much greater area. Upwelling is not a constant occurrence but is episodic, with events lasting days to weeks. The intensity of an upwelling event depends on the strength and duration of the prevailing northwest winds (Huyer, 1983). Associated with upwelling events are coastal jets or squirts, fast, narrow surface currents that develop along the shoreline as the upwelled water is swept offshore.

These areas of upwelling are regions of high primary productivity when compared to the open ocean (Small and Menzies, 1981). Annual primary production on the Oregon continental shelf is estimated to be in the range of 200-300 g of carbon per square meter per year, while values for the area beyond the continental shelf are estimated to be between 100-150 g of carbon per square meter per year (Anderson, 1972). Landry and others (1989) found high chlorophyll concentrations over the inner continental shelf off Oregon and Washington during summer upwellings, although substantial stocks of phytoplankton were also present throughout the winter as well.

A considerable amount of research has been conducted on the distribution and species composition of zooplankton along the central Oregon coast (Pearcy, 1976; Peterson and Miller, 1975; Miller and others, 1985; Shenker, 1985). Because plankton drift along with the prevailing water currents, their distribution and composition are dependent on the seasonal cycle of water masses. During the summer months, when surface waters are advecting south and away from the coast and subsurface waters are upwelled along the coast, the zooplankton community off of Oregon is comprised predominantly of species associated with subarctic waters. During the winter months, when the prevailing winds are from the southwest, the surface waters are moved onshore, and downwelling conditions occur along the coast, the zooplankton community includes species from southern and offshore waters (Peterson and Miller, 1976; Menzies, and others, 1980).

Other important planktonic forms include larvae of fishes and shellfishes. These are meroplankton and occur in the plankton for a limited duration each year. The zoea and megalopae larval stages of the Dungeness crab are known to occur inshore from January to May, apparently being retained in the area by inshore surface currents. The megalopae then metamorphose into juvenile crabs and settle out of the water column, moving into rearing areas of nearby estuaries. (Lough, 1976; Armstrong and others, 1986). Eggs and larvae of fish are also transient members of the inshore plankton community, and therefore timing of mining activities will be critical when larval and juvenile species are present in the water column. Information concerning the abundance and distribution of zooploankton off the central Oregon coast has been described by Richardson and Pearcy (1977), Richardson and others (1980), Brodeur and others (1984), Miller and others (1985), and Shenker (1985). To date, no similar studies have been conducted off southern Oregon.

Information specific to the plankton of the south coast is limited; however, Laurs (1967), studied a hydrographic line off Brookings which extended from 5 to 165 nautical miles offshore. This study provides a basis for understanding the general characteristics of the oceanographic conditions, particularly the relationships between upwelling and primary productivity. Chlorophyll concentrations were highest inshore during upwelling activity and offshore during late winter and spring, while the number of primary carnivores and herbivores (zooplankton) was highest in the fall after upwelling had begun to subside. Euphausiids, copepods, salps, and crab zoea were the most numerically dominant herbivores. Euphausia pacifica was the most abundant euphausiid identified during the study, with the size and seasonal variation of catches being substantially greater inshore than offshore. Highest mean catches and greatest seasonal variation for copepods species were observed at intermediate distances offshore.

Changes in the composition of fish species was evident in the offshore region during summer samplings. Fishes, chaetognaths, shrimps, and medusae were the most common primary carnivores sampled. Species representative of the subarctic-transitional water mass were nearly absent offshore, while their numbers were intermediate inshore. Species present offshore were apparently of southern and/or western waters. The relative abundance of the shrimps was lowest in summer and late winter, intermediate in fall, and highest in spring. Mean catches of shrimps were two to five times higher inshore than offshore. Sergestes similis and Pandulus jordani were the most abundant shrimp species sampled.

Satellite imagery off the Oregon coast has shown that coastal jets or squirts form tongue-shaped plumes that extend several hundred kilometers off of the southern portion of the state during the summer months (Abbott and Zion, 1987; Thomas and Strub, 1989). Coastal jets are associated with upwelling events, and their presence off the south coast indicates the oceanographic regime south of Cape Blanco varies significantly from that of the central and north Oregon coast. Because the pelagic environment is a dynamic system of physical, biological, and chemical processes, with its upwelling events and complex circulation patterns, our understanding of these processes and their interrelationships are not well understood. Long-term studies are needed to relate upwelling intensities and primary production in the area off southern Oregon. A review of physical oceanography and its effects on primary productivity for this region is presented in Landry and Hickey (1989).

Invertebrates. Benthic organisms are the bottom-dwelling animals of the ocean. They play an important role in secondary production in the nearshore environment by breaking down detrital matter and reworking bottom sediments as well as providing a food source to many demersal and benthic dwelling species. Benthic communities found in sandy, high-energy environments tend to be well adapted to natural disturbance such as high turbidity, burial, and scouring due to shifting sediments and bottom currents associated with storms or increased wave activity. (Sternberg and McManus, 1972; Rees and others, 1976; Oliver and others, 1980). Organisms such as clams and polychaete worms possess the ability to burrow freely through the sand, while other animals, such as crabs, are capable of migrating great distances along the sea floor.

Literature describing the benthic infaunal communities of the Oregon coast primarily focuses on areas off central Oregon (eg., Carey 1965; Carey 1972; Bertrand 1970; Hogue 1982). These studies discuss the composition, distribution, and abundance of benthic assemblages, as well as the oceanographic conditions that affect these assemblages. Additional information concerning the composition of benthic communities of the south coast is provided by the Corps of Engineers in their Ocean Dredged Material Disposal Site evaluations at the Rogue River disposal site (Corps of Engineers, Portland District, 1988). The results of the evaluations from the Rogue River (Gold Beach) disposal site indicate that the benthos of the offshore area was typical of a nearshore high-energy environment. The infaunal community was dominated by gammarid amphipods and polychaete worms; gastropods and cumaceans were also consistently found in all samples. Most species showed higher levels of abundance at the disposal site than at control sites. This result is different from that in Corps of Engineers studies at other Pacific Northwest ocean disposal sites. The higher densities could be due to enrichment at the disposal site or just a natural variation. Although the site has frequently received dredged material, the adjacent fauna show little evidence of negative impacts (U.S. Army Corps of Engineers, 1988).

Macroinvertebrate benthic species of commercial or recreational importance in the nearshore zone include Dungeness crab, sea urchins, razor clams, gaper clams, cockles, and Pittock clams. Dungeness crab (Cancer magister) is commercially important in the Pacific northwest. Extensive research has been conducted on this species, primarily on larval and juvenile crab biology (Lough, 1976; Stevens and others, 1984; Stevens and Armstrong, 1984). Information from ODFW provides records of numbers caught and port of landing for the crab fishery. Only male crabs of a certain size may be harvested during certain times of the year; therefore landings records provide no information regarding female or juvenile crabs. Currently, keeping of logbooks by commercial crab fishermen is not required, so information regarding area of catch is unavailable. A voluntary logbook program for the Oregon coast has been proposed by ODFW to local fisherman in hopes of providing some insight as to the preferred locations of the harvestable Dungeness crab catch (Darryl Demory, ODFW, personal communication, 1989). Commercial landings for the south Oregon coast are available from ODFW (Table 2).

The Oregon Department of Fish and Wildlife (ODFW) has identified an emerging commercial sea urchin fishery at the Port Orford and Rogue Reefs (Jean McCrae, ODFW, personal communication, 1989). The urchin harvest for the 1989 season is expected to exceed 2,000,000 pounds. This fishery could be adversely affected if sediments suspended during mining operations resettle in these areas.

Information concerning the distribution, abundance, and population dynamics of pink shrimp off the Oregon coast is available from Lukas (1979), PFMC (1980), Rothlisberg and Miller (1983), and ODFW reports. Catch data and fishery logbooks provide more extensive information concerning the distribution and abundance of adult shrimp (Starr and Zirges, 1985). Logbook data are being analyzed by ODFW as part of their computerized information system to describe the distribution and catch per effort rates off Oregon (Starr and Saelens, 1987).

Recent research has provided some information on the distribution and abundance of squid collected during surveys off Oregon and Washington (Jefferts and others, 1985; Starr, 1985; Brodeur and Pearcy 1986). Schools of market squid (Loligo opalescens) are found all along the Oregon coast, but no specific studies have been conducted to identify spawning areas along the south Oregon coast.

Table 2. Combined Dungeness Crab Landings and Effort (number of landings) for Port Orford, Gold Beach, and Brookings

Season	*Pounds	No. of vessels	Effort	lb/landing
1980-81	2,857,200	158	3576	799
1981-82	2,192,403	140	3224	680
1982-83	1,038,517	163	2777	374
1983-84	959,976	100	2658	361
1984-85	1,164,224	95	2802	415
1985-86	1,088,375	96	1977	550
1986-87	1,032,163	86	1889	546

* Based on landings made during months when the ocean season was open.

From ODFW, Marine Region

Market squid have been fished commercially off the central Oregon coast (Starr, 1985).

Fishes. The nearshore zone supports a variety of fish species. These include two major groups,mid-water (pelagic) and groundfish (benthic) species. Pelagic species include salmonids, mainly coho and chinook salmon and steelhead trout, and schooling species, such as Pacific herring, northern anchovy, and Pacific sand lance. Coho and chinook salmon are important species to both the commercial and recreational fisheries off Oregon. The commercial salmon troll fishery takes place over the entire Oregon coast, although most fishing activity takes place in depths of less than 150 m (Parmenter and Bailey, 1985). Little is currently known about the ocean phase of these species, although studies describing their abundance, distribution, and food habits of juveniles have been conducted (Brodeur and others 1987; Fisher and Pearcy, 1988). Recovery of tagged fish at sea provides insight to the ocean migration patterns of coho and chinook salmon (Pearcy and Fisher, 1988; Fisher and Pearcy, in prep). Ocean survival of coho salmon off Oregon and California has been correlated with the intensity of coastal upwelling in these areas (Nickelson, 1983; Nickelson, 1986; Fisher and Pearcy, 1988).

The commercial salmon troll fishery is a highly regulated fishery, with limits set on size, area, time, and number of fish allowed to be harvested each year. Fluctuations in annual harvests (Table 3) are difficult to assess due to the number of limitations placed on the fishery (ie., size limits, catch quotas, gear restrictions, etc.). Commercial landings for the combined Port Orford-Gold Beach-Brookings area in 1988 totaled over 580,000 pounds of chinook and over 105,000 pounds of coho salmon (ODFW, 1989a). To rebuild the Klamath River (California) salmon stocks, ODFW and California Fish and Game have required catch quotas and temporary fishing closures for the area south of Cape Blanco to Point St. George (CA) to prevent over-harvesting of these stocks.

Small schooling species are food sources for adult salmon and other commercially important species. Although the distribution, abundance, and seasonal variations of the northern anchovy and Pacific herring off Oregon and Washington have been described (Richardson, 1973; Laroche and Richardson, 1980; Richardson, 1981; Brodeur and Pearcy, 1986), little is known about the life history, food habits, and production dynamics of these forage fish species. During the mid 1970's, anchovy were occasionally commercially harvested as a bait fishery (David Fox, ODFW, personal communication, 1989) but now are utilized primarily by recreational fishermen. Pacific herring spawn in selected estuaries along the coast and are fished commercially at Yaquina Bay (Jerry Butler, ODFW, personal communication, 1989).

Groundfish species include rockfishes, flatfishes, sablefish, and cod. The most commercially valuable species for Oregon include sablefish, Dover sole, petrale sole, widow rockfish, and yellowtail rockfish (David Fox, ODFW, personal communication, 1989). These species are generally caught in the deepwater trawl fishery along the outer continental shelf and continental slope.

Information on flatfish species off Oregon is generally more complete than for other groundfish species. Literature describing the distribution, abundance, and composition of demersal assemblages as well as seasonal variations and food habits of juveniles is available (Pearcy and others, 1977; Laroche and Richardson, 1978; Hogue and Carey, 1982). Limited information concerning the spawning behavior and preferred areas of some flatfishes is also available (Hosie and Horton, 1977; Pearcy, 1978). Juvenile Dover sole tend to live in shallower water than adults, and females are also found in shallower water in the summer, while males remain in deeper water year round (Demory, 1975). Dover sole are the most important commercial flatfish species caught off Oregon. Despite fluctuations in catch rates over the years, they have consistently remained the dominant flatfish species caught.

Habitat disturbance caused by the mining operation could potentially result in the loss of

Table 3. Commercial Ocean Salmon Landings and Effort (number of landings)

	CHINOOK		COHO		
Port	Pounds	Number	Pounds	Number	Effort
1980					
Port Orford	252,342	25,671	95,359	15,975	2191
Gold Beach	101,255	10,126	21,000	3,010	714
Brookings	282,008	28,017	64,152	10,125	3728
1981					
Port Orford	108,825	10,664	142,649	23,206	1820
Gold Beach	47,595	4,961	28,372	4,414	470
Brookings	603,813	66,510	160,247	23,446	5029
1982					
Port Orford	251,752	26,499	74,882	12,961	2247
Gold Beach	98,209	9,524	8,847	1,509	967
Brookings	365,445	36,241	50,154	8,758	4613
1983					
Port Orford	46,220	4,970	26,594	7,776	809
Gold Beach	23,603	2,989	7,962	2,109	386
Brookings	113,591	14,856	52,226	13,911	2176
1984					
Port Orford	86,683	8,926	------	------	926
Gold Beach	25,926	3,231	104	22	191
Brookings	91,467	11,297	------	------	1004
1985					
Port Orford	61,225	4906	1,158	195	631
Gold Beach	214	12	-----	----	2
Brookings	4,316	408	182	23	19
1986					
Port Orford	137,835	17,028	30,922	6,702	852
Gold Beach	31,510	3,845	3,420	704	200
Brookings	279,016	35,642	66,277	14,862	2007

Table 3 (cont). Commercial Ocean Salmon Landings and Effort (number of landings)

	CHINOOK		COHO		
Port	Pounds	Number	Pounds	Number	Effort
1987					
Port Orford	329,780	32,616	38,233	6,609	1519
Gold Beach	8,009	871	719	133	54
Brookings	348,077	39,716	29,871	5,682	1168
1988					
Port Orford	289,947	27,387	76,866	12,267	1969
Gold Beach	6,236	633	16,191	2,208	36
Brookings	284,140	29,316	12,501	2,187	779

From ODFW, Marine Region

suitable spawning habitat for fishes that spawn in depths of less than 100 m. During the 1982 commercial groundfish season, a number of trawls were targeted at depths of less than 100 m in the area off the south Oregon coast (Cape Blanco south to Crook Point). Flatfish species made up the vast majority of the catch, with petrale sole (47,766 lbs.), English sole (41,815 lbs.), and Dover sole (25,111 lbs.) being the most abundant species caught. Fair amounts of ling cod (10,424 lbs.), Rex sole (9,409 lbs.), and rockfish species (5,618 lbs.) were also harvested in the area. Incidental species caught included sanddabs, sablefish, and butter sole (ODFW, 1989b). Most of these fish produce pelagic eggs, and some, such as petrale sole, have localized spawning grounds. Other species, like lingcod, lay demersal eggs that could be smothered or buried by sedimentation. The long-term effects from a temporary loss of spawning habitat due to mining disturbances is unknown. Most fish species are widely distributed along the Oregon coast; therefore, there may be a negligible effect on the population as a whole, although local populations may experience a decline in numbers.

Recreational fisheries are an important economic industry for Oregon. The principal sport species include coho and chinook salmon and bottom fish species (Table 4), black rockfish, canary rockfish, ling cod, and cabezon (Jerry Butler, ODFW, personal communication, 1989). Recreational fishing for most of the Oregon coast is limited by the range of charter and pleasure boats, and the type of boat facilities at the various ports. Most sport fishing on the south coast originates from the Gold Beach (Rogue River) and Brookings area, as Port Orford lacks adequate port facilities. Fishing occurs year round, but tends to be seasonal due to the weather. Recreational catch data from ODFW include information on the number of species caught and on the amount of fishing effort.

The Rogue River (Gold Beach) also supports an active in-river recreational fishery for chinook salmon and steelhead. The 1987 recreational fishery harvested over 6,000 fall chinook, 12,000 spring chinook, 5,000 summer steelhead, and 700 winter steelhead from the river (ODFW, 1989c). Timing of mining operations so as not to interfere with the migrations of either juvenile salmonids entering the ocean or adult salmonids returning to natal streams may be crucial to minimize straying of adults and to maintain the productivity of runs. It is unknown what effect a turbidity gradient would have on the migratory behavior of anadromous species.

Catch records from ODFW provide valuable information concerning both the commercial and recreational fisheries off Oregon, but this information is limited. These data do not reveal information about species that are not landed or individuals that are too small to be caught or kept legally. Some species are fished more intensely than others, which may be reflected in the data as a disproportionate amount of the target species being caught in a particular area. Catch data and landings reports reveal information about where the species are caught but are not necessarily unbiased data about their distribution. Fluctuations in catches could be due to a number of factors other than changes in the species abundance or distribution -- current markets, more efficient fishing gear, shifts in target species being harvested, government regulation, etc., all affect the number of individuals caught.

ODFW is currently involved in developing a long-term ocean management program designed to identify areas of biological significance and to provide insight as to how these resources respond to environmental change. This system will prove to be very useful in defining the locations of catch of certain species and in describing the relationships between habitats and species. At present, fishery data (pink shrimp and groundfish) for only three years have been entered into the system, but once more data are entered, ODFW expects to be able to identify areas of high species diversity or areas that contain a high percentage of gravid females or juvenile fish. A brief summary of the Ocean Habitat and Mapping (OHAM) program and sample maps are included in Appendix A.

Table 4. Ocean Salmon Sport Catch and Effort (number of landings)

	Port	Effort	Chinook	Coho
1980				
	Port Orford	214	12	54
	Gold Beach	4,073	419	1,194
	Brookings	51,734	4,370	31,765
1981				
	Port Orford	-----	-----	------
	Gold Beach	4,613	904	891
	Brookings	62,466	7,993	7,433
1982				
	Port Orford	-----	-----	------
	Gold Beach	6,785	1,357	1,112
	Brookings	54,569	14,181	15,799
1983				
	Port Orford	-----	-----	------
	Gold Beach	8,859	2,068	1,558
	Brookings	46,818	10,286	14,791
1984				
	Port Orford	3	0	0
	Gold Beach	5,038	912	1,586
	Brookings	32,935	8,133	9,905
1985				
	Port Orford	-----	-----	------
	Gold Beach	6,541	2,580	707
	Brookings	52,410	33,562	6,728
1986				
	Port Orford	-----	-----	------
	Gold Beach	4,381	1,175	845
	Brookings	48,052	10,668	10,866
1987				
	Port Orford	-----	-----	------
	Gold Beach	4,108	1,378	1,618
	Brookings	65,315	24,436	15,861

From ODFW, Marine Region

Marine Birds

Numerous species of marine birds occur along the Oregon coast. Information concerning the distribution and abundance of bird species is presented by Scott (1973), Varoujean (1979), Varoujean and Pitman (1979), Bertrand and Scott (1979), and Pitman and others (in press). A catalog of seabird colonies in Oregon is currently in preparation by personnel at U.S. Fish and Wildlife Service.

Rocky outcroppings are a major feature of the Oregon coast, particularly between Coos Bay and the Rogue River. Many of these rocky islands and sea stacks, which make up the Oregon Islands National Wildlife Refuge system, provide nesting sites for marine birds. Recent estimates indicate that the marine bird population for the south Oregon coast exceeds 122,000 (Roy Lowe, U.S. Fish and Wildlife Service, personal communication, 1989). Oregon's seabird population is dominated by the common murre and Leach's storm petrel; all other species combined account for less the 10 percent of the total population (Pitman and others, in press). Murre colonies are often extremely large, with tens of thousands of birds occupying rocky areas of the south coast during the breeding season. Leach's storm petrels are present off Oregon only during the summer months, but the south coast supports one of the largest breeding colonies of these birds on the entire West Coast (Parmenter and Bailey, 1985). Other species common to the south Oregon coast include pelagic cormorants, pigeon guillemots, black oyster catchers, and western gulls, Brandts cormorants, double-crested cormorants, and tufted puffins (Table 5).

Several species of birds that are of special concern include the brown pelican, peregrine falcon, and the Aleutian Canada goose. Each of these species is listed on the Federal endangered species list. Some south coast rocks and islands are former nesting areas for the peregrine falcon and current population increases may result in the reoccupation of some of these historic sites. The peregrine falcon is often associated with headlands, sand spits, and offshore rocks that are used as foraging areas. Aleutian Canada geese also are known to use these rocky outcroppings for feeding and resting during spring migrations. Brown pelicans are found locally all along the Oregon coast during the summer months (Roy Lowe, U.S. Fish and Wildlife Service, personal communication). Numerous other shorebirds and waterfowl also utilize the shoreline areas for nesting, feeding, and resting.

Noise and the general activity of a continuous mining operation located near one of these colonies could cause the area to be abandoned and therefore cause a reduction in the local population. Disturbance from vessel or air traffic may frighten birds off their nests, leaving their young vulnerable to exposure or predation. If mining occurs in areas heavily used by marine birds for foraging, prey species may be obscured due to turbidity. Food sources may also be reduced as a result of negative impacts to prey species. Buffer zones could be established around the colonies in order to minimize disturbance.

Marine Mammals

Information on marine mammals off Oregon other than seals and sea lions is limited. Gray whales traverse the Oregon coast during fall and spring migrations, and a small population of gray whales reside year round off the Oregon coast. Little is known about the movements and specific feeding habits of gray whales off the Oregon coast, although gray whales are known to feed extensively on benthic organisms. Studies in the Bering Sea have shown that gray whales feed on gammarid amphipods, mollusks, mysids, hydroids, and polychaetes (Rice and Wolman, 1971). Minke, humpback, and blue whales have also been sighted off the Oregon coast. Other cetaceans that are seen occasionally are the harbor porpoise, Pacific whitesided dolphin, and killer whales (Maser and others, 1981).

The results of the first year of a three-year study to assess the pinniped population of Oregon

Table 5. 1988 Summer Seabird Colony Counts from Black Point Rocks south to Hunters Island.

Location	Pelagic Cormorant	Bl Oyster Catcher	Pigeon Guillemot	Western Gull	Common Murre	Dbl Crstd Cormorant	Brandt's Cormorant	Tufted Puffin	Fk Tailed St Petrel	Leach's St Petrel	Cassin's Auklet	Rhino. Auklet
Black Point Rocks	24	1	4									
Tower Rock	138	2	9	10	1,011							
Colony 270-023.1		1										
Castle Rock	458	2	40	6		598						
Colony 270-025					300							
Colony 270-026	10		3	2								
Gull Rock	150	7	38	186	24,057		1,020	6				
Colony 270-027.1	46	1	2									
Colony 270-027.2	34											
Colony 270-027.3	26	1										
Colony 270-027.4		4	2									
Colony 270-027.5			2	2								
Needle Rock	198		11									
Best Rock	140	2	31	50	15,405		394					
Long Brown Rock	4		29	4								
Colony 270-031			3									
Square White Rock	106		2		4,016							
Seal Rock				16								
Conical White Rock	200		2		2,051		28					
West Conical Rock	104		15	6	1,161			8				
Arch Rock	94		5	32	69							
Klooqueh Rock		2	6	16								
Colony 270-037.1			16									
Colony 270-037.2	4		8									
Colony 270-038												
Tichenor Rock	12	2	4	22								
Colony 270-040	16		7									
Colony 270-040.1			5									
Colony 270-040.2			7									
Colony 270-040.3		1	4									
Colony 270-040.4				2								
Battle Rock			17									
Colony 270-040.6		2	1									
Colony 270-041			2	16								
Colony 270-042		2	2	18								

Table 5 (cont). 1988 Summer Seabird Colony Counts from Black Point Rocks south to Hunters Island.

Location	Pelagic Cormorant	Bl Oyster Catcher	Pigeon Guillemot	Western Gull	Common Murre	Dbl Crstd Cormorant	Brandt's Cormorant	Tufted Puffin	Fk Tailed St Petrel	Leach's St Petrel	Cassin's Auklet	Rhino. Auklet
Redfish Rocks (north)	56	2	1	2	1,399			1				
Redfish Rocks (N central)	42	2	3	8	816		32	1				
Redfish Rocks (E central)	336	1	14	84	5,017		150	2				
Redfish Rocks (S central)				4	1,771		14					
Redfish Rocks (south)		3	4	50	4,268			5				
Colony 270-047.1		2	6									
Colony 270-047.2		1	1									
Colony 270-047.3		5	13					2				
Colony 270-048			4	6	2,091		6					
Island Rock	302	1	42	1,538	12,865		762	300	P	P	P	P
Colony 270-050			1									
Colony 270-051		1										
Colony 270-052	4											
Colony 270-053	4		2				32					
Colony 270-054	6						10					
Lookout Rock	20	1	4									
Colony 270-054.2		1										
Colony 270-054.3		2										
Sisters Rock (north)	38		16									
Sisters Rock (south)			20									
Colony 270-057	118	3	3	68		206						
Colony 270-058		4	24									
Devil's Backbone	46		10	2								
Colony 270-060												
Colony 270-061	64	2	26	8								
Colony 270-061.1	4		2									
Colony 270-061.2	16		8									
Colony 270-062	36	2										
Colony 270-063				4	13,091		162					
Colony 270-064				16	2,026		30					
Hubbard Mound	188	3	27				28	2				
Colony 270-066							458	6				
Colony 270-066.1		3		2			32					
Colony 270-066.2	4		11	2								
Otter Point	2		34	2								
Double Rock	10	1	6	2								

Table 5 (cont). 1988 Summer Seabird Colony Counts from Black Point Rocks south to Hunters Island.

Location	Pelagic Cormorant	Bl Oyster Catcher	Pigeon Guillemot	Western Gull	Common Murre	Dbl Crstd Cormorant	Brandt's Cormorant	Tufted Puffin	Fk Tailed St Petrel	Leach's St Petrel	Cassin's Auklet	Rhino. Auklet
Needle Rock	104	2	16	46	519							
Pyramid Rock		2		2	1,884							
Colony 270-069.1	64											
Colony 270-069.2	52		14	2								
Cape Sebastian North	114		18									
Cape Sebastian South		2										
Hunters Island	390	2	104	880				100	X	19,740	40	160
TOTAL	3,784	78	711	3,118	91,933	804	3,158	433	X	>19,740	>40	>160

P = Birds probably present
X = Birds present

From U.S. Fish and Wildlife Service, Newport, Oreg.

are presented by Brown (1988). Monthly aerial photographic surveys were taken along the coast to document the seasonal distributions and abundances of the Steller (northern) sea lion, California sea lion, and harbor seal. Of particular importance on the southern Oregon coast are the Rogue and Orford Reefs. These areas are used by seal and sea lions as haul outs and are also used by Steller sea lions as a rookery on a year-round basis. This area supports the largest reproductive stock of Steller sea lions in United States waters south of Alaska. The current Oregon population is estimated to be about 1,500 individuals (Brown, 1988). After the breeding season (mid-July), most males migrate northward to locations in Alaska and British Columbia, while the female and pups remain in Oregon throughout the year (Parmenter and Bailey, 1985).

Although California sea lions are not year round residents of Oregon, adult and subadult males move through the nearshore area on their fall migrations to the north and spring migrations to the south. Females and their young generally remain in California year round. In 1984, a peak count of 1,938 individuals was taken at haul-out sites on the Oregon coast. Other studies have estimated the number of California sea lions passing through Oregon waters at about 5,500 animals (Bigg, 1985). Harbor seals are a non-migratory species which are present all along the Oregon coast. Current populations estimates for the south coast range from 300 to 500 individuals (Brown, 1988).

Survey counts of Stellar sea lions indicate that the Oregon population has remained fairly stable since 1977. The number of animals at the Rogue and Orford Reefs also seem to have not changed significantly, although the population of California sea lions off British Columbia and Washington have shown a dramatic increase since the early 1970's. No comparable surveys for wintering California sea lions in Oregon have been completed yet, but greater numbers of individuals would be expected. Statewide counts for harbor seals indicate that the number of animals has been increasing since the mid-1970's. The passing of the Marine Mammals Protection Act in 1972 is credited in part to the observed increases in pinniped populations (Brown, 1988).

Noise and general activity from the mining operation may cause seals and sea lions to flee their haul-out sites. Repeated or continuous disturbance may result in a long-term change in animal distribution. Such disturbance could also have impacts on the reproductive success of these species. The mining operation may also indirectly affect marine mammals by reducing zooplankton, benthos, or fish populations that serve as food sources.

III. REVIEW OF RELEVANT CASE STUDIES

Since little offshore mining is a currently being done in United States waters, it is difficult to assess the specific impacts from such an operation on the southern Oregon coast. Therefore, any discussion of potential environmental impacts must rely on the mining experiences of other countries and on information gathered from dredge and disposal operations. This section briefly discusses major conclusions from other studies, some of which are described in detail in the appendices.

Project NOMES

An ambitious study was initiated in 1972 to identify the environmental and biological impacts associated with a large-scale sand and gravel mining operation on the east coast of the United States (Padan, 1977). The New England Offshore Mining Environmental Study (Project NOMES) was a three-phase program consisting of one year of pre-mining baseline evaluations at the proposed area in Massachusetts Bay, a minimum of one year of sand and gravel extraction with a coinciding environmental and biological monitoring program, and a two-year study of post-mining monitoring to document changes in the mined area. The project was terminated in 1973, when a suitable disposal site could not be identified for the approximately 1 million cubic yards of material to be mined during the test period. The monitoring program would have included sediment dispersion modeling, water- and sediment-quality analyses, and an extensive course of biological monitoring focusing on the response of organisms to the presence of sediments.

Although Project NOMES was not completed, a wrap-up phase was conducted, and the following recommendations were offered for similar projects in the future (Padan, 1977):

1. Laboratory studies of the effects of turbidity on marine organisms should be conducted, including nonphysiological responses, such as organisms' avoidance of a turbidity plume. Results may be extremely relevant to local commercial fishermen.

2. Once a site has been agreed upon, a two-year period should be devoted to pre-mining studies. The first year should be devoted to the development of sampling and test procedures for coordinated use the second year. The main focus of the baseline studies should be the long-term effects of a change in substrate characteristics caused by the blanket of fine materials.

3. The mining test should be at a commercial scale and should continue for at least one year. A brief period of mining should not be extrapolated for long-term mining.

4. Although the period of mining must be well-monitored, the post-mining environment can be examined less frequently but should continue for at least two years.

The European Experience

During the mid 1970's, the International Council for the Exploration of the Sea (ICES) was established to identify environmental concerns in the North Sea, where sand and gravel mining operations have been occurring for over 50 years. Of particular concern to the European community is the potential loss of commercial fisheries to due to mining activities, although no direct negative effects of dredging on adult fish stocks were clearly demonstrated. Each participating country described its current mining scenarios as well as any environmental issues it had encountered or avoided. Based on the combined experiences of the group, ICES proposed a "Code of Practice" with recommendations to minimize the environmental effects of mining operations in the nearshore area. The Code requires that the exact area to be mined, as well as the amount and thickness of the overburden to be removed, be specified prior to mining. Important fishing grounds and spawning and nursery areas are excluded as potential mining areas. Also, the expected substrate composition for the area after mining must be described, including the amount of substrate suitable for spawning of commercially valuable species. Additionally, more research as to the biological, chemical, and physical effects from dredging operations is encouraged, and environmental impact statements are needed prior to licensing and excavation.

The Corps of Engineers Dredging Disposal Operations

The U. S. Army Corps of Engineers is responsible for maintaining over 40,000 km of navigable waterways, which requires the routine dredging of nearly 356,000,000 m^3 of material each year. About 30 percent of the material is disposed of at designated at-sea disposal sites (OTA, 1987). The River and Harbor Act of 1970 (Public Law 91-611) authorized the Corps of Engineers to conduct a program that addresses the environmental effects of dredging and disposal of dredged material. The objective of the Dredged Material Disposal Program (DMRP) was "to provide -- through research -- definitive information on the environmental impact of dredging and dredged material disposal operations and to develop technically satisfactory, environmentally compatible, and economically feasible dredging and disposal alternatives, including consideration of dredged material as a manageable resource" (U.S. Army Waterways Experiment Station, 1973). The information gathered during this research effort provides insight into the environmental effects of shallow-water mining, because similar activities are required in the lifting and redepositing of sediments in both types of operations (Office of Technology Assessment, 1987).

Regarding the effects of open-water disposal, the studies concluded that unless the dredged material was highly contaminated, the physical impacts caused by sediment disposal, such as burial of benthic communities, are likely to be of greater potential consequence than chemical or biological impacts. Biological effects are also unlikely to be of great consequence, due to the resiliency of most organisms (excluding larval stages) and the ability of many organisms to rapidly repopulate the affected areas. Except during times of fish migrations and spawning activities, turbidity is more likely to be an aesthetic than a biological problem. In general, areas of high wave activity appear to be influenced to a greater extent by naturally-occurring variations in the physical and chemical environment than by any disturbance created by dredging or disposal operations (U.S. Army Waterways Experiment Station, 1978). These results suggest that the natural variations characteristic of a high-energy environment will make it difficult, if not impossible, to generalize about the effects of mining without obtaining site-specific information concerning the proposed mining area (Office of Technology Assessment, 1987).

Although these conclusions are related to a short-term disposal operation, they may be relevant to the proposed mining scenario for the Oregon south coast. Similar dredging techniques will be used for the placer mining project, and unwanted materials will be disposed of at sea. A commercial-scale mining project would be a long-term operation requiring continuous disposal of tailings, unlike the Corps of Engineers dredging project. The area offshore is a high-energy environment heavily influenced by wave activity, and organisms indigenous to the area are well adapted to such conditions. It is unknown what effect a long-term, continuous mining operation will have on the biological communities within the affected area and whether or not results from transient dumping operations can be extrapolated to the proposed scenario on the south Oregon coast. Two DMRP investigation reports that assessed the impact of dredged material disposal on benthic communities and demersal finfish and decapod shellfish species are reviewed in Appendix B.

In addition to the Dredged Material Research Program, the Corps of Engineers also has site-specific information for Ocean Dredged Material Disposal Sites (ODMDS) located off the estuaries of most navigable coastal rivers in Oregon. For each site, physical, chemical, and biological studies were performed to determine the suitability of existing disposal sites for continued use. The biological sampling consists of collecting benthic invertebrate samples from stations located within the disposal site and from stations at adjacent control sites to determine if any negative effects of ocean dumping are apparent on the benthic community located at the disposal site. The results of the evaluations from the Rogue River (Gold Beach) and Chetco River (Brookings) disposal sites indicate that the benthos of the offshore areas were typical of a nearshore, high-energy environment (U.S. Army Corps of Engineers, 1988a, 1988b).

WestGold Mining in Alaska

Western Gold Exploration and Mining Company, Limited Partnership (or WestGold), has been mining a gold placer deposit offshore of Nome, Alaska, since 1985, and ENSR Consulting and Engineering (Anchorage, AK) has been performing the biological and environmental monitoring for the project (Rusanowski and others, 1989). Their findings are thus far inconclusive but do provide valuable insight into the environmental impacts created by such a mining operation. Damage to renewable resources, particularly the king crab fishery, and potential mercury contamination or bioaccumulation, are two primary concerns. Information on benthic recovery is available for sites that were mined one and two years previously (Jewett and others, 1989). Particular attention has also been paid to the potential impact on king crab through loss of habitat or food source. Trace-metal monitoring and bioaccumulation studies are performed regularly to collect information on the possibility of contamination of the environment. No significant difference was observed for catch-per-unit effort rates for crab pots fished in mined and non-mined areas for the 1987 or 1988 surveys. Post-mining sampling indicates decreases in the number of taxa, density, and biomass values one year after mining. Crustaceans were numerical dominants, particularly cumaceans. Two years after mining, increases in both density and biomass were evident, as well as a shift in species dominance from crustaceans to polychaetes. One year after mining, polychaetes accounted for 20 percent of the invertebrate abundance, while samples from two years after mining showed polychaetes accounted for nearly 75 percent of invertebrate abundance (Jewett and others, 1989).

Although the oceanographic conditions are very disimilar between Norton Sound and coastal Oregon, the WestGold mining operation may provide valuable insight about the potential environmental and biological impacts associated with a placer mining operation on the Oregon continental shelf. The research approach used by WestGold should be reviewed to evaluate appropriate monitoring approaches for the Oregon coast. A review of the WestGold mining operations is included in Appendix C.

Research Needs

Much of the existing literature suggests that the effects of an offshore mining project will be short lived. The high dilution factor of the nearshore zone will rapidly disperse the turbidity plume, and high sediment transport rates will act to smooth out tracks or mounds left behind by the extraction process. However, most studies to date have dealt with the effects of short-term and transient dredging, and their results may not be applicable to a long-term continuous mining operation.

Impacts will depend on a number of factors including the size the area to be mined and the oceanographic conditions of the proposed site. Information from similar dredging projects or from laboratory studies will not provide the complete answers on the potential environmental and biological consequences of a commercial-scale mining operation on the southern Oregon coast. Research and site-specific modelling will be required prior to mining activities in order to minimize the risks this type of operation may have on the biological communities and adjacent shoreline areas. Increased turbidity, sedimentation, noise, and general disturbance in the vicinity of sensitive habitats (spawning or nursery grounds, and nesting areas) or during critical periods (larval recruitment, and seasonal migrations) are likely to pose the greatest risks. Research to assess and monitor the effects of a placer mining operation on the Oregon continental shelf are described in Bottom and others (in press).

APPENDIX A

ODFW Ocean Habitat Analysis and Mapping Program

The Oregon Department of Fish and Wildlife is currently involved in developing a long-term ocean management program designed to identify areas of biological significance and to provide insight as to how these resources respond to environmental change. This Ocean Habitat Analysis and Mapping (OHAM) program is being created in response to the need for more detailed fishery resource information required in order to improve fisheries management and to help resolve resource user conflicts. The system is set up to store and analyze different types of biological and environmental data as well as economic data of the resources as reported in official landings records and in data provided in the Fisheries Economic Assessment Model by Jensen and Radtke (1987).

A pilot project was initiated to demonstrate how existing information can be used by the system. Data from logbooks and catch landings records for the commercial pink shrimp and groundfish fisheries were entered into the system to test the program. Using this information, computer-generated maps showing the average catch and the amount of fishing effort per 5-minute block (approximately 8 km by 8 km) were produced for the area off the Oregon coast (Figures A-1, A-2). This type of information can be used to highlight areas of high productivity (catch per unit effort) and to estimate the importance of a particular area for a given fishery. Bottom-sediment data are also being used to identify ocean habitats based on sediment types. By overlaying bottom substrate maps with catch data maps, species distributions and sediment types may be correlated.

The OHAM system will prove to be very useful in defining the locations of catch of certain species and in describing the relationships between habitats and species. This information, in conjunction with population dynamics models, will enable evaluation of the potential biological impacts of a particular management strategy. By including economic information, the economic trade-offs of different management strategies will also be identified. At present, only three years of fishery data (pink shrimp and groundfish) have been entered into the system, but once more data are entered, ODFW expects to be able to identify areas of high catch rates or areas that contain a high percentage of gravid females or juvenile fish.

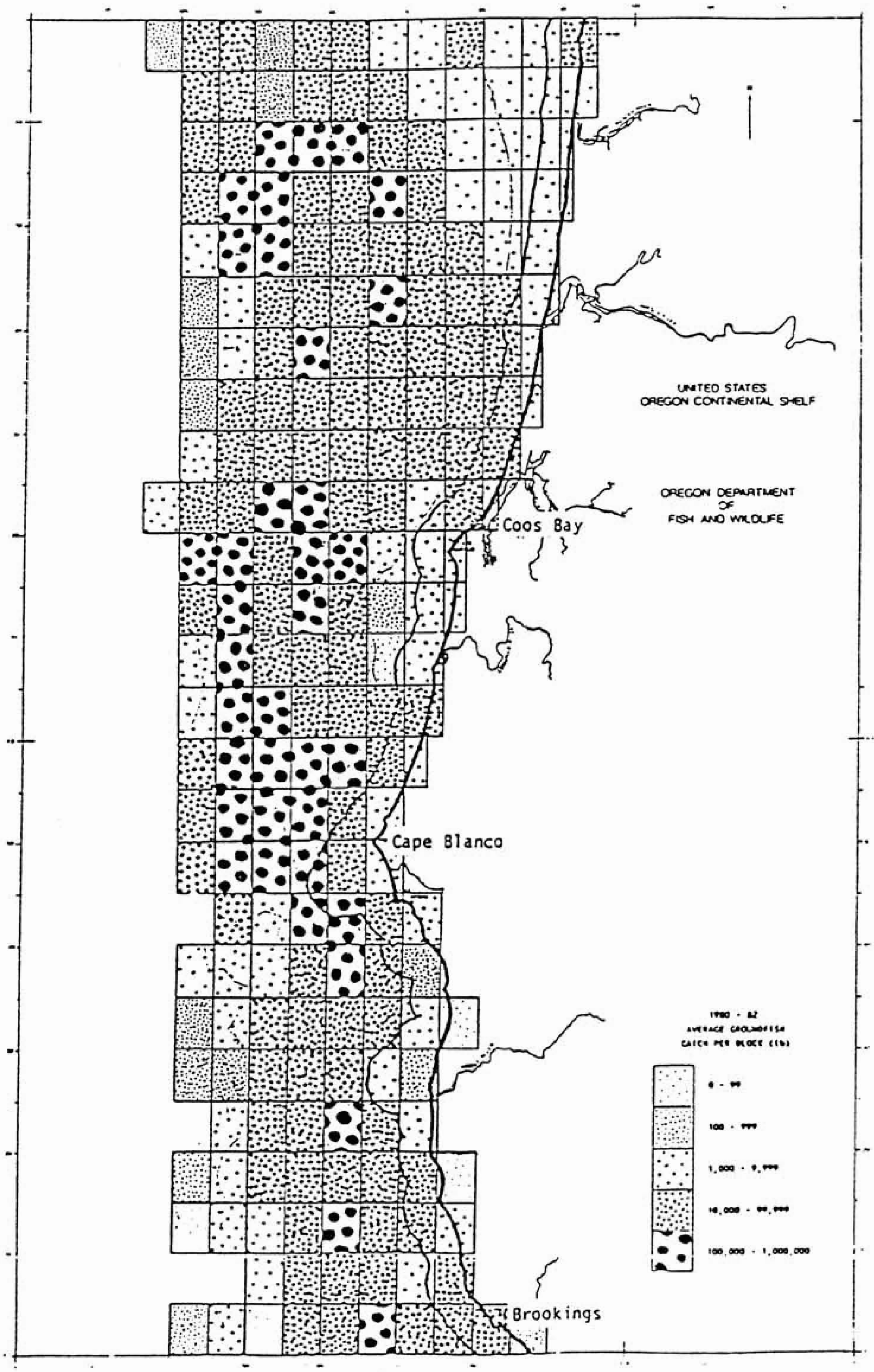


Figure A-1. ODFW Ocean Habitat Analysis and Mapping Project sample map. Courtesy of ODFW, Marine Region.

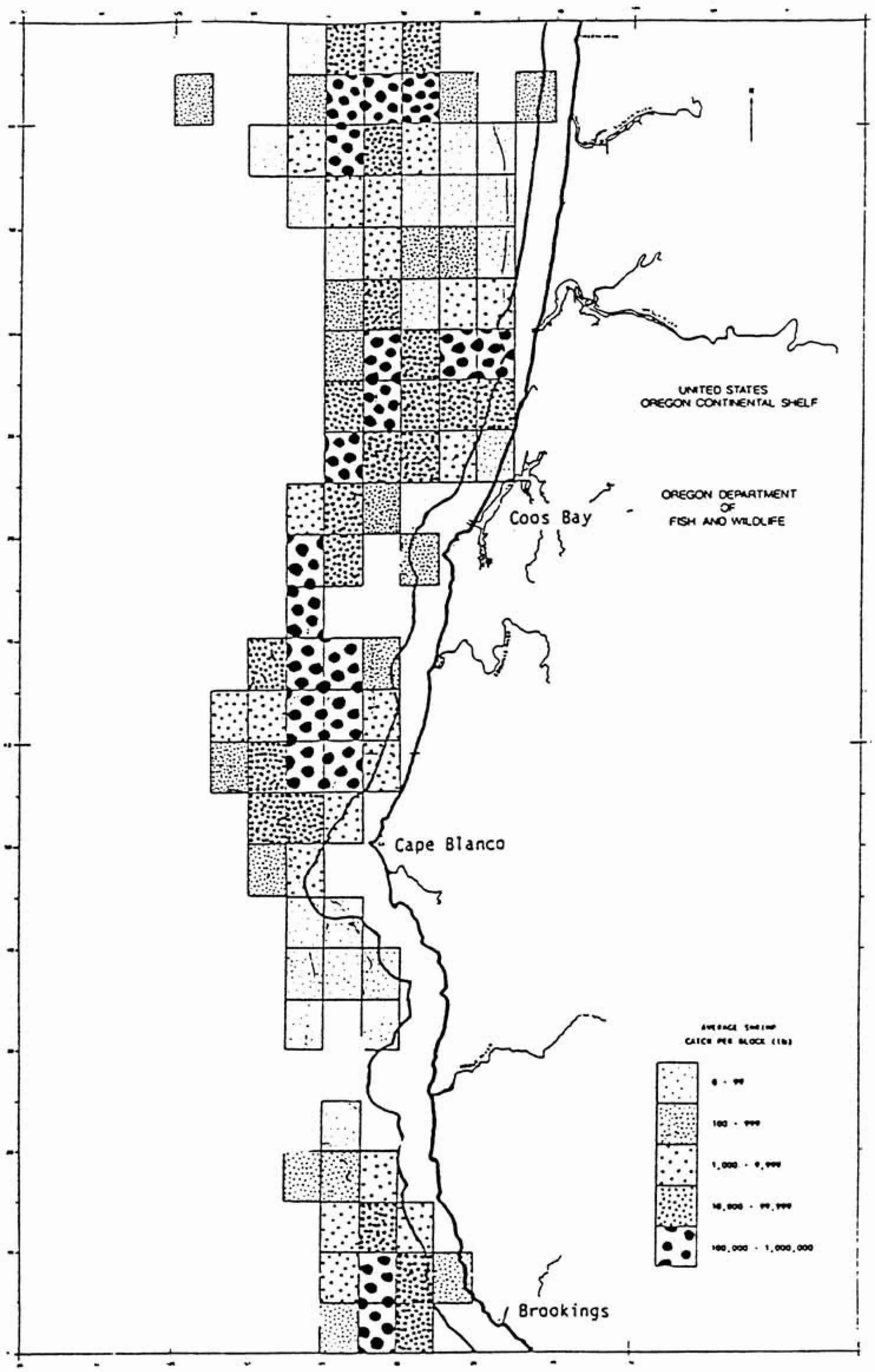


Figure A-2. ODFW Ocean Habitat Analysis and Mapping Project sample map. Courtesy of ODFW, Marine Region.

APPENDIX B

Aquatic Disposal Field Investigations, Columbia River Disposal Site, Oregon

This section reviews two research efforts undertaken as part of the Corps of Engineers' Dredged Material Research Program (DMRP). The general objective of the DMRP was to determine the degree and extent of impacts resulting from the disposal of dredged material on the biological communities in the area of the disposal site. The mouth of the Columbia River was chosen as one of five regional study sites. Phase I of the project was initiated in October of 1974 and consisted of the collection of baseline and pre-disposal information in the area offshore of the mouth of the Columbia River. Baseline studies continued through the second phase of the project, July-August 1975, during which time, 460,000 m^3 of dredged material was disposed of at the experimental site. The final phase of the study, conducted from September 1975 through April 1976, was a continuation of sampling within the study area to assess the effects of the disposal on the biological communities located there.

Part A: The Effects of Dredged Material Disposal on Benthic Assemblages

The initial purpose of this study was to collect baseline information on the benthic community structure of the nearshore zone (0 - 90 m) in the vicinity of the mouth of the Columbia River (Figure B-1) and to examine the spatial and temporal changes in this community. The second phase of the study was to identify and determine the relative significance of physical, chemical, and biological factors that dictate the rate of benthic colonization. Five sampling cruises were performed prior to the test disposal to establish baseline and pre-disposal conditions, and five sampling cruises were performed after the test disposal to evaluate post-disposal effects of disposed dredged material on the benthic community in the test site (Richardson and others, 1977).

Smith-McIntyre grabs, with a sampling surface area of 0.1 m^2, were used to collect macrofauna and sediment samples. Macrofauna samples were then washed through a 1.00-mm screen for collection and identification. Sediment samples were collected by removing the top 1 cm of surface of the sediment grab contents. Meiobenthic samples (retained by 0.50- to 1.00-mm screens) were obtained during the first two cruises but were later discontinued due to the long sorting time required per sample and the difficulties in identification of species. One grab per station for the remaining cruises was washed through a 0.50-mm screen in order to sample resident juvenile macrofauna. Five replicate macrofauna samples and one sediment sample were collected from each station.

Megafauna samples were collected with a 3-m beam trawl with a $1^1/_2$-inch stretch mesh and a $^1/_2$-inch stretch mesh liner. Each trawl was towed on bottom for 30 minutes, and the distance covered was measured with odometer wheels attached to the trawl frame. Two trawls were obtained at each station.

After analyzing the data collected during the baseline studies, it was determined that with the exception of one assemblage, there was little similarity between the benthic assemblages found in the Columbia River study area and benthic assemblages as documented from other parts of the Oregon-Washington continental shelf (eg. Lie, 1969; Lie and Kelley, 1970; Lie and Kisker, 1970; Carey, 1972). The range of values for species composition, biomass, and density of benthic assemblages in the study area was greater than the range of values reported from the entire Oregon-Washington continental shelf. The influence of the Columbia River -- sediment deposition and high primary productivity -- probably accounted for these differences (Richardson and others, 1977).

The distribution, composition, and seasonal constancy of benthic communities in the study area were interpreted in part to be the result of increases in the percent silt, clay, and organics in the sediments offshore and an increase in sediment stability due to reduced sediment stirring during winter

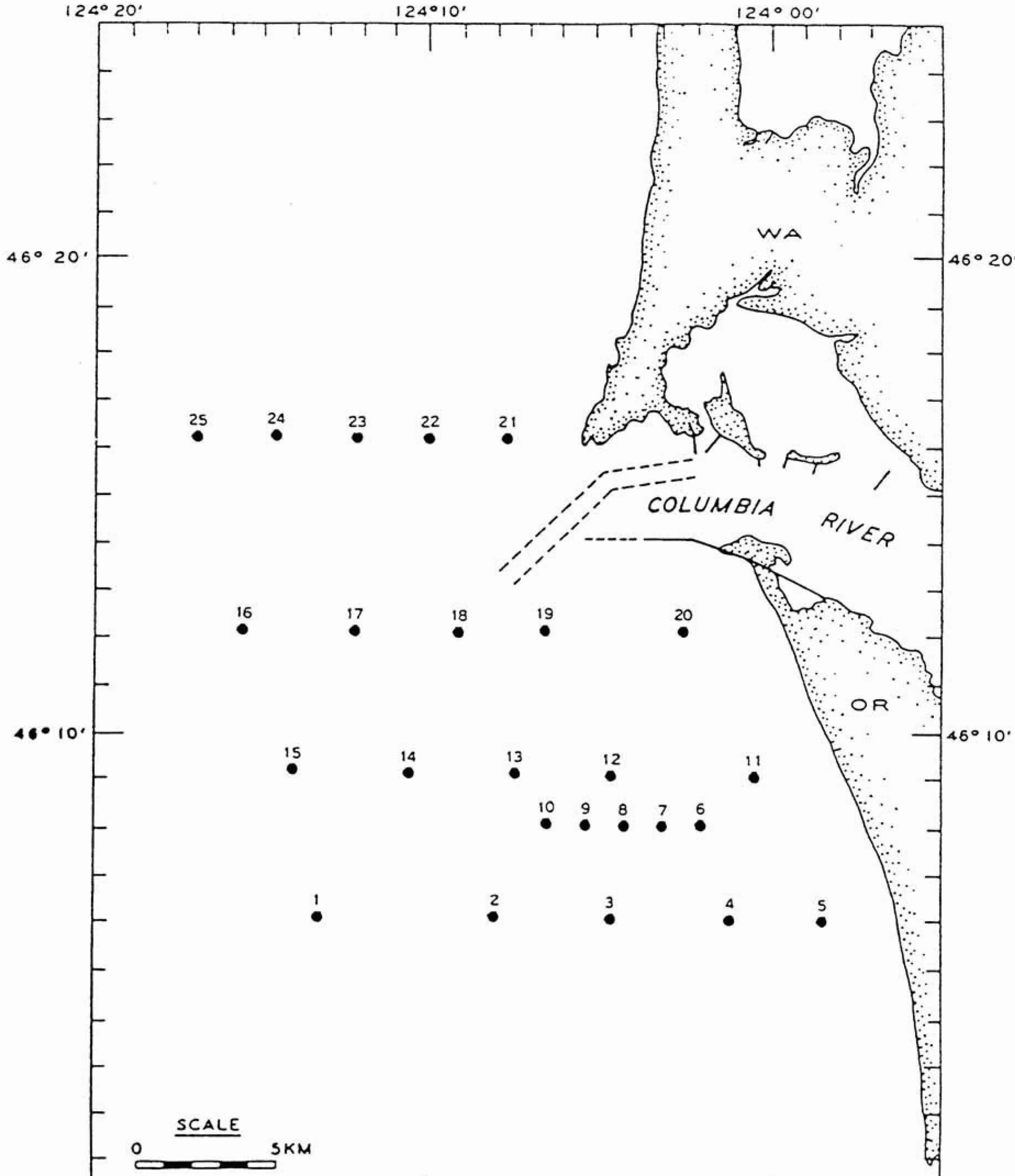


Figure B-1. Location of benthic sampling stations. From Richardson and others, 1977.

storms with depth (Richardson and others, 1977). Species diversity was related to the relative stability of the surrounding sediments. In general, diversity values were greater at sampling stations further offshore than stations located in shallower, nearshore areas. The sediment stability at the offshore stations also increased due to a reduction in sediment stirring by winter storms. A higher abundance of tube-dwelling polychaetes at the deeper stations also contributed to the increase in sediment stability at these stations. The lowest values of diversity were observed at stations that experienced considerable seasonal changes in sediment texture or grain size as a result of the deposition of fine-grained sediments at high flow from the Columbia River.

Biomass of the macrofaunal assemblages was related to the organic content of the sediment. As the amount of organic matter in the sediments increased, generally offshore, so did the biomass values for these communities (Richardson and others, 1977). The highest biomass values were found in areas of high silt deposition. Organic content was related to the percent silt and clay content of the sediments.

Assemblages exposed to the deposition of sediment from the Columbia River discharge had the lowest constancy between seasons of any stations in the study area. The seasonal constancy of abundance of dominant species was correlated to the seasonal stability of the surrounding sediment (Table B-1, Stations 16, 17). Komar and others (1972) concluded that short-period summer waves are capable of stirring the bottom to depths of 90 m, and long-period winter waves can stir the bottom to depths of 125 m and possibly 200 m. Benthic species that exist on these unstable sediments are probably well adapted to burial and scouring of sediments.

During the test disposal, two hopper dredges deposited 200 loads of dredged material (from the Columbia River) totaling 460,000 m^3. The disposal site was then sampled one, two, five, eight, and ten months after the test disposal. Samples obtained from the disposal site were divided into three groups, depending on their location relative to the disposal mound. Bathymetric surveys conducted after the disposal operation found a relatively circular deposit with a radius of about 750 m in the deposition area. Sampling stations located in the center of the mound (to a radius of about 230 m) were buried to a maximum depth of about 1.5 m stations located on the slope of the deposit were buried by 0.3 m to 0.6 m of material, and stations outside the disposal area probably were not directly affected by the disposal operation. Sediment texture samples were collected at each station along with benthic samples. The sediments near the test site prior to disposal were characterized by high factor loadings on the 2.75-ø and 3.25-ø grain size fractions. The dredged material was also sand, but had high factor loadings on the 2.00-ø and 2.50-ø grain size fractions. During disposal operations, the sediments at the area directly affected by the disposal were therefore changed from a well-sorted sand to a coarser,less well-sorted sand. The phi diameter (ø) is defined as the negative logarithm, base 2, of the diameter in millimeters (Inman, 1952).

Post-disposal sediment texture analysis for the 10-month period revealed a gradual increase in factor loadings on the 2.50-ø and 2.75-ø sediment size classes at the area exposed to direct disposal of the dredged material, indicating a return to the sediment texture characteristics of the area prior to disposal. Five months after the disposal operation, the sediment characteristics of the stations exposed to direct burial of the dredged material were nearly identical to that of the intermediate stations located on the slope of the mound. From this point on, subsequent analysis of community structure parameters were based on only two sets of stations, those affected (direct burial or intermediate) and those unaffected (outside the zone of deposition).

The stations exposed to direct burial of dredged material had significantly higher diversity and evenness values and significantly lower density of macrofauna when compared to unaffected stations. The significant difference in diversity and evenness persisted for at least eight months after disposal. During this period, both diversity and evenness increased at affected stations until April and at the

Table B-1. Sediment characteristics and community structure parameters for selected seasonal baseline stations. From Richardson and others, 1977.

	Sediment Characteristics			Community Structure Parameters				
	% Sand	% Silt	% Clay	H'	J'	SR	N/m2	B/m2
Station 1								
Dec 74/Jan 75	97.97	1.06	0.97	3.768	0.741	5.887	544	1.3540
April 1975	97.16	2.04	0.80	3.728	0.793	4.412	578	0.9414
June 1975	98.22	0.99	0.79	4.120	0.779	6.342	800	3.0786
Sept 1975	98.76	0.52	0.72	1.934	0.366	5.169	3113	1.7682
Jan 1976	96.29	1.39	0.92	2.858	0.632	3.850	606	0.6378
Station 4								
Dec 74/Jan 75	96.87	1.20	1.93	2.339	0.678	7.572	2856	23.4144
April 1975	94.40	2.90	2.70	2.817	0.470	8.903	2960	23.9885
June 1975	94.00	2.70	3.21	3.563	0.562	11.000	2880	18.5452
Sept 1975	94.41	2.74	2.84	3.877	0.591	12.178	4146	22.6546
Jan 1976	93.61	3.15	3.08	3.091	0.504	9.660	2530	24.8204
Station 12								
Dec 74/Jan 75	98.26	0.78	0.95	2.789	0.625	4.410	234	2.0396
April 1975	97.85	1.25	0.90	3.159	0.672	4.329	644	3.6262
June 1975	91.88	6.92	1.21	2.880	0.536	5.883	2128	9.7246
Sept 1975	95.88	2.98	1.15	2.110	0.411	4.672	2896	9.5252
Jan 1976	97.88	1.13	0.99	3.677	0.792	5.116	218	3.1920
Station 16								
Dec 74/Jan 75	62.94	31.13	4.93	3.657	0.655	6.669	2300	10.9624
April 1975	65.80	30.65	3.55	0.393	0.070	5.137	27782	12.9752
June 1975	17.07	62.80	20.14	2.378	0.438	5.337	5234	118.2954
Sept 1975	10.82	71.29	17.89	2.173	0.447	4.153	4326	73.0873
Jan 1976	91.41	7.33	1.26	1.226	0.243	4.427	2754	4.3550
Station 17								
Dec 74/Jan 75	85.56	12.88	1.57	2.977	0.556	6.490	950	1.6794
April 1975	73.33	24.85	1.83	0.332	0.059	4.955	26320	1.5858
June 1975	67.02	11.18	21.80	1.747	0.322	5.036	8370	23.9742
Sept 1975	21.85	64.98	13.17	2.173	0.447	4.153	2118	29.7808
Jan 1976	75.98	21.30	2.72	0.726	0.145	3.973	4890	5.1258

Parameters include diversity (H'; $H' = \sum p_i \log_x p_i$), evenness (J'; $J' = H'/\log_x S$), species richness (SR; SR = (S-1)/ln N), density (N/m2 - individuals/m2), and biomass (B/m2; grams ash-free dry weight/m2).

unaffected stations until June. A significant difference in density persisted throughout the ten-month post-disposal sampling period (Figures B-2, B-3, B-4). Density values also decreased significantly at the unaffected stations during the sampling period. This depression in the number of individuals at these sites was attributed to a series of intense winter storms occurring in December 1975 and January 1976, illustrating the strong seasonal fluctuations that may occur in shallow-water benthos.

The effects of sediment disposal on the abundance of the numerically dominant macrofaunal species was estimated by using the Friedman's two-way rank test. There was a significant reduction in the abundance of 11 of the dominant species at the stations exposed to direct burial as compared to the unaffected stations. Thirteen species showed no significant difference in abundance between affected and unaffected stations.

The species apparently most affected by the burial was the polychaete, Spiophanes bombyx. The disproportionate reduction in the abundance of this species compared to the abundance of other species at the station caused an increase in the evenness of species abundances and an increase in diversity values. Species density and species richness values were lower (except for September) at those stations exposed to direct burial, thus indicating the elimination of some species from the area.

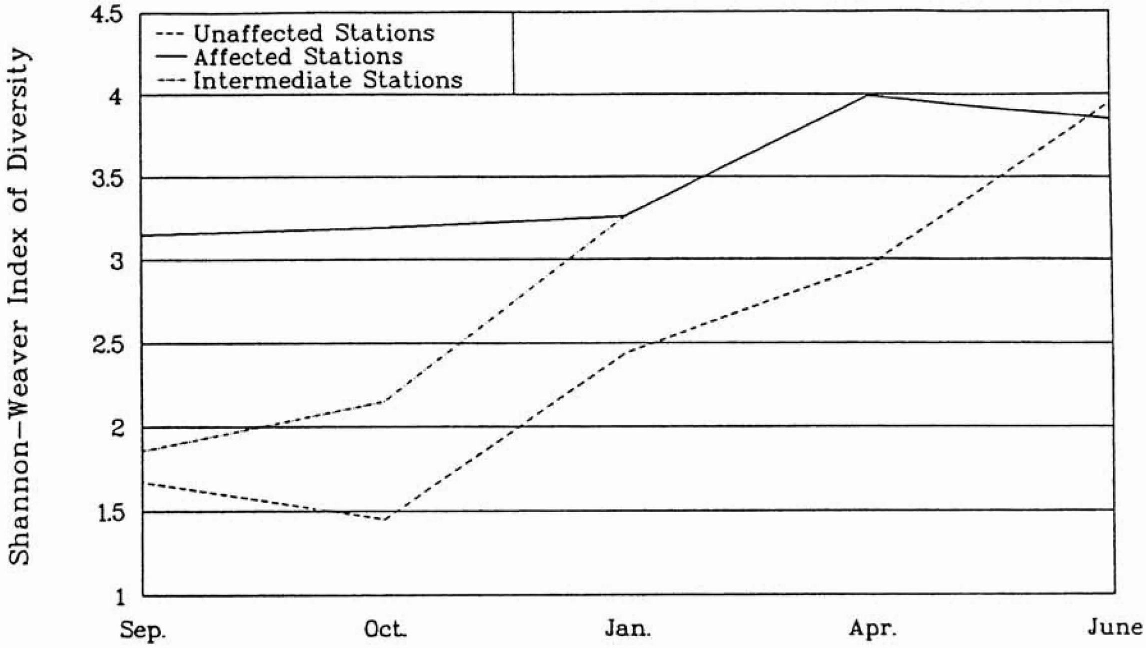
There was very little evidence of introduced species at the test site after the disposal operation. Most of the dominant species present in the dredged material (from the navigation channel) were also present in low numbers at the test site prior to disposal. With a few possible exceptions, those species that were dominant at the dredge site were either missing entirely from the affected stations or were found in greater numbers at the unaffected stations compared to the affected stations.

Sediment samples from the dredged area contained 0.95-1.26 percent silts and clays, while sediments at the test site after disposal contained less than 2 percent fines. Turbidity levels during and after disposal were the same as those prior to disposal (Sternberg and others, 1977); therefore, it was concluded that turbidity and introduced substances in the water column had no significant effect on the benthic community in the area of deposition. Sediment samples were also analyzed for total organic carbon and nitrogen and a series of possible contaminants (sulfides, ammonia, oil and grease, Cd, Cu, Fe, Pb, Mg, Hg, Ni, Zn). Values for total carbon and nitrogen were low in the dredged sediment and in the sediments at the test site after disposal and were not significantly different for those values reported for the *in situ* sediment at the test site prior to disposal. Values for possible contaminants were the same as would be expected for uncontaminated sediments (R. Holton, OSU, personal communication, 1977, as cited in Richardson and others, 1977).

The most apparent effect of the disposal on benthic assemblages was the significantly lower abundance of 11 of the 33 most abundant species present. In general, most of the species not significantly affected by the disposal of dredged material were more motile species capable of burrowing or migrating considerable distances over sediments -- shelled gastropods and mollusks, non-tube dwelling polychaetes, and cumaceans. Those species with a limited or no ability to burrow (tube dwelling polychaetes and amphipods) were probably eliminated from the site initially due to the effects of burial and smothering. The mechanism of the repopulation of benthos in the affected area is unknown but was probably accomplished by benthos burrowing up or migrating into the area, not as a result of the introduction of new species or larval recruitment into the area (Richardson and others, 1977).

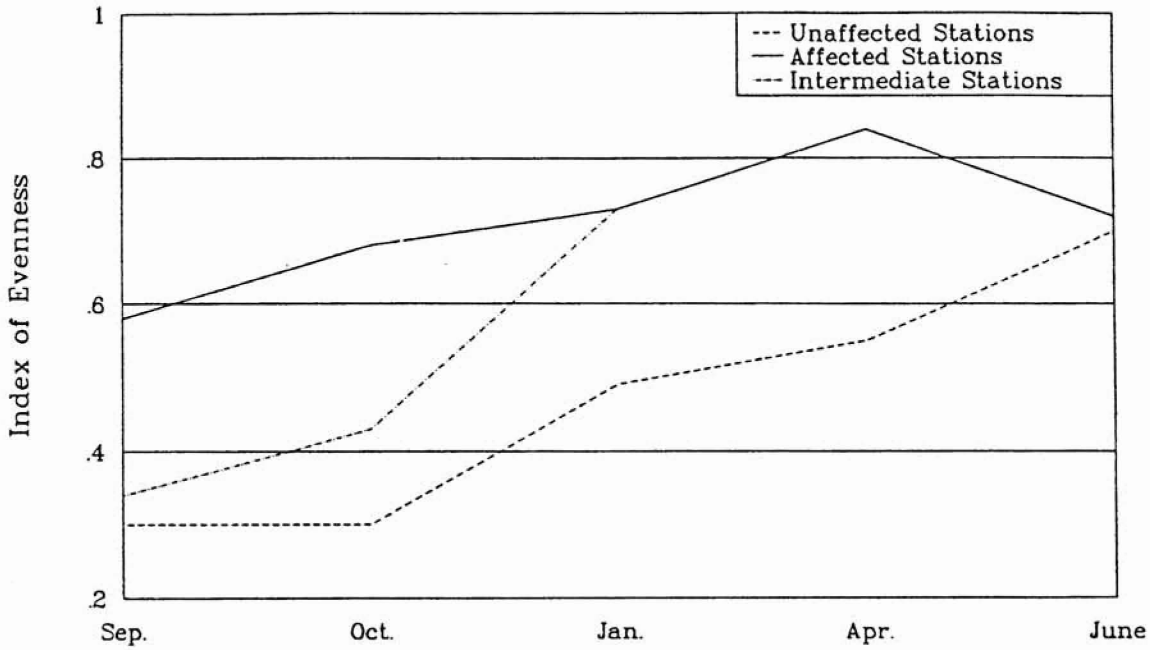
The principle short-term effects of dredged material disposal on benthic communities include the following: the direct burial or smothering of benthos by the dredged material; the increased turbidity from the disposal operation or from the resuspension of dredged materials through current or wave action; the introduction of pollutants, trace metals, or organic material from the dredged material or from resuspension of sediments; and textural changes in sediment or substrate type (Saila and others, 1977). The investigators concluded that the primary short-term factor affecting benthic

Figure B-2. The indicated diversity of benthic assemblages within the test site after disposal (Sept. 1975 – June 1976).



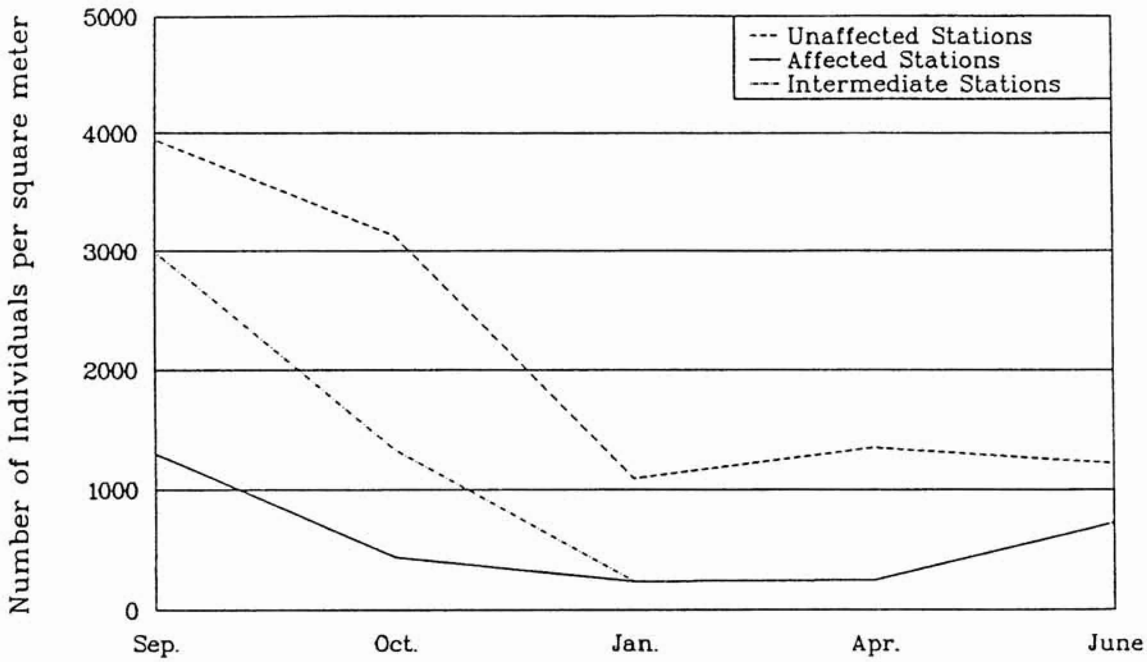
Sediment characteristics of the affected and intermediate stations were nearly identical in January 1976 and were treated as one set for subsequent samplings.

Figure B-3. Indices of evenness for benthic assemblages at the test site after disposal operations (Sept. 1975 - June 1976).



Sediment characteristics of the affected and intermediate stations were nearly identical in January 1976 and were treated as one set for subsequent samplings.

Figure B-4. Density (N/m2) for benthic assemblages within the test site after disposal (Sept. 1975 - Jun 1976).



Sediment characteristics of the affected and intermediate stations were nearly identical in January 1976 and were treated as one set for subsequent samplings.

community at the test site was probably the direct burial or smothering from deposition of the dredged material. A second possible short-term factor could have been the change in sediment grain size at the disposal site.

Part B: The Effects of Dredged Material Disposal on Demersal Fish and Decapod Shellfish Studies

The purpose of this particular study was to describe the composition, abundance, and distribution of demersal finfishes and decapod shellfishes; to describe feeding habits of dominant finfish species; and to assess the impact of dredged material disposal on finfish and decapod shellfish species in the disposal area (Durkin and Lipovsky, 1977).

Baseline data were collected at four pre-selected sites to provide information on the temporal and spatial distribution of species of finfishes and decapod shellfishes. Two of the sites selected have been used as disposal sites by the Corps of Engineers in previous channel dredging operations (sites B and C). One site is located north of the Columbia River shipping channel, and the other is located to the south of the channel. Neither site received additional material during the course of the study, and the last disposal operation was completed in October 1974, just prior to baseline sampling phase of this study. Two control sites were selected (sites A and D), one to north of the shipping channel and one to the south, to serve as a basis for comparison between the sites used for prior disposal and sites with no prior history of disposal (Figure B-5).

During the second phase of the study, baseline studies continued at the four initial sites, and a fifth site (site E) was selected in July to serve as the experimental disposal site. This site is located to the south of the shipping channel and has no prior history of disposal. Bathymetric surveys performed after the disposal operation revealed that a semicircular mound approximately 760 m in radius and 1.5 m deep at the center had been created (Sternberg and others, 1977).

Samples were collected using an 8-m semi-balloon shrimp net with a 38-mm mesh net and a 12-mm cod liner. Two parallel tows of five minutes each were conducted at each site on a monthly basis, weather permitting. Samples were not collected at all sites from December through March due to a heavy concentration of commercial crabbing gear in the area. Depths at the sampling stations varied between 17.5 m and 40 m. The experimental site was sampled more frequently during the actual disposal operation to assess direct impacts on numbers of finfish and decapod shellfish species. A subsample of the numerically dominant fish collected in tows from January 1975 through April 1976 was measured to determine the size structure of the population, and stomach contents were taken to determine trends in food utilization.

Diversity at the four comparative sites was variable, especially during the November 1974 through May 1975 sampling period (Figure B-6), largely due to the presence or absence of schooling northern anchovy in the study area. When high numbers of anchovy were caught, low diversity values resulted. Seasonal changes in species populations may occur but would require further investigation and exclusion of the variable catch of northern anchovy.

The range of diversity values observed at the test site did not differ substantially from the range of values observed at the other sampling stations. However, values at the test site were lower than those at the comparison sites for several months after disposal, then returned to values similar to those of the other sites within seven months of the disposal operation. This latent decrease in community diversity may be related to sediment deposition.

Species richness showed a lower trend based on fewer fish and species at the test site after disposal. Species richness values at the test site did recover by February 1976 and were similar to those values at the four comparative sites.

Evenness, or the distribution of individuals among species, also showed an instability from November 1974 to June 1975 due to presence or absence of northern anchovy. Afterwards, difference

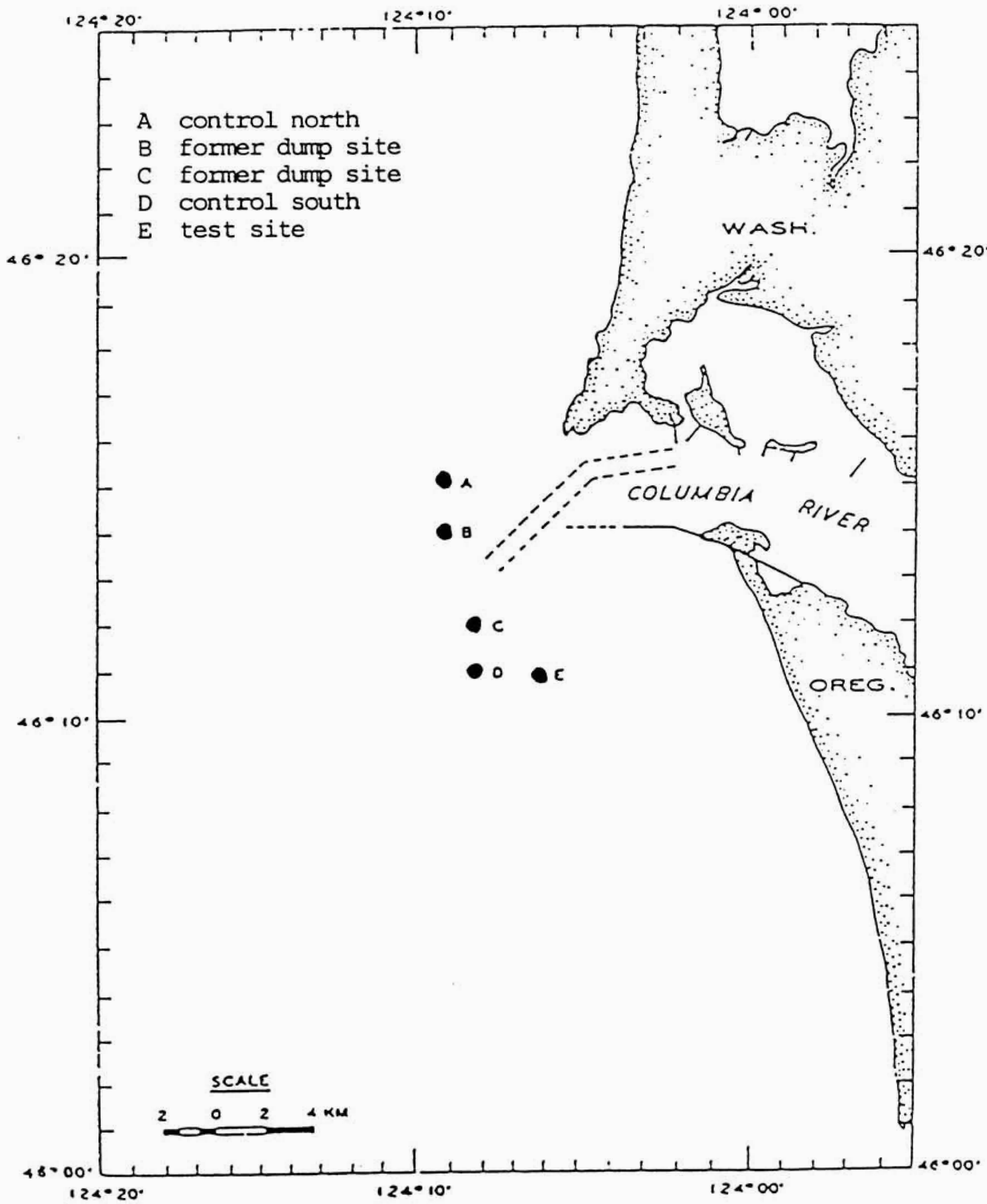
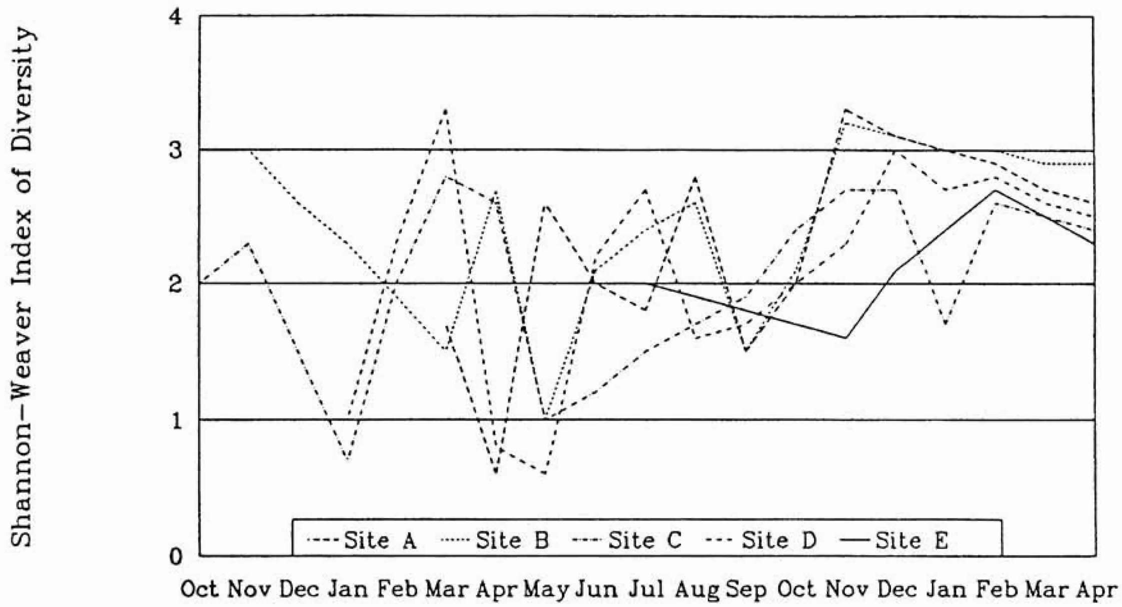


Figure B-5. Location of demersal sampling stations. From Richardson and others, 1977.

Figure B-6. The indicated diversity of demersal-associated finfish within the test site after disposal (October 1974 through April 1976).



Sampling at test site E began July 1975.

in evenness values were minimal at all sites, including the test site. This observed trend at the disposal site indicates a relatively consistent number of species apparently tolerant to deposition were present at the site during and after the disposal.

Average catch per unit effort (CPUE), the average catch of fish per minute per trawling, and average monthly number of fish species caught per tow also showed seasonal variations (Figure B-7). The presence or absence of northern anchovy greatly affected the CPUE values during initial baseline study phase from November 1974 to May 1975. The CPUE values in general appeared to be higher at the sites located north of the shipping channel than those located to the south, thus indicating spatial variations for some dominant species. Whitebait smelt, English sole, and Pacific tomcod were present at all sites. Pricklebreast poacher and showy snailfish were predominant at the sites north of the navigation channel, and butter sole and sanddabs were predominant at the sites south of the navigation channel. Northern anchovy and longfin smelt were present at all sites except the test site. Average monthly number of species taken per trawl effort suggest seasonal variations in the number of fish species present. Generally, more fish were caught in the winter and spring than in the summer and fall (Figure B-8).

The CPUE values at the test site during and after disposal were consistently low. The number of species present at the test site was low during disposal and remained low afterwards. Average trawl catches at the test site had the lowest number of species of all sites sampled during the disposal, and at one and three months after the disposal. Seven months after the disposal, the average monthly number of species caught at the test site was similar to those values observed at the comparative sites.

Sizes of dominant fish species were measured to determine if one size class was more affected by sedimentation than another. Although the small numbers of fish collected at the test site make this comparison difficult, in general, it appears that fish at the test site were usually smaller than those sampled at other sites. Butter sole was the only species common enough to provide data for post-disposal comparisons. Individuals were larger at the test site in July, significantly smaller in the August and September, and significantly larger in April. Sanddabs, English sole, whitebait, and longfin smelts and sand shrimp were smaller at the test site than at other sites during and after the disposal operation. These observations suggest the possible effects of sedimentation on different sizes of fish.

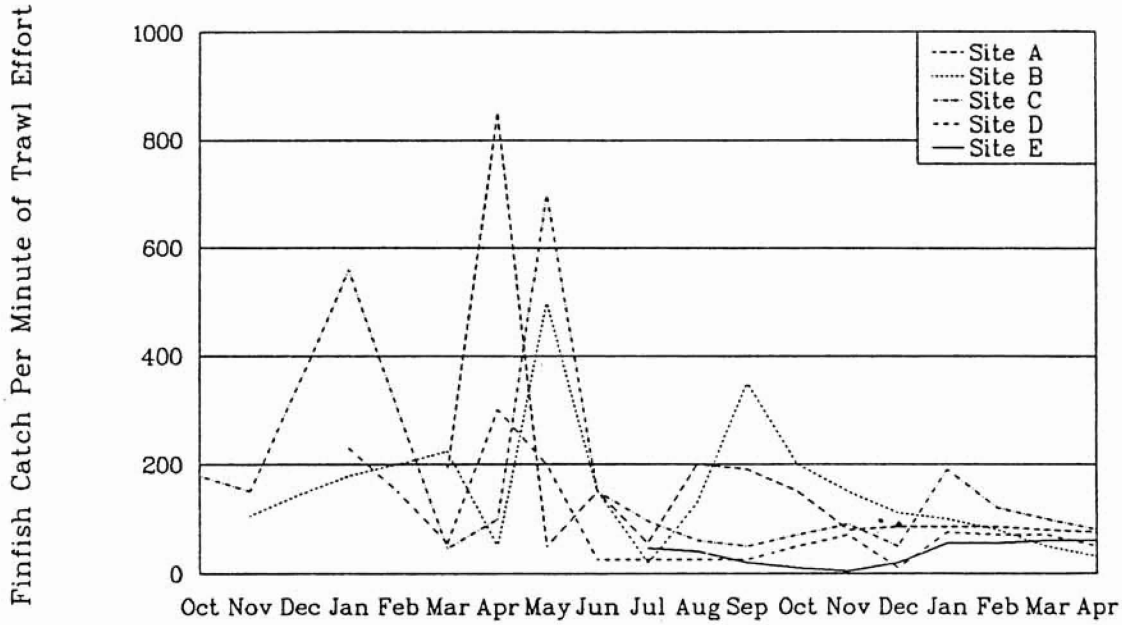
Changes in feeding habits are difficult to assess because fish may feed in another area prior to capture within the sampling site. Fish caught in the test during and immediately after disposal showed an increase in consumption of shrimp and small fish and a decrease in consumption of cumaceans, copepods, mysids, and amphipods compared to the diets of fish caught at the other sites. This change in food habit may indicate effects of disturbance on the community or it could be a normal seasonal variation in food selection for that area. One month after the test disposal, the feeding behavior of fish at the test site was similar to that of fish at the other four stations.

Crangonid shrimp species made up 95.9 percent of the entire decapod shellfish catch, while Dungeness crab accounted for only 3.8 percent of the catch. The greatest number of decapod shellfish species were collected during the November 1975 through April 1976 sampling period (Figure B-9). Similar results did not occur for the same season the previous year, thus no consistent pattern of seasonal availability was observed. Catches at the test site were low compared to the other sites during and immediately after disposal, although site D, also located to the south of the shipping channel, showed a similar pattern of low values. Six months after disposal, the test site had CPUE values similar to those observed at the other sites.

The investigators identified the following limitations of the study:

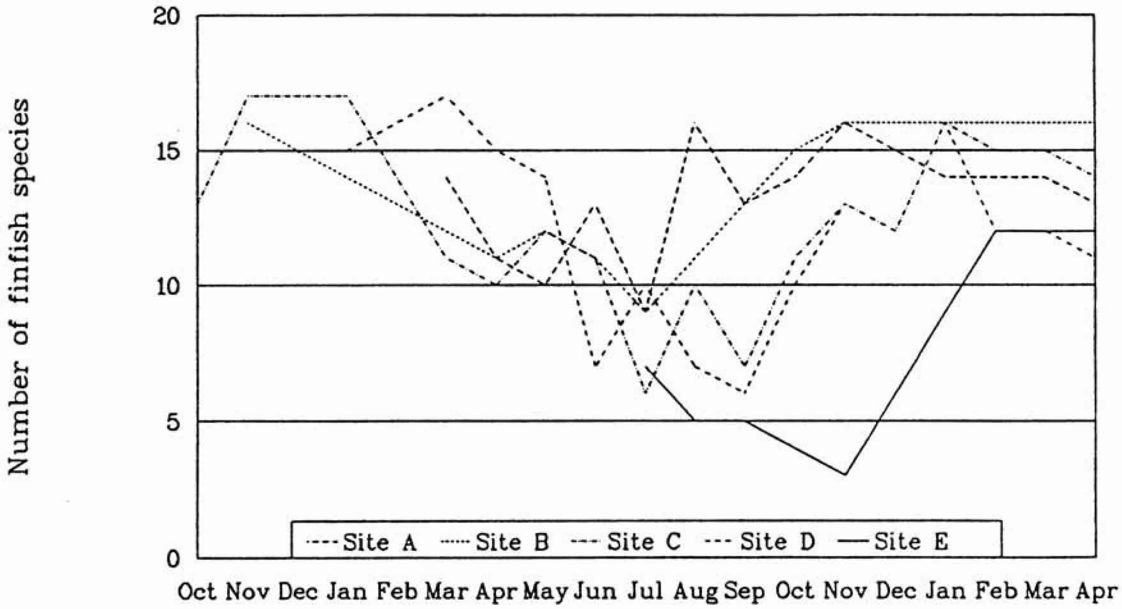
1. The study lacked a complete year of initial baseline data to establish the temporal and

Figure B-7. Comparative numerical catch of finfish per minute of trawl sampling effort (October 1974 through April 1976).



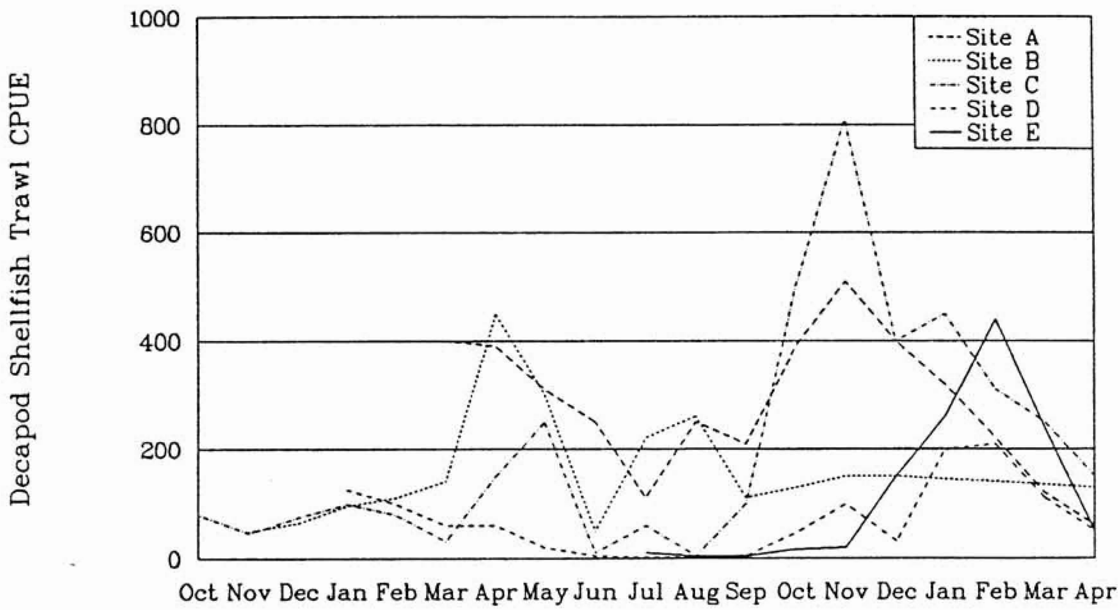
Sampling at test site E began July 1975.

Figure B-8. The average monthly number of finfish species captured (October 1974 through April 1976).



Sampling at test site E began July 1975.

Figure B-9. Comparative numerical catch of decapod shellfish per minute of trawl sampling effort (October 1974 through April 1976).



Sampling at test site E began July 1975.

spatial distribution characteristics of dominant species.

2. The designation of the test site location was made just prior to the disposal operation, thus limiting the amount of sampling at the site prior to disposal.

3. Because deposition by the dredge vessel was made in a semicircular track at various distances from the marker buoy, trawl samples were taken partially from areas not within the zone of deposition.

Despite these limitations, it appears that dredged material disposal did have an affect on the community structure values at the test site. Species diversity, species richness, and catch per unit effort values, which were similar initially to those of the other sites, fell during or after deposition but within seven months of cessation of the disposal operation returned to values corresponding to those from the other sites. Since no sampling occurred at the test site prior to disposal, it was assumed that the test site had a species assemblage similar to those at the other sites located south of the shipping channel.

APPENDIX C

Summary of Operations: WestGold, Nome, AK

In 1985, Inspiration Mines, Inc. (now Western Gold Exploration and Mining Company, Limited Partnership, or WestGold), initiated mining operations offshore of Nome, Alaska. The leased area is approximately 4 km offshore and extends 18 km along the coast, approximately 21,750 acres. A clamshell bucket and crane supported by a platform dredge were used in the start-up operation, then in 1986, the Bima, a large bucket-line mining vessel, was purchased for subsequent mining operations. The Bima is capable of recovering 45,800 m^3 of material per day with a process water discharge of 47.8 million gallons per day. Typically, the Bima processes between 7,600 and 15,300 m^3 of sediment per day. Currently, the vessel operates in 5 m to 13 m of water and digs to a depth of 10 m. In addition to actual mining activities, exploration activities (ie., core samples) take place throughout the year, while mining is restricted to only the ice-free season, mid-May to September. After three seasons of operation, approximately 225 acres have been mined and approximately 75,000 fine ounces of gold recovered (Rusanowski and others, 1989).

Through a series of public hearings, written testimonies, and agency discussions held during the permitting process, a list of environmental concerns and issues was compiled. These concerns served as a guideline for the development of the biological monitoring program, which then focused on providing answers to these concerns. A Project Review Committee was formed, including representatives from state, federal, and local agencies, mining project groups, and special interest groups. The purpose of this committee is to comment and review the work is currently underway rather than reviewing the project on an annual basis.

The major environmental issues are as follows:

1. Possible interference with present subsistence uses of the area through the loss of habitat, user accessibility, or animals avoiding the mined area.

2. Protection of renewable resources, particularly cod, salmon, herring fry, clams, shrimps, king crab, and seals.

3. Potential mercury contamination of the food chain, bioaccumulation, or increased mercury levels in some species (the area offshore has naturally high levels of mercury due to the covariance of mercury and gold, and from historical mining operations that used mercury (USDOI, 1988)).

4. Increasing mercury levels in the natural environment through the resuspension of mercury already in the sediment.

5. Degradation of the natural environment due to increased turbidity, smothering of habitable substrate, or possible interference with salmon migration.

6. The need for baseline data for the area to use as a basis to assess impacts.

7. Disruption of benthic habitat, specifically, the alteration of bottom topography or substrates, and the possible impacts these changes may have on benthic invertebrate communities, colonization rates, and king crab utilization of the area.

8. Possible impacts on the king crab fishery through loss of habitat or food sources or avoidance of mining area.

9. Dangers due to possible fuel spills or weather-related damage.

10. The ability to modify the monitoring program to address new issues or concerns.

Briefly, the monitoring program consists of a water- and sediment-quality component and a biological component designed to assess the potential effects of mining on the local ecosystem and subsistence resources. The program was developed in two phases, a pre-mining phase initiated in 1985 to collect biological and physical data in the Nome offshore area, and a second long-term monitoring phase initiated in 1986. This long-term environmental monitoring program consists of five areas that focus on the issues and concerns identified during the permitting process.

Side-scan sonar and bathymetric surveys are performed annually to assess changes in the seafloor topography. Sites are sampled in the mined area, in control areas, and at subsistence-use areas to provide a basis for distinguishing between changes resulting from the mining operation and those from natural occurrences. Surface-sediment samples are collected from each station used for benthos collection, using a 0.1-m^2 grab to a depth of 10 cm. Three replicates are obtained from each station, once per year.

Belt transect surveys are conducted once per year at each benthos station to assess king crab abundance and distribution. During the ice-covered season, a remote operated underwater vehicle (ROV) is used to videotape selected locations. The number and size of observed king crabs is used in the assessment of crab abundance and distribution. Sediment type is noted during crab observations to correlate preferred substrates with crab abundance and distribution. Also during the ice-covered season, daily and short-term movement of king crabs are assessed by capturing crabs, then releasing them with sonic tags. Catch rates for king crabs are also compared for mined and non-mined areas.

Benthos samples are collected at six sites within the mined, control, and subsistence use areas. Samples are collected from a 0.1 m^2 area using a Venturi-jet suction pump and a 1.00-mm mesh collection bag. Infauna are collected once per year during the ice breakup period in mid-May. A series of 35-mm photographs are also taken to document the sample site. Results are compared between seasons to look at recolonization rates of the mined substrate.

Water- and sediment-quality parameters are monitored according to a sampling regime specified in WestGold's National Pollutant Discharge Elimination System (NPDES) permit administered by the U.S. Environmental Protection Agency (EPA). The monitoring program includes the measurement of turbidity, salinity, temperature, and dissolved oxygen levels as well as testing for eight priority trace metals (As, Cd, Cr, Cu, Pb, Hg, Ni, Zn). Sampling locations include Bima process waters, the down current plume, and background control locations. These results are submitted in monthly Discharge Monitoring Reports to the Water Compliance Section of the EPA. This information is also provided in the annual report of the Project Review Committee (Rusanowski and others, 1989).

Six sampling stations were established within the leased area. Two sites, R6 and R7, were selected within the 'footprint' left by mining activities. Two sites, C2 and C3, were used as controls and were located adjacent to the mining sites, and two sites, S2 and S3, were subsistence-use sites, located approximately 10 km away from the mining sites. The two subsistence-use sites were also considered as control sites (Figure C-1).

During the 1988 mining season, data were collected for a three dimensional water quality and sediment-plume model, Disposal From a Continuous Discharge (DIFCD), developed by the U.S. Army Corps of Engineers Waterway Experiment Station (Demlow and others, 1989). The plume-monitoring program consists of a moored, up-current monitoring station that serves as a control station and a

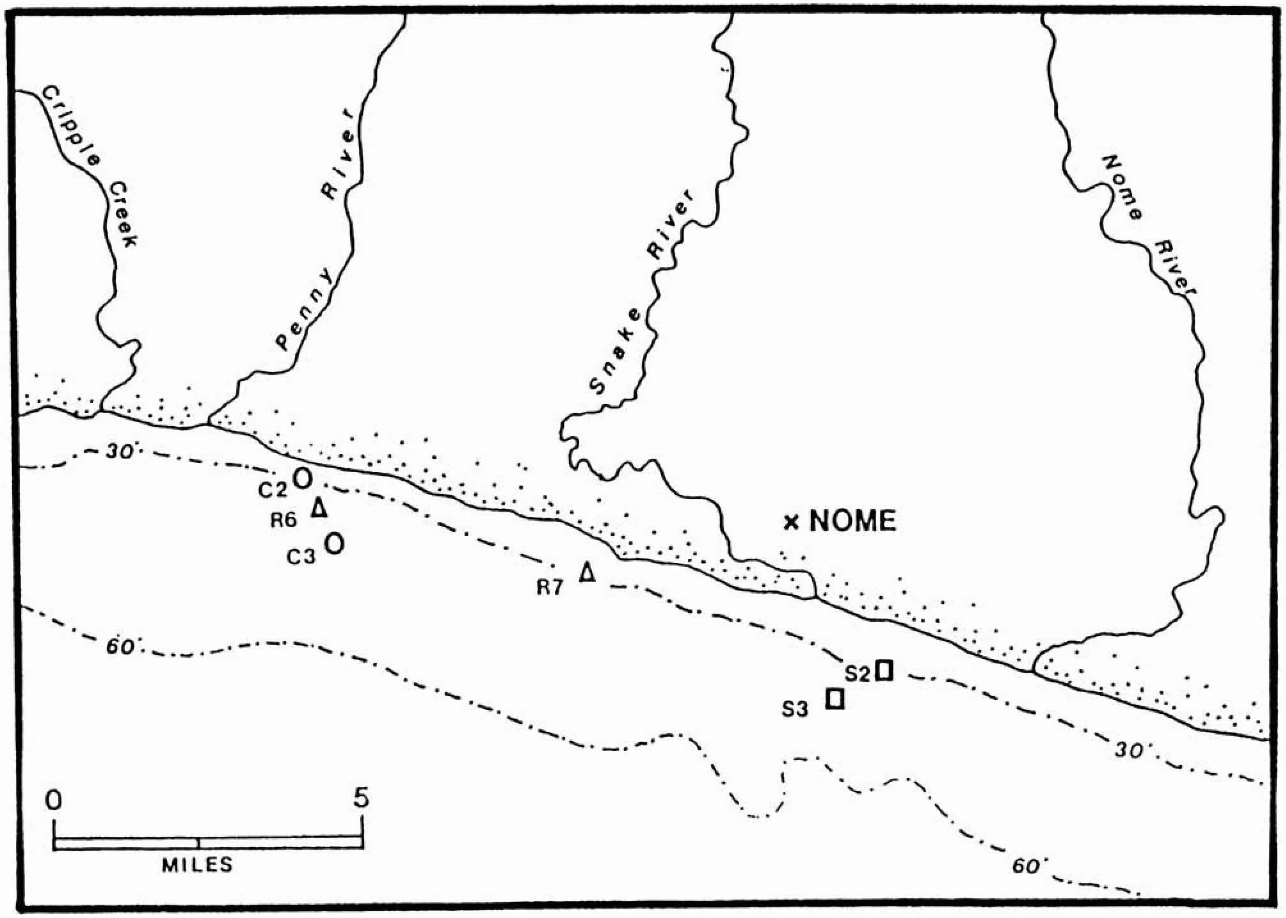


Figure C-1. Map of sampling stations for WestGold mining operations. From Rusanowski and Gardner, 1989.

down-current station that provides information on the dispersal pattern of the effluent plume. Turbidity, conductivity, and current speed and direction are measured as well as wave frequency, magnitude, and tidal changes. Portable instruments are used to make transects through the plume to define the shape and extent of the plume. Turbidity is measured using a nephelometer, which optically measures the amount of suspended particles in the sample. Sediment traps are located through out the study area at various distances from the point of effluent discharge. These samples provide information as to how far different sediment types travel from the point of discharge until they eventually resettle. Sediment samples are collected directly from the bucket line at the dredge site to identify the substrate composition currently being mined. The data collected during this sampling phase is used as input for the Wave-Current Sediment Resuspension Prediction model (WCSRP), which was developed to analyze the resuspension of bottom sediments.

The DIFCD model and sediment-resuspension model were used to determine at what distance from the point of effluent discharge water-quality standards are met, what range of conditions can be expected to be encountered during the life of the mining project, and which discharge configuration (discharge depth, discharge rate, diameter of discharge pipe, use of deflectors, etc.) results in the lowest possible turbidity and trace-metal concentrations at the edge of the plume mixing zone.

Results from the sediment surveys and side-scan sonographs revealed observable changes in the seafloor sediment type at the control area (Table C-1). This area was monitored to observe impacts from naturally occurring disturbance to the area and to assess natural sediment migration of the area. This site was not subjected to mining activity. In general, changes in overall seafloor sediment type composition were observed over the 1985-1988 sampling period, with the cobble fraction decreasing, and the sand/silt fraction increasing compared on an annual basis. These fluctuations are considered to be natural, but further evaluation of this area will be necessary to establish sediment migration. Results for the mined areas showed an overall increase in coarse-grained material, with an overall decrease in fine-grained material. This is probably due to the sorting of tailings at the outfall and considerable amounts of suspended fine grained material being removed from the area through current movement thus exposing the coarse-grained materials.

A survey of catch rates of red king crab was conducted in March of 1988, including site R6 (mined in 1986), site R7 (mined in 1987), and control site C2. Over a 10-day period, a total of 98 crabs were caught at the three sites (Jewett and others, 1989). The catch per unit effort values were not significantly different among sites. Similar results were observed during the 1987 sampling season.

Indirect impacts on the king crab are determined by examining stomach contents of crabs to determine major food items on mined and non-mined areas. Crabs taken from mined areas showed no significant difference in quantity or composition of food in the stomachs (Jewett and others, 1989). In 1988, eelgrass was identified as a new food source for crabs collected in the mined areas. Observations made from ROV surveys in the mined areas showed accumulations of eelgrass in the depressions left by mining activities. It appears that mining activities did not affect king crab utilization of mined substrates. This is probably due to the opportunistic feeding habits of the red king crab.

Trace metal analyses are conducted on king crabs and on their major food items. The sampling of organisms from higher trophic levels (ie., fishes, seals, etc.) is conducted only if organisms are provided to the program. At present, this is a voluntary task in the monitoring program. Results from trace metal analyses of king crab tissues indicate that all metal levels were within an order of magnitude of values reported in literature from other areas. The average mercury concentration values for king crab muscle tissue were within an order of magnitude those reported for other locations in Alaska. All trace metal levels except copper, were found to be present at lower levels in crab tissue samples than in sediment samples. Crab blood plasma contains hemocyanin, which is comprised of copper subunits; therefore, it would be expected that crab tissues would contain relatively high levels

Table C-1. Multi-year comparison of the percent composition of seafloor sediment at each sampling station. (From side-scan sonar surveys)

Control Area C2

Sediment Type	1985	1986	1987	1988
Cobble	58.2	62.0	N/A	53.9
Sand Wave	3.9	0.7	N/A	7.0
Sand/Fine Gravel	0.0	0.0	N/A	0.0
Sand/Silt	37.8	37.3	N/A	45.4

Mined Area R6

Sediment Type	1985	1986	1987	1988
Cobble	11	mined	0	42
Sand Wave	4	mined	0	5
Sand/Fine Gravel	44	mined	30	11
Sand/Silt	41	mined	70	42

Mined Area R7

Sediment Type	1986	1987	1988
Cobble	46	mined	3
Sand Wave	4	mined	2
Sand/Fine Gravel	23	mined	18
Sand/Silt	20	mined	77

From Rusanowski and Gardner, 1989.

of copper. After three years of monitoring, king crab have shown no general increase in trace metal levels through time and do not pose a health risk to subsistence users (Jewett and others, 1988).

Since the substrate is being removed and redeposited, there is almost complete destruction of fauna in the mined area. A major component of the biological monitoring program focuses on defining the amount of disturbance and determining the rate of recolonization and the species composition of the resulting community. It is difficult to resolve such issues after only three years of data, but preliminary findings suggest that two years after mining in sand substrates, an assemblage of infauna has recolonized that is similar to those communities at unmined sites.

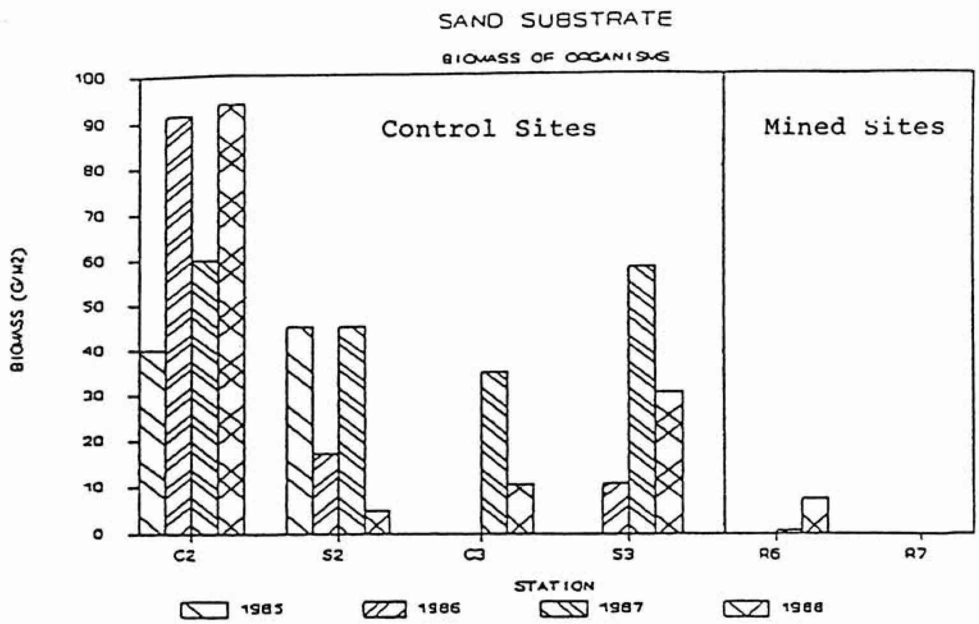
Comparisons of total number of taxa, density, and biomass of organisms collected from control and subsistence-use sites indicate that some year-to-year variation occurs at control stations, although no consistent patterns of increase or decrease are evident. Diversity indices and species richness values also show no apparent trends between years at any stations (Figures C-2, C-3).

Warwick (1986) suggested that the distribution of the number and biomass of individuals among species respond differently to disturbance. This difference can be demonstrated by the comparison of k-dominance curves for abundance and biomass of the species in the community. Species are ranked in order of importance on the x-axis (logarithmic scale) and percentage dominance on the y-axis (cumulative scale). In undisturbed communities, the species biomass curve will be above the species number curve; in a moderately disturbed community, the two curves will more or less coincide, and in a grossly disturbed community, the species numbers curve will lie above the species-biomass curve (Figure C-4). This procedure was originally used to detect pollution-induced effects on benthic communities but was later applied as a means of assessing natural and biological disturbance as well (Warwick and others, 1987).

Results of this analysis for the 1988 sampling season indicate that some level of natural disturbance was evident in three of the four unmined sites (Figures C-5, C-6) (Jewett and others,1989). Control-site C2 showed some degree of disturbance for the two highest ranked species, while subsistence-sites S2 and S3 showed more moderate levels of disturbance throughout the community. Disturbances may be intense ice scouring and mounding during the ice-breakup period. Control-site C3 showed no evidence of disturbance within the community. Mined-sites R6 and R7 reflected moderate levels of disturbance (Figures C-7).

Two stations were selected to monitor recolonization of benthic organisms following mining activities. Station R7 was mined in 1987, and R6 was mined in 1986. Post-mining data have been collected for one year at site R7 and for two years at site R6. Results from site R7 indicated extremely low values for density and biomass compared to unmined sites. These findings were similar to those found one year after mining at site R6. The k-dominance curves for site R7 showed the benthic community to be moderately disturbed.

Density and biomass values increased between 1986 and 1987 at site R6. Faunal dominance for the site shifted from crustaceans to polychaetes. In the 1987 survey, one year after mining, polychaetes accounted for nearly 20 percent of the species abundance, while crustaceans, particularly cumaceans, accounted for 66 percent of the species abundance. In 1988, two years after mining, polychaetes accounted for nearly 75 percent of the faunal population. Although the 1988 sampling revealed increases in both biomass and density values, the k-dominance curve reflected some disturbance at the site for the highest ranking species. The curves from 1987 indicate a relatively undisturbed community, whereas the 1988 curves are more characteristic of a moderately disturbed community (Figure C-8). Although the 1987 curves revealed no signs of disturbance within the community, the number of taxa, density, and biomass values all were extremely low compared to unmined sites. The density and biomass of the community apparently decreased proportionately, thus masking any evidence



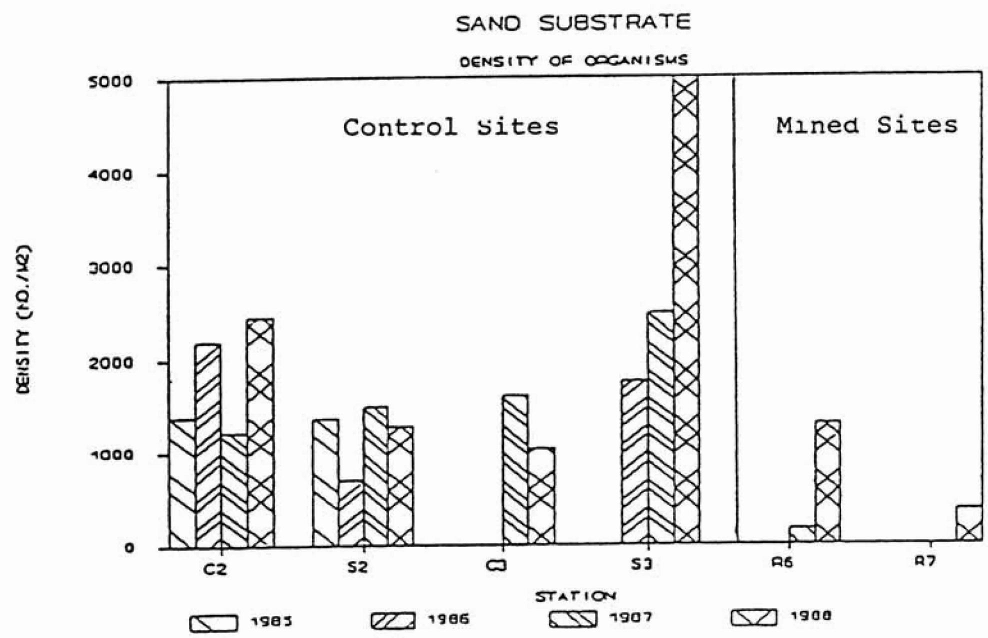
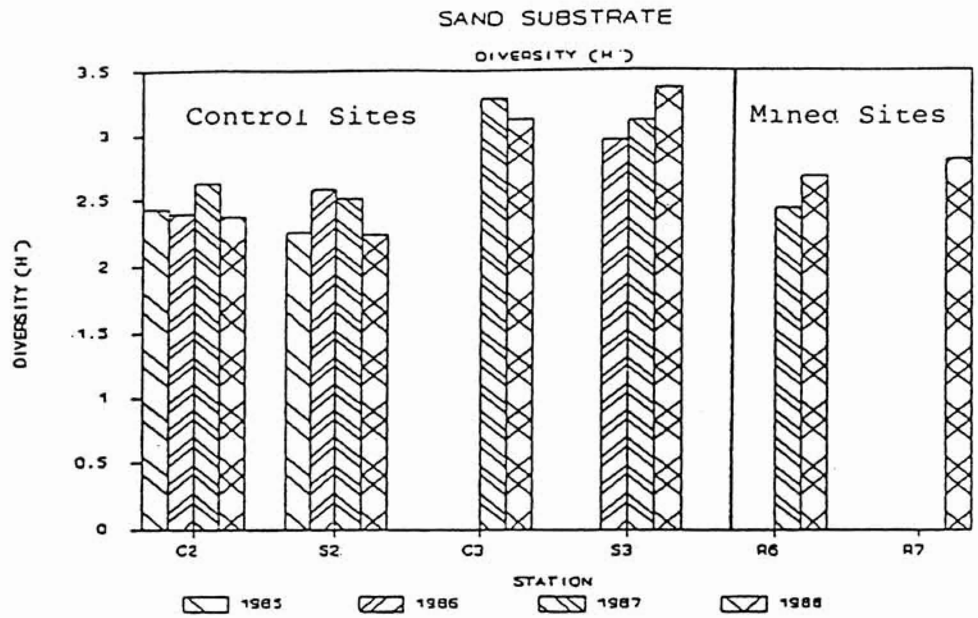


Figure C-2. Biomass and density values for sampling stations. From Rusanowski and Gardner, 1989.



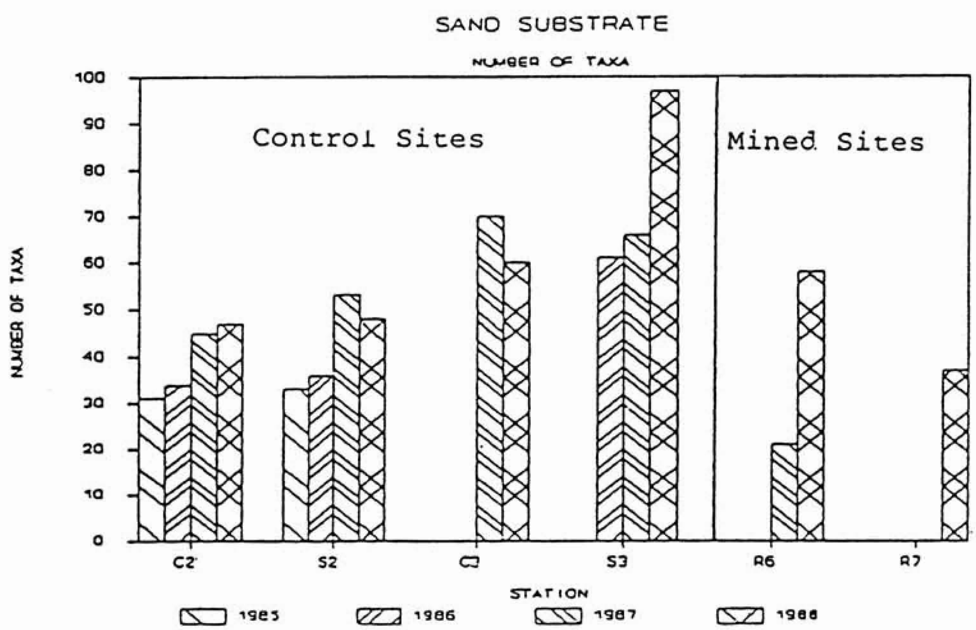


Figure C-3. Diversity and number of taxa for sampling stations. From Rusanowski and Gardner, 1989.

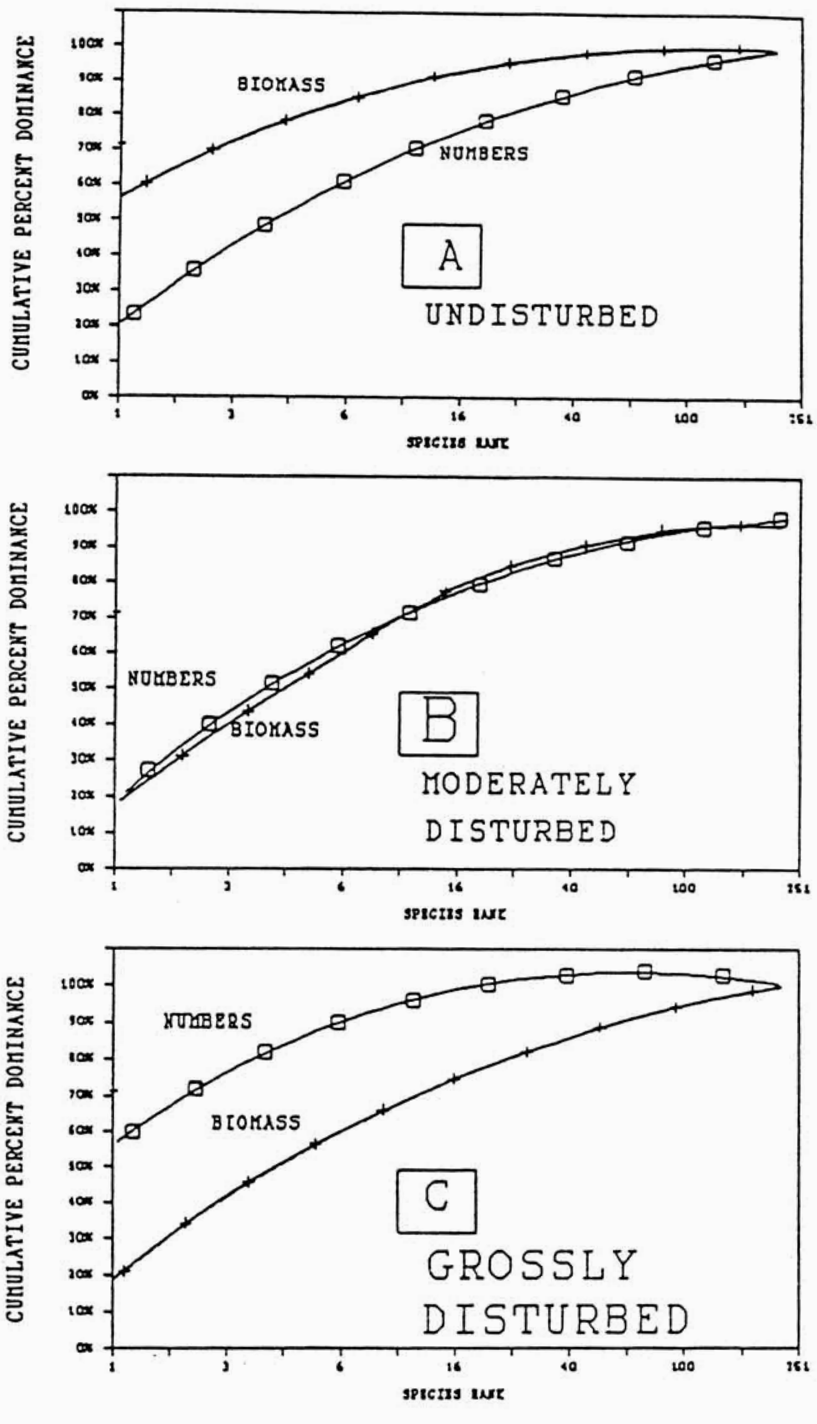
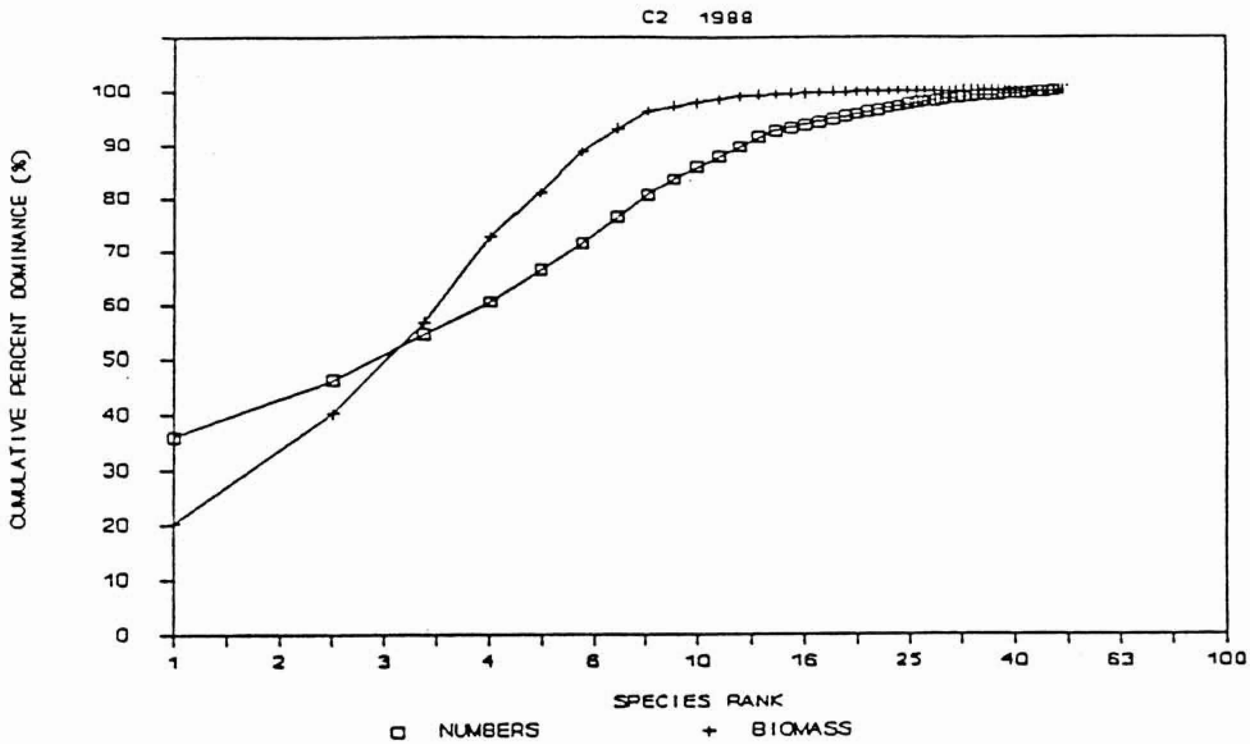
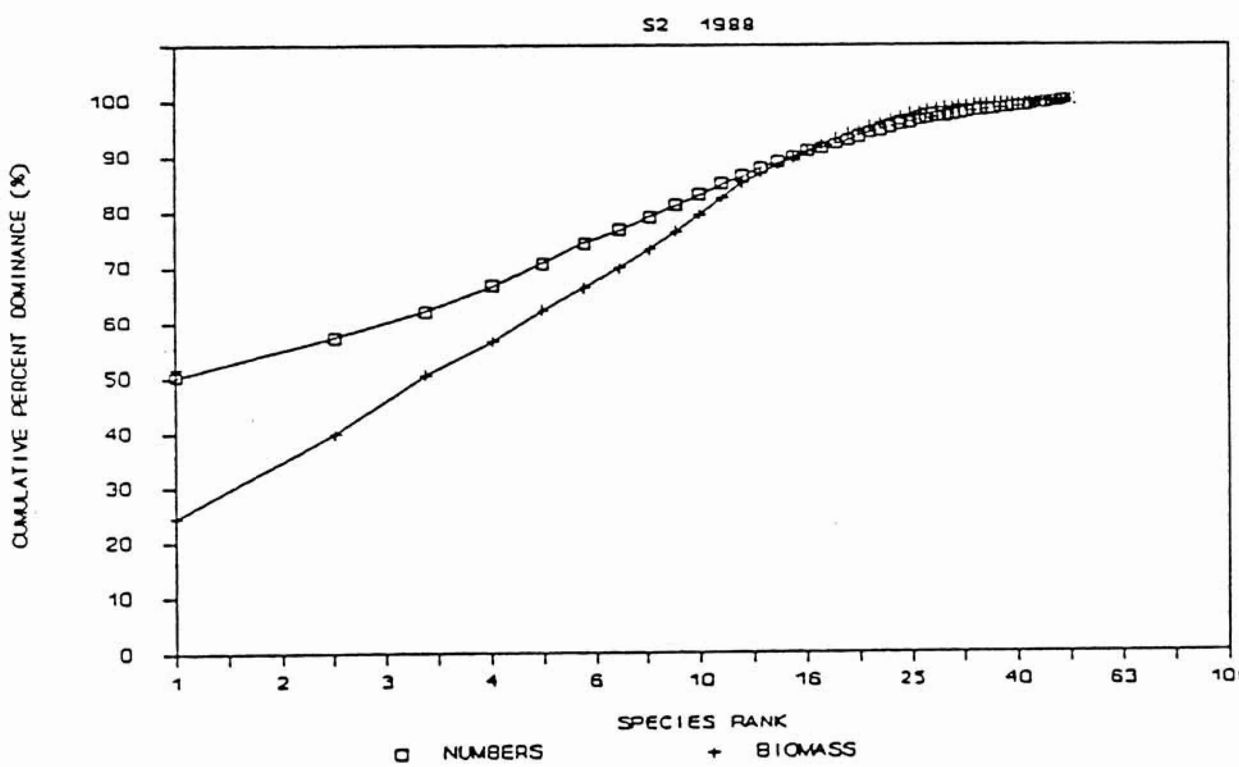


Figure C-4. Hypothetical k-dominance curves as described by Warwick (1968) and Warwick <u>et</u> <u>al</u>. (1987). (A) Undisturbed when the biomass curve lies above the numbers curve; (B) moderately disturbed when the biomass and numbers curves more or less coincide; (C) grossly disturbed when the numbers curve lies above the biomass curve.

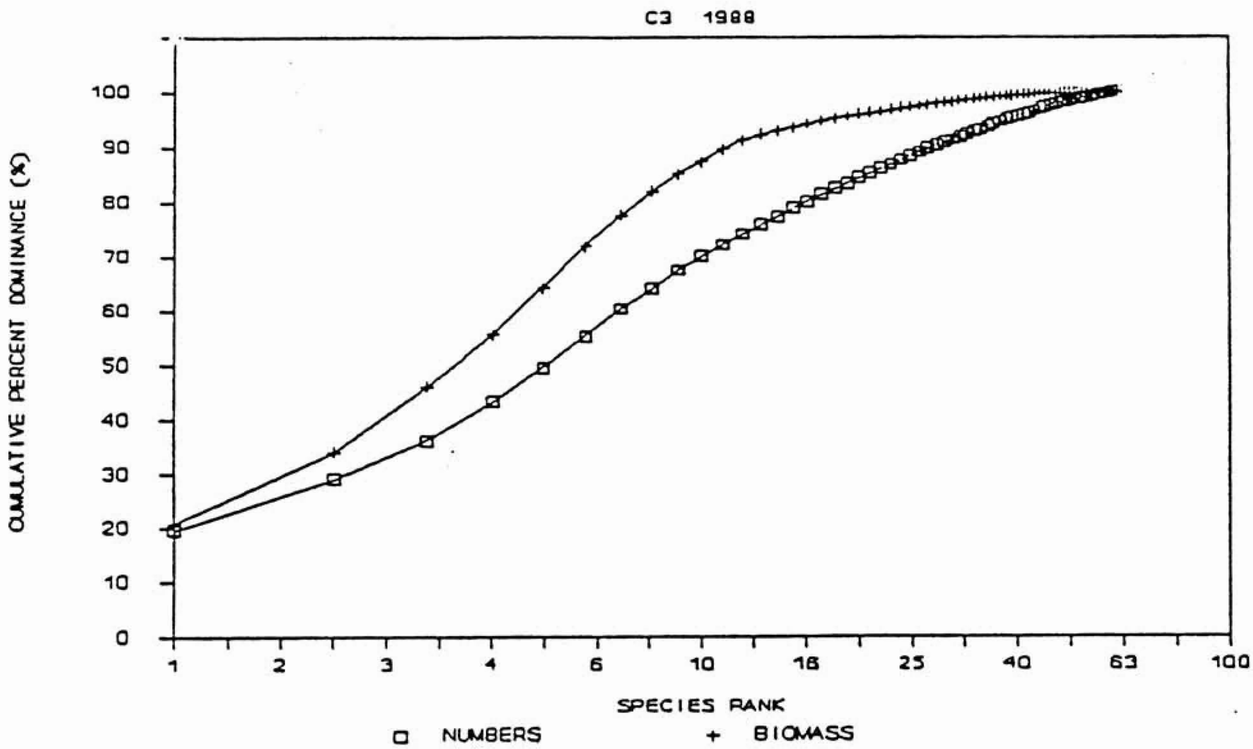
Figure C-5. K-dominance curves for sites C2 and S2.

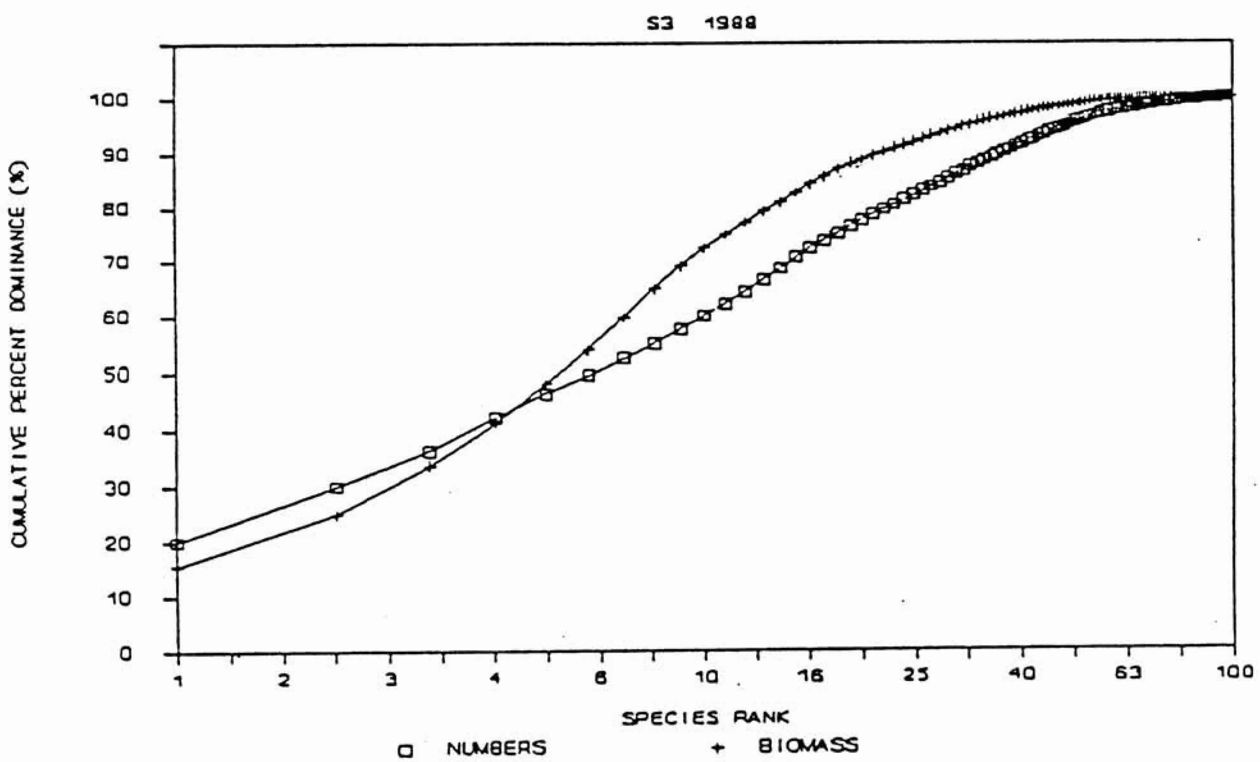




From Rusanowski and Gardner, 1989.

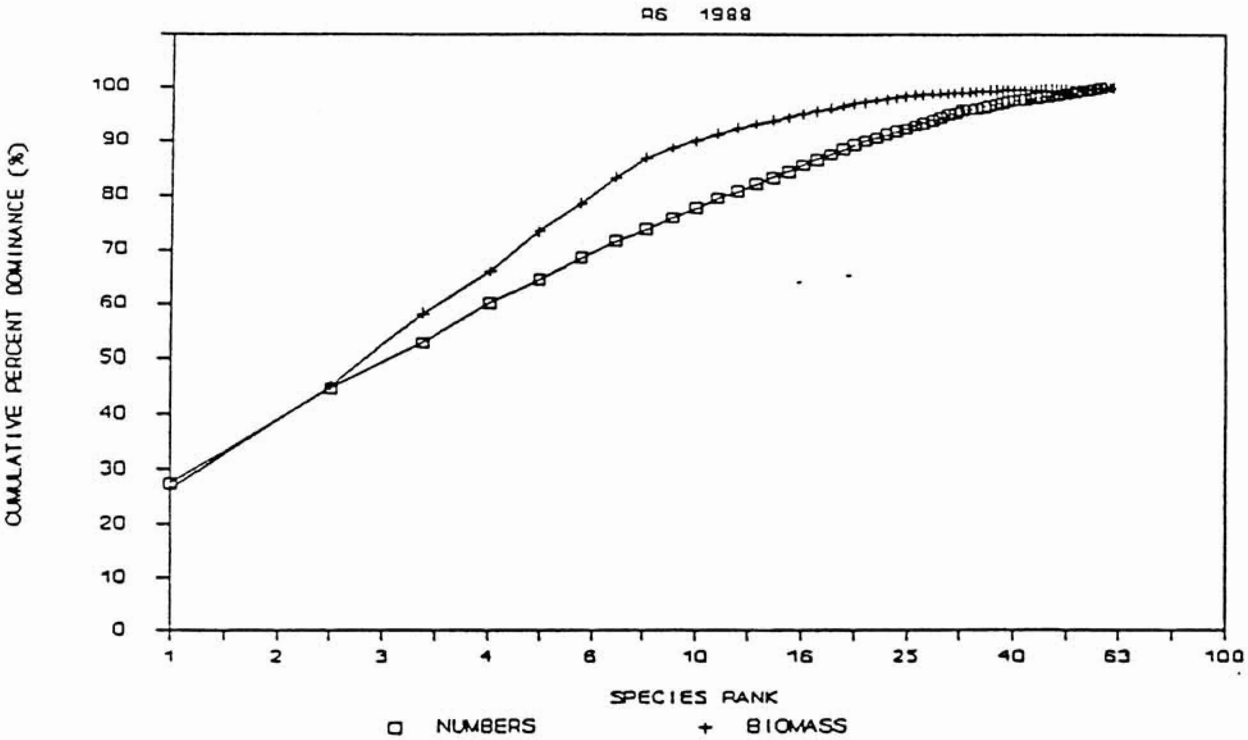
Figure C-6. K-dominance curves for sites C3 and S3.

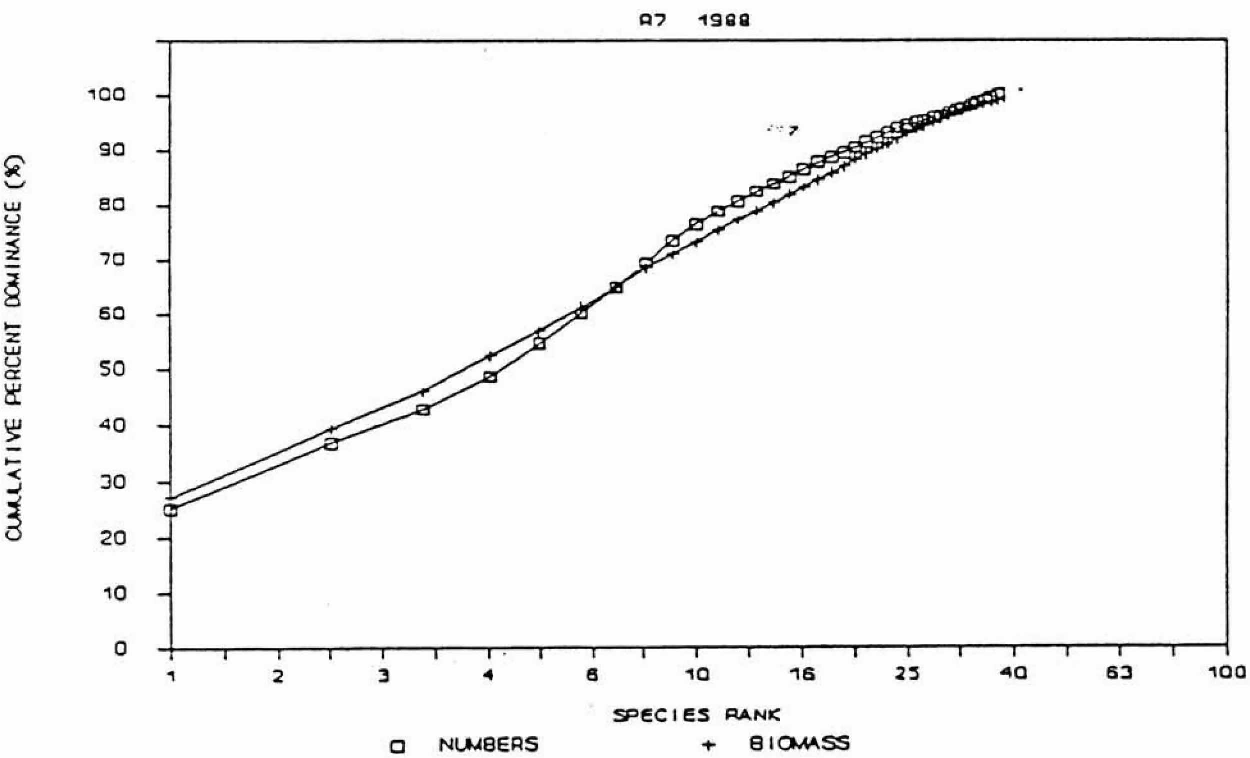




From Rusanowski and Gardner, 1989.

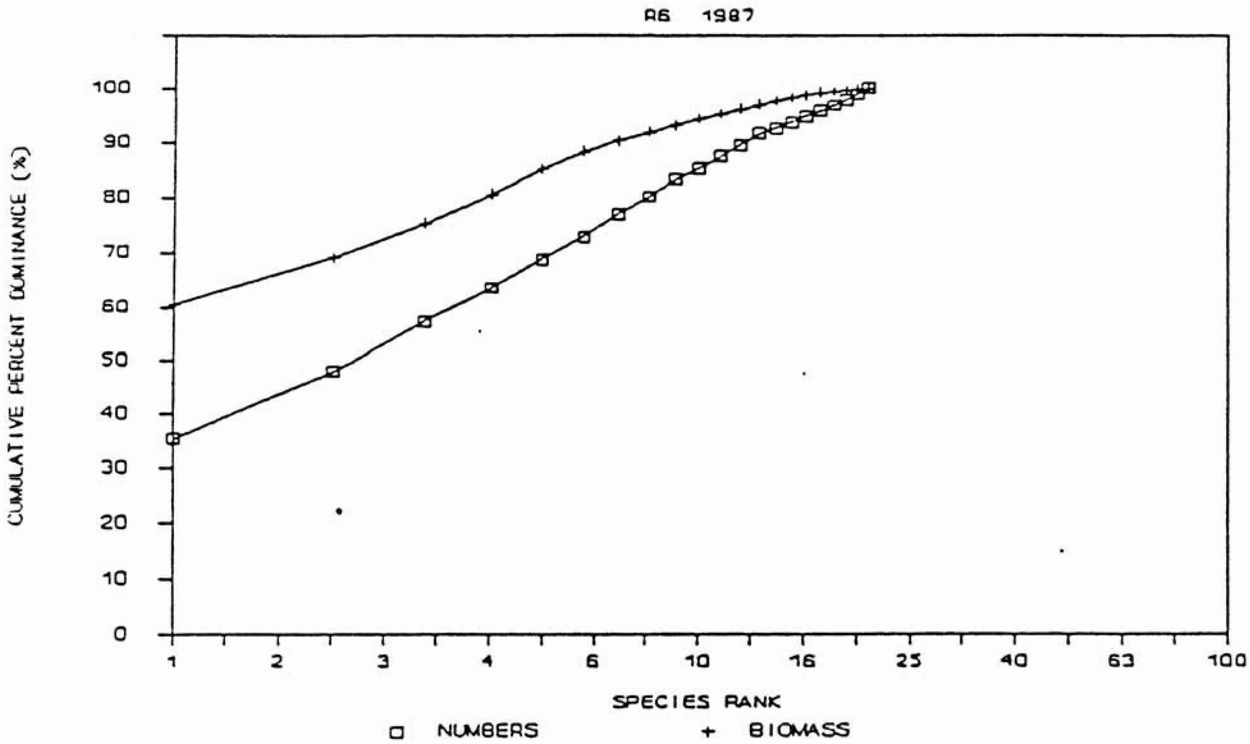
Figure C-7. K-dominance curves for sites R6 and R7.

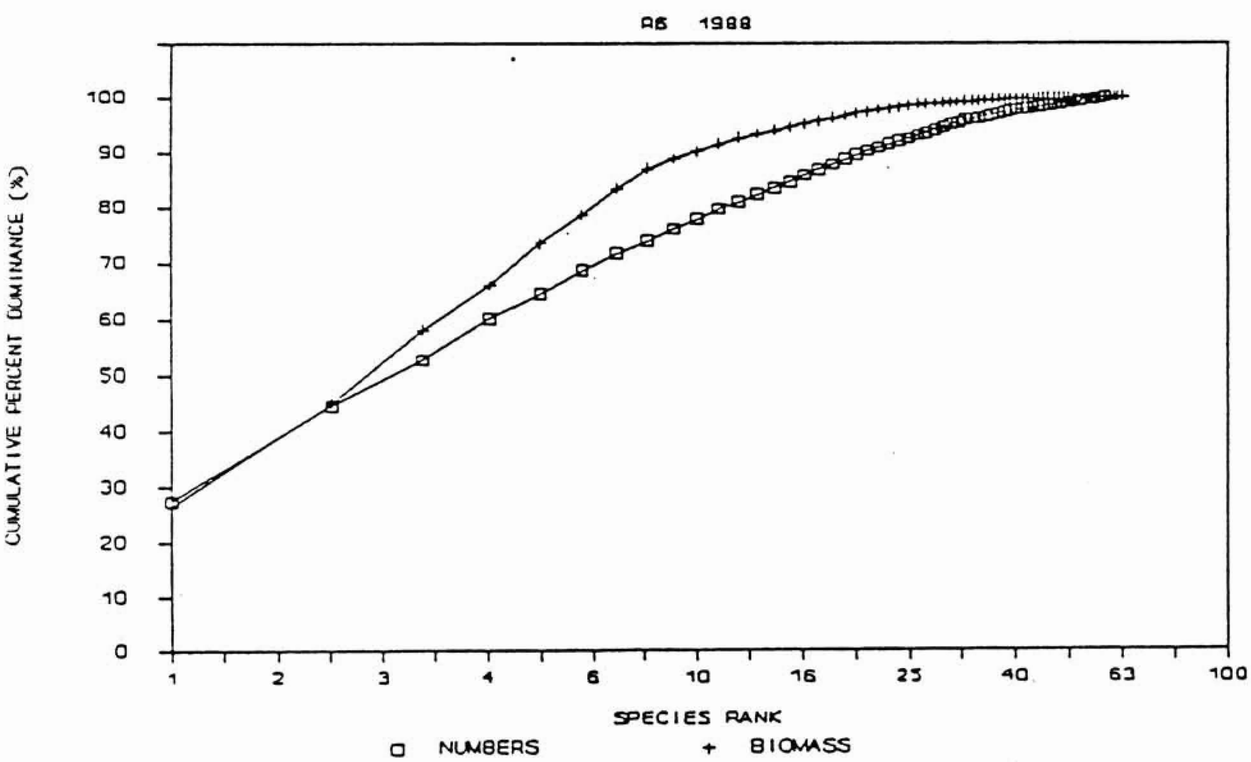




From Rusanowski and Gardner, 1989.

Figure C-8. Comparison of k-dominance curves for site R6 for years 1987 and 1988.





From Rusanowski and Gardner, 1989.

of disturbance that would have been born out in the k-dominance curves. Therefore, the curves must be used in conjunction with the other parameters (Jewett and others, 1989).

In conclusion, the low biomass and density values at site R7 one year after mining were similar to those values at R6 one year after mining. The k-dominance curves also indicated disturbance at the mined site, presumably as a result of mining activities in 1987. Results for site R6 (two years after mining) showed an increase in biomass and density values over the 1987 results (one year after mining), although the k-dominance curves still indicate some level of disturbance in the community. A comparison of k-dominance curves for R6 from the 1987 and 1988 surveys indicates that the community appears to be approaching an undisturbed state.

An identical benthic monitoring program was also performed for cobble substrate. The community-structure parameters (number of taxa, density, and biomass) on cobble substrate were variable, but not as variable as those observed on sand substrate. No consistent patterns of increase or decrease were apparent. One year after mining the cobble substrate, the number of taxa, density, and biomass were extremely low compared to unmined sites. Two years after mining, the community was still characterized by few taxa, low numbers of individuals, and low biomass. It appears that recolonization of cobble lags behind that of sand.

Trace metals of naturally occurring elements were analyzed for sediment samples collected from stations down-current of the Bima processing plume and from stations located within a control area. Down-current and background trace-metal levels in the sediment were usually not statistically different. Arsenic showed a higher concentration value at the control site compared to the value from the down-current site, an average value of 65.9 mg/kg versus 56.1 mg/kg, while cadmium concentration values were lower at the control site than at the down-current site, with an average value of 0.63 mg/kg versus 2.6 mg/kg. These differences could be due in part to the effects of redistribution of particles being discharged from the Bima.

The State of Alaska established a 500-m mixing zone for the dilution of effluent from the mining operation. At the edge of this zone, all water-quality criteria must be met. A 100-m mixing zone for trace metals is required by the EPA. In general, trace-metal criteria for water quality for all eight priority elements were met, with the exception of copper and mercury. Where effluent copper levels exceeded permit allowances, the influent levels did as well. Due to mercury contamination in the WestGold laboratory during the 1988 sampling season, all mercury data are suspect (Jewett and others, 1989). Concentrations of both lead and zinc were lower in the effluent samples than in the influent samples, thus indicating the probability of particle adsorption of these elements by the sediment during the processing operation. Although the data indicates, that the mining operation is not increasing trace-metal concentrations outside the mixing zone, contamination and analytical problems do not allow definitive conclusions to be drawn at this time. A more rigorous trace-metal monitoring program is being designed to resolve these issues in the future.

Turbidity values ranged from 0 to 213 NTU (Nephelometric Turbidity Units), with 0 being considered the natural background-turbidity level for the area. The majority of readings during the sampling period fell in the 0 to 20 NTU range. A value of 25 NTU above the background level was considered an acceptable level. Values greater than 130 NTU were considered to be inflated, due to the resuspension of sediment or errors instrument readings (Demlow and others, 1989).

Visual observations of the plume suggested that the width of the plume could vary greatly on a day-to-day basis and within a day. The variance in plume width was greatly influenced by the local oceanographic conditions and the sediment-silt content of the material being mined.

Sediment-trap samples located 1,500 m from the point of effluent discharge were comprised mainly of silt with some sand. Samples from the 500-m station were mainly fine sands. Samples collected from the bucket line showed that the substrate being dredged ranged from coarse sands to well-graded silts, with silt contents ranging from 6 to 40 percent. During periods of high wave activity, resuspension of previously settled material probably accounted for a significant portion of the turbidity observed.

A comparison of effluent turbidity data collected from the edge of the 500-m mixing zone during the 1987 and 1988 seasons indicates that substantially lower turbidity values were recorded in 1988 due to the implementation of a discharge jet that does not entrain air, which causes portions of the effluent plume to rise to the surface. However, discharge configurations (discharge depth, discharge rate, diameter of discharge pipe, use of deflectors, etc.) tested in the field indicated that no configuration resulted in substantially lower turbidity values. Any observed variations in plume width due to a particular discharge configuration could not be distinguished from variations caused by the influence of changing oceanographic conditions or the composition of the material being mined.

Using data collected on days when the turbidity level exceeded the 25 NTU above background criterion at the edge of the 500-m mixing zone, the DIFCD model was used to predict at what distance acceptable turbidity level would have been reached. The model predicted that the maximum distance from the point of effluent discharge where the criterion would have been met was 900 m, with the average distance being 725 m.

The model was also used to determine which discharge configuration would result in the lowest turbidity values at the edge of the 500-m mixing zone. The model could not predict any one configuration that would result in the lowest turbidity values for all possible mining conditions that may be experienced during the life of the project. The model was then used to predict what turbidity level would be encountered during the life of the mining project. The model predicted that for substrates comprised of low percentages of silts (less than 6 percent) and effluent discharge rates of less than 50 million gallons per day, the turbidity level at the edge of the 500-m mixing zone would comply with the 25 NTU above background level criterion. With higher silt percentages and greater discharge rates, turbidity levels could be as high as 162 NTU at the edge of the 500-m mixing zone.

The DIFCD model makes several assumptions that limit the effectiveness of the model results. The model does not allow for the resuspension of bottom particles; once materials have resettled on the seafloor, they remain there. A second limitation is that the model was developed in such a way as to assume that the vessel speed or local currents are strong enough to cause a "bending of the jet" before the bottom is encountered. The final assumption of the model is that the settling of suspended particles occur at a constant rate.

Much of the ongoing monitoring program is focused on providing sufficient data to show that renewable resources are not being significantly impacted by mining activities. Because the nearshore surf zone is a critical habitat for short periods of time during the summer, no mining activities take place within 0.4 km of the shore or in depths of less than 2.4 m. No mining is done within 1.6 km around the mouths of all known streams with anadromous runs of fishes. Water intakes for the Bima are screened to prevent entrainment of large animals, and intakes are positioned so that animals may swim by the front of the intake without becoming caught in the system.

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Section 4.0

MARKET DEFINITION

1. Current Markets

Placer resources offshore Oregon contain several minerals of possible economic and strategic importance, including chromite, ilmenite, garnet, zircon, magnetite, gold, and platinum group metals. The markets for these minerals will largely determine the feasibility of placer sands production off the Oregon coast.

Chromite

The primary market for chromite and refined products, including ferrochromium and chromium metal, consists of the metallurgical, refractory, and chemical industries. Chromium is used in the metallurgical industry as an additive with iron and carbon to form ferrochromium alloys. It enhances hardness, creep and impact strengths, and resistance to corrosion, oxidation, wear, and galling. Most of the metallurgical industry output is stainless steel; however, alloy steels, cast irons and nonferrous alloys also contain chromium.

The refractory industry uses chromite to make refractory brick and mortar needed for iron and steel processing, nonferrous alloy refining, glassmaking, and cement production.

Chromium is used by the chemical industry to produce pigments for paints and inks. Other uses of chromium chemicals include leather tanning, metal treatment, and textile dyes, and production of drilling mud.

The United States currently obtains its chromium through imports and recycled material. Imports come from the Republic of South Africa, Turkey, Zimbabwe, and Yugoslavia. Domestic chromite consumption was about 253,000 metric tons in 1988 in the chemical and metallurgical industries, and ferrochromium consumption was 184,000 metric tons.

While the world demand for chromium and ferrochromium remained steady in the 1970s, it is now strong because of increased stainless steel production in the United States, Japan, and Europe. Foreign production of ferrochromium has displaced some domestic production in recent years, resulting in a limited ferrochrome conversion capacity in the United States. Government stockpiling and United Nations sanctions against Southern Rhodesia (now Zimbabwe) in the past have contributed to price fluctuations in recent decades. Chromite prices reached a high of $345 per metric ton in 1976 and are now about $70 per metric ton.

Chromite prices vary depending upon the physical and chemical specifications of the ore. For the metallurgical industry, the chromic oxide content must be over 46% with a Cr:Fe ratio of about 1.5. The refractory industry needs chromic oxide content over 60% and a silica content below 1%. Other associated elements such as alumina also must be low in concentration. The industries consuming chromite concentrate require the above specifications and do not process the concentrate to meet their requirements.

In the year 2000, annual U.S. chromium consumption is estimated to be from 630,000 to 1,000,000 tons, assuming an average growth of 6.5% per year. The probable demand in 1990 is 400,000 tons. Chromium is considered strategic due to its use in steel alloys, especially for aircraft components.

Titanium

The market for the titanium mineral ilmenite is primarily for manufacturing titanium dioxide pigments. Commercial ilmenite concentrates must contain at least 50% TiO_2. Lower values would be difficult to sell but could be beneficiated by smelting to produce a high TiO_2 slag. Since 1985, prices have increased 20% per year to as high as $70 per metric ton in October 1989. TiO_2 slag now costs about $275 per metric ton.

In 1988, two firms in Florida produced ilmenite concentrate from placer sands. Ilmenite and titanium slag were consumed by ten companies in the U.S., with four titanium pigment producers using 99% of the total. The balance was used for welding rod coatings and manufacturing of metals, carbide, and chemicals.

The pigment industry consists of two sub-markets; pigment plants that use a chloride process and those that employ a sulfate process. While sulfate plants need 50% TiO_2 feed, chloride plants reportedly require a slightly higher TiO_2 feed. Current demand is met by Florida production and by imports of natural rutile (TiO_2) from Australia, Republic of South Africa, Canada, and Sierra Leone. Annual U.S. demand for processed ilmenite and slag is about 770,000 short tons.

The United States has two sulfate plants located in the east which require 117,000 short tons of feedstock annually. The 1988 value of U.S. ilmenite and titanium slag consumption was about $155 million. Rutile consumption in 1988 was about $157 million.

Sulfate process technology is losing favor due to waste disposal problems; the U.S. plants use slag rather than sulfateable ilmenite to reduce waste volume.

The feed quality requirements for the sulfate process include low levels of trace elements: 1) chromium sesquioxide (Cr_2O_3) less than 0.1%, 2) vanadium oxide (V_2O_5) less than 0.5%, and 3) the ratio of ferrous oxide to ferric oxide (FeO/Fe_2O_3) should be as high as possible.

Oregon ilmenite may or may not be sulfateable, and if not, would need upgrading by slagging or conversion to synthetic rutile. Both methods remove iron, producing higher TiO_2 content. Titaniferous slag has about 80% TiO_2, while synthetic rutile is about 92%. Oregon ilmenite would probably be too iron-rich and titanium-poor for the chloride process.

Oregon ilmenite could be used by the two existing slagging plants located in the Republic of South Africa and in Quebec, Canada (Mark Whitney, personal communication). After upgrading, the slag may be salable as a commercial product. Further testing would be required to determine which process would be most suitable.

Garnet

Garnet is used primarily as an abrasive, and to a lesser extent as a filtration agent.

The market for garnet in the U.S. was estimated by the U.S. Bureau of Mines to be about 40,850 short tons in 1988. The United States is a net exporter of garnet, although some is imported from Australia.

For new sources of garnet to be profitable, proper grain size as well as low production and transportation costs would be necessary.

Zircon

Zircon is used mainly in foundry sands, refractories, ceramics, abrasives, and as a source of zirconium metal.

The U.S. is a net importer of zircon even though domestic production has increased in recent years. The use of zircon in refractories, ceramics, chemicals, and as a source of hafnium, is expected to increase. The use of zirconium metal in the production of corrosion-resistant alloys and other specialty alloys is also expected to increase. Applications in structural ceramics and glazes for ceramic tile are also boosting demand.

There appears to be an unmet demand for zircon that has continued for two years. The price in October 1989 was $400 to $475 per metric ton.

Magnetite

Magnetite is used as an iron ore; the U.S. is a net importer of this commodity.

There are specialized uses for magnetite such as a flotation medium for coal and as a weighting agent for concrete. However, few statistics are available to substantiate magnetite supply and demand in those applications.

Gold and Platinum Group Metals

Gold is produced from about 435 lode and placer mines in the U.S. The principal uses are in jewelry and arts (58%), industrial (mainly electronic) (35%), and in dentistry (7%). The U.S. has traditionally been a net importer of gold, but has been self-sufficient since 1988. A meaningful net import-export balance is difficult to determine due to the large unrecorded investor stock changes.

Domestic mine production for 1989 will be about 7.4 million ounces. The 1989 average value was $382 per ounce, with an average value in December of $410.

There is no designated strategic stockpile supply of gold, but the U.S. Department of the Treasury maintains stocks of gold for economic purposes.

The platinum group metals (PGM) consist of platinum, palladium, rhodium, ruthenium, iridium, and osmium. Although platinum and palladium are produced in the U.S., the country relies heavily on imports of these and the remaining PGM's. Imports are primarily from the Republic of South Africa, Canada, and the United Kingdom. Uses include automotive catalysts, petroleum refining, jewelry, electronics, and investments.

The price for platinum was $475 per ounce at the end of October 1989.

2. Strategic Stockpile Programs

Current stockpile data are presented below. Trends for stockpiled tonnages, depending on the commodity, may be increasing, decreasing, or steady.

September 30, 1988, stockpile data:

Chromium

Material	Inventory		
metallurgical-grade chromite	1,500,000	metric	tons
chemical-grade chromite	270,000	"	"
refractory-grade chromite	355,000	"	"
high-carbon ferrochromium	487,000	"	"
low carbon ferrochromium	272,000	"	"
ferrochromium-silicon	52,000	"	"
metallurgical-grade chromite (non-stockpile grade)	215,724	"	"
chromium ferroalloys (non-stockpile grade)	18,835	"	"

Ilmenite/Rutile/Titanium

Material	Inventory
ilmenite	none
rutile	39,000 short tons
titanium sponge metal	25,965 " "
nonstockpile-grade sponge metal	10,866 " "

Gold and Platinum Group Metals

Material	Inventory
gold	none
platinum	440,000 oz
palladium	1,262,000 oz
iridium	30,000 oz

December 31, 1988, stockpile data:

Zirconium/Garnet/Magnetite

Material	Inventory
zirconium	none
garnet	none
magnetite	none

3. Expected Marketability

Garnet and magnetite appear to have saturated and stable domestic markets at the present time. However, there is demand for zircon is increasing.

There is currently ample demand for ferrochrome because of high levels of stainless steel production. Consequently, prices will likely continue to rise over the near term

(Mining Magazine, April 1989), then begin to fall when stainless steel production levels out.

Chromite in Oregon's offshore placer sands has Cr:Fe ratios in the range 0.2 to 1.43 as determined by preliminary microprobe analysis. These values are lower than the 1.5:1 ratio required by the metallurgical industry. However, the chemical industry has lower requirements for manufacturing sodium dichromate, chrome plating, tanning, and pigment production.

Since the price of chromite concentrate is determined mainly by its Cr:Fe ratio, further processing will not likely add value (Bruce Lipin, personal communication).

The U.S. is a net importer of ilmenite. The sands would probably be of sufficient quality for slagging plants, which enhances the TiO_2 content. Conversion to synthetic rutile would be another option. Using this procedure, iron would be removed to yield higher TiO_2, to make the ilmenite attractive for marketing.

Any gold recovered from the placer sands would be marketable.

Platinum group metals are primarily imported, mainly for automotive catalysts and jewelry. Current PGM prices are $480 per ounce for platinum and $142 per ounce for palladium. The Bureau of Mines reported (OFR 19-88) that world sources of platinum and rhodium, other than South Africa, would not meet U.S. industrial demand. This demonstrates the need for a domestic source of supply.

Section 5.0

ECONOMIC & STRATEGIC ANALYSIS

ECONOMIC OUTLOOK

The following preliminary economic analysis is based on geologic models of offshore deposits by Kulm and Peterson (1989) and a preliminary economic appraisal prepared by the U.S. Bureau of Mines (Wetzel and Stebbins, 1989). The utility of the geologic model and preliminary economic appraisal is constrained by the lack of adequate sampling of the offshore resources and the limited information available on the precious metal content.

The preliminary economic analysis reveals that the assumed volumes of placer deposits estimated by Kulm and Peterson (this volume) could support more than 20 years of operation. Recoveries of various products would likely range from 79% to 84%. The products of a mining and processing operation would be separate concentrates of chromite, ilmenite, precious metals, zircon, and garnet. At the assumed grades and metal prices, the rate of return would be negative without the recovery of precious metals, i.e., the hypothetical mining and processing operations appear unprofitable under the parameters of the scenario presented by Wetzel and Stebbins (this volume). The offshore deposits would be economically viable at present commodity prices if precious metals such as gold and platinum were present and recoverable in sufficient quantity to increase the rate of return by $3.00 to $3.50 per ton of dredged "ore".

The three resource areas, as modelled by Kulm and Peterson (this volume), contain variable proportions of recoverable products. The potentially valuable heavy minerals in all the resource areas in relative order of abundance are ilmenite (titanium) and magnetite (iron) with lesser quantities of chromite (chromium), garnet and zircon.

Precious metals are likely but sampling data are lacking to confirm their presence or abundance. The southernmost area, off the mouth of the Rogue River, contains a relatively higher proportion of chromite and garnet as compared to the central area, near Cape Blanco, which has a preponderance of ilmenite. The northernmost known area, off the Umpqua River, is predominantly ilmenite, with lesser amounts of garnet and chromite.

The economic outlook for the offshore minerals is dependent on assumed resource grades and commodity prices. The presently assumed resource grades are based on shallow samples that outline potential resource areas, but the sampling data are clearly inadequate to undertake definitive economic appraisals. The prices used in preliminary economic analysis (Wetzel and Stebbins, this volume) are based on recent market conditions. It should be noted that analyses of a few shallow samples revealed values of chromium oxide in chromite in the range of 26.9% - 41.6%, whereas the assumed market value of $54.42 per short ton is for concentrates containing greater than 40% chromium oxide. Similarly the relatively few ilmenite samples analyzed to date contain 41.9% - 47.4% titanium dioxide, whereas the assumed price in the marketplace is based on TiO_2 contents generally greater than 45 percent.

The price trend for titanium minerals has been increasing in recent years. Nominal prices for bulk lots have risen from about $20 U.S. per metric ton in the late 1970s to the range of $70 to $78 in early 1989. However, known resources are large and additional production capacity is under construction. The future price trend cannot be forecast with accuracy.

Chromite prices declined in the early 1980s as world steel production slackened. Some chromium product prices moved up in nominal dollars after mid-1983 although excess production capacity and exchange rate fluctuations probably moderated the price changes as demand rebounded. The outlook for chromite and chromium ferroalloy prices is uncertain and is subject to foreign exchange rates, U.S. policy on stockpiles, and possible dislocation of supplies due to political events in southern Africa.

Nominal zircon prices have increased over the period 1963 to 1989. However, prices in constant dollars have been generally stable except for some volatility in the mid-1970s.

Garnet prices in constant U.S. dollars have remained relatively steady during the past two decades although the relatively small size of the world market and variable quality of various garnet products makes generalization difficult. A substantial increase in production from new sources would likely destabilize prices.

STRATEGIC CONSIDERATIONS

The placer resources offshore Oregon may have a possible future strategic value to the United States. However, the strategic importance of these resources cannot be fully evaluated at this time because of the lack of definitive information on size, grade, and precious metal content. Furthermore, the resource areas, as used for the modelling and preliminary economic analysis, are defined from widely spaced shallow samples. In general, the offshore areas adjacent to Oregon have not been systematically examined for mineral resources.

In terms of strategic value, the possible mineral products can be ranked as follows in order of decreasing importance:

chromite, platinum group metals, zircon, and ilmenite. Gold may be of economic value but of lesser strategic value. Chromite and its refined products are the only current sources of chromium which is of utmost strategic importance to the United States. Chromium is an important and necessary component of alloy steels which have multiple industrial and defense applications. The strategic vulnerability is heightened due to the nation's current dependence on chromium raw material sources in southern Africa, Turkey, and Yugoslavia. There is no current mine production of chromite in the United States.

Platinum and associated metals such as palladium are possibly contained in the offshore deposits but the concentrations are not known. The nation is dependent for new mine supplies on southern Africa, Canada and a single source in the United States.

The mineral zircon is used as a raw material for a variety of commercial applications including a source of zirconium for alloys for nuclear applications. Imports from Australia and the Republic of South Africa furnish most of the current domestic supply of zircon.

Ilmenite is produced in Florida, Canada, Australia and the Republic of South Africa. The principal application is in the manufacture of pigments for paints. In the United States over 99% of the ilmenite consumed is used for pigments.

The United States produces significant and increasing quantities of gold and will likely be self-sufficient in the years ahead. Certain electronic applications could be considered strategic.

Magnetite is used worldwide as a source of iron. However, substantial domestic resources are available and major iron ore imports are obtained from Canada and Brazil.

Garnet is used principally for industrial applications, including abrasives and filtration, where substitutes are available. Domestic producers in Idaho, Maine, and New York have been the dominant suppliers to U.S. markets. Garnet has little, if any, strategic importance.

Section 6.0

RECOMMENDATIONS

The Task Force recommends limited collection of additional data on Oregon marine placer minerals and associated living resources.

Several subjects will have to be examined when considering potential development of placer deposits offshore southern Oregon. These include: a marketing analysis based upon resource description; questions concerning at-sea separation of heavy minerals; the existing physical and biological environment; and a mining impact analysis. In addition, a socio-economic analysis must be completed. These data gaps can be addressed in a stepwise fashion in the future.

Additional information is needed on placer mineral concentration and quality with depth in the sand section. Sampling to date is based upon box and piston cores with seabed penetrations of 40 centimeters and 1.0 meter, respectively. Sand thickness on the shelf ranges from zero in rocky areas to 15 meters depth north of Cape Blanco and to greater than 33 meters depth northwest of the mouth of the Rogue River - far thicker than the depth of current samples.

The onshore relict placer mineral deposits in marine terraces (e.g., Seven Devils and Pioneer mines) show significantly increased percentages of heavy minerals with depth. Since the offshore resources are believed to be an analog of these upland terrace deposits, it is reasonable to expect higher percentages of heavy minerals with depth offshore as well.

Drill holes in the onshore placer terraces have penetrated as much as 25 meters of sand with up to 12 meters of "chromiferous sand" at the bottom of the sand section (Griggs, 1945). Typical thicknesses of the Seven Devils Terrace are 7 meters with thicker areas up to 15 meters, while the Pioneer

Terrace is thinner at 4 meters. Both deposits have basal zones of elevated heavy mineral concentrations (Peterson, et al., 1987) and have a history of mining. While heavy mineral concentrations are widely variable, samples from mined areas exhibit the following averaged compositions by weight: chromite 32.8% (range 18.4 to 48.8%); ilmenite, 6.0% (range 2.8 to 8.3%); garnet 23.1% (range 10.2 to 28.8%); zircon 2.2% (range 1.5 to 3.0%); and rutile .3% (range .1 to .5%) (Griggs, 1945). Gold and platinum group metals are also present.

In conclusion, we recommend:

1) A drill sampling program for the Cape Blanco and Rogue River resource areas to examine the lateral extent and vertical dimension of placer mineral resource. By concentrating on one or two resource areas, a more focused program can be carried out. The Cape Blanco resource area has a good combination of features which lend themselves to a possible economic resource: a good Cr:Fe ratio in chromite compared to other locations, some gold likely, and close proximity to the Port of Coos Bay. The depositional environment represents a relict headland regime. The Rogue River resource area is likely to be relatively high in chromite and gold, and represents a river plume regime.

Cape Blanco would be the first priority for drill sampling, with the Rogue River resource as a second priority. The Umpqua resource area would be of lower priority at this time but might warrant exploration if results were favorable at the Cape Blanco and Rogue River sites.

An accepted method of sampling at depth in a shallow marine sand deposit is by vibracore drilling. Locations for drill stations would be derived from results of previous studies or by seismic gravity and magnetic surveys done as a part of a future cruise.

2) A continuing investigation of the existing environment to be undertaken concurrently with the mineral sampling program. Sampling should be designed to provide information on the physical attributes and biological inhabitants of the benthic and pelagic habitats. The stations at sea occupied for mineral sampling should be used for biological sampling. Benthos could be sampled with a dredge or corer. Infauna could also be sampled by subsets of the mineral samples. Demersal fish and invertebrates could be sampled by otter or beam trawl. Observations on seabird and marine mammal populations should be conducted in conjunction with bottom sampling if ship space is available.

3) In addition to the geologic and biologic studies to be performed, an analysis of the socio-economic effects of offshore placer mining will be needed if initial studies indicate economically recoverable minerals exist. Such an analysis should be based upon the scale of mining operation assumed in the U.S. Bureau of Mines report.

Appendix

RESPONSE TO COMMENTS

General

Comment: All Task Force business should be conducted in public, at well publicized meetings and with public participation.

Response: The Oregon Placer Minerals Task Force was established as a public process. The public will continue to be informed of, welcome at and have opportunity to comment in all future task force meetings.

Comment: One commenter asked who would be responsible if environmental damage occurred during lease development.

Response: The responsibility for damages resulting from a lessee's actions would ultimately fall upon the lessee. The type of environmental damage would dictate the appropriate remedies to be taken by the lessee. It is important to note that certain federal and state agencies have responsibilities related to a lessee's activities. In federal waters on the Outer Continental Shelf (OCS), the Director of the Department of the Interior's Minerals Management Service is responsible for the regulation of activities to assure that all operations conducted under a lease or right of use and easement are conducted in a manner that protects the environment and promotes orderly development of OCS mineral resources. The activities are to be designed to prevent serious harm or damage to, or waste of, any natural resource, any life, property, or the marine, coastal, or human environment. The Oregon Division of State Lands is responsible for administering mineral leases in offshore waters under state jurisdiction.

Comment: Concern was expressed by an individual that a placer mining operation would be of little benefit to the economics of communities along the southern Oregon coast - much less the Oregon economy in general.

Response: A placer mining operation along the southern Oregon coast would generate employment, tax revenues, and royalty and other income. Under present laws, the royalty income would accrue to the Common School Fund of the State of Oregon. Inasmuch as the magnitude of any of these revenue streams is contingent on the size of an operation, and given that no company has indicated a definite interest in, or proposed an operation to mine the placer sands along the southern Oregon coast, estimating the economic impact such an endeavor would have on the state of Oregon or local economies would be difficult. As a part of the process to evaluate any proposal to mine the placer deposits along the Oregon coast, an economic and fiscal analysis would be a valuable and appropriate part of the overall environmental impact analysis.

Comment: Placer deposits water depth ranges from 56 feet near shore to 295 feet seaward. Fifty-six feet happens to be prime sea urchin, sea cucumber, etc. depths.

Response: Harvest of sea urchins occurs primarily in water depths between 40 and 60 feet. The fishery occurs in rocky areas where placer deposits would not be extracted, thus dredging for placer deposits would not likely interfere with sea urchin fishing. Sea urchin populations on reefs could be adversely impacted if dredging occurred near enough that increased turbidity or siltation affected the reef.

Comment: Two hundred fifty dredging days per year would in our opinion ruin the Rogue salmon fishery.

Response: The salmon and steelhead runs on the Rogue River are some of the most important on the West Coast. Environmental changes caused by placer mining near the mouth of the Rogue may cause impacts for salmonids entering the river and should be evaluated. A dredge anchored in traditional salmon fishing areas could disrupt recreational and commercial fisheries; the extent of disruption would depend on the exact location of the anchored dredge.

Geology

Comment: A commenter stated that the resource report by Kulm and Peterson does not show a rationale for benefits to the local economy of Gold Beach, Oregon.

Response: The Task Force did not expect nor request that the resource report include a socio-economic analysis and identification of economic effects. The objective of the Kulm and Peterson report was to analyze currently available resource data to help the Task Force in its decision on whether or not to recommend an economic feasibility study. In the event a future decision is made to offer the minerals offshore Oregon for lease, a socio-economic assessment will be conducted.

Comment: Have the magnetic data been modelled? Why only magnetics? What about seismic?; Side-scan?

Response: Comment addressed in report.

Comment: Were only surficial samples taken?

Response: The report listed sampling equipment as Smith-McIntyre grab, Shipek sampler, and box-corer. The maximum depth of sampling was 40 cm.

Comment: How can these data be used for an economic model if there is not third dimension?

Response: The recommended 1990 work plan will present a program to sample the third dimension in the sediments.

Comment: How were the figures arrived at in ppb? Were the samples panned? Has a size analysis been completed on the gold?

Response: The figures were derived by analysis of analytical portions pre-concentrated from approximately 1000 g samples of sediment by procedures described in Figure 2 of Clifton, Phillips and Hubert, (Marine Sediment Sample Preparation for Analysis for Low Concentrations of Detrital Gold, U.S.G.S. Circular 545, 1967). These procedures, which do not include panning, are designed to concentrate all of the gold present in the original sample into the portions that are analyzed by a combination of wet chemical and atomic absorption techniques (with a minimum level of section of 0.1 to 0.2 ppm gold). The values thus obtained were converted to weight and the combined weight of gold in all the portions was then divided by the weight of the original sample, yielding values in the ppb range.

Size data for gold on the Oregon shelf are presented in U.S.G.S. Circulars 545 and 587 (1968) and a detailed size analysis is given for gold in an 80-pound sample of sand from a black-sand beach a short distance north of the mouth of the Rogue River in U.S.G.S. Professional Paper 625-C (Sample Size and Meaningful Gold Analysis, 1969). These studies indicate that the size distribution of gold in the shelf sand resembles that of gold on the present beaches; the gold ranges in size from about 0.040 to 0.250 mm in diameter and its maximum significant diameter is slightly more than 0.250 mm.

Comment: Does the Kulm and Peterson report say the processes which formed the on-shore placers are the same processes operating in the offshore today?

Response: The report uses this as an underlying assumption in developing the heavy mineral and magnetics models. A more thorough discussion of this relationship is found in the referenced papers Kulm (1988) and Peterson, et al. (1988).

Comment: The report by Kulm and Peterson is a good one in light of the limited information available.

Response: No response.

Comment: The title of the report could more accurately represent its contents if it were "An assessment of the composition and volumes of placer deposits off Cape Blanco, Rogue River and Umpqua River, Oregon."

Response: The existing title was adequate and the Task Force did not think the authors needed to make a change.

Comment: The presentation of a summary at the beginning of the report is very useful. This initiative should be carried one step further in refining it as a technical abstract of the report.

Response: The summary serves the purpose of a technical abstract, and does not need to be rewritten or relabeled.

Comment: Concern was expressed by an individual that the results of the magnetic model assessment of the offshore placer mineral deposits should be presented in the report and indicated to represent a lower bound of placer mineral content.

Response: Because these data are contained in other recently released reports by Kulm and Peterson, their inclusion in this report was not believed to be necessary.

Comment: The results of the magnetic model assessment are introduced as representing a minimum size of place deposits, yet are all but withdrawn as unreliable. The analysis suggested that mineral tonnages estimated with the magnetic model are 1/7 to 1/10 of those assessed using the alternate heavy minerals model. The estimates of the magnetic model should be provided in metric tons, along with an appropriate disclaimer as to their reliability, rather than be withheld. They provide a rough estimate of the lower bound of the placers' mineral content and are useful in this regard.

Response: Comment addressed in report.

Comment: The suggestion to conduct high resolution magnetic surveying and deep vibracoring would increase the quality of the information on placer deposits but is not supported by the economic appraisal of the mining operations (Wetzel and Stebbins, 1989). The phrase "are required to establish (mineral deposits)" should be reworded as "would improve estimates of." An appendix estimating the range of costs for various levels of surveying and/or coring should be developed and attached in order to provide readers some insight into how much it will cost to "assess" economic potentials of mining these deposits.

Response: No response.

Comment: A methods section should be prepared and inserted to describe in some detail the two alternate analytical models, their requisite data and their limitations. The brief section, "Placer Models," is a good start on a methods section but lacks the detail needed by the technical reader unfamiliar with these models.

Response: Comment addressed in report.

Comment: The section on heavy metal concentrations should list, once again, these minerals.

Response: Comment addressed in report.

Comment: The section on gold concentration should be labelled correctly.

Response: Comment addressed in report.

Comment: The phrase "10-20% in" is superfluous to a discussion of deposit depths and has been previously discussed in a discussion of mineral contents.

Response: No response.

Comment: The discussion of the magnetic model undervalues the utility of its assessment as a lower bound of placer mineral deposits. A ten percent difference between lower and upper bounds for estimates of 1-10 million metric tons for individual minerals does not seem unreasonable for a preliminary assessment.

Response: No response.

Comment: The observation that "the large total surface area represented by the heavy metals halos in the surface sediment probably over-estimates the total volume of the placers" is an important reference to the reliability of the heavy metals model. It should be included with the estimates of the heavy mineral model provided in the abstract, just as disclaimers for the magnetic model have been provided.

Response: Comment addressed in report.

Comment: In light of the treatment of the results and uncertainty of each model's assessment, the report seemed biased in favor or maximum estimates of the placer deposits. The report should be modified to provide a more technically objective presentation.

Response: No response.

Economics

Comment: Why a tailing suction hopper dredge? What are the ambient sea conditions? What will the dredge availability be with the rough sea conditions? Do they really think spirals will work even with swell compensation equipment in 25-40 ft. seas?

Response: The trailing-suction hopper dredge was selected primarily based on portability. Frequency of storm events, wave heights and open ocean conditions require a dredge that can be moved onsite or offsite relatively quickly and on short notice. Until a deposit is located and the specifics on water column depth and deposit geometry are known, there is no justification for attempting to speculate any further on what type of mining system will be employed. It would appear obvious that operations would not take place in 25 to 40 ft. seas.

Comment: It seems very complex for a gravity operation process on board. Wouldn't it be better to process the material onshore, perhaps at least the total heavy mineral fraction?

Response: The only onboard processing is spiral concentration. All separation of the heavy mineral fraction is done onshore.

Comment: Capital costs are unbelievable? They need to figure out more acceptable vessel economics.

Response: It was suggested by Mr. Rusanowski that capital costs of more than $45 million were high and a figure of about $20 million would be more realistic. It should be noted that over $20 million of the estimated capital is for research and development, engineering, and contingencies. Large R & D and contingencies amounts were included because it is believed that the deep water and typically rough seas would require more than the usual research and system modification prior to implementation. If in fact, existing technology can be successfully applied, then these cost categories can be reduced. Note that at present, base-case resources do not contain sufficient mineral values to exceed operating costs (without precious metal values) and thus, reduced capital costs would not enhance economics.

Comment: The report by Wetzel and Stebbins is a good study for a preliminary assessment. It integrates information on probable deposit sizes and compositions with transportation and processing projections and market information. The conclusion that "grades (of mineral deposits) from surface samples are too low to yield profitable operations without significant recovery of precious metals" is supported by the analysis.

Response: No response.

Comment: An abstract of the methods, results and conclusions would improve the information service of the report.

Response: Comment addressed in report.

Comment: The basis for estimating the mass of the mineral deposits should be provided along with the brief discussion of the resource models in a methods section.

Response: The release of this report includes the Kulm and Peterson report in the same publication. The Kulm and Peterson portion includes the basis for estimates and the resource models, they were not included in the Bureau of Mines report.

Comment: The uncertainty of the mineral content of the placer deposits is noted. Tables projecting the mineral contents of the placer deposits should include ranges which reflect some of this uncertainty rather than simple point estimates.

Response: The base-case models provided by OSU were determined by surface samples and are assumed to represent minimum mineral values. Because insufficient data exists to adequately estimate mineral content, the primary goal of this study was to estimate what mineral values would be required to constitute a viable mineral deposit offshore. As a result, 36 individual cashflow analyses were performed to make this determination. Every analysis indicated that precious metals must be recovered. Resource data on those metals does not yet exist. Thus, it would be premature to investigate other options until additional exploration is conducted.

Comment: The order or presentation of minerals should be the same in both the text and the tables. The convention may be either alphabetical or according to relative masses.

Response: Point well taken. Future investigations concerning Oregon's offshore placers will incorporate this suggestion.

Comment: It appears that the U.S. is a net exporter of ilmenite. This should be pointed out. Information on the costs of transporting ilmenite to the east coast would be appropriate.

Response: See the Market Definition section.

Comment: Information on the production, utilization, transportation (to the Great Lakes) and importation of magnetite is required in the discussion.

Response: Should reserves be defined offshore, a detailed market study should be included in any future studies. Such a study is not warranted at this time.

Comment: The discussion of zircon should provide transportation costs to the east coast.

Response: Zircon would be sold locally.

Comment: The discussion of dredging should provide details on the scale of the trenches and the probable proximity of parallel trenches.

Response: Extremely premature. A deposit with known dimensions would be required before this level of detail would be warranted.

Comment: It may be that the projected recovery of 61 tons of mineral concentrate for every 1,200 tons of sediment dredges is in error. The percentages of Table 1 sum to 4.63%; multiplying this times 1,200 tons at a recovery rate of 85% yields a concentrate value of 47 tons. If more details were provided on the calculation, the confusion would be avoided.

Response: Material balances are provided. Note that what you have calculated is a 100 percent pure heavy mineral concentrate which is not achievable. The additional material contained in the spiral concentrate would be predominantly quartz. Spiral calculations assume a concentrate containing approximately 80 percent heavy minerals.

Comment: The significance of the byproduct storage stockpile of magnetite and other minerals should be established. Is this waste requiring disposal or a valuable byproduct awaiting transshipment? How large will the stockpile be? What precautions and facilities are necessary to its storage? What are the conditions for its removal?

Response: Although these are all valid concerns, they would be appropriately addressed in a final company feasibility study, final EIS or company operating plan. Without measured reserves, not yet identified, these concerns cannot be addressed properly.

Comment: The discussion of beneficiations should detail the recovery rates for each mineral. A rough figure of 85% is provided; details should be provided prior to a discussion of beneficiation.

Response: All recovery rates are defined throughout the material balances.

Comment: The cost and revenue estimations in the discussions provide for scenarios at two times and four times the measured composition of surface mineral samples. It might be appropriate to provide for a "downside" scenario of one half of the baseline estimate as well for each of the minerals.

Response: Economic analyses of all models, even at two and four times the measured composition, represent "downside" scenarios. There is no point in investigating the potential for lower mineral values when the deposits already modeled fail to yield positive economics without precious metal values.

Comment: Ranges for mineral content, recovery rates and metal prices would improve the economic analysis.

Response: All analyses conducted to date demonstrate the need to determine a precious metal content. Until offshore placers are explored and data on precious metal content secured, there is no need for more detailed investigations of placer economics.

Biology

Comment: Concern was expressed by an individual that placer mineral mining activities would disturb kelp beds off the southern Oregon coast.

Response: Kelps require a solid substrate on which to grow. Consequently, sandy or unconsolidated sediments do not provide sufficiently stable conditions for kelp to secure to. Because placer mineral deposits are believed to occur typically in unconsolidated or semi-consolidated sands, it is unlikely that mining activities would directly disturb kelp plants. It is possible, however, that turbidity plumes generated by marine mineral mining operations could impact on kelp growth by reducing the amount of light available to kelp plants - thus limiting the rate of growth of the kelp. The specific magnitude of this impact would, among other factors, be contingent on the maturity of the plant and its proximity to the surface of the sea.

Comment: The areal extent and size of the deposits should be added to the text; for example, the Cape Blanco deposit covers an area of 48 Km^2.

Response: Comment addressed in report.

Comment: The conclusion of the need for modelling is not supported by the paragraph. In all cases water depths exceed 18 m.

Response: Comment addressed in report.

Comment: Burial has several effects on benthos related both to kinds of organisms and depth of burial. Information on this topic should be expanded. Major burial effects are usually absent in areas of less than 10 cm deposition.

Response: Comment addressed in report.

Comment: Need to document which species are slow to recruit to a new area. Potential impact is unsubstantiated. Later information presented conflicts with this paragraph.

Response: Comment addressed in report.

Comment: If a suction system is used then a turbidity plume will not occur as material is collected from the seafloor.

Based on past work with power plants and upwelling studies one would expect to get enhancement of phytoplankton.

Response: The phytoplankton response to such a plume in terms of net production is not possible to predict. The upwelling of nutrients from the bottom of the water column or the sediments would tend to stimulate primary production, while turbidity would tend to inhibit. But for "enhancement" to be beneficial, the stimulation of primary production would need apply largely to species of phytoplankton which tend to support valued portions of the nearshore food web.

Comment: Turbidity section lacks quantitative data to assess impacts potential and actual risks. Reference to vertical migration impacts are usually restricted to waters much deeper than occurs in these locations. Is there something unique to southern Oregon with respect to vertical migrations?

Response: The document is a literature review, not an environmental assessment, thus there is no quantitative assessment of turbidity impacts. There is nothing unique to the southern Oregon coast with respect to vertical migrations of the biota. Vertical migration may or may not prove to be a factor in an environmental assessment.

Comment: Perennial type turbidity effects need an areal component in order to assess potential risk or relevance. Need to relate potential area of impact to the real world. Long term effects can best be assessed by monitoring an actual mining project.

Reintroduction of substances is a problem with harbor dredging etc. The mechanism of placer formation is inconsistent with this kind of impact concern - need to place in perspective.

Response: An areal component should be addressed when the scale of the potential operation is known. The Oregon continental shelf is admittedly large compared to the scale of known dredging operations. Reintroduction of substances is generally related to the suspension of anoxic sediments. It is not clear how the mechanism of placer formation would affect the potential for reintroduction of chemical species other than to concentrate minerals containing heavy/trace metals such as chromium, iron, lead and mercury. Reintroduction of substances was not identified as a problem in the DOMES work, for example.

Comment: Nutrient discussion is minimal. Many plants are known to accumulate nutrients during upwelling events for use later when nutrients are scarce.

Response: The nutrient section is brief, as nutrient effects are not anticipated to be a constraining environmental factor for dredging on the Oregon continental shelf. How nutrient reservoirs or other sophisticated reactions to ambient nutrient concentrations might modify the phytoplankton response to nutrient loading in an upwelling system is beyond the scope of this literature review.

Comment: Release of trace metals is not observed in Nome operation.

Disturbances from mining activities are distance related. No information is included, yet standard buffers of 1 mile and less are used to protect biological resources. Again, need to provide a perspective for reader as to actual relevance of this kind of impact. This kind of impact is usually resolved by establishing the appropriate buffer zone.

Response: The Oregon Ocean Resources Management Task Force is addressing the appropriateness of buffer zones and "special management areas" as a means to protect sensitive marine environments from the impacts of various activities. The Oregon Ocean Resources Management Task Force clearly recognizes not only the limitations and advantages of buffer zones, but also is fully aware that the size of a buffer zone must be tailored to the specific need for, and degree of protection required.

Comment: Several comments were concerned with level of detail of environmental assessment in the literature review on environmental impacts.

Response: The document is a preliminary literature review whose purpose is to identify potential environmental concerns. Future environmental documents would, in the case of possible leasing actually analyze potential impacts.

Comment: There is more current information available on topic. Impact is not substantiated with any data. Many dredge projects are bothered by fish feeding close to area being disturbed.

Response: No response.

Comment: Where are sea urchin beds in relation to mining area?

Response: Sea urchin beds are located on rocky reefs. Once potential placer mining areas are located, we would be able to determine their proximity to urchin beds.

Comment: Where and in what depth of water does the groundfish trawl fishery occur. Need perspective for reader.

Response: The groundfish trawl fishery is comprised of several different types of fishing. Some groundfish activity occurs in water depths of 200-300 feet, most occurs in water depths of 600-3000 feet.

Comment: Why will dredging produce a permanent loss of spawning habitat? No evidence has been presented for spawning or loss.

There is lots of data available on turbidity effects and salmonids. Adult fish are tolerant of very high turbidity levels; so are juveniles. Problems are most common with eggs and fry.

Response: Comment addressed in report.

Comment: Need to define "near". Why can't this be handled with buffer zones?

Response: Comment addressed in report.

Comment: Where are reefs in relation to deposits? Distance is important to assess potential concern for this kind of impact.

Response: We do not know the exact location of all reefs near placer deposits. This would be one type of information needed to evaluate a mining proposal.

Comment: Data in table was compiled from side scan sonar records, not 0.1 m^2 grab samples.

R-6 1988 sand/fine gravel should read 11 not 23.

1987 sand/gravel should read 30 not 11.

Response: Comments addressed in report.

Comment: The report by Ross was well researched and well written. It compiles and reports information available in the literature. The report's conclusions are limited by the absence of detailed, site-specific information and the application of a conservative, scientific treatment of the general information which is available in the literature. The assessment of environmental impacts is therefore broad and vague, highlighting the uncertainty surrounding the mining's impacts rather than providing projections of these impacts.

Response: The level of treatment in the report is appropriate for a literature review. A possible future environmental assessment would make use of site-specific data and would project impacts.

Comment: An abstract of the methods, results and conclusions would improve the information service of the report.

Response: Since the report is a literature review, these sections are not deemed necessary by the task force.

Comment: A figure should be provided which depicts the deposits relative to the port of Port Orford, Gold Beach and Brookings. It would also be useful to depict important fishing reefs, holes and rocky outcroppings, sea lion haul-outs, and seabird rookeries.

Response: Locality maps are shown in section A, Figures 1 and 4. Compilation of data on fishery habitats, sea lion haul-outs and seabird colonies is beyond the scope of the literature review, and would be included in a possible future environmental assessment.

Comment: Tabulated reports of fishery landings should include commercial and recreational bottom fish and commercial shrimp as well as salmon and crab. In addition, economic information on price per pound and value of a recreational fishing day would be useful. This information would be important in assessing the potential economic consequences of environmental impacts.

Response: No response.

Comment: The list of important minerals in the placer deposits should be completed to include garnet and magnetite. Only chromite is of "strategic" importance and the reference to strategic minerals should indicate this.

Response: Comment addressed in report.

Comment: The heavy mineral range of 10-56% weight composition of placer deposits does not appear to agree with Kulm and Peterson (1989) and Wetzel and Stebbins (1989); it overestimates the lower limit. It is useful to have consistency across the reports so as to avoid confusing readers or misleading those who read only one of the reports. The overview of the placer deposits should therefore be based on Kulm and Peterson (1989) rather than Kulm (1988).

Response: Comment addressed in report.

Comment: It is appropriate to provide as much specific detail on the dredging activity as possible. Information in Wetzel and Stebbins (1989) suggests that the description of dredging on page 4 and the depictation understate the actual impact on the bottom. If dredging will seek to dig up the ocean bottom to a depth of 5 meters in something approaching a continuous excavation, then the text and figures should reflect this.

Response: Comment addressed in report.

Comment: The term "may" (backfill) is probably more accurate than "will".

Response: Comment addressed in report.

Comment: The description of the actual physical characteristics and impacts of dredge trenches across the bottom should be as precise as possible. Information should be obtained which provides more insight into the "series of shallow (dredge) tracts".

Response: Comment addressed in report.

Comment: The discussion of the mining and restoring effects of the "high energy nearshore environment" should involve specific information on the depth dependency of these processes.

Response: A possible future environmental assessment would contain data on sediment transport rates over the Oregon continental shelf.

Comment: The phrase "as well as from direct impacts" is appropriate in general discussion of impacts.

Response: Comment addressed in report.

Comment: The use of terms such as "temporary reduction," "short-term condition," and "local ecosystem" tend to minimize environmental impacts which are dependent upon the specific dredge operation and marine environment. This dependence is explained in the report by Owen (1977). Without the benefit of field work and analytical modelling, it seems inappropriate to introduce an assessment of the biological impacts of seabed dredging in terms which may be used to summarize the study unless specific and quantitative information is available to support such characterization.

Response: Comment addressed in report.

Comment: The "Destruction of Organisms" section is brief and understatedly qualitative. Have any scientific studies been conducted on this issue?

Response: Yes, the environmental effects of bottom (benthic) disturbance have been the subject of numerous scientific studies. The literature includes four major areas: (1) Deep Ocean Mining Environmental Studies (DOMES); (2) U.S. Army Corps of Engineers dredging environmental studies; (3) sand and gravel-related studies in the North Sea by the International Council for the Exploration of the Sea; and (4) marine disposal of land-derived mine tailings, largely from British Columbia, Canada. Much of this information is in the "gray" literature of government and private sector technical reports instead of refereed ("white") publications.

Comment: The reference to concern over loss of habitat with sand and gravel mining in the North Sea is useful. Is there any quantitative information available on the issue from ICES (1975)?

Response: Yes, there is quantitative environmental impact information from sand and gravel mining in the North Sea.

Comment: It does not appear that an analysis was conducted to predict the nature and size of the turbidity plume. Nor does it not appear that any modeling analyses were conducted in assessing the impacts of turbidity plumes on the pelagic (or benthic) environment. It is conjectural, therefore, to discuss the impacts of the turbidity plume and should be so noted.

Response: The entire report consists of conjectural discussions of environmental issues concerning potential placer mining in the Oregon continental shelf. It is a literature review, not an environmental assessment, and has been retitled to more clearly reflect this difference in the level of treatment.

Comment: The potential for deoxygenation and the production of hydrogen sulfide is an interesting issue. Is there any quantitative assessment of potential impacts to pelagic (and benthic) organisms?

Response: No such data exist for the Oregon continental shelf.

Comment: The potential nest mortality to seabirds due to disturbances cited is an interesting issue. Is there any quantitative assessment of the potential impacts to seabird colonies?

Response: Studies of this type have been conducted through the Minerals Management Service, Environmental Studies Program and the National Oceanic and Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program, both related to OCS oil and gas development activities. No data of this type exist for the Oregon coast.

Comment: The discussion of potential impacts from spills and major industrial accidents at sea deserves a more thorough discussion than four lines. Is there any quantitative assessment of spills in existing offshore mining operations?

Response: The report is a literature review, not an environmental assessment. The Draft Environmental Impact Statement for the Alaska Outer Continental Shelf, OCS Mining Program, Norton Sound Lease Sale (1989) contains a brief quantitative assessment of effects from accidental emissions.

Comment: The discussion of recreational fisheries on page 30 should include use of the waters above and adjacent to the placer deposits as favorite fishing "holes." This information might be obtained from ODFW or local fisheries associations.

Response: This information would be included in a possible future environmental assessment.

Comment: A more detailed description of: (1) the location of seabird rookeries; (2) the migration corridor of grey whales and Stellar sea lions; and (3) the location of sea lion haul-out reefs, relative to the placer deposits and shipping lanes are appropriate.

Response: These descriptions would be developed for a possible future environmental assessment after the deposits and shipping lanes have been identified.

Comment: The recommendations for study and monitoring from Project NOMES are useful. These recommendations reflect the state of environmental monitoring in the early 1970's, over fifteen years ago. It is very likely that this reference understates the extent of monitoring which would be required of placer mining operations in the 1990's--a fact which should be reflected in the discussion.

Response: The report is a literature review. It is quite possible that current monitoring requirements would be more extensive than those suggested by the NOMES study in 1973.

Comment: The limits to applying generalities from dredging and marine disposal by the Corps of Engineers is clearly stated. "It is unknown what effect a long-term, continuous mining operation will have on the biological communities within the affected area, and whether or not results from transient dumping operations can be extrapolated to the proposed scenario on the south Oregon coast." This uncertainty -- referenced here and elsewhere in the report -- should be emphasized in the discussion of research needs.

Response: The research needs section states: "However, most studies to date have dealt with the effects of short-term and transient dredging and their results may not be applicable to a long-term, continuous operation.