THE GOVERNMENT OF COOK ISLANDS

COOK ISLANDS

DEEP-SEA NODULE MINING PREFEASIBILITY STUDY

EXECUTIVE SUMMARY

July 1996

Job No. 23134-000

Bechtel Corporation

Mining & Metals

San Francisco, CA

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MAILING ADDRESS: Room 309, SA-16, Washington, D.C. 20523-1602
DELIVERY ADDRESS: 1621 North Kent Street, Suite 309, Arlington, VA 22209
• Phone (703) 875-4357 • FAX (703) 875-4009

BECHTEL
50 Beale Street
San Francisco, CA 94105-1895
Mailing address: P.O.Box 193965
San Francisco, CA 94119-3965

November 25, 1996

Professor David Cronan
Department of Geology
Imperial College
Prince Consort Road
London, SW7
United Kingdom

Dear Professor Cronan,

Dr. James Hein of the U.S. Geological Survey requested me to send you a copy of the Executive Summary of our report on the Cook Islands Deep Sea Nodule Mining study. I am pleased with your interest in this innovative project and enclose the requested copy for your use. Should you have further questions, please do not hesitate to contact me. My phone number is 1-415-768-6862, fax number is 1-415-768-3398 and my e-mail address is HBHATTYA@BECHTEL.COM

With best regards,

Harry B. Hattyar

Harry B. Hattyar
Study Manager

Bechtel Corporation

The U.S. Trade and Development Agency

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This study is intended for the sole use of the Cook Islands Government (the Client) in support of their consideration of whether and how to proceed with a deep-sea nodule mining project in the Cook Islands Exclusive Economic Zone (the Project). This Study is not intended to be or to provide the basis for any credit or other investment evaluation and should not be construed or otherwise considered as a recommendation that any recipient of this Study participate in the financing for the Project.

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EXECUTIVE SUMMARY

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INTRODUCTION

The purpose of this prefeasibility study is to examine various aspects of exploiting the deep-sea polymetallic nodule resources in the Cook Islands Exclusive Economic Zone. The study deals with the following subjects:

- Harvesting of nodules by the use of modern bottom trawling technology
- Handling and transportation of the nodules to a processing plant
- Examination of various processes of extracting valuable metals from the nodules
- Refining intermediate process products to pure metals
- Development of capital and operating cost estimates for the entire operation
- Development of a financial model for the project and performing a financial analysis of the project economics, including sensitivity studies
- Generating a plan for exploration, sample collection, equipment and process testing as necessary for the performance of basic engineering design and the updating of the capital and operating cost estimate for the project
- Development of a schedule for the engineering, procurement, construction and preoperational testing of all facilities

This study does not deal with the sale of the product metals, nor does it attempt to forecast future metal market trends.

PROJECT SCOPE

The Cook Islands Deep-Sea Nodule Mining Project is a grass-roots project for exploiting the manganese nodule deposits in the territorial waters of the Cook Islands. It can be divided into four phases, as follows:

- Phase I consists of the present prefeasibility study.
- Phase II encompasses exploration work at the target harvesting site, recovery of bulk sample of the nodules, bench testing and pilot-plant testing of the smelting and refining processes, plant site selection, designing of the trawl, outfitting a trawler and conducting test harvesting, and establishing the environmental baseline conditions in the harvest area.
- Phase III is the engineering, procurement and construction of the project and preoperational testing of the facilities.
- Phase IV designates full-scale production.

Physically, the project extends into several geographic areas as follows:

- Harvesting will take place in the Aitutaki Passage near latitude 16°S and longitude 160°W. Four dedicated trawlers will be used for harvesting. Each trawler will transfer the nodules into a bulk carrier vessel of about 30,000 tons capacity for transportation to the process plant. There will be three transport vessels employed by the project. One will be stationed at the harvesting site to receive the nodules from the trawlers, while the other two will be sailing to or from the processing plant.
- For the purpose of this study only, the processing plant is assumed to be located at Marsden Point near Whangarei, New Zealand. Existing harbor facilities will be used to unload the transport ships. The nodules will be stored at the plant site and reclaimed for smelting. The smelter will utilize coal for the reducing process and elementary sulfur for converting cobalt, nickel and copper to a sulfide matte. The granulated matte will be processed in a hydrometallurgical refinery adjacent to the smelter. The residue of the smelting operation (slag) will be stored at the plant.

BACKGROUND

The existence of manganese nodules on the ocean floor was discovered about 120 years ago; however, detailed and systematic study of their location, abundance and chemical composition did not commence until the late 1950s. Two developments spurred high levels of activities during the next decade or so. One was the discovery of the existence in the nodules of significant quantities of strategic metals, such as nickel, cobalt and copper, besides the basic iron and manganese. The other was the political instability in prime strategic metal-producing regions, such as the Shaba Province of Zaire.

The result of these two factors was the emergence of numerous exploration and development projects financed by various governments and private organizations. The primary target metals of these efforts were nickel and cobalt. The harvesting of the nodules was proposed to be by means of technologically complex mechanical or hydraulic systems that involved deep-sea submersible robot machinery and plants or similarly complicated devices.

Most of the manganese nodule resources lie in international waters and come under the jurisdiction of the United Nations. The prospect of having to deal with the U.N., the high cost of the harvesting systems, the inherent risks of developing a pioneering technology, and the long prospective payback on investment discouraged most private investors and many governments from pursuing the commercial exploitation of manganese nodules.

During the years 1974 through 1990, the government of the Cook Islands permitted exploratory expeditions by several nations and organizations in the Cook Islands Exclusive Economic Zone, which covers an area of approximately 2.5 million km^2. Within this area lie the Aitutaki Passage and the South Penrhyn Basin, both characterized by waters of some 5,000 metres in depth. The seabed there forms a flow channel for cold, mineral-rich, highly oxygenated Antarctic bottom water currents.

The combination of these factors and the prevailing high-pressure conditions at the abyssal depths is believed to result in the deposition of metal oxides on solids reaching the seabed and, thus, the formation of metal oxide nodules. The exploratory expeditions in the area of the Aitutaki Passage and the Penrhyn Basin revealed a great abundance of nodules, which in certain places cover up to 90 percent of the seabed and contain up to 50 kilograms of nodules per m^2. Additionally, nodules in this area contain exceptionally high quantities of cobalt.

In 1993, the East-West Center, Hawaii, performed an assessment of the Cook Islands manganese nodule resources and concluded that the in-place mineable nodules in an area of some 650,000 km^2 in size contain about 32.5 million tons of cobalt. Assuming that only 50 percent of the nodules can be harvested and only 80 percent of the contained cobalt can be recovered, the deposits represent 13 million tons of cobalt to be produced. Since the world cobalt consumption amounts to approximately 25,000 tons per year, the Cook Islands cobalt resource by itself could satisfy the current world demand for 520 years. The current value of this quantity of cobalt at a price of US $25.00 per pound is US $710 billion.

The government of the Cook Islands is anxious to utilize the nation's deep-sea nodule resources and obtained a grant from the U.S. Trade and Development Agency for the partial financing of the current study. An equal share of the cost of the study is paid by Bechtel. The prime objective of the study is to identify and investigate novel methods of harvesting, handling and processing the nodules. Novel methods in this context means technologies and processes that have been used in endeavors other than the mineral industry, or in applications within the mineral industry which are not related to nodule processing.

The harvesting of deep-sea manganese nodules has been the subject of R&D work for approximately twenty years. The 1993 East-West Center study "Cook Islands Manganese Nodule Resource Assessment, Economic and Policy Analysis" states that three systems of those that were considered have reached a stage of development where pilot-scale models were tested in an ocean environment. All three systems are associated with high capital and operating costs; however, they may be justified when the target harvesting quantity is sufficiently high. This is not the case with the proposed Cook Islands Deep-Sea Nodule Mining Project. The basic criterion for the Cook Islands operation is the production of 2,652 tons of cobalt per year, which represents approximately 10 percent of the current world consumption of the metal. In order to produce such quantity, 1,097,360 tons of wet nodules must be harvested and processed annually.

Because of this relatively low production rate, a consultant of the government of the Cook Islands suggested using trawlers and bottom trawls, such as are used in harvesting bottom-dwelling fish and shellfish. The current study made an evaluation of trawling, found it feasible and proceeded with the utilization of such a harvesting method. There are elements of uncertainty related to harvesting by trawls, the main one being that bottom trawling has never been done in waters deeper than about 1,200 metres, and the Cook Islands nodules lie at more than 5,000 metres in depth. Oceanographic research vessels have brought up nodules from those depths in numerous nodule resource sites by the use of dredges, reporting no difficulties with the operation. These sampling operations produced a few hundred kilograms of nodules at a time, far less than required for a commercial operation.

PMB Engineering, Bechtel's marine and offshore entity, evaluated the proposed trawling operation and a basic trawl design provided by a prominent supplier of trawls and fishing gear. It also used sophisticated computer simulation programs to examine the expected behavior of the trawling system, including the trawl rope, during deployment, trawling and retrieval. The studies found the proposed method technically feasible with no fatal flaws; however, they pointed to the need for a rigorous design, testing and evaluation program in the course of the implementation of the project.

HARVESTING

The harvesting of the nodules will be by the use of beam trawls towed on the seabed by trawlers. The harvest area is tentatively located between south latitudes 15° 30' and 16° 30' and west longitudes 159° and 160°. In order to produce 2,652 tons of cobalt, 1,097,360 tons of wet nodules must be harvested annually. Allowing for 330 harvesting days per year, this necessitates a daily harvesting rate of 3,325 tons.

Four trawlers will be required to meet the harvesting quantity requirements. The trawlers will be approximately 100 metres in length, with 20-metre beam and 3.5-metre draft. They will be equipped with differential GPS and dynamic positioning systems so as to accurately control movement to the extent of being able to execute fully preprogrammed harvesting cycles.

The harvest area of each trawler will be demarcated by a number of hydroacoustical transponders anchored to the seabed to form a long-baseline array of locators. The location of the transponders will be validated by the differential GPS of the trawler.

The trawls will be of the beam trawl design with a rigid front frame, a foot chain of heavy steel strung across to cause the nodules to bounce up in front of the trawl. The top and sides of the trawl frame will be fitted with hydrofoils to give proper orientation to the trawl (i.e., to keep it upright) during lowering and trawling. The bottom of the trawl net will be made of steel netting to ensure contact with the bottom, while the sides and top will be made of SPECTRA filament to make it float. The bottom will be protected by wear liners to minimize the abrasion damage to the net.

Each trawl will be equipped with a sonar transponder which will query the long-baseline transponders and from their response calculate its own location within a 1-metre radius. The same instrument package will contain an altitude sonar to sense the distance between the trawl and the seabed. Net guard monitors will keep track of the stretch in the net in order to sense the process of filling up with nodules.

Trawling will be at a speed of 1 metre per second, while lowering and raising will be at 2 metres per second, resulting in a harvesting cycle of approximately 180 minutes. This allows eight trawls per day at 100 percent availability. Each trawl will be able to recover a payload of 120 tons. The trawlers will be designed to take on a nodule load of 2,500 tons, representing 2.6 days of continuous harvesting. At the end of that period, the trawler will rendezvous with a transport ship and transfer its cargo to it by pumping a mixture of seawater and nodules.

TRANSPORTATION

The smelter and refinery for the processing of the nodules is, for the purpose of this study only, tentatively located near Whangarei, on the North Island of New Zealand. Custom-built ships with 30,000 tons capacity and approximately 175 metres length, 25 metres beam and 10 metres draft, will be used for transporting the nodules from the harvest site to the process plant. Three vessels with a utilization factor of 88 percent can accommodate the transportation operations.

The unloading of nodules will be by use of Marconaflo pumps, using seawater as the pumping medium. The loaded ship will tie up at an existing wharf, which will be equipped with two rail-mounted hoisting derricks to support the Marconaflo pumps. The holds of the ship will be flooded with seawater, and the Marconaflo units will be hoisted on board and lowered into selected holds. The lowering of the pump unit will continue until the hold is emptied to the required level, then the pump will be moved to the next designated hold. The process will be repeated until the ship is unloaded.

OPERATIONS

The base of the harvesting operations will be at Rarotonga. A warehouse for spare parts and supplies, including food, will be provided. The crews of the harvesting trawlers will be on duty for four weeks and off duty for two weeks. Every time a transport ship sails to the harvest site, it will stop at Rarotonga to take on board the crews of two trawlers and such supplies as are necessary. At the harvest site, the fresh crews will replace crews on two trawlers, which will board the loaded transport ship for the trip back to Rarotonga. After the debarkation of the crews, the transport ship will proceed to New Zealand.

The crews on the transport ships will work six weeks with two weeks off. The crew change will take place either at Rarotonga or in New Zealand, as determined by operations. The transport ships will take on supplies and fuel during nodule unloading in New Zealand and will resupply the trawlers at sea while on station to receive nodules.

A helicopter will be available in Aitutaki for emergency use by the harvesting trawlers and the transport ship stationed at the harvest site.

The harvested nodules will be delivered by transport ships to the process plant at an annual rate of 1,097,360 wet tons, which equals 665,000 dry tons. The nodules will be stored in two circular storage basins. At full capacity, 130,000 tons of nodules can be stored to provide the process plant with feedstock for 50 days.

The extraction of cobalt, nickel and copper will be in a two-stage process, first using pyrometallurgy to make a granulated sulfide matte. At the planned production rate, approximately 8,200 tons of matte will be made annually. This product will be treated further in the hydrometallurgical plant to make pure cathode cobalt and nickel, and unrefined copper powder in quantities of approximately 2,652, 1,718 and 955 tons per year, respectively.

SMELTING

Wet nodules will be reclaimed with a Marconaflo system, dewatered and fed to a rotary dryer that will be fired with pulverized coal. Dried nodules will be transferred by conveyor via a surge bin to a rotary reduction kiln. Crushed coal will be metered to the reduction kiln as a reducing agent along with dry nodules. The reduction kiln will be fired with pulverized coal to a temperature of about 950°C, which will result in the partial reduction of the metal oxides contained in the nodules.

The calcine will be discharged into transfer pots and moved by rail-mounted cars and crane to the charge bins of an electric furnace, where the final melting will take place. Manganese and most of the iron, in the form of oxides, will report to the slag, which will be tapped and granulated for disposal. The molten alloy of cobalt, nickel, copper, and some iron will be tapped into preheated, refractory lined pots for transfer into one of two Peirce-Smith converters. Flux will be added in the converter, the bath will be blown to oxidize the iron, and the iron oxide will be collected as slag. The converter slag will be recycled to the electric furnace. The blown bath will be sulfurized to convert the alloy into sulfide matte, which then will be granulated.

REFINING

Granulated matte will be received in a storage bin, from where it will be metered into a tower mill for comminution by wet grinding. The pulp will be pumped to a matte storage tank as feed to the leaching operations.

Leaching will take place in a two-step countercurrent leach circuit in which the first step will be cementation leaching and the second completion leaching. Solids will flow forward from the cementation to the completion leaching, while liquids will flow from completion to cementation via copper removal.

The leach solution, containing a variety of heavy metal ions, will be subjected to oxidation by the addition of chlorine gas and by blowing air through the solution. Iron, considered a contaminant here, will be removed by using solvent extraction in a series of mixer-settlers.

COBALT EXTRACTION

Purified liquor from the iron oxidation will be contacted with an organic solution in a series of mixer-settlers to extract the cobalt. The advance electrolyte circulating between the cobalt stripping and cobalt electrowinning will be purified by neutralization with cobalt carbonate in a series of agitated tanks, followed by a clarifying filter press.

Cobalt will be electrowon on cobalt starter sheets, which will be made by electrowinning using ruthenium-oxide-coated DSA titanium anodes. The passage of electrical current through the EW cells will result in the deposition of cobalt metal and the release of chlorine gas that is associated with the cobalt in its aqueous chloride solution. Anodes will be contained in fabric bags to capture chlorine gas, which will be recycled to leaching. A total of 18 EW cells will be required, 2 for starter sheets and 16 for commercial cathodes. The cells will be designed for 1 m^2 electrodes. Each cell will contain 39 cathodes and 40 anodes.

NICKEL EXTRACTION

Aqueous solution leaving the cobalt solvent extraction circuit will be fed to the nickel solution purification circuit, where organics from the cobalt solvent extraction step will be removed in a carbon column. Then, as with cobalt purification, the raffinate will be contacted, in three agitated reaction tanks installed in series, with nickel carbonate, to precipitate nickel hydroxide, lead sulfate, manganese dioxide, and other slightly soluble sulfates. The slurry exiting the third reactor tank will be fed to a filter press which will deliver clarified electrolyte to the nickel electrowinning.

Nickel will be electrowon on starter sheets and DSA titanium anodes to make the starter sheets. The size and construction of the EW cells will be identical to those in the cobalt circuit. The chlorine gas generated in the eletrowinning will be recirculated to leaching. There will be 12 EW cells, two for making starter sheet and 10 for production.

SULFUR REUSAL

Solids from the completion leach and from the filtration stage will consist primarily of elemental sulfur.

The residue material from the completion leaching will be dried in a Holoflite-type dryer and melted in a steam-heated sulfur melting vessel. The molten sulfur will be recycled to the smelter converters for making sulfide matte. Process losses of sulfur will be replaced by adding commercial sulfur to the melting vessel.

COPPER REMOVAL

The completion leach filtrate, where copper is present as both cuprous and cupric chlorides, will be pumped to copper removal in a seven-cell electrowinning operation. Copper EW will operate at high current density using titanium cathodes and titanium DSA anodes, and will employ electric vibrators to agitate the cathodes continuously. Copper will be collected from the cathodes as a powder which will fall to the bottom of the EW cells. The powder will be recovered, washed, filtered, packaged and sold for further refining.

RESIDUE HANDLING

The smelter will produce approximately 1,450 tons of residue - or slag - per day, which contains about 330 tons of manganese. The residue will be granulated for easy handling and discharged into an elevated hopper with a loadout gate at its bottom. Trucks, with 40 tons capacity, will drive under the bin and load the residue. They will transport the load to a stockpile for rear dumping.

In order to stockpile 25 years' of residue prod-uction of 11.3 million dry tons, an 80-metre high stockpile will be built with sloping sides and a base of 540 m in both length and width. The manganese content of such a stockpile is approximately 2.6 million tons. Although the availability of manganese from terrestrial sources is so abundant that it currently is not economical to extract it from the residue of nodule smelting, the situation may change in the future. For this reason, it may be prudent to stockpile the residue for potential future use. Alternately, the residue can be used for road building or landfilll.

MATERIALS HANDLING

Coal will be received in bottom-dumping 40-ton railcars, discharged into a receiving hopper, and transported by a belt conveyor to a conical stockpile. Reclaiming will be by front-end loader, which will dump into a reclaim hopper. A belt feeder will draw coal from the hopper and discharge into a lump breaker. The sized coal will travel via a belt conveyor to either the coal pulverizing plant or the reduction coal feed bin. Pulverized coal will be transported pneumatically to the use points.

Flux will be delivered in trucks and stored in a covered shed for reclamation by a front-end loader. A belt feeder will draw from a reclaim hopper, and the flux will be conveyed to a scalping screen. The oversize will be crushed and combined with the screen undersize for transportation by belt conveyor into a silica flux feed bin. A feeder system will deliver measured amounts of flux on demand to the converters.

Sulfur will be received in bulk containers and stored in the vicinity of the sulfur melter. Sulfur will be added to the melter as required, using a hoist.

Fuel oil will be delivered by trucks and received into a storage tank. A pump will transfer the oil via a distribution pipe system to the use points.

Hydrated lime will be received in bags and dissolved in an agitated mixing tank. A pump will transfer the milk-of-lime to the sump of the scrubber as required.

A one-story building will be provided to accommodate nonprocess facilities such as the offices, laboratories, change rooms, shops and a warehouse. The offices will be located in one end of the building, while the shop and warehouse will occupy the other end.

The general office will occupy an area of 800 m², divided into individual offices, lunchroom, conference room and service rooms. An additional 500 m² will be allocated for the metallurgical laboratory and its associated offices and computer rooms. In addition to the comfort heating and ventilation system, industrial exhaust systems will be provided in the laboratory as required. The change rooms will have a floor area of 300 m².

The shops will be allocated 1,000 m² of floor area, while the warehouse will occupy 600 m². In addition to the enclosed warehouse, there will be a fenced area outside the building for laydown and storage.

UTILITIES

Water is assumed to be purchased from available sources. A tank will be provided for combined plant water and fire protection water storage. The distribution of plant water will be through underground pipes. A portion of the incoming water will be chlorinated for use as potable water, which will be stored in a dedicated tank and distributed through the potable water pipe system.

Water will be used for the granulation of slag. It is estimated that the water evaporated in the granulation process and taken up by the slag will be approximately 150 m³ per day. There will be no water discharge from the plant other than the moisture content in the granulated slag.

Fire protection. The bottom portion of the plant water storage tank will be dedicated to fire protection water. One electric and one diesel-engine driven pump will be installed in parallel to supply water to a closed-loop buried fire water distribution system, which will be pressurized by a jockey pump.

Pressurized spray systems will be provided in the conveyor tunnels, warehouses and offices as determined by the requirements of the insurer and approved by the Owner.

Electrical power will be delivered to the plant via 115 kV, 50 Hz, 3-phase overhead lines. One 30 MVA transformer will step down the voltage to 11.5 kV for the smelting furnace feed, while two 16 MVA transformers installed in parallel will reduce the voltage to 3.3 kV for medium voltage plant distribution. Power will be stepped down to 420 V in the local electrical rooms for low-voltage use.

Compressed Air. Two air compressors installed in a compressor room will supply pressurized air to a reticulation system for the purpose of plant maintenance use.

Sanitary Sewer. The plant will utilize a modularized below-grade packaged sewage treatment plant. Effluent will be pumped to the slag granulation operation.

Communications. A communications system customary for industrial plants will be provided. The system will include a telephone network and two-way radios as required. Instrumentation data communication will utilize a fiber-optic system.

CAPITAL COST ESTIMATE

The capital cost estimate for this prefeasibility study is in first quarter 1996 U.S. dollars with no future escalation provided. The accuracy of the estimate is ±25 percent.

ESTIMATE BASIS

The estimate is based on the mechanical and electrical equipment lists and the following drawings, which are contained in Appendices A and C of the full report:

	Drawings
Site plan	*1*
Flow diagrams	*16*
Electrical single lines	*5*
Plans and sections of the process facilities	*6*

Civil quantity take-offs are based on historical data of similar facilities and plants. Roofing and siding were developed from the general arrangement drawing. Mechanical bulks are from the equipment list with provisions made for insulation, duct work and refractory. Yard piping was developed from the plot plan; all-in process piping was factored from mechanical equipment. Yard electrical equipment was defined from the equipment list and the single line diagrams. Electrical bulk materials and instrumentation were factored on the basis of mechanical equipment.

Construction labor rates were based on current experience in New Zealand and reflect recent productivity data. The hourly rates include base wages, fringe benefits, small tools and consumables, insurance, construction equipment, contractor nonmanual costs, overhead and profit. New Zealand craft productivity was derived by multiplying North American Mining and Metals standards by a factor of 1.2.

An allowance for common distributables was added at 3.5 percent of the direct costs to cover such expenses as common warehousing, salaries of managers, temporary facilities and vehicles, and surveying and testing services. Trawlers and transport ships were exempted.

The following allowances were added: 10 percent for ocean freight for imported equipment; and 2 percent for inland freight and port fees for local and imported material and equipment.

Spare parts have been provided for at 5 percent of the equipment costs, except for the electrowinning cells and marine vessels, which have no provision included.

Engineering, procurement and construction management costs were provided for at 15 percent of field direct costs, except for marine vessels which were put at 1 percent.

A provision for all risk insurance has been made at 0.5 percent of all the above costs.

Contingency is an amount of money allowed in an estimate for costs which, based on past experience, are likely to be incurred but are difficult or impossible to identify at the time the estimate is prepared. It is an amount which is expected to be expended during the course of the project for the scope as defined. Contingency does not include scope changes. Examples of contingency items include:

- Estimating errors or omissions
- Design development
- Pricing changes
- Schedule delays
- Delays in equipment and material deliveries
- Contractor's claims and their impacts

A provision of 15 percent was included as a contingency, except for the marine vessels, where 10 percent was provided.

PRICING

Plant equipment prices are based on budget and phone quotes for this study, and on recent price quotes for other studies, as indicated in Table 1. The remaining equipment was estimated using in-house data.

Table 1
Sources of Pricing
(in $1,000's)

Description	Budget Quotes	Phone Quotes	Recent Quotes	Estimated Values	Total
Marine facility	41,149	75,000	—	326	116,475
Process plant	45,244	—	5,089	17,173	67,506
Site development and utilities	291	—	171	8,180	8,642
Total	86,684	75,000	5,260	25,679	192,623
Percent of overall equipment (%)	45	39	3	13	—

ESTIMATE QUALIFICATIONS

The following items are presented as qualifications to the estimate:

- The project will be constructed on a greenfield site with no unusual soil conditions or requirement for major earthwork where spread footings can be utilized.
- Initial fills of reagents and resins are included.
- There is no labor availability problem.
- An existing port will be available at no capital cost.
- Utilities will be available at the site battery limits.
- Allowances have been provided for administration building furnishing and equipment as follows:
  - Laboratory equipment: $350,000
  - Shop equipment: $100,000
  - Office equipment and furnishing: $200,000

ESTIMATE EXCLUSIONS

The following items are excluded from the estimate:

- Financing charges and interest during construction
- Cost of any future studies except for an update of this study in Phase II
- Plant operating supplies, fuels and marine insurance beyond initial fills
- Escalation beyond first quarter 1996
- Taxes and duties

The capital cost estimate is summarized in Table 2, including the Phase II and Owner's costs.

Table 2

Capital Cost Summary

(Costs and Manhours in 1,000s)

Description	Manhours	Installation Labor Costs	Equipment Material & Subcontract Costs	Total Costs
Plant Equipment			*192,623*	*192,623*
Bulk Materials			*43,109*	*43,109*
Subcontracts	*55*		*5,100*	*5,100*
Installation Labor	*1,346*	*53,798*	*0*	*53,798*
Total Direct Costs	*1,401*	*53,798*	*240,832*	*294,630*
Spare Parts				*4,570*
Common Distributables				*6,920*
Ocean Freight and Inland Freight				*9,480*
EPCM Services				*31,370*
Project Insurance				*1,730*
Contingency				*47,400*
Total Project Costs				*396,100*
Phase II Work				*11,000*
Development Costs				*9,000*
Owner's Costs				*19,000*
Total capital Costs				*435,100*

The operating cost estimate for the Cook Islands Deep-Sea Nodule Mining Project is divided into five cost centers as follows:

- Marine operations consisting of harvesting and transportation of the nodules
- Smelter, including nodule unloading, smelting and slag disposal
- Hydrometallurgical refining to produce metals
- Maintenance for fixed plant facilities
- General and administration

The estimate is based on the process summarized above and on the material balances as shown in the process design criteria in Appendix B of the full report. The operating cost estimate is in first quarter 1996 US$ and its accuracy is ± 25 percent.

The operating costs for the marine operations were developed on the basis of information obtained from interviews with experienced marine shipping operators. Bechtel developed the flowsheets for the smelting and refining areas of the plant and estimated the consumable quantities and labor requirements.

The labor costs are taken from a New Zealand national wage and price survey and presented as total remuneration costs, including the base salary and value of all benefits, as of the fourth quarter of 1995. Electricity and coal budgetary prices were obtained from Northpower, Ltd. and Solid Energy North, respectively. Other consumable prices were available from Bechtel studies of similar operations. Maintenance supplies have been estimated at 4.5 percent of the plant equipment cost. A 10 percent contingency has been added for the consumables only, given the level of process definition developed for the study. General administration staff was estimated for the operation, and an allowance was made for office supplies, travel costs and the like. The estimated operating cost summary is shown in Table 3.

EXCLUSIONS

No allowance was made for the following potential expenses:

- Royalties, permits and licenses
- Escalation (all costs are in 1Q1996 US $)
- Credit for the sales of any products other than cobalt, nickel and copper
- Costs for environmental compliance other than those indicated on the process flow diagrams
- First-year startup costs or possible productivity gains
- Major rebuild costs
- Overtime costs

Table 3

Operating Cost Summary

Description	Total Cost ($/y)
Marine Operations:	
Harvesting	7,707,000
Transportation	9,914,000
SUBTOTAL	17,621,000
Smelting:	
Consumables	16,044,500
Labor	2,522,000
SUBTOTAL	18,566,500
Refining:	
Consumables	3,517,410
Labor	838,000
SUBTOTAL	4,355,410
Maintenance Labor	2,328,700
General and Administration	4,163,500
TOTAL OPERATING COSTS	47,035,110

The Cook Islands Deep Sea Nodule Mining Project will produce three end products: cobalt and nickel metal and copper powder. Of these, cobalt accounts for the majority (over 90 percent) of the revenues. In addition, the world market for cobalt is much smaller and less liquid than are the markets for nickel and copper. Because the market for cobalt has such a significant impact on the Project's feasibility, an overview of the cobalt industry has been provided in the study report and summarized here.

COBALT MARKET OVERVIEW

Cobalt production declines occurred in the 1990s due largely to political and social unrest and inadequate investment in Zaire, which was the world's dominant producer. It appears that cobalt consumption is not likely to grow as fast as the world economy in general. This is partly confirmed by U.S. consumption, which has grown significantly slower than GDP since 1993, probably due to reduced military aircraft engine procurement.

Seven firms currently account for 70-85 percent of the world's total cobalt production. Gecamines (Zaire), with production averaging over 10,000 tons per year, dominated the market until 1991. At its projected level of output of over 2,600 tons per year, the Project would be the world's fifth largest cobalt producer, accounting for over 10 percent of the world's estimated 1996 output. Major future expansions of global production capacity could come from the Diamond Fields project in Canada, Australia and Cuba, as well as expansion of capacity of existing mines. As in the case of about 60 percent of current cobalt production, Diamond Fields, Australia and Cuba are primarily nickel resources; and cobalt production will largely be determined by nickel production.

Another major factor in the supply of cobalt is the release to the market of U.S. Defense Logistic Agency stockpiles. These releases apparently are being managed to maximize revenue to the U.S. Treasury and may be completed or near completion before Cook Islands production could come on stream. Releases from stockpiles of the former Soviet Union apparently are now small and nearing completion.

There are indications that global cobalt refining capacity will be adequate for the indefinite future. It is not clear, however, whether all of this capacity is economically efficient or whether refiners are interested in taking on new sources of input.

Fragmentary evidence suggests that U.S. consumption patterns are more or less typical of the rest of the world. However, because of its aircraft engine and utility turbine industries, the U.S. share of superalloy consumption is relatively high. Compared to Japan, U.S. consumption for chemical applications is fairly low. It appears that the share of superalloy/hardfacing applications has stayed constant at somewhat over 40 percent, while the share of chemical applications has increased, and the share of magnetics has declined. Demand will probably continue to be fairly high in the superalloy area since much of it is accounted for by aircraft engines and power generation turbines, two applications that are expected to grow at a fairly healthy rate for the indefinite future.

Cobalt is not traded on a regular commodity-market basis as are other metals. It appears that most cobalt is sold on a spot market basis by producers or producers' agents. Because of the fact that cobalt is usually a by-product of nickel or copper production, its own production is not dictated by market conditions. Thus, in periods of excess cobalt supply (due to the production of copper and nickel growing faster than the demand for cobalt), producers typically build up cobalt inventories. When the demand for cobalt grows faster than the production of copper and nickel, producers release their inventories to the market. Since the size of cobalt inventories are not large relative to the total metals production of the producing companies, it is relatively easy for producers to hold large inventories when necessary. The producers' ability and willingness to build and release inventories tends to stabilize prices in the cobalt market.

In further investigations concerning the commercial viability of the development of the Cook Islands resource, more should be learned about the specific mechanisms of the cobalt market. In particular, it should be learned how much cobalt is sold under long-term contract. Knowledge should be developed concerning what types of customers are likely to negotiate such contracts and the contracts' terms and conditions.

COBALT PRICING

During the 1980s and before, the price of cobalt was largely controlled by Gecamines (Zaire) and ZCCM (Zambia). Beginning in the 1990s, Zaire and Zambia encountered severe production problems, and metal output fell sharply. The fall in output of these two major sources coincided with rapid escalation of prices for every year except 1993. It is reasonable to infer that the escalation of prices in the 1990s was due in large part to the coincident drop in supply.

The most likely scenario for future demand would seem to be slow growth, somewhat less than world GDP growth. Probably the major uncertainty concerning demand is the long-run possibility of substitution of other materials for cobalt in some applications. It appears that some substitutability is possible, and it may become quite important if the current price level is sustained. Another factor that helps limit price escalation is the possibility of recovery of cobalt from secondary and intermediate materials. A market study should look into where substitution and recovery might occur, at what prices, and to what extent.

The major uncertainties for cobalt pricing exist on the supply side. If supply increases faster than demand, prices will fall. This would certainly be the case if Gecamines were to regain its historical levels of production. This would require a permanent reduction in political unrest and an ability and willingness of the government of Zaire to invest (or let others invest) in production and refining. The prospects for a government that would be accommodating to dramatically increased production are unlikely in the short run. However, over the time frame for the Project, the emergence of an enterprise-oriented government that would aggressively expand production of Gecamines cannot be discounted completely.

Another uncertainty is when production will begin at major nickel deposits. This study was not able to develop a clear picture of how much cobalt would come from the new projects when they reach full production, but some estimates put it as high as 3,600 tons per year. This increase in world supply could have a significant depressing effect on cobalt price. In addition to new supply sources, improvements in cobalt extraction processes could boost production at existing cobalt operations. A new cobalt leaching technology which improves recovery significantly is now being deployed at locations in Australia. If this technology proliferates, world supplies of cobalt could expand and prices could decline.

To maintain the recent price level of about $28 per pound would require an increase in production corresponding to the increase of demand caused by world cobalt consumption growth. Some simple assumptions will give a general notion of the potential range of prices. If it is assumed that the growth of world demand for cobalt is 2 percent per year, then by the year 2005 production would have to grow by about 5,000 tons to maintain current prices if it is (unrealistically) assumed that nothing else would change. An increase of this magnitude could be attained by Gecamines alone returning to its previous level of output, even without any contribution from Cook Islands, Diamond Hills, Australia or Cuba. If Cook Islands, Diamond Hills, Australia and Cuba came into production and Gecamines returned to its previous level of production, it seems likely that prices would recede to around $20 in 1995 dollars.

PROJECT COMMERCIAL STRUCTURE

A preliminary Project commercial structure was developed based on Bechtel's understanding of the metals industry, on the likely concerns of potential lenders, on the interests of the Cook Islands Government, and on the interests of potential Project sponsors. It was assumed that the Project sponsors will choose to employ a limited recourse financial structure for the Project. In limited recourse structures, lenders and investors look to Project revenues for repayment of debt and return on investment. Equity investors' potential losses are limited to the amount of their equity investment. A limited recourse structure allows sponsors to take equity interest in the project and attract debt financing without placing their other corporate assets at risk.

In such a structure a Special Purpose Company (SPC) would be formed to own and operate the Project's assets. The SPC would then borrow directly from lenders, and the Project sponsors would invest equity in the SPC without being subject to direct recourse from lenders in the event the Project encounters financial distress. Because debt capital is so critical to a nonrecourse project structure, the lenders' requirements will dictate many of the Project's resulting credit supports and other commercial features.

Under the limited recourse financing structure, several important commercial arrangements must be developed to assure the Project's financial viability and to provide the credit support necessary to attract financing to the Project.

These include the following:

- Shareholder agreement
- Government approvals and permits
- Lump sum turnkey EPC contract
- Marine services contract
- Operations and maintenance contract
- Materials supply contracts
- Product marketing contract(s)
- Debt service reserve fund
- Insurance

A group of sponsors would likely fund the Phase II costs and provide the bulk of the Project equity. In addition to their capital contributions to the Project, these firms could ideally also provide contract services to the SPC in their particular areas of expertise to help mitigate specific and significant project risks. Firms that might participate in the sponsor group could include creditworthy entities with expertise in the following areas:

- Shipping and trawling operations, including ship building
- Engineering, procurement and construction (EPC) of processing facilities
- Metals refining and smelting operations
- Metals marketing

Lenders will likely require that significant project risks be mitigated through long-term contracts. To the extent that the sponsors may wish to provide these services, they would contract independently with the SPC to do so.

ECONOMIC ANALYSIS

While potential investments can be evaluated for their noneconomic benefits, such as job retention/creation, environmental benefits, etc., this analysis focuses only on the potential economic benefits.

A computer model of the expected Project commercial operations was developed to test the Project's economic performance on a pretax basis with no fees or royalties paid to the Cook Islands Government, as the Base Case. (As an Alternate Case, U.S. corporate tax structure, $15 million upfront fee and 2.5 percent of the operating income as a royalty payable to the Cook Island government were taken into account.) Using this model, economic projections and measures of financial performance were generated. In addition, a series of sensitivity analyses were conducted to determine the Project's economic viability under downside scenarios and its profitability in upside scenarios.

For the purposes of this analysis, it was assumed that the Project will be funded with 30 percent equity and 70 percent debt in a limited recourse financial structure. The Project is assumed to support the operating costs, including debt service, and generate returns for investors solely from its own cash flows. For details of the methodology, assumptions and basis of the analysis the full report should be perused.

The analysis is based on escalated U.S. dollars, with all original cost estimates expressed in April 1996 dollars which are then subjected to 3.0 percent inflation per year.

The Base Case analysis assumes that the Project will be implemented in three phases, including this prefeasibility study as Phase I. In Phase II, a number of technical and field tests will be completed to confirm the resource availability and the technical aspects of the proposed harvesting methods, smelting and refining operations. Phase II activities would probably be funded by the Project sponsors prior to financial closing.

Following the successful completion of the Phase II tests, it is assumed that the sponsors will arrange financing and that the Phase III activities would begin at financial closing. Phase III includes the actual construction of the trawlers, transport ships and processing facilities. Commercial operations would begin at the completion of the Phase III construction. The timing parameters of the analysis are shown in Table 4.

Table 4

Project Time Table

Parameter	Assumptions
Cost Estimate Date	*April 1996*
Financial Closing	*December 1997*
Start of Construction (Phase III)	*January 1998*
Start of Full Operations	*January 2001*
Project Life	*25 years*

The analysis is based on total unescalated capital costs of $435 million. Monthly vessel acquisition, engineering, procurement and construction (EPC) and Owner's costs are assumed to be expended on a straight line basis throughout the construction period.

Ship costs include building and outfitting the vessels to meet their unique requirements. The EPC costs cover the construction of the processing facilities, as well as the associated infrastructure. The Owners costs reflect the sponsors' costs incurred prior to commercial operations, including training of staff, oversight, permitting and startup costs. Development costs reflect the sponsors' recovery of costs incurred prior to financial closing. They include an allowance for the financial and legal advisor costs and other costs related to reaching financial closing. The Initial working capital is an allowance to cover the working capital requirements which commence at the beginning of the project operations.

The operation is designed to harvest and process approximately 1.1 million wet tons of nodules per year, based on four trawlers operating 330 days per year and using three vessels to transport the harvested nodules from the Cook Islands to the processing facility in New Zealand. In addition, the services of a research vessel will be engaged to monitor the environmental effects and to assist in the planning of harvesting.

The processing facility will operate at a constant production rate. In the first full year of operation, overall production efficiency is expected to be 80 percent as the plant ramps up to the full production level. During this period the fixed operating costs (i.e., insurance, labor, etc.) will accrue at the same rate as they would under 100 percent production efficiency.

The Project's sole source of revenue for the Base Case is the sale of cobalt and nickel metal and copper powder. For this analysis it was assumed that the initial product prices are about 10 percent below current spot market prices (in 1996 US$) and that these prices would escalate at 3.0 percent annually over the life of the project.

All operating costs have been estimated in April 1996 dollars and then escalated at 3.0 percent annually over the life of the project. A detailed breakdown of most of these costs is provided in Section 7 of the report. Additional operating costs include the following items:

- Research vessel costs to operate and maintain a specially equipped vessel to monitor environmental impact and to map sea bed resources as required.
- Insurance expenses for property and casualty insurance and other miscellaneous operating expenses that might be incurred.
- Marketing fees would be paid to a metals marketing firm for selling the project's products. An allowance has been made for these fees to be 0.5 percent of gross product revenues.

It was assumed that a base amount of working capital for the first year of operations will be funded at financial closing. For each operating year the required amount of working capital is calculated as follows:

Working Capital	=	*Receivables (at 45 days of revenues)*
	-	*Payables (at 45 days of operating expenses)*
	+	*Operating Cash (at 30 days of operating expenses)*
	+	*Inventories (30 days of revenues of all products)*

It was assumed that the Project will be financed on a limited recourse basis, wherein lenders depend solely on the assets and cash flow of the project for repayment without having any claims on the Sponsors. Typical of financings of this type, a debt/equity ratio of 70/30 was assumed, and that debt and equity funds are provided pro rata during the construction period.

It was also assumed that lenders will require level principal repayments and have assumed loan interest rates, tenor and fees representative of the specific Project risks and location. In addition, provisions were included for a Debt Service Reserve Fund to be funded at the completion of construction and to be maintained at an amount equal to 6 months of the current year's debt service. Required increases in this reserve fund would be paid out of operating cash flows and would be senior to any distributions to equity.

PERFORMANCE METRICS

The following economic performance metrics were considered in the course of the financial analysis:

Return on Investment (ROI) is the internal rate of return on the project's unleveraged after-tax annual cash flow, beginning at financial closing. It is independent of financial structure and thus is a basic and fundamental indicator of project economics. The ROI calculation used in this analysis is based on the project's pre-tax cash flow, determined as:

Cash Flow	=	*Revenues*
	-	*Operating Expenses*
	-	*Increase In Working Capital*
	-	*Capital Costs*

Return on Equity (ROE) is the internal rate of return on the pre-tax net equity cash flow for a project which includes debt in its capital structure. As such, it is based on the cash flow after the repayment of the principal and interest to the project's lenders.

Debt Service Coverage Ratio (DSCR) indicates the project's annual ability to repay debt. It is calculated as the annual ratio of funds available for debt service (earnings before depreciation, interest and taxes) to the total current portion of debt service payable (principal plus interest). Potential lenders would likely determine a minimum annual DSCR value based on the Project's exposure to specific operating and commercial risks. This exposure will, by necessity, be based on the results of the Phase II investigations, which will help establish base-line measures of operating performance.

BASE CASE RESULTS

The Base Case analysis projects positive cash flow in all operating years and demonstrates an ROI of 22 percent and an ROE of 29 percent. These economic indicators are likely to be above the assumed minimum threshold levels that potential lenders and investors might require for a project of this type.

The minimum DSCR value was found to be 139 percent which, while positive, cannot be deemed acceptable or unacceptable for a project of unknown risk. As noted above, however, potential lenders will determine an acceptable minimum level of DSCR by performing sensitivity analyses based on the Phase II results.

Attached as Appendix to Section 8, Project Economics, is output from the model for the Base Case, including the Data and Key Results, Sources and Uses of Funds during Construction, a Cash Flow Statement and an Income Statement.

A sensitivity analysis was conducted to determine the economic impact of changes in the assumed values of selected Project assumptions. This analysis tests the relative impact of changes in individual project assumptions, using ROI, ROE and DSCR as indicators of the Project's sensitivity to each particular assumption.

Based on the current understanding of the Project's economics, three assumptions were selected to be tested in this manner. For consistency, each assumption was varied by the same percentage amount relative to the Base Case. The factors selected were:

- Capital costs, including vessels and process plant EPC costs
- Operating costs
- Product prices (all products)
- The results of this sensitivity analysis are presented in Table 5.

These results indicate that the project's economics are relatively more sensitive to changes in product prices and capital costs, respectively, than to changes in operating costs. The results imply that the project's economics could be most significantly improved by securing higher product prices and would benefit less from comparably reduced operating costs.

It should be noted that the prices of the product metals have been quite volatile in the past and may well continue to fluctuate significantly in the future. These price assumptions were used as an indicator of the Project's economics under current market conditions and do not purport to predict future price movements or imply a prediction of price stability during the life of this Project.

Potential investors should investigate the economics of this Project using price expectations developed by experts in metals marketing. It is expected that a creditworthy entity with metals marketing expertise will ultimately provide product marketing services to the SPC under a marketing agreement. This agreement could include a floor pricing mechanism sufficient to guarantee operating margins and debt service.

Table 5

Results of Sensitivity Analysis

Sensitivity Factor	ROI (%)	ROE (%)	Min. DSCR (%)
Base Case	22	29	139
Capital Cost +15%	20	25	12
Capital Cost -15%	25	34	162
Operating Costs +15%	21	27	128
Operating Costs -15%	24	31	150
Product Prices +15%	26	35	170
Product Prices -15%	19	22	108

Cobalt prices have been historically volatile and difficult to predict, particularly over the past few years. Because cobalt provides the bulk of the project revenues, several alternate cobalt price scenarios were considered.

(Note that the indicated cobalt prices are as of April 1996, which are then escalated at an annual rate of 3 percent over the life of the project.) The results of this analysis are summarized in Table 6.

Table 6

Alternate Cobalt Price Sensitivitees

Cobalt Price (April 1996 $)	ROI (%)	ROE (%)	Min. DSCR (%)
$25.00 per pound (Base Case)	22	29	139
$20.00 per pound	18	21	101
$15.00 per pound	12	13	63

If the long-term price of cobalt falls to $20 per pound (in April 1996 dollars), the project remains economically viable, although a minimum DSCR value of only 101 percent would be a concern for potential lenders. At $15 per pound (also in April 1996 dollars) the project fails to generate enough revenue to cover debt service, even with the complete drawdown of the debt service reserve fund. At this price, which was seen as recently as 1993, additional funds would be needed from outside sources to maintain operations. Further analysis indicates that the project "breaks-even" as long as the long-term cobalt price does not drop from the assumed level by more than about 1/3 (i.e., as long as the price stays above $16.75 in April 1996 dollars).

ALTERNATE CASE

An Alternate Case was analyzed to show the potential impact of fees, royalties and taxes on the project economics. The Cook Islands Government (CIGOV) is likely to require an upfront license fee to gain initial access rights to the EEZ, and royalty payments in exchange for the right to exploit the nodule resources. In addition, since the CIGOV has not finalized its tax policy relative to this project, U.S. corporate tax treatment was applied as an indicator of possible after-tax returns. The following is a description of our assumptions relative to these factors:

CIGOV License Fee. The CIGOV license fee is an allowance for a $15 million payment at financial closing for project approvals and access rights, although the actual amount, terms and conditions of this fee have yet to be negotiated with CIGOV.

Royalties. These are expected to be paid to CIGOV in exchange for guaranteed access to the resource area and for the right to harvest nodules. While the terms of such royalty payments are yet to be negotiated, an allowance of 2.5 percent of operating income was included as an approximation of this expense.

Income Taxes. In this analysis it was assumed that U.S. tax and accounting standards would be applied to the project because the CIGOV's corporate tax policy toward this project has not yet been determined. The corporate income tax rate used in this analysis is 35 percent of taxable income, calculated as follows:

Taxable Income	=	*Operating Income*
	-	*Net Interest Expense*
	+	*Depreciation*

No allowance was made for withholding taxes on expatriated dividends or on interestpayments, nor for any tax holidays or other incentives which might be negotiated with the Cook Islands Government. Tax losses are carried forward for five years before they expire.

Depreciation. For tax purposes, the escalated project capital costs are depreciated on an accelerated basis, using a 7-year recovery period and a Modified Accelerated Cost Recovery System (MACRS) amortization schedule, as is consistent with U.S. depreciation rules for mining and metals processing assets. For book income purposes, these assets have an assumed useful life of 25 years and have been depreciated on a straight-line basis.

The Alternate Case results indicate that with government payments and taxes included the project is still viable. With an ROI of 17.5 percent and an ROE of 22.0 percent, it would still be likely to attract potential investors. The minimum DSCR is 131 percent in this case, and lenders would continue to need to evaluate the project's credit capacity in light of project-specific risks. For the Alternate Case, the long-term price of cobalt must stay above $17.25 (in April 1996 dollars) for the project to meet its debt service obligations.

The Cook Islands Deep-Sea Nodule Mining Project encompasses four phases. The current study represents Phase I of the project. Phase II will consist of exploration work at the targeted harvest site, metallurgical testwork on nodule samples, and other tests to prove the viability of trawling and materials handling methods. Also included in Phase II are the selection of a site for the process plant and the completion of the permitting process. The basic and detail engineering, as well as the procurement, construction and pre-operational testing activities, will fall within the scope of the Phase III work. Phase IV will begin with the commencement of commercial harvesting and plant operations. A bar graph type summary schedule is presented at the end of this executive summary.

EXPLORATION AND TESTWORK

This Phase II part of the project will consist of several tasks.

The area bordered by south latitudes 15° 30' and 16° 30', and west longitudes 159° and 160° is to be mapped with a hull-mounted multibeam sonar system to establish a bathymetry map. On the basis of the generated map, an area of approximately 1,100 km^2 (about 35 by 35 kilometres) will be selected for deep-towed vehicle mapping and sonar backscatter analysis to determine nodule abundance. This area is estimated to suffice for harvesting nodules at the planned rate during the first ten years of operations. Approximately 15 wet tons of nodules will be recovered from the area selected for detail mapping.

At twenty locations in the detail-mapped area, photographs and video recordings will be produced to document the nodule densities for correlation with the nodule density data derived from the backscatter analysis.

At five locations in the detail-mapped area, core samples will be taken by multiple-core-type samplers and the sediment examined for living organisms. At two of the locations, a tripod-mounted instrument package will be placed on the seabed for long-term observations. Temperature, current and sediment load data also will be collected and stored.

No harvesting ever has taken place to recover production-scale quantities on a sustained basis by the use of bottom trawls. For this reason, the proposed harvesting method will be tested in a full-scale operation at the proposed harvesting area.

The harvesting trawl will be designed and a one-quarter-scale model will be built and tested at an appropriate test facility. After the tests, a full-scale trawl will be built for the trial harvesting. A full-length cable, including an embedded electric cable, will be purchased for the test harvesting. The winch required for the operation will be custom-designed and built.

A trawler will be chartered for a period of two months plus transit time to and from the harvesting site, and will be outfitted with production-size harvesting equipment, instrumentation and auxiliary equipment as required.

It is highly probable that the chartered trawler already is equipped with a differential GPS. If not, the package will be purchased and installed. A long-baseline locator system consisting of hyrdoacoustical transponders anchored on the seabed, a battery-powered instrument package mounted on the trawl, a transponder and an HRP 400 processing unit located on the trawler will be purchases and installed to establish performance parameters during the test harvesting operation.

A testing organization will be selected to perform mineralogical examinations on selected nodules. Following these examinations, thermal processing tests will be conducted, followed by hydrometallurgical tests. Each of these test series would be performed sequentially, as the outcome of one would affect the substance of the following tests. The tests would be concluded with the producion of a report containing the test results and recommendations for the processes, including the design parameters.

Within the Phase II program, the Owner will evaluate the findings of the site-screening effort conducted in the course of this study and initiate a detailed selection process with the aid of project personnel and a local consultant. While the site selection is in progress, the project team, including the local consultant, will assemble the data required for the commencement of the permitting process.

If the plant is to be located in New Zealand, the document "Assessment of Environmental Effects" will be prepared for the project in conformance with the requirements of the Resource Management Act. Applications also will be prepared and lodged with the regional and district councils for land use, air discharge, water discharge and water use consents, thereby starting the statutory permitting process. With proper preparation and close cooperation with the regional and district councils, the permitting process is expected to take 9 to 12 months to complete.

At the end of the Phase II work, the prefeasibility study capital and operating cost estimates will be updated to a (15 percent accuracy, using information developed during Phase II, firm quotations on vessels and major process equipment, firm consumables prices, and various site-specific data.

A financial analysis and sensitivity studies will be produced on the basis of the new estimates. The updated report will serve the purpose of enabling the Owner to make a rational decision whether or not to proceed with project. Also, it will aid in arranging financing, should that be necessary.

BASIC ENGINEERING

Basic engineering will begin with a review of the results of the exploration and testing program. On the basis of the review, a detailed engineering, procurement and construction program will be developed.

Design criteria for the process, environmental design, mechanical, civil, structural, electrical and control systems will be developed. Project procedures will be established and published. Specifications and firm-price bid documents will be produced for the major and long lead-time equipment. Price quotations will be obtained for these items, bids will be evaluated, and purchase documents will be prepared.

Optimization studies will be made regarding the plant design as required and their results will be used in firming up the plant design. The mechanical and electrical equipment lists will be refined. General arrangement drawings, plot plan, earthwork drawings, electrical one-line diagrams, piping and instrumentation diagrams and other basic documents will be completed. During these activities, construction specialists will be part of the project team so as to ensure by their timely input that the constructability aspects of the plant are taken into account during the design.

DETAIL ENGINEERING, PROCUREMENT AND CONSTRUCTION

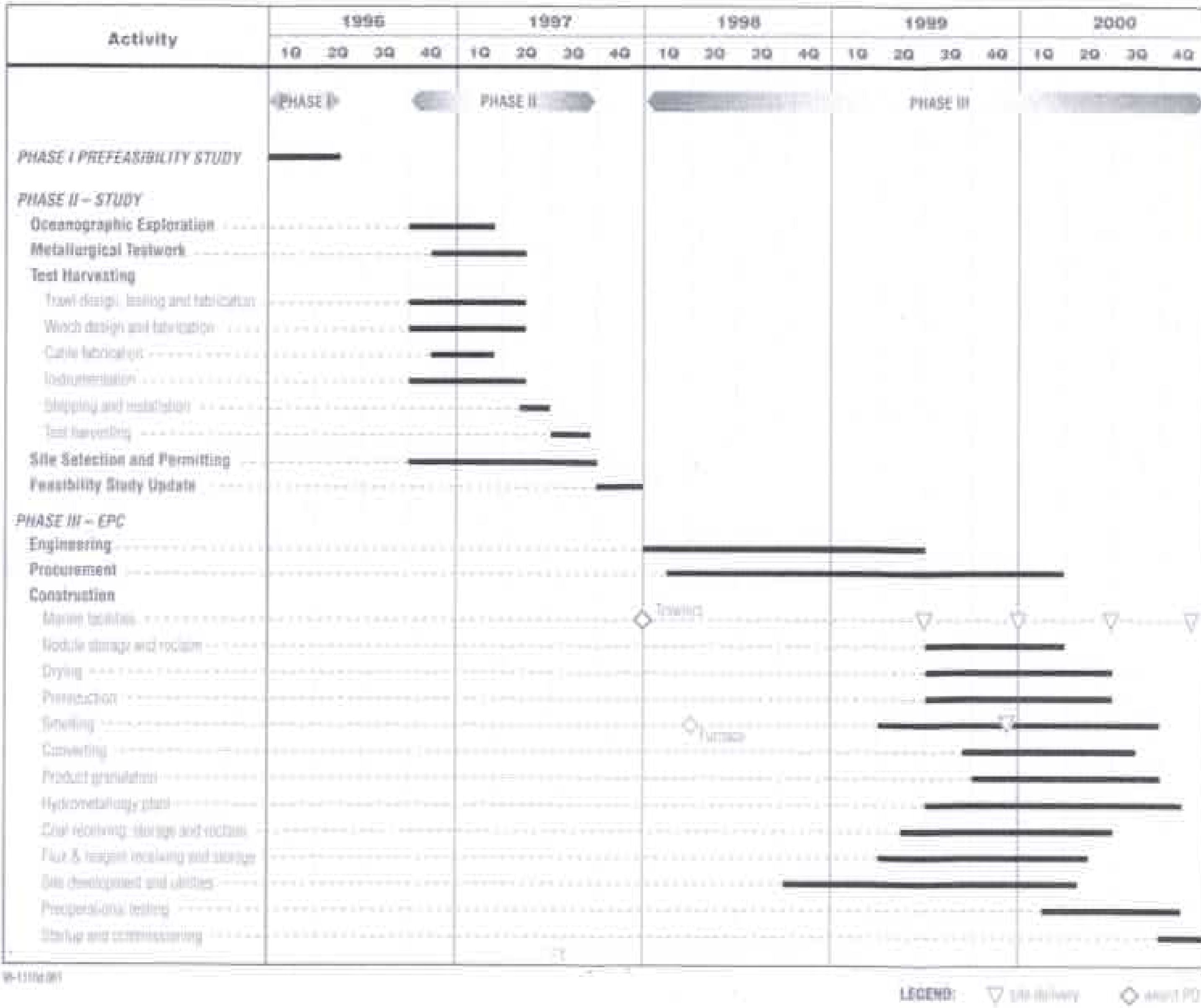
During this period of the project, purchase orders will be issued for the equipment already bid and evaluated, and work will proceed with the detail engineering. Procurement personnel will be augmented to support the purchasing and contracting activities.

The construction of the project can be achieved by contracting all of the work and managing and coordinating the contractors, or Bechtel can contract items such as the mass earthwork, siding and roofing, underground piping, etc., and perform all other work on a direct-hire basis. This latter arrangement has several advantages; the main one is that with the detail engineering and procurement proceeding in parallel and overlapping with construction, significant shortening of the project implementation period can be achieved. Generally, a shorter implementation period results in a significant increase in the net present value of the project.

During the entire basic and detail engineering phase of the project, project controls personnel will be an integral part of the project team. Their task will be to establish a detailed work plan and schedule for all aspects of engineering, procurement and construction. Also, they will monitor and report on the adherence to the plan. They will also monitor and report on deviations from the estimated costs of the project and give timely notice when design, quantity or price changes cause deviations from the project plan so that steps can be taken to control potential slippages of costs and schedule.

During the middle of the detail engineering effort, specialists will join the project to establish a program for preoperational testing and identify the need for training future plant operators. They will assemble operating manuals and establish training programs and, should the Owner so desire, hold training classes for the operating personnel.

Project Implementation Chart



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