CHAPTER 172

COASTAL ENVIRONMENT AND A NUCLEAR POWER PLANT

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INTRODUCTION

Regulatory requirements and social constraints make it necessary to evaluate the environmental effects of a project and to incorporate into the design features to minimize adverse environmental impacts. This paper presents a case history of efforts to meet these requirements for a coastal power plant in southern California.

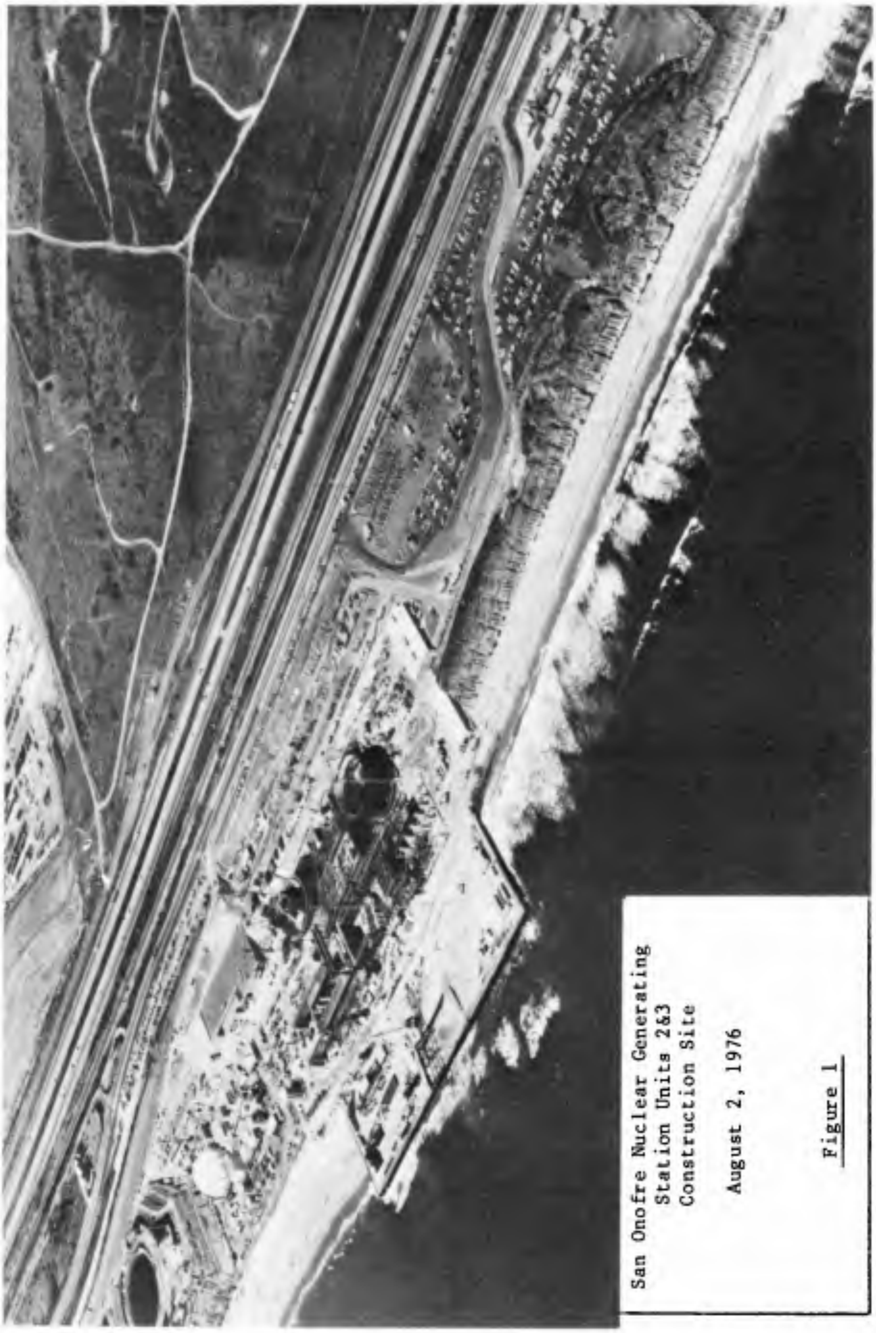
Southern California Edison Company and San Diego Gas & Electric Company are jointly now constructing two additional units to the existing San Onofre Nuclear Generating Station. Being added are Units 2 and 3. The site, about 84 acres (34 ha.), is located within Camp Pendleton, a United States Marine Corps Base, about halfway between San Diego and Los Angeles, Califoria.

The site (See Figure 1) is situated on the edge of a narrow coastal plain that extends from the coastline to a range of low hills, two miles inland, that have a maximum elevation of 1,725 feet (525 m) above sea level. The plain terminates at the beach in a line of wave-straightened cliffs, extending 60 to 80 feet (18 to 24m) above a narrow sandy beach. Numerous ravines are cut into the cliffs as a result of erosion by storm runoff from the coastal plain.

Oceanographic features at the San Onofre site include a sandy bottom which slopes gradually to a depth of 60 feet (18 m) at about 10,000 feet (3,000 m) offshore. Mean maximum summer surface water temperature is about 73°F (23°C). During the fall and winter the water column is usually thermally homogeneous with a minimum temperature of approximately 56°F (13°C).

Ocean currents at the site are chiefly tidally induced, although large scale low velocity circulation patterns are generally present. Very near to the southern California coast, local currents are influenced primarily by a combination of wind, tide, and local topography. The total current is ordinarily the sum of components due to wind, tide, and perhaps large-scale ocean circulations. Speed of the total current measured at San Onofre typically ranges from 0.10 to 1.75 knots, but averages 0.2 knots.

San Onofre, Units 2 and 3 are being constructed southeast of, and immediately adjacent to existing Unit 1. Both the existing and the units under construction generate electrical power by using pressurized water nuclear reactors. Unit 1 has a capacity of 450 MWe and began commercial operation in 1968. Units 2 and 3 will each have a rated electrical output of 1,100 MWe. Commercial operation of Unit 2 is scheduled to begin in October 1981, and Unit 3 in January of 1983.



San Onofre Nuclear Generating
Station Units 2&3
Construction Site

August 2, 1976

Figure 1

Both the existing and the proposed units use sea water in a once through system for cooling the main condensers. Each of the new units will have a completely separate once through cooling system with a flow rate of 1,850 cfs (3,100 m^3/min). The temperature rise of the seawater across the condensers is approximately 20°F (11°C).

EFFLUENT LIMITATIONS

Under the Environmental Protection Agency's (EPA) effluent guidelines and standards for steam electric power generating facilities, Units 2 and 3 are classified as "generating units" and are subject to a "no discharge of heat" limitation. The EPA has approved an exception to the "no discharge of heat" limitation for Units 2 and 3 on the basis that insufficient land is available to construct a recirculating cooling system (cooling towers). Because of this exception, the thermal components of the discharges from Units 2 and 3 are subject only to regulation by the "Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California" (Thermal Plan). Under the Thermal Plan the applicable guidelines are as follows:

(1) The temperature of the discharge shall not average more than 20°F (11.1°C) above that of the incoming ocean water.

(2) The discharge of elevated temperature waste shall not result in increases in the natural water temperature exceeding 4°F (2.2°C) at (a) the shoreline, (b) the surface of any ocean substrate, or (c) the ocean surface beyond 1000 feet from the discharge system. The surface temperature limitation shall be maintained at least 50% of the duration of any complete tidal cycle.

Southern California Edison Company requested and the California Regional Water Quality Control Board, San Diego Region, granted an exception to the specific water quality objectives of the Thermal Plan for the purpose of heat treatment to control marine fouling organisms in the cooling water system. The State Water Resources Control Board conditionally approved the exception to the Thermal Plan for heat treatment purposes contingent upon the Company completing studies which would permit the Regional Board to set precise limits on the frequency, temperature, and duration of heat treatments. These studies are described under "Environmental Impact of Plant Operation" below.

The Thermal Plan requires that exceptions be granted only in accordance with Section 316(a) of the Federal Water Pollution Control Act of 1972 and subsequent federal regulations. Section 316(a) requires the discharger to demonstrate that the proposal would assure the protection of aquatic communities in the receiving waters. EPA has approved the scope of the heat treatment studies being conducted for the State of California as being consistent with the requirements of 316(a) and as therefore being acceptable as a 316(a) demonstration.

A problem involved in measuring the thermal dispersion from a coastal power plant is that there could be significant natural temperature variability. At San Onofre, temporal variations in the ocean surface temperature of the order of 2°F can occur over a period of several minutes, and fluctuations over 5 days or so can be as great as 10°F.[1] Spatial variations in ocean surface temperatures of 2°F and greater are numerous over distances of just a few miles.

A paper in the Journal of Geophysical Research[2] presented the results of time series analyses of several years of coastal ocean temperature records. The records were analyzed using digital filtering, covariance and spectral analysis. The low-frequency component of the temperature signal showed a strong seasonal component in southern California. A period of midwinter warming was apparent in southern California. Intermediate frequency components showed strong correlations in southern California with the presence of distinct and substantial temperature events occurring almost simultaneously over distances of the order of 125 miles (200 km). High-frequency components have a large standard deviation in summer (1.4°F) and a low standard deviation in winter (0.7°F). These components are uncorrelated at stations even a few miles apart.

DESIGN FEATURES TO COMPLY WITH ENVIRONMENTAL REQUIREMENTS

A plan of the offshore circulating water system for Units 2 and 3 is shown in Figure 2. Both of the cooling water intakes will be located about 3,100 feet (945 m) offshore at a depth of about 30 feet (9 m). The outfall for Unit 2 will extend approximately 8,200 feet (2,500 meters) and for Unit 3 approximately 5,900 feet (1,800 meters) from the shoreline. The intake and discharge conduits will utilize 18 foot (5.5 m) ID reinforced concrete pipe.

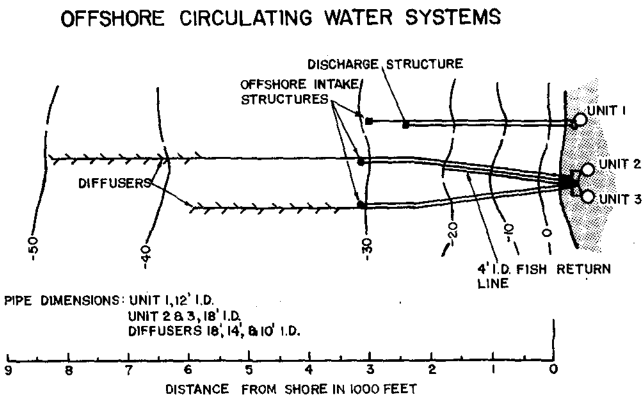
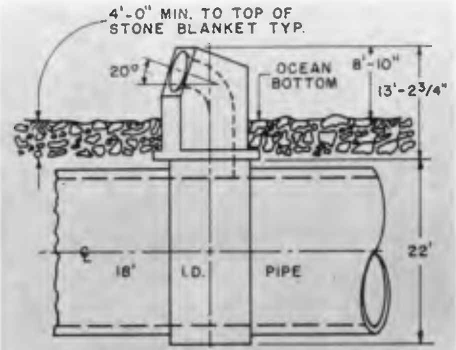


Figure 2

Each discharge utilizes a diffuser system designed to provide the necessary dilution to meet the California thermal regulatory requirements given above. Each discharge structure consists of a diffuser about 2,500 feet (760 m) in length containing 63 discharge nozzles, or diffuser ports, at the seaward end of the discharge conduit. The diffuser ports will be spaced approximately 40 feet (12 m) apart and will have a nominal throat diameter of approximately 2 feet (0.6 m). The nozzles, shown in Figure 3, will be oriented at a vertical angle of 20° above the horizontal and are aligned to direct the discharge offshore alternately at angles of 25° to the right and 25° to the left of the diffuser section centerline.



TYPICAL DIFFUSER PORT BLOCK

DIFFUSERS ARE MOUNTED ALTERNATELY 25° EACH SIDE OF CENTERLINE OF CONDUIT

Figure 3

Physical model studies at the California Institute of Technology were used to develop the diffuser design[3]. A number of different experimental investigations were performed in the course of developing the conceptual design for Units 2 and 3 discharge diffusers. Final confirming tests were conducted in order to provide a model evaluation of the system as finally designed.

The physical model studies predicted a surface delta T not greater than 2.5°F (1.4°C), 1000 feet (300 m) from the diffusers under the most adverse current conditions. The area studied was approximately 2 x 1.7 miles (3.2 x 2.7 km). The smallest delta T isotherm definable completely within the area studied was the 1.5°F (0.8°C) isotherm. The 1.5°F (0.8°C) delta T is about the lowest isotherm that can be measured with accuracy in the field because of the ambient surface temperature variations that exist at San Onofre.

The diffuser design produces a general offshore drift, one result of which is to minimize if not completely negate the problems of reentrainment and recirculation. The offshore drift is superimposed on the longshore current. When the tide reverses, this technique provides greater protection against reentrainment of previously discharged water into the plume.

The intake of fish at offshore intake structures is an unavoidable consequence of using seawater for cooling. Past developments have significantly reduced the number of fish entrapped. Continuing studies have resulted in incorporation into the circulating water system design, some unique features to further reduce fish mortality.

The cooling water intake structures for all coastal power plants in the Southern California Edison Company system utilize a velocity cap to reduce fish entrainment. The velocity cap (See Figure 4) is a concrete slab horizontally suspended by columns above the vertical intake pipe. The use of a velocity cap is based on modeling and prototype studies conducted by the Company in the late 1950's[4] The velocity cap forces water to enter as a horizontal flow rather than a vertical flow. The studies demonstrated that fish are better able to detect, or resist, a vertical flow than a horizontal flow and could therefore avoid being entrained into the cooling water intake structure. The intake of fishes was reduced 90% at stations fitted with the the prototype velocity cap.

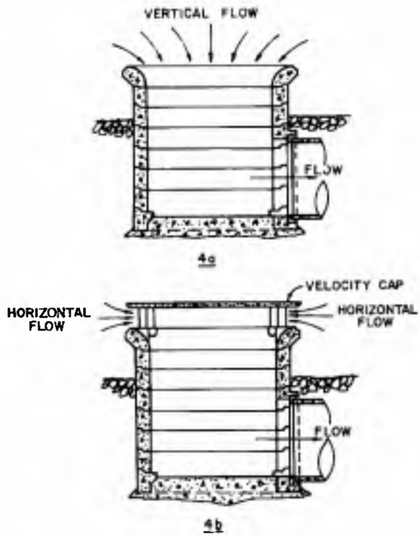
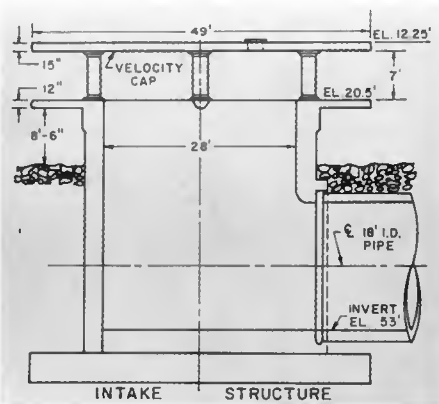


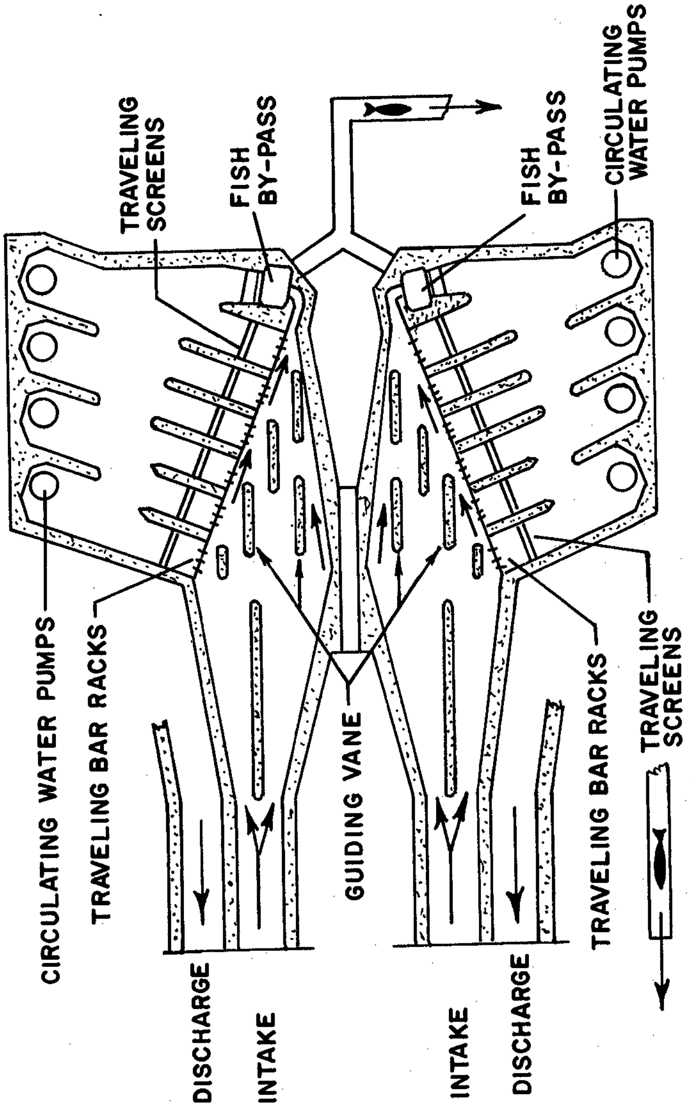
Figure 4.- CONVENTIONAL INTAKE STRUCTURE 4a WITHOUT VELOCITY CAP & 4b WITH VELOCITY CAP

Since the cooling water requirement for San Onofre, Units 2 and 3, is much greater than other plants, it was deemed necessary to develop further means of reducing fish mortality. In 1972, the Company sponsored additional studies to minimize fish entrainment at offshore intake structures and to safely remove fish already entrained into the generating stations' screen wells[5].



San Onofre Units 2&3
Figure 5

These later studies resulted in a slightly modified velocity cap design for San Onofre, Units 2 and 3, Figure 5. The Units 2 and 3 velocity cap design provides a lip extending out about 8 feet (2.5 m) from the vertical riser and a lower intake velocity.



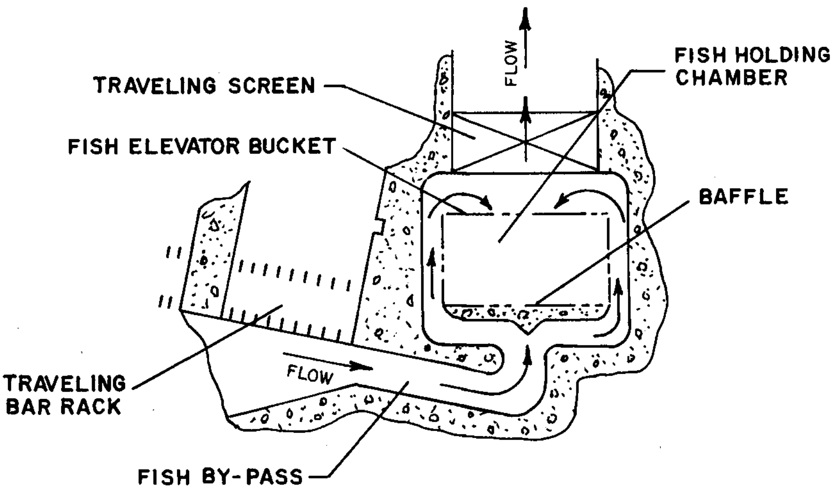
SAN ONOFRE SCREEN WELL CONCEPT

Figure 6

This geometry provides a uniform flow profile across the entrance. Water enters the structure at a velocity of approximately 1.7 feet per second (1/2 m per second) through the circumferential opening.

The fish conservation studies done in 1972 also resulted in a fish conservation system being incorporated into the design of the circulating water system for Units 2 and 3. A plan of the screen wells is shown in Figure 6. Each unit's screen well has a guiding system, fish collecting chamber and fish elevator. The screen well incorporates a system of traveling bar racks and screens to prevent large objects from entering the pump well. It was found that the design most effective for conserving fish was a concept that set the screen well at an angle to the flow stream. The first line of trash removal, trash bars, is positioned at an angle to the flow. Tests showed that all species of fish could be guided with trash bars at right angles to the frame and the frame set at an angle of 30°or less to the flow.

Fish that have entered the circulating water system are guided into the fish collecting chamber, a still water area, shown in Figure 7. A constant flow of water enters the chamber and flows through the screens at the back of the chamber, but fish are prevented from going further. Fish hover over the fish elevator bucket at the bottom of this chamber. The elevator (Figure 8) is a bucket which is periodically raised carrying fish, in water, out of the structure and deposits them into a gravity-flow sluicing channel. A common 4 foot (1.2 m) ID fish return conduit returns entrapped fish, unharmed, to the ocean. The velocity in the fish return conduit is about 5.3



FISH BY-PASS
AND HOLDING CHAMBER

Figure 7

feet per second (1.6m per second). Only one fish return conduit is required to serve both units, since each system will operate only a few times per day.

The fish outfall, shown in Figure 9, is in about 15 feet (5 m) of water and is approximately 2000 feet (610 m) offshore. The plan view of the circulating water system, in Figure 2, shows the location of the fish outfall. It is estimated that the fish conservation system, together with the velocity cap will reduce fish loss by more than 99%.

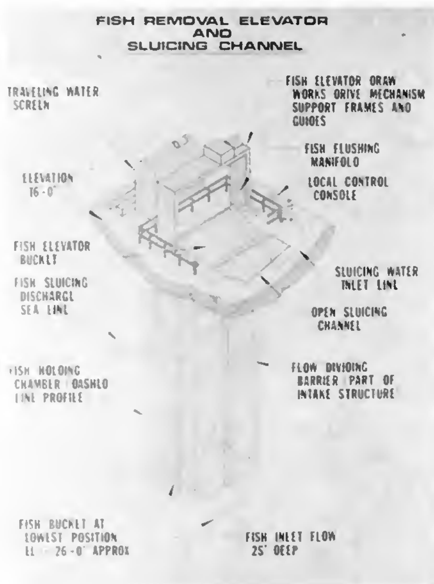
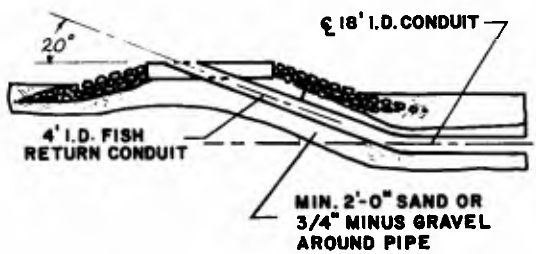


Figure 8

CONSTRUCTION

Site preparation for Units 2 and 3 began in the first quarter of 1974. As of August 1, 1976, construction of this facility was approximately 22% complete. In connection with site preparation for the new units, approximately 2,350,000 cubic yards (1,795,400 cubic meters) of spoil material was excavated from the bluffs. The surface terrace deposit material was disposed of at designated inland sites. The remaining material excavated from the underlying, very dense, fine to course sand, consisting of approximately 350,000 cubic yards (267,400 cubic meters), was deposited along the beach in front of the plant site to be redistributed by natural wave action for replenishment of the beaches in the area.

Figure 1 shows an offshore pad, constructed to serve as a laydown area and to allow the construction of the shore portion of the circulating water system and its interface with the offshore conduits, in the dry. The pad is about 1000 feet (300 m) long and extends



FISH OUTFALL STRUCTURE

Figure 9

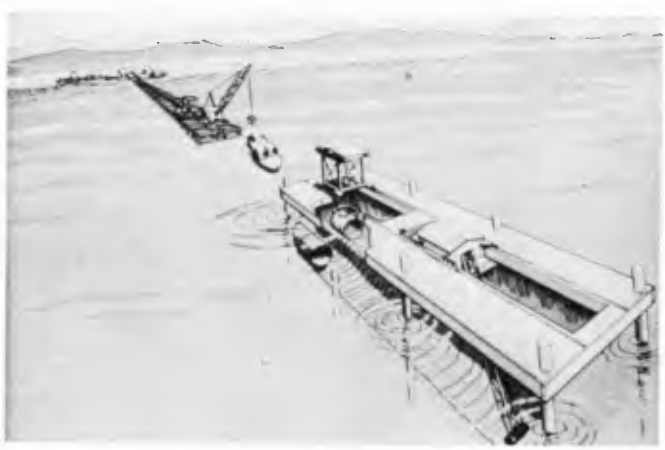
about 300 feet (90 m) offshore. It was constructed by depositing sand from the site excavation offshore, and then driving sheetpiling around the area. One can see that the pad acts as a groin and sand has built up on the northerly end. After the construction is complete the sheetpile wall will be removed and the shoreline will revert back to its normal configuration.

This was the same method used for the construction of Unit 1. From our experience with Unit 1, it is estimated that the shoreline will regain its original alignment with a somewhat wider beach within two years and within 5 years will be back to its original location.

Figure 10 is an artist rendering of the offshore conduit construction. A tressel will be utilized out to about 3000 feet (900 m) offshore, from there a jack-up barge will be used. The dimensions of this barge are about 100 x 300 feet (30 x 90 m). The 18 foot (5.5 m) ID pipe will be layed in 24 foot (7.3 m) sections, buried beneath the ocean bottom, with approximately a 4 foot (1.2 m) cover.

ENVIRONMENTAL IMPACT OF CONSTRUCTION

Extensive environmental monitoring is being conducted during construction to measure the effects of this activity. The monitoring programs include periodic examination of local beaches, intertidal cobble beds, established benthic stations and local kelp beds. The



Laying of 18' ID Cooling Water
Conduits Offshore of San Onofre

Figure 10

monitoring programs are designed to monitor mainly the effects of the construction dewatering discharge into the ocean, the offshore conduit construction and the disposal of sand on the beach. The programs include the following: (1) Water samples of the discharge into the ocean from the construction dewatering and hydrotesting operations are taken and analyzed weekly; (2) Aerial photographs are taken to record the areal extent of visual turbidity present in the ocean and to record placement of sand spoil on the beach; (3) Monthly, beach profiles are taken and bi-monthly intertidal cobble beds in the area are surveyed to determine the amount of inundation, and subsequent re-exposure, of the rocky substrate from sand disposal and from natural conditions; (4) Quarterly, marine biologists conduct intertidal, benthic and local kelp bed surveys.

To date, no irreversible effect upon the local biota can be attributed to the construction activity.

ENVIRONMENTAL IMPACT OF PLANT OPERATION

Heat treatment is the method used by the Southern California Edison Company for the control of fouling organisms within the offshore conduits. Coastal power plants presently heat treat approximately every 5 to 6 weeks by raising the temperature of the discharge to approximately 115°to 125°F (46°to 52°C). Presently, a study, as mentioned above under "Effluent Limitations", is being conducted to determine the optimum mode of heat treatment to control fouling organisms while minimizing adverse effect on marine life. This study consists of the following:

(1) Fouling organism temperature tolerance and growth rate studies.

(2) Data collection on fish and macroinvertebrates lost during heat treatment operation at Unit 1.

(3) Receiving water plankton study.

(4) Heat treatment plankton mortality study.

(5) Investigations of alternate methods for controlling marine fouling.

(6) Heat treatment thermal plume assessment.

(7) Report on method to minimize nekton entrainment.

These studies will permit the Regional Water Quality Control Board to set precise limits on the frequency, temperature, and duration of heat treatments. The heat treatment study is in progress and will continue through December of 1978. Preliminary data indicates that it may be possible to reduce the frequency, temperature and/or duration of the heat treatments, while still providing protection against excessive marine fouling growth.

An evaluation of the effect on the marine environment of operation of San Onofre Unit 1, and predictions of the effect from Units 2 and 3, is made possible by the San Onofre Unit 1 marine monitoring program in existence since 1963. The monitoring program includes both oceanographic and marine biological studies, and is independent of the monitoring being done for the construction. This program, conducted by consultants, is presently being carried out for Southern California Edison Company, by the Lockheed Ocean Laboratory of San Diego, California. An analysis of the environmental monitoring programs and the predicted thermal addition, show that there will be no adverse effects on the environment from the thermal discharge of Units 2 and 3 and that protection of the beneficial uses of the receiving waters at San Onofre is assured.

In addition to the above monitoring programs, a completely independent program is required as part of the permit process for San Onofre, Units 2 and 3 by the California Coastal Zone Conservation Commission. This program, as were the ones previously mentioned, is an extensive study of the marine environment in order to predict and eventually measure the effects of the proposed new generating units. This work, presently in progress, emphasizes the zooplankton and larval organisms, as well as evaluates compliance with regulatory requirements of state and federal water quality agencies.

It was specified that the California Coastal Zone Conservation Commission program should be designed and conducted under the direction of an independent Marine Review Committee consisting of 3 persons with professional experience in marine biology; one to be chosen by Southern California Edison Company, one to be chosen by opponents of the project, and one to be chosen by the Commission.

The Marine Review Committee program plan has been developed around two elements. The first is a comprehensive definition of the marine ecosystem as it now exists offshore in the vicinity of San Onofre. The second is the development of a predictive model that will utilize data from a special biological program, along with data from the operation of San Onofre Unit 1, to predict the perturbations that will be caused by Unit 2 and 3.

The special biological program has been developed to cover the main ecological elements of the offshore communities and to emphasize those groups that were expected to be the impacted most by plant operation. The biological program covers 6 major study areas:

(1) Determination of the area of ocean affected by the power plant cooling water intake system.

(2) Fish population dynamics as influenced by the cooling water system.

(3) Thermal effects on the structure of benthic ocean communities.

(4) Fish entrapment.

(5) Planktonic organisms entrainment into the intake.

(6) Development of mathematical models using data from the above elements to identify important relationships, test hypothesis, and redirect the program.

Results have not yet been obtained from these studies. The cost of these independent studies will be borne entirely by Southern California Edison and San Diego Gas & Electric Companies.

CONCLUSION

The greatest impact of "borrowing" ocean water for power plant cooling purposes occurs in altering the marine ecosystem immediately around the cooling system's intake and discharge structures. One of the principal environmental concerns in the design of intake systems is possible entrainment of marine organisms. In the design of discharge systems, acceptable limitations of waste heat additions to the receiving water bodies and the rapid dissipation of heat at the discharge outfall should be the main considerations. These considerations and efforts to mitigate adverse effects to the coastal environment have resulted in some unique design features for Units 2 and 3.

Marine monitoring programs, which are part of the project, provide ongoing surveys of the effect of all phases of plant construction and operation. Monitoring programs concerned with temperature dispersion and ecosystem changes indicate that the San Onofre, Units 2 and 3, outfall structures will have little impact upon the San Onofre area. The information obtained can be applied to the siting and design of future power facilities, and will serve as a contribution to basic biological and oceanographic research.

San Onofre Nuclear Generating Station Units 2 and 3 will make it possible to meet the growing public and industrial demand for power, while meeting the legal and social constraints related to environmental concerns.

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