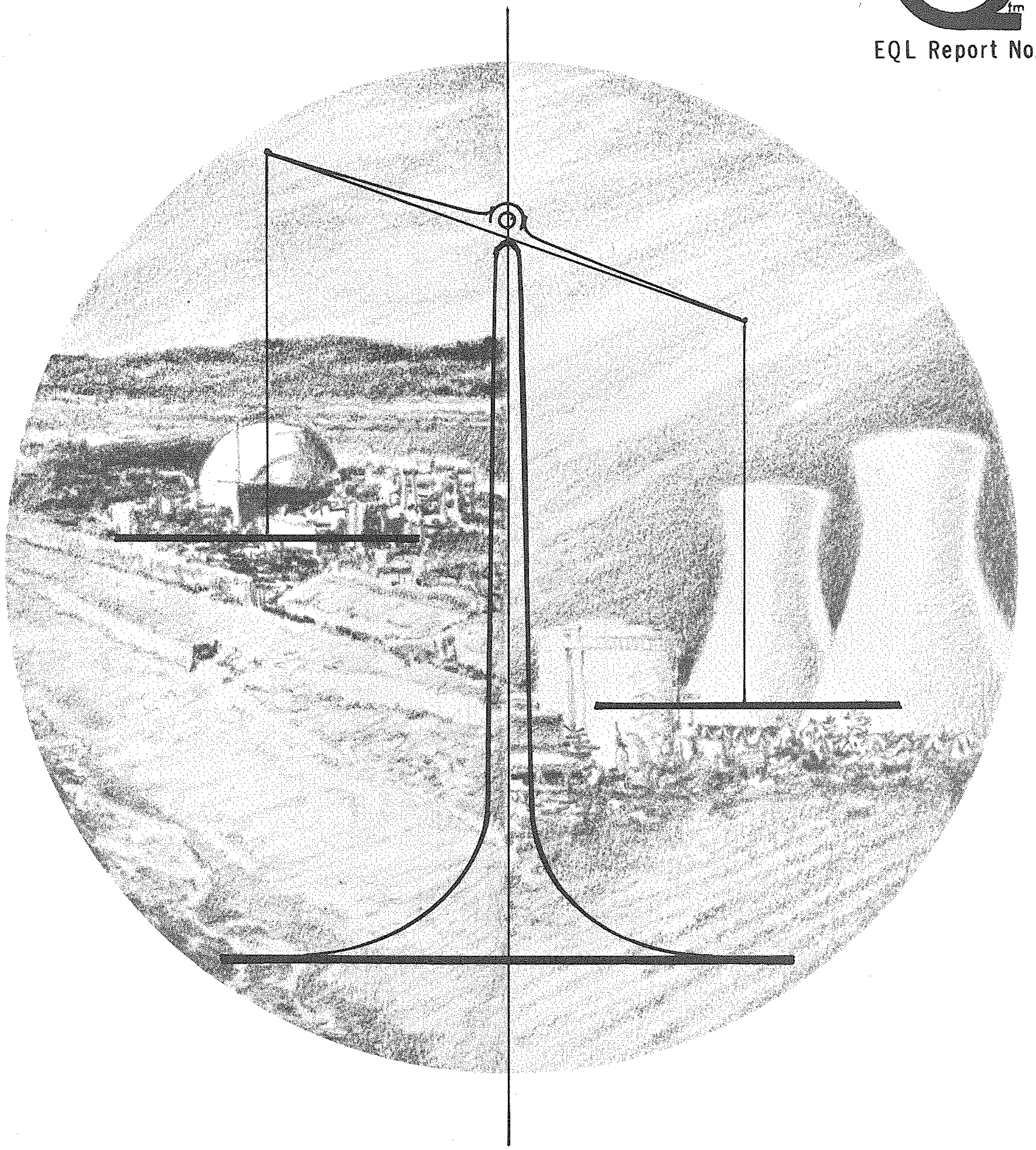
Siting Nuclear Power Plants in California
The Near–Term Alternatives

By MARTIN GOLDSMITH

EQL Report No. 8



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July 1973

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"However, without a major breakthrough in other types of cooling, the need for seawater cooling will continue to dictate the siting of the major portion of our nuclear power plant capacity within a relatively short distance from the oceans. . . .fresh water will soon become too precious to use consumptively for cooling when there are alternatives."

—Siting Thermal Power Plants in California,
State of California, The Resources Agency,
February 15, 1970.

I. INTRODUCTION

There are many issues presently being debated concerning the generation and utilization of electric power in California. Some are peculiar to a specific area, such as the level of air quality and how it is influenced by fossil-fuel power plants. Others are of general applicability, such as high-level waste disposal from nuclear reactors, which is of global concern.

It is the purpose of this study to investigate one particular aspect of the power problem. This is the question of the relative desirability of locating nuclear power plants at sites along the California coastline or at inland locations. In this introductory section, the basic problem will be outlined, including expected growth in electrical usage, and the nature of the controversy, which lies in the allocation of limited resources.

In subsequent sections, the environmental impacts of coastal and inland plant siting will be discussed in general, without reference to specific locations. Conflicting demands for limited resources (namely, the coastline area and cooling water supply) will also be explored and evaluated. Finally, with the aid of this generalized information, a comparison will be made of the siting alternatives.

A. Electric Energy Growth

The growth in electrical capacity and consumption in California has been studied extensively, and projections of future growth trends have been made. These studies and projections range in sophistication from the elaborate area-by-area analysis performed by the utilities themselves to simple extrapolations of past patterns.

A succinct summary of the California situation is given in several recent publications.[1,2] In the last decade, electrical consumption and generating capacity have been growing at a rate of approximately 8 percent per annum. The authors go on to estimate that if past patterns remain unchanged, growth will continue during the next ten years at a rate between 5 and 7 percent. They also point out that the difference between these numbers over the short term is not too significant, but over the long term, owing to their exponential nature, the growth curves will diverge widely, even for these apparently small differences. Thus, in ten years, at a 5-percent annual rate, a 63-percent increase in consumption is forecast; at 7 percent, the increase is 96 percent. Over a 20-year period, the increase is 157 percent for the former, and 286 percent for the latter.

There being no way to narrow this range of uncertainty, nor any certainty that the increase in consumption lies within the projected range, plans for the future power-plant siting must encompass the range of likely growth. The present lead time of five to ten years for the construction of generating and transmission facilities clearly poses a major problem for those concerned with orderly development. Nonetheless, the problem must be faced. To greatly reduce the growth rate below present levels will require changes in life style and commercial enterprise. There is, however, no mechanism for accomplishing this at the present time. Clearly, such changes require at least a few years for their accomplishment. Similarly, increases in the growth rate seem unlikely for the near future. To assume a 7-percent growth rate for this decade, then, is a reasonable supposition. Substantial deviations from this rate, if they occur at all, would tend to appear toward the end of the 70's, and would, of course, influence planning for future periods. (For an examination of the effect of growth rate change on the power plant siting problem, it may be fruitful to consider the situation where growth proceeds at a constant rate, thus, at a diminishing percentage rate. This assumption would reflect a situation in which conservation measures were being taken.)

The baseline from which these projections begin can be obtained from the Environmental Quality Laboratory (EQL) document previously cited. In Northern California, peak demand in 1972 was about 11,000 MW, which for a 20-percent margin (for maintenance and outage) calls for about 13,000 MW installed capacity. Available sources exceed this value at the present time. In Southern California, peak demand in 1972 was about 14,000 MW, and the 20-percent margin suggests that a 17,000-MW installed capacity is appropriate. Installed capacity, however, is barely keeping ahead of this level.

Proceeding from the base given, considering a 7-percent annual growth, 1200 MW per year should be added in Southern California at this time, and 900 MW in Northern California. In 1977 these values would be 1700 MW and 1250 MW, respectively. In 1982 the growth values would be 2400 MW per year in Southern California, and 1800 MW per year in Northern California. It is expected by many that nuclear power will be dominant in future years. The large nuclear reactors presently being installed will provide from 960 MW (Rancho Seco #1) to 1060 MW (Diablo Canyon #1), and projections for the future indicate that units of up to 1300 MW may be available. Thus, it is sobering to note that if most growth is met by nuclear power, in ten years perhaps three to four large nuclear units per year will be required; at present, the system of site selection, licensing, and construction is evidencing symptoms of constipation at the rate of far less than one unit per year.

However, part of the present generating plant growth includes pumped storage and fossil-fuel plants. But, within ten years, it is expected that pumped storage sites will not be available and that fuel shortages, price increases, and environmental restrictions might inhibit fossil-fuel plant construction. Thus, the nuclear units would be expected to fill the breach, provided the basic issues of safety and waste disposal can be resolved.

On the other hand, if good progress is made in gasifying coal, in alleviating the effects of strip mining, and so forth, much of California's power needs might be met by a remote coal-fueled generating capacity. If so, the nuclear siting problem would be substantially reduced. Meanwhile, it is prudent to consider the possibility that the above-mentioned levels of nuclear plant construction will be necessary.

B. Siting Requirements

A variety of physical factors must enter into the consideration of site selection. The basic requirements are clearly apparent. First, an actual building site is needed; that is, the utility must be able to acquire the necessary land. Second, in the case of nuclear plants, the land must be surrounded by an area in which human population and activity are limited in order to satisfy the safety-related criteria formulated by the Atomic Energy Commission (AEC). Consequently, use of most urban areas is precluded. This restriction is discussed in Section III. Third, the site must bear some reasonable geographic relationship to the utility system served. Considering the cost and environmental impact of transmission lines, this aspect deserves careful attention. Likewise, the site must offer reasonable access for the transport of equipment and personnel. Fourth, the site must offer suitable building conditions. In most areas of the country, this requirement may be restricted to consideration of foundation soil structure, and sometimes avoidance of areas subject to flood or other natural hazards. In California, a most serious additional problem is posed by the possibility of earthquakes. In this state, perhaps more attention has been devoted to this aspect of site selection than any other. The importance of this aspect is emphasized in Section III.

Finally, all thermal power plants require a means of cooling. It is possible that in the future, air-cooled (dry tower) plants will be built; but at this time, experience with them is limited. In the near term, cooling methods depend on a source of water, and this aspect will be a primary subject of study in Section IV.

C. Range of Siting Options

At the present time in the United States, power plant sites could be grouped into four classes. The first is coastal, where the plant is sufficiently close to the ocean that its cooling requirements are met by the once-through flow of ocean water. The second class includes plants built in proximity to lakes or rivers whose waters may be used for once-through cooling. The third class is a variant, where the body of cooling water is a small lake or pond whose prime purpose is plant cooling. The fourth class employs cooling towers, which need not be in proximity to any natural body of water. Here water is recirculated through the cooling towers, and make-up water can be supplied by various means.

In addition to these presently used classes of siting, other more novel possibilities may be open. For example, Offshore Power Systems, Inc., is developing the concept of barge-mounted nuclear power plants to be floated behind breakwaters on the continental shelf. This is being vigorously pursued on the Atlantic Coast, where the continental shelf is broad. In California, however, water depth drops off sharply near shore, in most places. The EQL is completing a study of this concept as applied to California conditions. In Europe, underground sites have been employed, and the EQL, with The Aerospace Corporation, is studying underground siting for California. The desirability of these schemes, however, is not yet established, although the previously discussed types are employed at various locations throughout the United States.

In California, coastal and inland siting has been employed. The nuclear plants at Humboldt, San Onofre, and Diablo Canyon are immediately adjacent to the ocean, and use its waters for cooling. On the other hand, the Rancho Seco plant, nearing completion near Sacramento, will use canal-fed cooling towers, and numerous fossil-fuel plants now in operation employ cooling towers at inland sites.

There are few large rivers or lakes in California, and their use, or misuse, is already a subject of concern. The regulations of the State Water Resources Control Board effectively preclude once-through cooling with natural inland waters. Even in other states, whose natural bodies of fresh water greatly exceed California's in number and size, power plant cooling is under sharp scrutiny, and restrictions on the use of once-through cooling are increasing. Thus, this category of site is not a realistic possibility in California except, perhaps, at a very few locations.

The use of cooling ponds cannot be ruled out, however, since they avoid the visual impact of large cooling towers, and if properly designed, can offer a recreational resource. Dr. John List, of Caltech, has made calculations of the water consumption of cooling ponds through loss by evaporation. His interesting conclusions, borne out by other independent calculations, state that the cooling pond uses more total water than an equivalent cooling tower. However, if the pond exists anyway (and all such bodies lose water by evaporation) the incremental consumption caused by its use as a cooling pond is lower than that of the cooling tower. Thus, if water is scarce, using an existing body of water as a cooling pond is favorable, but creating one is unfavorable. It may be that in California existing bodies of water, such as reservoirs, might be found suitable for use as cooling ponds. In comparison to cooling towers, the capital investment is apt to be less, and the water consumption is lower. However, considering the useful functions of reservoirs, for both recreation and as a water supply, the environmental impact may preclude such applications, since heating the reservoirs might jeopardize their other uses.

Thus, for a first cut at the comparison of near-term siting alternatives, attention will focus on coastal sites and inland sites using cooling towers. Some basic issues dividing advocates of coastal and inland siting arise from the commonly held (but not necessarily correct) presumption that inland sites have less environmental impact but are more expensive. Thus, we examine the inland site with minimum impact (maybe) and maximum cost (possibly) to gain further insight into the actual environmental and economic issues.

D. The Controversy

The controversy in this instance can be fairly simply drawn. Coastal siting is resisted because nuclear plants must be situated on remote portions of the coastline, thus altering the natural state there. The concern of California's citizens for their coastline was reflected in the passage of the Coastline Initiative in 1972. Moreover, some suspect that the use of sea water as a coolant will have a detrimental effect on the ocean. On the other hand, coastal siting is preferred by many because remote sites can be found, and the cooling requirements are expected to be met inexpensively, as compared to other alternatives.

The other side of the coin is inland siting using towers. Some feel that sufficient areas of lesser import, environmentally, than coastal sites can be found and should be used. However, water for cooling towers is required, and a substantial body of opinion holds that this is an inefficient and improper use of a precious resource.

Thus, the question finally comes down to the relative worth and proper utilization of two finite and precious and overworked resources – California water and California coastline. After briefly reviewing the environmental impacts of coastal and inland siting in Section II, the subjects of availability of coastal sites and availability of cooling water will be treated in Sections III and IV. Further site evaluation will be offered in Section V.

II. ENVIRONMENTAL IMPACT OF POWER PLANT SITING

The environmental impact discussed in this section will concern the non-safety related aspects of nuclear power plant siting and operation. Presently, all new plants must operate within strict AEC criteria for radioactive emissions which have been judged to offer adequate protection as far as the population is concerned, either from direct effects on people, or from indirect effects through food chains. These matters are extensively treated in the environmental impact statements for an individual plant, and more particularly in the safety analysis reports that must be submitted to the AEC before a construction license is granted for a nuclear plant.

Considerably more controversy surrounds the issue of safety in the case of an accident in the nuclear plant. This topic has been the subject of hearings and deliberations under AEC auspices, and is not considered in this study because the sole purpose of the study is to compare the desirability of various near-term alternatives for the siting of nuclear power plants in California. If it were found that all nuclear plants are basically unsafe, the study would no longer be relevant; if, however, the plants were found to be safe regardless of where they are sited, then the issue is not important in comparing alternate sites. A possible conclusion of the Emergency Core Cooling System (ECCS) hearings may be that existing plant designs must be de-rated to assure safety. There is also the possibility that the ECCS review will have the results that ECCS failure shall be considered a credible accident. (ECCS failure is not presently considered a credible accident, and is not taken into account in site evaluation and plant licensing.) In this instance, new containment design criteria, geological criteria, and requirements for very remote siting may be necessary. Perhaps even novel siting methods, such as undergrounding, would be suggested. At this time, it is not appropriate to speculate as to the probability, or, much less, the nature of such additional siting constraints. Therefore, it is assumed that the class of plants presently licensed and built are satisfactory and are candidates for various siting alternatives. It is repeated, however, that for the purposes of this study, this "ground-rule" remains only an assumption, not an assertion.

A. Coastal Sites

1. Visual

It is, of course, difficult to evaluate the visual impact of any construction because of the subjective nature of the aesthetic judgments required. In a setting of great natural scenic value, any man-made structure is an intrusion – usually an unwelcome one. On this basis then, a power plant will in some cases be of obvious impact. In some areas, however, man-made structures already exist, or the presence of such structures may be acceptable. However, not all structures are equally acceptable. In some cases, one might even argue that the grandeur of the natural setting may be enhanced by a man-made structure. Many people hold this opinion, for example, concerning the Bixby bridge, in the Big Sur coast area. Nuclear power plants, however, are not usually considered to be of inspired design in an aesthetic sense. On the other hand, they generally represent good examples of industrial architecture, and tend to be simple of form, of regular geometry, and relatively free of functional or decorative excrescence. In point of fact, the largest visual impact is often due to the switchyard structures which are almost invariably constructed adjacent to the nuclear power plant itself. The switchyards, first of all, are large. At one coastal site in California, the area occupied by actual buildings and their immediate surroundings is five acres, whereas, twenty-three acres are required for switchyard structures. At one inland site, the actual reactor buildings and ancillary structures occupy two acres, versus five acres devoted to the switchyard. Switchyards, moreover, are comprised of ungainly towers and a multitude of busy wires.

Short of burying them, there is little that one can do to eliminate the visual impact of the power plant itself; the reactors are massive and must be contained; likewise, the turbines and the auxiliary buildings are major constructions. Here, only good architectural design can mitigate the effect. In the case of switchyards, however, there is a technical possibility that might be exploited to minimize the visual impact. They can be placed entirely within buildings and greatly reduced in area and volume. This is accomplished through gas insulation, rather than air insulation of the conducting elements. The gas commonly used for this purpose is sulfur hexafluoride. This concept is relatively new, but the cost and practicality are worthy of detailed examination.

There can be further visual impact in the region of the power plant itself, owing to the power lines that must be used to transmit power into the transmission and distribution system of the utility. This effect can be mitigated by the undergrounding of the power lines. It has been argued that the high cost of such undergrounding (approximately a factor of ten increase, as compared to conventional transmission) is too expensive and technically too difficult to be considered for long distance, high voltage transmission. However, it may be possible to underground the lines for a few miles in the immediate vicinity of coastal plants, if indeed the visual impact of the plant could be made more acceptable by so doing. Present technology will support underground transmission up to a voltage of approximately 230 KV, but higher voltage underground cable is still in a developmental stage, and many of the lines serving major power plants are at 500 KV.

2. Recreational

The power plant need not physically interfere with use of the beach itself. Indeed, this is the case at several Southern California Edison (SCE) plants where the actual construction is set back from the beach, with water intakes and outlets passing under the beach and into the ocean. Thus, there is no effect on beach recreation. In some proposed designs, a small area of beach or coast is directly affected, where water intakes and discharges are located on the land-water interface.

The presence of power plant structures need not restrict camping, walking, birdwatching, fishing, and so forth. There is no doubt, however, that the presence of a power plant definitely interferes with contemplation of unspoiled nature for some distance away from the power plant. The nuclear power plants produce no loud noises, smells, or other interferences with noncontemplative recreational pursuits. In certain cases, it is possible that ancillary structures built in connection with the power plant may actually enhance the recreational value of an area. For example, in several locations it is proposed to build breakwaters in order to protect intake structures for the cooling water. Such breakwaters, if sufficiently large, might offer protection for small boat activity. Even the smaller structures may provide additional habitat for fish and a means by which the fishermen can gain access to the habitat. When power plants are installed, a substantial road must be constructed into the area for the use of construction workers and to permit the transport of material. Such a road can give access to an otherwise unavailable coastline; but is should also be noted that this may permit ready access to an otherwise unspoiled coast. Here again is an example of the argument that rages between advocates of recreation for the masses and advocates for areas difficult of access and available only to the few willing to make the effort to reach them.

3. Commercial

In the selection of sites for nuclear power plants, not only present population distributions are considered, but the likelihood of future development is estimated and weighed in the decision. The problem has not yet arisen in the case of nuclear power plants, but it is clear from consideration of other construction, such as oil refineries, air fields, and the like, that sites originally isolated and desirable for industrial development are overtaken by expanding community development, and a conflict quickly develops between the old and the new users. In the case of nuclear power plants, such encroachments would violate the intent of the AEC's population restriction criteria. At the present time, no mechanism exists to prevent such encroachment except through the denial of construction permits by local officials. Assuming, however, thoughtful, rational decisions on the part of local zoning authorities (with the possibility of more encompassing legislation that would prevent such encroachments), the presence of a nuclear power plant can clearly stop development in a widespread area. The desirability or undesirability of this fact can be determined only on a case-by-case basis. The coastal plan to be developed by the new Coastal Commissions is expected to deal with this land-use allocation.

4. Atmospheric

Emissions of conventional air pollutants (nonradioactive) from a nuclear power plant are essentially zero; thus, there is no impact on air quality from a coastal power plant. AEC regulations limit routine radioactive gaseous releases to levels that will cause no harm to people or other living things.

5. Terrestrial Wildlife

Once constructed, a nuclear power plant has relatively little effect on neighboring wildlife. Plant operations are nearly silent, and relatively few personnel are required to conduct operations. Permanent effects are caused, of course, by the fact that habitat has been removed or disturbed over the actual area of the plant. The more significant impact may occur during construction of the plant, where noise, dust, transport of goods, and personnel may drive away most wildlife, which generally avoid human company. The importance of these effects can be gauged only on a case-by-case basis. If the plant is otherwise acceptable, this effect would prove to have major impact only if rare or endangered species occupied the general area of the plant construction zone.

6. Oceanic Effects

The most commonly voiced environmental concern caused by coastal plant siting is the effect upon the ocean. Discharges of radiation, chemicals, and heat must be considered. In the case of radiation, the AEC guidelines for nuclear plant emissions strictly limit the escape of radioactive materials into the cooling waters which are returned to the ocean. The regulations take into consideration such factors as concentration of various chemicals by organisms in the food chain, and are written so that the permitted releases of radioactive chemicals, even if concentrated by organisms known to be present, and which are then consumed heavily by man or other organisms, will not present a hazard.

Chemical releases from nuclear plants are usually not a problem. However, special precautions are necessary in some cases. For example, in order to prevent the growth of marine organisms in the cooling water passages, chlorination of the cooling water is practiced periodically. However, the injection of the chlorine chemical is so controlled that the residual amounts remaining at the point of cooling water discharge will present no hazard to the oceanic environment. Other than this, chemicals are not ordinarily discharged in any amount into the cooling water stream. However, over the lifetime of the power plant, some corrosion of the copper-bearing condenser tubes does take place. Estimates have been made which indicate that up to 1000 pounds of copper might be deposited into the ocean each year.[3] Obviously, this copper would exist only in very minute concentrations at any given time. Nonetheless, concern has been expressed that in some areas, particularly along the East Coast, certain species of oysters, for example, might concentrate this copper in their bodies, conceivably presenting a hazard to the health of those eating them. Such a problem does not seem to have appeared at any point on the West Coast. The problem, incidentally, is not peculiar to nuclear plants, but exists for fossil-fuel plants as well. A careful review of the biological situation at any given power plant site would reveal the possibility of such an occurrence, but it is not considered to be a general problem in the California area.

The discharge of waste heat from the power plant represents the largest effect on the ocean, and is qualitatively the same for both fossil-fuel and nuclear power plants. However, nuclear power plants (per unit capacity) discharge up to 50 percent more heat to the ocean than a fossil-fuel plant. Nonetheless, the problems are the same, and the data that have been gained through years of operation of fossil-fuel plants are directly applicable to the nuclear plant. To put the problem in perspective, it requires over one million acre-feet per year (af/yr) of cooling water (once-through) for a nuclear power plant of 1000-megawatt capacity, if the temperature rise is restricted to 20°F as the water passes through the condenser tubes. Such a flow is equivalent to that of a very substantial river, and could become very serious in a stream even the size of the Sacramento River, the largest in the state of California, or in estuaries, such as some parts of San Francisco Bay, San Diego Bay, or other enclosed areas.

It is known for example, in the eastern United States that the AEC has ordered the Consolidated Edison Company to install cooling towers, rather than discharge the heat from the Indian Point generating plants into the Hudson River. This order was based on the fact that the entrainment of living organisms into the cooling system presents a hazard to the fishery of the area. In another region, southern Biscayne Bay, the direct discharge from a nuclear power plant was thought to present a danger through overheating of the shallow bay, with consequent deleterious effects on the marine organisms present.

In California, the situation is considerably better on several grounds. First, there are deep ocean areas close to shore where power plants might be located. There are slow currents in the ocean, as well as the turbulence generated by wind and wave. Thus, it is easier to obtain rapid diffusion of the heat from a power plant into a substantial area of the open ocean. Submerged offshore discharge conduits can be used for this purpose. As the heated water emerges from the discharge outfall, it mixes with the cooler ocean water and forms a slightly buoyant plume which moves with the ocean tides and currents. As the plume rises to the surface, there is some elevation of surface water temperature, and this elevated temperature causes increased heat transfer to the air by convection and radiation. Thus, the heat is eventually dispersed to the atmosphere. The availability of these physical mechanisms assures that it is possible to reject power plant heat into the ocean without endangering the ocean environment, if proper designs are used and if power plant population is not too great.

The second important factor in California is that State regulations exist to insure that such practices are indeed followed. The Water Resources Control Board, and the Regional Water Quality Control Boards have promulgated regulations concerning the required dispersal of heat from any discharge, including that from nuclear power plants. In addition, State regulations pertaining to the discharge of thermal waste in estuaries and rivers are very restrictive and effectively preclude the use of once-through cooling by a nuclear power plant in such a situation.

For coastal sites discharging heat into the open ocean, the pertinent regulations specify: "that the maximum temperature of thermal waste discharges shall not exceed the natural temperatures of receiving waters by more than 20°F." That is, at the immediate discharge point from an outfall, the temperature may not be more than 20 degrees above ambient. The regulations further specify that, "the discharge of elevated temperature wastes shall not result in increases in the natural water temperature exceeding 4°F at (a) the shoreline, (b) the surface of ocean substrate (that is, the bottom) or (c) the ocean surface beyond one thousand feet from the discharge system. The surface temperature limitation shall be maintained at least fifty percent of the duration of any complete tidal cycle." The meaning of these regulations is that the temperature at the shoreline can never exceed natural conditions by more than 4°F; the ocean bottom temperature, where much of the flora and fauna reside, cannot experience more than a 4°F increase, and that the area of ocean surface that might exceed a 4°F increase in temperature is strictly limited in area. Thus, the type of shoreline outfall presently in use at several locations, and being included in the Diablo Canyon plant of the Pacific Gas and Electric (PG&E) Company, is prohibited in future installations.

One might question whether the permitted four degree increase will have a substantial effect on coastal marine life. The answer seems to be in the negative. California is in a region where cold and warm water species tend to mingle, with warm water species predominating below Point Conception, and cool water species above. Because the warm water species of Southern California are existing at the colder part of their permissible range, some amount of heating is not harmful, and might even prove beneficial. Some cool water species of ocean plants (e.g., bull kelp) are sensitive to any increase in water temperature; thus, their population density may be affected somewhat by even the four degrees. However, it should be recognized that the annual variations in water temperature along the California coast usually exceed four degrees, that the temperature difference between the bottom of the ocean and surface may exceed four degrees, and that, in fact, daily variations in temperature of several degrees are frequently experienced. The Water Quality Control Board selected these values because they felt that the oceanic environment would be protected, and, indeed, data available at this time indicate that the regulations are conservative. Observed effects have been unimportant and acceptable. A possible exception is the 20°F temperature rise permitted in the condensers. Data indicate that a substantial percentage of small organisms entrained in the flow will be killed by the thermal effect. The overall importance of this loss, however, is still not well understood. But since extensive technical literature exists on the subject, detailed arguments are not covered in this document.

Thus, we see that if the Water Quality Control Board regulations are met, thermal discharge into California coastal waters might be considered unimportant. There is, however, one question: can these regulations be met? The answer is in the affirmative for an isolated plant. One straightforward means of accomplishing needed dispersal of the heated water is to use a multiple-outlet diffusion structure, rather than a single pipe exit for discharge of the heated water. This effectively breaks the discharge into numerous smaller jets which mix with a great quantity of ambient water, thus, achieving the wide dispersal of the heat and keeping maximum temperatures reached at the bottom, the surface, and the shore within appropriate limits. This is the method presently being contemplated for the San Onofre expansion proposed by Southern California Edison (SCE), and might well have been the method selected for discharge at the Mendocino plant, proposed by PG&E. The Environmental Engineering Sciences faculty at Caltech has pioneered in the analysis and design of such structures. The penalty, of course, is the added cost in plant construction. At Diablo Canyon, for example, PG&E has estimated in their environmental report[4] that the additional construction cost for the offshore conduit, as opposed to a simple deposition of the water at the edge of the ocean, is 28 to 42 million dollars. Shoreline discharge, which has been practiced at many plants presently operating, does not materially change the marine environment over extensive areas of the ocean; however, areas immediately adjacent to the plant (perhaps over a hundred or several hundreds of acres) have been affected; and it is to avoid these effects that the more elaborate diffusion-outfall designs are required.

Additional environmental effects are possible owing to the requirement for cooling water circulation. The discharge situation has been discussed, but the intakes where water is taken out of the ocean for use in the condensers may also have an adverse environmental effect. This is because, if not properly designed, the velocity of the intake water may entrain marine organisms and sweep them into the pumps, conduits, and condensers of the coolant loop. There are no means by which microscopic marine organisms can be protected from entrainment in the incoming stream. Although these organisms exhibit various degrees of temperature tolerability, there is no question that some of them are killed because of the heating that occurs in the condenser tubes. This is a function of the degree of heating and time of exposure to elevated temperature.

Greater concern has been expressed as to the entrainment of larger organisms, fish larvae, and even small fish which might be swept into the passages. It is possible to prevent the passage of large fish by the inclusion of racks, traveling screens, etc. This serves to protect not only the fish, but also the power plant. In some instances, the installations protect only the power plant; hence, the fish can be sucked against the racks and destroyed. What is being done on the West Coast to protect against this problem is to maintain the intake velocity of the water at very low levels and in the horizontal direction; thus, fish are capable of swimming against the intake suction and can keep themselves from being trapped in the collection mechanism. It now falls to the California regulatory bodies to assure that appropriate intake design practices are used to avoid needless destruction.

It is assumed in the discussion of diffuser outfalls that the warm water is mixing into a cool ocean current. Generally, there are gentle currents on the California coast, resulting from prevailing local winds and the general Pacific circulation. The local current is also affected by the tidal flow, which varies through the diurnal cycle. At some times during the day, the water may be "slack" at the outfall, and the temperature of the buoyant plume could rise somewhat. State regulations, however, provide for this eventuality.

Another difficulty may eventually arise. At the present time, the characteristics of the thermal discharge plume can be predicted and tested (with acceptable accuracy), using analytic and experimental techniques. As the plume moves downstream from the outfall, it spreads and cools. However, the persistence of the plume is not as well understood. If power plants could always be widely spaced, one might feel assured that the effects of an upstream (in relation to ocean current) plant would be dissipated by the time the waters entrained in the plume reached the next plant site, owing to heat transfer to the atmosphere and mixing.

In subsequent sections of this document, however, it will be shown that probably only restricted areas of the California coast can be used for nuclear plant sites. Therefore, it is more likely that some concentrations of plants will occur. If the plume of the first site retains a one-degree temperature rise on reaching another site, and is entrained by the intakes of the second site, the latter site will be able to increase its plume temperature by only three degrees, and so forth. Present methods do not seem adequate to predict such effects; thus, the potential seriousness of the temperature constraint cannot be assessed at this time.

B. Inland Sites

1. Visual

Choosing a site for a coastline plant permits the planner only a single degree of freedom because the coastline is essentially one-dimensional. Freed, however, from the constraint of being near the seashore, the planner now has two degrees of freedom; thus, in principle, the entire area of the region can be considered for plant siting. This additional freedom will permit the environmental impact of the power plant to be lessened, in some regards at least. Nuclear power plants require only small quantities of fuel. Therefore, proximity to major fuel shipping lines is not a key constraint (although means for delivery of the major components are required). As pointed out earlier, once-through cooling using vast quantities of river water is simply not permissible in California. Cooling towers or cooling ponds will be used, and the water supply to replace the evaporative losses from such systems is relatively small and can be brought to the plant from more distant water conveyance systems. Therefore, it will often be possible to select siting areas to minimize visual impacts. Obviously, this can be evaluated only on a case-by-case basis. In a visual sense, one marked feature of the inland plant is the possible use of cooling towers. Although cooling ponds often have the appearance of small lakes, cooling tower structures are large and may be obtrusive. Forced draft towers are relatively low in height and may be more easily concealed from view. However, the large hyperbolic natural draft towers being selected in many parts of the country are enormously high and large in diameter, rising to heights of 300 to 400 feet. In fact, these cooling towers dwarf the balance of the nuclear plant and dominate the landscape where they are situated. It is noted, for example, in the Rancho Seco environmental report[5] that the hitherto featureless flat lands surrounding Rancho Seco provided no landmark features, but now the cooling towers are the most predominant landmark in the area.

2. Recreational

The class of sites presently used for inland power plants and the ones contempleted in planning studies usually involve no impact on recreational use of the land. The siting areas selected were not being used for recreation purposes nor were they areas generally having any great potential for such use. In point of fact, the inland plant may end up yielding a benefit for recreation, if cooling ponds are used, as a rather large lake is created and might be used safely for recreational purposes. Even where cooling towers are used, it is often necessary (as is the case at Rancho Seco) for a small reservoir to be constructed in order to provide cooling water to the plant in case of interruption in the flow of water from the main canal. These reservoirs can be used for various types of water-oriented recreation, or simply as the nucleus for a park or similar purpose.

3. Commercial

Commercial impact of an inland nuclear power plant is exactly the same as that outlined for the coastal siting situation. There is, however, one additional observation that should be made; that is, a great part of the inland siting areas that one might contemplate may be agricultural areas. The nuclear power plant need not interfere with or restrict neighboring land for agricultural use.

4. Atmospheric

The major environmental problem that may result from inland nuclear power plant siting is that of thermal rejection from the cooling system. The total heat rejected by a 1000-megawatt nuclear power plant is equivalent to the solar heat that falls on perhaps three square miles of the surface of the earth. Clearly, the nuclear plant represents a concentrated heat source. In order to dissipate this heat from a cooling pond, 1000 to 2000 acres of surface might be required, but atmospheric heating and evaporation effects are less marked than they are in the case of the wet cooling tower.

There is no doubt that steam plumes from cooling towers can be noticed many miles away from the power plant under some atmospheric conditions and, hence, have a significant visual impact. Additionally, in the immediate vicinity of the plant, droplet fallout from the cloud or plume can be significant in some circumstances. Considerable debate has occurred over the importance of the fog plume from the cooling tower. In very cold climates, it is expected that some parts of the plume may produce ice on nearby roads, thus constituting a serious hazard. This is not thought to be a problem in the inland areas of California, where one might contemplate siting of nuclear plants, i.e., Central Valley or desert areas. However, considerable concern has been expressed that the plumes would tend to be accentuated by normally occurring conditions of stagnation, leading to such things as tule fog. Tule fog is already a serious problem in the Central Valley of California, and the interaction of the power plant and local meteorology is as yet, not well understood.

Experience with existing towers at fossil-fuel plants does not offer unequivocal guidance. For example, SCE has reported[6] that with towers at five locations on their system, ground fogging occurs only at one, but that it is frequent at that location. This station is fairly near the other stations, which do not report fogging. Thus, case-by-case investigations will surely be required to determine the acceptability of the cooling towers from the standpoint of fogging. Likewise, the design of towers will be important (e.g., natural-draft towers, with their great height, will tend to reduce ground fogging).

Concern has been expressed that evaporated water will make the general area more humid. The amount of water evaporated from one nuclear plant (1000 MW) is about equivalent to that evaporated from ten square-miles of irrigated fields. Such evaporation does not usually have substantial impact on local weather.

Another potential environmental problem with cooling towers arises from the phenomenon called "drift." Although most of the water used by a tower leaves as pure vapor, a small amount escapes as small water droplets, which contain whatever salts and chemicals are in the cooling water itself. In the past, very little data have been available on the actual behavior of towers in this regard. Drift rates were assumed to have various values, with 0.2 percent of the circulating water flow being a common quote. A 1000-MW electric plant might circulate water in its towers at the rate of one billion gallons/day; thus, the drift (at the 0.2 percent rate) would be 2 million gallons per day. Even if the salt concentration in the tower were only permitted to reach 1000 ppm (not much worse than the quality of Imperial Valley irrigation water) about eight tons per day of salt would escape in the drift, to be deposited somewhere as the droplets fell or evaporated. (This is roughly equivalent to the particulate matter emitted by a 1000-MW coal burning plant, using low ash fuel and very advanced pollution control equipment to meet the Federal regulations on new sources (0.1 lb/10^6 BTU input). This has been a problem in some tower installations. However, drift eliminators (devices to control the droplet escape) can greatly reduce the problem. Experimental data are now becoming available which indicate that drift rates of 0.01 percent are readily attainable. Thus, the particulate emissions would be less than 800 lbs/day. For greater salt buildup in the cooling water, the solid emissions would be proportionately greater. The solids will be very widely dispersed, and should pose no problem. This calculation is borne out by the environmental report[7] for the Rancho Seco Nuclear Generating Station of the Sacramento Municipal Utility District, a 900-MW unit using natural draft cooling towers. A drift rate of 72,000 gallons/day maximum is estimated, with a total solids content of less than 700 ppm. Thus, less than 600 lbs/day of solids will escape. This amount, diluted as it is in the atmosphere, will in no way approach the strict environmental upper limits imposed by the State and Federal governments on particulate emission from power plants.

5. Hydrologic

A nuclear power plant of 1000-megawatt capacity requires approximately 20,000 acre-feet of water annually for use in cooling towers. The 20,000 acre-feet so used are unavailable for use for other purposes. This question is discussed thoroughly in Section III. There can be additional hydrologic impacts. In order to prevent the accumulation of salts in the cooling tower system, it is necessary to discharge water from the tower, in addition to that evaporated away. This discharged water will have concentrated the salts that were introduced into the cooling tower system from the water supply. All water supplies contain some amount of dissolved solids. In the case of reclaimed or waste water, the solids content may be higher than that ordinarily used for irrigation or municipal purposes, but even water considered to be of good quality has the contained minerals. This mineral-laden outflow, called the blowdown, must be disposed of in some fashion.

If the plant is adjacent to a large stream, the blowdown can sometimes be easily diluted and absorbed into the stream system without harm.* Drainage or sewage systems running to tidewater may be available in some areas. In some areas of the country, oil field brines are reinjected deep into the ground, and such a method has been contemplated for the disposal of salt-laden waters from desalination plants. This method may also be feasible in the case of cooling tower blowdown. One good deep-injection well is capable of injecting over 1000 acre-feet annually, which may be enough to take care of the blowdown from a single nuclear unit, provided the input water is of adequate quality. The use of poorer quality water, which requires larger amounts of blowdown, would increase the required number of injection wells. The cost of such an injection well system is trivial, as compared to the other power plant costs involved. However, not all areas are suitable for reinjection, and precautions must be taken to avoid contamination of useful aquifers.

Another method that is being used in some areas of the Southwest, where cooling towers are in use, is to run the blowdown water into lined ponds and there evaporate it to dryness; the residual salts may then be disposed of carefully, as would any other chemical waste potentially harmful to the environment. Whether hydrologic impact will be important or not is a function of the individual site, but the problem is controllable with known technology and at modest cost.

III. COASTLINE SITE AVAILABILITY

A. Siting Criteria

The issue of power plant siting, particularly of nuclear power plants, on the coastline of California has become highly controversial. To explore the various aspects of the problem, one might begin with consideration of those factors that could act as constraints in any logical process of site selection. These constraints will be discussed in turn, but not necessarily in order of importance.

1. Land Use

First, the coastline is considered a valuable resource. Some concerned with natural values would describe it as an invaluable resource. But even putting such a view aside, its enormous value can be easily measured by examining the cost of coastline on the open market. Thus, the first constraint is that of land value or, looked at from a not strictly monetary standpoint, of conflicting land use. Clearly, some industries find coastal locations of great value or even as absolute necessities, e.g., for transportation. Interest in placing power plants on the coast is based wholly on monetary considerations – the ocean provides unlimited quantities of cooling water at low temperature, offering good plant efficiency at an advantageous construction cost. Because nuclear power plants do not require huge acreage, and because the plants involve enormous construction cost, the price of the land itself is usually but a small fraction of the total capital investment. As an example, consider a hypothetical two-unit plant occupying 500 acres. Total construction cost is of the order of $1 billion; yet, the land price is unlikely to reach even $10 million. Although some coastal areas involve much higher land prices, these are apt to be in developed industrial or residential regions from which nuclear plants are excluded. Thus, cost of land itself will not seriously restrict plant siting. This argument does not bear upon the viewpoint that coastline is invaluable. That point of view, manifested in the passage of the Coastline Initiative in November 1972, provides a non-monetary constraint to land use for which it is presently impossible to express a set of criteria for power plant siting. The creation of such criteria, or a coastline power plant siting plan, was called for in the initiative.

2. Environmental Protection

Another constraint is that of environmental protection. In addition to occupying its site, with whatever effects (visual and otherwise) the power plant may have right there, the plant may affect a much broader region. Usually, these effects come about owing to discharges into the air and water. Nuclear plants emit very little into the air – ordinary chemical pollutants are almost entirely absent, and radiological emissions are controlled to a very low level. Likewise, the nuclear wastes discharged in the cooling water flow are very closely controlled, and radiological effects are minimized.

* However, certain chemicals (such as chromates) are often used in cooling towers to control corrosion and growths. These substances can be harmful, and their discharge must be carefully regulated.

Considerable attention must also be paid to certain chemical discharges. Chief among these is the chlorine injected into the coolant flow to control marine growths that tend to foul the passages and surfaces. Care in design and operation will prevent damage to the ocean from this source. The major cause for concern has been the heat in the discharge. Typically, the cooling water is raised in temperature about 20°F in passing through the power plant. A plant of 1000-MW capacity requires a through-flow of over one million af/yr. The effect of this heated discharge on the aquatic environment has been carefully considered by the State Water Resources Control Board, and regulations have been promulgated to insure that the effects are not significant. The net result is that it is very difficult, or impossible, to site new plants on rivers, estuaries, or enclosed bays. On the open coast, however, it is possible to meet the State requirements by new engineering techniques and at a realistic cost – in some locations at least. Thus, environmental effects on the air are not real constraints on coastline plant siting, but requirements for thermal discharge control may make some locations unsuitable. These environmental questions are covered in more detail in Section II.

3. Distance from Population

Another constraint is that of distance from inhabited areas. The required separations are governed by AEC criteria which consider routine radioactive emanations, as well as those possible in case of malfunction or accident. There are no absolute fixed values for required population separation distance. Nonetheless, an examination of that aspect of the record of license applications for nuclear power plant construction has been conducted and is revealing.[8] Looking at the plots in Figure III-1, taken from the reference, where cumulative population vs. distance from the plant is shown, it is seen that no separation pattern outside the curve shown for the Indian Point site has been licensed. Among many workers, the "Indian Point criterion" has come to be taken as a limit; i.e., no site whose population distance curve lies above the Indian Point curve is acceptable. The Oak Ridge National Laboratory, (ORNL), using U.S. census data, has applied this "criterion" to the coastline of California. The work is as yet unpublished, but the authors[9] have kindly provided the data shown in Figure III-2. Excluded areas, according to the "Indian Point criterion", are shown on the map of Southern California. It is interesting to note that sites are permitted so close to existing population centers. The ORNL workers have also used the population distribution around the existing San Onofre plant as a criterion. The results are instructive; while "Indian Point" permits plants over much of the coastline of Southern California, "San Onofre" includes only a small area at that site, plus an area northwest of Santa Barbara toward Point Conception.

In view of the predictions of continued population growth in California and the known tendency for the population to concentrate in coastal areas, it would appear that the Indian Point criterion, applied to present population density, may be insufficiently conservative. The San Onofre distribution, when plotted on top of the data given in Figure III-1 (see Figure III-3), shows similarity to Palisades and other plants in the mid-range of density distributions. Now, using one or another population density distribution as a filter, the coastline area could be screened for suitable power plant sites, recognizing, of course, that the procedure is only a planning tool.

4. Seismicity

Another serious physical constraint, especially in California, is the seismic risk at a site. The AEC has set no absolute exclusion criteria based on seismic or geologic factors, but the siting guidelines in some ways effectively make some areas far less likely for siting. For example, the draft "Seismic and Geologic Siting Criteria"[10] do not preclude the siting of plants within zones which may be subject to surface faulting. The criteria simply set down a methodology for determining the geographic extent of the zone that might be subject to faulting, and call for a body of investigation to accompany applications for siting in such zones. The criteria also state that plant designs in such zones must be able to accommodate the faulting, with safety.

Although the language of the criteria does not preclude siting in highly seismic regions, even in the zone of faulting, in practical fact there are no accepted design techniques for plants which might be subject to the differential displacements of surface faulting. Several such sites have been considered in California. After lengthy investigations, and often acrimonious hearings and proceedings, the sites have been dropped from consideration. Thus, although no specific approved criteria can be cited which preclude plant sites in highly seismic areas, it is our judgment that such areas realistically should be excluded from consideration, for the near-term at least. At the very best, lengthy delays in licensing will be encountered in many zones in California, and recent history would indicate that sites in zones subject to faulting will be rejected.

Moreover, the seismic situation does not seem to be tending toward less restrictive regulation. On the contrary, some predictive theories for magnitude of ground shaking formerly accepted are now being reconsidered. Much of the data from the San Fernando earthquake of February 1971 have tended to confound simplistic relationships, and in the face of uncertainty, the normal and proper attitude of a regulatory body is to require greater margins of safety.

Our question is: how does the requirement for aseismic design constrain the location of nuclear power plants? In some recent siting-survey activity conducted for the EQL, the AEC criteria mentioned were applied to portions of Southern California, using known fault locations and zones. The areas which would require detailed mapping and investigation, according to the AEC metho-

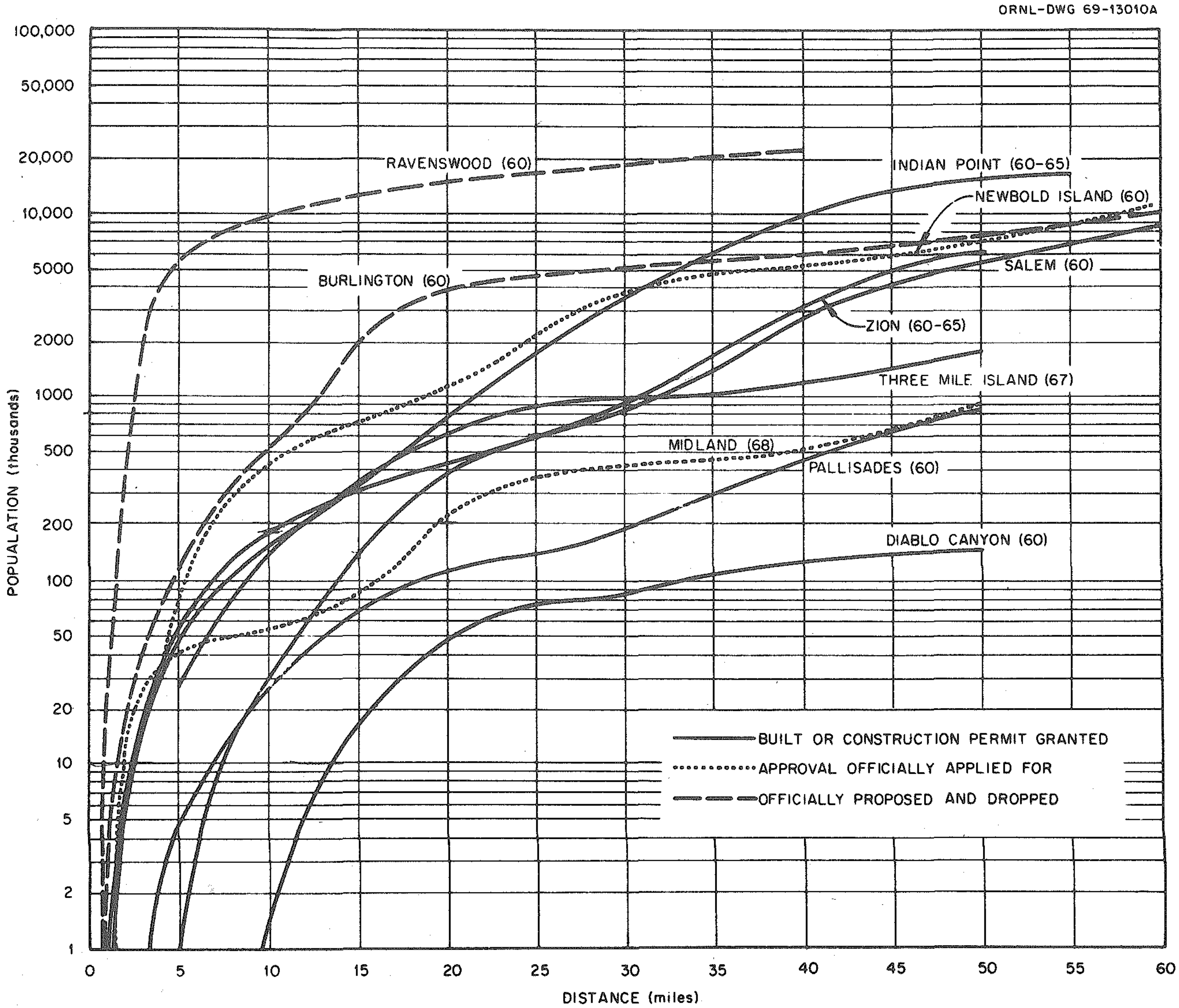

Figure III-1 Cumulative Population as a Function of Distance From Nuclear Plants in the U.S. – from H. Piper and G. West (Numbers in parentheses indicate date of population information.)

Figure III-2 Coastline of Southern California showing exclusions according to Indian Point Criterium.

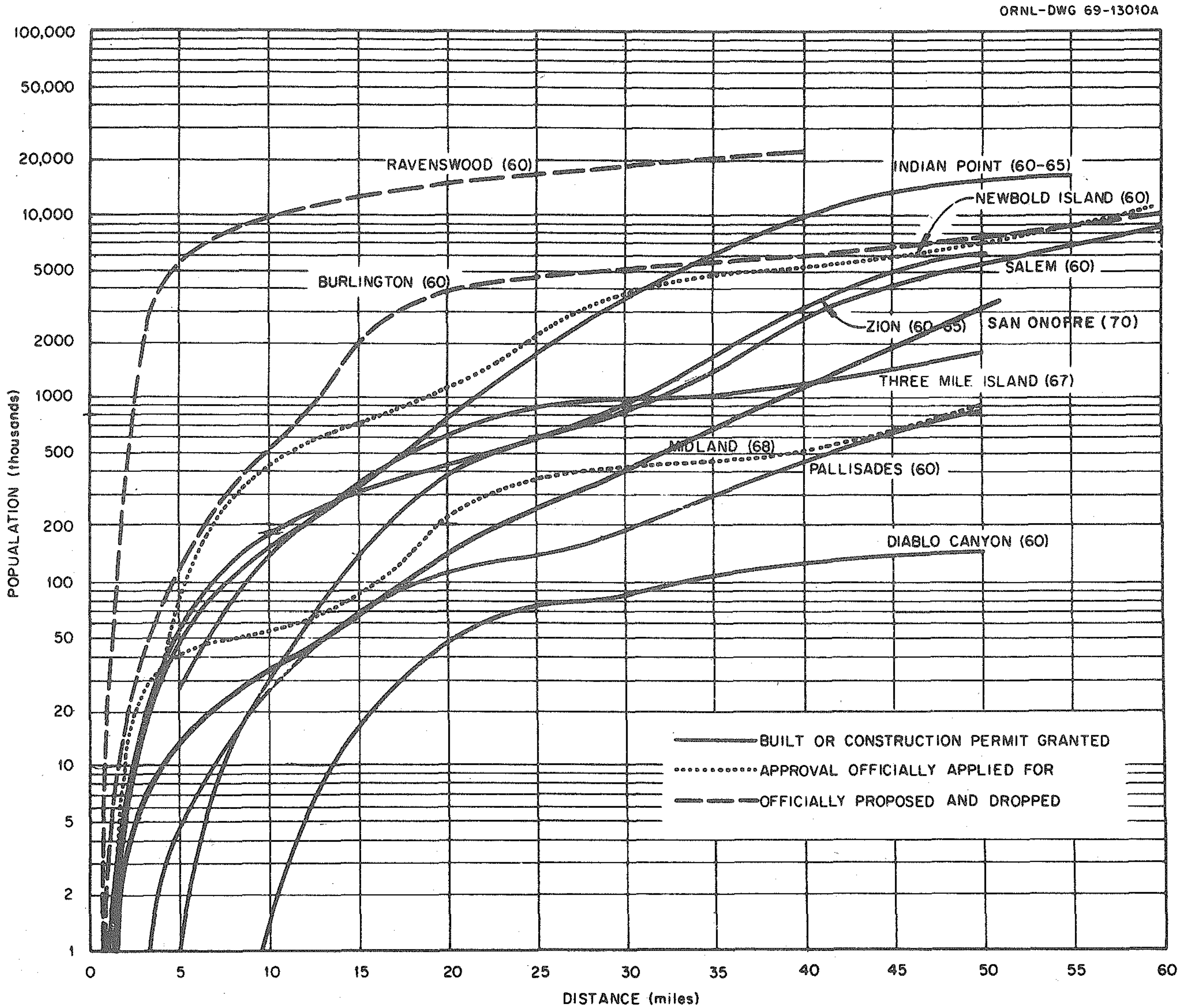

Figure III-3 Cumulative Population as a Function of Distance from Nuclear Plants in the U.S. (Figure III-1 plus San Onofre) dology, were determined. Examination of the results indicated a useful correspondence to the high-risk (Zone III) seismic areas given in a recent study by the State Division of Mines and Geology.[11] (Figure III-4 is reproduced from the reference.) The seismic risk calculation was based on intensity of shaking, using the Modified Mercalli (MM) scale. (Zone III corresponds to expected intensities of MM IX and up.)

There is no generally accepted quantitative relationship between the actual forces experienced in an earthquake and the subjective MM scale. More basically, the relationship of ground shaking to the magnitude of the earthquake is not precisely known. Finally, predicting maximum expected earthquake magnitude for a given fault is an approximate procedure. With all of these various loose relationships, and in the absence of definitive criteria, an authoritative statement as to areas suitable or unsuitable for plant siting cannot be easily made. After all, there has not yet been established an upper limit for earthquake force beyond which a nuclear power plant cannot be designed! Nonetheless, one is left with the feeling that some broad areas are unsuitable for siting, because (a) the geological investigation would prove too difficult or time consuming*, (b) the requirement to accommodate differential movement would need to be imposed, (c) the impressed forces would be too great for economic construction, and that these areas should be screened out in a broad survey of the coastal areas that might be suitable for nuclear power plants.

5. Geography and Geology

Other constraints are associated with geology and geography. Many of these are based on cost and not on some absolute exclusion criterion. For example, transmission distance to the utilities' grid is a factor in siting, but no upper limit on permissible transmission distance (within the State, at least) exists. In some areas it may be advantageous to locate the plant some distance from the coastline proper, and transport the water to the plant. Again, no absolute limit can be specified, but distances exceeding several miles, or involving elevation change of many hundreds of feet, are apt to be found economically noncompetitive. The question of the buildability of the site must also be considered. A plant can be built on soft ground, for example, but the cost, particularly in a region subject to earthquake, is apt to be prohibitive. Likewise, rugged terrain can be cut and filled and made buildable, but the cost of access and construction, not to mention the likely environmental insult, would probably preclude serious consideration of such terrain.

A person familiar with the California coastline will recognize that many of these classes of difficulty exist in profusion there. After all, much of the California population is concentrated near the coast, and the great San Andreas fault zone is quite near the coast over much of its length. The major transmission grid of the State runs not on the coast, but in the Central Valley and desert areas, and great areas of California are famous for their scenic and rugged coastline. Thus, it can be shown that only limited sections of the coastline may be suitable for power plant construction. This is somewhat in contrast to the image projected by some, where fears are aroused that a picket fence of nuclear power plants might be constructed down the length of the State's ocean frontage!

B. Coastline Siting Survey

Having discussed several of the major factors that constrain the selection of a nuclear power plant site, one can now attempt to make a quantitative estimate of the actual coastal areas that might be found suitable. To consider all factors in detail for the entire coast is a task quite beyond the scope of this investigation. It is also unnecessary, as exclusion by any one criterion means that consideration of other criteria for that area is unwarranted. It has already been pointed out that few absolute siting criteria exist. Thus, in an exploratory study such as this, a great measure of judgment enters. The method that will be used for the screening is presented without apology, but it is recognized that other investigators might have chosen different routes and might have obtained different results.

The first criterion that we have chosen to apply is that of seismic risk. For lack of a more satisfactory or detailed method, it will be assumed in this analysis that all seismic-risk Zone III areas shown in the "Urban Geology, Master Plan for California," report should be excluded because the seismic hazard is greater there. This is admittedly cavalier, but the purpose of this study is not to make definitive choices of power plant sites, but to illustrate the issues in question. In all probability, some areas in Zone III might prove to be acceptable; some in Zone II would prove seismically unacceptable. Nonetheless, even with the limited number of actual cases that have been considered in California, all commercial nuclear power sites for which construction permits have been granted (Humboldt, San Onofre, Rancho Seco, Diablo Canyon) lie outside Zone III.** Thus, our suggestion is (to accelerate the licensing process) that highly seismic areas should be avoided. Reference to Figure III-4 reveals that large stretches of California's coast lie within Zone III, and these areas are deemed to be unsuitable for purposes of the present study.

The next step in the screening process was to apply a population-spacing criterion. Again, lacking definite guidelines, we must arbitrarily set some standard. Therefore, it

* This is particularly true for coastal locations, where sea-bed investigation is required.

** It should be noted that the coastal area which contains San Onofre is being reevaluated and may be reclassified Zone III. It is also true that discussion of suitable seismic design criteria for San Onofre Units 2 and 3 delayed the construction license activity for a year.

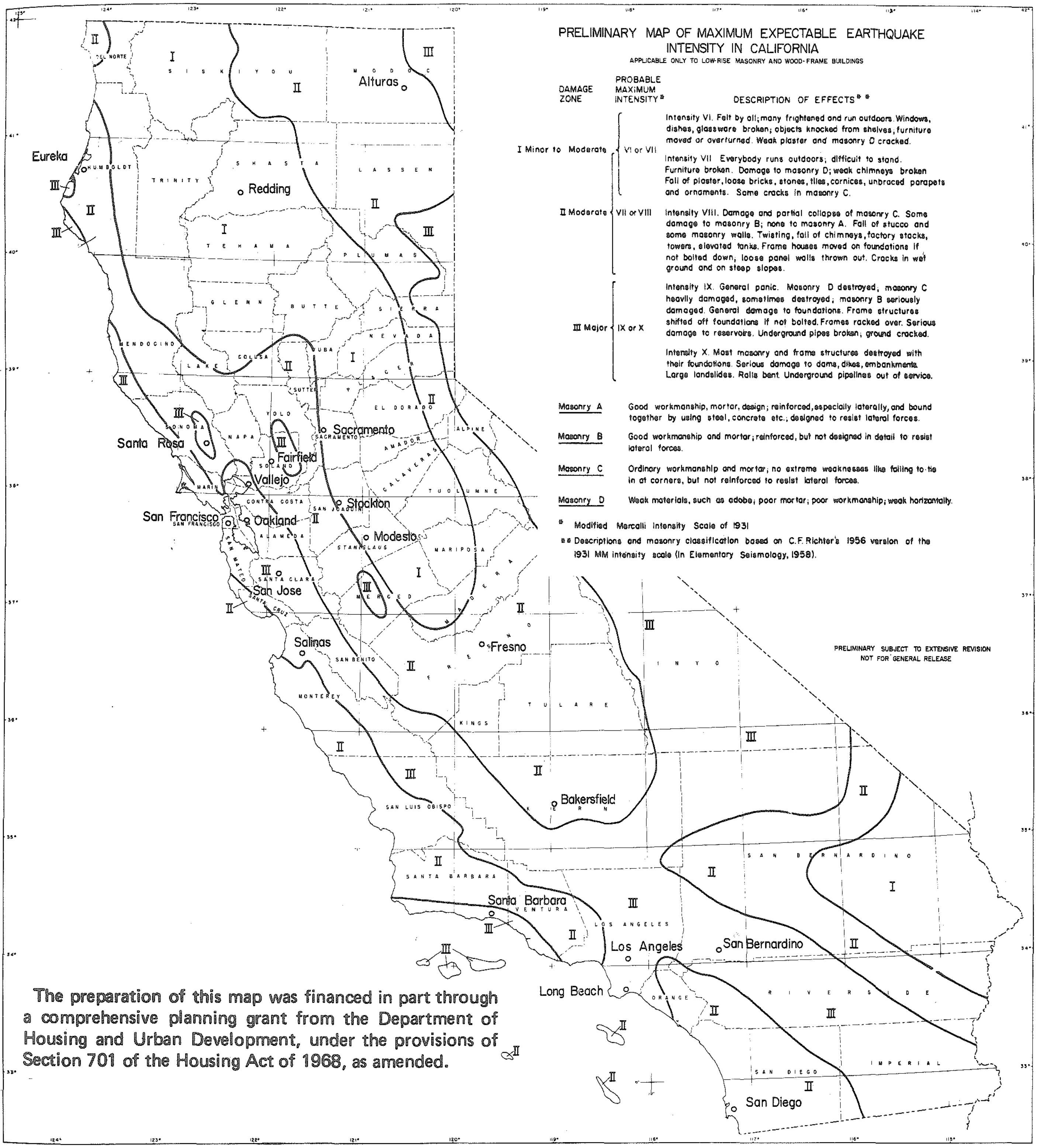

Figure III-4 Earthquake Intensity (from Urban Geology, Master Plan for California) was decided to use the population distribution for the Palisades (Michigan) plant as a selection criterion. This criterion has both conservative and unconservative aspects. Palisades is farther from population centers than other sites which have been licensed. On the other hand, it presently has only one 800-MW class reactor, whereas utility planning in California generally contemplates multiple 1200-MW class reactors at a site. Of course, plant design, local meteorology, and other factors are important in comparing locations, but of necessity are neglected here.

Because California is still increasing in population, particularly along the coast, it was decided to use 1980 population projections[12] for California in determining site separation from population centers. Geographical population distribution among cities and areas within counties was assumed to maintain present proportions. It was recognized that the data for Palisades (shown in Figure III-2) represent 1960 census data. That area, too, is growing, and the Preliminary Safety Analysis Report (PSAR) for the Palisades plant shows the 1980 population projections for that area. Unconservatively, but for fairness, it was decided to use the projected 1980 population distribution curve (as plotted in Figure III-5) for Palisades as the population separation criterion in this study. The method is simple. The 1980 population projected for any area in California is proportioned from the data given in reference 12. This population figure is entered into Figure III-5, and the exclusion distance is read off. A circle of that radius can then be constructed with the population center as the origin, and this represents the exclusion area. The populations and separation distances required for various cities are listed in Table III-1. Cities whose population exclusions would lie entirely within the seismic zone exclusion along the coast are not included.

The results of the seismic exclusion and population separation screening are shown in Figure III-6. The State map includes population centers lightly shaded, with population separation circles drawn in for coastal areas. The heavy shading represents seismic Zone III areas. Twelve separate stretches of coastline are identified, which are permissible according to the population and seismic criteria we have used. The results are also listed by county in Table III-2.

The procedure discussed above can be subjected to the criticism that the ground rules were arbitrary and too restrictive. On the other hand, there are those who, operating from the same body of data, have claimed that even more restrictive siting criteria should be employed in California. We have not tried here to break new ground. Rather, we have carefully considered present trends in licensing, and have attempted to be reasonable. One reviewer has characterized this portion of the study as "a behavioral analysis of the AEC". We are grateful for his insight.

Next, each of the numbered stretches of coastline must be examined for its suitability for the construction of power plants. Here, judgment must again be relied upon, for no firm criteria exist. Factors considered include favorable terrain, accessibility to transport, geology, and land use. The coastal data were taken from the recent "COAP".[13]

Simple statements regarding the siting criteria can be made. In the matter of terrain, what is desired is about 600 acres, relatively flat, in which at least the portion for the power plant itself is at less than 100 ft. elevation. For transport, either a nearby railroad or highway is desirable, preferably with some nearby point suitable for unloading heavy components from barges. Generally speaking, firmer ground is preferable to softer ground. By screening the 12 basic stretches for these factors, still more area can be eliminated from the list of potential siting locations. The result of this screening is summarized in Table III-3.

Of the original 1072 miles of California coastline, 512 miles were excluded by the seismic criterion, and an additional 344 miles were considered too close to population. Of the 215 miles remaining, 122 miles were considered unsuitable for building sites, leaving a buildable remainder of 93 miles. However, parts of this remainder are in existing built-up areas or parks, and additional areas have been designated as proposed parks. It was, therefore, deemed appropriate to exclude such areas from consideration. Consequently, only 52 miles of coast suitable for nuclear power plant construction remain.

Even this limited coastline availability may be in part illusory. The counties of Del Norte, Humboldt, and the northern portion of Mendocino are quite remote from load centers and the transmission grid. As such, stretches 1 to 7 may not be very desirable for the utility companies. Actually, the stretches in San Luis Obispo and San Diego counties are better located. Note that these areas correspond roughly to the location of the Diablo Canyon and San Onofre nuclear generating stations. These regions may prove to be the only ones which will be used for coastal siting in the near future.

The reader is again cautioned against taking the results of this siting survey as a complete or definitive study. Our omission of detailed descriptions of the areas deemed available for siting is deliberate. Without careful investigation of all factors, no site can be proclaimed suitable, and as stated, such investigation is quite beyond the scope of this study. However, the broad results laid out should indicate that nuclear power plant sites along the California coast do not exist in the profusion that some previous work might have suggested.

It is interesting to note that a study performed by RAND Corporation,[14] using an independent methodology, concluded that 55 miles of coastline might be available for

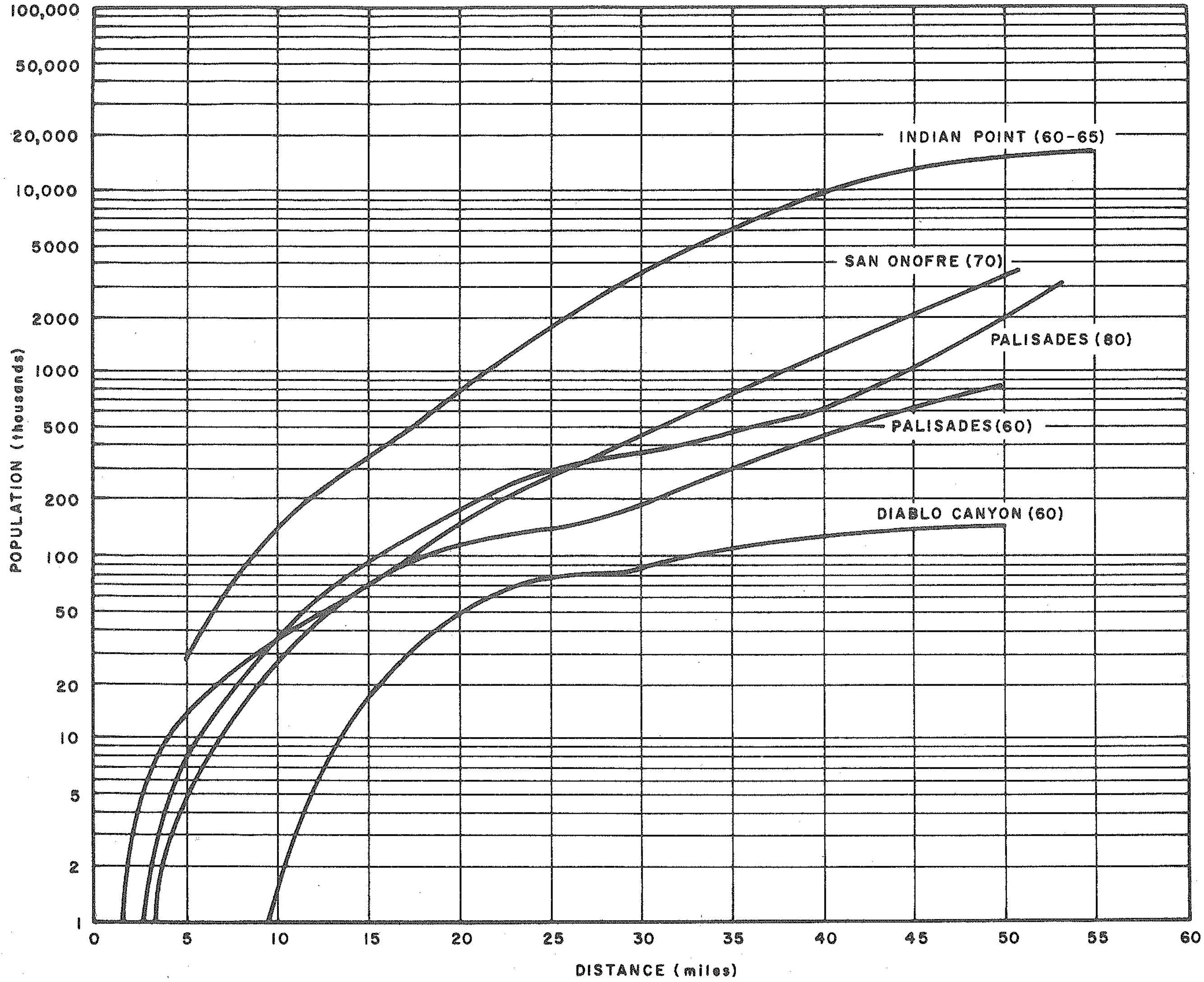

Figure III-5 Cumulative Population as a Function of Distance from Nuclear Plants – Selected Data

TABLE III-2

Mileage by County for Basic Exclusions and Basic Availability

COUNTY	COASTLINE LENGTH (miles)	BASIC EXCLUSIONS		BASIC COASTLINE AVAILABLE (miles)
		MEEI Zone III (miles)	Population Distance (miles)	
Del Norte	45	0	21	24
Humboldt	121	42	27	52
Mendocino	120	72	7	41
Sonoma	62	62	0	0
Marin	70	70	0	0
San Francisco	8	8	0	0
San Mateo	56	35	21	0
Santa Cruz	42	13	29	0
Monterey	111	17	37	57
San Luis Obispo	93	0	54	39
Santa Barbara	110	79	31	0
Ventura	41	41	0	0
Los Angeles	74	51	23	0
Orange	42	22	20	0
San Diego	76	0	74	2
TOTALS (Note 1)	1072	512	344	215

Note 1. Sums of individual items may not equal totals due to rounding.

TABLE III-3

Stretch Definitions by County with Further Possible Exclusions.

COUNTY OF CALIFORNIA	BASIC COASTLINE AVAILABLE (miles)	STRETCH DEFINITIONS			FUTURE POSSIBLE EXCLUSIONS/REMAINDERS (MILES)			
		No.	Length (miles)	COAP Sheet	Terrain and Geology Exclusion	Remainder	Land Use Exclusion	Suitable Coastline
Del Norte	24		(24.0)		(8.0)	(16.0)	(11.4)	(4.6)
		1	12.2	1-2	8.0	4.2)	0.2	4.0
		2	10.7	3-4	0	10.7	10.7	0
		3	1.1	5	0	1.1	0.5	0.6
Humboldt	52		(52.1)		(22.2)	(29.9)	(18.7)	(11.2)
		3	27.7	5-8	10.4	17.3	15.1	2.2
		4	5.2	8-9	1.0	4.2	2.8	1.4
		5	0.8	12	0.8	0	0	0
		6	8.4	14-15	0	8.4	0.8	7.6
		7	10.0	18-19	10.0	0	0	0
Mendocino	41		(40.9)		(29.6)	(11.3)	(3.3)	(8.0)
		7	40.9	19-23	29.6	11.3	3.3	8.0
Monterey	57		(57.3)		(57.3)	(0)	(0)	(0)
		8	57.3	60-66	57.3	0	0	0
San Luis Obispo	39		(39.3)		(4.6)	(34.7)	(8.3)	(26.4)
		8	22.2	66-68	2.8	19.4	3.2	16.2
		9	7.2	69-70	0	7.2	0	7.2
		10	8.1	72.-73	0	8.1	5.1	3.0
		11	1.8	75	1.8	0	0	0
San Diego	2		(1.6)		(0)	(1.6)	(0)	(1.6)
		12	1.6	103-104	0	1.6	0	1.6
Totals (Note 1)	215		215.2		121.7	93.5	41.7	51.8

Note 1. Sums of individual items may not equal totals due to rounding.

nuclear power plant siting. Our own number is almost suspiciously close! On the other hand, a study just completed by Holmes and Narver[15] shows 144 miles of coastline available for siting. That study used less restrictive criteria for population exclusion, seismic zoning, and land use.

There are two special cases of coastal siting that have been considered in California. The first is the use of the Channel Islands; the second is the creation of artificial islands near the shore. Unfortunately, both possibilities have technical problems.

The islands of Santa Catalina, San Clemente, Santa Barbara, and San Nicolas are surrounded by waters of considerable depth, ranging up to several thousand feet. The state-of-the-art of submarine cable construction and installation, at this time, will not support the notion of transmitting power from those islands to the mainland. When the technology becomes available, however, the possibility of siting nuclear power plants on those islands could be considered. It should also be recognized that many of the problems and conflicts that pertain to siting on the mainland coast are operative at these islands.

The islands of Anacapa, Santa Cruz, Santa Rosa, and San Miguel can be reached by underwater cable at depths of less than 1000 feet. Thus, these islands cannot be dismissed out of hand as the other, more southerly group. The seismic-risk map indicates, however, that these islands lie in Zone III, and according to our selection criteria, are excluded from consideration at this time.

The construction of artificial islands near the coastline to support oil drilling (Rincon, Long Beach) is a reality, and such a proposal has been made for the siting of nuclear power plants. The Bolsa Island project[16] planned by the Metropolitan Water District, the Department of Water and Power (Los Angeles) and Southern California Edison, was terminated for reasons of excessive cost, but interest remains alive. It should be pointed out, however, that Bolsa Island would not meet either of the two major criteria of this study. The location is too close to population centers and is in a zone of high seismicity. Moreover, it is generally thought that the filled ground of artificial islands is more prone to seismic problems than a firmer land base. We, therefore, assume for this study that offshore artificial islands must meet the same population and seismic criteria as coastal plants. Water shallow enough to support such a construction is found only fairly close to shore; therefore, by this reasoning, only those coastal locations unsuitable for reasons of buildability or land use might offer potential for artificial island siting. A review of our screening data reveals that it is unlikely that any such area exists. Part of the reason is that the steep, cliff-like portions of the coast excluded for reasons of buildability generally drop into fairly deep water close to shore. The cost of an artificial island increases sharply with water depth. Thus, it is concluded that, within the ground rules of this study, the offshore artificial island does not offer much potential for dealing with the siting problem.

C. Conclusion

It is concluded that (for the immediate future at least) the California coast offers limited potential for nuclear power plant sites. The two most promising areas have already been put to use, although considerable capacity expansion may well be possible near either location.

IV. COOLING WATER REQUIREMENTS AND SUPPLY

A. Introduction

This portion of the document will summarize briefly those parts of the complex California water picture that relate to water supplies for power plant cooling. First, cooling requirements are outlined. Next, the sources of data are mentioned, and the overall projected supply situation reviewed. Patterns of projected water demand are then outlined, with some discussion of the manner in which water is used. The amount of water used in power production and its cost impact are then put into this context. Finally, potential sources for cooling water supplies are listed and discussed. The economic strength of electric generation as a competitor for water is pointed out.

B. Power Plant Cooling Requirements

The amount of water required to cool a nuclear power plant will vary, according to a number of circumstances. It has already been pointed out that the use of an existing lake as a cooling pond is less consumptive of water than the use of an evaporative cooling tower. Only a few such bodies of water may exist, however, adjacent to suitable power plant sites. On the other hand, if the cooling pond is created solely for the use of the power plant, then the natural heat load from the sun, plus the heat load from the power plant, causes more water to be used than if evaporative towers were relied upon. Because of this fact, and because of the large area of land required for the cooling pond, it is generally considered that most inland plants in California (for the foreseeable future) would use evaporative cooling towers, either natural draft or mechanical draft.

These two types of towers are quite similar in the amount of water that they evaporate. They differ, of course, in their operating characteristics, their cost, and efficiency in different climatic conditions. However, for either mechanical or natural draft towers, approximately 20,000 acre-feet of water per year (af/yr) are consumed by a base-load nuclear plant of 1000-megawatt electrical capacity. To this evaporative load must be added any water that is required for blowdown. Blowdown is the non-evaporative water that is discharged from the tower in order to keep the circulating water in the cooling system at some specified and reasonable level of total solid content. Where fresh water of low mineral content is used for make-up, the blowdown can be very small, perhaps as little as 5 to 10 percent of the amount evaporated. However, if water high in solid content is used to feed the cooling system, it may be necessary to supply up to 25 percent or more of the evaporative consumption as blowdown. This is apt to be the case, for example, if waste waters from agricultural drainage are used for power plant cooling. In this case, even as much as 30,000 af/yr may be required for a 1000-MW plant.

Because this amount of water is equivalent to the supply for a city of over 100,000 people, it has often been thought that the cost of supplying these large quantities of water for power plant cooling would be economically prohibitive for electric utilities. This is not the case, however, for even if the water should cost $30 per acre-foot (a not unlikely value), the cost of producing the power is increased by less than 1/10 mill per kilowatt-hour (kw-hr). This increase is to be contrasted to the present six or seven mil (soon to increase markedly) total busbar production cost of the power and the cost to the retail consumer of 10 to 25 mills. Thus, the cost impact of the purchase price of water at ordinary water prices (up to $100 per acre-foot) may amount to only 1 to 3 percent of the price of the retail power.

There are technical possibilites that would reduce (or eliminate) cooling water requirements. First is the option of using dry cooling towers which reject heat to the air without evaporation. These are frequently used for industrial cooling, but are not often used for power plants, since they are expensive and reduce plant efficiency. There are several plants in the world equipped with dry towers, the largest being of 200-MW capacity. So far, their use has been restricted to areas of very limited water supply.

The application of dry towers to fossil-fuel and nuclear electric power plants has been extensively studied. A recent report prepared for the AEC[17] considered dry towers at specific nuclear power plant locations. When a wide, but reasonable, spectrum of assumptions was used, it was found that in the western region of the U.S. the busbar cost of electricity was increased by 0.7 to 1.2 mill/kw-hr. Aside from this cost increase, which may not of itself be prohibitive, other factors inhibit the immediate adoption of dry towers. First, the turbines presently used to drive the generators must be redesigned in the low-pressure stages to accommodate the higher discharge pressure associated with the dry tower. Also, utilities are reluctant to adopt dry tower technology for large power plants until extensive experience is available with models of significant size. Such experience is as yet unavailable.

Another possibility has been raised, namely, the use of combination wet-and-dry cooling towers.[18, 19] The concept is to use a dry mode of operation when dry-bulb temperatures are low (thus, saving on water use) and to use evaporative cooling when dry-bulb temperatures are high (thus, maintaining the thermodynamic efficiency of the power plant). The RAND study[19] does not assert that the wet/dry tower is cheaper than wet towers, but states that it offers a possibility for water conservation. In the area of Bakersfield, for example, the author estimates that a wet/dry tower would use only 23 percent as much water as a conventional wet tower. Here again, however, the utilities will require considerable time to acquire experimental experience before adopting such designs for major installations.

Another new technology promises advantages for cooling. At present, the high-temperature gas-cooled reactor (HTGR) uses conventional steam-generating equipment to produce power. However, owing to the higher permissible temperatures and the gas-cooled reactor, it is possible to generate the electricity using a direct gas turbine cycle. In this instance, it is also possible to reject the heat from the plant with dry towers without significant thermodynamic penalty, as compared to wet towers. Also, dry cooling tower cost will be lower than it would be for steam plants, owing to the higher reject temperatures. This promising concept is being studied at the Gulf General Atomic Company.[20] In this instance, no water for cooling would be required. [It should also be pointed out that the HTGR, even when driving steam turbines, because of its greater thermal efficiency as compared to light water reactors, requires less cooling water (about 70 percent as much) for equivalent electrical output.]

For the plants being planned today, these new cooling technologies are not available. With further technological development, plants to be installed in the later 1980's might employ some of these techniques.

C. Sources of Water Information

As would be expected, an enormous literature has been written on the subject of California water. The official records include:

a. Extensive Congressional hearings related to the authorization and operation of Corps of Engineers and Bureau of Reclamation projects.

b. The bulletin series of the Department of Water Resources of the State of California.

c. Reports of the Bureau of Reclamation, U.S. Geological Survey, various local water agencies, including organizations such as the Imperial Irrigation District and the Metropolitan Water District of Southern California.

d. Numerous books and research papers in technical and legal literature.

Two recent overall studies have been of particular value in the preparation of this document. The first is Bulletin Number 160-70, *Water for California, California Water Plan Outlook in 1970,* published by the Department of Water Resources of the State of California (herein referred to as Bulletin 160-70). The other is the *Comprehensive Framework Study, California Region,* prepared by the California Region Framework Study committee, for Pacific Southwest Inter-Agency Committee, Water Resources Council under the auspices of the Federal Water Resources Planning Act of 1966 (herein referred to as the Framework Study).

One must exercise great care in using data from the variety of water studies. The systems of projections and accounting are often not the same and lead to apparent discrepancies. Consider, for example, standard irrigation practice in which more water is applied to the land than is consumptively used. In this situation, a substantial residual amount of water flows from the land into drainage, and often is returned to waterways for further beneficial use. Water, however, is not charged for in this fashion; rather, the gross amount delivered to a user (withdrawal) is the usual basis of supply charges and projections. The water then discharged to a waterway for further use is again counted in supply. In this fashion, projections of both supply and demand are substantially higher than they would be if only consumption were listed. An example of this is to be found in the two referenced documents. Whereas for 1965, the Framework Study (page 25) indicates that the total developed water supply of California was 36.8 million af/yr, Bulletin 160-70 (page 145) shows that for 1967 the total net water supply in the State of California was 28,460,000 af/yr. Although both documents are internally consistent, it would obviously be difficult to make a meaningful comparison of the data shown in one to the data shown in the other without a great deal of effort to reconcile the ground rules of the calculations. For the most part, we have used data from the Framework Study to outline the problems of water supply for the cooling of electric power plants.

D. Water Supply in California

Presently developed water supplies include: (a) inter-region transfer, for example, water transported from the Colorado River into the Los Angeles Basin, the Imperial Valley, and other locations; (b) ground water, or water pumped from the ground and used by agricultural and urban areas; and (c) water transported within California, for example, as in the California Water Project, where water from the San Joaquin-Sacramento Delta is delivered eventually to Los Angeles and regions further south. As noted, the Framework Report states that in 1965 nearly 37,000,000 af/yr of water was made available in the State (includes 5 million af/yr from the Colorado River). With authorized projects, and others under construction, the Framework Study indicates that the developed water supply of the State would peak at about 41,000,000 af/yr in 1980, and then decrease slightly to 40,000,000 af/yr, owing in large part to the fact that California must eventually relinquish approximately 1,000,000 af/yr of its present Colorado River supply to Arizona as a consequence of the 1964 water allocation decision by the Supreme Court.

To put this supply in perspective, it is estimated that the run-off of water from California rivers and streams amounts to some 75,000,000 af/yr, on the average. Not all of this is developable in a useful way, but it does indicate that substantial further water development might be possible in California if it were required. There are, however, growing pressures to inhibit further water development because of the effects on natural environmental systems; indeed, substantial additional development of California water supplies may be found undesirable or impractical. Thus, these large run-off numbers do not necessarily indicate an availability of water for all who would like to have it.*

Even the projected number discussed may be subject to downward revision. For example, the recent Delta Water Decision of the State Water Resources Control Board, if sustained by court tests, may reduce the amount of the presently developed water supply available to State and Federal water projects by 1 to 2 million af/yr, largely in the Central Valley Project and the State Water Project.

Although presently unused supplies of fresh water in California will be available in coming years, there will also be substantial competition for their use among municipal, industrial, and agricultural users. In this competition, thermal electric power plants will take their place as industrial users, possibly with special priority status.

In addition to fresh water, however, additional sources of water may be suitable for power plant cooling. For example, in Bulletin 160-70 (page 78) it is estimated that over 2 million af/yr of municipal waste water now flows into the ocean and is lost as a fresh water resource. Until now, it has been more economical and/or politically feasible to bring new supplies of fresh water to the metropolitan areas than to provide the sewage treatment

* Note, for example, that the North Coast rivers have now been protected from development by State law.

and reclamation required to make this water suitable for further use. However, increasing concern for the environmental impact of sewage discharge has led to the requirement for more advanced sewage treatment. Moreover, as added increments of fresh water supply increase in cost, it is to be expected that substantial amounts (perhaps half of the presently discharged waste water) could be made available economically for useful purposes. Among the applications, power plant cooling, fortunately, does not require as high a level of treatment as if the water were to be used for municipal or even for agricultural purposes.

In addition, after single or multiple use of irrigation water, it is so reduced in quality that it is no longer suitable for agricultural purposes and is classed as waste water. For example, in the Imperial Valley the high salinity of the original Colorado River water permits only one-time application, and the excess water then drains from the Imperial Valley farms into the Salton Sea. This drainage amounts to about one million acre-feet annually. The growing level of agriculture in the southern San Joaquin Valley is bringing about similar problems. To help alleviate this problem, the San Luis drain is presently being constructed by the Bureau of Reclamation in the western San Joaquin Valley. The amount of water flowing to waste in the entire valley will in time exceed half a million acre-feet annually, and similar drainage and disposal projects may be required for other portions of the valley. With appropriate treatment, it is believed that this water may be suitable for use as a power plant coolant, even if it is no longer suitable for municipal or agricultural purposes.

E. Water Consumption Projections

As pointed out in Bulletin 160-70, determining present patterns of consumption of water is a difficult research task. Clearly then, future projections are still more difficult, and for a variety of reasons. The population of California is growing not only by the natural increase of births over deaths, which is a varying factor, but by migration — a factor that varies even more sharply according to the vicissitudes of the State's economy and the social and economic pressures in other parts of the United States. However, the future must be planned for, and the various water agencies and planning groups in the State of California have been performing this function for many years. In the years since World War II, if they have erred they have usually erred on the side of conservatism, and most water supplies in California have been more than ample to meet the needs of an increasing population. The projections of water requirements displayed in the Framework Study (Figure IV-1) are based on several varying sets of ground rules, the differences between which can be fairly easily understood.

In the late 1960's, the U.S. Department of Commerce made a series of population and economic projections for the United States. The studies were accomplished at the request of the Water Resources Council in cooperation with the Department of Agriculture; the so-called "OBERS Projections" were created for the entire nation. The OBERS Projections for the California region involved establishing a set of national projections, including population, employment, and productivity. From this set were developed projections of gross national product, income among industries and among regions. Population projections, for example, conform to Series C of the U.S. census, which embodies 1.3 percent average national annual population growth in the next 50 years. The OBERS Projections for California include in-migration and indicate that the population is expected to increase from 18.1 million in 1965 to 54.9 million in the year 2020. The population was assumed to be distributed in large measure as it is now, with the bulk of the population in the Southern California and the San Francisco-Oakland metropolitan areas.

The OBERS Projection called for much the same distribution of farming activities in the nation as is presently experienced. Shifting trends among regions were assumed to continue at a decreasing pace until 1980, when equilibrium proportions among regions would be reached. That is, California would continue to produce something akin to its present proportion of national food and fiber needs. This projection then enabled a calculation to be made for water requirements. For example, it was assumed that increasing affluence would require slightly higher per-capita requirements for water by the year 2020 in urban areas, up about 20 percent from present values. It was also assumed that increasing efficiency in agriculture would not require an increase in irrigated acreage proportional to the increase in population. There would be a substantial absolute increase nonetheless, and water would be used on irrigated lands in much the present fashion.

The Framework Study committee, however, created a separate set of projections for use in the California Region study, referred to as the Base Plan and shown in Figure IV-1, reproduced from the Framework Study. The Base Plan maintained the overall population growth as outlined in OBERS, but called for a different distribution in the State, which provided for somewhat greater growth in central and inland areas and somewhat reduced growth in south coastal regions. Additionally, the Base Plan called for California to assume a greater portion of food and fiber production in the United States, thus, leading to substantially greater projection for water use.

As the Framework Study was drawing to a close, however, the data from the 1970 census became available and the State Department of Finance produced a new set of population projections for the State of California. Among the more significant changes was a modification from the Series C census projections of fertility to the Series D, which contains a lower birth rate and indicates a smaller net

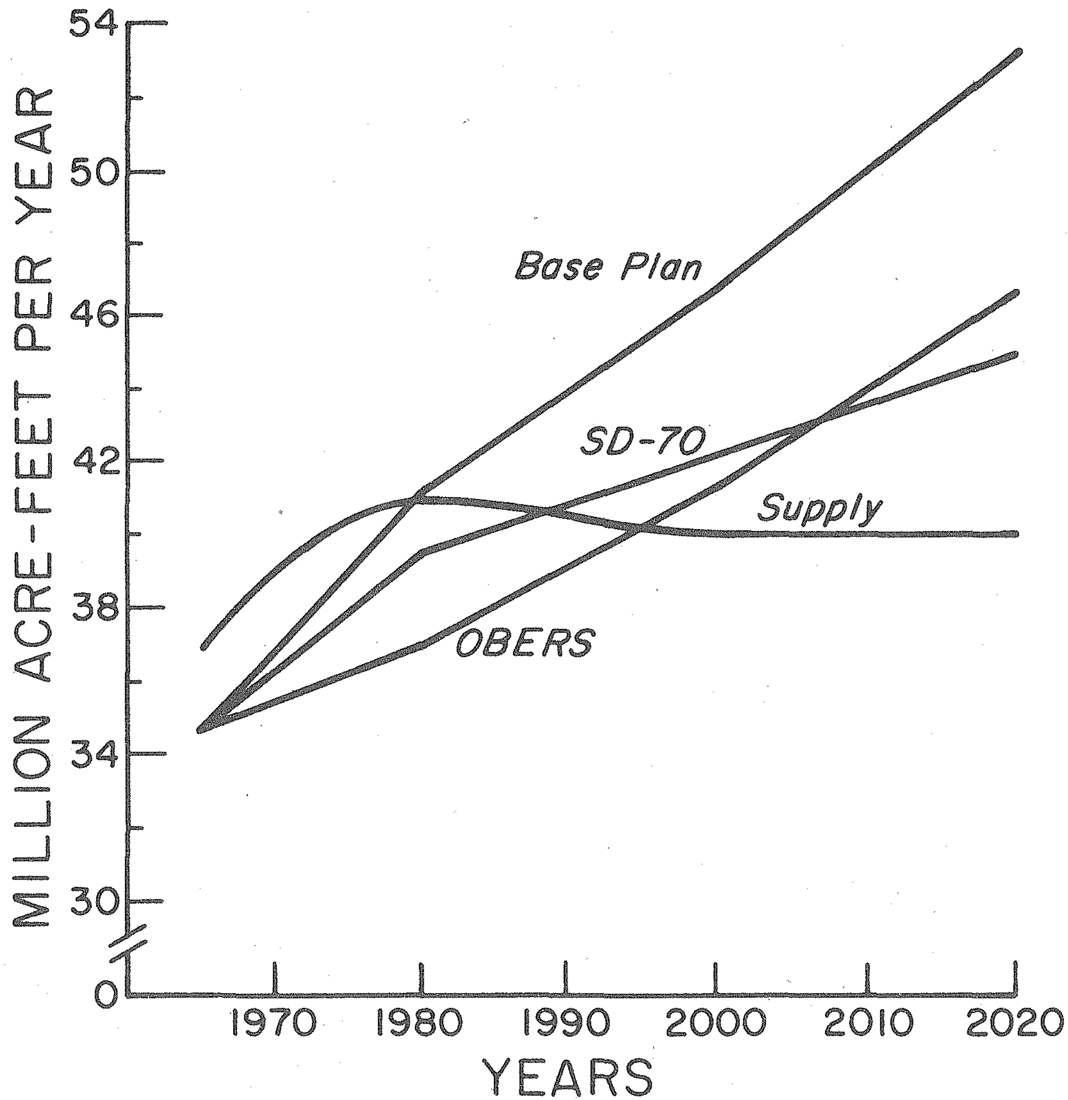

Figure IV-1 California Region Developed Water Supply and Water Development Requirements (from Framework Study) population for California in ensuing years. (In point of fact, the United States is now running at the still lower Series E fertility rate.) For example, in Series D the estimated annual population increase for the United States is about 1 percent, as compared to 1.3 percent for Series C. Migration to California was assumed to remain at the level of 200,000 annually, from 1974 to the year 2000. If these projections are carried out to the year 2020, the new 1970 projections indicate that the State population will total 44.8 million, as compared to the substantially higher number indicated in the OBERS Projection. (It is worthy of note that in FY 1972, according to the State Department of Finance, the population of the six counties of Los Angeles, Orange, Riverside, San Bernardino, San Diego, and Ventura increased only 0.75 percent, net, including in-migration.)

The Framework Study committee wished to take account of this new population projection without completely redoing the internal details of the study. It was, therefore, decided to scale such factors as personal income, food and fiber requirements, etc., largely on a basis of the reduced population projection directly; from this modification, the water requirements could be obtained by scaling. This revised water requirement is labeled SD-70 and appears in Figure IV-1. These three forecasts provide the basis for the discussion in the balance of the Framework Study.

The total of developed supplies, including projects authorized or under construction (and allowing for the cutback in Colorado River availability), is also shown in Figure IV-1, indicating that water is available from developed projects until 1980, even for the Base Plan and perhaps for an additional 15 years, if the OBERS Projections prevail. The thrust of the Framework Study would indicate that present supplies would satisfy projected needs (SD-70) until about 1989. However, the Base Plan, from which SD-70 was scaled (due to lowered population estimates), was a somewhat arbitrary rearrangement of the nationwide OBERS study. Let us, just arbitrarily, scale downward, not from the Base Plan, but from OBERS*, using the scaling ratio (SD-70/Base Plan). In other words, let us correct the OBERS Projection to reflect the reduced population estimates resulting from the 1970 census. In this case, the dashed curve shown in Figure IV-2 results, indicating that presently developed supplies will suffice for 50 years. Even in the event that aqueduct supply is diminished by 2 million af/yr, owing to the Delta Water Decision previously mentioned, the supply will suffice until 2005.

F. Water Usage In California

By far the overwhelming amount of water used in California is devoted to agricultural purposes. This fact is clearly shown in Figure A-17 of the Framework Study; of a total of approximately 35 million af/yr applied water requirement in the State, nearly 30 million is used in agriculture, with the balance devoted to municipal, industrial, and other purposes. However, it should be pointed out in projections for the future that a larger percentage will be devoted to urban applications. For example, in the Base Plan in the year 2020, approximately 39 million acre-feet would go to agriculture, while the balance of the estimated usage of 56 million acre-feet would be devoted to municipal, industrial, fish, wildlife, and miscellaneous uses. This distribution reflects, of course, the enormous increase in population postulated in these projections.

It will first be interesting to examine the mode of usage of municipal and industrial water in this state. It is very difficult to obtain data that clearly show the amount of water used by various classes of industry, housing, and other categories. In many cases, industrial water is developed on the property of the user, and records may or may not be available. In some areas, water is not metered, and in any case, extensive review of the delivery records would be required to gain an accurate picture of water usage. The amount of water used per capita in various municipal areas varies markedly with the climatic conditions, population density, and type of industry and commerce to be found. This type of information has been presented in Bulletin Number 166-1, *Municipal and Industrial Water Use*, prepared by the Department of Water Resources of the State of California. It would not be fruitful at this point to try to summarize the voluminous data presented. One might, however, categorize municipal and industrial use as involving about 200 gallons per day per capita in California, although the range varies from perhaps 150 gallons to over 300 gallons per day in different areas. These values, of course, vary throughout the year. However, we might take as an annual average for the State, for purposes of discussion, 200 gallons per day per capita. This figure includes the water: (a) used in industry that employs people, (b) used to water urban vegetation, (c) used within the home for washing and sanitary purposes, and (d) used for cooling of air conditioning and other industrial devices. Few data are available to show how this water usage is distributed.

It is interesting that the National Aeronautics and Space Administration, (NASA), in trying to apply its technical capabilities to civilian problems, has embarked on some studies of water usage. In a report prepared by the Martin-Marrietta Corp. for NASA,[21] it was concluded that individual daily water consumption inside the home (that is, excluding external uses for garden purposes, car washing, etc.) amounts to 62 gallons per day per person. They compared this with a finding reported by the Environmental Protection Agency of 64 gallons per person per day. In studies performed at the Langley Research

* The State Department of Water Resources, in private communication, states that it cannot agree with either OBERS or the 1969 Agricultural Census.

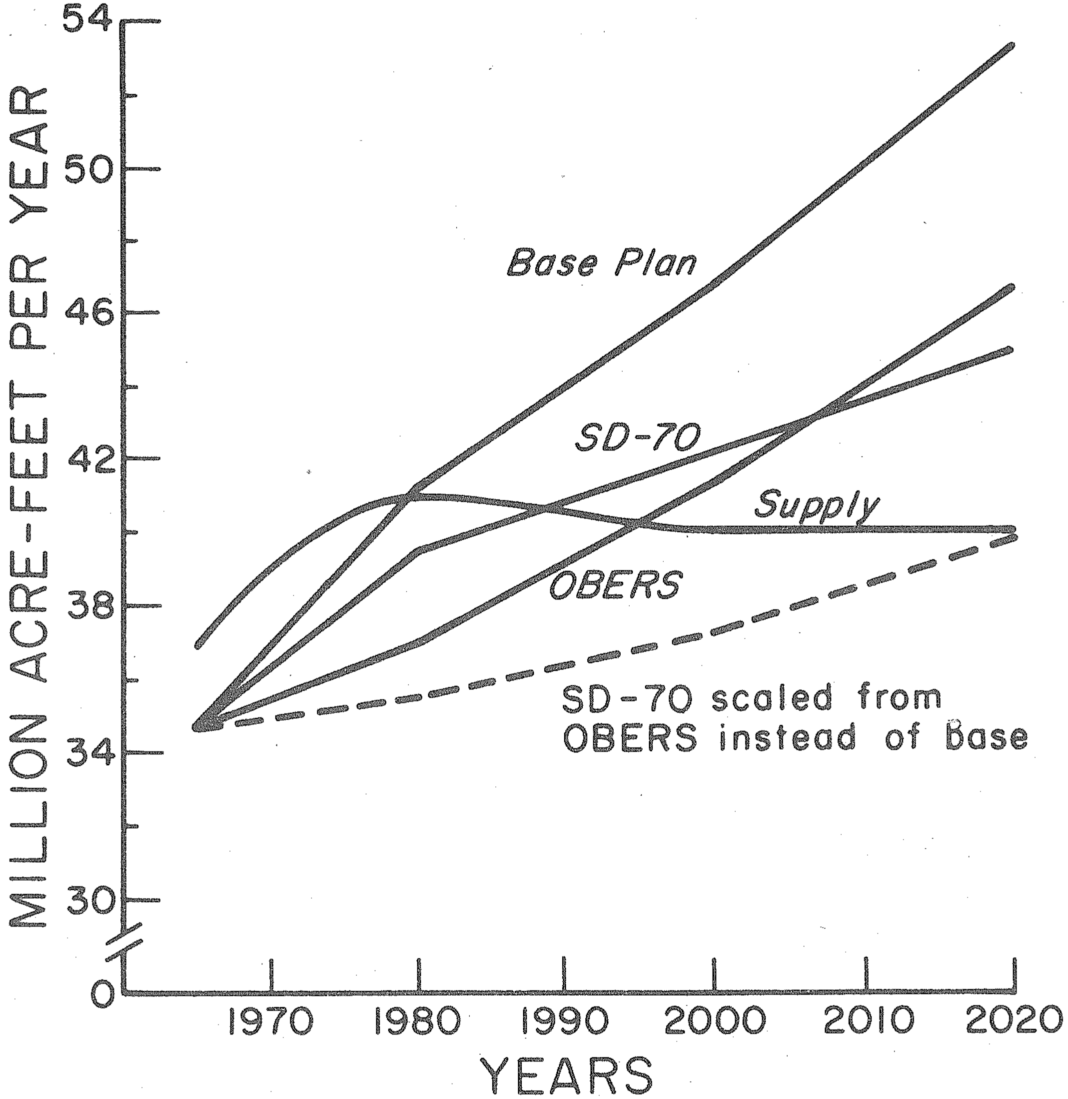

Figure IV-2 California Region Developed Water Supply and Water Development Requirements (Revised)

Center of the NASA, it was found that this per-capita water use in the home was divided in the following fashion:

Kitchen	12%
Laundry	23%
Bath	20%
Lavatory	4%
Toilet	41%

These data were taken in order that NASA could determine if the water and waste recycling methods developed for the space program could be applied in a beneficial way to our everyday lives. Considering the total number of about 65 gallons used in the home, as compared to 200 gallons used overall, it is clear that a substantial part of our urban water needs are directed to the requirements of industry and commerce and outside purposes, as might be expected. According to Bulletin 166-1, there are no clearly visible trends in the per-capita consumption of water through the years. Some areas have shown an increasing per capita use, others a declining one, with the bulk showing a relatively constant value. Although it is thought that a society growing in affluence uses somewhat more water per capita, it is also pointed out that with growing density of residence, urban area requirements for outside water diminish, making it difficult to determine absolute trends. However, in the projections of both the Framework Study and Bulletin 166-70, it has been assumed that per capita water usage would increase by 20 percent over the next 50 years.

Water plays a relatively small part in the overall economics of urban areas; i.e., it is absolutely necessary to survival of the area, but is not a strong cost factor in doing business. In agricultural regions, however, water strongly influences the economics of farming. Irrigated agriculture developed where ground supplies could be cheaply developed or where conveyance was relatively inexpensive and could be handled by local authorities. One of the most pervasive influences in the development of irrigated agriculture in the western United States was the Reclamation Act of 1902, which threw the power of the Federal government behind water projects that would bring water to otherwise undevelopable agricultural areas. The success of Bureau of Reclamation projects is known to all, and it is probably well to recognize certain aspects of water policy as they are embodied in the Reclamation Act and subsequent laws since passed.

Certain costs of Bureau of Reclamation projects may be assigned to the general good of the nation, and are not reimbursable by the persons who enjoy the benefits of delivered water. For example, the benefits of flood control or wildlife enhancement are borne by the general taxpayer. However, the water users are expected to repay the costs that are attributable to water supply development. However, the repayment pattern is not uniform for all. In the spirit of encouraging agricultural development in reclamation areas, the pricing policy provides that agricultural users will pay the allocated costs of the project for the water they take, but that their share of the repayment of the cost to the Federal government for the project's construction shall not include interest.

Some crops do not yield sufficient revenue to permit even this no-interest level of repayment. In some cases, the Bureau of Reclamation can deliver water to such areas at a rate set at what the user can afford, often much less than the normal rate. On the other hand, the users of water for municipal and industrial purposes pay their share of operating expense and repay their allocated construction cost with interest, although that interest is computed at the rate assigned to the Federal project, which is often substantially less than that found in the free money market.

Many reclamation projects are multi-purpose and can provide for the production of electric power as well as the transport of water. This power is used for purposes of operating the irrigation project, and the surplus is sold to governmental and private users. Power is sold at rates necessary to repay allocated cost, which is less than prevailing rates, according to the Bureau.[22] As noted, for some agricultural purposes it is not possible for the agricultural receiver to actually pay his allocable share of project cost. Quoting from the *Financial Analysis of the Authorized Central Valley Project,* a publication of the United States Department of Interior Bureau of Reclamation, of May 1972, "However, the annual net revenue from irrigation water sales is inadequate to repay the total allocated costs over the repayment period of the project. It is, therefore, necessary for the irrigation function to receive financial aid from other project functions." This statement is well illustrated in Table 7 of the quoted document, where one might focus on two particular components of project cost allocation and repayment: irrigation and commercial power. (The other components, for example, municipal and industrial water, the State's share of certain joint-use project facilities and non-reimbursable costs do not affect the comparison about to be made.) The cumulative investment (without interest) attributed to irrigation service through the year 2032 indicates that 1,150,000,000 dollars is to be compared to the cumulative investment (including interest) for the production of commercial power of 394,000,000 dollars. However, on the revenue side of the ledger, the irrigation payment is estimated to be about $743,000,000 while commercial power will earn approximately $1,267,000,000. Thus, even in an irrigation project in a highly productive agricultural area, the revenue generating aspects of the project are dominated by power production capability and these figures clearly show that intent of the Congress to provide for subsidized water for agricultural purposes is being carried out in the Central Valley Project.

The situation is somewhat different in the case of the State Water Project, owned and operated by the State of California. Here the legislature has provided that all users of water, be they municipal or agricultural, should repay their full and fair share of project costs. The State Water Project is a net consumer of electric power, rather than a producer; thus, no power revenues are gained. Costs of the State Water Project must be repaid, including interest on the bonds that were sold to finance construction of the project. The end result has been that in the Central Valley, for example, Federal areas might be receiving water at $7 per acre-foot, while nearby areas using water from the State Water Project would be paying twice that amount. This disparity has clear implications for agricultural patterns in the state. It is possible to grow low-value crops on Federally watered land because the price of water permits this activity. However, the higher cost of State-delivered water will generally restrict the farmer to irrigation of high-value crops, such as fruit, nuts, and selected vegetables.

G. Potential Water Supplies for Power Production

Let us suppose, for purposes of orientation, that the present exponential growth rate of electric consumption continues, although it has already been argued that this growth may not be realized. Most plant capacity needed in the 1970's has already, of necessity, been planned; therefore, it is of more interest to look off into the 1980's. The 1970 State-wide generating capacity of 30,000 MW is planned to have doubled by 1980, to 60,000 MW (although, realistically, this does not seem attainable at this time). By 1990 an additional 60,000 MW would be required. If this new capacity were to be entirely nuclear, using wet cooling towers, a water supply of approximately 1-1/2 million af/yr would be required. Undoubtedly, this estimate is too high, because it assumes that all the new capacity is base-loaded, but it serves to indicate that, potentially, power plant cooling could become a major water requirement in California. In the projections of Bulletin 160-70 and the Framework Study, the authors commented that by 2020 up to 3 million af/yr could be required for this purpose, although their demand projections included only 100,000 af/yr of water for cooling. (These studies assumed that most new power plant construction would be on the coast.) Considering that the vast State Water Project, which cost upward of $2 billion, supplies "only" slightly in excess of four million af/yr, this represents a substantial increment in demand. To place matters in perspective, however, that 3 million af/yr would supply over $50 billion worth of power plants.

However, these enormous projections are for a 50-year period, and, without doubt, changing patterns of growth and new technology will alter all our present notions. For the present, projections into the foreseeable, but still murky, future suggest that extensive inland siting in California might require one million af/yr in the next 20 years. Where could such supplies come from? There are several sources worth considering:

1. Reclaimed water from urban sewage
2. Agricultural waste water
3. Diversion from urban supply through conservation
4. Diversion from agricultural use
5. Use of developed supply in the event that anticipated demand growth does not occur.

These sources will be considered in turn.

1. Reclaimed Water from Urban Sewage

It is estimated that at the present time in California over 2 million af/yr of waste water is discharged directly to the sea in California. Less than 8 percent of this water (Bulletin 166-70, page 76) is reclaimed for further beneficial use, but it is thought that at least half could be used for irrigation or other similar applications. (For example, the city of Burbank presently cools its municipal electric plant with reclaimed municipal waste water, as is done in other localities in the U.S.). An even greater percentage might be useful for power plant cooling. Moreover, the projections of greatly increased power and water demands made for 1990 and beyond are related in part to increased population—thus, by 1990 California's population is expected to approach 30 million. Concomitantly, the rate of waste water flowing to the sea will grow to perhaps 3 million af/yr, and if only half is reclaimed, power plant cooling requirements could be met thereby.

Only small amounts of reclaimed water were included in the supply projections of Bulletin 160-70 and the Framework Study. Presently, the facilities for this reclamation do not exist, nor do the conveyance systems which would take the effluents from their near-ocean points of availability to the remote sites of utilization. However, the massive water quality control programs being created suggest that the sewage will receive substantial processing for pollution control, whether it is to be reused or not. Thus, the principal cost chargeable to power production for development of this source is that for transport to the appropriate power plant sites. The practicality and cost of doing this is strictly dependent on the particular situation. For example, the city of Sacramento discharges over 60,000 af/yr to the Sacramento River, and will be employing a high level of water treatment. Studies are presently under way to examine the cost and practicality of conveyance systems to potential power plant sites. Because such sites are from 30 to 50 miles away over fairly level terrain, it is expected that conveyance would not cost more than $50/acre-ft.

On the other hand, if the Los Angeles basin were to transport its waste water several hundred miles to remote sites in the desert, it might be expected that water cost could be as much as $100/acre-ft; but this is still a fairly small increment to the cost of power.

If the reclaimed water were made suitable for municipal re-use, then this new increment of supply could be used to replace water diverted from the municipal supply. Because many municipal systems obtain water from distant sources, it might be possible to locate the power plant near the source or conveyance system, thus, obviating the need for a reclaimed water conveyance.

2. Agricultural Waste Water.

Even the best quality of irrigation water contains dissolved minerals. If such water is applied to land without adequate drainage, either to surface conveyance systems or aquifers, the minerals accumulate and poison the soil. Thus, it is common for an excess of irrigation water to be applied in order to flush the land. In many cases, this excess water is reused as an agricultural supply. Finally, however, this water becomes too degraded for further use and must be removed. This disposal occurs after only one application in some areas, for example, the Imperial Valley. There, waste water is accumulated by surface and sub-surface drains (there are reported to be 16,000 miles of tile drain in the Valley), and finally flows into the Salton Sea, which is almost totally maintained by agricultural waste water.

In the San Joaquin Valley, the expansion of irrigated agriculture has brought about drainage problems. The Bureau of Reclamation is constructing the San Luis Drain to serve the San Luis Federal irrigation area. The drain will flow north and empty into the lower reaches of the Delta. Other areas of the San Joaquin Valley will probably require similar drainage facilities in the future. In these areas, waste water is (or is planned to be) collected and routed to the central drain system; in other areas, drainage flows in smaller streams, where it would be less accessible for power plant cooling purposes.

The irrigation drainage from the Imperial Valley flows into the Salton Sea in large quanitites, amounting to one million a/f in 1967.[23] The two main watercourses are the New and Alamo Rivers, which have annual flows less than and over 500,000 a/f, respectively. Is this water available for power plant cooling? This is a difficult question, and not entirely technical. The only legal status of the Salton Sea is that of an agricultural sump. However, it has become a heavily used recreational resource, particularly since the introduction of a productive saltwater fishery. As with any closed sump system acting as an evaporation pond, the total salinity of the Sea is steadily increasing. Without remedial measures, the Sea will not be able to support the present marine ecology within a few more years. The remedial measures presently under study are expensive. Although probably feasible technically, they may not be implemented. If the Sea is to be lost as a recreational resource in any case, the interruption of the feed flows may be acceptable. However, if remedial measures are undertaken to maintain the salinity of the Sea (most probably by diking off part of its surface to act as an evaporation pond), taking of the feed water might not be permitted. (If there is any substantial dimunition of in-flow, the volume of the Sea will, of course, shrink and the level of salinity rise.) Suppose, however, that the interruption of the New and Alamo River flows were permitted: there remain problems with the use of the water for plant cooling.

The Imperial Valley is a highly seismic region, and it is doubtful that a nuclear plant could be licensed there, as seismic design criteria are steadily becoming more restrictive. It might be necessary to transport the water to more suitable sites in the higher ground, either to the east or west of the valley. A pressure pipeline would probably be required to traverse the valley (a more expensive solution than an open canal); thus, water transport costs could amount to $30/acre-ft or more.

The water contains approximately 3000 ppm total dissolved solids, and water of this quality, although not useful for most domestic, industrial, or agricultural purposes, can be used in cooling towers (Marley Corporation is constructing such units for the Potomac Electric Power Company at this time). The water will probably require chemical treatment to cope with the problem of nutrients and other substances found in drainage. Thus, it is not technical factors which prevail, but the social decision as to what is to be done with the Salton Sea.

Another area where agricultural waste waters are being aggregated is the San Joaquin Valley. In the Federal San Luis District, the main drain is under construction. In a communication from the Bureau of Reclamation to Prof. Charles Washburn,[24] the following forecast is made for the buildup of flow in the San Luis Drain:

Year	Acre-Feet/Year
1977	12,000
1982	45,000
1987	73,000
1992	108,000
1997	142,000
2002	150,000

It is seen that by the middle of the next decade, perhaps 2000-2500 MW of generating capacity could be supported by the San Luis Drain. Because the increasing drainage indicates increasing rates of water usage, it could be inferred in the earlier years that a surplus of fresh water exists and could be used for cooling. This surplus does not exist for a long-term commitment to cooling use, however. There is the possibility that the early surplus can be used for cooling, with transition made to the use of waste water in later years. Thus, up to 6000 MW of nuclear-generating capacity might eventually be supported by the San Luis system.

In Bulletin 127 *San Joaquin Master Drain*, California Department of Water Resources, even larger waste flows, ranging in excess of 300,000 af/yr, are forecast for the balance of the San Joaquin Valley. Here again, a transition from surplus fresh water initially, to drain water in later years, might be envisioned. Thus, in the southern Central

Valley area, a total cooling water supply of nearly one-half million af/yr might be contemplated. Only a detailed study will reveal the practicality of the notion, but the enormous revenue-generating potential of electric power may offer a welcome additional resource in planning the necessary waste-water disposition system, which has so far proven difficult to finance from the agricultural base alone. In addition to conveyance costs, the use of drain waters will require other expenditures. In some cases, chemical treatment of the water will be necessary to insure efficient operation of the cooling system. Another factor is the seasonal nature of irrigation and drainage. In a study of the San Joaquin drain area,[25] the seasonal variation of the waste water flow was estimated. To permit a constant supply rate to a power plant, storage would be necessary. A simple calculation indicates that for the variation pattern referenced, storage capacity for nearly 30 percent of the annual total flow is needed if the total flow is to be utilized. Thus, if a drain system passes 100,000 af/yr, and one wished to use all of it for power plant cooling, a storage capacity of 30,000 acre-feet would have to be provided.

3. Reductions in Municipal and Industrial Use

In addition to the development of new supplies, water could be made available for power plant cooling by more efficient use of present supplies. It has proven very difficult to obtain data on the details of water usage in industry. Additionally, no single industry uses such large quantities that a fractional saving would appreciably increase the utility of present supply. The subject is summarized in Bulletin No. 166-1, *Municipal and Industrial Water Use,* Department of Water Resources, August 1968. However, it is clearly indicated there that soft spots exist in the urban use pattern where savings could be made. For example, in communities with unmetered water, the per-capita consumption is 30 to 40 percent higher, as compared to equivalent metered districts. However, water use in the major population centers in California is already metered. Because of the marked local variations in water usage patterns, it is difficult to make a state-wide estimate of the value of water conservation measures.

There are however, one or two almost universal water-consuming devices whose performance bears examination. Consider, for example, the ubiquitous water closet. In a series of recent studies by the Environmental Protection Agency, National Aeronautics and Space Administration, U.S. Geological Survey, and commercial organizations, the use of water in homes has been studied. These studies indicated that approximately 40 percent of household water use is attributed to toilets. This demand amounts to about 25 gallons per day per capita. The typical household toilet uses about 5 gallons for each flush. However, a variety of toilets are manufactured which require only 2 gallons per flush, and it is reported that ordinary household units can be made to operate properly, using only 2-1/2 gallons. Thus from 10 to 15 gallons/capita-day could be saved simply by revising or replacing these household fixtures. This water, used for power plant cooling, would correspond to 10 to 15 kw-hrs generation.

At this time, the total per-capita electrical requirement for California citizens is about 16 kw-hrs/day. Thus, if our electric requirements double over the next ten years, as some projections indicate, most or all of the generating capacity required could be cooled by water saved with more efficient toilet fixtures.

It has been argued that the use of fresh water to cool power plants in California is somehow unthinkable, or at least immoral.[26] In view of this exposition of how we actually use a small fraction of our water, the argument seems less than satisfying. It should not be inferred, however, that such conservation practices are necessary or recommended. The total economic and conservation implications would have to be considered; e.g., the additional benefits owing to reduction of loading on sewer system, as well as the alternative conservation measures that might be taken in agriculture or other areas. What are the costs, in dollars and energy, that would come about through replacement of existing hardware? It is not the purpose of the present study to resolve such issues, but only to point out possible sources of cooling water. One should also recognize that greater efficiency in urban water use may reduce the potential for waste water reclamation.

4. Agricultural Water

At the present time, over 85 percent of the water used in California is for irrigation purposes. This use amounts to nearly 30 million af/yr. Obviously, with such a large base, even small fractional improvements in water usage could release large quantities of water for other purposes. Such conservation measures are usually taken only in response to economic pressure (high water prices) or absolute limits on supply which are below demand levels. For example, Israel, with very marked limitations on water supply, is a center of research on such agricultural practices as drip irrigation. This technique is being carefully considered in some parts of Mexico, where again, water supply is far short of what could be profitably used on the available land. In the U.S. such practices have become of interest only in those areas where water is expensive, and the crops are high-value (e.g., tomatoes in San Diego county). Overall, an improvement of 5 percent in efficiency of irrigation would yield 1-1/2 million af/yr, sufficient for cooling all power plants that might be required in the 1980's. Such a glib argument is not satisfying, however. After all, the extra water made available could also be used as it is presently, for more agricultural purposes.

The question of the proper role of agriculture in the economy of California is not simple, and is covered in a vast body of in-depth study. The Framework Study (Appendix IV, *Economic Base and Projections,* Comprehensive Framework Study, California Region, June 1971) points out that in 1965, crops, livestock and agricultural processing accounted for about 12 percent of "gross domestic output" in California. Owing to the more rapid growth projected for other sectors of the economy, this share was expected to fall.

Simply as examples, we draw upon a few specific cases covered in the Framework Study. The study points out that the Base Plan projections call for two- to three-fold increases in rice and cotton production in California in the next 50 years. This is thought to be unrealistic in some quarters, owing to technological progress and changes in the world markets. Thus, the Framework Study (page 118) calculates the effect on their projections, if production of these commodities should remain at 1965 levels (their baseline year). It also shows that projected water requirements for California would drop by 4.6 million af/yr, or 8 percent but that gross regional product would drop by only $715 million, or 0.07 percent. (It should be pointed out that if one crop becomes less profitable, usually another crop replaces it. However, the values of crops are functions of supply, and our capacity to absorb agricultural products is not infinite.)

The calculation demonstrates two points. First, the actual water demands made are subject to market forces and government programs and controls, and second, that major manipulation of these sectors need not result in major dislocations of the regional economy, although specific agricultural areas will of course be influenced enormously.

Another example from the Framework Study is feed grain production in California. It comments on the influence of economic forces (page 54): "... it can be shown that there is possibility for a substantial reduction in water requirements with relatively little impact on employment, income, or net returns." California produces a small fraction (2 percent) of the nation's feed grains, so a reduction of production in California would have a small effect nationwide. Of the feed grain used in the State, approximately one-half is imported (from other regions). California produces from these grains (1964) 64 percent of its beef and 2 percent of its pork.

The Framework Study goes on to state that in its Base Plan projection, California would use (in 2020) 15 million af/yr for feed. It then shows the impact of reducing this consumption by 5 million af/yr (9 percent of the regional supply.) Gross regional product decreases by $357 million (0.056 percent). No clear statement is made in the Framework Study summary as to the amount of water being applied to feed grains at the present time. To clarify this point, Table IV-1 has been constructed from data taken from *Agricultural Statistics – 1972,* Department of Agriculture, U.S.G.P.O. A review of the 1969 Census of Agriculture, U.S. Department of Commerce, Part 48, California, reveals (Table 30) that most of the feed grain acreage in California (oats being a notable exception) is irrigated. The question is, how much water is used per acre for different areas and crops? Feed grains and hay use somewhat less than other crops. The Department of Water Resources[27] suggest 0.8 ft/yr as a statewide average. One can infer a somewhat larger number from data shown in Appendix IV of the Framework Study.[28]

TABLE IV-1

1971 FEED GRAIN PRODUCTION
(U.S. Dept. of Commerce)

TYPE	ACRES (1,000's)	PRODUCTION (1,000 bushels)	PRICE ($/bushel)
Corn			
California	264	24,816	1.48
U.S.A.	63,819	5,540,253	1.06
Oats			
California	102	4,896	0.84
U.S.A.	15,734	875,775	0.602
Barley			
California	1,087	57,611	1.31
U.S.A.	10,135	462,484	0.961
Sorghum			
California	405	28,755	1.34
U.S.A.	16,601	895,349	1.03
Total			Average
California	1,858	116,078	1.22
U.S.A.	106,289	7,773,861	0.91

But let us take, as an example, the irrigation of sorghums. Application of even one foot of water each year requires over 400,000 acre-feet of water, and produces gross revenue of $38.5 million. *(California State gross product in 1970 approximated $80 billion.) This amount of water, evaporated in the cooling towers of nuclear power plants, would support the generation of 1.63×10^{11} kw-hrs (about the amount of electric energy consumed in California in 1970), which at a wholesale price of one cent per kw-hr would have a value of $1.63 billion. Clearly, the economic "clout" of electrical generation is very great. In this instance, the electric utility could pay less than $100/acre foot for the water, and that revenue would be greater than the total gross value of the crop foregone! The incremental cost to the power user would amount to about 0.24 mill/kw-hr, or 2+ percent at wholesale.

Since the economic importance of electric power is sometimes overlooked, some gross comparisons are instructive. Consider a nuclear power plant of 1000-MW capacity. It will produce about 7×10^9 kw-hrs-per year (at 80 percent load factor), with a retail value of perhaps $100 million. It might use 25,000 af/yr for cooling, an amount sufficient to irrigate 5,000 – 10,000 acres, depending on the region. Even in such highly productive areas as the Imperial Valley or the San Joaquin Valley, gross annual agricultural revenue averages about $500/acre, so, at the most, agricultural revenue would decrease by $2.5 to $5 million. This economic disparity is of small comfort to the deprived agricultural area, however. But, consider that the plant represents an installed value of perhaps $400 million or more ($400/kw is not a bad estimate for nuclear plants built today and prices are escalating rapidly). Property taxes vary in California, but 2 percent of real value is a conservative estimate. The tax revenue yielded to the local area by the power plant can amount to $8 million. Thus, local tax revenue greatly exceeds the gross farm income lost, owing to this alteration in water use! It seems clear that in an economic comparison, power generating facilities pose formidable competition to agriculture. It is not unreasonable to suppose, therefore, that some small fraction of water intended for use in agriculture could be diverted for power plant cooling. If the fraction so diverted eventually amounted to perhaps 5 percent, or 1-1/2 million af/yr, it would support 60,000 MW installed capacity (operating as base-load plants), about three times the present generating capacity in California.

5. Changing Forecast

The possible sources of cooling water so far delineated were all cast in terms of diversions or savings in water consumption patterns and uses. It is recognized, however, that today there is an excess of developed water supply, as compared to present needs on an overall State-wide basis, inasmuch as major development and conveyance systems have recently been completed which were designed to satisfy our needs for many years into the future. A question remains, however; for how many years into the future will present supplies be sufficient? It has already been indicated that a water projection based on 1970 census forecasts and the OBERS plan shows ample water supplies extending into the next century.

If this projection is correct, it is suggested that surplus water may be available for cooling throughout the useful life of the power plants to be built for the next 10 to 20 years. During this time, new technology will probably be developed which may reduce or obviate the need for cooling water (e.g., nuclear gas turbine cycles, wet/dry cooling towers). Thus, the use of water for cooling power plants, starting now, would not require the development of new water supplies.

The problem of forecasting is always beset with uncertainty. However, all present trends in the United States, and California in particular, point to population levels well under even the SD-70 projections. This translates into reduced water requirements. In a recent press statement, Mr. William Gianelli, Director of the State Department of Water Resources, stated that the State Water Project would have an excess capacity until after the turn of the century. If this is true, there will be many water contractors (agencies which buy State water) who will find it difficult to sell enough water to fulfill the terms of their contract. Such agencies might even welcome the opportunity of relinquishing a portion of their allocation and obligation for a period of 30 to 50 years.**

H. Conclusion

In contrast to the commonly held view that water is very scarce in California, it is seen that the major question is actually one of distribution and use, both geographic and economic. Several sources of cooling water have been identified (reclaimed municipal water, agricultural waste water, conservation of municipal water, diversion from low-value agriculture, use of developed but presently unused supplies), almost any one of which could provide for anticipated expansion of electric generation in the next 10 to 15 years. To use some of this water for power plants may require, to be sure, that we change our viewpoint and consider water, to some extent at least, an economic commodity. Obviously none is available from agricultural supplies, if we feel impelled to continue to supply water to whoever wishes it, at whatever price one feels the user can afford (as long as some other revenue source, such as the

* Agricultural products have generally increased in price in the recent past, but the price for electrical energy is likewise escalating.

** The Metropolitan Water District of Southern California, recognizing the difficulties faced by the electric utilities, has recently agreed to supply 100,000 af/yr from its Colorado Aqueduct for power plant cooling. This action was made possible only because MWD can obtain sufficient replacement supplies from the State Water Project.

electricity consumer or the general taxpayer, will make up the deficit). It is not the purpose of this discussion to pinpoint one source or another as being the preferred one for coolant water, but rather point out that a menu of potential supplies exists. To allocate these supplies to power plant use is a technical, economic, and political decision, and may even require changes in law. Thus, this discussion is not a road map to a water supply, but simply an indication that the objective is attainable.

V. INLAND SITING AREAS

A. General

Owing to the great diversity of the inland areas of California, it is not as easy to develop a simple site-screening procedure, as was the case for the coastal region. Because of the greater physical area (call it two orders of magnitude, or more) available, one would expect that a multitude of sites could be found. To give some feeling for the possibilities, however, it is worthwhile to examine a few cases.

First, let us apply the seismic and population criteria to the entire State, as was done for the coast. In Figure V-1, heavy shading shows Seismic Risk Zone III, and population separation circles have been drawn around all population centers of over 50,000 persons (1980 projections). What do we learn from examining Figure V-1? Certain regions will present great difficulties for siting. The coastal mountain region between Monterey and Santa Barbara is partially clear of seismic or population exclusions, but it is known that no substantial supplies of cooling water exist, except along the coast.

The great Sacramento–Stockton–San Francisco population complex makes it appear that nuclear sites in that area will be difficult to find.* The south coastal region, between Los Angeles and San Diego, may offer a few possibilities, one of which will be taken as an example. The promising areas are the eastern desert in Southern California, the Central Valley, and the Sierra foothills. Generally, mountainous areas of Northern California would seem less desirable for construction.

B. Examples of Specific Siting Areas

1. East Desert

Great areas of San Bernardino and Riverside Counties are in low seismic zones, with sparse population. In these areas two possible sources of cooling water exist. The first is the water flowing in the MWD Colorado Aqueduct. The MWD has agreed to sell to the Southern California Edison Company (SCE) and other utilities up to 100,000 af/yr of that water. They will have an ample supply from the State Water Project to take care of deliveries presently being made from Colorado River water. Some legal arrangements and permits remain to be completed, but SCE has announced their intention to purchase two HTGR systems and to site them in the eastern desert, using 40,000 af/yr of this aqueduct water.

Because the population growth rate in Southern California may decrease still further in the future, and because of the slowly deteriorating quality of the Colorado River water, MWD may find it possible or even desirable to allocate additional amounts of Colorado Aqueduct water for power production in years to come. Because of the limited firm entitlement MWD has to Colorado River water, the maximum available from that source is approximately one-half million af/yr, sufficient for possibly a 20,000-MW capacity. It is emphasized that this presents only an upper limit, not necessarily a likely allocation.

A second source of water for the east desert area is agricultural waste water from the Imperial Valley. Unfortunately, the valley itself is a highly seismic area; thus, the water would have to be conveyed to the eastern parts of Riverside or San Bernardino counties. In gross terms, from 50 to 100 miles of conveyance, probably pressure pipeline, would be necessary. Diversion structures on the New or Alamo Rivers would probably be required. The terrain to be traversed is mountainous, and elevation differences of over 1000 feet are likely. Thus, the water, although free at the source, will assuredly not be free at the point of use. A careful study of siting possibilities should be made, trading off the cost of water conveyance and distance to the desert transmission lines. If a major plant capacity were to be installed in this region (e.g., 5000 MW), it is likely that a wholly new transmission corridor to the Los Angeles regional load center would be appropriate.

An alternate location for a generating station using Imperial Valley drain water might be on the western edge of the valley, near the international border. This is just outside the seismic Zone III area, at the foot of the Peninsular Range of mountains. However, careful geologic review would be necessary to establish suitability. Not only are water conveyance distances shorter to this point, but elevation differences are less, as compared to most of the east desert areas. No transmission lines exist in this area; thus, about 70 miles or more of new right-of-way would be required to reach the San Diego area.

2. San Joaquin Valley

Moving northward, a possible siting area is in the Tulare Basin region of the southern San Joaquin Valley. Agricultural waste waters are a genuine problem in this

* We note that the Rancho Seco site (Sacramento Municipal Utility District) is just within the population separation circle we have set.

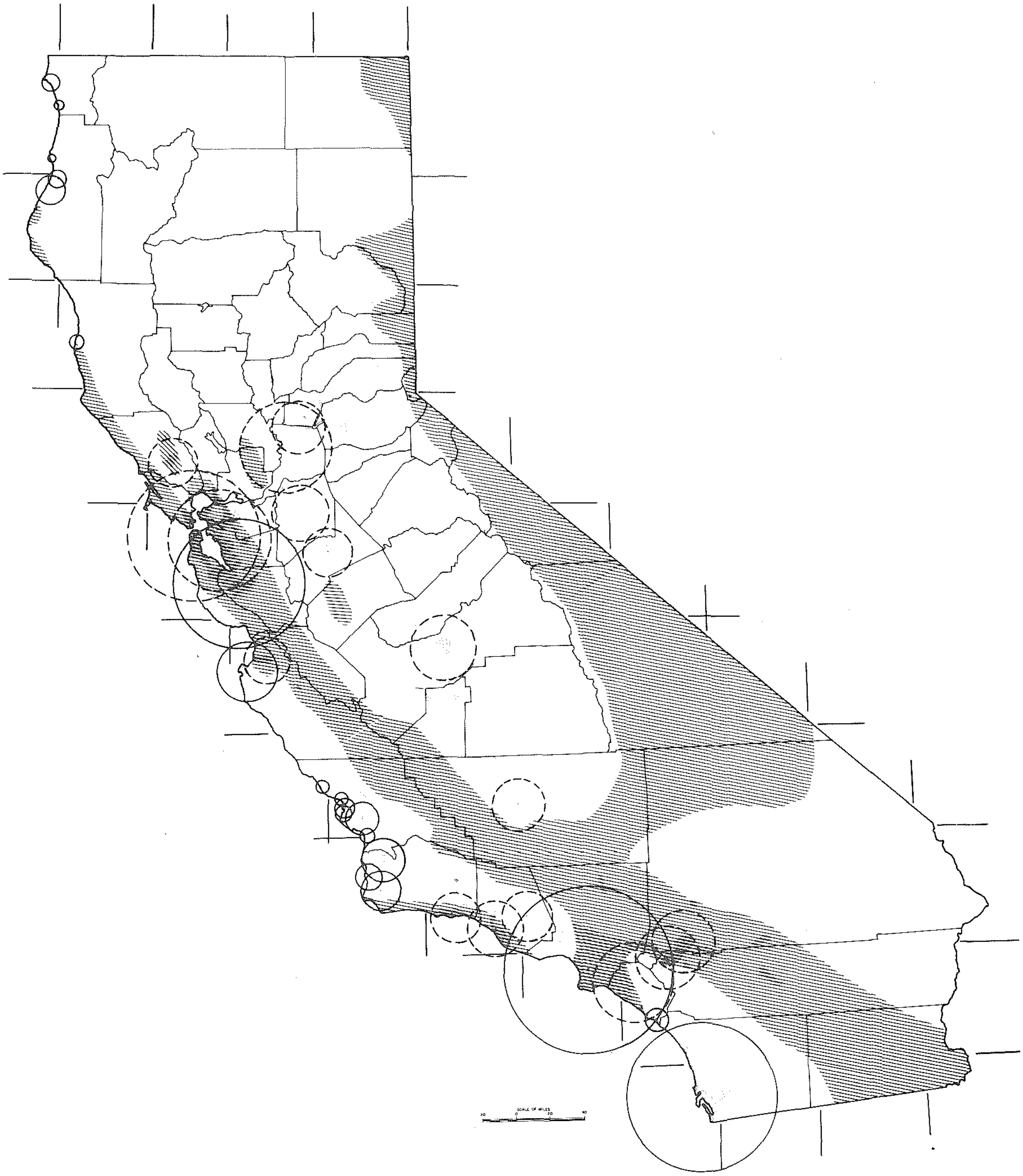

Figure V-1 Siting Area Exclusions [Shaded areas - seismic exclusion; circles - population exclusion (only towns over 50,000 shown in inland areas)] region and if a power plant could help alleviate the situation, its presence might be welcomed. No adequate man-made system for accumulating the drainage yet exists, but there may be accumulation in natural aquifers which could be tapped. In reducing the water level of unusable aquifers (by pumping), the drainage situation might be improved, even lacking a surface or sub-surface drainage system.* The map in Figure V-1 indicates that it is possible to avoid both population centers and seismic zones in the Tulare Basin area. The area northeast of Tulare Lake is such a spot, for example, and lies within 30 miles of a major PG&E transmission facility (Gates sub-station). Some of the problems that might be encountered in using these waste waters have been reviewed by the State Department of Water Resources.[29] In their study, it is estimated that 54,000 af/yr of drain water would be available in 1980 in the Central Tulare Lake area.

Further north, perhaps in the western portion of Stanislaus County, it may be possible to use San Luis Drain water, as discussed in Section IV. Water conveyance and electric transmission distance are minimized in this area. Here it is possible to avoid the Modesto-Stockton-South Bay population separation circles and remain within seismic Zone II, as depicted in Figure V-1.

Still further north, in the Delta area, it is difficult to avoid population, and that area seems less likely for siting purposes. The eastern side of the San Joaquin Valley and the Sierra foothills offers many satisfactory areas from the standpoint of population and seismicity. However, there are no apparent sources of waste water, although such waters could be pumped in from areas previously discussed. Lacking a waste water supply, a utility would have to buy its water supply from existing water-right owners in that region.

3. Sacramento Valley

This above-mentioned situation is generally the case in the Sacramento Valley, where little or no agricultural waste water exists; thus, arrangements would have to be made for the purchase of fresh water supplies. This has been done by the Sacramento Municipal Utility District (SMUD) for their Rancho Seco plant. SMUD has contracted for 75,000 af/yr from the Folsom South Canal with the Bureau of Reclamation; thus, they will be able to expand considerably beyond the single 960-MW nuclear plant that is about to go into operation there.

Another possibility in that area is the use of effluent from the Sacramento sewage system. It is reported that 60,000 af/yr may be available from this source. Were it transported to the Rancho Seco site, for example, additional capacity of 2 to 3 thousand MW could be located there.

In the more northern reaches of the Sacramento Valley, population centers are few and seismic risk is low. Large supplies of low cost irrigation water exist. No specific areas are suggested by this study as preferred, but if institutional barriers to the use of irrigation water for power plant cooling can be overcome, the opportunities here seem numerous. In particular, in this and other areas, the use of existing reservoirs as cooling ponds is worthy of detailed examination.

C. Conclusion

Without exercising the option of diverting present irrigation water for cooling, it appears that substantial supplies of cooling water, in or near areas suitable for nuclear power plant siting, are presently identifiable for a time frame beginning in 1980. By water source, these are:

Colorado Aqueduct	100,000 af/yr
Imperial Valley Drains	100,000-500,000* af/yr
Tulare Lake	50,000 af/yr
San Luis Drain	10,000-75,000 af/yr
Sacramento Area**	50,000-100,000 af/yr

* One-half of total flow.
** Beyond requirements for Rancho Seco Number 1.

It would appear that inland areas suitable for siting, having accessible water, could support the construction of at least 10,000 MW of nuclear generating capacity. It is quite possible, if the Imperial Valley drainage is exploited, that another 20,000 MW could be provided for.

VI. COST FACTORS

Until quite recently, the choice of a power plant site could be based almost exclusively on economic factors. The objective of providing power at lowest cost could be translated into siting criteria that involved cooling water, proximity to load centers, availability of fuel, and so forth. Certain of these factors involve capital outlay, and others influence operation cost (some affect both). To permit ready comparison of alternatives, it is sometimes convenient to annualize the capital costs and compute the kw-hr cost of delivered power. To do this in detail is complex, and a very accurate accounting system is necessary for utility operations. In this study, however, only broad comparisons are being drawn, and highly simplified assumptions can be employed. For example, capital cost can be annualized at a rate of 15 percent, to cover return of capital, profit (or interest); the plant utilization factor (for these base-load

* Note, however, that the act of pumping may cause earth subsidence, which could endanger the power plant itself, as well as surrounding areas.

plants) is assumed to be 85 percent, which may be representative of at least the first decade of plant operation. No attempt will be made to estimate the total construction and operating costs of nuclear power plants, much less of other methods of generating electricity. Instead, only those elements influenced in a major way by the class of site will be considered. Included are cooling systems, cooling water conveyance, and transmission, as well as some lesser items. The nuclear steam supply, turbine/generator, and other major elements are assumed to have equivalent cost, regardless of location. In making these comparisons, a number of factors bring about confusion and uncertainty. One major difficulty for utilities at this time is the rapid escalation of construction costs with each passing year. For simplicity, as closely as is possible, this document will try to use current dollar values. Probably not all cost elements will escalate at the same rate; thus, comparisons for future times based on current cost may be somewhat skewed.

Interest rates vary, of course, and influence the optimum balance between capital cost and operating cost. Here again, no attempt is made to consider the variability. All of these details are of great importance to a public utility and to regulatory bodies when a particular site development is being considered.* It is the purpose of this study, however, to investigate major cost impacts of alternative classes of site in a broad-brush fashion.

It has been commonly assumed that power plants situated on the coastline offer significant economic advantage, as compared to inland sites. This evaluation dates back for a number of years, even to a time when nuclear power plants existed only as a dream for the future. The comparison was soundly based. Most power plants could be located near load centers which, in California, were along the coast; thus, transmission lines were short. The ocean water was picked up and discharged using simple, economical structures. Ample land was still available for development, even near cities. Today, however, many of these factors are changing and the economic advantage of the coastal plant may be reduced. This is particularly true for nuclear plants which cannot be situated near population centers, and which may be further restricted in location by seismic and other criteria.

First, let us consider the issue of land costs. Even prime agricultural land, inland, is presently valued at about $1000/acre. Coastal land on the other hand, is rarely available for ten times that price. A site for a two-unit (1100 MW each) nuclear power plant might typically occupy 500 acres of land. The inland plant, therefore, enjoys a land acquisition cost advantage of several millions of dollars; but overall, this is a small fraction of the cost of constructing a two-unit plant (which with its transmission lines may approach a one billion dollar investment).

Another site-peculiar cost element to be considered is that of providing protection from earthquake forces. There being no seismic equivalent of the lightning rod, no particular added feature of the plant can be isolated for examination. The aseismic design permeates the entire complex, from foundations to cable trays. A search of existing literature has so far yielded no adequate treatment of aseismic design cost, and discussion with utility and industry leaders has elicited only the opinion that no generalized study has been done. (Some are of the viewpoint that no generalized study would have validity.) However, a recent study of power plant cost[30] by the RAND Corporation suggests that a differential of 1.0 mill/kw-hr in the cost of electricity results from siting in Risk Zone II, instead of Zone I. As previously noted, it is the opinion of the present author that Zone III siting is unlikely in the near future.

A major site-dependent cost factor is the transmission system necessary to connect the power plant into the utility grid. Here again, the total impact of location on cost to the utility is difficult to generalize. In addition to the clearly identifiable circuits linking the plant to the existing grid, the grid itself may well require expansion to accommodate the increased input, and the cost of this will vary from point to point. For simplicity of comparison, however, this aspect will be ignored, and only the new circuit mileage connecting the plant to the grid will be considered. Line losses are ignored, together with the requirement for lines which bring power to the site to support the plant operations, such as start-up.

For sites removed from load centers, California utilities might generally utilize 500 kv circuits. For system reliability, either three 500-kv single circuits, on two separate routings, or two double-circuit lines, have been planned for two-unit nuclear plants (viz., Diablo Canyon and Mendocino). For planning purposes, the cost of a single-circuit line is often given as $150 thousand/mile, for normal construction conditions with right-of-way in low value areas; although some recent utility estimates indicate somewhat higher values.[31] This capital cost does not consider the effects on system stability or line losses associated with increased length. These lines can be of substantial length for remote plant locations. For example, at Diablo Canyon one route is 79 miles, and the other planned for two lines is 84 miles. At the proposed Mendocino site, the transmission corridors were to be 112 and 134 miles long, with two lines on the shorter leg. The transmission lines were estimated to cost in excess of $60 million.

A serious cost increase has recently been imposed on coastal plants. In order to meet the requirements for

* Even so, the accuracy and value of the detailed estimates are open to question. In one case, a major California utility calculated a 3-percent differential in the cost of power delivered from alternate sites, and declared that the "expensive" site was economically unacceptable. Subsequent to the initiation of construction at the preferred site, estimated capital outlays nearly doubled.

limiting the temperature rise experienced at the shore and in the sea, it is necessary to install extensive outfall systems. Avoiding entrainment of floating organisms often requires intake structures of increased complexity. The cost differentials for such added features can only be estimated for a particular site, owing to the enormous variety of coastal and ocean conditions between sites. As has been noted, at the Diablo Canyon site of PG&E, it was estimated that the offshore diffuser system, using mined tunnels under the sea bed, would increase cost between 38 and 42 million dollars. The California water quality control regulations were passed after Diablo Canyon was approved. All future plants would have to meet the new regulations, which the Diablo Canyon shoreline discharge does not.

For Mendocino, PG&E has estimated the cost of several alternative cooling designs,[32] again with the conduits tunneling through the sea bed. With shoreline intake and near-shore discharge, construction cost is shown as $83 million. For offshore discharge, with diffusers, the cost is $93 million, and to incorporate offshore intake, in addition, runs the construction cost to $110 million. The cooling water may be free, but to use it is not! (It is worth noting that a $10 million capital cost would be reflected as about 0.1 mill/kw-hr in the cost of generated electricity).

In Supplement No. 2 of the Diablo Canyon Environmental Report, PG&E estimated the cost of installing cooling towers at the site as an alternative to once-through cooling. The tower cost was reported to be $38 million (mechanical-draft towers), but no note was made of savings that might be possible owing to elimination of shoreline intake and discharge. Exact cost comparisons are not always possible to make from published data, and in any case are site-peculiar. One might infer, however, that cooling towers and off-shore diffuser structures are roughly equivalent in capital cost. This comparison can be misleading, and the total cost of evaporative cooling will be discussed in subsequent paragraphs.

Another type of construction has been utilized for outfall diffuser systems, where ocean conditions permit. This is pipe laid on the ocean floor. Such systems have been used in Southern California waters. The Southern California Edison Company, in its Environmental Report (Construction Permit Stage) for San Onofre Units 2 and 3, offered cost comparisons between various types of cooling systems. A single-point off-shore discharge system, with offshore intake, is listed as having a capital cost of $27.6 million, but the diffuser system necessary to meet State water quality standards would require $44.7 million capital cost. SCE also estimates the cost of a cooling tower system using salt water, and shows an $81 million capital outlay. In addition, a cooling tower system suffers from lowered efficiency and capacity of the power plant, resulting from the poorer condenser performance. SCE has indicated that they prefer the diffuser system as being the most economical plan which meets the State standards at San Onofre.

One major objection to coastal sites for power plants is based on the desire to retain the coastline for recreation, unencumbered by even the sight of an industrial facility. A means of reconciling the desire to use ocean water for cooling while preserving the shoreline area is to set the power plant back some distance from the ocean and bring the water to the plant via conduits. The cost of this water transport will depend on the distance to be covered and the elevation of the plant above the sea. As with most other factors, the cost will be highly site-dependent. Nonetheless, for purposes of assessing the general worth of the notion, it is important to estimate the economic penalty in some way. The pumping structure will still have to be near the water's edge. Usually these installations are partially below grade, and for aesthetic purposes they could be fully buried. From this point outward, the intake and outfall systems are the same as those for a plant at the water's edge. Now, however, the conduits must run a greater distance to the power plant. If we ignore the cost of the additional pumping requirement to overcome the pressure drop in the longer pipes and possible elevation differences, the cost of the conduits themselves will be a lower limit to the extra cost of the set-back facility.* The cost of buried conduit of these sizes (15 to 18 feet in diameter) is not a firmly established value, but $5 million per mile is thought to be representative. Each 1000 MW class unit requires two such conduits (intake and discharge); thus, this set-back will cost perhaps $10 million per mile, ignoring pumping cost. This cost might be reduced somewhat if an open canal could be used in lieu of buried conduit.

When cooling towers are used for inland plants, it will be necessary to transport the make-up water from its source to the location of the plant. Although a plant location might be found immediately adjacent to the supply, more commonly some conveyance will be necessary. The least expensive method is usually an open canal, but this is often not possible, owing to topography and existing land use. For purposes of this study, it is conservative to assume that a pipeline will be employed. The total flow rates involved are well within the bounds of common engineering practice. For a two-unit nuclear plant, for example, perhaps 50,000 af/yr (about 50 million gallons/day) would be required. To transport this amount over level ground for distances of tens of miles, using a single set of pumps, suggests that a concrete pipe of perhaps five foot diameter would be appropriate. Standard estimating handbooks indicate that the installed cost for such a pipe ranges from $50-$70/foot, or $250 thousand to $370 thousand per mile. Pump cost might amount to $1.5 million, but is of course sensitive to any elevation gain, the length of the pipeline, and so forth. Costs for such a water conveyance are usually optimized, balancing pressure loss, pump cost, pipe size, and similar factors. Clearly, conveyance cost is site-peculiar. On the

* An additional environmental penalty accrues, as the entrained organisms are exposed to elevated temperature for longer times, making for increased mortality.

other hand, the cost for water conveyance seems roughly equivalent per mile to that for transmission, a fact also noted in the previously referenced RAND Corporation study of power plant costs. It should be remembered that none of these conveyance costs include the price of obtaining the water. In some cases, water will be purchased from existing supplies, while in others a supply must be developed from ground or surface water. Clearly, the cost of the water could vary over an enormously wide spectrum, and is totally site-peculiar.

The true complete cost of a closed-cycle cooling system, using towers or ponds, is difficult to assess. First, there is the capital cost of the equipment, which is relatively straightforward. Also, the cost of operating the system must be calculated. This includes the electric operating power, chemical water treatment, and maintenance. More difficult to evaluate is the loss of plant efficiency which often results from higher cooling water temperatures (as compared to cooling with ocean water). This enters into fuel costs, and is somewhat a function of the climatic conditions in the area. Another important factor is related to the efficiency loss; for the same size nuclear steam system, less power is produced by the plant, owing to the higher reject-heat temperature. This is a loss in plant capacity, and for the same investment one simply gets less, or equivalently, the investment per kilowatt capacity is higher. To assign a dollar value to this loss requires careful consideration of the particular situation. In some utilities, the loss might be made up by peaking units, while in others additional base-load capacity may be appropriate. Thus, no set accounting scheme can be used in all cases.

The calculation of cooling tower total costs has been widely considered in published literature. For present purposes, it is not fruitful to carry out a critical review of such studies, pointing out the differences between them. Rather, it is the similarity of cost estimates among several sources that is of interest. For example, Hauser[33] calculates the incremental cost for power generated in nuclear plants using alternative cooling methods. Table 4 of his report is shown below.

Table 4. Total Cost Addition to Generation Cost (L. J. Hauser)

Source	Mill per kilowatt-hour*
Fresh water	Base
Cooling Ponds	0.0871
Sea Coast	0.0336
Wet Cooling Towers (mechanical draft)	0.2097
Wet Cooling Towers (natural draft	0.1986
Dry Cooling Towers	0.8168

Hauser emphasized that these are average figures and will vary from site to site. He then observes that, with the exception of dry towers, the cost increases are less than 5 percent.

In a working paper[34] of the Federal Water Pollution Control Administration, the authors compare the work of Hauser and others. The cost penalty for wet mechanical draft towers, estimated by Hauser (in an earlier paper than referenced above) to be 0.1557 mill/kw-hr, can be compared to other results, which range from 0.150 to 0.2 – 0.3 mill/kw-hr. The lower estimates were based on public agency financing. The interesting point made in the document is that wet towers add only 3 percent or less to the customers' actual cost.

In another paper,[35] Leung and Moore report on estimates of increased cost owing to the use of wet cooling towers, compared to the use of once-through ocean water, for fossil-fuel-fired plants. Their figure is 0.167 mill/kw-hr (about 2.4 percent) incremental increase in cost of generation.

All of the estimates quoted are for earlier time periods, and the rapid escalation of construction and operating cost would call into question the absolute values of estimated increment. However, the percentage increase would tend to remain constant. This can be compared to a recent study of alternative nuclear siting techniques, for California conditions, by Holmes and Narver.[36] In this study (Table D-26), electrical generation costs are compared for a capital-fixed rate charge at 15 percent. A value of 8.86 mill/kw-hr is shown for coastal plants, while a cost of 9.65 mill/kw-hr is computed for inland sites. The cost penalty is, thus, 8.9 percent for inland siting.

From the detailed comparisons given in the references, one would conclude that one-fourth to one-third of the incremental cost of generation for the closed-cycle cooling system is due to capital expenditures, above the cost of a simple once-through sea-water system. As previously pointed out, however, new water-quality regulations for ocean discharge will further increase the cost of the circulating sea-water system; thus, reducing the differential between ocean-cooled and tower-cooled plants. Moreover, as has been indicated, coastal sites may involve substantially more transmission in Central and Northern California areas. This will further reduce (and in fact may eliminate or reverse) the capital cost advantage of coastal siting.

On the other hand, the calculations cited made no explicit provision for the cost of the water. This contribution is easily found, however. If a 1000-MW nuclear

* It is the author's view that carrying cost numbers to four significant figures is unjustified by the accuracy of the input data in generalized studies.

power plant consumes 25,000 af/yr and produces 7.5×10^9 kw-hrs/year, the cost in mill/kw-hr is equal to 0.0033 times the cost of water in dollars/acre-foot. Even if water were as expensive as $100/acre-foot (including conveyance) the generation cost would be increased by only 5 percent (at today's low rates). In the future, with other costs rapidly escalating, the percentage may be even less. Moreover, some sources of water will undoubtedly be available at much lower cost. Thus, the total cost of generation at inland plants, as compared to coastal plants, might be higher by 3 to 10 percent.

Because generation represents only a fraction of the cost of electricity delivered to the customer, it is clearly seen that inland siting will introduce only a small increment of increased cost, perhaps 1 to 4 percent, to the electric bills of the customer. Although unwelcome, this increment is probably acceptable. In fact, when all cost factors and operating losses are considered, it may turn out that some well-chosen inland locations offer a slight cost advantage, as compared to coastal sites meeting all present siting criteria. It is concluded, therefore, that cost does not represent a barrier to the general notion of siting nuclear power plants at inland locations in California.

VII. SUMMARY AND CONCLUSIONS

Present electrical demand growth in California and the various problems associated with alternate means of generation suggest that nuclear power plants will continue to be favorably considered by the electric utilities. Increased concern for plant safety and for environmental values is reflected in ever more stringent siting requirements by the various licensing bodies. Although coastline siting has been emphasized by utility planners, inland siting has been chosen in selected cases. Availability of cooling water has been a prime constraint for inland siting, while environmental and seismic constraints have strongly influenced coastal choices.

This study concludes that the unavoidable environmental impact of coastal siting is mostly associated with the visual presence of the plant. The effects of the discharged cooling water can be minimized by straightforward (but expensive) engineering methods. The environmental impact of inland plants is largely associated with the prominent cooling towers and their discharges.

A survey reveals that approximately half of the California coastline is probably unacceptable for nuclear power plants, owing to seismic problems. Over half of the remainder is unsuitable, owing to proximity to population centers. After reasonable criteria for terrain and geology are applied, just over 100 miles of coastline remain for consideration, and one-half of these are probably unsuitable, owing to land-use conflicts. Thus, only a short stretch in the area of San Onofre, and a longer stretch in the region of Diablo Canyon, remain in Southern and Central California. Other potential siting areas are in the far northern portions of the State.

Substantial quantities of cooling water for inland sites can be found. Most likely sources are agricultural waste water and presently unused supplies of fresh water. In future years use of reclaimed municipal water and/or greater efficiency in fresh water utilization may be necessary to provide supplies of cooling water. By then, technical development may greatly reduce or eliminate the need for cooling water. Reallocation of agricultural irrigation water to power plant use is also economically feasible.

Inland siting areas to exploit existing water supplies can be found in the eastern desert areas of Southern California and in portions of the Central Valley. Such areas, selected for their remoteness, may offer the best opportunity for acceptable siting of new plants.

The cost penalty for inland siting, as compared to coastal siting, is very small. The retail cost of power is estimated to increase by less than 4 percent, owing to the cooling system costs. With increased environmental restriction on coastal plants, the cost advantage could actually be with the inland plants.

Thus, it is concluded that the choice of inland sites in California is feasible, both technically and economically. With the limited availability of suitable coastal siting areas, and growing concern for coastline preservation, it is likely that inland areas offer a better opportunity for expeditious site selection and licensing.

EPILOGUE

"It was with some misgivings that we entered into our discussions on this subject with Edison.

The misgivings lay, of course, in the fact that in this semi-arid coastal plain of Southern California it seems wasteful to use fresh water to cool power plants, when the vast Pacific Ocean lies right alongside us.

However, the increasingly severe restrictions on building any kind of power plant on the coastal plain are forcing the electric utilities to consider this alternative.

Because of this, our Board agreed that we had an obligation to provide water for this purpose. Most of the electricity produced will be for the benefit of the people of the District.

Fortunately, with our new supply from the State Water Project, we should be able to meet the needs of these desert power plants."

—Frank M. Clinton,
General Manager, MWD
Aqueduct News, March 1973

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