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ENVIRONMENTAL ASSESSMENT

**Geothermal Loan
Guarantee Program**

Westmorland Development Project

Imperial County, California

April 1979

U.S. DEPARTMENT OF ENERGY

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April 1979

U.S. DEPARTMENT OF ENERGY

Assistant Secretary for Resource Applications
Washington, D.C. 20545

MASTER

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SUMMARY

The action assessed is the guaranty of a loan by DOE to finance geothermal exploration, development, and testing by Mapco Geothermal, Inc. and Republic Geothermal, Inc. in the Westmorland area of Imperial County, California. Initial drilling and flow testing of up to three production wells will occur in the exploratory phase. Exploration is proposed for either or both of two portions of the leasehold area. If exploration confirms the presence of a viable resource in the Sweetwater area, the preferred site based on limited temperature data, then up to 19 new production wells and three new injection wells may be drilled and tested there in preparation for the construction of a 55-MW double-flash electric power plant. If, however, the Sweetwater resource proves infeasible, further exploration and possible full-field development may occur instead at the Dearborn-Kalin-Landers area. At this site, up to 19 new production wells and three new injection wells may be drilled and tested, with six existing wells also used for injection. This environmental assessment chiefly addresses effects of the drilling and testing program. A more detailed analysis of the impacts of power generation will be possible after the initial project phases have identified the exact location for the proposed plant and the nature of the geothermal resource at this location.

The environmental effects of the drilling and testing program covered by this loan guaranty are not expected to be significant. The drilling plan will minimize loss of agricultural land by placing pads in the corners of fields and drilling more than one well from a pad where practical. Geothermal water will be contained in impermeable sumps or tanks or injected into saline aquifers. The levels of air contamination from emissions from well testing and equipment operation are not expected to be significant. Use of mufflers on drilling rigs is expected to reduce noise reaching nearby residences to acceptable levels. No significant direct or indirect loss of wildlife habitat is expected.

The environmental effects of resource development and utilization would be more intensive and longer lasting than those of exploration.

The effects of expanded well drilling and testing will be the same as for the exploratory wells but on a larger scale. If during plant operation fluid injection does not equal fluid withdrawal, subsidence of the land surface could occur. Induced seismicity is unlikely, because fluids will be introduced by low-pressure injection to aquifers which are shallower than the depth of earthquake origin. Contamination of surface waters and shallow groundwaters will be prevented by injection of brines in properly cased wells. A more detailed analysis of the impacts of power generation on waterfowl in the Salton Sea refuges will be possible after the initial project phases have identified the likely location of the power plant and transmission lines.

Emission control equipment should not be necessary to prevent unacceptable ambient concentrations of H_2S and other noncondensable gases. If steam condensate is used in the cooling towers, salt drift should not be a problem unless high concentrations of boron or other potentially toxic chemicals are present in the flash condensate. Noise levels during plant operation will be approximately 60 dBA at 150 m (500 ft).

Total land disturbed by drilling and power plant construction will be less than 20 ha (50 acres). Drilling and construction would employ approximately 100 people, many of whom would come from the local area. Local housing and community services are adequate to supply the needs of the project.

Proper design, siting, and operation of wells, transmission lines, and the plant should mitigate environmental effects.

1. DESCRIPTION OF THE PROPOSED ACTION

The Federal action addressed by this environmental assessment (EA) is DOE support of a private geothermal venture by the guaranty of a loan through the Geothermal Loan Guaranty Program authorized by Title 10, Part 790, of the *Code of Federal Regulations* (10 CFR Part 790). This EA was prepared to fulfill DOE's objectives under the "Guidelines for Environmental Review" contained in 10 CFR Part 711 and 10 CFR Part 790 to evaluate the environmental impacts of proposed DOE actions.

The applicant for loan guaranty assistance proposes to locate, drill, and flow test up to 19 new production wells and three new injection wells. Six existing wells may also be used for injection if exploration and development occur in the Dearborn-Kalin-Landers area. The leasehold area extends into both the Salton Sea Known Geothermal Resource Area (KGRA) and the Brawley KGRA and is planned as an integral part of resource exploration and development activities in other parts of the KGRAs not included in this loan guaranty application.

This EA will assess the potential impacts of exploration and site development activities directly supported by the geothermal loan guaranty. It will also address, in general terms, possible impacts of power plant construction and operation that may follow the successful development of the geothermal field, although power plant construction and operation will not be funded with loan guaranty support.

1.1 SITE LOCATION AND SURFACE FEATURES

The area in which the proposed project will be located consists of about 16,400 ha (41,000 acres) of privately owned land in the extensively irrigated Imperial Valley desert near Westmorland in Imperial County, California (Fig. 1.1). A total of 8,299 ha (20,747 acres) within this area is leased by the loan guaranty applicant. The leasehold area is located approximately 150 km (95 miles) east of San Diego and 280 km (175 miles) southeast of Los Angeles, within Townships 12S and 13S, Ranges 12E, 13E, and 14E, San Bernardino Base Meridian. The leasehold area is bounded by 33°10'N and 33°00'N latitude and 115°33'W and

Fig. 1.1. Map of the Westmorland leasehold area and vicinity, showing nearby towns, the Salton Sea, and the Brawley and Salton Sea Known Geothermal Resource Areas.

115°45'W longitude. It surrounds the town of Westmorland and extends to within 2 km (1.2 miles) of the city of Brawley. It borders the Salton Sea National Wildlife Refuge and lies within 10 km (6 miles) of the Wister Waterfowl Management Area. The Salton Sea and Brawley KGRAs overlap the northern edge and southeastern corner, respectively, of the leasehold area.

The leasehold area borders the Salton Sea, a large (97,000-ha or 375-sq mile) inland saline sea. The Alamo River, approximately 1.5 km (1 mile) to the east of the leasehold area, and the New River, which passes through the leasehold area, both flow roughly northward to the Salton Sea. The Imperial Valley is surrounded by a series of mountain ranges including the Jacumba, Vallecito, Santa Rosa, Orocopia, and Chocolate mountains. Federal land in Imperial County is primarily used for military purposes; it includes the Salton Sea Naval Test Base northwest of the leasehold area, a parachute recovery test area west of Brawley, and another test area northeast of the leasehold area in the Chocolate Mountains. The leasehold area is traversed by irrigation canals, drainage ditches, and roads used by the Imperial Irrigation District for operation and maintenance of the irrigation system upon which the agriculture of the valley depends (Fig. 1.2). Irrigation waterways include the Vail and West Side Main Canals, the Timothy, Trifolium, and Vail Drains, and additional drains and laterals. State Highway 86 runs through the leasehold area and connects it with Brawley and El Centro. The area contains numerous residences and several feed lots, but the chief land use is agriculture.

1.2 PROJECT DESCRIPTION

The proposed project is part of an exploration and development program in an area of the Imperial Valley near the Salton Sea and Brawley KGRAs. The overall objective of the project is to drill sufficient wells to supply a 55-MW(e) power plant to begin commercial operation in 1981. This EA addresses the initial reservoir exploration phase of drilling and flow testing geothermal production and injection wells in representative areas of the Westmorland geothermal leasehold, as well as power plant construction and operation.

Fig. 1.2. Map of the Westmorland leasehold area showing proposed and existing drill sites.

The first phases of the project will consist of drilling and flow testing up to one new production well and one new injection well from a single well pad in the Sweetwater area south of Westmorland. If this first phase of the project is successful, the remaining phases of site development could result in the drilling of up to 18 additional production wells and two additional injection wells there. A total of five drilling sites may be used. If the first phase of the project is not successful in the Sweetwater area, then exploration will shift to the Dearborn-Kalin-Landers area north of Westmorland. Six wells have been drilled in this area to date, and these would be used for injection wells. If exploration and development occur in the Dearborn-Kalin-Landers area, then up to 19 new production wells and three new injection wells may be drilled and tested.

Activities beyond the loan guaranty phases of the project, assuming positive indicators of an adequate geothermal reserve, will include power plant construction and power plant operation.

1.2.1 Exploration and drilling

The proposed well locations will be based on photogeological investigations and other geophysical surveys that do not significantly disturb the local environment. These surveys may include: (1) cross-dipole studies in which a line 3 to 5 km (2 to 3 miles) long is laid out and charged with electricity, (2) geochemical analysis of water and soils, (3) gravimetric surveys, and (4) time domain electromagnetic soundings to determine the depth of the heat resources.

1.2.1.1 Site and road preparation

Drilling activities for the new wells require level drilling pads. No new roads will need to be constructed, since drilling sites will be located along field boundaries, which are accessible from existing roads.

The proposed well sites will be cleared, leveled, and compacted for areas of up to 4000 m² (1 acre) each to provide drill pads. As many as 1.6 ha (4 acres) could receive minor disturbances for other

equipment, for sumps, and for laydown areas at each site; a more likely figure, however, is 0.8 ha (2 acres). A drilling mud sump lined with low-permeability bentonite clays will be provided at each site to hold the drilling fluids, and each site will be sloped toward the sump to provide a drainage catchment. Figure 1.3 is a layout of a typical drilling site arrangement. Each drill site will be large enough for two to four wells.

1.2.1.2 Well drilling and testing

Typical geothermal drilling practices will be used in this project. A hole of decreasing diameter will be drilled and a conductor pipe and surface casing installed as a part of the drilling operation. The hole will be drilled using a closed system of circulating "mud" that consists principally of water, bentonite clay, and caustic soda. Approximately 620 m³ (0.5 acre-ft) of water is used for mud-drilling operations. The mud discharged at the surface is separated from the drill cuttings and held in an impermeable sump for recycle or evaporation.

Approximately 25 workers will be employed for drilling a well, with about seven workers onsite at a time. An additional five to eight people will be on the drill site intermittently to perform specialized services associated with the drilling operations.

Initial well testing will involve flows into the mud pit; muds and debris will be trucked to an approved sanitary landfill or will be neutralized and made arable. Subsequent flow testing will be made through a steam-water separator from which the gases will be discharged to the atmosphere and liquids will be injected into the injection well. All drilling equipment will be equipped with mufflers, and steam vents will be elevated or isolated from test personnel.

1.2.2 Field development and construction

After completion of exploration, positive indications of an adequate resource will allow for consideration of field development and power plant construction with a view to producing up to 55 MW of electricity.

Fig. 1.3. Equipment layout of a geothermal drill pad.

The number of additional wells required for full-scale power production will be determined during prolonged flow testing. As many as 28 wells (19 for production and 9 for injection) may be required, spaced at minimum intervals of 408 m (1300 ft) with about 16 ha (40 acres) per well site. Thus, 55 MW of electricity would require up to 224 ha (560 acres), assuming two wells per drill pad, within a 1.6-km (1 mile) radius of the power plant. The actual amount of land disturbed in this area would be limited to 0.8 ha (2 acres) per well for well sites and roadways, plus up to 8 ha (20 acres) for the power plant — a total of up to 19 ha (48 acres) out of the total 224 ha (560 acres) involved. The wells will be connected by aboveground pipelines that follow the roadways wherever possible. Pipelines are heavily reinforced to resist rupturing. If any pipe were to rupture, it could be isolated by use of shutoff valves, so that any spill would be of short duration.

Excavation for the construction of buildings and transmission lines and the movement of equipment and supplies into the area will create the principal sources of impact during construction. A construction force of less than 100 persons is expected at any one time. Total construction time is expected to be about two years.

1.2.3 Plant operation

The power plant tentatively planned for this project is a 55-MW double-flash plant in which flashed steam will be used in a direct cycle to drive the turbine. An alternative system, although not currently planned for use, would be a binary cycle. The effluents and potential environmental impacts of plant operation depend upon plant design. The two types of designs are considered below.

Either design will require about $643 \text{ m}^3/\text{hr}$ or $5.6 \times 10^6 \text{ m}^3/\text{yr}$ (4500 acre-ft/yr) of water for cooling system makeup and/or injection (Sect. 3.2.7). At this time no specific guarantees of water exist for the Westmorland project. Possible sources of outside water for the project include (1) irrigation waste water, (2) fresh irrigation water, and (3) treated waste from local facilities. Use of irrigation wastewater is assumed in this assessment.

1.2.3.1 Direct cycle

The higher temperature fluid must be partially flashed to steam prior to power production. To accomplish separation of the geothermal fluid into a vapor phase and a liquid phase, flash units are operated at a pressure below the vapor pressure of the geothermal fluid. Flashing causes the vapor to be withdrawn from the geothermal fluids in quantities dependent on the pressure difference between the flash unit and the geothermal fluid and on the heat content of the fluid. The flash units may be located at the well site or at a central site serving a number of surrounding wells.

Direct flashing may involve single- or multistage flashing. In multistage flashing, the liquid fraction of the geothermal fluid is fed to flash units operating at successively lower pressures. The steam flashed from each multistage unit is fed to the turbine at the point where its pressure matches that of the expanding steam from preceding stages. Multistage flashing increases the amount of energy recovered and reduces the well flow rate and cooling requirements. The number of flash stages in a plant depends on an economic analysis, balancing increased capital costs with reduced operating costs. The low temperature and pressure of geothermal steam require large turbines relative to the generating capacity.

Particulates are removed from the vaporizing separators by centrifugal action or with scrubbing devices before the vapor is fed to the turbine. Noncondensable gases may be removed by an initial flash stage before they are fed to the turbine or by ejection from condensers after being fed to the turbine. Energy losses resulting from an initial flash for removal of the noncondensable gases must be balanced against energy losses due to inefficient turbine operation caused by the presence of the noncondensable gases. Hydrogen sulfide is controlled at The Geysers by incineration of the exhaust gas, by scrubbing, or by precipitation of sulfur in the cooling towers by injection of an iron-based catalyst. Future control methods will involve the removal of elemental sulfur in a Stretford process or pretreatment of the steam with metal oxide sorbents prior to passage through the turbine.

1.2.3.2 Binary cycle

In the binary cycle, the lower temperature geothermal fluid is used to boil a working fluid in heat exchangers, and the working fluid is expanded through a turbine. The proper choice of a working fluid is vital to the design of an efficient binary cycle. If a supercritical Rankine cycle is used, the critical temperature of the working fluid must be less than the temperature of the geothermal fluid. In addition to critical temperature, the relative size of the turbine, the operating pressure of the cycle, and the condensing temperature are important in selection of a working fluid. More heat is extracted from the geothermal fluid by the binary cycle using the proper working fluid than by the direct-flash cycle, which loses the latent heat of the flashed steam. The binary fluid usually results in a smaller turbine, thereby providing a potential capital cost savings.

Both the geothermal brine and the working fluid are contained in closed-loop systems. Therefore, noncondensable gases do not present serious problems in a binary cycle arrangement. Hypersaline brines may cause significant corrosion, erosion, and scaling in heat exchangers, however. These problems may be solved by direct flashing to provide steam for the working-fluid heat exchangers. Such a measure reduces corrosion and scaling, because only the relatively clean vapor comes in contact with the heat exchanger tubes. The release of noncondensable gases becomes significant, however.

The binary cycle is in the process of being scaled up, but it is still considered experimental. A 30-kW binary cycle plant using 81.5°C (178.7°F) geothermal water and Freon as the working fluid has been operated in Paratunka, U.S.S.R. Other Freon plants have been operated in Japan. In the United States, binary cycle development using isobutane as the working fluid is progressing in Niland, California, and equipment development is under way in East Mesa, California.

1.2.4 Site restoration

Indications of an inadequate resource at any stage in the exploration activities can result in abandonment of the project. Abandoned wells will be plugged with cement or welded shut below ground level. In cases where further work at the site is anticipated, no further restoration will be performed. Otherwise, the disturbed area will be backfilled and replanted.

If the project is abandoned after power plant construction, abandonment will involve plugging all of the wells, dismantling the facility, and removing all salvageable equipment. Nonrecoverable items will be disposed of in a manner to permit the replanting of as much of the disturbed area as possible.

1.3 KNOWN ENVIRONMENTAL ISSUES

Geothermal exploration and development are being carried on extensively in the Imperial Valley. Therefore, several environmental issues are already well established. These include water use, surface and groundwater contamination, subsidence, seismicity, air contamination, and noise. These and other potential environmental impacts will be treated in Sect. 3.

REFERENCES FOR SECTION 1

1. F. A. Kingery (WESTEC Services, Inc.), personal communication to F. E. Sharples (Oak Ridge National Laboratory), October 23, 1978.

2. DESCRIPTION OF THE EXISTING ENVIRONMENT

The following sections contain a description of the existing environment in the Imperial Valley, including geology, soils, geothermal resources, hydrology and water quality, atmospheric characteristics, noise, ecology, land use, water use, demography and socioeconomics, and historical and archaeological sites and natural landmarks.

2.1 GEOLOGY, SOILS, AND GEOTHERMAL RESOURCES

The Imperial Valley occupies part of the Salton Trough, an extensive rift valley in Southern California and Northern Mexico. The rocks in the valley are structurally deformed and faulted, consisting of a sequence of sedimentary formations overlying a basement complex of metamorphic and igneous units. Imperial Valley soils are alluvial in nature, being derived from sediments deposited by the Colorado River. Classification is made on the basis of texture, rather than composition. The geothermal resources of the Imperial Valley include six known Geothermal Resource Areas (KGRAs). Temperature gradient measurements made in the valley indicate the presence of additional geothermal resources.

2.1.1 Geology

2.1.1.1 Regional setting

The Salton Trough (Fig. 2.1) is a topographic and structural depression extending northwestward from the Gulf of California to the San Geronio Pass. This rifted crustal zone is approximately 200 km (124 miles) in length; its width varies from 5 to 130 km (3 to 81 miles). Within the Salton Trough, the Imperial Valley is bounded by the Salton Sea on the northwest, the Santa Rosa Mountains on the west, and the Chocolate and Orocopia mountains on the east.

The Imperial depression is filled by as much as 6000 m (20,000 ft) of Cenozoic clastic sediments. These sediments are primarily nonmarine (fluvial and deltaic) deposits derived from the Colorado River; however,

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Fig. 2.1. Regional setting of the Salton Trough, showing the location of Westmorland with respect to the Imperial Valley. Modified after W. A. Elders, "Regional Geology of the Salton Trough," in *Geothermal Development of the Salton Trough, California and Mexico*, ed. by T. D. Palmer, J. H. Howard, and D. P. Lande, Lawrence Livermore Laboratory, Livermore, Calif., 1975.

some marine and lacustrine sediments and aeolian sands (Sand Hills) are present as well. The underlying basement complex in the area consists primarily of Mesozoic metamorphic rocks. Metamorphic and igneous rocks of pre-Cenozoic and Tertiary age comprise the bordering mountain ranges.¹⁻⁴

2.1.1.2 Cenozoic stratigraphy of the valley

Figure 2.2 is a geologic column for the northwestern Imperial Valley, the part of the valley which represents the Westmorland area most accurately. Three Cenozoic time-rock units are represented: Miocene, Pliocene, and Pleistocene. The oldest (Miocene) Cenozoic strata are of marine origin; younger formations are nonmarine (terrigenous). In general, the grain size of the sediments diminishes toward the center of the valley. Larger-grained material, such as fanglomerates (derived from alluvial fans), occurs along the valley margins.³

The Imperial Formation is the only recognizable stratigraphic unit of Miocene age in the northwestern Imperial Valley. Ranging up to 900 m (3000 ft) in thickness, it is primarily a shallow-marine claystone containing minor interbedded sandstones and calcareous oyster-shell reefs.³

Four distinguishable rock units comprise the Pliocene strata, which have a total section thickness of 4000 m (13,000 ft). From oldest to youngest, they are: (1) the Canebrake Conglomerate, (2) the Truckhaven Rhyolite, (3) the Palm Spring Formation, and (4) the Borrego Formation. The Canebrake is a fanglomerate 0 to 1200 m (4000 ft) thick. In the vicinity of Westmorland, there is probably very little, if any, of this unit present. The Truckhaven Rhyolite, which consists of as much as 90 m (300 ft) of volcanic material, overlies the Canebrake horizon. The Palm Spring Formation is comprised of up to 2100 m (7000 ft) of feldspar-rich sandstones and clays. The Borrego consists of fine-grained lacustrine sediment up to 1800 m (6000 ft) thick.³

The Pleistocene section of the northwestern Imperial Valley is well represented, locally overlying Pliocene strata with apparent unconformity. Thicknesses are approximate; however, in the Westmorland area, they are probably near the high end of the range. The Pleistocene is subdivided into two formations, which total perhaps 600 m (2000 ft) in thickness. The

lowermost formation is the Ocotillo Conglomerate, which is a series of fan-glomerates that rim the perimeter of the valley. Interfingering with the Ocotillo, and grading downward into it, is the Brawley Formation. The Brawley is primarily a fine-grained lacustrine deposit located within the central portion of the valley. Overlying the Brawley Formation are alluvial, terrace, and lacustrine deposits of recent age. This 0 to 90 m (300 ft) thick series of sediments was derived from ancient Lake Coahuila.³

Before 1954, four deep wells had been drilled for oil in the Imperial Valley within a 32-km (20-mile) radius surrounding and including Westmorland (Fig. 2.3). The wells ranged in depth from 2232 to 3753 m (7323 to 12,313 ft). Nonmarine sand and clay were encountered to total depth, with as much as 900 m (3000 ft) of lacustrine clay occurring at the top of the section. No marine (Miocene) sediments were penetrated.³

2.1.1.3 Surficial features and tectonism

A number of surficial features of geologic origin are apparent in the vicinity of the Imperial Valley (Fig. 2.3). These features include faults, volcanic landforms, and the remnants of ancient (but geologically recent) Lake Coahuila.

The Imperial Valley is considered to be a rift zone with a number of transform faults. The most prominent of these faults are the San Jacinto, Imperial, and San Andreas (Fig. 2.4), which have segments of surface rupture during an historic earthquake or segments with seismic fault creep. All of the major faults have right-lateral strike-slip motion along an essentially vertical plane of rupture, but little or no vertical displacement. These fault zones range in width from several hundred meters to several kilometers. Between the transform faults are offset rift zone segments. Most volcanic activity is coincident with these segments, whereas the strongest earthquakes occur along the transform faults.^{3,5}

Volcanics are manifested by recent-age obsidian buttes, which are exposed approximately 16 km (10 miles) north-northwest of Westmorland, at the southeast end of the Salton Sea. Additional recent volcanic rocks in the Westmorland area have probably been covered by lacustrine sediments.^{3,4}

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Fig. 2.3. Geologic map of Imperial Valley and adjacent areas.
 Source: T. M. Dibblee, Jr., "Geology of the Imperial Valley Region, California," chap. II in *Geology of Southern California*, ed. by R. H. Jahns, California Department of Natural Resources, Division of Mines, Bulletin 170, San Francisco, 1954. (See legend, next page).

LEGEND FOR FIG. 2.3

- CONTACT BETWEEN FORMATIONS
- FAULT, SOLID WHERE ACCURATELY LOCATED, AND DASHED WHERE CONCEALED OR INFERRED; ARROWS INDICATE LATERAL MOVEMENT
- STRIKE AND DIRECTION OF DIP OF BEDDING IN METASEDIMENTS
- ⛏ QUARRY
- ⚡ ABANDONED WELL DRILLED FOR OIL OR GAS WITH DEPTH IN FEET

Fig. 2.4. Possible relationship between pull-apart basins and strike-slip faulting in the Salton Trough. Modified after W. A. Elders, "Regional Geology of the Salton Trough," in *Geothermal Development of the Salton Trough, California and Mexico*, ed. by T. D. Palmer, J. H. Howard, and D. P. Lande, Lawrence Livermore Laboratory, Livermore, Calif., 1975.

The shoreline of prehistoric Lake Coahuila can be observed near the base of the mountains on the southwest side of the Imperial Valley. The lake level stood approximately 15 m (50 ft) above sea level, or 100 m (300 ft) above the present valley floor. Lake Coahuila was created when the Colorado River delta (Fig. 2.1) sealed off the northern extension of the Gulf of California. The sediments deposited in Lake Coahuila (represented by the symbol Qa in Fig. 2.3) covered a wide area, concealing the surface expressions of many geologically active but currently dormant faults within the Imperial Valley.^{3,4}

2.1.1.4 Seismicity

The Imperial Valley is one of the most seismically active regions of the United States (Fig. 2.5). In the valley, the probability is high that the horizontal acceleration associated with an earthquake will exceed 40% of gravity in a 50-year period (Table 2.1). Since the threshold for major damage is considered to be 20% of gravity, major damage from an earthquake can be expected to recur in less than a 50-year interval somewhere within the Imperial Valley.⁶⁻⁸ Earthquakes intense enough to have produced surface rupture along the Imperial and Coyote Creek faults have occurred in the Imperial Valley during this century (Fig. 2.6). Other faults associated with the San Jacinto have either historical records of surface rupture, or display evidence of seismic fault creep or offset recent strata. According to Greensfelder,⁸ the San Jacinto fault zone [40 km (25 miles) southwest of Westmorland] and the San Andreas fault zone [40 km (25 miles) north of Westmorland] have maximum credible earthquake magnitudes of 7.5. Algermissen and Perkins,⁶ however, estimate the maximum credible magnitude for the Imperial Valley as a whole to be 7.9 (modified Mercalli intensity of XI).

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Fig. 2.5. Preliminary map of horizontal acceleration (expressed as percent of gravity) in rock with 90% probability of not being exceeded in 50 years. Modified after S. T. Algermissen and D. M. Perkins, *A Probabilistic Estimate of Maximum Acceleration in Rock in the Contiguous United States*, U.S. Geological Survey Open File Report 76-416, Denver, Colo., 1976.

Table 2.1. Earthquake intensity and magnitude scale

Modified Mercalli intensity	Approximate equivalent shallow magnitude	Corresponding horizontal acceleration (% gravity)	Effects
I		<0.03	Not generally felt
II	2.5	0.03–0.05	Felt by few at rest
III		0.05–0.1	Felt noticeably indoors
IV	3.5	0.1–0.3	Windows rattled
V		0.3–0.5	Windows broken
VI		0.5–1	Objects upset
VII	5.5	1–3	Moderate damage
VIII	6	3–5	Very destructive to weak structures
IX		5–10	Total destruction of weak structures
X		10–30	Only best buildings survive
XI	8	30–50	Few buildings survive
XII	8.5	50–>100	Total destruction

Source: Modified after H. O. Wood and F. Neumann, "Modified Mercalli Intensity Scale of 1931," *Bull. Seismol. Soc. Am.* 21:278–283 (1931).

Active Faults

• Well Location

Earthquake Locations

~~~~~
Total length of fault zone that breaks Holocene deposits or that has had seismic activity.

—————
Fault segment with surface rupture during an historic earthquake, or with a seismic fault creep.

○ Holocene volcanic activity
(Amboy, Pisgah, Cerro Prieto and Salton Buttes)

○ 1899 M7+
Approximate epicentral area of earthquakes that occurred 1769-1933.

○ 1952 M7.7
Earthquake epicenters since 1933, plotted from improved instruments.

Fig. 2.6. Historically recorded earthquakes and surface rupture along faults of the Imperial Valley. Source: VTN Consolidated, Inc., *Environmental Analysis Record, Proposed Geothermal Exploration, South Brawley Prospect, California*, CUI Venture, Irvine, Calif., 1977.

2.1.2 Soils

There are ten areally extensive soils in the Westmorland geothermal field area. The basic soil properties are given in Table 2.2. The soils are similar, especially with regard to land use capabilities and limiting factors. The soils are generally saline, stratified, corrosive, and deep. Irrigation has created perched water tables within 2 m (6.6 ft) of land surface, particularly where clay-rich layers are present.

2.1.3 Geothermal resources

Six known Geothermal Resource Areas (KGRAs) in the Imperial Valley have been identified by the U.S. Geological Survey on the basis of temperature gradient measurements (Fig. 2.7). These KGRAs are the Salton Sea, Brawley, Heber, East Mesa, Dunes, and Glamis KGRAs. The Westmorland area also appears to be one in which anomalously high temperature gradients exist. All of the geothermal resources in the Imperial Valley consist of saline, liquid-dominated systems¹. The salinity gradient increases to the northwest, with reported total dissolved solids (TDS) concentrations ranging from 10,000 to 350,000 ppm. (Seawater has a TDS content of 35,000 ppm.) Salinity of Imperial Valley geothermal reservoir fluids is a problem, because scaling and corrosion increase with increasing concentration of total dissolved solids.

According to current estimates, there is a potential for a maximum generating capacity of 5000 MW(e) in the Imperial Valley.¹⁰ Demonstration plants have been constructed at Niland (Salton Sea KGRA) and East Mesa, and a great deal of interest has been shown in the areas around Brawley, Heber, and Westmorland. Although the Salton Sea region is more promising in terms of heat content, the other areas might be more easily developed because of lower total dissolved solids concentrations.

2.2 HYDROLOGY AND WATER QUALITY

2.2.1 Surface water

The leasehold area lies within the 22,000-km² (8400-sq-mile) Salton Sea watershed. The saline Salton Sea, California's largest inland body of water,

Table 2.2. Characteristics of soils in the Westmorland project area

Soil name and description	Land capability classification	Texture	Permeability	Available water capacity, to a depth of 152 cm [cm (in.)]	Land use capability	Limiting factors or remarks
Udifluvents, saline	VIII w1	Undifferentiated	Moderate		Potential for wetland wildlife	High water tables, flood hazard, salinity
Indio loam, wet	II w1, irrigated	Very fine to medium	Moderately slow to moderate	25(10)	Cropland, urban use	Dusty when dry, low bearing strength
Indio-Vint complex	II sl, irrigated VIII sl, dryland	Fine	Moderately slow to moderately rapid	25(10)	Desert recreation, cropland, urban use	Dusty when dry, low bearing strength
Meloland and Holtville loams, wet	II w3, irrigated	Very fine to fine	Slow	20-23 (8-9)	Cropland, urban use	Plastic, low bearing strength
Holtville silty clay, wet	II w5, irrigated	Very fine to medium	Slow	20(8)	Cropland, urban use	Plastic, low bearing strength
Imperial-Glenbar silty clay loams, wet, 0-2% slopes	III w3, irrigated	Very fine to fine	Slow	20-25 (8-10)	Cropland, urban use	Plastic, low bearing strength
Imperial silty clay, wet, 0-2% slopes	III w5, irrigated	Very fine to fine	Slow	20(8)	Cropland, urban use	Plastic, low bearing strength
Meloland very fine sandy loam, wet	III w3, irrigated	Very fine to coarse	Slow	25(10)	Cropland, urban use	Low bearing strength
Rositas fine sand, wet, 0-2% slopes	III w4, irrigated	Fine	Moderately rapid	10(4)	Cropland, urban use	Low bearing strength
Vint loamy fine sand, wet	II w4, irrigated	Very fine to fine	Moderately rapid	14(6)	Cropland, urban use	Low bearing strength

Source: U.S. Department of Agriculture, Soil Conservation Service, El Centro, Calif., 1978.

Fig. 2.7. Temperature gradient map of the Imperial Valley, showing Known Geothermal Resource Areas (KGRAs). Source: W. A. Elders, "Regional Geology of the Salton Trough," in *Geothermal Development of the Salton Trough, California and Mexico*, ed. by T. D. Palmer, J. H. Howard, and D. P. Lande, Lawrence Livermore Laboratory, Livermore, Calif., 1975.

measures 970 km^2 (375 sq miles) in area. It is located in the northwestern corner of Imperial County (Fig. 1.1) at an elevation of about 70 m (230 ft) below sea level. The watershed area includes the Imperial and Coachella Valleys in California, as well as the Mexicali Valley in the Republic of Mexico.

The Salton Sea was formed in 1905 to 1907 when the flooding Colorado River washed out early diversion structures and entered the basin via the New and Alamo rivers. The Salton Sea remained when the Colorado had been brought under control. Drainage in the Imperial Valley is toward the Salton Sea. Approximately 90% of surface inflow to the Salton Sea is provided by the New and Alamo rivers. During 1967, the total annual surface inflow was $1.54 \times 10^9 \text{ m}^3$ (1,251,000 acre-ft). Of this total, the Alamo and New rivers contributed about 57% and 35%, respectively, while minor channels, including the Whitewater River, the Salt and San Felipe creeks, and drainage canals, contributed about 8%.²

An elaborate system of canals distributes Colorado River water via the All-American Canal throughout the Imperial Valley. More than 2250 km (1400 miles) of drains, augmented by about 32,000 km (20,000 miles) of underground tile, carry irrigation drainage to the New and Alamo Rivers for discharge to the Salton Sea.¹¹ Figure 1.2 shows the location of the West Side Main Canal, the New River, and the Vail Canal in the leasehold area. Not shown in the figure, but important to the irrigation system, are the many laterals, ditches, and drains, which in general run along section and lot boundaries, parallel to roadways. The drains maintain a favorable salt balance in the irrigated lands by carrying away the salt-laden drainage water. The Imperial Valley irrigation is based on a gradual elevation difference: the mean elevation gradient between Westmorland, at -50 m (-165 ft), and the Salton Sea is about 1.7 m/km (9 ft/mile).

Water quality in the Imperial Valley can generally be described as poor but adequate for agriculture with continual remedial effort (leaching and water table control). Leaching of soil salts by the irrigation system has degraded the quality of irrigation return water. From 1960 to 1972 a net amount of approximately 5.5 million metric tons (6 million tons) of salt were removed by the irrigation system from valley soils.¹¹ The salinity of

Colorado River water has also been increasing. Prior to 1955, Colorado River water diverted to the Imperial Valley had a total dissolved solids (TDS) concentration of about 735 ppm (1.0 ton/acre-ft); by 1974 TDS levels were about 875 ppm (1.19 tons/acre-ft), and by 2000 the TDS may reach 1340 ppm (1.82 tons/acre-ft).¹¹ Water quality in the Imperial Valley has also suffered from the increased use of agricultural fertilizers, from pesticides and herbicides, and from discharges of waste waters and effluents.¹²

Table 2.3 shows selected water quality parameters measured for the New River in the leasehold area during the period 1966-67. A high degree of mineralization is evident. Drinking water standards for nitrate, TDS, sulfate, and chloride are exceeded; recommended irrigation water limits for molybdenum are also exceeded. However, drinking water is not taken from the New River and it is not used as a source of irrigation water (see Sect. 2.7); the river only serves to carry irrigation return to the Salton Sea.

The Salton Sea has experienced increasing salinity as a result of stabilized water levels and input of surface waters with high amounts of dissolved solids. At 38,000 ppm, Salton Sea water is slightly greater in total salt concentration than ocean water, and is different in ionic composition. The salinity of the Salton Sea is increasing annually by about 500 ppm.¹³

2.2.2 Groundwater

The groundwater reservoir is Cenozoic valley-fill deposits overlying the pre-Tertiary basement complex. A complicated system of aquifers and confining layers lies beneath the soil surface, rather than a unique water-bearing stratum of gravel and sand.¹¹

Groundwater movement is directed toward the Salton Sea, at a flow rate of approximately 6×10^7 m³/year (50,000 acre-ft/year).¹⁴ Other groundwater discharge includes evaporation and irrigation uptake.

Groundwater recharge is dominated by water diverted from the Colorado River. Other sources such as tributary areas, precipitation, and local runoff represent a minor contribution. Major sources of groundwater recharge are:¹⁵

Table 2.3. Selected water quality parameters for the New River in the lease hold area (1966–67).
Drinking water standards and recommended irrigation water limits are given for comparison.

Parameter	Measured concentration (mg/liter) ^a	EPA drinking water standard (mg/liter)	EPA irrigation water limit (mg/liter) ^b
Aluminum	0.7		5
Barium	0.44	1 ^c	
Boron	0.28		0.75
Chloride	1144	250 ^d	
Chromium	<0.001	0.05 ^c	0.10
Copper	0.004	1 ^d	0.20
Fluoride	0.7	1.4 ^{c,e}	1.0
Hardness (as CaCO ₃)	1020		
Iron	0.02	0.3 ^d	5.0
Lead	<0.001	0.05 ^c	5.0
Manganese	0.003	0.05 ^d	0.20
Molybdenum	0.022		0.010
Nickel	0.002		0.020
Nitrate	14	10 ^c	
Sulfate	798	250 ^d	
Total dissolved solids (TDS)	3473–3990	500 ^d	
Vanadium	0.005		0.10
Zinc	0.025	5 ^d	2.0

^aCalifornia Department of Water Resources, *Geothermal Wastes and the Water Resources of the Salton Sea Area*, Bulletin No. 143-7, State of California, The Resources Agency, Sacramento, 1970.

^bU.S. Environmental Protection Agency, *Water Quality Criteria 1972*, Ecological Research Series, EPA-R3-73-033, 1973.

^cU.S. Environmental Protection Agency, *National Interim Primary Drinking Water Regulations*, *Fed. Regist.* 40(248) (1975).

^dU.S. Environmental Protection Agency, *National Secondary Drinking Water Regulations, Proposed Regulations*, *Fed. Regist.* 42(62) (1977).

^eBased on an estimated average daily maximum air temperature exceeding 27°C (80°F).

1. irrigation water — $5 \times 10^8 \text{ m}^3/\text{year}$ (400,000 acre-ft/year);
2. leakage from the All-American and Coachella canals — estimated at $3 \times 10^8 \text{ m}^3/\text{year}$ (250,000 acre-ft/year) and $2 \times 10^8 \text{ m}^3/\text{year}$ (150,000 acre-ft/year), respectively, from 1950 to 1967;
3. groundwater underflow from tributary areas in the San Felipe Creek drainage basin in western Imperial Valley — $1.2 \times 10^7 \text{ m}^3/\text{year}$ (10,000 acre-ft/year); and
4. precipitation — $1.2 \times 10^7 \text{ m}^3/\text{year}$ (10,000 acre-ft/year).

Groundwater quality in the Imperial Valley varies greatly with location. Total dissolved solids vary from a few hundred parts per million to more than 10,000 ppm. Lower values result when groundwater has been locally derived from precipitation rather than from the more saline deposits in the central part of the valley. Higher concentrations result when groundwater is discharged principally by evaporation and where salts are leached from irrigated soils. Where recharge from diverted Colorado River water is substantial, groundwater quality resembles that of the river, being dominated by sulfate; elsewhere, sodium, chloride, and bicarbonate dominate.² Shallow groundwaters in the leasehold area are considered saline and are not beneficially used.¹⁶

2.3 ATMOSPHERIC CHARACTERISTICS

2.3.1 Climate

The Westmorland leasehold area is in the Southeast Desert Air Basin of California, which includes all of Imperial County as well as portions of the counties of San Diego, Riverside, San Bernardino, Los Angeles, and Kern. The basin is generally flat, with some mountainous areas. Because the region is located at a latitude typified by descending, dry air masses and because the coastal mountains isolate the basin from the marine air masses to the west, the region is arid. Skies are generally clear, with an average of more than 8 hr of sunshine every day, even in December and January.

2.3.1.1 Temperature and humidity

Temperatures vary considerably during the course of the year. Heating of homes is necessary during the winter, and there are occasional frosts. Summer temperatures may exceed 45°C (113°F). Records maintained by the Imperial Irrigation District at their weather station in Imperial show that in 1975 the mean monthly temperatures ranged from approximately 13°C (55°F) in January to 33°C (92°F) in July and August. Minimum and maximum monthly temperatures typically differed by 25 to 30°C (45 to 55°F), and ranged from a minimum of -0.5°C (31°F) in January to a maximum of 46°C (115°F) in July and August. Large fluctuations also occur on a daily basis: considerable insolation and heating of the ground and air during the daytime is followed by radiative loss of heat from the ground to the clear sky at night. The extreme temperatures recorded at Imperial range from -9°C (16°F) in 1937 to 48°C (119°F) in 1936, 1943, and 1970.

The Southeast Desert Air Basin is an arid region, with relative humidities in summer commonly dropping below 10%.

2.3.1.2 Wind characteristics

Solar heating of the air causes strong updrafts. Sparse vegetation in the Imperial Valley does little to impede the resulting surface winds, which regularly exceed a velocity of 10 m/sec (22 mph).

The National Oceanic and Atmospheric Administration station at El Centro, about 20 km (15 miles) south of the city of Westmorland, has maintained wind data; these data are considered generally applicable to the Westmorland leasehold area because of the flat terrain and the proximity of the two areas. As shown in Table 2.4, for the period 1954 to 1958 prevailing winds were mostly from the west and southwest during all but the summer months, at which time southeasterly winds predominated. The winter months were the calmest; the spring months were the windiest. Atmospheric stability, which is inversely related to the potential for pollutant dispersion, has been calculated from the 1954 to 1958 meteorological data from El Centro, based on Pasquill stability categories. As shown in Table 2.5, neutral to stable conditions occur about 68% of

Table 2.4. Percent distribution of mean wind velocities and prevailing wind direction at El Centro (1954–1958)

Velocity [m/sec (mph)]	Time of year (values are in percent)			
	December–February	March–May	June–August	September–November
Calm	9	4	5	8
0.5–1.5 (1.1–3.4)	20	11	10	13
2.1–3.1 (4.7–6.9)	36	27	30	37
3.6–5.1 (8.1–11.4)	23	28	31	27
5.7–8.2 (12.8–18.3)	7	16	15	10
8.7–10.8 (19.5–24.2)	3	8	5	4
10.8 (24.2)	1	5	3	1
Prevailing wind direction	W	W, WSW	SE, WSW, W	W, WSW

Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, *Seasonal and Annual (Day/Night) Wind Distribution of Pasquill Stability Classes – Star Program Station #23199, El Centro, California, 1/54-12/58*, Environmental Data Service, National Climatic Center, Ashville, N.J., 1975.

the time and slightly to extremely unstable conditions prevail about 32% of the time. The area therefore has limited dispersion capabilities. As would be expected from Table 2.5, atmospheric stability is most pronounced during the winter months when neutral to stable conditions occur 76% of the time.¹⁷

2.3.1.3 Precipitation

Rainfall records at Holtville, which is about 37 km (22 miles) southeast of Westmorland, indicate that mean annual rainfall since 1937 is 6.6 cm (2.6 in.), although it was only 4.6 cm (1.8 in.) during the 12-month period ending June 1975.¹⁸ Long-term mean monthly rainfall ranged from zero in May and June to 1.3 cm (0.5 in.) in December, averaging about 0.55 cm (0.2 in.) per month. From July 1974 to June 1975, monthly rainfall ranged from zero in August, November, May, and June to 2.3 cm (0.9 in.) in April, averaging about 0.38 cm (0.15 in.) per month.

During the period from November to March, there is an average of about 3 hr/month of rain.

2.3.2 Air quality

Although pollution potential (Sect. 2.3.1.2) is fairly high, air quality in the Imperial Valley is fairly good, as a result of the sparse population and low level of heavy industry. However, suspended particulates are often excessive. Particulate pollutants consist primarily of fugitive dust generated by agricultural tilling. During the driest months, dust storms contribute to this total. Motor vehicles produce the bulk of gaseous pollutants.

In addition to the dust sources mentioned above, the Imperial County Air Pollution Control District itemized another 9.3 metric tons/day (10.2 tons/day) of total particulate emissions for Imperial County in the year 1975.¹⁹ Of this total, 73.5% was contributed by agricultural product processing plants and debris burning, with lesser contributions from asphalt and concrete batching, incineration, and steam and power plants (altogether 15.7%) and from vehicular sources (10.8%). The same study identified as

Table 2.5 Percent distribution of atmospheric stability classes at El Centro (1954–1958)

Stability class	Atmospheric condition	Occurrence (percent)
A	Extremely unstable	4
B	Unstable	14
C	Slightly unstable	14
D	Neutral	10
E	Slightly stable	16
F	Stable	42

Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, *Seasonal and Annual (Day/Night) Wind Distribution of Pasquill Stability Classes – Star Program Station #23199, El Centro, California, 1/54-12/58*, Environmental Data Service, National Climatic Center, Asheville, N.J., 1975.

emissions in Imperial County in 1975: 26.5 metric tons/day (29.1 tons/day) of reactive organic gases, 14.2 metric tons/day (15.6 tons/day) of NO_x , 0.3 metric ton/day (0.3 ton/day) of SO_x , and 110 metric tons/day (121 tons/day) of CO. Vehicular sources accounted for 76%, 58%, 67%, and 92% of these totals respectively. By comparison, in San Diego County immediately to the west, annual emissions of CO have been estimated at about 13 times the rate for Imperial County.

Table 2.6 presents air quality data for El Centro from October 1974 to September 1975, along with applicable California state standards. Measured sulfur dioxide did not exceed the 0.50-ppm standard; but ozone reached or exceeded the 0.10-ppm standard during three months, particulates exceeded the $100\text{-}\mu\text{g}/\text{m}^3$ standard every month, and lead exceeded the standard during December. During 1976, monthly average particulate concentrations at El Centro ranged from 101 to $198\text{ }\mu\text{g}/\text{m}^3$, with individual observations ranging from <50 to almost $400\text{ }\mu\text{g}/\text{m}^3$.¹⁸ Average monthly peak concentrations of SO_2 ranged from 0.01 to 0.03 ppm; those of O_3 ranged from 0.01 to 0.04 ppm.¹⁸ At Brawley, average monthly concentrations of particulates were almost 1.8 times as high as values for El Centro, and individual observations approached $500\text{ }\mu\text{g}/\text{m}^3$.²⁰

2.3.3 Regulations and Standards

The regulations issued by the Imperial County Air Pollution Control District (APCD) are mostly directed at the control of emissions from agricultural and petroleum industries. Those APCD regulations considered pertinent to geothermal operations are as follows:

Rule 113. Ringelmann No. 1 smoke opacity value not to be exceeded more than three minutes in any hour.

Rule 114. Dust, fumes, or particulate emissions are limited to 0.2 grains per standard cubic foot.

Rule 116. Any sulfur compounds, expressed as SO_2 , cannot be in excess of 0.2 percent by volume.

Table 2.6. Gaseous and particulate pollutant concentrations in ambient air, El Centro, October 1974 to September 1975

Pollutant	Sampling period	Concentration units	Month												California standards
			Oct. 1974	Nov. 1974	Dec. 1974	Jan. 1975	Feb. 1975	March 1975	April 1975	May 1975	June 1975	July 1975	Aug. 1975	Sept. 1975	
O ₃	Hourly	ppm	0.08	0.08	0.06	0.09	0.12	0.08	0.09	0.13	0.10	0.08	0.08	0.09	0.10 ppm
SO ₂	Hourly	ppm	0.01	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.50 ppm
Particulates	24-hr	µg/m ³	220	160	245	172	105	209	134	142	358	343	194	205	100 µg/m ³
Lead	24-hr	µg/m ³	0.65	0.48	2.18	1.43	1.22	0.65	0.43	0.52	0.34	0.53	0.53	0.52	1.5 µg/m ³ (30-day average)

Source: VTN Consolidated, Inc., *Environmental Analysis Record, Proposed Geothermal Exploration, South Brawley Prospect, California*, CUI Venture, Irvine, California, 1977.

Rule 117. Nuisance emissions are not permitted.

Rule 121. The emission of dust and fumes, expressed in lb/hr, is limited by equivalent process rates.

In addition to the county APCD rules, the California Air Resources Board has enacted Source Review Rules as the basis for a permit-to-construct. These rules impose a detailed evaluation of any process which will emit 20 lb/hr or 150 lb/day of any pollutant for which there is a national standard — except carbon monoxide, which may discharge up to 150 lb/hr.

The leasehold area is located in the Southeast Desert Air Quality Control Region and is presently designated as a Class II region under EPA Significant Deterioration Regulations. Table 2.7 shows the allowable increases in pollutant concentrations over the baseline air quality concentrations for particulates and SO₂ for this area designation.

The applicable Federal and State of California Ambient Air Quality Standards are shown in Table 2.8. Of particular interest is the peak 1-hr H₂S standard of 0.03 ppm required by the State of California.

2.4 NOISE

Noise is any undesirable sound; for analytical purposes it is assumed to decrease in desirability as intensity increases. The ear's response to sound intensity is logarithmic rather than linear. Therefore perceived loudness is measured in decibels (dB), which represent the logarithms of sound power ratios. Normally, decibels are stated with respect to the threshold of hearing (auditory 0), which is at a level of 10^{-6} μ W/m², or 0.0002 microbar. The least perceptible increase in sound level is about 1 dB, and a 10-dB increase roughly corresponds to a doubling of loudness.

The human ear does not respond uniformly over the entire frequency range of audible sound, however. It is most sensitive to frequencies from 1000 to 4000 Hz and significantly less sensitive to frequencies at the low and high ends of the spectrum. A sound of 100 Hz, for example, must be at a level of ~ 32 dB above auditory 0 to be perceived at all by a person with normal

Table 2.7. Allowable pollutant increases for EPA Class II regions^a

Pollutant	Increase in concentration ($\mu\text{g}/\text{m}^3$)		
	Annual geometric mean	24-hr maximum	3-hr maximum
Particulate matter	10	30	
Sulfur dioxide	15	100	700

^aClass II applies to areas in which deterioration normally accompanying moderate, well-controlled growth would be considered insignificant. All values are allowable increases in pollutant concentrations over the baseline air quality concentration.

Source: "Prevention of Significant Air Quality Deterioration," *Fed. Regist.* 38 (December 5, 1974, as amended June 12, 1975).

Table 2.8. Ambient air quality standards

Pollutant	Averaging time (hr)	California standards, concentration ^{a,b} [ppm ($\mu\text{g}/\text{m}^3$)]	National standards ^{b,c}	
			Primary concentration ^d [ppm ($\mu\text{g}/\text{m}^3$)]	Secondary concentration ^e [ppm ($\mu\text{g}/\text{m}^3$)]
Oxidant (ozone)	1	0.10 (200)	0.08 (160)	0.08 (160)
Carbon monoxide	12	10 (11 mg/m^3)		
	8		9 (10 mg/m^3)	9 (10 mg/m^3)
Nitrogen dioxide	1	40 (46 mg/m^3)	35 (40 mg/m^3)	35 (40 mg/m^3)
	1 year		0.05 (100)	0.05 (100)
Sulfur dioxide	1	0.25 (470)		
	1 year		0.03 (80)	
	24	0.04 (105)	0.14 (365)	
	3			0.5 (1300)
Suspended particulate matter	1	0.5 (1310)		
	1 year (geometric mean)			
	24	(60)	(75)	(60)
Sulfates	24	(100)	(260)	(150)
Lead	30 days	(25)		
Hydrogen sulfide	1	(1.5)		
Hydrocarbons (corrected for methane)	3 (6-9 AM)	0.03 (42)		
Ethylene	8		0.24 (160)	0.24 (160)
	1	0.1		
Visibility-reducing particles	1 observation	0.5		

^aCalifornia standards are values that are not to be equaled or exceeded. These standards are promulgated in ppm.

^bEquivalent units given in parentheses are based upon a reference temperature of 25°C and a reference pressure of 760 mm of mercury. All measurements of air quality are to be corrected to a reference temperature of 25°C and a reference pressure of 760 mm of mercury (1,013.2 millibar). Parts per million (ppm) in this table refers to ppm by volume, or micromoles of pollutant per mole of gas.

^cNational standards, other than those based on annual averages or annual geometric means, are not to be exceeded more than once per year. National standards are promulgated in $\mu\text{g}/\text{m}^3$ or mg/m^3 (the values given in parentheses).

^dNational Primary Standards: The levels of air quality necessary, with an adequate margin of safety, to protect the public health. Each state must attain the primary standards no later than three years after that state's implementation plan is approved by the Environmental Protection Agency (EPA).

^eNational Secondary Standards: The levels of air quality necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant. Each state must attain the secondary standards within a "reasonable time" after implementation plan is approved by the EPA.

^fIn sufficient amount to reduce the prevailing visibility to less than 10 miles (16 km) when the relative humidity is less than 70%. Prevailing visibility is defined as the greatest visibility which is attained or surpassed around at least half of the horizon circle, but not necessarily in continuous sectors.

Source: Mapco Geothermal Inc. and Republic Geothermal, Inc., *Application for Loan Guaranty: Westmorland Development Project*, 1977.

hearing.²¹ Because of this variable sensitivity of the ear, noise sources of equal intensity in decibels but different frequency characteristics will differ in audibility and acceptability. Noise measurements taken for the purpose of assessing human acceptability are usually done with sound level meters equipped with an A-weighted network, which approximates the frequency response of the human ear and yields readings in dBA. This network modifies the linear decibel readings taken at various frequencies as follows: 63 Hz (-26.2 dB), 125 Hz (-16.1 dB), 250 Hz (-8.6 dB), 500 Hz (-3.2 dB), 1000 Hz (+0 dB), 2000 Hz (+1.2 dB), 4000 Hz (+1.0 dB), 8000 Hz (-1.1 dB), 16,000 Hz (-6.6 dB).²² Therefore, any two sounds of 60 dBA, for instance, should be perceived as equally loud, regardless of their frequency spectra. Table 2.9 gives some common sound levels in dBA.

Sound levels decrease, or attenuate, with distance according to physical laws of wave propagation. Roughly, there is a 6 dB decrease with doubling of distance from a source. Thus, a noise which is measured at 90 dBA at 15 m (50 ft) will be ~84 dBA at 30 m (100 ft), ~60 dBA at 400 m (1/4 mile), ~54 dBA at 800 m (1/2 mile), and ~48 dBA at 1.6 km (1 mile). This 6-dB decrease is a conservative estimate based on simple spreading of energy; it does not take into consideration absorption of sound by the atmosphere or by vegetation. These additional factors are difficult to assess, however, without setting up detailed models. Therefore, for the purposes of this assessment, attenuation estimates will be based on a 6-dB decrease with doubling of distance and a 35-dB decrease at 800 m (1/2 mile) from a noise source.

2.4.1 Noise characteristics of the site

Ambient noise levels were measured at several locations near the Westmorland leasehold area in January 1976, October 1976, and March 1977 (Table 2.10). Compared to most urban and suburban locations (see Table 2.9 and data on city traffic in Brawley, Table 2.10), the leasehold area is relatively quiet. The locations which measured 30 to 38 dBA are very quiet.

Table 2.9. Typical "A"-weighted sound levels and human response

Sound source	dBA ^a	Response criteria	Intensity ($\mu\text{W}/\text{m}^2$)
Carrier deck jet operation	150		10^9
	140	Painfully loud, limited amplified speech	10^8
	130	Maximum vocal effort	10^7
Jet takeoff [60 m (200 ft)]			
Unmuffled geothermal well venting [15 m (50 ft)]	120		10^6
Discotheque	110		10^5
Jet takeoff [610 m (2000 ft)]			
Shout [0.2 m (0.5 ft)]	100		10^4
Heavy truck [15 m (50 ft)]		Very annoying, hearing damage (8 hr)	
Muffled geothermal well venting [30 m (100 ft)]	90		10^3
Pneumatic drill [15 m (50 ft)]	80	Annoying	10^2
Freight train [15 m (50 ft)]			
Freeway traffic [15 m (50 ft)]		Telephone use difficult	
	70	Intrusive	10^1
Air conditioning unit [6 m (20 ft)]	60		1
Light auto traffic [15 m (50 ft)]	50	Quiet	10^{-1}
Living room			
Bedroom	40		10^{-2}
Library			
Soft whisper [5 m (15 ft)]	30	Very quiet	10^{-3}
	20		10^{-4}
Broadcasting studio	10	Just audible	10^{-5}
	0	Threshold of hearing	10^{-6}

^aTypical A-weighted sound levels taken with a sound-level meter and expressed as decibels on the scale. The "A" scale approximates the frequency response of the human ear.

Source: Council on Environmental Quality, *Environmental Quality - The First Annual Report of the Council on Environmental Quality*, transmitted to Congress, August 1970.

Table 2.10. Ambient sound-level measurements near the Westmorland project area

	Location ^a										
	1	2	3	4	5	6	7	8	9	10	11
Date	Oct. 7, 1976	Oct. 7, 1976	Oct. 7, 1976	Jan. 15, 1976	Jan. 15, 1976	Jan. 15, 1976	Jan. 15, 1976	Jan. 15, 1976	March 2, 1977	March 2, 1977	March 2, 1977
Time	3:25 PM	4:25 PM	5:20 PM						1:35–1:55 PM	2:24–2:40 PM	3:00–3:20 PM
Noise level, dBA Random noise, dBA	44	37	33	38	36	65	75	85	30–32 32–52	30–32 32–49	31–34 34–70
Noise level, dB											
22–44 Hz	42	42	48								
44–88 Hz	48	42	43	58							
88–177 Hz	41	42	34	52							
177–355 Hz	44	32	32	40							
355–710 Hz	40	32	32	33							
710–1420 Hz	40	33	34	30							
1420–2840 Hz	39	33	36	21							
2840–5680 Hz	37	32	34	14							
5680–11,360 Hz	32	32	32	14							
11,360–22,720 Hz	31	31	32								

^aLocations:

- 1: Westmorland area, corner of Young and Kornbloom Roads.
- 2: Westmorland area, end of Wendel Road.
- 3: Westmorland area, end of Buchard Road.
- 4: Niland, geothermal well Woolsey No. 1, corner of Gentry and Gruble Roads.
- 5: Salton Sea Wildlife Refuge at Foss Road.
- 6: Brawley, corner of South First and Main Streets, low traffic density.
- 7: Brawley, corner of South First and Main Streets, normal car and truck traffic.
- 8: Brawley, corner of South First and Main Streets, mostly truck traffic.
- 9: Brawley, geothermal project area, well site 1-28.
- 10: Brawley, geothermal project area, well site 2-28.
- 11: Brawley, geothermal project area, Mercer residence.

Sources: R. A. Nyholm and L. R. Anspaugh (Eds.), *Imperial Valley Environmental Project: Quarterly Data Report*, UCID-17444-1, Lawrence Livermore Laboratory, Livermore, Calif., April 13, 1977.

Energy Research and Development Administration, Geothermal Loan Guaranty Program, San Francisco Operations Office, *Environmental Impact Assessment for CUI Venture: Application for Geothermal Loan Guaranty (South Brawley Project)*, EIA/GE/77-7, August 1977.

2.4.2 Noise regulations

This assessment is concerned with community noise. The province of worker habitat and its relationship to tools and machinery is administered by the Federal Department of Labor under the Occupational Safety and Health Act (May 29, 1971).

California state law was amended in 1972 to require a noise element for all city and county general plans. The noise element for Imperial County was adopted on October 1, 1974.²³ This document deals almost exclusively with transportation sources of noise (airports, state highways and county roads, railroads, and water vehicles). However, general noise guidelines based on U.S. Department of Housing and Urban Development (HUD) criteria are set forth in the noise element (Table 2.11). The State of California requires that the 45 dB contour not be exceeded for hospitals, rest homes, or outdoor recreation areas.²³

The Environmental Protection Agency suggests an L_{dn} (day-night time-averaged level) of 55 dBA for outdoor residential areas.²⁴ Since an L_{dn} is calculated using a 10-dB penalty for nighttime hours, this suggested level corresponds to a continuous, 24-hr sound level of about 49 dBA.

Permissible noise levels for geothermal development in Imperial County are explicitly stated in *Terms, Conditions, Standards, and Application Procedures for Initial Geothermal Development - Imperial County*, prepared by the Imperial County Department of Public Works.²⁵ Two classes of drilling and production noise standards are set up: Class I and Class II. Class II is further broken down into the zoning categories of industrial, commercial, residential (dense), residential (normal), and open space. Continuous generation of wide-band noise must be limited to the levels shown in Fig. 2.8. Measurements are to be taken at the parcel boundary, which is by definition at a minimum distance of 100 ft (30 m) from any well. Fig. 2.8 also shows the overall maximum noise levels (in dBA) which would be reached if all the individual specified values were attained. The prescribed levels may be exceeded by 10% if the noise is intermittent and during daylight hours.

Under Class II standards, it is stipulated that all work in preparation of the site for drilling shall be done between the hours of 7 AM and 7 PM;

Table 2.11. Imperial County noise categories

Imperial County rating	HUD rating	Description
Critical	Clearly unacceptable	Exceeds 80 dBA for 60 min per 24-hr time span, or exceeds 75 dBA for 8 hr per 24-hr time span.
Concern	Normally unacceptable	Exceeds 65 dBA for 8 hr per 24-hr time span, or loud repetitive sounds on site.
Caution	Normally acceptable	Exceeds 65 dBA for less than 8 hr per 24-hr time span.
Allowable	Clearly acceptable	Does not exceed 45 dBA for more than 30 min per 24-hr time span.

Source: Imperial County Planning Department, *Imperial County Noise Element*, adopted October 1, 1974.

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Fig. 2.8. Permissible noise levels for geothermal development in Imperial County. Measurements are to be taken at the parcel boundary, which is by definition a minimum of 100 ft (30 m) from any well.
Source: Imperial County Department of Public Works, *Terms, Conditions, Standards, and Application Procedures for Initial Geothermal Development - Imperial County*, May 1971.

and no drill pipe shall be racked or made up except between the hours of 7 AM and 7 PM (except where sound proofing is provided or in case of emergency). Drilling may be on a 24-hr basis providing all other circumstances are met.

For the present project, Class I standards apply to the following ten well sites: Dearborn Farms Nos. 1 and 2; Kalin Farms Nos. 1 and 2; Kellogg Nos. 1 and 2; and Landers Nos. 1-4.²⁶ Class II standards apply to the following 15 sites: Buckingham Nos. 1 and 2; Griset Nos. 1-6; Huffman-Allen Nos. 1 and 2;²⁷ and Sweetwater Nos. 1-50. (See Fig. 1.2 for locations of wells.) The zoning category I (industrial) applies to the well sites in Class II,²⁸ except for those at Sweetwater, which are classified as residential, normal (RN).

2.5 ECOLOGY

2.5.1 Terrestrial ecology

2.5.1.1 Vegetation

The Westmorland leasehold area is located within the hot Colorado desert of southern California. The natural vegetation of the region consists of two major plant communities: the creosote bush scrub and the alkali sink.²⁹ The creosote bush scrub, which is widespread over the Colorado desert, consists of stands of widely spaced shrubs. Common species include creosote bush (*Larrea divaricata*), bur-sage (*Franseria dumosa*), and various species of cacti and flowering desert annuals. The alkali sink community occurs in poorly drained, saline habitats such as that found along the shore of the Salton Sea. Characteristic species include saltbush (*Atriplex* spp.), iodine bush (*Allenrolfea occidentalis*), and *Suaeda torreyana*.

Most of the land in the Imperial Valley on which these natural plant communities would occur has been converted to agricultural and urban uses. In the vicinity of the Westmorland, the remaining areas of natural vegetation are confined to locations along the New River and to the Salton Sea National Wildlife Refuge (Fig. 1.1). Riparian vegetation along

portions of the river consists of salt cedar (*Tamarix gallica*), arrowweed (*Pluchea sericea*), screwbean mesquite (*Prosopis pubescens*), and willows (*Salix* spp.). Freshwater marshes are located along the lower New River and on the wildlife refuge at the confluence of freshwater and the Salton Sea. Rooted aquatic plants such as cattails (*Typha* spp.), sedges (*Carex* spp.), and bulrushes (*Scirpus* spp.) are common in this habitat. Along the margins of the marshes are dense stands of salt cedar and "cane" (*Phragmites communis*). Portions of the natural vegetation in the wildlife refuge have been modified by planting of cover and grain crops for waterfowl use.

2.5.1.2 Wildlife

Since all the possible well sites are on land which is agricultural, potential sites represent very poor wildlife habitat. Riparian vegetation along portions of the New River provides some of the only remaining natural wildlife habitat on the leasehold area. A variety of common desert animals and waterfowl species occur in this habitat.

The nearby Salton Sea and its associated wetlands are also important waterfowl and shorebird habitat. The most attractive areas for the birds are the southern part of the sea and the deltas of the New and Alamo rivers. The leasehold area borders portions of the large Salton Sea National Wildlife Refuge, which is the wintering area for a large segment of the Pacific Flyway. A total of 105 species of water-associated birds have been recorded at the refuge.³⁰ The Salton Sea is the winter home of Canada, snow, and white-fronted geese and many species of ducks — primarily pintail, American pigeon, and green-winged teal. Winter duck populations at the refuge exceed 200,000 birds.³¹ Snow geese usually number about 20,000 and the Great Basin Canada goose flock reaches 8000.³ No other comparable area in the west has the tremendous flocks of shorebirds that use the wetlands around the Salton Sea. The American avocet, black-necked stilt, willet, marbled godwit, and many species of sandpipers, plovers, and phalaropes use the Sea as a place to feed and rest. Twenty-four species of water-associated birds are known to nest on the refuge.³⁰ Gull-billed terns and laughing gulls, which nest nowhere else in the western United States, nest on the refuge.

2.5.2 Aquatic ecology

The New River and the Salton Sea are the major surface waters in the leasehold area and its immediate vicinity (Fig. 1.2). The area also contains numerous irrigation and drainage waterways. The irrigation system supports populations of striped bass (*Morone saxatilis*), black crappie (*Pomoxis nigromaculatus*), channel catfish (*Ictalurus punctatus*), bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), and various nongame fish.³² Irrigation drains in the Imperial Valley serve as fresh-water habitat to support limited public fishing activity.¹⁶

The Salton Sea supports a salt-water sport fishery (see Sect. 2.7) of orangemouth corvina (*Cynoscion xanthulus*), sargo (*Anisotremus davidsoni*), and bairdiella or gulf croaker (*Bairdiella icistius*). The desert pupfish (*Cyprinodon macularius*) is native to the area, and threadfin shad (*Dorosoma petenense*), mudsucker (*Gillichthys mirabilis*), striped mullet (*Mugil cephalus*), and mosquito fish (*Gambusia affinis*) have also become established.¹ However, the introduction of fish species into the Salton Sea — from the flooding Colorado River, from the Gulf of California, and through attempts to introduce additional sport fish — has generally been unsuccessful.

Planktonic algae are abundant in the Salton Sea; they thrive on the salts and dissolved nitrogen and phosphorus to the point where the eutrophic symptoms of water discoloration, oxygen deficiencies, and localized fish kills result. Among the macroinvertebrates, only the pile worm (*Neanthus succinea*), amphipods (*Carinogammarus mucronatum*), and barnacles (*Balanus amphitrite*), all introduced from 1930 to 1957, are abundant. Mollusks and crustaceans were introduced into the Salton Sea, to expand the salt-water fishery, but they were not successful. A native fauna of copepods (*Cyclops dimorphus*), nematodes (*Spilophorella* spp.), rotifers (*Brachionus plicatilis*), and protozoans is also present in the Salton Sea.

Barnacles, mullet, and shad feed on the plankton. The pile worm is a detritivore and is in turn the principal food organism for the bairdiella, the mudsucker, and the sargo. The orangemouth corvina is the top predator in the system; it feeds primarily on shad, bairdiella, mudsucker, and, to a lesser extent, sargo.¹

Increasing salinity in the Salton Sea is seen as a threat to the present fishery. Elimination of some game fish within ten years is possible due to egg and larval mortality if salinity exceeds 40,000 ppm.¹³ Studies are under way to investigate the feasibility of controlling salinity.²

2.5.3 Endangered species

Five species classed as endangered on the Federal list³³ and by the California Fish and Game Department³⁴ are known to occur in the vicinity of the Salton Sea. These include the yuma clapper rail (*Rallus longirostris yumanensis*), southern bald eagle (*Haliaeetus leucocephalus leucocephalus*), California least tern (*Sterna albifrons brownii*), American peregrine falcon (*Falco peregrinus anatum*), and the California brown pelican (*Pelecanus occidentalis californicus*). All species are associated with the Salton Sea and its peripheral wetlands. Of the five species, only the yuma clapper rail breeds in the vicinity of the Salton Sea. The other four species of birds are recorded as occurring on the Salton Sea Wildlife Refuge as rare or occasional visitors or migrants.³⁰

Two separate studies of clapper rails and rail habitat in southern California identified five areas of importance to clapper rails in the Imperial Valley. Of these five areas, two are situated just outside the boundaries of the leasehold area. These areas are on the New River delta and in the South Unit of the Salton Sea National Wildlife Refuge (see Fig. 2.9).³⁵ The nearest proposed well sites to either of these areas are about 3 km (2 miles) away; they are Griset Nos. 3 and 6 and Kellogg Nos. 1 and 2 (see Fig. 1.2).

None of the species on the proposed Federal list of endangered plants³⁷ are known to occur in the leasehold area, itself.

2.6 LAND USE

The primary land use in the Westmorland area is intensive, irrigated agriculture. Unirrigated land is desert. The commerce and industry of the area are almost exclusively related to support of farming.

Fig. 2.9. Areas in which Yuma clapper rails were sighted in 1974, in relation to the Westmorland leasehold area. Number of birds in each habitat is indicated. Source: G. I. Gould, Jr., *Yuma Clapper Rail Study - Censuses and Habitat Distribution, 1973-74*, Administrative Report No. 75-2, California Department of Fish and Game, Wildlife Management Branch, 1975.

2.6.1 The leasehold area

Land use in the leasehold area, as in the rest of the valley, is predominantly irrigated agriculture. The major crops are cotton and sugar beets. Six cattle feedlots and approximately 80 residences outside of Westmorland itself are located within the geothermal leasehold (Fig. 1.2). A duck club in Range 12, Township 12, just northeast of the New River delta, is the only recreational land use there. The leasehold area borders the Salton Sea, which is heavily used for fishing and boating, and it also borders the Salton Sea National Wildlife Refuge, an area which attracts hunters and bird watchers. The leasehold area surrounds the town of Westmorland, which contains businesses and residences.

2.6.2 Imperial County

Crops and agriculture-based industry constitute the primary land uses in Imperial County; these activities generate revenue and jobs. Table 2.12 shows land-use acreages in the county in 1970. Table 2.13 summarizes the county's agricultural production for 1976, including the ten most productive crops. In 1970, 177,000 ha (437,336 acres) were under irrigation; in 1974, the net total area under irrigation was 183,000 ha (449,762 acres), indicating an increase of less than 3% in four years.¹¹

The 1976 annual crop report indicates that the agricultural industry produced a gross income of more than half a billion dollars during 1976, maintaining Imperial County among the top five agricultural counties in the United States.

All irrigated land in Imperial County has been reclaimed from the desert through a massive water project which began in 1901. Unprecedented floods from 1904 to 1907 created the Salton Sea, and in 1928 the Hoover Dam and the All-American Canal were constructed. The All-American Canal is 128 km (79.7 miles) long, and the entire gravity-run water and power system operates 2638 km (1639 miles) of canals and 2247 km (1396 miles) of drains to irrigate the desert and provide one of the most productive agricultural areas in the United States.

Table 2.12. Land-use practices in Imperial county, 1970

	Field and row crops	Orchards	Pasture	Range	Forest	Urban	Federal noncropland	Private noncropland	Total
Area									
Acres	443,000	2,300	2,100	0	2,000	34,354	1,500,000	785,000	2,741,460
Hectares	179,000	930	850	0	810	13,900	607,300	317,800	1,109,900
Percent of total	16	0.01	0.01	0	0.1	1.3	55	28	

Source: California Soil and Water Conservation Needs Inventory, California Conservation Needs Committee, 1970.

Table 2.13. Imperial county agricultural production for 1976^{a, b}

Crop	Area		Yield		National average yield ^b		Value
	(acres)	(hectares)	(tons)	(metric tons)	(tons)	(metric tons)	
Alfalfa (cube and dehydrated)	25,000	10,100	7.72	7.00			\$16,438,000
Alfalfa (hay)	146,100	59,100	8.28	7.51	2.87	2.60	83,889,000
Cotton (lint)	71,000	28,700	0.48	0.44	0.23	0.21	45,988,000
Sorghum (grain)	17,000	6,900	2.64	2.39	1.37	1.24	5,214,000
Sugar beets	58,000	23,500	25.45	23.09	19.3	17.5	37,000,000 ^c
Wheat	156,000	63,200	2.66	2.41	0.92	0.83	50,801,000
Total field crops	669,000	270,900					265,780,000
Asparagus	4,270	1,730	1.80	1.63	1.05	0.95	8,685,000
Cantaloupes	8,850	3,580	6.37	5.78	6.60	5.99	14,071,000
Lettuce	43,900	17,800	13.35	12.11	11.50	10.43	69,365,000
Tomatoes	1,766	715	10.87	9.86			7,984,000
Total vegetables	76,838	31,110					121,806,000
Fruit and nut crops	3,617	1,460					3,380,000
Livestock and dairy	924,000 head						113,432,000
Apiary products							960,000
Seed and nursery crops	6,371	2,580					15,355,000
Total							\$520,716,000

^aOffice of the Agricultural Commissioner, "Imperial County Agriculture, 1976"; United States Department of Agriculture, "Agricultural Statistics, 1976," U.S. Government Printing Office, Washington, 1976.

^b1975 data.

^cIncludes government payments.

Recreational uses in Imperial County center around the desert climate and the large open desert areas that surround the irrigated and populated areas of Imperial Valley. Recreational activities include hunting, camping, and use of dune-buggies in outlying areas; water sports at the Salton Sea and Salton Sea State Park; and golfing around El Centro and Brawley. The Anza-Borrego Desert State Park is situated just east of the county line in San Diego County. Many sight-seeing activities associated with historical and geological characteristics of the desert are available in the southwestern corner of the county.

2.6.3 Prime and unique farmland

Prime farmlands are those whose value derives from their suitability as cropland based on soil and water conditions. Unique farmlands are those whose value derives from their suitability for growing specialty crops. The Council on Environmental Quality (CEQ) has directed Federal agencies to strive to assure that such farmlands are not irreversibly converted to other uses unless other national interest override the importance of their preservation or otherwise outweigh the environmental benefits derived from their protection. In accordance with this policy, the Soil Conservation Service, U.S. Department of Agriculture, has issued 7 CFR Part 657 — final rules concerning classification and inventory of prime and unique farmlands.

The Soil Conservation Service has determined that none of the proposed well sites, except for those at Sweetwater, are on prime farmland. All of the well sites at Sweetwater, however, are on prime, irrigated, farmland (Appendix).

2.6.4 Aesthetics

The visual environment of the geothermal leasehold area is dominated by features which reflect the impact of man: tilled fields, telephone and electrical lines, roads, canals, and houses. However, the topography is flat, and on a clear day it allows vistas of the mountain ranges which surround the valley.

When the area was evaluated according to Bureau of Land Management (BLM) criteria for scenic quality, it received a rating of 1 out of a possible 24 points. The criteria are taken from a BLM manual for evaluating scenery and sightseeing potential for recreational use opportunities. Criteria on which ratings are based include land form, color, water vegetation, and uniqueness as a scenic resource area. These ratings evaluate the variation and interest represented by an area and the uniqueness of the area as a visual resource in a region. The leasehold area also received a negative value for intrusions; this indicates that the surrounding area contains many man-made elements that do not enhance its overall scenic quality.

2.7 WATER USE

In 1901, the Imperial Valley acquired appropriative rights to water from the Colorado River. The Imperial Irrigation District (IID) provides water to the valley — via the All-American Canal and Coachella Branch — for irrigation and for municipal and industrial purposes. Water use within the valley is under the jurisdiction of the IID.

With its system of canals, drains, outlets, and laterals, the IID provides for the irrigation and drainage of about 180,000 ha (450,000 acres) of farmland. From 1974 to 1976, an annual average of about $3.65 \times 10^9 \text{ m}^3$ (2,950,000 acre-ft) of Colorado River water was imported into the IID system.³⁸ The IID shares in California's use of $6.622 \times 10^9 \text{ m}^3/\text{yr}$ (5.362×10^6 acre-ft/yr) of Colorado River water, as determined by the 1931 "Seven-Party Agreement." Part of the IID's allocation results from a third-priority right to a portion of $4.75 \times 10^9 \text{ m}^3/\text{yr}$ (3.85×10^6 acre-ft/yr) shared with the Palo Verde Irrigation District and the Yuma Project, California Division. The remainder results from a sixth-priority right to a portion of $3.7 \times 10^8 \text{ m}^3/\text{yr}$ (3×10^5 acre-ft/yr), shared with the Palo Verde Irrigation District.³⁹ A 1964 U.S. Supreme Court decree limits California's allotment to $5.4 \times 10^9 \text{ m}^3/\text{yr}$ (4.4×10^6 acre-ft/yr),³⁸ which is nevertheless exceeded by California's actual current use rate due to low demands on the river water on the part of other users.

The Central Arizona Project is a water development project which will allow the region including Phoenix and Tucson to utilize about $1.5 \times 10^9 \text{ m}^3/\text{yr}$ ($1.2 \times 10^6 \text{ acre-ft/yr}$) of Colorado River water.⁴⁰ It is expected that when this project is completed in 1979-80 the IID will have its allocation reduced to $3.2 \times 10^9 \text{ m}^3/\text{yr}$ ($2.6 \times 10^6 \text{ acre-ft/yr}$); this allocation will result entirely from the third-priority right.⁴¹ The expected result of the reduced importation of Colorado River water by the IID is increased competition for water in the Imperial Valley.

The adequacy of the allotment to satisfy irrigation requirements may be affected by changes in the efficiency of irrigation water use — such as reduction of seepage and evaporation losses in the canal network, or changes in the method of application of the irrigation water — and changes in the total salinity of the irrigation water. Imported Colorado River water had a salinity of about 875 ppm in 1974, and its salinity is projected to rise to 1340 ppm by the year 2000. Salinity control programs have been proposed to alleviate this problem.¹¹ As irrigation water salinity rises, more salt residues are left in the soil after evapotranspiration from the agricultural fields. Consequently, relatively greater amounts of water are then required to achieve soil salinity control through leaching of soil salts.

Municipal and industrial use of the imported Colorado River water accounts for less consumption than does irrigation. Of the $3.4 \times 10^7 \text{ m}^3$ (27,400 acre-ft) of water delivered by the IID for municipal and industrial use in 1975, the town of Westmorland accounted for only about 3%. Brawley, El Centro, and Calexico were major users, with a combined total greater than 60%.⁴²

Groundwater in the leasehold area is saline and not beneficially used.¹⁶ The role of surface waters of the leasehold area in the support of fisheries and wildlife is discussed in Sect. 2.5. The total annual recreational value of the Salton Sea has been estimated to be \$11,000,000. Approximately one-third of this total is related to fishing; the remainder is related to hunting, boating, swimming, water skiing, camping, and picnicking.¹

The County of Imperial is willing to permit the limited use of agricultural water for geothermal pilot plant operations.⁴³ This is one facet of the evolving relationship between geothermal development and the agricultural economy of Imperial Valley.

2.8 DEMOGRAPHY AND SOCIOECONOMICS

The 1974 population of Imperial County was 83,676 persons; there was a growth of 12.3% between 1970 and 1974. Present density is 8 persons per square kilometer (20 persons per square mile). The largest population centers in the area are El Centro (21,300 persons), 33 km (20 miles) south of the project area and Brawley (14,010 persons), 1.7 km (1 mile) to the southeast. Nearby small towns are Westmorland (1,417 persons), Calipatria (2,074 persons), and Niland (1,137 persons). Sixty-five percent of the county residents live in incorporated areas. (These figures are based on Imperial County estimates.⁴⁴)

The population of the county is approximately equally divided between Spanish Americans (46%) and other groups. The median age in Imperial County is significantly lower than that for the State of California as a whole (24.0 years as opposed to 28.1 years). This difference reflects the higher percentage of people in the county under 18 years of age (41.5%, as opposed to 33.3% statewide). Educational level compares unfavorably with the rest of California; the median number of school years completed is only 10.8 in Imperial Valley compared to 12.4 for the entire state. Of those people 25 years of age and older, 43.1% have completed high school and only 7.3% have completed college.²⁰

Agriculture provides the economic base for Imperial County. Most of the county's industries are agriculture related: for example, fertilizer and food processing. Agriculture provides the principal employment. Table 2.14 lists the major economic sectors by number of employers. The 1973 median family income was \$8256; the unemployment rate at that time was 7%.

Housing available in the valley covers the full range from houses for sale through rental houses, apartments, and trailer courts to motels and hotels. Domestic water supplies and sewage treatment facilities are adequate in the area.

Table 2.14. Sources of employment in Imperial County, 1976

Employment source	Number of employees
Agriculture	8,800
Government	8,050
Retail trade	5,500
Services	3,200
Manufacturing	2,150
Transportation/communication/utilities	1,400
Construction	700
Finance/real estate/insurance	600
Total	35,500

Source: Imperial County Planning Department, *Population Periodical*, El Centro, Calif., 1976.

2.9 HISTORICAL AND ARCHAEOLOGICAL SITES AND NATURAL LANDMARKS

2.9.1 Historical sites

The "National Register of Historic Places"⁴⁵ lists two sites in Imperial County as having important national historical value worthy of preservation. These sites are: Fages-De Anza Trail Southern Emigrant Route in Anza-Borrego Desert State Park about 80 km (50 miles) southwest of the leasehold area, and Yuma Crossing and Associated Site near Winterhaven about 110 km (70 miles) southeast of the leasehold area. Both of these sites are associated with the westward migration of pioneers and settlers of the western United States.

Three properties which have been determined to be eligible for inclusion in the National Register are: Glamis Vicinity, Chocolate Mountain Archaeological District; Lake Cahuilla, Lot 1; and Lake Cahuilla, Lot 2.⁴⁵

2.9.2 Archaeological sites

Aboriginal populations in the Imperial Valley from about 1400 B.C. until the late 1800s were concentrated in land along the New and Alamo rivers. Although these areas have been disturbed by farming, remnants of the sites have been found on farmed land near the rivers. In 1856, a segment of Indian trail was recorded in the general vicinity of the leasehold area confirming aboriginal activity in the area.⁴⁶ An archaeological examination of several proposed drilling sites (Griset 3 and 6, Griset 2 and 5, Griset 1 and 4, Huffman-Allen 1 and 2, Buckingham 1 and 2 and Sweetwater 1 and 2 - Fig. 1.2) did not disclose any archaeological resources.⁴⁷ It is the opinion of the senior archaeologists at Imperial Valley College Museum that the well sites have been totally impacted by agricultural development and that it is not possible that resources are present *in situ* on the surface, nor are they likely to exist in subterranean strata.⁴⁸

2.9.3 Natural landmarks

Two natural landmarks in Imperial County are listed in the "National Registry of Natural Landmarks": the Sand Hills, about 130 km (80 miles) southeast of the leasehold area and the San Felipe Creek area about 25 km (15 miles) west of the leasehold area.⁴⁹

REFERENCES FOR SECTION 2

1. David Layton and Donald Ermak, *A Description of Imperial Valley, California, for the Assessment of Impacts of Geothermal Energy Development*, UCRL-52121, Lawrence Livermore Laboratory, Livermore, Calif., 1976.
2. California Department of Water Resources, *Geothermal Wastes and the Water Resources of the Salton Sea Area*, Bulletin No. 143-7, The Resources Agency, Sacramento, Feb. 1970.
3. T. M. Dibblee, Jr., "Geology of the Imperial Valley Region, California," Chap. II of *Geology of Southern California*, ed. by R. H. Jahns, California Department of Natural Resources, Division of Mines, Bulletin 170, San Francisco, 1954.
4. C. R. Longwell, "History of the Lower Colorado River and the Imperial Depression," Chap. IV of *Geology of Southern California*, ed. by R. H. Jahns, California Department of Natural Resources, Division of Mines, Bulletin 170, San Francisco, 1954.
5. W. A. Elders, "Regional Geology of the Salton Trough," in *Geothermal Development of the Salton Trough, California and Mexico*, ed. by T. D. Palmer, J. H. Howard, and D. P. Lande, Lawrence Livermore Laboratory, Livermore, Calif., 1975.
6. S. T. Algermissen and D. M. Perkins, *A Probabilistic Estimate of Maximum Acceleration in Rock in the Contiguous United States*, U.S. Geological Survey Open File Report 76-416, Denver, Colorado, 1976.
7. Association of Engineering Geologists, *Major Earthquakes and Recently Active Faults in the Southern California Region* (map), 1973.

8. R. W. Greensfelder, Maximum Credible Rock Acceleration from Earthquakes in California, Map Sheet 23, California Division of Mines, 1974.
9. U.S. Department of Agriculture, Soil Conservation Service, open file data for Imperial County, California (Davis, Calif.).
10. J. L. Renner, D. E. White, and D. L. Williams, "Hydrothermal Convection Systems," in *Assessment of Geothermal Resources of the United States - 1975*, ed. by D. E. White and D. L. Williams, U.S. Geol. Surv. Circ. 726, 1975.
11. Imperial Irrigation District, *The Colorado River and Imperial Valley Soils*, Bulletin No. 1075, El Centro, Calif. (no date).
12. California Department of Transportation, *Geotechnical Report - San Bernardino County, Riverside and Imperial County*, Southern California Association of Governments, San Diego, 1974.
13. M. Goldsmith, *Geothermal Development and the Salton Sea*, EQL Memorandum No. 17, Environmental Quality Laboratory, California Institute of Technology, Pasadena, 1976.
14. G. H. Hughes, A. G. Hely, and B. Irelan, *Hydrologic Regimen of Salton Sea, California*, U.S. Geol. Surv. Prof. Pap. 486-C, 1966.
15. O. J. Loeltz, B. Irelan, J. H. Robinson, and F. H. Olmsted, *Geohydrologic Reconnaissance of the Imperial Valley, California*, U.S. Geol. Surv. Prof. Pap. 486K, 1975.
16. California Regional Water Quality Control Board - Colorado River Basin Region, *Waste Discharge Requirements for Republic Geothermal Inc.*, Orders No. 75-61, 76-52, 77-1, Palm Desert, Calif., 1975-77.

17. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, *Seasonal and Annual (Day/Night) Wind Distribution of Pasquill Stability Classes - Star Program Station #23199, El Centro, California 1/54 - 12/58*, Environmental Data Service, National Climatic Center, Ashville, N.J., 1975.
18. University of California, Imperial Valley Agricultural Field Station, Holtville, Calif., *Weather Data - Annual Summary Report, 1974-1975*, 1976.
19. Imperial County Air Pollution Control District, Emissions Inventory for the Imperial County Portion of the Southeast Desert Air Basin, transmitted by J. V. Taylor, Assistant Air Pollution Control Officer, Imperial County, El Centro, Calif., 1976.
20. VTN Consolidated, Inc., *Environmental Analysis Record, Proposed Geothermal Exploration, South Brawley Prospect, California*, CUI Venture, Irvine, Calif., 1977.
21. W. A. van Bergeijk, J. R. Pierce, and E. E. David, Jr., *Waves and the Ear*, Doubleday and Co., Inc., New York, 1960, Fig. 4.1, p. 71.
22. W. Burns, *Noise and Man*, J. B. Lippincott Co., Philadelphia, 1968, Appendix G, p. 296.
23. Imperial County Planning Department, *Imperial County Noise Element*, adopted October 1, 1974.
24. U.S. Environmental Protection Agency, *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety*, 550/9-74-004, March 1974.
25. Imperial County Department of Public Works, *Terms, Conditions, Standards, and Application Procedures for Initial Geothermal Development - Imperial County*, May 1971.

26. Imperial County Planning Commission, Geothermal Exploration Permits No. 50-75 (issued November 25, 1975) and 80-76 (issued September 6, 1976).
27. Imperial County Planning Commission, Geothermal Exploration Permit No. 87-77 (issued February 24, 1977).
28. Richard Mitchell (Planning Director, Imperial County Planning Department), personal communication, January 5, 1978.
29. P. A. Munz and D. E. Keck, *A California Flora*, University of California Press, Berkeley, 1968.
30. U.S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, *Birds of the Salton Sea National Wildlife Refuge*, Refuge leaflet 186-R3, U.S. Government Printing Office, Washington, D.C., 1970.
31. U.S. Department of the Interior, *Final Environmental Statement for the Geothermal Leasing Program*, vol. II, U.S. Government Printing Office, Washington, D.C., 1973.
32. U.S. Energy Research and Development Administration, Division of Geothermal Energy, *Environmental Impact Assessment, Hydrothermal Sub-program*, EIA/GE/77-2, 1977.
33. U.S. Department of the Interior, "Endangered and Threatened Wildlife and Plants," *Fed. Regist.* 42(135): 36421-31 (1977).
34. California Fish and Game Department, *At the Crossroads, 1976: A Report on California's Endangered and Rare Fish and Wildlife*, Sacramento, Calif., 1976.
35. G. I. Gould, Jr., *Yuma Clapper Rail Study - Censuses and Habitat Distribution, 1973-74*, Administrative Report No. 75-2, California Department of Fish and Game, Wildlife Management Branch, 1975.

36. W. W. Bennett and R. D. Ohmart, *Progress Report: Ecology of the Clapper Rail (Rallus longirostris yumanensis) in Imperial Valley, California*, for the University of California, Lawrence Livermore Laboratory, Livermore, Calif., 1976.
37. U.S. Department of the Interior, "Endangered and Threatened Species: Plants," *Fed. Regist.* 41(117): 24524-72 (1976).
38. Imperial Irrigation District, *From Desert Wasteland to Agricultural Wonderland: The Story of Water and Power*, Fact Booklet, El Centro, Calif., 1977.
39. San Diego Gas and Electric Company, *Sundesert Nuclear Plant, Units 1 and 2, Environmental Report, Construction Permit Stage*, vol. 1, San Diego, Calif., 1977.
40. U.S. Department of the Interior, Bureau of Reclamation, *Lower Colorado River Reclamation* (pamphlet), 0-538-611, Washington, D.C., 1974.
41. L. R. McGlockin (Office of the General Manager, Imperial Irrigation District), personal communication, December 7, 1977.
42. San Diego Gas and Electric Company, *Responses to Comments by County of Imperial Planning Director on Sundesert Environmental Report*, Docket No. 50-582/583, San Diego, Calif., 1977.
43. Imperial County Planning Department, *Geothermal Element, Imperial County General Plan*, 1977.
44. Imperial County Planning Department, *Population Periodical*, El Centro, Calif., 1976.
45. U.S. Department of the Interior, Advisory Council on Historic Preservation, National Park Service, "National Register of Historic Places," *Fed. Regist.* 42(21): 6197-6362 (1977).

46. Letter from Michael A. Barker (Chief Curator, Imperial Valley College Museum, El Centro, California) to Richard Mitchell (Planning Director, Imperial County Planning Department), January 11, 1977.
47. J. von Werlhof and S. von Werlhof, *Archaeological Examinations of Ten Proposed Geothermal Drill Test Sites near Salton Sea*, Imperial Valley College Museum, El Centro, Calif., 1977.
48. Westec Services, Inc., *South Westmorland Geothermal Exploration Project, Draft Environmental Impact Report*, Appendix D, September 1978.
49. U.S. Department of the Interior, National Park Service, "National Registry of Natural Landmarks," *Fed. Regist.* 40(87): 19503-19508 (1975).

3. POTENTIAL ENVIRONMENTAL IMPACTS

The potential environmental impacts of the proposed action during the phases of exploration and power generation are evaluated as they relate to geology, water and air quality, noise, ecology, land and water use, socioeconomics, and historical and archaeological resources and natural landmarks.

3.1 IMPACTS OF EXPLORATION

Some geological exploration, well drilling, and testing have already been carried out in the leasehold area, with impacts being largely confined to loss of agricultural land. This section is concerned with the effects of further drilling and testing of exploration wells, confirmation wells, and injection wells.

3.1.1 Geological impacts

No significant geological impacts are anticipated during the exploration and testing phases of development. The principal geological impacts to be addressed are subsidence and induced seismicity. These phenomena are not likely to occur unless substantial quantities of fluid are produced over a long period of time without injection. The initial clean-out flows for the exploratory and confirmation wells will not be injected; however, the liquid volume per well for a series of initial flows will not exceed 100,000 barrels.¹ Liquid geothermal fluids produced in sustained flow tests subsequent to the initial clean-out flows will be disposed of by means of reinjection into the subsurface at depths of at least 760 m (2500 ft). Because each injection well will be close to a production well [within approximately 150 m (500 ft)] and injection will take place at depth, no measurable subsidence or low-magnitude induced seismicity is expected.

3.1.2 Impacts on water quality

There are no expected significant effects on water quality in the leasehold area as a result of exploration, based on the waste discharge requirements² adopted by the California Regional Water Quality Control Board, Colorado River Basin Region. Geothermal fluids may contain toxic constituents in addition to their heat content.³ Geothermal fluids thus far produced and anticipated in the leasehold area contain from 15,000 to 75,000 ppm total dissolved solids (TDS). However, contamination of surface waters, such as irrigation or drainage waterways, the New River, or the Salton Sea, will be prevented by the containment or injection of potentially harmful fluids (Sect. 1.2.1.2). Drilling fluids, which may be toxic or nontoxic depending on choice of additives, and produced geothermal fluids will not be released to the environment; steel tanks and leakproof sumps will be used for fluid containment. Drilling muds and debris will be disposed of by removal to approved landfill sites. Groundwater in the leasehold area is considered saline and is not beneficially used. Nevertheless, injection zones will contain at least 10,000 ppm TDS or will be as saline as the fluids to be injected, so that deep groundwater quality is not adversely affected.²

The consumption of about 620 m³ (0.5 acre-ft) of agricultural water for use in drilling each well will represent an insignificant fraction of the total annual flow into the Salton Sea. In fact, overall water use may decrease due to the retirement of agricultural land for drilling sites (Sect. 3.1.6). Thus, although the consumption of large quantities of agricultural water for the cooling of geothermal power plants (approximately 643 m³/hr or 5.6 x 10⁶ m³/yr) may accelerate the increasing salinity of the Salton Sea,⁴ the smaller requirement for exploratory drilling for this project would not have a measurable effect.

Drainage of the well sites toward the sumps will ensure that surface runoff of fluids will be contained. The impermeability of the sumps (Sect. 1.2.1.1) will prevent potential pollution of groundwater by drilling fluids and wastes, by contaminated surface runoff, and by produced geothermal fluids. The integrity of the sumps will also protect surface waters from pollution from underflow of contaminated shallow

groundwater. Adherence to adequate drilling practices, such as proper casing and cementing (Sect. 1.2.1.2), will prevent contamination of fresh-water aquifers by geothermal fluids or by the commingling of aquifers.

3.1.3 Impacts on air quality

Air quality impacts will result from equipment operation and release of geothermal gases. Diesel drives for the drilling rigs typically consume 2000 liters/day (550 gal/day) of fuel, resulting in emissions of approximately 23 kg/day (5 lb/day) of CO, 9 kg/day (20 lb/day) of exhaust hydrocarbons, 107 kg/day (236 lb/day) of NO_x, 7 kg/day (15 lb/day) of SO_x, and 7.5 kg/day (17 lb/day) of particulates.^{5,6}

The emissions associated with the operation of diesel-powered equipment for five days to prepare a well pad would be equivalent to those associated with a single day of drilling. A small amount of polluting emissions will result from the operation of delivery trucks and private vehicles. These emissions will not result in any further decline in the air quality of the area.

Noncondensable geothermal gases will be released during drilling and well testing. While the weight of the drilling mud should prevent a large release of gases to the surface during drilling, some gases will escape. These gases will be released to the atmosphere from the water/steam separator at the well, from the drilling mud cooling tower, and from the liquid sump. Maintenance of sufficient pressure within the well to protect against blowouts should result in acceptably low levels of gaseous emissions during drilling.

Well testing will result in the direct release of steam and a variety of other gases and particulates for a minimum of 30 days per well. Other shorter test flows may also be necessary. Concentrations of noncondensable gases in fluids produced from five existing wells in the Westmorland vicinity are presented in Table 3.1. In each case carbon dioxide comprises over 90% of the noncondensable gases. Hydrogen sulfide, the gas of greatest concern, was found to constitute only 0.18 mole % of noncondensable gas from Magma Max No. 4, a well less than 1.5 km (1 mile) north of the leasehold area. Hydrogen sulfide was

Table 3.1. Westmorland "unflashed" well fluids noncondensable gas composition

Parameters	Landers No. 2	Landers No. 3	Kalin Farms No. 1	Dearborn Farms No. 2	Magma Max No. 1 ^b
Noncondensables (mole %)					
Carbon dioxide	96.465	92.996	92.28	95.8	98.14
Hydrocarbons	2.156	1.336	7.10	3.0	0.68
Nitrogen	1.167	5.356	0.62	1.0	0.02
Oxygen	0.000	0.000	0.00	0.2	0.00
Hydrogen	0.003	0.032	NA ^a	NA	0.00
Hydrogen sulfide	0.000	0.000	NA	NA	0.18
Argon	0.041	0.096	NA	NA	NA
Total noncondensables in steam (wt %)	14.9	41	9.3	NA	NA

^aNot available.

^bD. G. Miller, A. J. Piwinski, and R. Yamauchi, *The Use of Geochemical-Equilibrium Computer Calculations to Estimate Precipitation from Geothermal Brines*, UCRL-52197, Lawrence Livermore Laboratory, Livermore, Calif., 1977.

Source: Mapco Geothermal Inc. and Republic Geothermal, Inc., *Application for Loan Guaranty: Westmorland Development Project*, 1977.

detected in water from Landers No. 2 and No. 3 (Table 3.1) but not in gas samples; no H_2S odor was detectable at these flowing wells. These observations suggest that no odor problems will arise from the testing of wells in this area. None of the other gases are expected to create health or odor problems. Should direct venting of the steam and gaseous components to the atmosphere prove undesirable from the standpoint of air quality, the developers are prepared to treat the fluid prior to discharge.¹ Dust raised by equipment, which might otherwise reduce crop production by coating the leaves, will be controlled by spraying and/or graveling. Permits to drill and flow 20 wells have been granted by the Imperial County Air Pollution Control District on the condition that the concentrations of noncondensable gases are measured and reported.

3.1.4 Noise impacts

Noise production during exploration falls into three phases: site preparation, well drilling, and well testing. Site preparation may take up to a week per site and will involve grading and surfacing of drill pads; no road grading operations are anticipated, since existing county and agricultural roads will be used for access. Noise levels during site preparation will probably reach 85 to 95 dBA at 15 m (50 ft) from the source (Fig. 3.1), and will be attenuated to about 50 to 60 dBA at 800 m (1/2 mile) which approximates the distance to the nearest residences for most proposed well sites. For the wells to which Class II standards apply (Sect. 2.4.2), all work in preparation of the site for drilling must be done between 7 AM and 7 PM.

All drilling equipment will be supplied with hospital-type mufflers. Noise levels during mud drilling are typically about 85 to 90 dBA at 15 m (50 ft) and 50 to 55 dBA at 800 m (1/2 mile) (Fig. 3.1). Measurements taken by Republic Geothermal at the Westmorland well Landers No. 1 on March 18, 1977 included levels of 72, 75, 77, and 79 dBA at 30 m (100 ft) and 58 dBA at 150 m (500 ft).⁷ Air drilling, which is considerably noisier than mud drilling, will not be used at this site. Drilling will be performed on a 24-hr basis for about five weeks per well. A total of about 22 new wells are to be drilled. The duration of impacts could

Fig. 3.1. Noise levels from geothermal operations. Source: Modified after VTN Consolidated, Inc., *Environmental Analysis Record, Proposed Geothermal Exploration, South Brawley Prospect, California*, CUI Venture, Irvine, Calif., 1977; including data obtained from Dwight Carey (Republic Geothermal, Inc.) and Philip Leitner (St. Mary's College, Calif. — consultant, Lawrence Livermore Laboratory).

therefore be as long as 110 weeks (just over two years). If two or three wells are drilled at a time, the period of drilling would be 55 or 37 weeks respectively. In the case of multiple drilling operations, noise levels would be greater, although the addition of sound levels is not a simple algebraic process. The total noise level of two sounds of equal intensity is 3 dB higher than that of either individual sound. Addition of unequal sound levels involves an increment of less than 3 dB (according to a scale of values) above the level of the louder sound. The worst case for two wells being drilled simultaneously would thus be about 88 to 93 dBA at 15 m (50 ft) from both wells, or about 53 to 58 dBA at 800 m (1/2 mile).

At the geothermal field in East Mesa, California, venting of geothermal fluids typically produces noise levels of about 85 dBA at 15 m (50 ft),⁸ which will attenuate to about 50 dBA at 800 m (1/2 mile). A flow test at Westmorland well Landers No. 3 on March 17, 1977 yielded noise levels of 58 to 69 dBA at 30 m (100 ft) and 35 dBA at 800 m (1/2 mile).⁷ These levels are probably somewhat lower than average, however. Test procedures at Westmorland call for a minimum of 30 days of continuous testing as well as a number of shorter test flows. Again, if more than one well is tested at a time, noise levels would be greater than for single well testing. For each test the steam will be separated from the waste and vented directly to the atmosphere; steam vents and other sources of noise from testing will be either elevated or isolated from test personnel.

During all three phases of exploratory activity, noise levels will thus be between 65 and 95 dBA at 15 m (50 ft); after site preparation is complete, levels will probably not exceed 90 dBA.

The Imperial County Planning Department regulates noise levels at the boundary of a parcel of land undergoing geothermal development under the *Terms, Conditions, Standards, and Application Procedures for Initial Geothermal Development - Imperial County*⁹ (Sect. 2.4.2). Curves for the maximum noise levels legally permitted are presented in Fig. 2.8; the upper two curves are applicable to the present project sites except for those at Sweetwater, for which the zoning category is residential, normal (RN). Permitted noise levels for Imperial County are low. In comparison,

Lake County, California, which contains part of The Geysers Known Geothermal Resource Area, bases its regulations on levels of 81 to 83 dBA at 30 m (100 ft).¹⁰

Typical noise emission curves for diesel trucks running on a level roadway [at 30 m (100 ft)] and for a geothermal drilling rig are shown in Fig. 3.2, as compared to the Imperial County noise standards. It can be seen that these curves at various points exceed the levels permitted by the county at the parcel boundary, especially in the middle region of the sound spectrum where the human ear is most sensitive. The overall noise level for the drilling rig was 75 dBA at 30 m (100 ft). Overall noise levels for diesel trucks, based on the data presented in the figure, are 74 and 76 dBA at 30 m (100 ft). Accelerating diesel trucks and diesel trucks running on an up-grade normally produce levels of 82 and 79 dBA at 30 m (100 ft) respectively (see ref. 11 for frequency curves).

As stated above, it is very likely that standard construction equipment used in the project area will produce levels up to 90 and 95 dBA at 15 m (50 ft), or 84 and 89 dBA at 30 m (100 ft). Typical well drilling and well testing will produce levels of 85 dBA at 15 m (50 ft), or 79 dBA at 30 m (100 ft). The county noise standards can only be met if site preparation, well drilling, and well testing are carried on farther than 30 m (100 ft) from the parcel boundary, defined as a minimum of 100 ft from any well. Diesel trucks operating at a distance of 120 m (400 ft) from the boundary would satisfy the county Class II standards; other construction activities would have to take place at a distance of at least 240 m (800 ft), and drilling and flow test operations would have to be located about 120 m (400 ft) from the boundary. In addition, a well may not be sited closer than 400 m (1320 ft) to a school. Westmorland Elementary School is located about 400 m north of the Sweetwater sites Nos. 3 and 4. If standard geothermal exploration activities are carried on at any of the wells at a distance of 30 m (100 ft) from the parcel boundary, the activities will be in violation of county noise standards. The applicant is in contact with the Imperial County Planning Department to work out an arrangement which would satisfy the county on this point.

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- CLASS I STANDARDS, NOISE LEVELS AS MEASURED AT THE PARCEL BOUNDARY, WHICH IS DEFINED TO BE A MINIMUM OF 100 ft FROM ANY WELL.
- CLASS II STANDARDS (INDUSTRIAL), NOISE LEVELS AS MEASURED AT THE PARCEL BOUNDARY, WHICH IS DEFINED TO BE A MINIMUM OF 100 ft FROM ANY WELL.
- DIESEL TRUCK, LEVEL ROADWAY (AT 100 ft) [ADAPTED FROM CUNNIFF, 1977].
- ☆ GEOTHERMAL DRILL RIG AT WESTMORLAND WELL LANDERS NO. 1, 3/18/77 (AT 100 ft).

Fig. 3.2. Comparison of Imperial County noise standards and typical noise emissions of diesel trucks and geothermal drill rigs. Modified after: P. F. Cuniff, *Environmental Noise Pollution*, John Wiley and Sons, New York, 1977; Imperial County Planning Department, *Imperial County Noise Element*, adopted Oct. 1, 1974; Dwight Carey (Republic Geothermal, Inc.), personal communication to E. D. Giddings (Oak Ridge National Laboratory), January 9, 1978; and Imperial County Department of Public Works, *Terms, Conditions, Standards, and Application Procedures for Initial Geothermal Development - Imperial County*, May 1971.

*The Imperial County Noise Element*¹¹ applies to noise levels at residences. The nearest residences to most well sites are about 800 m (1/2 mile) away, except for the Sweetwater sites 3 and 4. Because Westmorland Elementary School is located, also, at about 800 m from well sites, special regulations apply. Residential standards will be satisfied under these more stringent requirements. Conservative sound attenuation estimates for residences at 800 m (1/2 mile) would yield levels of about 50 to 60 dBA. Such levels exceed Imperial County's "allowable" category (Table 2.11) but do not exceed the "caution" category (HUD's "normally acceptable" category) which specifies levels not to exceed 65 dBA for more than 8 hr in a 24-hr period. Based on these estimates, the noise levels produced in residential areas during exploration would be acceptable.

3.1.5 Ecological impacts

3.1.5.1 Impacts on terrestrial ecology

All presently proposed drill sites are on agricultural land. The construction of drill pads and testing and support facilities at these sites will not involve loss of wildlife habitat. Because of the exploratory nature of the project, the exact location of all future drill sites cannot be predicted. However, it is anticipated that all future sites will be located on agricultural land. Thus, there should be no disturbance of natural vegetation or wildlife habitat as a result of future drilling and testing activities.

Atmospheric emissions during drilling and flow-testing should not affect biota on or near the site (Sect. 3.1.3).

A study of the effects of geothermal development and noise on wildlife in the Salton Sea area is in progress. The study is one of many being conducted for Lawrence Livermore Laboratory. Preliminary results indicate that noise produced during well drilling and testing should not significantly affect wildlife near the leasehold area. The majority of wildlife using the adjacent refuge are overwintering ducks, geese, and shorebirds. Overwintering waterfowl do not tend to be particularly

sensitive to disturbance from noise. Birds on the refuge are currently exposed to noise and activity related to intensive cultivation of adjacent lands, including noise from agricultural machinery and crop dusting. Drilling and testing related to the proposed project should not add significantly to current levels of activity associated with agriculture. The distance from the refuge boundary to the closest proposed drilling and testing site is more than 0.8 km (1/2 mile). At this distance, noise from drilling and testing should not affect wildlife on the refuge. If it becomes necessary in the future to drill a well closer to the refuge, additional studies will be needed.

3.1.5.2 Impacts on aquatic ecology

The consumption of 600 m³ (0.5 acre-ft) of water for drilling each well will represent an insignificant fraction of total annual flow into the Salton Sea. Therefore, adverse aquatic effects would not be expected to result from flow reductions of surface water into the Salton Sea.

Protection of water quality in surface waters (irrigation and drainage waterways, the New River, and the Salton Sea) by proper site preparation, drilling, and flow-testing practices (Sect. 1.2.1.2) will result in the protection of resident aquatic biota. No releases of potentially harmful fluids to surface waters are expected, either directly via runoff, or indirectly via underflow of shallow groundwater.

3.1.6 Impacts on land use

Approximately 0.8 ha (2 acres) of land will be required for each geothermal drillsite. Assuming two wells per drill pad, a total of 22 new wells will require 11 sites, which would occupy 9 ha (22 acres) or 0.005% of the irrigated land in Imperial County. While this land is highly productive, particularly the Sweetwater sites which are classified as prime farmland, the loss of 9 ha cannot be considered significant. After drilling and testing is completed, all but 325 m² (less than 0.1 acre) of land at each well site could be returned to agricultural use.

The noise, steam, and other emissions associated with well drilling and testing are not expected to interfere with agricultural land use. Drilling and test liquids will be confined to the drilling pad, and the gaseous emissions should not damage crops or livestock (Sect. 3.1.3). Existing evidence suggests that noise emissions (Sect. 3.1.4) should not interfere with livestock production.¹² Subsidence is expected to be negligible during well testing (Sect. 3.1.1) and would not interfere with irrigation drainage.

3.1.7 Impacts on water use

The drilling of each well will require consumption of about 620 m³ (0.5 acre-ft) of agricultural water. This will represent an insignificant fraction of current water use in the Imperial Valley and of flow into the Salton Sea. In fact, the use of agricultural land for drilling pads may reduce the demand for irrigation water by about 12,000 m³ (10 acre-ft) per pad. This is only true at the present time because agricultural water supplies more than satisfy requirements for farmable land. This is expected to change within the next decade (see Sect. 2.7).

No contamination of surface water is expected. Consequently, water uses which are sensitive to changes in water quality, such as irrigation or fishery habitat, are not expected to be adversely affected. Shallow groundwater, which is not considered to be beneficially used, is also not expected to be contaminated.

In the event that the amount of water used by agricultural operations in the Salton Sea area approaches the total entitlement of the Imperial Irrigation District (IID), use of canal water for drilling might compete with irrigation requirements for fresh water. Completion of the Central Arizona Project around 1979-80 will likely cause a reduction in the amount of Colorado River water brought into the IID system (see Sect. 2.7), with a resulting increased competition for water between geothermal development and irrigation requirements. Use of either presently unused water (return or ground) or water specially imported (as in tank trucks) might then be necessitated. However, this is not anticipated during the exploration phase of this project.

3.1.8 Socioeconomic impacts

The drilling of each new well, requiring approximately 30 days under normal circumstances, will employ approximately 25 workers. Most will already be residents of the Imperial Valley and will already be employed in the geothermal well drilling industry. Some local industries will experience an increase in business due to the drilling of these wells: primarily service industries such as trucking, construction and fuel suppliers. Motels and restaurants may also experience a slight increase in revenues. Because small plots of agricultural land will be taken out of production to create the drillsites (Sect. 3.1.6), there will be a corresponding decrease in agricultural revenues. (See Sect. 3.2.8 for detailed analysis).

Local and state governments will receive increased revenues due to increased sales taxes and income taxes. There should be no increased revenues from property taxes, resource tax assessments, or production royalties until resource utilization begins. Both the state and local governments will experience small increases in costs due to some increase in the use of public services and the costs of regulating the operations; however, this will be offset to some extent by the permit fee structure.

Due to the flatness of the topography, the proposed project will have some visual impact during both the drilling and testing operations. Both the drilling derrick and any steam or water vapor plume resulting from production testing should be visible for several miles. This would probably not be considered a visual intrusion by most residents of the Imperial Valley. A recent public opinion poll of valley residents by the University of California at Riverside indicates that about 90% are in favor or strongly in favor of geothermal development. The visual intrusion will probably be more disturbing to nonresident recreational users of the Salton Sea; however, since no drilling will be done in the shore zone the impact should be acceptable.

3.1.9 Impacts on historical and archaeological resources and natural landmarks

There are no listed historical sites or natural landmarks close enough to the leasehold area to be potentially affected by exploration activities (Sect. 2.9). Several sites were examined by archaeologists from the Imperial Valley College Museum. In their opinion, no cultural resources are likely to exist at the proposed drill sites because of agricultural use in the past (Sect. 2.9.2). Should geothermal exploration and development uncover any prehistoric material, activities will cease until a qualified archaeologist evaluates the discovery.

3.2 IMPACTS OF POWER GENERATION

If the exploration program establishes the existence of a marketable resource, the program will proceed to the phase of generating electrical power. The sections that follow will treat the impacts of field development, power plant construction, transmission line construction, and power plant operation.

3.2.1 Geological impacts

During field development and plant construction, there should be no geological impacts. As wells are completed, they will be shut in until power generation occurs. No fluid will be produced or injected during field development except during brief flow testing, as discussed in Sect. 3.1.1.

When power generation begins, there is potential for subsidence throughout the leasehold area. According to Atherton et al.,¹³ subsidence is considered to be a definite hazard in liquid-dominated systems, even under normal pressure conditions and particularly if the reservoir contains beds of clay, silt, or shale. Injection will mitigate but not entirely eliminate subsidence. Ideally, injection should take place in the same aquifer as production. The injection wells must, however, be separated from production wells to prevent mixing of relatively cool return water with the hot reservoir water. Injection into a shallower

aquifer may aggravate subsidence.¹⁴ Furthermore, the reservoir rock surrounding the injection well (or the well itself) may become clogged with calcite, silica,¹⁵ or salt scale.

Two injection scenarios are possible. One is a closed-circuit binary system in which the hot reservoir fluid [$>163^{\circ}\text{C}$ (325°F)] will pass through a heat exchanger and then be injected without being flashed into steam. Because there is little water lost in the binary cycle, a minimum of subsidence will be produced with reinjection into the production zone. This system, however, may involve higher operating cost and possible heat exchanger fouling from scaling and may not be appropriate for use with Westmorland brines, the characteristics of which are not completely known.

In a second operating scenario, the hot water will either flash to steam and drive a turbine directly, or the first-stage flash steam will pass through a heat exchanger and reboil the condensate for an additional steam flash which drives the turbine.¹ If the water condensed from steam in the steam-flash turbine cycle is sufficiently pure, it may be used as cooling-tower makeup water and blowdown from cooling towers will be injected. This method of operation may cause significant subsidence, because as much as 20% of the production water will not be returned through injection wells (Sect. 3.2.7). As a result, reservoir pressure will decline, leading to the compaction of interbedded and overlying clays. In such a case, subsidence might be prevented by injecting a volume of irrigation waste water equal to the volume of condensate evaporated in the towers.

Subsidence will be monitored at Westmorland by tying into an existing survey net and obtaining preoperative baseline data.¹⁴ Natural subsidence in the Westmorland geothermal field area is occurring at an average annual rate of 5.8 cm (2.3 in.). Vertical ground level movements totaling 29 cm (11.4 in.) were recorded from 1972 to 1977.¹⁶ This natural rate of subsidence is not expected to be noticeably accelerated by sediment compaction resulting from the withdrawal of geothermal fluids during well testing and initial production.

It is possible that induced seismicity will result from injection of fluid. Evans¹⁷ has shown a correlation between seismicity and fluid injection at Rocky Mountain Arsenal near Denver, Colorado. He also showed that injection by gravity flow significantly reduced the seismicity. Therefore, he concluded that high levels of induced seismicity are unlikely to occur unless the fluid is injected under pressure. Wellhead pressures between 34 and 68 atm (500 and 1000 psi) produced significant induced seismicity at Rocky Mountain Arsenal.¹⁷ The present project calls for injection by gravity flow, which involves very low wellhead pressures (1 atm psi). This process is not likely to cause significant induced seismicity. The Imperial Valley is an active seismic region, however, and possible induced seismicity must remain a matter for concern. Nearly all naturally occurring earthquakes take place at depths greater than 6 km (4 miles) in the Imperial Valley, but the zone of production and injection of fluid will probably be no deeper than 2.5 km (1.5 miles) in the Westmorland project area.¹

3.2.2 Impacts on water quality

There are no expected significant effects on water quality in the leasehold area as a result of the drilling and flow testing required in field development. These activities will be similar to but more intensive than the exploration drilling and flow testing considered in Sect. 3.1.2. Potential water quality impacts will be prohibited in accordance with waste discharge requirements (similar to Orders No. 75-61, 76-52, and 77-1) issued by the California Regional Water Quality Control Board, Colorado River Basin Region.

Fluids will be safely contained in the transmission facilities (pipelines and associated valves and equipment) during power plant operation. Potentially harmful fluids generated during plant operation, such as waste geothermal fluid, cooling system blowdown, and toxic or corrosive chemicals used for descaling, if necessary, will be injected into groundwater aquifers sufficiently saline so that neither groundwater, already saline in the leasehold area and not beneficially used, nor surface water will be degraded.

Water quality impacts from increased salinity are possible for the Salton Sea, as a result of irrigation waste water withdrawals during plant operation. It has been estimated⁴ that the annual use of $7.4 \times 10^6 \text{ m}^3$ (6000 acre-ft) of irrigation waste water for cooling a 100-MW flash-steam geothermal plant would lower the Salton Sea water level by about 7.5 cm (3 in.) and increase the salinity by approximately 350 mg/liter. The corresponding interpolation for a 55-MW plant with a water consumption of about $643 \text{ m}^3/\text{hr}$ (equivalent to $5.6 \times 10^6 \text{ m}^3/\text{year}$ or 4500 acre-ft/year) would be an eventual drop in water level of about 5.2 cm (2 in.) and a salinity increase of 240 mg/liter over roughly 20 years. Superimposed on the present salinity level of 38,000 mg/liter and the present annual rate of increase in salinity of $500 \text{ mg liter}^{-1} \text{ year}^{-1}$, the additional water use would accelerate the approach to the critical salinity level for the survival of fish larvae, which is 40,000 mg/liter. Thus, the maximum impact of the Westmorland project plant operation is an increment to the already-existing salinization trend. It must be emphasized that salinization is ongoing with or without geothermal development. Also, the salinity of the Salton Sea may well exceed the critical level before the Westmorland project reaches operational stage, about four years.

3.2.3 Impacts on air quality

Following resource confirmation, drilling and flow testing will be expanded up total of 22 wells. Two or three wells may be drilled simultaneously, but the emissions associated with three simultaneous drilling operations should still be nonsignificant. More than one well should not, and probably would not, be test-flowed to the atmosphere on the same day.

Grading and operation of equipment during plant construction will raise dust and release diesel fumes (Sect. 3.1.3). Dust will be controlled by the sprinkling and graveling of roads.

Operation of a power plant will result in contamination of the air by noncondensable gases and cooling tower drift. Hydrogen sulfide emissions must be maintained at a sufficiently low level to prevent violation of the California ambient air quality standard of 30 ppb. The results of existing gas analyses suggest that gas treatment will not be necessary (Sect. 3.1.3). Concentrations below 30 ppb are below the nuisance level for humans and have no negative effects on plants.¹⁸ Other noncondensable gases that may be emitted include CO₂, CO, NH₃, NO_x, N₂, CH₄, H₂, and Hg. On the basis of existing well test data (Table 3.1), it is not anticipated that any of these gases will exist in sufficient concentrations to cause concern.

Particulates which are potentially toxic to vegetation may also occur in very small amounts in geothermal fluids. At The Geysers, for example, these include boron, mercury, and arsenic. Only boron from cooling tower drift at The Geysers is known to have caused localized damage to certain susceptible plant species in areas surrounding some power plant units. Big-leaf maple trees within 150 to 300 m (500 to 1000 ft) of certain older units suffer loss of leaf color and early leaf drop. Affected foliage was found to have abnormally high boron concentrations. Oak, bay, and conifer species in the same area are more tolerant and exhibit little or no damage. Drift control measures incorporated in the design of newer units appears to have eliminated the problem by reducing cooling tower drift.¹⁹ Mitigation of possible cooling tower drift impacts on crop plants in the Imperial Valley can thus probably be achieved by incorporation of drift control measures at the time of power plant design. Since negative impacts would also most likely be extremely localized and would only affect certain sensitive plant types, choice of boron-tolerant crop plants and/or creation of modest, noncultivated buffer zones around cooling towers should also prevent significant damage if boron is found to be a substantial component of produced geothermal fluids.

The evaporation of as much as 643 m³/hr (170×10^3 gal/hr) of water from the cooling towers will not have a significant effect on the climate of the area. Because of the warm dry climate of the valley, the tower emissions will typically not saturate the air (there will be no visible

plume) except at night during the winter, when low temperatures and high atmospheric stability prevail.²⁰ The increase in ground-level mean monthly relative humidity will be less than 1% and therefore should not affect vegetation.

3.2.4 Noise impacts

The noises associated with power plant construction would primarily result from the operation of heavy equipment and would be similar to those described in Sect. 3.1.4 for drill pad construction (up to 95 dBA). The county noise standards would apply in the same way as stated in Sect. 3.1.4.

Table 3.2 presents noise measurements made at The Geysers generating units 5 through 11 by Pacific Gas and Electric Company. Noise levels are high at the plant site (70 to 94 dBA) due to the operation of turbines and gas ejectors, but the noise measurements farther than 60 m (200 ft) from the plant [60 dBA at 150 m (500 ft)] are dominated by the cooling towers. The overall plant noise at 1000 m (0.6 mile) is 40 to 50 dBA.²¹ The noise emissions of a plant at Westmorland would be similar. Noise levels would be "clearly acceptable" (according to HUD criteria, Table 2.11), if the plant was sited at least 800 m (1/2 mile) from residences, and levels would be "normally acceptable" and legally permissible up to a distance of about 150 m (500 ft) from residences and more than 400 m (1320 ft) from Westmorland Elementary School.

3.2.5 Ecological impacts

3.2.5.1 Impacts on terrestrial ecology

Atmospheric emissions during well field development and power plant operation should have no significant effect on air quality (Sect. 3.2.3) and should not affect biota.

Since almost the entire leasehold area consists of agricultural or urban land, construction and development related to power generation should not result in loss of natural vegetation or wildlife habitat. However, depending upon the locations of the power plant and associated transmission

Table 3.2. A-weighted sound levels from various noise sources at The Geysers
at a typical power plant operating at full load

Noise source description	Distance from noise source		Sound level (dBA re. 20 micropascals)
	(m)	(ft)	
Cooling tower	1.5-3	5-10	81-85
Outside turbine-generator building	7.5	25	70-75
Steam jet gas ejector	1-3	3-10	88-93
Around turbine-generator unit inside building	1-1.5	3-5	92-94
Random locations on turbine- generator floor			90-94
Total plant noise at plant fence line	6-20	20-70	67-83
Total plant noise ^a	150	500	60 ± 5

^aTotal noise from plant at distances greater than 60 m (200 ft) is primarily from cooling tower only. The noise from steam jet gas ejector falls off rapidly as a function of distance from source because of small radiating surface area and high frequency content.

Source: R. C. Bush, "An Overview of PG&E's Audible Noise Measurements Program at The Geysers," pp. 169-73 in *Proc. Geothermal Environmental Seminar 1976*, Lake County, Calif., October 1976.

lines, power generation could affect waterbirds using the nearby Salton Sea and its refuges. The increased noise and human activity associated with the power plant could affect waterfowl use of breeding and wintering areas if the plant were located directly adjacent to such an area. Placement of the power plant in close proximity to areas of the New River delta or the South Unit of the Salton Sea Wildlife Refuge, where yuma clapper rail breeding habitat has been identified (Fig. 2.9), would require careful and detailed consideration of potential adverse impacts on this endangered species.

The proximity to the northern Westmorland leasehold area of waterfowl feeding and resting areas, both on the refuges and on private hunting clubs, necessitates careful consideration of transmission line routing. Transmission lines associated with the power plant could cause increased bird mortality through collisions with lines and towers. Waterfowl are particularly subject to collisions with power lines when the lines are adjacent to feeding and resting areas where the birds are flying low. In addition to direct mortality, transmission lines could cause changes in patterns of waterfowl use of adjacent land, thereby possibly affecting hunter success. Transmission routes should be chosen to avoid major waterfowl flight patterns. A study to identify major flight patterns in the Salton Sea region is currently under way as part of the Imperial Valley Environmental Project under the direction of Lawrence Livermore Laboratory. Results of the first year of observations indicate that major flight patterns generally parallel the south shore of the Salton Sea and follow the courses of the New and Alamo Rivers inland.²² There are also a number of movements of waterfowl from the shore of the Salton Sea inland up to 5 km (3 miles) to feeding areas.

In summary, power plant operation could be a source of adverse impacts to waterbirds using the Salton Sea and its refuges. Whether or not such impacts occur and the degree of impact will be highly dependent upon the location of the power plant and transmission lines. Because of the exploratory nature of the project, the ultimate location of the well field and power plant will not be known for some time. Transmission line routes cannot be described until the market for the power has been defined and

the location of the power plant is known. Therefore, it is recommended that the applicant consult with the Department of Energy after the initial phases of the project have identified the location of the well field. At this time it will be possible to make a more detailed analysis of power plant and transmission line placement, taking into account results of biological studies now in progress in the Salton Sea region.

3.2.5.2 Impacts on aquatic ecology

Aquatic biota in the Salton Sea and freshwater habitats are not expected to be significantly affected by field development if proper site preparation, drilling, and flow testing practices are followed and fluid transportation facilities are carefully maintained (see Sect. 3.2.2). Potentially harmful fluids generated during plant operation, such as waste geothermal fluid and cooling system blowdown, will be injected and are not expected to pollute either surface waters or groundwaters (see Sect. 3.2.2).

The fisheries and associated recreation resources of the Salton Sea, however, may be adversely affected by the consumptive withdrawal of irrigation waste water for injection or cooling. The Salton Sea is presently at a salinity level of about 38,000 mg/liter, and its salinity is increasing annually by about 500 mg/liter. It has been estimated that the salt-water fishery in the lake will be eliminated due to larval mortality when salinity reaches 40,000 mg/liter.⁴ The estimated annual use of about 5.6×10^6 m³ (4500 acre-ft) of irrigation waste water for a 55-MW geothermal plant could eventually increase the salinity by an additional 240 mg/liter (see Sect. 3.2.7) and potentially shorten the remaining lifetime of the Salton Sea fishery resource. This estimate is based on the assumption that because 100% of the fluid production must be injected, all of the flash must be made up from agricultural waste water. Actually, a blowdown of between 5 and 20% of flash will be injected (Sect. 3.2.2), so that the waste water requirements will be 80 to 95% of the flash. It must be emphasized that the salinization is ongoing with or without geothermal development. Also, the salinity of the

Salton Sea may well exceed the critical level before the Westmorland project reaches the operational stage, about four years. .

The possibility also exists that the withdrawal of water from the irrigation drains could have adverse effects on resident fish (Sect. 2.5.2), as a result of impingement at the intake structure and/or entrainment in the cooling system. At this time, the intake structure design, flow velocities, and location are unknown.

3.2.6 Impacts on land use

Construction of a geothermal power plant and associated facilities would disturb less than 40 ha (100 acres) of land. Development of each well site would disturb 0.8 ha (2 acres) during drilling and testing and would occupy 324 m² (0.08 acres) after that period. The total acreage disturbed would depend on the total number of wells drilled and on the number of wells drilled per pad. Twenty-one wells (14 production and 7 injection) would disturb 11.2 ha (28 acres) if all injection wells share a pad with a production well, as is the current practice: A 55-MW(e) power plant with associated facilities (cooling tower, switchyard, parking area, etc.) could require up to 8 ha (20 acres). Because Imperial County requires that pipelines and transmission lines follow roads and other existing rights-of-way as much as possible,^{9,23} land requirements for these facilities would be negligible. A plant could be tied into the existing electrical transmission grid at a 92-kV line through Calipatria and Brawley or a 161-kV line just to the east, which would make possible the sale of some power to southwestern Arizona or San Diego as well as to the Imperial Valley itself. This connection would require less than 1 ha (2.5 acres) for tower bases. While San Diego constitutes the best market for Imperial Valley geothermal energy, major new transmission lines to this market and their location are only in the planning stages by San Diego Gas and Electric Company. Southern California Edison (SCE) is planning a nearby line north of the Salton Sea to bring SCEs share of the Palo Verde nuclear project production to its service area.²⁴

While availability of irrigable land currently limits Imperial Valley agricultural production, by the time a power plant could be built water availability probably will have become limiting (Sect. 2.7). Thus, careful design and siting of the geothermal facilities could result in a minimal decrease in agricultural production.

Neither noise nor geothermal gases are expected to interfere with existing land uses (Sects. 3.2.3 and 3.2.4). Drift from cooling towers, a potential source of soil salinization and crop damage from salts, will not be a problem if steam condensate is used in the towers as anticipated. The rate of salt deposition on agricultural fields would be small relative to the approximately 6000 kg/ha (5500 lb/acre) of salt added to the fields in the Colorado River water used for irrigation, which has a total dissolved solids content of 900 ppm. The concentration of chemicals such as boron, arsenic, magnesium, or mercury in the flash condensate cannot be calculated at this time. Their incorporation into cooling tower drift is possible and therefore effects on surrounding cropland are possible (Sect. 3.2.3). Appropriate controls will have to be instituted if analyses of the distribution and chemical content of drift indicate potential damage to crops.

Natural subsidence is taking place in the Westmorland geothermal field area at an average rate of 5.8 cm (2.3 in.) per year.¹⁶ Subsidence is of concern in the Imperial Valley because of its highly developed irrigation system. The average slope of irrigation canals is 1.7 m/km (9 ft/mile) toward the Salton Sea. Substantial subsidence could reduce or reverse the flow of irrigation water toward the Salton Sea, resulting in extensive loss of arable land. Subsidence, a gradual process (sometimes delayed), will be extensively monitored (Sect. 3.2.1). If the process appears to be accelerating, steps to arrest its progress will be taken before damage or loss of agriculture occurs.

3.2.7 Impacts on water use

In addition to the expected cumulative water use required in the drilling of production and injection wells for the generation of 55 MW of electricity, approximately 643 m³/hr (5.6×10^6 m³/year) of irrigation

waste water will be needed for cooling, or for injection to compensate for the condensate required as makeup water in the cooling system. In a flash system, the condensate would fulfill makeup water requirements. However, it will be necessary to inject 100% of the withdrawal volume to ensure against subsidence (Sect. 3.2.1). This requirement could be met by injecting the liquid portion of the geothermal fluid plus an amount of irrigation waste water equivalent to the cooling tower makeup (condensate less blowdown).

The annual consumptive withdrawal of irrigation waste water for injection would account for ~1% of the annual discharge to the Salton Sea from the New River and <0.5% of the combined discharges of the New and Alamo rivers. These effects on the Salton Sea could be significant, resulting in lowered water levels and increased salinity (Sects. 3.2.2 and 3.2.5.2). Unless a regional salinity-control program is successful, geothermal development in general may aggravate the salinization problem, jeopardizing the value of the Salton Sea as a fishery, wildfowl, and hunting resource. The maximum impact of the Westmorland project plant operation would be an increment to the already-existing salinization trend. It must be emphasized that salinization is ongoing with or without geothermal development. Also, the salinity of the Salton Sea may well exceed the critical level before the Westmorland project reaches the operational stage, about four years.

The agricultural economy of the Imperial Valley depends on the intricate system of irrigation waterways (canals, drains, outlets, and laterals), and the irrigation system is in turn dependent on a shallow topographic gradient (Sect. 2.2.1). Ground subsidence due to withdrawal of geothermal fluids (Sect. 3.2.1) could seriously affect drainage and irrigation patterns in the Imperial Valley and, consequently, interfere with present irrigation land use patterns in and around the project area (Sect. 3.2.6).

3.2.8 Community and socioeconomic impacts

Full field development would require employment for drilling, power plant construction, and transmission line construction. Drilling operations

would require two or three crews, 60 to 90 persons for approximately one year. Construction of a power plant would require 50 to 75 persons over a period of two years. Transmission line construction would require 10 to 30 persons for a few months. Many of these workers could be recruited locally.

Housing needs might be met in part by construction of a work camp. Otherwise, the housing needs of workers and their families recruited from outside the area would be met by Brawley and other valley communities. Large housing deficits or large strains on community services are unlikely to result from this project. However, the current high overall population growth of the area may create problems unless adequate planning is carried out.

Operation of the power plant would require approximately 35 employees. Employment and demand on housing and community services would be considerably reduced from that experienced during the construction period. The value of the plant to the tax base would be large relative to the demand for services created by the plant and its employees.

Resource utilization in the geothermal field, with up to 28 active wells (19 for production and 9 for injection) and a 55-MW power plant, will remove, as a worst case, 224 ha (560 acres) from agricultural production. The determination of a dollar value for specific crops grown on an area of this size is impossible, because of the practices of crop rotation and year-round multicropping.²⁵ The following estimate of the decrease in agricultural revenues stemming from removal of land from crop production is based on a University of California, Riverside study.²⁵ This study characterizes agricultural land in each of the four Known Geothermal Resource Areas (KGRAs) within the Imperial Valley according to percentage of each crop type grown. The Westmorland geothermal leasehold overlaps both the Brawley and the Salton Sea KGRAs (see Fig. 1.1). Agricultural resource data for the Brawley Area is considered representative of the central portion of the valley, while data for the Salton Sea KGRA is typical of the northern valley. As the Westmorland geothermal leasehold is largely in the central Imperial Valley, the estimate will be based on data for the Brawley KGRA.

Table 3.3 presents an agricultural resources summary for all crop types. Assuming that each crop type is grown in the same proportion in the Westmorland geothermal leasehold area as in the KGRA, the net annual crop value for a 224-ha (560-acre) area is estimated to be about \$334,000. This amount is roughly equivalent to the loss of agricultural revenues that the change in land use could produce. However, of the total 224 ha, the area of land actually disturbed is smaller by more than an order of magnitude (Sect. 1.2.2). Much of the area for wells and power plant may not need to be totally removed from crop production.

Loss of agricultural revenues will potentially be offset by income from leasing fees and royalties from resource utilization. Lease information in many cases is considered proprietary and is not generally available.

3.2.9 Impacts on historical and archaeological resources and natural landmarks

Operation of a geothermal well field and electrical generating facility will affect historical or natural landmark resources only if transmission-line corridors transect such sites. No transmission-line corridors have yet been delineated; however, restrictions will be such that historical and cultural resource areas will be avoided.

3.3 SITE RESTORATION AND DECOMMISSIONING

Any production well which does not produce an economic resource will be shut in utilizing procedures required by the California Division of Oil and Gas. All equipment will be removed from the site, and the wellhead will be chained closed and enclosed within a wire fence. Mud and waste pits will be pumped dry, and the area will be regraded to original contour except for an area approximately 324 m² (0.08 acres) surrounding the wellhead. The reclaimed area will be available for agricultural production. The State of California, the California Regional Water Quality Control Board, and County of Imperial have all imposed restoration requirements on geothermal developments, and both the State and County require \$100,000 bonds to insure adequate compliance.

Table 3.3. Brawley KGRA agricultural resources summary

Classification	Fields	Field acres	Annual crop value ^a	Annual labor cost
All field crops	193	13,975	\$ 7,169,175	\$ 363,350
Major field crops	113	7,527	6,616,233	1,482,819
Mixed field and vegetables	54	2,610	3,249,450	963,090
Major vegetables	10	365	588,015	197,465
All vegetable crops	0	0		
Tree crop	1	66	46,992	52,800
Abandoned land	11	332		
Feed lot	11	483		
Pasture	9	117		
Total agriculture	402	25,475	\$17,669,865	\$3,059,524
Nonagriculture	39	4,143		
Total KGRA	441	29,618		

^a1975 data.

If, following plant operation, production wells are depleted, the pipelines will be dismantled and the wells will be abandoned. If the demand for agricultural land is sufficiently great, the wells could be cut off below ground level after being cemented shut. The power plant and transmission lines may be dismantled and disposed of at the end of the plant's useful life (approximately 40 years).

3.4 ACCIDENTS

The most likely serious accident is an uncontrolled release of geothermal fluids. Release of fluids may occur at the wellhead (blowout), in the well bore, or in pipelines. Blowouts can occur during exploratory drilling, field development, or full-scale production. Blowout-prevention equipment will be used on both the exploration and production wells; nevertheless, malfunctioning equipment, judgment error, or negligence occasionally lead to blowouts. Blowouts can occur at any time during exploratory drilling or field development when geopressured fluids or the potential for steam flashing are encountered. During full-scale production, they are most likely to occur when workover rigs are being used to replace worn-out casing. Blowouts can also occur if casings rupture at a shallow depth. Blowouts that occur below ground are controlled by cement injection through directional relief wells.

Geothermal blowouts do not carry the risk of fire that oil field blowouts do. Nevertheless, they are difficult to handle because of the presence of superheated steam or hot brine. Blowouts may result in surface cratering; destruction of crops; contamination of the surface, water, and atmosphere; excessive noise; waste of geothermal energy; and injury to personnel. Blowout-released brines, because of their high salinity and temperature, could destroy crops, salinate soils beyond the tolerance of plants, render irrigation water unusable, and contribute to the salinization of the Salton Sea. The land area affected by destruction of agricultural crops would be difficult to estimate and would be dependent on the location, flow rate, and duration of the brine release. It is estimated that the largest probable area of direct impact due to any single excursion would be on the order of 5 ha (10 acres).

Casing may rupture during the production stage as a result of, (1) subsidence caused by withdrawal of fluids, (2) earthquakes, (3) landslides, and (4) corrosion. Induced seismicity is unlikely at this site (Sect. 3.2.1) and landsliding is essentially impossible. Although some subsidence may occur in the immediate vicinity of production wells, large-scale subsidence should be prevented by injection. The most likely causes of casing failure are natural seismicity and corrosion. Cement packing around the casing is intended to contain the fluids in the event of a casing failure. However, large displacement along a fault may rupture the cement packing as well. Furthermore, hot acidic brine will, in time, decompose most cements. If the casing ruptures in a groundwater aquifer and reservoir fluids are geopressured or steam-flashed, groundwater contamination and waste of geothermal energy will occur. If rupture takes place in the cap rock or reservoir, little or no damage to the environment or waste of energy will result, but the well would have to be recompleted.

Ruptured geothermal pipelines may cause intense but short-duration surface spills. Whereas blowouts and ruptured well casings may be difficult to bring under control, pipelines can be isolated by shutting in the appropriate wells and, if necessary, closing down the generating plant.

REFERENCES FOR SECTION 3

1. Mapco Geothermal Inc. and Republic Geothermal, Inc., *Application for Loan Guaranty: Westmorland Development Project*, 1977.
2. California Regional Water Quality Control Board — Colorado River Basin Region, *Waste Discharge Requirements for Republic Geothermal Inc.*, Orders No. 75-61, 76-52, 77-1, Palm Desert, Calif., 1975-77.
3. R. M. Cushman, S. G. Hildebrand, and R. W. Brocksen, *The Potential Impacts on Aquatic Ecosystems from the Release of Trace Elements in Geothermal Fluids*, ORNL/TM-6057, Oak Ridge National Laboratory, Oak Ridge, Tenn., 1977.
4. M. Goldsmith, *Geothermal Development and the Salton Sea*, EQL Memorandum No. 17, Environmental Quality Laboratory, California Institute of Technology, Pasadena, 1976.
5. VTN Consolidated, Inc., *Environmental Analysis Record, Proposed Geothermal Exploration, South Brawley Prospect, California*, CUI Venture, Irvine, Calif., 1977.
6. Environmental Protection Agency, Office of Air and Waste Management, *Compilation of Air Pollution Emission Factors*, 2nd ed., Research Triangle Park, N.C., 1975.
7. Dwight Carey (Republic Geothermal, Inc.), personal communication to E. D. Giddings (Oak Ridge National Laboratory), January 9, 1977.
8. Philip Leitner, personal communication to G. W. Suter (Oak Ridge National Laboratory), December 12, 1977.
9. Imperial County Department of Public Works, *Terms, Conditions, Standards, and Application Procedures for Initial Geothermal Development*, May 1971.

10. Mark Walters (Lake County Planning Department), information presented at the LLL/GRIPS Geothermal Noise Workshop, University of California at Davis, November 14-15, 1977.
11. Imperial County Planning Department, *Imperial County Noise Element*, adopted October 1, 1974.
12. U.S. Environmental Protection Agency, *Effects of Noise on Wildlife and Other Animals*, U.S. Government Printing Office, Washington, D.C., 1971.
13. R. W. Atherton et al., *The Analysis of Subsidence Associated with Geothermal Development*, vol. 1, Systems Control, Inc., Palo Alto, Calif., 1976.
14. U.S. Department of the Interior, *Final Environmental Statement for the Geothermal Leasing Program*, vol. II, U.S. Government Printing Office, Washington, D.C., 1973.
15. Energy Research and Development Administration, *Environmental Assessment of the Hawaii Geothermal Project Well Flow Test Program*, November 1976.
16. Neil B. Crow (Lawrence Livermore Laboratory, Livermore, Calif.), personal communication to M. S. Moran (Oak Ridge National Laboratory), June 1978.
17. D. M. Evans, "Man-made Earthquakes in Denver," *Geotimes* 10:11-18 (1966).
18. R. Thompson, "Behavior of H₂S in the Atmosphere and its Effects on Vegetation," pp. 193-97 in *Proc. Geothermal Environmental Seminar 1976*, Lake County, Calif., October 1976.

19. C. J. Weinberg, "Environmental Aspects of Geysers Geothermal Operations," pp.38-3 to 38-22 in *Proc. Environmental Aspects of Non-conventional Energy Resources-II*, Denver, Colorado, Sept. 1978.
20. R. E. Kelly, *Atmospheric Dispersion and Noise Propagation at Imperial Valley Geothermal Fields*, UCRL-52053, Lawrence Livermore Laboratory, Calif., April 1976.
21. Ronald C. Bush (Pacific Gas and Electric Company), data presented at the LLL/GRIPS Geothermal Noise Workshop, University of California at Davis, November 14-15, 1977.
22. P. Leitner and G. S. Grant, *Observations on Waterbird Flight Patterns at Salton Sea, California, October 1976-February 1977*, prepared for Lawrence Livermore Laboratory, Livermore, Calif., a contribution to the Imperial Valley Environmental Project, 1978.
23. Imperial County Planning Department, *Geothermal Element, Imperial County General Plan*, 1977.
24. National Economic Research Associates, Inc., *Review of Westmorland Development Project Geothermal Loan Guaranty Application*, 1978.
25. C. Johnson, *Effects of Geothermal Development on the Agricultural Resources of the Imperial Valley*, U. C. Riverside, DLRI Report No. 12, 1977.

4. COORDINATION WITH STATE, LOCAL, AND REGIONAL PLANS

There are no known conflicts with state, local, or regional plans. The project has been coordinated by the applicant's formal requests for permits or opinions from state and county agencies having jurisdiction or interests in the area of the proposed project. Agencies contacted include:

State of California

California Division of Oil and Gas

California Regional Water Quality Control Board — Colorado
River Basin Region

County of Imperial

Imperial County Air Pollution Control District

Imperial County Planning Department

Imperial County Department of Public Works

Federal

U.S. Soil Conservation Service

U.S. Geological Survey

U.S. Fish and Wildlife Service

Other

Imperial Irrigation District

5. ALTERNATIVES

Alternatives of two types are possible in the case of the Westmorland development project. First are decisions based on results of the proposed exploration (Summary, p. iii). Failure to confirm the viability of the geothermal resource at Sweetwater, the first area to be explored, would result in a decision to shift to the Landers sites. Second is denial of the requested loan guaranty support. The project will probably not be realized without the proposed Federal support of a commercial loan to finance it.

APPENDIX

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

2828 Chiles Road, Davis, California 95616

December 7, 1977

Dr. Robert B. Craig, Group Leader
Environmental Impacts Program
Oak Ridge National Laboratory
Post Office Box X
Oak Ridge, Tennessee 37830

Dear Dr. Craig,

I have reviewed the proposed geothermal project in the Imperial Valley of California near Westmorland and have made the following determinations:

1. None of the proposed well sites are on prime farmland.
2. The above project will not have significant primary or secondary adverse impact on, or directly or indirectly cause the irretrievable conversion of Prime or Unique Agricultural Lands (as defined by the Soil Conservation Service, in Land Inventory and Monitoring Memorandum #3 dated October 15, 1976) to other uses;
3. Is in consonance with the Secretary of Agriculture's Memorandum 1827 dated October 26, 1973 and Supplement #1 dated June 21, 1976 and;
4. Will conform with the Council on Environmental Quality's Memorandum on Prime and Unique Farmland dated August 30, 1976.

DARWYN H. BRIGGS, Chairman
USDA Land Use Committee