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AN ANALYSIS OF ENVIRONMENTAL REGULATIONS GOVERNING THE
DISPOSAL OF GEOTHERMAL WASTES IN CALIFORNIA

MASTER

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LIST OF ACRONYMS

CAM	California Assessment Manual
CDOG	California Division of Oil and Gas
CFR	Code of Federal Register
DOHS	Department of Health Services
EPA	Environmental Protection Agency
GI	Geothermal Incorporated
KGRA	Known Geothermal Resource Area
mg/kg	Milligrams per kilogram
mg/l	Milligrams per liter
PCBs	Polychlorinated Biphenyls
ppm	Parts per million
RCRA	Resource Conservation and Recovery Act
SDWA	Safe Drinking Water Act
STLC	Soluble Threshold Limit Concentration
TDS	Total Dissolved Solids
TSCD	Toxic Substance Control Division
TTLC	Total Threshold Limit Concentration
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water
WDRs	Waste Discharge Requirements
WET	Waste Extraction Test
WRCB	Water Resources Control Board

1.0 INTRODUCTION

1.1 Background

Geothermal resources are subsurface sources of the earth's natural heat energy which are believed to result from the decay of radioactive elements present in the crust and upper mantle. Accessible geothermal resources are generally located in the outer ten miles of the earth's crust. The three types of geothermal resources include hydrothermal, geopressured, and hot dry rock.

Hydrothermal resources are subsurface reservoirs of steam, which are termed vapor-dominated, or reservoirs of hot water, which are called liquid-dominated. Geopressured systems are very deep reservoirs of brine under high pressure which also frequently contain large quantities of dissolved methane. Hot dry rock and molten magma lie everywhere beneath the earth's crust. Although they contain tremendous quantities of energy in the form of heat, they are usually too deep to utilize economically by present technologies.

Of the three geothermal resources, hydrothermal resources are currently utilized for a variety of purposes. Vapor-dominated systems can be used directly to generate electricity but very few of these systems are known to exist. Water-dominated systems with a temperature greater than 150°C can also be used to generate electricity but is done at a lower efficiency. Process or space heating is generally the most efficient use for liquid-dominated systems when the temperature is below 150°C.

1.2 Objectives and Scope

The primary objective of this study was to evaluate the federal and state regulations governing the disposal of sludges and liquid wastes associated with the production of electricity from geothermal resources. Additional objectives were to determine current disposal practices, near/far term disposal requirements, and the potential for alternate disposal methods or beneficial uses for these materials.

The period of performance for this study was four months. Due to this time constraint, it was decided to conduct a thorough review of only one state with additional states considered if time permitted. California was selected to be evaluated first since it is the state where the majority of geothermal activities are currently underway in the United States.

In order to address the objectives of this study, efforts were concentrated in two separate areas. Since this study was a regulatory analysis, the applicable federal and state regulations had to be identified and reviewed. The second area of concentration pertained to the geothermal resources, technologies, and waste streams. Information had to be gathered on the types of wastes generated and their characteristics. A computerized literature search was performed as the starting point of this study to identify previous work in these areas. An intensive telephone campaign was conducted to speak with those individuals who are involved with any aspect of the regulation, generation, or disposal of geothermal wastes. More than 50 individuals were contacted representing federal, state, regional and county agencies, as well as the geothermal

industry, electric power utilities, operators of waste disposal facilities, national laboratories, and private consulting firms. Meetings were held with more than 20 individuals during a week spent in California. Tours were also made at five geothermal facilities and a waste disposal site presently accepting geothermal wastes.

It is essential to recognize two main factors affecting geothermal waste streams which make them very site specific. The geothermal resource itself will have a significant effect on the characteristics of and the elements present in the waste streams. Geothermal resources vary not only from area to area but also from well to well within a given area. In addition, different geothermal technologies or a variation in processes within a given technology will result in different residuals.

1.3 Geothermal Resources

Geothermal fluids contain a number of inorganic elements and heavy metals. The chemical composition is governed by those elements found naturally in the producing reservoir and by their solubility in water at existing temperature and pressure. Elements which have been found in geothermal fluids include sodium, potassium, calcium, chlorine, silicon, arsenic, boron, mercury, iron, lead, copper, and zinc. Many of these are found only in trace amounts. The toxicity of the element depends on the chemical state in which it is found.

Geothermal resources also contain noncondensable gases such as carbon dioxide, hydrogen sulfide, ammonia, methane, boron, and radon. Although airborne emissions were beyond the scope of this study, these gases are mentioned because solid wastes are generated in controlling their release. Carbon dioxide generally is the most common gas. Hydrogen sulfide is found in small quantities but it is one of the gaseous emissions of most concern at geothermal power plants. Hydrogen sulfide has an offensive odor which can be detected at very low concentrations and is very toxic at high concentrations.

Many geothermal resources are known to exist in the world. The U.S Geological Survey has designated those areas in the United States identified as having potential for production of electrical energy as known geothermal resource areas (KGRAs). Many of these KGRAs are located in California. The most well known is the Geysers KGRA in northern California. Not only is it very large, but it is one of the few vapor-dominated systems known to exist. The Geysers is located in Sonoma and Lake Counties about 90 miles north of San Francisco.

All of the KGRAs in the Imperial Valley of southern California are liquid-dominated systems. Significant differences have been reported in the temperature, salinity, noncondensable gas content, and chemical constituents of these resources. Salinity is often measured by the total dissolved solids (TDS) in the geothermal fluids. Table 1.1 presents the range of temperatures and salinity for four KGRAs in the Imperial Valley. As has been previously mentioned, not only do the characteristics of geothermal fluids vary from KGRA to KGRA, but also within a given KGRA. This can be seen in Tables 1.2-1.4. These tables present very limited data and are only included to illustrate the variation in concentration, measured in parts per million (ppm), of chemical constituents from different wells within a given KGRA.

TABLE 1.1

**Approximate Temperatures and Ranges of Salinity for
Four KGRAs in the Imperial Valley**

<u>KGRA</u>	<u>Approximate Temperature</u>	<u>Approximate Salinity (TDS in ppm)</u>
Brawley	500°F (260°C)	70,000 - 200,000
East Mesa	360°F (180°C)	14,000 - 20,000
Heber	370°F (190°C)	2,000 - 50,000
Salton Sea	500°F (260°C)	250,000 - 350,000

Source: Westec Services, Inc., 1981.

TABLE 1.2

Characteristics of Unflushed Fluid From Four Wells in the East Mesa KGRA

<u>FLUID COMPONENTS</u>	<u>CONCENTRATION (ppm)</u>			
	<u>Mesa 6-1</u>	<u>Mesa 6-2</u>	<u>Mesa 8-1</u>	<u>Mesa 31-1</u>
<u>Key Species:</u>				
pH	5.45	6.21	6.27	6.27
Chloride	16850	2142	500	510
Sulfate	42.8	156	173	183
Bicarbonate	202	560	417	845
Carbonate*	0	0	0	0
Hydrogen Sulfide	3.0	1.5	1.0	0.3
Ammonia	40.8	14.7	4.95	2.5

Other Species:

TDS	26300	5000	1600	2900
Silica	320	269	389	274
Calcium ion	1360	16.4	8.5	8.9
Barium	14	0.25	0.15	0.15
Sodium	8100	1700	610	730
Arsenic	0.26	0.22	0.05	0.025
Boron	9.75	7.45	1.6	2.5
Potassium	1050	150	70	85
Fluorine	0.99	1.23	1.6	1.42

*No value for free carbon dioxide is available.

Source: Ellis and Conover, 1981.

TABLE 1.3**Characteristics of Geothermal Fluid From Two Wells in the Heber KGRA***

FLUID COMPONENTS	CONCENTRATION (ppm)	
	WELL NOWLIN NO. 1	WELL HOTZ NO. 2

Key Species:

pH	7.1	7.4
Chloride	9000	8242
Sulfate	1000	148
Hydrogen Sulfide	2	-
Bicarbonate	20	-
Carbonate	4	-
Carbon Dioxide	100-180	-
Ammonia	5-13	-

Other Species:

Silica	120	187
Sodium	3600	4720
Potassium	360	231
Lithium	6.6	4.1
Calcium	880	1062
Barium	-	3.0
Magnesium	2.4	23
Fluorine	1.6	1.5
Aluminum	0.04	12
Boron	4.8	8
Copper	0.2	0.4
Iron	0.9	5
Manganese	-	0.9
Lead	0.1	0.6
Strontium	-	42
Zinc	0.7	0.1
TDS	14100	16330

*There are only traces of carbon dioxide, hydrogen sulfide, and other noncondensable gases.

-:Data not available.

Source: Ellis and Conover, 1981.

TABLE 1.4

Characteristics of Geothermal Fluid From Three Wells in the Salton Sea KGRA

FLUID COMPONENTS	CONCENTRATION (ppm)		
	WELL SINCLAIR 1 (Flashed Fluid)	WELL MAGMAMAX 1 (Flashed Fluid)	WELL IID 1 (Flashed Fluid and Condensate)
<u>Key Species:</u>			
pH	5.3	6.1	5.2
Chloride	93,650	120,374	155,000
Sulfate	58	10	56
Bicarbonate	60	4,472*	150
Carbonate	0	0	0
Hydrogen Sulfide	-	-	16
Ammonia	340	558	409
<u>Other Species:</u>			
TDS	183,700	203,406	257,800
Silica	350	426	400
Calcium	14,550	23,090	28,000
Sodium	36,340	46,282	50,400
Potassium	7,820	7,789	17,500
Magnesium	780	108	54
Boron	210	-	390
Iron	166	168	2,290
Manganese	410	-	4,100
Barium	540	55	235
Strontium	360	100	400

*Total carbon dioxide.

-: Data not available.

Source: Ellis and Conover, 1981.

1.4 Geothermal Technologies

The technology used to convert geothermal resources to electricity is different for vapor-dominated systems than for liquid-dominated systems. Vapor-dominated systems utilize a well established technology which has been used by industry for a long time. Steam is collected from production wells and sent directly to a turbine where electricity is generated by a generator. After passing through the turbine, the steam is at a lower temperature and pressure. This effluent is cooled in either direct contact or surface condensers and waste heat is vented to the atmosphere through the cooling towers. The condensate is reinjected into the geothermal producing zone. Some variation to this technology is required to produce electricity from liquid-dominated systems.

There are two different technologies used when dealing with liquid-dominated resources and the one utilized depends primarily on the temperature and pressure of the geothermal fluids. These technologies are either a flashed steam system or a binary fluid system.

The liquid-dominated systems are either reservoirs of hot water or a mixture of liquid and vapor. When fluid from a liquid-dominated system is brought to the surface, it experiences a reduction in pressure which causes some of the fluid to flash to steam in the well. Common practice for these types of systems is to maintain the reservoir pressure while the fluid is produced. It is then sent to a chamber where the pressure is reduced. Approximately 15% of the hot water is flashed to steam. If the remaining water is at a high enough temperature, it can be flashed again in a second chamber to produce additional steam. In either case, the spent fluid is pumped back into the geothermal producing zone. For liquid-dominated systems with high TDS, the spent brines may be treated to allow some of the solids to settle prior to subsurface injection. The steam is sent to a turbine generator where electricity is produced.

In the binary cycle process, a secondary fluid with a boiling point less than water is used in addition to the geothermal brines. This secondary, or working fluid is usually a mixture of isobutane and other hydrocarbons. The brine and the working fluid are in separate closed loop systems. The hot geothermal fluids are pumped through heat exchangers and then reinjected into the production zone. The brine is maintained at a pressure high enough to prevent it from flashing to steam and to reduce mineral precipitation. The working fluid is vaporized as it passes through the heat exchanger and is then used to drive a conventional turbine generator. The vapor is condensed back into a fluid before returning to the heat exchanger.

1.5 Wastes from Geothermal Power Plants

Wastes from geothermal power plants can be produced during well drilling, construction activities, plant operations, and use of sanitary facilities by onsite workers. The term waste is being used in this report to mean any material, or by-product, for which there is no use or reuse and which is discarded. The geothermal wastes considered in this study were limited to geothermal drilling muds and to the sludges and liquid by-products generated from geothermal power production. Issues associated with airborne emissions, and the disposal of plant construction wastes or sanitary wastes were beyond the scope of this study. Additional state agencies and regulations would be involved with these issues.

Wastes resulting from the drilling of geothermal wells are silt, soil, formation cuttings, and drilling muds. Drilling muds generally consist of bentonite and additives such as lignite, caustic soda, bicarbonate of soda, graphite, soda ash, soda phosphate, barium sulfate, sodium sulfate, sodium polyacrylate, cotton seed hulls, cement, and water. The actual mixture depends on the specific site conditions and application.

Wastes generated from plant operations can include spent geothermal fluids, sludges from air pollution abatement systems and cooling towers, and separated solids from preinjection treatment of spent brines if necessary. Occasionally, scale from process lines, valves, and turbines must also be removed and disposed. These wastes generally consist of heavy metals and salts. The exact characterization of each waste stream is highly site dependent.

Different technologies utilized for geothermal power production result in the generation of different waste streams. In addition, the specific process used within a given technology which will affect the waste streams. One example of this is in the area of air pollution abatement. The two most commonly used hydrogen sulfide abatement processes are the Stretford process and the iron catalyst-hydrogen peroxide-sodium hydroxide system. These two systems produce different residuals.

2.0 FEDERAL LEGISLATION

Many federal regulations have been enacted in the past two decades in an effort to preserve and protect the environment. Federal environmental regulations are generally written such that individual states can assume primacy over a federal program provided that the state develops its own program in accordance with federal guidelines. The U.S. Environmental Protection Agency (EPA) is delegated the responsibility of implementing federal environmental legislation. EPA sets standards and criteria for a particular environmental issue, and then provides technical assistance and guidance to states to develop and enforce their own programs. The state program must be at least as strict as the federal regulations and may adopt even more stringent requirements. The state program must also receive approval from EPA before it can replace the federal program.

The two pieces of federal legislation which pertain to the disposal of sludges and the injection of fluids associated with power production from geothermal resources are The Resources Conservation Recovery Act and The Safe Drinking Water Act. Both of these Acts have programs for which individual states can assume primacy. The state of California had developed and adopted several environmental regulations prior to enactment of these two federal Acts. However, the state regulations must be made consistent with the federal regulations. The state must demonstrate that it can enforce equivalent standards and must receive authorization from EPA to administer its own program.

The basic objectives of these two federal Acts are very important as they represent the fundamental principles upon which a state program must be built. Therefore, they are briefly summarized and their applicability to the disposal of sludges and liquid wastes resulting from geothermal energy production is discussed.

2.1 Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA), Public Law 94-580, was enacted in 1976 by Congress in response to widespread environmental problems resulting from the mismanagement of and improper practices for disposal of solid and hazardous wastes. The basic premise behind RCRA was to "promote the protection of health and the environment and to conserve valuable material and energy resources." RCRA calls for regulations to control the disposal of solid and hazardous wastes and to encourage resource recovery, recycling and conservation. The major objectives of this Act are to provide technical and financial assistance to state and local governments for the development of solid waste management programs, establish minimum requirements and criteria for solid waste plans, promote resource recovery, reuse, and recycling of wastes, and to establish controls on the management of hazardous wastes. Regulations were promulgated by the U.S. EPA as a result of RCRA and are outlined in many different sections of the Code of Federal Register (CFR). These sections are listed in Table 2.1 for illustrative purposes.

Subtitle C of RCRA establishes controls on the management of hazardous waste including instituting a "cradle-to-grave" tracking system from the source of hazardous waste generation to the location of final disposal. A waste manifest which physically accompanies the waste along its route is an integral

TABLE 2.1

Sections of the Code of Federal Register Pertaining to RCRA

<u>PART</u>	<u>TITLE</u>
40 CFR 260	EPA General Regulations for Hazardous Waste Management
40 CFR 261	EPA Regulations for Identifying Hazardous Waste
40 CFR 262	EPA Regulations for Hazardous Waste Generators
40 CFR 263	EPA Regulations for Hazardous Waste Transporters
40 CFR 264	EPA Regulations for Owners and Operators of Permitted Hazardous Waste Facilities
40 CFR 265	EPA Interim Status Standards for Owners and Operators of Hazardous Waste Facilities
40 CFR 270	EPA Regulations for Federally Administered Hazardous Waste Permit Programs
40 CFR 271	EPA Requirements for Authorization of State Hazardous Waste Programs

part of this tracking system. A comprehensive regulatory system was also established for all hazardous waste management operations including generation, transportation, treatment, storage, and disposal. These regulations establish notification, record keeping, and reporting requirements as well as specific requirements for generators, transporters and operators of waste facilities. Owners or operators of hazardous waste treatment, storage or disposal facilities were also required to obtain a permit from EPA in order to continue to operate legally. In addition, Subtitle C of RCRA authorized EPA to define hazardous wastes, develop criteria for the identification of hazardous wastes, and prepare a list of those wastes which have been identified as hazardous.

A hazardous waste is defined in RCRA as a solid waste which due to its physical or chemical characteristics may cause an increase in mortality or serious illness or pose a substantial hazard to human health or the environment when improperly managed. The four characteristics developed by EPA for the identification of hazardous wastes include ignitability, corrosivity, reactivity, and toxicity. Guidelines or standard testing procedures have also been established to determine whether a material exhibits these characteristics. EPA has also, in accordance with RCRA, promulgated lists of wastes from non-specific sources, from specific sources, and as discarded commercial chemical products which are to be regulated as hazardous under RCRA.

Several wastes have been identified which are to be excluded from the RCRA requirements and are listed in 40 CFR §§261.4(b). Among these wastes are "drilling fluids, produced waters, and other wastes associated with the exploration, development, or production of crude oil, natural gas, or geothermal energy." Therefore, these wastes associated with geothermal energy are presently excluded from regulation as hazardous wastes under RCRA. This could change however, as many of the wastes listed in 40 CFR §§261.4(b) were to be excluded pending further study by the U.S. EPA. This study was anticipated to be completed and submitted to Congress by December 31, 1985.

It is also important to note that while EPA has excluded some wastes which would otherwise be regulated as hazardous wastes under RCRA, not all states have adopted the same exclusions. Therefore, state regulations may apply to wastes that have been exempted from the federal program.

The state of California adopted a hazardous waste control law and developed a hazardous waste management program before enactment of RCRA. In fact, RCRA was based in part on the California hazardous waste control law although RCRA established more permitting requirements. The California hazardous waste program is more stringent than RCRA in that it does not give exclusions to small generators. In addition, it classifies some substances as hazardous that are not considered hazardous under RCRA. One example of this is vanadium. The details of the California hazardous waste regulations are discussed in Chapter 3.

2.2 Safe Drinking Water Act

The Safe Drinking Water Act (SDWA), Public Law 93-523, was enacted by Congress in 1974 with the objective of establishing federal guidelines and programs to protect the quality of drinking water supplies in the United States. This Act was intended to be a preventative statute rather than an aquifer restoration program. The SDWA authorized the U.S. EPA to set maximum levels of specific contaminants permitted in drinking water sources and to regulate the injection of substances into the subsurface.

Section C of the SDWA promulgated the Underground Injection Control (UIC) program and required the U.S. EPA to establish minimum requirements for effective UIC programs. The requirements of this program are outlined in several different sections of the Code of the Federal Register, which describe the basic UIC program requirements, as well as permitting, monitoring, record keeping, and reporting requirements. A summary of the sections of the CFR which pertain to the UIC program is presented in Table 2.2

The primary objective of the UIC program is to protect underground sources of drinking water (USDW) from contamination by the injection of fluids through wells. A well is defined in the UIC program as "a bored, drilled, or driven shaft, or a dug hole, whose depth is greater than the largest surface dimension." The UIC program defines five classes of injection wells according to the type of fluid being injected and the location of the injection zone with respect to underground drinking water sources. As can be seen from Table 2.3, the injection wells used for purposes related to geothermal resources are categorized as Class V wells.

TABLE 2.2
Structure of the UIC Program

<u>PART</u>	<u>TITLE</u>	<u>SUMMARY</u>
40 CFR 124	Procedures for Decision Making	Describes EPA procedures on receiving permit applications, preparing draft permits, issuing public notice, inviting public comment, holding public hearings on draft permits, assembling an administrative record, responding to comments, issuing a final permit decision, and allowing for administrative appeal of final permit decision. Also sets forth the public participation requirements that must be met by UIC programs.
40 CFR 144	Underground Injection Control Program	Defines regulatory framework of EPA administered permit programs. Describes general elements of the UIC program, including definitions and classifications. Sets forth general program requirements, including the performance standards applicable to all injection activities, basic elements that all UIC programs must contain and provisions for waiving permit of rule requirements. Sets forth authorization of underground injection by rule, authorization of underground injection by permit, permitting procedures and minimum required specific conditions which must be included in all permits.
40 CFR 145	State UIC Program Requirements	Describes the required elements of a State application for primacy to administer an UIC program. Sets forth the necessary elements of a State submission and sets forth EPA procedural requirements for approval, revision, and withdrawal of State programs.
40 CFR 146	UIC Program: Criteria and Standards	Sets forth the technical criteria and standards that must be met in permits and authorization by rule as required in 40 CFR 144.
40 CFR 147	State UIC Programs	Sets forth the applicable UIC programs for each of the states, territories, and possessions identified pursuant to the SDWA as needing an UIC program.

TABLE 2.3

UIC Classification of Wells

<u>CLASS</u>	<u>TYPE OF FLUID</u>
I	Hazardous, industrial, or municipal waste injected below lowermost USDW.
II	Fluids produced during conventional oil or gas recovery; fluids associated with enhanced recovery of oil or gas; and storage of liquid hydrocarbons.
III	In situ production or solution mining of sulfur, uranium or salts.
IV	Hazardous or radioactive waste injected into or above USDW.
V	Geothermal fluids produced for heating, aquaculture and production of electric power; storm runoff; fluids used in experimental technologies; all other fluids or discharges not included in Classes I, II, III, or IV.

The SDWA required the U.S. EPA to list each state for which an UIC program may be necessary to assure that underground injection will not endanger drinking water sources and to establish by regulation a program for EPA administration of UIC programs in the absence of an approved State program in a listed state. Each individual state can administer its own UIC program provided it satisfies the minimum requirements of the federal program defined by EPA and provided the program is approved by EPA. In some cases, EPA will regulate a UIC program covering all classes of wells for a state. However, where a state program regulates only certain classes of wells, the federal program will cover only the remaining classes.

The federal UIC regulations institute a three year program to evaluate Class V wells. An inventory of all Class V wells was to be conducted within one year. An assessment was then to be performed on these wells to determine the adequacy of any current federal and state regulations. This assessment is currently underway.

Prior to the federal UIC program, the California Division of Oil and Gas had developed its own comprehensive set of regulations governing the use of geothermal wells. These regulations are discussed in Section 3.5. The California Division of Oil and Gas has requested authorization from EPA to administer geothermal injection wells under the SDWA since they have an ongoing and proven underground injection control program for these wells.

3.0 CALIFORNIA LEGISLATION

California has historically demonstrated that it is a state concerned with maintaining a balance between development and utilization of natural resources, protection of the health, safety, and welfare of the people of the state, and preserving and protecting the quality of the environment. There are several state agencies involved with this goal. Generally a given state agency develops and adopts state policy which is then carried out and enforced by regional boards or divisions within that agency.

The program for managing hazardous wastes in California is based on several state regulations which are implemented by several different agencies. The management of hazardous waste is very complex and is frequently considered to be in a state of flux. This is in part due to the number of agencies and regulations involved, but also due to the frequency with which regulations change or are proposed to be changed. A few of the California waste regulations have been recently enacted and it could take several years before they are fully implemented. New legislation is continuously being introduced. One such example is the Torres bill, SB 1048, which proposes to create an environmental affairs agency to coordinate management of hazardous wastes. The proposed approach would not disrupt the basic structure of the present hazardous waste management program in that it would leave intact the authority of state and regional water control boards to set and protect state water quality standards. However, the governor of the State of California has recently proposed to completely reorganize the state hazardous waste management program and its implementation. Although the State Assembly defeated this proposal in July, the governor intends to submit a revised plan.

The California state agencies charged with administering regulations governing the disposal of sludges and liquid wastes from geothermal power production are the California State Water Resources Control Board, the California Department of Health Services, and the California Division of Oil and Gas. The California State Water Resources Control Board is divided into nine regional boards which regulate the disposal of wastes to land. The California Department of Health Services is charged with the responsibility of developing criteria to define and identify hazardous wastes. The control of toxic substances is also a duty of the Department of Health Services and the state is divided into four divisions for this purpose. The California Division of Oil and Gas has jurisdiction over all wells used in connection with oil, gas, or geothermal activities and requires that they are drilled, operated, maintained, and abandoned in such a manner to safeguard life, health, property, public welfare, and to encourage maximum economic recovery. The state of California is divided into three geothermal districts. The geographic distribution of the subdivisions for each of these three state agencies is given in Appendix A. It should also be mentioned that the California Waste Management Board is involved in the permitting of nonhazardous waste disposal sites.

There are several California state regulations governing the disposal of wastes which must be evaluated for this study. A detailed discussion of each of these regulations is presented in the following sections. Emphasis is placed on the applicability of these regulations to geothermal wastes when possible. The basic structure of each of these regulations is presented in Appendix B.

3.1 California Porter-Cologne Water Quality Act

The California Porter-Cologne Water Quality Act was enacted by California statutes in 1969 and is administered by the State Water Resources Control Board (WRCB). The objective of the state legislature in enacting this Act was to delegate the primary responsibility for the coordination and control of water quality to the State Board and its nine Regional Boards. The powers and duties of these Boards associated with this responsibility are outlined in this Act.

The California Porter-Cologne Water Quality Act authorized the WRCB to formulate and adopt a state policy to preserve and protect the quality of the waters of the state. Any activity or factor which may affect water quality shall be regulated by the State Board to achieve the highest quality of the water possible considering all demands being made on those waters. This Act also delegated the responsibility of developing a classification scheme for wastes and waste disposal sites to the State Board. Some of the additional duties of the WRCB from this Act include a yearly evaluation of state needs for water quality research, coordinating water-quality-related investigations of state agencies, and implementing a state-wide water quality information storage and retrieval program.

The nine Regional Water Quality Control Boards implement the state water quality policy set forth by the WRCB. Each regional board formulates and adopts water quality control plans for all areas within its region based on the state policy.

3.2 California Regulations on Discharges of Wastes to Land

The WRCB is charged with the responsibility of protecting the quality of the waters of the state by provisions of the Porter-Cologne Water Quality Act. To meet this responsibility, the WRCB established regulations for waste disposal to land including specific geologic and siting criteria for waste disposal sites and developed systems for classifying wastes and disposal sites. These regulations and classification schemes were adopted in 1971 and described in Subchapter 15 of Title 23 of the California Administrative Code.

On October 18th 1984, the State Board adopted amendments to the waste discharge regulations which were approved by the Office of Administrative Law on November 26th 1984. These newly adopted regulations represent a significant revision of the previous Subchapter 15 regulations. There are quite a few new requirements particularly for construction standards and water quality monitoring at waste disposal operations. New waste and disposal site classification schemes have been adopted as well. However, many of the procedures used by the regional boards to implement and enforce state policy have remained the same.

For the purposes of this discussion, any waste disposal site which was either operated or permitted to operate before the October 1984 regulations became effective shall be referred to as "existing waste disposal sites" and those sites which were permitted to operate after the effective date of the October 1984 regulations shall be referred to as "new waste disposal sites." All existing waste disposal sites shall be reviewed, reclassified, and, where

feasible, modified to meet the requirements of the new regulations. This could take several years to complete and until each existing site is individually reviewed, it will continue to operate under the previous classifications and regulations. Any new waste disposal site or expansion at existing waste disposal sites shall comply with the new regulations. Therefore, in order to comprehend the disposal requirements at existing waste disposal sites and the disposal requirements which must be met for new disposal sites, discussions are presented for both sets of WRCB waste discharge regulations.

3.2.1 Regulations prior to October 1984: The State Board established a system for **classifying wastes** based on the degree to which each type of waste could degrade water quality. The wastes were categorized into three groups depending on their toxicity. Group 1 wastes contain or consist of substances which are lethal, injurious, or damaging to man or other living organisms and which could significantly degrade water quality. Hazardous fluids from industrial operations, brines from geothermal plants, and rotary drilling muds containing toxic materials are among the wastes categorized in this Group. Wastes categorized as Group 2 wastes consist of or contain substances which are chemically or biologically decomposable, and would not significantly degrade the quality of usable waters. Group 2 wastes would include municipal garbage, paper, cardboard, street refuse, solid organic matter from water treatment processes, and ashes from household burning. Group 3 wastes are inert solids which do not decompose and are not water soluble, such as concrete, asphalt, glass, and inert plastics.

The State Board also developed a system for **classifying waste disposal sites** based on the degree of protection provided for water quality and according to the wastes that could be received. Class I waste disposal sites had to meet several specific geologic conditions to provide complete protection for water quality for all time. Group 1, 2, and 3 wastes can be accepted at these disposal sites. Class II-1 waste disposal sites overlie usable aquifers but either have natural geologic conditions or modifications which prevent lateral and vertical migration of the wastes. These sites accept Group 2 and Group 3 wastes. After approval from the appropriate Regional Board, they can also accept certain Group 1 wastes. Class II-2 disposal sites may have lateral and vertical hydraulic continuity with underground sources of water but the geologic and hydraulic features underneath and adjacent to the site provide adequate protection for water quality. Only Group 2 and Group 3 wastes can be accepted at these disposal sites. Class III waste disposal sites are sites which could potentially intercept ground water and are restricted to receiving Group 3 wastes only.

The State Board has also established specific requirements regulating the **disposal of wastes to land** which are implemented and enforced by the nine regional boards. These requirements represent the minimum acceptable standards and procedures for the proper management of wastes. Any regional board can adopt and enforce additional requirements imposing further restrictions or conditions with respect to the disposal of wastes which might degrade the quality of water within their region provided that these requirements are consistent with state policy.

Any person proposing to discharge a waste in a manner that could affect the water quality of the state must file a report of the discharge with the

appropriate regional board. This report must contain specific information as required by the regional board. Should a report be received which is inadequate, the regional board has the authority to request additional information.

The regional boards regulate the disposal of wastes to land by issuing waste discharge requirements (WDRs). These orders contain the Boards' findings with regard to proposed discharges, list discharge specifications and limitations, prohibitions, provisions for compliance including time schedules, and, where applicable, concentration limits for specific wastes. Waste discharge requirements may specify certain conditions or areas where the discharge of waste, or certain types of waste, will not be permitted. Every disposal site must have a WDR before it can operate. These orders are issued on a site by site basis and are tailored to meet the needs of a given site based on many factors such as the geologic conditions, the climate, and specific waste characteristics. The regional boards also issue monitoring requirements and reporting schedules to operators of waste disposal sites.

A regional board can revise or revoke WDRs when necessary. If a discharge of waste occurs which is found to be in violation of its WDR, the regional board may issue a Cease and Desist order until the appropriate remedial action can be identified and taken. Any person discharging waste must also report any material change or proposed change in the character, location, or volume of the discharge to the regional board. Strict penalties and fines may be imposed on any person discharging or proposing to discharge wastes who fails to submit a report to the regional board or who knowingly submits false information.

3.2.2 October 1984 Amendments: Amendments to the California Administrative Code Subchapter 15, Discharges of Waste to Land, were adopted by the WRCB in October 1984. Included in these amendments are new systems for classifying wastes and disposal sites. These systems are based on the same principals as in the previous regulations. Under these new regulations, however, wastes are now classified as Hazardous, Designated, Nonhazardous, or Inert wastes and waste management units are categorized as Class I, Class II or Class III.

The definition of hazardous waste is the same as that defined by the California State Department of Health Services in the Hazardous Waste Control Act (Chapter 6.5 of Division 20 of the California Health and Safety Code). Discharge of hazardous wastes shall be permitted at Class I waste management units only. Designated wastes consist of or contain substances which could be released at concentrations in excess of applicable water quality objectives or which could degrade water quality. These wastes will generally be discharged at Class II waste management units and would also be accepted at Class I waste sites. Nonhazardous solid wastes include all putrescible and nonputrescible solid, semi-solid, and liquid wastes. Discharges of nonhazardous solid wastes will generally be at Class III waste sites. Inert wastes are defined as those wastes which do not contain hazardous waste, significant quantities of decomposable wastes, or soluble materials at concentrations in excess of applicable water quality objectives. Inert wastes do not have to be disposed of at classified waste management units. As in the previous regulations, regional boards regulate the discharge of wastes to land by issuing waste discharge requirements.

The newly adopted regulations establish waste management requirements for waste treatment, storage or disposal in landfills, surface impoundments, waste piles, or land treatment facilities. These regulations establish specific construction standards for and water quality monitoring requirements at waste management units. For example, new Class I waste management units are required to institute a detection monitoring program, have a double liner containment system, and a system for leachate collection and removal in order to accept hazardous wastes.

Existing waste management units will be reclassified according to the criteria of this subchapter and will be required to comply with applicable construction standards of this subchapter as feasible. Complete provisions and time schedules for this are included in these new regulations. Owners or operators of existing waste management units were required to submit a technical report within six months of the effective date of these regulations to the appropriate regional board outlining the measures necessary to upgrade their facility to meet the new regulations. The regional board will review each site and revise WDRs to incorporate reclassification and retrofitting requirements, and a time schedule for meeting these requirements. All existing sites will be reviewed within five years. This review and reclassification process is currently underway.

Nine different activities are identified as being exempt from the provisions of this chapter although they are still generally regulated by WDRs. These exemptions have specific conditions and are outlined in Section 2511 of this chapter. Included in these exemptions are the discharge of drilling mud and cuttings from well drilling operations, provided that such discharges are to on-site sumps and do not contain halogenated solvents. At the end of drilling operations, the discharger shall either remove all wastes from the sump or remove all free liquids from the sump and cover the residual wastes, provided that representative sampling of the sump contents after liquid removal shows residual solid wastes to be nonhazardous. Disposal of drilling wastes to on-site sumps are regulated by the appropriate regional board through the issuance of WDRs.

3.3 California Hazardous Waste Control Act

The California Hazardous Waste Control Act (Chapter 6.5 of Division 20 of the California Health and Safety Code) has been amended many times since it was first enacted in 1972. This Act delegated many responsibilities to the California Department of Health Services (DOHS) with regard to controlling hazardous waste in an effort to protect the public health and the environment. The California State Legislature had several reasons for instituting this Act. Among these reasons were the increase in hazardous waste generation in the state; the long-term risks to public health, to air quality, and to water quality resulting from landfill disposal of many types of untreated hazardous waste and from the improper handling, storage, use and disposal of hazardous waste; and the tremendous restoration costs associated with inappropriate practices of handling and disposal of hazardous wastes.

This Act authorized the DOHS to prepare a list of wastes which are determined to be hazardous and a list of wastes determined to be extremely hazardous. In Section 25117 of the Health and Safety Code, a "hazardous waste" is defined as "a waste, or combination of wastes, which, because of its quantity, concentration, or physical, chemical, or infectious characteristics may either:

- (a) Cause, or significantly contribute to, an increase in mortality or an increase in serious irreversible, or incapacitating reversible illness.
- (b) Pose a substantial present or potential hazard to human health or environment when improperly treated, stored, transported, disposed of, or otherwise managed."

Unless stated otherwise, a hazardous waste shall be understood to also include an extremely hazardous waste.

Section 25115 of the Health and Safety Code defines an "extremely hazardous waste" as "any hazardous waste or mixture of hazardous wastes which, if human exposure should occur, may likely result in death, disabling personal injury, or serious illness caused by the hazardous waste or mixture of hazardous wastes because of its quantity, concentration, or chemical characteristics."

The DOHS was also required to establish, and adopt by regulation, criteria and guidelines for the identification of hazardous and extremely hazardous waste. Any waste which meets these criteria shall be handled, stored, used or disposed of in accordance with permits or requirements issued by the DOHS unless it is already adequately regulated by another government agency. In that case, the DOHS may waive it from the provisions of this chapter. Wastes from drilling for geothermal resources have been exempt from the requirements of this chapter since the disposal of these materials is regulated by the regional water quality control boards.

Any analysis of wastes as required by this chapter shall be performed at a laboratory which has been certified by the DOHS. This Act authorized the DOHS to establish regulations governing the criteria for laboratory certification, the certification process, and the procedures to be used by hazardous waste laboratories to analyze and identify wastes. These tests and laboratory procedures were required to employ standard methods or be specific tests developed by the DOHS.

The Hazardous Waste Control Act also authorized the DOHS to establish minimum standards and regulations for the handling, processing, use, storage and disposal of, and the recovery of resources from, hazardous and extremely hazardous wastes. These standards apply to the use and operation of hazardous waste facilities. Regulations were also required to be adopted by the DOHS for the recycling of hazardous wastes.

A hazardous waste manifest is required by the DOHS to be used when transporting hazardous wastes. The DOHS shall determine the form and manner in which a manifest is to be completed and the information that the manifest shall contain. Although the form and the required information of the manifest shall be consistent with the federal regulations, the DOHS has the authority to request additional information.

In coordination with federal acts, the DOHS was charged with the responsibility of establishing regulations which would allow the state to administer a state hazardous waste program in lieu of the federal program defined in RCRA. In order to be able to administer their own hazardous waste program, the California hazardous waste regulations had to be made consistent with the federal regulations and DOHS had to demonstrate that they could enforce equivalent standards. While these regulations are required to conform with corresponding regulations developed by the U.S. EPA, the DOHS has the authority to adopt more stringent standards than the federal regulations.

The DOHS also had specific duties from this Act with regard to research and technology transfer. A few of these duties include:

- Coordinate research and development regarding methods of hazardous waste handling, storage, use, processing and disposal and many conduct appropriate studies relating to hazardous wastes.
- Maintain a technical reference center on hazardous waste disposal, recycling practices, and related information for public and private use.
- Determine existing and expected rates of production of hazardous waste.
- Investigate market potential and feasibility of use of hazardous wastes and recovery of resources from hazardous wastes.
- Promote recycling and recovery of resources from hazardous wastes and encourage the reduction or exchange of hazardous waste.
- Prepare a report every two years containing an assessment of the best available technologies for the treatment, storage, recycling, source reduction and disposal of hazardous wastes.

3.3.1 Toxic Pits Cleanup Act of 1984: This Act was approved by the governor of California on September 29th 1984 and amended to the Hazardous Waste Control Act. The objective of the State Legislature was to institute a program which would ensure that existing surface impoundments were either made safe or closed in order to protect water quality and public health. The State WRCB and its nine regional boards are responsible for implementing this Act.

Any person discharging liquid hazardous wastes or hazardous wastes containing free liquids into a surface impoundment is required to file a hydrogeological assessment report to the appropriate regional board unless they

intend to close the impoundment. This report must contain extensive information and be prepared by a qualified individual. The required content of this report is described in Section 25208.8 of the Health and Safety Code. The State Board was authorized to adopt a fee which would be assessed upon persons discharging these wastes into a surface impoundment. The fees are based upon the cost of administering the provisions of this Act.

The Toxic Pits Cleanup Act establishes regulations for the discharge of restricted hazardous wastes, liquid hazardous wastes, and hazardous wastes containing free liquids into a surface impoundment. A restricted hazardous waste is defined in Section 25122.7 of the Health and Safety Code to mean:

(a) Any hazardous waste which contains any of the following substances:

(1) Liquid hazardous wastes containing free cyanides at concentrations greater than or equal to 1,000 milligrams per liter (mg/l).

(2) Liquid hazardous wastes containing any of the following metals or elements, or compounds of these metals or elements, at concentrations greater than, or equal to, any of the following:

Arsenic.....	500 mg/l
Cadmium.....	100 mg/l
Chromium (VI).....	500 mg/l
Lead.....	500 mg/l
Mercury.....	20 mg/l
Nickel.....	134 mg/l
Selenium.....	100 mg/l
Thallium.....	130 mg/l

(3) Liquid hazardous wastes having a pH less than or equal to two.

(4) Liquid hazardous wastes containing polychlorinated biphenyls (PCBs) at concentrations greater than, or equal to, 50 mg/l.

(5) Hazardous wastes containing halogenated organic compounds in total concentration greater than, or equal to, 1,000 milligrams per kilogram.

(b) Any hazardous waste designated by the department as a restricted hazardous waste because of its toxicity, mobility, or persistence in a land disposal environment, or its ability to accumulate in plants or animals.

The main provisions of the Toxic Pits Cleanup Act are outlined in Table 3.1. Mechanisms exist to have a surface impoundment exempt from provisions of this Act. These exemptions are evaluated on a site-by-site basis.

TABLE 3.1

Provisions of the Toxic Pits Cleanup Act of 1984

<u>DATE</u>	<u>PROVISION</u>
01-01-85	Prohibit the discharge of restricted hazardous wastes containing cyanide wastes or PCBs into a surface impoundment.
07-01-85	Prohibit the discharge of any restricted hazardous waste into a surface impoundment.
01-01-86	Deadline for submitting an application of an exemption from Section 25208.4(a) of the Health and Safety Code to appropriate regional board.
12-31-87	Deadline for granting or denying a request for an exemption from Section 25208.4(a) of the Health and Safety Code by a regional board.
06-30-88	Prohibit the discharge of liquid hazardous wastes or hazardous wastes containing free liquids into a surface impoundment if the surface impoundment contains hazardous waste and is within one half mile of a potential source of drinking water. A surface impoundment meeting these conditions would be required to close.
01-01-89	Prohibit the discharge of any liquid hazardous waste or hazardous wastes containing free liquids into a surface impoundment, unless the surface impoundment is double lined, as specified in Section 25208.5(b), equipped with a leachate collection system, and ground water monitoring is conducted, in accordance with RCRA, the regulations and guidance documents adopted pursuant thereto, and the regulations adopted by the State Board and the DOHS.

3.4 California Hazardous Waste Management Regulations

These regulations were developed by the California DOHS as the **minimum standards for the management of hazardous and extremely hazardous wastes** and are contained in Chapter 30 of Division 4 of Title 22 of the California Administrative Code. They outline the requirements for permitting hazardous waste facilities and registration of hazardous waste haulers. These regulations establish the criteria for identification of hazardous and extremely hazardous wastes. A list of wastes, by chemical name and by common name, which are considered to be hazardous are also included in these regulations.

The California Hazardous Waste Management Regulations apply to the management of any liquid, semisolid, or gaseous waste which conforms to the DOHS definition of hazardous waste (Section 25117 of the California Health and Safety Code). Radioactive wastes are not subject to the provisions of this chapter.

It is possible to seek permission from the DOHS to have a hazardous waste classified as nonhazardous. A written application must be submitted to the DOHS which includes a general description of the waste, a chemical analysis of the waste identifying the hazardous components and their concentration which was performed at a DOHS approved laboratory, the proposed methods of handling, transporting, storing, treating, and disposing of the waste, and a summary of evidence indicating why the waste should not be classified as hazardous with technical data to support the statement. Provisions also exist to seek a variance from the requirements of this chapter for a particular waste.

The producer of any waste is required to have the waste analyzed using acceptable standard methods to determine whether it contains a hazardous material. If it is determined to be hazardous, the generator must ensure that the waste is taken to an appropriate site. A hazardous waste facility cannot operate in California without first obtaining a permit from the DOHS. The producer of a hazardous waste must also ensure that the wastes are transported by a hauler who is registered with the DOHS.

A hazardous waste manifest is required to be used for recording all hazardous wastes transported off-site to waste management facilities. The hazardous waste manifest requires information in three distinct sections where a separate section is completed by the hazardous waste producer, by the hazardous waste hauler, and by the operator of the off-site facility respectively.

The producer must provide the chemical composition of the waste on the manifest indicating whether the waste is hazardous or extremely hazardous. A copy of the manifest must be given to the registered hazardous waste hauler by the producer when transfer of custody of the waste occurs. The hauler of the waste must complete the Hauler of Waste section of the manifest and submit a copy of the completed manifest to the producer prior to removing the waste. The producer must submit a copy of each manifest used containing all information required in the Producer of Waste and Hauler of Waste sections of the manifest on a monthly basis to the DOHS.

The hauler must have a copy of the completed manifest in his possession while transporting the hazardous waste and will provide the operator of the hazardous waste facility accepting the waste with a completed copy of the manifest. The operator must inspect the wastes before accepting them and then completes the Disposer of Waste section of the manifest. The operator shall keep on file a copy of the completed manifest and shall send a copy of the completed manifest to the producer of the waste. The operator shall also send copies of all hazardous waste manifests accepted during each month to the DOHS on a monthly basis.

The DOHS has adopted criteria and guidelines for the identification of hazardous and extremely hazardous wastes. These criteria are based primarily on a system of characterizing wastes in respect to the properties of corrosivity, chemical reactivity, ignitability, and toxicity to animals and fish. Toxicity is defined to include acute and chronic effects and carcinogenicity.

Any waste is a hazardous waste which contains a substance listed in Table 3.2 at a concentration in milligrams per liter (mg/l) which exceeds its listed soluble threshold limit concentration (STLC) or at a concentration in milligrams per kilogram (mg/kg) in the waste which exceeds its listed total threshold limit concentration (TTLC). **All wastes must be analyzed for these substances using prescribed standard analytical methods or alternate methods that have been approved by DOHS.** The acceptable method of analysis for each substance is provided in subdivisions (1) through (4) of Section 66700 of these regulations.

The DOHS mandates that the waste extraction test (WET) shall be used to determine the amount of extractable substance in the waste if the total concentration of any substance listed in Table 3.2 equals or exceeds the STLC value but does not exceed the TTLC value. **Neither the EPA's Extraction Procedure Toxicity Test nor any of the other proposed methods are acceptable to the DOHS as equivalent or optional to WET for determining the extractability of these substances.** The WET was developed by the DOHS and the procedure for its use is described in subsection (f) of Section 66700 of these regulations. The DOHS selected citric acid as the extraction solution for its WET. The basis for this was that citric acid is functionally similar to naturally occurring organic and biochemical matter found in landfills and soils, has been used by researchers to test the extractability of toxic metals in various wastes, and as a moderate complexing agent, it is more likely to provide a conservative prediction of the environmental mobility of toxic materials in wastes than other known chelating agents.

Table 3.3 provides the TTLC values of persistent and bioaccumulative toxic substances in extremely hazardous wastes.

3.5 California State-Wide Geothermal Regulations

The geothermal policy of the State of California declares that the people of the state have a direct and primary interest in the development of geothermal resources. It has also determined that the State Oil and Gas Supervisor has authorization to regulate geothermal wells in a manner to encourage maximum economic recovery while safeguarding life, health, property, and public welfare. The State Supervisor is also mandated to regulate geothermal wells for the purpose of preventing damage to surface and ground waters that are suitable for irrigation and domestic use.

With respect to these responsibilities, the California Division of Oil and Gas (CDOG) adopted state-wide geothermal regulations which are contained in Subchapter 4 of Title 14 of the California Administrative Code. These

TABLE 3.2

The Soluble and Total Threshold Limit Concentration Values of Inorganic and Organic Persistent and Bioaccumulative Toxic Substances in Hazardous Wastes

INORGANIC SUBSTANCES	STLC mg/l	TTLIC mg/kg
Antimony and/or antimony compounds.....	15	500
Arsenic and/or arsenic compounds.....	5.0	500
Asbestos.....	—	1.0 (as percent)
Barium and/or barium compounds (excluding barite).....	100	10,000*
Beryllium and/or beryllium compounds.....	0.75	75
Cadmium and/or cadmium compounds.....	1.0	100
Chromium (VI) compounds.....	5	500
Chromium and/or chromium (III) compounds.....	560	2,500
Cobalt and/or cobalt compounds.....	80	8,000
Copper and/or copper compounds.....	25	2,500
Fluoride salts.....	180	18,000
Lead and/or lead compounds.....	5.0	1,000
Mercury and/or mercury compounds.....	0.2	20
Molybdenum and/or molybdenum compounds.....	350	3,500
Nickel and/or nickel compounds.....	20	2,000
Selenium and/or selenium compounds.....	1.0	100
Silver and/or silver compounds.....	5	500
Thallium and/or thallium compounds.....	7.0	700
Vanadium and/or vanadium compounds.....	24	2,400
Zinc and/or zinc compounds.....	250	5,000
ORGANIC SUBSTANCES		
Aldrin.....	0.14	1.4
Chlordan.....	0.25	2.5
DDT, DDE, DDD.....	0.1	1.0
2,4-Dichlorophenoxyacetic acid.....	10	100
Dieldrin.....	0.8	8.0
Dioxin (2,3,7,8-TCDD).....	0.001	0.01
Endrin.....	0.02	0.2
Heptachlor.....	0.47	4.7
Kepone.....	2.1	21
Lead compounds, organic.....	—	13
Lindane.....	0.4	4.0
Methoxychlor.....	10	100
Mirex.....	2.1	21
Pentachlorophenol.....	1.7	17
PCBs.....	5.0	50
Toxaphene.....	0.5	5
Trichlorethylene.....	204	2,040
2,4,5-Trichlorophenoxypropionic acid.....	1.0	10

Note: STLC and TTLIC values are calculated on the concentrations of the elements, not the compounds. TTLIC values are calculated on a wet-weight basis. In the case of asbestos and elemental metals, applies only if they are in a friable, powdered or finely divided state.

* Excluding barium sulfate.

TABLE 3.3

Total Threshold Limit Concentration Values of Persistent and Bioaccumulative Toxic Substances in Extremely Hazardous Wastes

SUBSTANCES	TTLIC mg/kg
Aldrin.....	140
Arsenic and/or arsenic compounds.....	50,000
Beryllium and/or beryllium compounds*.....	7,500
Cadmium and/or cadmium compounds*.....	10,000
Chlordan.....	250
2,4-Dichlorophenoxyacetic acid.....	10,000
Dieldrin.....	800
Dioxin (2,3,7,8-TCDD).....	1
Endrin.....	20
Heptachlor.....	470
Kepone.....	2,100
Lead compounds,**organic.....	1,300
Lindane.....	400
Mercury and/or mercury compounds.....	2,000
Mirex.....	2,100
PCBs.....	5,000
Selenium and/or selenium compounds*.....	10,000
Thallium and/or thallium compounds*.....	70,000
Toxaphene.....	500
2,4,3 Trichlorophenoxypropionic acid.....	1,000

*In the case of elemental metals, applies only if they are in a friable, powdered or finely divided state.

**Dry weight basis.

regulations establish requirements and procedures for the drilling, blowout prevention, completion and production, subsidence detection and abatement, injection, and abandonment of geothermal wells.

Of particular importance to this study are the comprehensive injection regulations. The fundamental requirements of these regulations are described below. It is important to note that each injection project is evaluated individually and is subject to specific requirements as required by CDOG.

In order to initiate an injection project, an applicant is required to submit to CDOG information describing the proposed project, the injection zone, and zones which could potentially be affected by the project. This information should include reservoir conditions, the proposed method of injection, source of injection fluid, estimates of daily amount of water to be injected, an analysis of the fluid to be injected, and an analysis of the fluid from the intended zone of injection. Additional information may be requested by CDOG for a specific project. The project must receive approval from CDOG prior to

beginning drilling or injection. An applicant is required to demonstrate the mechanical integrity of the casing of an injection well. Individual well drilling and completion programs must also be approved by CDOG prior to beginning injection.

Once an injection project is approved, surveillance of these projects is necessary to establish that the injected fluid is confined to the intended zone of injection. Operators must file monthly injection reports with CDOG and perform casing integrity tests periodically. CDOG inspectors are required to conduct on-site inspections of injection projects and annual meetings are held with the operator to review injection data. Operators are also required to report changes in operating procedures or equipment to CDOG. Strict penalties and fines may be imposed on any person found guilty of violating these regulations.

CDOG has requested authorization from EPA to administer their underground injection control program for geothermal wells under the umbrella of the SDWA.

4.0 WASTE DISPOSAL PRACTICES

Prior to the disposal of any material, the California state DOHS requires it to be analyzed using standard analytical methods to determine if it is hazardous or nonhazardous. The analytical results are compared to the threshold limiting concentration for the parameters as established in the California Administrative Code, "Title 22, Environmental Health." These parameters and their threshold concentrations originally came from the California Assessment Manual (CAM) prior to being adopted into law. They are therefore referred to by many regulatory and industry representatives in the state as the CAM levels. If the analysis of a waste indicates any of the parameters equal or exceed the CAM levels, the waste must be disposed of off-site at a site approved for the disposal of hazardous materials. These analyses required by the DOHS represent the ~~minimum~~ requirements for waste management. Additional restrictions or requirements may be imposed by regional or county regulatory agencies.

This study focuses on geothermal activities in two areas of California: The Geysers KGRA and the Imperial Valley. The current disposal practices for geothermal wastes from these two areas are discussed below.

4.1 The Geysers KGRA

The Geysers is located in Sonoma and Lake Counties approximately 90 miles north of San Francisco. It is a vapor-dominated system and conventional steam turbine generators are used to generate electricity. The ultimate disposal site for any waste generated at the Geysers will depend upon the waste classification. Any geothermal waste determined to be hazardous must be disposed at a Class I or Class II site (or by former WRCB classifications, a Class I or II-1 site). The closest Class I sites are the IT Environmental Corporation Benicia disposal facility located northeast of Benicia in Solano County and the IT Environmental Corporation Vine Hills and Baker facility approximately two miles east of Martinez in Contra Costa County. The two closest sites formerly classified as Class II-1 which are authorized to accept geothermal wastes are both located in Lake County. These sites are the Geothermal Incorporated (GI) site in Middletown and the IT Environmental Corporation Benson Ridge site in Kelseyville.

In accordance with DOHS regulations, all wastes generated from operations at the Geysers are analyzed for the CAM parameters and their threshold concentrations. Although boron is not listed as one of the CAM parameters it is also regulated in some instances. Boron is known to inhibit plant growth and is therefore a concern to agriculture. It is present in the geothermal resource at the Geysers and has been measured at high concentrations in some of the waste streams. Lake County has set a limit of 100 mg/l for the STLC of boron in an effort to protect agriculture in the region. In addition, the Central Valley regional water quality control board set discharge specifications for the GI waste disposal site in Lake County limiting the concentration of boron in geothermal wastes which can be accepted for disposal in ponds without double liners and in ponds with dual liners and leachate collection.

Most of the solid wastes generated at the Geysers had been trucked to the two Class II-1 disposal sites in Lake County. However, the GI site received a cease and desist order from the Central Valley regional board to mitigate and clean up evaporation pond leachate into local ground water and to implement a pond relining retrofit schedule to prevent further leakage. Neither of these two sites is accepting geothermal wastes at the present time. Both will have to retrofit their ponds to the 1984 Subchapter 15 regulations including installation of double liners and a leachate collection system before being able to accept any more geothermal wastes. The GI site has seven ponds and anticipates having two of these ponds retrofitted by winter. The geothermal wastes which would have been disposed at these two sites are being hauled to the IT Corporation Class I sites at Benicia and Martinez.

4.1.1 Drilling Wastes: During drilling and testing of wells, the drilling muds and fluids are stored in sumps located at each drilling site. These sumps are usually sized to handle wastes from one to three wells. Every drilling mud sump must have a WDR from the appropriate regional board. The Geysers has units operating in two different counties. These counties are under the jurisdiction of two different regional water quality control boards. Any discharges of waste to land in Sonoma County are regulated by the North Coast Region water quality control board whereas discharges of waste to land in Lake County are regulated by the Central Valley Region water quality control board.

On-site drilling mud sumps are built to the specifications of the former Class II-1 disposal site. These specifications require that the sumps are lined with at least two feet of compacted clay or soil cement having a permeability of 1×10^{-6} centimeters per second, or less, and have a minimum freeboard of three feet at all times.

After drilling is completed, the sump material must be analyzed to determine if it is hazardous or nonhazardous. If the material is nonhazardous, the liquids are pumped off the top of the sump and reinjected. The solid and semisolid material is left in the sump which is sealed in accordance with its WDR to provide a permanent disposal site. If the analytical test results indicate that the material is hazardous, it must be disposed off-site at an approved site. According to conversations with California regulatory and geothermal industry representatives, geothermal drilling wastes are generally determined to be nonhazardous.

The concentration of specific elements present in drilling wastes will vary from sump to sump. Analytical test results for six drilling mud sumps sampled in March 1985 were received from one company involved with geothermal drilling activities at the Geysers. This data was provided under the condition that the actual tables of analytical test results not be reproduced. However, the results for these six sumps show that the total and soluble concentration for the 20 inorganic parameters listed in Title 22 of the California Administrative Code are all well within regulatory limits. For example, the regulatory criteria for TTLC of arsenic is 500 mg/kg (see Table 3.2). The analytical results indicate a range of total concentration of arsenic from 3 to 47 mg/kg in these six sumps. The regulatory criteria for STLC of arsenic is 5.0 mg/l and the WET soluble concentration of arsenic ranged from below 0.2 to 1.2 mg/l for these six sumps. As a second example, the regulatory criteria for TTLC of zinc is 5,000 mg/kg. The total concentration of zinc ranged from 14 to 40 mg/kg in these six sumps. Zinc has a regulatory criteria for STLC of 250 mg/l

and the WET soluble concentration of zinc in these six sumps ranged from 0.5 to 2.0 mg/l. In fact, half of the inorganic parameters listed in Title 22 were found in these sumps by analytical methods in concentrations of at least two orders of magnitude below the CAM levels. These analytical test results demonstrate that drilling wastes are nonhazardous on a consistent basis.

4.1.2 Operational Wastes: Operational wastes can include steam condensate and sludges from condensate, cooling towers, and hydrogen sulfide abatement systems. Some of the steam condensate is used in the cooling towers and the rest is reinjected to the geothermal producing zone. When the steam condensate is heavily laden with dissolved solids, it will interfere with the injection process. In this case, the condensate goes to a sump where some solids or sludge settles out prior to subsurface injection.

The condensate sludge is dewatered, resulting in a filter cake which is then analyzed as required prior to disposal. According to one industry representative, half of the time this waste is nonhazardous. The rest of the time, one or two elements, frequently arsenic and mercury, are found in concentrations equal to or slightly greater than the regulatory criteria.

Analytical test results submitted to the North Coast Region water quality control board for steam condensate sludge from two units at the Geysers show that, for these particular results, the total and soluble concentrations for all but one of the regulated parameters are well within the CAM limits. However, the soluble concentration of arsenic in the WET extract for one of these samples was 12 mg/l which exceeds the regulatory arsenic STLC criteria and renders the sample hazardous. Analytical test results on condensate sludge ponds from four additional units at the Geysers were also received from the company which provided analytical data on drilling sumps. While the actual tables of analytical results cannot be duplicated here, the data show that these condensate pond sediments would be considered borderline hazardous due to arsenic and mercury levels which hover around the regulatory limits. According to conversations with geothermal industry representatives, there analytical data are considered to be fairly typical of condensate pond sludge at the Geysers.

The disposal practice for this condensate sludge was to dispose of it at the Class II-1 sites in Lake County. Since these sites are closed for retrofitting, this material is currently being hauled to the Class I disposal site in Benicia. It should also be mentioned that the North Coast Region water quality control board has allowed some tested, nonhazardous condensate pond sludge to be placed in drilling waste disposal sumps on a site-by-site basis.

Cooling towers act as a concentrating unit for the dissolved solids in the geothermal fluid. According to one Lake County regulatory official, the elements most frequently found in cooling tower sludges are arsenic, boron, mercury, and zinc. Analytical test results for a representative composition of cooling tower sludge from one unit at the Geysers were discussed with a geothermal industry representative during meetings in California. These data are considered proprietary and actual values could not be disclosed. However, the elements in this sample which were found in concentrations exceeding regulatory criteria were arsenic, mercury, nickel, and zinc.

The largest quantity of operational wastes will be generated by the hydrogen sulfide abatement system. In addition to the elements typically found in these wastes, additional elements may result from the specific process used. For example, iron used in one process may be found in the waste stream whereas vanadium is used directly in the Stretford process and is frequently found in the Stretford wastes. Many of the newer units at the Geysers use the Stretford process. Elemental sulfur is formed by this process. Analytical tests performed on wastes from the Stretford process were discussed with a geothermal industry representative during a trip to California. These data were also considered proprietary. Although the actual values could not be disclosed, this sample had concentrations of arsenic, boron, mercury, vanadium, and zinc which exceeded the CAM levels.

During operation of the plant a scale builds up over a long period of time on the valves, pipes, and turbine blades. This scale accumulates in small quantities and has been found to have high concentrations of arsenic. It is removed periodically and disposed in an approved disposal site.

4.2 Imperial Valley

The Imperial Valley of southern California is one of the most important agricultural areas of the United States. It also has tremendous potential for geothermal energy development. Nine KGRAs have been identified in this Valley, all of which are liquid-dominated systems. The variation in temperature and chemical composition of some of these geothermal resources was discussed previously in Section 1.3. The most significant variation is in the TDS content which has been reported to range from 2,000 to 350,000 ppm.

The geothermal activities in the Imperial Valley are located in Imperial County and employ different technologies. These activities are in various stages of development. Several are small demonstration projects. The first commercial scale binary geothermal power plant has recently begun operations and the nation's first commercial scale dual flash geothermal project is also scheduled to start up in this area.

The type and quantity of geothermal wastes produced will vary depending upon the geothermal development activities occurring at any given time. As has been emphasized previously different technologies may generate some different residuals. In addition, due to the significant variation in chemical composition, there may be obstacles unique to a given KGRA which may affect the characteristics of waste streams generated from development in that KGRA.

There are five disposal sites in Imperial County authorized to accept geothermal wastes. The IT Corporation Imperial Valley Class II-1 site is permitted to accept geothermal wastes associated with drilling activities and plant operations. These wastes are limited to drilling muds, workover and cleanout fluids, testing fluids, brines and residues (inorganic solids and filter press cake/sludge), cooling water pretreatment sludge, and cooling tower and boiler blowdown sludges from geothermal sources. Certain areas of the Brawley, Calexico, Holtville, and Salton City Class II-2 disposal sites can accept geothermal drilling wastes as approved by the appropriate regional water quality control board. These five disposal sites, as well as any discharge of waste to land in Imperial County, are regulated by the Colorado River Basin Region water quality control board.

4.2.1 Drilling Wastes: Unlike the geothermal drilling wastes generated at the Geysers, drilling wastes generated in the Imperial Valley are not permanently disposed of on-site. This is partially due to the agriculture in this area. Water is diverted from the Colorado River and distributed by a series of canals to support agriculture in the Valley. Excess water is diverted by drainage ditches to the Salton Sea. In order to protect agriculture from heavy metals and other constituents in these geothermal drilling wastes and to prevent any additional salts and dissolved solids from entering the Salton Sea, these wastes are hauled to off-site facilities for disposal.

The regional board requires that geothermal drilling wastes which contain TDS in excess of 6,000 ppm must be disposed at a Class I or Class II-1 site. Geothermal drilling wastes with TDS less than 6,000 ppm which do not contain compounds of arsenic, barium, lead (organic or inorganic), and zinc in concentrations exceeding the limits specified in WDRs may be discharged at certain Class II-2 disposal sites.

4.2.2 Operational Wastes: Wastes generated during operation of geothermal plants in the Imperial Valley include brine and residues, pretreatment sludge from cooling towers, and sludges from cooling towers and boiler blowdown. A scale also gradually deposits on the turbine which must be periodically removed and disposed in an approved site.

The operational waste generated in the largest quantity is brine and associated solids. Spent brines are reinjected to the geothermal producing zone. The brines from the binary plant are kept under pressure to prevent solids from precipitating and are completely reinjected. At the Salton Sea flash plant, 80 to 90% of the brine is reinjected. The Salton Sea brine has a very high TDS content and must be treated prior to subsurface injection. A crystallizer-clarifier process is utilized which produces clarified brine and sludge after several steps. The clarified brine passes through media filters and is then reinjected. The sludge is thickened and then sent to a filter press where a filter cake is formed. The volume of sludge is greatly reduced by this process.

Analytical test results were received for 15 samples of filter press sludge under the agreement that the tables of data would not be reproduced in this report. These samples were analyzed during the period from February 1, 1985 through August 1, 1985. The results for these samples show that the total and soluble concentration for the 20 inorganic parameters listed in Title 22 of the California Administrative Code are below regulatory criteria with the exception of copper. The analytical results indicate the total copper concentration ranges from 320 to 3,600 mg/kg in these 15 samples. Five of these samples exceeded the regulatory copper TTLC criteria of 2,500 mg/kg. The WET soluble concentration of copper in these samples ranged from below 1.0 to 120 mg/l. Seven of these samples exceeded the regulatory STLC criteria of 25 mg/l for copper.

The disposal practice for filter press sludge has been to haul it to the Imperial Valley Class II-1 site. However, methods which reduce metals from this sludge below CAM limits are currently being investigated. A second method to render this sludge nonhazardous is by fixing it in an admix. This results

in a material which has reasonable properties for construction of roads and levees. This material has been analyzed and the results show that all regulated parameters are well below the CAM levels.

The remaining operational wastes are generated in small quantities. They are analyzed for the CAM parameters prior to disposal, however, no analytical data could be obtained for these wastes. Current practice is to haul them to the Imperial Valley Class II-1 site for disposal.

5.0 SUMMARY AND CONCLUSIONS

There are several state regulations pertaining to the disposal of wastes in California. The California state agencies charged with administering these regulations are the California State Water Resources Control Board, the California State Department of Health Services, and the California Division of Oil and Gas.

The State Water Resources Control Board adopted a state policy to preserve and protect the quality of the waters of the state and regulate any activity which may affect water quality. Its nine regional boards implement the state policy and each board regulates the discharge of wastes to land within its own region through the issuance of waste discharge requirements. The State Board also developed a classification scheme for wastes and for waste disposal sites.

The California State Department of Health Services developed criteria to define and identify hazardous wastes. The California Hazardous Waste Control Law and hazardous waste management regulations provide for a program to ensure the safe handling, storage, use, processing, and disposal of hazardous wastes. Prior to the disposal of any material, the Department of Health Services requires that it be analyzed for specific substances using standard analytical methods to determine if it is hazardous or nonhazardous. The analytical results are compared to the threshold limiting concentration for the parameters as established in the California Administrative Code, "Title 22, Environmental Health." If the material is determined to be hazardous, it must be disposed of off-site at a site approved for the disposal of hazardous materials. Hazardous wastes can only be transported by a hauler who is registered with the Department of Health Services. A hazardous waste manifest must be used for recording all hazardous wastes transported off-site to waste management facilities.

The California Division of Oil and Gas has authorization to regulate geothermal wells in a manner to safeguard life, health, property, and public welfare, and to encourage maximum economic recovery. The California Division of Oil and Gas adopted state-wide geothermal regulations which establish requirements and procedures for the drilling, blowout prevention, completion and production, subsidence detection and abatement, injection, and abandonment of geothermal wells. All geothermal injection activities must be approved by and receive a permit from the California Division of Oil and Gas. The comprehensive injection regulations establish procedures for obtaining a permit, specific project information required, well casing testing requirements, and monthly reporting requirements. These regulations represent the basic requirements for injection projects. Each project is evaluated individually and additional requirements may be imposed by the California Division of Oil and Gas for a specific project. The California Division of Oil and Gas has recently requested authorization from EPA to administer geothermal injection wells under the Safe Drinking Water Act since they have an ongoing and proven underground injection control program for these wells.

Sludges and liquid wastes are generated from geothermal power plant operations and during well drilling. These wastes include drilling muds and cuttings, spent brine, inorganic residuals from treatment of brines, sludges from air pollution abatement processes and cooling towers, and process scale. The characteristics of geothermal wastes depend upon the geothermal resource and the specific geothermal technology. The chemical composition of geothermal resources is governed by those elements found naturally in the producing reservoir and by their solubility in water at existing temperature and pressure. Significant differences have been reported in the temperature, salinity, noncondensable gas content, and chemical composition of these resources. The chemical constituents also vary within a given geothermal resource. In addition, several different geothermal technologies are used to convert geothermal resources to electricity which affect the waste streams generated.

The ultimate disposal for geothermal wastes will depend upon the waste classification. In accordance with California regulations, wastes from geothermal power plants are analyzed by standard methods prior to disposal. Analytical results have indicated that some of these wastes have substances in concentrations exceeding state regulatory criteria and must therefore be disposed offsite at an approved disposal site. It is important to note that the quantity of waste generated from geothermal power plant operations which are determined to be hazardous represent a very small fraction of all hazardous wastes generated in the state.

The two areas of California where geothermal activities are concentrated are the Geysers KGRA and the Imperial Valley. There are some minor differences in the current disposal practices for geothermal wastes generated at these two areas. At the Geysers, drilling wastes are disposed in on-site sumps which are regulated by either the North Coast Region or the Central Valley Region water quality control boards. Excess steam condensate is reinjected into the geothermal producing zone. Sludges from cooling towers and hydrogen sulfide abatement systems were transported to the Class II-1 disposal sites in Lake County. Those sites are currently closed and these sludges are hauled to Class I disposal sites in Benicia and Martinez. Although the state does not require that wastes be analyzed for boron, Lake County and the Central Valley Region board have established criteria for boron in geothermal wastes from the Geysers. The three substances that receive the most attention at the Geysers are arsenic, boron, and hydrogen sulfide. In the Imperial Valley, drilling wastes are disposed off-site at either Class II-1 or Class II-2 sites. Brines are reinjected to the geothermal producing zone. Brines with high TDS, particularly those from the Salton Sea KGRA, must be treated prior to subsurface injection. The inorganic residues are dewatered and pressed into a filter cake. The remaining operational wastes are transported to the Imperial Valley Class II-1 disposal site.

Based on conversations with geothermal industry representatives, there do not appear to be any difficulties meeting the California state regulations for disposal of geothermal wastes and there appear to be adequate disposal sites for geothermal wastes. The two main concerns seem to be the high cost of disposal and the long term liability associated with hazardous waste disposal.

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APPENDIX A

Geographic Distribution of the Subdivisions of Selected

California State Agencies

Figure A.1 Regional water quality control boards of the State Water Resources Control Board.

Figure A.2 Toxic substance control divisions (TSCD) of the Department of Health Services.

Figure A.3 Geothermal districts of the California Division of Oil and Gas

APPENDIX B

Structure of Selected California State Regulations

TABLE B.1

Structure of the California Porter - Cologne Water Quality Act

Chapter	1 :	Policy
Chapter	2 :	Definitions
Chapter	3 :	State Water Quality Control
Chapter	4 :	Regional Water Quality Control
Chapter	5 :	Enforcement and Implementation
Chapter 5.5 :		Compliance with the Federal Water Pollution Control Act as amended in 1972
Chapter	6 :	State Financial Assistance
Chapter	7 :	Water Reclamation
Chapter	8 :	Federal Assistance for Treatment Facilities
Chapter	9 :	Municipal Waste Water Treatment Plant Classification and Operator Certification
Chapter	10 :	Water Wells and Cathodic Protection Wells

TABLE B.2

Structure of the Subchapter 15 Discharges of Waste to Land

Article 1 : General

Article 2 : Waste Classification and Management

Article 3 : Waste Management Unit Classification and Siting

Article 4 : Construction Standards

Article 5 : Water Quality Monitoring for Classified Waste Management Units

Article 6 : Confined Animal Facilities

Article 7 : Mining Waste Management

Article 8 : Closure and Post-Closure Maintenance

Article 9 : Compliance Procedures

Article 10 : Definitions

TABLE B.3

Structure of the California Hazardous Waste Control Act

Article 1 :	Findings and Declaration
Article 2 :	Definitions
Article 3 :	Hazardous Waste Technical Advisory Committee
Article 4 :	Listings
Article 4.5 :	State Regulation of Existing Hazardous Waste Facilities
Article 5 :	Standards
Article 5.5 :	Coordination with Federal Acts
Article 6 :	Transportation
Article 6.5 :	Hazardous Waste Haulers
Article 7 :	Treatment, Recycling, and Disposal Technology
Article 8 :	Enforcement
Article 8.3 :	Hazardous Waste Enforcement Coordinator and Strike Force
Article 8.5 :	Hazardous Waste Testing Laboratories
Article 9 :	Permitting of Facilities
Article 9.5 :	Surface Impoundments
Article 10 :	Prohibited Chemicals
Article 11 :	Hazardous Waste Disposal Land Use
Article 12 :	Financial Responsibility and Closure and Maintenance of Facilities

TABLE B.4

Structure of the California Hazardous Waste Management Regulations

Article 1 :	Definitions
Article 2 :	Scope
Article 3 :	Enforcement and Inspections
Article 4 :	Hazardous Waste Facility Permit
Article 5 :	Hazardous Waste Hauler Registration
Article 6 :	Requirements for Management of Hazardous and Extremely Hazardous Wastes
Article 7 :	Additional Requirements for Management of Extremely Hazardous Wastes
Article 8 :	Fees
Article 9 :	Hazardous Wastes and Hazardous Materials
Article 10 :	Extremely Hazardous Wastes and Extremely Hazardous Materials (Section Repealed)
Article 11 :	Criteria for Identification of Hazardous and Extremely Hazardous Wastes
Article 12 :	Recyclable Hazardous Wastes
Article 13 :	Infectious Waste
Article 14 :	Prohibited Chemical Toilet Additives
Article 15 :	Land Disposal Restrictions

TABLE B.5

Structure of the California State-Wide Geothermal Regulations

Article	1 :	General
Article	2 :	Definitions
Article	3 :	Drilling
Article	4 :	Blowout Prevention
Article	5 :	Completion and Production
Article	6 :	Injection
Article	7 :	Subsidence
Article	8 :	Abandonment
Article	9 :	Complaints and Appeals