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SITE 300 HAZARDOUS WASTE ASSESSMENT PROJECT

Interim Report: December 1981

Preliminary Site Reconnaissance and Projected Work Plan

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ABSTRACT

This document was prepared to outline the scope and objectives of the Hazardous Waste Assessment Project (HWAP) at Site 300. This project was initiated in October, 1981, to investigate the existing solid waste landfills in an effort to satisfy regulatory guidelines and assess the potential for ground-water contamination. This involves a site-specific investigation (utilizing geology, hydrology, geophysics and geochemistry) with the goal of developing an effective ground-water quality monitoring network. This goal will be accomplished in three phases: (1) Initial Site Reconnaissance, (2) Exploration and Analysis, and (3) Final System Installation and Analysis. The proposed work plans for Phases 1 and 2 of the project are presented.

Initial site reconnaissance work has begun and we report the results, to date, of our geologic and hydrogeologic studies. All known solid waste disposal locations are underlain by rocks of either the Late Miocene Neroly Formation or the Cierbo Formation, both of which are dominantly sandstones interbedded with shale and claystone. The existence of a regional confined (artesian) aquifer, as well as a regional water-table aquifer is postulated for Site 300. Preliminary analysis has led to an understanding of directions and depths of regional ground-water flow.

I. INTRODUCTION

A new project known as the Hazardous Waste Assessment Project (HWAP) for Site 300 is being launched to assess whether the solid waste landfills have any effect on the environment. The assessment will involve characterization of the geology, hydrogeology and the migratory behavior of toxic materials (uranium, beryllium, etc.) currently buried in eight landfills. The potential for the introduction of contaminants during past operations will be reviewed and a detailed plan for compliance with regulations will be developed and implemented. This project will require support primarily from K-Division with the overall coordination of the effort by the Toxic Waste Control Group.

The project originated because of a number of recent new state and federal laws concerning hazardous waste disposal. These regulations are now administered through the Title 22, Division 4, Chapter 30 - California Administrative Code, "Minimum Standards for Management of Hazardous and Extremely Hazardous Wastes" and Title 23, Chapter 3, Subchapter 15, "Waste Disposal to Land."

This document reviews the information obtained, to date, and presents our preliminary interpretations based on initial site reconnaissance work. The projected Work Plan for Phases 1 and 2 of the Site 300 investigation is also presented. This plan is open to further review and modification based upon the results of hydrogeologic and geophysical studies now in progress.

II. PROJECT SCOPE

The overall objective of this project is to investigate the existing hazardous waste landfills at Site 300 in an effort to satisfy regulatory guidelines and assess the potential for ground-water contamination. The primary requirement states that discharge must remain within the designated disposal area at all times. A secondary requirement states that the presence/absence of wastes in the ground-water must be established. Because a variety of waste materials are handled at Site 300, we will conduct a site-specific investigation with the goal of improving the already existing ground-water quality monitoring plan that will allow us to:

- o Delineate the location, nature and extent of any ground-water contamination that may have occurred as a result of contaminant inputs from hazardous waste landfills,
- o Provide documentation of the baseline or pre-disturbance chemical composition of the ground water,
- o Design and install an economically feasible state-of-the-art monitoring system for assessment of the effectiveness of waste management or for provision of early warning so that remedial measures may be taken.

The project we propose is divided into 3 phases. Figure 1 shows the work breakdown structure that describes the relationship and interface between the various technical elements. During each phase, tasks can be broken down into 4 work groups: (1) engineering geology, (2) geophysics, (3) hydrogeology, and (4) geochemistry.

Phase 1. Site Reconnaissance: This includes both a preliminary and final assessment of geological, hydrological, geochemical and geophysical conditions to establish the potential for ground-water contamination. Every effort will be made to find existing information (e.g. reports, well logs, maps, memorandums) and/or collect and interpret field data to determine subsurface conditions in order to minimize drilling costs.

Phase 2. Exploration and Analysis: After completion of the initial site reconnaissance, an Exploration and Analysis program will begin. This will include designs for an initial ground-water monitoring and sampling network, an exploratory drilling and sampling field program and laboratory support studies. The exploratory drilling program will be implemented such that all wells be completed as monitoring wells. It is presently anticipated that this will significantly reduce the amount of work to be done in Phase 3 of the project.

This program will include the minimum number of wells necessary to verify hydraulic gradients across landfill areas and establish whether contaminants have entered the ground-water region. A report will be issued at the end of Phase 2 allowing a final site reconnaissance based upon the additional geological, geophysical, hydrological and geochemical information obtained.

Phase 3. Final System Installation and Analysis: Based upon the results obtained from Phase 2, a final ground-water monitoring network will be designed for each landfill area. If in Phase 2, no contamination is found and hydraulic gradients have been well established, no further drilling or laboratory supports studies may be necessary. A final project report will then be issued.

If, however, ground-water contamination is observed, a monitoring network, based on regulatory standards, will be implemented. Data from field surveys can be analyzed to quantify the spread of contaminants and to predict something about probable future movements.

III. INITIAL SITE RECONNAISSANCE WORK

There are eight solid waste disposal pits located at Site 300. The specific locations are plotted on the map in Fig. 2. In addition, another landfill, south of Building 845, was recently identified. Although other hazardous materials have been buried in some of the older landfill areas, the largest volume of hazardous waste generated at Site 300 is primarily from the firing table debris. Only depleted uranium (D-38), beryllium and thorium are permitted in the landfills at Site 300. On an annual basis, this amounts to about 850 Kg of D-38 and 125 Kg of beryllium in debris that occupies approximately $1600m^3$ and weighs 7.1×10^7 Kg (Roberts, 1980). The operational controls used at the landfills to limit the quantity of hazardous waste present at any given time were derived using guidelines established by the NRC (Title 10, Part 20.304.)

The restrictions state that: (1) the total quantity of radioactive materials buried at any one location and time may not exceed approximately 0.1 curies in any given location (equal to 300 Kg of D-38), (2) burial is at a minimum depth of four feet, and (3) successive burials are separated by distances of at least six feet and not more than 12 burials are made in any year.

Initial field reconnaissance work has been completed. Besides the initial field observations, this has involved an evaluation of existing information available for the Site 300 area. Site specific observations concerning the geologic setting of the landfill areas have been compiled. There are presently two available geologic maps of the Site 300 area. These are the maps of Huey (1948), shown in Figures 3 and 4, and Dibblee (1980) shown in Figures 5 and 6.

1. Geologic Setting

Site 300 is located in the eastern portion of the Altamont Hills, an elevated area that separates the Livermore Valley to the west from the San Joaquin Valley to the east. Summit elevations within the Altamont Hills generally range from about 1000 to 2000 feet above mean sea level; local relief is generally in the order of 200 to 400 feet.

The Altamont Hills are underlain by a sequence of late Cretaceous to Late Tertiary marine sedimentary rocks. These have been subdivided by Dibblee (1980) into six mapable units of which two, the Miocene Cierbo and Neroly Formations, are pertinent to the Hazardous Waste Assessment Project at Site 300.

The Cierbo Formation is exposed chiefly in the western portion of Site 300 (see Fig. 5, map unit Tmss). It consists dominantly of tan to gray, poorly cemented, fine to coarse grained, locally pebbly, sandstone with clay shale interbeds. The Cierbo Formation has been found to directly underlie the Pit 7 area, an observation at variance with published mapping.

Overlying the Cierbo is the late Miocene Neroly Formation (map unit Tn). The other known landfill locations, as well as most of Site 300, are underlain by rocks of this formation (Huey, 1948, Dibblee, 1980). These consist dominantly of fine to coarse grained bluish sandstones but contain locally significant amounts of conglomerate, shale and claystone. The bluish color is imparted to the sandstone by a montmorillonoid group mineral. Neroly Formation beds are commonly jointed; three sets with 0.5-2 foot spacings were noted in many outcrops. In outcrops, joint surfaces are clean or coated with caliche. Joint surface mineralization and degree of joint opennness with depth are presently unknown.

Although porous beds probably exist within the Neroly and Cierbo formations, fracture flow may be dominant in the rocks beneath Site 300. The claystone and shale interbeds within these formations could act as perching and/or confining horizons and their presence may further complicate the hydrologic system.

The rocks beneath Site 300 have been deformed into several relatively gentle anticlinal and synclinal folds (see Fig. 4). Principal folds are the Patterson anticline that trends through the north-central portion of the Site and an unnamed syncline located further to the northeast (see Fig. 5). The overall degree of deformation within the rocks beneath Site 300 is less than that often seen in rocks of similar age in the California Coast Ranges.

The Altamont Hills are bounded on the west by the active Greenville Fault zone (Carpenter and others, 1980). A number of faults have been mapped within the Altamont Hills (Huey, 1948, Herd, 1979, Dibblee, 1980). Herd (1979) has suggested that some of these faults show evidence of late Quaternary movement.

Two faults have been mapped within the Site 300 boundaries (Dibblee, 1980). These are the Carnegie Fault, located near the southwestern boundary of the site (see Fig. 5), and the Elk Ravine Fault which passes through the northeastern portion of Site 300. Neither of these faults has been studied in detail and the Elk Ravine Fault des not appear on geologic maps of the Site 300 area published prior to Dibblee's work (Huey, 1948, California Division of Mines and Geology, 1966).

Soils underlying solid waste disposal at Site 300 are generally thin (probably less than two feet at most locations) and consist dominantly of silty, gravelly sands and sandy silts. These materials are mostly non-plastic and non-cohesive. They appear to contain little clay and appear readily erodible.

Reconnaissance geologic descriptions of each of the known landfills at Site 300 follow:

Pit 1: Pit 1 is an active landfill located in a small drainage basin tributary to Elk Ravine. The pit is located near the center of Section 16 about one-fourth mile southeast of the ATA construction site. Pit 1 is the only active landfill site in the East Area of Site 300 and is rapidly filling.

Surface drainage from Pit 1 is to the south toward Elk Ravine. Surface soils are silty, gravelly sands and appear shallow and erodible. These soils have been used between cells and as cover material on the landfill. Neroly Formation beds exposed in bluffs north of the pit strike about N40°W and dip 15°NE. They consist dominantly of fine grained sandstone with minor tuffaceous shale interbeds.

Dibblee (1980) maps a branch of the Elk Ravine Fault as passing beneath the northerly portion of the Pit 1 site. Little is known about the Elk Ravine Fault. Woodward-Clyde Consultants (1979) did not discuss it during their geotechnical appraisal of the nearby ATA site. However, it should be noted that their report was issued prior to the publication of Dibblee's map.

Pit 2: Pit 2 is located about 1000 feet south-southwest of Pit 1 and is in Elk Ravine at the confluence of several major drainages. Pit 2 is inactive. Reportedly, material was buried here to depths of 6 to 8 feet and then covered with local soil. Recent erosion that post dates burial has resulted in gullies up to three feet deep across the pit area.

Surface soils in the vicinity of the pit consist of silty, gravelly sands with traces of clay. Bedrock consists of poorly cemented sandstone and conglomerate of the Neroly Formation. The beds are nearly flat lying. The

Elk Ravine Fault is mapped by Dibblee (1980) as passing through the waste disposal site.

Pit 7 Area: The Pit 7 area consists of an active landfill (Pit 7) and several older disposal pits (3, 4 and 5) located nearby. The site is located on the Alameda-San Joaquin County line near the center of Section 17. Surface drainage is southeast and then east to Elk Ravine.

Field reconnaissance revealed that the Pit 7 area is underlain by beds of the upper Miocene Cierbo Formation as described by Huey (1948). As stated previously, this observation is at variance with published geologic maps that include the Site 300 area (Huey, 1948, Dibblee, 1980). Exposures in the walls of the cut made for the active pit show poorly cemented, coarse grained sandstone overlain by clay shale. The beds dip gently to the northeast. It appears that the waste is in direct contact with the sandstone as there is no evidence of an impermeable bottom lining.

Local soils exposed at the top of the pit excavation consist of sandy to clayey silts. These may have potential as impermeable lining materials but percolation tests on compacted specimens would be needed in order to make a definite determination.

Characteristics of the older disposal areas could not be visually observed but are probably similar to Pit 7. Some debris was noticeable projecting through the sandy surface soil blanket.

Pit 8: Pit 8 is an inactive landfill located in the SW 1/4 Sec. 15 about 400 feet east of Building 801. A mudflow occurred at this site in 1978 inundating the area around Building 801. There is evidence of past erosion of natural soils and waste materials by a west-flowing tributary to Elk Ravine.

Surface soils beneath Pit 8 consist of erodible silty sands and gravels which appear thin. Bedrock is exposed in a cut face north of Building 801 and also a short distance upstream from the debris dam which is located east of Building 801. The rock consists of jointed Neroly sandstone with claystone interbeds. The rock sequence strikes northwest and dips gently downstream to the southwest.

Pit 6: Pistol Range Area: This site is located in the NW 1/4 Sec. 33 along the south boundary of Site 300 adjacent to Corral Hollow. The Carnegie Motorcycle Park is located immediately south of the site across Corral Hollow. Ground water moving through alluvium beneath Corral Hollow constitutes a shallow aquifer that furnishes potable water to scattered residences in the area and may also serve the motorcycle park.

Waste was disposed of in trenches excavated into terrace deposits and possibly in part into the underlying highly fractured bedrock. The pits were covered with a shallow blanket of local soil.

The terrace deposits appear thin and consist of silty sand and gravel locally underlain by a dense clay bed. Bedrock is exposed along the southern boundary of the site and consists of highly fractured, steeply dipping, Neroly Formation sandstone and shale. Dibblee (1980) maps the Carnegie Fault as passing roughly beneath the site. The fault separates the steeply dipping beds seen south of the site from gently dipping rocks exposed in the hills to the north. According to Dibblee, beds of the Plio-Pleistocene Livermore Formation are displaced by the Carnegie Fault but younger terrace deposits (mapped as Qoa) are not displaced.

A spring exists about 300 feet southeast of the Pistol Range site. The spring issues from the contact between the terrace deposits and bedrock sequence and discharges into a drainage ditch. The exposure is in the access road cut and is inadequate to permit determination of the nature of the contact. However, a clay bed within the terrace deposits overlies the spring area and shows no evidence of disturbance.

Building 845 Site: This inactive waste disposal location was recently discovered. The site is about 100 feet south of Building 845 in the east half of Sec. 21. The site is on the lower edge of the hillside and appears to be outside the main path taken by surface runoff.

Waste has been covered with local soil, a slightly plastic clayey, gravelly silt. Exposures of moderately jointed Neroly Formation sandstone occur north and west of the disposal site.

2. Hydrogeologic Setting

In their report of a geological and seismological investigation, Thorpe and Wright (1976) give a brief description of the hydrology at Site 300. Their statement is given below in its entirety:

> "Site 300 has a semi-arid climate, with an average yearly rainfall of about 0.25 m (Huey, 1948). The streams of the site are all intermittent, flowing only briefly during the wetter months. The main drainage channel of the area, Corral Hollow Creek, runs along the southern and southeastern site boundaries. In the southwestern corner of the site several springs occur along the traces of major faults.
>
> At least 17 water wells have been drilled at Site 300, only 7 of which are currently in active or standby use. Water in the inactive wells is either of poor quality or nonexistent. The main source of water comes from wells along Corral Hollow, where the water table is 9 m or less below the ground surface. Elsewhere on the site, ground-water has been located in valleys at depths ranging from 15 to 60 m."

R. Stone (1976) suggests that water-table conditions at Site 300 are sufficiently straightforward that the following generalization is applicable; "the water table ... reflects the ground surface topography, but with diminished relief".

These previous statements summarize what was known about the regional hydrology of Site 300 at the beginning of the present investigation. As an initial part of our reconnaissance, we collected valuable first-hand information on the location of springs, some of which are newly identified, and wells which have been plotted on the Site Map in Fig. 2. The assistance of Site 300 personnel was invaluable in locating the springs during October before the seasonal rains commenced.

Several older capped wells have been made accessible for our use (W12, W13, W15, W17). A preliminary water-level contour map based on October water levels, piezometric measurements and spring locations has been plotted on Dibblee's map (Fig. 5). An initial review of the existing on-site well data has been completed. Available information concerning depths of wells, perforation intervals, water-bearing units, and static water levels has been tabulated in Table 1. Records of previous pumping tests have not yet been analyzed.

Table 1

Information Compiled From Drill Logs of Boreholes at Site 300

Borehole	Depth (Ft)	Perforations (Ft)	Land Surface Elevation (Ft)	Static Water Depth (Ft) (Date)	Driller's Notes (W.B.=Water Bearing) (ss = sandstone) (sh = shale)	(Ft)
W1	152	80-148	1023	60 (12/81) 68 (3/56)	W.B. yellow ss W.B. br ss	70-80 110-140
W2	144	52-144	915	120 (3/56)	W.B. blue clay W.B. yellow clay W.B. sand & gravel W.B. sand & [illegible] W.B. sand & gravel	20-25 25-38 80-90 100-112 120-134
W3	160	49-148	1000	38.1 (12/81) 38 (3/56)	W.B. br ss	38-55
W4	180/517	40-80 300-517	540	19 (4/56) Flow 0 (4/79)	Artesian at 303' W.B. blue ss br ss br ss & shale	 19-53 53-100 145-165
W5	257	none	975	---	Dry, not cased	
W6	152	42-146	530	30 (8/56)	W.B. gravel yellow clay & rk	30-45 45-55
W7	180	60-180	509	17.8 (12/81)	Artesian at 120'(br ss-soft) W.B. br ss (hard)	 90-105
W8	150	54-62 78-102 126-138	1249	5.9 (12/81) 11 (1/58)	W.B. (Trickle) W.B. (Crack) W.B. (Best Water)	30 55 126-134
W9	178	none		-- (3/58)	Dry, not cased	
W10	258	none		170	No water to 161' Well not cased	

Table 1 - cont'd.

Borehole	Depth (Ft)	Perforations (Ft)	Land Surface Elevation (Ft)	Static Water Depth (Ft) (Date)	Driller's Notes (W.B.=Water Bearing) (ss = sandstone) (sh = shale)	(Ft)
W11	310	none	1544	230	Well not cased W.B. br ss & sh blue sh	 133-158 230-270
W12	268	140-256		129.3 (12/81)		
W12A	109.5 (sounded 12/81)			Dry (12/81)		
W13	310	130-232 238-306		208.8 (12/81) 135 (4/59)	W.B. blue ss & sh gray ss & sh br & gray ss & sh blu sand & gravel	160-175 175-199 235-276 290-310
W13A	165.1 (sounded 12/81)			Dry (12/81)		
W14	185			Dry (11/60)		
W15	150	70-124		46.2 (12/81) 65 (11/60)		
W16	240			Dry (11/60)		
W17	240		1051.0	66 (12/81) 215 (11/60)		
W18	310/545	150-232 235-306 425-475		135 Flow 0 (10/79)	Artesian @ 400' 1st Water @ 160' W.B. gravel	 296-320
CCP1				13.7 (12/81)		

Table 1 - cont'd.

Borehole	Depth (Ft)	Perforations (Ft)	Land Surface Elevation (Ft)	Static Water Depth (Ft) (Date)	Driller's Notes (W.B.=Water Bearing) (ss = sandstone) (sh = shale)	(Ft)
CCP2	560				blk sh & fire sand gray/blk fire sand & sh	385-448 461-545
Farmer's Well				130	Located between W12 & W13	
USGS #1	120	none		23 (2/80)	Not cased (located North of W8) 1st water level @ 53'	
USGS #2	120	none		15 (3/80)	Not cased (North of W8) 1st water level @ 78'	
USGS #3	120	none		15 (2/80)	Not cased (North of W8) 1st water level @ 48'	
CDF 1				14.4 (12/81)		
CDF 2				13.9 (12/81)		
MS 1				30 (12/81)		

Based on our initial reconnaissance, we postulate that there is a regional confined aquifer as well as a regional water-table aquifer at Site 300. The existence of an unconfined (water-table) aquifer and a confined (artesian) aquifer separated by a confining bed is clearly evidenced in the general services area located in the southeast corner of Site 300. Wells 4 and 18 penetrate both aquifers whereas wells 6 and 7 intercept only the unconfined aquifer. Because wells 4 and 18 are perforated in both aquifers they serve as hydraulic conduits between the aquifers which previously were hydraulically separated by one or more beds of extemely low vertical permeability (confining beds). This recent hydraulic connection is indicated by the gradual increase in pressure within nearby well 6. Pressures in the underlying artesian aquifer tapped by wells 4 and 18 have migrated outward from them locally through the overlying unconfined zone which they also tap.

This description is consistent with a previous interpretation of a pumping test in September 1979 involving wells 4 and 18 (Olsen, 1980). The slow response of well 4 to a sequence of pumping, cessation-of-pumping, followed by capping of well 18 was explained in terms of the interconnection within well 4 of the two aquifers.

Based on these observations, a number of simple generalizations can be made which will lead eventually to postulating directions and depths of regional ground-water flow:

1.) There exists an unconfined (water-table) aquifer.

2.) There exists a confined (artesian) aquifer.

3.) The two aquifer systems are separated effectively.

4.) This observed hydraulic separation requires a regionally extensive confining bed to exist between them.

5.) The two systems can be and have been hydraulically connected locally by vertical boreholes that intercept both.

6.) Even though systems of permeable vertical fractures are observed to occur and in places may be sufficiently interconnected to serve as a hydraulic conduit between the two aquifers, such natural connections are not sufficiently widespread to alter the basically regional aspect of the hydraulic separation.

Figure 5 shows the water-level contour map based on spring-location and water-well level data obtained from field reconnaissance. This information has been superimposed on Dibblee's (1980) geologic map. Based on a preliminary analysis, it seems that along the southern and southeastern boundary of Site 300 both the confined aquifer and the unconfined aquifer flow generally southeastward towards Corral Hollow. One can expect them ultimately to discharge into the creek. Along the southwestern side of the upper part of Elk Ravine (within Site 300) the ground-water flow is generally northeastward towards the ravine. This is likely true of both the confined and the unconfined aquifers. There must, therefore, exist a ground-water divide between Elk Ravine and Corral Hollow for each of the two aquifers.

The major question concerns the most likely location for a ground-water divide. For the unconfined aquifer, this location probably lies along the major surface-water divide between the Elk Ravine and Corral Hollow drainage basins. For the confined aquifer, Patterson anticline is the most likely ground-water divide for the following reasons:

1.) The confined aquifer must receive its recharge from somewhere between Elk Ravine and Corral Hollow.

2.) Because the Neroly formation is exposed at land surface near the general services area, where wells 4, 6, 7, and 18 are located, the confined aquifer is probably either a lower member of the Neroly or the Cierbo formation which conformably underlies the Neroly.

3.) The Cierbo formation is exposed over a sizeable area in the west central part of Site 300 between Elk Ravine and Corral Hollow. It is reasonable to postulate that recharge for the confined aquifer takes place in this area.

4.) Because the saturated zone of the exposed Cierbo formation lies from a few tens to a few hundred feet below land surface (depending largely on land elevation), the primary recharge to the confined aquifer beneath the Neroly formation probably occurs in deeply incised Cierbo ravines during the rainy season.

5.) The essentially east-west trending Patterson anticline essentially bisects the exposed Cierbo formation. Although the Patterson anticline probably does not control the direction of the flow within the unconfined aquifer, this structure probably controls the direction of flow in the confined aquifer beneath the Neroly formation.

Based on the foregoing observations, one would expect a component of flow in the confined aquifer to be northward between Patterson anticline and the nearest syncline to the north (mapped by Huey (1948) and Dibblee (1980) as roughly parallel to Elk Ravine). One would also expect another component of flow in the confined aquifer to be largely southeast between Patterson anticline and Corral Hollow. Observed water levels in wells and springs tend to corroborate this expectation.

If these proposed interpretations are true, one would also expect an eastward component of flow in the confined aquifer following the plunge of Patterson anticline. The eastern limit of Patterson anticline merges with Elk Ravine near building 812. At this very point, Elk Ravine has incised the Neroly formation so deeply that the Cierbo formation is exposed (Huey, 1948). One would expect ground water to discharge near the point where the plunging Patterson anticline meets the exposed contact between the Neroly and Cierbo formations. A spring is located precisely at this location.

Similiarly, one would expect springs to occur within incised valleys along the north side of the Carnegie fault. The regional confining bed is either sheared, fractured, or removed by erosion along the fault trace such that artesian water in the underlying Cierbo is hydraulically free to flow to land surface. Such springs do exist along the north side of the Carnegie Fault.

We can, therefore, conclude that treating Patterson anticline as a ground-water divide for the confined aquifer and the Cierbo formation, where exposed, as the primary recharge zone is a reasonable working hypothesis. A corollary to this hypothesis is: Within the exposed Cierbo formation the unconfined (water-table) aquifer is hydraulically more closely connected to the confined aquifer beneath the Neroly formation than it is to the unconfined (water-table) aquifer of the Neroly formation which underlies a major portion of Site 300.

Flow within the unconfined (water-table) aquifer of the Neroly formation is not easily defined. The general direction of water-table ground-water flow is expected to coincide with muted or highly smoothed gradients of land-surface topography. The permeability of the Neroly formation is likely to vary from place to place (heterogenous) and may differ depending on direction of flow (anisotropic). One might expect perched aquifers above the regional water table to occur locally, further complicating the ground-water picture at any specified location.

The source of some of the intermittent springs at Site 300 may be the local water table. Such springs are expected to occur at the toe of exposed permeable material, such as landslide or terrace deposits, where there is an exposed downgradient contact with underlying impermeable material, such as the Neroly formation or hydraulically tight fault. Part of our task is to try to distinguish springs whose source is a water-table aquifer from those whose source is a confined aquifer.

These interpretations will now be applied to the site specific landfill areas to predict local ground-water gradients.

Pit 1: The surface water drainage in the vicinity of Pit 1 is generally south to southeastward towards Elk Ravine. Therefore, the inferred direction of ground-water flow within the unconfined (water-table) aquifer is also southward and eastward. The underlying Neroly formation, however, dips toward the northeast. Since the postulated direction of flow within the confined aquifer follows the geologic structure, it is correspondingly towards the northeast. Unless the postulated Elk Ravine fault controls ground-water flow locally in some unforeseen way, we expect ground water in the two postulated aquifers beneath the site to flow in distinctly different directions.

Pit 2: The hydrologic environment of Pit 2 is dominated by surface water flow during the rainy season and by related erosion and mass transport of solid material downstream. The land surface of Pit 2 is probably closest to the underlying water table because of its valley location. The inferred direction of ground-water flow in the unconfined aquifer is southeastward as for Pit 1. The postulated direction of flow in the confined aquifer is towards the northeast. Water level fluctuation in well 17 located several hundred feet downstream will be monitored carefully, especially for high water levels during the rainy season. The depth to water in December 1981 was 66 feet.

Pit 7 Area: According to geologic reconnaissance, the Cierbo formation directly underlies the Pit 7 area. Therefore, we postulate the existence of only a unconfined (water-table) aquifer. The contact between the Cierbo and Neroly formation is immediately down gradient topographically to the southeast of this area. All other disposal pits in Site 300 are located on the Neroly formation. Hence, the Pit 7 area (which includes Pits 3, 4, 5, and 7) is the only disposal site that is postulated to recharge the confined aquifer system directly. The general direction of ground-water flow is expected to be eastward towards Elk Ravine. Whether it is more northeastward or southeastward depends on the sensitivity of the ground-water gradient to local details of topography and structure.

Pit 8: Pit 8 is located between the Elk Ravine Fault to the south and an unnamed syncline to the north. Similar to Pit 1 the direction of stratigraphic dip is distinct from the general direction of surface water drainage.

The inferred direction of flow within the unconfined aquifer is southwestward toward Elk Ravine. Water within the confined aquifer is expected to flow northeastward parallel to the regional structural dip (Dibblee, 1980).

Pit 6 (Pistol Range Area): The surface drainage in the vicinity of Pit 6 is southeastward towards Corral Hollow. Both the unconfined and confined aquifer flows are generally parallel to the surface flow. One can expect them to discharge ultimately into the creek. The water-table aquifer is expected to be no more than 50 feet below surface.

IV. PROJECTED WORK PLAN

This section presents the proposed work plans necessary for the completion of Phases 1 and 2 of the project. It is estimated that this work will be finished by June, 1982. The work breakdown structure diagram illustrated in Fig. 1 shows the interaction between the various technical elements. Tasks 1-4 of Phase 1 will be coordinated and completed concurrently. A more detailed site evaluation will occur after additional information is obtained from Phase 2.

1. Phase 1: Site Reconnaissance

Task 1: Geological Assessment

The following is the program of additional geologic studies necessary to meet Phase 1 requirements for each of the six known solid waste disposal locations. If other solid waste disposal locations are identified at Site 300, these will be inspected and plans formulated for their investigation. General geologic studies will include an examination of well-exposed sections of the Cierbo and Neroly formations in order to assist in projecting stratigraphy beneath the landfills. This work will also provide data on potential confining beds and provide stratigraphic sections for correlations across known and inferred faults.

Pit 1: A geologic map of the pit and its environs (scale 1" = 200') will be prepared. The map will include the drainage basin above the pit and an area extending about 1000 feet downstream. Since Pit 1 is located near the crest of a drainage divide, the map will be extended southeastward across the divide to include the northerly portion of the adjacent gully. The map will include locations of all outcrops, stratigraphic and structural data and contacts between major lithologic units if these can be estimated based upon outcrops and float. Faults and lineaments will be shown. The map will also show locations of slides or slumps and areas of thicker colluvial or alluvial soils. Waste disposal areas and the locations of wells, springs and boreholes will be shown on the map. Following completion of mapping, a technical memo summarizing field observations will be prepared.

A branch of the Elk Ravine Fault has been mapped through the Pit 1 area. Little is known concerning this fault. Surface mapping will be supplemented with airphoto studies in an effort to identify the fault trace and, if judged necessary, a trench or bulldozer cut excavated in an effort to expose it. The trench will be logged in accordance with generally accepted geologic practices, and State of California requirements.

Pit 2: A geologic map will be prepared for the pit and its environs. The map area would extend about 1000 feet upstream and downstream from the pit area and include the lower slopes of hills on both sides of the ravine. The map could be made continuous with that for Pit 1 and mapping accomplished as one project. Data plotted will be as for Pit 1. Following completion of mapping, a technical memo summarizing field observations will be prepared.

Pit 7 Area: A geologic map will be prepared for the area of the active pit and the 4 adjacent older disposal sites. The map will extend from the crest of the drainage divide northwest of Pit 7 to at least 1000 feet downstream from the older waste disposal locations. The map area will extend to about elevation 1450 on the valley sides northeast and southwest of the pits. Data plotted will be as for Pit 1 and a technical memo will be prepared following completion of mapping.

Pit 8: A geologic map will be prepared for the pit site and its environs. The area to be mapped will include the drainage basin above Pit 8 and the area downstream to Elk Ravine. Data plotted will be as for Pit 1 and a technical memo will be prepared following completion of mapping.

Pistol Range Area (Pit 6): A geologic map will be prepared for the site and its environs. The area to be mapped will extend from the first major cross drainage upstream of the site to the trailer home located about one-fourth mile downstream. The elevation 750 contour will be used to define the northern limit of the site and the south side of Corral Hollow will define the south limit of the study area. A blow up of a small portion of the Midway 7 1/2 minute quadrange will have to be used as a base map for the area south of Tesla Road since the detailed Site 300 map does not extend into that area. Data plotted will be as for Pit 1 and a technical memo will be prepared following completion of mapping.

Additional data will be collected concerning the Carnegie Fault. This will include closer examination of the spring southeast of the Pistol Range site, airphoto study, and reconnaissance along the fault trace. If judged necessary, a bulldozer cut or trench will be excavated across the fault and logged in accordance with generally accepted geologic practices and State of California requirements.

Building 845 Site: Study of this site is currently proposed to be limited to geologic mapping pending determination of the degree of hazard posed by it. The map area will include the small drainage basing upstream from the site and an area extending about 1000 feet downstream. Data plotted will be as for Pit 1 and a technical memo will be prepared following completion of mapping.

Task 2: Hydrological Assessment

The initial hydrologic assessment involves understanding as much as possible about the regional ground-water flow prior to any drilling activities. Besides the information already presented, additional studies are proposed prior to Phase 2 activities.

1. Further gathering of existing data, particularly from immediately surrounding areas. Whatever information is available on precipitation and evaportranspiration rates will be gathered. Similar information will be gathered for possible surface-water runoff, septic tank percolation tests, and water wells.

2. All available data will be analyzed more fully. For example, analysis of earlier pumping tests on site may give information of flow characteristics of both the unconfined (water-table) aquifer and the confined aquifer.

3. Data that controls regional flow will be plotted in more detail than it is at present. These maps, largely on overlays, will be plotted on the same scale.

   A) A base map showing topography and locations of water-level measurements.

   B) Water-level contour overlays showing both seasonal low water levels, and seasonal high water levels. Water levels will be measured on a monthly basis.

   C) The relationship and location of major structural features, such as faults, synclines and anticlines. Information from the geologic studies will be included.

   D) Contacts between geologic formations, especially the Neroly and Cierbo. Using the elevations of these contacts and other information, contour roughly where the base of the Neroly can be expected. Information from the geologic studies will be included.

   E) Outlines of the major drainage basins. The drainage areas above each disposal pit will be included.

Analysis of these maps will help determine critical locations where more detailed information is required and what the nature of this information must be. For example, the influence of the postulated Elk Ravine Fault on ground-water flow is unknown. This fault is plotted by Dibblee (1980) but not by Huey (1948). It is necessary to combine geological and geophysical assessments to determine the possible influence of the Elk Ravine Fault on regional ground-water flow.

Task 3: Geophysical Assessment

It is hoped that surface geophysical methods may be useful as a cost effective first approximation for determining the depth to the water table and tracking any potential ground-water contaminant plumes. This information will be used in planning the ground-water quality monitoring network necessary for Phase 2 by allowing a more effective selection of drilling locations. Surface geophysics is relatively new in the field of contaminant hydrogeology, but at some sites has been shown to be extremely effective (University of Waterloo, 1981). The following plan is based on an intitial reconnaissance of Site 300 hydrogeologic conditions and an assessment of appropriate geophysical techniques.

Dipole-Dipole Resistivity Survey

Based on our initial evaluation of the applicability of geophysical methods, we propose an initial dipole-dipole resistivity survey using a Scintrex transmitter and IPR-8 receiver as was done in the investigation of the Las Positas fault for the Site Seismic Safety Program. The equipment is currently available, personnel are familiar with its operation, and we have resistivity codes on hand for interpreting the data. Pit 2, Pit 7, and Pit 6 are the best localities to use for initial data collection. Pits 2 and 7 are preferable because of the less complicated nature of the bedrock at those localities.

A dipole-dipole survey is, in our judgment, the best way to start because the method is designed for detailed soundings producing cross sections showing both horizontal and vertical variations of resistivity with depth.

Phase 1 deliverables will include (1) dipole-dipole resistivity profiles for Sites 2, 7 and 6, and (2) initial model interpretations of the data, including the depth and extent of zones of different resistivities and relatives resistivities in those zones.

Inductive Resistivity Survey

Geonics Ltd. produces an inductive very low frequency (VLF) resistivity measuring system (the EM 34-3) designed for reconnaissance surveys where the subsurface can be approximated with a two-layer model (Geonics Ltd., 1980). The EM 34-3 will be evaluated as a tool for use in rapid reconnaissance measurements to be used once the subsurface has been characterized with the dipole-dipole survey. Such an evaluation would include consideration of use of the VLF system in a possible monitoring capacity. The advantage of the EM 34-3 is the ability to obtain field data rapidly over large areas. Should it prove useful, the tool would easily pay for itself in reduced drilling costs. This instrument can be rented from Geonics on a weekly basis.

Phase 1 deliverables will include an evaluation and comparison of the double-dipole and EM 34-3 systems for characterizing depth to water table and location of anomalies. If EM 34-4 proves effective with sites 2, 7, and 6, the remaining landfill areas will also be examined for potential ground-water contaminant plumes. Limits on accuracy of locations will be reported as well as recommendations for further work.

Induced Polarization and Seismic Refraction

Depending upon the success of the above system and upon time and budgetary constraints, induced polarization (IP) and seismic refraction techniques could also be evaluated. The Scintrex equipment is designed for use in the IP mode and measurements could be made simultaneously with the dipole-dipole resistivity measurements. Seismic refraction has been shown to be useful in determining the water table at the LLNL site and probably would give useful results in the bedrock situation at Site 300. Use of seismic refraction would be somewhat more manpower and time intensive as well as only giving information about the water table, with no possibility of detecting contaminant migration. If a geophysical investigation of either the Elk Ravine or Corral Hollow faults is deemed warranted, established seismic refraction (as well as resistivity) techniques could be applied to determine fault locations. A proposal will be submitted, if necessary, at that time.

Task 4: Geochemical Assessment

Geochemistry is important both as the ultimate means of assessing any ground-water contamination, and in a support role providing additional information toward understanding site hydrogeology. Very little information is available on site hydrogeochemistry because ground-water monitoring has been restricted to the general services area. Ground-water characterization studies are proposed in an effort to understand the potential flow regimes.

It is intended to geochemically sample all available wells (approx. 20) and springs (approx. 6). This sampling program has two goals in mind: to identify any noticeable contamination and to aid in additional interpretation of hydrogeological conditions present. The geochemical data listed below in Table 2 are necessary to identify contaminants, common ground-water systems (i.e. age and origin) and likely secondary mineralization that may occur within the ground-water system.

Table 2

Summary of Geochemical Analyses

pH, E^{H}_{Pt}, Conductivity, Dissolved oxygen, gross γ, β^-, and α.

Cations: Ca^{2+}, Mg^{2+}, Na^+, K^+, Fe_{Total}, Si^{4+}, $NH_4^+{}_{Total}$, Al^{3+}, As_{Total} (and As^{3+}/As^{5+}), Sr^{2+}, Pb^{2+}, Be^{2+}, U_{Total}, Hg^{2+}

Anions: Cl^-, SO_4^{2-}, S^{2-}_{Total}, HCO_3^-, NO_3^-, PO_4^{3-}, F^-

Organics: Total Organic Carbon, Total Identifiable Chlorinated Hydrocarbons (TICH)

Isotope Analyses: $^{18}O/^{16}O$, $^{2}H/^{1}H$, $^{12}C/^{13}C$, $^{234}U/^{235}U/^{238}U$, ^{3}H

Proper field sampling and analysis techniques for the chemical components of ground water are essential in order to protect the integrity of the dissolved species before, during and after sampling. In addition, several measurements must be made in the field.

1. Field analysis will include the following:

pH - Battery operated digitial pH meter.

Conductivity - Battery operated unit from NURE program.

Alkalinity - ($CO_3^{2-}/HCO_3^{-}/CO_2$) - Titration; will use Hach digital cartridge buret with cartridges.

Iron - Colorimetric; recommend purchase of Hach Model IR-18 KIT for 0-5 ppm.

Sulfide - Recommend purchase of Hach model HS-6 test kit for analysis down to 0.1 ppm sulfide.

Dissolved Oxygen - We will use a Leeds & Northrup model 7931 electrode monitor system. We also recommend purchase of Hach test kit model OX-DT which should be capable of a detection limit of about .05 ppm.

Eh - Measurement with battery operated unit from NURE program. This measurement, however, will probably not be very meaningful.

Two sets of samples will be taken at each location (i.e. well or spring). These will include an acidified and nonacidified sample, along with a 0.2μ filtered acidified and nonacidified sample. Sample containers will be pre-acid-leached polyethylene bottles. All well samples will be taken with a positive displacement pump (such as the Bennett Pump), which will be cleaned between sampling to avoid cross contamination. This type of pump assures goechemical integrity (i.e. avoids concentration changes, pump contamination and degassing problems). Several well volumes will be pumped to insure a representative sample.

2. General laboratory analyses will be done by an independent State Certified laboratory (Brown & Caldwell). In addition, we will do several measurements in-house for comparative purposes. These in-house measurements include the following:

Major Cations and Trace Metals - By ICP Spectrometry using the old NURE system. They can do about 22 constitutents (including Beryllium). For those wells nearest landfill locations uranium will be done by isotope dilution since detection limits by ICP are not likely to be adequate for those concentrations expected.

Arsenic Speciation for Redox Potential - (As^{+5}/As^{+3}) by ICP Spectrometry. This should be more useful than the field Eh measurement and will provide information concerning the oxidation state of ground waters.

Sulfate and Chloride - By Technician Auto Analyzer.

3. Stable isotope analysis will be determined (Global Geochemistry) and used as conservative geochemical tracers of ground water extending classical hydrogeological tools. $^{2}H/^{1}H$ and $^{18}O/^{16}O$ analyses can provide information concerning the origin of ground water, identification of different water masses, flow path analyses, assessment of rock-water interactions and indirect water age determinations. $^{13}C/^{12}C$ can provide information about the carbon geochemistry of the water and, in particular, help in understanding recharge environments.

4. Radioactive isotopes of interest are tritium and the uranium-decay series. Tritium analyses (^3H), may allow identification of very young water, as well as inferring any potential contamination. If uranium is present in significant amounts, isotopic analyses will be done in-house to determine whether the source is natural or derived from the landfills.

2. Phase 2: Exploration and Analysis

Task 1: Design of Initial Monitoring System

The purpose of the initial monitoring system is to verify the inferred hydraulic gradients across each landfill area and immediately determine if any contaminants have entered the ground water regime. This is to be done at a minimum cost effort. If we see no contamination at any sites during Phase 2, we may decide to limit the number of wells in Phase 3, or we may decide no further drilling activities are necessary. Another alternative is to place a directional drillhole in the unsaturated zone under the landfill, completing the well with multi-level suction lysimeters. This would provide information concerning the rate of any contaminant leaching and possibly allow remedial treatments before the aquifer becomes contaminated. This would be most appropriate if contamination were found only in the unsaturated zone. This type of monitoring system would set a precedent and may be more appropriate for areas, such as Site 300, where leachate transport is expected to be slow and the water table is often in excess of 30 m.

Initial monitoring well locations will be determined after the completion of Phase 1 activities. The downgradient well location will be placed in close proximity to the landfill in the path of surface runoff. However, if geological or geophysical surveys yield any unexpected results, we will take this information into account in choosing well locations. We must avoid drilling into the landfill, since it would be impossible to know whether or not any contamination found was due only to drilling activities.

The monitoring system we recommend is listed below. Proposed well locations can be seen in Fig. 2.

Pit 1 and 2 Complex: This area is the most complex both geologically and hydrologically. A total of three wells will be completed at this site. One well will be placed north of both Pits 1 and 2 as well as northeast of the projected Elk Ravine Fault. This well will be drilled to about 350 ft. and separately completed in both the confined and unconfined (water-table) aquifer. The well represents the upgradient direction in the unconfined aquifer and the downgradient direction in the confined aquifer. Special procedures will be employed when drilling and completing this well to avoid any contamination from one aquifer to the next. This well will allow us to check if the vertical hydraulic gradient is upward from the confined aquifer. Such a discharge environment would minimize the potential for downward migration of contaminants from the water-table aquifer to the confined aquifer. The two other wells will be located immediately southward of each pit. This represents the downgradient hydraulic flow direction for the unconfined aquifer. Both these wells will be drilled to approximately 150 ft., and completed in the water-table aquifer only. Well 17 represents another downgradient monitoring well which is considered part of this monitoring network.

Pit 8 Area: Two wells will be drilled and completed into the unconfined aquifer to depths of approximately 150 ft. The upgradient well is located northeast of the pit; the downgradient well is immediately southwest of Pit 8.

Pit 7 Area: Two wells will be drilled and completed into the unconfined aquifer. Well depths are approximately 150 ft. The upgradient well is located northwest of Pit 7; the downgradient well is immediately southeast of Pit 5.

Pit 6 Area: Two wells will be drilled and completed into the unconfined aquifer. Well depths are expected to be approximately 50 ft. The upgradient well is located north of the pit; the downgradient well is planned immediately south towards Corral Hollow.

For good geochemical sampling 3 inch or 4 inch boreholes are more than adequate for all monitoring well completions. If conventional monitoring wells are used, they should be completed using potable PVC with teflon wrapped threaded joints (avoid glued joints), or other inert materials. However, we suggest completing these exploratory wells for multi-level ground-water sampling and observation of piezometric data in each water-bearing stratum encountered. This will reduce the number of wells necessary to obtain the needed information. The Barcad system seems to be a good approach as we can obtain both hydrologic and geochemical information at numerous levels. However, we are evaluating several different alternatives for multi-level well completions as the Barcad system would need modification in order to obtain valid piezometric data for the suggested well depths. Ground-water sampling and analysis will be done in accordance with procedures outlined previously.

Tasks 2 and 3: Drilling Activities and Laboratory Support Studies

There are several requirements necessary in the drilling of ground-water monitoring wells. Drill rods, split spoon samplers and any equipment must be washed before it goes down the borehole. Cross contamination is a very significant problem. Drilling with mud additives or foam destroys the hydrogeochemical integrity of the well, no matter what efforts at flushing occur afterward. There are numerous drilling methods available for shallow drilling, but we are limited with respect to deep wells. Rotary drilling with air or water looks to be the most acceptable method. However, in order to obtain representative samples in the unsaturated zone for pore water extraction and analysis, we must avoid drilling with water until absolutely necessary. Therefore, we envision auger drilling until hard rock is encountered; then switching to rotary drilling with water.

1. Geological Activities

A split spoon sampler or modified California sampler will be used in the overburden to obtain soil samples for identification and continuous core (Nx or larger) will be obtained in rock. The samples and cores will be described in the field by a geologist. Samples and core will be labeled, photographed and boxed. Arrangements will be made for weatherproof core storage at Site 300. Resistivity-self potential logs and either natural gamma or gamma/gamma logs will be run in the boreholes. If conditions permit, a televiewer may be lowered into the holes to obtain additional structural information.

2. Hydrological Activities

This part of the hydrogeologic work plan pertains to site specific migration of fluids. The vadose zone lies between land surface and the top of the water-table aquifer. This represents the zone through which any contaminants must travel before reaching the ground water. To predict movement through this zone, one must know depth, permeability, water content, and moisture tension (negative pressure) of material within this zone. Soil samples and core from the unsaturated zone will be processed for volumetric moisture content. Undisturbed samples are required for permeability tests. Values for water content, permeability and moisture tension will be determined in the laboratory. A pressure plate moisture extraction apparatus is available at LLNL.

3. Geochemical Activities

There are several geochemical activities which need to occur during the initial exploratory drilling. These can be outlined as follows:

A) Obtain samples of geologic units for size analysis, optical examination, x-ray diffraction and bulk chemical analyses. This information would allow a preliminary understanding of retardation and sorption of potential contaminants. We may chose to include some support laboratory studies pending these analyses.

B) Field monitoring of cores and cuttings for gross changes in organic carbon compounds as well as some inorganic compounds by a hand-held photo ionization detector.

C) Specifying locations for soil samples to obtain material for pore water extraction and analysis (method of P. J. Patterson et al., 1978) in the unsaturated zone. This would be done where any noticeable activity changes occur, as well as at periodic intervals.

D) It is our understanding that Hazards Control will be sampling soils in the path of surface runoff and in close proximity to the landfill areas. If exploratory wells are placed in close proximity to the landfills, there is no need for additional soil sampling locations unless contamination is detected in the unsaturated zone at these locations. If we see contamination in the unsaturated zone, we should include soil sampling and placement of suction lysimeters in Phase 3.

4. Geophysical Activities

Further investigation may be needed to refine data concerning the location of contaminated areas and water table depths. Either EM-34-3 or the dipole-dipole survey equipment may prove useful in a monitoring capacity. Other methods, such as seismic refraction may be needed to further characterize fault locations or to determine the extent of interconnection on confined and unconfined aquifers at specific site locations.

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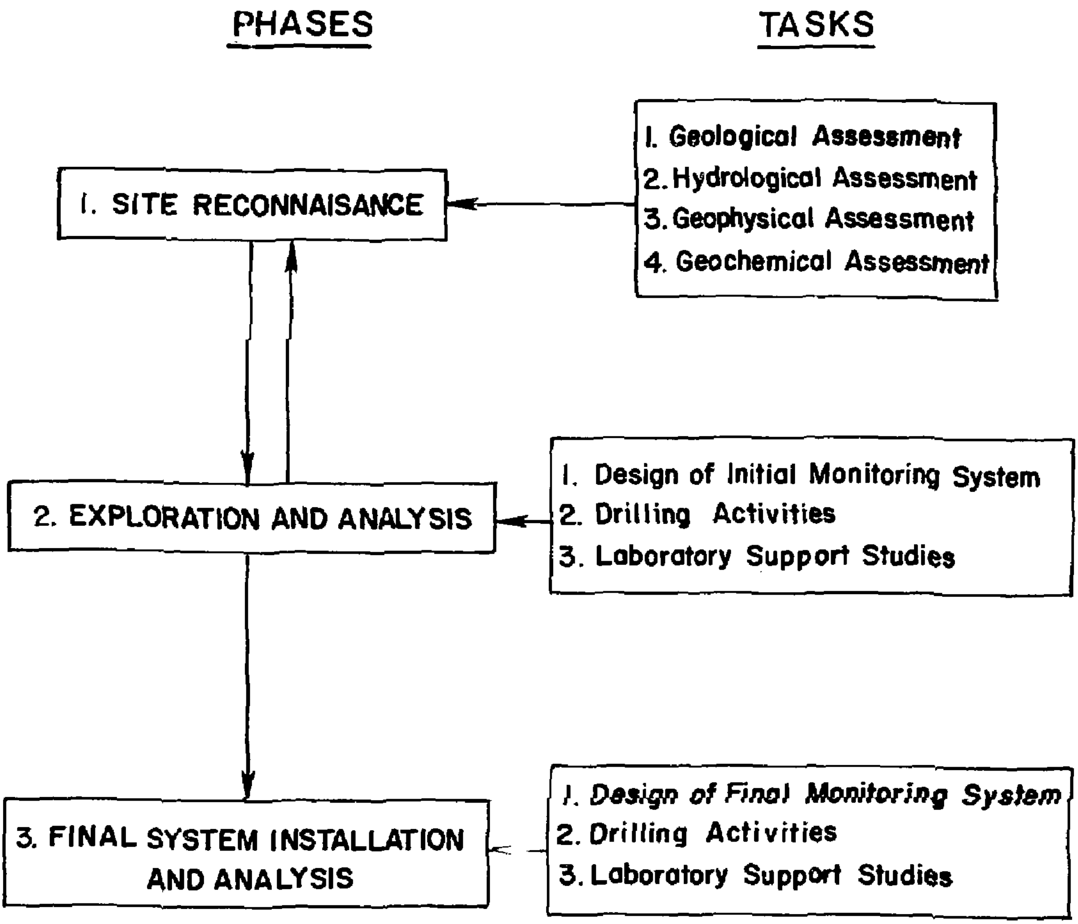

Fig. 1 Work Breakdown Structure Diagram

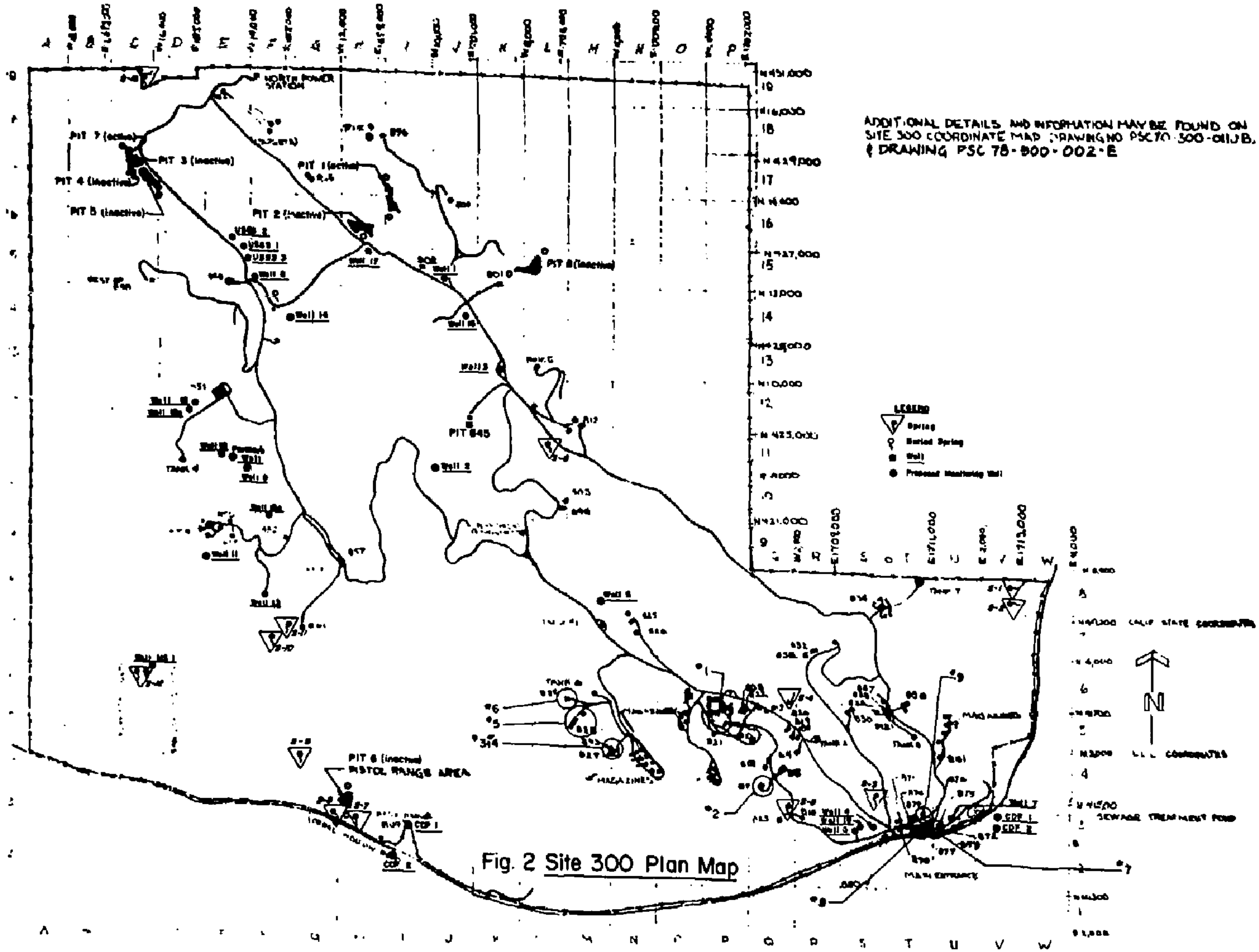

Fig. 2 Site 300 Plan Map

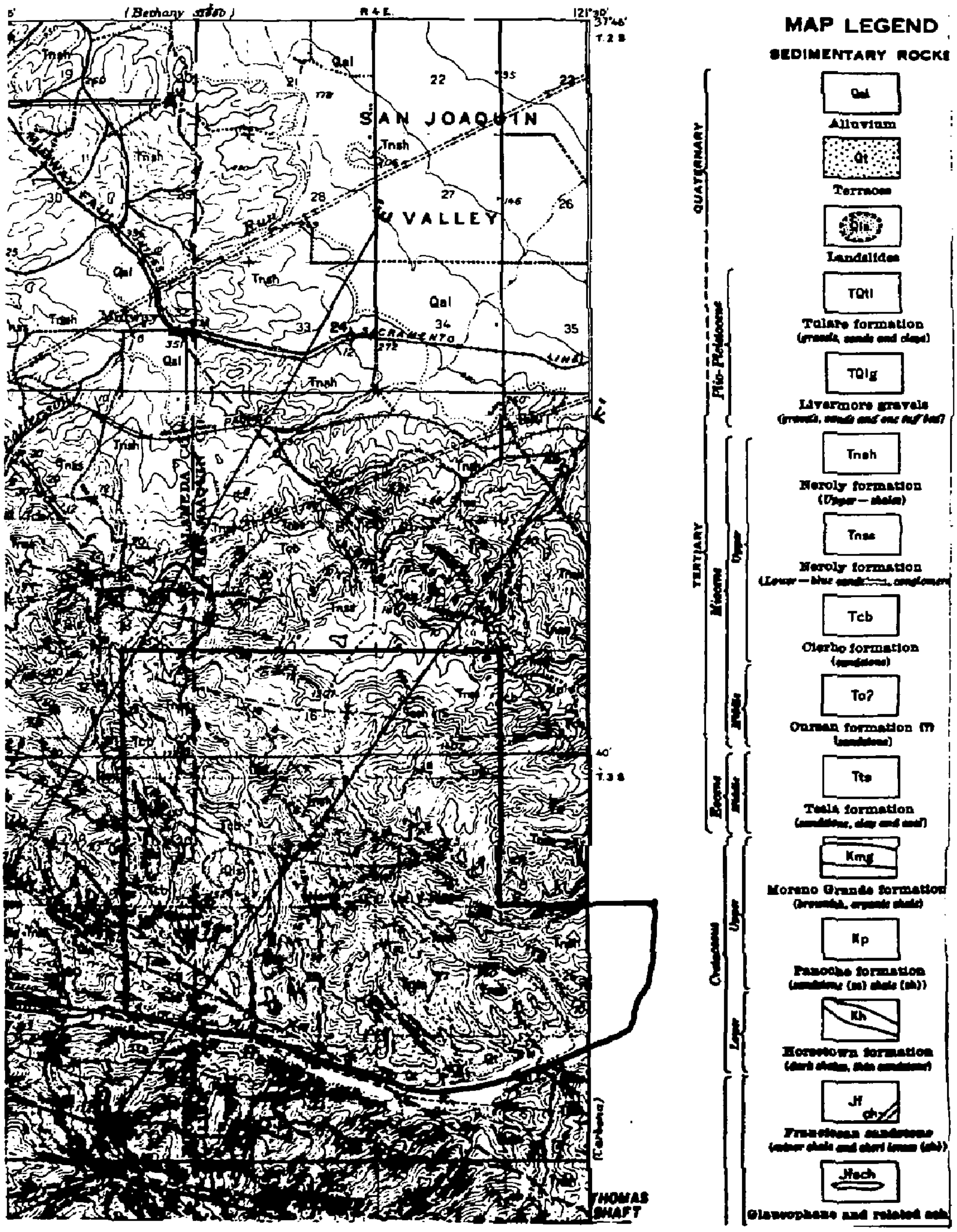

Fig. 3 Geologic Map of Site 300 by Huey, 1948

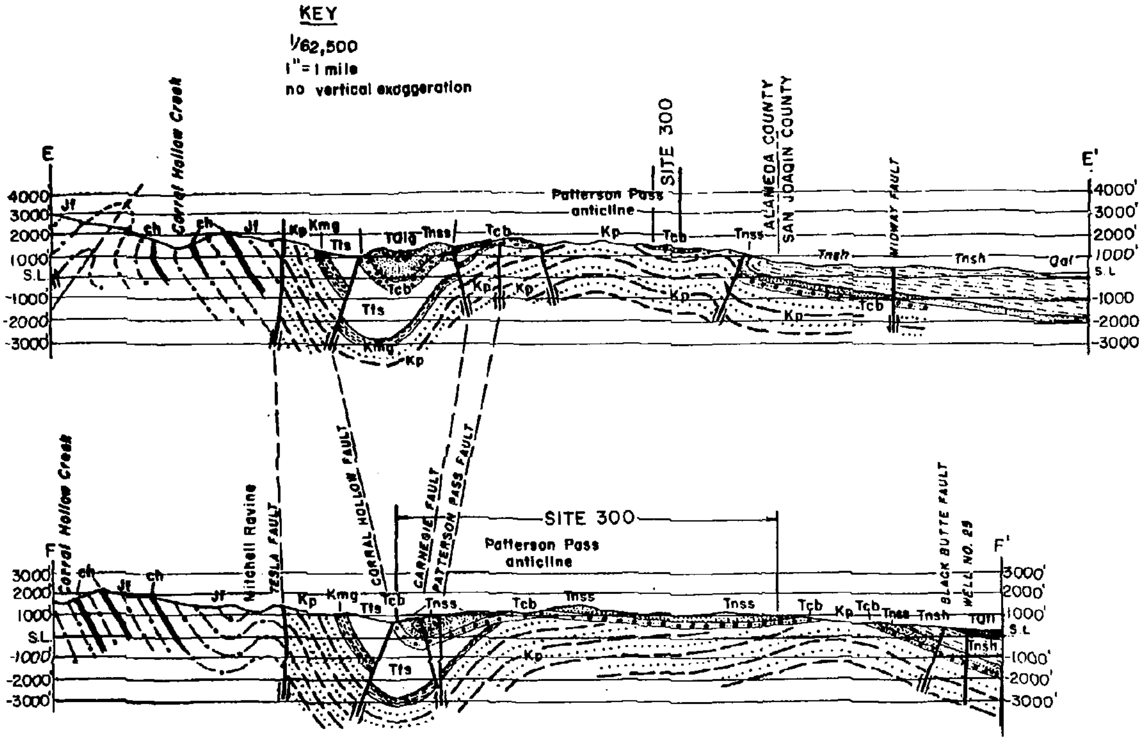

Fig. 4 Geologic Cross Section from Huey, 1948

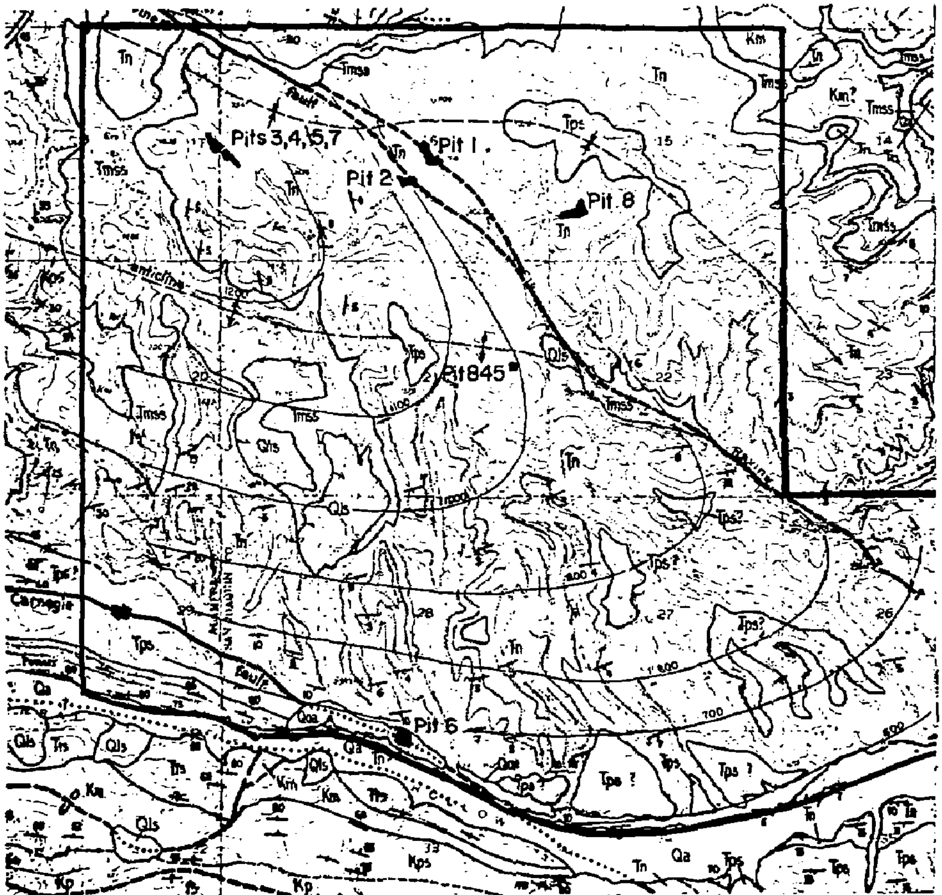

Fig. 5 GEOLOGIC MAP OF SITE 300
by Dibblee, 1980

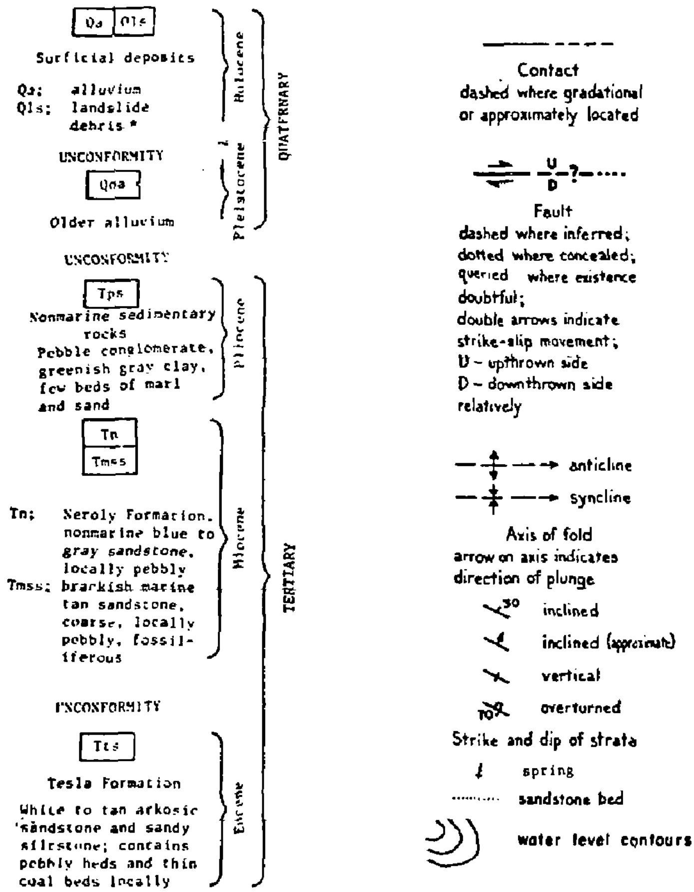

Fig. 6 Legend for Geologic Map of Site 300 by Dibblee 1980