DRAFT
REMEDIAL INVESTIGATION
AND
FEASIBILITY STUDY REPORT

UNION PACIFIC RAILROAD YARD
SACRAMENTO, CALIFORNIA

Volume 2: Feasibility Study Report

Prepared For:

UNION PACIFIC
RAILROAD COMPANY

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0.0 EXECUTIVE SUMMARY

This Executive Summary provides a brief description of the Feasibility Study (FS) which has been conducted for the Union Pacific Railroad (UPRR) Sacramento Shops Yard. The study was performed in response to an Enforceable Agreement dated March 26, 1987, executed between UPRR and the California Department of Health Services (DHS). The Remedial Investigation (RI) Report forms Volume 1 of this document. The RI Report describes the site and investigations. The FS Report describes the development and evaluation of potential remedial alternatives for the site.

The FS was conducted to develop, screen, and evaluate remedial alternatives for the UPRR Sacramento Shops Yard site. The result of the FS process is a detailed evaluation of the most feasible actions for remediating contaminated soil and groundwater at the site. A site-wide remedial action plan (RAP) incorporating the preferred remedial alternatives for the site will be prepared following review of the FS by DHS and the local community.

The FS Report includes:

- Purpose and Organization of the Report, Summary of the Remedial Investigation and Baseline Risk Assessment (Section 1.0);
- Identification and Screening of Technologies (Section 2.0);
- Development and Screening of Alternatives (Section 3.0);
- Detailed Analysis of Alternatives (Section 4.0); and

- Comparative Analysis of Alternatives (Section 5.0).

Section 1.0 of this report presents discussions of (1) the purpose and organization of the FS Report, (2) background information on the site, (3) a summary of the nature and extent of contamination, and (4) a summary of the site baseline risk assessment.

Section 2.0 of this report presents (1) selection of potential exposure pathways (summarized in Table 1), (2) the development of remedial action objectives (RAOs), (3) identification of areas and volumes of affected soils and groundwater (operable units), (4) screening of remedial technologies that may be used at the UPRR Sacramento site, and (5) an evaluation of selected process options for each of these representative remedial technologies.

Chemical-specific RAOs for soil and groundwater are developed by comparing potential risk-based residual concentrations to applicable and relevant or appropriate requirements (ARARs), background concentrations, and detection limits. RAOs which protect human health and the environment and which are technically feasible and achievable are chosen from among these four possibilities, and summarized in Tables 2 and 3. The results presented here include only chemical-specific remedial objectives. Protectiveness may also be achieved by reducing potential exposures; thus exposure pathways may be controlled in lieu of remediating media to the concentrations derived here.

Three operable units (OUs) for soil (S1-petroleum hydrocarbon containing soil, S2-arsenic and/or lead containing soil, and S3-petroleum hydrocarbon and/or arsenic and/or lead containing soil), and two groundwater OUs (G1-on-site shallow groundwater containing aromatic compounds and off-site shallow groundwater containing chlorinated solvents, and G2-on-site groundwater containing low levels of solvents and metals in the shallow aquifer and a deeper zone) are described. The total volumes of soil and groundwater to be remediated are estimated. The total estimated soil volume is approximately 116,000 cubic yards. The total estimated groundwater volume is approximately 7.3 million cubic feet. The calculations are summarized in Tables 4 and 5.

No prospective soil remedial technologies are screened from consideration in Section 2.0. Representative process options for capping, biological treatment (in situ and ex situ bioremediation), ex situ chemical treatment (soil washing), thermal treatment (off-site incineration), and in situ chemical treatment (fixation) are retained. Disposal by landfilling is also retained.

None of the prospective groundwater remedial technologies are screened from further analysis. Methods of physical and chemical pretreatment, biological treatment and three effluent polishing techniques (ultraviolet light/hydrogen peroxide oxidation, air stripping, and carbon adsorption) are retained. Representative process options for containment (pumping and injection), collection (extraction) are considered. Additionally, several treated water disposal methods, both on- and off-site, are retained. Potential techniques for management of residual levels of contaminants, including landfilling, thermal destruction, and carbon regeneration are also retained.

In Section 3.0, retained technologies are combined into remedial action alternatives designed to address the important site problems and the significant pathways of contaminant migration discovered during the RI. The purpose of the analysis is to develop preliminary and final candidate alternatives for the site which protect human health and the environment, comply with ARARs and meet the RAOs, are cost-effective and encompass a range of appropriate remedial management options. Options include elimination of contaminated on-site soil and groundwater on- and off-site, reduction of contaminants to acceptable levels, prevention of exposure by control of exposure pathways, or some combination of the above elimination, reduction, and exposure prevention options.

During the evaluation, preliminary alternatives are eliminated from further consideration if they (1) do not effectively protect human health and the environment, (2) are flawed with respect to administrative or technical feasibility, or (3) are significantly higher in cost than other alternatives without corresponding increase in benefits, health protection or reliability. Screening of preliminary alternatives produces a small group of final candidate alternatives.

Many preliminary alternatives could be assembled from the technologies described in Section 2.0. In addition, because remediation of the UPRR Sacramento site involves soil containing arsenic, lead and petroleum hydrocarbons, and groundwater on- and off-site containing aromatic and chlorinated organic compounds, the number of plausible alternatives is potentially unmanageable. In order simplify the alternative development process, alternatives are developed for each OU independently for soil and groundwater. Due to the overlapping nature of the contaminant distribution in soil, one OU (soil OU S3), is the dominant area on the site and the screening of soil alternatives is focused on soil OU S3. The total number of alternatives formed by combining technologies is further reduced by recognizing that certain technologies which survived the technology screening are not applicable to all OUs and are screened from consideration as appropriate.

Eleven final candidate alternatives, presented in Tables 13 and 14, are retained for further analysis. As discussed in the National Contingency Plan (NCP), final candidate alternatives encompass the complete range of options, including no action, containment, treatment as the principle element, and no long term residuals management.

- Five alternatives are retained for OU S3. These alternatives include capping, excavation, soil washing, in situ bioremediation, and partial and full treatment.

- For groundwater OU G1, the four final candidate alternatives involve monitoring, treatment of extracted groundwater, and handling of residuals. The alternatives differ in the methods of treatment and treated water discharge. Additionally, one method, in situ bioremediation, would treat contaminants in the groundwater.

- For groundwater OU G2, the two final candidate alternatives involve monitoring and containment.

Final candidate alternatives are fully described in Section 4.0 of the report. In addition to the descriptions, there is a narrative discussion which describes the assessment of the alternatives against nine evaluation criteria commonly used in the FS process. The discussion focuses on how and to what extent the nine criteria are addressed. The nine criteria are:

- Overall protection of human health and the environment;
- Compliance with ARARs, or more appropriately for soils, RAOs;

- Long-term effectiveness;
- Reduction of mobility, toxicity, and volume;
- Short-term effectiveness;
- Implementability;
- Cost;
- Agency acceptance; and
- Community acceptance.

Sections 4.1 and 4.2 present detailed descriptions and analyses.

Section 5.0 presents a comparative analysis of the final candidate alternatives for soil and groundwater remediation. The soil and groundwater alternatives are compared in terms of the nine evaluation criteria in Section 4.0.

The comparison of soil alternatives yields a range of remedial options which, with the exception of the no action alternative, are protective of human health and the environment. All four action alternatives reduce the site risks below the 1×10^{-6} (one cancer per million exposed individuals) cancer risk level. Three action soil alternatives (SA-4, SA-5, and SA-8), rely on a combination of vegetative and artificial covers and soil treatments to reduce potential human health and environmental risks. The full excavation and treatment (SA-9) alternative reduces concentrations of target chemicals in all site soils to meet the RAOs. The full excavation and treatment alternative also provides the greatest long term effectiveness and permanence, while the hot spot reduction by on-site treatment (SA-5), and in situ treatment and stabilization (SA-8) alternatives offer the next level of protection and permanence.

The full excavation and treatment (SA-9) alternative provides the greatest reduction in toxicity, mobility, and volume, while the hot spot reduction by on-site treatment (SA-5), and in situ treatment and stabilization (SA-8) alternatives offer the next levels of reduction of mobility and toxicity. The containment (SA-4) alternative does not provide any reduction of contaminant volume, but the mobility and toxicity is greatly reduced by leachate control. The greatest short term effectiveness would be provided by the containment (SA-4) and in situ treatment (SA-8) alternatives, while the hot spot reduction (SA-5) and full excavation and treatment (SA-9) alternatives are progressively more difficult to implement. For the purposes of comparison, all remedial alternatives have been planned to operate over a time period of five years.

The containment (SA-4) alternative is the most easily implementable, and the hot spot reduction by on-site treatment (SA-5), the in situ treatment and stabilization (SA-8), and full excavation and treatment (SA-9) alternatives are progressively more difficult to implement, and potentially provide limited short-term health risks by progressively more disruptive remedial activities.

The most expensive of the alternatives is the full excavation and treatment (SA-9, $15 million), followed by the hot spot reduction and on-site treatment (SA-5, $9 million), in situ treatment (SA-8, $6 million), and containment (SA-4, $3 million). All but the no action alternative provides the same health risk reduction for soils remediation.

The comparison yields preferred alternatives for each groundwater OU. For groundwater OU G1, treatment and reclamation are favored along with in situ bioremediation. The preferred alternative for groundwater OU G2 is institutional actions, although containment is also favorably considered. Additional characterization as well as treatability and pilot studies are required to select the most feasible groundwater remedial action.

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1.0 INTRODUCTION

1.1 PURPOSE AND ORGANIZATION OF THE FEASIBILITY STUDY REPORT

This draft Feasibility Study (FS) Report discusses soil and groundwater remedial measures for the Union Pacific Railroad (UPRR) Sacramento Shops Yard. This FS report is intended to satisfy a section of the Enforceable Agreement dated March 26, 1987, executed between UPRR and the California Department of Health Services (DHS). A final FS will be generated following receipt of comments from DHS and the community on this Draft FS and completion of further off-site groundwater investigations aimed at characterizing impacted groundwater.

The California Site Mitigation Decision Tree Manual (DHS, 1986) and the Environmental Protection Agency (EPA) Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA, 1988a) were used as guides in performing this FS. The organization of this report and the FS process are summarized as follows:

- Site Background Information (Section 1.2);
- Define soil and groundwater RAOs that are protective of both human health and the environment (Section 2.2);
- Evaluate extent of soil and groundwater containing contaminants of interest at levels above RAOs and the associated clean-up volume (Section 2.3);
- Develop general response actions for mitigation of site problems associated with the affected soils and groundwater (Section 2.4);

- Identify and screen remedial technologies and process options most appropriate for the site based on effectiveness, implementability, and cost (Section 2.5);
- Develop and screen remedial action alternatives from a combination of selected technologies and remedial strategies for mitigation of the site (Section 3.0);
- Perform a detailed analysis of the remedial action alternatives (Section 4.0); and
- Perform a comparative analysis of the final candidate alternatives (Section 5.0).

1.2 BACKGROUND INFORMATION

1.2.1 Site Description

A detailed discussion of site background and features is contained in the draft Remedial Investigation (RI) Report (Dames & Moore, 1990c). A brief summary of the information from the RI report follows.

This site is located within the Sacramento city limits in an area of mixed commercial, light industrial, and residential land use (Figure 1). On the west, residences are separated from the northern portion of the site by a 100 to 150 foot strip of railroad right-of-way, and from the southern portion of the site by one to two blocks of commercial, light industrial, and institutional buildings. To the south, the Sutterville Road overpass separates the site from several blocks of light industrial establishments. Single family residences adjoin most of the eastern and northern site boundaries; the residences on the northern boundary are separated from the site by a narrow alleyway.

Sacramento has warm, dry summers and mild winters. Mean monthly precipitation data are provided in Figure 2. The mean annual precipitation for Sacramento is 16.86 inches. The maximum recorded annual precipitation is greater than 37 inches and minimum less than 5 inches. The maximum mean monthly precipitation is 3.5 inches and occurs during January, and the minimum mean monthly precipitation is 0.2 inches and occurs during July. The months of November, December, January, February and March exceed 2 inches mean monthly precipitation. The maximum recorded precipitation occurring in a 24-hour period is more than 7 inches and rainfall intensities of 1/4-inch per hour are not uncommon.

Average monthly wind speed and prevailing direction data from the Sacramento Executive Airport located approximately two miles south of the site are summarized in Figure 3. The prevailing wind direction is from the southwest 60 percent of the year with an average speed of 8.0 mph. The dominant southwest winds occur primarily during the spring and summer.

Mean monthly evaporation data for the Davis Agricultural Station are summarized in Figure 4. The mean annual evaporation is 75.6 inches. The maximum mean monthly evaporation of 12.1 inches occurs in July and the minimum mean monthly evaporation of 1.4 inches occurs in December.

1.2.2 Site History

The Sacramento Shops Yard was established by Western Pacific Railroad in the early 1900s to maintain and rebuild steam locomotive boilers and to refurbish rail cars. Diesel engine repair and maintenance began in the mid 1950s. The site was purchased by UPRR in 1982, and operations were discontinued in 1983. Buildings and structures on the site were demolished by 1987. The salient features of the rail yard prior to demolition activities are presented on Figure 5.

The operation of the railroad yard necessitated on-site use and storage of potentially hazardous materials and chemicals. Potentially hazardous materials identified through a site history analysis included:

- Fuels and oils stored in above ground and underground tanks;

- Metals such as arsenic, lead, and copper which could have originated from sandblasting, painting, machining, welding, bearing manufacture, and application of fungicides and herbicides;

- Asbestos used in boilers and pipes of steam engines; and

- Solvents, cleaners, and degreasers used to clean and strip railcars in the maintenance facilities.

Currently, the site contains construction debris, concrete pads that served as former building foundations, miscellaneous rail yard equipment, and a subsurface storm-water drainage system with manholes and sumps. The site surface soils have been disturbed and contain sparse plant species of no rare or unusual significance. The current site conditions and topography are indicated on Figure 6. With the exception of a low northwest/southeast trending scarp which runs across the northern portion of the site, the site generally slopes slightly to the north.

1.2.3 Remedial Investigation

The RI has been performed in phases since 1987. This phased approach targeted potentially hazardous substances present in soil, groundwater, and air. A first phase RI was completed and a report presented to DHS on June 10, 1988. The results of the overall extensive investigation were presented by Dames & Moore in a February 10, 1990, Draft RI Report. A subsequent Draft RI (August 1990) includes details of off-site groundwater investigations and forms Volume 1 of this RI/FS Report.

On-site soils have been characterized in the RI by evaluating the data generated from 53 exploratory borings, over 250 test pits, and numerous additional exploratory excavations (Figures 7 and 8). Over 600 soil samples were collected and analyzed for approximately 5,000 metal analytes, and approximately 700 analyses were performed for over 6,000 organic analytes.

On-site and off-site groundwater has been evaluated by the installation of 31 groundwater monitoring wells (Figure 9), the completion of 34 Cone Penetrometer Test (CPT) holes and 27 Hydropunch™ (HP) sample holes (Figure 10). During five rounds of monitoring well sampling, groundwater samples were collected and analyzed for volatile chlorinated organic compounds and aromatics, metals, and selected water quality parameters. Fifty-four HP samples were analyzed for volatile chlorinated organic compounds and aromatics.

1.2.4 Interim Remedial Measures

Specific interim remedial measures were conducted prior to and during the course of the RI/FS process. The main activities included:

- Removal and appropriate off-site disposal of approximately 1,600 cubic yards of wood debris and soil suspected of containing asbestos.

- Removal of an 18,000 gallon concrete underground fuel storage tank. This tank was purged of its fluid contents (15,800 gallons of Bunker Oil and water) then steam cleaned and demolished. Demolition materials were left stockpiled on-site. The 15,800 gallons of fluid and an additional 1,500 gallons of rinsate were transported under State of California Uniform Hazardous Waste Manifest and disposed of as hazardous waste at Gibson Oil & Refining Company in Bakersfield, California.

- Removal of a 1,000 gallon underground storage tank. Residual fluids from this tank were transported under State of California Uniform Hazardous Waste Manifest and disposed of as hazardous waste at Gibson Oil & Refining Company in Bakersfield, California. The 1,000 gallon tank was transported under State of California Uniform Hazardous Waste Manifest and disposed of at H & H Ship Service Company in San Francisco, California.

- Cleaning of the 72,000 gallon underground concrete fuel storage tank which currently remains on-site. Approximately 1,600 gallons of rinsate from these operations were transported under State of California Uniform Hazardous Waste Manifest and disposed of as hazardous waste at Gibson Oil & Refining Company in Bakersfield, California.

- Removal and appropriate off-site disposal of approximately 150 cubic yards of soil containing hydrocarbons. The soil was transported as hazardous by railcar under State of California Uniform Hazardous Waste Manifest and disposed of at the USPCI facility in Lake Point, Utah.

- Removal and appropriate disposal of approximately 70,000 gallons of water containing very low concentrations of residual hydrocarbons. This water was disposed of under Sacramento County permit into the county sewer system.

1.2.5 Geology and Hydrogeology

The site is located in the Sacramento Valley and is underlain by sediments which are characteristic of flood plain deposits laid down by continually shifting streams. The soils, therefore, consist of a heterogeneous mixture of clays, silts and sands. Detailed descriptions of site and regional geology and hydrogeology are contained in the RI Report (Dames & Moore, 1990c).

Railyard activities were more intensive in the southern end of the site; therefore, more extensive subsurface investigation was conducted there. The typical soil stratigraphy can be summarized as follows:

Depth (ft)	Material
0-2	Fill; mainly derived from native soils relocated during site leveling; also contains man-made materials in some locations.
2-25	Silty clay and clayey silt; contains a low permeability hardpan layer near the surface over much of the site. Perched groundwater may be present at some locations above this hardpan layer.
25-35	Sands, silts, and clays; interbedded fine grained materials, fining upwards. The water table can extend upward into this material.
35-50	Sand, fine to medium grained; maximum thickness 25 feet thinning to 4 feet in the southwest corner of the site, and absent in the southeast and northeast corners of the site. The base of the sand is the base of the shallow aquifer zone.
50-60	Clay and silty clay aquitard zone; varies in thickness from 10 feet to 40 feet, becomes siltier with depth.
60-150	Interbedded sands, silts and clays.

The fill is distributed with varying thickness across the site as shown in the isopach map in Figure 11. The fill is generally thicker towards the northern end of the site where it extends 8 to 12 feet in some areas. The other stratigraphic units listed above appear to be continuous over the site, although their thickness and texture vary. Two additional soil zones were identified in the northern portion of the site: an interbedded fine grained zone, and a medium grained sand zone. Cross sections through various portions of the site are presented in the RI Report.

Groundwater is encountered at a depth of approximately 30 feet beneath the site surface. The uppermost, shallow aquifer is composed mainly of the fine to medium grained channel sand zone, although the aquifer appears unconfined and extends into the finer overlying material. The horizontal hydraulic gradient for the site ranges from approximately 0.002 in the northern portion of the site to 0.003 in the southern portion. Groundwater flow direction evaluated during the RI varied across the site from primarily due south in the northern portion to southeast in the southern portion. Most of the site groundwater investigation was conducted within this shallow, uppermost aquifer. Both the shallow aquifer zone and the underlying aquitard appear nearly continuous across the site but their thicknesses vary. The aquitard is underlain by a deep aquifer zone consisting of interbedded sands, silts, and clays. Groundwater flow and contaminant transport appear to be controlled by shallow aquifer channel sands.

1.2.6 Nature and Extent of Contamination

1.2.6.1 Soil Contamination

The analytical results from the RI soil sampling indicate metals and organics, principally diesel-range petroleum hydrocarbons, are the primary chemicals in soil at the site. The primary metals measured at elevated levels in site soils were arsenic and lead. Copper was also identified in isolated areas and was generally associated with elevated levels of lead. Although the bulk of asbestos-affected soil was removed, one small remaining area with detectable amounts of asbestos was noted. Elevated concentrations of metals and hydrocarbons were detected mainly in the upper two feet of soil in fill material. Asbestos was limited almost exclusively to surface soil. The extent of soil affected by the above categories of potentially hazardous materials is described in greater detail in the following text.

Arsenic Distribution

The spatial distribution of arsenic in soils is depicted in arsenic concentration maps at four different depths within a range from zero to nine feet. The arsenic distribution is indicated on Figures 11 - 14. Based on the concentration isopleth figures, approximately one-quarter of the site surface soils appear to have been affected by arsenic. The isopleth figures indicate the areal extent and concentration of the arsenic-impacted soil decreases rapidly with depth, and appears to be associated with surface and fill soils, rather than underlying native soils.

Elevated arsenic levels were measured in the ground surface to the 0.5 foot depth range in the following areas as shown on Figure 11:

- The Switching Area and Railroad Tie and Utility Pole Storage area along the western boundary of the site northern portion;

- The northwest corner of the site;

- Near the Flammable Material Storage Area adjacent to the Coach and Paint Shop in the site southern portion; and

- The Lye Vat and Rattler Pit Area in the site southwestern corner.

The majority of soils containing arsenic elevated above a regional background of 8-16 ppm are located at depths less than approximately two feet below ground surface with the highest concentrations in the 0.0- to 0.5-foot range. Other soils with elevated arsenic appear to be limited to fill materials in the central portion of the site. The soil fill in this area has a maximum thickness of approximately nine to ten feet. The draft RI Report concludes that the migration of arsenic has been restricted or impeded by the low permeability soil underlying the fill in all portions of the site.

Lead Distribution

The spatial distribution of lead in soils is depicted in lead concentration distribution maps presented on Figures 15 - 18. Based on the concentration figures, approximately one-third of the site surface soils appear to have been affected by lead. The lead isopleths show levels of lead generally elevated above a regional background of 22 ppm to be fairly widespread across the yard. Additionally, they indicate the approximate areal extent of the lead-impacted soil decreases rapidly with depth. The majority of lead impacted soil is less than two feet below ground surface with the surface to 0.5 foot range having the highest concentrations. Beyond this depth, lead appears to be primarily limited to fill materials which, in the central portion of the site, achieves a maximum depth of approximately nine to ten feet. As with arsenic, the draft RI Report concludes that the vertical migration of lead has been restricted or impeded by the low permeability of the native soil underlying the fill material throughout the site.

Elevated lead levels were measured in the ground surface to 0.5-foot depth range in similar areas as arsenic (refer to Figures 11 and 15) and are outlined below:

- The northwest corner of the site;
- The Switching Area and Railroad Tie and Utility Pole Storage Area along the western boundary of the site northern portion;
- Near the Flammable Material Storage Area adjacent to the Coach and Paint Shop in the site southern portion; and
- The Lye Vat and Rattler Pit Area in the site southwestern corner.

Lead is somewhat more widespread across the site than arsenic and it also appears:

- In fill materials in the central portion of the site; and

- Distributed generally in the active southern portion of the site.

Copper Distribution

Copper was found at elevated concentrations during the RI, but the health risk assessment concluded that copper is not of significant concern for the UPRR site. Additionally, since the limited amount of copper on-site was found in areas that contain elevated lead, soils containing copper will likely be remediated as part of the site remediation activities for lead. Therefore, copper will not be further considered in this FS report.

Organics Distribution

Over 700 soil organic chemical analyses were performed during the RI. Over 500 samples were analyzed for petroleum hydrocarbons as TPH (total petroleum hydrocarbons) and TPH/gasoline. The distribution of total petroleum hydrocarbons, primarily diesel range, are provided in Figures 19-21. About 40 percent of the TPH samples contained detectable concentrations of total range hydrocarbons. Less than 20 percent of the samples contained detectable concentrations of gasoline range hydrocarbons, most of these at low levels.

Soil samples were also analyzed for volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). Based on the findings of the RI, diesel-fuel range hydrocarbons are the only significant organic constituents in the soils that will be addressed in the FS. Elevated concentrations of aromatic and halogenated organic compounds were detected in groundwater and they are considered in this FS.

Asbestos

Soil analysis results suggest that small amounts of asbestos are present at low concentrations in the immediate vicinity of the former Asbestos Storage Building (see Figure 5). The Draft RI concluded that the source of the asbestos was residual waste remaining from building debris piles that were removed as an interim remedial measure (IRM). Asbestos concentrations remaining at the site will be subject to IRM removal in the near future and will not be addressed as a part of the FS process.

1.2.6.2 Groundwater Contamination

The analytical results from groundwater monitoring well and Hydropunch^{TM} in situ groundwater sampling indicate solvents and metals are the primary chemicals in groundwater at the site (See Figures 22 and 23). There are two primary groups of organic chemicals detected at the site: chlorinated volatile organics and aromatics. The aromatic compounds benzene, toluene, xylene and ethylbenzene appear primarily to be restricted to the Oil House Area of the site. The chlorinated volatile organic compounds 1,1-dichloroethylene (1,1-DCE), 1,2-dichloroethane (1,2-DCA), 1,1,1-trichloroethane (1,1,1-TCA), 1,1-dichloroethane (1,1-DCA), and trichloroethylene (TCE) appear distributed more widely and have been detected off-site. The primary metals measured in groundwater in excess of background levels were lead and nickel. The distribution of metals and solvents in groundwater is described in greater detail below.

Lead

Lead was detected in 17 of the 31 monitoring wells sampled, at concentrations ranging from 10 to 63 μg/l. Several of the measured lead concentrations exceed the expected background concentration range of 1 to 9 μg/l. One value exceeds the federal MCL of 50 μg/l (63 μg/l in MW-30), and previous groundwater analytical results for monitoring well MW-30 included a 20 μg/l lead value. Additional fluctuation of measured lead concentrations were observed in the analytical results from MW-11: in the previous round of sampling, lead was detected at 57 μg/l, and in the latest round of sampling lead was not detected in MW-11.

Nickel

Nickel was detected in 25 of 31 monitoring wells sampled. Concentrations ranged from 10 to 450 μg/l. Many of the measured values were above the expected background concentration range of 1 to 12 μg/l (Johnson, 1985), and two of the measured values exceeded the state applied action level (AAL) of 400 μg/l. Of the 25 monitoring wells analyzed at least twice for nickel, 14 of the wells indicated an increase in the relative concentration in nickel by 50 % or more, 7 of the wells showed a relatively low change in concentration, and 4 of the wells showed a decrease in nickel concentration. Based on this data, it appears there is a general increase in nickel concentrations in groundwater at the site. Alternatively, based on the broad range of nickel concentration fluctuations, a sampling or instrumental procedure may be contributing to what may be an apparent increase in nickel. A source of nickel has not been identified on-site. The highest concentrations (450 and 420 μg/l were measured in wells MW-23 and MW-24 (Figure 1), respectively, indicating that either an off- and/or on-site source is possible based on groundwater flow direction.

Aromatic Hydrocarbons

The aromatic compounds benzene, toluene, xylene, and ethylbenzene appear restricted primarily to the Oil House Area of the site. Benzene, toluene, xylene, and ethylbenzene were detected at concentrations up to 12,000, 250, 530, and 1,200 μg/L, respectively, in monitoring well MW-13. Aromatic compounds appear to be limited to the upper portion of the shallow aquifer zone.

Benzene was detected at low concentrations during the May 1990 round of sampling in monitoring wells downgradient of the Oil House Area and along the eastern site boundary (MW-29, MW-30, and MW-31 on Figure 8). This is the first detection of benzene in a monitoring well outside of the former Oil House Area. Concentrations of benzene were 6.2, 2.4 and 1.1 μg/L for groundwater samples from monitoring wells MW-29, MW-30, and MW-31, respectively.

Aromatic compounds were not detected off-site during the April/May 1990 Hydropunch™ sampling.

Chlorinated Volatile Organic Compounds

Five general impacted areas of the site have been identified in the Draft RI Report on the basis of chlorinated volatile organic compound groundwater sample analytical results:

Area	Constituent	Monitoring Well
Oil House	1,1,1-TCA, 1,1-DCA, 1,2-DCA, 1,1-DCE, 1,2-DCE, TCE	MW-4, MW-12, MW-13, MW-14
Coach and Paint Shop	1,1,1-TCA, 1,1-DCA, 1-1-DCE	MW-15, MW-16
Fueling Station	1,1,1-TCA, 1,1-DCA, 1,1-DCE, 1,2-DCE	MW-7
Office (South of Oil House)	1,1,1-TCA, 1,1-DCA, 1,1-DCE, TCE	MW-17, MW-18
Store House (North of Oil House)	1,1,1-TCA, 1,1-DCA, 1,1-DCE, TCE	MW-11, MW-33

The highest concentrations measured in the monitoring wells listed above are those in the Oil House Area (MW-4, MW-12, MW-13, and MW-14).

The chlorinated volatile organic compounds, primarily 1,1-DCE, 1,2-DCA, and TCE have been measured off-site at concentrations exceeding the MCLs. The highest concentrations were detected along the eastern site boundary along 24th Street, downgradient of the former Oil House Area. Concentrations of the chlorinated volatile organic compounds decreased downgradient of the Oil House from about 400 μg/L to about 140 μg/L along West Curtis Drive near Sutterville Road. This indicates a chlorinated volatile organics plume of approximately 1,200 feet in length. Preliminary groundwater modeling has been completed and the results are provided in Figure 29.

1.2.7 Baseline Health Risk Assessment

The results of the baseline Health Risk Assessment (HRA), indicate that exposures to lead, arsenic and PAHs provide the greatest potential concern for human health. The pathways providing the largest contribution to health risks were from inhalation of resuspended dust and from soil ingestion. Crop ingestion from vegetables, either grown in backyard gardens in on-site soils, or in off-site soils receiving particle deposition, presented lower health risks when compared to soil ingestion or inhalation. Lifetime cancer risks from inhalation and soil ingestion exposure to arsenic were 10^{-4} in areas with concentrations elevated above background (concentrations exceeding 8 mg/kg arsenic in soil) to 10^{-5} in areas with arsenic concentrations below 8 mg/kg. Lifetime cancer risks from inhalation and soil ingestion exposure to carcinogenic PAHs are 10^{-5}. Arsenic risks are above the acceptable risk range of 10^{-7} to 10^{-4} recommended by EPA to be achieved by a typical site remedial action.

Exposures to lead in areas with elevated concentrations (concentrations exceeding 190 mg/kg in soil) result in blood lead levels that may exceed currently accepted threshold levels of 15 ug/dL blood (micrograms per deciliter of blood, where 1 deciliter = 100 milliliters). Exposures of children to elevated concentrations of lead in soil can result in blood lead levels up to 94 ug/dL. Exposures to lead in areas with lower lead concentrations (concentrations below 190 mg/kg in soil) were predicted to result in blood lead levels of 8.4 ug/dL blood (in children).

The baseline health risk assessment (HRA) evaluated potential exposures and health risks of residents currently living near the site and future residents who may live at the site. Health risks were estimated based on a reasonable maximum exposure (RME) scenario. The RME scenario is defined as the highest exposure that is reasonably expected to occur at a site. The intent of the RME scenario is to develop an estimate of exposure well above average but which is still within the range of possible exposures. The assumptions used in developing the RME exposure scenario are health-protective, in that they assume exposures to the 95 percent upper confidence limit (UCL) of the average level of chemicals at a site. Such assumptions are endorsed by the EPA because they are not likely, in actuality, to underestimate the exposures or health risks from the site. The assumptions used in estimating the RME and the rationale for those assumptions are presented in detail in Appendix F, Baseline Health Risk Assessment, of this report. Use of the RME scenario reflects compliance with guidance provided by the Risk Assessment Guidance for Superfund: Human Health Evaluation Manual Part A (EPA, 1989) and also with the California Department of Health Services (DHS).

The chemicals of primary concern, identified in the HRA, included arsenic, lead, cadmium and nickel, polycyclic aromatic hydrocarbons (PAHs) and total petroleum hydrocarbons (TPHs). The metals identified have demonstrated carcinogenic effects in laboratory animals or in epidemiological studies. Low-level exposure to lead is also associated with neurological and behavioral effects, particularly in children. PAHs have been shown to be carcinogenic in laboratory animals. Chlorinated and aromatic volatile organic compounds (VOCs) and metals have been detected in groundwater at the site, however these are of lower human health concern because exposures to groundwater have not been identified at this time.

The exposure pathways addressed in this HRA are specified for either current or future residential land use. The current residential land use exposure pathways for off-site residents are:

- Inhalation of resuspended dust;
- Soil ingestion (unauthorized entry on-site);
- Soil ingestion (off-site);
- Crop ingestion (deposition of resuspended dust onto off-site soil);
- Dermal exposure (unauthorized entry on-site); and
- Dermal exposure (deposition of resuspended dust onto off-site soil).

The future residential land use exposure pathways for on-site residents are:

- Inhalation of resuspended dust;
- Soil ingestion (on-site);
- Crop ingestion (vegetables raised in backyard gardens in on-site soils); and
- Dermal exposure (on-site soils).

A complete groundwater exposure pathway was not identified in the HRA. Aquifers near the site that have been impacted by contaminants are not used for drinking water, while existing drinking water supplies are distant from the site. A groundwater modeling study based on a 30-year release scenario indicated that contamination in groundwater would not affect existing drinking water wells (RI, Volume 1 of this report).

2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

2.1 INTRODUCTION

The purpose of this section of the FS is to identify technologies that may be applicable to the UPRR - Sacramento site. The identification of remedial technologies is completed in the order and sections as follows:

- RAOs are developed which describe goals for protecting human health and the environment, Section 2.2;
- Volumes of media (soil, groundwater) to be remediated are calculated, Section 2.3;
- General response actions are identified which may satisfy the RAOs, Section 2.4;
- Applicable technology types and process options are identified and screened, Section 2.4;
- Technology types are evaluated for effectiveness, implementability, and cost, Section 2.5.

2.2 REMEDIAL ACTION OBJECTIVES

RAOs are site-specific goals for remediation of soil and groundwater which are protective of both human health and the environment. RAOs may be developed from ARARs or through risk assessment.

ARARs are identified from the range of contaminants and pathways identified in the RI and other risk assessment tasks. Factors considered in selecting ARARs include:

- Chemical type;
- Affected media (air, soil, surface water, groundwater, biota);
- Specific goals and objectives of the requirement; and
- Circumstances under which an ARAR may be waived.

Waivers for ARARs include implementation of interim remedial measures (IRMs) and circumstances in which compliance with an ARAR would result in greater health risks than would otherwise be obtained.

ARARs are available largely for contaminants in groundwater or surface water. ARARs are unavailable for contaminants in soil or in air. Health risks associated with toxicants in soil or air will be addressed through toxicity and risk assessment methodologies.

The Baseline Health Risk Assessment (HRA) evaluated existing site conditions as characterized in the RI, identified existing and potential exposure pathways from the site, estimated potential exposures of surrounding populations and the environment through those pathways, and characterized the potential risks resulting from exposure to site contaminants. From the suite of chemicals detected in soil or groundwater at the site, the HRA identified selected chemicals that were of human health concern. These chemicals represent the most suitable candidates for developing RAOs.

2.2.1 Contaminants of Interest

2.2.1.1 Soil

The chemicals of concern in soils are arsenic, lead, PAHs and diesel range TPH. Based on the HRA, lead and arsenic in soils at the site are of greatest human health concern. The cancer risks associated with PAHs in the soil are approximately one order of magnitude lower than the cancer risks associated arsenic. Also, PAHs are found in more limited areas of the site than lead or arsenic. TPHs were also detected in limited areas of the site, however, evaluation of petroleum hydrocarbons detected in soils is limited by a lack of a human health criteria for these compounds. The health risks potentially associated with exposure to the TPHs were therefore assessed using toxicity data for the various known toxic or carcinogenic constituents of the TPH family of compounds.

2.2.1.2 Groundwater

The HRA did not identify a complete exposure pathway from contaminant sources to drinking water sources, hence chemicals in groundwater were not considered to be a threat to human health. There are ARARs for some of the chemicals detected in groundwater. These chemicals are chlorinated volatile organic and aromatic compounds and metals, and their ARARs are listed in Table 3.

2.2.2 Exposure Pathways

The HRA identified the following soil exposure pathways for purposes of calculating risk based residual concentrations.

- Inhalation of fugitive dust emissions;
- Ingestion of soil on-site;
- Deposition of fugitive dust emissions off-site and uptake in off-site backyard gardens and exposure through crop ingestion; and
- Ingestion of crops from backyard gardens grown on-site.

Table 1 summarizes the soil exposure pathways.

2.2.3 Development of Remedial Action Objectives

2.2.3.1 Soil Remedial Action Objectives

The risk based residual concentrations are presented in Table 1. This table presents soil concentrations equivalent to various acceptable intake levels such as Reference Doses (RfDs), or acceptable cancer risk levels. Risk based concentrations are compared to background concentrations, regulatory standards, and detection limits to choose the chemical-specific remedial objective. Table 2 summarizes these values and the soil RAOs selected for the UPRR site. Chemical-specific ARARs define acceptable levels of exposure and can be used in establishing preliminary RAOs. However, chemical-specific ARARs are not available for the UPRR site soil contaminants. Concentration of TPHs detected in soils at the site in some areas exceed the California Leaking Underground Fuel Tank (LUFT) guidelines. Therefore, the remediation or removal of soils from those areas exceeding the LUFT guidelines is also addressed in this FS.

The following concentrations of lead, arsenic, and TPHs were selected as the RAOs for the soils at this site:

- Lead - 190 mg/kg, based on the on-site soil ingestion pathway;
- Arsenic - 8 mg/kg, based on the background concentrations of arsenic in soils; and
- TPH - 1,000 mg/kg, based on LUFT guidelines.

The RAO for lead is the health-based residual concentration in soil, insofar as it is unlikely to result in blood lead levels above 15 ug/dL. Attaining this concentration of lead in soil is likely to reduce risks to acceptable levels for all pathways.

The RAO for arsenic was set at the measured local background level, because health-based concentrations for arsenic would result in soil arsenic levels below background. Selection of background as a level RAO reduces risk from arsenic to levels comparable to arsenic in uncontaminated soils distant from the site.

The RAO selected for diesel hydrocarbons is based on LUFT guidelines. The soil cleanup level for diesel hydrocarbons is 1,000 mg/kg TPHs.

These RAOs are the chemical concentrations in soil which must be achieved to allow unrestricted site use for all of the pathways evaluated in the risk assessment. If the recommended remedial actions at the site cannot meet these RAOs, then site use limitations or controls on exposure pathways may be appropriate in order to meet acceptable health risk levels.

2.2.3.2 Groundwater Remedial Action Objectives

Groundwater RAOs will be set at the drinking water ARARs for chemicals of concern until a more complete understanding of the extent of the on- and off-site groundwater contamination is developed. These chemicals are identified and the ARARs used as RAOs are provided in Table 3.

2.3 IDENTIFICATION OF OPERABLE UNITS

This section of the FS report identifies volumes of soil and groundwater with contaminants in concentrations exceeding the RAOs and hence requiring remedial action. The areas with soil and groundwater contamination have been divided into units anticipated to require similar remedial actions, as provided in the CERCLA guidance documents (EPA, 1988a). These areas are called Operable Units (OUs). The division of the site into OUs was based on the presence of a variety of different chemicals of concern, different media requiring remedial action, and the variety of material handling techniques required. The soil and groundwater OUs are discussed in the following sections.

2.3.1 Soil Operable Units and Volumes

Based on the results of the soil investigation conducted as part of the RI, several areas have been identified at the UPRR-Sacramento site which are subject to mitigation (Figures 25-27). These areas are identified by their key characteristics, including the principal chemicals, volume and average depth of contamination above RAOs as summarized in Table 4. Several areas exhibit the same principal contaminants distributed at similar depth, and therefore, are combined into a single soil OU based on the type of technology that can be applied in a remedial cleanup effort. Thus, the contaminated areas are combined into three soil OUs as outlined in Table 6 and indicated in Figures 24, 25, and 26. The OUs were separated on the assumption that soils affected by TPH only, or As and Pb only, could be remediated differently than soils affected by As, Pb and TPH together.

The three OUs are described separately although there is a spatial overlap between OUs and so the volumes stated below are not additive:

- Soil Operable Unit S1 is shown on Figure 24, and the principal chemicals of concern are diesel and gasoline range petroleum hydrocarbons. The estimated area of S1 which contains greater than 1,000 ppm total petroleum hydrocarbons is approximately 106,000 square feet, or roughly 2.5 acres and the estimated total volume is approximately 24,500 cubic yards of soil.

- Soil Operable Unit S2 is shown on Figure 25, and the principal chemicals of concern are arsenic and lead. The estimated area of S2 which contains greater than 8 mg/kg arsenic or 190 mg/kg lead is approximately 1,150,000 square feet, or roughly 26 acres, and the estimated total volume is approximately 107,000 cubic yards of soil.

- Soil Operable Unit S3 is shown on Figure 26, and consists of soil that contains arsenic, lead, or diesel and gasoline range hydrocarbons at levels greater than 8 mg/kg, 190 mg/kg, and 1,000 mg/kg, respectively. The materials in S3 are estimated to cover approximately 1,150,000 square feet or roughly 26.5 acres, and total approximately 116,000 cubic yards.

2.3.2 Groundwater Operable Units and Volumes

Impacted groundwater can initially be divided into five separate plumes that relate to impacts from chlorinated solvents, aromatic hydrocarbons, and metals (See Figure 27). These plumes are described as follows:

Plume A	Off-site groundwater containing chlorinated solvents primarily 1,1-DCE but also containing 1,1,1-TCA, 1,1-DCA, 1-2-DCA, and TCE.
Plume B	On-site groundwater containing aromatic hydrocarbons such as benzene, toluene, xylene, and ethylbenzene.
Plume C	On-site groundwater containing chlorinated solvents as discussed above for Plume A.

Plume D — Deep zone aquifer containing chlorinated solvents such as 1,1-DCE, 1,1-DCE, and TCE.

Plume E — On-site groundwater containing the metals nickel, chromium, and lead.

These plumes are combined to form the following groundwater OUs.

G1 — Consists of Plume A containing the chlorinated solvents and Plume B which contains aromatic hydrocarbons.

G2 — Plumes C, D, and E are combined to form OU G2. This plume contains low-level chlorinated solvents and metals.

The spatial distribution of the various metals, and aromatic and chlorinated solvents is shown on Figure 27. This figure was developed using data from the Hydropunch and Groundwater Investigation (Dames & Moore, 1990b). The approximate boundaries of the OUs are based on the extent of the various compounds that exceeded the state maximum contaminant level (MCLs), state action levels (AL), or were an order of magnitude above background if no MCLs or ALs were available. The areal extent and volume of each plume is summarized in Table 5.

Volumes for Plume A are based on the two modeling simulations reported in the Hydropunch and Groundwater Investigation Report (Dames & Moore, 1990b). The model simulated the extent of contamination for releases over 10 years and releases over 30 years. The two values of Plume A give the range of volumes possibly affected. However, it needs to be understood that the exact extent of contamination has not been defined and these volumes represent estimates based on modeling results. These volume estimates will be refined as more data become available.

The approximate boundary of Plume A for the 30-year simulation was established as the 6 μg/L concentration contour for 1,1-DCE and encompasses about 976,000 square feet (Figure 28). The concentration of 6 μg/L is the state MCL for 1,1-DCE. An average thickness of 25 feet was used to compute the volume. The thickness was taken as the distance between the elevation of the water table and the base of shallow zone sand. Using the above dimensions and assuming a porosity of 0.3 (Bouwer, 1978), the volume of off-site groundwater containing chlorinated solvents above 6 μg/L is approximately 7.32 x 10^6 cubic feet. The distribution of other contaminants is also included within the chlorinated solvent plume.

The areal extent of Plume A for the 10-year simulation, about 527,800 square feet (Figure 27), is much smaller than for the 30-year simulation. The approximate boundary of the plume is based on both the extent of chlorinated solvents found above MCLs during the interim investigation and results from the 10-year simulation. The lateral edge of the plume is based on sampling results while the downgradient edge is based on the 10-year model simulation. The thickness of the aquifer is known to vary over the extent of the plume, therefore, the plume was divided into separate subvolumes, each of equal thickness. The total volume of Plume A was then estimated by calculating each separate subvolume. Subvolumes were calculated by determining the areal extent of the plume between elevation contours for the base of the sand. Subvolumes were determined for thicknesses of 20.0, 22.5, 25.0 and 30.0 feet and are given in Table 6. As before, a porosity of 0.3 was used. The total volume was estimated to be 3.71 x 10^6 cubic feet.

Aromatic compounds define the extent of Plume B. This plume is completely contained within the extent of Plume A. The areal extent of Plume B is approximately 7,519 square feet. The thickness was estimated to be about ten feet since the aromatics appear to be mostly limited to the upper part of the aquifer. The total volume was estimated to be about 226 x 10^4 cubic feet.

The volume of Plume C, 2.39 x 10^5 cubic feet, is based on an areal extent of about 53,110 square feet, a thickness of 15 feet (based on the distance between the water table and base of the sand in this area), and a porosity of 0.3. The volume of Plume D, 3.55 x 10^5 cubic feet, is based on contaminants found in the deep aquifer zone. The areal extent was estimated to be 11,834 square feet while the thickness was assumed to be 10 feet. Again, the porosity was assumed to be 0.3. Figure 30 is a schematic that shows the relation with depth of Plumes A, B, and D.

Metals in groundwater occur sporadically across the site. However, a small OU was defined inside Plume E. The areal extent was estimated to be about 9,780 square feet using a thickness of 15 feet and a porosity of 0.3, the volume is about 4.40 x 10^4 cubic feet.

2.4 GENERAL RESPONSE ACTIONS

General response actions applicable to groundwater and soil at this site have been developed to satisfy the RAOs. The range of general response actions in this report include source reduction and exposure pathway control measures. Source reduction measures lower the concentrations of contaminants in soil and groundwater to meet the RAOs. Pathway control measures prevent exposures after the contaminant concentrations at the site have been reduced to an acceptable residual risk level.

2.4.1 Soil

For the soil OUs, the applicable general response actions are as follows:

- No action;
- Institutional actions;
- Containment actions;
- Treatment actions; and
- Disposal actions.

Consideration of the no action response is a recommendation under the NCP, and is included for the baseline evaluation. The institutional action response includes site access restrictions, land use limitations, and regulatory actions that do not actively treat chemicals in the affected media, but instead control human and environmental exposures. Containment of soil is used to reduce potential transport of contaminants by sequestering the soil with, for example, a cap or vault. Treatment of soil includes several methods for reducing the concentration of contaminants from the soil or reducing the mobility of the contaminants. Disposal of soil includes both disposal of contaminated soil and/or residuals from treatment processes.

Each of these general response actions represents several remedial technologies that may be used to implement the response action. Some of these are technologies that were used as examples above to show how response actions are implemented. In the next section, a complete list of the remedial technologies is developed and screened.

These general response actions for addressing site-specific soil contamination and exposure pathways are summarized in Table 8.

2.4.2 Groundwater

For the groundwater OUs, the applicable general response actions are as follows:

- No action;
- Institutional actions;
- Containment actions;
- Collection/treatment actions; and
- Collection/discharge actions.

Consideration of the no action response is recommendation under the NCP, and is included for the baseline evaluation. Institutional actions could include site access restrictions, land use limitations, zoning laws, and local regulatory actions that can be used to prevent exposure to contaminated groundwater. Institutional actions also include monitoring of groundwater quality. Future actions could be based on the monitoring data. Physical groundwater containment may include the installation of caps and vertical or horizontal barriers. Hydraulic groundwater containment would be accomplished by pumping, injection, infiltration, or a combination of these. Collection/treatment actions involve the pumping of contaminated groundwater and removal or reduction of the contaminants prior to discharge of the effluent. This response action may then require management, disposal, and/or treatment of residuals such as vapors or spent carbon. Collection and discharge includes pumping groundwater and then discharging the effluent directly to either an on-site use or off-site approved disposal point.

2.5 IDENTIFICATION AND SCREENING OF APPLICABLE TECHNOLOGY TYPES AND PROCESS OPTIONS

In this section, applicable technology types and process options for each general response action are identified and screened. To conform with the definitions set forth in the Guidance for Conducting Remedial Investigation and Feasibility Studies under CERCLA (EPA, 1988a), the term "technology types" refers to general categories of technologies, such as chemical treatment, thermal destruction, solidification, or capping. The term "process options" refers to specific processes within each technology type. For example, the chemical treatment technologies include such process options as precipitation, stripping, carbon adsorption and reverse osmosis.

After identification, process options within each technology type are also identified. Process options and/or entire technology types may be eliminated from further consideration on the basis of technical implementability. This is accomplished by using readily available information from the RI site characterization, including contaminant types, concentrations, and site characteristics to screen options that cannot be effectively implemented at the site.

Process options are chosen that would most favorably represent the entire technology type. The process options identified as potentially applicable to the UPRR-Sacramento site were chosen for alternative screening because they were either proven effective or possessed some other feature that, by engineering judgement, would make them more implementable or attractive as remedial processes.

2.5.1 Identification and Initial Screening of Process Options and Remedial Technologies

For the identified general response actions, potential remedial technology types and processes are identified and screened in Figures 30 and 31 for soil and groundwater respectively. The figures summarize the technology screening; technologies and individual processes that have been screened from further analysis are shaded. Screening comments for the remedial technologies and process options are included in Figures 30 and 31 and detailed descriptions of process options are provided in Appendix A.

Remedial technologies were initially screened on the basis of technical implementability. On this basis, several remedial technologies and individual process options were eliminated for both soil and groundwater. For soil, most of the remedial technologies and process options were retained except soil vapor extraction which was eliminated because it is not applicable to the site. Additionally, on-site disposal was eliminated on the technical infeasibility of permitting and constructing a RCRA facility.

For groundwater, containment by use of vertical and/or horizontal barriers has been ruled out as a general response action due to the depth of the base of the shallow aquifer which would prevent the installation of an effective vertical barrier. Capping would not be effective for mitigating groundwater flow from the area because groundwater flow from the site is composed primarily of lateral flow across the site through the shallow aquifer channel sands with negligible recharge from the site. Hydraulic containment by use of infiltration galleries is not implementable due to soil conditions and the existence of a hardpan layer. Groundwater collection utilizing subsurface drains is not potentially applicable to the deep aquifer at the site.

In terms of groundwater treatment, thermal destruction is not a potentially applicable technology since large volumes of groundwater need to be treated. The type and level of contaminants in the water also make this technology impractical. Reverse osmosis has been screened out because it is not feasible for large volumes of groundwater and because it is more commonly used for removal of dissolved solids. All other process options considered were found to be potentially applicable to the site. These options will be evaluated in more detail and screened in the next section.

2.5.2 Evaluation of Process Options

In this step, process options were evaluated in more detail and further screened using the following three criteria:

- Effectiveness
- Implementability
- Cost

To enable selection of representative process options for remedial technologies, the evaluation focuses on effectiveness factors with less effort directed at the implementability and cost evaluation. The result of this evaluation is the selection of one or more process options to represent each remedial technology as necessary. The process options evaluation is summarized in Figures 32 and 33. Screening comments are summarized within the following descriptions of screening criteria.

2.5.2.1 Effectiveness

Specific technology processes were evaluated for their effectiveness relative to other processes within the same technology type. This evaluation focused on:

1. The potential effectiveness of process options in handling the estimated areas or volumes of media and meeting the goals identified in the RAOs;

2. The effectiveness of the process options in protecting human health and the environment during the construction and implementation phase; and

3. The reliability and proven application of the process with respect to the contaminants and conditions at the site.

Soil

The no action process option is not effective in achieving the RAO but is retained for a baseline comparison.

Institutional actions are effective in reducing direct contact and ingestion pathways of exposure to soil contaminants. They may have applicability at this site and are retained for development of alternatives.

Capping process options may be used in conjunction with other processes and are retained for further analysis.

Treatment process options which reduce the toxicity, mobility, and volume of the soil contaminants are available and are retained for development of alternatives.

Groundwater

For groundwater, the no action process option will include monitoring due to the Porter-Cologne Act requirements and the aquifer nondegradation policy of the RWQCB.

Institutional actions have applicability at this site and are retained for development of alternatives. Access and deed restrictions are effective in limiting exposure pathways. Monitoring will assist in early detection of any off-site migration and also will be needed to evaluate the clean-up.

Physical and chemical pretreatment are effective and reliable technologies. Precipitation as a process option can be effective for removal of metals. The choice of one or any combination of these pretreatment methods will be dependent on the requirements of the effluent polish process.

Effluent polish procedures can all, theoretically, be effective in removal of contaminants present in the groundwater. However, their effectiveness at this site will need to be verified by treatability studies before making the decision of selecting one or a combination of processes.

Ex situ bioremediation is not an effective option for the contaminant concentrations present in groundwater and is screened out from further evaluation.

2.5.2.2 Implementability

Implementability encompasses both the technical and institutional feasibility of utilizing a specific technology process. Technical implementability was used as an initial screening criteria for technology types and process options to eliminate those that were clearly ineffective or unworkable at the site. Therefore, the subsequent, more detailed evaluation of process options places greater emphasis on the institutional aspects of implementability, such as the ability to obtain necessary permits for off-site actions, the availability of treatment, storage, and disposal services (including capacity), and the availability of necessary equipment and skilled workers to implement the technology.

Soil

Institutional actions and containment processes are easily implementable and are retained for development of alternatives.

Soil flushing is not technically implementable due to questionable environmental controls and recovery of solvents from the in situ soils. The fine-grained soils of this site would be difficult to flush solvents through and, consequently, collection and extraction of elutriate would be very difficult.

Chemical fixation is retained, however it has implementability constraints if fixation does not adequately stabilize the target chemicals. Treatability tests will be required during the remedial design phase if this process option is adopted for site remediation.

In situ vitrification, is an innovative technology which is still in the developmental stages. The technology has primarily been used for solidification of inorganic wastes and is considered by EPA to be the "best" available technology for stabilizing arsenic in soil; however, organic wastes are partially combusted and volatilized by the treatment process. In situ vitrification has not been utilized for large-scale stabilization. This process option has therefore been screened out.

Groundwater

Institutional actions are easily implemented on-site and have been retained for further development of alternatives. The implementability of access and deed restrictions for the off-site plume is not known at this time.

In situ bioremediation process options may be implementable for the off-site plume and have been retained for further evaluation. However, its implementability and effectiveness under site-specific conditions should be verified by pilot-scale studies.

Management of treatment residuals by thermal destruction or landfilling on-site will be unacceptable to the public and permitting will be very difficult and is screened out. Carbon regeneration off-site will be the representative process option for management of treatment residuals if carbon adsorption is the selected treatment process option. Off-site landfilling has not been screened out for sludge residuals resulting from pretreatment which may have to be landfilled or partially treated and landfilled.

2.5.2.3 Cost

Cost plays a limited role in the screening of process options. For screening purposes, relative capital and operating costs are generally used rather than detailed estimates. The cost analysis was based on engineering judgment, and each process was evaluated as to whether costs are high, medium, or low relative to other process options in the same technology type. This procedure is considered appropriate because the greatest cost consequences in site remediation are usually associated with the degree to which different general technology types are used. For example, containment, treatment and excavation have major cost differences, whereas using different process options within a technology type usually has a lesser effect on cost.

The exact process option to be used for site remediation will be determined during development of the Remedial Action Plan, subsequent to agency and community acceptance of the select site-wide remedial action. The groundwater treatment process options will have to be evaluated and compared based on treatability study results and detailed capital and operating costs before one process or a combination is finally selected for the Remedial Action Plan.

3.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

In this step of the FS, the remedial technologies and process options that remain following the screening process are combined to form remedial action alternatives designed to address the affected soils and groundwater at the site and the significant pathways of potential contaminant migration. The purpose of the following analysis is to develop preliminary and final candidate remedial alternatives for the site which protect human health and the environment and encompass a variety of waste management alternatives, including:

- Elimination of contaminated soil and groundwater at the site;
- Complete reduction of contaminated soil and groundwater to RAOs;
- Partial reduction to an acceptable low risk level and prevention of potential off-site migration;
- Control of potential exposure pathways; or
- Some combination of the above.

The development of alternatives requires that the following tasks be completed:

- Develop RAOs which describe goals for protecting human health and environment;
- Define media-specific OUs and calculate volumes of media requiring remediation;
- Identify general response actions to satisfy RAOs;
- Identify and initially screen applicable technologies and process options;

- Evaluate remaining technologies and process options for effectiveness, implementability, and cost; and

- Combine general response actions and process options for each medium or OU to form alternatives.

During the evaluation, preliminary alternatives are eliminated from further consideration if they:

1) Do not effectively protect human health and the environment;

2) Are flawed with respect to administrative or technical feasibility; or

3) Are significantly higher in cost than other alternatives without a corresponding increase in benefit, protection, or reliability.

Screening of preliminary alternatives produces a manageable group of the most appropriate final candidate alternatives which are evaluated in detail in subsequent sections of the FS Report.

The RI, summarized in Section 1.0 of this report, did not indicate a strong interaction between the soil and groundwater media. For the purposes of developing and screening alternatives, the selected alternatives have been combined into media-specific alternatives for remediation of soil and groundwater. These alternatives are evaluated separately in the following sections.

3.1 DEVELOPMENT OF SOIL ALTERNATIVES

Soil remedial alternatives have been developed which cover a full range of actions and accompanying implications with regards to response and possible consequences. We have examined no action, institutional controls, actions which would reduce or eliminate migration, control of potential exposure pathways, contaminant source reduction and removal, and alternatives which would require restricted future land use as well as those which would allow essentially unrestricted uses.

3.1.1 Introduction

Nine alternatives were developed from the initial screening of remedial technologies and process options as discussed in Section 3.1.2. These alternatives were based on the areas identified by overlaying contaminant distribution maps for each of arsenic, lead, and TPH at different depths. The combined site-wide contaminant distribution is presented in Figures 34 through 39. These figures show the areas affected by each key contaminant above the RAO, namely:

Arsenic (As) > 8 mg/kg
Lead (Pb) > 190 mg/kg
Total Petroleum Hydrocarbons (TPH) > 1,000 mg/kg

The depths of affected soils above the RAOs are also shown on Figures 34 through 39. The volumes of soils which are affected by a combination of either one, two or three of the key contaminants are presented in Table 4. This table represents the total volume of soil (± 20%) above the site RAOs. The area of soil above the RAOs has been delineated as a soil OU. The recommended soil OUs for remediation of the site are discussed in Section 2.3 and shown in Figures 24 through 26. The OUs were identified as follows:

S1 - TPH
S2 - AS or Pb
S3 - AS, Pb and/or TPH

Within these soil OUs are zones of higher concentrations referred to as "hot spots" which are soils containing:

As > 100 mg/kg
Pb > 1,000 mg/kg
TPH > 1,000 mg/kg

The hot spots are shown on Figure 38.

3.1.2 Identification of Soil Alternatives

A total of nine alternatives, including no action, limited action, a range of treatment alternatives covering the management of residual contaminants, and a non-residual alternative have been selected for further development and screening (Table 9). These alternatives are summarized below:

Alternative 1: **No Action** - This alternative would leave the site in its present condition.

Alternative 2: **Institutional Controls** - This alternative would provide institutional controls such as zoning and voluntary land use limitations, fencing, and periodic soil and groundwater monitoring to evaluate the potential migration of target chemicals off-site.

Alternative 3: **Limited Action** - This alternative would combine dust control by irrigation and revegetation with land use limitations and access restrictions to reduce the exposure pathways. Periodic monitoring of soil and groundwater would be required to evaluate potential migration.

Alternative 4: **Containment** - This alternative would place a cap over soil containing target chemicals at concentrations which exceed the RAOs. This alternative would include dust control, land use limitations, excavation controls, and periodic monitoring of soil, groundwater, and cap integrity.

Alternative 5: **Excavation and On-Site Treatment** - This alternative would involve excavation of arsenic and lead hot spots and treatment by soil washing on-site. Excavation and bioremediation would be used for TPH soils above RAOs. Other soils above the RAOs would be remediated by dust control and capping. Periodic monitoring of soil, groundwater, and cap integrity would be required.

Alternative 6: **Excavation and Off-Site Disposal** - Hot spots for arsenic, lead and TPH would be excavated and transported for off-site disposal. Dust control and a cap for other areas above the RAOs would be included as well as periodic monitoring of soil, groundwater, and cap integrity.

Alternative 7: **Excavation and Off-Site Treatment and Disposal** - Similar to Alternative 6 in all respects except for treatment of the excavated soil off-site before disposal.

Alternative 8: **In Situ Treatment** - This alternative would focus on in situ bioremediation of TPH and in situ soil stabilization techniques for metals with capping, dust control and periodic monitoring of soil, groundwater and cap integrity.

Alternative 9: **Full Treatment** - This alternative would combine the representative technologies and process options identified in Alternatives 5, 6, 7, and 8 to excavate and treat all soil above the RAOs.

These alternatives are screened in Section 3.2 in terms of their suitability for the remediation of each of the soil OUs. Because some of the alternatives are not suitable for remediation of all of the soil OUs, a screening of applicable alternatives is performed on the basis of effectiveness, implementability, and cost.

3.2 SCREENING OF SOIL ALTERNATIVES

Each of the nine identified alternatives are analyzed in terms of effectiveness, implementability, and cost for remediating contaminated soils in the three soil OUs, namely:

S1 - TPH
S2 - As, Pb
S3 - As, Pb and/or TPH

These soil OUs are shown in Figures 25 through 27. Due to the overlapping nature of the contaminant distribution, OU S3 is the dominant area on the site (Figure 26). The screening of the soil remedial alternatives in this section is therefore focused on OU S3. More detailed consideration of S2 and S1 is provided in Section 4.0 under detailed analysis of soil alternatives.

The screening criteria include the following factors:

- Effectiveness - Protection of human health and the environment.
  - Compliance with the ARARs or RAOs.
  - Reduction in toxicity, mobility and volume.

- Implementability - Technical feasibility.
  - Availability of technology and expertise.
  - Administrative approval.

- Cost - Rough-order-of-magnitude or relative estimate of costs.

3.2.1 Soil Alternative 1 - No Action

Soil alternative 1 (SA-1) would leave the site in its present condition. Analysis of this alternative is required as a baseline only. The alternative would not meet the site RAOs nor provide protection of human health and the environment as indicated by the baseline health risk assessment. It would not reduce the toxicity, volume, or mobility of the soil contaminants.

The no action alternative is readily implemented, requires no technology or expertise, but would not meet with regulatory or community approval.

There would be no costs associated with the no action alternative. SA-1 is retained as a baseline requirement.

3.2.2 Soil Alternative 2 - No Action with Institutional Controls

Soil alternative 2 (SA-2) would provide deed restrictions and zoning constraints on future land use. For example, excavation and future activities could be limited to areas outside the hot spots. Siting of some developments which could expose the public to higher potential health risks would not be permitted, fencing of the site would be required, and periodic soil and groundwater monitoring would be undertaken to detect target chemicals moving off-site.

Due to the potential for dust generation, SA-2 would not provide consistent and long-term protection of human health and the environment nor does it meet the site RAOs. It would also unduly limit future use of the site. SA-2 would not provide any reduction in toxicity, mobility, or volume of the soil contaminants except for the natural biodegradation of TPH.

SA-2 would be difficult to implement because zoning and land use limitations that significantly limit future land use are unlikely to be acceptable to the state or community.

The cost of acquiring approvals could be high, but probably less so than implementing a remedial technology alternative for the site. However, there is little likelihood of successful approval, the reduction in land value is very high, and, therefore, zoning and severe land use restrictions are a relatively costly alternative action. SA-2 is rejected as an applicable alternative for the UPRR site.

3.2.3 Soil Alternative 3 - Limited Action with Institutional Controls

Soil alternative 3 (SA-3) provides source control of the soil OUs by combining the institutional controls in SA-2 with dust control of affected soils during the dry summer months using irrigation and revegetation of the soil OUs. Dust has been identified as a potential exposure pathway for arsenic and lead, although site particulate monitoring shows that it is not a significant pathway. Ingestion and direct contact with soil is the more significant pathway and could be limited by revegetation of site soils.

SA-3 would be effective in providing a greater level of protection of human health and the environment and improved compliance with the site RAOs.

The toxicity and mobility of the site contaminants would be partially reduced by dust control and revegetation processes. There would not be a major reduction in volume of contaminants except for the biodegradation of the shallow soil TPH enhanced by the irrigated soil-plant system.

The irrigation of the site could be readily implemented with agricultural technology using potable, reclaimed, or untreated groundwater. Administrative approval is likely for a short-term interim remedial measure but acceptance by the state or community is not likely in the long term.

The cost of revegetation and summer irrigation of the soil OUs is estimated at $5,000/acre to establish vegetation and $1,000/acre per year to continue irrigation. This alternative would potentially have relatively high "hidden costs in that it could significantly reduce the value of the land for future development.

SA-3 is applicable for the site but screened out for detailed analysis because of low ranking.

3.2.4 Soil Alternative 4 - Containment with Institutional Controls

Soil alternative 4 (SA-4) would combine the institutional and source controls in SA-3 with a cap over soil with concentrations of target chemicals which exceed the RAOs. In addition to periodic soil and groundwater monitoring, periodic inspections of the cap integrity would be required. The cap could consist of an asphalt or concrete cover over soil hot spots and a soil cover over the remaining soils with concentrations of chemicals which exceed the RAOs.

SA-4 would provide short-term protection of human health and the environment and would meet site RAOs, however, the integrity of the cap could be damaged and not provide long-term protection. The toxicity and mobility of As, Pb and TPH would be reduced by controlling the exposure pathways. The volume of soil contaminants would not be reduced except for limited natural biodegradation of TPH by soil bacteria beneath the covers. Overall, this alternative does not meet the federal and state goals for reducing the volume of As and Pb contaminants.

Implementing a range of suitable covers for various soil types and contaminants is technically feasible, however, the integrity of the cover materials deteriorates over time depending on the design life and cost level of construction. Administrative approval for the use of caps for the long term would require land use limitations or zoning restrictions on the soil OUs and would not allow unrestricted land use. However, the use of caps could be more readily approved as a short- to medium-term solution for the site remediation.

The costs of constructing natural soil and vegetative covers and artificial covers could be on the order of $10,000/acre to $100,000/acre, respectively. If there is no contaminant source reduction and the capping alternative is only considered to be a short- to medium-term or temporary solution, then the investment is a relatively high cost.

SA-4 offers significant advantages for site remediation and is therefore accepted for detailed analysis.

3.2.5 Soil Alternative 5 - Limited Excavation and On-site Treatment with Institutional Controls

Soil alternative 5 (SA-5) would combine the excavation of hot spot areas for As, Pb and TPH and on-site treatment by soil washing (As, Pb) and bioremediation (TPH). Surface soils with As, Pb and TPH concentrations above the RAOs but less than the hot spot levels would be remediated by a combination of soil treatment, capping, and dust control depending on concentrations and contaminant type. Periodic monitoring of soil, groundwater, and cap integrity would be required to detect the migration of target chemicals.

SA-5 would be effective in protecting human health and the environment and in meeting the RAOs. The toxicity, mobility and volume of the majority of contaminated soils would be reduced. There are readily implementable technologies which can be designed after the completion of site-specific treatability studies.

Approval for this alternative is likely because SA-5 meets the evaluation criteria and does not provide significant restrictions on future land use.

Costs for this alternative are roughly estimated at $100-200/ton. The direct cost of implementing this long-term alternative will be significantly higher than the preceding alternatives which relied on land use limitations, capping, and site access restrictions, to meet the protection of human health and the environment as well as meeting the site RAOs. However, this factor is significantly mitigated by less severe limitations on future uses of the land.

SA-5 provides a suitable alternative for site remediation and is accepted for detailed analysis.

3.2.6 Soil Alternative 6 - Limited Excavation and Off-Site Disposal with Institutional Controls

Soil alternative 6 (SA-6) would excavate As, Pb and TPH hot spots and transport these soils off-site to an approved landfill facility for disposal. Capping and dust control would be implemented for other soils above the RAOs. Periodic monitoring of soil, groundwater, and cap integrity would be required to detect potential migration of target chemicals.

SA-6 would provide protection of human health and the environment and comply with site ARARs. The mobility and volume of the majority of soil contaminants would be significantly reduced at the site. However, off-site landfill disposal does not meet federal and state goals for reducing toxicity and volume of contaminants. Therefore, administrative feasibility must be lower for this alternative.

Costs for this alternative are roughly estimated at $200-400/ton depending on distance to a permitted facility, taxes, and the potential future liabilities related to possible identification as a responsible party to any future landfill disposal site cleanup.

SA-6 has been rejected for future detailed analysis on the basis of implementability and cost.

3.2.7 Soil Alternative 7 - Limited Excavation and Off-Site Treatment and Disposal

This soil alternative (SA-7) is similar to SA-6 except the excavated soil would be transported to an off-site treatment facility before final disposal.

SA-7 offers similar protection to human health and the environment and complies with site ARARs. There would be significant reduction in toxicity, mobility, and volume of soil contaminants.

The availability of off-site treatment facilities is limited. There are, however, acceptable and implementable technologies. Administrative feasibility for off-site treatment would be rated higher than off-site disposal without treatment.

The costs of off-site treatment and disposal are expected to be very high because of the limited number of existing treatment facilities. It is estimated that off-site treatment and disposal may cost on the order of $500-600/ton depending on distance to the treatment facility, taxes, treatment costs, and final disposal costs for the treated soil.

On this basis, SA-7 is considered to be an applicable alternative for the site but screened out for further detailed analysis on the basis of implementability and cost.

3.2.8 Soil Alternative 8 - In Situ Treatment with Institutional Controls

Soil alternative 8 (SA-8) would focus on in situ treatment of hot spots rather than excavation. Bioremediation would be used for TPH-affected soils and in situ stabilization techniques for As and Pb. Capping and dust control of other soils above the RAOs would be required during in situ treatment of hot spots. Periodic soil, groundwater, and cap integrity monitoring would be required.

SA-8 would offer increased protection of human health and the environment and meet the site RAOs by limiting dust generation caused by excavation, and the noise of construction activities. However, the bioremediation would require a longer period of time to reduce the contaminant levels than excavation. The toxicity and mobility of As, Pb and TPH would be significantly reduced by in situ treatment. The volume of TPH would be reduced by biodegradation. The As and Pb would remain in the soil in a fixed or immobile form, which is relatively more stable against weathering, leaching, or erosion and transport.

There are implementable techniques for in situ soil treatment and receiving regulatory approval is likely for a well-planned, designed, and operated systems.

The costs of in situ treatment should be less than excavation alternatives because of the lower capital, operational, and maintenance requirements. It is estimated that costs would be $100-200/ton, depending on the contaminant concentration.

SA-8 is retained for detailed analysis.

3.2.9 Soil Alternative 9 - Full Treatment

Soil alternative 9 (SA-9) would combine representative process options and remedial technologies from SA-5 (excavation and on-site treatment) and SA-8 (in situ treatment) to excavate and treat all soil containing concentrations of target chemicals above the RAOs. Reliance on dust control or capping to achieve protection of human health and the environment would be unnecessary.

SA-9 would reduce the toxicity, mobility and volume of soil contaminants to insignificant levels. The volume of excavated soils would be approximately five times greater than the limited excavation and treatment alternatives. Therefore, the time required for implementing and completing this alternative would be greater than other alternatives. The technologies are available but may require scaling-up to meet the estimated volumes of soil exceeding the RAOs. Approval of a full excavation and treatment alternative would be likely except for consideration of the time (approximately 5 years) and disruption caused by a large-scale excavation and treatment operation on the adjacent community.

The costs for this alternative will be the highest of all alternatives retained for consideration because the volume of affected soil is approximately five times greater. It is estimated that costs would run from $100-150/ton for this alternative.

SA-9 is retained for further detailed analysis in Section 4.0.

3.2.10 Soil Alternatives Retained for Detailed Analysis

Table 11 summarizes the alternatives remaining after screening of soil remediation alternatives for the soil OUs. The soil alternatives which remain following screening are:

- SA-1 - No Action
- SA-4 - Containment with Institutional Controls
- SA-5 - Limited Excavation and On-Site Treatment with Institutional Controls
- SA-8 - In Situ Treatment with Institutional Controls
- SA-9 - Full Treatment

3.3 DEVELOPMENT OF GROUNDWATER ALTERNATIVES

Groundwater remedial alternatives have been developed which cover a full range of actions and accompanying implications with regards to response and possible consequences. We have examined no action, institutional controls, actions which would reduce or eliminate migration, control of potential exposure pathways, contaminant source reduction and removal, and alternatives which would require restricted future groundwater use as well as those which would allow essentially unrestricted uses.

3.3.1 Introduction

A total of six alternatives were developed from the initial screening of remedial technologies, process options, and the retained alternatives, and are presented in Table 12. These alternatives are based on the current understanding of the site hydrogeology, extent of known groundwater contamination, and groundwater modeling. As additional groundwater data become available, the groundwater portion of this FS may be modified.

The groundwater OUs were described in Section 2.3 as follows:

- G1 - On- and off-site plumes containing chlorinated solvents and aromatic hydrocarbons; and

- G2 - On-site plume containing low levels of chlorinated solvents and metals.

The boundary of the groundwater OUs is defined by the groundwater RAOs, which are the state maximum contaminant levels (MCLs) for drinking water, state recommended action levels for drinking water, or levels significantly above background, as appropriate.

3.3.2 Identification of Groundwater Alternatives

The six alternatives developed for groundwater media are described below:

Alternative 1: **No Action** - This alternative only includes periodic groundwater monitoring. This alternative is included primarily for comparison purposes, as required by the NCP.

Alternative 2: **Limited Action** - The limited action alternative for groundwater restricts access to the aquifer by limiting drilling through permit restrictions. Since the plume is located in an area serviced by the city water supply, (from treated surface water) public access to the aquifer is expected to be minimal. Periodic groundwater monitoring is included.

Alternative 3: **Hydraulic Containment** - This alternative uses hydraulic containment to prevent movement of the plume. Extraction and injection wells are used to construct the hydraulic barriers necessary for hydraulic containment. Access to the aquifer is restricted and groundwater is monitored.

Alternative 4: **Extract and Discharge** - This alternative restricts use of the aquifer, extracts impacted groundwater, provides pretreatment, if necessary, and directly discharges the extracted groundwater to the public owned treatment works (POTW). Management of sludge residuals will be achieved by off-site disposal or thermal destruction.

Alternative 5: **Extract/Treat and Reclaim** - This alternative includes a groundwater extraction, pretreatment, polishing treatment for the effluent and discharge for reclamation use. Extraction wells would be placed for optimum containment and/or capture of the plume.

Pretreatment would reduce suspended solids by filtration and adjust pH as necessary. Management of sludge residuals would be achieved by off-site disposal or thermal destruction. Following pretreatment, effluent polishing with UV/oxidation, air stripping, Granular Activated Carbon (GAC), or any combination of the above, would be used to reduce contaminants to discharge standards. Discharge would be for on-site reclamation use such as dust control, irrigation, or used for soil washing in soil remediation. Discharge could also potentially be used for off-site reclamation, for example, irrigation of local parks. If GAC is the selected treatment option, the spent carbon would be transported off-site and regenerated.

Alternative 6: **In Situ Bioremediation** - This alternative uses in situ bioremediation in conjunction with pretreatment and polish techniques to treat groundwater to achieve RAOs. Nutrients and/or bacteria are introduced to enhance the breakdown of the contaminants of interest. The injection wells are used in conjunction with extraction wells to circulate the nutrients and create a hydraulic boundary to contain the plume.

These alternatives are screened in Section 3.4 in terms of their suitability for the remediation of each of the groundwater OUs. Specifically, the screening of the applicable alternatives is performed on the basis of effectiveness, implementability, and cost.

3.4 SCREENING OF GROUNDWATER ALTERNATIVES

Each of the six identified alternatives are analyzed in terms of effectiveness, implementability, and cost for remediating groundwater in the two groundwater OUs, namely:

- G1 - On- and off-site plumes containing chlorinated solvents and aromatic hydrocarbons; and

- G2 - On-site plume containing low levels of chlorinated solvents and metals.

The screening criteria include the following factors:

- Effectiveness - Protection of human health and the environment.
  - Compliance with the ARARs.
  - Reduction in toxicity, mobility, and volume.

- Implementability - Technical feasibility.
  - Availability of technology and expertise.
  - Administrative approval.

- Cost - Rough-order-of-magnitude or relative estimate of costs.

3.4.1 Groundwater Alternative 1 - No Action

Groundwater Alternative 1 (GA-1) would only monitor the groundwater aquifer. Analysis of this alternative is included as a baseline only. The alternative is not effective in protecting the environment, and would not meet the site RAOs, or reduce the toxicity, mobility, or volume of the groundwater contaminants.

The no action alternative is technically feasible but may not be administratively feasible since it is unlikely to receive regulatory or community approval.

There would be no costs associated with the no action alternative, other than ongoing monitoring. GA-1 is retained as a baseline alternative.

3.4.2 Groundwater Alternative 2 - Limited Action

Groundwater Alternative 2 (GA-2) would provide deed restrictions and zoning constraints on future use of the contaminated aquifer. The limited action alternative includes groundwater monitoring. The limited action alternative would provide short-term protection by denying access to groundwater, however, this alternative would not reduce the toxicity, mobility, or volume of groundwater contaminants. Monitoring would be effective in determining changes in concentrations in the aquifer.

The limited action alternative could be difficult to implement because aquifer use restrictions may not be acceptable to the state, local authorities, or the community for off-site contamination. It may be feasible for on-site contamination.

The limited action alternative for the on-site plume has a low cost. However, the off-site plume monitoring and aquifer use restrictions may require more complex and costly compliance requirements.

The likelihood of successful approval of this alternative for the off-site plume is uncertain but could be obtained during the FS review period. There is more likelihood of approval for this alternative for the on-site groundwater OU G2. Therefore, GA-2 is retained as an applicable alternative for the site.

3.4.3 Groundwater Alternative 3 - Hydraulic Containment

Hydraulic containment provides source control by interception of on-site contamination using extraction and injection wells. The hydraulic containment alternative includes groundwater monitoring, zoning, deed, and aquifer access restrictions. This alternative would not meet the RAOs, nor reduce the toxicity, but would potentially reduce the mobility of contamination.

This alternative could be effective in protecting human health and the environment by controlling the extent of the plume and allowing the contaminant concentrations to reduce by natural degradation. This alternative may not be effective for a spatially extensive contaminant.

The hydraulic containment alternative is technically feasible based on the current understanding of site hydrogeology and extent of on-site contamination, but will probably not be feasible off-site from both technical and administrative viewpoints.

The costs associated with hydraulic containment and monitoring are moderate to high for the on-site plume and rank high for the off-site plume.

The likelihood of successfully implementing this alternative for the off-site and on-site groundwater OU G1 is not high, although there is a likelihood that this alternative could be used for the on-site groundwater OU G2. Therefore, GA-3 is retained as an applicable alternative for the site.

3.4.4 Groundwater Alternative 4 - Extract, Pretreat, and Discharge

Groundwater Alternative 4 (GA-4) provides removal of contaminated groundwater with pretreatment and disposal to a POTW. This alternative would provide short-term and long-term protection to human health and the environment. GA-4 would reduce toxicity, mobility, and volume by using reliable technologies. The effectiveness of these technologies to achieve the RAOs could be verified by performing treatability tests during the development of the Remedial Action Plan if this alternative is selected for site remediation.

Further evaluation of the technical feasibility based on effluent discharge requirements will be needed. Implementation of this alternative will require that a discharge permit be obtained from the appropriate agencies. Allowable contaminant levels and flow rates of discharge to a POTW need to be determined during the permit process. The administrative feasibility of this alternative will not be finally known until permit applications are reviewed and decided upon by the agencies.

This alternative has a moderate cost. The discharge to the POTW would require fees for permit application, connection, treatment, usage, and piping to the discharge point. The pretreatment system would have a moderate capital cost. Extraction and monitoring costs would also be part of the cost for implementing this alternative. Pilot and laboratory scale treatability tests for this alternative prior to remedial design would also be a significant cost contributor. GA-4 is retained as an applicable alternative for the site.

3.4.5 Groundwater Alternative 5 - Extract, Treat, and Reclaim

Alternative GA-5 would remove and treat contaminated groundwater from the aquifer, then use the treated water for a variety of reclamation uses. This alternative would provide short-term and long-term protection to human health and the environment and reduce toxicity, mobility, and volume of contaminants.

GA-5 is technically and administratively feasible although the implementability of installation of off-site extraction wells is not known at this time. Reclamation of treated water is technically feasible. It can be used on-site as dust control or wash water for the soil remediation process. Use of reclaimed water for irrigation and dust control would require special permits and a water balance evaluation.

This alternative would be high in cost. The major cost for these alternatives would be the capital and operating cost of the treatment system. The pilot and laboratory scale treatability tests for this alternative prior to remedial design would also be a significant cost contributor. GA-5 has been retained as an applicable alternative for the site.

3.4.6 Groundwater Alternative 6 - In Situ Bioremediation

Groundwater Alternative, GA-6 would provide reduction of groundwater contamination through biological activity.

In situ bioremediation is an innovative technology and its effectiveness would have to be demonstrated by a laboratory treatability test pilot scale test if this alternative was selected for site remediation. This testing would take one to two years.

Environmental impacts of this alternative would have to be further evaluated as to the effect of injecting nutrients and an oxygen source into the aquifer. This alternative could potentially be effective in reducing toxicity, mobility, and volume of contamination. This alternative could be administratively feasible.

This alternative would be high in cost. The major cost for these alternatives would be the capital and operating cost of the treatment system. The pilot and laboratory scale treatability of these alternatives prior to remedial design is also a significant cost contributor. GA-6 is retained as an applicable alternative for the site.

3.4.7 Selection of Final Groundwater Alternatives

The following groundwater alternatives have been screened for detailed analysis and retained for evaluation in Section 4.0:

Retained Alternatives for Operable Unit G1

- G1-A2 - Limited Action - Monitoring, Deed/Zoning Restrictions
- G1-A4 - Extraction/Pretreatment/Discharge to POTW
- G1-A5 - Extract/Treat/Reclaim
- G1-A6 - In Situ Bioremediation

Retained Alternatives for Operable Unit G2

- G2-A2 - Limited Action - Monitoring/Deed/Zoning Restrictions
- G2-A3 - Hydraulic Containment/Monitoring

4.0 DETAILED ANALYSIS OF ALTERNATIVES

This section presents detailed analysis of the previously screened soil and groundwater alternatives for the UPRR-Sacramento site.

Each of these alternatives is evaluated in the following sections against nine criteria, namely:

- Overall protection of human health and the environment;
- Compliance with ARARs, or more appropriately for soils, the RAOs;
- Long-term effectiveness;
- Reduction of mobility, toxicity, and volume;
- Short-term effectiveness;
- Implementability;
- Cost;
- State acceptance; and
- Community acceptance.

4.1 DETAILED ANALYSIS OF SOIL ALTERNATIVES

A range of alternatives have been carried through for detailed analysis including the no action alternative; three alternatives requiring some level of institutional controls to manage residual contamination at the site; and one alternative which would leave negligible residual contamination at the site. All alternatives, except the no action alternative, have been screened and selected for their potential to protect human health and the environment and to reduce risk from the presence of As, Pb, and TPH to acceptable levels. As discussed in Section 3.0, soil OU S3 is the predominant soil OU, and as such, the following discussion of alternatives addresses the three OUs through consideration of S3.

The soil alternatives which have been carried through for detailed analysis are as follows:

- SA-1 - No Action
- SA-4 - Containment with Institutional Controls

- SA-5 - Limited Excavation and On-Site Treatment with Institutional Controls
- SA-8 - In Situ Treatment with Institutional Controls
- SA-9 - Full Treatment

The primary components of each selected soil alternative are shown in Table 11. The detailed costs for these soil alternatives are based on a five year implementation schedule.

4.1.1 SOIL ALTERNATIVE SA-1

No Action

This Soil Alternative (SA-1) would leave the site in its present condition. No remedial activities would be undertaken and there would be no institutional controls such as land use limitations, access restrictions, or monitoring of soil and groundwater to detect potential migration of contaminants. This is the situation which was assessed in the baseline health risk assessment. This alternative is included as a recommendation of the NCP and as a baseline upon which to judge the effectiveness and cost of other remedial alternatives.

4.1.1.1 Overall Protection of Human Health and the Environment (SA-1)

SA-1 would provide no control over dust migration, or the potential for leaching to the groundwater, or ingestion of soil particles or direct contact with the skin. There would be no land use restrictions or access restrictions such as are currently in place. As such, the no action alternative provides no protection to human health or control of exposure pathways and the migration of contaminants in the environment.

4.1.1.2 Compliance with ARARs (SA-1)

Because there is no action, SA-1 would not meet with any site ARARs or the RAOs, with the possible exception of the natural biodegradation of TPH to the 1,000 ppm level over a long period of time.

4.1.1.3 Long-Term Effectiveness (SA-1)

The no action alternative would not be effective in the long-term in meeting the RAOs.

4.1.1.4 Reduction in Mobility, Toxicity and Volume (SA-1)

Levels of As and Pb would not be significantly reduced in mobility or toxicity under the no action alternative. There would be continuing movement of soil particles containing As and Pb by wind and water erosion. However, a reduction in overall mobility and toxicity would arise from the leaching of As and Pb below 1-2 feet in the soil when these chemicals reached the low permeability iron hydroxide layer. There would be no reduction in the volume of As and Pb at the site except for that lost by wind and water erosion.

TPH would not be immobilized by the no action alternative and there would be the potential for transport of TPH through the vadose zone to groundwater during periods of high rainfall and percolation. There would be some reduction in toxicity and volume due to natural rates of biodegradation. However, this process is expected to be relatively insignificant without enhancement by nutrients and oxygen to increase bacterial breakdown of TPH.

4.1.1.5 Short-Term Effectiveness (SA-1)

There would be no additional risks posed to the community or the adjacent workforce or the environment from the no action alternative over that stated in the baseline health risk assessment.

4.1.1.6 Implementability (SA-1)

There are no implementability concerns because there is no action.

4.1.1.7 Cost (SA-1)

There are no costs associated with the no action alternative (Table 15).

4.1.1.8 State Acceptance (SA-1)

The level of state acceptance for this alternative will be evaluated during the FS review period.

4.1.1.9 Community Acceptance (SA-1)

Community acceptance of this alternative will be obtained during the FS review period and the public meeting to discuss the Draft RI/FS.

4.1.2 SOIL ALTERNATIVE SA-4

Land Use Limitations
Access Restrictions
Periodic Soil and Groundwater Monitoring
Irrigation and Revegetation to Control Dust
Capping with Vegetative and Artificial Covers

SA-4 would provide containment of soils above RAOs with institutional controls further limiting the exposure and migration pathways. Fencing, signs and possible site security would be maintained to restrict public access during the remedial activities but site access restrictions would not apply after the establishment of suitable covers. Land use limitations such as zoning and deed restrictions would alert future land owners and occupants to the presence of soil which could exceed health risk levels under certain circumstances and control site activities such as excavation.

Irrigation and revegetation would be used to control dust and establish vegetation on suitable soils. An artificial cover of concrete would be constructed to contain "hot spots" exceeding the threshold limits (As - 100 mg/kg, Pb-1,000 mg/kg, TPH-1,000 mg/kg). A soil and vegetative cover would then be placed over remaining soils exceeding the RAOs. The vegetative cover would be mowed and mulched onto the surface twice each winter growing season for five years to establish a summer dust control mulch layer.

These covers would be designed to limit infiltration of water beyond the root zone or impermeable artificial cap, prevent intrusion into the hot spot zones, and would require minimal maintenance and periodic inspection. Because the soil contaminants are contained on-site rather than treated or removed, it would be necessary to institute periodic soil and groundwater monitoring to detect any migration of contaminants off-site.

4.1.2.1 Overall Protection of Human Health and the Environment (SA-4)

The vegetative and artificial covers would be engineered to provide overall protection of human health and the environment by controlling exposure pathways and limiting public access to the site during remedial activities. Access to the site could be uncontrolled after construction of the covers. However, any future land use activities requiring disturbance of the cap, such as excavation, would be controlled by land use limitations and deed notices.

4.1.2.2 Compliance with ARARs (SA-4)

There are no ARARs for soil for As, Pb, and TPH, however, the containment and institutional controls alternative is likely to attain RAOs through proper engineering design and deed restrictions.

4.1.2.3 Long-Term Effectiveness (SA-4)

This alternative would be effective in the long-term if the land use limitations and access restrictions are adhered to and the integrity of the vegetative and artificial covers is maintained through periodic inspection and maintenance, as are necessary for any similar measures, regardless of level or presence of contaminants. There would need to be an acceptance of the costs and responsibility for maintaining the covers by the current or future land owners or occupants through the transfer of title, condition of occupancy, or by transfer to the City and/or County.

The certainty of ongoing maintenance would decline with time. This may be addressed through routine regulatory review of cover integrity and performance every five years in order to provide adequate protection of human health and the environment.

4.1.2.4 Reduction of Mobility, Toxicity, and Volume (SA-4)

SA-4 would provide significant reduction in the mobility and toxicity of As, Pb and TPH by controlling the exposure pathway to air, groundwater, soil ingestion, and skin contact. The contaminants would remain on-site, and except for the natural biodegradation of TPH, there would be no significant reduction in the volume of contaminants.

4.1.2.5 Short-Term Effectiveness (SA-4)

The construction of vegetative and artificial covers would require site preparation involving grading and earthworks. Subsequent dust generation would need to be controlled to avoid exposure and the potential for slight increase in health risk for the community and site workers. The covers could be constructed during a six-month construction period from May to October to avoid most rainfall interruptions to the construction schedule.

4.1.2.6 Implementability (SA-4)

There are no special materials requirements for constructing the caps and all necessary materials would be sourced locally. It is likely that the site would provide some suitable soil cover materials although this would increase the overall disturbed area requiring dust control and revegetation. A grading permit would be required from local agencies, and it could be necessary to import soils to the site.

The actual soil volume required to cover the estimated 24.0 acres of soil OUs above the RAOs to a depth of 0.5 feet is estimated to be approximately 21,500 cubic yards.

The area of hot spots requiring a concrete or asphalt cover is estimated to be 10,000 square yards.

4.1.2.7 Cost (SA-4)

Costs are presented in Table 16.

The net present cost of this alternative is estimated to be $3,066,000 with a capital cost of $2,954,000 and an operations and maintenance cost of $26,000 per annum in 1990 costs for initial summer irrigation, mowing and mulching for five subsequent years, cover inspections, and monitoring of soil and groundwater.

4.1.2.8 State Acceptance (SA-4)

The level of state acceptance of this alternative will be evaluated during the FS review period and discussed in the final RI/FS.

4.1.2.9 Community Acceptance (SA-4)

The community opinion and acceptance of this alternative can be determined during the FS review period and through the public meeting to discuss the Draft RI/FS and reported in the final RI/FS.

4.1.3 SOIL ALTERNATIVE (SA-5)

Excavation of Hot Spot Areas
Soil Washing
Bioremediation
Chemical Fixation
Capping with Vegetative and Artificial Covers
Dust Control
Periodic Monitoring and Cap Inspections

SA-5 would provide excavation of soil hot spots exceeding 100 mg/kg As, 1,000 mg/kg Pb, and 1,000 mg/kg TPH. Excavated soils would be treated by either soil washing and/or chemical fixation and bioremediation. The soil washing solution would be developed through treatability studies, but it is likely to be a cation and anion exchange solution capable of exchanging As and Pb from the soil matrix.

Because the soil OU S3 containing As, Pb, and TPH occupies the majority of the site hot spots, it would probably be necessary to treat hot spot soils through a two-stage process.

The most proven and effective soil washing process is a heap leach system. This system would be constructed on a high density polyethylene (HDPE) liner to enhance bioremediation of stockpiled soils followed by soil washing when TPH is present at concentrations of 1,000 mg/kg or greater. The heap leach system would be designed as a waste management unit in accordance with Subchapter 15 of Title 23 of the California Code of Regulations (CCR). The leachate would pass through the on-site water treatment system, including an oil/water separator to separate TPH followed by a floc tank or similar process to precipitate out the insoluble fraction containing As and Pb and other dissolved metals.

The cleaned soils would be returned to the excavated holes. Treated leachate would be recycled through the soil washing unit for a number of cycles until no further treatment is required. The treated water could be used for irrigation, dust control, or discharged to a POTW. The floc and fines would be dewatered and stabilized with either quick lime or pozzolan to form a stable waste, evaluated as to appropriate disposal method, and disposed either off-site or on-site.

Other soils containing As above RAOs which exceed the RAOs but which are not above hot spots criteria, would be treated with an application of ferrous sulphate to immobilize arsenic as ferric arsenate (Sims, et. al., 1986). Soils containing Pb above RAOs would be treated with lime to pH 6.5 to 7.0 to immobilize Pb. A 0.5-foot cover of soil and suitable vegetation would be established to control the exposure pathways.

Periodic monitoring of soil, groundwater, and cover integrity would be required.

4.1.3.1 Overall Protection of Human Health and the Environment (SA-5).

SA-5 will provide overall protection of human health by reducing the source volumes through excavation and treatment of hot spot soils. This process also reduces the residual contaminants to be managed on the site and limits the migration potential of contaminants through the environment. The potential risk from accidental excavation leading to skin contact, inhalation, and ingestion will be greatly reduced or eliminated through the excavation, treatment, and containment processes proposed in SA-5.

4.1.3.2 Compliance with ARARs (SA-5).

There are no ARARs for As, Pb, and TPH in soil, so SA-5 was evaluated against the site RAOs.

Soil washing of hot spots should remove over 90 percent of the As and Pb in the soil (Lauch, et. al., 1989). The actual amount will be determined by treatability studies if this technology is considered acceptable by the state and the community. The As and Pb are likely to be concentrated within the fines (silt and clay fraction) and the iron hydroxide coatings on the sand and gravel which would be removed by selective screening and washing of the fraction less than 2 millimeters diameter.

A 90 percent reduction in As and Pb would bring the majority of hot spot soils into compliance with the RAOs. The residual soils which exceed the RAOs would be stabilized with ferrous sulphate and quick lime to immobilize the As and Pb in the clean backfilled soils.

Bioremediation of hot spot areas which have elevated levels of TPH, and in some cases, polyaromatic hydrocarbons (PAHs) would result in a soil with a residual level less than 1,000 mg/kg of TPH.

4.1.3.3 Long-Term Effectiveness (SA-5).

Chemical fixation of surface soils with As and Pb above the RAOs but less than the hot spots would provide long-term protection. Ferrous sulphate in a 1:1 ratio with soil arsenic can be used for this purpose (Sims, et. al., 1986). Alum, lime and organic matter such as straw incorporated into soil will also immobilize As.

A vegetative cap would reduce dust and provide an exposure pathway barrier. Together with the hot spot excavation and treatment, these processes would provide long-term effectiveness by reducing residual contaminant concentrations and consequently the concern over potential leaching and migration.

Periodic monitoring of soil, groundwater, and cap integrity would be required to assess the adequacy of residuals management and any maintenance requirements.

4.1.3.4 Reduction of Mobility, Toxicity, or Volume (SA-5).

SA-5 would result in a significant reduction in mobility of TPH in soils through bioremediation and As and Pb in soils through chemical fixation. The toxicity of As, Pb, and TPH would be reduced by all the SA-5 treatment processes and stabilization of As and Pb sludge following soil washing. Bioremediation of TPH would reduce the overall volume of TPH by biodegradation. The volume of As and Pb stabilized from the soil washing sludge would be reduced if the stabilized sludge is removed for off-site disposal.

Capping of non-hot spot areas in excess of RAOs would reduce the toxicity and mobility of As, Pb, and TPH and also reduce the risk to acceptable levels.

4.1.3.5 Short-Term Effectiveness (SA-5).

The excavation and treatment of hot spots in the SA-5 alternative would potentially produce a short-term increase in health risk for the site workers and local community. These potential short-term risks would exist during the life of the clean-up operations. Protective measures are readily available and implementable through temporary covers, dust control, site access restrictions, and routine worker health and safety measures.

4.1.3.6 Implementability (SA-5).

SA-5 process options are readily available and reliable technologies. The excavation of soil hot spots would require on-site chemical testing of soils to establish the boundaries and volumes of soils for excavation and treatment. This would require some time lag between excavation and treatment which could require short-term stockpiling. Stockpiles may also be treated in a two-stage process of bioremediation.

The cover materials and equipment are readily available through local vendors.

4.1.3.7 Cost (SA-5)

Costs are presented in Table 17. The costs are based on 30,000 cubic yards of excavated soil, with 25,000 cubic yards treated by bioremediation, and the same amount for soil washing.

The net present cost of this alternative is estimated to be $9,180,000 with a capital cost of $5,110,000 and an operations and maintenance cost of $908,000 per annum for operating the heap leach and bioremediation facility for five years, dust control, summer irrigation, and monitoring.

4.1.3.8 State Acceptance (SA-5)

The level of state acceptance for this alternative and its remedial components will be ascertained during the FS review period.

4.1.3.9 Community Acceptance (SA-5)

The community attitude and acceptance of this remedial approach will be evaluated during the FS review period and at the public meeting.

4.1.4 SOIL ALTERNATIVE SA-8

In Situ Bioremediation of TPH
In Situ Stabilization of As and Pb
Chemical Fixation
Vegetative Cover
Dust Control
Periodic Soil and Groundwater Monitoring

SA-8 focuses on a remedial alternative which would provide less site disturbance by treating hot spot soils with in situ processes rather than excavating large volumes of soil for on-site treatment.

TPH hot spots will be treated for TPH reduction by in situ bioremediation. A nutrient solution and oxygen-source would be injected into the TPH-rich soils to enhance the natural population of biodegrading microbes. The time required to reduce TPH below 1,000 ppm will depend upon source concentrations. Bench scale treatability studies would be undertaken to determine biodegradation rates, nutrient requirements, and residual levels if this process option is accepted for site remediation. Areas outside the hot spots which have elevated TPH would be bioremediated by the increased biological activity in the irrigated soil-plant system in the vegetative cover.

Soil OU S2 hot spots which contain As and Pb without TPH would be stabilized in situ by using a rotary auger to incorporate lime into Pb-rich areas and ferrous sulphate into As-rich areas to immobilize these chemicals. These hot spots are mainly in the fill soils which are expected to have a density and texture suitable for soil mixing to eight to ten feet deep. Less permeable soils would have a layer of lime and/or ferrous sulphate incorporated into the top one foot of soil to immobilize Pb and As. A cap of vegetative cover, cement, or asphalt would be constructed over these S2 hot spot areas, depending on the results of treatability tests and the risk assessment calculations for the residual contaminants.

Non-hot spot S2 soils above the RAOs would be chemically fixed to a depth of 0.5 feet with lime and/or ferrous sulphate to stabilize Pb and As and then capped with a soil and vegetative cover to control potential surface migration.

A two-stage treatment process would be required to reduce the S3 As, Pb, and TPH levels. The bioremediation of TPH would need to be undertaken first because the permeability of the soil needs to be maintained in order to inject the nutrient and oxygen sources to enhance bacterial growth and biodegradation. When TPH levels have been reduced below 1,000 mg/kg the hot spot area could then be worked with a rotary auger to incorporate lime and ferrous sulphate to immobilize the Pb and As respectively. This method would have the probable added effect of further reducing TPH concentrations. The existing permeability and density of the fill soils would allow this stabilizing material to enter and lower the permeability of the zone as a means of reducing leachate generation.

Dust control and periodic soil, groundwater, and cap monitoring would be performed during the in situ treatment period which could last several (approximately two to five) years for the TPH hot spots depending on the rate of biodegradation.

4.1.4.1 Overall Protection of Human Health and the Environment (SA-8)

In situ treatment would reduce the risk of human contact through inhalation and direct skin contact by limiting the dust generation and exposed soils that would result from excavation. Properly engineered in situ treatments would prevent the mobilization of contaminants through either the air, soil, or groundwater pathways. There would be less site disturbance and noise resulting from the remedial operations and therefore less impacts on the environment.

4.1.4.2 Compliance with ARARs (SA-8)

There are no soil ARARs relevant to this alternative. The RAOs would be met by biodegradation of TPH to the 1,000 mg/kg level. Residual As and Pb would be immobilized rather than removed or reduced in volume or to a concentration less than the RAOs. Attainment of the RAOs is, therefore, not met by stabilization or immobilization techniques. However, treatability tests to establish the effectiveness of leaching potential for these stabilization and fixation techniques could be undertaken to evaluate this technology if this is an acceptable alternative for site remediation.

4.1.4.3 Long-Term Effectiveness (SA-8)

The long-term risk for soils containing only residual TPH is marginal because of the degradation of TPH through in situ bioremediation treatment. On the other hand, the stabilized As and Pb hot spots would still have a small potential to leach from the stabilized matrix, and would require some management of the stabilized hot spots and the residual risk.

There are reliable long-term controls through the use of artificial and vegetative caps, land use limitations and deed notices which alert future land users of the nature of the subsurface materials and their associated risks. However, the effectiveness of these controls can decrease with time if maintenance and management is not continued.

4.1.4.4 Reduction of Mobility, Toxicity, and Volume (SA-8)

In situ treatment of TPH could effectively reduce hot spot concentrations and the mobility, toxicity, and volume of TPH chemicals in soils containing TPH only.

TPH could also be reduced in the presence of As and Pb with a two-stage treatment process involving an initial bioremediation step.

The mobility and toxicity of As and Pb would be effectively reduced by in situ stabilization and surface capping although there would be no reduction in the volume of the soil contaminant.

4.1.4.5 Short-Term Effectiveness (SA-8)

SA-8 offers protection of the community and site workers during the remedial activities because there would be little site disturbance and exposure of contaminated soils. Similarly there would be negligible environmental impacts from the remedial activities because the in situ treatments can be controlled to avoid transfer of treatment slurries outside the target hot spot.

The time required to attain the RAOs for TPH would depend upon the rate of biodegradation, whereas stabilization of the As and Pb hot spots could be achieved over a shorter period of time. It is estimated that one to two years would be required to treat the hot spots by bioremediation and soil stabilization. Chemical fixation and vegetative covers for other soils above the RAOs would be established over a six- month construction schedule.

4.1.4.6 Implementability (SA-8)

The in situ treatments would require bench scale and pilot scale treatability studies to determine the nutrient requirements for bioremediation and the operating parameters for in situ stabilization. The latter technique would require more emphasis on pilot scale trials to determine the suitability of the fill material as a hydraulically conductive media for the incorporation of a lime and ferrous sulphate mixture. This stabilization technology is probably less proven than bioremediation for in situ waste applications although there is available case history in the use of soil stabilization by lime techniques to modify soil properties, reduce water flow, and limit contaminant transport.

In situ treatments other than bioremediation may be difficult to implement if there are regulatory concerns about the effectiveness of contaminant containment or adequacy of controls over soil stabilization. The technology to undertake the techniques is readily available from drilling vendors.

4.1.4.7 Cost (SA-8)

Cost are presented in Table 18.

The costs of SA-8 are estimated on the basis of 25,000 cubic yards of TPH hot spots requiring bioremediation and 25,000 yards of As and Pb hot spots requiring in situ stabilization. The total hot spot volume is approximately 30,000 cubic yards because about 25,000 cubic yards overlaps in the S3 OU with As, Pb and TPH combined in the same soil volume.

The net present cost of the SA-8 alternative is estimated to be $6,335,000 with a capital cost of $4,835,000 and an operations and maintenance cost of $340,000 per annum for operation of the bioremediation system, dust control, summer irrigation, mowing and mulching of the initial vegetative cover, and periodic monitoring.

4.1.4.8 State Acceptance (SA-8)

The level of state acceptance for this alternative will be determined during the FS review period.

4.1.4.9 Community Acceptance (SA-8)

The community acceptance of this alternative will be determined during the FS review period and at the public meeting.

4.1.5 SOIL ALTERNATIVE SA-9

Excavation
Soil Washing
Chemical Fixation
In Situ Bioremediation
Ex Situ Bioremediation
Revegetation and Dust Control during treatment

The aim of SA-9 would be to leave negligible residual contaminants in the soil above the RAOs (As, 8 mg/kg, Pb, 190 mg/kg, and TPH, 1,000 mg/kg). There would be no need for deed restrictions or periodic monitoring of soil, groundwater or cap integrity. SA-9 would be essentially a zero maintenance "walk away" alternative. This would be a full treatment alternative which would not rely on protective caps or natural mechanisms of contaminant degradation and immobilization to achieve protection of human health and the environment. Because all site soils above the RAOs would be effectively excavated and treated, there would be major earthworks and soil processing operation required to clean the soils to the RAOs. It is estimated that 116,000 cubic yards excavated from approximately 24 to 26 acres will be required for full treatment. Consequently, the area and duration of disturbance greatly exceeds other soil remedial alternatives. The expected cleanup for SA-9 could require at least four to five years to achieve the RAOs.

The TPH hot spot areas not containing As and Pb would be treated by in situ bioremediation with nutrients and an oxygen source introduced to enhance biodegradation. The surface soils would be mulched with rice straw, alfalfa hay, and nutrients incorporated into the top one foot of soil. The area would be irrigated to sustain a vigorous grass cover and soil microflora in the root zone to biodegrade TPH and PAH compounds. The vegetative cover would be mown and mulched several times before each winter growing season to encourage root growth and organic matter levels in the top one foot of the root zone.

As and Pb containing soils would require excavation of the hot spot areas and stockpiling in an HDPE-lined heap leach system and soil washing with a cation (Pb) and anion (As) exchange solution. The cleaned soils would be returned to the excavated holes as clean backfill once the limit of the soils above the RAOs had been reached as confirmed by on-site soil testing. The leachate containing the As and Pb would be collected on the liner and transferred to a tank where the dissolved and suspended fraction would be precipitated using a floc of alum, ferric chloride, lime or a similar precipitate to remove Pb and As.

Treatability studies in the remedial design phase would look at the feasibility and cost of leaching the As and Pb from the soil matrix by chemical treatment if this SA-9 alternative is accepted. The As and Pb sludge would require dewatering and chemical fixation followed by off-site disposal of the sludge at a RCRA-permitted facility.

The surface 0.5 feet of soils containing As and Pb outside the hot spot areas would also require treatment. The extent of the surface excavation of soils would probably be identified by markers. Excavation equipment would be controlled and restricted to traffic corridors outside the marked areas to avoid tracking contaminated soil over clean areas. These soils would then be excavated, cleaned, and returned to the surface during hot spot excavation. Revegetation would be implemented to establish a stable soil surface.

As, Pb, and TPH containing soils would require either in situ bioremediation of the TPH hot spots while other site soils were being treated or an ex situ bioremediation facility for stockpiled soils on the site. This area would need to be controlled to restrict community and worker access and exposure to the soils because of the levels of TPH, As, and Pb. Following bioremediation of soils to the RAOs for TPH (1000 mg/kg), the stockpiled soils would be heap leached on the same lined facility. Water containing the cation-anion exchange solution would probably be an effective leaching fluid for removing As and Pb in soils because of their distribution on soil fines and iron hydroxides attached to sand and gravel fractions. However, the As, Pb, and TPH containing soils may also require a surfactant washing fluid to remove residual TPH from the soil matrix in order to effectively elute the As and Pb from the soils. The As and Pb would be concentrated in the floc tank sludge and may then be further removed from the dewatered sludge and concentrated in volume by selective extractants to separate any soil fines from the sludge. The on-site groundwater pretreatment plant, or a special treatment process, would then be used to clean the wash water for recycling through the soil washing system or for site irrigation to assist revegetation. These chemical treatment requirements for As and Pb could be evaluated in treatability studies by bench scale testing and pilot scale trials if this soil alternative is accepted for site remediation.

4.1.5.1 Overall Protection of Human Health and the Environment (SA-9)

SA-9 provides full soil treatment for the soil OUs above the RAOs. Consequently, there should be no residual levels of contaminants requiring management on monitoring. This alternative should reduce the future risk of human contact with residual contaminants, limit the migration potential along exposure pathways, and provide a high level of overall protection for the environment. However, the SA-9 alternative could cause extensive short-term disturbance and increase risk of exposure to soil contaminants during remedial activities.

4.1.5.2 Compliance with ARARs (SA-9)

There are no site or soil-specific ARARs for the As, Pb, and TPH contaminants. Therefore, the RAOs were used for evaluating compliance.

The full treatment alternative proposes treating all soil OU soils above the RAOs to the required compliance levels without leaving residual contaminants buried or fixed on-site.

4.1.5.3 Long-Term Effectiveness (SA-9)

SA-9 could provide long-term effectiveness by removing soil contaminants above RAOs. Therefore, there should be no reliance on long-term management, maintenance, or monitoring requirements. Limitations on land use or access restrictions would not be required after remediation was completed.

4.1.5.4 Reduction of Mobility, Toxicity, and Volume

The full treatment alternative would reduce the toxicity, mobility, and volume of As, Pb, and TPH contaminants by removal from the site (As, Pb) and biodegradation (TPH).

4.1.5.5 Short-Term Effectiveness (SA-9)

SA-9 would potentially produce an increased risk to the local community and site workers during remedial activities due to the extensive soil excavation volumes. The increased risk from dust generation could be reduced by dust control mitigation and restrictions of on-site access during remediation. There could be an associated noise and traffic disturbance throughout the life of the remedial activities because of the scale of the soil excavation and treatment operations. This impact could be mitigated by limiting site operations to five-day shifts when the majority of the adjacent community would be at work. It is expected that this disturbance would continue throughout the anticipated four to five years of the remedial project.

Dust control and periodic soil, groundwater, and cap monitoring would be required during the in situ treatment period which could last several years for the TPH hot spots depending on the rate of biodegradation.

4.1.5.6 Implementability (SA-9)

SA-9 proposes readily available and implementable technology. Treatability studies would be required to establish the operational parameters but the equipment to operate the treatment processes are readily available from vendors. The treatment technologies should be reliable and there should be no difficulties in monitoring the effectiveness of contaminant removal. Approvals for off-site disposal of the fixed sludge from the soil washing operation would be required because an on-site disposal facility may be difficult to permit due to the high As and Pb concentrations and an on-site disposal facility would require significant land use limitations and access restrictions.

4.1.5.7 Cost (SA-9)

A detailed cost estimate is presented in Table 19.

The volume of soil for treatment by bioremediation is estimated to be 25,000 to 30,000 cubic yards followed by soil washing for a total volume of 100,000 to 125,000 cubic yards.

The net present cost of this alternative is estimated to be $14,950,000 with a capital cost of $5,746,000 and an operations and maintenance cost of $2,093,000 per annum during treatment.

4.1.5.8 State Acceptance (SA-9

The level of state acceptance for this alternative will be evaluated during the FS review.

4.1.5.9 Community Acceptance (SA-9)

The community acceptance and attitude towards this alternative will be obtained during the FS review and from the public meeting.

4.2 DETAILED ANALYSIS OF GROUNDWATER ALTERNATIVES

The groundwater alternatives that have been carried through for detailed analysis are as follows:

- Limited Action - monitoring and institutional actions;
- Hydraulic containment and monitoring;
- Extraction/Pretreatment/Discharge to POTW;
- Extract/Treat/Reclaim; and
- In Situ Bioremediation.

The primary components of each selected groundwater alternative are shown on Table 12.

4.2.1 ALTERNATIVE G1-A2

- Groundwater Use Limitations, Deed Notices and Zoning Restrictions
- Groundwater Monitoring

Groundwater Use Limitations, Deed Notices and Zoning Restrictions

Groundwater use limitations could be noticed in the deed which would regulate the use or sale of the UPRR-Sacramento property. Restriction would be instituted on well drilling to control the potential exposure of the public to contaminants and uncontrolled use of groundwater.

Limitations may also be included for off-site properties by agreement with land owners. Details of such agreements would be worked out in the remedial design phase if this alternative is considered reasonable for implementation.

Groundwater Monitoring

The sampling program would be designed to monitor any changes in contaminant concentrations and provide early warning of further contaminant migration, if any. The monitoring program would involve sampling 13 to 20 wells utilizing existing wells and possibly some additional wells. These wells would be sampled and groundwater analyzed quarterly. The results of the first four quarters would provide information on deciding the nature and frequency of future monitoring.

4.2.1.1 Overall Protection of Human Health and Environment

Potential human health risks associated with future use of off-site groundwater would be controlled by implementation of institutional actions. However, the environment would not be protected because the contaminated groundwater would remain in the aquifer.

4.2.1.2 Compliance with ARARs

The groundwater monitoring and access restrictions would not comply with the chemical-specific ARARs. Groundwater exceeding the RAOs would be left in the aquifer and monitored.

4.2.1.3 Long-Term Effectiveness

The institutional controls for this alternative would reduce the potential future risk of human contact with contaminated groundwater or discharge to other environmental media. The long-term adequacy and reliability of these controls would be difficult to assess because effectiveness would largely depend on the ability and willingness of public agencies to enforce the groundwater use and access restrictions.

4.2.1.4 Reduction of Toxicity, Mobility, or Volume

There would be no major change in levels of toxicity, mobility, or volume of contaminants by implementing this alternative. However, toxicity could be reduced somewhat by diffusion and natural degradation.

4.2.1.5 Short-Term Effectiveness

The potential risks to the community, workers and the environment during implementation and sampling would be low. RAOs would not be met in a measurable timeframe.

4.2.1.6 Implementability

This alternative would be technically feasible. Since the plume is mainly off-site, landowner permits for monitoring wells would be required. Groundwater use limitations and access restrictions would also require off-site property owner's consent. Additional remedial actions may be easily implemented.

4.2.1.7 Cost

Costs for Alternative G1-A2 are presented in Table 20. Estimated capital costs are $57,500. The costs are based on 10 to 30 years of groundwater monitoring at a cost of $51,000 to $68,000 per annum, for a net present cost of $1,102,827.

4.2.1.8 State Acceptance

The probability of state acceptance of this alternative is unknown. Further information will be obtained during the FS comment period.

4.2.1.9 Community Acceptance

The probability of community acceptance of this alternative is unknown. Further information will be obtained during the FS comment period.

4.2.2 ALTERNATIVE G1-A4

Off-site Groundwater Extraction
Pretreatment
Discharge to POTW

Off-Site Groundwater Extraction

Groundwater recovery wells would be placed off-site. The location and number of the wells would be determined during remedial design. Recovery wells would be screened from approximately 25 to 50 feet below ground surface. A pump test and aquifer modeling would be performed in the remedial design phase to provide the information necessary to accurately estimate pumping rates. The typical pumping rate in extraction systems is in the range of 10 to 100 gallons per minute (gpm). Wells would be placed and pumped at a rate to maximize plume capture and to contain contaminant migration.

To construct extraction wells, landowner permission and local agency permits would be required. The legal requirements of the landowners, may complicate the installation process.

Pretreatment

Pretreatment of extracted groundwater may consist of physical or chemical pretreatment to upgrade the water to achieve permit criteria for discharge to POTW.

The pretreatment may not be necessary, depending on the quality of pumped water and permit requirements. The type of filtration and the specific processes would be identified based on permit requirements.

Discharge to POTW

Permits must be obtained for discharge to POTW. The flow rate and the concentration of contaminants allowed at the POTW would be identified in the permit. Water would be pumped through underground piping to the point of discharge.

4.2.2.1 Overall Protection of Human Health and Environment

Potential future health risks associated with off-site groundwater would be significantly reduced by implementation of the extraction system.

There are several potential environmental issues. Easements or land use permits would be required for the installation of a pipeline to carry the water from the extraction system to the POTW. Extraction of groundwater would result in a localized reduction of the water table, and discharge via POTW would impact effluent receiving water bodies. The main impact to be considered would be an additional flow to the POTW which will be addressed in the permitting process.

4.2.2.2 Compliance with ARARs

The extraction system would be operated until the levels of contaminants in the aquifer reach the RAOs. This alternative would meet the chemical-specific ARARs.

Discharge to a POTW would require action-specific ARARs reduced to levels of contaminants to achieve permit criteria. These ARARs need to be met in order to discharge to POTW.

4.2.2.3 Long-Term Effectiveness

Extraction of contaminated groundwater would occur until RAOs were reached. This would reduce any potential risk to acceptable levels. Residuals from the pretreatment process would be properly treated or disposed off-site. It is not likely that these residuals would be hazardous.

Treatment of the extracted groundwater at a POTW could degrade the organic contaminants into non-toxic compounds.

This alternative would not leave any untreated wastes or treatment residuals on-site.

4.2.2.4 Reduction of Mobility, Toxicity, and Volume

In this alternative, the volume of contamination would be reduced to residual amounts by the groundwater extraction system.

If necessary, the extracted water would be pre-treated prior to discharge to the POTW. The low residual VOCs in the discharged water would be further degraded in the POTW to reduce toxicity, volume, and mobility.

This alternative could satisfy the statutory preference for treatment as a principal element.

4.2.2.5 Short-Term Effectiveness

The potential risks to the community and workers during groundwater extraction would be low.

The time required for meeting remedial objectives cannot be estimated accurately at this point. The pump test and groundwater modeling would provide the information necessary to estimate the anticipated timeframe. Typical time frames range from 10 to 30 years.

4.2.2.6 Implementability

The technical feasibility of this alternative is promising. The system would be simple to construct and performance would be easily monitored.

The main scheduling factors would be the time required for the local agencies to establish allowable POTW discharge levels and issue a permit and construction phase. This could take a minimum of three to six months.

4.2.2.7 Cost

Costs are presented in Table 21. The costs are based on extraction of a minimum of 7 million cubic feet of water requiring treatment over at least a 10-year period. The maximum net present cost of the G1-A4 alternative is estimated to be $2,311,247 with capital costs of $349,499 and an operations and maintenance cost of $128,200 for groundwater and effluent monitoring, and extraction and treatment system operation.

4.2.2.8 State Acceptance

The probability of state acceptance of this alternative is unknown. Further information on this issue will be obtained during the FS comment period.

4.2.2.9 Community Acceptance

The probability of community acceptance of this alternative is unknown. Further information on this issue will be obtained during the FS comment period.

4.2.3 ALTERNATIVE G1-A5

- Off-site Groundwater extraction
- Pretreatment
- Effluent Polish
- Reclamation of Treated Groundwater

Off-Site Groundwater Extraction

Groundwater recovery wells would be placed off-site. The location and number of the wells would be determined during remedial design. Recovery wells would be screened from approximately 25 to 50 feet below ground surface. A pump test and aquifer modeling would be performed to provide the information to accurately estimate pumping rates. The typical pumping rates in extraction systems are often in the range of 10 to 100 gpm. Wells would be placed and pumped at a rate to maximize plume capture and to contain contaminant migration.

To construct off-site extraction wells, landowner permission and local agency permits would be required. The legal requirements of the landowners may complicate the installation process for off-site wells.

Pretreatment

Pretreatment of extracted water may consist of physical or chemical pretreatment depending on the influent criteria for the treatment polishing step. The quality of extracted groundwater would also have an effect on the specific choice of pretreatment systems. Pretreatment may consist of filtration to remove suspended solids and fine silt, if present. Adjustment of the pH of the water may be needed if an air stripping unit is utilized. Precipitation of dissolved solids may be required to achieve the final polished effluent criteria.

Treatment - Polishing Technique

Effluent polishing would be required to meet discharge criteria. Possible techniques include carbon adsorption, air stripping, or an UV-oxidation system.

Carbon adsorption concentrates the organic contaminants in the pumped water on activated carbon. As the carbon looses its effectiveness, it is regenerated off-site.

Air stripping removes VOCs from groundwater through volatilization. Depending on the emission rate, the volatilized chemicals may need to be collected by activated carbon. The carbon would require regeneration or disposal.

A UV-oxidation system destroys contaminants through the use of ultra-violet light and an oxidizing chemical such as hydrogen peroxide or ozone. This process produces no residuals.

Carbon adsorption and air stripping are well demonstrated and documented technologies. Once the groundwater plume and aquifer parameters have been characterized, groundwater models could be used to predict the contaminant concentrations in extracted groundwater. This information could then be used to estimate the size and cost of these process options.

UV-oxidation treatment systems are not as well demonstrated. A pilot scale test of this process would be conducted in conjunction with a pump test to obtain necessary data to evaluate the feasibility of this type of system.

Reclamation

Reclamation involves re-use of the treated water for agricultural, commercial, or industrial uses. Potential on- or off-site uses of reclaimed water include landscape and vegetative cover, irrigation, on-site dust control during remediation and construction activities, and process water for soil remediation activities.

4.2.3.1 Overall Protection of Human Health and Environment

Potential future health risks associated with off-site groundwater would be significantly reduced by implementation of the extraction system.

There are several potential environmental impacts. Easements or land use permits would be required for the installation of wells, pipelines, or treatment facilities off-site. Extraction of groundwater would result in a localized reduction of the water table.

Reclamation use of the treated water would reduce the impact on potable water resources.

The clean-up of the aquifer would address the environmental concern of the contaminated aquifer.

4.2.3.2 Compliance with ARARs

The extraction system would be operated until the levels of contaminants in the aquifer reach the RAOs. This alternative would meet the chemical-specific ARARs.

Reclamation use would require action-specific ARARs related to water use, contaminant levels, and flow rates. These ARARs would need to be met for off-site uses such as irrigation or dust control.

4.2.3.3 Long-Term Effectiveness

Extraction of contaminated groundwater would occur until RAOs were met. This would reduce any potential risk to acceptable levels. Residuals from the pretreatment process would be properly treated or disposed off-site. It is not likely that these residuals would be hazardous.

Effluent polishing may result in spent carbon which must be managed. This material would be regenerated off-site by the carbon supplier.

This alternative should not leave any untreated wastes or treatment residuals on-site.

4.2.3.4 Reduction of Toxicity, Mobility, or Volume

If necessary, the extracted water would be pretreated prior to polishing. The toxicity and volume of VOCs would be reduced by the polishing process. Carbon adsorption would concentrate the volume on a small amount of carbon. Treatment of the carbon would further reduce the volume. Air stripping would either reduce the toxicity by dispersing the chemicals in the air or reduce the volume by concentrating the chemicals on carbon. UV-oxidation should completely destroy the VOCs.

This alternative would satisfy the statutory preference for treatment as a principal element.

In this alternative, groundwater exceeding the RAOs would be extracted, and would reduce the volume of contaminated groundwater in the aquifer.

4.2.3.5 Short-Term Effectiveness

The potential risks to the community and workers during groundwater extraction would be low. Potential risks from air stripper emissions and spent carbon transport off-site could be easily mitigated.

The time required for meeting the RAOs can not be estimated until the extent of the plume and the aquifer characteristics have been determined.

4.2.3.6 Implementability

The technical feasibility of this alternative is promising. The system should be relatively simple to construct and performance would be easily monitored. The primary constraint on implementability would be the ability to locate wells and pipelines on off-site property.

4.2.3.7 Cost

A range of costs are provided in Tables 22-27 utilizing different flow rates and effluent polishing technologies. The costs are based on extraction of a minimum of 7 million cubic feet of water requiring treatment over at least a 10-year period. The maximum net present cost alternative G1-A5 is estimated to be $6,737,066 with maximum capital cost of $538,271 and maintenance cost of $404,200 for groundwater and effluent monitoring, and extraction and treatment system operation.

4.2.3.8 State Acceptance

The probability of state acceptance of this alternative is unknown. Further information could be obtained during the FS comment period.

4.2.3.9 Community Acceptance

The probability of community acceptance of this alternative is unknown. Further information could be obtained during the FS comment period.

4.2.4 ALTERNATIVE G1-A6

In Situ Bioremediation

This technology is relatively new and has not been applied to many groundwater plumes containing chlorinated solvents. For this site, in situ bioremediation would be implemented by injecting water supplemented with appropriate metabolic compounds. Typically, this is done to stimulate the indigenous microbial population of the aquifer. These microorganisms would then either metabolize or co-metabolize the contaminants present in the groundwater (U.S. EPA, 1985, Remedial Action at Waste Disposal Sites).

In situ bioremediation systems are most effective when they are used in conjunction with a groundwater pump and treat system (U.S. EPA, 1988b, Cost of Remedial Action Model Users Manual).

Bacterial activity appears to both increase the rate at which contaminants are degraded and to enhance the mobility of the remaining compounds. This combined effect results in a shorter time for remediation.

Different chemical types are broken down under different chemical conditions (McCarty, 1985). Aromatic compounds are broken down under aerobic conditions but not anaerobic conditions. Chlorinated organic solvents, on the other hand, are degraded under anaerobic conditions but not aerobic conditions. Typically, sources of oxygen, nitrogen, phosphorus, methane, nitrate, and/or sulfate must be injected into the treatment zone. Extracted groundwater must be treated to remove contaminants prior to re-injection.

Prior to selecting this alternative, bench scale and pilot scale treatability tests would be required. This alternative would also require Alternative GA-4 to be implemented, with the reclaimed water being supplemented with nutrients and re-injected into the aquifer. However, due to the biological activity, few extraction wells may be required.

4.2.4.1 Overall Protection of Human Health and Environment

Potential future health risks associated with off-site groundwater would be significantly reduced by implementation of the bioremediation system.

The clean-up of the aquifer would address the environmental concern of the contaminated aquifer. Potential impacts on degradation of water quality due to injected nutrients would need to be evaluated during a pilot scale test.

4.2.4.2 Compliance with ARARs

The capability of this alternative to comply with ARARs cannot be fully evaluated without a pilot study. However, the extraction system would be operated until the levels of contaminants in the aquifer have reached the RAOs. This alternative would meet the chemical-specific ARARs.

Reclamation use would require action specific ARARs related to water use, contaminant levels, and flow rates. These ARARs would need to be met.

Addition of nutrients to the aquifer and stimulation of the indigenous microbial population would require additional action-specific ARARs to be met.

4.2.4.3 Long-Term Effectiveness

The long-term effectiveness of this alternative would be similar to that of Alternative GA-5. The persistence of the indigenous microbes and injected nutrients would need to be evaluated during a pilot study.

4.2.4.4 Reduction of Mobility, Toxicity, and Volume

In this alternative, groundwater exceeding the RAOs would be biologically treated or extracted. The mobility of the contaminants may be enhanced; however, this would improve the efficiency of extraction. This alternative may remediate the groundwater in less time than GA-4 or GA-5 and yield less water which must be treated or polished. A pilot study would be required during the remedial design phase to assess the actual performance of this alternative.

In this alternative, groundwater exceeding the RAOs would be extracted. This would reduce the volume of contaminated groundwater in the aquifer to zero.

4.2.4.5 Short-Term Effectiveness

A pilot study would be required to evaluate the short-term effectiveness of this alternative. In addition to the items discussed in Section 7.3.5, other potential concerns related to this alternative include the impact of the stimulated bacteria, the fate of injected nutrients, and the types of degradation products which may be present. These issues would be addressed in a pilot scale study.

4.2.4.6 Implementability

The technical feasibility of this alternative cannot be fully assessed prior to conducting a pilot study to evaluate the effectiveness and potential environmental consequences. A major constraint on implementability would be the ability to locate wells and pipelines on off-site property.

4.2.4.7 Cost

The cost of this alternative cannot be estimated prior to conducting a pilot study.

4.2.4.8 State Acceptance

The probability of state acceptance of this alternative is unknown. Further information will be obtained during the FS comment period.

4.2.4.9 Community Acceptance

The probability of community acceptance of this alternative is unknown. Further information will be obtained during the FS comment period.

4.2.5 ALTERNATIVE G2-A2

- Groundwater Use Limitations, Deed Notices and Zoning Restrictions
- Groundwater Monitoring

Groundwater Use Limitations, Deed Notices and Zoning Restrictions

Groundwater use limitations could be noticed in the deed which would regulate the use of the aquifer beneath the UPRR-Sacramento property affected by OU G2. Restrictions would be instituted on well drilling to control the potential exposure to or release of contaminants. The limitations would run with the land title if the property was sold by UPRR.

Groundwater Monitoring

The sampling program would monitor changes in levels of contaminant concentration and provide an early warning system for any further potential contaminant migration. The monitoring program would involve sampling two to four wells. Sampling frequency would initially be conducted on a quarterly basis which would continue to provide data for trend analysis. After one year, sampling might be reduced if changes in groundwater were not significant.

4.2.5.1 Overall Protection of Human Health and Environment

Potential health risks associated with on-site groundwater would be reduced by implementation of institutional actions since the purpose of these actions would be to restrict future access to and use of contaminated groundwater.

4.2.5.2 Compliance with ARARs

Contaminant levels would decrease only from natural degradation and diffusion. Concentrations are relatively low and do not exceed RAOs by a large amount. Source areas have not been identified, which suggests contaminant levels should not increase. Monitoring of the plume should continue, and if monitoring indicates migration of the plume, then other remedial actions should be taken.

4.2.5.3 Long-Term Effectiveness and Performance

The institutional controls for this alternative would reduce the potential future risk of contact with contaminated groundwater. These controls would be easy to enforce on-site through access restrictions to private property.

Untreated contaminated water would be left in place in the aquifer on-site. The concentrations are low and unlikely to exceed the RAOs.

4.2.5.4 Reduction of Toxicity, Mobility, or Volume

There would be no reduction in the mobility or volume. Toxicity would be reduced from natural degradation and diffusion. Since no treatment process or materials are used, there are no after-treatment residuals.

4.2.5.5 Short-Term Effectiveness

The potential risks to the community and workers during implementation and sampling should be very low. Environmental impacts should be nominal. However, RAOs would not be met in a measurable timeframe.

4.2.5.6 Implementability

State and local approval would be needed for this alternative. Monitoring wells are already in place and additional wells may be easily installed. Personnel are readily available to collect and analyze samples.

Additional remedial actions may be easily implemented depending on the alternative chosen for G2. If treatment is selected for G1, costs of pumping and treating from G2 would be relatively low when compared to developing a treatment system for G2 only.

4.2.5.7 Cost

Costs are presented in Table 28. The costs are based on 10 to 30 years of groundwater monitoring of G2 at an annual cost of $6,800 to $13,600 per annum for a net present cost of $226,565.

4.2.5.8 State Acceptance

The probability of State acceptance of this alternative is unknown. Further information will be obtained during the FS comment period.

4.2.5.9 Community Acceptance

The probability of community acceptance of this alternative is unknown. Further information will be obtained during the FS comment period.

4.2.6 ALTERNATIVE G2-A3

- Groundwater Use Limitations, Deed Notices and Zoning Restrictions
- Hydraulic Containment
- Groundwater Monitoring

Groundwater Use Limitations, Deed Notices and Zoning Restrictions

Groundwater use limitations could be notice in the deed which would regulate the use or sale of the UPRR-Sacramento property affected by OU G2. Restrictions would be instituted on well drilling to control the potential exposure to contaminants.

Hydraulic Containment

Groundwater plumes appear to be controlled by channelized deposits which limit the lateral movement of contaminants. Channeling aids in hydraulic containment since lateral movement is restricted by a physical barrier.

The extent of these channels would need to be clarified before the system could be fully defined.

The plume could be contained by paired extraction/injection wells or by injection wells only to create a hydraulic barrier to prevent contaminant movement. Injection water would need to be monitored frequently to assure nondegradation of the aquifer. Injection wells would need to be installed on the downgradient end of the plume to create the hydraulic barrier. Injection water may be supplied by a treatment system or other extracted groundwater. Injection water would need to be monitored frequently to assure nondegradation of the aquifer. An extraction well upgradient of the plume might be needed to help flatten the gradient so plume movement is prevented. Piezometers would need to be installed for water level measurement to monitor the effectiveness of the hydraulic barrier.

Groundwater Monitoring

The sampling program would monitor changes in contaminant concentrations and provide an early warning system for any further contaminant migration. The monitoring program would involve sampling 2 to 4 wells. Sampling frequency would initially be conducted on a quarterly basis which would continue to provide data for trend analysis. After one year, sampling might be reduced if changes in groundwater were not significant.

In addition to groundwater, the injection water would need to be closely monitored to comply with the Porter-Cologne Water Quality Control Act.

Institutional Controls

The institutional controls for this alternative would reduce the potential future risk of contact with contaminated groundwater. These controls would be easy to enforce on-site.

Untreated water would be left in the aquifer on-site, but the quantity does not greatly exceed the RAOs.

4.2.6.1 Overall Protection of Human Health and Environment

Potential health risks associated with on-site groundwater would be reduced by implementation of institutional actions since these actions are designed to restrict use of contaminated groundwater.

Environmental impacts would occur to groundwater. Extraction would result in localized depression of the water table while injection would result in a local rise in the water table.

4.2.6.2 Compliance with ARARs

Contaminant levels would decrease only from natural degradation. Hydraulic containment would prevent lowering of concentration through dispersion.

Action specific ARARs relating to injection of clean water or treated groundwater would need to be met.

4.2.6.3 Long-Term Effectiveness

Hydraulic containment would require careful monitoring of water levels to assess performance of the system. Pumps would need to be maintained to insure proper long term performance. The effectiveness of the injection well(s) might decrease with time if the permeability of the aquifer around the injection well were to decrease. This is a relatively common occurrence for injection wells.

The institutional controls for this alternative would reduce the potential future risk of contact with contaminated groundwater. These controls would be easy to enforce on-site.

Untreated water would be left in the aquifer on-site, but the quantity does not greatly exceed the RAOs.

4.2.6.4 Reduction of Toxicity, Mobility, or Volume

Toxicity should slowly decrease over time with natural degradation of the contaminants. Mobility and volume would be maintained by the hydraulic containment. Since no treatment process or materials would be used, there would be no after-treatment residuals.

4.2.6.5 Short-Term Effectiveness

Risk to the community or workers would be low. The system could be controlled to prevent groundwater spills. For example, if a pipe or fitting fails, the system could be designed to sense the failure and shut down the pumps.

RAOs would not be met in a measurable time frame.

4.2.6.6 Implementability

This alternative should be technically feasible. System components such as wells and pumps are easy to construct and install.

Injection of water into the aquifer would require permits from the RWQCB. Discharge to groundwater is permitted only when "nondegradation" of the receiving water is demonstrated, pursuant to the Porter-Cologne Water Quality Control Act.

4.2.6.7 Cost

Costs are presented in Table 29. The costs are based on extraction and injection of groundwater to create a hydraulic barrier to prevent further migration of contaminated groundwater.

The maximum net present cost of the G2-A3 alternative is estimated to be $1,495,940 with capital cost of $79,516 and operation and maintenance cost of $88,400 for groundwater and injection water monitoring and extraction and injection system operation.

4.2.6.8 State Acceptance

The probability of state acceptance of this alternative is unknown. Further information will be obtained during the FS comment period.

4.2.6.9 Community Acceptance

The probability of community acceptance of this alternative is unknown. Further information will be obtained during the FS comment period.

5.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

In Section 4.0, Detailed Analysis of Alternatives, each alternative has been analyzed independently without consideration of the other alternatives. In this section, the relative performance of each alternative is evaluated with regard to each specific criterion. The purpose of this comparative analysis is to identify the advantages and disadvantages of each alternative relative to one another.

In order to be eligible for selection, an alternative must, in general, meet the criteria set forth for Overall Protection of Human Health and the Environment, and Compliance with ARARs. Each alternative is then compared for long-term effectiveness and performance; reduction of toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; and cost. State and community acceptance will be addressed after formal comments have been received on the Draft RI/FS.

5.1 SOIL ALTERNATIVES

This section evaluates and compares each of the five detailed alternatives on the basis of the following criteria:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

Comments on the alternatives by the state and the community will be obtained during the FS review period and the public meeting.

5.1.1 Overall Protection of Human Health and the Environment

Each of the alternatives, except Alternative SA-1 (No Action), offer adequate risk reduction to protect human health and the environment by meeting the RAOs through elimination of chemicals, reduction to acceptable levels, or exposure pathway controls.

Each of the four action alternatives reduces risk below the 1×10^{-6} cancer risk level. However, these risk reduction levels are achieved through different approaches to residual containment management. Consequently, some alternatives would require more detailed deed notices and place more stringent restrictions on future land use than other alternatives.

For example, Alternative SA-4 would reduce risk below 1×10^{-6} by capping hot spots with concrete and soils above the RAOs with a vegetative cover. This would reduce the risk below 1×10^{-6} for the dust pathway and the direct skin contact and soil ingestion pathway. However, future excavation activities on the site, particularly in hot spot areas, would require deed restrictions covering health and safety and possible remediation. Nonetheless, Alternative SA-4 would be protective of human health and would limit infiltration of rainwater and leachate generation to groundwater.

Alternatives SA-5 and SA-8 provide for hot spot treatment and vegetative covers. The TPH would be biodegraded and removed but the As and Pb would remain in a stabilized matrix in the soil. Human health protection would be even higher than in Alternative SA-4 and the environment would be protected by source removal and stabilization against leaching.

Alternative SA-9 would provide for full treatment by leaving negligible residual contaminants on the site. There would be no need for stringent deed restrictions on future land use. Risks should be reduced greatly below the 1×10^{-6} cancer levels and there would be no contaminants of any significance left to leach to groundwater.

5.1.2 Compliance with ARARs

There are no soil ARARs relevant to this site. The chemical-specific RAOs established for As (8 mg/kg), Pb (190 mg/kg), and TPH (1,000 mg/kg) are used for comparative purposes.

All the alternatives except Alternative SA-1 provide a risk reduction by covering and treating soils above the RAOs. Alternatives SA-5 and SA-8 provide a significant reduction in soil contaminants above the RAOs and Alternative SA-9 provides full treatment of soils above RAOs leaving negligible residual As, Pb and TPH.

5.1.3 Long-Term Effectiveness and Permanence

All the alternatives, except the no action Alternative SA-1, offer long-term effectiveness and permanence based on various degrees of institutional controls and treatment. Alternative SA-9 offers the highest level of long-term effectiveness because there are no residuals left on-site. Alternatives SA-5 and SA-8 offer the next level of long-term effectiveness because of the reduction of hot spot As, Pb and TPH concentrations (Alternative SA-5) and in situ stabilization of As and Pb (Alternative SA-8).

Alternative SA-5 offers the least long-term effectiveness due to the greater reliance on land use limitations and concrete cap integrity above the residual contaminants. There is also a more demanding requirement for monitoring of contaminant migration and maintenance of the vegetative cover integrity.

5.1.4 Reduction of Toxicity, Mobility or Volume through Treatment

Alternatives SA-5, SA-8, and SA-9 offer treatment technologies for reducing the toxicity and mobility of As, Pb, and TPH. The volume of TPH is reduced by biodegradation in all three alternatives. The volume of As and Pb contaminated soils is greatly reduced by off-site removal of As and Pb in the excavation and treatment alternatives (SA-5, SA-9). The volume of As and Pb soil is slightly increased (5-10%) in Alternative SA-8 by the in situ stabilization technique. However, the stabilized soil is greatly reduced in As and Pb mobility.

Alternative SA-4 offers no treatment beneath the concrete cap and vegetative cover. Therefore, the volume of contaminated soil remains the same although the toxicity and mobility of the contaminants is greatly reduced by leachate control.

5.1.5 Short-Term Effectiveness

Alternatives SA-4 (Containment) and SA-8 (In Situ Treatment) offer the best short-term effectiveness because there are no additional potential health risks to the community or site workers from excavation of hot spot soils. The full treatment Alternative SA-9 would require excavation of approximately 120,000 cubic yards of soil and Alternative SA-5 would require 30,000 cubic yards of excavation. Dust control and access restrictions would keep these risks mitigated. All four action alternatives would require the same level of vegetative cover establishment, so site disturbance and dust control will be the same for each alternative.

It is estimated that each of the action soil alternatives (SA-4, SA-5, SA-8, and SA-9) would run over a five-year period.

5.1.6 Implementability

Alternative SA-4 would be the simplest to construct requiring approximately four acres of unreinforced concrete caps over hot spot areas and 24 acres of vegetative cover. The concrete caps would be buried beneath the vegetative cover to maintain cap integrity. The necessary limitations for land use and future access to the hot spot areas on the site would require negotiations for administrative approval.

Alternative SA-5 would require construction of an HDPE-lined leach pad for bioremediation and heap leaching of As and Pb. This facility would be classified as a waste management unit under CCR Title 23, Subchapter 15, and would need to meet with regulatory approval of the design, operation, and closure post-closure maintenance. The most complex technical task is to select a suitable leaching solution through treatability tests and pilot trials for the removal of As and Pb from the soil matrix. Approximately 5,000 cubic yards per annum would need to be treated on the leach pad, which would cover an area approximately 1,700 square yards.

Alternative SA-9 would require an HDPE-lined leach pad to treat approximately 25,000 cubic yards per year. The leach pads would be approximately three yards high and require a total surface area of approximately 8,400 square yards of lined leach pad. The technical issues over bioremediation and leachate extraction of As and Pb are the same. Similarly, regulatory approval of the heap leach operation and the monitoring, closure and post-closure requirements would be the same but over a much greater area than Alternative SA-5.

Alternative SA-8 (In Situ Treatment) is the easiest and least disruptive alternative to implement. The bioremediation and soil stabilization techniques are readily available and proven for these kinds of soil applications.

Alternatives SA-5, SA-8, and SA-9 would all require extensive treatability tests during the remedial planning and design phase to optimize treatment processes.

5.1.8 Cost

Costs have been estimated for capital, annual operations, and total costs for each of the five soil alternatives in Tables 16 to 19 over a period of five years to achieve remediation by treatment. Costs for monitoring, maintenance or management of site institutional controls have not been estimated beyond this five-year period. The costs for total annual, total capital, and net costs for each alternative are summarized in the following text.

Alternative SA-4 (Containment) has a total capital cost of approximately $3 million, while Alternatives SA-5, SA-8 and SA-9 have total capital costs of $5.1, $4.8 and $5.7 million, respectively. The annual costs are affected by the level of treatment operations and vary from $26,000 per annum for monitoring and maintenance of vegetative and concrete caps in Alternative SA-4 to $2 million per annum for full treatment by bioremediation and heap leaching.

The approximate net costs for soil alternatives the five-year comparative period are as follows:

Alternative	Description	Net Cost
1	No Action	$0
4	Containment with Institutional Controls	$3.1 million
5	Limited Excavation and On-Site Treatment with Institutional Controls	$9.2 million
8	In Situ Treatment with Institutional Controls	$6.3 million
9	Full Treatment	$15.0 million

5.2 GROUNDWATER

A detailed cost estimate is required to screen objectives. However, the full extent of the off-site groundwater plume is not known at this time, so detailed costs are not complete for the groundwater remediation. To address this issue, a range of costs for the various alternatives were developed for use in the detailed analysis. This was done so that the feasibility study could be carried forward along with the remedial investigations.

Costs for the five groundwater alternatives are presented in Tables 20 through 29. An attempt was made to determine a possible range of present-worth costs based on changing a variety of criteria including flow rates from extraction wells to the expected life of the project. It should be emphasized that, since the extent of groundwater contamination has not yet been determined, the estimated costs given in Tables 20 through 29 are preliminary and will likely change to include a smaller range, once the groundwater investigation is complete.

A variety of assumptions were made to arrive at the preliminary cost estimates. The number of extraction wells and/or injection wells; pump rates of 10 and 100 gpm were used for the extraction wells; a project life of both 10 and 30 years; no combination of polish techniques (i.e., GAC); along with air stripping or GAC with UV-oxidation; the frequency and scope of effluent and groundwater monitoring does not change over the life of the project; and well maintenance costs are minimal over the life of the project. Other assumptions concerning the cost associated with plant demolition at the end of the project life or indirect capital costs are listed in the tables.

An interest rate of five percent was used as suggested in the guidance document for conducting remedial investigations and feasibility studies under CERCLA.

The full extent of these plumes, the aquifer parameters, and plume behavior have not been fully characterized at this time. Therefore, a full comparison of alternatives and an assessment of the need for treatment is preliminary at this time. As a result, the alternative which permits additional remedial actions to be implemented the easiest should be preferable. As more data becomes available, additional analyses of all alternatives will need to be conducted.

5.2.1 Operable Unit G1

This OU consists of the off-site VOC and on-site aromatic plumes. Alternative GA-2, Institutional Actions, would not provide for protection of the environment and would not comply with ARARs due to the concentrations of contaminants and the size of the plume. Therefore, this alternative is not eligible for selection and is not included in the comparative analysis.

This comparative analysis is conducted for the remaining alternatives:

- Alternative 4 - Extract/Pretreat/Discharge to POTW
- Alternative 5 - Extract/Pretreat/Polish/Reclamation
- Alternative 6 - In Situ Bioremediation.

Since the extent of the plume and the aquifer parameters have not been characterized and treatability tests have not been conducted, a final comparison cannot be made at this time. This preliminary comparison will concentrate on the general features of each alternative. As new data becomes available from the off-site groundwater investigation, more detailed and site-specific comparisons will be made in the Final RI/FS.

5.2.1.1 Long-Term Effectiveness and Permanence

All three alternatives result in a high degree of long-term effectiveness and permanence because they remove or degrade the contaminants in the groundwater. Alternative GA-4 relies on the capability of a POTW to destroy or remove the contaminants from water. In Alternative GA-5, UV-oxidation, completely destroys the VOCs while air stripping and carbon adsorption result in emissions or residuals which must be managed. Alternative GA-6 may leave some nutrients and high levels of non-pathogenic bacteria in the aquifer. A pilot test will be required to evaluate these effects.

5.2.1.2 Reduction of Toxicity, Mobility, or Volume Through Treatment

All three alternatives use treatment to remove the contaminants from water or destroy them. Alternative GA-4 relies on the capability of a POTW to destroy or remove the contaminants. In Alternative GA-5, air stripping and carbon adsorption transfer the contaminants to other media (air or carbon, respectively). These methods would be effective in reducing the volume of contaminated material. However, any reduction in toxicity or mobility depends on how these residuals are managed. Treatability tests would be required to evaluate the levels of residuals. UV-oxidation completely breaks down the organic compounds.

Alternative GA-6 includes the implementation of Alternative GA-5. In situ bioremediation may increase the rate at which contaminants are destroyed or degraded. A pilot study would be necessary to determine the efficiency of this process.

5.2.1.3 Short-Term Effectiveness

All three alternatives include pumping groundwater. The impacts to the community, workers, and the environment from this activity would be similar for all three. Alternative GA-4 would increase discharges from the POTW to receiving waters and reduce the excess capacity of the POTW. Alternative GA-5 may result in air emissions of toxic organic compounds or the off-site transportation of hazardous waste. This alternative also provides a positive impact by providing reclaimed water for use on- or off-site and reducing the demand on potable water supplies. The full range of possible impacts from Alternative GA-6 cannot be evaluated without a pilot study.

The time until RAOs are achieved cannot be realistically estimated at this time. However, Alternatives GA-4 and GA-5 would achieve clean-up of the aquifer through extraction of groundwater. Therefore, the remediation time frame for these two alternatives should be identical. Due to biological activity, the time to reach the RAOs for Alternative GA-6 should be shorter than for Alternatives GA-4 and GA-5.

5.2.1.4 Implementability

All three alternatives are technically feasible, although a full evaluation of Alternative GA-6 would require a pilot study. The primary constraint would be the ability to locate wells, pipelines, and/or treatment facilities on public or private land off-site. This may limit the administrative feasibility of some alternatives more than others. These issues will be dealt with during the comment and review period and may be further discussed after that time.

5.2.1.5 Cost

The net present cost of Alternative GA-2 for 10 years is $394,000 and for 30 years is $1,045,000. The net present cost of Alternative GA-4 for 10 years is $1,199,000 and for 30 years is $2,311,000. Depending on the polishing process used, the net present cost of Alternative GA-5 for 10 years will range from $1,253,000 to $1,992,000. The net present cost of Alternative GA-5 for 30 years will range from $2,418,000 to $6,727,000. Costs for Alternative GA-6 were not developed, pending a treatability test. Cost details are summarized in Tables 20 through 27.

5.2.2 Operable Unit G2

This OU consists of small on-site VOC, chromium, nickel, and lead plumes. Concentrations of contaminants within these plumes are at the RAOs or exceed them by only a small amount, especially when compared to G1. Therefore, it may be possible to provide Overall Protection of Human Health and the Environment and Compliance with ARARs without implementing treatment.

This comparative analysis is conducted for the following alternatives:

- Alternative GA-2 - Institutional Actions
- Alternative GA-3 - Hydraulic Containment

5.2.2.1 Long-Term Effectiveness and Permanence

The institutional actions in both alternatives should be easy to enforce on-site and should reduce the potential future risk of contact with contaminated groundwater. Alternative GA-3 should prevent off-site migration of the plumes. However, the efficiency of the injection wells may increase over time and additional monitoring requirements may be necessary.

5.2.2.2 Reduction of Toxicity, Mobility, or Volume Through Treatment

Treatment is not a component of either alternative. However, groundwater concentrations may be attenuated by dispersion and natural degradation in Alternative GA-2, but only by natural degradation in Alternative GA-3 since groundwater flow is essentially stopped.

5.2.2.3 Short-Term Effectiveness

Potential risks to the community and workers during remedial action are low for both alternatives. Alternative GA-3 could cause local variations in the water table and in groundwater flow patterns.

5.2.2.4 Implementability

Both alternatives are technically feasible. Alternative GA-3 would require permits for injection of water and compliance with the Porter-Cologne Water Quality Control Act must be maintained. Alternative GA-2 would allow other remedial actions to be easily implemented, both for G2 and G1.

Alternative GA-3 may preclude the implementation of other remedial actions due to the injection and possible pumping of groundwater. This alternative may also affect, or be effected by, remedial actions for G1.

5.2.2.5 Cost

The net present cost of Alternative GA-2 for 10 years is $52,500 and for 30 years is $209,000. The net present cost of Alternative GA-3 for 10 years is $631,000 and for 30 years is $1,438,000. Cost details are presented in Tables 28 and 29.

GROUNDWATER ALTERNATIVES		
Alternative	Description	Net Cost* (in Millions)
G1-A2	Limited Action - Monitoring Groundwater Use Limitations Access/Zoning Restrictions	$1.1
G1-A4	Extraction/Pretreatment Discharge to POTW	$2.3
G1-A5	Extract/Treat/Reclaim	$6.7
G1-A6	In Situ Bioremediation	Unknown
G2-A2	Limited Action - Monitoring Groundwater Use Limitations Access/Zoning Restrictions	$0.27
G2-A3	Hydraulic Containment/ Monitoring	$1.5

*Highest estimated range of cost.

5.3 EVALUATION

Preliminary and final candidate soil alternatives and final candidate groundwater alternatives were ranked independently by a group of Dames & Moore technical specialists. Both preliminary and final candidate soil alternatives were included in the ranking analysis to provide a basis for comparison of the initial screening of alternatives and selection of final candidate alternatives.

The criteria used to analyze alternatives qualitatively were the same seven criteria utilized for the detailed analysis of Section 4.0:

- Overall protection of human health and environment;
- Compliance with ARARs or RAOs;
- Long-term effectiveness;
- Reduction in toxicity, mobility, and volume;
- Short-term effectiveness;
- Implementability; and
- Cost.

A modified Delphi decision analysis system was used in which six Dames & Moore technical specialists with academic training and professional experience in hazardous substance site investigations and cleanup completed a qualitative evaluation and provide scoring for the alternatives. The results of the analysis are provided in Table 31.

The ranking evaluation provides a comparative qualitative analysis of the soil and groundwater alternatives on the basis of seven criteria. The intent of this ranking is not to select the final alternatives for soil and groundwater, but instead to provide a basis to qualitatively evaluate and validate the FS process. Altogether different criteria may be utilized or one criterion may dominate the final alternative selection process.

5.3.1 Soil Alternatives Ranking

Ranking of the preliminary and final candidate soil alternatives indicates the four final candidate action alternatives (SA-4, SA-5, SA-8, and SA-9), which all ranked relatively closely, are all potential candidates for final selection. The four final candidate action alternatives (SA-4, SA-5, SA-8, and SA-9) would provide overall protection of human health and the environment at different costs (Table 30). The no action soil alternative was carried through only as a baseline for comparison and would not be protective of human health and the environment.

The in situ treatment and stabilization alternative (SA-8), which was ranked highest among the soil alternatives, would provide moderate reduction of toxicity, mobility, and volume, good short-term protectiveness, implementability is medium, and the cost moderate. The hot spot reduction by on-site treatment alternative (SA-5) would provide moderate reduction of toxicity, mobility, and volume, moderate short-term effectiveness, implementability is medium, and the cost is moderate to high. The full excavation and treatment alternative (SA-9) would provide the greatest reduction of toxicity, mobility, and volume, low short-term effectiveness, implementability is medium, and the cost is highest among the soil alternatives. The containment alternative (SA-4) would provide no reduction in volume and satisfactory control of contaminant mobility, provides the greatest short-term effectiveness, is the easiest to implement (technically), and has the lowest cost.

Alternatives SA-2, SA-3, SA-6, and SA-7 were eliminated from further consideration during the initial screening of alternatives. These alternatives scored in the lower half of the ranking evaluation. Alternative SA-1, the no action alternative, ranked lowest but was carried through as a baseline for comparative analysis.

5.3.2 Groundwater Alternatives Ranking

Ranking of the final candidate groundwater alternatives indicates some alternatives are more feasible and preferred over other alternatives.

For G1 the most feasible alternatives are Alternative GA-5, Pump/Pretreat/Polish/Reclamation use and Alternative GA-6, in situ Bioremediation. Alternative GA-4 relies on an off-site treatment facility (POTW) to treat extracted groundwater. Operations at this facility are beyond the control of the site owner and remediation system operator. Alternative GA-5 provides a large positive benefit in the form of reclaimed water. The best polishing process option would need to be determined by conducting treatability tests. As discussed earlier, Alternative GA-6 also requires the implementation of Alternative

GA-5. The potential advantage of in situ bioremediation is the shorter remediation time frame. However, a full pilot study would be required to fully evaluate the feasibility of Alternative GA-6.

For G2 the most feasible alternative is Alternative GA-2, Institutional Actions. Alternative GA-3 may interfere with other present or future remedial actions, whereas Alternative GA-2 will allow additional remedial actions to be easily implemented. The only advantage Alternative GA-3 has is that it may prevent off-site migration of the plumes. However, if monitoring conducted as part of Alternative GA-2 indicates a plume may be moving off-site, other remedial actions may be employed. Until additional information is collected regarding G2, Alternative GA-2 appears to be the most feasible.

6.0 REFERENCES

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U.S. Environmental Protection Agency (U.S. EPA) 1988b. Cost of Remedial Action Users Manual.

U.S. Environmental Protection Agency (EPA), 1989. Risk Assessment Guidance for Superfund: Human Health Evaluation Manual, Part A.

TABLES

TABLE 1

EXPOSURE PATHWAYS CONSIDERED IN THE HEALTH RISK ASSESSMENT
AND CORRESPONDING RISK BASED RESIDUAL CONCENTRATIONS
UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

Chemical	Pathway[a]	Media	Residual Concentration (mg/kg)				
			Cancer Risk-Based				Non-Cancer Effects[b]
			10^{-4}	10^{-5}	10^{-6}	10^{-7}	
Arsenic	Soil ingestion - on-site	Surface soil	42	4.2	0.42	0.042	--
	Inhalation		158	15.8	1.6	0.16	-
Lead	Soil ingestion - on-site	Surface soil	-	-	-	-	190

Notes:

[a] Risk-based residual concentrations estimated for all pathways contributing significantly to health risks.

[b] Noncancer effects for residual concentrations of lead in soil are based on achieving blood-lead levels less than 15 ug/dL.

TABLE 2

REMEDIAL ACTION OBJECTIVES - SOIL
UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA
mg/kg

	Maximum Site Concentration	Average Site Surface Concentration	Detection Limit	Background Sample Average Concentration[1]	Regional Background Concentration Range[2]	Health Risk Based Concentration[3]	TTLC	LUFT	Remedial Action Objective
Arsenic	600	29	0.60	8	8-16	0.42	500	--	8
Lead	17,900	321	1.4	22	10-150	190	1,000	--	190
TPH (Diesel)	88,161	8,979	10	--	--	--	--	1,000	1,000

All values are indicated in mg/kg (ppm).

[1] Average of park soil sample analysis.

[2] Shacklette and Boergnan, 1984.

[3] Risk Assessment section of the UPRR RI report. Arsenic concentration equal to a 10^{-6} lifetime cancer risk from soil ingestion. Lead concentration provides a blood-lead level below the 15 µg/dL level of concern (CDC, 1988).

TABLE 3

REMEDIAL ACTION OBJECTIVES
GROUNDWATER
UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA
µg/l

Chemical	ARAR[a]	Regional[b] Background	Detection Limit	Highest[c] Concentration On-Site	Remedial Action Objective
Benzene	1	--	0.5	12,000	1
Toluene	100[d]	--	0.5	400	100
Xylene	1,750	--	0.5	1,600	1,750
Ethylbenzene	680	--	0.5	1,200	680
1,1,1-TCA	200	--	0.5	39	200
1,1,2-TCA	32	--	0.5	7.1	32
1,1-DCA	5	--	0.5	22	5
1,1-DCE	6	--	0.5	820	6
1,2-DCA	0.5	--	0.5	360	0.5
PCE	5	--	0.5	3.5	5
TCE	5	--	0.5	13	5
Chloroform	100	--	0.5	11	100
Arsenic	50	0-20	5	30	50
Chromium	50	1-20	4	111	50
Lead	50	0-9	10	63	50
Nickel	400[e]	1-12	10	450	400

a The ARARs are the state maximum contaminant levels (MCLs) for drinking water, and are based on health-related and technological and economic feasibility of control, except for toluene and nickel.

b Regional background from Johnson, 1985.

c Highest concentration measured on-site during five rounds of sampling.

d California DHS recommended drinking water action level (AL), strictly health-based, listed in the absence of an MCL.

e California DHS applied action level, strictly for utilization with Site Mitigation Decision Tree Manual in risk assessment for direct exposure to humans. Listed in the absence of an MCL and AL.

TABLE 4

VOLUMES OF AFFECTED SOILS
ABOVE REMEDIAL ACTION OBJECTIVES AND HOT SPOTS
UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA
(in cubic yards)

Target Chemicals	Depth Interval in Feet					Total Cubic Yards 0-10
	0-0.5	>0.5-1.5	0-1.5	>1.5-5	>5-10	
Soil Operable Unit S1						
TPH ≥ 1,000 mg/kg	–	–	5,756	11,498	7,111	24,365
Soil Operable Unit S2						
AS ≥ 8 mg/kg and/or Pb ≥ 190 mg/kg	21,113	13,689	–	45,137	27,148	107,087
Soil Operable Unit S3						
TPH ≥ 1,000 mg/kg and/or AS ≥ 8 mg/kg and/or Pb ≥ 190 mg/kg	21,252	15,559	–	49,117	29,667	115,595
Hot Spots*						
TPH ≥ 1,000 mg/kg and/or AS ≥ 100 mg/kg and/or Pb ≥ 1,000 mg/kg	1,852	4,607	–	13,352	8,222	28,043

* = Hot Spot volumes are contained within Soil Operable Units S1, S2, and S3
– = Concentration Contour Map not completed for this interval.
As = Arsenic
Pb = Lead
TPH = Petroleum Hydrocarbons, primarily diesel range

TABLE 5

VOLUMES OF EFFECTED GROUNDWATER
ABOVE REMEDIAL ACTION OBJECTIVES
UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

Plume	Description	Areal Extent (ft^2)	Volume (ft^3)
A	Off-site chlorinated solvents	527,800* (976,320)**	3.71×10^{6}* (7.32×10^{6})**
B	On-site aromatic hydrocarbons	7,519	2.26×10^{5}
C	On-site chlorinated solvents	53,110	2.39×10^{5}
D	Deep zone aquifer chlorinated solvents	11,834	3.55×10^{4}
E	On-site metals	9,780	4.40×10^{4}

* 10-Year Release Scenario

** 30-Year Release Scenario

TABLE 6

SUMMARY OF SOIL OPERABLE UNITS
UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

Operable Unit	Parameter	Surface Area (Acres)	Volume (Cubic Yards)
S1	Total Petroleum Hydrocarbons ≥ 1000 ppm	*	24,492
S2	Arsenic ≥ 8 ppm and/or Lead ≥ 190 ppm	26.35	107,087
S3	Total Petroleum Hydrocarbons ≥ 1000 ppm and Arsenic ≥ 8 ppm and/or Lead ≥ 190 ppm	26.53	115,595

* Very few surface soil samples collected and analyzed for TPH. Visual observation indicates minimal TPH at surface.

TABLE 7

VOLUME SUMMARY FOR PLUME A, 10-YEAR SIMULATION
UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

Subvolume (Subsurface Zone)	Thickness (ft)	Area (ft^2)	Volume (ft^3)
1	20	44,400	266,500
2	22.5	238,500	1,610,000
3	25	236,800	1,775,800
4	30	8,100	61,100
Total		527,800	3,713,300

Thickness is based on a groundwater table elevation of -5 feet mean sea level datum.
Area and volume rounded to nearest hundred.

TABLE 8

GENERAL RESPONSE ACTIONS
UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

Media	General Response Actions
Soil	No Action Institutional Actions Containment Treatment Disposal
Groundwater	No Action Institutional Actions Collection Treatment Disposal - Treated Water Management - Treatment of Residuals

TABLE 9

SUMMARY OF SOIL REMEDIAL ACTION ALTERNATIVES
UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

General Response Actions	Remedial Technology	Process Options	Alternatives								
			1	2	3	4	5	6	7	8	9
No Action	None	None	x								
Institutional Action	Monitoring	Periodic soil and groundwater sampling		x	x	x	x	x	x	x	
	Access Restrictions	Fencing		x	x	x	x	x	x	x	
		Zoning and Deed Restrictions		x	x	x	x	x	x	x	
Containment	Dust Control	Irrigation		x	x	x	x	x	x	x	
	Capping	Vegetation			x	x	x	x	x	x	
		Clay									
		Asphalt									
		Concrete				x	x	x	x		
		Multimedia									
Treatment	Physical/ Chemical	Soil Washing					x				x
		Fixation								x	x
	Theoretical	Off-site Incineration							x		
	Biological	Ex Situ Bioremediation					x				x
		In Situ Bioremediation								x	x
Removal	Excavation	Heavy Construction Equipment					x	x	x		x
Disposal	Landfill	Off-Site						x	x		

TABLE 10

SUMMARY OF GROUNDWATER REMEDIAL ACTION ALTERNATIVES
UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

General Response Actions	Remedial Technology	Process Options	Alternatives					
			1	2	3	4	5	6
No Action/ Institutional Action	Monitoring	Groundwater Monitoring	x	x	x	x	x	x
	Access Restrictions	Zoning & Deed Restrictions		x	x			
Containment/ Collection	Hydraulic Containment/Extraction	Injection Wells			x			x
		Extraction Wells			x	x	x	x
Treatment	Physical Pre-Treatment	Filtration						
		Flocculation						
	Chemical Pre-Treatment	pH Control				x	x	
		Precipitation/Flocculation						
	Effluent Polish	UV/H_2O_2					x	
		Air Stripping					x	
		Granular Activated Carbon					x	
	Biological Treatment	In Situ Bioremedation						x
Discharge	On-Site	Reclamation Use					x	
	Off-site	Local POTW				x		
Management Treatment of Residuals	On-Site	Carbon Regeneration					x	
	Off-Site	Disposal					x	x
		Incineration						

TABLE 11

COMPONENTS OF SCREENED SOIL ALTERNATIVES
UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

Action	SA-1	SA-4	SA-5	SA-8	SA-9
Institutional Controls					
Deed Restrictions	--	x	x	x	--
Fencing	--	x	x	x	--
Monitoring	--	x	x	x	--
Containment					
Dust Control	--	x	x	x	--
Revegetation	--	x	x	x	--
Soil Cover	--	x	x	x	--
Artificial Cover	--	x	x	--	--
In Situ Treatment					
Chemical Fixation	--	--	--	x	x
Bioremediation	--	--	--	x	x
Ex Situ Treatment					
Soil Washing	--	--	x	--	x
Bioremediation	--	--	x	--	x

-- No Action
x Action

TABLE 12

COMPONENTS OF SCREENED GROUNDWATER ALTERNATIVES
UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

Action	G1-A2	G2-A2	G2-A3	G1-A4	G1-A5	G1-A6
INSTITUTIONAL						
Zoning & Deed Restriction	x	x	x	--	--	--
Monitoring	x	x	x	x	x	x
CONTAINMENT/COLLECTION						
Injection Wells	--	--	x	--	--	x
Extraction Wells	--	--	x	x	x	x
TREATMENT						
pH Control	--	--	--	x	x	--
UV/H_2O_2	--	--	--	--	x	--
Air Stripping	--	--	--	--	x	--
Granular Activated Carbon	--	--	--	--	x	--
In Situ Bioremediation	--	--	--	--	--	x
DISCHARGE						
Reclamation Use	--	--	--	--	x	--
Local POTW	--	--	--	x	--	--
MANAGEMENT OF RESIDUALS						
On-Site Carbon Regeneration	--	--	--	--	x	--
Off-Site Disposal	--	--	--	--	x	--

-- No Action
x Action

TABLE 13

FINAL CANDIDATE SOIL ALTERNATIVES
UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

SA-1	NO ACTION
SA-4	CONTAINMENT/INSTITUTIONAL CONTROLS
SA-5	EXCAVATION/ON-SITE TREATMENT
SA-8	IN SITU TREATMENT
SA-9	EXCAVATION/FULL TREATMENT

TABLE 14

FINAL CANDIDATE GROUNDWATER ALTERNATIVES
UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

Retained Alternatives - Operable Unit G1	
G1-A2	Limited Action-Monitoring, Groundwater Use Limitations, Access/Zoning Restrictions
G1-A4	Extraction/Pretreatment/Discharge to POTW
G1-A5	Extract/Treat/Reclaim
G1-A6	In Situ Bioremediation
Retained Alternatives - Operable Unit G2	
G2-A2	Limited Action - Monitoring, Groundwater Use Limitations, Access/Zoning Restrictions
G2-A3	Hydraulic Containment/Monitoring

TABLE 15
DETAILED COST ESTIMATE
SA-1 - No Action

rnative: SA-1: No Action

CAPITAL COSTS

ct Capital Costs

Item	Units	Quantity	Cost per Unit	Total
DEVELOPMENT				$0
Subtotal-Site Work				$0
TAL EQUIPMENT				$0
Subtotal-Capital Equipment				$0
DIRECT CAPITAL COST SUBTOTAL				$0

FUTURE COSTS

Item	Units	Quantity	Cost per Unit	Annual Cost	Years Incurred
SAMPLING/ MONITORING				$0	
ANNUAL MOWING/MULCHING				$0	
MATERIALS HANDLING				$0	
Annual Cost Subtotal				$0	
SYSTEM OPERATION AND MAINTENANCE				$0	
Annual O&M Suntotal				$0	
TOTAL ANNUAL FUTURE COSTS				$0	

TABLE 15 (Continued)
DETAILED COST ESTIMATE
SA-1 - No Action

Alternative: SA-1: No Action

Indirect Capital Costs

Item	Units	Quantity	Cost per Unit	Total
Engineering and Design		10%		$0
Construction Management		7%		$0
Permitting		5%		$0
Testwork		2%		$0
Start-up		10%		$0
INDIRECT CAPITAL COSTS SUBTOTAL				$0
CAPITAL COST SUBTOTAL				$0
CONTINGENCY		15%		$0
TOTAL CAPITAL COSTS				$0

PLANT DEMOLITION	
5% of Capital Equipment	$0
NET PRESENT COST OF ALTERNATIVE	$0

TABLE 16
DETAILED COST ESTIMATE
SA-4 - Containment With Institutional Controls

Alternative: SA-4: Containment with Institutional Controls

CAPITAL COSTS

Direct Capital Costs

Item	Units	Quantity	Cost per Unit	Total
SITE DEVELOPMENT				
Institutional Controls				
Deed Restrictions	ls	1	$50,000	$50,000
Access Restrictions	ls	1	$200,000	$200,000
Clear & Grub	ac	5	$900	$4,500
Disposal	ac	5	$225	$1,125
Concrete Cap				
Rough Grading	sf	100000	$2	$235,000
Fine Grading	sf	200000	$1	$270,000
Base Preparation	sf	200000	$2	$400,000
Cap	sf	200000	$3	$600,000
Soil Cap				
Soil Cover	cy	21500	$12	$258,000
Irrigation	ac	24	$500	$12,000
Revegetation				
Hydroseed	ac	24	$1,700	$40,800
Subtotal-Site Work				$2,071,425
CAPITAL EQUIPMENT				
				$0
Subtotal-Capital Equipment				$0
DIRECT CAPITAL COST SUBTOTAL				$2,071,425

FUTURE COSTS

Item	Units	Quantity	Cost per Unit	Annual Cost	Years Incurred
SAMPLING/ MONITORING					
Cap Inspections	yr	2	$1,000	$2,000	5
Soil Monitoring	yr	1	$5,000	$5,000	5
Water Monitoring	yr	1	$5,000	$5,000	5
ANNUAL MOWING/MULCHING					
Mowing/Mulching	ac	24	$500	$12,000	5
Annual Cost Subtotal				$24,000	
SYSTEM OPERATION AND MAINTENANCE					
Cap Maintenance	yr	1	$2,000	$2,000	5
Annual O&M Subtotal				$2,000	
TOTAL ANNUAL FUTURE COSTS (5 years)				$26,000	

TABLE 16 (Continued)
DETAILED COST ESTIMATE
SA-4 - Containment With Institutional Controls

Alternative: SA-4: Containment with Institutional Controls

Indirect Capital Costs

Item	Units	Quantity	Cost per Unit	Total
Engineering and Design		10%		$207,143
Construction Management		7%		$145,000
Permitting		5%		$103,571
Testwork		2%		$41,429
Start-up		0		$0
INDIRECT CAPITAL COSTS SUBTOTAL				$497,142
CAPITAL COST SUBTOTAL				$2,568,567
CONTINGENCY		15%		$385,285
TOTAL CAPITAL COSTS				$2,953,852

PLANT DEMOLITION

5% of Capital Costs	$0
NET PRESENT COST OF ALTERNATIVE	$3,066,418

TABLE 16 (Continued)
DETAILED COST ESTIMATE
SA-4 - Containment With Institutional Controls

lternative: SA-4: Containment with Institutional Controls
OTES
oncrete cap to be tailgated and hand spread, quick screed, and broom finish
o reinforcing in the concrete
epairs by caulking cracks
ydroseed with native grasses

TABLE 17
DETAILED COST ESTIMATE
SA-5 - Limited excavation and On-Site Treatment With Institutional Controls

-native: SA-5: Limited Excavation and On-Site Treatment with Institutional Controls

CAPITAL COSTS

:t Capital Costs

Item	Units	Quantity	Cost per Unit	Total
DEVELOPMENT				
itutional Controls				
Deed Restrictions				$50,000
Access Restrictions				$200,000
- & Grub	ac	26	$900	$23,400
›bery Disposal	ac	26	$225	$5,850
Cover	cy	18500	$12	$222,000
›seed	ac	24	$1,700	$40,800
gation	ac	24	$500	$12,000
ical Fixation	ac	24	$500	$12,000
Subtotal-Site Work				$566,050
TAL EQUIPMENT				
Leach Liner & Equip	each	1	$1,500,000	$1,500,000
iate Trtmt System	each	1	$500,000	$500,000
ell Development	each	1	$750,000	$750,000
Subtotal-Capital Equipment				$2,750,000
DIRECT CAPITAL COST SUBTOTAL				$3,316,050

FUTURE COSTS

Item	Units	Quantity	Cost per Unit	Annual Cost	Years Incurred
SAMPLING/ MONITORING					
Soil Samples	yr	50	$400	$20,000	5
Water Samples	yr	50	$400	$20,000	5
Groundwater monitoring	yr	1	$5,000	$5,000	5
ANNUAL MOWING/MULCHING					
Mowing/Mulching	ac	24	$500	$12,000	5
MATERIALS HANDLING					
Dust Control, Water Truck	cy/yr	6000	$1	$3,000	5
Excavation					
Shallow, Scraper	cy/yr	1600	$8	$12,800	5
Deep, Excavator	cy/yr	4400	$5	$23,760	5
On-Site Transport					
Front End Loader	cy/yr	18000	$2	$36,000	5
10 cy Dump	cy/yr	12000	$5	$58,800	5
Backfill and Compaction					
Import	cy/yr	1000	$12	$12,000	5
Treated Soil	cy/yr	5000	$5	$25,000	5
Hazardous Soil Disposal	ton/yr	600	$325	$195,000	5
Annual Cost Subtotal				$423,360	
SYSTEM OPERATION AND MAINTENANCE					
Heap Leach Plant O&M	yr	1	$150,000	$150,000	
Leachate Trtmt Plant O&M	yr	1	$200,000	$200,000	
BioCell Plant O&M	yr	1	$135,000	$135,000	
Annual O&M Subtotal				$485,000	
TOTAL ANNUAL FUTURE COSTS				$908,360	

TABLE 17 (Continued)
DETAILED COST ESTIMATE
SA-5 - Limited excavation and On-Site Treatment With Institutional Controls

ernative: SA-5: Limited Excavation and On-Site Treatment with Institutional Controls

irect Capital Costs

Item	Units	Quantity	Cost per Unit	Total
ineering and Design		10%		$331,605
struction Management		7%		$232,124
mitting		5%		$165,803
twork		2%		$66,321
rt-up		10%		$331,605
INDIRECT CAPITAL COSTS SUBTOTAL				$1,127,457
CAPITAL COST SUBTOTAL				$4,443,507
TINGENCY		15%		$666,526
AL CAPITAL COSTS				$5,110,033

PLANT DEMOLITION

5% of Capital Equipment	$137,500
NET PRESENT COST OF ALTERNATIVE	$9,180,256

TABLE 17 (Continued)
DETAILED COST ESTIMATE
SA-5 - Limited excavation and On-Site Treatment With Institutional Controls

ernative: SA-5: Limited Excavation and On-Site Treatment with Institutional Controls
es:
l Washing system capacity is 20 to 100 cy/day (5,000 to 25,000cy/yr)
of soil to be treated: 30,000 cy (25,000 cy by bioremediation followed by soil washing of the same soil)
5,000 cy/yr, anticipate 5 yrs of operation
Cell sized to handle 10,000 cy/yr, 2 loads of 5,000cy-6mo. treatment
ardous soil disposal: 10% of total treated, 1.5 tons/cy, costs include stabilization, tipping fees, and trucking (Kettleman Hills)
l Samples: 1 per 100 yds treated, 50/yr
er Samples: 25 gallons per cy, 1 samples per 2500 gallons, 50/yr
l cover to be any clean fill, spread, no compaction
roseed with native grasses

TABLE 18
DETAILED COST ESTIMATE
SA-8 - In Situ Treatment With Institutional Controls

Alternative: SA-8: In-Situ Treatment with Institutional Controls

CAPITAL COSTS

Direct Capital Costs

Item	Units	Quantity	Cost per Unit	Total
SITE WORK				
Institutional Controls				
Deed Restriction	ls	1	$50,000	$50,000
Access Restriction	ls	1	$200,000	$200,000
BIOREMEDIATION				
Extraction Wells	each	10	$5,000	$50,000
Reinjection Wells	each	20	$6,250	$125,000
IN SITU STABILIZATION				
Chemical Fixation	cy	30000	$60	$1,800,000
CHEMICAL FIXATION OF SURFACE SOILS				
Clear and Grub	ac	24	$900	$21,600
Shrubbery Disposal	ac	24	$225	$5,400
Surface Soil Fixation	ac	24	$1,000	$24,000
Soil Cover	cy	21500	$12	$258,000
Hydroseed	ac	24	$1,700	$40,800
Subtotal-Site Work				$2,574,800
CAPITAL EQUIPMENT				
Soil Irrigation System	sf	420000	$0.15	$63,000
Leachate Trtmt Plant	each	1	$500,000	$500,000
Subtotal-Capital Equipment				$563,000
DIRECT CAPITAL COST SUBTOTAL				$3,137,800

FUTURE COSTS

Item	Units	Quantity	Cost per Unit	Annual Cost	Years Incurred
SAMPLING/ MONITORING					
Groundwater Samples	yr	1	$5,000	$5,000	5
Soil Samples	yr	1	$5,000	$5,000	5
ANNUAL MOWING/MULCHING					
Mowing/Mulching	ac	24	$500	$12,000	5
Annual Cost Subtotal				$22,000	
SYSTEM OPERATION AND MAINTENANCE					
Irrigation System O&M	yr	1	$3,000	$3,000	5
Leachate Trtmt Plant O&M	yr	1	$300,000	$300,000	5
Well O&M	yr	1	$15,000	$15,000	5
Annual O&M Subtotal				$318,000	
TOTAL ANNUAL FUTURE COSTS				$340,000	

TABLE 18 (Continued)
DETAILED COST ESTIMATE
SA-8 - In Situ Treatment With Institutional Controls

Alternative: SA-8: In-Situ Treatment with Institutional Controls

Indirect Capital Costs

Item	Units	Quantity	Cost per Unit	Total
Engineering and Design		10%		$313,780
Construction Management		7%		$219,646
Permitting		5%		$156,890
Testwork		2%		$62,756
Start-up		10%		$313,780
INDIRECT CAPITAL COSTS SUBTOTAL				$1,066,852
CAPITAL COST SUBTOTAL				$4,204,652
CONTINGENCY		15%		$630,698
TOTAL CAPITAL COSTS				$4,835,350

PLANT DEMOLITION

5% of Capital Costs	$28,150
NET PRESENT COST OF ALTERNATIVE	$6,335,522

TABLE 18 (Continued)
DETAILED COST ESTIMATE
SA-8 - In Situ Treatment With Institutional Controls

ernative: SA-8: In-Situ Treatment with Institutional Controls
ction Well Radius of influence: 100' (total zone of influence = 200')
injection well per extraction well
spot soil Fixation performed by crawler drill rig with hollow stem augers; surface soil fixation (1 ft) performed with agricultural machinery
n of cement per 10 ton of soil
fixation area will require clear & grub
fixation requires 80 working days
emediation requires 5 years

TABLE 19
DETAILED COST ESTIMATE
SA-9 - Full Treatment With Institutional Controls

ernative: SA-9: Full Treatment with Institutional Controls

CAPITAL COSTS

ect Capital Costs

Item	Units	Quantity	Cost per Unit	Total
E DEVELOPMENT				
titutional Controls				
Deed Restrictions				$50,000
Access Restrictions				$200,000
ar & Grub	ac	24	$900	$21,600
ubbery Disposal	ac	24	$225	$5,400
raction Wells	each	20	$5,000	$100,000
njection Wells	each	40	$6,000	$240,000
l Cover	cy	21500	$12	$258,000
roseed	ac	24	$1,700	$40,800

Subtotal-Site Work				$915,800
ITAL EQUIPMENT				
p Leach Liner & Equip	each	1	$1,500,000	$1,500,000
chate Trtmt System	each	1	$500,000	$500,000
l Irrigation System	sf	420000	$0.15	$63,000
cell Development	each	1	$750,000	$750,000

Subtotal-Capital Equipment				$2,813,000
DIRECT CAPITAL COST SUBTOTAL				$3,728,800

FUTURE COSTS

Item	Units	Quantity	Cost per Unit	Annual Cost	Years Incurred
SAMPLING/ MONITORING					
Soil Samples	yr	50	$400	$20,000	5
Water Samples	yr	50	$400	$20,000	5
Grdwater Samples	yr				
ANNUAL MOWING/MULCHING					
Mowing/Mulching	ac	24	$500	$12,000	5
MATERIALS HANDLING					
Dust Control, Water Truck	cy	25000	$1	$12,500	5
Excavation					
Shallow, Scraper		19000	$8	$152,000	5
Deep, Excavator	cy	6000	$5	$32,400	5
On-Site Transport					
Front End Loader	cy	75000	$2	$150,000	5
10 cy Dump	cy	50000	$5	$245,000	5
Backfill and Compaction					
Import	cy	2500	$12	$30,000	5
Treated Soil	cy	22500	$5	$112,500	5
Hazardous Soil Disposal	ton	2500	$325	$812,500	5

Annual Cost Subtotal				$1,598,900	
SYSTEM OPERATION AND MAINTENANCE					
Heap Leach Plant O&M	yr	1	$150,000	$150,000	
Leachate Trtmt Plant O&M	yr	1	$200,000	$200,000	
Irrigation System O&M	yr	1	$6,500	$6,500	
Well O&M	yr	1	$3,000	$3,000	
BioCell Plant O&M	yr	1	$135,000	$135,000	

Annual O&M Subtotal				$494,500	
TOTAL ANNUAL FUTURE COSTS				$2,093,400	

TABLE 19 (Continued)
DETAILED COST ESTIMATE
SA-9 - Full Treatment With Institutional Controls

ernative: SA-9: Full Treatment with Institutional Controls

irect Capital Costs

Item	Units	Quantity	Cost per Unit	Total
ineering and Design		10%		$372,880
struction Management		7%		$261,016
mitting		5%		$186,440
twork		2%		$74,576
rt-up		10%		$372,880
INDIRECT CAPITAL COSTS SUBTOTAL				$1,267,792
CAPITAL COST SUBTOTAL				$4,996,592
TINGENCY		15%		$749,489
AL CAPITAL COSTS				$5,746,081

PLANT DEMOLITION

5% of Capital Equipment	$140,650
NET PRESENT COST OF ALTERNATIVE	$14,950,057

TABLE 19 (Continued)
DETAILED COST ESTIMATE
SA-9 - Full Treatment With Institutional Controls

ernative: SA-9: Full Treatment with Institutional Controls
es:
. Washing system capacity is 20 to 100 cy/day (5,000 to 25,000cy/yr); select 100 cy/day option
of soil to be treated: 120,000 cy
25,000 cy/yr, anticipate 5 yrs of operation
Cell sized to handle 10,000 cy/yr, 2 loads of 5,000cy-6mo. treatment
ardous soil disposal: 10% of total treated, 1.5 tons/cy, costs include stabilization, tipping fees, and trucking (Kettleman Hills)
l Samples: 1 per 100 yds treated, 50/yr
er Samples: 25 gallons per cy, 1 samples per 2500 gallons, 50/yr
raction well radius of influence: 75'
einjection wells per 1 extraction well
tons/cy
orted soil: 21,500 cy initially
10% reduction in volume

TABLE 20
DETAILED COST ESTIMATE
G1-A2 - Limited Action

Alternative: LIMITED ACTION (G1-A2)

CAPITAL COSTS

Direct Capital Costs

Item	Units	Quantity	Cost per Unit	Total
SITE WORK				
Zoning and Deed Restrictions				$50,000
Subtotal-Site Work				$50,000
CAPITAL EQUIPMENT				
Subtotal-Capital Equipment				$0
DIRECT CAPITAL COST SUBTOTAL				$50,000

Indirect Capital Costs

Item	Units	Quantity	Cost per Unit	Total
Engineering and Design		10%		$0
Construction Management		7%		$0
Permitting		5%		$0
Testwork		2%		$0
Start-up		10%		$0
INDIRECT CAPITAL COSTS SUBTOTAL				$0
CAPITAL COST SUBTOTAL				$50,000
CONTINGENCY		15%		$7,500
TOTAL CAPITAL COSTS				$57,500

FUTURE COSTS

Item	Units	Quantity	Range of Annual Costs		Years Incurred
SAMPLING/ MONITORING					
Groundwater Monitoring	yr	1	$51,000 -	$68,000	10-30
Annual Cost Subtotal			$51,000 -	$68,000	
SYSTEM OPERATION AND MAINTENANCE			$0	$0	
Annual O&M Subtotal			$0	$0	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS			$51,000 -	$68,000	

PLANT DEMOLITION	
5% of Capital Costs	$0

NET PRESENT COST OF ALTERNATIVE $451,308 - $1,102,827

TABLE 21
DETAILED COST ESTIMATE
G1-A4 - Pretreatment and Discharge

Alternative: PRETREATMENT AND DISCHARGE (G1-A4)

CAPITAL COSTS

Direct Capital Costs

Item	Units	Quantity	Cost per Unit	Total
SITE WORK				
Extraction Well	ea	3	$15,600	$46,800
Subtotal-Site Work				$46,800
CAPITAL EQUIPMENT				
Pretreatment System	ea	1	$180,000	$180,000
Subtotal-Capital Equipment				$180,000
DIRECT CAPITAL COST SUBTOTAL				$226,800

Indirect Capital Costs

Item	Units	Quantity	Cost per Unit	Total
Engineering and Design		10%		$22,680
Construction Management		7%		$15,876
Permitting		5%		$11,340
Testwork		2%		$4,536
Start-up		10%		$22,680
INDIRECT CAPITAL COSTS SUBTOTAL				$77,112
CAPITAL COST SUBTOTAL				$303,912
CONTINGENCY		15%		$45,587
TOTAL CAPITAL COSTS				$349,499

FUTURE COSTS

Item	Units	Quantity	Range of Annual Costs		Years Incurred
SAMPLING/ MONITORING					
Groundwater Monitoring	yr	1	$51,000 -	$68,000	10-30
Effluent Monitoring	yr	1	$10,200	$10,200	10-30
Annual Cost Subtotal			$61,200 -	$78,200	
SYSTEM OPERATION AND MAINTENANCE					
Pretreatment System			$50,000 -	$50,000	10-30
Annual O&M Subtotal			$50,000 -	$50,000	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS			$111,200 -	$128,200	

PLANT DEMOLITION	
5% of Capital Costs	$9,000

NET PRESENT COST OF ALTERNATIVE $1,199,156 - $2,311,247

TABLE 22
DETAILED COST ESTIMATE
G1-A5 - Treatment With GAC and Reclaim, Q=10 gpm

Alternative: TREATMENT W/GAC AND RECLAIM (G1-A5), flow rate = 10 gpm

CAPITAL COSTS

Direct Capital Costs

Item	Units	Quantity	Cost per Unit	Total
SITE WORK				
Extraction Well	ea	3	$15,600	$46,800
Subtotal-Site Work				$46,800
CAPITAL EQUIPMENT				
Pretreatment System	ea	1	$180,000	$180,000
Treatment System (GAC) flow rate = 10 gpm	ea	1	$58,000	$58,000
Subtotal-Capital Equipment				$238,000
DIRECT CAPITAL COST SUBTOTAL				$284,800

Indirect Capital Costs

Item	Units	Quantity	Cost per Unit	Total
Engineering and Design		10%		$28,480
Construction Management		7%		$19,936
Permitting		5%		$14,240
Testwork		2%		$5,696
Start-up		10%		$28,480
INDIRECT CAPITAL COSTS SUBTOTAL				$96,832
CAPITAL COST SUBTOTAL				$381,632
CONTINGENCY		15%		$57,245
TOTAL CAPITAL COSTS				$438,877

FUTURE COSTS

Item	Units	Quantity	Range Annual	of Costs	Years Incurred
SAMPLING/ MONITORING					
Groundwater Monitoring	yr	1	$51,000 -	$68,000	10-30
Effluent Monitoring	yr	1	$10,200	$10,200	10-30
Annual Cost Subtotal			$61,200 -	$78,200	
SYSTEM OPERATION AND MAINTENANCE					
Pretreatment System	yr	1	$50,000 -	$50,000	10-30
Treatment System	yr	1	$8,000 -	$28,000	10-30
Annual O&M Subtotal			$58,000 -	$78,000	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS			$119,200 -	$156,200	

PLANT DEMOLITION	
5% of Capital Costs	$11,900

NET PRESENT COST OF ALTERNATIVE $1,347,408 - $2,828,154

TABLE 23
DETAILED COST ESTIMATE
G1-A5 - Treatment With UV-OX and Reclaim, Q=10 gpm

Alternative: TREATMENT W/UV OX AND RECLAIM (G1-A5), flow rate = 10 gpm

CAPITAL COSTS

Direct Capital Costs

Item	Units	Quantity	Cost per Unit	Total
SITE WORK				
Extraction Well	ea	3	$15,600	$46,800
Subtotal-Site Work				$46,800
CAPITAL EQUIPMENT				
Pretreatment System	ea	1	$180,000	$180,000
Treatment System (UV/OX) flow rate = 10 gpm	ea	1	$22,500	$22,500
Subtotal-Capital Equipment				$202,500
DIRECT CAPITAL COST SUBTOTAL				$249,300

Indirect Capital Costs

Item	Units	Quantity	Cost per Unit	Total
Engineering and Design		10%		$24,930
Construction Management		7%		$17,451
Permitting		5%		$12,465
Testwork		2%		$4,986
Start-up		10%		$24,930
INDIRECT CAPITAL COSTS SUBTOTAL				$84,762
CAPITAL COST SUBTOTAL				$334,062
CONTINGENCY		15%		$50,109
TOTAL CAPITAL COSTS				$384,171

OPERATION AND MAINTENANCE COSTS

Item	Units	Quantity	Range of Annual Costs		Years Incurred
SAMPLING/ MONITORING					
Groundwater Monitoring	yr	1	$51,000 -	$68,000	10-30
Effluent Monitoring	yr	1	$10,200	$10,200	10-30
Annual Cost Subtotal			$61,200 -	$78,200	
SYSTEM OPERATION AND MAINTENANCE					
Pretreatment System	yr	1	$50,000 -	$50,000	10-30
Treatment System	yr	1	$2,600 -	$21,000	10-30
Annual O&M Subtotal			$52,600 -	$71,000	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS			$113,800 -	$149,200	

PLANT DEMOLITION

5% of Capital Costs	$10,125

NET PRESENT COST OF ALTERNATIVE $1,252,780 - $2,667,616

TABLE 24
DETAILED COST ESTIMATE
G1-A5 - Treatment With Air Strip and Reclaim, Q=10 gpm

Alternative: TREATMENT W/AIR STRIP AND RECLAIM (G1-A5), flow rate = 10 gpm

CAPITAL COSTS

Direct Capital Costs

Item	Units	Quantity	Cost per Unit	Total
SITE WORK				
Extraction Well	ea	3	$15,600	$46,800
Subtotal-Site Work				$46,800
CAPITAL EQUIPMENT				
Pretreatment System	ea	1	$180,000	$180,000
Treatment System (AIR) flow rate = 10 gpm	ea	1	$20,000	$20,000
Subtotal-Capital Equipment				$200,000
DIRECT CAPITAL COST SUBTOTAL				$246,800

Indirect Capital Costs

Item	Units	Quantity	Cost per Unit	Total
Engineering and Design		10%		$24,680
Construction Management		7%		$17,276
Permitting		5%		$12,340
Testwork		2%		$4,936
Start-up		10%		$24,680
INDIRECT CAPITAL COSTS SUBTOTAL				$83,912
CAPITAL COST SUBTOTAL				$330,712
CONTINGENCY		15%		$49,607
TOTAL CAPITAL COSTS				$380,319

OPERATION AND MAINTENANCE COSTS

Item	Units	Quantity	Range of Annual Costs		Years Incurred
SAMPLING/ MONITORING					
Groundwater Monitoring	yr	1	$51,000 -	$68,000	10-30
Effluent Monitoring	yr	1	$10,200	$10,200	10-30
Annual Cost Subtotal			$61,200 -	$78,200	
SYSTEM OPERATION AND MAINTENANCE					
Pretreatment System	yr	1	$50,000 -	$50,000	10-30
Treatment System	yr	1	$5,000 -	$5,000	10-30
Annual O&M Subtotal			$55,000 -	$55,000	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS			$116,200 -	$133,200	

PLANT DEMOLITION

5% of Capital Costs	$10,000

NET PRESENT COST OF ALTERNATIVE $1,267,584 - $2,417,929

TABLE 25
DETAILED COST ESTIMATE
G1-A5 - Treatment With GAC and Reclaim, Q=100 gpm

Alternative: TREATMENT W/GAC AND RECLAIM (G1-A5), flow rate = 100 gpm

CAPITAL COSTS

Direct Capital Costs

Item	Units	Quantity	Cost per Unit	Total
SITE WORK				
Extraction Well	ea	3	$18,100	$54,300
Subtotal-Site Work				$54,300
CAPITAL EQUIPMENT				
Pretreatment System	ea	1	$180,000	$180,000
Treatment System (GAC) flow rate = 100 gpm	ea	1	$115,000	$115,000
Subtotal-Capital Equipment				$295,000
DIRECT CAPITAL COST SUBTOTAL				$349,300

Indirect Capital Costs

Item	Units	Quantity	Cost per Unit	Total
Engineering and Design		10%		$34,930
Construction Management		7%		$24,451
Permitting		5%		$17,465
Testwork		2%		$6,986
Start-up		10%		$34,930
INDIRECT CAPITAL COSTS SUBTOTAL				$118,762
CAPITAL COST SUBTOTAL				$468,062
CONTINGENCY		15%		$70,209
TOTAL CAPITAL COSTS				$538,271

OPERATION AND MAINTENANCE COSTS

Item	Units	Quantity	Range of Annual Costs		Years Incurred
SAMPLING/ MONITORING					
Groundwater Monitoring	yr	1	$51,000 -	$68,000	10-30
Effluent Monitoring	yr	1	$10,200	$10,200	10-30
Annual Cost Subtotal			$61,200 -	$78,200	
SYSTEM OPERATION AND MAINTENANCE					
Pretreatment System	yr	1	$50,000 -	$50,000	10-30
Treatment System	yr	1	$79,000 -	$276,000	10-30
Annual O&M Subtotal			$129,000 -	$326,000	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS			$190,200 -	$404,200	

PLANT DEMOLITION

5% of Capital Costs	$14,750

NET PRESENT COST OF ALTERNATIVE	$1,992,195 - $6,737,066

TABLE 26
DETAILED COST ESTIMATE
G1-A5 - Treatment With UV-OX and Reclaim, Q=100 gpm

Alternative: TREATMENT W/UV OX AND RECLAIM (G1-A5), flow rate = 100 gpm

CAPITAL COSTS

Direct Capital Costs

Item	Units	Quantity	Cost per Unit	Total
SITE WORK				
Extraction Well	ea	3	$18,100	$54,300
Subtotal-Site Work				$54,300
CAPITAL EQUIPMENT				
Pretreatment System	ea	1	$180,000	$180,000
Treatment System (UV/OX) flow rate = 100 gpm	ea	1	$225,000	$225,000
Subtotal-Capital Equipment				$405,000
DIRECT CAPITAL COST SUBTOTAL				$459,300

Indirect Capital Costs

Item	Units	Quantity	Cost per Unit	Total
Engineering and Design		10%		$45,930
Construction Management		7%		$32,151
Permitting		5%		$22,965
Testwork		2%		$9,186
Start-up		10%		$45,930
INDIRECT CAPITAL COSTS SUBTOTAL				$156,162
CAPITAL COST SUBTOTAL				$615,462
CONTINGENCY		15%		$92,319
TOTAL CAPITAL COSTS				$707,781

OPERATION AND MAINTENANCE COSTS

Item	Units	Quantity	Range of Annual Costs (low)	Range of Annual Costs (high)	Years Incurred
SAMPLING/ MONITORING					
Groundwater Monitoring	yr	1	$51,000 -	$68,000	10-30
Effluent Monitoring	yr	1	$10,200	$10,200	10-30
Annual Cost Subtotal			$61,200 -	$78,200	
SYSTEM OPERATION AND MAINTENANCE					
Pretreatment System	yr	1	$50,000 -	$50,000	10-30
Treatment System	yr	1	$26,000 -	$210,000	10-30
Annual O&M Subtotal			$76,000 -	$260,000	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS			$137,200 -	$338,200	

PLANT DEMOLITION

5% of Capital Costs	$20,250

NET PRESENT COST OF ALTERNATIVE $1,746,953 - $5,886,494

TABLE 27
DETAILED COST ESTIMATE
G1-A5 - Treatment With Air Strip and Reclaim, Q=100 gpm

Alternative: TREATMENT W/AIR STRIP AND RECLAIM (G1-A5), flow rate = 100gpm

CAPITAL COSTS

Direct Capital Costs

Item	Units	Quantity	Cost per Unit	Total
SITE WORK				
Extraction Well	ea	3	$18,100	$54,300
Subtotal-Site Work				$54,300
CAPITAL EQUIPMENT				
Pretreatment System	ea	1	$180,000	$180,000
Treatment System (AIR) flow rate = 100 gpm	ea	1	$20,000	$20,000
Subtotal-Capital Equipment				$200,000
DIRECT CAPITAL COST SUBTOTAL				$254,300

Indirect Capital Costs

Item	Units	Quantity	Cost per Unit	Total
Engineering and Design		10%		$25,430
Construction Management		7%		$17,801
Permitting		5%		$12,715
Testwork		2%		$5,086
Start-up		10%		$25,430
INDIRECT CAPITAL COSTS SUBTOTAL				$86,462
CAPITAL COST SUBTOTAL				$340,762
CONTINGENCY		15%		$51,114
TOTAL CAPITAL COSTS				$391,876

OPERATION AND MAINTENANCE COSTS

Item	Units	Quantity	Range Annual	of Costs	Years Incurred
SAMPLING/ MONITORING					
Groundwater Monitoring	yr	1	$51,000 -	$68,000	10-30
Effluent Monitoring	yr	1	$10,200 -	$10,200	10-30
Annual Cost Subtotal			$61,200 -	$78,200	
SYSTEM OPERATION AND MAINTENANCE					
Pretreatment System	yr	1	$50,000 -	$50,000	10-30
Treatment System	yr	1	$5,000 -	$5,000	10-30
Annual O&M Subtotal			$55,000 -	$55,000	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS			$116,200 -	$133,200	

PLANT DEMOLITION

5% of Capital Costs	$10,000

NET PRESENT COST OF ALTERNATIVE $1,279,142 - $2,429,487

TABLE 28
DETAILED COST ESTIMATE
G2-A2 - Limited Action

Alternative: LIMITED ACTION (G2-A2)

CAPITAL COSTS

Direct Capital Costs

Item	Units	Quantity	Cost per Unit	Total
SITE WORK				
Zoning and Deed Restrictions				$50,000
Subtotal-Site Work				$50,000
CAPITAL EQUIPMENT				$0
Subtotal-Capital Equipment				$0
DIRECT CAPITAL COST SUBTOTAL				$50,000

Indirect Capital Costs

Item	Units	Quantity	Cost per Unit	Total
Engineering and Design		10%		$0
Construction Management		7%		$0
Permitting		5%		$0
Testwork		2%		$0
Start-up		10%		$0
INDIRECT CAPITAL COSTS SUBTOTAL				$0
CAPITAL COST SUBTOTAL				$50,000
CONTINGENCY		15%		$7,500
TOTAL CAPITAL COSTS				$57,500

FUTURE COSTS

Item	Units	Quantity	Range of Annual Costs		Years Incurred
SAMPLING/ MONITORING					
Groundwater Monitoring	yr	1	$6,800 -	$13,600	10-30
Annual Cost Subtotal			$6,800 -	$13,600	
SYSTEM OPERATION AND MAINTENANCE			$0	$0	
Annual O&M Subtotal			$0	$0	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS			$6,800 -	$13,600	

PLANT DEMOLITION

5% of Capital Costs	$0

NET PRESENT COST OF ALTERNATIVE	$110,008 -	$266,565

TABLE 29
DETAILED COST ESTIMATE
G2-A3 - Hydraulic Containment

Alternative: HYDRAULIC CONTAINMENT (G2-A3)

CAPITAL COSTS

Direct Capital Costs

Item	Units	Quantity	Cost per Unit	Total
SITE WORK				
Extraction Well	ea	1	$15,600	$15,600
Injection Well	ea	2	$18,000	$36,000
Zoning and Deed Restrictions				$50,000
Subtotal-Site Work				$101,600
CAPITAL EQUIPMENT				
Subtotal-Capital Equipment				$0
DIRECT CAPITAL COST SUBTOTAL				$101,600

Indirect Capital Costs

Item	Units	Quantity	Cost per Unit	Total
Engineering and Design		10%		$5,160
Construction Management		7%		$3,612
Permitting		5%		$2,580
Testwork		2%		$1,032
Start-up		10%		$5,160
INDIRECT CAPITAL COSTS SUBTOTAL				$17,544
CAPITAL COST SUBTOTAL				$119,144
CONTINGENCY		15%		$17,872
TOTAL CAPITAL COSTS				$137,016

OPERATION AND MAINTENANCE COSTS

Item	Units	Quantity	Range Annual	of Costs	Years Incurred
SAMPLING/ MONITORING					
Groundwater Monitoring	yr	1	$51,000 -	$68,000	10-30
Injection Monitoring	yr	2	$20,400	$20,400	10-30
Annual Cost Subtotal			$71,400 -	$88,400	
SYSTEM OPERATION AND MAINTENANCE					
Annual O&M Subtotal			$0 -	$0	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS			$71,400 -	$88,400	

PLANT DEMOLITION

5% of Capital Costs	$0

NET PRESENT COST OF ALTERNATIVE $688,347 - $1,495,940

TABLE 30

COMPARATIVE ANALYSIS
COST AND RISK REDUCTION FOR SOIL REMEDIAL ALTERNATIVES
UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA[a]

Alternatives	Description	Air Risk	Soil Risk	Total Risk	Risk Reduction	Cost
SA-1	No Action	5×10^{-4}	3×10^{-4}	8×10^{-4}	–	$0
SA-4	Containment with Institutional Controls	0	0	0	100%	$3.1 million
SA-5	Limited Excavation with On-site Treatment and Institutional Controls	0	0	0	100%	$9.2 million
SA-8	In Situ Treatment with Institutional Controls	0	0	0	100%	$6.3 million
SA-9	Full Treatment	0	0	0	100%	$15.0 million

[a]All remedial alternatives block inhalation and soil ingestion pathways. Residual levels of lead and arsenic remaining in the soil do not represent potential exposures to current or future residents.

TABLE 31

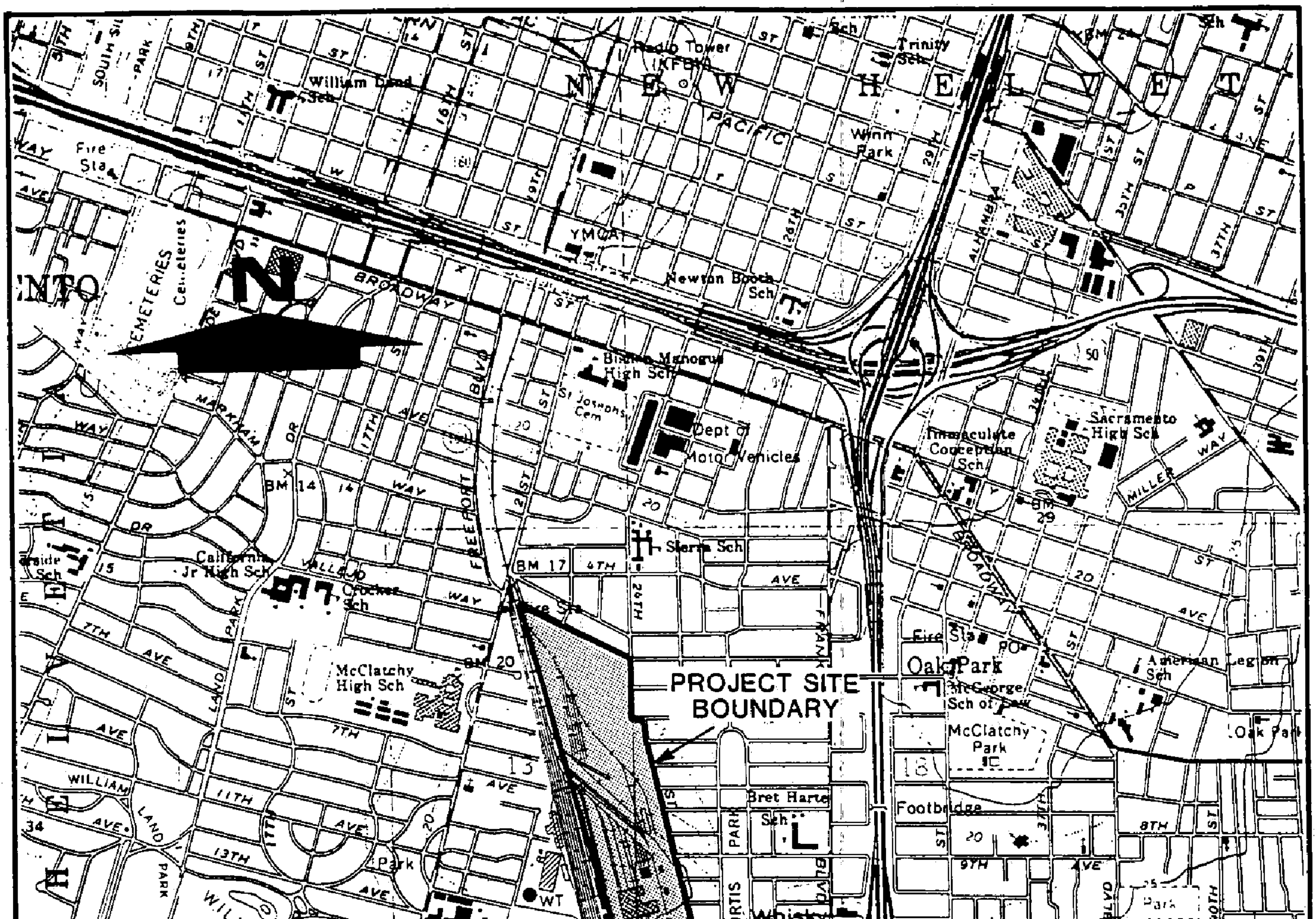
RANKING OF ALTERNATIVES
UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

Soil Alternatives		
Rank	Alternative	
1	SA-8	In Situ Treatment
2	SA-5	Excavation and On-Site Treatment
3	SA-9	Full Treatment
4	SA-4	Containment
5	SA-7	Excavation and Off-Site Treatment and Disposal
6	SA-6	Excavation and Off-Site Disposal
7	SA-3	Limited Action
8	SA-2	Institutional Controls
9	SA-1	No Action

Groundwater Alternatives		
Operable Unit G1		
Rank	Alternatives	
1	G1-A5	Extract/Treat and Reclaim
2	G1-A4	Extract and Discharge
3	G1-A6	In Situ Bioremediation
4	G1-A2	Limited Action

Operable Unit G2		
Rank	Alternatives	
1	G2-A2	Limited Action
2	G2-A3	Hydraulic Containment

FIGURES



0 1000 2000 3000 FEET

SCALE

REFERENCE:

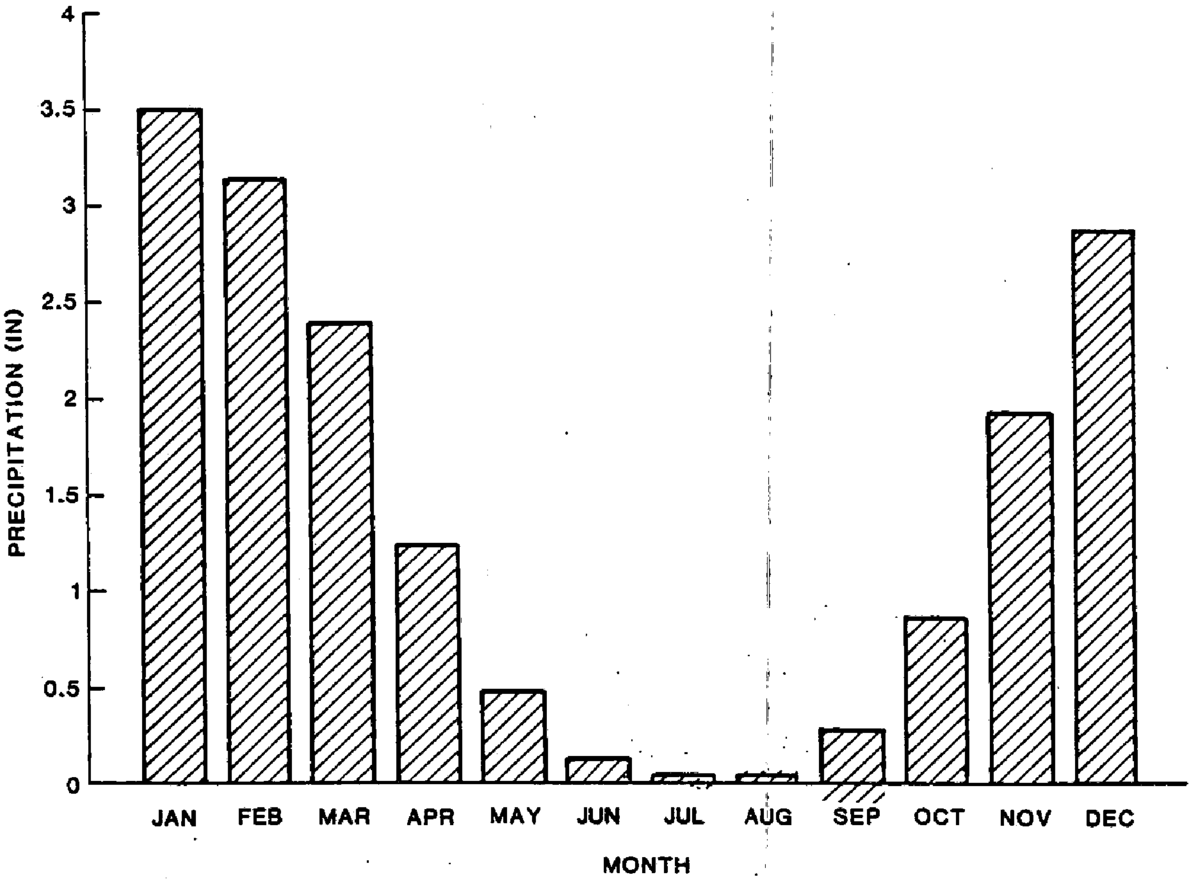
USGS 7.5' QUADRANGLE SACRAMENTO EAST, 1967 AND SACRAMENTO WEST, 1967

FIGURE 1

SITE VICINITY MAP

UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

Dames & Moore



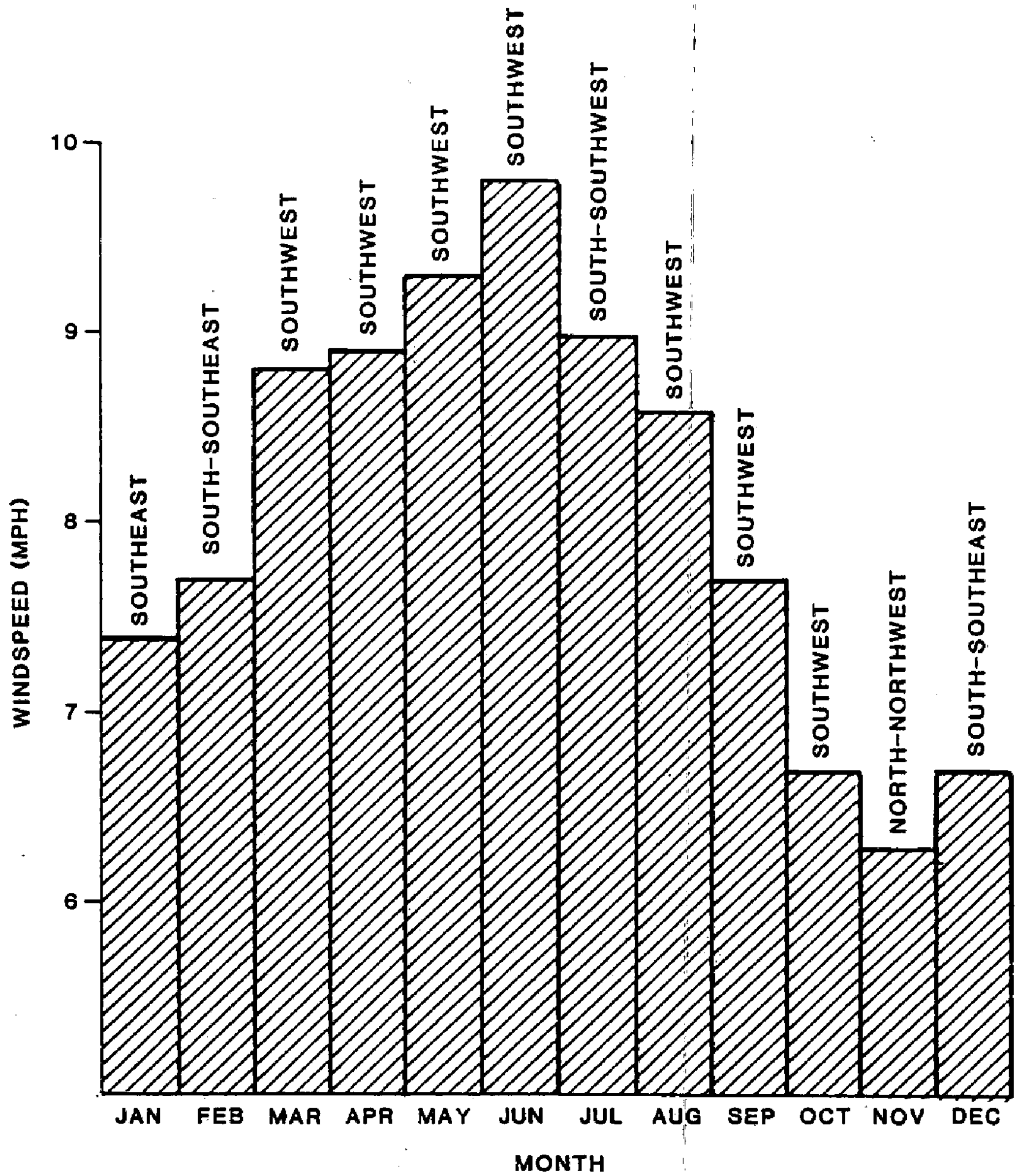
REFERENCE: CLIMATOLOGICAL DATA ANNUAL SUMMARY
CALIFORNIA (1900-1986), NOAA.
ENVIRONMENTAL DATA AND INFORMATION SERVICE.
ASHEVILLE, NORTH CAROLINA

FIGURE 2

MEAN MONTHLY PRECIPITATION

UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

Dames & Moore



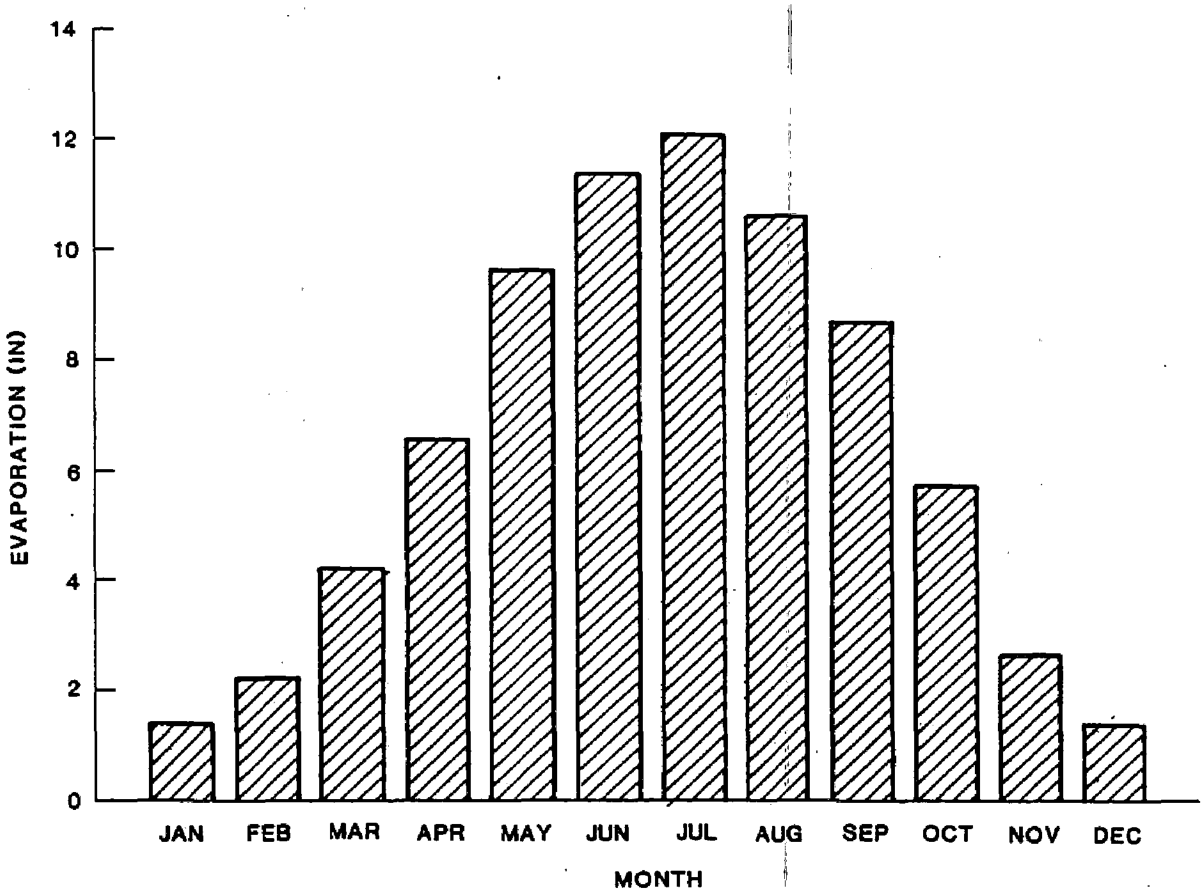
REFERENCE: NOAA TECHNICAL MEMORANDUM NWS WR-65 (REVISED)
CLIMATE OF SACRAMENTO, CALIFORNIA, JANUARY 1988
U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FIGURE 3

AVERAGE MONTHLY WIND SPEED & PREVAILING WIND DIRECTION (1948-1986)

UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

Dames & Moore



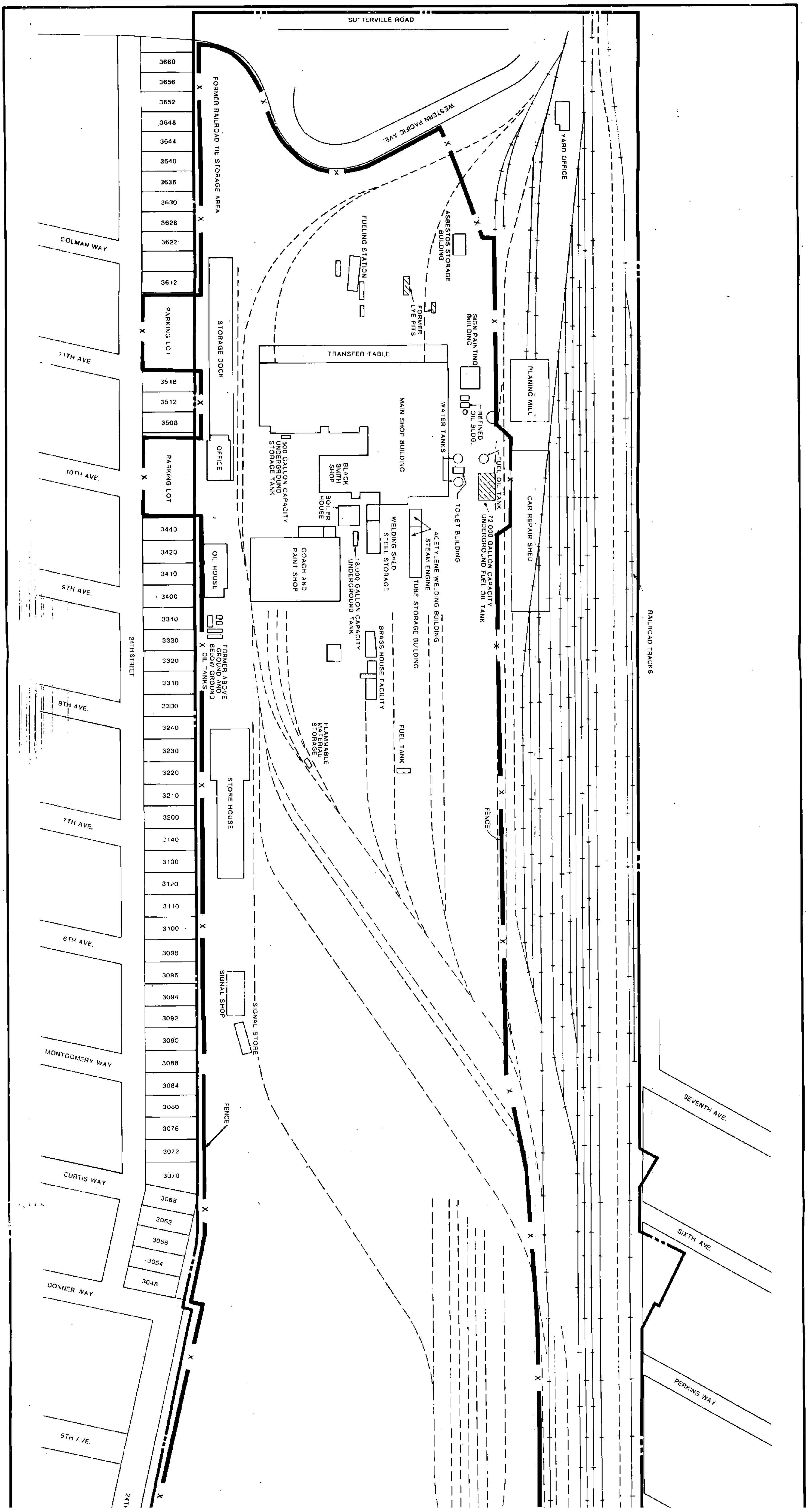
REFERENCE: CLIMATOLOGICAL DATA ANNUAL SUMMARY
CALIFORNIA (1900–1986)
NOAA

FIGURE 4

MEAN MONTHLY EVAPORATION

UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

Dames & Moore



SUTTERVILLE ROAD
WESTERN PACIFIC AVE.
FORMER RAILROAD TIE STORAGE AREA
YARD OFFICE
FUELING STATION
ASBESTOS STORAGE BUILDING
FORMER LYE PITS
SIGN PAINTING BUILDING
PLANING MILL
STORAGE DOCK
TRANSFER TABLE
MAIN SHOP BUILDING
WATER TANKS
REFINED OIL BLDG.
FUEL OIL TANK
72,000 GALLON CAPACITY UNDERGROUND FUEL OIL TANK
CAR REPAIR SHED
TOILET BUILDING
OFFICE
500 GALLON CAPACITY UNDERGROUND STORAGE TANK
BLACK SMITH SHOP
BOILER HOUSE
WELDING SHED
STEEL STORAGE
ACETYLENE WELDING BUILDING
STEAM ENGINE
TUBE STORAGE BUILDING
OIL HOUSE
COACH AND PAINT SHOP
18,000 GALLON CAPACITY UNDERGROUND TANK
BRASS HOUSE FACILITY
FORMER ABOVE GROUND AND BELOW GROUND OIL TANKS
FLAMMABLE MATERIAL STORAGE
FUEL TANK
STORE HOUSE
FENCE
SIGNAL SHOP
SIGNAL STORE
RAILROAD TRACKS
PARKING LOT
PARKING LOT
24TH STREET
COLMAN WAY
11TH AVE.
10TH AVE.
9TH AVE.
8TH AVE.
7TH AVE.
6TH AVE.
MONTGOMERY WAY
CURTIS WAY
DONNER WAY
5TH AVE.
SEVENTH AVE.
SIXTH AVE.
PERKINS WAY
3660
3656
3652
3648
3644
3640
3636
3630
3626
3622
3612
3516
3512
3508
3440
3420
3410
3400
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3140
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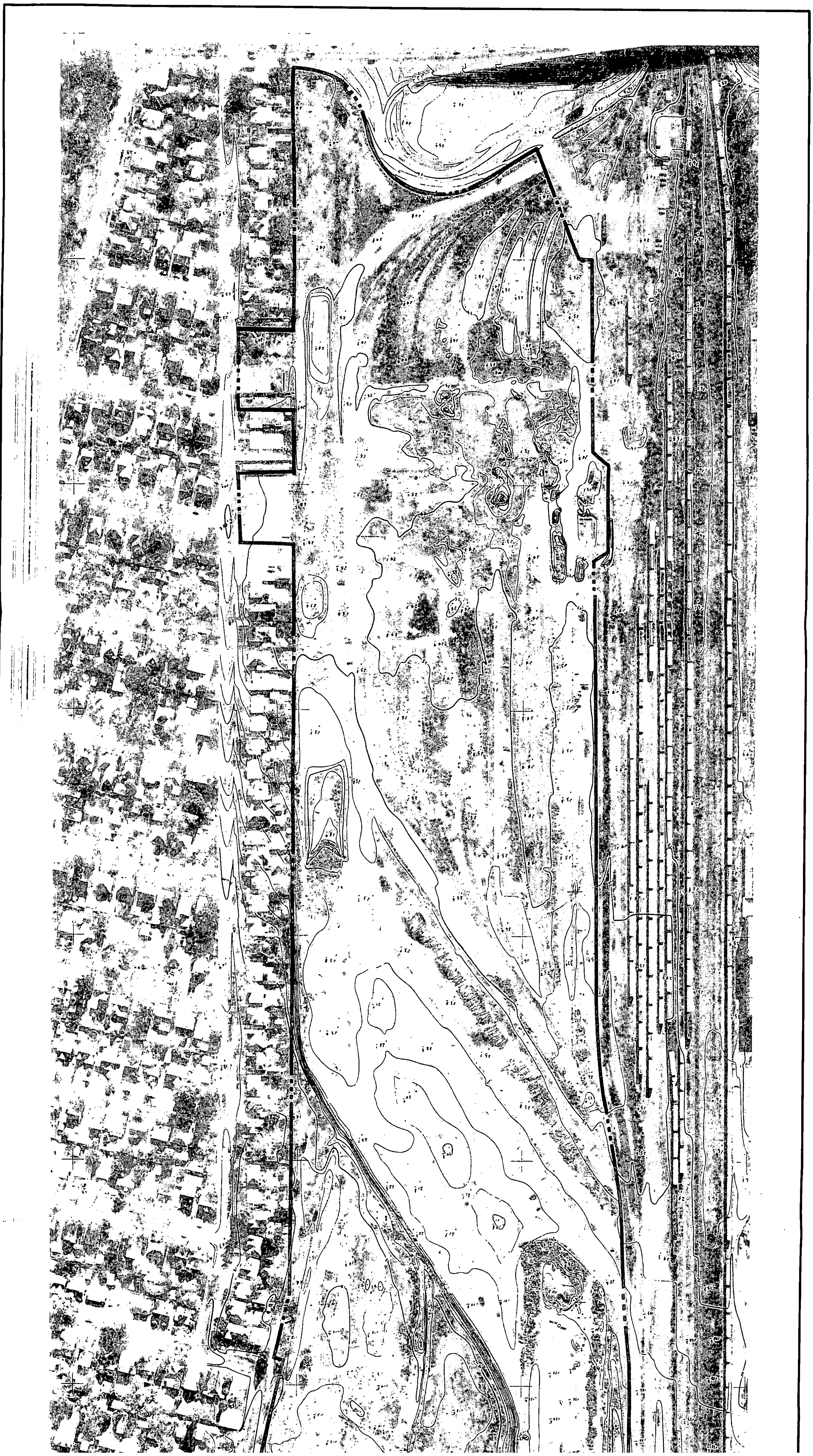
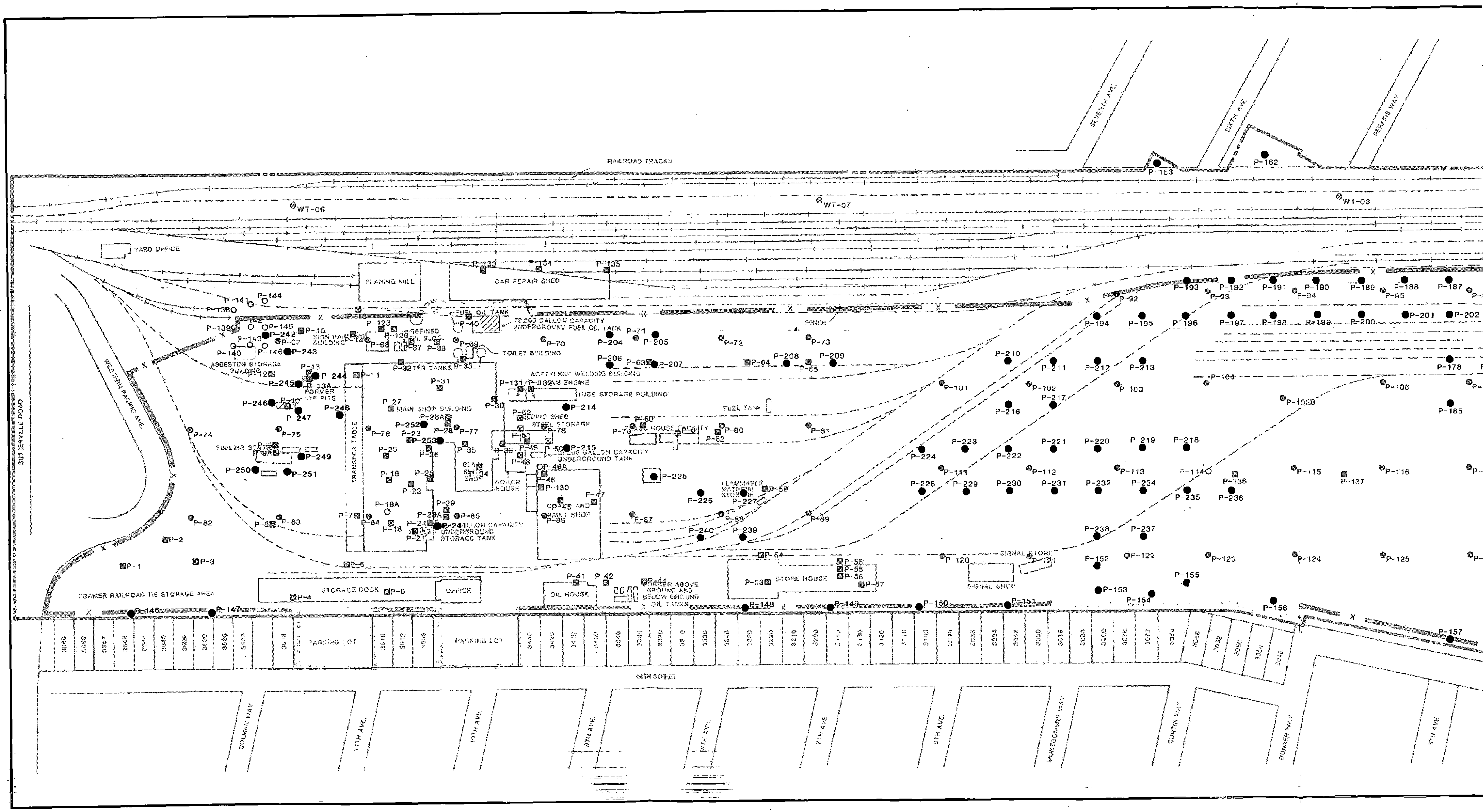
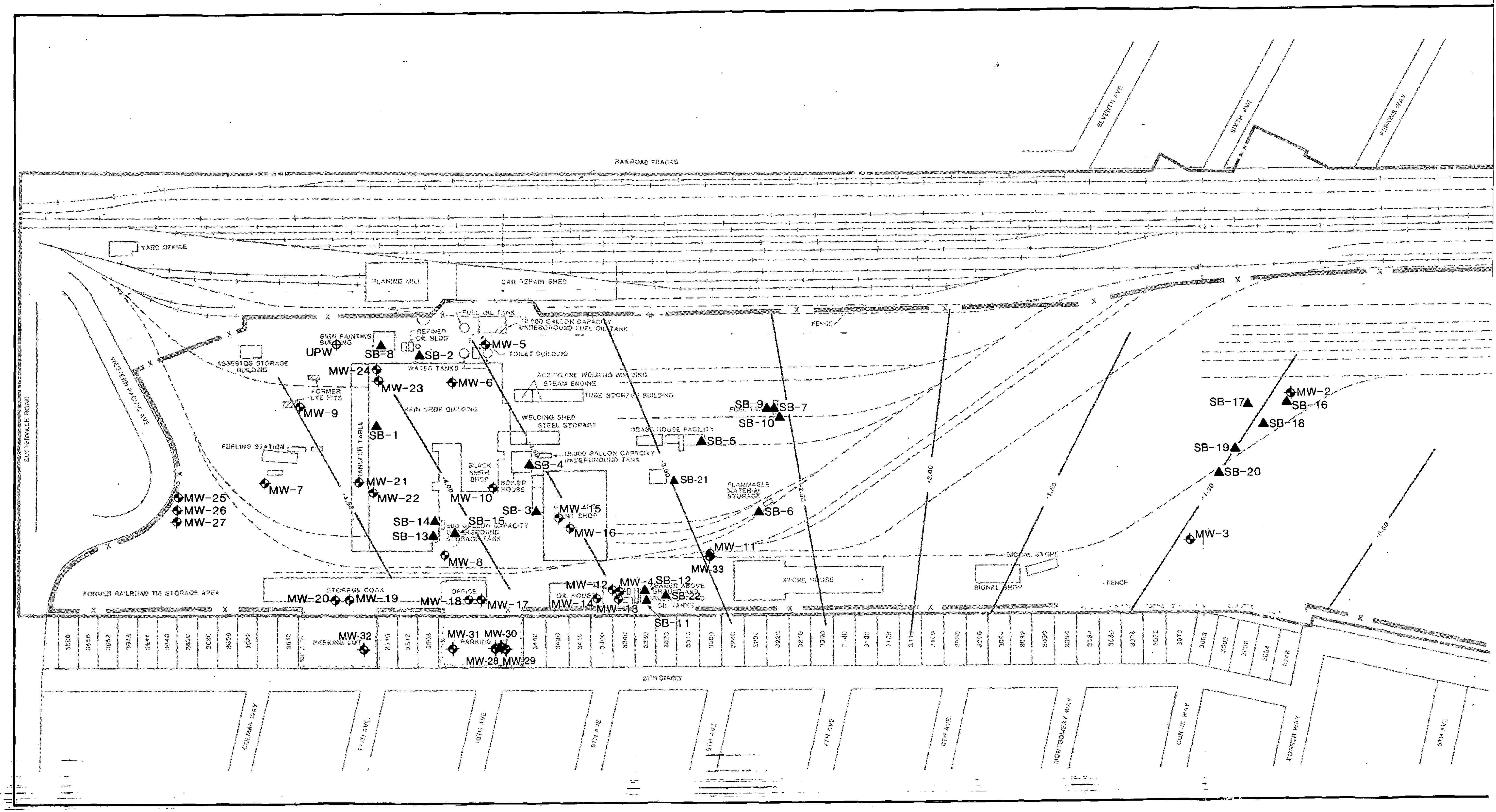
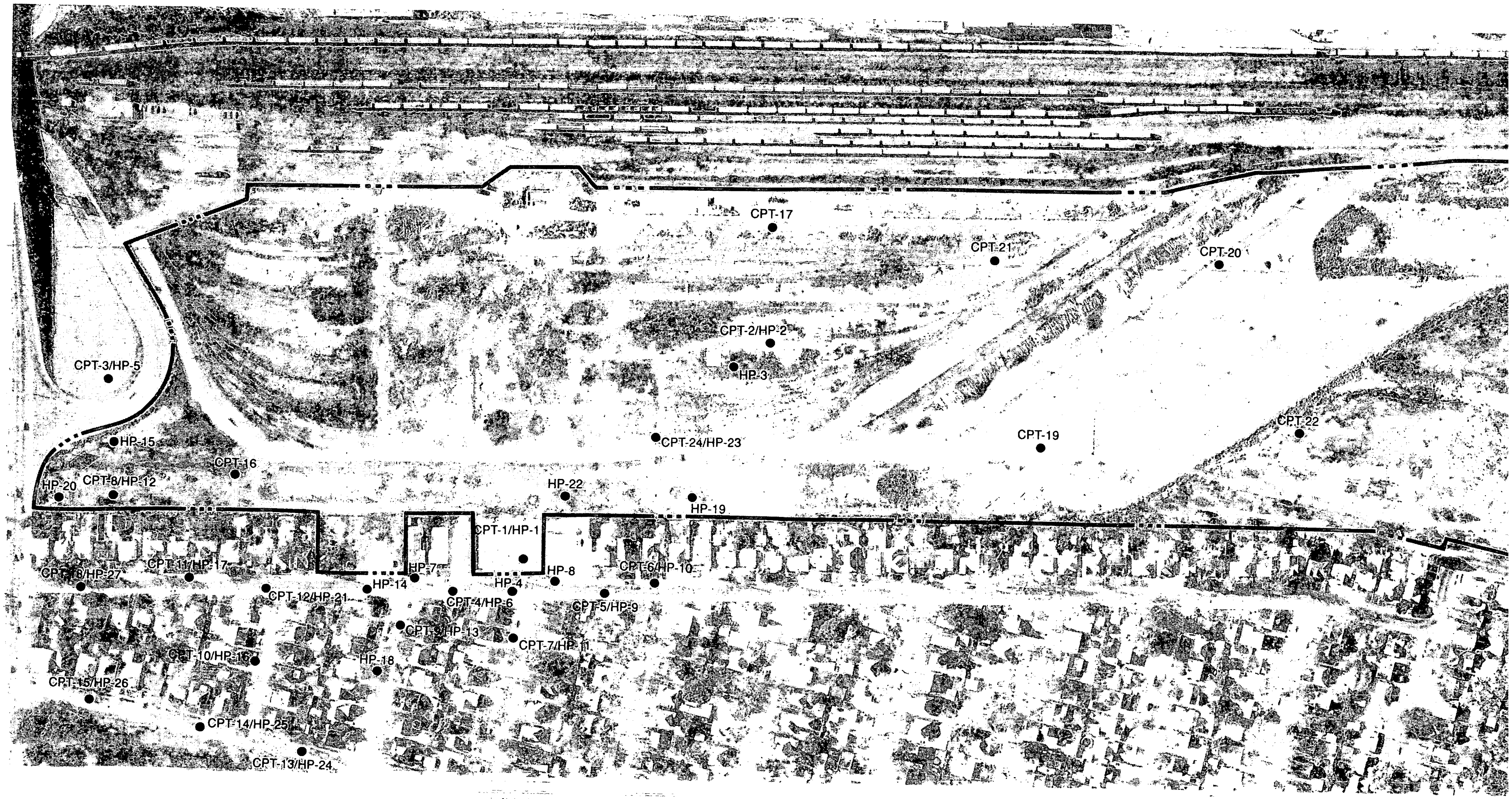
3048





RAILROAD TRACKS
SEVENTH AVE.
SIXTH AVE
PERKINS WAY
YARD OFFICE
PLANING MILL
CAR REPAIR SHED
FUEL OIL TANK
TOILET BUILDING
ACETYLENE WELDING BUILDING
TUBE STORAGE BUILDING
FUEL TANK
FENCE
SUTTERVILLE ROAD
WESTERN PACIFIC AVE.
ASBESTOS STORAGE BUILDING
FORMER LYE PITS
TRANSFER TABLE
MAIN SHOP BUILDING
BOILER HOUSE
FLAMMABLE MATERIAL STORAGE
SIGNAL STORE
SIGNAL SHOP
STORAGE DOCK
OFFICE
OIL HOUSE
STORE HOUSE
FORMER RAILROAD TIE STORAGE AREA
PARKING LOT
PARKING LOT
24TH STREET
11TH AVE.
10TH AVE.
9TH AVE.
8TH AVE.
7TH AVE.
6TH AVE.
MONTGOMERY WAY
CURTIS WAY
DONNER WAY
5TH AVE


RAILROAD TRACKS
SEVENTH AVE
SIXTH AVE
PERKINS WAY
YARD OFFICE
PLANING MILL
CAR REPAIR SHED
FUEL OIL TANK
FENCE
SIGN PAINTING BUILDING
REFINED OIL BLDG
UPW
SB-8
SB-2
MW-5
TOILET BUILDING
ASBESTOS STORAGE BUILDING
WATER TANKS
MW-24
MW-23
MW-6
FORMER LYE PITS
MW-9
MAIN SHOP BUILDING
ACETYLENE WELDING BUILDING
STEAM ENGINE
TUBE STORAGE BUILDING
SB-1
WELDING SHED
STEEL STORAGE
BRAKE HOUSE FACILITY
SB-5
SB-9
SB-7
SB-10
FUELING STATION
BLACK SMITH SHOP
SB-4
18,000 GALLON CAPACITY UNDERGROUND TANK
SB-21
MW-21
MW-22
MW-7
BOILER HOUSE
MW-10
MW-25
MW-26
MW-27
SB-14
SB-13
SB-15
SB-3
MW-15
MW-16
FLAMMABLE MATERIAL STORAGE
SB-6
MW-8
MW-11
MW-33
SIGNAL STORE
SIGNAL SHOP
STORE HOUSE
FENCE
FORMER RAILROAD TIE STORAGE AREA
STORAGE DOCK
OFFICE
MW-20
MW-19
MW-18
MW-17
MW-12
MW-4
SB-12
OIL HOUSE
MW-14
MW-13
SB-22
OIL TANKS
SB-11
SB-17
MW-2
SB-16
SB-18
SB-19
SB-20
MW-3
-4.50
-4.00
-3.00
-2.50
-2.00
-1.50
-1.00
-0.50
PARKING LOT
MW-32
MW-31
MW-30
MW-28
MW-29
WESTERN PACIFIC AVE
SUTTERVILLE ROAD
21TH STREET
COLMAN WAY
11TH AVE
10TH AVE
9TH AVE
8TH AVE
7TH AVE
6TH AVE
MONTGOMERY WAY
CURTIS WAY
CONNER WAY
5TH AVE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CPT-21
CPT-20
CPT-2/HP-2
HP-3
CPT-3/HP-5
HP-15
CPT-24/HP-23
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CPT-22
CPT-16
HP-20
CPT-8/HP-12
HP-22
HP-19
CPT-1/HP-1
CPT-11/HP-17
HP-7
HP-4
HP-8
CPT-6/HP-10
HP-14
CPT-12/HP-21
CPT-4/HP-6
CPT-5/HP-9
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HP-18
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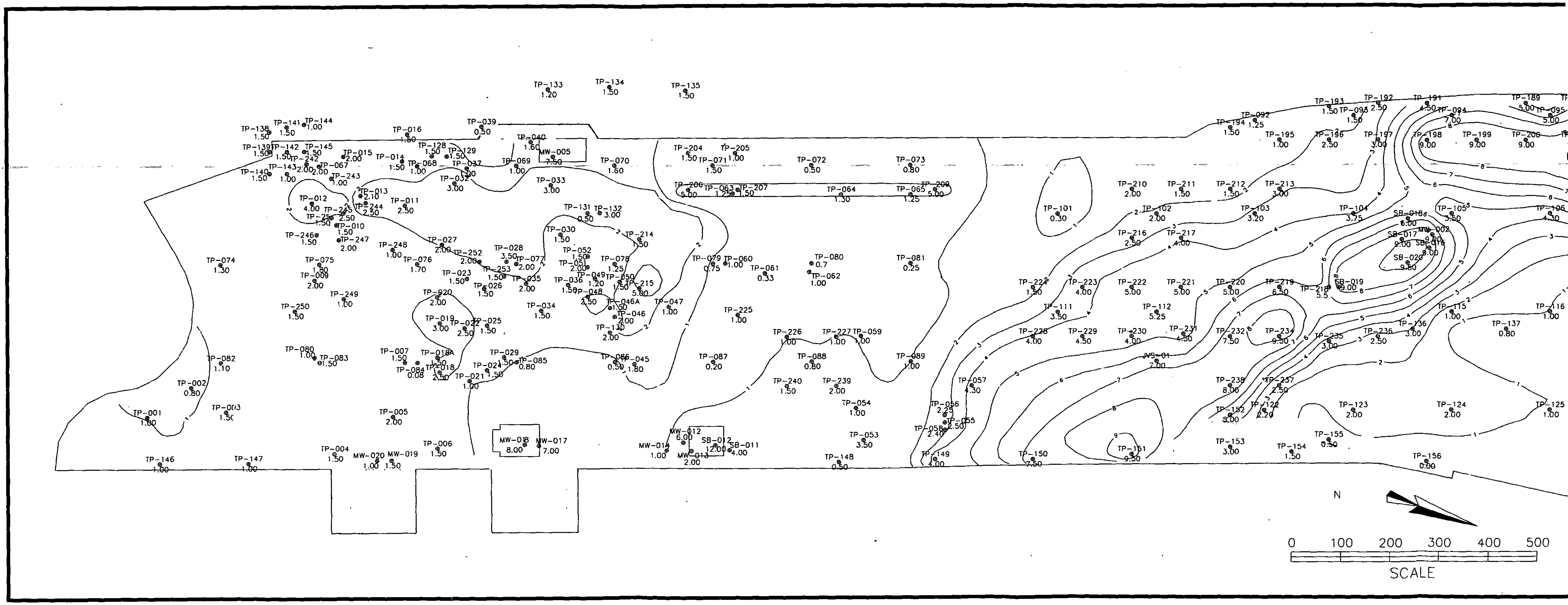
CPT-14/HP-25
CPT-13/HP-24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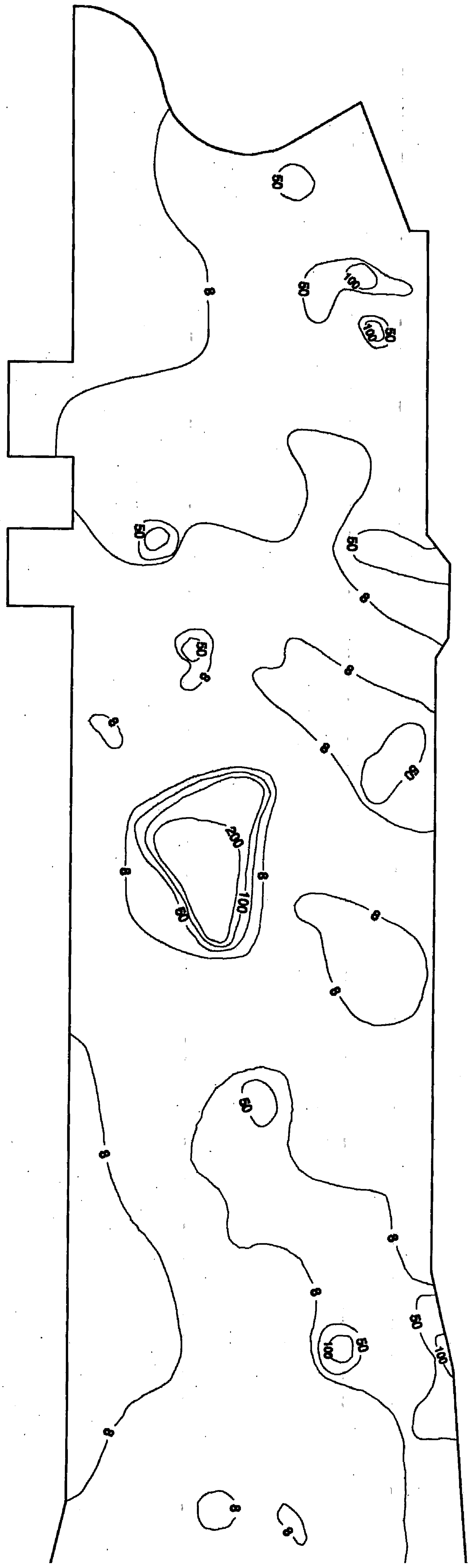

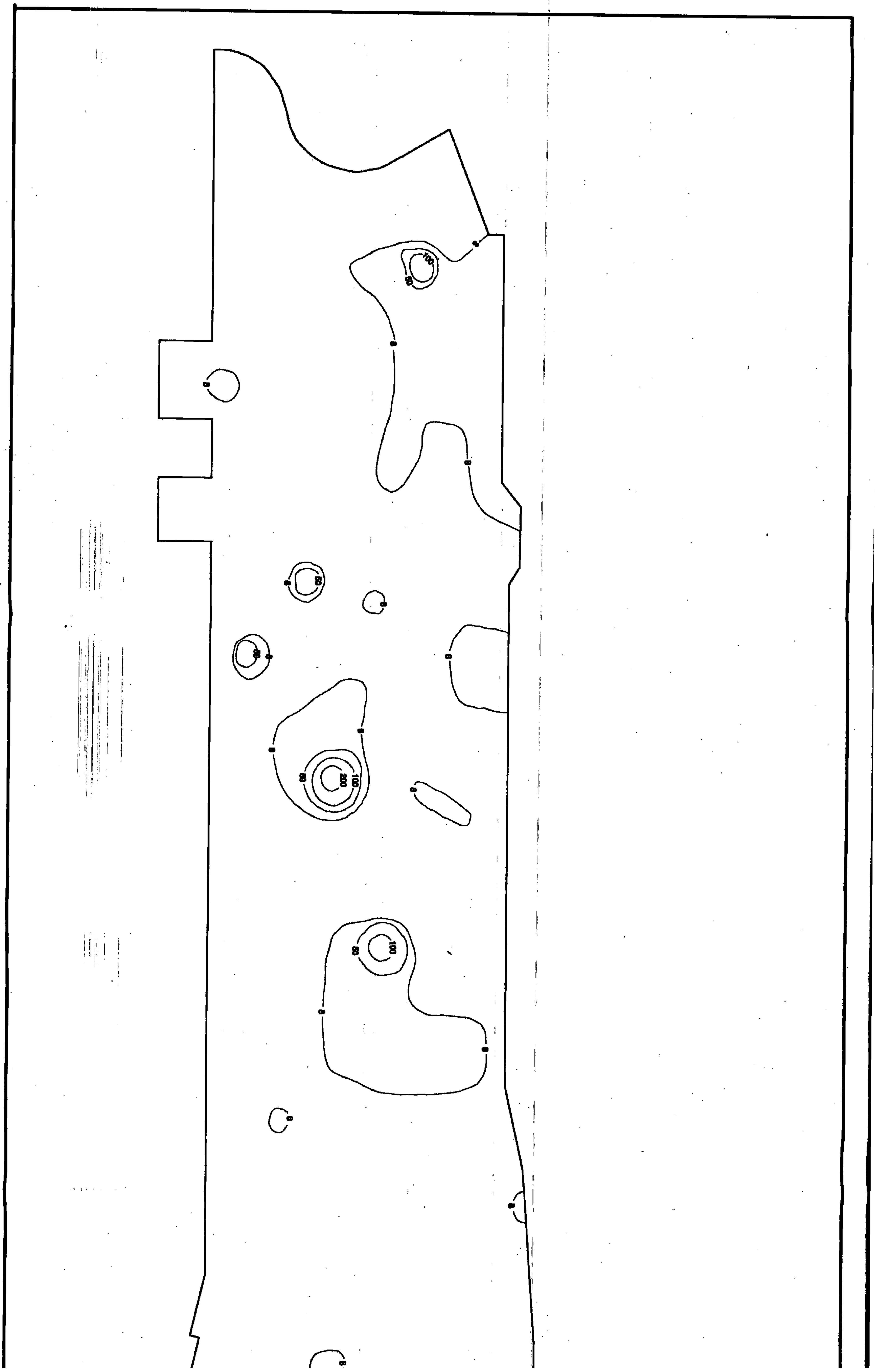

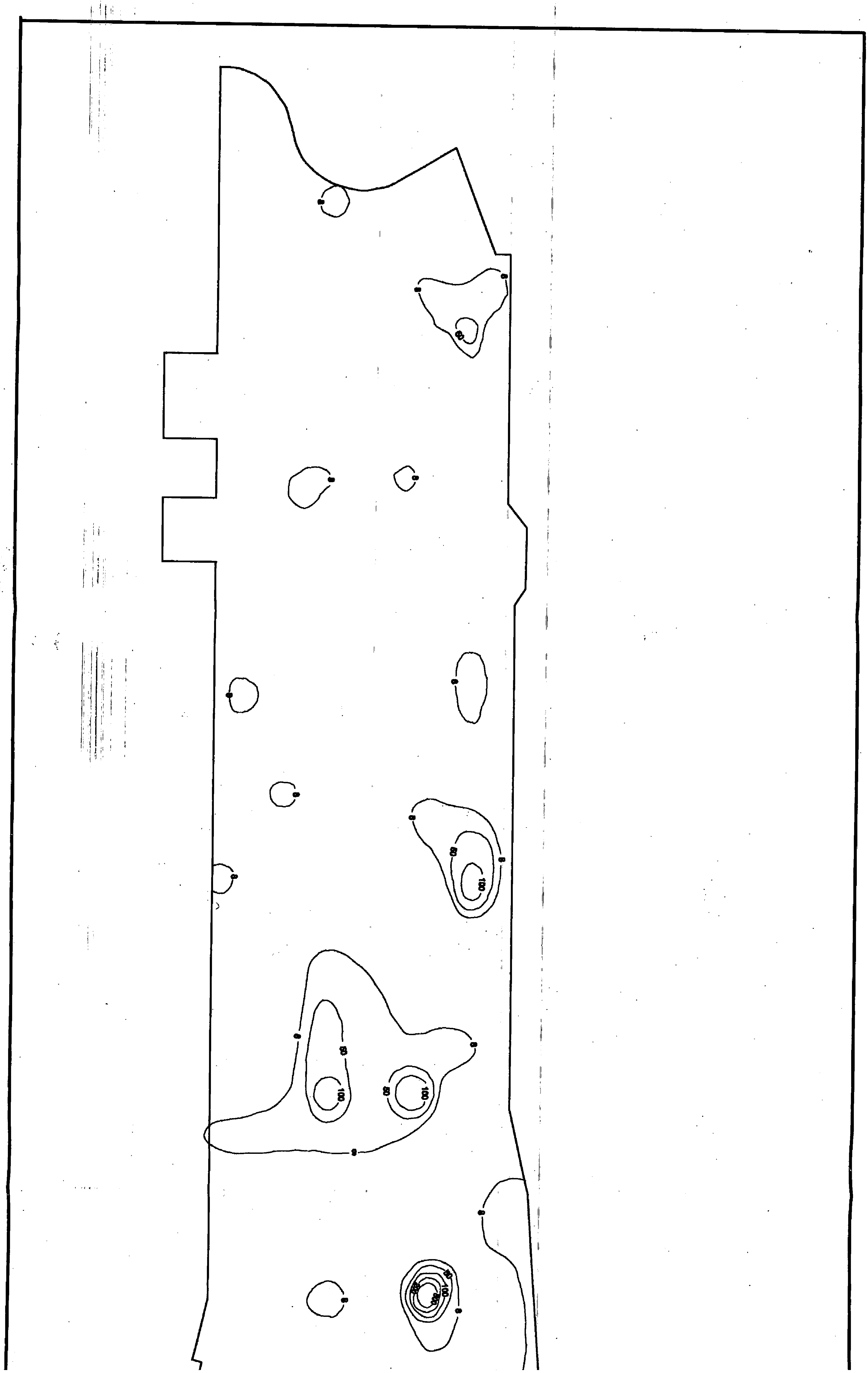

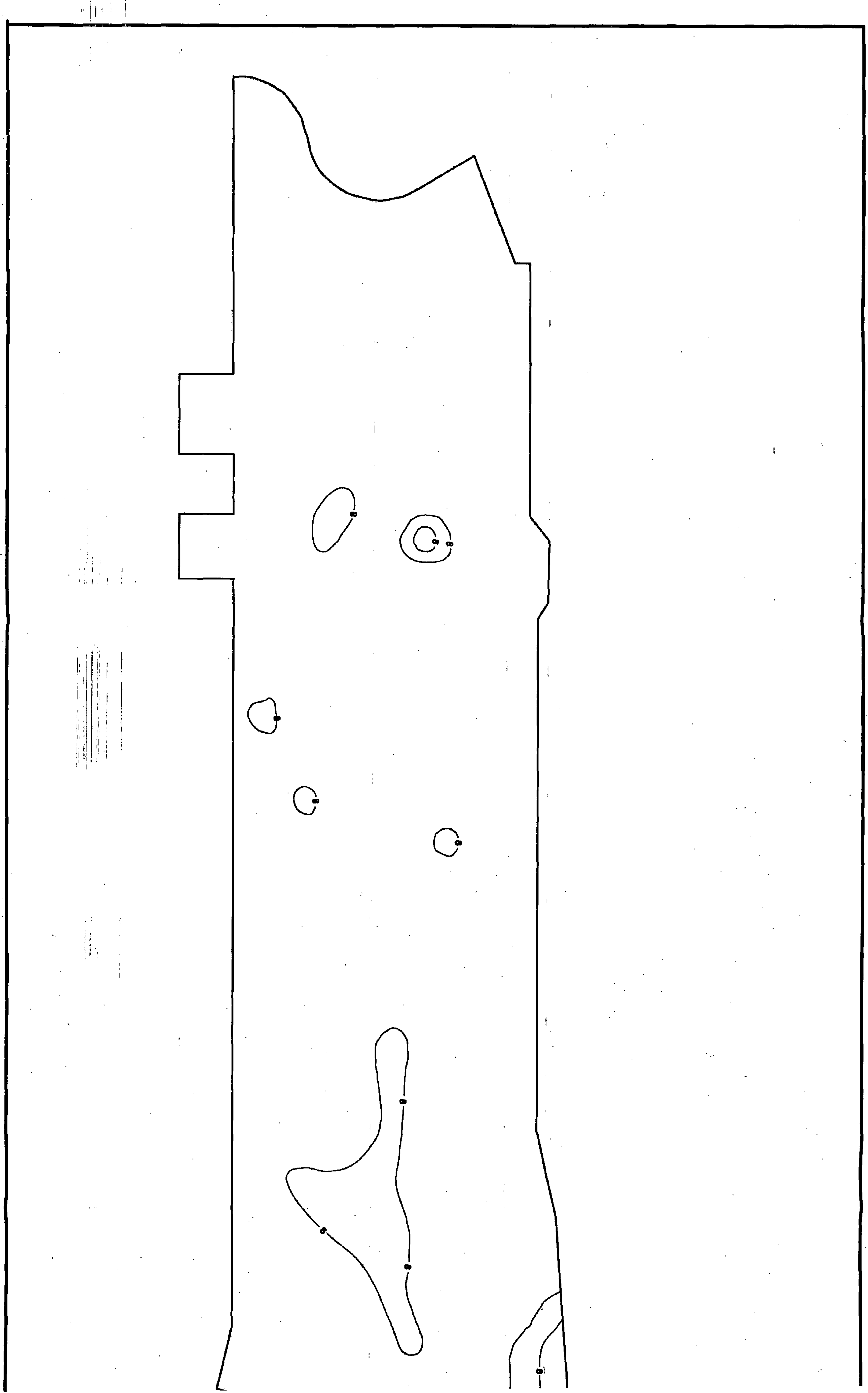

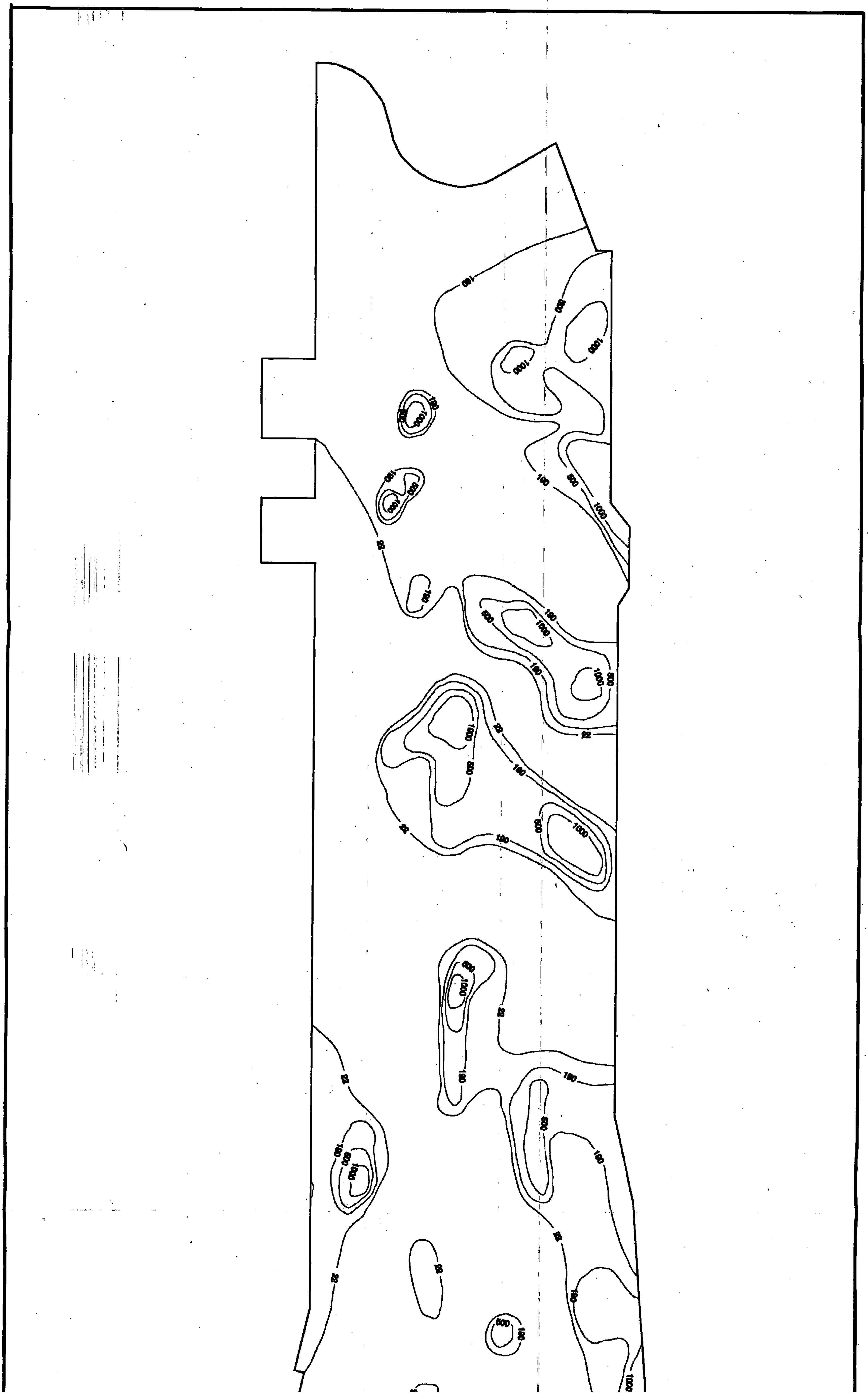
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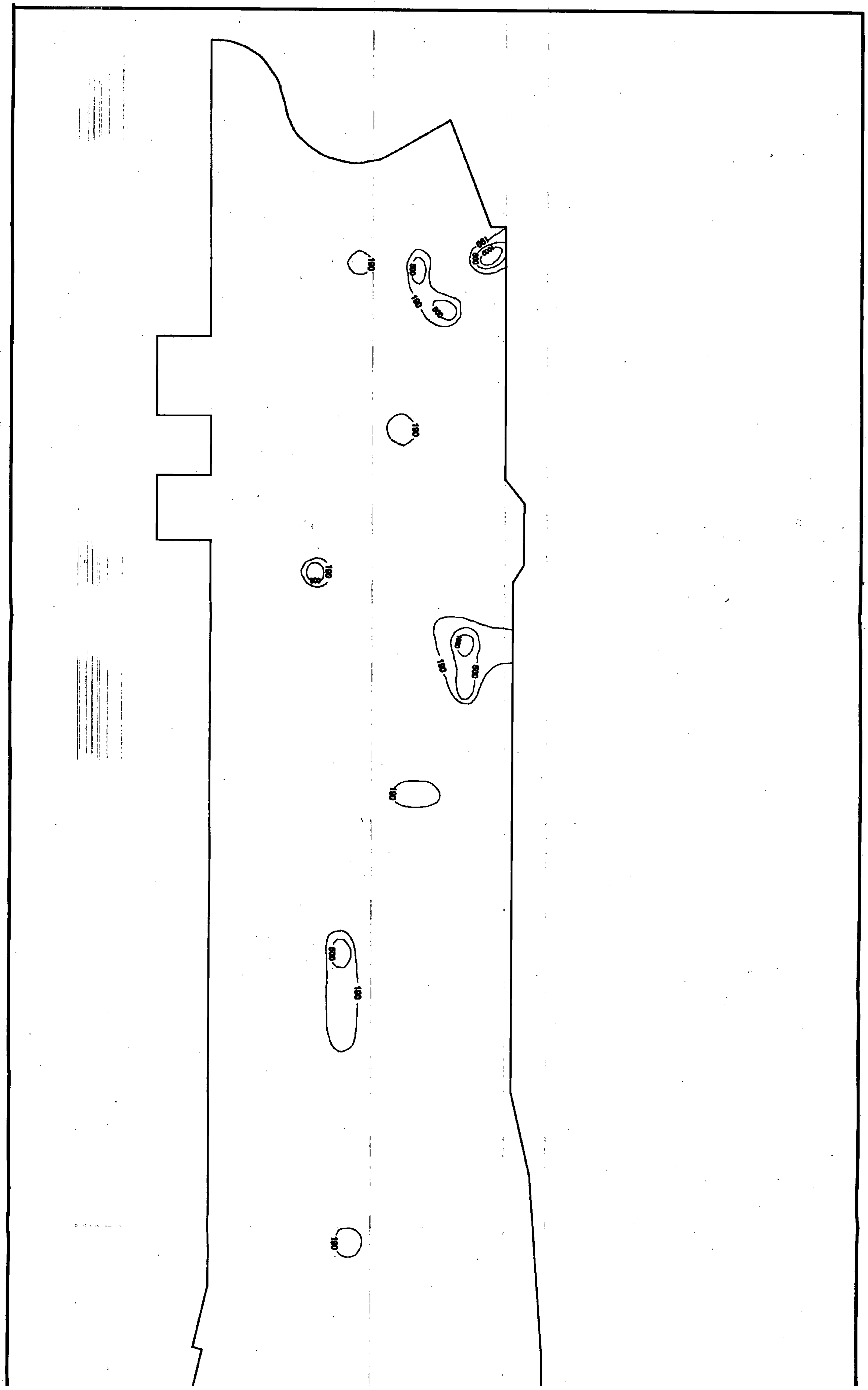
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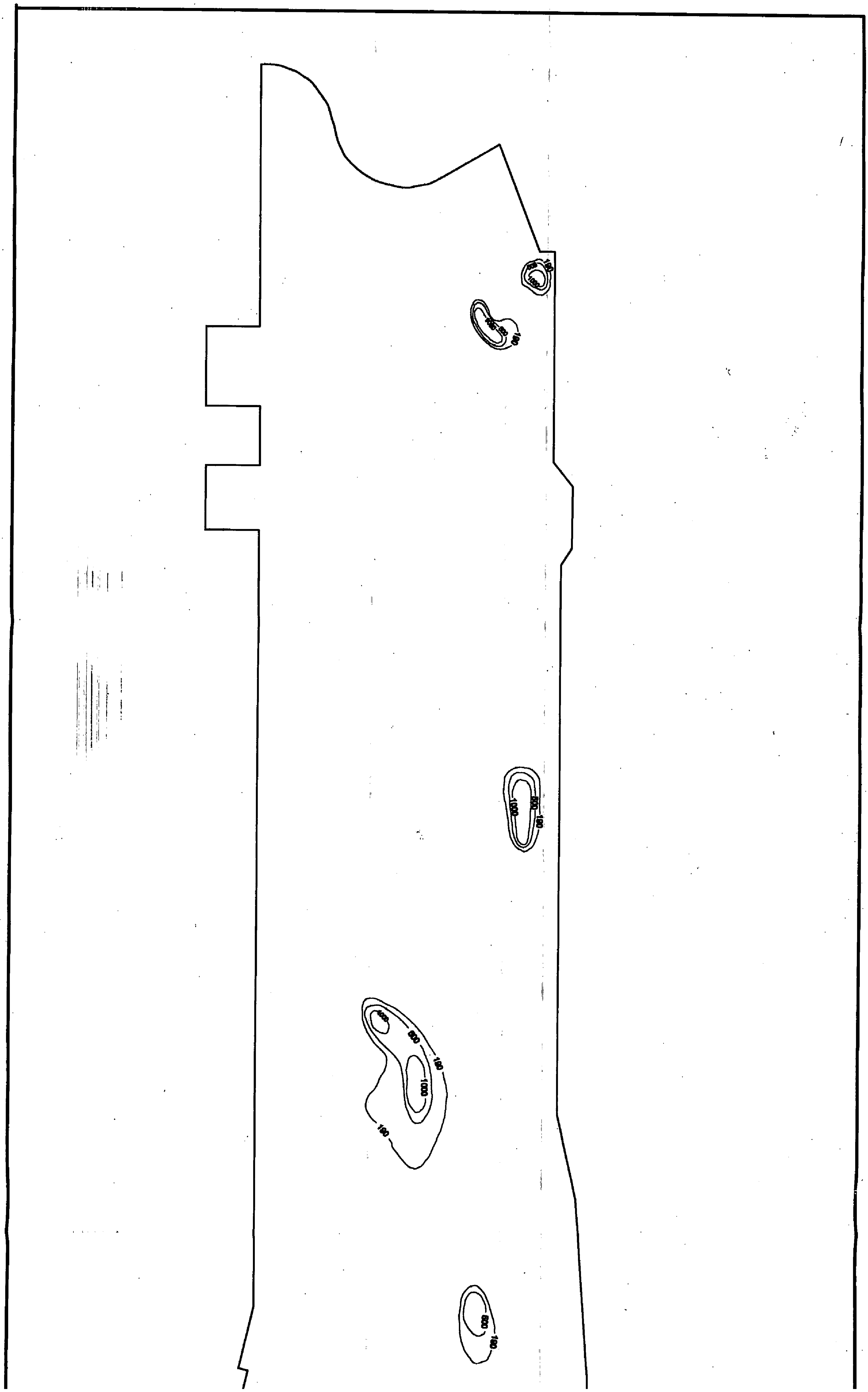

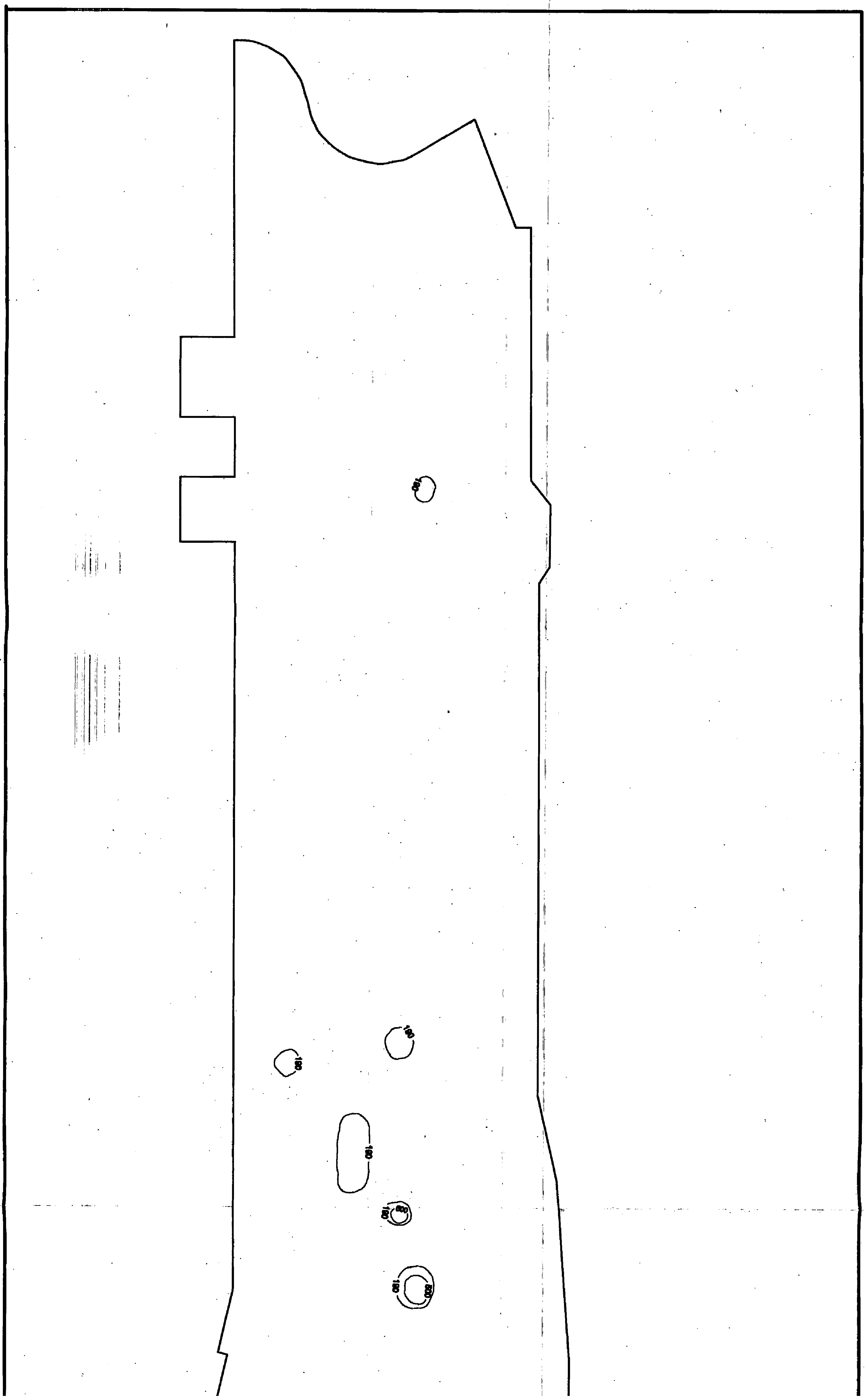
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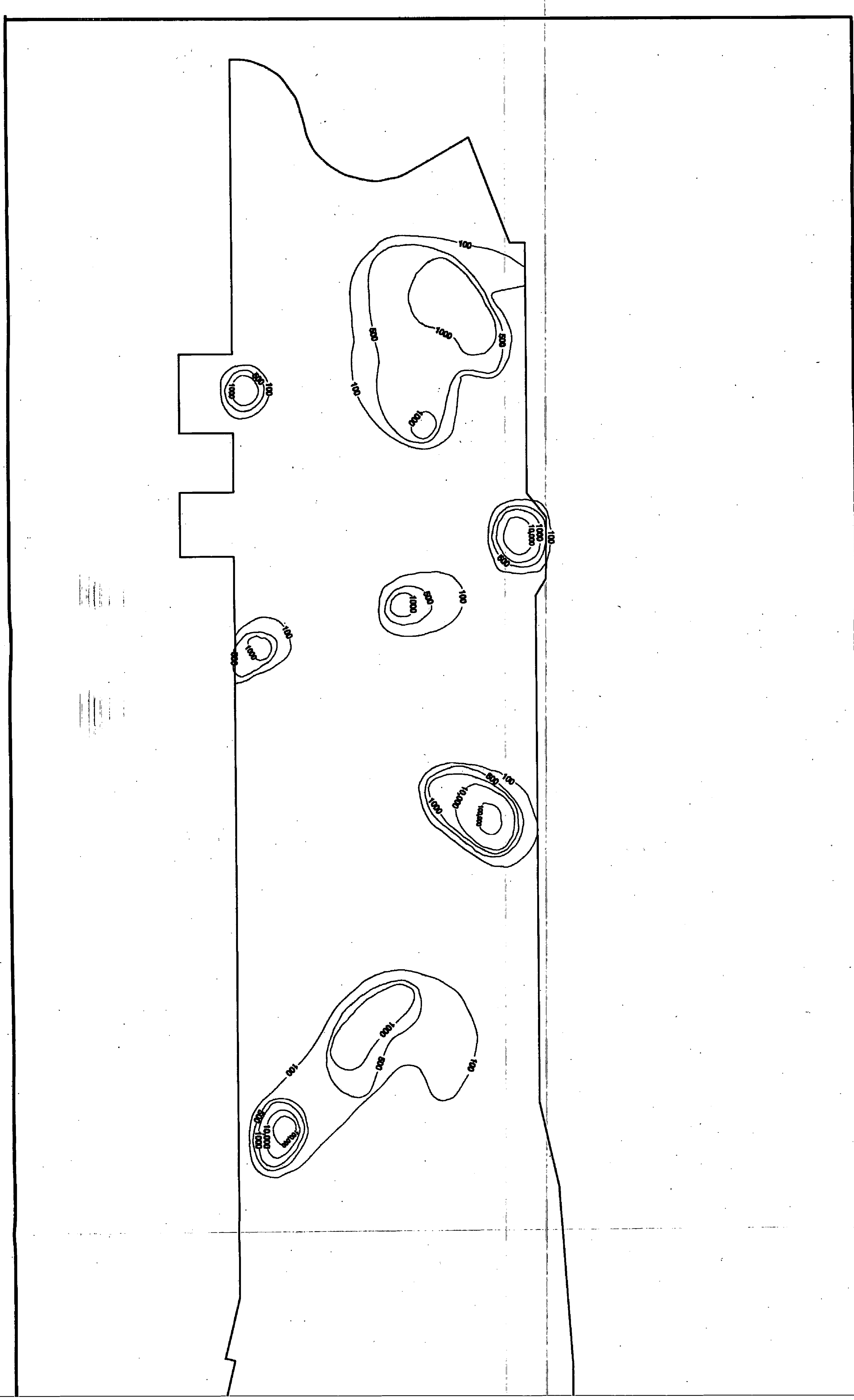
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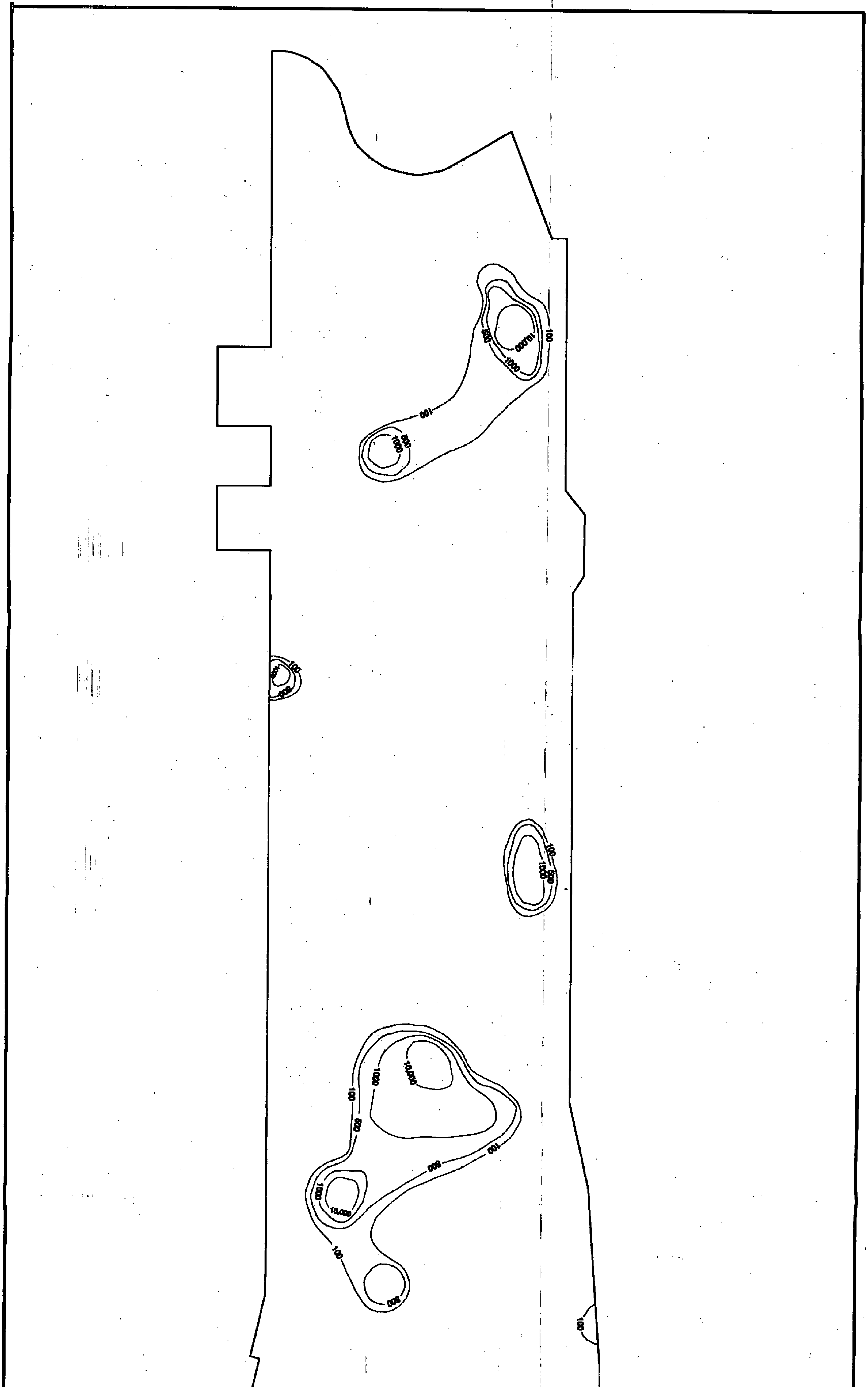

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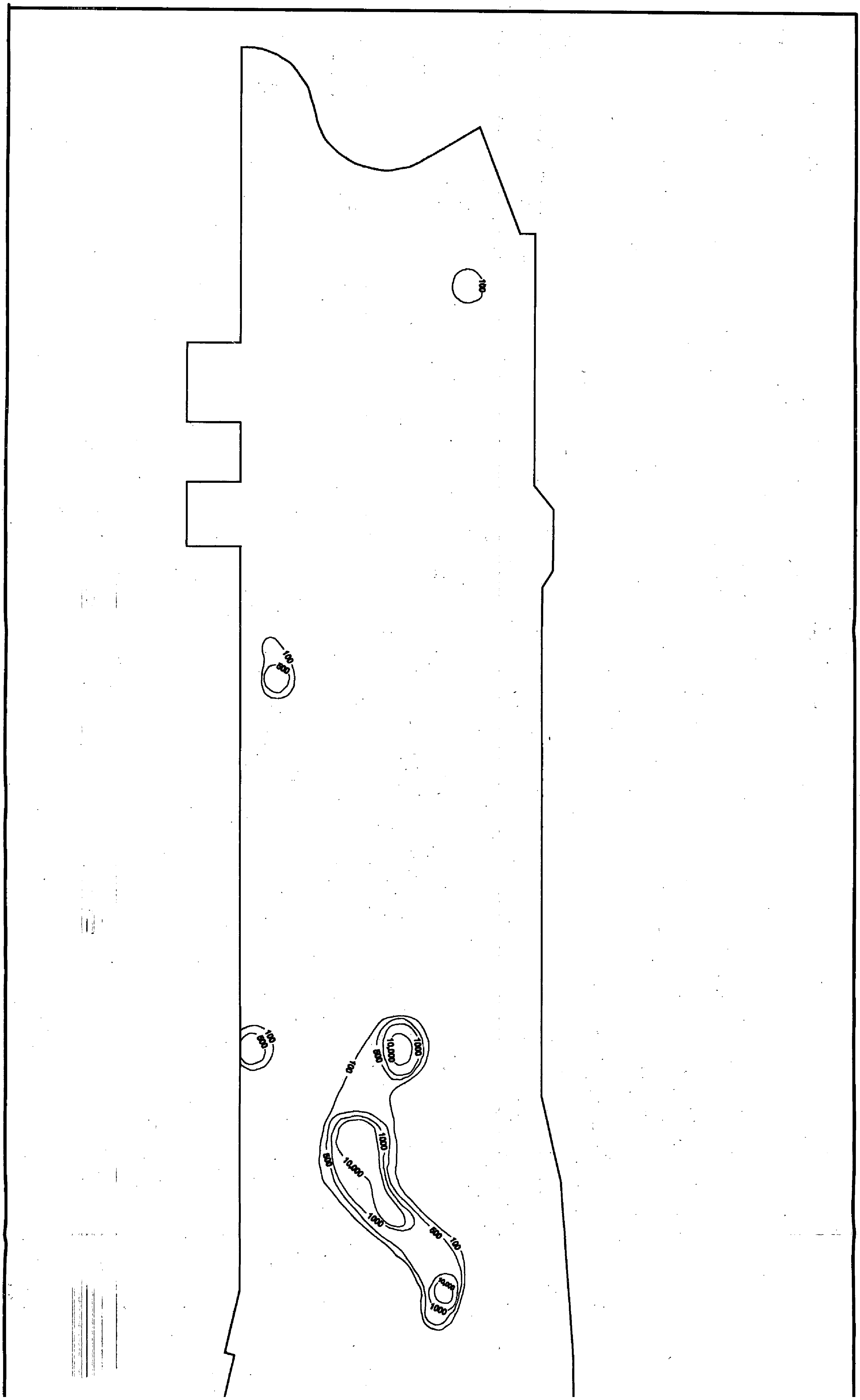

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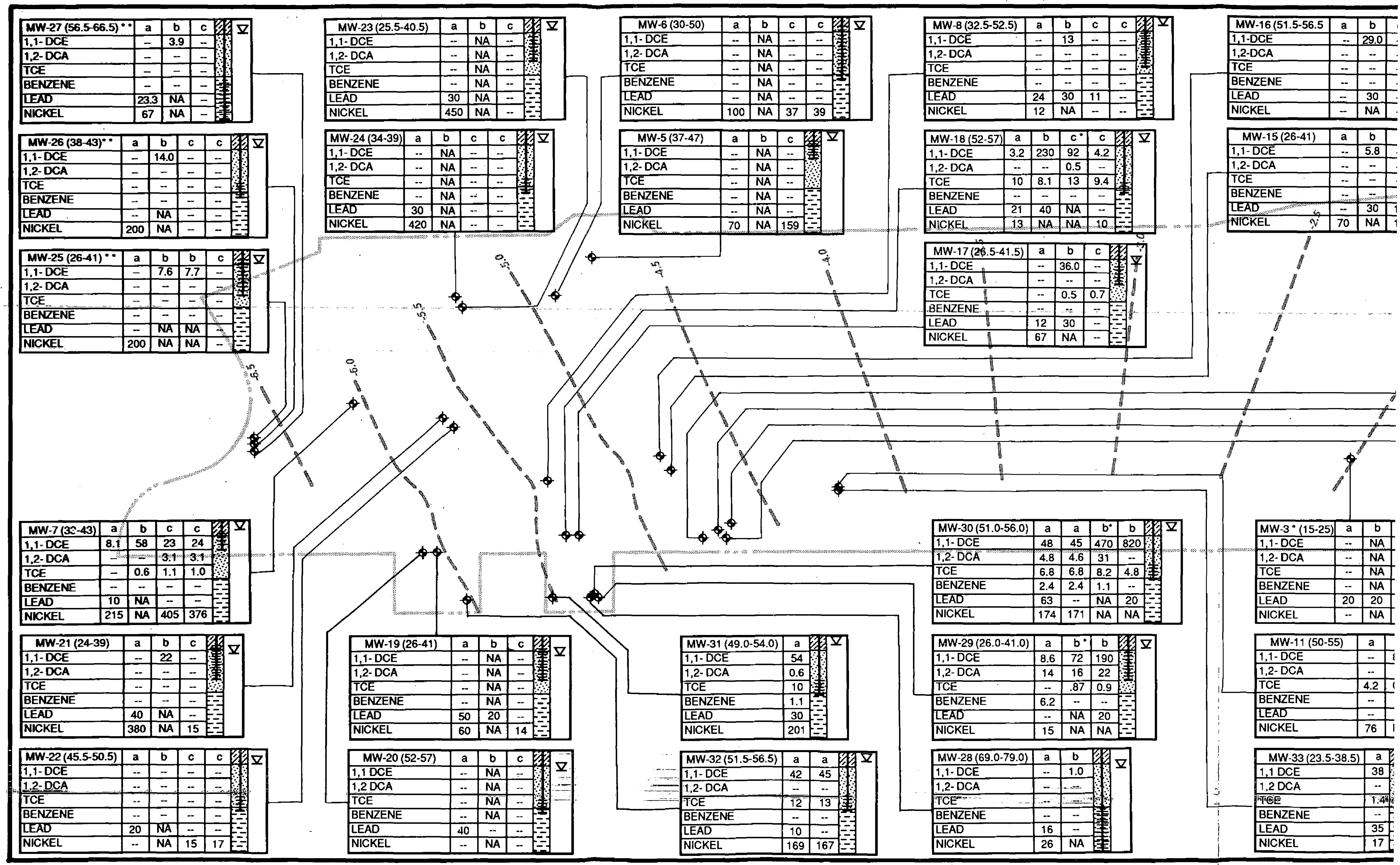


MW-27 (56.5-66.5)**	a	b	c
1,1- DCE	--	3.9	--
1,2- DCA	--	--	--
TCE	--	--	--
BENZENE	--	--	--
LEAD	23.3	NA	--
NICKEL	67	NA	--

MW-26 (38-43)**	a	b	c	c
1,1- DCE	--	14.0	--	--
1,2- DCA	--	--	--	--
TCE	--	--	--	--
BENZENE	--	--	--	--
LEAD	--	NA	--	--
NICKEL	200	NA	--	--

MW-25 (26-41)**	a	b	b	c
1,1- DCE	--	7.6	7.7	--
1,2- DCA	--	--	--	--
TCE	--	--	--	--
BENZENE	--	--	--	--
LEAD	--	NA	NA	--
NICKEL	200	NA	NA	--

MW-23 (25.5-40.5)	a	b	c
1,1- DCE	--	NA	--
1,2- DCA	--	NA	--
TCE	--	NA	--
BENZENE	--	NA	--
LEAD	30	NA	--
NICKEL	450	NA	--

MW-24 (34-39)	a	b	c	c
1,1- DCE	--	NA	--	--
1,2- DCA	--	NA	--	--
TCE	--	NA	--	--
BENZENE	--	NA	--	--
LEAD	30	NA	--	--
NICKEL	420	NA	--	--

MW-6 (30-50)	a	b	c	c
1,1- DCE	--	NA	--	--
1,2- DCA	--	NA	--	--
TCE	--	NA	--	--
BENZENE	--	NA	--	--
LEAD	--	NA	--	--
NICKEL	100	NA	37	39

MW-5 (37-47)	a	b	c
1,1- DCE	--	NA	--
1,2- DCA	--	NA	--
TCE	--	NA	--
BENZENE	--	NA	--
LEAD	--	NA	--
NICKEL	70	NA	159

MW-8 (32.5-52.5)	a	b	c	c
1,1- DCE	--	13	--	--
1,2- DCA	--	--	--	--
TCE	--	--	--	--
BENZENE	--	--	--	--
LEAD	24	30	11	--
NICKEL	12	NA	--	--

MW-18 (52-57)	a	b	c*	c
1,1- DCE	3.2	230	92	4.2
1,2- DCA	--	--	0.5	--
TCE	10	8.1	13	9.4
BENZENE	--	--	--	--
LEAD	21	40	NA	--
NICKEL	13	NA	NA	10

MW-17 (26.5-41.5)	a	b	c
1,1- DCE	--	36.0	--
1,2- DCA	--	--	--
TCE	--	0.5	0.7
BENZENE	--	--	--
LEAD	12	30	--
NICKEL	67	NA	--

MW-16 (51.5-56.5	a	b
1,1-DCE	--	29.0
1,2-DCA	--	--
TCE	--	--
BENZENE	--	--
LEAD	--	30
NICKEL	--	NA

MW-15 (26-41)	a	b
1,1- DCE	--	5.8
1,2- DCA	--	--
TCE	--	--
BENZENE	--	--
LEAD	--	30
NICKEL	70	NA

MW-7 (33-43)	a	b	c	c
1,1- DCE	8.1	58	23	24
1,2- DCA	--	--	3.1	3.1
TCE	--	0.6	1.1	1.0
BENZENE	--	--	--	--
LEAD	10	NA	--	--
NICKEL	215	NA	405	376

MW-21 (24-39)	a	b	c
1,1- DCE	--	22	--
1,2- DCA	--	--	--
TCE	--	--	--
BENZENE	--	--	--
LEAD	40	NA	--
NICKEL	380	NA	15

MW-22 (45.5-50.5)	a	b	c	c
1,1- DCE	--	--	--	--
1,2- DCA	--	--	--	--
TCE	--	--	--	--
BENZENE	--	--	--	--
LEAD	20	NA	--	--
NICKEL	--	NA	15	17

MW-19 (26-41)	a	b	c
1,1- DCE	--	NA	--
1,2- DCA	--	NA	--
TCE	--	NA	--
BENZENE	--	NA	--
LEAD	50	20	--
NICKEL	60	NA	14

MW-20 (52-57)	a	b	c
1,1 DCE	--	NA	--
1,2 DCA	--	NA	--
TCE	--	NA	--
BENZENE	--	NA	--
LEAD	40	--	--
NICKEL	--	NA	--

MW-31 (49.0-54.0)	a
1,1- DCE	54
1,2- DCA	0.6
TCE	10
BENZENE	1.1
LEAD	30
NICKEL	201

MW-32 (51.5-56.5)	a	a
1,1- DCE	42	45
1,2- DCA	--	--
TCE	12	13
BENZENE	--	--
LEAD	10	--
NICKEL	169	167

MW-30 (51.0-56.0)	a	a	b*	b
1,1- DCE	48	45	470	820
1,2- DCA	4.8	4.6	31	--
TCE	6.8	6.8	8.2	4.8
BENZENE	2.4	2.4	1.1	--
LEAD	63	--	NA	20
NICKEL	174	171	NA	NA

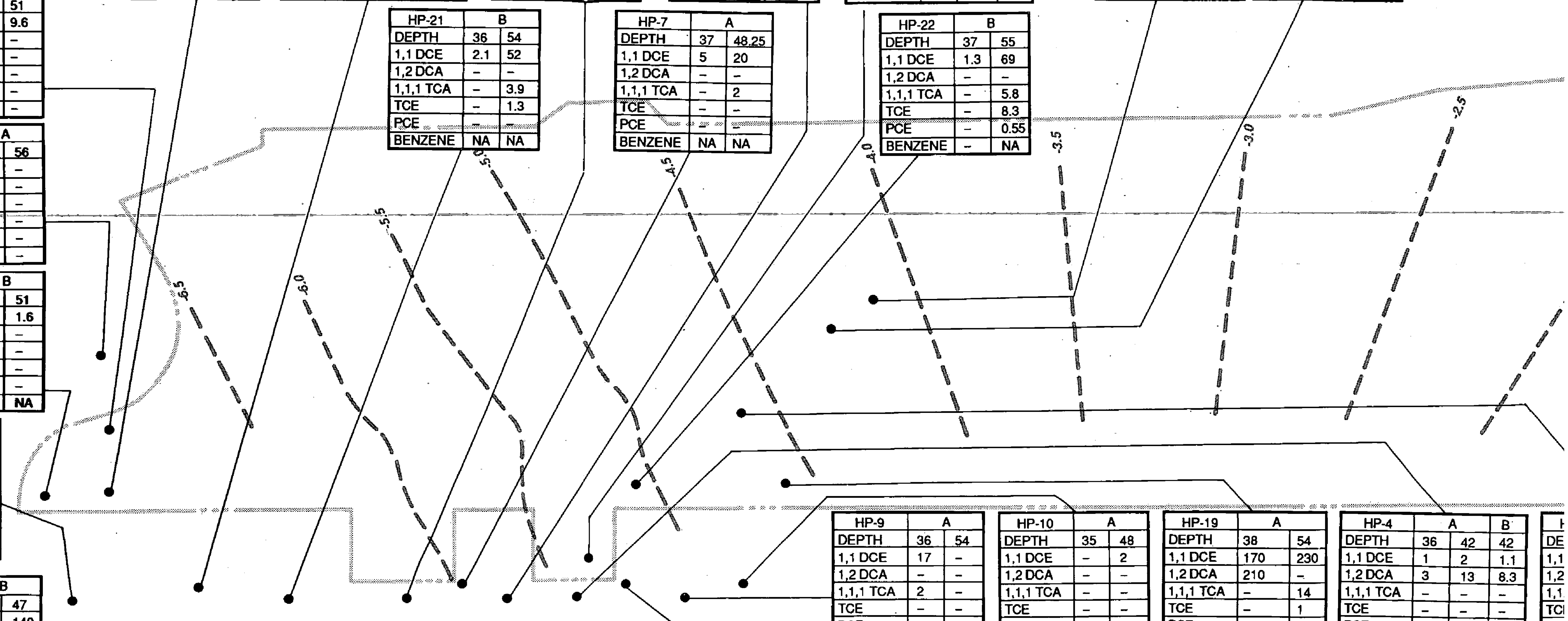
MW-29 (26.0-41.0)	a	b*	b
1,1- DCE	8.6	72	190
1,2- DCA	14	16	22
TCE	--	.87	0.9
BENZENE	6.2	--	--
LEAD	--	NA	20
NICKEL	15	NA	NA

MW-28 (69.0-79.0)	a	b
1,1- DCE	--	1.0
1,2- DCA	--	--
TCE	--	--
BENZENE	--	--
LEAD	16	--
NICKEL	26	NA

MW-3* (15-25)	a	b
1,1- DCE	--	NA
1,2- DCA	--	NA
TCE	--	NA
BENZENE	--	NA
LEAD	20	20
NICKEL	--	NA

MW-11 (50-55)	a
1,1- DCE	--
1,2- DCA	--
TCE	4.2
BENZENE	--
LEAD	--
NICKEL	76

MW-33 (23.5-38.5)	a
1,1 DCE	38
1,2 DCA	--
TCE	1.4
BENZENE	--
LEAD	35
NICKEL	17



HP-12	A	
DEPTH	38	49
1,1 DCE	23	14
1,2 DCA	–	–
1,1,1 TCA	–	–
TCE	–	–
PCE	–	–
BENZENE	–	–

HP-17	B		
DEPTH	37.5	47	54
1,1 DCE	1	–	–
1,2 DCA	–	–	–
1,1,1 TCA	–	–	–
TCE	–	–	–
PCE	–	–	–
BENZENE	NA	NA	NA

HP-14	A	
DEPTH	37	48
1,1 DCE	14	240
1,2 DCA	2	5
1,1,1 TCA	1	32
TCE	–	5
PCE	–	–
BENZENE	NA	NA

HP-6	A	
DEPTH	37	53.5
1,1 DCE	63	130
1,2 DCA	17	–
1,1,1 TCA	7	5
TCE	–	–
PCE	–	–
BENZENE	–	NA

HP-1	A		B
DEPTH	36	56	56
1,1 DCE	NA	430	NA
1,2 DCA	NA	–	NA
1,1,1 TCA	NA	42	NA
TCE	NA	7	NA
PCE	NA	–	NA
BENZENE	–	–	0.59

HP-2	A	
DEPTH	36	52
1,1 DCE	–	5
1,2 DCA	–	–
1,1,1 TCA	–	1
TCE	–	–
PCE	–	–
BENZENE	–	–

HP-3	A	
DEPTH	36.5	57
1,1 DCE	–	3
1,2 DCA	–	–
1,1,1 TCA	–	1
TCE	–	–
PCE	2	–
BENZENE	–	–

HP-21	B	
DEPTH	36	54
1,1 DCE	2.1	52
1,2 DCA	–	–
1,1,1 TCA	–	3.9
TCE	–	1.3
PCE	–	–
BENZENE	NA	NA

HP-7	A	
DEPTH	37	48.25
1,1 DCE	5	20
1,2 DCA	–	–
1,1,1 TCA	–	2
TCE	–	–
PCE	–	–
BENZENE	NA	NA

HP-22	B	
DEPTH	37	55
1,1 DCE	1.3	69
1,2 DCA	–	–
1,1,1 TCA	–	5.8
TCE	–	8.3
PCE	–	0.55
BENZENE	–	NA

HP-15	B	
DEPTH	37	51
1,1 DCE	–	9.6
1,2 DCA	–	–
1,1,1 TCA	–	–
TCE	–	–
PCE	–	–
BENZENE	–	–

HP-5	A	
DEPTH	42	56
1,1 DCE	4	–
1,2 DCA	–	–
1,1,1 TCA	–	–
TCE	–	–
PCE	–	–
BENZENE	–	–

HP-20	B	
DEPTH	37	51
1,1 DCE	4.5	1.6
1,2 DCA	–	–
1,1,1 TCA	–	–
TCE	–	–
PCE	–	–
BENZENE	–	NA

HP-27	B
DEPTH	47
1,1 DCE	–
1,2 DCA	–
1,1,1 TCA	–
TCE	–
PCE	–
BENZENE	NA

HP-26	B	
DEPTH	39	47
1,1 DCE	13	140
1,2 DCA	–	–
1,1,1 TCA	1	8.8
TCE	–	6.5
PCE	–	–
BENZENE	NA	NA

HP-25	B	
DEPTH	37	54
1,1 DCE	2.1	44
1,2 DCA	1.6	9.4
1,1,1 TCA	–	4.7
TCE	–	–
PCE	–	–
BENZENE	NA	NA

HP-9	A	
DEPTH	36	54
1,1 DCE	17	–
1,2 DCA	–	–
1,1,1 TCA	2	–
TCE	–	–
PCE	–	–
BENZENE	–	–

HP-10	A	
DEPTH	35	48
1,1 DCE	–	2
1,2 DCA	–	–
1,1,1 TCA	–	–
TCE	–	–
PCE	–	–
BENZENE	–	–

HP-19	A	
DEPTH	38	54
1,1 DCE	170	230
1,2 DCA	210	–
1,1,1 TCA	–	14
TCE	–	1
PCE	–	–
BENZENE	14,000	3

HP-4	A		B
DEPTH	36	42	42
1,1 DCE	1	2	1.1
1,2 DCA	3	13	8.3
1,1,1 TCA	–	–	–
TCE	–	–	–
PCE	–	–	–
BENZENE	–	NA	NA

HP-24	B	
DEPTH	40	50
1,1 DCE	–	–
1,2 DCA	–	–
1,1,1 TCA	–	–
TCE	–	–
PCE	–	–
BENZENE	NA	NA

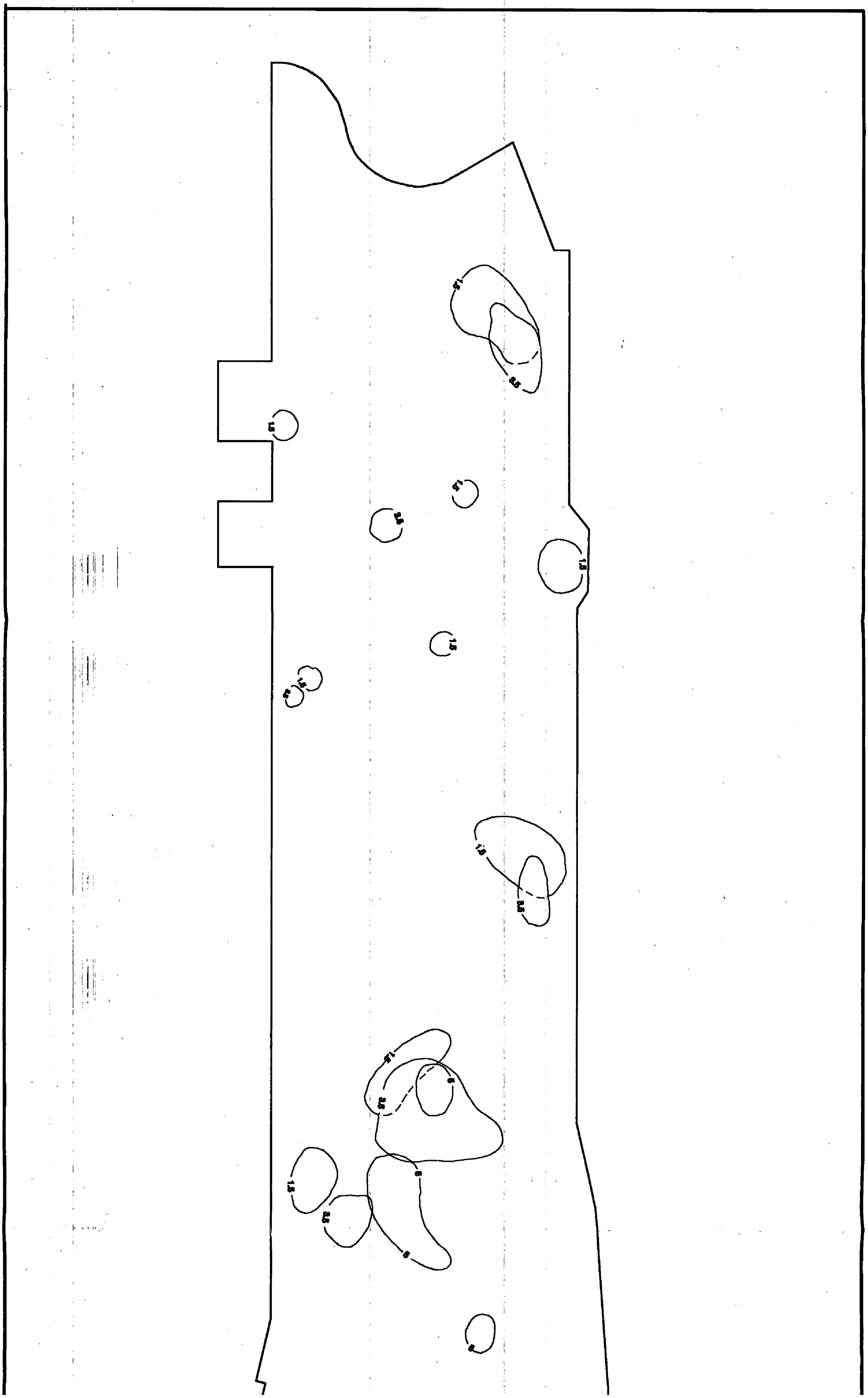
HP-18	A		B	
DEPTH	37	51	37	51
1,1 DCE	–	79	NA	45
1,2 DCA	–	–	NA	–
1,1,1 TCA	–	5	NA	4
TCE	–	–	NA	–
PCE	–	–	NA	–
BENZENE	NA	NA	–	NA

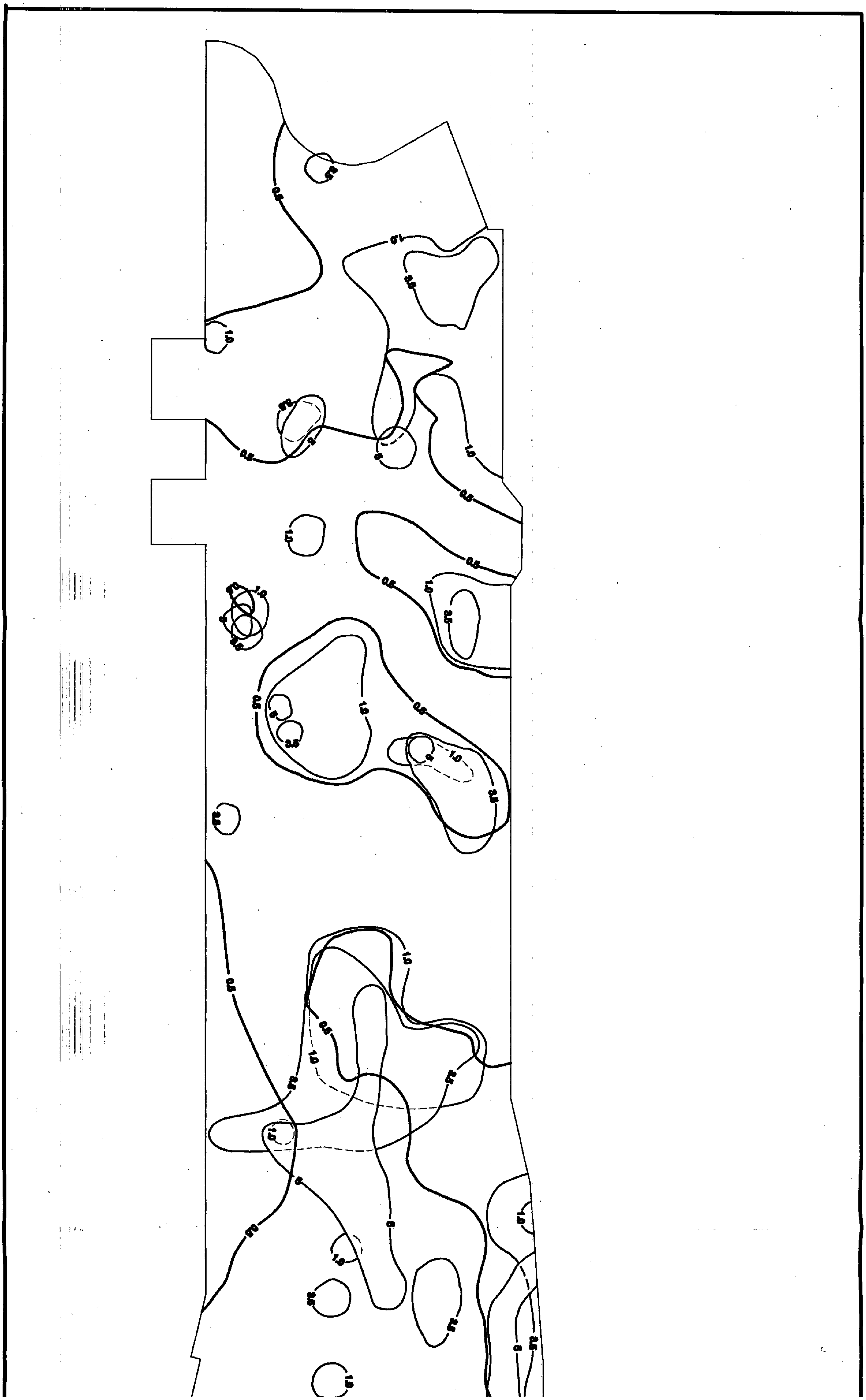
HP-16	B	
DEPTH	36	54
1,1 DCE	9.5	270
1,2 DCA	–	1.1
1,1,1 TCA	1.2	34
TCE	–	3.8
PCE	–	–
BENZENE	NA	NA

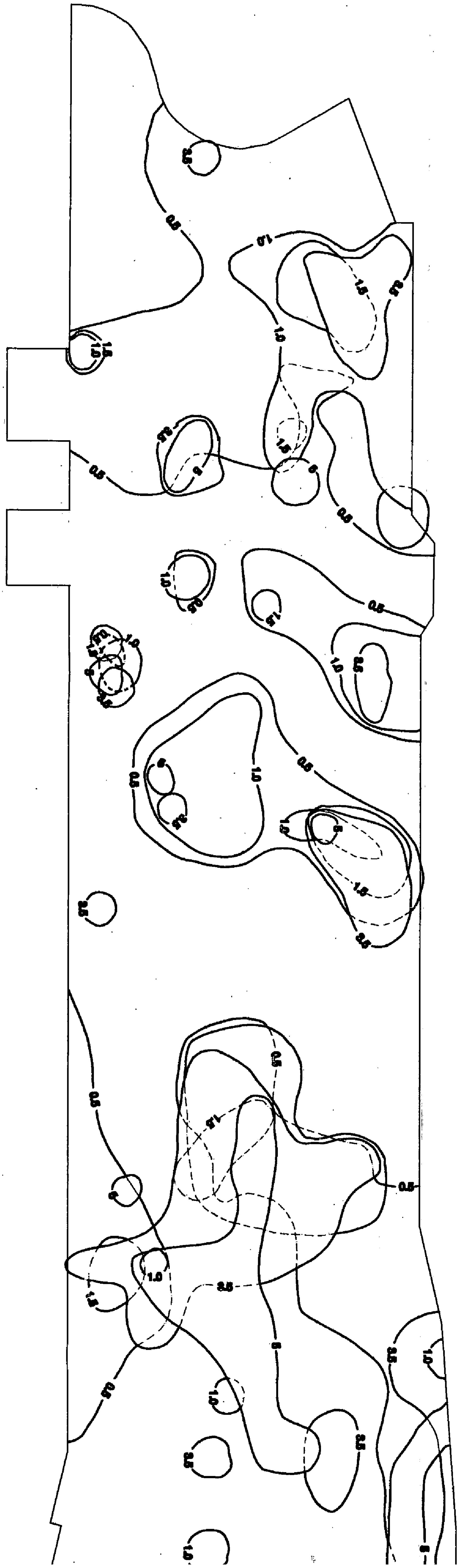
HP-11	A	
DEPTH	36	50
1,1 DCE	–	–
1,2 DCA	–	–
1,1,1 TCA	–	–
TCE	–	–
PCE	–	–
BENZENE	–	–

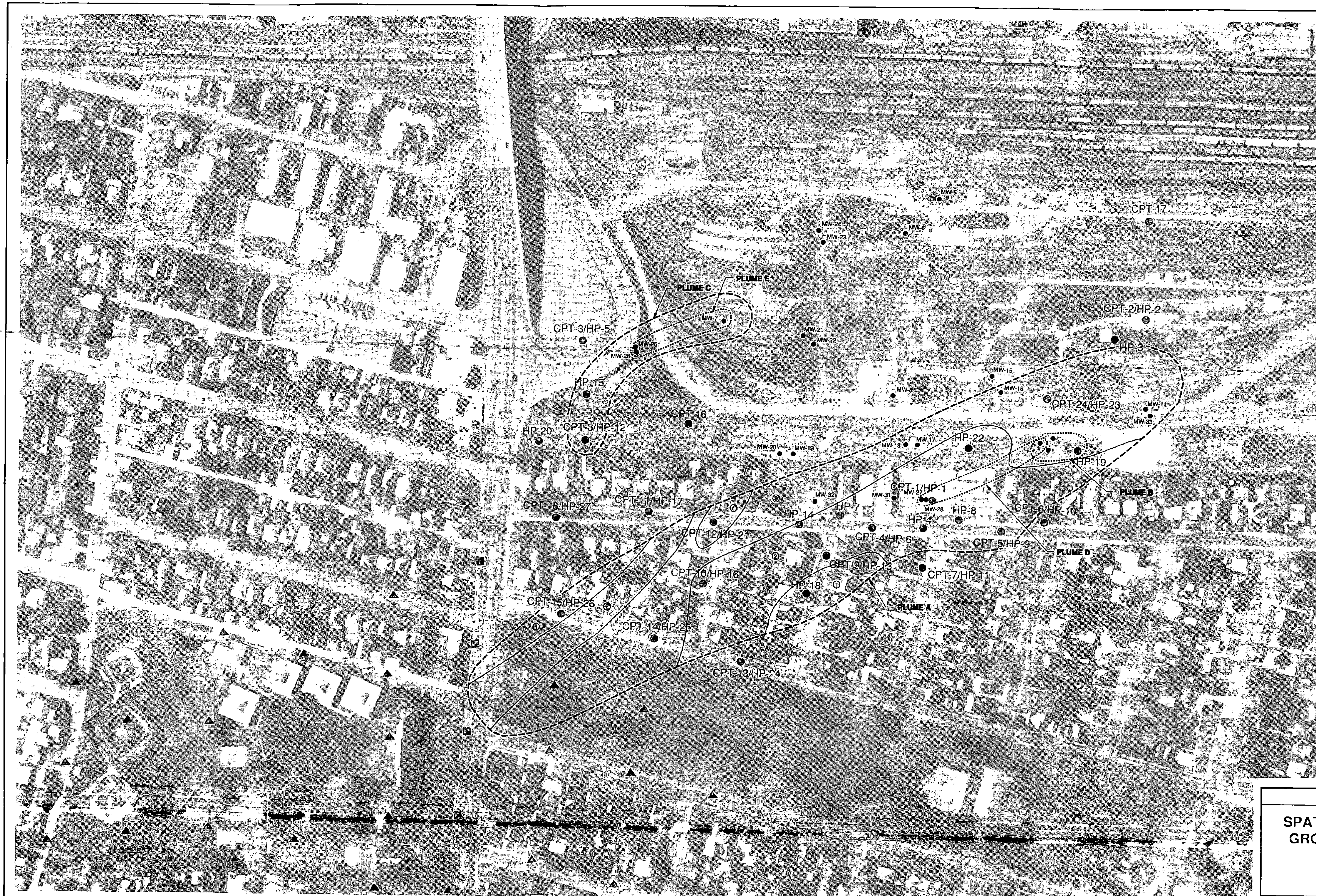
HP-13	A	
DEPTH	36	51
1,1 DCE	2	320
1,2 DCA	2	2
1,1,1 TCA	–	27
TCE	–	4
PCE	–	–
BENZENE	–	NA

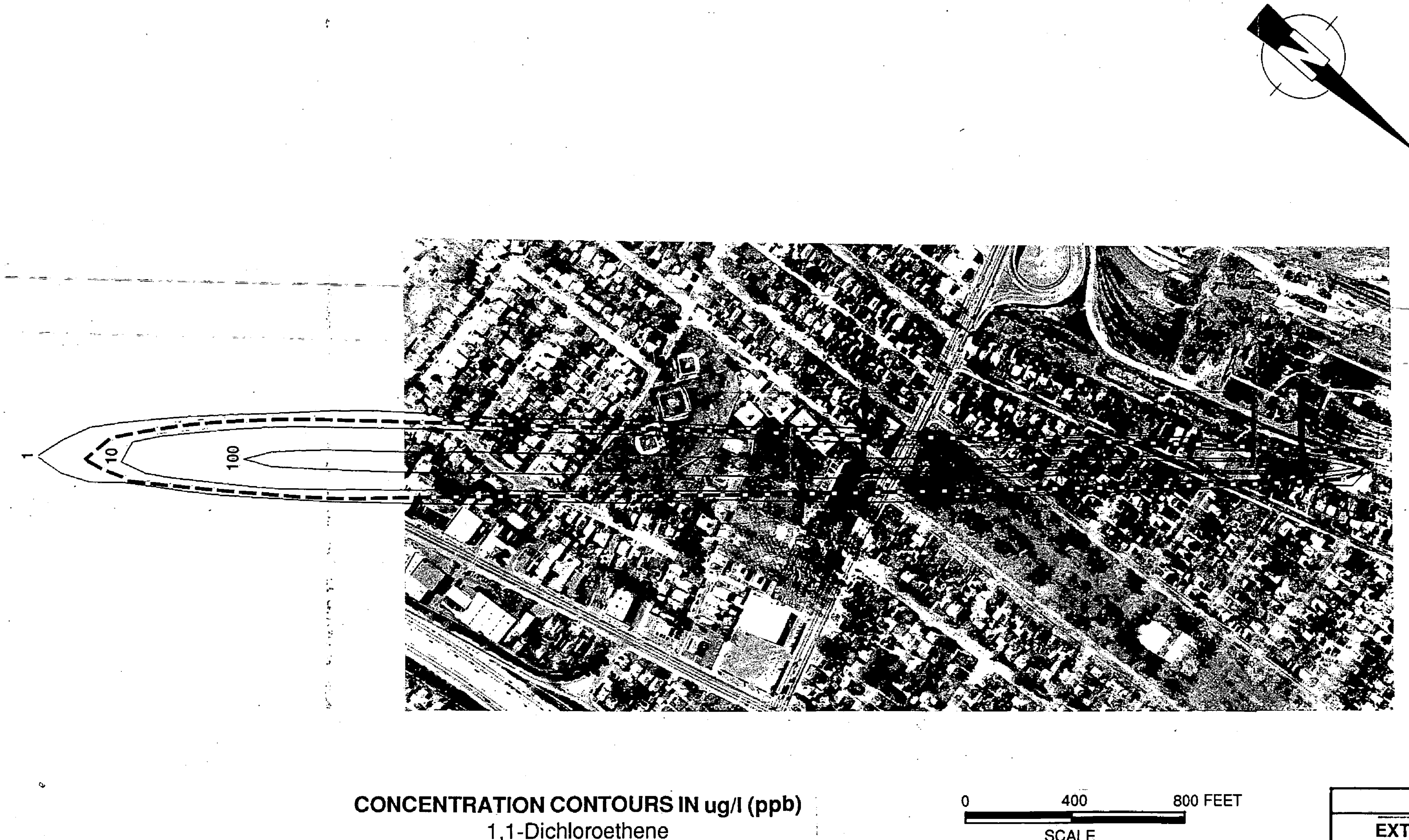
HP-8	A		B
DEPTH	36	54	54
1,1 DCE	–	410	450
1,2 DCA	1	–	–
1,1,1 TCA	–	35	25
TCE	–	–	–
PCE	–	–	–
BENZENE	–	–	NA








CPT-17
CPT-2/HP-2
HP-3
CPT-24/HP-23
MW-11
MW-33
MW-5
MW-24
MW-23
MW-9
PLUME C
PLUME E
MW-7
MW-21
MW-22
CPT-3/HP-5
MW-25
MW-26
HP-15
MW-15
MW-16
MW-8
CPT-16
HP-20
CPT-8/HP-12
MW-20
MW-19
MW-18
MW-17
HP-22
HP-19
PLUME B
CPT-1/HP-1
MW-27
MW-28
MW-31
MW-32
CPT-18/HP-27
CPT-11/HP-17
HP-14
HP-7
HP-8
HP-4
CPT-6/HP-10
CPT-12/HP-21
CPT-4/HP-6
CPT-5/HP-9
PLUME D
CPT-9/HP-13
CPT-7/HP-11
CPT-10/HP-16
HP-18
PLUME A
CPT-15/HP-26
CPT-14/HP-25
CPT-13/HP-24



CONCENTRATION CONTOURS IN ug/l (ppb)
1,1-Dichloroethene

EXPLANATION:

ESTIMATED EXTENT OF 6 ppb LINE (MCL)

FIGURE 28

EXTENT OF GROUNDWATER OPERABLE UNIT G-1, 30 YEAR RELEASE SENARIO

UNION PACIFIC RAILROAD
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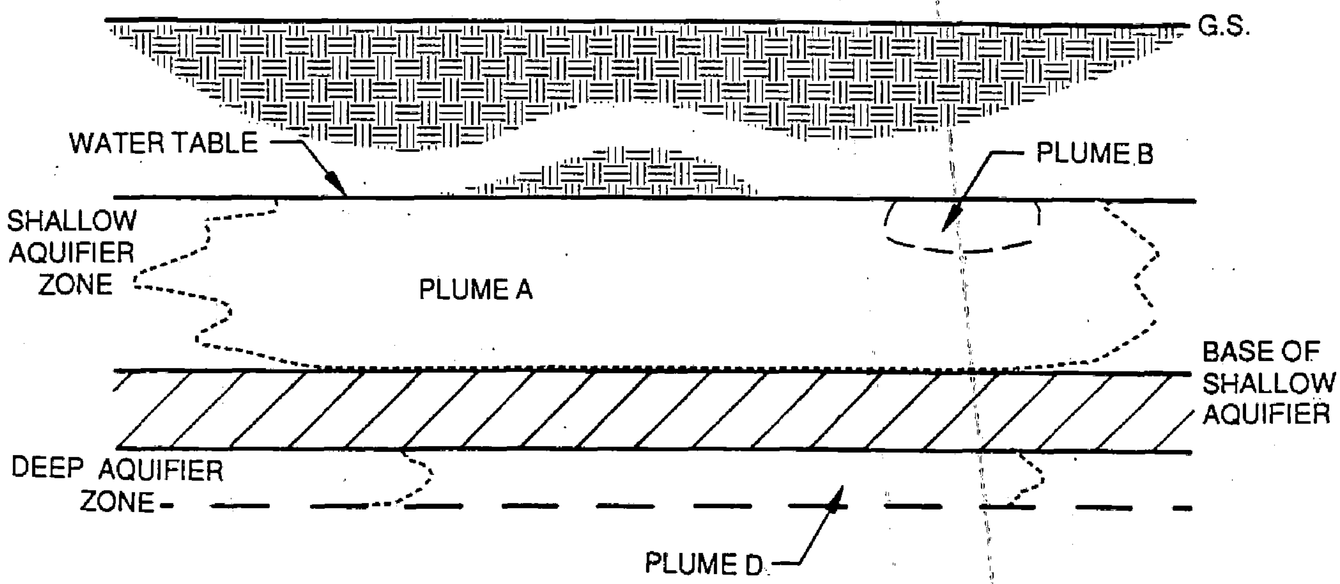

NOT TO SCALE

FIGURE 29

SCHEMATIC SHOWING GENERAL RELATIONS BETWEEN PLUMES A,B AND D

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GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTIONS	SCREENING COMMENTS
NO ACTION	NONE	NOT APPLICABLE	NO ACTION	REQUIRED FOR CONSIDERATION UNDER NCP
INSTITUTIONAL ACTION	ACCESS RESTRICTION	ZONING AND DEED	CONTROLS SITE ACCESS	POTENTIALLY APPLICABLE
		FENCING	CONTROLS SITE ACCESS	POTENTIALLY APPLICABLE
	MONITORING	PERIODIC SOIL SAMPLING	MONITORING FOR POTENTIAL OFF-SITE MIGRATION	POTENTIALLY APPLICABLE
CONTAINMENT	CAPPING	VEGETATION	LIMITS SURFACE WATER INFILTRATION AND CONTROLS DUST	POTENTIALLY APPLICABLE
		CLAY ASPHALT CONCRETE MULTIMEDIA	PREVENTS SURFACE WATER INFILTRATION AND CONTROLS ACCESS TO CONTAMINANTS	POTENTIALLY APPLICABLE
TREATMENT	PHYSICAL/CHEMICAL TREATMENT	SOIL WASHING	CONTAMINANTS WASHED FROM SOIL BY MEANS OF EXTRACTION PROCESS	POTENTIALLY APPLICABLE
		SOIL FLUSHING	AQUEUOS SOLUTION IS INJECTED INTO THE SOIL AND CONTAMINATED ELLUTRIATE IS COLLECTED.	POTENTIALLY APPLICABLE
		FIXATION	CHEMICAL FIXATION OF METALS IN SOIL	POTENTIALLY APPLICABLE
		SOIL VAPOR EXTRACTION	USE OF SOIL VENTING SYSTEM TO REMOVE VOLATILE HYDROCARBONS	NOT READILY APPLICABLE FOR DIESEL HYDROCARBONS
	THERMAL TREATMENT	ON-SITE INCINERATION	COMBUSTION OF CONTAMINANTS USING ON-SITE INCINERATOR	NOT APPLICABLE ON-SITE
		OFF-SITE INCINERATION	TRANSPORT OFF-SITE FOR INCINERATION	POTENTIALLY APPLICABLE
		IN-SITU VITRIFICATION	INVOLVES GLASSIFICATION AT VERY HIGH TEMPERATURES	POTENTIALLY APPLICABLE
	BIOLOGICAL TREATMENT	EX-SITU BIOREMEDIATION	MIXING OF EXCAVATED SOIL WITH NUTRIENTS AND MICROBES TO DEGRADE CONTAMINANTS	POTENTIALLY APPLICABLE FOR HYDROCARBONS
		IN-SITU BIOREMEDIATION	IN-SITU APPLICATION OF NUTRIENTS AND MICROBES TO DEGRADE CONTAMINATES	POTENTIALLY APPLICABLE FOR HYDROCARBONS
REMOVAL	EXCAVATION	HEAVY CONSTRUCTION EQUIPMENT	REMOVAL OF SOILS FOR DISPOSAL OR TREATMENT	POTENTIALLY APPLICABLE
DISPOSAL	LANDFILL	ON-SITE	CONSTRUCTION OF AN ON-SITE LANDFILL	NOT APPLICABLE AT THIS SITE
		OFF-SITE	DISPOSAL OF SOILS IN APPROPRIATE OFF-SITE LANDFILL	POTENTIALLY APPLICABLE

EXPLANATION:

SCREENED FROM FURTHER ANALYSIS

FIGURE 30

IDENTIFICATION AND INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS - SOIL

UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

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GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
NO ACTION	NONE	NOT APPLICABLE	NO ACTION	REQUIRED FOR CONSIDERATION UNDER NCP
INSTITUTIONAL ACTION	ACCESS RESTRICTION	ZONING AND DEED RESTRICTIONS	GROUNWATER ACCESS RESTRICTION FOR PROPERTIES OF INFLUENCE	POTENTIALLY APPLICABLE
	MONITORING	GROUNDWATER MONITORING	PERIODIC MONITORING OF WELLS	POTENTIALLY APPLICABLE
CONTAINMENT	SUBSURFACE BARRIERS	SLURRY WALL	TRENCH AROUND AREAS OF CONTAMINATION IS FILLED WITH SOIL (OR CEMENT) BENTONITE SLURRY	WILL PROVIDE LITTLE BENEFIT TO CLEAN UP OF THE AQUIFER AND DUE TO THE REQUIRED DEPTH WILL NOT BE READILY APPLICABLE
		GROUT INJECTION	PRESSURE INJECTION OF GROUT IN A REGULAR PATTERN OF DRILLED HOLES	
	CAPPING	CLAY AND SOIL ASPHALT CONCRETE MULTIMEDIA CAP	USE OF IMPERMEABLE MEDIA OVER AREAS OF INFLUENCE TO PREVENT INFILTRATION TO GROUNDWATER	CAPPING WILL PROVIDE LITTLE BENEFIT TO CLEAN UP OF THE AQUIFER
	HYDRAULIC CONTAINMENT	INJECTION PUMPING INFILTRATION	USE OF HYDRAULIC BARRIERS TO PREVENT FURTHER MIGRATION OF CONTAMINATION	POTENTIALLY APPLICABLE
COLLECTION	EXTRACTION	EXTRACTION WELLS	EFFECTIVE IN REMOVING CONTAMINANTS	POTENTIALLY APPLICABLE
	SUBSURFACE DRAIN	INTERCEPTOR TRENCHES	PERFORATED PIPE TRENCHES BACKFILLED WITH POROUS MEDIA TO COLLECT CONTAMINATED WATER	NOT APPLICABLE FOR DEEP AQUIFER
DISCHARGE	ON-SITE	RECHARGE WELLS	RECHARGE OF TREATED WATER TO AQUIFER	POTENTIALLY APPLICABLE
		RECLAMATION USE	EFFLUENT USE FOR ON-SITE DUST CONTROL AND AS PROCESS WATER FOR SOIL REMEDIATION	POTENTIALLY APPLICABLE
	OFF-SITE	LOCAL POTW	DISCHARGE OF TREATED WATER TO LOCAL POTW	POTENTIALLY APPLICABLE
		DISCHARGE TO RIVER	DISCHARGE OF TREATED WATER TO RIVER	NOT APPLICABLE
		RECLAMATION USE	EFFLUENT RECLAMATION FOR INDUSTRIAL OR AGRICULTURAL USE	POTENTIALLY APPLICABLE

FIGURE 31

IDENTIFICATION AND INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS-GROUNWATER

UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

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GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
TREATMENT	PHYSICAL PRETREATMENT	FILTRATION	SUSPENDED SOLIDS REMOVAL	POTENTIALLY APPLICABLE
		FLOCCULATION	SOLIDS REMOVAL UTILIZING CHEMICAL ADDITIVES	POTENTIALLY APPLICABLE
	CHEMICAL PRETREATMENT	PH CONTROL	PH ADJUSTMENT OF INFLUENT WATER AS REQUIRED	POTENTIALLY APPLICABLE
		PRECIPITATION/ FLOCCULATION	TSS, AND METALS REMOVAL BY TREATMENT WITH POLYMERIC AGENT AND/OR LIME	POTENTIALLY APPLICABLE
	THERMAL DESTRUCTION	ROTARY KILN	COMBUSTION IN A HORIZONTALLY ROTATING CYLINDER DESIGNED FOR UNIFORM HEAT TRANSFER	DUE TO LARGE VOLUMES OF LOW LEVEL SOLVENT CONTAMINATION IS NOT APPLICABLE
		FLUIDIZED BED	INJECTION OF NUTRIENTS AND BACTERIA TO DEGRADE CONTAMINANTS	
	BIOLOGICAL TREATMENT	EX-SITU BIOREMEDIATION	GROUNDWATER EXTRACTION AND TREATMENT IN A BIOREACTOR	POTENTIALLY APPLICABLE
		IN-SITU BIOREMEDIATION	INJECTION OF NUTRIENTS AND BACTERIA TO DEGRADE CONTAMINANTS	POTENTIALLY APPLICABLE
	EFFLUENT POLISH	UV/H_2O_2 OXIDATION	DESTRUCTION OF CARBON-CHLORINE BONDS BY UV/H_2O_2 OXIDATION	POTENTIALLY APPLICABLE
		AIR STRIPPING	MIXING LARGE VOLUMES OF AIR WITH WATER IN A PACKED COLUMN TO PROMOTE TRANSFER OF VOC'S TO AIR	POTENTIALLY APPLICABLE
		GRANULAR ACTIVATED CARBON	ABSORBTION OF CONTAMINANTS ONTO ACTIVATED CARBON BY PASSING WATER THROUGH CARBON COLUMN	POTENTIALLY APPLICABLE
		REVERSE OSMOSIS	CONCENTRATES CONTAMINANTS BY MEMBRANE SEPARATION	NOT READILY APPLICABLE
MANAGEMENT OF TREATMENT RESIDUALS	THERMAL DESTRUCTION	ON-SITE	INCINERATION OF SLUDGES, CARBON OR OTHER RESIDUALS BY INCINERATION AT ON-SITE OR OFF-SITE FACILITY	POTENTIALLY APPLICABLE
		OFF-SITE		
	LANDFILLING	ON-SITE	DISPOSAL OF SLUDGES, CARBON OR OTHER RESIDUALS AT LANDFILL	POTENTIALLY APPLICABLE
		OFF-SITE		
	CARBON REGENERATION	ON-SITE	STEAM REGENERATION	POTENTIALLY APPLICABLE
		OFF-SITE	TRANSPORT OFF-SITE FOR REGENERATION	POTENTIALLY APPLICABLE

EXPLANATION:

(shaded box) SCREENED FROM FURTHER ANALYSIS

FIGURE 31 CONTINUED

IDENTIFICATION AND INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS-GROUNWATER

UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

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GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	COST
NO ACTION	NONE	NOT APPLICABLE	DOES NOT ACHIEVE REMEDIAL OBJECTIVES	REQUIRED FOR CONSIDERATION	NONE
INSTITUTIONAL ACTION	ACCESS RESTRICTION	ZONING AND DEED; FENCING	REDUCES DIRECT CONTACT AND INGESTION PATHWAYS	IMPLEMENTABLE	LOW-MODERATE
	MONITORING	PERIODIC SOIL SAMPLING	NOT EFFECTIVE IN ACHIEVING REMEDIAL OBJECTIVES	IMPLEMENTABLE; IT MAY HAVE APPLICABILITY TO MONITOR CLEAN UP	LOW-MODERATE
CONTAINMENT	CAPPING	VEGETATION; CLAY; ASPHALT; CONCRETE; MULTIMEDIA	REDUCES INFILTRATION OF SURFACE WATER AND DUST GENERATION. EFFECTIVE IN COMBINATION WITH OTHER PROCESSES IN MEETING REMEDIAL OBJECTIVES	IMPLEMENTABLE	HIGH
TREATMENT	PHYSICAL/CHEMICAL TREATMENT	SOIL WASHING	EFFECTIVE; NEED TREATABILITY TEST	IMPLEMENTABLE	HIGH
		SOIL FLUSHING	EFFECTIVE	FINE GRAINED SOILS DIFFICULT TO FLUSH SOLVENTS THROUGH; EXTRACTION OF SOLVENTS NOT FEASIBLE	HIGH
		FIXATION	EFFECTIVE FOR METALS NEED TREATABILITY TEST	IMPLEMENTABLE	HIGH
	THERMAL TREATMENT	OFF-SITE INCINERATION	EFFECTIVELY DESTROYS MOST ORGANIC CONSTITUENTS; DOES NOT REMOVE METALS	LOW PUBLIC ACCEPTABILITY; REQUIRES AIR PERMIT	HIGH
		IN-SITU VITRIFICATION	EFFECTIVE	INNOVATIVE TECHNOLOGY FOR ARSENIC STABILZATION; NOT PROVEN AT LARGE SCALE	VERY HIGH
	BIOLOGICAL TREATMENT	EX-SITU BIOREMEDIATION; IN-SITU BIOREMEDIATION	EFFECTIVE IN REMOVING DIESEL HYDROCARBONS; NEED TREATABILITY TEST TO VERIFY SITE SPECIFIC EFFECTIVENESS	IMPLEMENTABLE	MODERATE
REMOVAL	EXCAVATION	HEAVY CONSTRUCTION EQUIPMENT	EFFECTIVE AND RELIABLE	IMPLEMENTABLE	MODERATE-HIGH
DISPOSAL	LANDFILL	OFF-SITE	PROVIDES SECURE STORAGE; DOES NOT ELIMINATE CONTAMINANTS	MAY HAVE APPLICABILITY IF WASTE NOT SUBJECT TO LAND BAN	VERY HIGH

EXPLANATION:

(shaded) SCREENED FROM FURTHER ANALYSIS (shaded: SOIL FLUSHING, IN-SITU VITRIFICATION)

FIGURE 32

EVALUATION OF PROCESS OPTIONS - SOIL

UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

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GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	COST
NO ACTION	NONE	NOT APPLICABLE	DOES NOT ACHIEVE REMEDIAL ACTION OBJECTIVE	NOT ACCEPTABLE TO LOCAL GOVERNMENT/PUBLIC	NONE
INSTITUTIONAL ACTION	ACCESS RESTRICTION	ZONING DEED RESTRICTIONS	EFFECTIVE IN PREVENTING USE OF CONTAMINATED GROUNDWATER	MAY BE IMPLEMENTABLE AND COULD HAVE APPLICABILITY	LOW MODERATE
	MONITORING	GROUNDWATER MONITORING	USEFUL FOR DOCUMENTING CONDITIONS	EASILY IMPLEMENTABLE AND MAY HAVE APPLICABILITY	LOW
CONTAINMENT	HYDRAULIC CONTAINMENT	INJECTION	EFFECTIVE IN CONTAINING CONTAMINATION	IMPLEMENTABLE ON-SITE; MAY BE DIFFICULT TO IMPLEMENT OFF-SITE	MODERATE
		PUMPING			
		INFILTRATION	EFFECTIVE	NOT IMPLEMENTABLE DUE TO SOIL CONDITIONS	MODERATE
COLLECTION	EXTRACTION	EXTRACTION WELLS	EFFECTIVE IN REMOVING CONTAMINANTS	READILY IMPLEMENTABLE	MODERATE
DISCHARGE	ON-SITE	RECHARGE WELLS	EFFECTIVE AND RELIABLE	IMPLEMENTABLE, WILL HAVE APPLICABILITY FOR USE IN CONJUNCTION WITH HYDRAULIC CONTAINMENT	MODERATE
		RECLAMATION USE	EFFECTIVE AND RELIABLE	IMPLEMENTABLE; PERMIT REQUIRED	LOW
	OFF-SITE	LOCAL POTW	DEPENDS ON SYSTEM CAPACITY	MAY BE IMPLEMENTABLE; PERMITTING REQUIRED.	MODERATE
		RECLAMATION USE	EFFECTIVE AND RELIABLE	IMPLEMENTABLE; HAS TO MEET TITLE 22 CRITERIA	LOW-MODERATE

FIGURE 33

EVALUATION OF PROCESS OPTIONS-GROUNDWATER

UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

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GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	COST
TREATMENT	PHYSICAL PRETREATMENT	FILTRATION	EFFECTIVE AND RELIABLE; CONVENTIONAL TECHNOLOGY; REQUIRES MANAGEMENT OF SLUDGE RESIDUALS	READILY IMPLEMENTABLE	MODERATE
		FLOCCULATION			
	CHEMICAL PRETREATMENT	PH CONTROL			
		PRECIPITATION/ FLOCCULATION			
	BIOLOGICAL TREATMENT	EX-SITU BIOREMEDIATION	NOT VERY EFFECTIVE	TECHNICALLY NOT FEASIBLE	HIGH
		IN-SITU BIOREMEDIATION	INNOVATIVE TECHNOLOGY	MAY HAVE APPLICABILITY TO OFF-SITE PLUME	HIGH
	EFFLUENT POLISH	UV/H_2O_2 OXIDATION	VERY EFFECTIVE	READILY IMPLEMENTABLE	HIGH
		AIR STRIPPING	EFFECTIVE. OFF GAS MAY NEED TREATMENT	READILY IMPLEMENTABLE; REQUIRES AIR PERMIT	HIGH
		GRANULAR ACTIVATED CARBON	VERY EFFECTIVE	READILY IMPLEMENTABLE	HIGH
MANAGEMENT OF TREATMENT RESIDUALS	THERMAL DESTRUCTION	ON-SITE	EFFECTIVE AND RELIABLE	NOT ACCEPTABLE TO PUBLIC	HIGH
		OFF-SITE	EFFECTIVE AND RELIABLE	IMPLEMENTABLE	HIGH
	LANDFILLING	ON-SITE	PROVIDES SECURE STORAGE; DOES NOT DESTROY CONTAMINANTS	NOT IMPLEMENTABLE	HIGH
		OFF-SITE	PROVIDES SECURE STORAGE; DOES NOT DESTROY CONTAMINANTS	IMPLEMENTABLE IF NOT SUBJECT TO LAND BAN	HIGH
	CARBON REGENERATION	ON-SITE	NOT VERY EFFECTIVE FOR HEAVIER HYDROCARBONS	IMPLEMENTABLE	HIGH
		OFF-SITE	EFFECTIVE AND RELIABLE	IMPLEMENTABLE	MODERATE

EXPLANATION:

SCREENED FROM FURTHER ANALYSIS

FIGURE 33 CONTINUED

EVALUATION OF PROCESS OPTIONS-GROUNDWATER

UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

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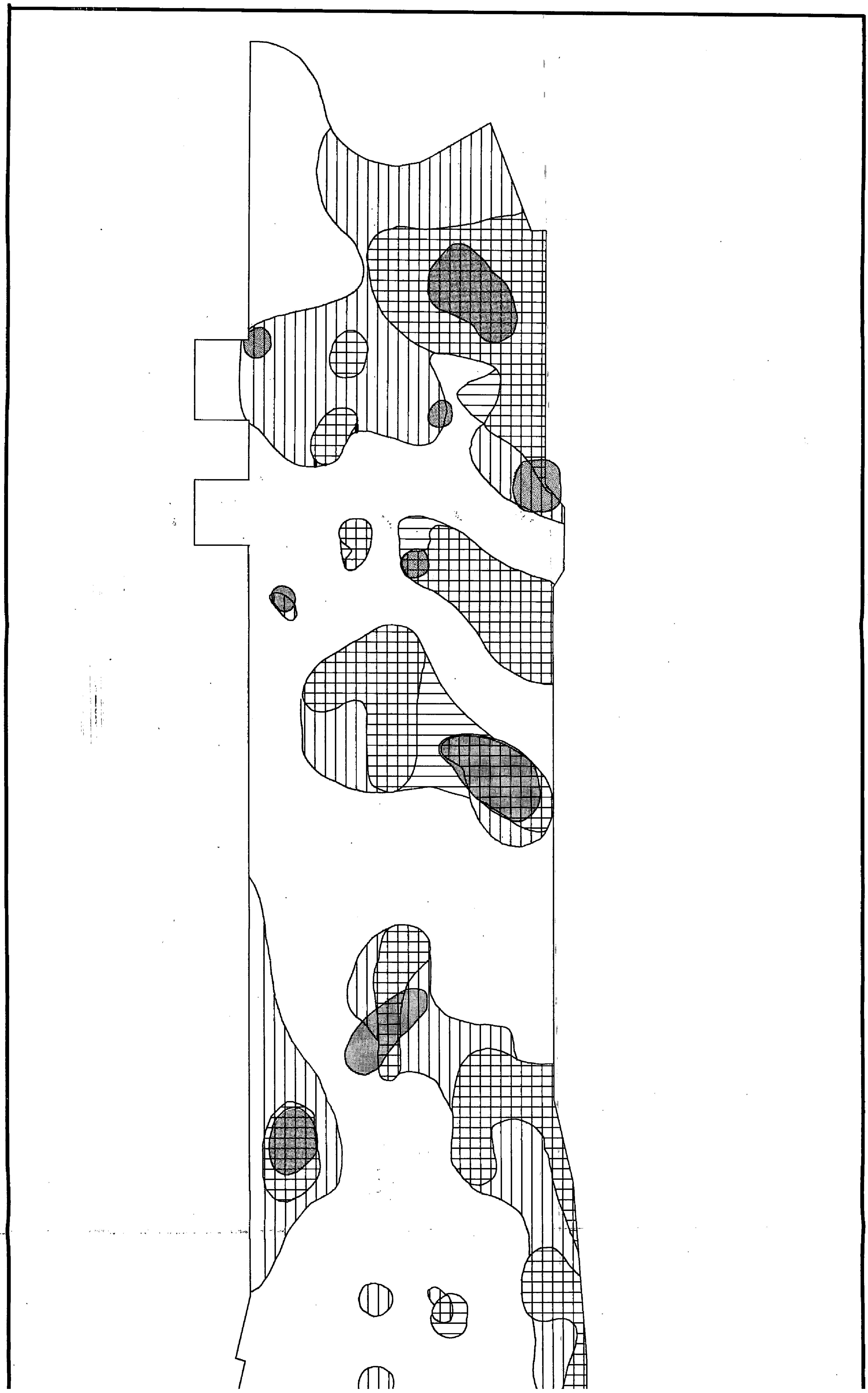
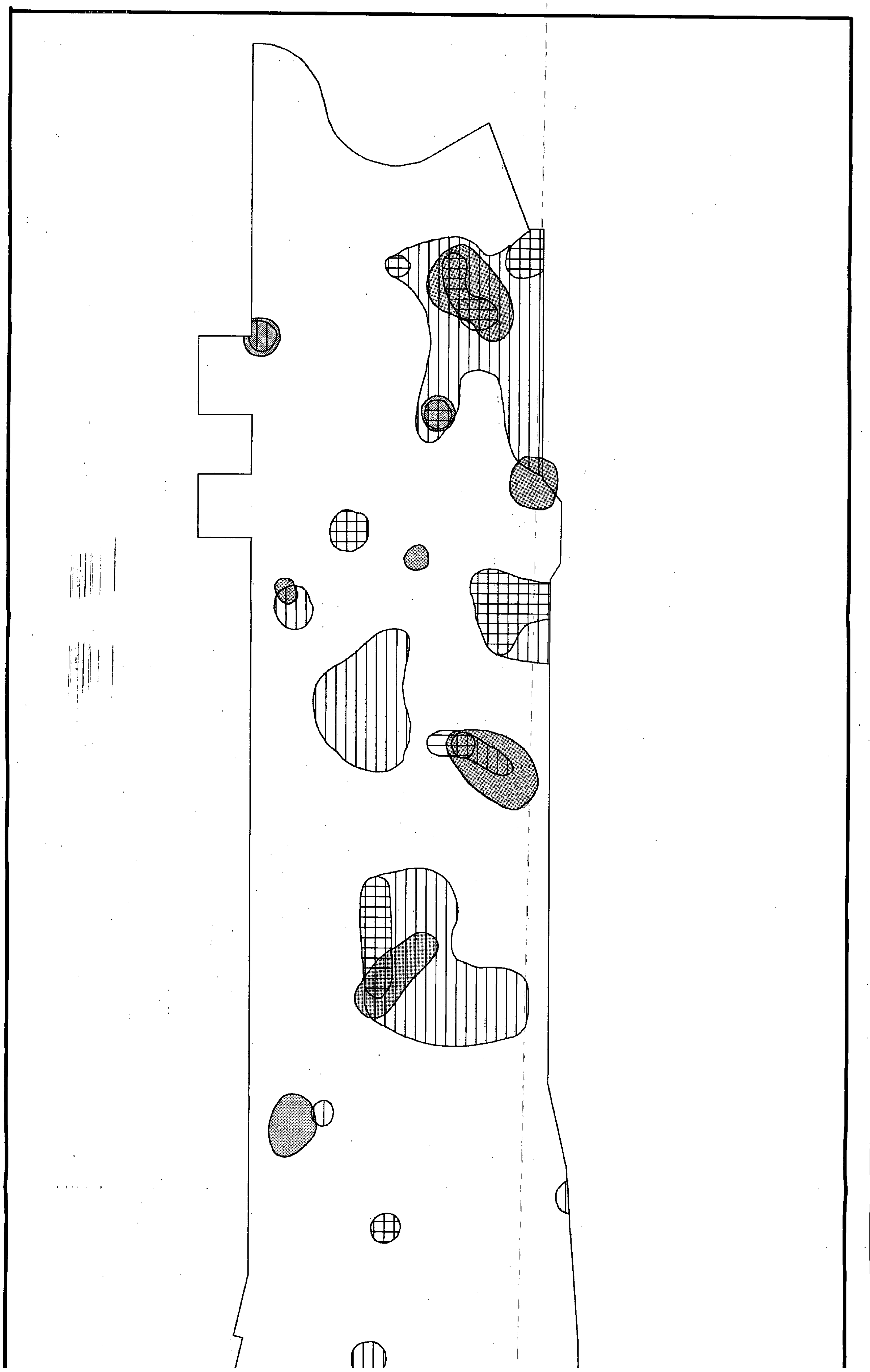
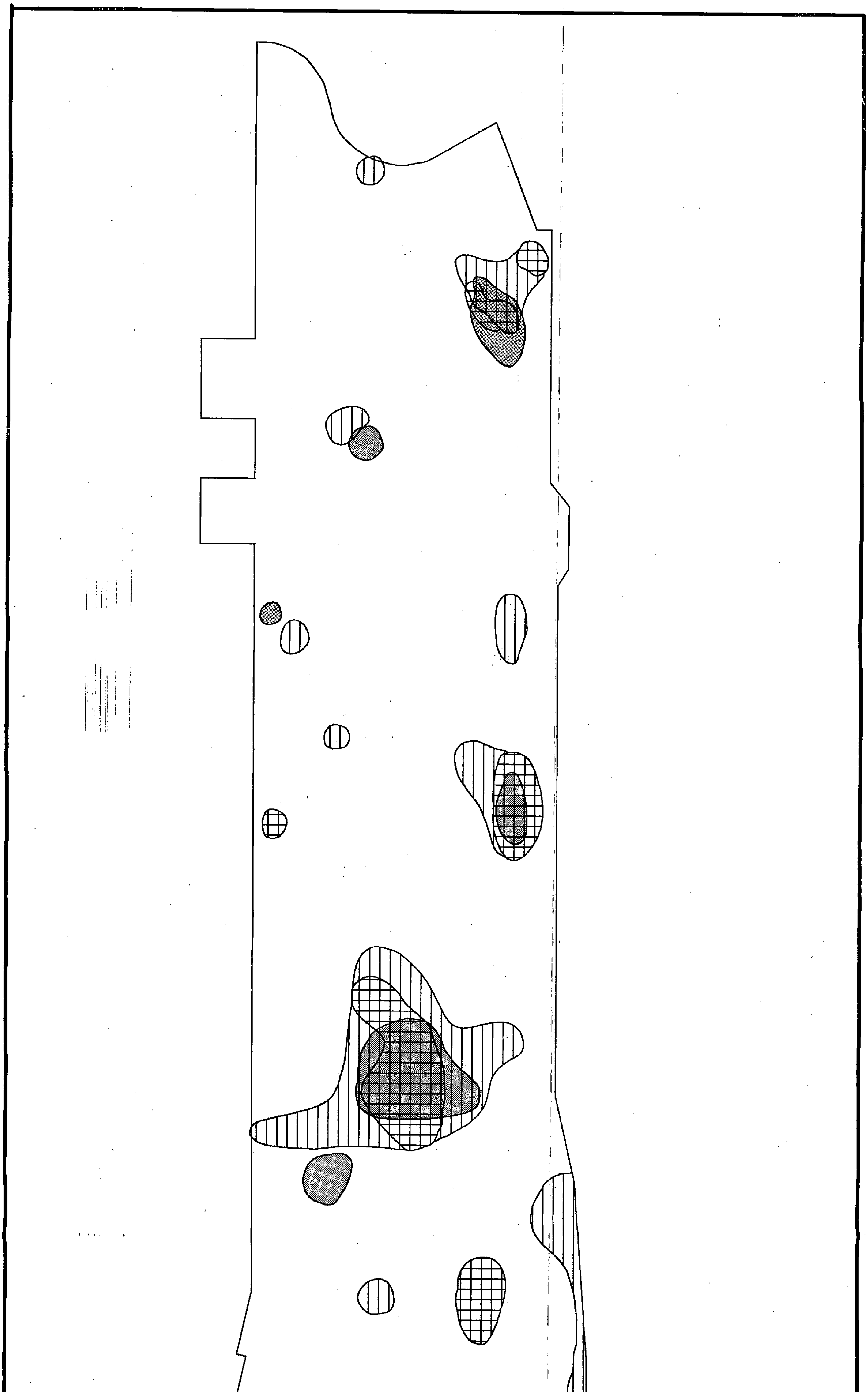
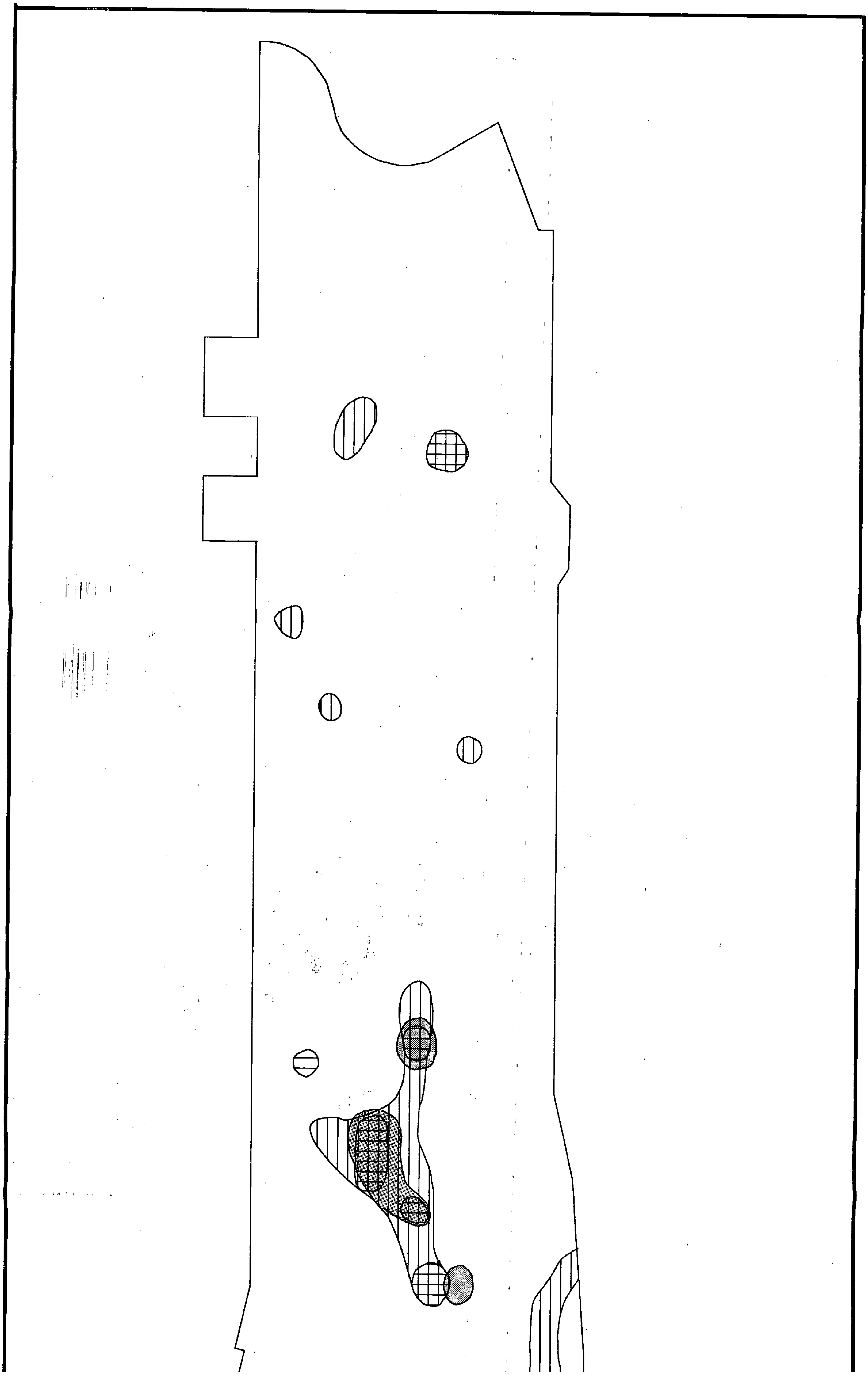
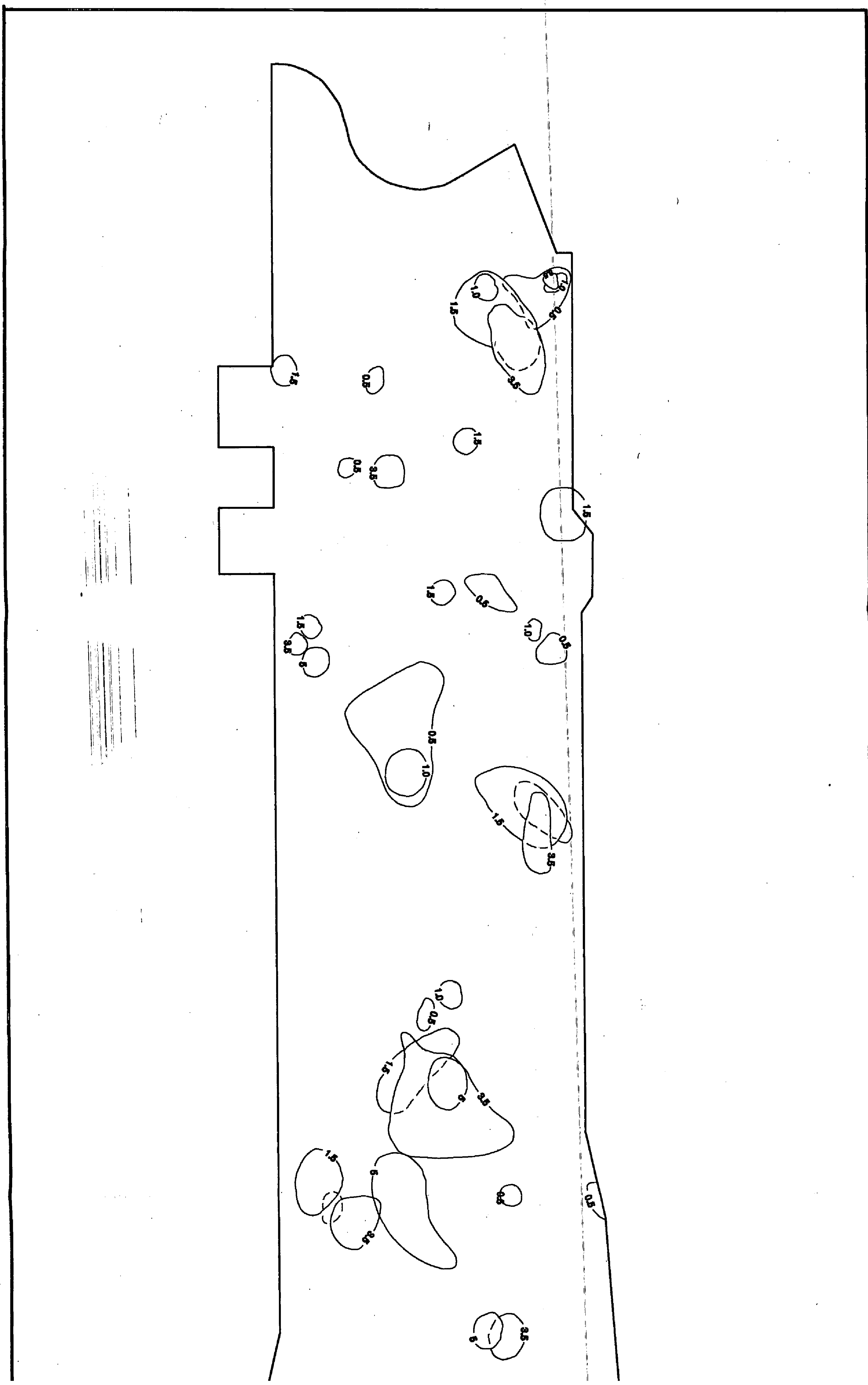
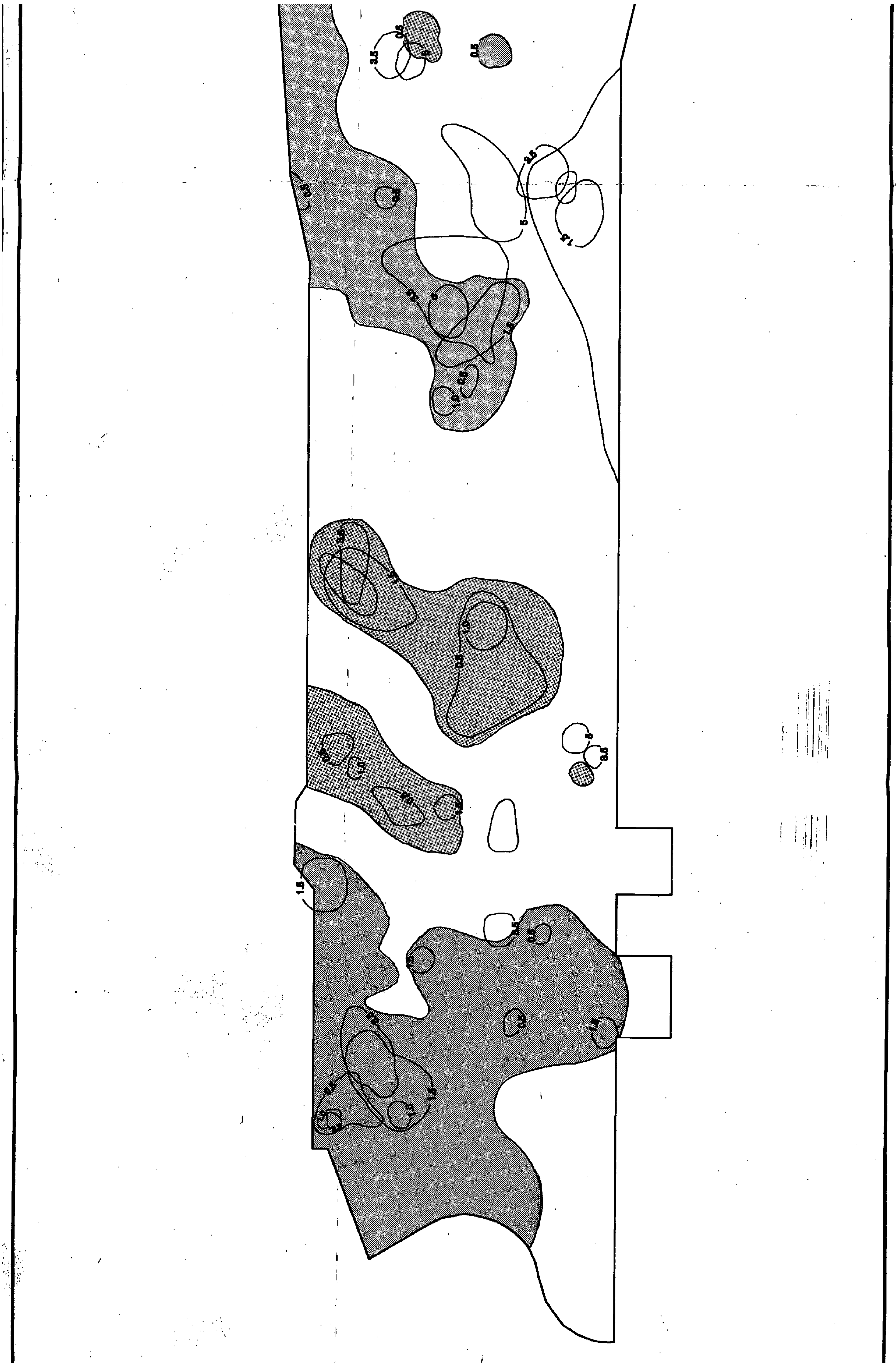












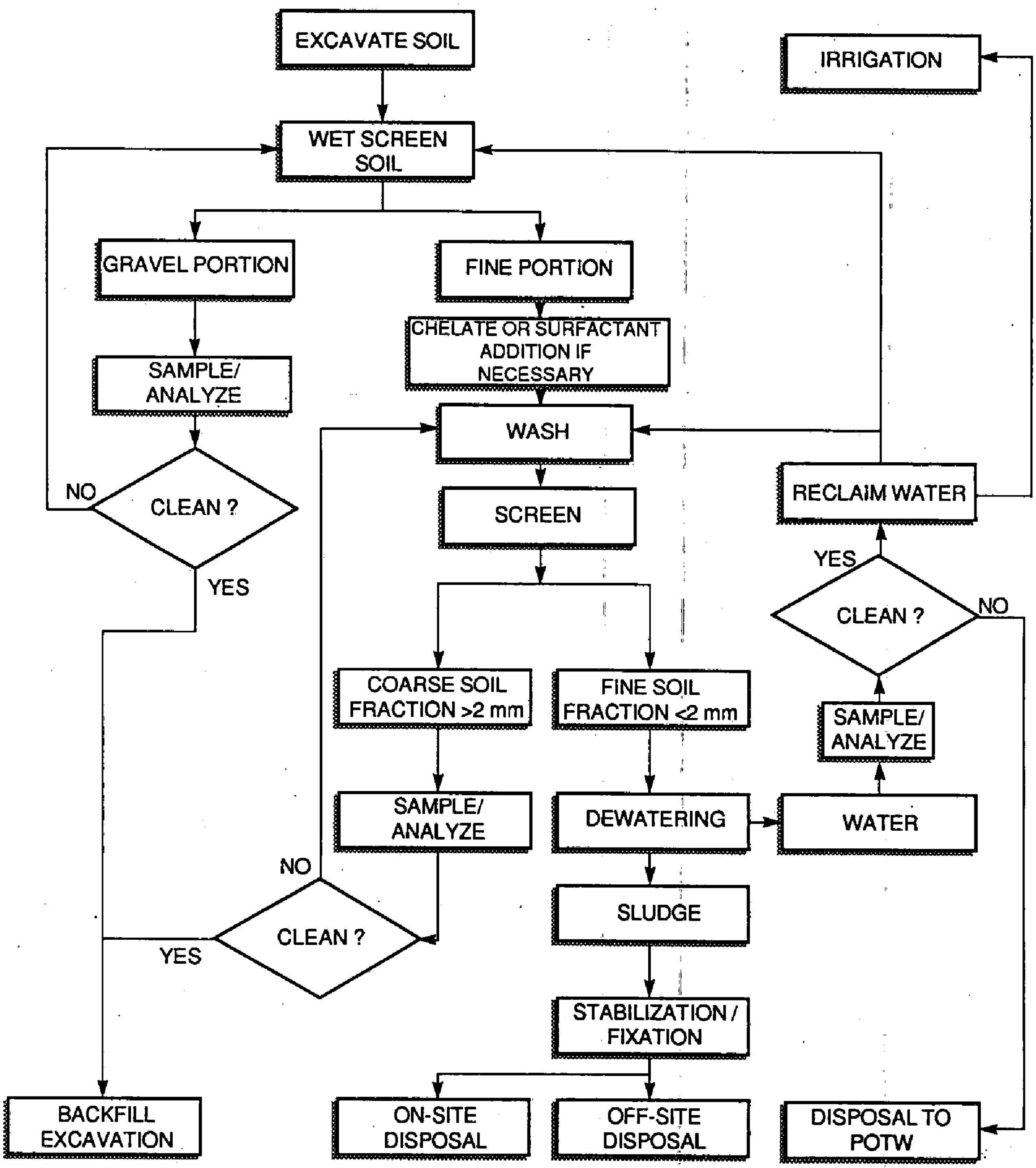


FIGURE 40

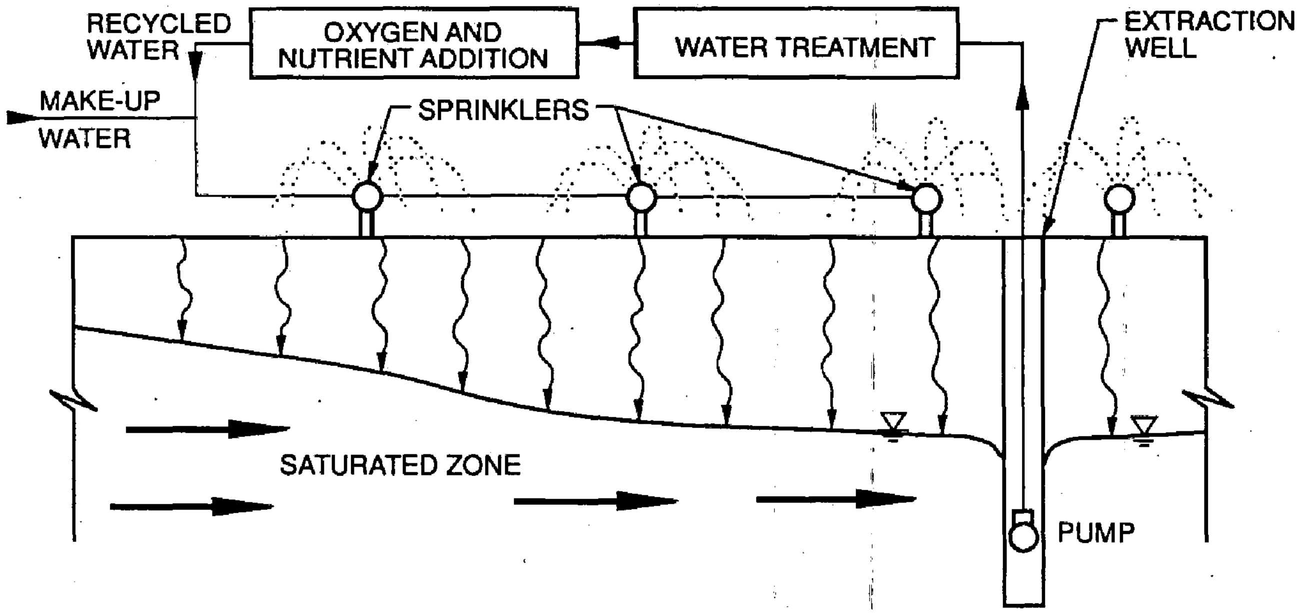
SCHEMATIC FOR SOIL WASHING

UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

DAMES & MOORE

90-511

Surface Water Application and Groundwater Recovery



Infiltration Gallery Application and Groundwater Recovery

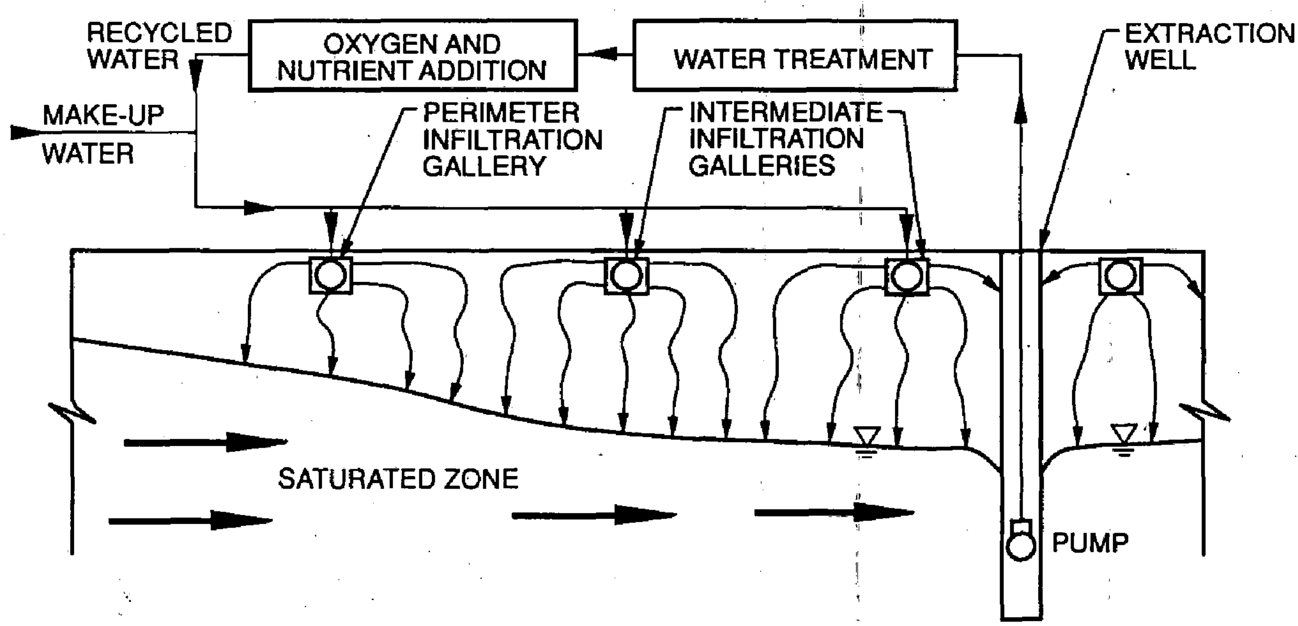


FIGURE 41

SCHEMATIC FOR IN SITU SOIL BIOREMEDIATION

UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

DAMES & MOORE

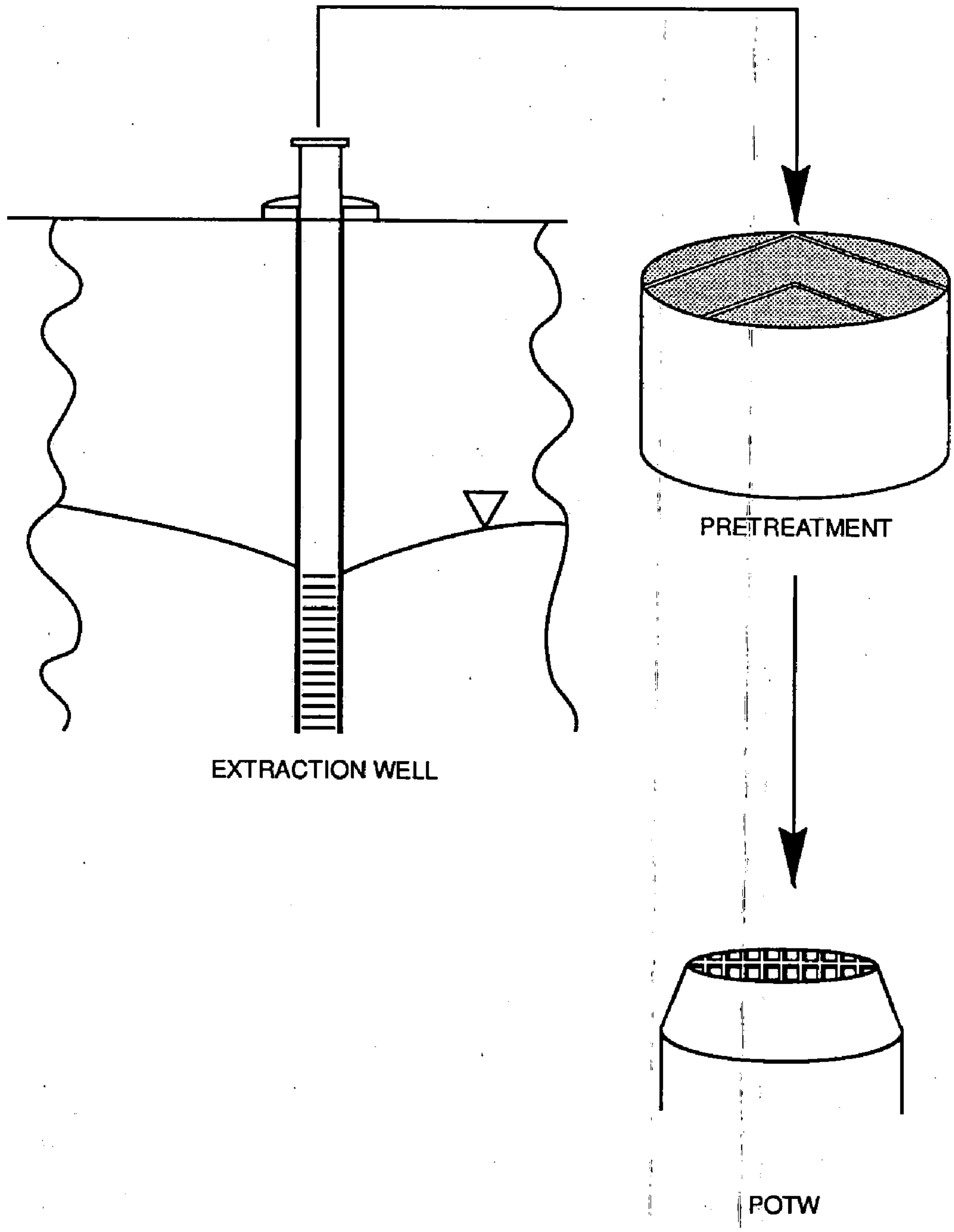


FIGURE 42

SCHEMATIC ALTERNATIVE G1-A4

UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

DAMES & MOORE

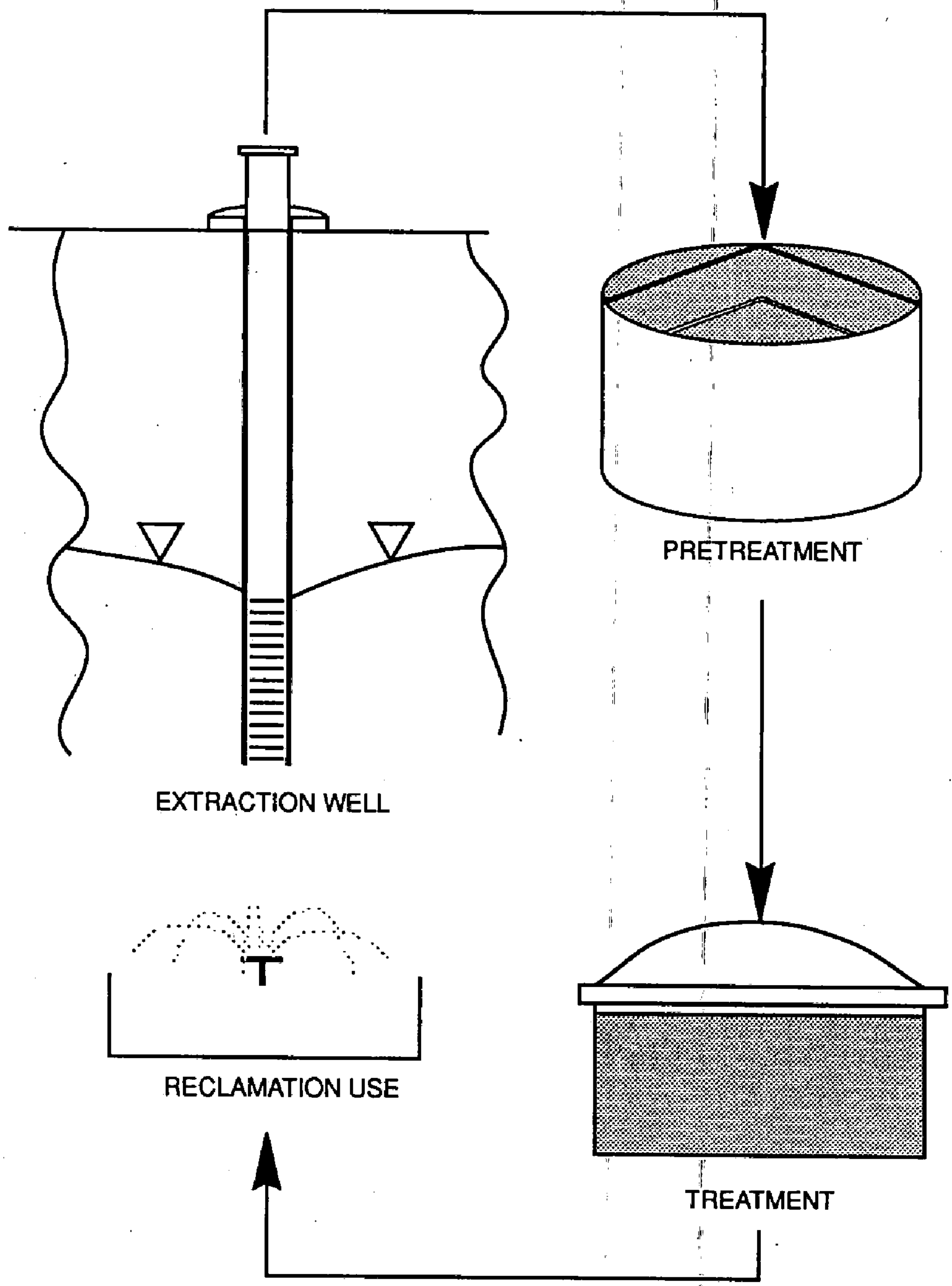


FIGURE 43

SCHEMATIC ALTERNATIVE G1-A5

UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

DAMES & MOORE

90-503

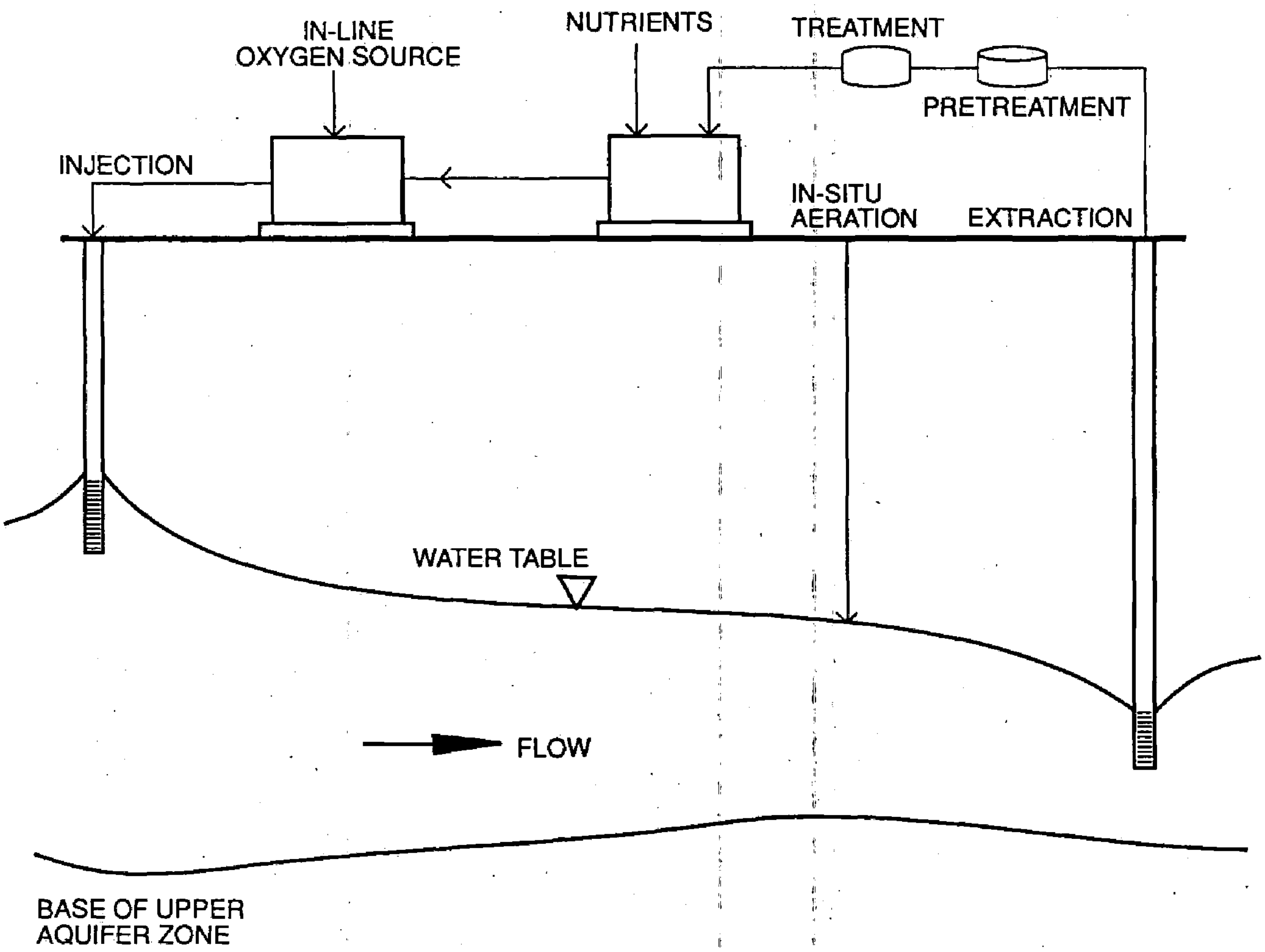


FIGURE 44

SCHEMATIC ALTERNATIVE G1-A6

UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

DAMES & MOORE

90-504

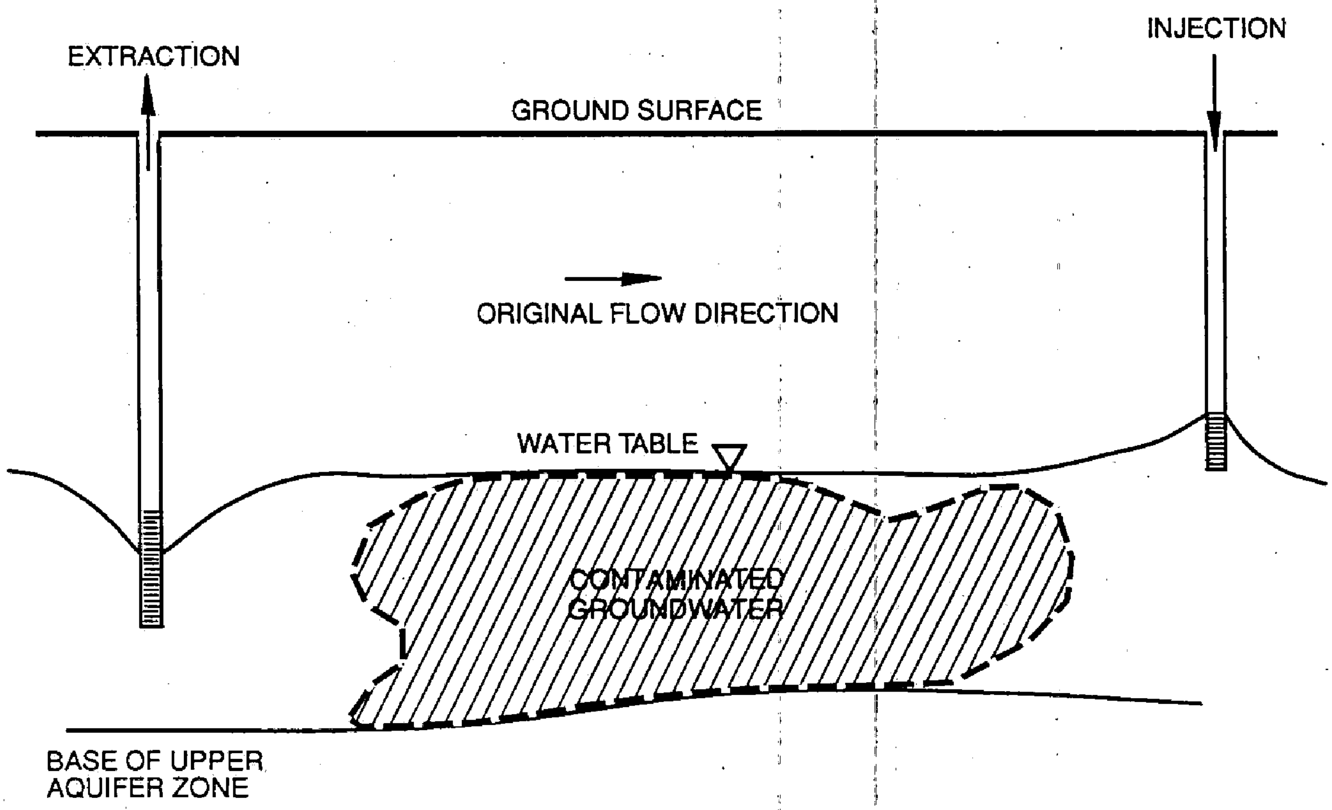


FIGURE 45

SCHEMATIC ALTERNATIVE G2-A3

UNION PACIFIC RAILROAD
SACRAMENTO, CALIFORNIA

DAMES & MOORE

90-506