Sept. 1992

WORK PLAN
ON-SITE GROUNDWATER INTERIM REMEDIAL MEASURE
UNION PACIFIC RAILROAD YARD
SACRAMENTO, CALIFORNIA

DAMES & MOORE

SEPTEMBER 1992
PROJECT NO. 00173-072-044

SAC49.001

DAMES & MOORE
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September 25, 1992

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Attention: Mr. James L. Tjosvold, P.E., Chief
Sacramento Responsible Party Unit
Site Mitigation Program

Re: Transmittal of Work Plan
On-Site Groundwater Interim
Remedial Measure
Union Pacific Railroad Yard
Sacramento, California
Project No. 00173-072-044

Dear Mr. Tjosvold:

Union Pacific Railroad Company (UPRR) has requested that Dames & Moore transmit the above-referenced Work Plan. Presented in the Work Plan is UPRR's approach for design and installation of an on-site groundwater interim remedial measure (IRM) at the Union Pacific Railroad Sacramento yard. The California Environmental Protection Agency, Department of Toxic Substances Control (DTSC) has directed UPRR to conduct the on-site groundwater IRM.

Ltr2DTSC.IRM

If you have any questions or require further clarification, please contact Tim Parker at (916) 387-7527.

Sincerely,

DAMES & MOORE

Timothy K. Parker
Project Manager

Donald P. Walker
Hydrogeologist

John D. Fawcett, P.E.
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Enclosure

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WORK PLAN
ON-SITE GROUNDWATER INTERIM REMEDIAL MEASURE
UNION PACIFIC RAILROAD YARD
SACRAMENTO, CALIFORNIA

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UNION PACIFIC RAILROAD YARD
SACRAMENTO, CALIFORNIA

1.0 INTRODUCTION

This Work Plan contains the technical rationale and proposed approach for implementing an on-site groundwater interim remedial measure (IRM) at the Union Pacific Railroad Sacramento Yard (the site). The California Environmental Protection Agency, Department of Toxic Substances Control (DTSC) directed UPRR to conduct the IRM.

The proposed IRM addresses collection and treatment of contaminated groundwater present in the first hydrostratigraphic zone contained within the site boundary. The proposed IRM does not constitute the final remedial measure, but is an interim step to address impacts to groundwater until a full-scale remediation system is designed and installed.

The extent of groundwater impacts in the first hydrostratigraphic zone has been evaluated by the installation of numerous monitoring wells, conducting cone penetration tests (CPT) and groundwater sampling using the Hydropunch™ (HP), and by conducting an aquifer pumping test. The plume originates on-site in the Central Fill Area, just south of MW-2, and extends a distance of approximately 4,800 feet (Dames & Moore, 1991b). The IRM addresses the on-site portion, or approximately one-third of the total plume length.

The objectives in implementing the IRM are as follows:

- Limit off-site migration of on-site contaminants in the first hydrostratigraphic zone;
- Decrease the mass of contaminants within the plume; and
- Provide data on the effects of long-term pumping of the first hydrostratigraphic zone including:
    - First hydrostratigraphic zone response;
    - Water quality variation;
    - Groundwater treatment system operation and discharge; and
    - Interaction between the first and second hydrostratigraphic zones.

This data will be utilized in developing the final groundwater remedial measure.

The Work Plan is organized into 6 sections. Section 2 presents the design basis and rationale for selection of a) extraction well location and flow rate, b) treated groundwater discharge location, and c) unit processes for groundwater treatment. A groundwater flow model was used to develop the pumping rates and well locations needed to produce an adequate hydraulic barrier (i.e., capture zone) to minimize migration of contaminants off-site. The capture zone analysis focused on using existing wells to produce the desired results. Discharge options include injection wells or connection to the sanitary sewer. Three different groundwater treatment technologies are considered: low-profile air strippers, granular activated carbon, and ultraviolet photolysis/hydrogen peroxide oxidation (UV-Oxidation). Section 2 concludes with the rationale for selection of the preferred groundwater extraction, treatment, and discharge elements that constitute the complete remedial system concept.

Section 3 presents information on the salient components of the IRM system design. A process flow diagram and system layout plan are included that depict the size and location of the IRM system. The proposed IRM system consists of extracting groundwater from two existing wells, treating extracted groundwater using low profile air stripping, and discharging treated groundwater to the sanitary sewer.

Permitting requirements, implementation and schedule are discussed in Section 4. The planned start-up date for implementation of the IRM is the week of December 21, 1992.

Section 5 proposes monitoring requirements during start-up and operation, and Section 6 includes a list of references used to prepare this Work Plan.

2.0 DESIGN BASIS

This section presents the basis for the design of the IRM. The design elements discussed include groundwater extraction flow rates, contaminant concentrations, discharge, and treatment.

2.1 EXTRACTION WELL FIELD

A capture zone analysis was performed to design an extraction well field capable of capturing impacted groundwater on-site in the first hydrostratigraphic zone. The capture zone analysis focused on using existing wells to produce the hydraulic barrier necessary to capture the on-site portion of groundwater Operable Unit 1 (GW-1) shown in Figure 1. The approach used to design the well field included groundwater modeling and particle tracking to estimate capture zone size and shape for various well locations and pump rates. The parameters and boundary conditions used in model development and model results are discussed below.

2.1.1 Model Development

The model used to conduct the capture zone analysis was the United States Geological Survey (USGS) Modular Three-Dimensional Finite-Difference Groundwater Flow Model (MODFLOW) which simulates groundwater flow. MODFLOW was used interactively with MODPATH, a particle tracking software, to estimate capture zone boundaries.

Parameterization

The first hydrostratigraphic zone was modeled as a two dimensional, unconfined aquifer based on the interpretation of the hydrogeology developed from well installation, pump test, and CPT/HP investigations. Specific parameters used in the model development which included bottom elevation of aquifer, groundwater elevation, hydraulic conductivity, and porosity, are provided in the following table.

MODEL INPUT	
PARAMETER	**VALUE**
Bottom Elevation[1]	-15 to -40 ft. MSLD
Groundwater Elevation[2]	-4 to -18 ft. MSLD
Hydraulic Conductivity[3]	266 ft/day. $K_y = 0.85\ K_x$
Porosity[3]	0.20

Notes: [1] Bottom elevations vary across the model, ranging from -15 to -40 feet MSLD, and are based on structural contours of the sand channel found within the first hydrostratigraphic zone (Dames & Moore, 1990).

[2] Groundwater elevations are based on water levels measured in December 1991 (Dames & Moore, 1992a). They represent the most recent levels at the time of model development.

[3] Hydraulic conductivity is assumed constant across the model and is based on pump test results conducted in MW-4 (Dames & Moore, 1992b). The geometric mean of hydraulic conductivity (K) was estimated from data using wells MW-11, 13, 14, 17, 18, 29, 30, and 33 (Table 1). The aquifer was modeled as anisotropic, also based on pump test results, with $K_y = 0.85\ K_x$. Porosity is assumed to be 20% (0.20) across the entire model and was based on published values typical of the aquifer materials found on site (Freeze and Cherry, 1979).

Boundary Conditions

Constant head boundaries are used for the up- and down-gradient (north and south respectively) ends of the model grid. No flow boundaries are used for the east and west boundaries of the model. Head values are set so that simulated steady state water levels approximate actual gradient conditions for water levels measured in December 1991. Figure 2 shows simulated water levels and residuals for the set of constant head values used in the model. The residuals are the difference between the simulated and actual water levels. Development of the boundary conditions was established during calibration and is discussed in the following section.

2.1.2 Model Calibration

The model was calibrated to assumed steady state conditions. Calibration was performed using trial-and-error. This method involves the assignment of initial parameter values to each node in the grid. During calibration, parameter values are modified in sequential model runs to match simulated (modeled) heads with predetermined calibration targets (actual water levels). The selected calibration target was the December 1991 observed water levels, plus or minus one-half foot. These levels were chosen since they represent the most recent water levels when the model was initially developed and they are still considered representative since water levels and the gradient change very little over time. A one-half-foot calibration target was selected because this value represents about 5 percent of the overall water level variation measured in the wells (from about -4 feet to -13 feet). The degree of calibration at a specific well is expressed as a residual. Therefore, residuals in the range of +0.5 to -0.5 fall within the one-half-foot calibration target.

A list of wells and their residuals is shown in Table 2. Out of 36 wells, 32 are within ± 0.5 foot of the calibration target. Residuals of thirty-five wells are within ± one foot, and the residual of only one well (MW-1) is greater than one foot. Figure 2 shows the final calibrated water table surface. The residuals, or differences between actual water levels and simulated heads, are also posted on this figure. As the figure shows, the largest residuals are for wells at the north end of the site (MW-1, 2, and 3), while the smaller residuals are for wells near the center of the site. The larger residuals at the northern end of the model and also in the area of MW-25, 26 and 27 may be due to changes in material properties not addressed in the model. MW-1, 2, 3, 25, 26, and 27 are not in the sand channel where the value of K used in the model was estimated. However, the particle tracking results shown in Figure 2 suggests the model produces an adequate prediction of the flow field to estimate the extraction well field.

Model calibration also used particle tracking to measure model performance. Once the simulated water levels were within acceptable limits, a source was set to correspond with the suspected source area just south of MW-2. Particles were tracked under steady state conditions and their path was compared to the configuration of GW-1 in the Addendum Remedial Investigation/Feasibility Study Report (Dames & Moore, 1991b). Figure 2 illustrates the comparison between the modeled particle tracking and the outline of GW-1. The simulated particle track follows the axis of the plume for the entire length with some deviation occurring near well MW-38.

2.1.3 Capture Zone Analysis

Extraction Wells

Once the model was calibrated, it was then used to select extraction well locations and pump rates. The objective of the extraction well field is to create a hydraulic barrier close to the site boundary using the existing wells while minimizing pumping and maximizing capture zone width sufficiently to capture the on-site contaminated groundwater. Particle tracking using MODPATH linked to MODFLOW was used to estimate capture zone effectiveness. Various pump rates and locations were used to optimize the capture zone. Locations for extraction wells focused on using existing wells, so that additional wells would not need to be installed. The capture zone modeling indicates that pumping existing wells MW-32 and MW-4 at 20 gpm each produces the desired results. Figure 3 illustrates the resulting capture zone.

In addition to producing an adequate capture zone there are additional advantages to using MW-4 and MW-32 as extraction wells. MW-4 is fully screened across the first hydrostratigraphic zone, it is located in an area that has been extensively characterized (both water quality and hydraulically), it is within the area of highest water quality impacts of benzene, toluene, xylene, and ethyl benzene (BTXE), and it is large enough (4 inches in diameter) to use a submersible pump. MW-32 is added as an extraction well due to its location, as it provides an added measure of capture of on-site groundwater impacts that occurs down-gradient of MW-4. Well MW-32 is also located in an area of the plume where the second hydrostratigraphic zone appears to be impacted at the same order of magnitude as the first zone. Both wells are constructed with continuous-slot stainless steel screen which maximizes well screen open area, increasing well efficiencies.

Influent Quality

Chemicals of concern are primarily volatile organic compounds (VOCs) including chlorinated hydrocarbons and aromatic hydrocarbons. Table 3 lists these contaminants of concern and their expected concentrations. The chemical concentrations of the extracted water were developed using two sources. Concentrations for MW-4 are based on sampling results conducted during the aquifer pump test since they represent an estimate of water quality under pumping conditions. No sampling results under pumping conditions are available for well MW-32. Therefore, quarterly monitoring results are used to estimate MW-32 water quality. The highest concentrations measured to date, as reported in the Transmittal of Second Quarter 1992 Groundwater Monitoring Data (Dames & Moore, 1992c), is assumed to represent effluent quality from MW-32. The highest concentrations measured to date is assumed to represent worst-cast conditions.

Nickel is also a potential contaminant in groundwater. The maximum contaminant level (MCL) for nickel has recently been lowered to 100 μg/L, while concentrations found in MW-4 and MW-32 have been as high as to 200 μg/L. Nickel was not analyzed during the MW-4 aquifer pump test; therefore, only quarterly sampling results are available. The highest concentrations measured to date is 200 μg/L for both wells and is reported in Table 3. How the presence of nickel affects treatment and discharge options is discussed in Sections 2.2 and 2.3.

Table 3 not only lists the constituents of concern and their estimated concentrations from wells MW-4 and MW-32, but it also shows an estimate of influent concentrations based on mixing of the flows from the two extraction wells. This combined influent quality is what was used to evaluate the various treatment options in Section 2.3.

2.1.4 Well Equipment

During implementation of the IRM, MW-4 and MW-32 will each be equipped with a four-inch submersible pump. Each pump will be designed to provide the necessary flow against the expected hydraulic head (estimated to be 45 to 50 feet). Anticipated flow rates necessary to generate required hydraulic control will be considered as well as the potential for higher flows that may be required at well field start-up. The extraction wells will include low level switches to control groundwater levels and prevent dewatering of the well and potential pump damage. The groundwater extraction pumps will be operated from a central control panel which will have start-up and shut-down switches for the pumps.

Piping from the extraction well to the treatment unit will be designed in terms of capacity and strength. In most cases piping will be underground in a bedded trench to prevent vehicular damage or vandalism.

The existing well head completions for MW-32 and MW-4 will be modified for use as extraction wells. Currently, MW-32 is a surface completion with an existing pump used for groundwater sampling. This pump will be removed and replaced with a suitable groundwater extraction pump. MW-4 has an aboveground completion but is covered by an outer casing. MW-4 also has an existing pump used for groundwater sampling which will be replaced with a suitable groundwater extraction pump. The well head modifications will also include placement of a protective structure or vault over both extraction wells.

2.2 EFFLUENT DISCHARGE OPTIONS

Three discharge options were reviewed for disposal of treated groundwater. These options are:

- Discharge to the sewer along 24th Street;
- Discharge to the sewer using the 114 inch line located on-site; and
- Discharge using subsurface injection.

Disposal along 24th Street is considered because of its location, and disposal in the 114-inch line is considered because of its greater flow capacity. Subsurface injection is considered as an alternative to discharge to the sewer. To evaluate the different options, a number of issues were evaluated, including:

- Distance between potential discharge points and the treatment system;
- Permit fees for the different discharge options;
- Discharge limits required by either the City of Sacramento, the County of Sacramento, or the Regional Water Quality Control Board (RWQCB) (depending on discharge option);
- Size and capacity of the different sewer lines; and
- Dry weather flow in different sewer lines.

Each of the options are discussed below in terms of their advantages, disadvantages and implementability. The discussion considers the issues listed above and how they affect treatment system alternatives and costs. Preliminary costs for discharge options are listed in Table 4.

2.2.1 Discharge to 24th Street Sewer

Discharge along 24th Street was considered due to its proximity to the pumping wells and expected location of the treatment system. The advantage of using the sewer along 24th Street is the relatively short distance required for trenching. Additional trench required for discharge would be about 150 feet. However, there are several disadvantages and limitations to its implementability.

Limitations to this option include the relatively small size of the existing sewer line (14 inches). An evaluation would be required to assess whether the line has the capacity to carry the normal maximum flow plus the treated effluent. Low, dry weather flow would allow for little flexibility in quality of effluent and discharges would not be allowed during storm events. The 14-inch lines along 24th Street directly serves a number of residences. If this line is used and a resident has a problem, such as a backed up line, then the groundwater discharge could be considered a contributing factor. In addition, the 14-inch line may not be able to provide additional capacity in the event of future groundwater extraction rate increases.

Discharge limits would be set if the sewer line is used. The County of Sacramento, Water Quality Division (operators of the Publicly-Owned Treatment Works (POTW)) would set pre-treatment limits that follow 40 CFR Part 414 (Table 5). The City of Sacramento, Department of Utility Services, Flood Control and Sewers Division (owners of the sewer lines) set discharge limits based upon Maximum Contaminant Levels (MCLs) (Table 4). According to the City, the concentration of the total wastewater flow in a particular sewer cannot exceed MCLs. Therefore, if a discharger intends to discharge a waste stream above the MCL, a study must be conducted to ensure that the concentration of the total combined waste stream (i.e., treated groundwater combined with the base flow in the sewer) does not exceed MCLs. There is an exception to the MCL stipulation. If a discharger can ensure that the existing sewer line does not leak, permission to discharge above MCL may be authorized. Finally, any waste stream discharge above the MCLs must also be approved by the RWQCB.

Costs for discharge into the 24th Street sewer would be about $26,000 per year based on a flow of 40 gpm. Exact fees would be determined once a discharge permit is submitted to the County of Sacramento. In addition to permit fees, a sewer tap fee would cost about $2,300, while trenching and piping would cost about $1,500, and the study to evaluate the sewer capacity would cost about $2,500. The sewer tap fee is paid to the City for them to install a 4-inch line connected to the sewer. The cost of installing this line is $91 per foot; and the length of the tap would be about 25 feet (distance from the sewer line in the center of the street to the edge of the property line).

2.2.2 Discharge to the 114-inch Main Sewer

Discharge into the 114-inch line was considered since the line crosses the site and permits to discharge groundwater to this line have been obtained in the past. The advantage of using this line is its capacity to carry the treated groundwater discharge and it has a high, dry weather flow of about 4,000 gpm allowing for some flexibility in the quality of effluent. Although discharge during high flow (usually during storm events) is not allowed, it is a larger pipe and therefore may allow more flexibility than the line along 24th Street for discharge during storm events. The limitation of this option is its distance from the extraction wells and the expected location of the treatment system. Trenching required for discharge would be about 1,400 feet or about 9 times the distance required for discharge along 24th Street.

As with the sewer line along 24th Street, discharge limits would be set if the 114-inch sewer line is used. The County of Sacramento, Water Quality Division (operators of the POTW) would set discharge limits that follow 40 CFR Part 414 (Table 5). The City of Sacramento, Department of Utility Services, Flood Control and Sewers Division (owners of the sewer lines) would set discharge limits that follow MCLs (Table 4), unless certain criteria are met. These criteria include the stipulation that the integrity of the sewer line is checked to ensure the line does not leak if the concentrations of the combined flow (combination of treated groundwater discharge plus the sewer's dry weather flow) is not below MCLs. In addition, discharge above MCLs requires approval by the RWQCB. The dry weather flow in the 114-inch line is large enough (100 times that of expected treated groundwater discharge) so, if discharge of treated groundwater above MCLs occurs, it should immediately be reduced below MCLs. Therefore, the integrity of the line would not need to be checked. For example, if nickel is discharged at 200 μg/L (twice the MCL) into the 114-inch sewer line at 40 gpm, dilution due to the dry weather flow would reduce nickel levels to 2 μg/L (dilution factor of 100 times). This should be allowable under City of Sacramento criteria.

Costs for discharge into the sewer would be about $26,000 per year based on a flow of 40 gpm. Exact fees would be determined once a discharge permit is submitted to the County of Sacramento. In addition to permit fees, a sewer tap fee would cost about $2,700, while trenching and piping would cost about $7,000. The sewer tap is installed by the City at a cost of $91 per foot. The length of the tap required for the 114-inch line is assumed to be 30 feet though the length may vary depending where the actual tap is located.

2.2.3 Subsurface Injection

Subsurface injection was considered because of its relatively lower operating cost (no County of Sacramento discharge fees), no limitation to discharge during the rainy season, and it is environmentally favorable. Limitations include potential maintenance concerns with well clogging, no flexibility with quality of treated effluent (leading to potentially higher treatment costs), high initial cost for well installation, and distance from the extraction wells and expected location of the treatment system. Trenching required would be about 1,400 feet or the same as with the 114-inch sewer line.

Discharge limits would also be set if subsurface injection is used. An application for Waste Discharge Requirements (WDRs) would need to be filed with the RWQCB. The application would be used to set discharge limits for reinjection. These limits would probably be non-detect for all of the organic constituents and background for nickel (Table 5) (i.e., nickel may need to be treated if final discharge is subsurface injection). If treatment of nickel is required, then treatment costs would increase. This is discussed in more detail in Section 2.3.

Costs for injection would include about $10,000 for well installation, about $1,200 for permitting and about $7,000 for trenching and piping.

2.2.4 Discussion and Selection of Discharge Option

The three different options of treated effluent discharge, their expected costs and a description of their advantages and disadvantages have been discussed above. Based on this discussion, the recommended option is discharge to the 114-inch sewer line. Though this alternative is more costly than discharging to the 24th Street line (because of its distance from the pumping wells and the treatment system), the large, dry weather flow and the large capacity of the line makes it advantageous for disposal of treated effluent. The large base flow in the 114-inch line allows for flexibility in treatment efficiency that cannot be tolerated with the other two options due to stricter discharge requirements. In addition, a study is required to evaluate the capacity of the 24th Street line, but is not required of the 114-inch line.

Discharge to the 114-inch sewer line is also more advantageous, at this time, than subsurface injection because of the flexibility in effluent quality allowed when discharging to the sewer that is not allowed for subsurface injection. Nickel would need to be treated to background levels for subsurface injection which would add significantly to the treatment system cost estimate (about $100,000 annually, see Table 8). The extra cost to design, construct, and operate a nickel removal system required to meet subsurface injection discharge criteria, will exceed the discharge fee savings if not discharging to the sewer. Treatment of groundwater to remove nickel is not needed when discharging to the 114-inch sewer line.

2.3 TREATMENT ALTERNATIVES

Three technologies were evaluated for the treatment of extracted groundwater from wells MW-4 and MW-32. These technologies were evaluated based upon technical and cost considerations. These three technologies are:

- Air stripping;
- Granular Activated Carbon; and
- UV-Oxidation.

As discussed in Section 2.1, the combined flow rate from MW-4 and MW-32 is expected to be 40 gpm. Also discussed in Section 2.1 and listed on Table 3, is an estimate of contaminant concentrations in groundwater influent based on mixing of the flows from the two extraction wells.

The constituents listed in Table 3 are primarily volatile organic compounds which can be removed from groundwater by either of the three technologies listed above. Each of the technologies are easily implemented though a bench scale test is required to estimate the proper UV-Oxidation system for the site. Each of the technologies are also readily available for installation.

Since each of the technologies are technically feasible, readily available, and implementable, costs were used as the predominant criteria to evaluate which option to use. Costs for the three technologies were developed using quotes from vendors and were based on the flow rates and concentrations estimated in Section 2.1. The costs developed for the evaluation include treatment system purchase and operation for one year. Projected costs for each treatment alternative include a lump sum for components common to all the treatment technologies such as extraction well pumps, vaults, filters, trenching, piping and wiring. The estimates are intended to provide a relative cost comparison between the different treatment alternatives; therefore, actual costs may vary.

2.3.1 Air Stripper

Air stripping can be successfully used for the removal of volatile organic constituents from extracted groundwater. The type of air stripper most suited for the site is a "packless" or low profile air stripper. This type of system is being considered because it is not as obtrusive as standard air stripping towers that can stand 30 feet tall. The removal mechanism is the transfer of the compound from a liquid phase (groundwater) to a vapor phase (air). An air stripper takes advantage of a volatile organic compound's tendency to move from the liquid to gas phase. This is accomplished by maximizing the area of contact between air and water. In a low profile air stripper, the air/water interface is maximized by aerating water through diffuser trays.

Since the chemicals are transferred from the liquid phase to gas phase, the gas used to strip the contaminants from the water (off-gas) may have to be cleaned since it now contains the chemicals. The mass loading to air is low (0.13 lbs/day) and,therefore, off-gas treatment may not be required by the local air district (Lonnie Adams, personal communication, 1992). However, because of uncertainties regarding mass loading and because of a desire to minimize potential community concerns, vapor phase carbon will be used to remove the chemicals from the off-gas. Other technologies, such as thermal oxidation or catalytic conversion, are available, but they are relatively more costly than vapor phase carbon for the off-gas concentrations expected at the site.

Table 6 lists the costs for purchase and operation (over one year) of a low profile air stripper with treatment of off-gas. The first year costs range from $181,000 to $199,000, depending on the system. The operation and maintenance costs are based on a vapor phase carbon use rate of 11 pounds per day, water quality samples collected once per month, electricity costs of 0.08313 $/kWh, system maintenance cost based upon one eight-hour day per month, and discharge fees discussed in Section 2.2.

2.3.2 Granular Activated Carbon (GAC)

GAC can be successfully used for the removal of organic contaminants from the extracted water. The principal removal mechanism is selective adsorption of organic molecules onto the activated carbon. This is a process which involves the transfer of contaminants from one media to another (transfer from water to carbon) system. Removal efficiencies for organic compounds depend on the solubility and sorption characteristics of the compounds. The organic compounds detected in GW-1 have solubilities and sorption characteristics suitable for activated carbon treatment. As adsorption sites on the carbon are used up by the contaminants, the carbon becomes saturated and needs to be replaced by fresh carbon. Saturated carbon is shipped off-site and regenerated (i.e., the contaminants are destroyed) for re-use.

Table 7 lists the costs for purchase and operation (over one year) of GAC systems. The costs range from about $256,000 to $282,000 depending on the system used. Total capital costs are $91,000 to $114,000 while operation and maintenance costs range from $142,000 to $191,000 depending on the system. The operation and maintenance costs are based on a liquid phase carbon use rate of 161 pounds per day (provided by vendors), costs for carbon replacement and regeneration (vary depending on vendor), and monitoring costs from sampling collecting water quality samples at a rate based on size of the carbon unit and carbon use rate (see Table 7). The higher carbon use rate for liquid phase carbon, compared to vapor phase (see Section 2.3.1), is due to the lower removal efficiency of liquid phase carbon compared to vapor phase carbon.

2.3.3 UV-Oxidation

In this process, the chemical bonds of the organic compounds are broken through photolysis by subjecting the influent to ultraviolet light and adding hydrogen peroxide to oxidize the components into carbon dioxide, water, and chlorine. The basic advantage of the system is that it destroys the organic compounds rather than transferring them from one medium to another, as in the case of activated carbon. The system has been used successfully in similar situations in recent years. Unlike the GAC and air stripper treatment systems, however, this system would require bench scale testing to determine if it would be effective at the site.

Table 8 lists the costs for purchase and operation (over one year) of a UV-Oxidation system. These costs were provided by vendors after supplying them with the chemistry and flow data discussed in Section 2.1. As the table shows, the capital cost of is relatively high and can reach up to $180,000. Operation and maintenance costs are $110,000, while total costs can reach up to almost $290,000 for one year. Table 8 also illustrates the cost of using only UV-Oxidation for treating the constituents found on-site versus combining UV-Oxidation with carbon polishing. The costs show that using UV-Oxidation alone is more costly than using UV-Oxidation with carbon and illustrates how using only UV-Oxidation is inefficient at removing contaminants at the low levels found on-site.

2.3.4 Treatment System Summary

As shown in Tables 6 through 8, the most cost effective treatment technology is air stripping with treatment of off-gas. The purchase price of the system is about the same as GAC and about half the cost of UV-Oxidation. Total capital costs for air stripping are comparable to GAC, but operation and maintenance costs for air stripping are much less than GAC and UV-Oxidation resulting in a lower yearly cost than the other treatment technologies.

Besides costs, other advantages and disadvantages of the three candidate treatment technologies were also considered when selecting the IRM groundwater treatment technology. A summary of the advantages and disadvantages is provided in Table 9. For example, though air stripping is cost effective and easily implemented, there is the potential for clogging due to scaling. GAC treats to non-detect, but liquid phase carbon use is very high, and GAC beds may also require periodic backflushing to clear any clogging that may occur due to biofouling. The advantage of UV-Oxidation is that it destroys the contaminants. There are no waste products produced as compared to GAC (spent carbon) and air stripping (contaminated off-gas). However, UV-Oxidation can also biofoul (reduces UV light effectiveness) and is also very expensive to operate.

As mentioned in the beginning of the section, each of the alternatives evaluated is implementable and technically feasible. The advantages and disadvantages regarding production of waste and potential for fouling that are listed in Table 9 are fairly similar, however, cost of treatment (both capital cost and operation and maintenance costs) can vary significantly from technology to technology. Based on these costs and the advantages and disadvantages listed in Table 9, air stripping with off-gas recovery is the preferred alternative for treating groundwater during the IRM.

3.0 SYSTEM DESIGN

The IRM system consists of extraction of groundwater from two existing wells, treatment using low profile air stripping, and discharge of treated effluent to a sanitary sewer. The layout of the IRM system is provided in Figure 4. The design basis and process flow diagram for the IRM is illustrated in Figure 5 and discussed below. Design details, including size of the pumps, pipes, holding tanks, type of instrumentation, pipe material, valving, controls, and fencing will be described in subsequent engineering design documents prepared in order to obtain permits and ensure the system is properly constructed.

3.1 EXTRACTION WELL FIELD

The extraction well field consists of existing wells MW-4 and MW-32. Each well will be pumped at 20 gpm, using 4-inch submersible pumps, for a total flow of 40 gpm. Expected contaminant concentrations from the extracted groundwater is shown in Figure 5 and listed in Table 3. The extracted groundwater will be pumped through piping buried in a trench located near the fence on the east side of the site (Figure 4).

3.2 TREATMENT SYSTEM COMPONENTS

Groundwater extracted from MW-4 and MW-32 will be pumped to the treatment system that is proposed to be located in the Former Oil House Area on an existing concrete pad (Figure 4). The system will be designed to process the combined 40 gpm flow from the extraction wells. Influent water will be piped from the extraction wells to an influent holding tank that will be located near the air stripper. Water will be pumped from the influent holding tank through a bag filter, used to remove any sediment or particles, and into the low profile air stripper.

The water will be treated in an air stripper capable of moving 600 CFM of air through the system to treat the 40 gpm of water. Air used to treat the water will be treated with vapor phase carbon before discharge to the atmosphere. The off-gas from the stripper will be passed through a booster pump to maintain proper air flow through a small heater and the vapor phase carbon units. A small heater is used to decrease the relative humidity and enhance the removal efficiency of the vapor phase carbon. Two granular activated carbon filters in series will be used to remove the VOCs from the off-gas prior to discharge to the atmosphere.

3.3 EFFLUENT DISCHARGE

The air stripper will be designed with an effluent holding tank as part of the air stripper system. Treated effluent water will exit the air stripper and will be pumped by the effluent discharge pump through underground piping to the discharge point in an existing 114-inch sewer line located approximately 1,600 feet to the north (Figure 5). Subsurface piping will be installed along the fence on the east side of the site, from the treatment system location to the 114-inch sewer (Figure 4). A 4-inch sewer tap, installed by the City of Sacramento, will receive the effluent discharge and connect to the 114-inch sewer line.

3.4 CONTROLS

The IRM system operation controls will be centralized and located near the groundwater treatment system. The system controls will be automated, and will include indicator activated switches and relays to provide continuous operation of the system. Alarms and manual override switches will also be included in case of system malfunction, and for shut-off during scheduled maintenance.

The extraction well submersible pumps will be equipped with automated water level activated switches. Pumps will switch on and off automatically, based on the water level in the well.

The influent holding tank will be equipped with a water level indicator and controller to operate the influent tank discharge pump. The tank will also be equipped with high level alarm to shut the system down if the water level in the tank becomes too high. Similar controls will be provided for the effluent holding tank that is part of the air stripper.

A water level and control switch will also be provided for the discharge point. Since discharge cannot occur during high flows (storm events) in the sewer line, necessary controls will be provided at the discharge point to shut down the system if water levels reach a predetermined level.

4.0 PERMITTING AND SCHEDULE

The permitting requirements for the IRM discussed in Section 3.0 are outlined below, along with a schedule to implement construction and operation of the system.

4.1 PERMITS

A number of permits are required for building and operating the treatment system. These permits which include air permits (for both the air stripper and the off-gas treatment unit), building permit, discharge permit, and a memorandum of understanding, are summarized in the following table and discussed below.

PERMIT REQUIREMENTS

PERMIT	AGENCY	APPROXIMATE COST (ONE YEAR)
Building	City of Sacramento, Building Department	(1)
Discharge	County of Sacramento, Water Quality Division	$26,000
MOU	City of Sacramento, Department of Utility Services, Flood Control and Sewers Division	None
Air	County of Sacramento, Metropolitan Air Quality Management District	$800

(1) Cost to be determined upon submittal.

The initial air permits will be obtained from the County of Sacramento, Metropolitan Air Quality Management District, at a cost of approximately $800 each ($1,600 total), and will take about four weeks to process (Lonnie Adams, personal communication, 1992). The combined annual renewal cost for the air permit is about $1,600 per year.

The building permit will be obtained from the City of Sacramento Building Department and may either be obtained over the counter or may require some time for plan check. Plan review and cost are determined when the drawings are submitted for review.

Discharge requires a permit from the County of Sacramento, Water Quality Division and a Memorandum of Understanding (MOU) from the City of Sacramento, Department of Utility Services, Flood Control and Sewers. The discharge permit is for use of the POTW, will dictate effluent criteria, and costs about $26,000 annually depending on the final flow rate. The annual discharge permit cost includes monthly treatment fees of about $500 to $600 and monthly industrial discharge fees of about $1,500 a month (assuming a flow of 40 gpm). The exact fee will not be assessed until the permit is submitted to the County (Sam Harader, personal communication, 1992). Effluent criteria required by the POTW will follow federal pretreatment discharge requirements as outlined in CFR Part 414 (Sam Harader, personal communication, 1992). Projected pretreatment standards are listed in Table 5.

An MOU with the City of Sacramento (City) is required to discharge to City sewer lines. The MOU dictates effluent limits of treated groundwater, place of discharge, and allowable flow rate (Craig Chalmers, personal communication, 1992). Currently, there are no costs associated with the MOU, however, fees may be assessed at a later date. These future fees are unknown at this time.

4.2 SCHEDULE

The overall schedule is driven by an objective to initiate operation of the IRM before the end of 1992. To meet the aggressive schedule demands, timely approval of this work plan by the DTSC is essential. A tentative schedule for the implementation of the IRM is presented on Figure 6. As the figure shows, design activities will be completed by the end of October, construction will be finished by the middle of December, and the IRM system start-up is planned for the third week of December 1992.

5.0 SYSTEM OPERATION AND MAINTENANCE

Upon receipt of authorizations to proceed from appropriate agencies, issuance of permits, and completion of construction activities, operation of the remedial system will commence. Operation will commerce concurrently with an active maintenance and monitoring program. A formal operation, maintenance, and monitoring manual will be prepared prior to remedial system start-up. The operation, maintenance, and monitoring manuals will address:

- Operation, maintenance, troubleshooting, and monitoring procedures which are expected to minimize downtime and adequately assess system performance and status;
- Monitoring the movement of the plume to evaluate the performance of the pumping treatment system in achieving the remedial goals including further evaluation of system modifications which will enhance the achievements of these goals; and
- Monitoring the treatment system influent and effluent streams to evaluate compliance with effluent guideline limitations and the performance of the treatment system, plus monitoring the system's operation for performance and evaluating system modifications which will improve this performance.

The following subsections present a discussion of the procedures that will be used for training, maintenance, and operation and monitoring of the initial phase off-property groundwater treatment system.

5.1 OPERATION AND MONITORING

It is currently anticipated that the IRM will be designed to operate automatically with manual inspection occurring on a regular basis or as dictated by system needs. The purpose of these inspections will be to evaluate system performance and to initiate changes in operating parameters which will optimize performance. In addition, appropriate emergency controls will be installed to automatically shut down the treatment system if any component fails.

The initial phase remedial system will be monitored in two parts, aquifer control monitoring and treatment system monitoring. Each of these parts have separate monitoring objectives and monitoring programs, however, the sampling associated with the two monitoring programs will be coordinated to the fullest extent possible.

The aquifer control monitoring objectives are to evaluate the site-specific aquifer response to pumping and movement and reduction in extent of VOC-impacted groundwater in the first hydrostratigraphic zone.

Aquifer response and capture zone development will be evaluated based on water level measurements taken from wells in both the first and second hydrostratigraphic zones. Water levels will be measured in the wells listed in Table 10 on a schedule that will vary over time. Water levels will be measured frequently during start-up and initial operation and then measured less frequently as time progresses. The reduction and movement of groundwater contaminants in the first hydrostratigraphic zone will be evaluated using water quality samples collected from MW-4 and MW-32. As with water levels, water quality samples will be collected more frequently during start-up and then less frequently as operation continues. Samples from the wells will be analyzed for chlorinated solvents (EPA Method 601) aromatic hydrocarbons (EPA Method 602), TPH gasoline (EPA Method 8015) and nickel (EPA Method 200.7). Table 10 shows a proposed schedule for monitoring during start-up. The schedule calls for frequent monitoring during the first week of operation, and less frequent monitoring as operation continues. Monitoring during regular operation (after start-up) would occur monthly. The planned IRM monitoring activities will occur in addition to the routine quarterly monitoring currently conducted at the site.

Monitoring of the treatment system will occur concurrently with the monitoring of aquifer response. The purpose of this sampling is to evaluate system operation and to adjust system controls to optimize performance. Effluent samples will be analyzed for the same parameters as the extraction wells including chlorinated solvents (EPA Method 601), aromatic hydrocarbons (EPA Method 602), TPH gasoline (EPA Method 8015), and nickel (EPA Method 200.7). Air quality and loading to the vapor phase carbon units will be calculated based upon the mass difference between influent flow (MW-4 and MW-32) and effluent flow. The schedule for treatment system monitoring during start-up is shown in Table 10. In the future, this list of chemical parameters may be reduced and focused on key target parameters found to be relevant to IRM activities.

5.3 MAINTENANCE

A preventative maintenance program will be developed for the initial phase remedial system. The maintenance program will consist of bi-monthly surveys of the system to assess if potential problems are occurring or may develop. Each survey will include inspection of the following items:

- Integrity of treatment unit and associated piping, extraction wells, recharge wells, and surface water discharge system;
- Groundwater monitoring system; and
- Integrity of emergency shut-off controls.

The results of these surveys will be recorded and maintained in the project file. The survey records will include inspection observations and copies of laboratory reports including, QA documentation for samples taken during the inspection period. The survey records will also summarize areas in need of maintenance. A schedule for correcting system defects identified during the survey and documentation of the corrective actions taken will be maintained in the project file.

6.0 REFERENCES

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TABLES

TABLE 1
HYDRAULIC CONDUCTIVITIES USED IN GROUNDWATER MODEL
UNION PACIFIC RAILROAD YARD
SACRAMENTO, CALIFORNIA

WELL	HYDRAULIC CONDUCTIVITY	
	CM/SEC	FT/DAY
MW-11	0.13	368
MW-13	0.06	170
MW-14	0.05	141
MW-17	0.05	141
MW-18	0.16	453
MW-29	0.16	453
MW-30	0.16	453
MW-33	0.08	227
Geometric Mean = 266 ft/day		
MW-15	0.11	312
MW-16	0.07	198

Notes:

- All values obtained during November 1991 aquifer pump test (Dames & Moore, 1992b).
- Geometric mean developed using results from MW-11, 13, 14, 17, 18, 29, 30 and 33.

TABLE 2
MODEL RESIDUALS
UNION PACIFIC RAILROAD YARD
SACRAMENTO, CALIFORNIA

WELL (ft)	ACTUAL[1] ELEVATIONS (ft)	SIMULATED[2] ELEVATIONS (ft)	RESIDUALS[3] (ft)
MW-1	-3.82	-5.12	1.30
MW-2	-5.04	-5.72	0.68
MW-3	-5.2	-6.01	0.81
MW-4	-7.47	-7.57	0.10
MW-5	-7.41	-7.70	0.29
MW-6	-7.67	-7.82	0.15
MW-7	-8.72	-8.49	-0.23
MW-8	-8.15	-8.07	-0.08
MW-11	-7.05	-7.24	0.19
MW-13	-7.53	-7.60	0.07
MW-14	-7.6	-7.67	0.07
MW-15	-7.57	-7.71	0.14
MW-16	-7.57	-7.70	0.13
MW-17	-8.02	-8.04	0.02
MW-18	-8.08	-8.08	-0.00

Notes:

1 Represent groundwater elevations (MSLD) measured in December 1991 (Dames & Moore, 1992a).

2 Modeled groundwater elevations simulated using MODFLOW.

3 Residuals equal the differences between actual and simulated water levels.

TABLE 2 (Continued)
MODEL RESIDUALS
UNION PACIFIC RAILROAD YARD
SACRAMENTO, CALIFORNIA

WELL (ft)	ACTUAL[1] ELEVATIONS (ft)	SIMULATED[2] ELEVATIONS (ft)	RESIDUALS[3] (ft)
MW-19	-8.69	-8.49	-0.20
MW-20	-8.76	-8.53	-0.23
MW-21	-8.33	-8.26	-0.07
MW-22	-8.32	-8.24	-0.08
MW-23	-8.04	-8.05	0.01
MW-24	-8.02	-8.05	0.03
MW-25	-9.29	-8.82	-0.47
MW-26	-9.3	-8.82	-0.48
MW-27	-9.29	-8.83	-0.46
MW-29	-8.1	-8.06	-0.04
MW-30	-8.13	-8.07	-0.06
MW-31	-8.26	-8.21	-0.05
MW-32	-8.7	-8.49	-0.21
MW-33	-7.06	-7.24	0.18
MW-34	-9.38	-9.09	-0.29
MW-35	-9.39	-9.11	-0.28

Notes:

1 Represent groundwater elevations (MSLD) measured in December 1991 (Dames & Moore, 1992a).

2 Modeled groundwater elevations simulated using MODFLOW.

3 Residuals equal the differences between actual and simulated water levels.

TABLE 2 (Continued)
MODEL RESIDUALS
UNION PACIFIC RAILROAD YARD
SACRAMENTO, CALIFORNIA

WELL (ft)	ACTUAL[1] ELEVATIONS (ft)	SIMULATED[2] ELEVATIONS (ft)	RESIDUALS[3] (ft)
MW-36	-10.71	-10.86	0.15
MW-38	-13.05	-12.93	-0.12
MW-39	-14.67	-14.78	0.11
MW-42	-6.13	-6.53	0.40
MW-43	-5.3	-5.90	0.60
		RMSE[4] =	0.24

Notes:

1 Represent groundwater elevations (MSLD) measured in December 1991 (Dames & Moore, 1992a).

2 Modeled groundwater elevations simulated using MODFLOW.

3 Residuals equal the differences between actual and simulated water levels.

4 RMSE is the root mean square error and equals

$$\frac{1}{n} \sum_{i=1}^{n} \sqrt{(R^2_i)}$$

where R = residual and n = the number of readings.

TABLE 3
ESTIMATED INFLUENT CONCENTRATIONS
UNION PACIFIC RAILROAD YARD
SACRAMENTO, CALIFORNIA
(All units in μg/L)

PARAMETER	MW-4[1]	MW-32[3]	FINAL[4] INFLUENT
1,1-Dichloroethylene	81	240	161
1,1-Dichloroethane	9.2	21	15
1,2-Dichloroethane	8.8	ND	4.4
1,1,1-Trichloroethane	2.1	20	11
Trichloroethylene	5.4	16	11
Benzene	120	ND	60
Toluene	6.6	ND	3.3
Ethyl Benzene	5.6	ND	2.8
Xylene	9.4	ND	4.7
TPH Gasoline	150	ND	75
Nickel	200[2]	200	200

Notes:

1 Concentrations based upon sampling performed at end of MW-4 aquifer pump test (Dames & Moore, 1992b).

2 Nickel was not analyzed during pump test sampling, therefore, value based upon quarterly sampling results.

3 Concentrations based upon highest values measured to date during quarterly sampling (Dames & Moore, 1992c).

4 Calculated concentration based upon a combined flow of 20 gpm each from MW-4 and MW-32.

TABLE 4
DISCHARGE OPTIONS
PRELIMINARY COSTS
UNION PACIFIC RAILROAD YARD
SACRAMENTO, CALIFORNIA

FEES	OPTION		
	DISCHARGE TO 24TH STREET SEWER	DISCHARGE TO 114-INCH SEWER	DISCHARGE TO SUBSURFACE INJECTION
Well Construction	$0	$0	$10,000
Discharge Permit	$26,000[2]	$26,000[2]	$1,200
Trenching	$1,500	$7,000	$7,000
Sewer Tap	$2,300	$2,700	$0
Capacity Evaluation	$2,500	$0	$0
SUBTOTAL	$32,300	$35,700	$18,200
Nickel Treatment[1]	$0	$0	$100,000
TOTAL	$32,300	$35,700	$118,200

(1) Discharge using subsurface injection may require treatment of nickel to reduce concentrations from 200 ppb to background levels. This treatment would add approximately $100,000 annually to the treatment system costs.

(2) These annual fees are estimates, only. True costs not determined until permit is submitted.

TABLE 5
DISCHARGE LIMITS
UNION PACIFIC RAILROAD YARD
SACRAMENTO, CALIFORNIA

	DISCHARGE TO SEWER		
	POTW [1]	City of Sacramento [2]	Subsurface Injection
Parameter	Monthly Average (µg/L)	µg/L	µg/L
1,1-Dichloroethylene	22	6	ND [3]
1,1-Dichloroethane	22	5	ND
1,2-Dichloroethane	180	0.5	ND
1,1,1-Trichloroethane	22	200	ND
Trichloroethylene	26	5	ND
Benzene	57	1	ND
Toluene	28	100	ND
Xylene	NL	1,750	ND
Ethyl Benzene	142	680	ND
Nickel	1,690	100	12 [5]
TPH Gasoline	NL	NE [4]	ND

Notes:

(1) Pretreatment requirements as prescribed by the County of Sacramento, Water Quality Division for Industrial Discharge to the Sewer. Discharge limits follow 40 CFR Part 414, Pretreatment Standards for Organic Chemical Manufacturers (Sam Harader, personal communication 1992).

(2) Discharge requirements as outlined in the Draft Memorandum of Understanding between the City of Sacramento and the discharger. The MOU requires that the discharger guarantees the contaminant levels in the discharge do not exceed the maximum contaminant levels set forth in the California Code of Regulations, Title 22, Article 5.5, §64444.5 *Primary Standards - Organic Chemicals; Maximum Contaminant Levels*, and Article 4 §64435, *Primary Standards - Inorganic Chemical and Physical Quality; Maximum Contaminant Levels* ("State Standards"), unless the permit from the Regional Sanitation District specifically lists and approves individual contaminant overages with corresponding maximum amounts, and the discharge performs a sewer line integrity assessment and repair. Groundwater discharge with contaminant levels that exceed the State Standards cannot be discharged into sewer lines that exfiltrate to the surrounding soil. The discharger must perform a sewer line integrity assessment if contaminant levels approved by the Regional Sanitation District and the RWQCB exceed the levels set forth in the State Standards. The discharge shall repair or rehabilitate exfiltrating sewer lines to the satisfaction of the City prior to the discharge.

(3) ND = Non-detect.

(4) NE = No MCL or Action Level exists.

(5) Background value as reported in Transmittal of Additional Groundwater Investigation Results and Quarterly Groundwater Monitoring Data (Dames & Moore, 1992a).

(6) Not listed.

TABLE 6
LOW-PROFILE AIR STRIPPER AND VAPOR PHASE CARBON
TREATMENT SYSTEM COMPARISON COSTS
UNION PACIFIC RAILROAD YARD
SACRAMENTO, CALIFORNIA

VENDOR	SYSTEM [1]	PURCHASE PRICE	COMMON EQUIPMENT PURCHASE AND INSTALLATION COSTS [2]	TOTAL CAPITAL COST	SYSTEM O&M COSTS [3] (one year)	TOTAL COST [4] (over one year)
NEEP AND WESTATES	2621 AND VSC 1200	$44,000	$75,000	$119,000	$74,000	$193,000
NEEP AND CAMERON-YAKIMA	2621 AND TSU 2000S	$37,000	$75,000	$112,000	$69,000	$181,000
ESI AND WESTATES	4 TRAY AND VSC 1200	$48,000	$75,000	$123,000	$76,000	$199,000

Notes: (1) System type, size, and costs based on vendor information using flow rate of 40 gpm and contaminant loading based on sample results from MW-4 pump test and MW-32 quarterly monitoring.

(2) Common equipment costs include costs for equipment (such as well pumps, discharge pumps, vaults, tanks, filters, valves, piping and wiring) and construction.

(3) System operation and maintenance costs for air stripping include:

- Power costs (0.08313 $/kWh) to run the 3 HP blower, 7.5 kW heater, and costs for system maintenance.
- Maintenance costs are included in operation costs and assume one day per month for cleaning, 8 hrs a day, at $80 per hour.
- Monitoring costs based on sampling MW-4, MW-32 and effluent once a month for 601/602 and Nickel.
- Carbon regeneration costs based on carbon use rate of 11 lbs/day.
- Size of carbon unit dependent on rate of air flow (i.e. type of system), size shown above applicable to 600 cfm unit only.
- Vapor phase carbon system comprised of two units in series.
- Permitting costs for water and air discharge.

(4) Costs for engineering and design are not included.

TABLE 7
GRANULAR ACTIVATED CARBON
TREATMENT SYSTEM COMPARISON COSTS
UNION PACIFIC RAILROAD YARD
SACRAMENTO, CALIFORNIA

VENDOR	SYSTEM (1)	PURCHASE PRICE (2)	COMMON EQUIPMENT PURCHASE AND INSTALLATION COSTS (3)	TOTAL CAPITAL COSTS	SYSTEM O&M COSTS (4) (one year)	TOTAL COST (5) (over one year)
WESTATES	PV-80	$16,000	$75,000	$91,000	$191,000	$282,000
EXCELTRANS	CWS-8000	$39,000	$75,000	$114,000	$142,000	$256,000

Notes:

(1) System type, size, and costs based on vendor information using flow rate of 40 gpm and contaminant based on sample results from MW-4 pump test and MW-32 quarterly monitoring (Table 3).

(2) Systems comprised of two carbon units in series. Each Westates unit contains 2,000 lbs. of carbon, each Exceltrans unit contains 8,000 lbs.

(3) Common equipment costs include costs for equipment (such as well pumps, discharge pumps, tanks, filters, valves, piping and wiring) and construction.

(4) Operation and maintenance costs for carbon units based on:

- Carbon use rates of 161 pounds per day and costs for carbon exchange.
- Monitoring costs include both manpower and analytical costs and are based on sampling MW-4, MW-32 and effluent for 601/602 and Nickel.
- Monitoring frequency of effluent is dependent on the system (time of saturation). Westates system sampled every 12 days. Exceltrans system sampled every 49 days.
- Permitting costs for water discharge.

(5) Costs for engineering and design are not included.

TABLE 8
UV OXIDATION
TREATMENT SYSTEM COMPARISON COSTS
UNION PACIFIC RAILROAD YARD
SACRAMENTO, CALIFORNIA

VENDOR	SYSTEM (1)	PURCHASE PRICE	COMMON EQUIPMENT PURCHASE AND INSTALLATION COSTS (2)	TOTAL CAPITAL COSTS	SYSTEM O&M COSTS (3) (one year)	TOTAL COST (4) (over one year)
SOLARCHEM	30kW RAYOX	$105,000	$75,000	$180,000	$110,000	$290,000
	30kW RAYOX W/CARBON	$85,000	$75,000	$160,000	$107,000	$267,000

Notes:

(1) System type, size, and costs based on vendor information using flow rate of 40 gpm and contaminant based on sample results from MW-4 pump test and MW-32 quarterly monitoring.

(2) Common equipment costs include costs for equipment (such as well pumps, discharge pumps, tanks, filters, valves, piping and wiring) and construction.

(3) Operation and maintenance costs for UV Ox was provided by the vendor.

- Monitoring costs assumed to be the same as for air stripping.

(4) Costs for engineering and design not included.

TABLE 9
SUMMARY OF COSTS, ADVANTAGES, AND DISADVANTAGES
CANDIDATE TREATMENT TECHNOLOGIES
UNION PACIFIC RAILROAD YARD
SACRAMENTO, CALIFORNIA

OPTION	ESTIMATED COST	ADVANTAGES	DISADVANTAGES
Air Stripping	Capital Cost: $112,000 O&M Cost: $69,000	• Low operation and maintenance costs; • Well proven and easily implementable technology. • Low profile system compatible with site.	• Possible clogging of air holes due to scaling or biofouling; • Off-gas treatment assumed to be required
Granular Activated Carbon	Capital Cost: $114,000 O&M Cost: $142,000	• Well proven and easily implementable; • Treats to non-detect.	• High carbon usage cost compared to vapor phase; • Carbon use may vary depending on influent concentrations; • May require periodic backflushing of carbon beds; • Biofouling of carbon bed is possible.
UV-Oxidation	Capital Cost: $180,000 O&M Cost: $110,000	• Destroys contaminants, no waste products to manifest or treat off-site.	• High capital cost; • Requires bench scale test; • Biofouling potential of UV lamps.

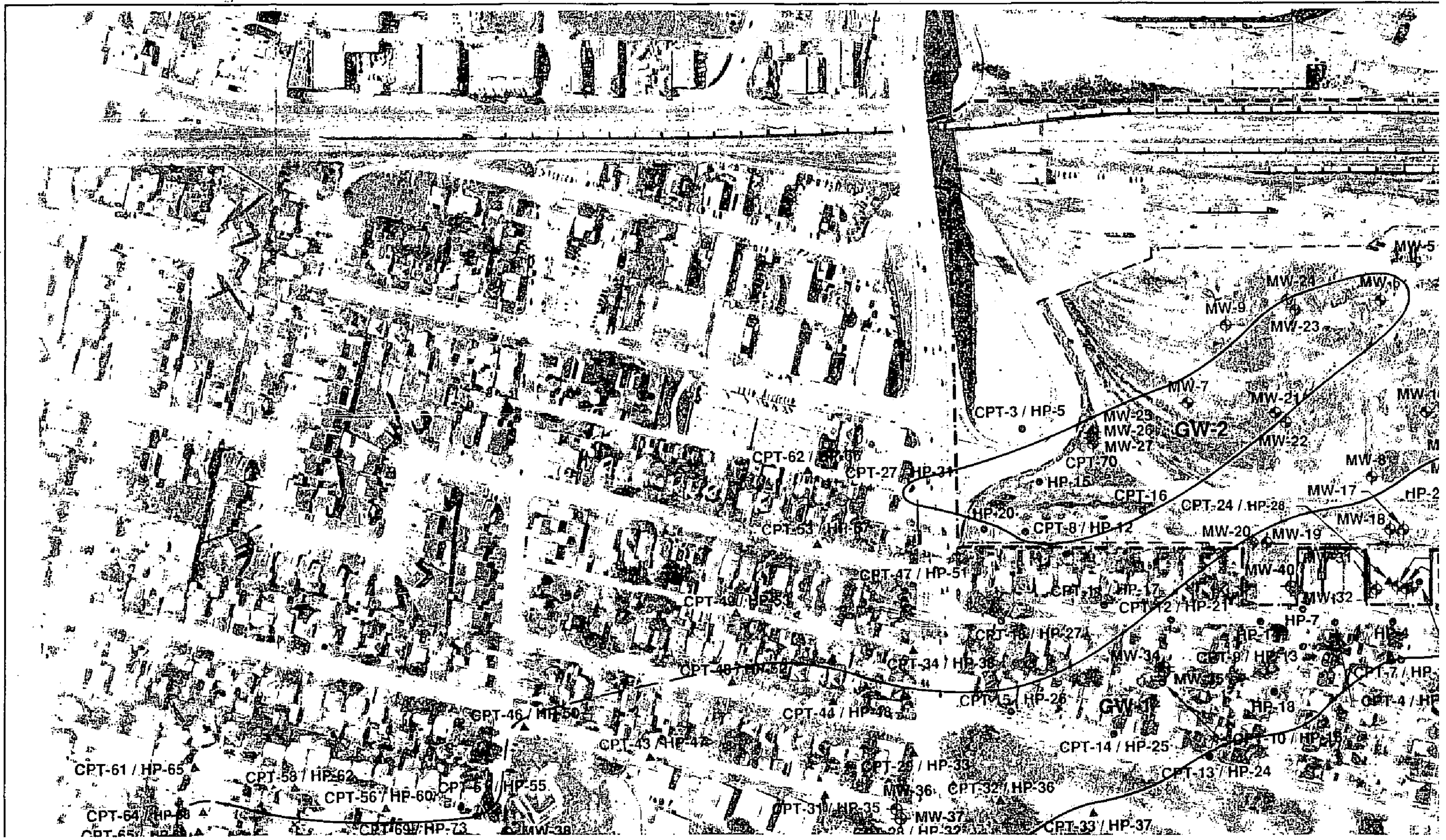
Capital Cost - Based on 1992 dollars.
O&M Cost - Per year, based on 1992 dollars.

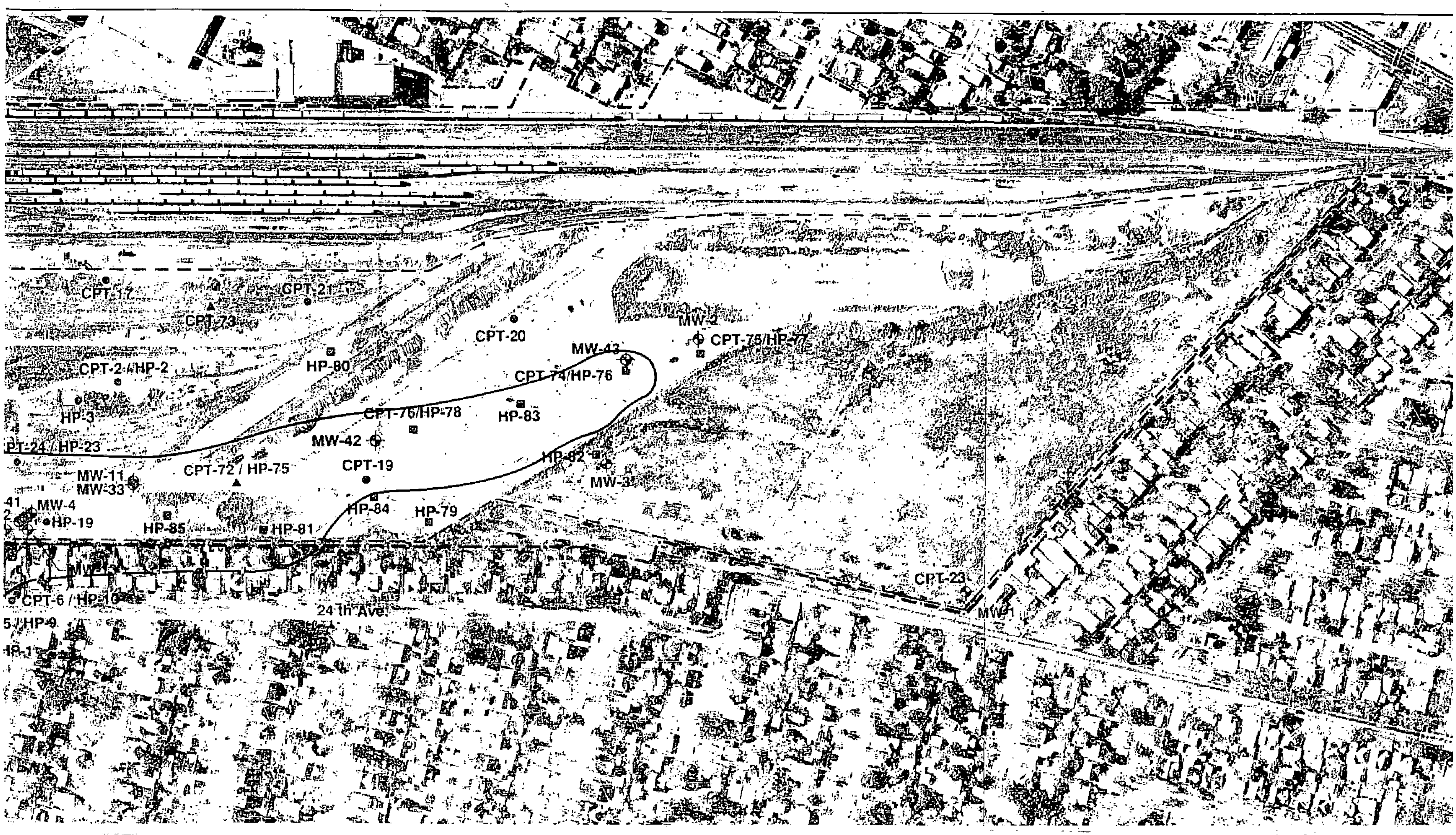
TABLE 10
START-UP MONITORING SCHEDULE
UNION PACIFIC RAILROAD YARD
SACRAMENTO, CALIFORNIA

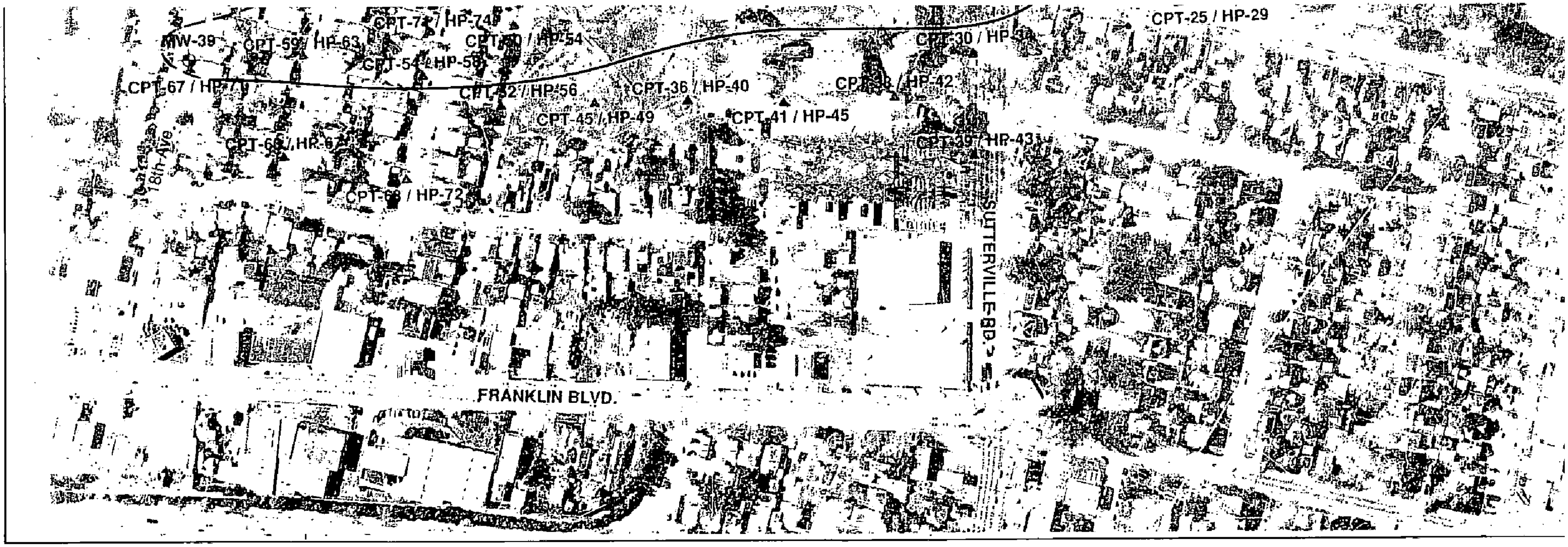
	DAYS AFTER START-UP																											
Well	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
MW-4	L,Q	L	L,Q	L	L			L,Q				L,Q							L,Q							L,Q		
MW-11	L	L	L	L	L			L				L							L							L		
MW-12	L	L	L	L	L			L				L							L							L		
MW-13	L	L	L	L	L			L				L							L							L		
MW-14	L	L	L	L	L			L				L							L							L		
MW-15	L	L	L	L	L			L				L							L							L		
MW-16	L	L	L	L	L			L				L							L							L		
MW-17	L	L	L	L	L			L				L							L							L		
MW-18	L	L	L	L	L			L				L							L							L		
MW-19	L	L	L	L	L			L				L							L							L		
MW-20	L	L	L	L	L			L				L							L							L		
MW-28	L	L	L	L	L			L				L							L							L		
MW-29	L	L	L	L	L			L				L							L							L		
MW-30	L	L	L	L	L			L				L							L							L		
MW-31	L	L	L	L	L			L				L							L							L		
MW-32	L,Q	L	L,Q	L	L			L,Q				L,Q							L,Q							L,Q		
MW-33	L	L	L	L	L			L				L							L							L		
MW-40	L	L	L	L	L			L				L							L							L		
MW-41	L	L	L	L	L			L				L							L							L		
Influent[1]	Q		Q					Q				Q							Q							Q		
Effluent	Q		Q					Q				Q							Q							Q		
Air[2]	Q		Q					Q				Q							Q							Q		

L = Water Level Measurement.
Q = Water Quality Measurement for VOCs, TPH Gasoline, and Nickel.
[1] = Influent quality will be calculated based on results of sampling MW-4 and MW-32.
[2] = Mass discharge of air will be calculated based upon the mass difference between influent flow (MW-4 and MW-32) and effluent flow.

FIGURES


MW-5
MW-24
MW-6
MW-9
MW-23
MW-7
MW-21
CPT-3 / HP-5
MW-25
MW-26
MW-27
GW-2
MW-22
CPT-70
MW-8
CPT-62
CPT-27 / HP-31
HP-15
CPT-16
MW-17
CPT-24 / HP-28
MW-18
HP-20
CPT-8 / HP-12
MW-20
MW-19
CPT-47 / HP-51
MW-40
MW-32
HP-7
MW-34
CPT-34 / HP-38
MW-35
HP-18
GW-1
CPT-46 / HP-50
CPT-44 / HP-48
CPT-14 / HP-25
CPT-43
CPT-13 / HP-24
CPT-61 / HP-65
CPT-56 / HP-60
HP-55
MW-36
CPT-32 / HP-36
MW-37
CPT-33 / HP-37
CPT-4 / HP


CPT-17
CPT-21
CPT-73
CPT-20
MW-2
CPT-75/HP-77
MW-43
CPT-2 / HP-2
HP-80
CPT-74/HP-76
HP-3
CPT-76/HP-78
HP-83
PT-24 / HP-23
MW-42
HP-82
MW-11
MW-33
CPT-72 / HP-75
CPT-19
MW-3
41
MW-4
HP-19
HP-85
HP-81
HP-84
HP-79
CPT-23
CPT-6 / HP-10
24 th Ave
MW-1
5 / HP-9
HP-1



EXPLANATION

Exploratory Holes

April - May, 1990 Locations

September - October, 1990

February, 1991 Locations

CPT-13 Cone Penetration Test

HP-2 Hydropunch Sample

Monitoring Well Location

Boundary of Groundwater Operable Unit GW-1 and GW-2

Fence Line

Property Boundary

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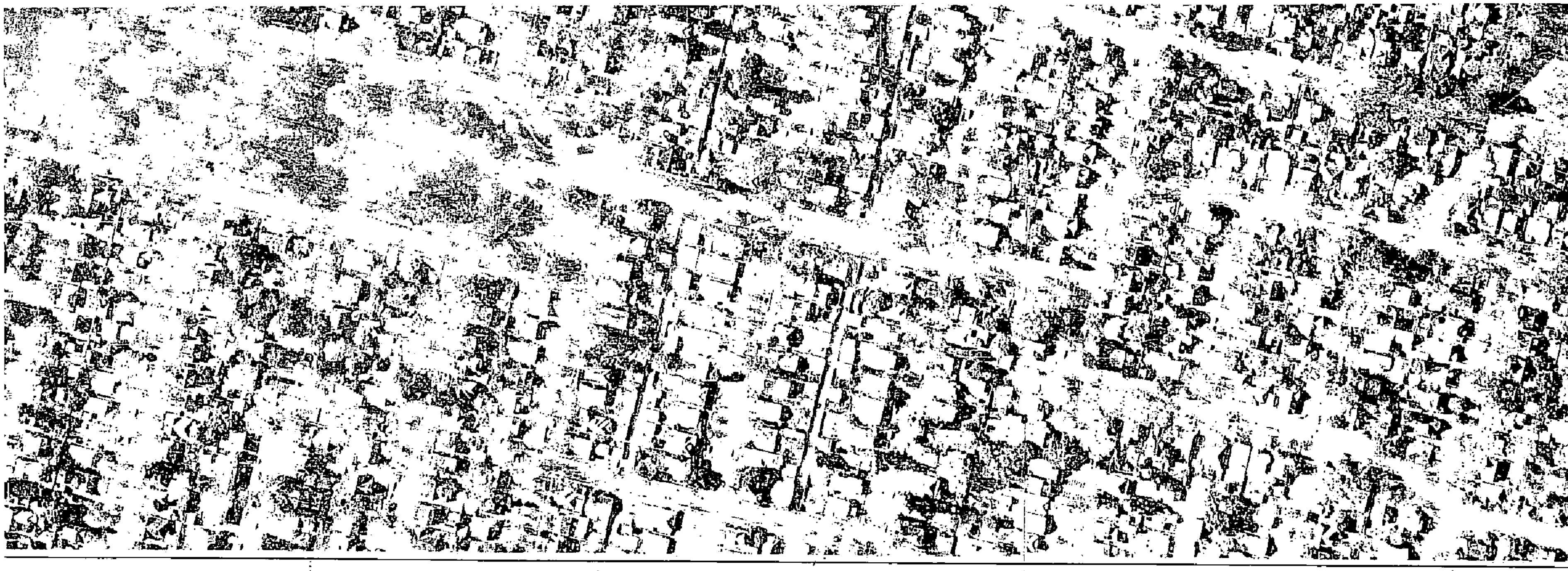
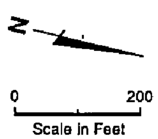
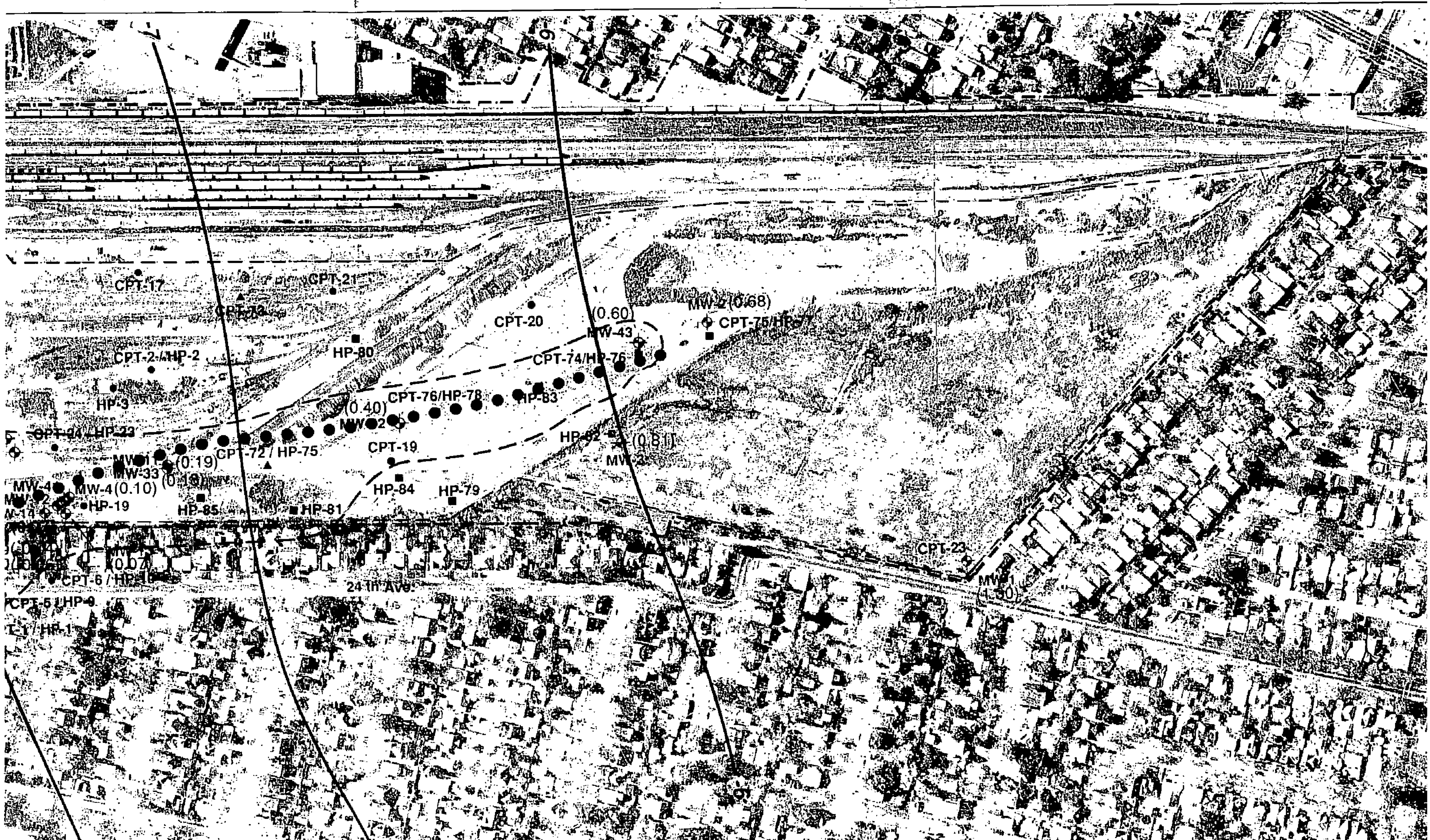


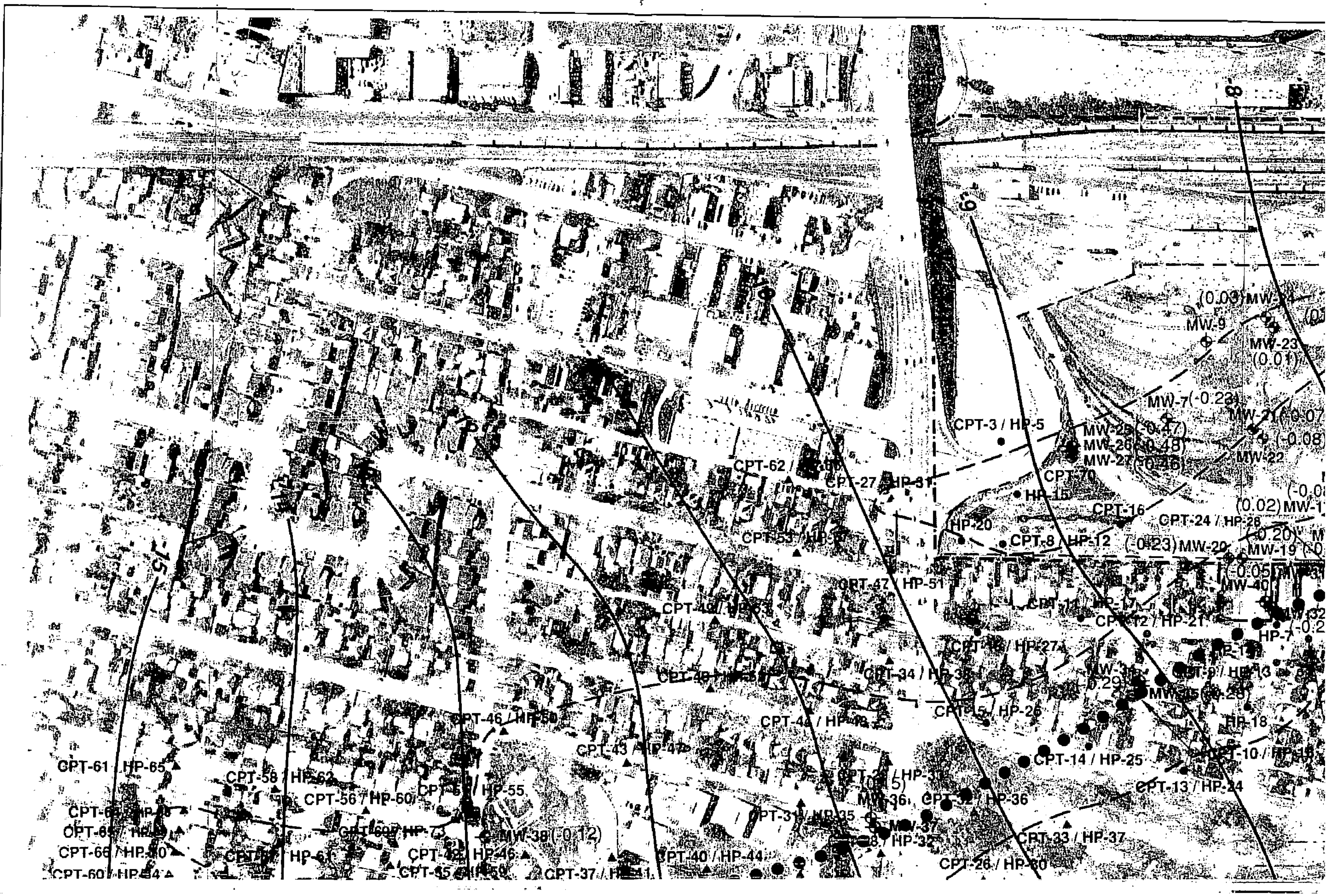


LOCATION OF GROUNDWATER OPERABLE UNITS

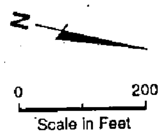
Union Pacific Railroad Yard
Sacramento, California
SEPTEMBER 1992

FIGURE 1


CPT-17
CPT-21
CPT-20
MW-2 (0.68)
(0.60)
MW-43
HP-80
CPT-2 / HP-2
CPT-74/HP-76
HP-3
CPT-76/HP-78
HP-83
(0.40)
CPT-24 / HP-23
HP-82
(0.81)
MW-3
CPT-72 / HP-75
CPT-19
(0.19)
MW-33
MW-4 (0.10)
HP-84
HP-79
HP-19
HP-85
HP-81
CPT-23
MW-1
(1.50)
(0.07)
24th Ave
CPT-5 / HP-9



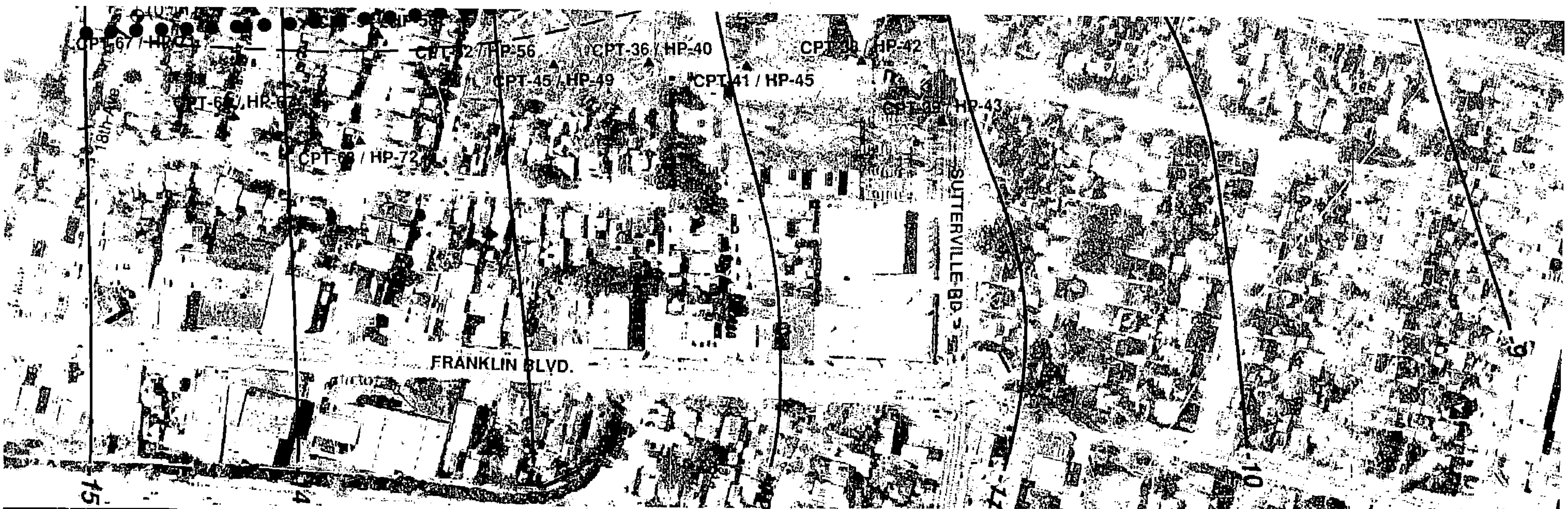
MW-9
MW-23
(0.01)
MW-7 (-0.23)
CPT-3 / HP-5
MW-25 (-0.47)
MW-26 (-0.48)
MW-27 (-0.46)
MW-22
CPT-27 / HP-31
CPT-70
HP-15
CPT-16
CPT-24 / HP-28
HP-20
CPT-8 / HP-12
(-0.23) MW-20
MW-19
CPT-47 / HP-51
CPT-12 / HP-21
HP-7
CPT-34 / HP-38
CPT-15 / HP-26
HP-18
CPT-46 / HP-50
CPT-44 / HP-48
CPT-43 / HP-47
CPT-14 / HP-25
CPT-10
CPT-13 / HP-24
CPT-61 / HP-65
CPT-58 / HP-62
CPT-56 / HP-60
MW-36
CPT-32 / HP-36
CPT-31 / HP-35
MW-37
MW-38 (-0.12)
CPT-33 / HP-37
CPT-66 / HP-70
CPT-42 / HP-46
CPT-40 / HP-44
CPT-26 / HP-30
CPT-37



RESIDUALS AND SOURC
PARTICLE TRACKING RESUL

Union Pacific Railroad Y
Sacramento, Califo
SEPTEMBER 1

FIGUR



ATION

Source Particle Path Over Time (Source near MW-2)

Simulated Groundwater Elevation Contours
One Foot Intervals

Monitoring Well

Residual

Boundary of Groundwater Operable Unit GW-1 and GW-2

atory Holes

April - May, 1990 Locations

September - October, 1990

February, 1991 Locations

Cone Penetration Test

Hydropunch Sample

Fence Line

Property Boundary

NOTES

1. Particle tracking simulated using MODFLOW and MODPATH
2. Parameters used:
   K = 266 feet per day
   $K_y = 0.85\ K_x$
   n = 0.20
3. Modeled as steady state
4. Residual is difference between modeled and actual water level.

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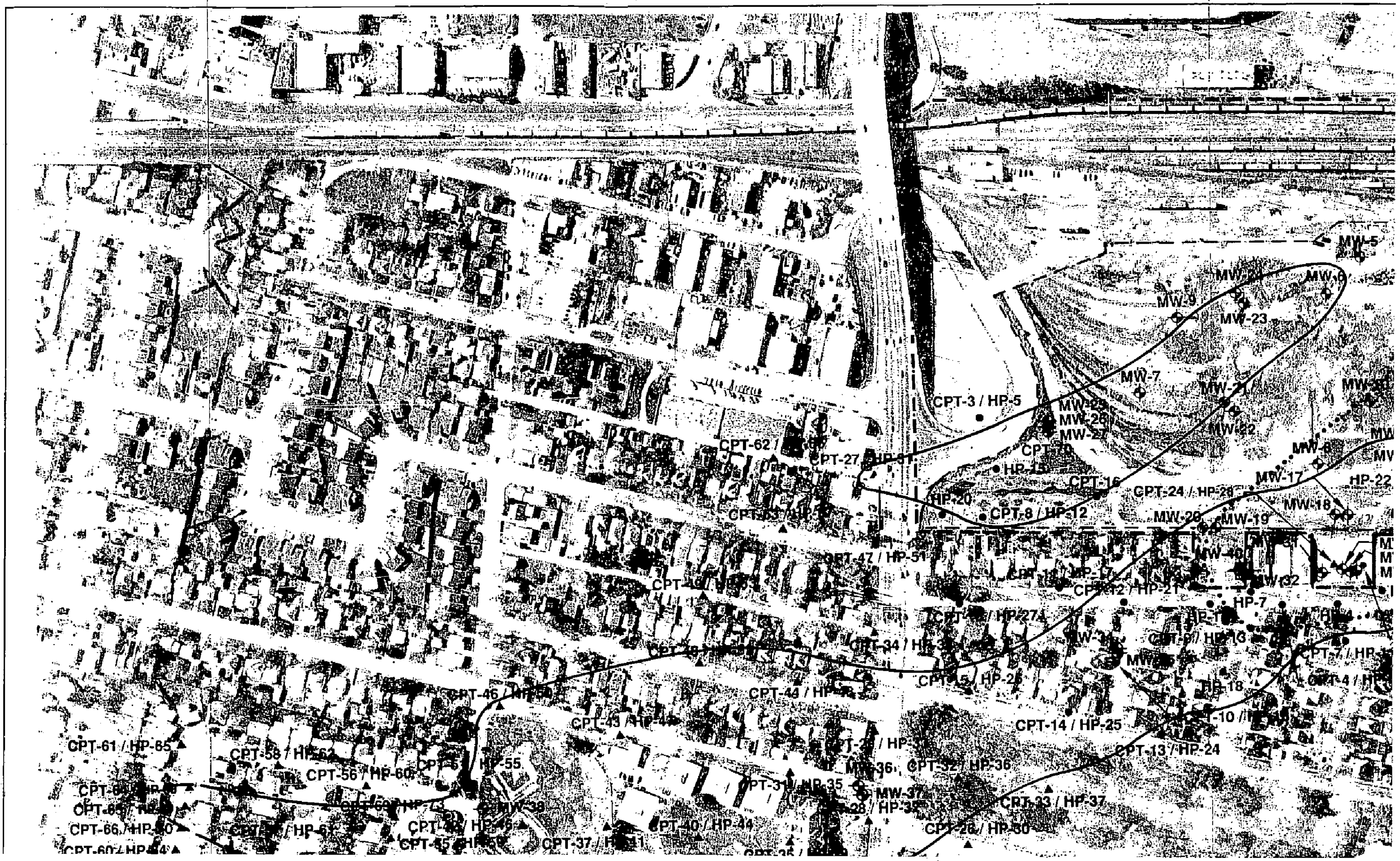
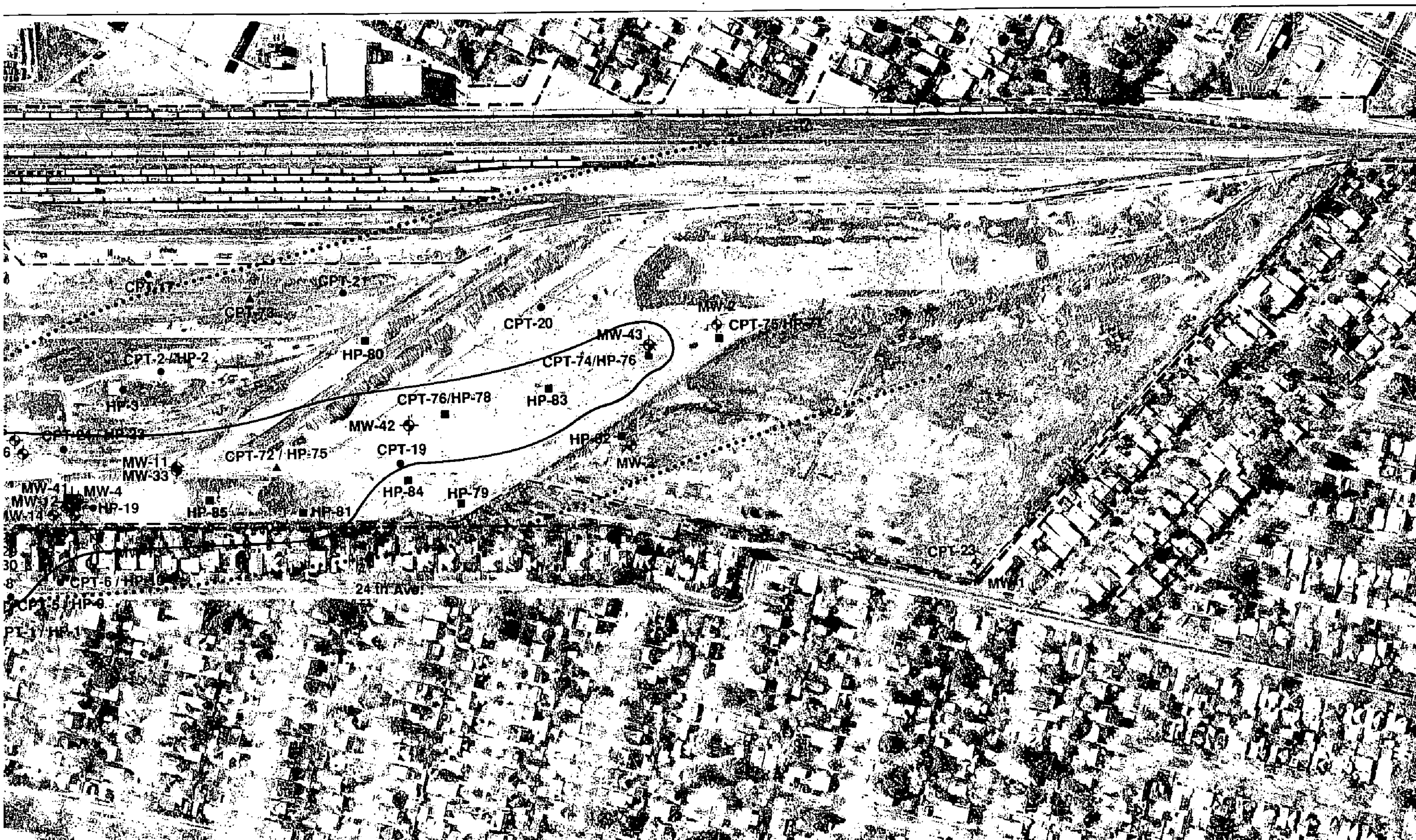
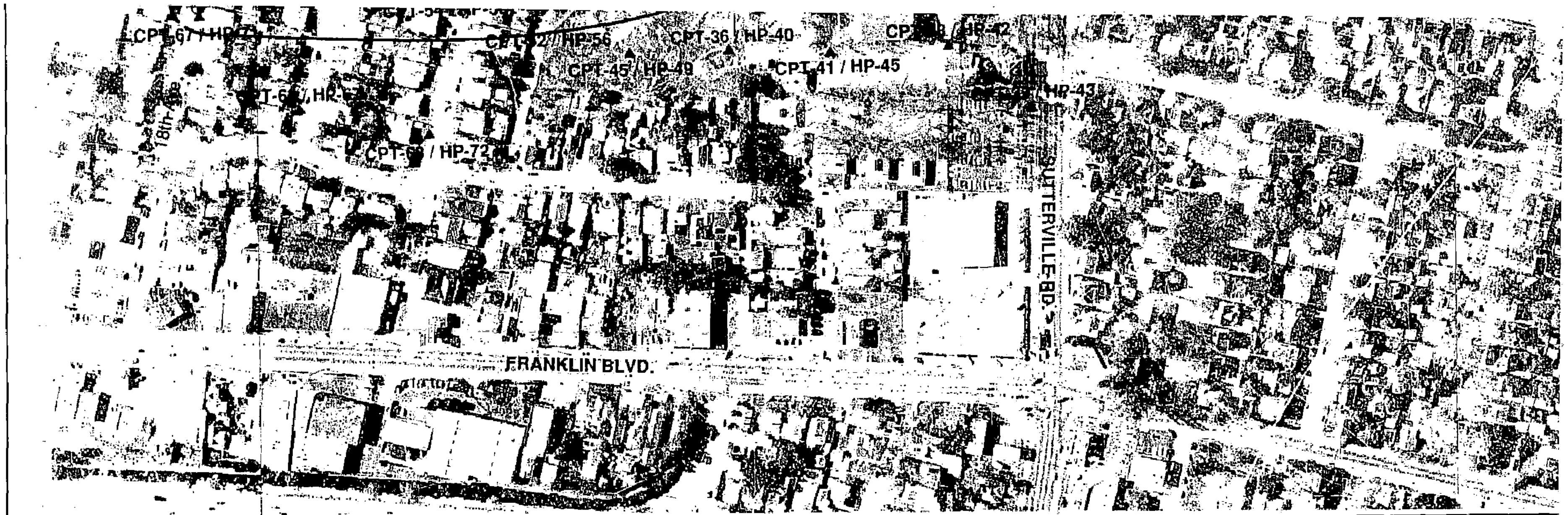

MW-5
MW-9
MW-23
MW-7
CPT-3 / HP-5
MW-26
MW-27
MW-22
MW-8
MW-17
HP-22
MW-18
CPT-16
CPT-24 / HP-28
HP-15
HP-20
CPT-8 / HP-12
MW-20
MW-19
CPT-62
CPT-47 / HP-51
MW-32
HP-7
CPT-12 / HP-21
HP-18
CPT-46
CPT-44 / HP-48
CPT-14 / HP-25
CPT-13 / HP-24
CPT-61 / HP-65
CPT-58
CPT-56 / HP-60
MW-36
CPT-32 / HP-36
CPT-31 / HP-35
MW-37
CPT-33 / HP-37
MW-38
CPT-40 / HP-44
CPT-37
CPT-26 / HP-30
CPT-4
CPT-10



CPT-17
CPT-73
CPT-21
CPT-20
MW-2
CPT-75/HP-77
MW-43
CPT-74/HP-76
HP-80
CPT-2 / HP-2
HP-3
CPT-76/HP-78
HP-83
MW-42
HP-82
MW-2
CPT-72 / HP-75
CPT-19
MW-11
MW-33
MW-4
HP-19
HP-85
HP-81
HP-84
HP-79
CPT-6 / HP-6
24th Ave
CPT-1 / HP-1
CPT-23
MW-1



EXPLANATION

- Capture Zone
- Extraction Well

Exploratory Holes

- April - May, 1990 Locations
- September - October, 1990
- February, 1991 Locations

CPT-13 Cone Penetration Test

HP-2 Hydropunch Sample

Monitoring Well Location

Boundary of Groundwater Operable Unit GW-1 and GW-2

Fence Line

Property Boundary

NOTES

1. Flow rate equals 20gpm from each extraction well (MW-9 and MW-32)
2. Capture Zone simulated using MODFLOW and MODPATH
3. Parameter used:
   $K = 266$ feet per day
   $K_y = 0.85 K_x$
   $n = 0.20$
4. Results shown at steady state
5. Groundwater Operable Unit boundaries from Addendum Remedial Investigation / Feasibility Study (Dames & Moore 1991b).

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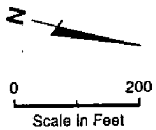

CAPTURE ZONE ANALYSIS RESI

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SEPTEMB

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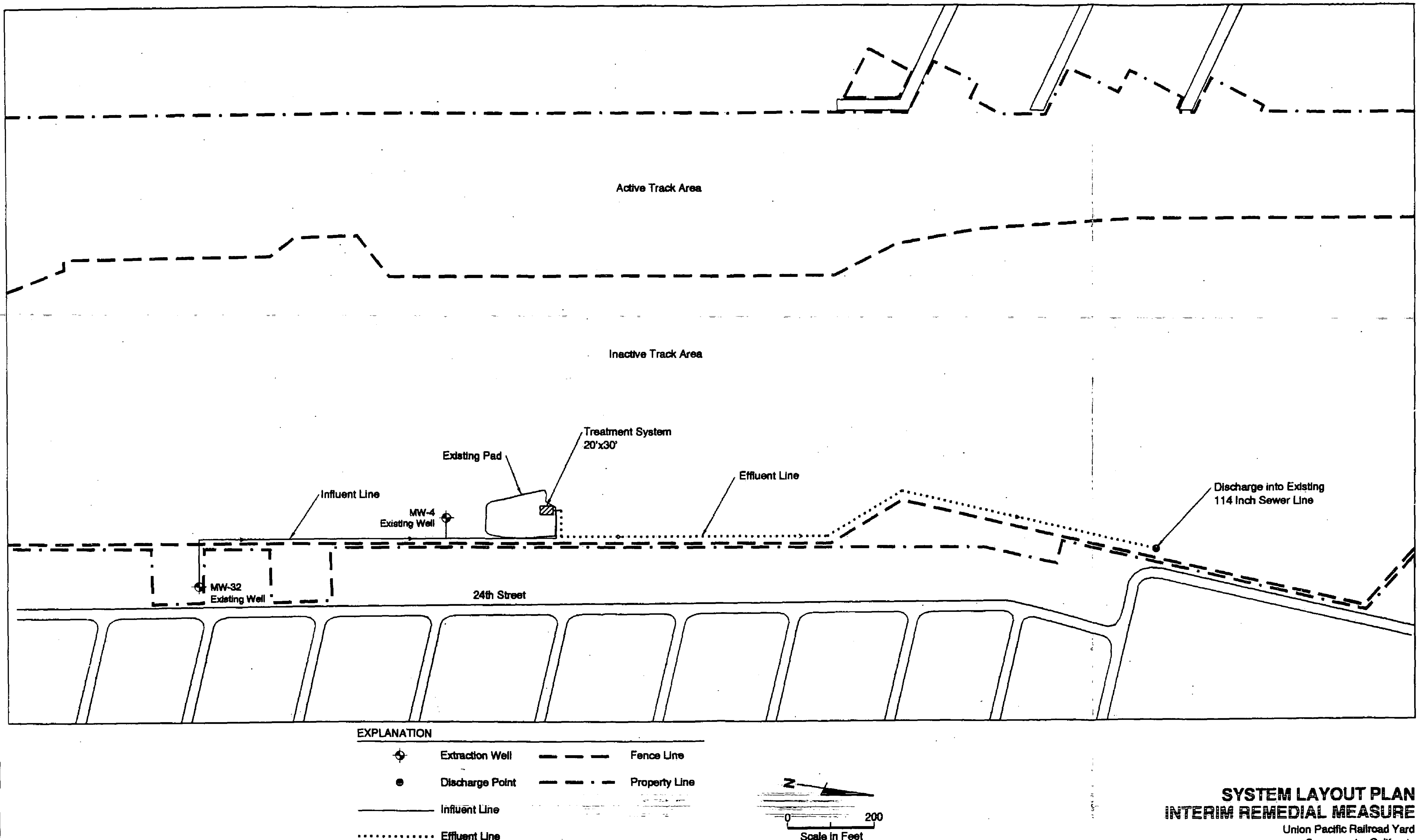


SYSTEM LAYOUT PLAN
INTERIM REMEDIAL MEASURE

Union Pacific Railroad Yard
Sacramento, California
SEPTEMBER 1992

DAMES & MOORE

00173-072-044 SJR REMED 9/24/92

FIGURE 4

Process Stream Flows and Quality

Flow Stream	WATER (1) ①	②	③	④	⑤	AIR (2) ⑥	⑦	⑧
Parameter / Flow Rate	20 GPM	20 GPM	40 GPM	40 GPM	AS NEEDED	600 CFM	600 CFM	600 CFM
1,1 Dichloroethylene	240	81	161	6	6	ND	1.4	ND
1,1 Dichloroethane	21	9.2	15	5	5	ND	0.1	ND
1,2 Dichloroethylene	ND	8.7	4.4	0.5	0.5	ND	0.03	ND
1,1,1 Trichloroethane	20	2.1	11	2	2	ND	0.1	ND
Trichloroethylene	16	5.4	11	5	5	ND	0.1	ND
Benzene	ND	120	60	1	1	ND	0.5	ND
Toluene	ND	6.6	3.3	1	1	ND	0.02	ND
Ethyl Benzene	ND	5.6	2.8	1	1	ND	0.02	ND
Xylenes (Total)	ND	9.4	4.7	1	1	ND	0.03	ND
TPH Gasoline	ND	150	75	UK	UK	ND	UK	ND
Nickel	200	200	200	200	200	ND	ND	ND

(1) All units in ug/L

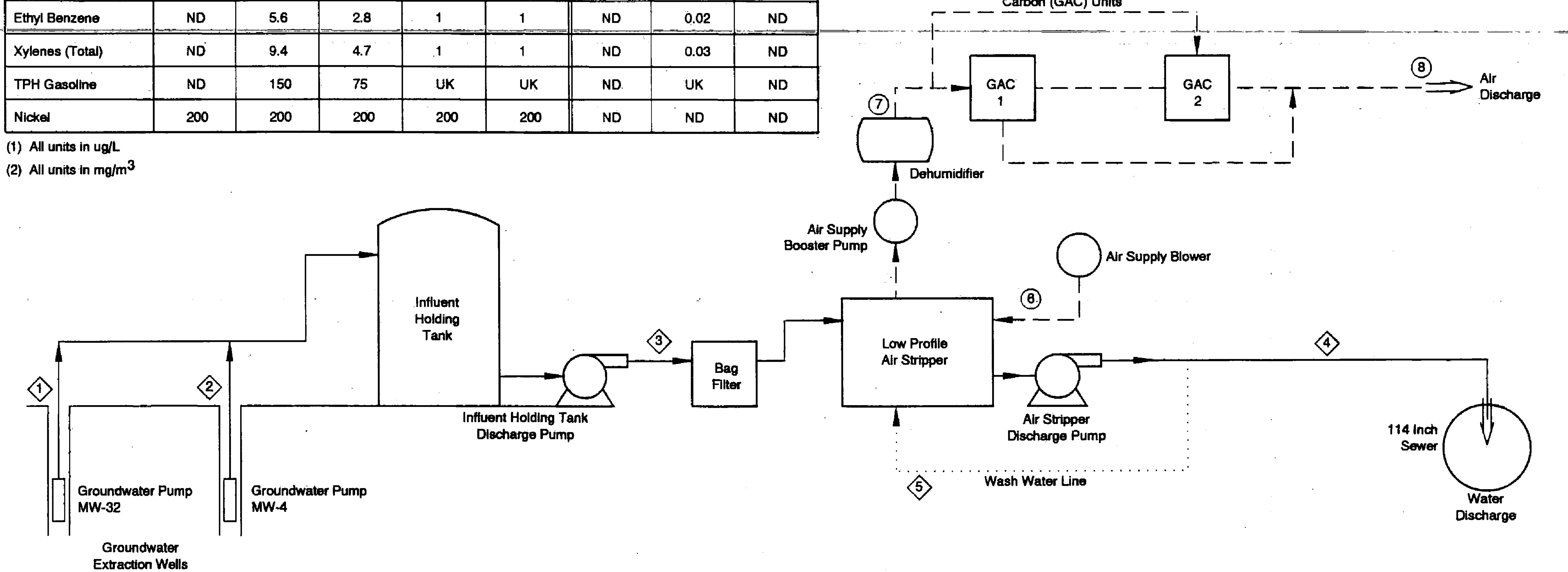
(2) All units in mg/m^3

EXPLANATION

- ——— Groundwater Flow
- ······ Wash Water Flow
- — — — Air Flow
- ND Non - Detect
- UK Unknown

NOTES:

1. Use two existing wells MW-4, and MW-32, for groundwater extraction.
2. MW-4 and MW-32 are both 4 inch, PVC, about 55 feet deep, with water levels about 30 feet below ground surface.
3. Each well will pump 20 gpm.
4. Air stripper will be low profile, "packless", stripper.
5. Treatment of air - stripper off gas by GAC units in series.
6. Air flow through the stripper is expected to be 600 CFM
7. Air discharge concentrations expected to be non-detect (ND)
8. Effluent water quality expected to be below MCL's for VOC's.
9. Effluent holding tank included in air stripper



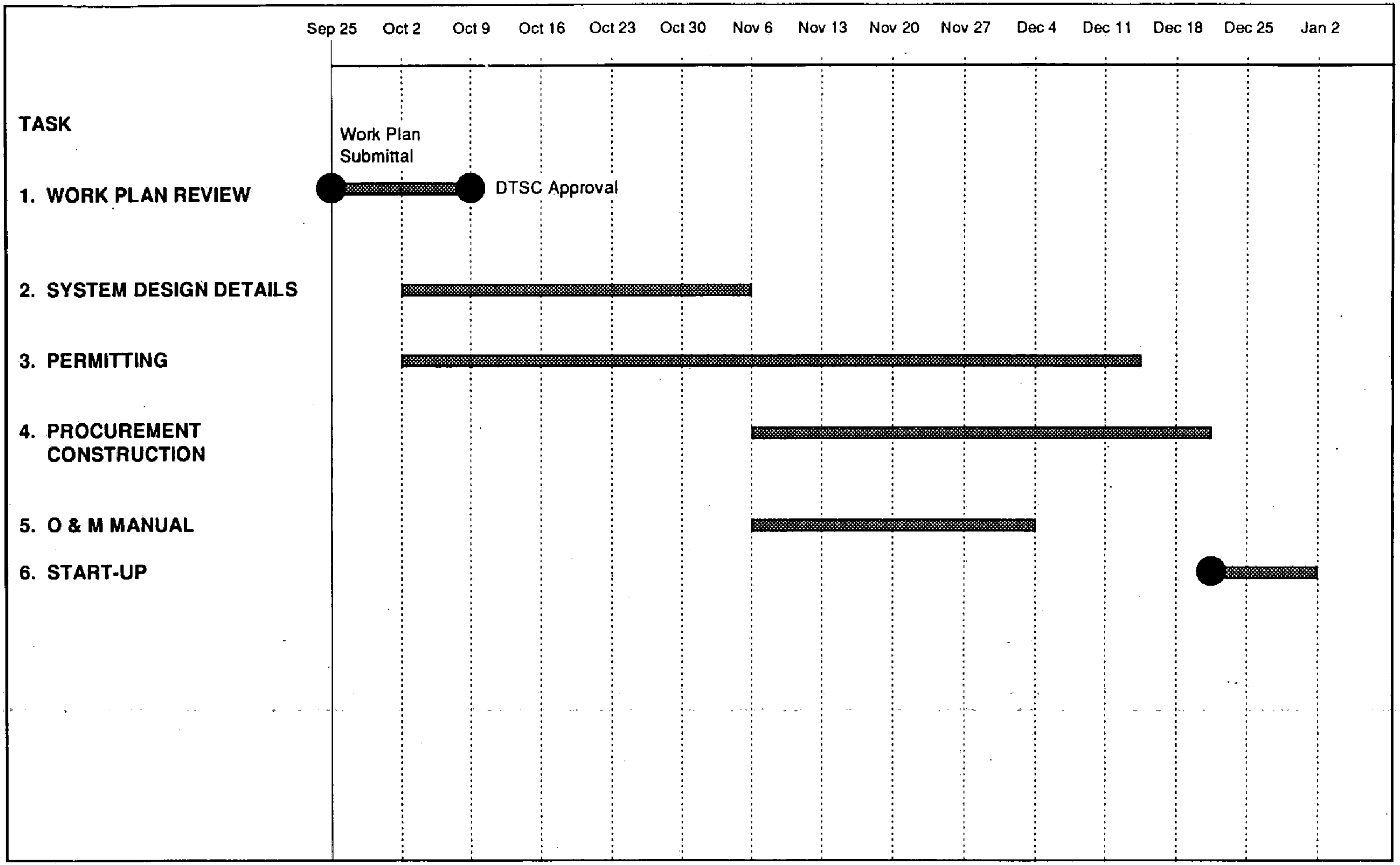
PROCESS FLOW DIAGRAM

Union Pacific Railroad Yard
Sacramento, California
SEPTEMBER 1992

DAMES & MOORE

00173-072-044 SJR 9/9/92 PRO-FLOW

FIGURE 5



SCHEDULE
ON-SITE GROUNDWATER IRM
Union Pacific Railroad Yard
Sacramento, California
SEPTEMBER 1992

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00173-072-044 .IRM

FIGURE 6