



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue
Seattle, Washington 98101

NOV 17 1992

Reply To
Attn Of: HW-113

MEMORANDUM

SUBJECT: Approval of Five-Year Review Status of United Chrome Superfund Site
FROM: *Barbara Neelon for*
Randall F. Smith, Director
Hazardous Waste Division
TO: Dana A. Rasmussen
Regional Administrator

This memorandum requests your approval, on the attached signature page, of the five-year review status of the United Chrome Superfund site in Corvallis, Oregon. The Record of Decision for the site was issued prior to the enactment of the Superfund Amendments and Reauthorization Act of 1986 (SARA).

Five-year reviews are not statutorily required for pre-SARA remedies. However, it is EPA policy to conduct a five-year review at a pre-SARA site if the remedial action results in hazardous substances remaining at the site above levels that allow for unlimited use and unrestricted exposure.

As indicated in the 1991 Interim Close Out Report for the United Chrome site, the intent of the five-year review policy is being fulfilled by extensive reviews that occur on a regular basis and that are documented in biennial EPA performance evaluations and monthly City of Corvallis reports. Consequently, a separate, formal five-year review is not necessary to ensure that human health and the environment are being protected by the remedial action being implemented at the United Chrome site.

In addition, applicable and relevant or appropriate requirements (ARARs) for the remedy have been reviewed. Specifically, the discharge limits for the on-site treatment plant have been adjusted to be consistent with the local limits for the POTW (publicly owned treatment works).

Attached is the Performance Evaluation of Site Remediation, the biennial report prepared by EPA's contractor for the United Chrome site. This evaluation shows that the chromium concentrations in the upper groundwater zone have been significantly reduced and that the chromium plume has been

contained. Also attached is the September 1992 monthly operations report prepared by the City of Corvallis.

EPA will initiate a more formal five-year review process after the cleanup goals are achieved and oversight is reduced if hazardous substances remain at the site above levels that allow for unlimited use and unrestricted exposure.

Attachments

cc: Hugo Fleishman, HQ (with reports)
Al Goodman, OOO
Paul Burnet, DEQ

DECLARATION

I have determined that the intent of the five-year review policy is being fulfilled for the United Chrome site. Human health and the environment are being protected by the remedial action being implemented at the site. Chromium concentrations in the groundwater have been significantly reduced and the chromium plume has been contained.

Approved by:

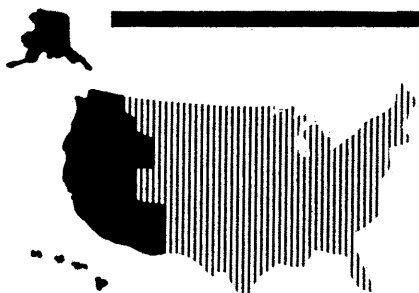


Regional Administrator

NOV 30 1992

Date

ARCSWEST



*Remedial Activities at
Selected Uncontrolled
Hazardous Waste Sites in
the Zone of Regions IX and X*

**PERFORMANCE EVALUATION
OF SITE REMEDIATION
for the
UNITED CHROME PRODUCTS SITE
CORVALLIS, OREGON
April 1989 to May 1991**



*Environmental Protection Agency
Contract No. 68-W9-0031*

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NOV 18 1992

SUPERFUND REMEDIAL BRANCH

**PERFORMANCE EVALUATION
OF SITE REMEDIATION
for the
UNITED CHROME PRODUCTS SITE
CORVALLIS, OREGON
April 1989 to May 1991**

Prepared by

CH2M HILL

September 1991

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EXECUTIVE SUMMARY

This report presents an evaluation of groundwater extraction and treatment system performance for the United Chrome Products site in Corvallis, Oregon and summarizes performance data for the period of operation between April 1989 and June 1991. Remedial action of contaminated groundwater at the site began in August 1988 and discussion of operations data preceding April 1989 has been included where necessary to assist in describing performance characteristics and site history.

The United Chrome extraction and treatment system has been in operation for 35 months, during which time approximately 9.7 million gallons of contaminated groundwater containing 26,732 pounds of hexavalent chromium Cr(VI) have been removed. To accelerate removal of Cr(VI) from contaminated soils and to provide supplemental recharge for the upper zone, 5.2 million gallons of city-supplied water have been recharged through two infiltration basins and one infiltration trench. A summary of semiannual performance data for the period between August 1988 and June 1991 is provided in Table ES-1.

Evaluation of site operations data indicates the extraction system has achieved considerable success in reducing the magnitude of Cr(VI) concentrations present in the upper zone, has prevented offsite migration of the contaminant plume, and reduced discharges of contaminated groundwater to local surface drainage ditches. This success can be measured by the Cr(VI) concentration decreases observed in the groundwater extraction and observation well monitoring network, and results of periodic sampling of surface water downstream of the site. Hexavalent chromium concentrations have been reduced from 1,923 mg/l in August 1988 to 87 mg/l in June 1991. The observation wells used to monitor for plume breakthrough and remediation progress at interior points of the plume confirm hydraulic performance of the extraction system. Ten of the 11 monitoring wells tested in April 1991 were below the site cleanup goal of 10 mg/l Cr(VI). This system has demonstrated that remedial action goals can be met with continued operation of the system.

This evaluation presents several recommendations designed to increase the concentration of Cr(VI) in the plant influent while decreasing the volume of extracted groundwater requiring treatment. These recommendations, if effective, will continue to provide for a timely remediation schedule and should assist in reducing the costs of operating the onsite treatment plant. Many of the recommendations discussed have been incorporated in a revised Pumping Plan for the upper zone extraction system that is part of the Fifth Amendment to the Administrative Order and is included as Appendix B to this report.

Performance testing of the onsite treatment system indicates effective treatment of extracted groundwater can be obtained at concentrations as low as 10 mg/l Cr(VI). System performance at low concentrations can be maintained by optimizing chemical

feed rates and reducing plant throughput below the existing rate of 72 gpm. The testing also demonstrates that large volumes of extracted groundwater can be treated successfully to reduce Cr(VI) to Cr(III) using a batch reaction process. An alternative method (not tested) that also provides for reduction of Cr(VI) to Cr(III) could use static mixers installed in the plant effluent pipe to disperse chemical reactants. Either technique has application under a “reduce and discharge” scenario.

A description and cost estimate for EPA and City of Corvallis proposed discharge limits using several alternative treatment schemes is also presented. These options include:

- Option A--Operation of the treatment plant as is under EPA discharge limits.
- Option B--Operation of treatment plant under a “reduce and discharge” program. Extracted groundwater would be treated to reduce Cr(VI) to Cr(III). The treated groundwater would be discharged under City of Corvallis proposed “local limits.”
- Option C--Modification of the treatment plant to permit automated operation. Treated groundwater would be discharged under EPA discharge limits.
- Option D--Operation of the treatment plant under a “reduce and discharge” program. Extracted groundwater will be treated to reduce Cr(VI) to Cr(III) and the effluent discharged under EPA limits.

The cost estimate compares each alternative in terms of annual and present value costs, and cost per pound of Cr(VI) removed. The cost estimates indicate that treatment costs, presently estimated at \$40 per pound of Cr(VI) removed, will double to \$80 per pound of Cr(VI) removed by late 1992 under the existing treatment program. Potential cost savings from \$10 to \$40 per pound of Cr(VI) removed may be realized in 1992 by implementing either Options B, C, or D.

Table ES-1
United Chrome Products Site
Summary of Remediation Accomplishments
August 1988 to June 1991

Period	Cr(VI) Extracted			Extraction Gallons			Recharge Gallons			Average Extraction Rate ^b (gpm)	Average Concentration ^b (mg/l)
	Pounds	Percent of Total ^a	Cumulative Pounds	Gallons	Percent of Total	Cumulative Gallons ^a	Gallons	Percent of Total ^a	Cumulative Gallons		
Aug 88 - Dec 88	3,501	13	3,501	264,619	3	264,619	239,209	4	239,209	10.0	1,589
Jan 89 - Jun 89	3,854	14	7,355	358,252	4	622,871	169,700	3	408,909	12.1	1,290
Jul 89 - Dec 89	6,021	23	13,376	1,071,150	11	1,649,021	961,475	15	1,370,384	7.5	661
Jan 90 - Jun 90	6,823	26	20,199	2,344,100	24	4,038,121	1,256,815	19	2,627,199	10.9	343
Jul 90 - Dec 90	4,117	15	24,316	2,674,170	28	6,712,291	2,082,382	32	4,709,581	11.7	185
Jan 91 - Jun 91	2,416	9	26,732	3,010,450	31	9,722,741	1,779,475	27	6,489,057	14.5	97
TOTALS	26,732	100		9,722,741	100		6,489,057	100			

^aPercentage of total is based on cumulative pounds of chromium, extraction gallons, and recharge gallons for the period August 1988 to June 1991.

^bWeighted (monthly gallonage) average.

Chapter 1

INTRODUCTION AND OBJECTIVES

Chapter 1

INTRODUCTION AND OBJECTIVES

This report is the second performance evaluation of the United Chrome groundwater remedial action program. The first performance evaluation completed in April 1989 focused on startup performance observed during the first six months of operation (August 1988 to April 1989). This performance evaluation is for the period April 1989 to June 1991 and its purpose is to assess the validity of initial predictions made during the remedial design by comparing actual performance with expected performance, to identify deviations that may affect the remedial action timetable and goals, and to determine in general if the remedial action objectives can be met using the selected alternative.

The primary steps of the evaluation were to: 1) review general performance criteria, 2) evaluate the effectiveness of the upper zone remedial action, 3) assess overall performance of the treatment facility and its operation, and 4) identify cost-effective modifications and treatment scenarios to improve overall system performance.

The tasks completed included:

- Review extraction system operations data generated since the previous performance evaluation (April 1989) to identify cleanup trends and evaluate the effectiveness of the current pumping plan.
- Evaluate the monitoring program to obtain a balance between technical adequacy and cost-effectiveness.
- Review equipment performance and maintenance schedules to identify deficiencies or items in need of replacement.
- Develop and implement a study to evaluate the performance of the treatment system to identify modifications necessary to sustain system performance as Cr(VI) concentrations continue to decrease.
- Develop cost estimates to identify treatment plant operation costs for onsite treatment, with and without removal of trivalent chromium, from the plant effluent.

These evaluation tasks were performed based on CH2M HILL's understanding of system design, construction and performance, knowledge of facility operations, and performance criteria. Specific tasks related to the treatment system study were performed with the cooperation and assistance of City of Corvallis operating staff.

The contents of this report are presented in five chapters. Chapter 1 provides background information on site history and report organization. Chapter 2 describes operation and performance of the groundwater extraction system and offers recommendations intended to accelerate cleanup of areas where progress has been slow. Chapter 3 presents results of a study conducted to evaluate treatment system performance for low influent Cr(VI) concentrations and the feasibility of performing batch treatment of large volumes of extracted groundwater to convert Cr(VI) to Cr(III). Chapter 4 describes several options for treating extracted groundwater at the site with a cost estimate and comparison against the existing treatment scheme for each. Chapter 5 provides conclusions and an evaluation of remedial action effectiveness.

BACKGROUND

The United Chrome Products site, in Corvallis, Oregon, is a former industrial hard chrome plating facility sited on approximately 8 acres just north of the Corvallis Airport. The site and all contiguous properties are owned by the City of Corvallis.

Facility operations and waste management practices resulted in hexavalent chromium [Cr(VI)] contamination of surface water (local drainageways), soils, and groundwater at the site. Figure 1-1 shows a plan view of the site and the extent of groundwater contamination initially present in the upper zone and deep aquifer.

The local subsurface is characterized by two water-bearing zones separated by a silty-clay aquitard. The upper zone consists mostly of silt and is the primary zone of contamination. The deep aquifer consists of a sand and gravel mixture that is capable of supplying potable water for commercial and residential use.

The contaminant plume in the upper zone extended about 300 feet downgradient from the source areas with Cr(VI) concentrations up to 19,000 mg/l detected prior to remediation startup. The deep aquifer plume extends about 400 feet downgradient from the source area with Cr(VI) concentrations up to 223 mg/l measured. Groundwater remediation in the deep aquifer began on July 25, 1991.

A Comprehensive Environmental Response Compensation and Liability Act (CERCLA) remedial investigation and feasibility study was completed in August 1985 by CH2M HILL and Ecology & Environment, Inc. On September 12, 1986, EPA signed the Record of Decision (ROD), specifying remedial action measures and goals for the site.

One element of the remedy selected by EPA and the Oregon Department of Environmental Quality (DEQ) consisted of the installation of a series of shallow wells to extract groundwater from the upper zone and the construction of an onsite treatment facility to

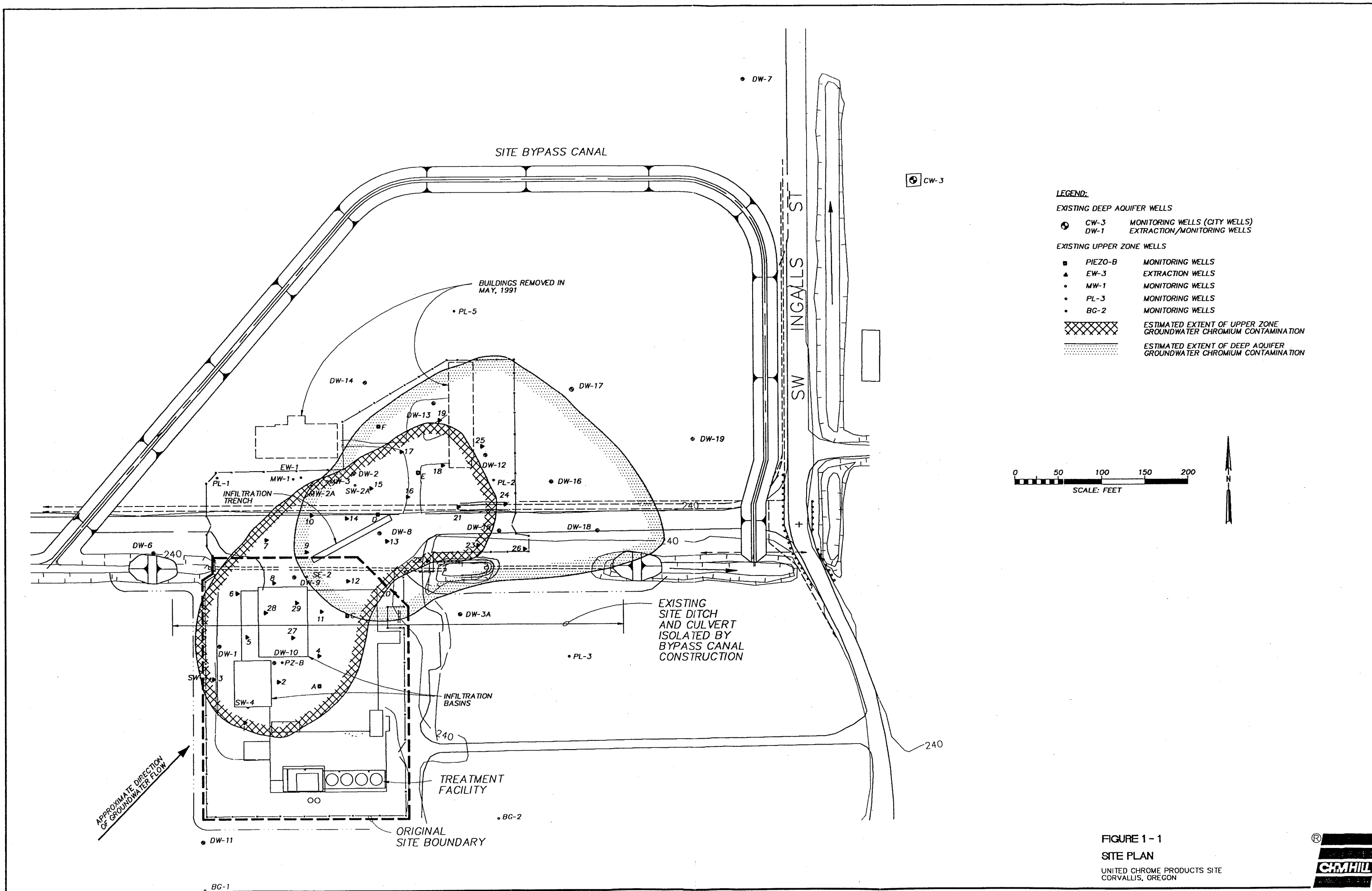


FIGURE 1 - 1
SITE PLAN

UNITED CHROME PRODUCTS SITE
CORVALLIS, OREGON



remove chromium contamination from extracted groundwater. Construction was completed in July 1988 and startup began shortly thereafter in August 1988.

Operation of the upper zone groundwater extraction and treatment system has been regulated under an EPA Administrative Order. The initial version of the Administrative Order required the City of Corvallis to operate systems at the site 40 hours per week. The Administrative Order was amended in October 1989 and a clause added requiring the City to extract a minimum of 80,000 gallons of groundwater per week. The Order was amended again in October 1990 with the extraction quota increased to 100,000 gallons per week.

This system has now been in operation for 35 months and has achieved considerable success in decreasing the magnitude of Cr(VI) concentrations present, reducing the volume of the contaminant plume, and preventing further migration of Cr(VI) beyond the initial plume boundaries. As the remedial action system continues to operate at the site, periodic assessment of its performance is necessary to establish the effectiveness of the implemented alternative and to identify measures that will permit remedial objectives to be achieved in a timely and cost-effective manner.

Chapter 2

GROUNDWATER EXTRACTION SYSTEM

Chapter 2

GROUNDWATER EXTRACTION SYSTEM

OBJECTIVES AND APPROACH

This section presents a summary and evaluation of operations data for the upper zone groundwater extraction system, infiltration basins, trench, and observation well monitoring network for the period between August 1988 and June 1991. The objectives for this evaluation were: 1) to gain additional insight on the performance of the system, 2) to confirm remediation progress, 3) to identify measures or alternative strategies to accelerate cleanup, and 4) to define future monitoring requirements to obtain a balance between technical adequacy and cost effectiveness.

The approach used in conducting the evaluation consisted of compiling and reviewing data provided in monthly progress reports prepared by the City of Corvallis and comparing the performance data with remedial action objectives developed for the upper zone. This approach considered three aspects of site operations:

- Performance of the infiltration basins and trench in terms of effectiveness in flushing Cr(VI) from highly contaminated soils in the unsaturated zone, delivery of supplemental recharge to the upper zone, and assessment of their impact on the site groundwater flow system
- Performance of individual extraction wells and well groups to identify areas of the plume where well interference effects or other adverse conditions may be slowing remediation progress
- Location, schedule, and monitoring parameters to determine whether existing practices are adequate and/or redundant to confirm hydraulic containment of the plume, document aquifer response to infiltration and pumping, and confirm remediation progress at interior areas of the plume

Recommendations and facility modifications implemented by the City of Corvallis since startup in August 1988 have significantly increased operations efficiency at the site. These improvements, in concert with operator experience, have contributed substantially to the increased performance of the groundwater extraction and treatment systems.

REMEDIATION PROGRESS

A summary of cumulative extraction gallons and pounds of Cr(VI) removed at each well location through December 1990 is provided in Figure 2-1. Total extraction

quantities range from 61,000 gallons (EW-10) to 681,000 gallons (EW-27) and Cr(VI) yields vary from 39 pounds (EW-23) to 2,886 pounds (EW-9).

COMPARISON WITH ROD GOALS

Remediation goals for the United Chrome site are described in the *Remedial Investigation Feasibility Study Report* (CH2M HILL and Ecology and Environment, 1985) and in the *Record of Decision* (EPA, 1986). The cleanup objective for the upper zone at United Chrome is to reduce Cr(VI) concentration in groundwater to less than 10 mg/l. This objective has been interpreted such that remediation will continue until water quality monitoring in upper zone wells consistently satisfies this criteria.

As of June 1991, 4 extraction wells (EW-4, EW-17, EW-18, and EW-23) and 10 of the 11 observation wells used for semiannual sampling have Cr(VI) concentrations equal to or less than 10 mg/l. In the remaining extraction wells, nine vary from 10 mg/l to 100 mg/l and ten range from 100 mg/l to 530 mg/l.

CLEANUP TRENDS AND LIMITATIONS

Monitoring data indicate that remediation progress is highly variable with cleanup rates influenced primarily by the well location and volume of water that can be flushed through a given area. To evaluate cleanup trends, Cr(VI) concentrations have been plotted against gallons of water extracted for several different well locations (Figure 2-2). The increasing concentration trend present during the early stages of pumping at Well EW-6 (Figure 2-2) is characteristic for many of the Wells at United Chrome. This pattern results from a variable distribution of contaminant mass in the upper zone. Extraction wells in the vicinity of Infiltration Basin No. 1 (EW-6 and EW-28) have yielded the largest volume of groundwater and exhibit the greatest overall decrease in Cr(VI) concentration, and may be used as a baseline to evaluate and forecast progress at other locations.

The concentration of chromium in extracted groundwater for the combined well flows has decreased dramatically from 1,923 mg/l to 87 mg/l in 35 months of operation (Figure 2-3). The rate of decline has decreased in recent months and is beginning to exhibit an asymptotic or “tailing” effect. This condition is also present at individual well locations and may result from any one or combination of contaminant transport and geochemical processes occurring in the subsurface. These processes include:

- Variable length contaminant flow paths--Contaminated water at the perimeter of a well capture zone must travel a greater distance (at lower velocity) to reach the extraction point.
- Diffusion of Cr(VI) from fine grained sediments--Localized variations in the rate of groundwater flow arise in heterogenous settings because of the interlayering of high and low permeability sediments. Pumping

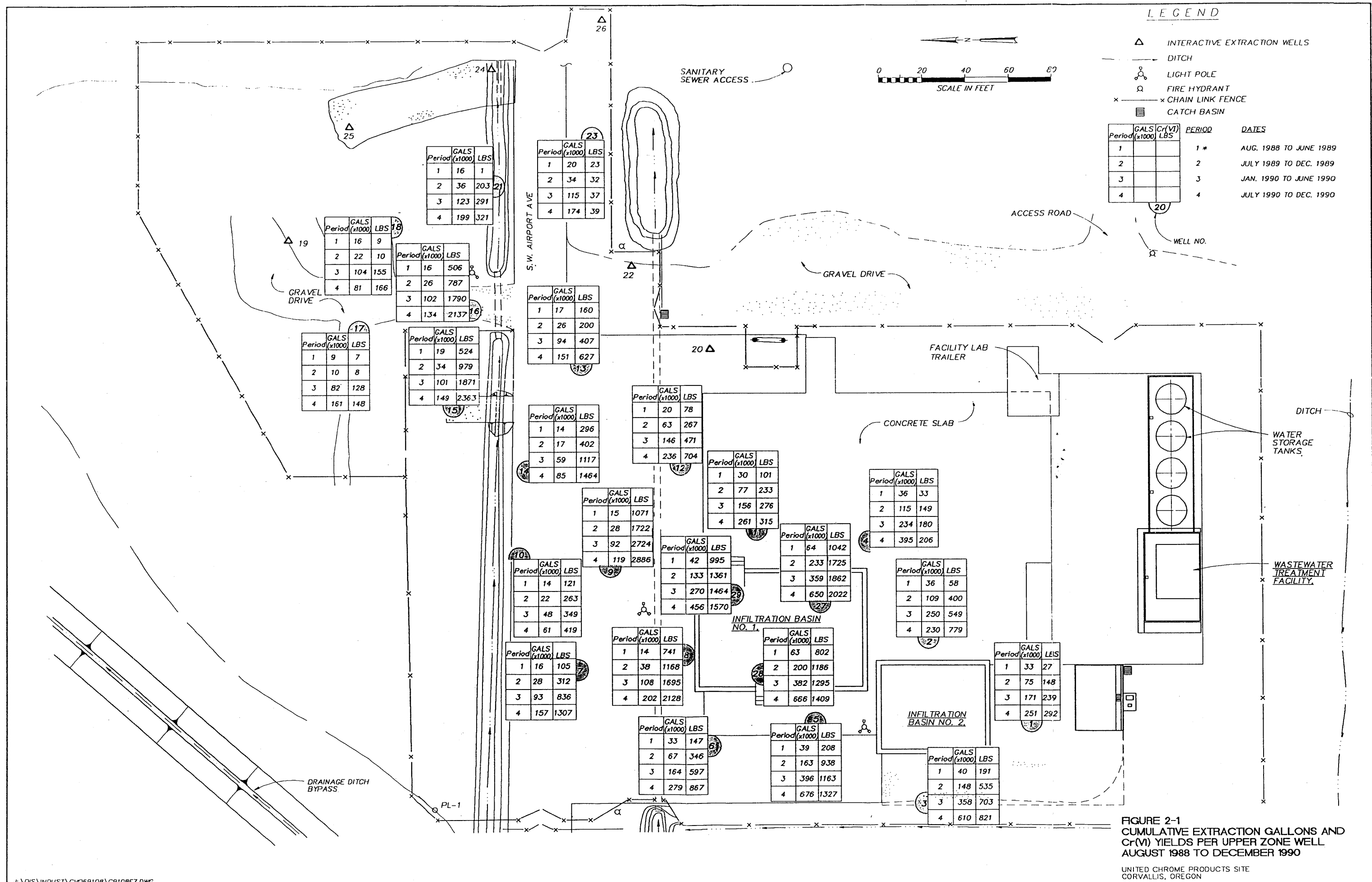


FIGURE 2-1
CUMULATIVE EXTRACTION GALLONS AND
Cr(VI) YIELDS PER UPPER ZONE WELL
AUGUST 1988 TO DECEMBER 1990

UNITED CHROME PRODUCTS SITE
 CORVALLIS, OREGON

Figure 2-2
United Chrome Products Site
Cr(VI) Concentration Trends

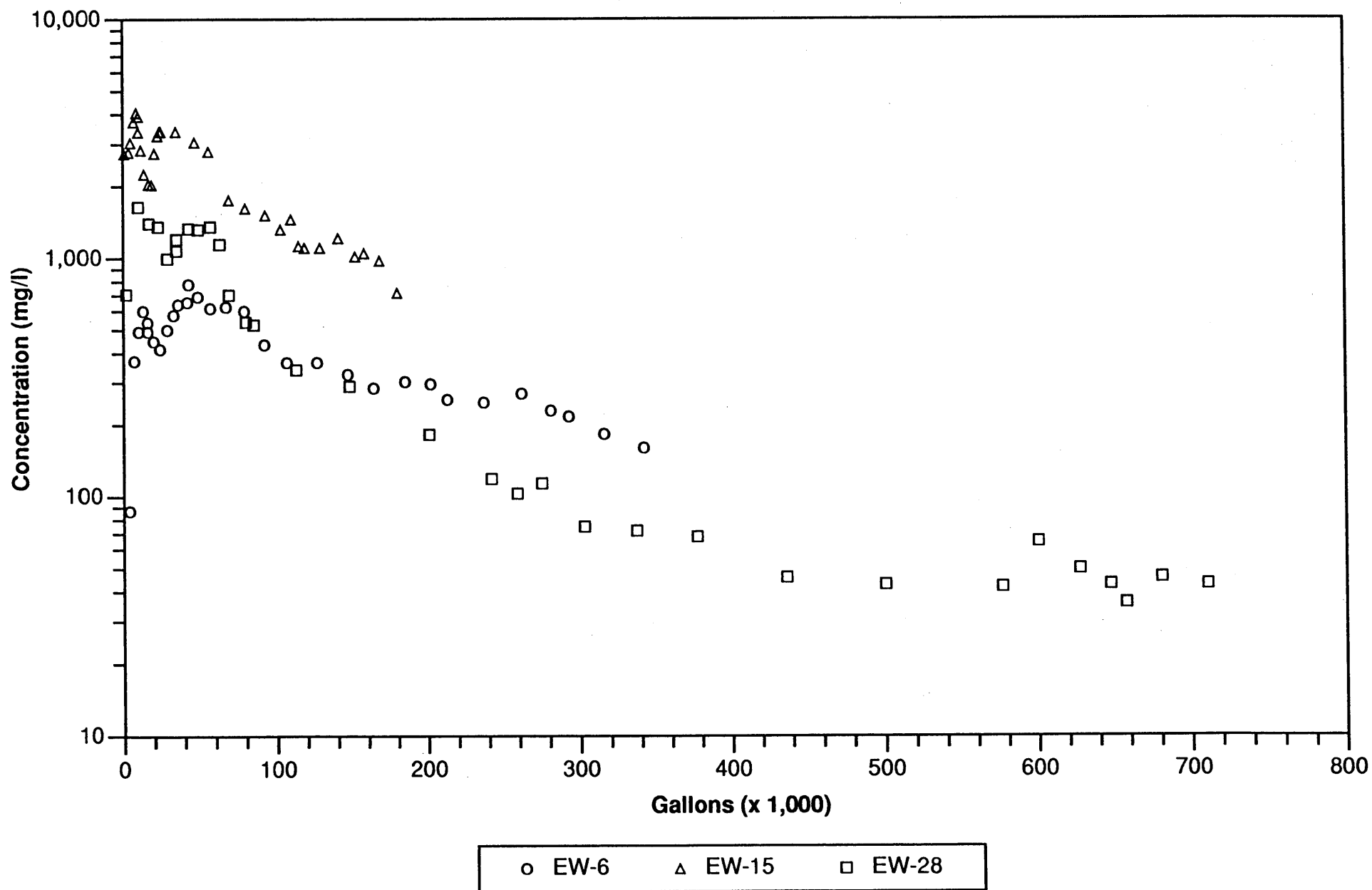
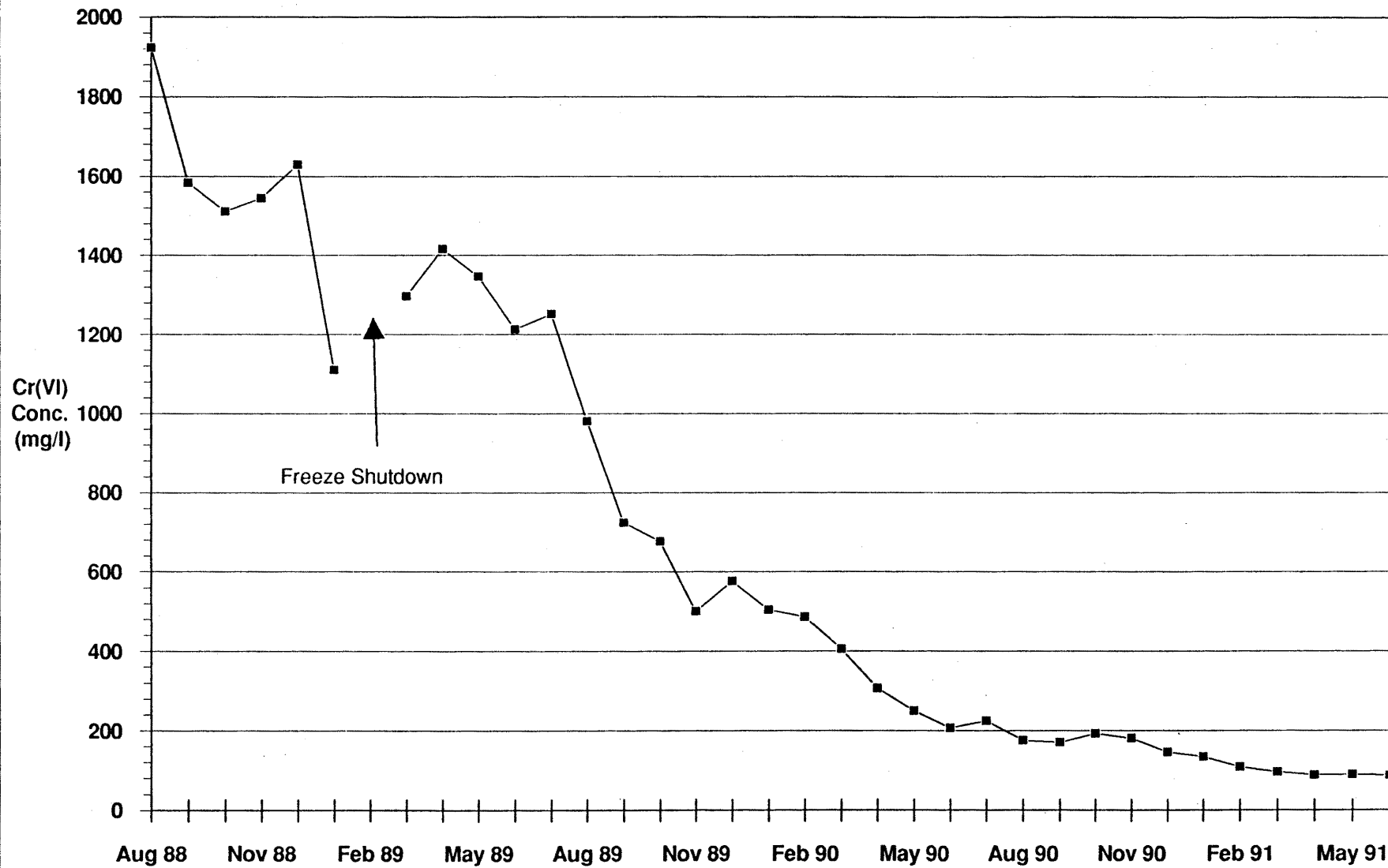


Figure 2-3
Average Monthly Influent Cr(VI) Concentration



induces rapid flushing of the high permeability zones; however, contaminants are removed very slowly by diffusion from the low permeability zones. The rate of diffusion is dependent primarily on the concentration gradient present between the two zones. Low permeability sediments can act as leaky contaminant reservoirs.

- Hydrodynamic isolation--Localized areas of velocity stagnation (zero flow) often develop between pumping wells. These zones can only be remediated by modifying existing flowline patterns by changing the location of pumping wells, or by altering pumping rates among existing wells.
- Desorption of Cr(VI) from soil particles and dissolution of solid phase Cr(VI)--Both of these processes frequently result in the slow release of contaminants, often at concentrations well below their chemical equilibrium levels. This condition results in extraction of large volumes of low concentration water rather than small volumes of high concentration water, unless the pumping approach is modified to account for these effects.

As the total mass of recoverable Cr(VI) in the subsurface is reduced, the influence of these processes becomes more apparent. Because these processes are not well understood, accurate prediction of future remediation progress is increasingly difficult.

CLEANUP DURATION

The time required to attain the remediation goal of 10 mg/l in the upper zone groundwater has been addressed in previous reports using two approaches. The variable common to both methods is the time required to remove a pore volume of contaminated groundwater.

A pore volume is defined as the volume of contaminated groundwater present within the pore spaces (water filled voids) of aquifer material bounded by the contaminant plume boundary. At the United Chrome site, a single pore volume has been estimated to contain 2.6 million gallons of water (within the 10 mg/l concentration contour). The time required to remove a pore volume is simply the pore volume (gallons) divided by the total pumping rate (gallons/min). At a sustained rate of 10 gpm, a pore volume at United Chrome is extracted every 6 months. However, due to the highly variable well yields at the site, some areas are flushed more rapidly than others, resulting in reduced cleanup rates at low water yield areas of the site.

The first approach, described in an appendix of the first performance evaluation (*Performance Evaluation of the United Chrome Groundwater Extraction and Treatment Facility*, CH2M HILL, 1989), used a two-step model based on an equilibrium groundwater Cr(VI) concentration of 52 mg/l [Adsorption and Desorption of Cr(VI) in an Alluvial Aquifer near Telluride, Colorado, *Journal of Environmental Quality*, 1985]. The remedial action timeframe is equal to the time required to lower the initial concentration to

the equilibrium concentration [assumed to be two to three times the pore volume extraction (PVE) rate], plus the time required to lower the concentration from the equilibrium value to the cleanup level (assuming an exponential rate of decline). Interpretations made from this graphical model indicate a remediation time frame of approximately 15 years for a PVE rate of 1 year (average over the past 35 months) and 8 years for a PVE rate of 0.5 years (average of the past 12 months).

The second approach involves the use of a laboratory column leach test to simulate the removal of Cr(VI) from a contaminated soil core taken from upper zone material (*Appendix B, Stage 2 Deep Aquifer Drilling Technical Report*, CH2M HILL, 1990). The results from this test indicate that CR(VI) concentrations can be decreased from 1,000 mg/l to less than 10 mg/l in six to nine pore volume flushes or 3 years to 5 years at current extraction rates. However, this estimate is for fluid flow in one dimension. The actual number of pore volumes that must be extracted will be greater because of the complex environment in which groundwater moves and the presence of sediment heterogeneity.

Uncertainties about sediment heterogeneity, distribution of contaminant mass, variable groundwater extraction rates, and seasonal weather patterns that limit groundwater availability make it difficult to estimate the timeframe required to achieve the remediation goals set forth in the ROD. The actual cleanup time will consist of a lengthy transitional period where individual wells attain the goal of 10 mg/l at different times. Periodic re-evaluation of remediation performance will be used to develop pumping schedules that provide for a timely remediation schedule.

OPERATIONS AND PERFORMANCE HISTORY

This section presents operations and monitoring data for the infiltration basins and trench, extraction well system, and observation well network. Each system is discussed separately, accompanied by a brief description and schematic diagram where necessary to depict construction and operation details. Operations data are presented using graphical and/or tabular summaries to illustrate data trends.

INFILTRATION BASINS AND TRENCH

System Components

Two infiltration basins and one infiltration trench are located as shown in Figure 2-4. The basins release water to the subsurface through open bottoms, flushing Cr(VI) from soils in the vadose zone to the water table for recovery by adjacent extraction wells. The flushing process also provides a source of groundwater recharge for the upper zone extraction wells to replace water removed by pumping.



The basins are a component of the original remedial design and have operated continuously except for a 5-month period between December 1988 and April 1989.

The infiltration trench was constructed by the City of Corvallis in May 1990 and began operation shortly thereafter. The trench is expected to increase extraction well yields along the longitudinal axis of the plume and will operate primarily during the summer and early fall months to provide supplemental recharge as decreased precipitation and underflow reduce the amount of water available for extraction. Another important benefit of the trench is the higher groundwater velocities created by the increased hydraulic head. This condition should accelerate removal of contaminated groundwater from wells in this vicinity.

Water is discharged into each basin through an outlet controlled manually or by a float valve that maintains the water level at a relatively constant depth. The water depth may vary from zero to 4 feet above ground between water inputs.

The infiltration trench operates in a similar manner, but delivers water directly to the subsurface (depth of 8 feet) through a 4-inch-diameter perforated pipe. This method provides for a controlled release of water directly to the water table.

The water used for basin and trench inflows has been obtained from the City drinking water system. In the future, groundwater extracted from deep aquifer remediation may be used to supplement this source.

System Performance

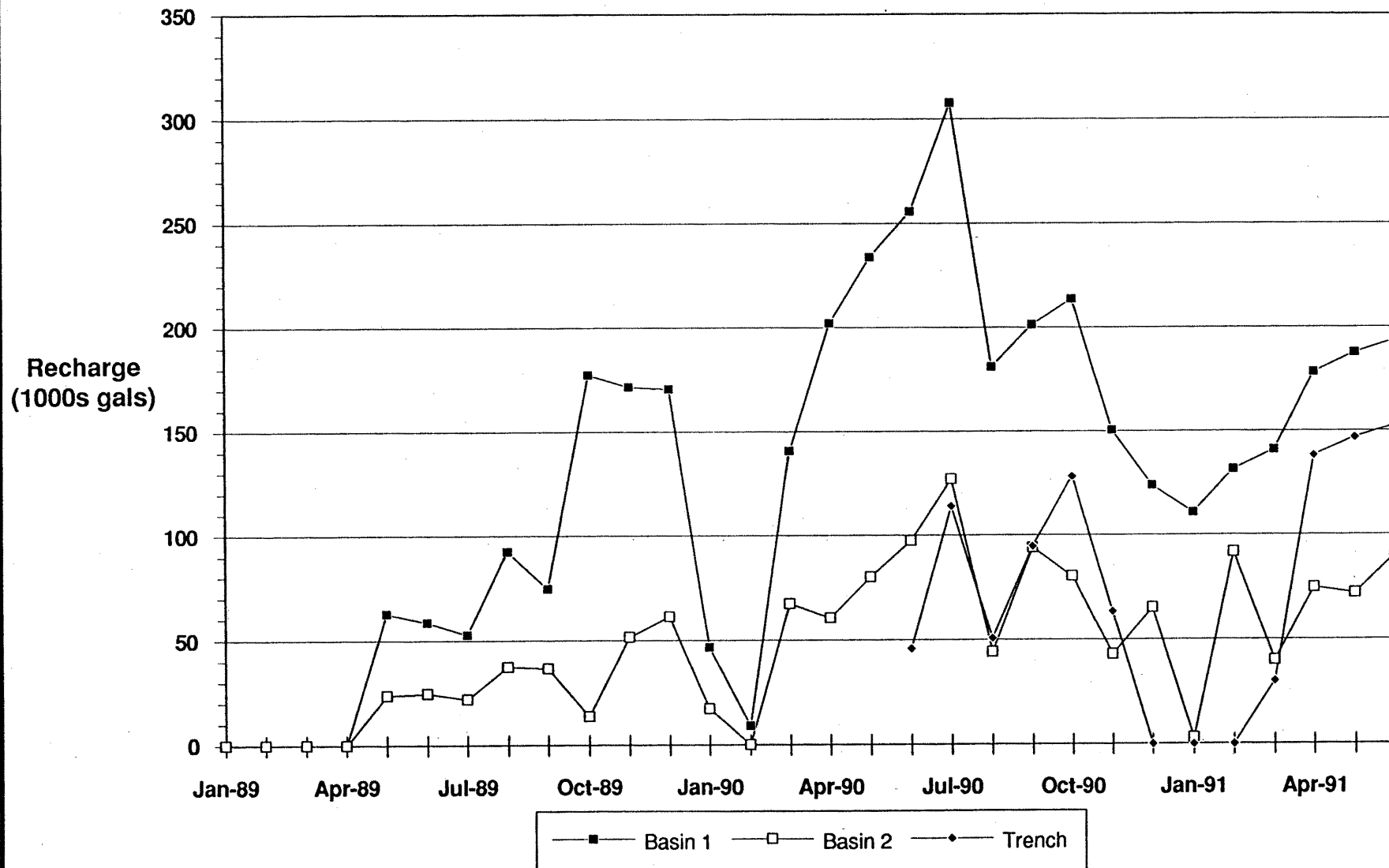
Monthly water inflows to Basin No. 1 have averaged approximately 146,000 gallons (3.3 gpm), 55,000 gallons (1.3 gpm) for Basin No. 2, and 83,000 gallons (1.9 gpm) for the infiltration trench. The larger inflows to Basin No. 1 are due to the greater infiltration surface area, a gravel bottom that extends to a depth of 10 feet, and the hydraulic influence of three wells (EW-27, EW-28, and EW-29) that withdraw water from beneath the basin. A summary of monthly water inflows to the infiltration basins and trench is provided in Figure 2-5.

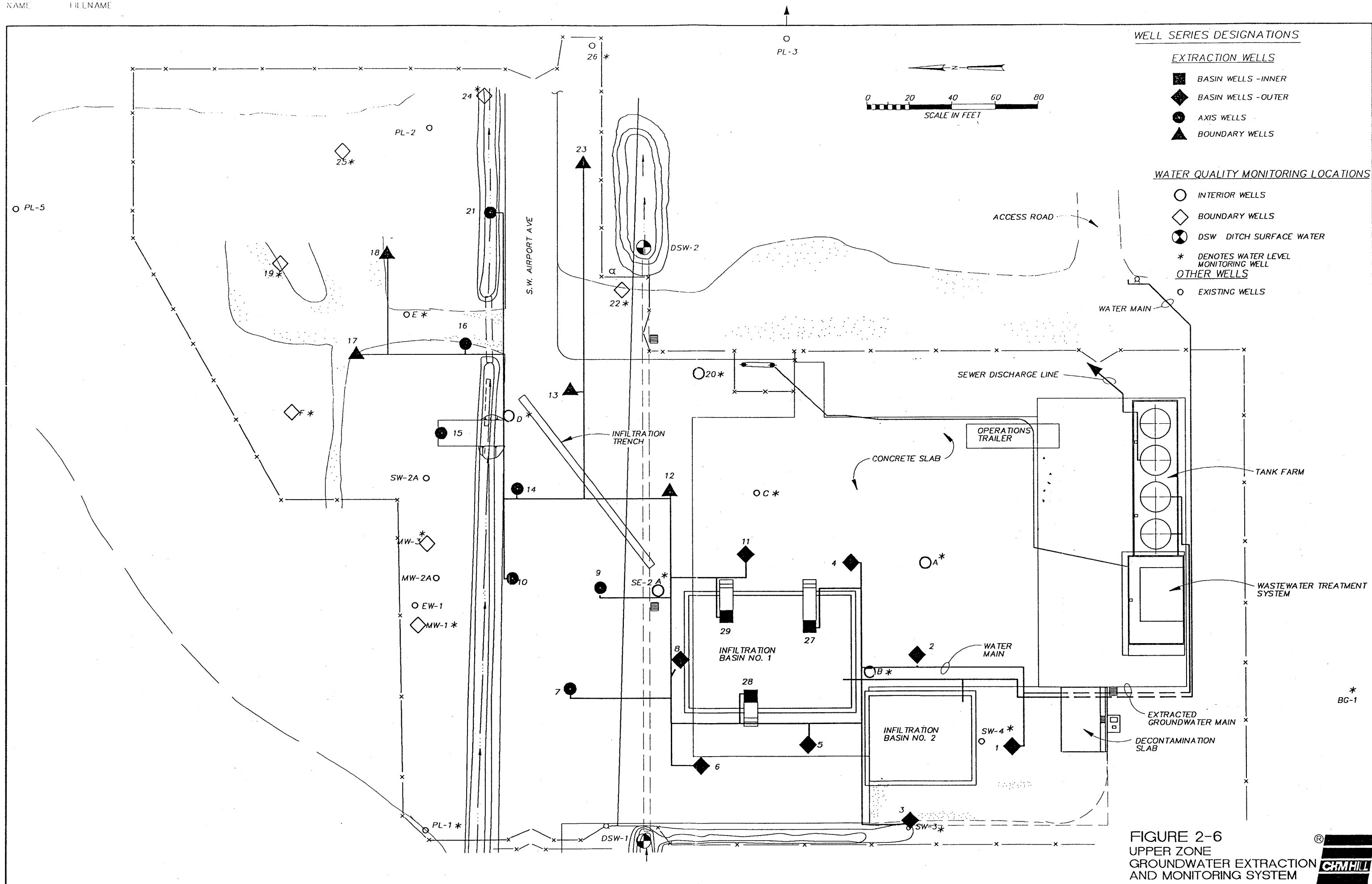
The success of the basins is demonstrated by the increase in extraction gallons for the Basin Well group (Figure 2-6) and concurrent decrease in Cr(VI) concentrations. Monthly extraction rates for wells in this group average 15,000 gallons versus 5,000 gallons to 7,000 gallons for many of the other wells. Hexavalent chromium concentrations have also decreased significantly from over 2,000 mg/l to less than 50 mg/l in wells EW-27 and EW-29 and from 8,000 mg/l to 360 mg/l in EW-8.

System Maintenance

The basins have required little maintenance to date. Visual monitoring for leakage along the basin walls is routinely performed and no significant problems identified.

Figure 2-5
Monthly Discharge Distribution





Maintenance tasks that may enhance infiltration rates include periodic scarification and drying of floor material to break up sediment and biological mats. Scarification could be performed with a backhoe bucket.

GROUNDWATER EXTRACTION SYSTEM

System Components

The groundwater extraction system shown in Figure 2-6 includes 23 upper zone extraction wells. Each well (Figure 2-7) is equipped with a submersible pump, high and low water level sensors to control pump operation, isolation valves and flow control hardware, sample port, and control panel. Discharge from the wells is directed through an aboveground polyethylene (HDPE) pipe network to four 14,000-gallon influent holding tanks, located on the east side of the treatment plant.

Pumping Plan

To simplify operation of the extraction well network, the site pumping plan consolidated individual extraction wells into three groups: the Basin Wells, Axis Wells, and Boundary Wells (Figure 2-6). Initially, each group was to be operated according to a two-phase pumping cycle with an optional recovery period implemented if well operating efficiencies (time pump on divided by total extraction time) decreased below 50 percent or water levels in downgradient wells declined below a level representing 50 percent of the seasonally adjusted saturated thickness.

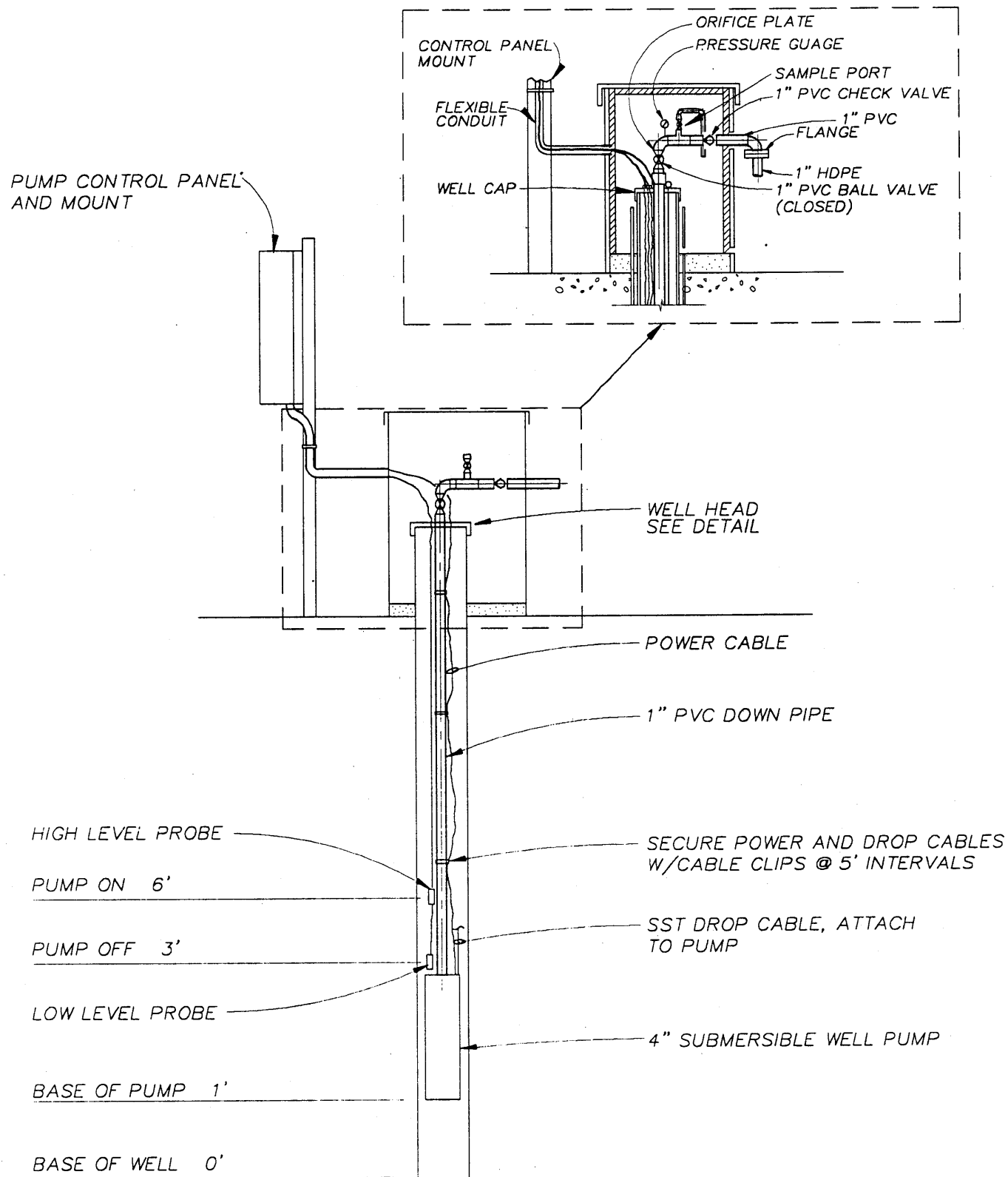
The current pumping strategy has focused on continuous and aggressive pumping from all wells in the extraction network. This approach has resulted in significant contaminant removal, but will likely require modification as the mass of easily removed Cr(VI) decreases.

Evaluation of 1990 operations data indicates that well operating efficiencies generally exceed the 50 percent operations efficiency except during seasonally low water level periods (July to October). The Axis and Boundary Well groups are affected the most by low water conditions.

System Performance

Since startup in August 1988, the groundwater extraction system has run on average approximately 18 hours per day of operation. During the past year, this period has increased to 23 hours per day. Extended periods of freezing weather in February 1989 and December 1990 required the shutdown of all systems for approximately 4 weeks and 3 weeks, respectively.

The average 1988 to 1991 extraction rate for the combined well flows is 10.4 gpm and averaged 11.5 gpm during 1990. The flow rates measured during the past 12 months



NOTE: PROBE SETTINGS SHOWN REPRESENT INITIAL CONDITIONS AND HAVE BEEN CHANGED TO OPTIMIZE WELL YIELDS.

FIGURE 2-7

EXTRACTION WELL
INSTALLATION DETAIL

UNITED CHROME REMEDIAL ACTION



are very near the 18,000 gallons per day (12.5 gpm) anticipated from the predesign study.

System performance has enabled the 100,000 gallons per week extraction quota to be achieved for 7 of the past 9 months that this quota has been in effect. Prior to October 1990, an 80,000-gallon-per-week extraction quota was required.

Significant variations in well yields across the site are reflected in the rate and magnitude of cleanup achieved (Figure 2-8). Most notable, the Basin Well group (11 wells), that accounts for 60 percent to 90 percent of the monthly extraction gallons, has shown significant cleanup progress in terms of Cr(VI) concentration reductions. Wells in this group had initial Cr(VI) concentrations varying from 200 mg/l to 4,000 mg/l and for June 1991 they have concentrations varying from 10 mg/l to 360 mg/l.

The Axis Well group (seven wells) also shows substantial cleanup progress but at a slower rate due to lower groundwater velocities and lack of recharge water in this area. Both conditions should be corrected by continued operation of the infiltration trench. This well group accounts for 15 percent of the monthly extraction volume and had initial Cr(VI) concentration ranging from 950 mg/l to 8,000 mg/l that presently vary from 120 mg/l to 530 mg/l.

The Boundary Well group (five wells) provides on average approximately 15 percent of the total monthly extraction gallons. This well group had initial Cr(VI) concentrations from 120 mg/l to 690 mg/l and they presently vary from 1 mg/l to 210 mg/l. Three of these wells (EW-17, EW-18, and EW-23) have been shut off and will continue to be monitored on a monthly basis for Cr(VI) concentration.

One variable (independent of upper zone hydraulic characteristics) that also influences the amount of groundwater extracted by a well is the size of the orifice plate installed in each well. Figure 2-9 shows a comparison of theoretical versus actual well yields for the combined well flows. The theoretical extraction curve was generated by combining the flow ratings (orifice plate sizes) for all of the wells assuming a 100 percent operating efficiency. The actual extraction curve was obtained by multiplying the theoretical curve by the average monthly efficiency. These curves indicate that orifice plate selection is an important consideration in controlling extraction rates. A combined flow rate from 12 gpm to 15 gpm could be achieved based on past operation conditions.

System Maintenance

Routine maintenance operations performed at the site have included repairs to well head components, pump repairs, well redevelopment, and flushing of effluent pipelines.

Well Head Repairs. Normal maintenance includes repair or replacement of cycle counters and piping, where leaks have developed as a result of freeze damage.

Pump Repairs. Well pumps in EW-3, EW-5, EW-27, EW-28, EW-29 were rebuilt in October 1990 because of accelerated wear of the impeller seal rings, occurring around the 8,000-hour operating mark. This condition results from the presence of silt and clay particles in extracted groundwater. Periodic cleaning of these well pumps and several others has been required to removed sediment buildup since October 1990.

Well Redevelopment. Eleven extraction wells (EW-6, EW-7, EW-8, EW-10, and EW-12 to EW-18) were redeveloped in August 1990 using a high-pressure water jet and overpump technique. Redevelopment increased the monthly yield for this particular group of wells by approximately 9,000 gallons.

Flushing of Effluent Pipes. Routine monitoring of extraction well line pressure gauges identified several instances of increased operating pressures in effluent pipelines. This condition occurs as a result of silt and clay particle deposition in the pipe, reducing the cross-sectional area of the pipe. These deposits have been periodically removed by flushing the pipe with high-pressure water or by flushing a “pig” through the line to dislodge blockages.

MONITORING

Monitoring activities at the United Chrome site have been intensive and are critical to assessing the performance of the groundwater extraction program. Monitoring activities preformed at the site include the tasks listed in Table 2-1. This information is compiled on a monthly basis and reported by the City of Corvallis.

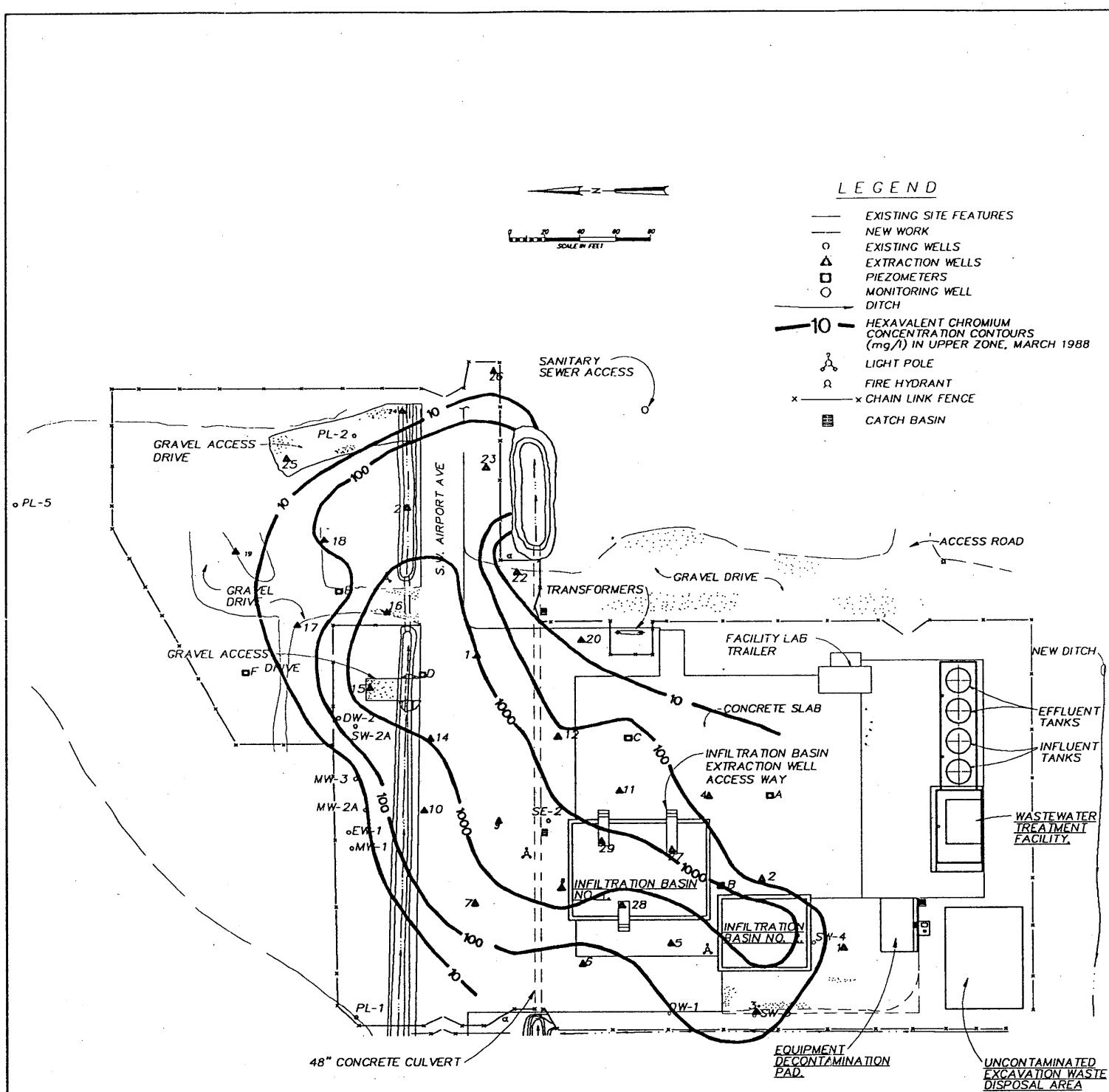
EXTRACTION WELL CONCENTRATION AND FLOW MEASUREMENTS

Measurements of extraction well Cr(VI) concentrations and groundwater flow rates are the primary parameters used to monitor the success of remedial action at the United Chrome site. A significant reduction in the magnitude and volume of the contaminant plume has been achieved during the past 35 months of operation. The reduction in Cr(VI) concentrations observed in each of the 23 extraction wells is given in Table 2-2.

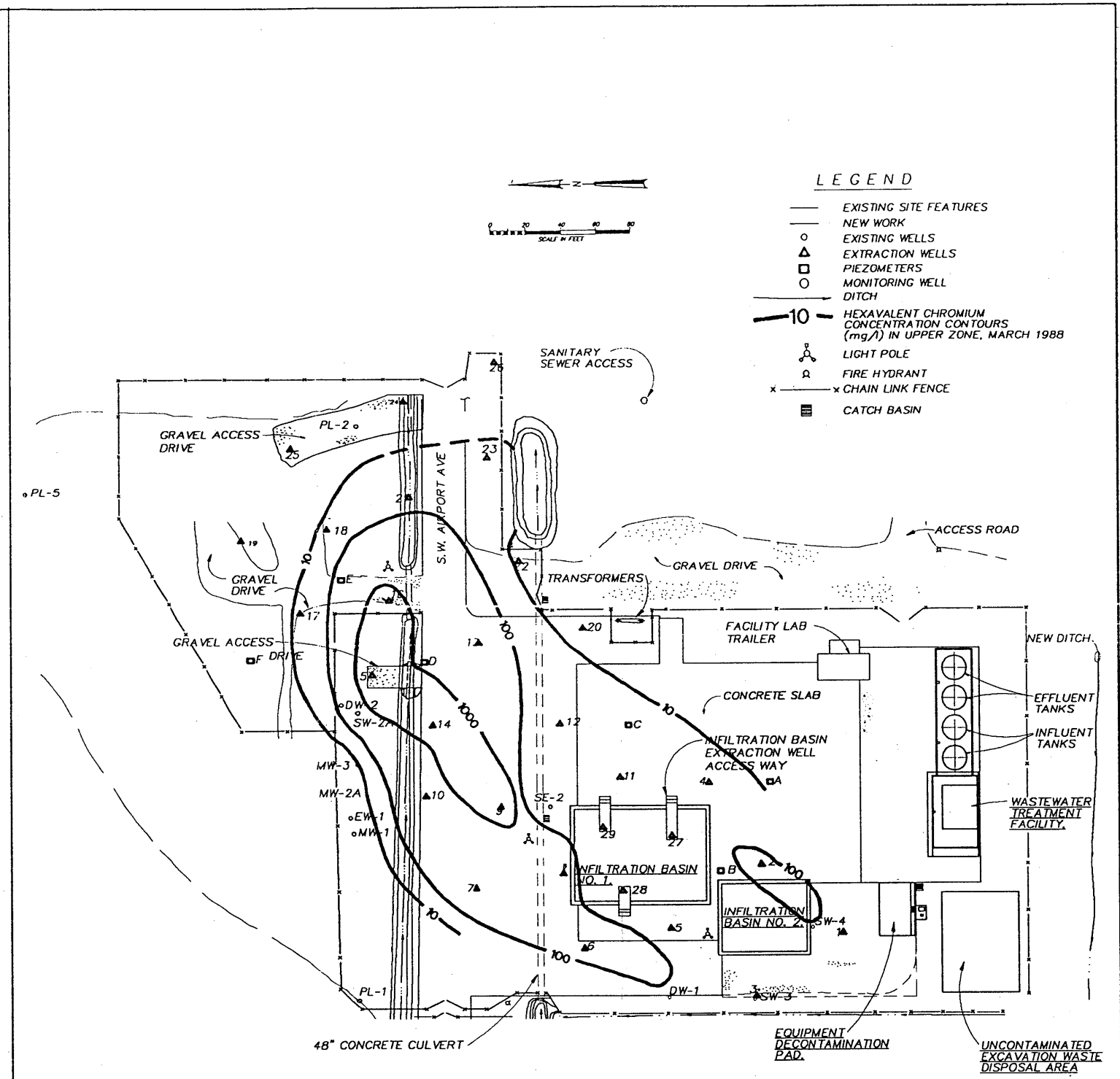
PLUME CONCENTRATION MONITORING

Periodic sampling of observation wells at the site is performed to confirm hydraulic containment of the plume at the downgradient site boundary and to assess cleanup progress at interior points within the plume. Observation wells are nonextraction points and serve to provide an independent check of cleanup progress.

Water quality data from these location (Table 2-3) indicates a significant decrease in Cr(VI) concentrations from the pre-extraction conditions present in March 1988.



Cr (VI) CONCENTRATION CONTOURS, MARCH 1988

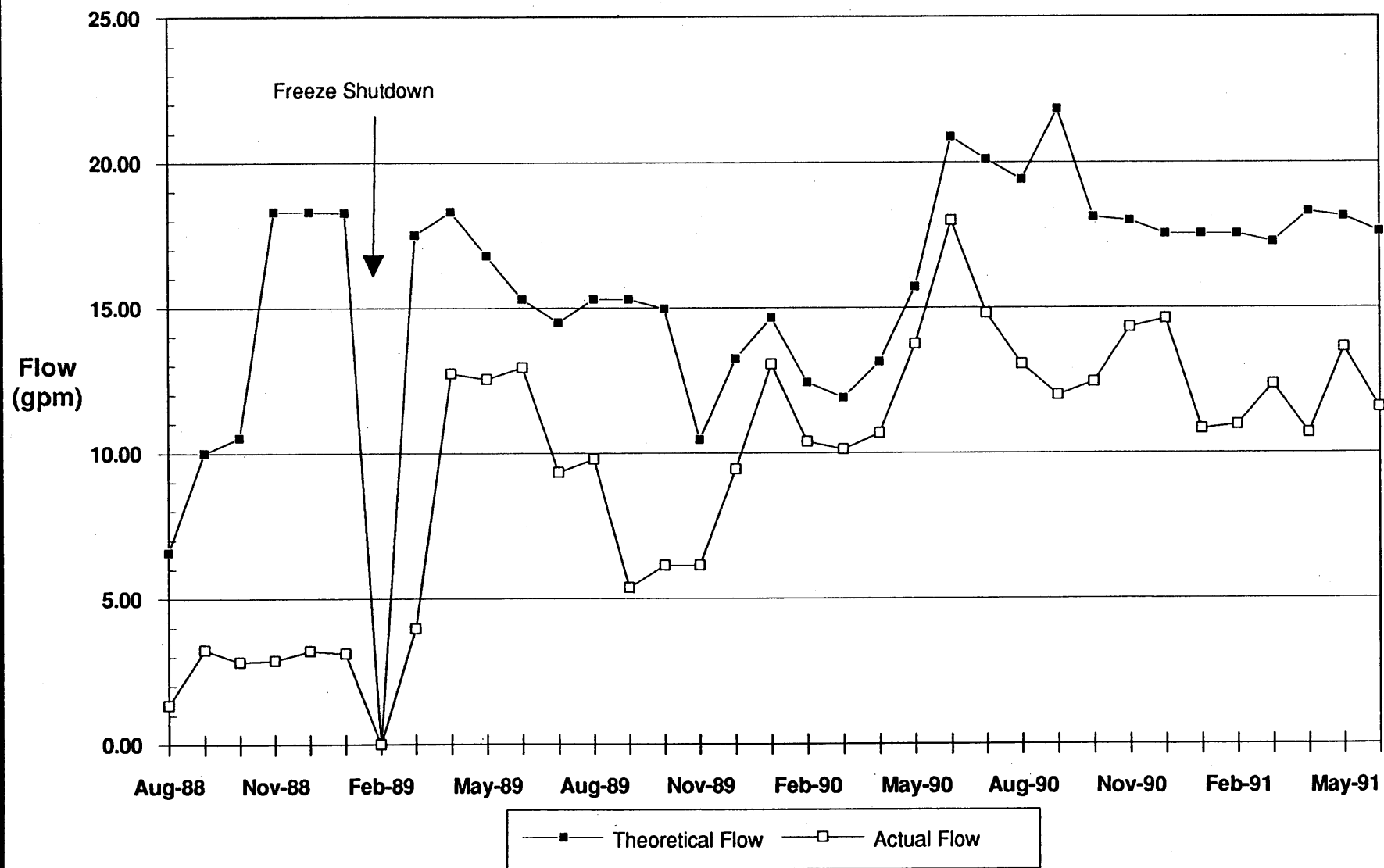


Cr (VI) CONCENTRATION CONTOURS, DECEMBER 1990

FIGURE 2-8
Cr (VI) CONCENTRATION[®]
CONTOURS
UNITED CHROME PRODUCTS SITE
CORVALLIS, OREGON



Figure 2-9
Combined Extraction Well Flows



**Table 2-1
Existing Upper Zone Monitoring Tasks and Reporting Schedule**

Component	Task	Locations	Frequency	Reporting Frequency^a
Extraction System	Water levels in select wells	BG-1, BG-2, SE-2A, SW-2A, SW-3, SW-4, PZ-A, PZ-B, PZ-C, PZ-D, PZ-E, PZ-F, PL-1, PL-2, PL-3, PL-5, MW-1, MW-2A, MW-3, EW-19, EW-20, EW-22, EW-24, EW-25, EW-26.	Weekly	Monthly
	Wellhead measurements ^b	All extraction wells	Daily when onsite	Monthly
	Calculated flow rate	All extraction wells	Daily when onsite	Monthly
	Water quality [Cr(IV)]	All extraction wells	Twice per month	Monthly
	Combined flow measurements (rate, total)	At inlet to influent tank(s)	Daily when onsite	Monthly
Boundary Monitoring Wells	Water quality [(Cr(VI)), indicator parameters]]	MW-3, PZ-F, EW-19, EW-22, EW-24, EW-25	Biannually ^c	Biannually
Interior Monitoring Wells	Water Quality [(Cr(VI)), indicator parameters]]	PZ-A, PZ-B, PZ-D; SE-2A, EW-20	Biannually ^c	Biannually
Infiltration Basins	Flow (gal)	Basin No. 1 and Basin No. 2	Daily (during use)	Monthly
Infiltration Trench	Flow (gal)	Trench	Daily (during use)	Monthly
Treatment System	Influent water quality (Cr VI)	At inlet to influent tanks	Each day onsite	Monthly
	Effluent water quality (Cr VI, Total Cr)	At effluent tank outlet	Each day onsite	Monthly
	Influent and effluent water quality Priority Pollutant Metals		Quarterly	Quarterly
Surface Water	Water quality [(Cr(VI)]	At three locations downstream of site	Quarterly	Quarterly
^a All results may be requested at any time by the technical assistant in verbal format or draft. ^b Pump cycles, pump hours. ^c Sampling conducted in September and March of each year.				

Table 2-2
Semiannual Cr(VI) Concentrations in Extraction Wells

Well ID	Cr(VI) Concentration (mg/l)						
	Initial	Sep-88	Mar-89	Sep-89	Mar-90	Sep-90	Mar-91
EW-1	53	54	66	240	93	71	30
EW-2	31	64	6	601	301	162	113
EW-3	144	183	445	400	120	48	32
EW-4	21	47	60	196	59	16	19
EW-5	148	202	507	681	160	62	37
EW-6	45	87	450	781	366	255	160
EW-7	320	563	543	1,368	1,026	1,065	171
EW-8	5,220	5,542	4,507	2,604	1,620	474	403
EW-9	6,860	6,889	6,436	6,507	263	1,147	411
EW-10	250	403	244	3,101	422	573	129
EW-11	197	237	113	470	113	51	16
EW-12	107	360	244	526	298	176	150
EW-13	1,050	985	955	581	499	356	220
EW-14	1,010	1,439	10	5,836	1,938	3,396	450
EW-15	2,740	2,780	2,844	3,405	1,763	1,111	719
EW-16	3,220	3,187	3,266	2,903	1,991	1,065	705
EW-17	86	85	58	36	29	8	7
EW-18	120	NM	36	33	41	13	7
EW-21	315	310	643	564	130	47	22
EW-23	163	164	82	52	9	3	2
EW-27	922	1,334	1,362	841	199	75	39
EW-28	706	1,646	1,335	526	114	42	43
EW-29	4,310	3,622	1,459	761	160	66	50

NM = Not measured.

Table 2-3
United Chrome Site
Semiannual^a Cr(VI) Concentrations in
Observation Wells

Wells	Mar-88 (mg/l)	Apr-89 (mg/l)	Apr-90 (mg/l)	Nov-90 (mg/l)	Apr-91 (mg/l)
	Before Startup	After Startup			
PZ-A (I)	127	34	12	6.8	3.0
PZ-B (I)	867	525	20	7.6	6.6
PZ-D (I)	4,240	67	60	< 1.0	<0.1
PZ-F (B)	0.15	<0.1	<0.1	0.14	0.1
SE-2A (I)	NA	3,450	290	15	62
MW-3 (B)	3.83	1.3	0.12	0.64	0.19
EW-19 (B)	3.81	1.9	0.6	0.37	<0.1
EW-20 (I)	3.6	27	18	5.8	9.2
EW-22 (B)	1.34	<0.1	NA	0.1	<0.01
EW-24 (B)	0.046	<0.1	<0.1	0.12	<0.1
EW-25 (B)	0.034	<0.1	<0.1	0.12	<0.1

^aSampling not performed in September 1989 or September 1990.

Notes:

(I) = Interior wells

(B) = Boundary wells

NA = Not available

GROUNDWATER LEVEL MEASUREMENTS

Water level measurements are taken at weekly and monthly intervals in many of the upper zone and deep aquifer wells at the site. This monitoring schedule has generated a comprehensive data base to assess seasonal variations and the impact of basin and trench use on the upper zone groundwater flow system.

The depth to groundwater varies seasonally in the upper zone between 2 feet and 11 feet below ground surface. Provided in Figure 2-10 is a groundwater elevation hydrograph depicting fluctuations for background conditions (upgradient Well BG-2) and for Piezometer PZ-B and PZ-D located in the vicinity of the infiltration basins and trench. The graph illustrates the effect that the basins and trench have on upper zone water levels when in use and the magnitude of seasonal declines that generally begin in March and continue through October.

Figure 2-11 shows how the infiltration basins and trench influence the vertical gradient. Changes in the vertical gradient occur as water levels in the upper zone around these structures increase in response to infiltration from them. The vertical gradient is significant because it represents the driving force that moves water from the upper zone to the deep aquifer (downward gradient) or from the deep aquifer to the upper zone (upward gradient). Due to the contrast in contaminant levels between the two zones, an upward gradient is desired to minimize movement of groundwater carrying Cr(VI) from the upper zone and to provide a flushing mechanism to mobilize Cr(VI) from the aquitard. This graph also shows two periods (background location) where the gradient reverses from a downward direction (July 1990 to February 1991) to an upward direction (March 1990 to June 1990 and February 1991 to June 1991). This reversal is absent in the vicinity of the-basins and less apparent around the trench.

SURFACE WATER SAMPLING

Monitoring of surface water flows from the United Chrome site has been performed to assess the impacts of groundwater discharge to the drainage ditch along the east site boundary and to evaluate the performance of the extraction system in preventing additional releases to this ditch.

Between April 1989 and March 1990, surface water samples were collected at monthly intervals from 11 locations downstream of the United Chrome site extending from the site boundary to the Booneville Slough and Kiger Island bridge. In response to the data gathered from this program, the number of sample points was reduced to three and the sample frequency decreased to quarterly. Surface water quality data from this program is summarized in Figure 2-12.

The surface water monitoring program has demonstrated significant decreases in Cr(VI) concentrations at Location No. 5 from values exceeding 100 mg/l in September

Figure 2-10
Groundwater Elevation Hydrograph

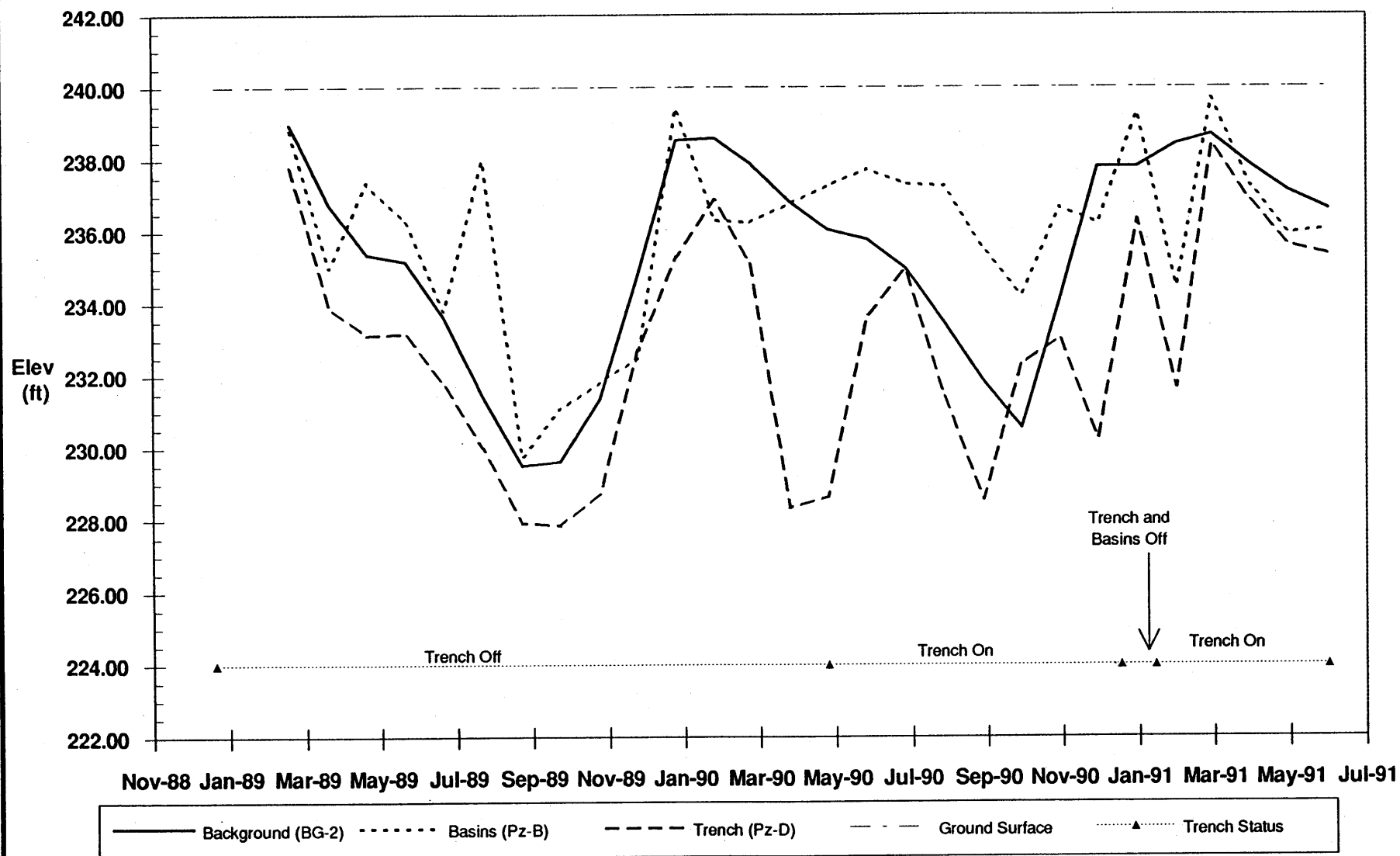
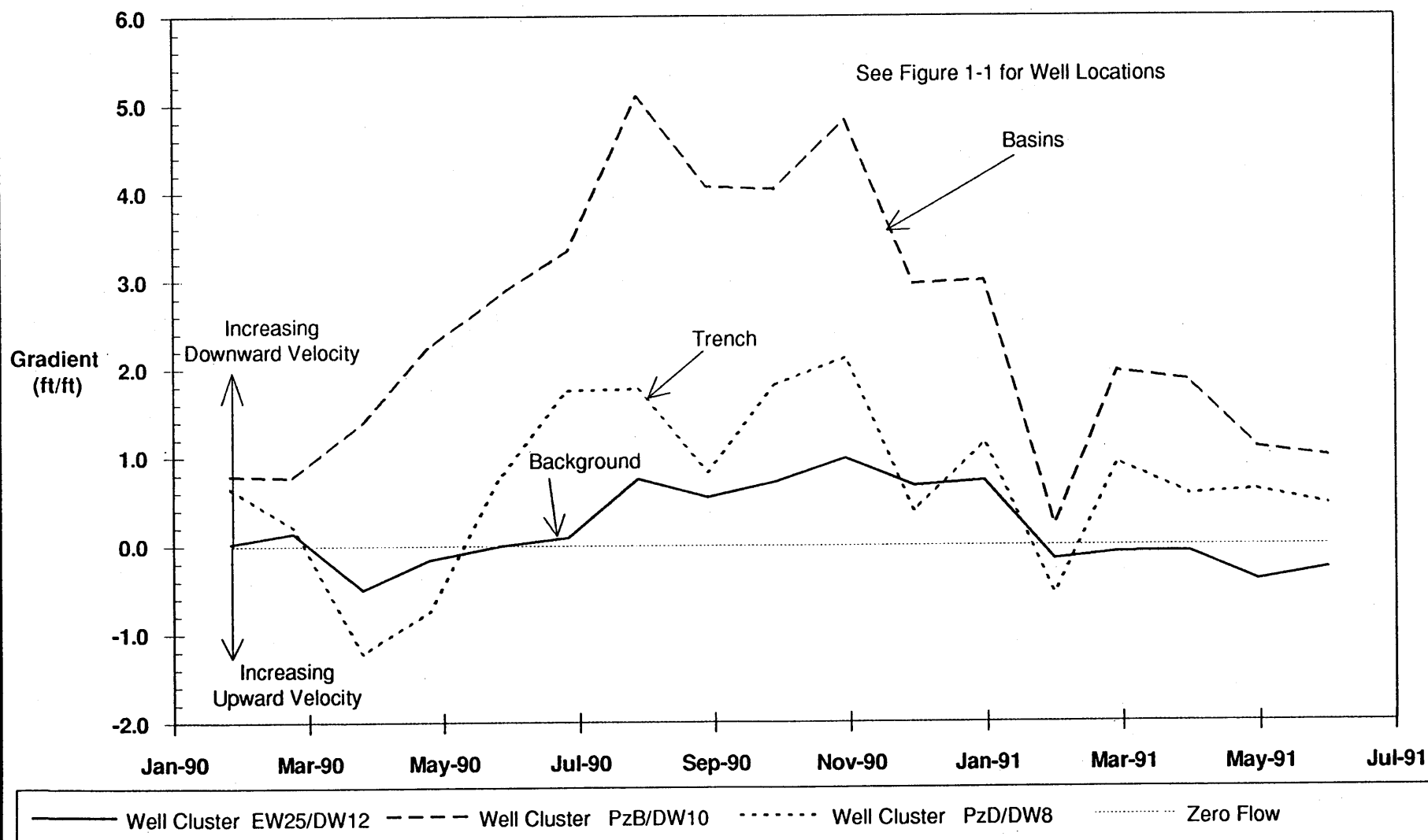


Figure 2-11
Upper Zone - Deep Aquifer
Vertical Gradient Trends



and December 1988 to less than 1 mg/l in November 1989. This site is in the open ditch just downstream of the 4-foot-diameter concrete culvert that passes through the site.

SITUATIONS AND RECOMMENDATIONS

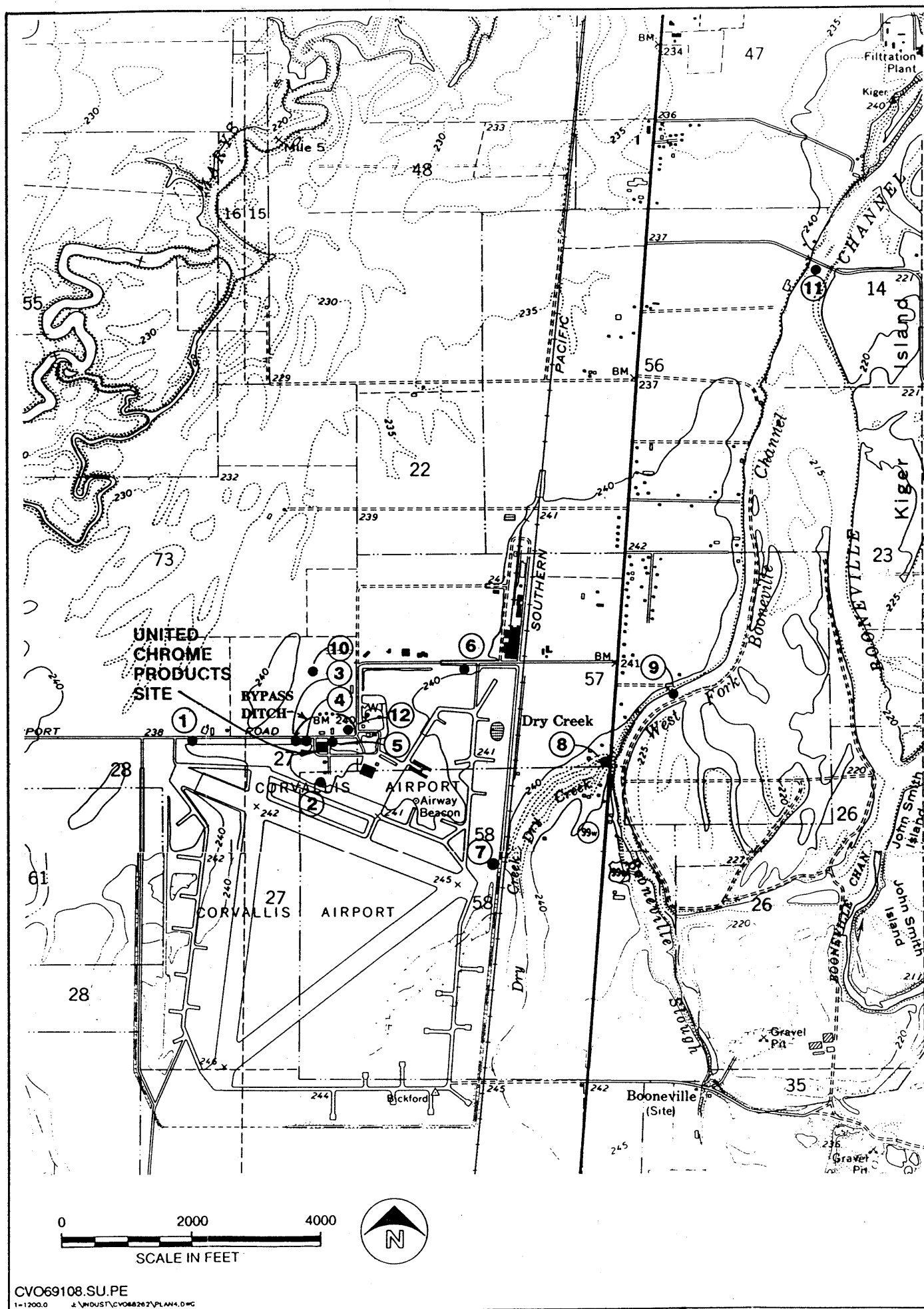
Evaluation of monitoring data collected during 3 years of system operation has identified several operational procedures and monitoring schedules that should be modified. These changes may increase Cr(VI) recovery per gallon of groundwater extracted and will permit a reduced level of effort in terms of data gathering requirements necessary to establish extraction system performance. These recommendations include:

- **Infiltration Basin Operations**--The basins have flushed most of the soluble chromium from vadose zone soils. Removal of solid phase hexavalent chromium (BaCrO_4) and soluble Cr(VI) may require longer contact times to generate higher Cr(VI) concentrations per gallon extracted. Operation of the basins should be modified to increase contact time between infiltration water and solid phase Cr(VI) and/or sorbed Cr(VI). The basins should also be used to deliver recharge water to other areas within the extraction well network.
- **Extraction System Operations**--Aggressive operation of EW-27, EW-28, EW-29, and the Boundary Well group is resulting in the production of large volumes of low concentration water while also decreasing the amount of recharge available to wells in the Axis group. Operation of these wells should be reduced or discontinued.
- **Monitoring Schedules**--Increased confidence in system operations and aquifer response to pumping will permit a reduction in the monitoring frequency and number of monitoring locations. Monitoring activities in the upper zone must also be modified to gather data on the hydraulic interaction between the upper zone and deep aquifer once deep aquifer groundwater extraction begins in July 1991.

A description of the problems identified and recommendations is presented in the following sections.

INFILTRATION BASIN AND TRENCH OPERATIONS

Situation: The three interior Basin Wells (EW-27, EW-28, and EW-29) together have averaged approximately 100,000 gallons per month during the past year at concentrations presently approaching 40 mg/l. Aggressive operation of these wells has resulted in significant mass removal. However, a large fraction of the water derived from these



SAMPLE LOCATION												
SAMPLE DATE	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>
1989												
April	<0.1	<0.1	1.12	0.17	0.28	0.15	0.18	0.22	<0.1	a	<0.1	
May	<0.1	b	b	<0.1	1.16	2.76	2.32	0.33	0.29	b	<0.1	
June	<0.1	b	b	1.28	1.24	<0.1	<0.1	<0.1	<0.1	b	<0.1	
July	b	b	b	b	4.4	b	<0.1	b	<0.1	b	<0.1	
August	b	b	b	b	15	b	<0.1	b	<0.1	b	<0.1	
September	b	b	b	b	17.6	b	b	b	<0.1	b	<0.1	
October	b	b	b	b	<0.8	<0.67	<1.0	b	<0.1	b	<0.1	
November	b	b	b	b	0.22	0.15	0.23	b	<0.1	b	<0.1	
December	b	b	b	b	0.82	0.10	<0.1	b	<0.1	b	<0.1	
1990												
January	<0.1	<0.1	c	c	0.62	<0.1	<0.1	<0.1	<0.1	a	<0.1	
February	<0.1	b	c	c	0.32	<0.1	<0.1	<0.1	<0.1	b	<0.1	
March	<0.1	b	c	c	0.72	<0.1	<0.1	<0.1	<0.1	b	<0.1	
June (d)					2.05						<0.1	<0.1
August					0.60						<0.1	b
December					0.43						<0.1	<0.1
1991												
March					0.40						<0.1	<0.1

Comments:
a = Interference with sample, no color development.
b = No surface water to sample.
c = Ditches were modified January 1990, samples 3 and 4 were discontinued.
d = Sampling frequency reduced to quarterly at locations 5, 11, and 12.
No other locations sampled.

b:sample

FIGURE 2-12
**Cr (VI) CONCENTRATIONS IN
SURFACE WATER (mg/l)**
APRIL 1989-MARCH 1991
UNITED CHROME REMEDIAL ACTION
CORVALLIS, OREGON

wells is likely low Cr(VI) concentration infiltration water that has had little contact time with contaminated soils beneath the basins or is potentially following shortened flow paths to the extraction point due to higher pumping rate in these wells.

Recommendation: To promote downward and lateral movement of infiltration water away from the basins and concurrently increase the soil contact time, the size of the flow control orifice plates should be reduced in these wells. The optimum size and combination will be one that maintains a water table surface that slopes towards the north and northeast. Initially, the plates could be reduced approximately 50 percent from their present size to 0.5 gpm, 0.5 gpm, and 0.8 gpm for EW-27, EW-28, and EW-29, respectively. Groundwater elevations and Cr(VI) concentrations in the Basin Well group should be periodically evaluated to establish groundwater flow patterns and Cr(VI) concentration trends to assess the impact of this change.

Situation: A downward vertical gradient will result in continued movement of Cr(VI) from the upper zone to the deep aquifer. The rate at which this occurs (advective transport) is proportional to the magnitude of the gradient, the permeability, and porosity of aquitard material. The transport process can be controlled by manipulating the gradient in a manner that either reduces its magnitude to a negligible level or reverses its direction such that groundwater flow is upward from the deep aquifer to the upper zone.

Recommendation: To reduce the magnitude of the downward vertical gradient between the upper zone and deep aquifer in the vicinity of the basins, water levels inside the basins should be maintained at a lower level (ground surface initially). Upper zone and deep aquifer water levels in select wells will be measured on a weekly basis and used to calculate and document vertical gradient trends. This data will be used to develop further pumping and basin operation guidelines (if required) to create the desired condition.

Situation: Monitoring of water inflows to the basins and trench is performed; however, no guidelines have been developed to determine how much water is necessary to optimize extraction system performance without creating adverse flow conditions. In the past, system inflows have been assumed to be self-regulating; however, review of operating data indicates periods when more water is recharged than extracted.

Recommendation: Implement a water balance that accounts for basin and trench inflows and compares them against withdrawals from extraction wells likely to be influenced by their use. A method to track water inflows and withdrawals for this purpose has been developed for the infiltration basins and the Basin Well group and the infiltration trench and the Trench Well(s) group using the approach described in the following subsection. An infiltration extraction ratio will be calculated each week these structures are in operation and it will be used to regulate inflows for the following week. The extraction well groups for the water balance calculations are described in Table 3 of the Pumping Plan included as Appendix B.

Water Balance Guidelines

Initial guidelines for maintaining control of water inflows to the basins and trench were developed through a review of historic operating trends and analysis of potential water recharge and extraction sources (water balance). The historic review compared monthly basin and trench inflows versus extraction well withdrawals in the Basin and Trench Well(s) groups using an infiltration to extraction ratio (Figure 2-13).

The water balance shown in Figure 2-14 was prepared by estimating contributions from precipitation recharge, artificial recharge, and groundwater underflow. Precipitation recharge was estimated using actual precipitation data and potential evapotranspiration rates. No correction was applied to account for runoff or basin evaporation. Artificial recharge was obtained from the monthly reports prepared by the City of Corvallis. Groundwater underflow, representing the volume of water entering the site due to movement of groundwater, was assumed to occur along the entire perimeter of the plume. The saturated thickness was calculated using the water elevation from an upgradient well and the elevation for the base of the upper zone.

Based on the data generated for the period between January 1989 to June 1991, artificial recharge accounts for approximately 50 percent of the total water budget, groundwater underflow contributes 20 percent, and precipitation recharge 30 percent. This distribution suggests that the basins and trench be regulated to approximately 50 percent of the total groundwater extraction amount during extended wet periods (between the months of October through April), and 80 percent of the total extraction amount during dry periods (May through September). On an annual basis this amounts to an infiltration to extraction ratio of 0.65.

EXTRACTION SYSTEM OPERATIONS

Situation: Extraction well yields vary significantly across the site (Figure 2-15) from several hundred gallons per well per month during summer to 40,000 gallons per well per month during peak extraction periods. This broad range results primarily from the well's location relative to a recharge source such as the infiltration basins, or along the site perimeter where groundwater underflow availability increases due to reduced well interference effects. The apparent lack of underflow has slowed remediation progress along the plume core and led to the construction of the infiltration trench in May 1990.

Recommendation: To further increase yields for wells along the plume axis (Axis Well group), especially when the trench is not operating, recharge water from low concentration wells in the Basin and Boundary groups can be diverted to Axis Wells by reducing flow rates, operating them in a pulsed manner, or shutting them off.

Figure 2-13
Monthly Infiltration/Extraction Ratios

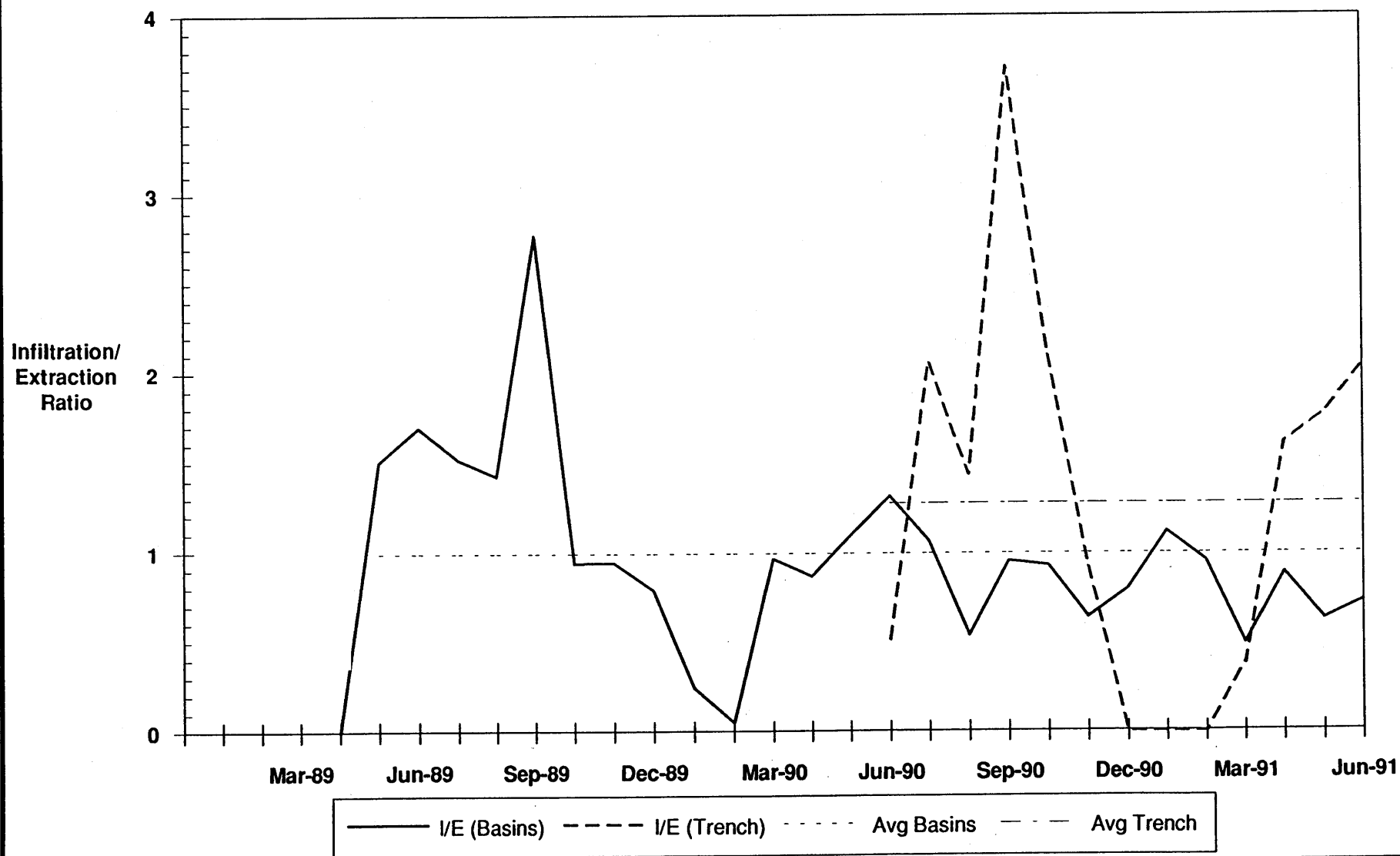


Figure 2-14
Monthly Recharge Distribution

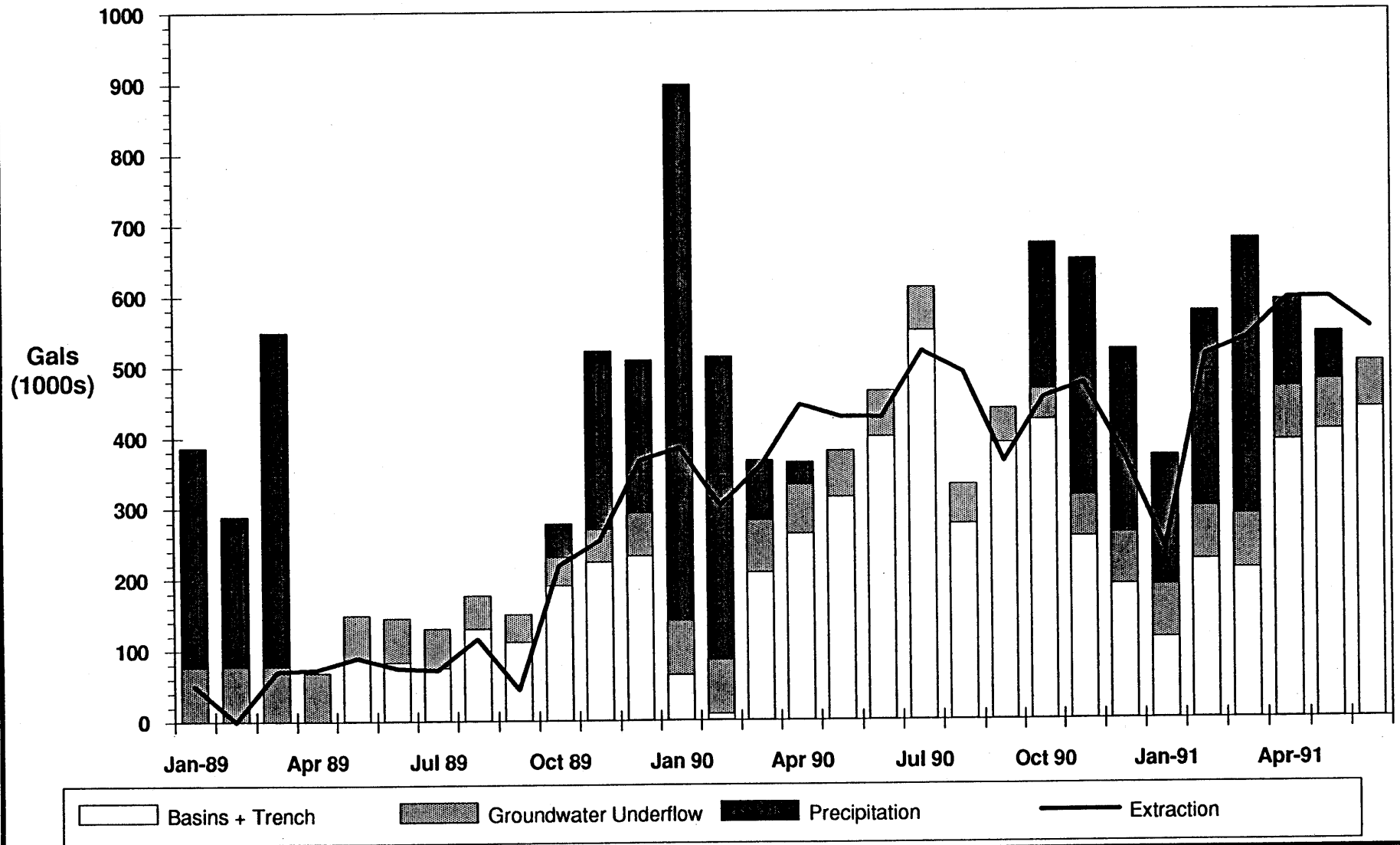
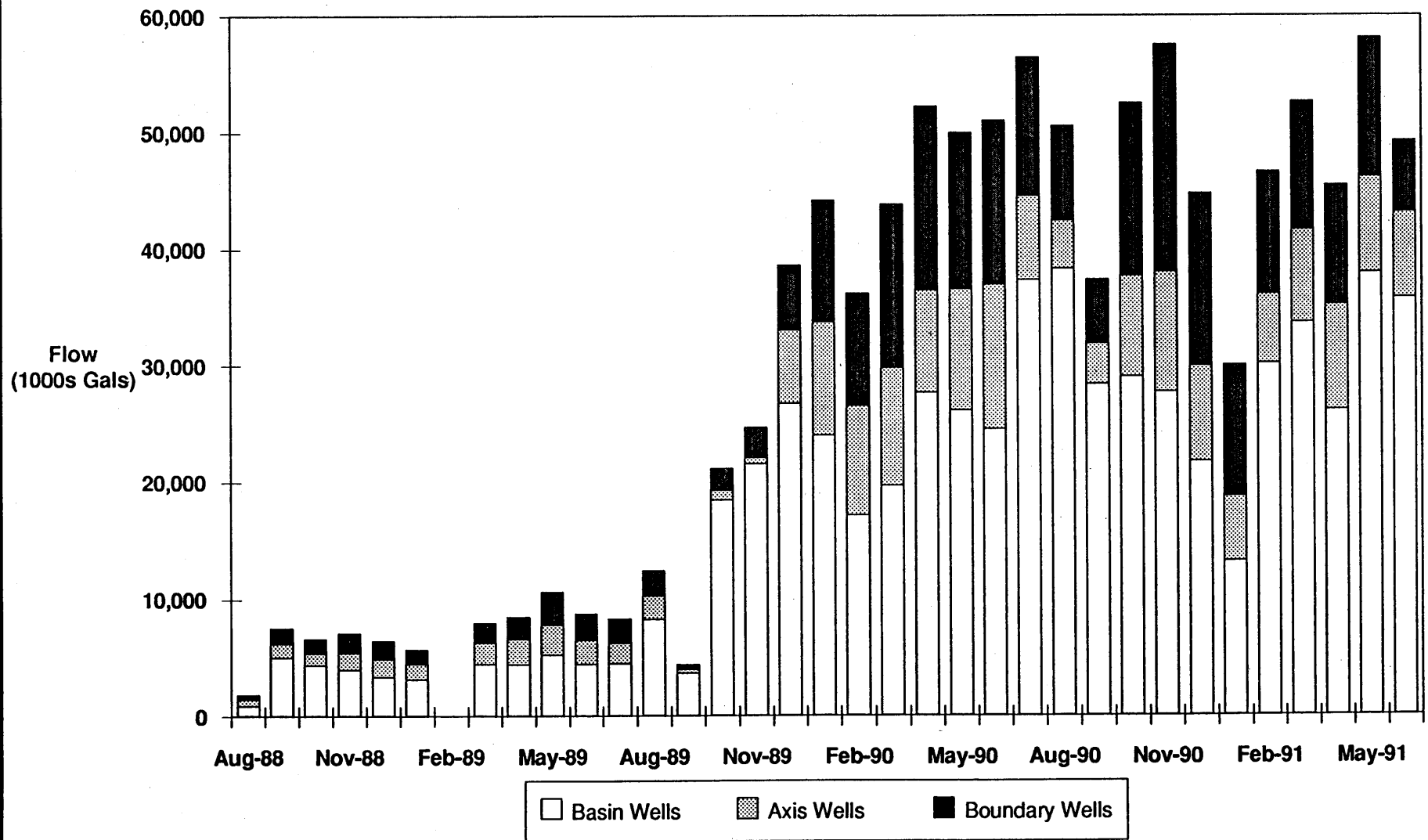


Figure 2-15
Average Monthly Flow
by Extraction Well Group



One possible approach would consist of reducing orifice plate sizes in Basin Wells EW-8, EW-28 and EW-29 to promote lateral movement of water from Basin No. 1 towards the north and northeast. A pulsed schedule for the Boundary Well group and Wells EW-4 and EW-11 will also increase underflow for wells in the Axis Well group.

Shutoff Criteria

Situation: The ROD specifies a 10-mg/l Cr(VI) cleanup goal for the upper zone wells; however, the description of how the goal should be applied and whether or not a compliance period is necessary was not given. As Cr(VI) concentrations in extracted groundwater continue to decrease, it will be advantageous to shut off wells that demonstrate compliance with the ROD cleanup goal. By turning off these wells, the volume of extracted groundwater requiring treatment will be reduced, groundwater flow paths between wells will be altered, thereby stimulating recovery of contaminated groundwater from stagnant zones, and additional groundwater underflow will be available to recharge other well locations.

Recommendation: The following criteria should be met before a well is shut off.

1. Monthly Cr(VI) concentration measurements in extracted groundwater are less than 10 mg/l Cr(VI) for 2 consecutive sampling events timed at least 1 month apart.
2. Shutoff of the well will not adversely affect hydraulic containment of the contaminant plume. This criteria will be confirmed through semiannual sampling of downgradient observation wells as described in Table 3 of the Pumping Plan (Appendix B).
3. Groundwater flow between the upper zone and deep aquifer will not be adversely affected as determined by the presence of steep downward gradients through potential Cr(VI) source areas in the upper aquitard. This condition will be monitored on a weekly basis using the upper zone-deep aquifer well pairs indicated in Table 3 of the Pumping Plan (Appendix B).

Wells that have been shut down due to low Cr(VI) concentration shall be monitored for Cr(VI) on a monthly basis for 1 year and quarterly thereafter. If monitoring indicates that the Cr(VI) concentrations exceed 10 mg/l, groundwater extraction from the well will resume and continue for a minimum of 2 months before the well will again be considered for shutdown.

Well Maintenance

Situation: Due to the small particle size of upper zone soils (silt and clay), penetration of this material into the sand pack will continue to occur, resulting in reduced well

yields. Significant accumulations of sediment in the bottom of the well may signal sediment breakthrough and will reduce hydraulic efficiency of the well.

Recommendation: Sediment accumulations in the extraction wells should be monitored on an annual basis. Buildup exceeding a depth of one foot signals the need for redevelopment of the well.

MONITORING REQUIREMENTS

Situation: Rigorous data collection schedules at the United Chrome site have established a comprehensive data base in which to evaluate aquifer responses to infiltration and pumping. This data base, combined with increased confidence in system performance, standardization of site operations, and a reduction in the magnitude of contamination present, will permit remedial action performance to be evaluated using a reduced monitoring schedule.

Recommendation: The amended Upper Zone Monitoring and Reporting schedule [Table 3 of the Pumping Plan (Appendix B)] provides for increased time intervals between monitoring events and triggers other monitoring tasks only when certain performance parameters fall outside specified ranges.

Several new tasks have been added to provide early warning of potential adverse conditions and to assess hydraulic interactions resulting from startup of the deep aquifer groundwater extraction system in July 1991. These tasks, some of which have already been discussed, include:

- Comparing measured flow at the treatment plant with the combined extraction well (calculated) flows. This comparison will identify the presence of sediment blockages in header pipes and erosion of orifice, plates.
- Addition of MW-1 to the semiannual sampling network to monitor for plume breakthrough at the northwest site boundary.
- Calculating infiltration-extraction water balances and vertical gradients for the infiltration basin and Trench Well(s) groups.

REFERENCES

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2. CH2M HILL. Workplan for the Continuation of Phase II Remedial Action. December 1990.

3. CH2M HILL. Performance Evaluation of the United Chrome Groundwater Extraction and Treatment Facility. April 1989.
4. CH2M HILL and Ecology and Environment. Feasibility Study Report. 1985.
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Chapter 3

GROUNDWATER TREATMENT SYSTEM

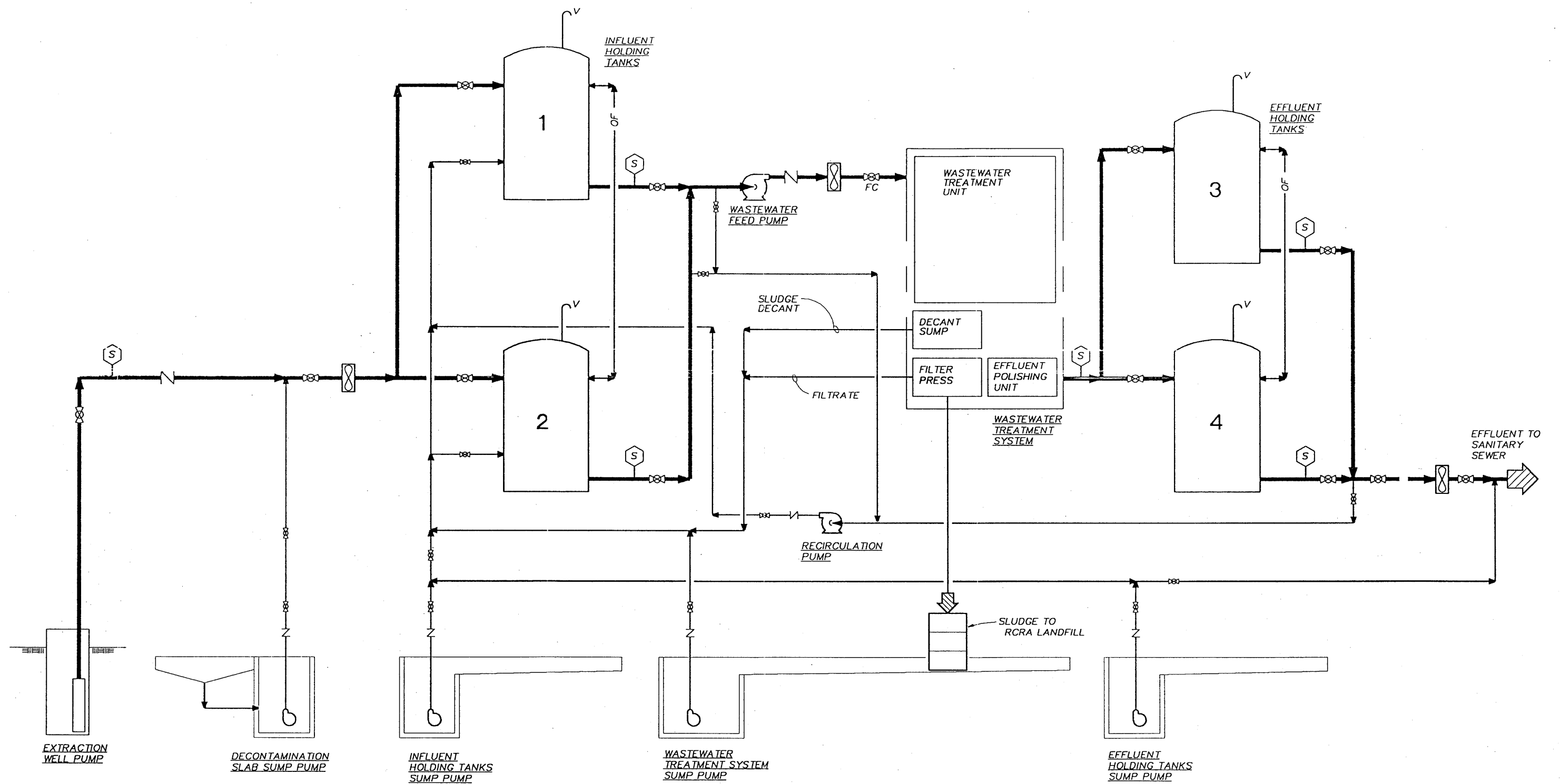


FIGURE 3-1
PROCESS FLOW DIAGRAM
GROUNDWATER TREATMENT SYSTEM
UNITED CHROME PRODUCTS SITE
CORVALLIS, OREGON

Chapter 3

GROUNDWATER TREATMENT SYSTEM

OBJECTIVES AND APPROACH

This section presents a brief review of the treatment system history, an evaluation of treatment system performance, and experimental results from recent performance tests.

The City of Corvallis has made numerous plant modifications to increase system performance in response to decreasing Cr(VI) concentration in the influent. Hexavalent concentrations have dropped from about 1,300 mg/l to 90 mg/l from the time of the first performance evaluation until the present. Throughput rates have been increased from 28 gpm to over 70 gpm during the same period.

As groundwater remediation proceeds at the United Chrome Products Site, Cr(VI) concentrations in extracted groundwater will continue to decrease below the current level of approximately 90 mg/l. With the assistance of City of Corvallis operators, CH2M HILL conducted several tests to evaluate performance of the treatment system as the Cr(VI) concentration continues to drop below the lower design limit of 200 mg/l. The objectives for these tests were to:

1. Examine system performance (throughput rate and/or removal efficiency) over a range of Cr(VI) concentrations between 120 mg/l and 10 mg/l.
2. Examine chromium removal efficiency over a range of flow rates while operating at low concentrations to identify any benefit of increased clarification area (or equivalently, decreased upflow velocity in the lamella tubes).
3. Determine the effectiveness of batch treating extracted groundwater in onsite holding tanks to reduce Cr(VI) to Cr(III).

The testing was performed between January 17 and January 25, 1991, by City of Corvallis treatment system operators. To evaluate treatment system performance at low influent concentrations, extracted groundwater was diluted in the treatment system feed tanks with city water. Groundwater was diluted to the following concentrations for performance testing: 92, 50, 43, 18, and 12 mg/l. These tanks were pumped through the treatment system, and the effluent Cr(VI) and total chromium concentration were measured and documented.

To achieve the second objective, a feed tank containing extracted groundwater was diluted to approximately 11 mg/l and run through the treatment plant. The effluent from this run was sampled at three different flow rates: 60 gpm, 45 gpm, and 30 gpm. All three flow rates used the same feed tank in order to minimize feedstock variability.

On January 25, 1991, an experiment was conducted to reduce Cr(VI) to Cr(III) using 11,500 gallons of groundwater in a batch treatment process employing equipment available at the site.

SYSTEM DESCRIPTION

The treatment system at United Chrome was purchased as a package unit from Wastewater Treatment Systems (WTS) during the initial site remediation and plant construction in 1988. The flow scheme for the package unit as originally designed is shown in Figure 3-1.

Wastewater enters the first chamber in the unit and is mixed with sulfuric acid to adjust the pH of the water to approximately 2.5. This chamber is mixed with a shaft-mounted agitator. The same chamber is used for mixing sodium metabisulfite, which reduces the Cr(VI) to Cr(III). Water overflows from the first chamber into a second chamber where caustic is added to raise the pH to about 8.5 to form chromium hydroxide precipitate. After mixing, this chamber then overflows to a flocculation chamber. Anionic polymer is introduced in the overflow channel between the caustic addition chamber and the flocculation chamber. After mixing, water leaves the flocculation chamber through an opening in the bottom of the chamber wall. The water flows under lamella packs in the clarification chamber, then up through the lamella channels. While flowing, floc particles formed in the flocculation chamber fall to the bottom of the clarifier section; treated water leaves through the top of the tubes. This effluent is then discharged through a holding tank into the City of Corvallis sewer.

Clarifier sludge is pumped to tanks, where sludge thickening takes place. After settling, the water is decanted to the effluent tanks, and sludge is processed through the filter press. Water from the filter press is recycled to the flocculation chamber and sludge is placed in containers for offsite disposal at a RCRA landfill.

Chemical addition is accomplished through metering pumps. These pumps are controlled by a programmable logic controller (PLC), which is given set points for pH and oxidation-reduction potential (ORP) by the operators. As process conditions vary, the metering pump stroke and speed is manipulated by the operators to optimize the control loop dynamics.

HISTORICAL SUMMARY

EARLY OPERATIONAL HISTORY

Between August 1988 and April 1989, the monthly average concentration of Cr(VI) in extracted groundwater decreased from 1,923 mg/l to 1,416 mg/l. The average wastewater throughput rate of the treatment system was 28.3 gpm, and it operated for

510 hours during this period, for an average of 15 hours per week. The low weekly hours resulted from filter press processing limitations. Sludge filtering was the slowest portion of the treatment scheme, often requiring the press to operate continuously even when the treatment system was not running in order to process sludge backed up in the clarifier and integral or self-contained thickening tank.

Additional performance data compiled for the April 1989 Performance Evaluation indicated that the treatment system was not functioning efficiently at the design throughput rate of 25 gpm. A number of modifications were suggested to permit the treatment system to run at design flow rates, and to address areas that deserved attention to improve overall operability of the plant.

Treatment System Modifications

Following the April 1989 performance evaluation, many of the recommendations were implemented by the City of Corvallis, CH2M HILL, and WTS, as shown in Table 3-1. Other modifications, also listed in Table 3-1, were made or are planned that improved plant performance.

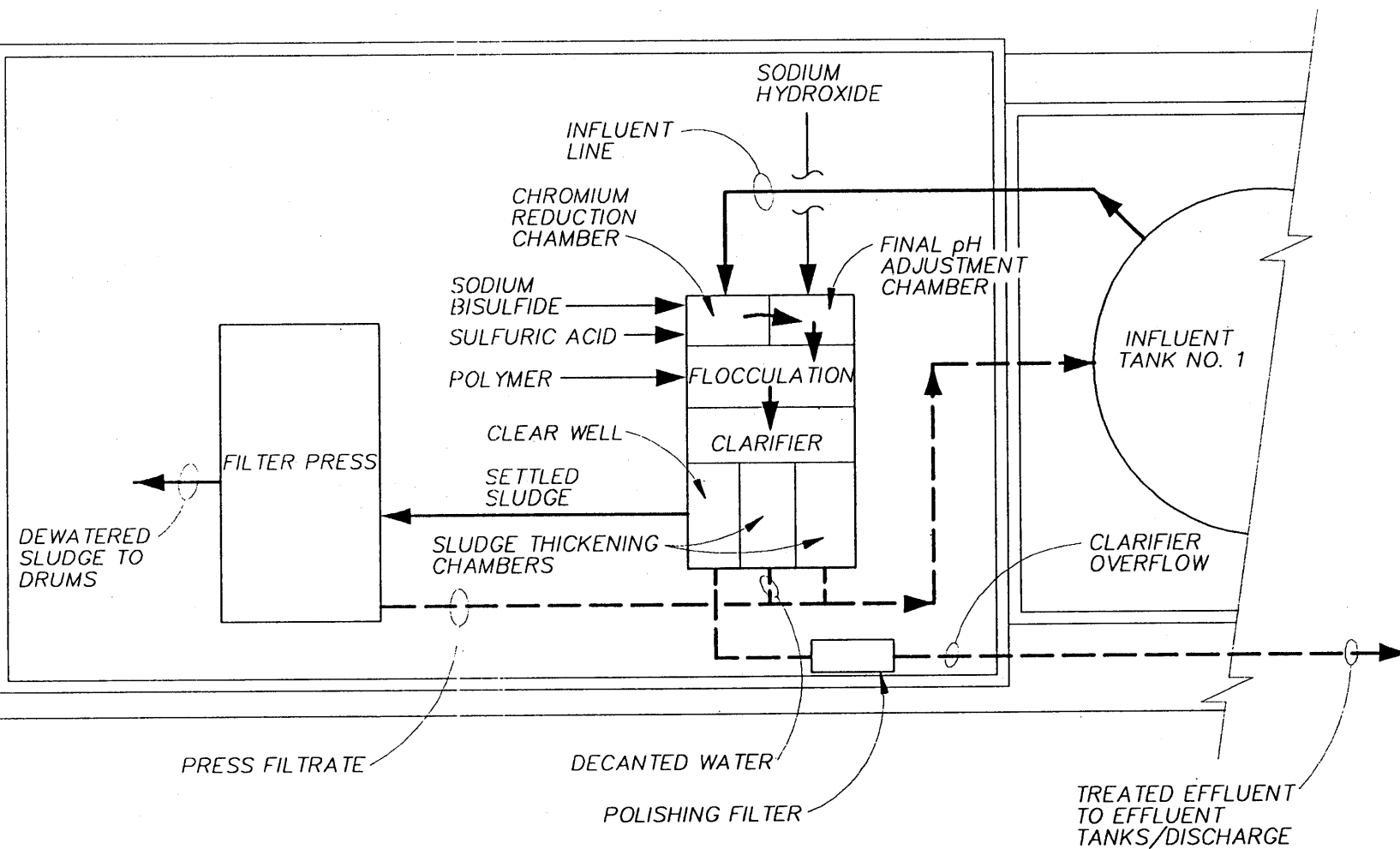
Process Modification--Sludge Handling

In addition to the modifications described in Table 3-1, process changes have been implemented. The main change has been associated with the sludge handling system. Figure 3-2 shows a schematic flow diagram of the treatment system, as originally supplied by WTS. Process modifications include the addition of two new 6,000-gallon sludge thickening tanks, resulting in the configuration shown in Figure 3-3. The new sludge thickening tanks have replaced the integral sludge thickening tanks supplied by WTS. This setup increases sludge storage capacity and the, solids content feed to the filter press.

The clarification section of the treatment system is run with a very high (up to 15 percent of the incoming flow) underflow fraction. This allows a significant amount of settling and sludge compaction to occur in the new sludge thickening tanks. Effluent water is decanted off the settled sludge periodically and discharged to the final effluent tank. The tanks are operated so that one sludge tank is filled while the other is emptied. The bottom drain of the tank being emptied feeds the filter press while the water layer is decanted and mixed with the clarifier overflow for discharge. At the end of the day, the treatment system stops operating and the sludge in the filled tank is allowed to settle overnight. The next day the cycle is repeated with the two tanks switching roles. By using the large volume provided with these tanks, sludge settling and compaction can be maximized. This reduces the volume of sludge to be processed by the filter press. This change in operations has made the treatment process more flexible, which, when combined with increased filter press capacity, has eliminated the earlier problem associated with sludge processing.

Table 3.1
Treatment System Improvements

Date	Modification	Description
Process Equipment		
July 1989	Filter Press	Original 6-cubic-foot press removed, replaced with new 12-cubic-foot press.
July 1989	Sludge Pump	Original Wilden —4 sludge pump replaced with Wilden —8 to increase capacity.
Oct. 1989	Filter Press	Filter press filtrate line replumbed from the sludge thickening tank to the clarifier.
Dec. 1989	Air Compressor	Original compressor removed, replaced with larger unit to accommodate the new press.
Dec. 1989	Air Drier	Regenerative air drier added to dry process air, address freezing problems with wet process air.
Aug. 1990	Sludge Thickening	Replaced two 900-gallon sludge thickening tanks with two 6,000-gallon tanks.
Ancillary Equipment		
Jan. 1989	Polishing Filters	Damaged by freezing, removed from process.
April 1989	Influent Flow Measurement	Reduced meter size to provide more accurate measurement.
Dec. 1989	Caustic Storage	NaOH/KOH mixtures are now used during cold months to inhibit freezing of caustic solution.
May 1990	Influent/Effluent Tank Area	Added permanent ladders, catwalks, and rails over the tanks. Installed analog level measurement on all four tanks.
Jan. 1991	Influent/Effluent Pumps	Changed from 1-1/2- to 2-hp pumps.
Feb. 1991	Influent/Effluent Tanks	Tank No. 3 replumbed to use for influent rather than effluent storage.
July 1991	Influent/Effluent Tanks	Tank No. 4 replumbed to use for influent rather than effluent storage. Treatment plant effluent discharged directly to the sewer.
Facilities		
May 1990	Chemical Storage Building	Building designed and constructed.
May 1990	Locker Room	Building designed and constructed.



LEGEND

- CHEMICAL ADDITIVES
- CHROMIUM STREAMS
- - - - TREATED STREAMS

FIGURE 3-2
ORIGINAL TREATMENT SYSTEM[®]
PROCESS FLOW DIAGRAM
 UNITED CHROME PRODUCTS SITE
 CORVALLIS, OREGON



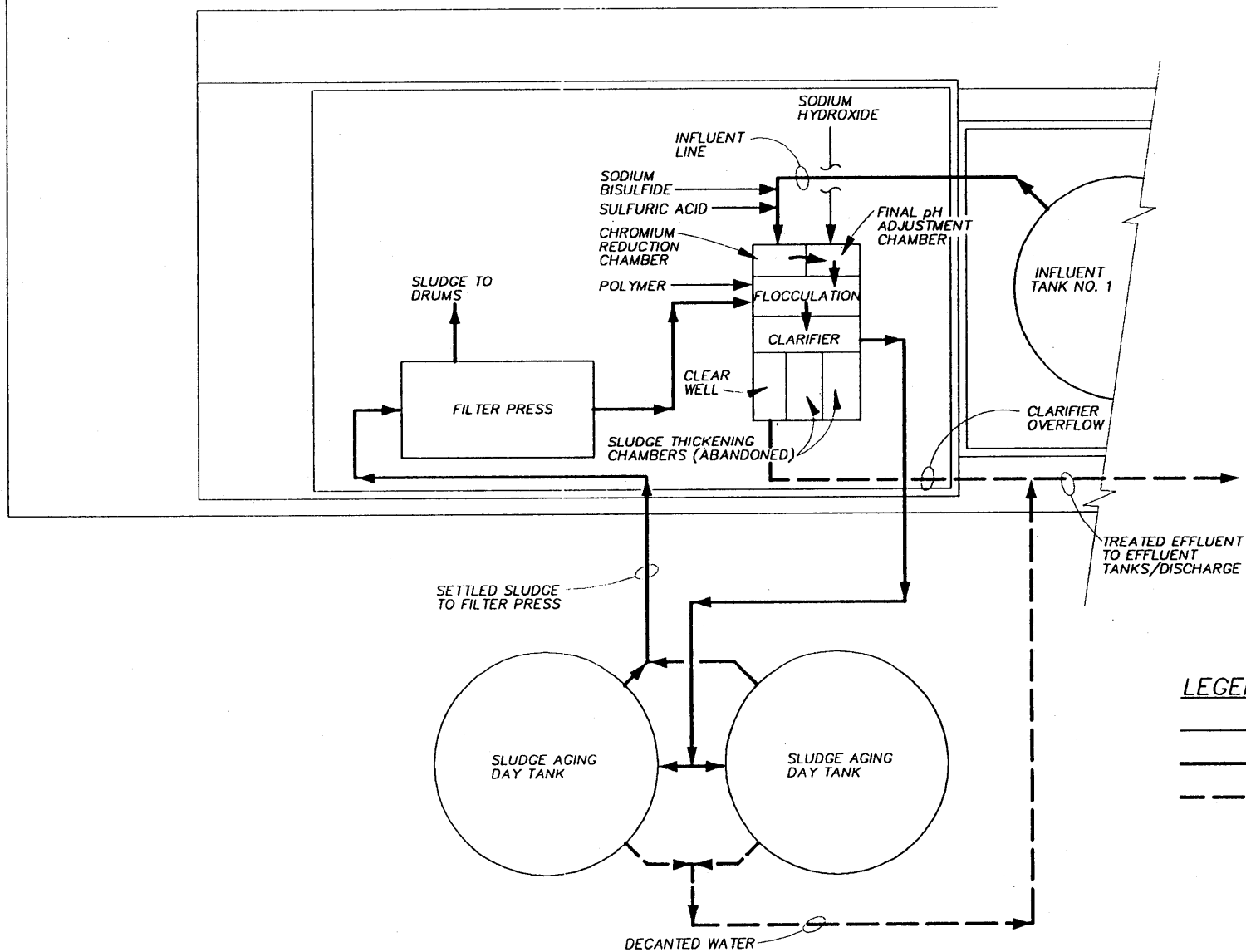


FIGURE 3-3
MODIFIED TREATMENT SYSTEM[®]
PROCESS FLOW DIAGRAM
 UNITED CHROME PRODUCTS SITE
 CORVALLIS, OREGON



INFLUENT/EFFLUENT STORAGE TANKS

Operation of the four 14,000-gallon storage tanks has been modified to meet changing operation demands. Initially, two tanks were used for influent and two tanks for effluent storage, as shown in Figure 3-1. A demand for additional influent storage was created when plant throughput rates increased and the number of days of plant operation dropped from 7 to 4 days in early 1991.

Piping from Tank No. 3 was modified for use as an influent storage tank rather than effluent storage in early 1991. Tank No. 4 is expected to be used as an influent storage tank beginning in early August 1991 as the need arises.

Changing the use of Tanks No. 3 and 4 from effluent to influent storage has changed the way that effluent is stored and discharged into the city sewer. Initially, effluent was stored in either Tank No. 3 or 4, tested for compliance with discharge limits, then discharged to the sewer. When Tank No. 3 was modified for use as an influent tank, Tank No. 4 began operating in a flow-through mode rather than a batch mode. Effluent will be discharged directly to the sewer when Tank No. 4 begins operation as an influent storage tank in the near future. The decision to move from batch discharge, with compliance testing prior to discharge to the sewer, to direct discharge, with compliance testing after discharge, was based on the operators' demonstrated ability to reliably treat the influent to meet the discharge standards.

RECENT OPERATIONS HISTORY

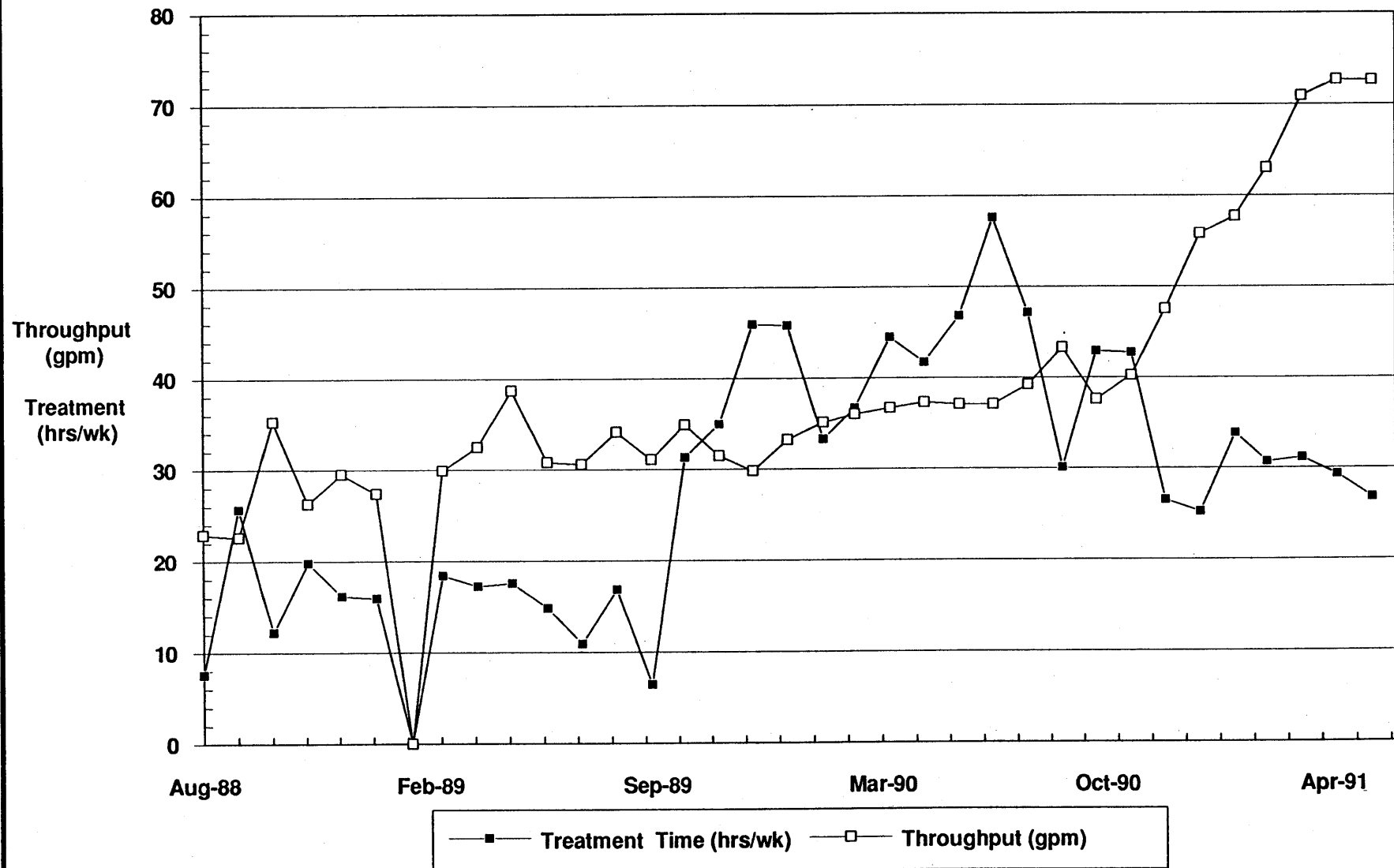
As a result of plant modifications, the average wastewater influent throughput rate has increased from 28 gpm to 72 gpm, and the operating period from 15 hours to 30 hours per week between April 1989 and June 1991. Figure 3-4 shows treatment system throughput rates and average hours of operation per week between August 1988 and June 1991. Throughput rates have exceeded 70 gpm since April 1991.

PERFORMANCE TESTING

As the concentration of Cr(VI) in groundwater continues to decrease, performance of the treatment system will likely be affected, the primary area of concern being clarifier operation. CH2M HILL, with assistance from the City operators, conducted tests to evaluate the impact of decreasing Cr(VI) concentrations on treatment system performance. This study, the subsequent experimentation, and results are presented in the following sections.

The performance tests were completed between January 17, 1991 and January 25, 1991. Treatment system operation over a range of Cr(VI) concentrations was evaluated to identify potential process modifications necessary to sustain effective operation.

Figure 3-4
Average Plant Throughput and Weekly Treatment Time



To supplement this objective, a range of feed rates were tested at a single Cr(VI) concentration (11 mg/l) to evaluate treatment efficiencies resulting from a lower velocity through the clarifier lamella tubes. In full-scale implementation, lower tube velocity can be obtained by reducing the system throughput rate, or by adding more lamella tubes to increase clarification area. Since the addition of the two 6,000-gallon sludge thickening tanks, the integral thickening tanks have been unused. Lamella packs similar to those in the clarifier section could be installed in these unused compartments to increase the effective clarification area.

Alternative operation schemes suggested by the City involve reduction of Cr(VI) to Cr(III) without using the mix tanks and agitators in the package treatment system. To obtain data on the kinetics and completeness of the reduction reaction and its dependence on mixing, experiments using extracted groundwater were performed in an influent tank to simulate a batch reaction process. The test used minimal agitation with chemical reagents added in incremental steps.

In addition to evaluating performance of the existing treatment system, the City of Corvallis has expressed a desire to examine alternative operating schemes that would require minimal or no use of this system to treat extracted groundwater. The City of Corvallis has also indicated that local discharge limits may be acceptable for regulating effluent discharge characteristics, as opposed to the current limits developed and supported by the EPA and DEQ.

CH2M HILL has included an evaluation of one alternative treatment scenario using local discharge limits as proposed by the City of Corvallis. This scenario is outlined and compared with the existing treatment scheme to provide an indication of the economic costs associated with regulating treated effluent under present EPA discharge criteria.

DILUTE FEED RUNS

Purpose and Objectives

The purpose of these tests was to observe performance of the treatment system at influent Cr(VI) concentrations between 120 mg/l and 10 mg/l. Feed rates were held constant at a high rate (60 gpm) to evaluate performance at rates proposed for future treatment system operation.

Equipment and Procedures

To provide feed for each run, City of Corvallis operators filled one of the 14,000-gallon influent tanks to a predetermined height, then filled the remaining volume of the tank with city water to dilute the chromium concentration. It was assumed that the extracted water was approximately 120 mg/l Cr(VI). This feed tank was then fed to the treatment system using standard procedures. For an initial period, operators would adjust operating parameters to reach effective treatment and achieve steady-state operation. One feed tank was used per batch for most runs. Table 3-2 lists the process

variables held constant, and those that were changed over the tests. This table is included to show the range of conditions used at steady-state for the runs during this performance test. Individual run conditions are included in Appendix A.

Table 3-2 Dilute Feed Run Variables			
Constants	Independent Variables		Dependant Variables
	Variable	Range	
Feed Rate	Feed Cr(VI) Concentration	92-12 mg/l	Effluent Cr(Total) mg/l
pH Set Points	ORP Set Point (Kf)	1840-1870	Effluent Cr(6+) mg/l
	Caustic, Acid Control	Pump Adjustments	Effluent pH
	Underflow rate	9.2-4.7 gpm	
	Polymer Addition	0.067-0.092 gpm	
	Volume/test	3,100-21,800 gal	

Once the process reached steady-state (determined mainly by inspecting the clarity of the lamella tube overflow), the effluent was sampled for total and hexavalent chromium.

Discussion of Results

Results from five runs with different Cr(VI) concentrations and three variable feed rate runs are summarized in Table 3-3. The variable feed rate runs were performed without interrupting feed to the system over a 1-day period. Two feed tanks were used, both of which contained a measured level of Cr(VI) at 10.8 mg/l.

Table 3-3 Dilute Feed Run Summary				
Constant Feed Rate	Influent		Effluent	
	Cr(VI) (mg/l)	Flow Rate (gpm)	pH	Cr (tot), Cr (VI) (mg/l)
Run No.				
1	92	60	7.9	6.4, 2.5
2	50	60	8.0	6.4, 2.4
3	43	60	7.8	10.4, 2.4
4	12	60	7.6	6.6, 1.7
5	18	60	8.8	6.4, 1.0
Variable Feed Rate				
6	11	60	7.6	7.6, 0.95
7	11	30	7.6	5.6, 0.95
8	11	45	7.4	5.8, 0.50

Run data sheets for these first five runs are included in Appendix A. Most of these runs indicate the treatment system is capable of removing chromium from dilute feed streams to near the current discharge limit of 6 mg/l. Chromium concentrations above 6 mg/l were due mainly to incomplete reduction of Cr(VI) to Cr(III) in the reaction section of the treatment system. It is expected that with continued operation of the treatment system, operating parameters could be fine tuned and effluent Cr(VI) concentration could be controlled at around concentrations of 0.95 mg/l or less. This would lower the total chromium concentration to less than 6 mg/l in most of the cases tested. Run No. 6 demonstrates that effective reduction to 0.95 mg/l of Cr(VI) is obtainable at 60 gpm with dilute feed streams.

Extracted groundwater has higher concentrations of other metals (e.g., specifically, calcium and magnesium) than present in the city water. Calcium and magnesium concentrations typically vary from 60 to 2,000 mg/l and 24 to 570 mg/l, respectively. By diluting the extracted water with city water for use as experimental feed, nonchromium metal concentrations were obtained that were lower than those present in the actual influent stream. These metals may affect treatment system performance by forming metal hydroxide coprecipitates that will settle out concurrently or entrap chromium floc in the clarifier and thickening tanks. Lower concentrations of nonchromium metals in the experimental versus the actual feed stream are not expected to affect the treatment system study results. In actual practice, performance should be enhanced by a higher concentration of these metals.

Sludge underflow rates from the clarifier to the thickening tanks for the runs previously described ranged from approximately 4.7 to 9.2 gpm. This flow rate was calculated based on known diaphragm pump volumes per exhaust, and PLC set points for on/off pulsing of the two sludge pumps. At these rates, and for the overflow concentrations given above, a mass balance can be used to calculate the sludge concentration in the stream from the clarifier to the thickening tanks. These calculated values are shown in Table 3-4.

Table 3-4						
Sludge Mass Balance Data and Calculated Values						
Run	Influent		Effluent		Sludge Underflow	
	Feed (gpm)	Cr(VI) (mg/l)	Rate (gpm*)	Cr(tot) (mg/l)	Rate (gpm)	Cr(tot) (mg/l*)
1	60	92	52	6.4	9.2	560
2	60	50	52	6.4	9.2	290
3	60	43	57	10.4	4.7	420
4	60	12	57	6.6	4.7	74
5	60	18	57	6.4	4.7	150
*Indicates calculated value						

Relatively low effluent chromium concentrations for all of the test runs indicate that the clarifier performs effectively at low influent chromium concentrations. Low underflow chromium concentrations from the clarifier may require lower flow rates as well to optimize thickening tank operation.

Conclusion

The dilute feed runs indicate that successful treatment of extracted groundwater with Cr(VI) concentrations expected in the future (10 to 100 mg/l) is possible with the existing equipment. Flow rates up to 60 gpm can be treated. Clarifier operation over this concentration range appears to be fairly smooth. No step-wise breaks in effluent characteristics were observed. Results indicate that clarifier performance may be enhanced slightly at feed concentrations of approximately 10 mg/l by increasing clarifier area or lowering throughput rates.

Chemical reaction kinetics indicate a slower rate of reduction from Cr(VI) to Cr(III) in dilute solutions. It is expected that the high effluent Cr(VI) levels observed in Runs 1 to 4 (Table 3-3) can be corrected by adjusting chemical addition rates. These adjustments can be performed during daily operations.

The City of Corvallis reports that the United Chrome treatment plant routinely treats 120,000 gallons per week during normal operations. The City has indicated that a 4-day work week is planned for future site operation. To maintain the current operational output, the treatment system must operate for 7 hours per day at 60 gpm. Given the underflow rates observed, 1,700 gallons to 3,700 gallons per day will flow to the sludge thickening tanks. Since the tanks hold 6,000 gallons each, and there are two of them, there is sufficient volume (retention time) in these tanks to operate at low influent Cr(VI) concentrations. As influent chromium concentrations continue to decrease in extracted groundwater, the operation of these tanks may have to be modified (lower underflow rates) to increase retention time necessary to obtain the desired sludge characteristics.

BATCH TESTS

Purpose and Objectives

Future plant operations may involve treating extracted groundwater to reduce Cr(VI) to Cr(III) without using the treatment system. The purpose of this test was to investigate the reduction reaction (rate and degree of completion) and confirm that it can be carried out on a large scale using simple equipment and procedures available onsite.

Equipment and Test Procedure

One of the four 14,000-gallon water tanks on the site was used as the batch reduction vessel. This tank was filled with 11,500 gallons of extracted water and a sock-type agitator was used to mix the tank contents with compressed air. A sample was obtained

and analyzed at 143 mg/l Cr(VI). Chemicals were added using an —1 Wilden diaphragm pump and piping associated with the process sump. Five gallons of 98 percent sulfuric acid were added and the tank contents were mixed for 15 minutes. Two samples were obtained from the top and the drain of the tank, and a pH of 2.4 was measured. Sodium metabisulfite (in solution at 4 pounds per gallon) was then added stepwise through the sump pump and piping, and the tank contents were sampled and analyzed.

Discussion of Results

Table 3-5 shows Cr(VI) concentrations and oxidation reduction potential (ORP) in the tank following the sodium metabisulfite additions, and the elapsed times between additions and sample collection.

Table 3-5 Batch Test Results						
Sodium Metabisulfite Added (lbs)			Time Allowed Until Sample Collected (min)	Cr(VI) (mg/l)	ORP (mv)	pH
Step	Amount	Cumulative				
1	20	20	15	110	--	--
			60	116	--	--
2	20	40	15	84	300	--
3	20	60	30	47	290	--
4	20	80	15 overnight	2.7	270	--
				2.6 (top sample) 2.7 (drain sample)		2.9

Conclusion

Based on these results, it appears that batch treatment is effective in reducing Cr(VI) to Cr(III) and can be accomplished using equipment available at the United Chrome Site.

The batch process (as performed during the test) requires approximately twice as much sodium metabisulfite (3,000 mg/gal versus 1,500 mg/gal) per gallon of water treated when compared with the existing process. This amount could likely be decreased by improving the mixing technique.

The 15-minute reaction time used during the test is slightly longer than the retention time currently provided in the reduction compartment of the treatment system.

PERFORMANCE TESTING CONCLUSIONS

Based on our review of the treatment plant operations and recent plant performance tests, the following conclusions have been drawn.

1. Numerous modifications to the treatment plant equipment and operations, as well as steadily decreasing Cr(VI) groundwater concentrations, have resulted in a dramatic increase in plant production rates over the last 3 years.
2. Results from performance testing indicate that the treatment plant is capable of being operated at flow rates of up to 60 gpm while treating groundwater at Cr(VI) concentrations down to 10 mg/l.
3. Batch processing to treat contaminated groundwater was found to be effective in reducing Cr(VI) to Cr(III) using equipment available at the site. This process may be suitable for future treatment of the chromium-contaminated groundwater.

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Chapter 4

ALTERNATIVE OPERATION SCENARIOS

Chapter 4

ALTERNATIVE OPERATION SCENARIOS

Operation of the United Chrome treatment plant for removal of chromium from extracted groundwater represents the primary cost associated with remediation of contaminated groundwater at the site. Presently estimated at \$271,000 per year for 1991, this cost may be reduced by treating groundwater using variations of the existing scheme or through pretreatment to reduce Cr(VI) to Cr(III) with subsequent discharge to the sanitary sewer where final treatment would be provided by the City of Corvallis Wastewater Treatment Plant (POTW). Descriptions and annual cost estimates for four possible options (including the existing scheme) are discussed in a later section of this chapter.

An important element for successful evaluation of each option and future treatment operations planning is the cost incurred per pound of chromium removed. To estimate this cost, it was necessary to estimate the concentration of Cr(VI) and the volume of extracted groundwater that can be expected from the upper zone wells. These values may also be used for estimating daily chromium loadings to the City of Corvallis POTW under a “reduce and discharge” scenario.

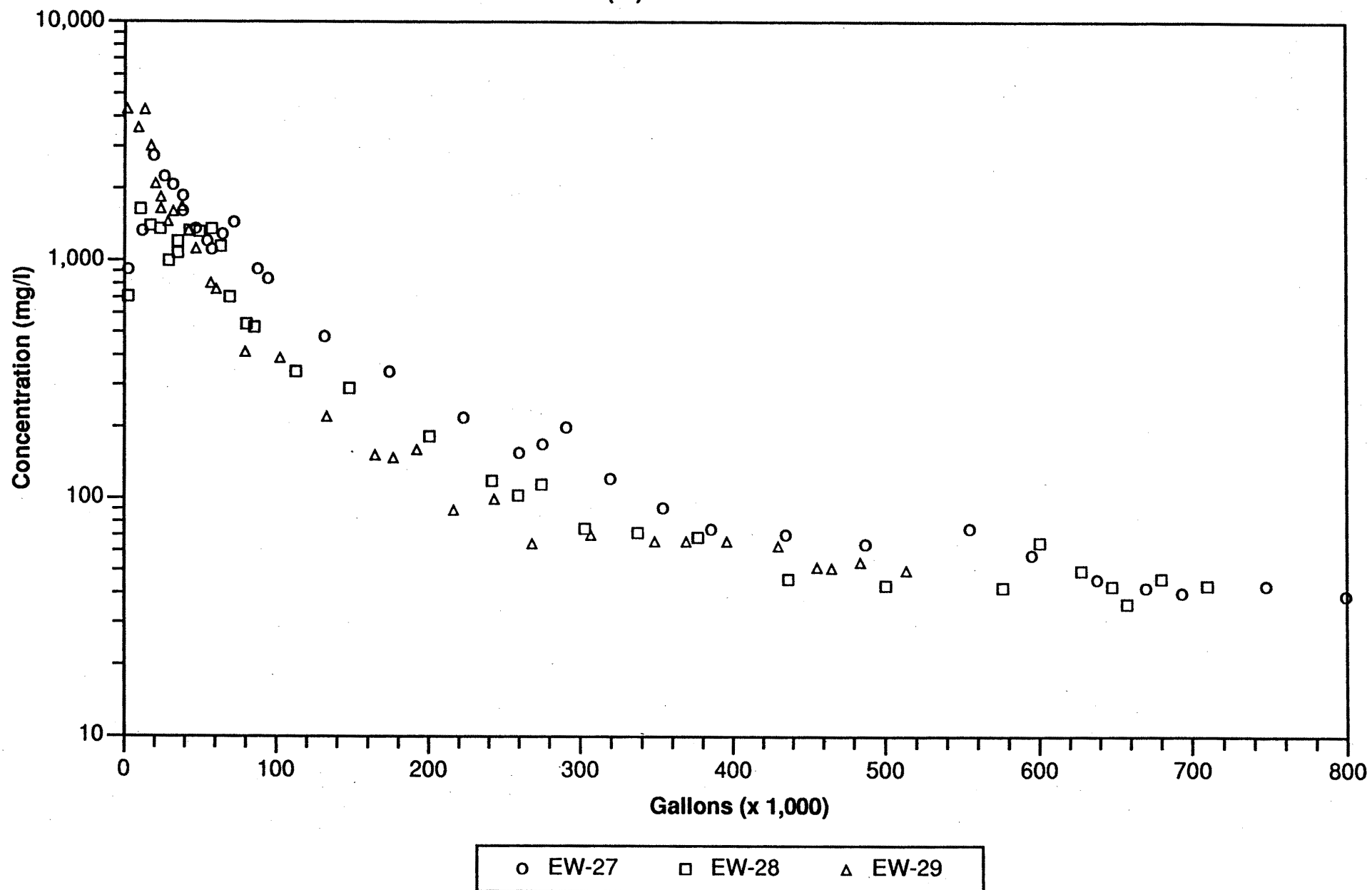
A description of the approach used, assumptions made, and potential application of this concentration “forecast” is presented in the following sections.

APPROACH

Evaluation of concentration trends in upper zone wells (where trend patterns exist) indicates that Cr(VI) concentrations have decreased in a manner that is dependent upon the concentration present and the volume of groundwater generated by the well. The approach used to estimate Cr(VI) concentrations for all of the wells was based on a trend observed at well locations EW-27, EW-28, and EW-29 (Figure 4-1) where Cr(VI) concentrations have shown a significant overall decrease (thereby providing rate constants for a wide range of concentrations) and large volumes of groundwater have been extracted.

Concentration trends were segregated into three ranges (less than 70 mg/l, 70 mg/l to 500 mg/l, and greater than 500 mg/l) and a curve fitting method used to generate an equation for each concentration range. Each segment (for the three concentration ranges) of the overall curve is represented by a power function of the form:

Figure 4-1
United Chrome Products Site
Cr(VI) Concentration Trends



$$C = C_o \exp(-A \cdot Q)$$

Where: C = Concentration estimate at time correlating with Q
 C_o = Initial concentration value
 Q = Extraction gallons generated by the well
 A = Rate constant

As shown in the equation, each curve segment requires an initial concentration value (C_o) for a specific range. This value is used over the entire range as long as the concentration estimate remains within the given limits. For each well, initial Cr(VI) values were selected from historical trends observed during the past year. The value selected generally represents the highest value preceding a period of steady concentration decline. When the Cr(VI) concentration in a well drops into the next lower range, the last value generated for the higher range is used as the initial value (C_o) for the lower range.

Since an extraction gallon value is required in the exponential term, it was necessary to estimate future extraction gallons for each well. Due to seasonal influences at the site, values were estimated for periods of high (January through June) and low (July through December) groundwater conditions. Individual well flows were estimated from an assumed orifice plate size (for low and high conditions), a hydraulic efficiency of 0.75, and an operations efficiency of 0.9. The combined flow estimate for all 23 wells is equal to a 14,400 gallons per day for low groundwater and 20,000 gallons per day for high groundwater conditions.

The rate constant term was determined from the shape of the concentration versus extraction gallons curve for the three wells EW-27, EW-28, and EW-29.

ASSUMPTIONS

Assumptions were made to simplify the analysis and deviations from them will result in concentration values that differ from the estimates. These assumptions include:

Ideal Behavior. Concentration trends are assumed to follow patterns observed in wells EW-27, EW-28, and EW-29 (uniform decreasing trend). Variations in the nature and rate of contaminant release at individual well locations will likely cause deviations from the estimated values.

Uniform Extraction Flow Rates. Extraction well flow rates (all 23 wells) are assumed to remain constant (except for seasonal differences) for the duration of the forecast. Cyclic pumping of extraction wells or turning off wells will result in different extraction volumes, thereby altering the flow balance and overall concentration.

APPLICATION

Hexavalent chromium concentration estimates for each extraction well were generated for two points (corresponding to mid-low September and mid-high March groundwater conditions) per year for the years spanning 1991 through 1998. Using a flow weighted average, individual well concentrations were then combined to obtain the Cr(VI) concentration for all wells (Figure 4-2). Concentration values for the period preceding 1991 were taken from the City of Corvallis operating reports for the month of June.

Individual well concentration values were also combined with the estimated flow rates to establish daily Cr(VI) loading to the onsite treatment plant (Figure 4-3). Daily loading values for the years preceding 1991 were taken from City of Corvallis monthly reports and calculated by dividing annual Cr(VI) removal by the number of operating days. For the years 1991 through 1998, 330 operating days per year have been assumed.

One potential application of Figure 4-3 is to estimate the point in time at which daily Cr(VI) extraction yields attain a particular action level. Two potential action levels (12.7 lbs/day and 7 lbs/day) proposed for use at the United Chrome site are shown on this graph, compared with existing conditions and predicted yields. It should be noted that the action levels shown are for total chrome [primarily Cr(III) and Cr(VI)].

The 12.7 lbs/day total chromium limit proposed by the City of Corvallis was obtained through an evaluation of existing chromium discharges to the POTW. After allocating chromium discharges to existing sources with a reserve set aside for future growth, the City determined that up to 12.7 lbs/day of chromium could be safely accepted from the United Chrome site by the POTW. An action level of 7 lbs/day of total chromium has been suggested by EPA and DEQ. This limit was determined to result in a POTW sludge concentration of less than 1,000 mg/kg chromium assuming 80 percent removal of chromium by the POTW.

DEVIATION FROM ESTIMATED CONDITIONS

Since the concentration forecast has been prepared using several assumptions, the information provided in the graphs must be used cautiously. The transition period between actual versus estimated concentrations (1991 data) is not uniform and, therefore, many of the early concentration estimates could be high.

Because the function used to estimate concentration is dependent on extraction gallons, deviations from the assumed flow rates will influence the concentration forecasts. As individual wells attain the remediation goal of 10 mg/l, they may be shut off. Turning off extraction wells will result in alteration of contaminant flowpaths and may result in concentration spikes as new flowpaths are established.

Figure 4-2
Cr(VI) Concentration in Combined Well Flows
Actual and Projected

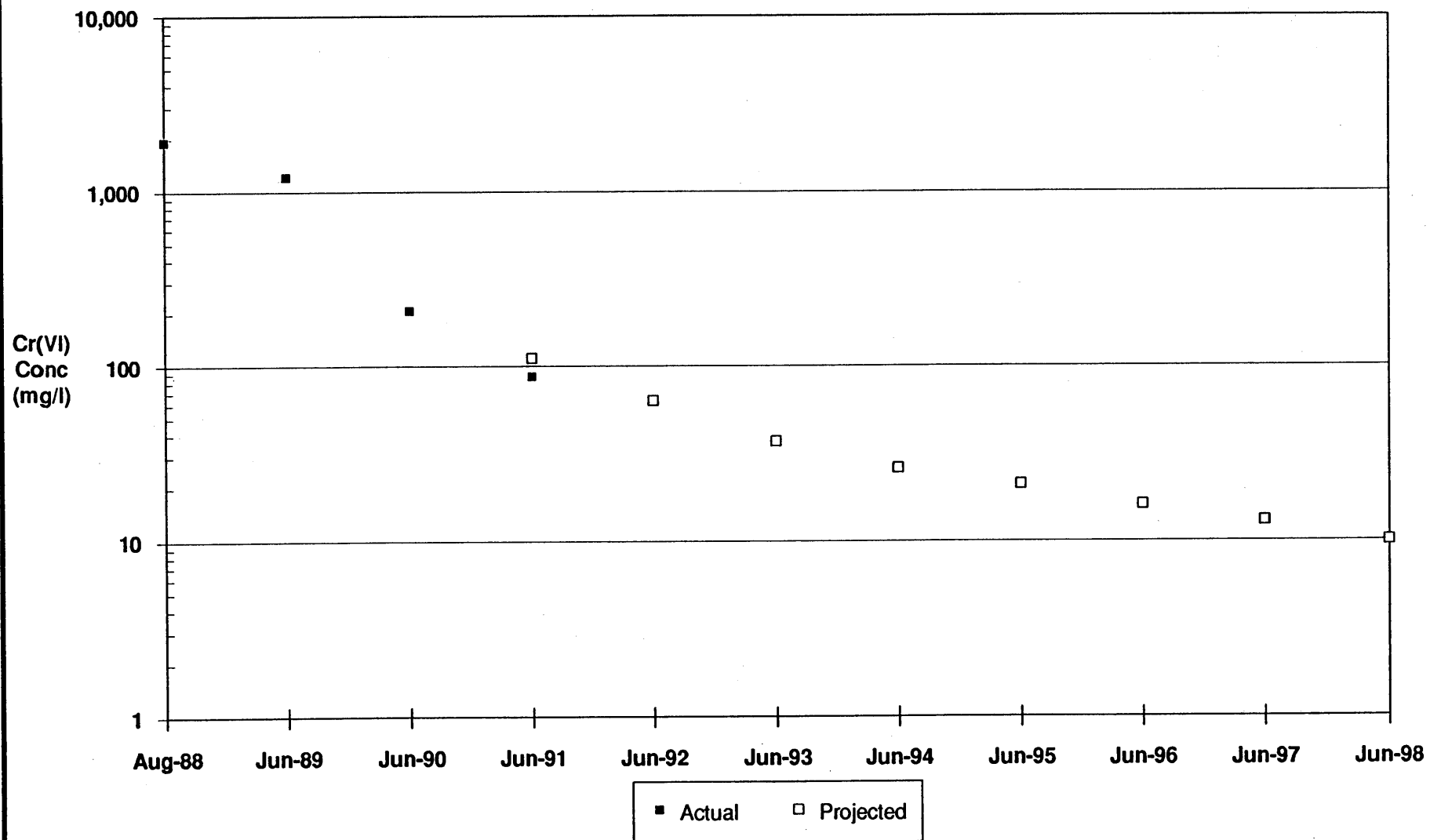
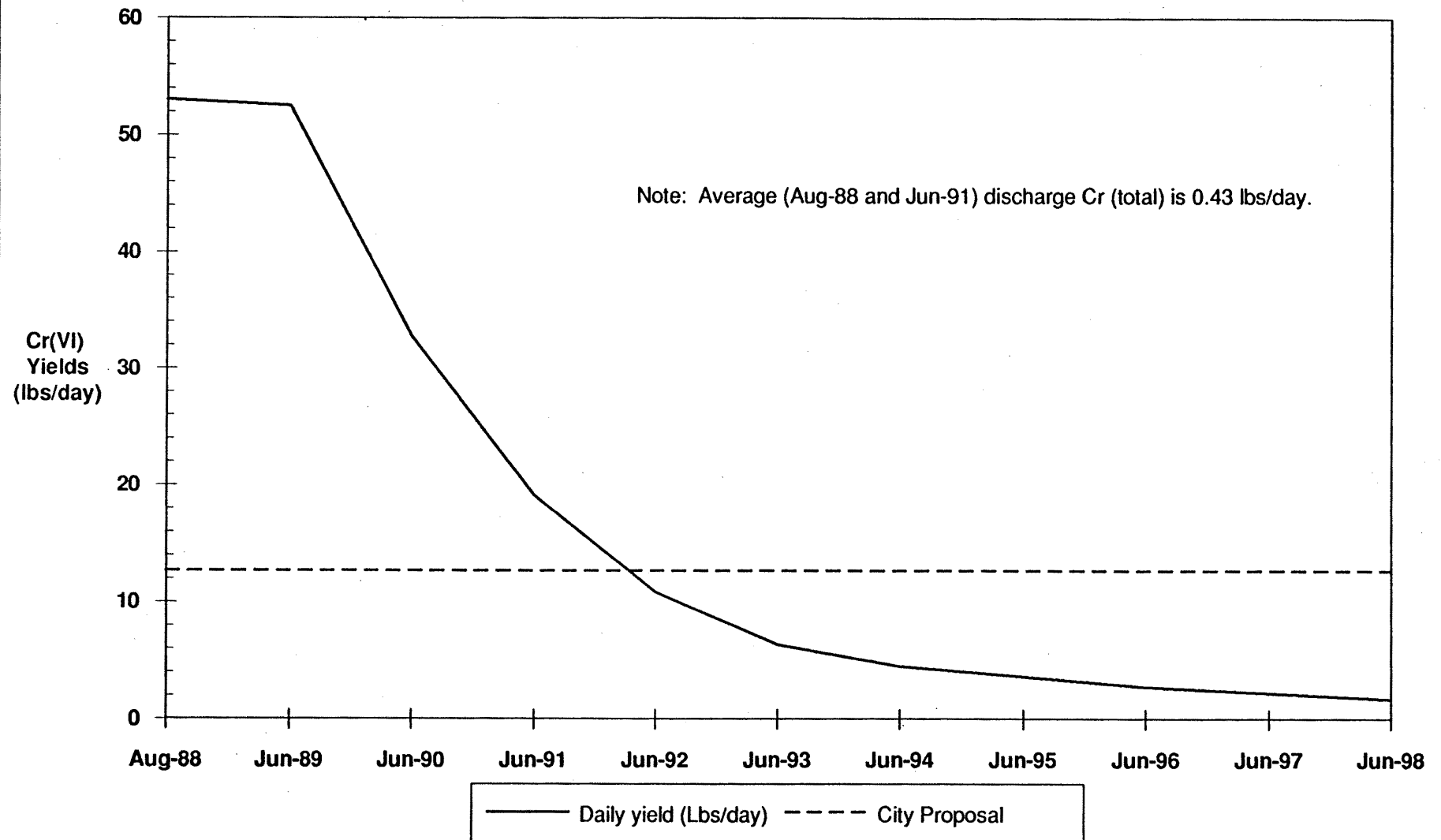


Figure 4-3
United Chrome
Daily Cr(VI) Yields and Discharge Limits



OPERATING ALTERNATIVES

A number of options are available for future operation of the United Chrome treatment plant involving alternative effluent discharge limits and operating schemes. The discharge criteria under which the treatment system performs are central to any operating alternative. Since 1988, the United Chrome site has operated under discharge criteria specified by the EPA. In late 1990, the City performed an evaluation of the fate of Cr(total) and Cr(III) in the Corvallis POTW. Groundwater, treated to convert Cr(VI) to Cr(III), was discharged to the sewer system. The results of this study, as interpreted by the City, indicate that local discharge limits higher than those presently required by the EPA are permissible. Current EPA criteria and alternative limits proposed by the City of Corvallis are summarized in Table 4-1.

Table 4-1 Discharge Criteria Options		
Criteria	EPA	City Proposal
Groundwater to be treated	All groundwater with 10 mg/l or more Cr(total)	Groundwater above daily limits for Cr(total)
Discharge concentration	6 mg/l Cr(total) or less	12.7 lb/day Cr(total)
Effluent sampling	Daily (composite/grab)	Weekly

Other options that implement either the EPA or City effluent discharge limits for chromium involve operation of the treatment plant for different periods during the day. Presently, the plant operates on an intermittent schedule (less than 4 days per week). Alternatively, the plant could be operated in a continuous mode (24 hours per day).

OPERATING SCHEMES

EPA DISCHARGE LIMITS

Under EPA discharge limits, the treatment plant would continue to operate as it does now. Filter press operation will continue to decrease as the volume of sludge generated diminishes. This condition presents no serious problem and can be accommodated by using the sludge thickening tanks for long-term storage to hold and decant sludge for intermittent feed to the press.

LOCAL DISCHARGE LIMITS PROPOSED BY THE CITY

Under the City-proposed local discharge limit, a number of operating schemes would be possible. One option would be to separate flows from high and low Cr(VI) concentration wells into two streams. This would permit the low concentration stream to be treated using only the reduction [Cr(VI) to Cr(III)] step. Treatment of the high concentration stream would include reduction, precipitation, and clarification with subsequent discharge of treated effluent to the city sewer. Clarifier sludge would continue to be processed by the filter press and disposed at a RCRA landfill. Separation of the streams would reduce the volume of water requiring full treatment and minimize the time required to process extracted groundwater.

The reduction step in the treatment of the low chromium concentration stream could be handled using batch tanks or an in-line plug-flow reactor. The use of batch tanks would require operators to perform necessary chemical additions once a day. Capital additions such as piping for chemical additions, permanent agitators, pumps, and computer control and instrumentation would be required to varying degrees, depending on the desired tradeoff between labor and capital expenditures.

Alternatively, use of an in-line plug-flow reactor for the reduction step would be possible. As shown in the process flow diagram in Figure 4-4, extracted water would be mixed with sulfuric acid using an injector mounted through the transfer pipe wall. Following this injector, dispersion of the acid to attain uniform pH in the wastewater would occur using a static in-line mixer. Sodium metabisulfite would be introduced and mixed in the same way, followed by a pH adjustment using caustic (NaOH). A static mixer would probably not be required following the caustic addition because slow mixing will reduce the potential for precipitation of chromium hydroxide in the relatively long pipe conveying the treated effluent to the sewer. Capital additions such as injectors, static mixers, metering pumps, and control and instrumentation would be required to implement this process. Operating labor would be limited to maintaining chemical feed stock and effluent sampling and analysis.

CONTINUOUS (AUTOMATED) OPERATION

Currently, the treatment plant is started up and shut down daily, although it was designed to operate continuously. The startup and shutdown activities induce unavoidable process upsets. Thus, under present conditions, the system requires close attention and can be operated only during those hours of the day when operators are present. A more stable operation might be achieved by reducing the current flow rate of 70 gpm (for 7 hours a day, 4 days per week) to an equivalent rate of 12 gpm (for 24 hours a day, 7 days a week), while maintaining the overall flow rate of 120,000 gallons per week. Swings in composition and feed rate that typically occur with the daily startup/shutdown sequence would be eliminated. Computer control of chemical additions would be more stable under constant flow and composition conditions.

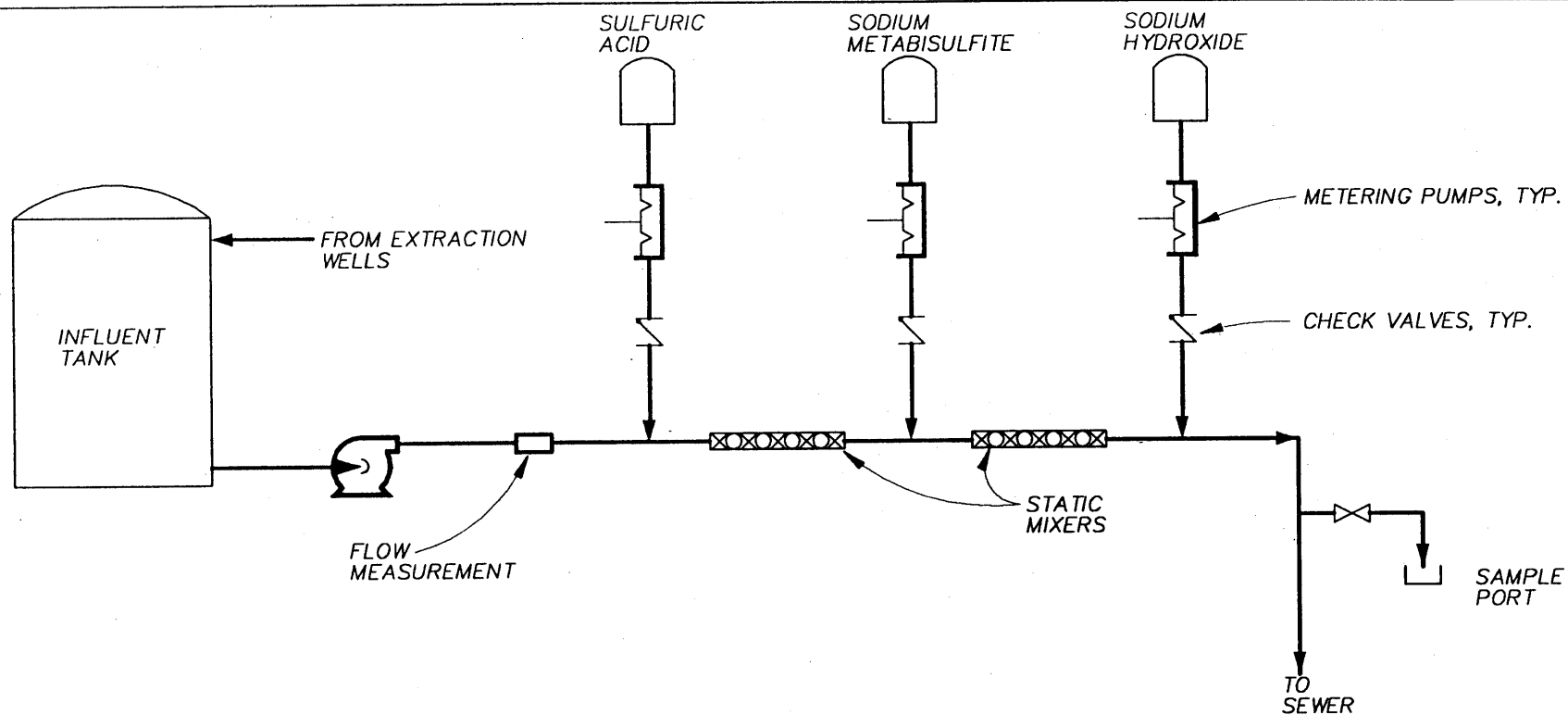


FIGURE 4-4
IN-LINE PLUG-FLOW REACTORS
SCHEMATIC DIAGRAM

UNITED CHROME PRODUCTS SITE
CORVALLIS, OREGON



Continuous unattended operation would require capital additions, including instrumentation to notify POTW operations staff via telephone when critical process variables deviate from specified ranges. Currently, the treatment plant uses a telephone based dead-man system for operator safety and automatic shutdown control logic. The system would be modified to include safety and operational features for unattended operation to minimize operational labor costs.

COST COMPARISON

Four alternative programs for future operation of the United Chrome treatment plant have been compared on the basis of annual costs. The four options are:

Option A--Continued operation of the existing treatment plant on a part-time basis under current EPA discharge criteria

Option B--Operation of treatment plant under City-proposed local limit discharge criteria using a plug-flow reactor to reduce Cr(VI) to Cr(III) prior to sewer discharge

Option C--Continuous (automated) operation of the treatment plant under EPA discharge criteria

Option D--Operation of treatment plant under EPA discharge criteria using a plug-flow reactor to reduce Cr(VI) to Cr(III)

Major assumptions used in generating cost estimates for each of the options are summarized in Table 4-2. Cost estimates for each option appear in Table 4-3. All material costs were inflated 5 percent annually; all labor costs were assumed to increase 6 percent annually. The discount rate used to compute net present value (NPV) was 8 percent.

These options are presented as a basis for making comparisons of alternative operating schemes. Option A provides a benchmark against which modified operating conditions can be compared. Under Option A, the treatment system is unchanged; operation continues as it does now under EPA discharge criteria. Treatment system equipment and operating variances allow for many creative schemes, three of which are described as Options B, C, and D.

Option B involves modified operation of the plant to continuously reduce the fraction of influent flow with a chromium content below the local limits proposed by the City. Reduction of Cr(VI) to Cr(III) would occur using a plug-flow reactor and the treated water discharged to the POTW. Option B assumes continued operation of the treatment system for the remaining fraction of extracted water exceeding the local discharge

**Table 4-2
Major Assumptions For Cost Estimates**

Assumption	Option			
	A	B	C	D
Capital additions	None	Plug-flow reactor	Monitoring devices	Plug-flow reactor
Discharge limits	EPA	City of Corvallis	EPA	EPA
Treatment rate	120,000 gpw	120,000 gpw	120,000 gpw	120,000 gpw
Annual inflation rate (labor)	6 percent	6 percent	6 percent	6 percent
Annual inflation rate (materials)	5 percent annual increase	5 percent	5 percent	5 percent
Annual chemical use (except polymer)	Caustic--7,022 gal/mo; sodium metabisulfite-- 2,899 lb/mo; sulfuric acid--4,065 gal/mo	Same as A	Same as A	Same as A
Annual analytical requirements	\$5,500 onsite analysis; 60 hr/yr offsite QA; \$2,000 GW chemical analysis	\$5,500 offsite analysis; 60 hr/yr offsite QA; \$2,000 GW chemical analysis	Same as B	Same as B
Power cost (City of Corvallis rate)	\$0.054/kW-hr	\$0.054/kW-hr	\$0.054/kW-hr	\$0.054/kW-hr
Annual maintenance cost (PV)	\$20,000	\$7,000	\$7,000	\$10,000
Annual PPE cost (PV)	\$1,200	\$200	\$1,200	\$1,200
Annual polymer use	16.9 lb/mo	4 lb/mo--1991 only	16.9 lb/mo	16.9 lb/mo
Operating labor	1.5 FTE	1.0 FTE--1991; 0.7 FTE thereafter	1.1 FTE	1.0 FTE
Supervisory labor	0.2 FTE	0.2 FTE--1991; 0.1 FTE thereafter	0.2 FTE	0.2 FTE
Annual sludge production*	144 cf/mo--1991; 10% annual decrease	34 cf/mo--1991 only	144 cf/mo--1991; 10% annual decrease	144 cf/mo--1991; 10 percent annual decrease
Annual physical exams/ health and safety training	6	4	2	2
*Sludge production = (extraction rate -discharge limit) x sludge density Options A, C, D: (17.28 lb/d - 12.7 lb/d) x (cf / 4 lbs) x (30 d/mo) = 34 cf/mo Option B: (17.28 lb/d - 1.92 lb/d) x (cf / 4 lbs) x (30 d/mo) = 144 cf/mo				

limits for the duration of 1991. It is expected that the rate of total chromium being extracted will equal the local limit by the end of 1991. At that time, the treatment system would be abandoned and the entire extraction flow continuously reduced in the plug flow reactor before discharge to the POTW.

Option C involves unmanned operation of the existing treatment system. The total weekly flow would remain constant; however, the flow would be treated over seven 24-hour periods rather than four 10-hour periods as it does now. Monitoring equipment would be installed to alert personnel at the POTW to required operator intervention.

Option D involves modification of the treatment plant to continuously treat effluent to reduce chromium using the same plug-flow reactor as Option B. The amount of chromium discharged would meet EPA discharge criteria. Reduced effluent would be dumped to settling tanks; sludge would be pumped out periodically; decant would be discharged to the POTW.

Note in Table 4-3 that the estimated net present value of continuing treatment plant operation in the present mode through 1998 (Option A) is \$1,544,000. The net present value of operating the plant continuously without changing the discharge limit (Option C) is \$1,367,000. Installation and operation of a plug-flow reactor to reduce the extraction flow under present discharge limits (Option D) has an estimated net present value of \$1,259,000, compared to use of the plug-flow reactor under proposed City limits (Option B) at \$736,000. The greatest impact on costs results from changes in the assumptions regarding operating labor and sludge handling. Costs for maintenance, polymer, and capital additions impact the net present value of the various options to a lesser degree.

A comparison of net present values of the various options indicates that a change from the current operating scheme (Option A) to operation of the plug-flow reactor under new discharge limits (Option B) may potentially result in a total savings of approximately \$800,000. A change from the current system to a continuous unmanned system (Option C) may result in a savings of over \$180,000, and use of a plug-flow reactor operated under EPA discharge limits (Option D) may result in savings of \$285,000.

COST EFFECTIVENESS

The cost-effectiveness of the four alternatives has been evaluated on the basis of treatment cost per pound of chromium removed from groundwater. The ratio of the annual present value cost of each alternative to the expected amount of chromium removal provides a measure of the effectiveness of the various operating alternatives. The expected cost per pound of chromium removed through 1998 is presented in Figure 4-5 for Options A through D. The most cost-effective alternative that does not involve a change in the discharge limits would be the plug-flow reactor (Option D), at a cost savings over the existing system of about \$10/lb of chromium removed by June

1992, followed by continuous operation of the existing facility (Option C), at a cost savings of about \$6/lb.

Implementation of Options C and D will maintain the current EPA discharge limits (average is 0.43 lb/day total chromium). A change in site operations as presented in Option B would result in chromium discharge of 12.7 lb/day to the POTW and environment or approximately 2.3 tons of recoverable chromium annually. A savings in the first year from Option B of \$130,000 would result in an incremental cost of about \$20 per pound of chromium.

United Chrome Cost Estimate 1-Aug-91					Table 4-3 Annual Cost Estimates for Options A through D								Material Inflation Rate = 0.05 Labor Inflation Rate = 0.06		
Task	Quantity	Units	Unit Cost	Cost Ref	1991	1992	1993	1994	1995	1996	1997	1998	Total	NPV(8%)	
OPTION A--CONTINUE SYSTEM OPERATION UNMODIFIED															
Operations Labor--A															
Operator Labor	2	FTE	\$52,417	City	\$78,626	\$83,343	\$88,344	\$93,644	\$99,263	\$105,219	\$111,532	\$118,224	\$778,193	\$589,712	
Supervisor Labor	0	FTE	\$66,100	City	\$13,220	\$14,013	\$14,854	\$15,745	\$16,690	\$17,691	\$18,753	\$19,878	\$130,845	\$99,153	
Maintenance Material and Labor--A															
Annual Maintenance	1	ls	\$20,000	'90 est	\$20,000	\$21,200	\$22,472	\$23,820	\$25,250	\$26,765	\$28,370	\$30,073	\$197,949	\$150,005	
Expendable Material & Energy--A															
PPE	1	ls	\$1,200	'90 est	\$1,200	\$1,200	\$1,200	\$1,200	\$1,200	\$1,200	\$1,200	\$1,200	\$9,600	\$7,448	
Chemicals															
Caustic (0.0133 #/gal H2O)	7,022	#/mo	\$0	Van R	\$16,011	\$16,011	\$16,011	\$16,011	\$16,011	\$16,011	\$16,011	\$16,011	\$128,089	\$99,371	
Polymer (3.2X10^-5 #/galH2O)	17	#/mo	\$3	Van R	\$659	\$659	\$659	\$659	\$659	\$659	\$659	\$659	\$5,272	\$4,090	
Sodium Bisulfite (5.5#/#Cr6+)	2,899	#/mo	\$0	Van R	\$11,220	\$11,220	\$11,220	\$11,220	\$11,220	\$11,220	\$11,220	\$11,220	\$89,764	\$69,639	
Sulfuric Acid (.0077 #/galH2O)	4,066	#/mo	\$0	Van R	\$4,001	\$4,001	\$4,001	\$4,001	\$4,001	\$4,001	\$4,001	\$4,001	\$32,004	\$24,829	
Pump & Process Elect	10,493	kWh/mo	\$0	City	\$6,799	\$6,799	\$6,799	\$6,799	\$6,799	\$6,799	\$6,799	\$6,799	\$54,396	\$42,200	
Miscellaneous Services--A															
Physical Exams	6	ea	\$500	'90 est	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$24,000	\$18,619	
Health & Safety Training	6	ea	\$200	'90 est	\$1,200	\$1,200	\$1,200	\$1,200	\$1,200	\$1,200	\$1,200	\$1,200	\$9,600	\$7,448	
Analytical Requirements---A															
Onsite Analyses	1	ls	\$1,000	'90 est	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$8,000	\$6,206	
Offsite Analyses															
Offsite Lab QA	100	hr/yr	\$30	'90 est	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$24,000	\$18,619	
6 mo chem analysis of GW	2	ls	\$2,000	'90 est	\$4,000	\$4,000	\$4,000	\$4,000	\$4,000	\$4,000	\$4,000	\$4,000	\$32,000	\$24,826	
Disposal of Wastes---A (assumes 10% reduction in press production/yr and 5% inflation)															
Sludge	144	ft3/mo	\$48	city	\$82,944	\$74,650	\$67,185	\$60,466	\$54,420	\$48,978	\$44,080	\$39,672	\$472,393	\$381,924	
TOTAL COSTS--A (Labor = 46%)					\$246,880	\$245,296	\$244,945	\$245,766	\$247,712	\$250,743	\$254,825	\$259,937	\$1,996,105		
TOTAL NPV--A						\$246,880	\$227,127	\$210,001	\$195,097	\$182,076	\$170,653	\$160,583	\$151,670		\$1,544,088

United Chrome Cost Estimate 1-Aug-91					Table 4-3 Annual Cost Estimates for Options A through D								Material Inflation Rate = 0.05 Labor Inflation Rate = 0.06	
Task	Quantity	Units	Unit Cost	Cost Ref	1991	1992	1993	1994	1995	1996	1997	1998	Total	NPV(8%)
OPTION B--RUN WTS SYSTEM FOR 3 YRS, CONTINUOUS TREATMENT W/O Cr(III) REMOVAL														
Operations Labor--B														
Operator Labor	1.0 to 0.7	FTE	\$52,417	City	\$54,417	\$38,893	\$41,227	\$43,701	\$46,323	\$49,102	\$52,048	\$55,171	\$378,882	\$290,924
Supervisor Labor	0.2 to 0.1	FTE	\$66,100	City	\$13,220	\$7,007	\$7,427	\$7,873	\$8,345	\$8,846	\$9,376	\$9,939	\$72,032	\$56,187
Capital Additions--B														
Plug-Flow Reactor														
Transfer pump (0-20 gpm)	1	ea	\$600	est.	\$600									
1" Piping	30	ft	\$2	est.	\$60									
½" tubing	30	ft	\$2	est.	\$45									
Kenics Static mixer (1"x6 element)	2	ea	\$258	UPC	\$516									
Metering Pumps	3	ea	\$800	est.	\$2,400									
Injector apparatus	3	ea	\$250	UPC	\$750									
Accumulator	3	ea	\$150	est	\$450									
Flow meter (0-20 gpm)	1	ea	\$500	est.	\$500									
Backpressure control valves	3	ea	\$256	UPC	\$768									
Mechanical	1	ls	\$1,500	est	\$1,500									
Electrical	1	ls	\$1,500	est.	\$1,500									
Control (programming, wiring, parts)	1	ls	\$1,000	est.	\$1,000									
Engineering	1	ls	\$2,522	est.	\$2,522									
Total					\$12,611	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$12,611	\$12,611
Miscellaneous Material & Energy--B														
Annual Maintenance	1	ls	\$15,000	'90 est	\$15,000	\$15,000	\$15,000	\$10,000	\$10,000	\$10,000	\$10,000	\$10,000	\$95,000	\$75,980
Expendable Material & Energy--B														
PPE	1 to 0.5	ls	\$200	'90/6	\$200	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$900	\$721
Chemicals														
Caustic (.0133#/gal H2O)	7,022	gal/mo	\$0	Van R	\$16,011	\$16,011	\$16,011	\$16,011	\$16,011	\$16,011	\$16,011	\$16,011	\$128,089	\$99,371
Polymer (3.2X10^-5 #/galH2O)	4	lb/mo	\$3	Van R	\$156	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$156	\$156
Sodium Metabisulfite (5.5#/#Cr6+)	2,899	lb/mo	\$0	Van R	\$11,220	\$11,220	\$11,220	\$11,220	\$11,220	\$11,220	\$11,220	\$11,220	\$89,764	\$69,639
Sulfuric Acid (.0077 #/galH2O)	4,066	gal/mo	\$0	Van R	\$4,001	\$4,001	\$4,001	\$4,001	\$4,001	\$4,001	\$4,001	\$4,001	\$32,004	\$24,829
Pump & Process Elect	5,730	kWh/mo	\$0	City	\$3,713	\$2,933	\$2,933	\$2,933	\$2,933	\$2,933	\$2,933	\$2,933	\$24,244	\$18,984
Miscellaneous Services--B														
Physical Exams	4	ea	\$500	'90 est	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000	\$16,000	\$12,413
Health & Safety Training	4	ea	\$200	'90 est	\$800	\$800	\$800	\$800	\$800	\$800	\$800	\$800	\$6,400	\$4,965
Analytical Requirements--B														
Onsite Analysis	1	ls	\$1,000	'90 est	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$8,000	\$6,206
Offsite Analyses														
Offsite Lab QA	100	hr/yr	\$30	'90 est	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$24,000	\$18,619
6 mo chemical analysis of GW	2	ls	\$2,000	'90 est	\$4,000	\$4,000	\$4,000	\$4,000	\$4,000	\$4,000	\$4,000	\$4,000	\$32,000	\$24,826

United Chrome Cost Estimate					Table 4-3							Material Inflation Rate = 0.05		
1-Aug-91					Annual Cost Estimates for Options A through D							Labor Inflation Rate = 0.06		

Task	Quantity	Units	Unit Cost	Cost Ref	1991	1992	1993	1994	1995	1996	1997	1998	Total	NPV(8%)
Disposal of Wastes--B														
Sludge	34 to 0	ft3/mo	\$48	city	\$19,584	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$19,584	\$19,584
TOTAL COSTS--B	(Labor = 48%)				\$158,933	\$105,965	\$108,719	\$106,638	\$109,733	\$113,013	\$116,490	\$120,175	\$939,666	
TOTAL NPV COSTS--B					\$158,933	\$98,116	\$93,209	\$84,653	\$80,657	\$76,915	\$73,408	\$70,121		\$736,013

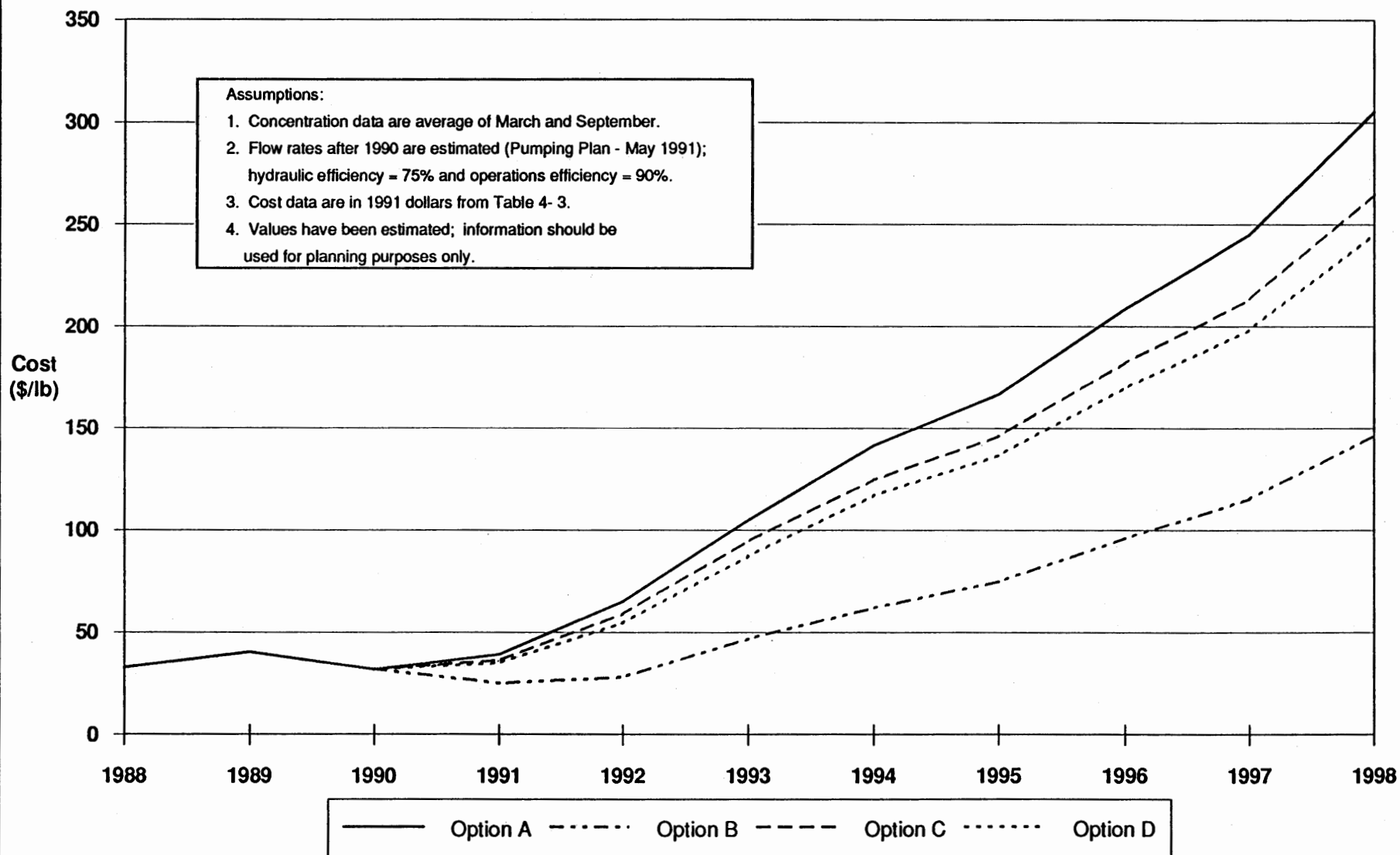
United Chrome Cost Estimate 1-Aug-91					Table 4-3 Annual Cost Estimates for Options A through D								Material Inflation Rate = 0.05 Labor Inflation Rate = 0.06	
Task	Quantity	Units	Unit Cost	Cost Ref	1991	1992	1993	1994	1995	1996	1997	1998	Total	NPV(8%)
OPTION C--CONTINUOUS WTS SYSTEM OPERATION														
Operations Labor--C														
Operator Labor	1	FTE	\$52,417	City	\$57,659	\$61,118	\$64,785	\$68,672	\$72,793	\$77,160	\$81,790	\$86,697	\$570,675	\$432,455
Supervisor Labor	0	FTE	\$66,100	City	\$13,220	\$14,013	\$14,854	\$15,745	\$16,690	\$17,691	\$18,753	\$19,878	\$130,845	\$99,153
Capital Additions--C														
Control (programming, wiring, parts)	1	ls	\$2,000	est										
Electrical	1	ls	\$1,500	est										
Mechanical	1	ls	\$500	est										
Engineering	1	ls	\$800	est										
Total					\$4,800	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$4,800	\$4,800
Maintenance Material & Labor--C														
Annual Maintenance	1	ls	\$20,000	'90 est	\$20,000	\$21,200	\$22,472	\$23,820	\$25,250	\$26,765	\$28,370	\$30,073	\$197,949	\$150,005
Expendable Material & Energy--C														
PPE	1	ls	\$1,200	'90/6	\$1,200	\$1,200	\$1,200	\$412	\$412	\$412	\$412	\$412	\$5,660	\$4,750
Chemicals														
Caustic (0.0133 #/gal H2O)	7,022	#/mo	\$0	Van R	\$16,011	\$16,011	\$16,011	\$15,223	\$15,223	\$15,223	\$15,223	\$15,223	\$124,149	\$96,673
Polymer (3.2X10^-5 #/galH2O)	17	#/mo	\$3	Van R	\$659	\$659	\$659	\$659	\$659	\$659	\$659	\$659	\$5,272	\$4,090
Sodium Bisulfite (5.5#/Cr6+)	2,899	#/mo	\$0	Van R	\$11,220	\$11,220	\$11,220	\$10,432	\$10,432	\$10,432	\$10,432	\$10,432	\$85,824	\$66,941
Sulfuric Acid (.0077 #/galH2O)	4,066	#/mo	\$0	Van R	\$4,001	\$4,001	\$4,001	\$3,213	\$3,213	\$3,213	\$3,213	\$3,213	\$28,064	\$22,132
Pump & Process Elect	10,493	kWh/mo	\$0	City	\$6,799	\$6,799	\$6,799	\$6,011	\$6,011	\$6,011	\$6,011	\$6,011	\$50,456	\$39,503
Miscellaneous Services--C														
Physical Exams	4	ea	\$500	'90 est	\$2,000	\$2,000	\$2,000	\$1,212	\$1,212	\$1,212	\$1,212	\$1,212	\$12,060	\$9,715
Health & Safety Training	4	ea	\$200	'90 est	\$800	\$800	\$800	\$800	\$800	\$800	\$800	\$800	\$6,400	\$4,965
Analytical Requirements--C														
Onsite Analyses	1	ls	\$1,000	'90 est	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$8,000	\$6,206
Offsite Analyses														
Offsite Lab QA	100	hr/yr	\$30	'90 est	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$24,000	\$18,619
6 mo chem analysis of GW	2	ls	\$2,000	'90 est	\$4,000	\$4,000	\$4,000	\$4,000	\$4,000	\$4,000	\$4,000	\$4,000	\$32,000	\$24,826
Disposal of Waste--C (assumes 10% reduction in press production/yr and 5% inflation)														
Sludge	144	ft3/mo	\$48	city	\$82,944	\$74,650	\$67,185	\$60,466	\$54,420	\$48,978	\$44,080	\$39,672	\$472,393	\$381,924
TOTAL COSTS--C (Labor = 40%)					\$229,313	\$221,672	\$219,986	\$214,667	\$215,114	\$216,556	\$218,956	\$222,282	\$1,758,547	
TOTAL NPV COSTS--C					\$229,313	\$205,252	\$188,603	\$170,409	\$158,116	\$147,386	\$137,979	\$129,700		\$1,366,758

United Chrome Cost Estimate 1-Aug-91					Table 4-3 Annual Cost Estimates for Options A through D								Material Inflation Rate = 0.05 Labor Inflation Rate = 0.06	
Task	Quantity	Units	Unit Cost	Cost Ref	1991	1992	1993	1994	1995	1996	1997	1998	Total	NPV(8%)
OPTION D--CONTINUOUS TREATMENT W/ Cr(III) REMOVAL														
Operations Labor--D														
Operator Labor	1	FTE	\$52,417	City	\$52,417	\$55,562	\$58,896	\$62,429	\$66,175	\$70,146	\$74,355	\$78,816	\$518,796	\$393,141
Supervisor Labor	0	FTE	\$66,100	City	\$13,220	\$14,013	\$14,854	\$15,745	\$16,690	\$17,691	\$18,753	\$19,878	\$130,845	\$99,153
Capital Additions--D														
Plug-Flow Reactor														
Transfer pump (0-20 gpm)	1	ea	\$600	est.	\$600									
1" Piping	30	ft	\$2	est.	\$60									
½" tubing	30	ft	\$2	est.	\$45									
Kenics Static mixer (1"x6 element)	2	ea	\$258	UPC	\$516									
Metering Pumps	3	ea	\$800	est.	\$2,400									
Injector apparatus	3	ea	\$250	UPC	\$750									
Accumulator	3	ea	\$150	est	\$450									
Flow meter (0-20 gpm)	1	ea	\$500	est.	\$500									
Backpressure control valves	3	ea	\$256	UPC	\$768									
Mechanical	1	ls	\$1,500	est	\$1,500									
Electrical	1	ls	\$1,500	est.	\$1,500									
Control (programming, wiring, parts)	1	ls	\$1,000	est.	\$1,000									
Engineering	1	ls	\$2,522	est.	\$2,522									
Total					\$12,611	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$12,611	\$12,611
Maintenance Material & Labor--D														
Annual Maintenance	1	ls	\$10,000	'90 est	\$10,000	\$10,000	\$10,000	\$10,000	\$10,000	\$10,000	\$10,000	\$10,000	\$80,000	\$62,064
Expendable Material & Energy--D														
PPE	1	ls	\$1,200	'90/6	\$1,200	\$1,200	\$1,200	\$1,200	\$1,200	\$1,200	\$1,200	\$1,200	\$9,600	\$7,448
Chemicals														
Caustic (.0133#/gal H2O)	7,022	gal/mo	\$0	Van R	\$16,011	\$16,011	\$16,011	\$16,011	\$16,011	\$16,011	\$16,011	\$16,011	\$128,089	\$99,371
Polymer (3.2X10^-5 #/galH2O)	17	lb/mo	\$3	Van R	\$659	\$659	\$659	\$659	\$659	\$659	\$659	\$659	\$5,272	\$4,090
Sodium Metabisulfite (5.5#/#Cr6+)	2,899	lb/mo	\$0	Van R	\$11,220	\$11,220	\$11,220	\$11,220	\$11,220	\$11,220	\$11,220	\$11,220	\$89,764	\$69,639
Sulfuric Acid (.0077 #/galH2O)	4,066	gal/mo	\$0	Van R	\$4,001	\$4,001	\$4,001	\$4,001	\$4,001	\$4,001	\$4,001	\$4,001	\$32,004	\$24,829
Pump & Process Elect	9,443	kWh/mo	\$0	City	\$6,119	\$6,119	\$6,119	\$6,119	\$6,119	\$6,119	\$6,119	\$6,119	\$48,953	\$37,977
Miscellaneous Service--D														
Physical Exams	4	ea	\$500	'90 est	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000	\$16,000	\$12,413
Health & Safety Training	4	ea	\$200	'90 est	\$800	\$800	\$800	\$800	\$800	\$800	\$800	\$800	\$6,400	\$4,965
Analytical Requirements--D														
Onsite Analysis	1	ls	\$1,000	'90 est	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000	\$8,000	\$6,206
Offsite Analyses														
Offsite Lab QA	100	hr/yr	\$30	'90 est	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$24,000	\$18,619
6 mo chem analysis of GW	2	ls	\$2,000	'90 est	\$4,000	\$4,000	\$4,000	\$4,000	\$4,000	\$4,000	\$4,000	\$4,000	\$32,000	\$24,826

United Chrome Cost Estimate					Table 4-3							Material Inflation Rate = 0.05		
1-Aug-91					Annual Cost Estimates for Options A through D							Labor Inflation Rate = 0.06		

Task	Quantity	Units	Unit Cost	Cost Ref	1991	1992	1993	1994	1995	1996	1997	1998	Total	NPV(8%)
Disposal of Wastes--D (assumes 10% reduction in press production/yr and 5% inflation)														
Sludge	144	ft3/mo	\$48	city	\$82,944	\$74,650	\$67,185	\$60,466	\$54,420	\$48,978	\$44,080	\$39,672	\$472,393	\$381,924
TOTAL COSTS--D	(Labor = 40%)				\$221,202	\$204,235	\$200,945	\$198,651	\$197,295	\$196,825	\$197,197	\$198,376	\$1,614,726	
TOTAL NPV COSTS--D					\$221,202	\$189,107	\$172,278	\$157,695	\$145,018	\$133,957	\$124,268	\$115,750		\$1,259,275

Figure 4-5
Estimated Cost of Chromium Removal



Chapter 5

EVALUATION OF REMEDIAL ACTION

Chapter 5

EVALUATION OF REMEDIAL ACTION

Groundwater extraction and onsite treatment have been effective in remediation of the upper zone at the United Chrome Site. The threat of offsite migration of Cr(VI) contaminated groundwater in the upper zone and discharge of this groundwater into site drainage ditches has been mitigated in accordance with the recommended alternative.

Achieving the remedial objective of 10 mg/l Cr(VI) with the existing extraction and infiltration system will require several more years of operation. Many of the well locations will likely attain this level in the next one to two years; however, some areas will be more difficult and require longer periods for remediation.

One area of the site where remediation has been slowed is along the longitudinal axis of the plume. Progress in this area has been limited due to recharge water constraints. The infiltration trench is expected to provide some relief; however, even at sustained infiltration rates of 100,000 gallons per month, water limitations may still exist. Additional recharge obtained by reducing pumping rates at low-concentration wells and shutting off or intermittently operating wells with Cr(VI) concentrations less than 10 mg/l will help mitigate this condition. These actions represent passive measures that may be implemented at no cost and may potentially increase the Cr(VI) concentration present in the influent and reduce the volume of water requiring treatment.

Construction of additional infiltration trenches would likely help deliver water in a controlled manner to areas where it can be best utilized. However, the benefits of additional water would have to be balanced against the risk of increased, vertical gradients over a wider area of the aquitard and the ability of the extraction system to capture this water.

Remediation could also be accelerated by constructing new extraction wells along the plume core. The benefit of this action results from the reduced flow path length contaminated groundwater travels to the extraction point. Due to low apparent groundwater velocities in this area, this action could prove effective. The water generated by these wells can be handled with the additional storage capacity provided by conversion of the last effluent tank to influent storage and tank capacity freed up as existing wells are shut off.

The United Chrome groundwater treatment system and operations have undergone significant modification since operation began in 1988. Changes that arose from limited performance outlined in the first performance evaluation, along with decreasing groundwater Cr(VI) concentrations, have allowed the treatment system to function at greater than design capacities. As groundwater Cr(VI) concentrations continue to drop, the treatment system can continue to effectively remove chromium from the extracted groundwater with minimal process changes. Reductions in the operation

schedule are expected as concentrations continue to drop and additional wells become clean and are shut down.

Testing has indicated that the treatment system will continue to perform efficiently as influent Cr(VI) concentrations decrease. There has been no indication of performance upsets resulting from low influent Cr(VI) concentrations. Testing has also indicated that lower flow rates may improve treatment system performance slightly, and that batch processing of extracted groundwater is effective in reducing Cr(VI) to Cr(III).

As discussed in Chapter 4, many alternatives for treatment of extracted groundwater using variations of the existing scheme are available. These alternatives can be implemented with minimal capital expenditure and may result in significant savings as a result of reduced operating costs.

Appendix A
TREATMENT PLANT EVALUATION FIELD DATA

Chrome run 1

United Chrome Performance Test Experimental Run Datasheet

Run # 1

Initial data:

Tank #	1	2		
Dilution (%:%)	50:50	50:50		
Post-Dilution Cr6+ (mg/l)	56	92		
Gallons Treated	12300	9470		

Control Data:

Date 1/17/91

Tank #	1	2	Avg		
Time (hrs)	3.4	2.6			
Influent Flow(gpm)	60	60	60		
Acid Adjust pH			2.5		
ORP(Kf,setpoint)			1840	20.4	mv
Caustic Adjust pH(setpoint)			8.5	7.9	(actual)
Polymer Flow(stroke)			40%		
Polymer Flow(speed)			50%	0.0667	gpm(est)
Sludge Recycle Flow(gpm)			0		
Underflow pump 1(on sec:off sec)			60:150	5.4	gpm
Underflow pump 2(on sec:off sec)			45:180	3.8	gpm
<u>Result Data:</u>					
Overflow Cr Tot (mg/l)			6.4		
Overflow Cr 6+ (mg/l)			2.5		

Comments: $ORP(mv) = (1550 + (10.24Kf))/1000$
Underflow Wildens: 0.1 gallon/exhaust,
190 exhausts/min (when on) = 19 gpm

Setpoints were developed for tank1, tank 2 therefore caused
high Cr6+, realistic Cr T ~3.9
Poly fed = 900 ppm (0.09%)

Chrome run 2

United Chrome Performance Test Experimental Run Datasheet

Run # 2

Initial data:

Tank #	1	2		
Dilution (%:%)	75:25	50:50		
Post-Dilution Cr6+ (mg/l)	24	50		
Gallons Treated	11900	8230		

Control Data:

Date 1/18/91

Tank #	1	2	Avg		
Time (hrs)	3.3	2.3			
Influent Flow(gpm)	60	60	60		
Acid Adjust pH			2.5		
ORP(Kf,setpoint)			1870	20.7	mv
Caustic Adjust pH(setpoint)			8.5	8.0	(actual)
Polymer Flow(stroke)			40%		
Polymer Flow(speed)			55%	0.0733	gpm(est)
Sludge Recycle Flow(gpm)			0		
Underflow pump 1(on sec:off sec)			60:150	5.4	gpm
Underflow pump 2(on sec:off sec)			45:180	3.8	gpm
<u>Result Data:</u>					
Overflow Cr Tot (mg/l)			6.4		
Overflow Cr 6+ (mg/l)			2.4		

Comments: ORP(mv) = (1550 + (10.24Kf))/1000
Underflow Wildens: 0.1 gallon/exhaust,
190 exhausts/min (when on) = 19 gpm

Setpoints were developed for tank1, tank 2 therefore caused
high Cr6+, realistic Cr T ~3.9
Poly fed = 900 ppm (0.09%)

Chrome run 3

United Chrome Performance Test Experimental Run Datasheet

Run # 3

Initial data:

Tank #	1	2		
Dilution (%:%)		50:50		
Post-Dilution Cr6+ (mg/l)		43		
Gallons Treated		6270		

Control Data: Date 1/19/91

Tank #	1	2	Avg		
Time (hrs)		1.7			
Influent Flow(gpm)		60	60		
Acid Adjust pH			2.5		
ORP(Kf,setpoint)			1860	20.6	mv
Caustic Adjust pH(setpoint)			8.5	7.8	(actual)
Polymer Flow(stroke)			50%		
Polymer Flow(speed)			45%	0.0750	gpm(est)
Sludge Recycle Flow(gpm)			0		
Underflow pump 1(on sec:off sec)			30:150	3.2	gpm
Underflow pump 2(on sec:off sec)			15:180	1.5	gpm

52.83 #/Ton(e)

Result Data:

Overflow Cr Tot (mg/l)			10.4		
Overflow Cr 6+ (mg/l)			2.35		

Comments: $ORP(mv) = (1550 + (10.24Kf))/1000$
Underflow Wildens: 0.1 gallon/exhaust,
190 exhausts/min (when on) = 19 gpm

Poly fed = 900 ppm (0.09%)

Chrome run 4

United Chrome Performance Test Experimental Run Datasheet

Run # 4

Initial data:

Tank #	1	2		
Dilution (%:%)	75:25			
Post-Dilution Cr6+ (mg/l)	12.4			
Gallons Treated	10530			

Control Data:

Date 1/19/91

Tank #	1	2	Avg		
Time (hrs)	2.9				
Influent Flow(gpm)	60		60		
Acid Adjust pH			2.5		
ORP(Kf,setpoint)			1860	20.6	mv
Caustic Adjust pH(setpoint)			8.5	7.8	(actual)
Polymer Flow(stroke)			50%		
Polymer Flow(speed)			45%	0.0750	gpm(est)
Sludge Recycle Flow(gpm)			0		
Underflow pump 1(on sec:off sec)			30:150	3.2	gpm
Underflow pump 2(on sec:off sec)			15:180	1.5	gpm
<u>Result Data:</u>					
Overflow Cr Tot (mg/l)			6.6		
Overflow Cr 6+ (mg/l)			1.65		

Comments: $ORP(mv) = (1550 + (10.24Kf))/1000$
Underflow Wildens: 0.1 gallon/exhaust,
190 exhausts/min (when on) = 19 gpm

Poly fed = 900 ppm (0.09%)

Chrome run 5

United Chrome Performance Test Experimental Run Datasheet

Run # 5

Initial data:

Tank #	1	2		
Dilution (%:%)		75:25		
Post-Dilution Cr6+ (mg/l)		17.6		
Gallons Treated		11600		

Control Data: Date 1/20/91

Tank #	1	2	Avg		
Time (hrs)		3.2			
Influent Flow(gpm)		60	60		
Acid Adjust pH			2.5		
ORP(Kf,setpoint)			1860	20.6	mv
Caustic Adjust pH(setpoint)			8.5	8.8	(actual)
Polymer Flow(stroke)			50%		
Polymer Flow(speed)			55%	0.0917	gpm(est)
Sludge Recycle Flow(gpm)			0		
Underflow pump 1(on sec:off sec)			30:150	3.2	gpm
Underflow pump 2(on sec:off sec)			15:180	1.5	gpm
<u>Result Data:</u>					
Overflow Cr Tot (mg/l)			6.4		
Overflow Cr 6+ (mg/l)			1.0		

157.75 #/Ton(e)

Comments: $\text{ORP(mv)} = (1550 + (10.24\text{Kf}))/1000$
Underflow Wildens: 0.1 gallon/exhaust,
190 exhausts/min (when on) = 19 gpm

Poly fed = 900 ppm (0.09%)

Appendix B

PUMPING PLAN

Attachment 4 OF THE ADMINISTRATIVE ORDER PUMPING PLAN

PART 1. PURPOSE

1.1 General

- A. This document is an enforceable document drafted pursuant to and incorporated into the Administrative Order. This document may be modified as described in the Administrative Order.
- B. This Pumping Plan presents instructions for operating and monitoring the groundwater extraction and infiltration/injection systems at the United Chrome Pretreatment Facility. The approach presented in this plan is based on the current understanding of groundwater conditions in the upper zone and deep aquifer and their anticipated response to pumping and infiltration. This pumping plan has been amended from previous versions to reflect changes in the upper zone pumping strategy and deep aquifer groundwater extraction startup expected to commence in June 1991.
- C. During deep aquifer startup, the potential for adverse hydraulic interaction between the upper zone and deep aquifer will be further evaluated. This monitoring will likely require modification to upper zone extraction and infiltration system operations to minimize these effects. Modifications will be incorporated as addendums to the pumping plan as they are identified.
- D. The pumping plan is organized into three sections that include:
 - Part 2--Upper Zone Operations
 - Part 3--Deep Aquifer Operations
 - Part 4--Data Reporting and Communications

PART 2. UPPER ZONE OPERATIONS

2.1 Objectives

- A. Objectives of the upper zone extraction and infiltration programs are:
 - 1. Timely remediation of hexavalent chromium [Cr(VI)] contaminated soil and groundwater. To efficiently achieve this objective, infiltration and aggressive groundwater extraction have been, and will continue to be, focused on areas of the plume with the highest Cr(VI) contamination. This approach led to the installation of the two infiltration basins in the

dry well and plating tank source areas in 1988 and to the construction of the infiltration trench in 1990. As high Cr(VI) concentrations drop to relatively low levels in response to focused remediation, infiltration and aggressive groundwater extraction will be redirected at other high concentration areas of the plume.

2. Lateral hydraulic containment of the plume. This objective has been, and will continue to be, achieved by adjusting infiltration and groundwater extraction rates to control horizontal gradients in the vicinity of the plume.
3. Minimize adverse downward vertical gradients between the upper zone and deep aquifer in the upper zone plume area resulting from upper zone infiltration. Monitoring and regulating infiltration flow rates will be employed to achieve this objective.

2.2 Pumping Strategy

- A. To coordinate pumping operations, individual extraction wells have been grouped into three categories based on their location. These three groups include the basin wells, axis wells, and boundary wells as shown in Figure 1. The strategy for pumping and recovery phases for each extraction well group is presented in Table 1. The wells will be operated as much as possible under the pumping cycle (Phases 1 and 2). The recovery cycle will be used when necessary to allow downgradient axis wells to recover. The recovery phase will be implemented when water levels decrease below 50 percent of the seasonal saturated thickness and/or well yields are consistently low.
- B. During the pumping cycle, the City shall operate extraction wells at their highest capacity until the specified number of gallons have been extracted each week. Once the weekly quota is met, the wells may be shut off (but not for more than 2 days) to allow the groundwater zone to recover. It is anticipated that the wells will be allowed to rest from 0.5 to 2 days each week. This pulsed pumping pattern should induce a more effective remediation, as the resting phase provides time to replenish the original saturated thickness and allow contaminants to diffuse out of low permeability zones into adjacent higher permeability zones.
- C. During Phase 1 of the pumping cycle (Table 1), the infiltration basins will be active and the basin and axis well groups will be pumped continuously while the boundary wells are permitted to rest (Table 1). During Phase 2, all extraction wells will be pumped (infiltration basins and trench active). Phases 1 and 2 will be alternated on approximately a monthly basis during the pumping cycle to alter flowline patterns and disrupt stagnant zones.

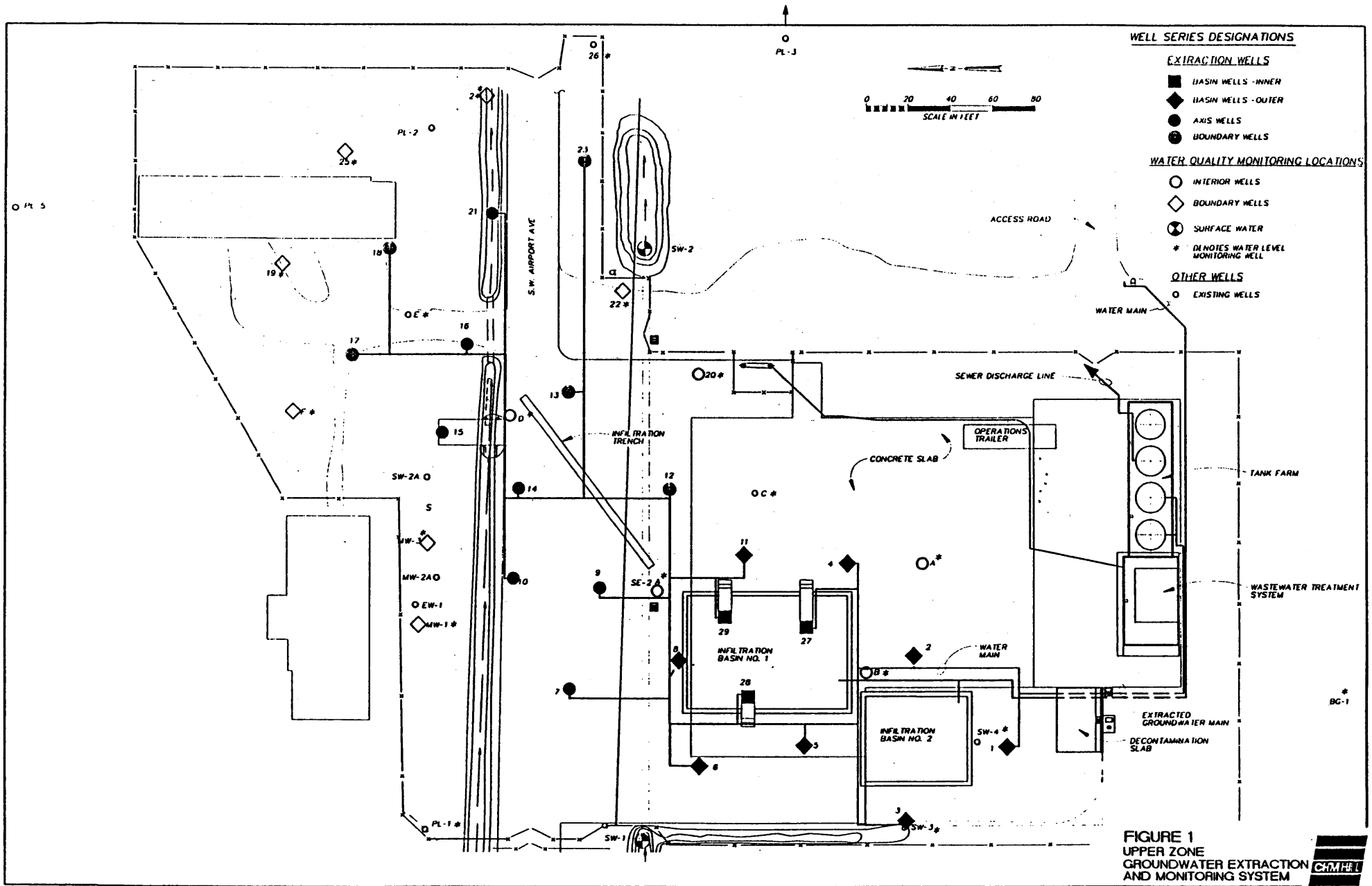


Table 1 Upper Zone Pumping Schedule		
Pumping Phase	Active Pumping Well Groups^a	Flow Rates
Pumping Cycle:		
Phase 1	Basin Wells--Outer (1, 2, 3, 4, 5, 6, 8, 11)	See Table 2
	Basin Wells--Inner (27, 28, 29)	See Table 2
	Axis Wells (7, 9, 10, 14, 15, 16, 21)	See Table 2
Phase 2:	All extraction wells	See Table 2
Recovery Cycle		
	Axis Wells (7, 9, 10, 14, 15, 16, 21)	See Table 2
^a See Figure 1 for well locations. Boundary wells = 12, 13, 17, 18, 23		

- D. During the recovery cycle (0.5 to 2 days duration), the City shall shut off the basin and boundary wells and continue to pump the axis well group. The infiltration basins and trench will be idled during the recovery cycle.
- E. The pumping rates for individual extraction wells will be controlled by the size of the orifice plate. Two orifice plate sizes are given for each well for the periods from December through May and June through November (Table 2).

The orifice plate size given is intended to maximize well yields while accounting for seasonal effects and maintaining minimum operating efficiencies of 50 percent. Orifice plate sizes are less than optimum in Wells EW-8, EW-11, EW-27, EW-28, and EW-29 to promote lateral infiltration from Basin No. 1 towards the axis wells.

- F. Monthly variations in water levels may permit larger (or smaller) orifice plates to be installed to optimize well operating efficiency. These adjustments, if necessary, will be coordinated with EPA's Technical Assistant and will be performed by the City operators.

Table 2
Upper Zone Extraction Well Flow Rates

		Orifice Plate Size (gpm)	
Well Array	Well Number	December-May	June-November
Basin Wells:			
Outer	1	0.8	0.62
	2	1.1	1.1
	3	1.4	1.4
	4	1.1	0.8
	5	1.8	1.4
	6	0.8	0.8
	8	0.8	0.62
	11	0.8	0.62
Inner	27	0.44	0.44
	28	0.44	0.44
	29	0.8	0.62
Axis Wells			
	7	0.62	0.62
	9	0.8	off
	10	0.62	0.44
	14	0.62	0.44
	15	0.62	0.44
	16	0.62	0.44
	21	0.8	0.62
Boundary Wells			
	12	0.8	0.62
	13	0.62	0.51
	17	1.02	0.62
	18	0.8	0.44
	23	0.62	0.44

^aEfficiency = Pump hours/total extraction hours (weekly), if efficiency consistently drops below 50% and/or if the wells are cycling excessively (greater than 120 cycles per day) the orifice plate size will be reduced accordingly.

G. A written request to cease extraction at a well can be submitted to EPA when Cr(VI) concentrations in the extracted groundwater have been shown to be at or below 10 mg/l. EPA's approval of the request will be based on the following criteria:

1. Cr(VI) concentrations in the groundwater extracted from the well has been measured to be at or below 10 mg/l for two consecutive sampling events timed at least one month apart.
2. No adverse groundwater flow conditions in the upper zone are expected to be created by the proposed well shutdown.
3. No adverse groundwater flow conditions between the upper zone and deep aquifer are expected to be created by the proposed well shutdown.

Wells that have been shutdown due to low Cr(VI) concentration, as described above, shall be monitored for Cr(VI) on a monthly basis for one year and quarterly thereafter. If monitoring indicates the Cr(VI) concentrations exceed 10 mg/l, groundwater extraction from the well will resume in accordance with this Pumping Plan, and continue for a minimum of two months before the well will again be considered for shutdown.

2.3 Infiltration Basins

- A. The infiltration basins were designed to flush Cr(VI) from unsaturated soils to adjacent extraction wells for recovery, while also providing supplemental recharge for the upper zone. The contaminant source areas beneath the basins have been significantly cleaned up as a result of basin recharge. To continue to obtain the most efficient use of the basins, infiltration and extraction operations will concentrate on directing recharge from Basin No. 1 towards the axis well group. The City will achieve this by pumping at below maximum rates in Wells EW-27 and EW-28 and incrementally increasing the pumping rates in successive downgradient wells to obtain the desired gradient direction (northeast).
- B. To maintain a favorable water balance between infiltration basin recharge and extraction well withdrawals, the City will maintain a weekly water balance as indicated in Table 3. Recharge quantity (gallons) in Basin No. 1 and Basin No. 2 will be regulated by the City to vary between 50 percent and 60 percent of the total upper zone extraction amount. The City will also make discrete comparisons between the weekly basin recharge quantity and the weekly extraction from the basin well group. The total recharge added to the basins (including precipitation) will be regulated by the City to vary between 60 and 70 percent of basin well group extraction quantity.

- C. The City shall meter weekly inputs to the basins uniformly throughout the week to maintain a relatively constant recharge rate. Sporadic inputs will be avoided.
- D. Each infiltration basin has a staff gauge set at the 4-foot mark corresponding to the top of the basin wall. The City shall monitor water levels inside the basins to help establish infiltration rates.
- E. The City shall compare infiltration basin and neighboring piezometer groundwater elevations with deep aquifer well groundwater elevations to evaluate vertical gradient trends. These evaluations may require that basin water levels be lowered on a seasonal basis. These adjustments will be initiated by the Technical Assistant and, after approval by EPA, will be incorporated as addendums to the Pumping Plan.

2.4 Infiltration Trench

- A. The infiltration trench is intended to supplement natural recharge along the plume axis during the dry months from June through November. The City shall maintain the water level inside the trench at an elevation approximately 2 feet below ground surface except as modified herein.
- B. The City shall maintain a weekly water balance between trench recharge and extraction well withdrawals as shown in Table 3. Recharge gallons will be regulated to average from 50 to 60 percent of the extraction amounts calculated from the specified well group.
- C. The City shall meter weekly inputs to the trench uniformly throughout the week to maintain a relatively constant recharge rate. Sporadic inputs will be avoided.
- D. The City shall compare infiltration trench water levels with upper zone piezometers (Pz-D, MW-3, and EW-25) and deep aquifer wells (DW-2, DW-8, and DW-12) to evaluate vertical gradient trends. These evaluations may require that trench water levels be lowered on a seasonal basis. These adjustments will be initiated by the Technical Assistant and, after approval by EPA, will be incorporated as addendums to the Pumping Plan.

2.5 Monitoring Schedule

- A. Groundwater and treatment system monitoring tasks and frequencies are presented in Table 3. The City shall communicate any problems encountered during monitoring activities to the EPA's Technical Assistant through telephone conversations.

Table 3 Upper Zone Monitoring and Reporting Schedule				
Component	Task	Locations	Frequency	Reporting Requirements^a
Extraction System	Water levels in select wells	BG-1, SW3, SW-4, PZ-A, PZ-B, PZ-C, PZ-D, PZ-E, PZ-F, SE-2A, PL-1, MW-1, MW-3, EW-19, EW-20, EW-22, EW-24, EW-25, EW-26.	Monthly	Monthly
	Wellhead measurements ^b	All extraction wells	Weekly	Monthly
	Water quality (Cr(IV))	All extraction wells	Quarterly	Quarterly
	Flow rate, line pressure	Inlet to influent storage tanks	Weekly	Monthly
	Calculated flow rate and corrected volume through well ^c	All extraction wells	Weekly	Monthly
	Total depth measurements	All wells	Annually	Annually
Boundary Monitoring Wells	Water quality [(Cr(VI), indicator parameters)]	MW-1, MW-3, PZ-F, EW-19, EW-22, EW-24, EW-25	Biannually ^d	Biannually
Interior Monitoring Wells	Water Quality [Cr(VI), indicator parameters)]	PZ-A, PZ-B, PZ-D; SE-2A, EW-20	Annually ^e	Annually
Monitoring Wells	Total depth measurements	All wells	Annually	Annually
Infiltration Basins	Flow (gal), infiltration basin water elevation and vertical gradients	Vertical Gradient Clusters; PZ-B, DW-10; SE-2A, DW-9	Weekly (during use)	Monthly
	Water Balance	EW-1, EW-2, EW-3, EW-4, EW-5, EW-6, EW-8, EW-11, EW-27, EW-28, EW-29	Weekly	Monthly
Infiltration Trench	Flow (gal), water elevation and vertical gradients	Vertical Gradient Clusters: MW-3, DW-2; PZ-D, DW-8; SW-3, DW-1; EW-25, DW-12	Weekly (during use)	Monthly
	Water Balance	EW-9, EW-10, EW-12, EW-13, EW-14, EW-15, EW-16	Weekly	Monthly
Treatment System	Influent water quality (Cr VI)		Each day onsite	Monthly
	Effluent water quality (Cr VI, Total Cr)		Each day onsite	Monthly
	Influent and effluent water quality Priority Pollutant Metals ^f		Annually	Annually
	Comparison of measured flow/calculated flow ^g		Weekly	Monthly
Surface Water	Water quality [(Cr(VI))]	At upstream and downstream ends of onsite culvert	Biannually ^d	Biannually
^aAll results may be requested at any time by the technical assistant in verbal format or draft. ^bPump cycles, pump hours, line pressure. Functional inspections will be performed more frequently. ^cCorrected well volume = [calculated volume at well] $\frac{\text{total measured flow (plant)}}{\text{total calculated flow (all extraction wells)}}$. ^dSampling will be conducted in September and March of each year. ^eSampling will be conducted in September of each year. ^fAnalysis will include at a minimum: Be, Cd, Cr, Cu, Pb, Hg, Ni, Se, Ag, T1 ^gIf difference between calculated vs measured flow exceeds 20%: 1) Volumetric flow check and, 2) Extraction well line pressures will be checked and appropriate corrective measures implemented.				

- B. Additional monitoring requested by the Technical Assistant (e.g., water levels) will be coordinated with the City operators to allow a reasonable period of time for completion.

PART 3. DEEP AQUIFER OPERATIONS

3.1 Objectives

- A. Objectives of the deep aquifer injection and extraction programs are:
1. Timely cleanup of the Cr(VI) contaminated groundwater.
 2. Minimize adverse vertical gradient conditions between the upper zone and deep aquifer in the upper zone plume area resulting from deep aquifer pumping. To efficiently achieve these first two objectives, clean water injection into two wells and extraction from up to seven wells will be implemented. The deep aquifer injection is expected to reduce draw-down near extraction wells and enhance groundwater flushing in areas with known high Cr(VI) concentrations.
 3. Lateral hydraulic containment of the plume. This objective will be achieved by adjusting injection and groundwater extraction rates to control horizontal gradients in the vicinity of the plume.
- B. This section of the pumping plan presents the approach for operating the United Chrome deep aquifer groundwater extraction system under a pilot program during the first year of operation. A 1-year period is planned to assess the impacts of seasonal effects on deep aquifer extraction system performance and to provide sufficient data to identify impacts on upper zone operations. During the pilot program, water level measurements and water quality sampling will be performed on a regular basis to: 1) characterize vertical gradient trends, estimate the lateral extent of the capture zone; 2) identify or demonstrate the absence of contaminant breakthrough pathways; and 3) document the progress of plume remediation. This data will also be useful in calibrating future extraction well pumping rates and flow rate balances to achieve optimum performance. It may be necessary for EPA or their Technical Assistant to amend the proposed strategy during the pilot program to respond to unforeseen conditions. The deep aquifer groundwater extraction and monitoring system layout is shown in Figure 2.

3.2 Pumping Strategy

- A. During the early stages of pumping, the deep aquifer groundwater extraction program will focus on capture and containment of the Cr(VI) contaminant

plume. This objective will require continuous pumping of the extraction wells 24 hours per day, 7 days a week. Once control of the plume has been established, the program can consider alternate pumping schemes to expedite contaminant removal. The startup schedule for turning on the extraction and injection wells is presented in Figure 3.

- B. The initial pumping strategy is designed to pump from up to seven extraction wells (DW-2, DW-8, DW-12, DW-13, DW-15, DW-16, DW-18) at a rate of 2.5 gpm each, or 17.5 gpm total. Maximum well yields are significantly greater than this. However, low pumping rates are specified to minimize the magnitude of downward vertical gradients between the upper zone and deep aquifer that will be generated by deep aquifer groundwater extraction. The potential for pumping rates greater than 2.5 gpm will be evaluated as vertical gradient trends are better understood.
- C. The extraction system has been designed to be flexible by permitting the operator to adjust pumping parameters to match actual field conditions and to operate each well independent of the others.

3.3 Injection Wells

- A. The City shall inject clean water into Wells DW-9 and DW-10 at rates of 5 gpm each. Water is being injected to minimize the impact of increased vertical gradients resulting from extraction while also providing a flushing mechanism to enhance contaminant mobility.

3.4 Monitoring Schedule

- A. The purpose of implementing a pilot program is to calibrate and refine the initial pumping strategy based on computer simulations of actual site conditions. The conceptual pumping strategy was developed using many simplifying assumptions that do not fully apply at the site. The validity of these assumptions will be assessed through the pilot program and will result in a pumping strategy tailored to actual site conditions and experience rather than the initial predictive assumptions.
- B. During the pilot program, the City shall collect water level measurements and contaminant concentration data (Table 4) to prepare a data base from which a long-term pumping strategy can be developed. The pilot program will include data collection and analysis to identify conditions and trends that influence pumping rates and contaminant flow paths to wells at the site. At the end of the pilot program, a long-term pumping strategy will be prepared by EPA.

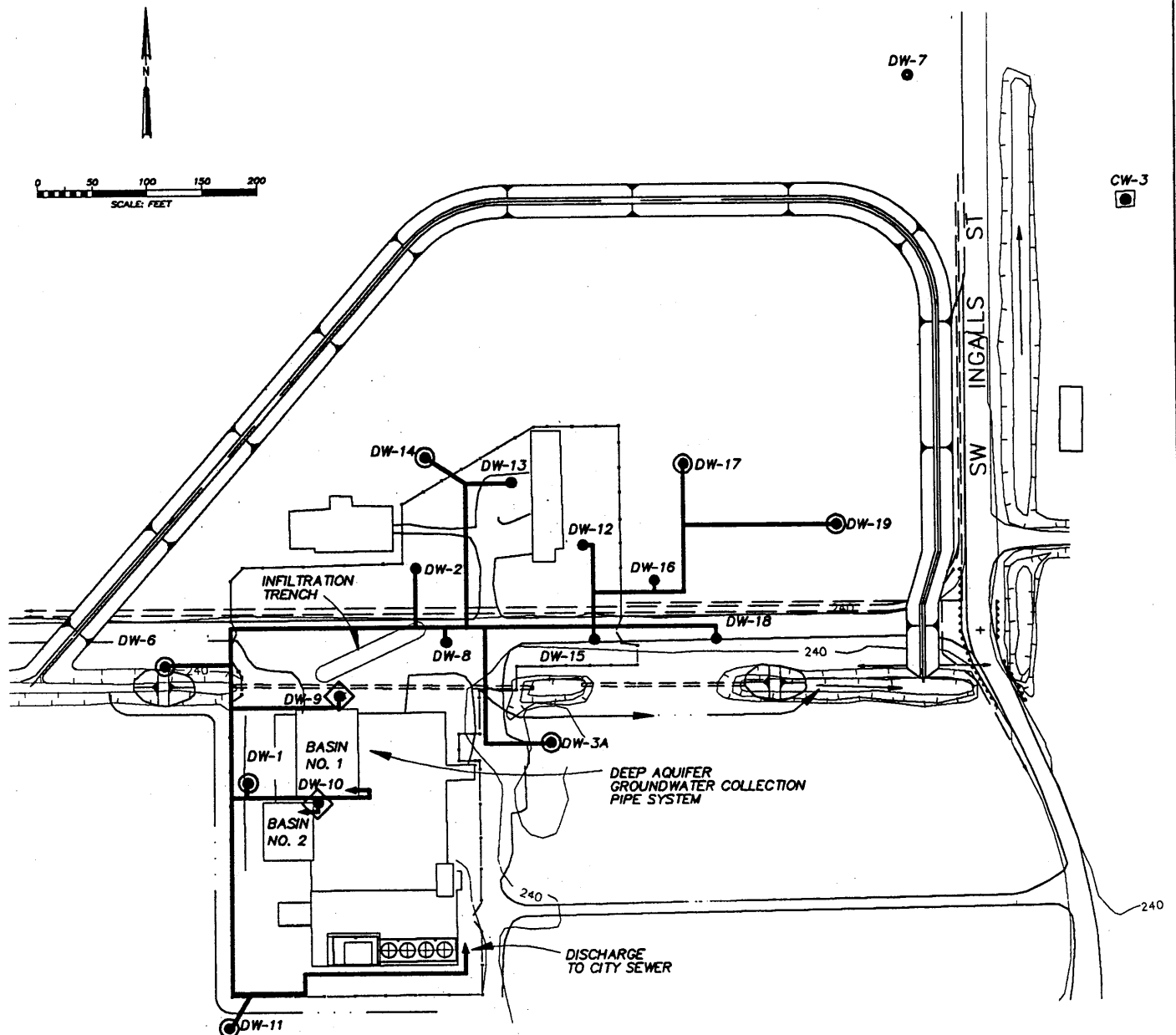


FIGURE 2
DEEP AQUIFER SYSTEM

UNITED CHROME PRODUCTS SITE
CORVALLIS, OREGON



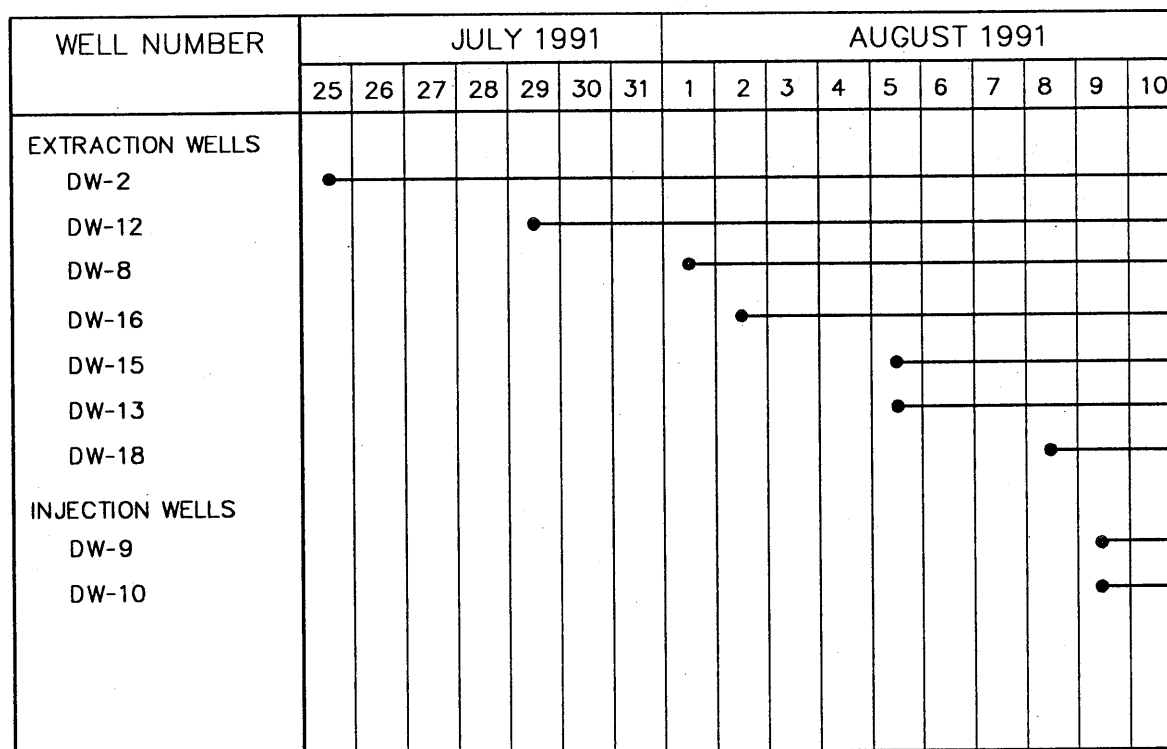


FIGURE 3
DEEP AQUIFER
EXTRACTION + INJECTION WELL
STARTUP SCHEDULE



C. Specific objectives for the monitoring program include:

1. Define the optimum pumping rates and flow balance between wells to minimize adverse well interference effects and vertical gradients between the upper zone and deep aquifer, and promote uniform and rapid contaminant flushing within the plume area.
2. Document and calibrate the extraction system to compensate for the effects of seasonal changes in groundwater elevations.
3. Develop and improve system performance evaluation criteria and monitoring schedules.

3.5 Performance Evaluation

A. To evaluate, the effectiveness of the deep aquifer groundwater extraction program, a performance evaluation will be conducted by EPA after several months of operations data have been compiled and reviewed.

B. The elements of the initial performance evaluation will likely include the following:

1. Analysis of Operations Data. This will include tabular summaries, graphical plots and statistical analysis of water quality data, well performance, mass balance estimates, and system operation hours.
2. Evaluate Monitoring System and Schedule. The sampling schedule (frequency and locations) will be evaluated to obtain a balance between technical adequacy and cost-effectiveness.
3. Evaluate Overall System Progress. This assessment will include characterizing progress to date and forecasting of cleanup levels based on current information.
4. Operation Modifications. System modifications and changes in operating strategy will be assessed based in the performance evaluation. Operation considerations that may be amended include pumping rates, pumping strategy (pulse pumping), increased usage of injection wells to enhance flushing rates, or improved contaminant recovery technologies.

Table 4
Deep Aquifer
First Year Monitoring and Data Reporting Schedule

	Task	Locations	Frequency ^b			Reporting Requirement
			First Month	Months 2 to 3	Months 4 to 12	First Year
Extraction Wells	Well head measurements/ inspection ^a	DW-2, DW-8, DW-12, DW-13, DW-15, DW-16, DW-18	Daily	Weekly	Weekly	Monthly
	Water level measurements	DW-2, DW-8, DW-12, DW-13, DW-15, DW-16, DW-18	Daily	Weekly	Monthly	Monthly
	Water quality sampling [Cr(VI)]	DW-2, DW-8, DW-12, DW-13, DW-15, DW-16, DW-18	Weekly	Monthly	Biannually	Quarterly
	Total Depth	DW-2, DW-8, DW-12, DW-13, DW-15, DW-16, DW-18	-----	-----	Annually	Annually
Monitoring Wells	Water level measurements	DW-1, DW-3A, DW-6, DW-7, DW-11, DW-14, DW-17, DW-19, CW-3,	Daily	Weekly	Monthly	Monthly
	Water quality sampling [Cr(VI)]	DW-1, DW-3A, DW-6, DW-7, DW-11, DW-14, DW-17, DW-19,	-----	-----	Biannually	Quarterly
	Total Depth	DW-1, DW-3A, DW-6, DW-7, DW-11, DW-14, DW-17, DW-19	-----	-----	Annually	Annually
Injection Wells	Well head measurements/ inspection ^b	DW-9, DW-10	Daily	Weekly	Weekly	Monthly
	Water balance	All active extraction wells	Weekly	Weekly	Monthly	Monthly
Notes: ^a Measurements include flow rate (gpm), flow totalizer (gallon), line pressure, and functional inspection. ^b Scheduled tasks will be performed at uniformly spaced intervals (monthly=beginning and midmonth; quarterly=March, June, September, December; biannually = march, September; annually = September).						

PART 4. DATA REPORTING AND COMMUNICATIONS

- A. City reporting requirements are provided in Table 3 and Table 4. Reports are to be generated by the City of Corvallis on a monthly and quarterly basis. Biannual and annual monitoring data will be submitted with the quarterly reports. The monthly summary report and quarterly comprehensive reports will be submitted to the Technical Assistant. Daily and weekly data reports will be made available upon request. It is anticipated these interim reports will only be requested during deep aquifer startup operations and special studies.
- B. The monthly report will be a summary of operations statistics as shown in Appendix A. The quarterly report will be comprehensive, including data from water levels, water quality, and will include plots as identified in Appendix B.
- C. The City shall make all daily site operations data available to the EPA or their Technical Assistant upon telephone request. It is recognized that this information is draft and may not be quality assured.
- D. The City's monthly and quarterly reports are due by the 15th of the following month.

4.1 Meeting Schedule

- A. Meeting to review facility operations data will be held at the site in accordance with the Scope of Work.
- B. Meeting notes will be recorded by the Technical Assistant on a form similar to Appendix C.

4.2 Communications

- A. Communications between the City operators and EPA's Technical Assistant are critical to successful execution of the pumping plan. Deviations from the pumping plan and responses to unusual conditions or problems with the extraction system will be communicated to the Technical Assistant.

4.3 Pumping Plan Updates

- A. This pumping plan will be periodically reviewed and update through addendums prepared by EPA or their Technical Assistant.

**APPENDIX A TO THE
PUMPING PLAN
Monthly Report Format**

OPERATING REPORT

(Month, Year)

UNITED CHROME GROUNDWATER EXTRACTION AND TREATMENT FACILITY

Prepared by

City of Corvallis

Date: _____

**UNITED CHROME
GROUNDWATER EXTRACTION and TREATMENT FACILITY
OPERATIONS REPORT page ____ of ____**

**_____
(month, year)**

NARRATIVE SUMMARY

WEATHER SUMMARY

SAMPLING SUMMARY

GROUNDWATER MONITORING SUMMARY

UPPER ZONE EXTRACTION SYSTEM ACTIVITIES

UPPER ZONE INFILTRATION SYSTEM ACTIVITIES

DEEP AQUIFER EXTRACTION SYSTEM ACTIVITIES

DEEP AQUIFER INJECTION SYSTEM ACTIVITIES

PRETREATMENT FACILITIES OPERATIONS SUMMARY

SITE MEETING SUMMARY

UNITED CHROME
GROUNDWATER EXTRACTION and TREATMENT FACILITY
OPERATIONS REPORT page ____ of

(month, year)

DATA SUMMARY

UPPER ZONE EXTRACTION SYSTEM

MONTH

CUMULATIVE

Days of operation
Total hours system on
Total gallons pumped
Lb Cr(VI) removed
Total gallons recharge to basins and trench
 Gallons recharge to Basin No. 1
 Gallons recharge to Basin No. 2
 Gallons recharge to trench

DEEP AQUIFER EXTRACTION SYSTEM

Days of operation
Total hours system on
Total gallons pumped
Extraction gallons to:
 Sewer
 Trench
 Basin No. 1
 Basin No. 2
Lb Cr(VI) removed
Total gallons recharge to injection wells
 Gallons to DW-9
 Gallons to DW-10

TREATMENT SYSTEM

Days of operation
Total hours system on
Total gallons treated
Total "off-spec" gallons retreated
Gallons H₂SO₄ used
Lbs. NaHSO₃ used
Gallons NaOH used
Lbs. polymer used

TREATMENT PRODUCTS

Total gallons discharged
Average concentration Cr-total (mg/l)
 Treatment plant
 Deep Aquifer
Average concentration Cr(VI) (mg/l)
 Treatment Plant
 Deep Aquifer
Total cu ft sludge produced

UTILITIES

Total electric (kWh)
Total water used (cu ft)

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY
OPERATIONS REPORT page ____ of ____

(month, year)
GROUNDWATER ELEVATION

<u>Date</u>	<u>Groundwater Elevation</u>																		
	<u>BG-1</u>	<u>SW-3</u>	<u>SW-4</u>	<u>PZ-A</u>	<u>PZ-B</u>	<u>PZ-C</u>	<u>PZ-D</u>	<u>PZ-E</u>	<u>PZ-F</u>	<u>SE-2A</u>	<u>PL-1</u>	<u>MW-1</u>	<u>MW-3</u>	<u>EW-19</u>	<u>EW-20</u>	<u>EW-22</u>	<u>EW-24</u>	<u>EW-25</u>	<u>EW-26</u>

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY
OPERATIONS REPORT page ____ of ____

(month, year)

DEEP AQUIFER WATER LEVEL DATA

<u>Date</u>	Groundwater Elevation																	
	DW-1	DW-2	DW-3A	DW-6	DW-7	DW-8	DW-9	DW-10	DW-11	DW-12	DW-13	DW-14	DW-15	DW-16	DW-17	DW-18	DW-19	CW-3

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY
OPERATIONS REPORT page ____ of ____

(month, year)

VERTICAL GRADIENT DATA

<u>Date, Time</u>	<u>Well Cluster^a</u>			<u>Well Cluster^b</u>			<u>Well Cluster^c</u>			<u>Well Cluster^d</u>			<u>Well Cluster^e</u>		
	<u>Groundwater Elevation</u>		<u>Gradient</u>	<u>Groundwater Elevation</u>		<u>Gradient</u>	<u>Groundwater Elevation</u>		<u>Gradient</u>	<u>Groundwater Elevation</u>		<u>Gradient</u>	<u>Groundwater Elevation</u>		<u>Gradient</u>
	<u>PZ-B</u>	<u>DW-10</u>		<u>SE-2A</u>	<u>DW-9</u>		<u>PZ-D</u>	<u>DW-8</u>		<u>MW-3</u>	<u>DW-2</u>		<u>EW-25</u>	<u>DW-12</u>	

Notes:

- ^aGradient = Elev (PZ-B – DW-10)/2.5¹ (+) = downward (–) = upward direction
^bGradient = Elev (SE-2A – DW-9)/4.0¹ (+) = downward (–) = upward direction
^cGradient = Elev (PZ-D – DW-8)/4.0¹ (+) = downward (–) = upward direction
^dGradient = Elev (MW-3 – DW-2)/5.5¹ (+) = downward (–) = upward direction
^eGradient = Elev (EW-25 – DW-12)/5.2¹ (+) = downward (–) = upward direction
- Water level measurements will be performed on the same day.

**UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY
OPERATIONS REPORT page ____ of ____**

(month, year)

UPPER ZONE

EXTRACTION SYSTEM					INFILTRATION SYSTEM						
Daily Operation			Daily Flow	Weekly Flow	Daily Basin #1	Daily Basin #2	Weekly Basins	Weekly ratio ^a infiltration/ extraction	Daily Trench	Weekly Trench	Weekly Ratio ^a infiltration/ extraction
<u>date</u>	<u>day</u>	<u>hours</u>	<u>gallons</u>	<u>gallons</u>	<u>gallons</u>	<u>gallons</u>	<u>gallons</u>		<u>gallons</u>	<u>gallons</u>	
1											
2											
3											
4											
5											
6											
7											
8											
9											
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26											
27											
28											
29											
30											
31											
Total		_____	_____		_____	_____			_____		
Max		_____	_____		_____	_____			_____		
Min		_____	_____		_____	_____			_____		
Avg		_____	_____		_____	_____			_____		

^aTo be calculated with well group shown in Table 3 and corrected extraction well flow rates.

UNITED CHROME
GROUNDWATER EXTRACTION and TREATMENT FACILITY
OPERATIONS REPORT page ____ of ____

(month, year)

DEEP AQUIFER

EXTRACTION SYSTEM					INJECTION SYSTEM			
Daily Operation			Daily Flow	Weekly Extraction	Water to DW-9	Water to DW-10	Weekly Injection	Weekly Ratio
<u>date</u>	<u>day</u>	<u>hours</u>	<u>gallons</u>	<u>gallons</u>	<u>gallons</u>	<u>gallons</u>	<u>gallons</u>	<u>infiltration/</u> <u>extraction</u>
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								
29								
30								
31								
Total		_____	_____		_____	_____		
Max		_____	_____		_____	_____		
Min		_____	_____		_____	_____		
Avg		_____	_____		_____	_____		

**APPENDIX B TO THE
PUMPING PLAN
Quarterly Report Graph Format**

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY
OPERATIONS REPORT page ____ of ____

(month, year)

Graph (#) Time	Average CR(VI) Concentration (mg/l) ^a		Rate of Extraction (gpm)		Upper Zone		Deep Aquifer		Gallons Treated		Pounds Cr(VI) Removed		Cumulative Pounds Cr(VI) Removed	
	(1)	(2)	(3)		(4)		(5)		(6)	(7)	(8)		(9)	
	Upper Zone	Deep Aquifer	Upper Zone	Deep Aquifer	Gallons Recharged	Gallons Extracted ^b	Gallons Injected	Gallons Extracted	Upper Zone	Deep Aquifer Discharge to Sewer Basins	Upper Zone	Deep Aquifer	Upper Zone	Deep Aquifer
1988 AUG														
SEP														
OCT														
NOV														
DEC														
1989 JAN														
FEB														
MAR														
APR														
MAY														
JUN														
JUL														
AUG														
SEP														
OCT														
NOV														
DEC														
1990 JAN														
FEB														
MAR														
APR														
MAY														
JUN														
JUL														
AUG														
SEP														
OCT														
NOV														
DEC														
1991 JAN														

^aUse a flow weighted method $C_{\text{flow}} = \frac{\sum_{i=1}^n C_i Q_i}{\sum_{i=1}^n Q_i}$ C_i = concentration at extraction well I, Q = calculated flow at extraction well I.

^bUse measured flow at treatment plant.
Quarterly periods 1 = December, January, February (winter)
 2 = March, April, May (spring)
 3 = June, July, August (summer)
 4 = September, October, November (fall)

**APPENDIX C TO THE
PUMPING PLAN
Meeting Notes Form**

UNITED CHROME OPERATIONS

SITE MEETING NOTES

DATE: _____

TIME: _____

ATTENDEES: _____

PERFORMANCE CRITERIA REVIEW

GALLONS PUMPED: _____

FREEZE/MAINTENANCE DAYS: _____

PUMPING & INFILTRATION: _____

MONITORING: _____

TREATMENT SYSTEM: _____

SCOPE OF WORK CHECKLIST: _____

OTHER: _____

PROGRESS SINCE LAST MEETING

EPA OPERATION INSTRUCTIONS

PUMPING PLAN:

MONITORING SCHEDULE:

TREATMENT SYSTEM:

PHASE II ACTIVITIES:

OTHER:

OPERATORS COMMENTS

ACTION ITEMS

RESPONSIBILITY

TIME FRAME

ACTION ITEM



Public Works
1245 NE 3rd Street
P.O. Box 1083
Corvallis, OR 97339-1083
(503) 757-6916
FAX (503) 757-6920

September 14, 1992

Loren McPhillips
Superfund Site Manager
USEPA, Region 10
1200 Sixth Avenue, HW-113
Seattle, WA 98101

UNITED CHROME MONTHLY REPORT

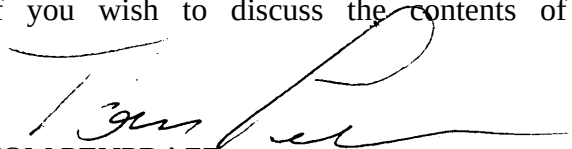
Attached is the United Chrome operations report for the month of August, 1992. A summary of significant events for the month is as follows:

- * More than 29,200 pounds of chrome have been removed over the past 49 months of operation. Ninety-two pounds of chrome were removed from the upper aquifer during the past month.
- * The infiltration system basins and trench operated continuously during the month to provide sufficient recharge of the upper aquifer. The lack of precipitation limited the extraction rate to less than seven gallons per minute.
- * Continuous operation of the upper zone extraction system produced 304,000 gallons of ground water during the month. Extraction wells 4, 17, 18, 21 and 23 remain off after testing below the cleanup standard of 10 mg/l. EW-3 has tested below the cleanup standard in July and August. The City will submit to EPA a request to shut off EW-3 following September testing.
- * The daily pounds of chrome extracted averaged less than three pounds per day for the month, well under the daily discharge limit of seven pounds per day. No sludge was generated this month.
- * The concentration of Cr6+ in the upper aquifer ground water extracted this month averaged just 36 mg/l. This is a 98 % reduction in concentration from startup of the operation in August, 1988.
- * The deep aquifer well field operated continuously during the month producing more than 755,000 gallons of ground water for discharge. The concentration of Cr6+ fluctuated from 0.44 mg/L to 0.54 mg/L.

LOREN MCPHILLIPS
UNITED CHROME MONTHLY REPORT
September 14, 1992
Page 2

- * Discrete sampling and testing of deep aquifer wells confirms that 95 % of the Cr6+ extracted comes from DW-8. This well had a chrome concentration of 3.4 mg/l. Concentrations in other deep wells ranged from 0.12 to < 0.1 mg/l. The City will do additional testing and monitoring of the deep well system to monitor DW-8 chrome concentrations over the next 12 months to determine the significance and impact of these concentrations on the cleanup strategy.

If you wish to discuss the contents of the August report, contact me at (503) 757-6916.



TOM PENPRAZE
UTILITY OPERATIONS DIVISION MANAGER

TP/eao

cc: Rolland Baxter, Public Works Director
Daniel Hanthorn, Wastewater Operations Supervisor
Scott McKinley, CH2M Hill
Paul Burnet, ODEQ

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY
MONTHLY REPORT
August, 1992

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DATA SUMMARY

EXTRACTION SYSTEMS	MONTH	CUMULATIVE
SHALLOW		
Days of operation	31	1184
Total hours system on	741.0	24383.9
Total gallons pumped	304950	15127861
Lbs. Cr6+ removed	92	29299
Total gallons infiltration water	393575	10719566
Gallons recharge to basin #1	150500	5739352
Gallons recharge to basin #2	105975	2523364
Gallons recharge to trench	137100	2456850
DEEP		
Days of operation	31	404
Total hours system on	737.3	9668.7
Total gallons pumped	755750	9426936
Lbs. Cr6+ removed	3.14	55.94
TREATMENT SYSTEM		
Days of operation	31	994
Total hours system on	741.0	9194.3
Total gallons treated	304950	15736400
Total 'off-spec' gallons retreated	0	4200
Gallons H2SO4 used	0	9045
Lbs. NaHSO3 used	0	96245
Gallons NaOH used	0	20800
Lbs. polymer used	0.0	556.0
TREATMENT PRODUCTS		
FULLY TREATED		
Total gallons discharged	0	12544110
Average Total-Cr (mg/L)		4.3
Average Cr6+ (mg/l)(a)		2.0
Lbs. chrome discharged	0.0	488.1
REDUCED ONLY		
Total gallons discharged	304950	2946070
Lbs. chrome discharged	92	1826
SLUDGE		
Total cu.yds. produced	0.00	260.62
UTILITIES		
Total electric (kwh)	7437	344599
Total water used (cu.ft.)	96080	2043040

Notes: (a) Cumulative average concentration for Cr6+ calculation is based on 12049790 gallons completely treated, tested, and discharged since 4/25/89.

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY
MONTHLY REPORT
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DATE	DAY	EXTRACTION SYSTEM			INFILTRATION WATER					
		OPERATION	daily	weekly	Basin #1	Basin #2	Basins1&2	infiltration/	infiltration/	Trench
		hours	FLOW gallons	FLOW gallons	weekly gallons	weekly gallons	weekly gallons	extract ion %(a)	extract ion %(b)	weekly gallons
1	S									
2	S									
3	M									
4	T	95.7	38220	66760	35500	25875	61375	92	129	33000
5	W									
6	T									
7	F									
8	S									
9	S									
10	M									
11	T	165.6	66040	66040	37200	26100	63300	96	132	33900
12	W									
13	T									
14	F									
15	S									
16	S									
17	M									
18	T	168.3	73700	73700	40200	27300	67500	92	132	35100
19	W									
20	T									
21	F									
22	S									
23	S									
24	M									
25	T	166.8	62380	62380	37600	26700	64300	103	136	35100
26	W									
27	T									
28	F									
29	S									
30	S									
31	M	144.6	64610							

NOTES:

1. Infiltration/extraction ratio (a) compares weekly infiltration in Basins 1&2 with weekly flow from all upper zone extraction wells. Balance goal is 50-60%.
2. Infiltration/extraction ratio (b) compares weekly infiltration in Basins 1&2 with corrected weekly flow from the Basin Well Group (EW-1,EW2,EW-3, EW-4,EW-5,EW-6,EW-8,EW-11,EW-27,EW-28, and EW-29). Balance goal is 60-70%.
3. Infiltration/extraction ratio ©) compares weekly trench infiltration with corrected weekly flow from wells EW-9,EW-10,EW-12,EW-13,EW-14,EW-15, and EW-16. Balance goal is 50-60%.

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY
MONTHLY REPORT
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DEEP AQUIFIER

DATE	DAY	EXTRACTION SYSTEM				INJECTION SYSTEM				
		OPERATION hours	EXTRACTION gallons	weekly EXTRACTION gallons	Cr6+ mg/L	pH	DW-9 INJECTION gallons	DW-10 INJECTION gallons	weekly INJECTION gallons	weekly INJECTION/ EXTRACTION ratio
1	S									
2	S									
3	M									
4	T	92.0	97360	169600			18800	44790	63590	0.37
5	W				0.51	7.7				
6	T									
7	F									
8	S									
9	S									
10	M									
11	T	166.0	170400	170400			18830	44420	63250	0.37
12	W				0.44	7.5				
13	T									
14	F									
15	S									
16	S									
17	M									
18	T	168.0	171700	171700			19060	44460	63520	0.37
19	W				0.50	7.6				
20	T									
21	F									
22	S									
23	S									
24	M									
25	T	167.2	169800	169800			18690	43570	62260	0.37
26	W				0.54	7.6				
27	T									
28	F									
29	S									
30	S									
31	M	144.1	146490							
TOTAL		737.3	755750				75380	177240		

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY
MONTHLY REPORT
August, 1992

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TREATMENT SYSTEM

DATE	DAY	PLANT operation hours (complete treatment)	DAILY flow gallons	WEEKLY flow gallons	INFLUENT Cr6+ mg/L
1	S				
2	S				
3	M				
4	T	0.0	38220	38220	
5	W				43
6	T				
7	F				
8	S				
9	S				
10	M				
11	T	0.0	66040	66040	
12	W				31
13	T				
14	F				
15	S				
16	S				
17	M				
18	T	0.0	73700	73700	
19	W				29
20	T				
21	F				
22	S				
23	S				
24	M				
25	T	0.0	62380	62380	
26	W				40
27	T				
28	F				
29	S				
30	S				
31	M	0.0	64610		
TOTAL		0.0	304950		

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY
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TREATMENT SYSTEM PLANT EFFLUENT									
DATE	DAY	Complete treatment				Convert & discharge			
		gallons	Cr-T mg/L	Cr6+ mg/L	pH	gallons	Cr-T mg/L	Cr6+ mg/L	pH
1	S								
2	S								
3	M								
4	T					38220			
5	W						43	0.42	8.7
6	T								
7	F								
8	S								
9	S								
10	M								
11	T					66040			
12	W						31	0.62	7.9
13	T								
14	F								
15	S								
16	S								
17	M								
18	T					73700			
19	W						29	0.32	7.8
20	T								
21	F								
22	S								
23	S								
24	M								
25	T					62380			
26	W						40	0.56	7.7
27	T								
28	F								
29	S								
30	S								
31	M					64610			

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY
MONTHLY REPORT
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TREATMENT SYSTEM

DATE	DAY	H2SO4 gallons	CHEMICAL USE ADDED TO DAY TANKS			polymer batches	SLUDGE PRODUCED	
			NaHSO3 lbs	NaOH gallons			cu. yds.	DRY WT. %
1	S							
2	S							
3	M							
4	T							
5	W							
6	T							
7	F							
8	S							
9	S							
10	M							
11	T							
12	W							
13	T							
14	F							
15	S							
16	S							
17	M							
18	T							
19	W							
20	T							
21	F							
22	S							
23	S							
24	M							
25	T							
26	W							
27	T							
28	F							
29	S							
30	S							
31	M							
TOTAL		0	0	0		0	0.00	

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY
 OPERATIONS REPORT
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VERTICAL GRADIENT DATA

	Well Cluster (A)			Well Cluster (B)			Well Cluster (C)			Well Cluster (D)			Well Cluster (E)		
	Groundwater Elevation		Gradient	Groundwater Elevation		Gradient	Groundwater Elevation		Gradient	Groundwater Elevation		Gradient	Groundwater Elevation		Gradient
DATE	PZ-B	DW-10		SE-2A	DW-9		PZ-D	DW-8		MW-3	DW-2		EW-25	DW-12	
1															
2															
3															
4															
5	236.59	225.59	4.400	233.33	237.83	-1.125	233.46	225.06	2.100	229.26	224.59	0.849	229.69	224.68	0.963
6															
7															
8															
9															
10															
11															
12	236.54	225.16	4.552	233.24	236.88	-0.910	233.31	224.63	2.170	229.04	224.17	0.885	229.34	224.24	0.981
13															
14															
15															
16															
17															
18															
19	236.25	224.66	4.636	232.97	237.23	-1.065	233.21	224.16	2.263	228.64	223.69	0.900	228.00	223.75	0.817
20															
21															
22															
23															
24															
25															
26	236.44	224.17	4.908	233.13	237.57	-1.110	233.42	223.68	2.435	228.60	223.19	0.984	228.34	223.27	0.975
27															
28															
29															
30															
31															

Notes

- Gradient (A)=Elevation(PZ-B - DW-10)/2.5
 Gradient (B)=Elevation(SE-2A - DW-9)/4.0
 Gradient (C)=Elevation(PZ-D - DW-8)/4.0
 Gradient (D)=Elevation(MW-3 - DW-2)/5.5
 Gradient (E)=Elevation(EW-25 - DW-12)/5.2
- (+)=downward. (-)=upward direction

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY
MONTHLY REPORT page 8 of 8
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NOTES

SAMPLING AND MONITORING

Sampled and tested DW-2, DW-8, and DW-12.
Results indicate that virtually all deep well
chrome is being extracted from DW-8. The Cr6+
concentration has increased from 1.4 to 3.4 mg/L.

EW-3, EW-4, EW-18, and EW-21 continue to test below
10 mg/L. EW-4, EW-18, and EW-21 turned off after testing.

WEATHER

Received 0.4" rain this month.

PRETREATMENT FACILITY

EW-3 cycle meter was replaced.

GRAPH	GRAPH	Ave. Cr6+ OF EXTRACTED GROUNDWATER (A)	RATE of EXTRACTION (GPM) (B)	GALLONS DISCHARGED (C)	GALLONS RECHARGED to basins (D)	GALLONS EXTRACTED SHALLOW ZONE (E)	GALLONS TREATED (F)	POUNDS Cr6+ REMOVED (G)	HOURS OPERATED SHALLOW ZONE (H)
1988	AUG	1923	8.9	13390	0	15523	45820	249	29
	SEP	1573	7.3	75390	146594	70044	153090	924	159
	OCT	1512	10.5	64360	85415	61353	113660	773	97
	NOV	1543	12.3	55050	7200	62139	137550	800	83.8
	DEC	1629	13.0	72370	0	55560	125700	755	71.3
1989	JAN	1110	14.5	59840	0	50112	115210	464	58
	FEB	1203	0.0	0	0	0	0	0	0
	MAR	1296	14.7	92680	0	70390	145360	761	79.7
	APR	1131	11.4	85020	0	73240	148230	865	107
	MAY	1147	11.4	88390	86384	89750	179630	1008	131.2
	JUN	1058	14.0	98547	83316	74760	120660	756	88.8
	JUL	1239	9.9	53490	74700	71940	88210	751	120.9
	AUG	981	9.5	135860	130000	116060	151690	950	204
	SEP	724	3.8	64350	111200	44580	52940	269	194.7
	OCT	676	5.9	264400	190900	218480	288480	1232	618.8
	NOV	500	6.5	271900	223100	253880	290680	1059	651.7
	DEC	576	10.0	344090	231575	366210	361330	1760	613.1
1990	JAN	504	12.3	385810	64200	384350	400820	1615	519
	FEB	487	11.9	310720	9140	302490	308220	1229	423.5
	MAR	406	10.5	356980	208075	357500	348760	1210	565.9
	APR	306	10.4	423110	262600	444720	430800	1137	716.1
	MAY	250	10.3	410730	313750	427800	410410	893	690.6
	JUN	207	10.5	461290	409506	427240	459120	739	675.9
	JUL	225	12.3	582650	548664	520650	563130	978	707.7
	AUG	176	11.2	507880	275828	490740	487760	722	727.8
	SEP	171	8.7	372230	389875	363840	344250	520	694.9
	OCT	192	10.5	441690	422015	454100	425880	728	723.9
	NOV	181	14.1	470080	257000	474330	453610	717	561.2
	DEC	146	15.5	350010	189000	370540	332840	452	398.7
1991	JAN	134	12.6	345250	110775	240340	371500	270	318.7
	FEB	110	13.4	560530	223425	513290	515700	468	640.7
	MAR	96	14.7	550450	210925	537150	511230	431	608.8
	APR	89	15.5	629160	391300	593740	582830	443	637.1
	MAY	90	16.1	596990	406200	573970	561890	431	595.5
	JUN	81	13.7	548300	436850	551960	514190	373	670.9
	JUL	70	10.5	488870	311450	467360	479630	272	740.3
	AUG	49	8.6	402660	279450	384280	376060	157	744.0
	SEP	63	2.9	154090	170375	126550	141980	67	719.4
	OCT	61	5.8	235780	257225	261310	207900	134	745.4
	NOV	64	9.2	321740	119245	383820	302900	205	693.7
	DEC	69	11.7	478110	105300	502730	456610	289	715.4
1992	JAN	64	11.9	510560	220060	526120	477810	283	736.3
	FEB	59	10.8	445830	167635	445910	422420	218	691.0
	MAR	59	10.3	481740	353350	458270	481740	225	742.6
	APR	51	10.9	439940	296025	471260	439940	202	718.8
	MAY	51	9.1	417100	481925	405360	417100	174	745.5
	JUN	48	7.6	346010	398850	327000	346010	130	719.6
	JUL	42	7.6	340170	382850	340170	340170	119	746.0
	AUG	36	6.9	304950	393575	304950	304950	92	741.0

UNITED CHROME EXTRACTION SYSTEM DATA SUMMARY

GRAPH	(OMIT) (GRAPH) TREATMENT HOURS (I)	ACCUMULATED POUNDS of Cr6+ REMOVED (J)	DEEP ZONE GALLONS EXTRACTED/ DISCHARGED (K)	DEEP ZONE OPERATION HOURS (M)	DEEP ZONE RATE OF EXTRACTION (N)
1988	AUG	33.4	249	0	
	SEP	113.0	1173	0	
	OCT	53.6	1946	0	
	NOV	87.1	2746	0	
	DEC	71.1	3501	0	
1989	JAN	70.1	3965	0	
	FEB	0.0	3965	0	
	MAR	81.0	4726	0	
	APR	75.9	5591	0	
	MAY	77.4	6599	0	
	JUN	65.2	7355	0	
	JUL	48.1	8106	0	
	AUG	74.1	9056	0	
	SEP	28.4	9325	0	
	OCT	137.9	10557	0	
	NOV	153.8	11616	0	
	DEC	201.9	13376	0	
1990	JAN	201.4	14991	0	
	FEB	146.3	16220	0	
	MAR	161.4	17430	148660	
	APR	195.5	18567	0	
	MAY	183.6	19460	0	
	JUN	206.0	20199	0	
	JUL	253.3	21177	11781	
	AUG	207.3	21899	48305	
	SEP	132.5	22419	0	
	OCT	188.8	23147	0	
	NOV	187.9	23864	0	
	DEC	116.7	24316	0	
1991	JAN	111.0	24586	0	
	FEB	149.0	25054	0	
	MAR	135.2	25485	0	
	APR	137.0	25928	0	
	MAY	128.9	26359	0	
	JUN	118.0	26732	0	
	JUL	108.0	27004	36500	
	AUG	83.3	27161	628350	745.8
	SEP	34.1	27228	707150	717.2
	OCT	48.4	27362	694100	740.0
	NOV	71.0	27567	686670	719.2
	DEC	106.6	27856	707380	740.1
1992	JAN	114.0	28139	711050	742.0
	FEB	94.2	28357	671200	690.3
	MAR	632.1	28582	714200	743.6
	APR	636.3	28784	689900	718.6
	MAY	727.5	28958	731300	745.4
	JUN	719.6	29088	705800	722.5
	JUL	746.0	29207	778840	746.5
	AUG	741.0	29299	755750	737.3

[illegible]

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

MONITORING WELL LOG page 2 of 3

August, 1992

[illegible]

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

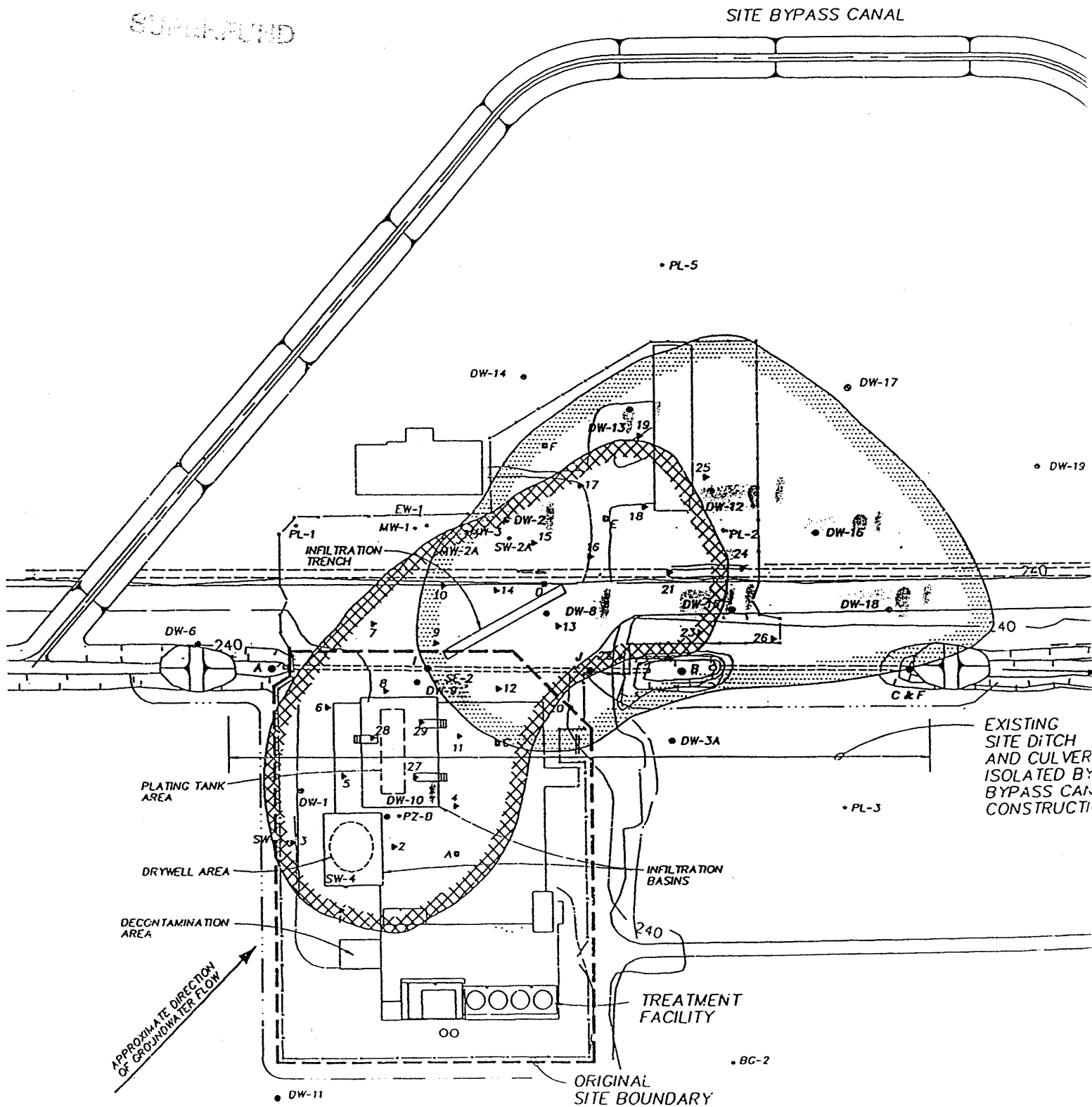
MONITORING WELL LOG

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August, 1992

WELL	DW-1	DW-2	DW-3A	DW-6	DW-7	DW-8	DW-9	DW-10	DW-11	DW-12	DW-13	DW-14	DW-15	DW-16	DW-17	DW-18	DW-19	CW-3
Casing elevation (feet):																		
	240.91	240.64	242.25	240.99	242.48	241.56	241.19	241.59	242.86	240.65	240.85	241.50	241.57	240.47	240.30	241.64	240.93	241.68
Water elevation (feet):																		
DAY																		
1																		
2																		
3																		
4																		
5	225.51	224.59				225.06	237.83	225.59		224.68								
6																		
7																		
8																		
9																		
10																		
11																		
12	225.09	224.17	224.80	224.99	224.43	224.63	236.88	225.16	225.55	224.24	223.77	224.65	224.72	224.67	224.63	224.51	224.59	224.31
13																		
14																		
15																		
16																		
17																		
18																		
19	224.57	223.69				224.16	237.23	224.66		223.75								
20																		
21																		
22																		
23																		
24																		
25																		
26	224.09	223.19				223.68	237.57	224.17		223.27								
27																		
28																		
29																		
30																		
31																		

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UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

DEEP AQUIIFIER WELL LOG

WELL DW-2

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	Cr6+ mg/L	FLOW gallons	FLOW gpm	WELLHEAD PRESSURE psi
1					0.33			
2								
3								
4	164.0	1				25180	2.6	65
5								
6								
7								
8								
9								
10								
11	166.0	4				25320	2.5	65
12								
13								
14								
15								
16								
17								
18	168.0	1				25670	2.5	64
19								
20								
21								
22								
23								
24								
25	167.2	2				25530	2.5	64
26					0.12			
27								
28								
29								
30								
31								
TOTAL	665.2					101700		

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY
DEEP AQUIIFIER WELL LOG

WELL DW-8

August, 1992

DATE	FLOW gallons	FLOW gpm	COND. umhos	pH	Cr6+ mg/L	WELLHEAD PRESSURE psi
1					1.4	
2						
3						
4	26240	2.7				57
5						
6						
7						
8						
9						
10						
11	26420	2.7				57
12						
13						
14						
15						
16						
17						
18	26760	2.7				57
19						
20						
21						
22						
23						
24						
25	26630	2.7				56
26					3.4	
27						
28						
29						
30						
31						
TOTAL	106050					

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

DEEP AQUIFIER WELL LOG

WELL DW-9

August, 1992

DATE	WATER INJECTED gallons	FLOW gpm
1		
2		
3		
4	18800	1.9
5		
6		
7		
8		
9		
10		
11	18830	1.9
12		
13		
14		
15		
16		
17		
18	19060	1.9
19		
20		
21		
22		
23		
24		
25	18690	1.9
26		
27		
28		
29		
30		
31		
TOTAL	75380	

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

DEEP AQUIFIER WELL LOG

WELL DW-10

August, 1992

DATE	WATER INJECTED gallons	FLOW gpm
1		
2		
3		
4	44790	4.6
5		
6		
7		
8		
9		
10		
11	44420	4.5
12		
13		
14		
15		
16		
17		
18	44460	4.4
19		
20		
21		
22		
23		
24		
25	43570	4.3
26		
27		
28		
29		
30		
31		
TOTAL	177240	

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

DEEP AQUIFIER WELL LOG

WELL DW-12

August, 1992

DATE	FLOW gallons	FLOW gpm	COND. umhos	pH	Cr6+ mg/L	WELLHEAD PRESSURE psi
1					0.12	
2						
3						
4	24580	2.5				53
5						
6						
7						
8						
9						
10						
11	24780	2.5				52
12						
13						
14						
15						
16						
17						
18	25140	2.5				52
19						
20						
21						
22						
23						
24						
25	24950	2.5				52
26					< 0.1	
27						
28						
29						
30						
31						
TOTAL	99450					

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

DEEP AQUIIFIER WELL LOG

WELL DW-13

August, 1992

DATE	FLOW gallons	FLOW gpm	COND. umhos	pH	Cr6+ mg/L < 0.1	WELLHEAD PRESSURE psi
1						
2						
3						
4	21660	2.2				53
5						
6						
7						
8						
9						
10						
11	21790	2.2				53
12						
13						
14						
15						
16						
17						
18	21820	2.2				52
19						
20						
21						
22						
23						
24						
25	21710	2.2				52
26						
27						
28						
29						
30						
31						
TOTAL	86980					

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

DEEP AQUIFIER WELL LOG

WELL DW-15

August, 1992

DATE	FLOW gallons	FLOW gpm	COND. umhos	pH	Cr6+ mg/L < 0.1	WELLHEAD PRESSURE psi
1						
2						
3						
4	20350	2.1				66
5						
6						
7						
8						
9						
10						
11	19820	2.0				66
12						
13						
14						
15						
16						
17						
18	19320	1.9				65
19						
20						
21						
22						
23						
24						
25	19100	1.9				65
26						
27						
28						
29						
30						
31						
TOTAL	78590					

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

DEEP AQUIIFIER WELL LOG

WELL DW-16

August, 1992

DATE	FLOW gallons	FLOW gpm	COND. umhos	pH	Cr6+ mg/L	WELLHEAD PRESSURE psi
1					0.10	
2						
3						
4	29070	3.0				65
5						
6						
7						
8						
9						
10						
11	29200	2.9				65
12						
13						
14						
15						
16						
17						
18	29550	2.9				65
19						
20						
21						
22						
23						
24						
25	29360	2.9				65
26						
27						
28						
29						
30						
31						
TOTAL	117180					

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

DEEP AQUIFIER WELL LOG

WELL DW-18

August, 1992

DATE	FLOW gallons	FLOW gpm	COND. umhos	pH	Cr6+ mg/L	WELLHEAD PRESSURE psi
1					0.10	
2						
3						
4	23840	2.4				56
5						
6						
7						
8						
9						
10						
11	24040	2.4				66
12						
13						
14						
15						
16						
17						
18	24350	2.4				56
19						
20						
21						
22						
23						
24						
25	24130	2.4				55
26						
27						
28						
29						
30						
31						
TOTAL	96360					

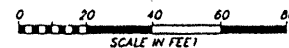
WELL SERIES DESIGNATIONS

- ▲ AXIS WELL ARRAY (6)
- ◆ BASIN WELL ARRAY (12)
- PERIPHERAL WELL ARRAY (5)

MONITORING WELLS

- INTERNAL SHALLOW (9)
- ◇ BOUNDARY SHALLOW (16)
- DEEP AQUIFER (5)

PL-3



SEWER DISCHARGE LINE

ACCESS ROAD

WATER MAIN

OPERATIONS TRAILER

CONCRETE SLAB

TANK FARM

WASTEWATER TREATMENT SYSTEM

EXTRACTED GROUNDWATER MAIN
DECONTAMINATION SLAB

GROUNDWATER EXTRACTION AND MONITORING SYSTEM

Dw-6

BG-2

BG-1

S.W. AIRPORT AVE

DW-3A

DW-4

WATER MAIN

INFILTRATION BASIN NO. 1

INFILTRATION BASIN NO. 2

SE-2

DW-2

SW-2A

MW-3

MW-2A

EW-1

MW-1

PL-1

DW-1

SW-3

Dw-6

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-1

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						11	0.55		
2									
3									
4	164.0	3						5412	0.50
5									
6									
7									
8									
9									
10									
11	165.5	4						5462	0.50
12									
13									
14									
15									
16									
17									
18	168.3	1						5554	0.51
19									
20									
21									
22									
23									
24									
25	167.2	3						5518	0.51
26									
27									
28									
29									
30									
31									
TOTAL	665.0							21945	2.01
elevation:		240.9							

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-2

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						26	0.75		
2									
3									
4	163.9	2						7376	1.60
5									
6									
7									
8									
9									
10									
11	165.8	4						7461	1.62
12									
13									
14									
15									
16									
17									
18	168.4	1						7578	1.64
19									
20									
21									
22									
23									
24									
25	167.2	3						7524	1.63
26									
27									
28									
29									
30									
31									

TOTAL	665.3							29939	6.49
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elevation: 241.52

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-3

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						8	0.55		
2									
3									
4	164.0	1						5412	0.36
5									
6									
7									
8									
9									
10									
11	165.5	4						5462	0.36
12									
13									
14									
15									
16									
17									
18	168.3	1						5554	0.37
19						8.2			
20									
21									
22									
23									
24									
25	167.2	3						5518	0.38
26									
27									
28									
29									
30									
31									

TOTAL	665.0							21945	1.47
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elevation: 240.84

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-4

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						3.8	0.38		
2									
3									
4	0.0	0							
5									
6									
7									
8									
9									
10									
11	0.0	0							
12									
13									
14									
15									
16									
17									
18	161.2	3						3675	0.12
19						3.6			
20									
21									
22									
23									
24									
25	0.0	0							
26									
27									
28									
29									
30									
31									

TOTAL	161.2							3675	0.12
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elevation: 241.55

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-5

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						18	0.55		
2									
3									
4	164.1	1						5415	0.81
5									
6									
7									
8									
9									
10									
11	165.5	4						5462	0.82
12									
13									
14									
15									
16									
17									
18	168.2	1						5551	0.83
19									
20									
21									
22									
23									
24									
25	167.3	2						5521	0.83
26									
27									
28									
29									
30									
31									

TOTAL	665.1							21948	3.29
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elevation: 241.11

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-6

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
			cycle meter out			58	0.99		
1									
2									
3									
4	77.6							4609	2.23
5			cycle meter replaced						
6									
7									
8									
9									
10									
11	73.2	787						4348	2.10
12									
13									
14									
15									
16									
17									
18	71.5	784						4247	2.05
19									
20									
21									
22									
23									
24									
25	67.4	790						4004	1.94
26									
27									
28									
29									
30									
31									

TOTAL	289.7							17208	8.32
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elevation: 241.06

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-7

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						34	0.75		
2									
3									
4	73.6	535						3312	0.94
5									
6									
7									
8									
9									
10									
11	69.2	539						3114	0.88
12									
13									
14									
15									
16									
17									
18	66.7	525						3002	0.85
19									
20									
21									
22									
23									
24									
25	61.7	520						2777	0.79
26									
27									
28									
29									
30									
31									

TOTAL	271.2							12204	3.46
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elevation: 241.42

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-8

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						130	0.75		
2									
3									
4	106.9	454						4811	5.22
5									
6									
7									
8									
9									
10									
11	110.0	436						4950	5.37
12									
13									
14									
15									
16									
17									
18	138.6	221						6237	6.76
19									
20									
21									
22									
23									
24									
25	164.0	25						7380	8.00
26									
27									
28									
29									
30									
31									

TOTAL	519.5							23378	25.35
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elevation: 241.21

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-9

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						27.5	0.55		
2									
3									
4	0.0	0							
5									
6									
7									
8									
9									
10									
11	0.0	0							
12									
13									
14									
15									
16									
17									
18	0.0	0							
19									
20									
21									
22									
23									
24									
25	0.0	0							
26									
27									
28									
29									
30									
31									

TOTAL 0.0 0 0.00

elevation: 214.12

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-10

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						90	0.38		
2									
3									
4	30.2	123						689	0.52
5									
6									
7									
8									
9									
10									
11	29.0	119						661	0.50
12									
13									
14									
15									
16									
17									
18	27.6	117						629	0.47
19									
20									
21									
22									
23									
24									
25	26.4	86						602	0.45
26									
27									
28									
29									
30									
31									

TOTAL	113.2							2581	1.94
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elevation: 241.45

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-11

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						11	0.38		
2									
3									
4	163.9	0						3737	0.34
5									
6									
7									
8									
9									
10									
11	165.8	0						3780	0.35
12									
13									
14									
15									
16									
17									
18	168.4	0						3840	0.35
19									
20									
21									
22									
23									
24									
25	167.0	0						3808	0.35
26									
27									
28									
29									
30									
31									

TOTAL	665.1							15164	1.39
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elevation: 241.5

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-12

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						64	0.99		
2									
3									
4	71.3	414						4235	2.26
5									
6									
7									
8									
9									
10									
11	68.5	421						4069	2.17
12									
13									
14									
15									
16									
17									
18	65.8	406						3909	2.09
19									
20									
21									
22									
23									
24									
25	64.4	412						3825	2.04
26									
27									
28									
29									
30									
31									

TOTAL	270.0							16038	8.56
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elevation: 241.1

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-13

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						32	0.75		
2									
3									
4	54.9	300						2471	0.66
5									
6									
7									
8									
9									
10									
11	52.7	294						2372	0.63
12									
13									
14									
15									
16									
17									
18	47.2	242						2124	0.57
19									
20									
21									
22									
23									
24									
25	47.5	238						2138	0.57
26									
27									
28									
29									
30									
31									

TOTAL	202.3							9104	2.43
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elevation: 241.13

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-14

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						76	0.38		
2									
3									
4	90.9	506						2073	1.31
5									
6									
7									
8									
9									
10									
11	88.4	525						2016	1.28
12									
13									
14									
15									
16									
17									
18	58.7	506						1954	1.24
19									
20									
21									
22									
23									
24									
25	83.8	442						1911	1.21
26									
27									
28									
29									
30									
31									

TOTAL	348.8							7953	5.04
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elevation: 241.6

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-15

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						90	0.99		
2									
3									
4	52.1	555						3095	2.32
5									
6									
7									
8									
9									
10									
11	49.0	549						2911	2.18
12									
13									
14									
15									
16									
17									
18	42.0	486						2495	1.87
19									
20									
21									
22									
23									
24									
25	42.3	501						2513	1.89
26									
27									
28									
29									
30									
31									

TOTAL	185.4							11013	8.27
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elevation: 240.45

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-16

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						63	0.75		
2									
3									
4	61.9	370						2786	1.46
5									
6									
7									
8									
9									
10									
11	57.5	367						2588	1.36
12									
13									
14									
15									
16									
17									
18	37.0	278						1665	0.87
19									
20									
21									
22									
23									
24									
25	44.7	313						2012	1.06
26									
27									
28									
29									
30									
31									
TOTAL	201.1							9050	4.75

elevation: 241.05

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-17

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						0.8	1.25		
2									
3									
4	0.0	0							
5									
6									
7									
8									
9									
10									
11	0.0	0							
12									
13									
14									
15									
16									
17									
18	0.0	0							
19									
20									
21									
22									
23									
24									
25	0.0	0							
26									
27									
28									
29									
30									
31									
TOTAL	0.0							0	0.00

elevation: 240.8

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-18

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						0.14	0.75		
2									
3									
4	0.0	0							
5									
6									
7									
8									
9									
10									
11	0.0	0							
12									
13									
14									
15									
16									
17									
18	72.6	371						3267	0.00
19						0.17			
20									
21									
22									
23									
24									
25	0.0	0							
26									
27									
28									
29									
30									
31									
TOTAL	72.6							3267	0.00

elevation: 240.81

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-21

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						1.2	0.75		
2									
3									
4	0.0	0							
5									
6									
7									
8									
9									
10									
11	0.0	0							
12									
13									
14									
15									
16									
17									
18	90.8	376						4086	0.04
19						1.3			
20									
21									
22									
23									
24									
25	0.0	0							
26									
27									
28									
29									
30									
31									
TOTAL	90.8							4086	0.04

elevation: 239.54

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-23

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						1.5	0.55		
2									
3									
4	0.0	0							
5									
6									
7									
8									
9									
10									
11	0.0	0							
12									
13									
14									
15									
16									
17									
18	0.0	0							
19									
20									
21									
22									
23									
24									
25	0.0	0							
26									
27									
28									
29									
30									
31									
TOTAL	0.0							0	0.00

elevation: 240.48

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-27

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						13	0.38		
2									
3									
4	163.9	3						3737	0.41
5									
6									
7									
8									
9									
10									
11	165.8	4						3780	0.41
12									
13									
14									
15									
16									
17									
18	168.3	0						3837	0.42
19									
20									
21									
22									
23									
24									
25	167.1	0						3810	0.41
26									
27									
28									
29									
30									
31									

TOTAL	665.1							15164	1.64
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elevation: 245.59

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-28

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						20	0.38		
2									
3									
4	164.1	2						3741	0.62
5									
6									
7									
8									
9									
10									
11	165.5	2						3773	0.63
12									
13									
14									
15									
16									
17									
18	168.2	1						3835	0.64
19									
20									
21									
22									
23									
24									
25	157.2	3						3584	0.60
26									
27									
28									
29									
30									
31									

TOTAL	655.0							14934	2.49
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elevation: 245.62

UNITED CHROME GROUNDWATER EXTRACTION and TREATMENT FACILITY

EXTRACTION WELL LOG

WELL E-29

August, 1992

DATE	HOURS	CYCLES	COND. umhos	pH	WATER LEVEL feet	Cr6+ mg/L	ORIFICE SIZE gpm	CALCULATED FLOW gallons	CHROME REMOVED lbs
1						16	0.25		
2									
3									
4	163.9	3						2459	0.33
5									
6									
7									
8									
9									
10									
11	165.8	4						2487	0.33
12									
13									
14									
15									
16									
17									
18	168.3	1						2525	0.34
19									
20									
21									
22									
23									
24									
25	167.1	3						2507	0.33
26									
27									
28									
29									
30									
31									

TOTAL	665.1							9977	1.33
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elevation: 245.45