8.0 SENSITIVITY ANALYSIS

The scores for the evaluation criteria and estimated costs assigned to each remedial action alternative are based on assumptions regarding factors including the volume of contaminated soil and water, the concentration of contaminants, discount rate, and the length of time required to implement the alternative. The actual circumstances of the remediation can only be determined after treatability studies, pilot systems, or full-scale treatment systems are constructed. The ranking of the alternatives could change depending upon how sensitive the alternatives are to changes in the costing assumptions. This sensitivity analysis identifies how the effectiveness, implementability, and cost of each groundwater, soil, and surface water alternative is affected by changes in the key variables shown in Table 8-1.

Table 8-1

Key Variables for Sensitivity Analysis

Groundwater Alternatives	Surface Water Alternatives	Soil Alternatives
Vary Discount Rate from 5% to 0 and 10%	Vary Discount Rate from 5% to 0 and 10%	Vary Discount Rate from 5% to 0 and 10%
Adjust Cleanup Time to Reach Higher and Lower Cleanup Goal Concentrations	Increase Cleanup Time by 100%	Cleanup to Ecological Risk Levels
Increase O&M Contingency by 100%	Increase O&M Contingency by 100%	Increase Scope and Bid Contingencies by 100%

The key variables selected for groundwater and surface water focus on the effects of future costs. Since the groundwater and surface water alternatives tend to have longer remediation times relative to soil actions, the present worth of annual costs, such as O&M, far outweigh capital costs.

Changes in the discount rate show the time value of money. The selection of a 5% discount rate was selected as the baseline case based on the recommendation of the U.S. EPA CERCLA Guidance. This guidance also suggests that a 10% discount rate be applied in the sensitivity analysis. A 0% discount rate is also used to show the case where inflation offsets time value of money.

Changes in the cleanup goal show the effects of changes in volumes of water (but not pumping rate) which must be processed during the corresponding different cleanup time. Changes in the O&M contingency percentages show the effects of variation of factors such as inlet concentrations of contaminants (degradation products of TCE) and equipment life cycles. The sensitivity analysis would be repetitive if performed for all alternatives at every site. Since sensitivity will vary more among alternatives for the same site than for the same alternative at different sites, the strategy selected was to analyze sensitivity for all alternatives at the following selected sites:

- Use Group F representative site (SS030) for Alternatives 1, 2, 3, 5, and 7.
- Use Group G representative site (SD034) for Alternative 9.
- Use Group E representative site (SS029) for Alternatives 4, 6, and 8.
- Use Group J representative site (SD033) for Alternatives 10, 11, 12, 13, 14, and 15.
- Use Group K representative site (FT003) for Alternatives 16, 17, 18, 19, and 20.
- Use Group Q representative site (SD034) for Alternatives 21 and 22.

Two of the key variables selected for soil focus on present (capital) costs, because four of the seven soil alternatives have no future costs. Changes in the discount rate show the time value of money which impacts the monitoring costs associated with capped areas and operating costs associated with bioventing and SVE. Changes in the contaminated soil volume show the effects of changes in cleanup requirements such as reducing ecological as well as human health risk. Changes in the scope and bid contingency show the effects of variation in the alternative complexity such as increased utility crossings.

The cost sensitivity of the alternatives to these key variables is shown in Tables 8-2, 8-3, and 8-4. A discussion of the sensitivity analysis is provided below.

8.1 Groundwater Alternatives Sensitivity Analysis

The implementability of the groundwater alternatives is not sensitive to discount rate fluctuations, but implementability is sensitive to cleanup goal (cleanup time) and O&M contingency (percentages) changes. The cleanup time decreases as the cleanup goal concentration increases. The implementability of the groundwater cleanup alternatives decreases when the cleanup time or O&M contingency is increased since either more time or greater resources would be required to implement the actions.

Groundwater cleanup costs were very sensitive to changes in discount rate and increased cleanup time at a discount rate of 0%, moderately sensitive to increased cleanup time at a discount rate of 5%, and slightly sensitive to changes in O&M contingency (Table 8-2). The present worth costs increased as much as 570% when the discount rate was decreased to zero, and decreased by approximately 40% when the discount rate was increased to 10 percent. Cleanup goals of 0.5, 5, 50, and 500 μg/L, which correspond to cleanup times of 127, 77, 36, and 10 years, respectively, were assessed.

For Alternative 5, the present worth costs decreased as much as 38% and increased as much as 428% when the cleanup goal was varied from 500 to 0.5 μg/L for a discount rate of 0%; the present worth costs decreased as much as 47% and increased as much as 2% when the cleanup goal was varied from 500 to 0.5 μg/L for a discount rate of 5 percent. The present worth costs increased 14% when the O&M contingency costs were doubled.

Table 8-2

Results of Sensitivity Analysis for Groundwater Alternatives Costs

Alternative[1]	TCE Cleanup Goal (µg/L)	Discount Rate 0%	Discount Rate 5%	Discount Rate 10%	Double O&M Contingency	Sensitivity Assessment
1		No cost impact			No cost impact	Not sensitive
2	500	48% decrease in cost	60% decrease in cost	—		Very sensitive to discount rate; very sensitive to decreased cleanup goal at a discount rate of 0%, and moderately sensitive to decreased cleanup goal at a discount rate of 5%; slightly sensitive to O&M requirements.
	50	83% increase in cost	15% decrease in cost	—		
	5	290% increase in cost	Base Cost Case	48% decrease in cost	17% increase in cost	
	0.5	543% increase in cost	2% increase in cost	—		
3	500	37% decrease in cost	46% decrease in cost	—		Very sensitive to discount rate; very sensitive to decreased cleanup goal at a discount rate of 0%, and moderately sensitive to decreased cleanup goal at a discount rate of 5%; slightly sensitive to O&M requirements.
	50	64% increase in cost	12% decrease in cost	—		
	5	224% increase in cost	Base Cost Case	37% decrease in cost	13% increase in cost	
	0.5	418% increase in cost	2% increase in cost	—		

1 The base cost evaluation assumptions are cleanup to 5 µg/L (MCL for TCE), 5% discount [illegible] and O&M contingency of 21%.

Table 8-2

(Continued)

Alternative[1]	Discount Rate				Double O&M Contingency	Sensitivity Assessment
	TCE Cleanup Goal (μg/L)	0%	5%	10%		
4	5	440% increase in cost	Base Cost Case	34% decrease in cost	12% increase in cost	Very sensitive to discount rate; slightly sensitive to O&M requirements.
5	500	38% decrease in cost	47% decrease in cost	—		Very sensitive to discount rate; very sensitive to decreased cleanup goal at a discount rate of 0%, and moderately sensitive to decreased cleanup goal at a discount rate of 5%; slightly sensitive to O&M requirements.
	50	66% increase in cost	12% decrease in cost	—		
	5	229% increase in cost	Base Cost Case	38% decrease in cost	14% increase in cost	
	0.5	428% increase in cost	2% increase in cost	—		
6	5	555% increase in cost	Base Cost Case	30% decrease in cost	12% increase in cost	Very sensitive to discount rate; slightly sensitive to O&M requirements.
7	500	37% decrease in cost	46% decrease in cost	—		Very sensitive to discount rate; very sensitive to decreased cleanup goal at a discount rate of 0%, and moderately sensitive to decreased cleanup goal at a discount rate of 5%; slightly sensitive to O&M requirements.
	50	64% increase in cost	12% decrease in cost	—		
	5	222% increase in cost	Base Cost Case	37% decrease in cost	13% increase in cost	
	0.5	416% increase in cost	2% increase in cost	—		

[1] The base cost evaluation assumptions are cleanup to 5 μg/L (MCL for TCE), 5% discount rate, and O&M contingency of 21%.

Table 8-2

(Continued)

Alternative[1]	Discount Rate				Double O&M Contingency	Sensitivity Assessment
	TCE Cleanup Goal (μg/L)	0%	5%	10%		
8	5	570% increase in cost	Base Cost Case	44% decrease in cost	15% increase in cost	Very sensitive to discount rate; slightly sensitive to O&M requirements.
9	Not Applicable	3% increase in cost	Base Cost Case	3% decrease in cost	4% increase in cost	Not sensitive to discount rate; not sensitive to O&M requirements.

[1] base cost evaluation assumptions are cleanup to 5 μg/L (MCL for TCE), 5% discount and O&M contingency of 21%.

Table 8-3

Results of Sensitivity Analysis for Surface Water Alternatives Costs

Alternative[1]	Discount Rate		Doubled Cleanup Time[2]		Double O&M Contingency	Sensitivity Assessment
	0%	10%	0%	5%		
10	No cost impact		No cost impact		No cost impact	No effect.
11	95% increase in cost	39% decrease in cost	290% increase in cost	23% increase in cost	14% increase in cost	Very sensitive to discount rate; very sensitive to increased cleanup time at a discount rate of 0%, and slightly sensitive to increased cleanup time at a discount rate of 5%; moderately sensitive to O&M requirements.
12	79% increase in cost	32% decrease in cost	242% increase in cost	17% increase in cost	14% increase in cost	Very sensitive to discount rate; very sensitive to increased cleanup time at a discount rate of 0%, and slightly sensitive to increased cleanup time at a discount rate of 5%; moderately sensitive to O&M requirements.
13	85% increase in cost	35% decrease in cost	261% increase in cost	21% increase in cost	16% increase in cost	Very sensitive to discount rate; very sensitive to increased cleanup time at a discount rate of 0%, and slightly sensitive to increased cleanup time at a discount rate of 5%; moderately sensitive to O&M requirements.
14	No cost impact		No cost impact		No cost impact	Not effected since this alternative has no O&M requirements.
15	No cost impact		No cost impact		No cost impact	Not effected since this alternative has no O&M requirements.

[1] The base cost evaluation assumptions are 5% discount rate, 30 year cleanup time, and O&M contingency of 21%.
[2] The effect of doubling cleanup time is examined at discount rates of 0% and 5%.

Table 8-4

Results of Sensitivity Analysis for Soil Alternatives Costs

Alternative[1]	Discount Rate		Increase Cleanup Requirements to Ecological Risk Levels	Double Scope and Bid Contingencies	Sensitivity Assessment
	0%	10%			
16	No cost impact		No cost impact	No cost impact	No cost impact.
17	61% increase in cost	25% decrease in cost	64% increase in cost	9% increase in cost	Very sensitive to discount rate and stricter cleanup levels. Slightly sensitive to increased contingencies.
18	No cost impact		61% increase in cost	26% increase in cost	Very sensitive to stricter cleanup levels and increased contingencies.
19	No cost impact		30% increase in cost	25% increase in cost	Very sensitive to stricter cleanup levels and increased contingencies.
20	No cost impact		14% increase in cost	26% increase in cost	Moderately sensitive to stricter cleanup levels. Very sensitive to increased contingencies.
21	2% increase in cost	2% decrease in cost	0%	18% increase in cost	Slightly sensitive to discount rate; not sensitive to stricter cleanup; moderately sensitive to increased contingencies.
22	8% increase in cost	6% decrease in cost	0%	14% increase in cost	Slightly sensitive to discount rate; not sensitive to stricter cleanup; moderately sensitive to increased contingencies.

[1] The base cost evaluation assumptions are 5% discount rate, 20% scope contingency, 15% bid contingency, and cleanup of contaminated soil associated with human health risk.

The moderate change in present worth costs for increased cleanup time at a 5% discount rate reflects the dampening effect of present worth analysis on future cost beyond 50 years. The present worth factor asymptotically approaches a value of 20 for a 5% discount rate.

Figures 8-1 and 8-2 present additional detail on the effects of a selected cleanup level on the time to clean up a representative site, Site SS030. These two figures, which display the same information on two different scales, show how the cleanup time increases as the cleanup goal decreases. Appendix C presents the details on how these cleanup times were calculated, as well as similar figures for the other representative sites. Table 8-5 indicates how the time to clean up (both in years and as a percentage) increases if the cleanup goal for TCE decreases from 5 μg/L to 0.5 μg/L. The 5 μg/L value is the MCL (base case) for TCE and the 0.5 μg/L value is selected as a potential more stringent cleanup level.

Figures 8-1 and 8-2 and Table 8-5 indicate that the time to clean up SS030 would increase from 77 years to 127 years (a 65% increase) if the cleanup level were to drop from 5 μg/L to 0.5 μg/L. For all sites, the ranges of increases would be from 32% to 600%. The increase in cleanup time significantly impacts implementability in that the operation of a treatment system would have to be maintained by Travis AFB over a much longer period of time. Implementability would also be negatively impacted by having to manage and discharge increased volumes of treated groundwater.

8.2 Surface Water Alternatives Sensitivity Analysis

Sensitivity of effectiveness, implementability, and cost of the surface water alternatives varied with changes in the key variables shown in Table 8-1. Effectiveness showed the least sensitivity, while cost showed the greatest sensitivity to changes in the key variables.

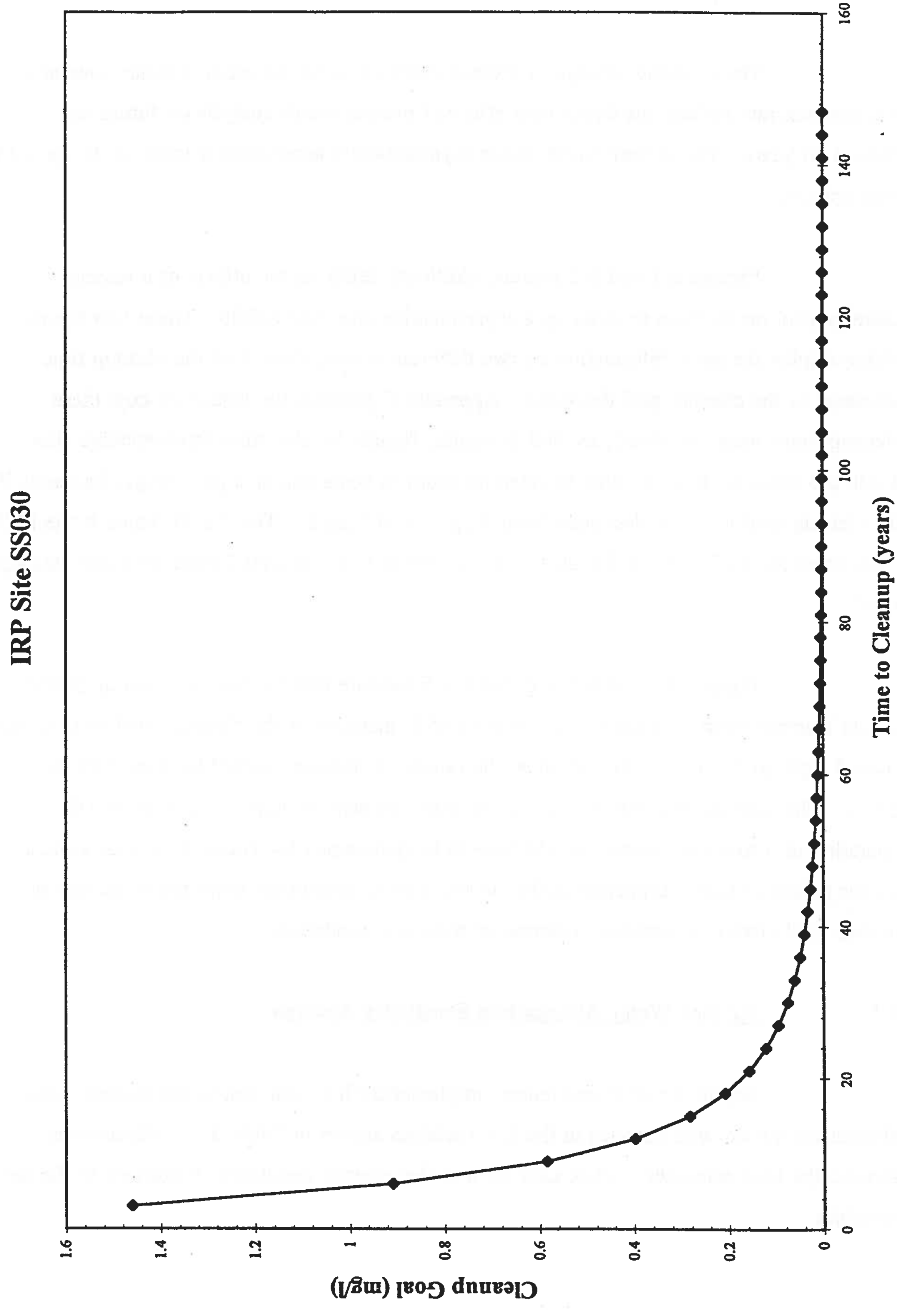

Figure 8-1. Time to Cleanup Curve

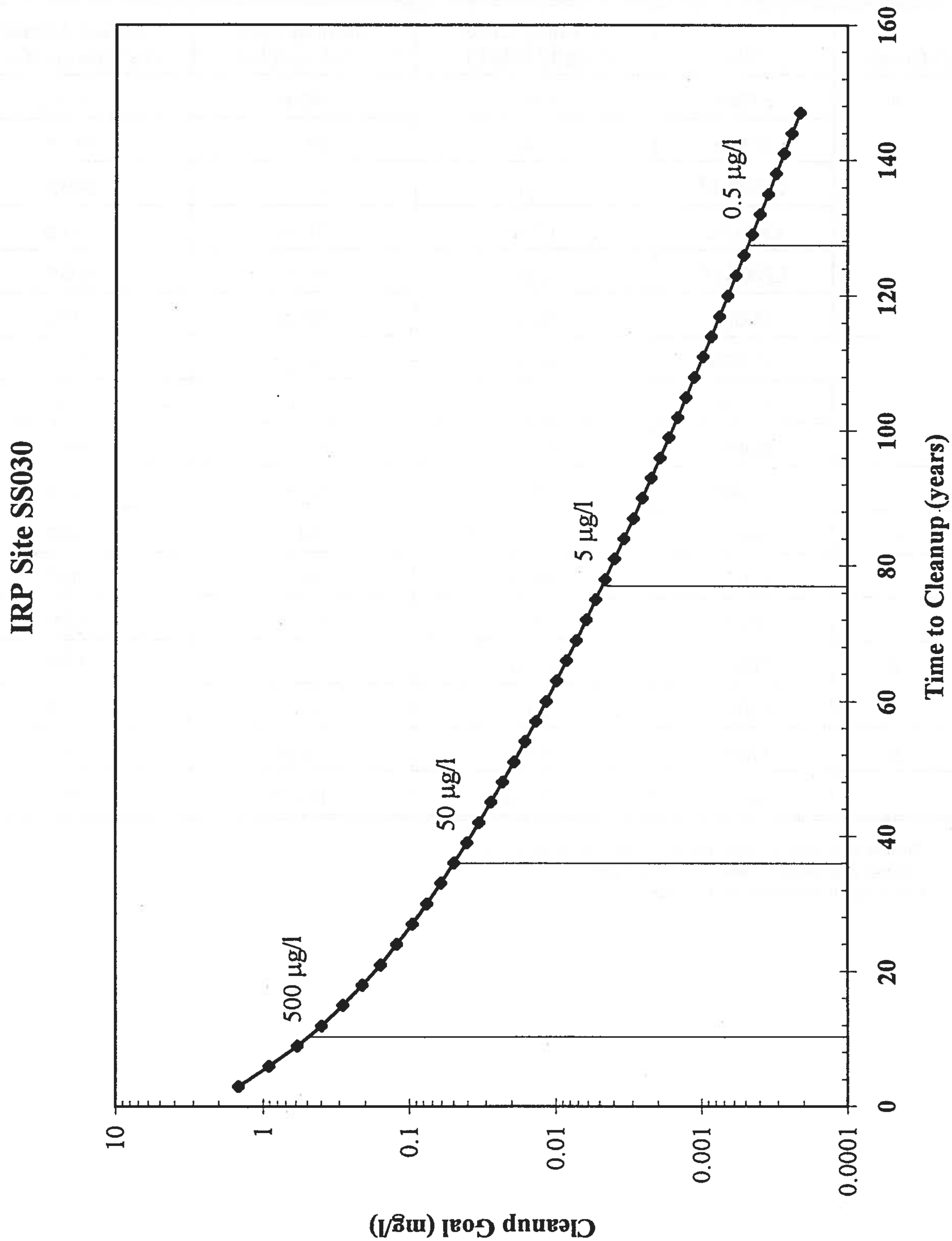

Figure 8-2. Time to Cleanup Curve

Table 8-5

Time to Cleanup Sensitivity to Cleanup Goal

Group	Site	Cleanup Goal 5 µg/L[1] (MCL)	Cleanup Goal 0.5 µg/L[1]	Percent Increase in Cleanup Time
A	FT004	95 yr	149 yr	57%
	LF006	7 yr	29 yr	314%
	LF007-B[2]	3 yr	12 yr	300%
	LF007-C	12 yr	38 yr	217%
	LF007-D[2]	2 yr	10 yr	400%
	SD031	28 yr	63 yr	125%
B	SDO36	60 yr	112 yr	87%
	SS015	17 yr	45 yr	165%
	SD033	85 yr	150 yr	76%
C	FT005	15 yr	65 yr	333%
D	SS016	193 yr	254 yr	32%
E	SSO29	149 yr	209 yr	40%
F	SS030	77 yr	127 yr	65%
G	SD034	60 yr	107 yr	78%
	ST032[3]	2 yr	4 yr	100%
H	SS035	3 yr	21 yr	600%
I	SD037	111 yr	166 yr	50%

1 Cleanup goal concentrations for TCE unless otherwise noted.
2 Cleanup goal concentrations for chlorobenzene.
3 Cleanup goal concentrations for benzene.

Generally, the effectiveness of the surface water alternatives is not sensitive to changes in the key variables, except for the increased cleanup time variable. Unlike the groundwater analysis, the cleanup time for surface water is not coupled to a specific cleanup goal. The effectiveness of cleanup alternatives decreases with increased cleanup time.

The implementability of the surface water alternatives is not sensitive to discount rate fluctuations, but implementability is sensitive to cleanup time and O&M contingency (percentages) changes. The implementability of the surface water cleanup alternatives decreases when the cleanup time or O&M contingency is increased.

Surface water cleanup costs were very sensitive to changes in discount rate and increased cleanup time at a discount rate of 0%, slightly sensitive to increased cleanup time at a discount rate of 5%, and moderately sensitive to changes in O&M contingency (Table 8-3). The present worth costs increased as much as 95% when the discount rate was decreased to zero, and decreased as much as 39% when the discount rate was increased to 10 percent. The present worth costs increased as much as 290% when the cleanup time was doubled for a discount rate of zero; the present worth costs increased as much as 23% when the cleanup time was doubled for a discount rate of 5%. The present worth costs increased as much as 16% when the O&M contingency costs were doubled.

8.3 Soil Alternatives Sensitivity Analysis

Sensitivity of the effectiveness, implementability, and cost of soil alternatives also varied with changes in the key variables shown in Table 8-1. Effectiveness showed the least sensitivity, while cost showed the greatest sensitivity to changes in the key variables.

The effectiveness and implementability of the soil alternatives are not sensitive to discount rate fluctuations. Effectiveness is sensitive to cleanup time changes, and implementability is sensitive to both cleanup time and scope and bid contingencies changes. The effectiveness of soil cleanup alternatives decreases with increased cleanup time. The implementability of soil cleanup alternatives decreases with increased cleanup time or scope and bid contingencies.

Soil cleanup costs were very sensitive to changes in all three key variables (Table 8-4). Alternative 17 showed a 61% increase in present worth cost when the discount rate was decreased to zero, and a 25% decrease in present worth costs when the discount rate increased to 10 percent. Alternatives 17, 18, 19, and 20 showed increased present worth costs between 14 and 64% when the cleanup requirement was increased to include reducing ecological risks and increased present worth costs of 9 to 26% when the scope and bid contingencies were doubled. Alternatives 21 and 22 showed an increased present worth cost of 2 to 8% when the discount rate was decreased to zero and a decrease in present worth cost of 2 to 6% when the discount rate was increased to 10 percent. Alternatives 21 and 22 also showed a 14 to 18% increase in present worth cost when the scope and bid contingencies were doubled.

9.0 COMPARATIVE ANALYSIS SUMMARY

This section summarizes the comparative analyses for the groups and presents conclusions. The results of the sensitivity analysis are also factored into this section. The alternative with the highest benefit/cost ratio and total effectiveness score is indicated for each group. However, this summary does not recommend implementation of specific alternatives, as this is not an objective of the Feasibility Study (FS). This is because the CERCLA criteria evaluation process used in this FS cannot account for results from confirmatory sampling, final cleanup goals, and all elements of detailed design. In addition, the prepared cost estimates have an accuracy of +50/-30 percent. The Proposed Plan will recommend specific alternatives or combinations of alternatives. The conclusions are organized by medium in the following sections.

9.1 Summary of the Groundwater Groups

For all groups, Alternative 1, the no action alternative, does not effectively meet the CERCLA criteria. In particular, this alternative was rated 0 for each of the two threshold criteria, i.e., Protective of Human Health and the Environment, and Compliance with ARARs. Since the threshold criteria are minimum standards that must be achieved, the no action alternative should not be considered at any of the sites without supplementary risk management. Institutional actions (Alternative 2) was rated 0 for compliance with ARARs. Additionally, because institutional actions provide some protection of human health and the environment at relatively low cost, this alternative should be considered at some sites.

The groundwater groups are generally of two types: those which would require metals treating and those which would not. Alternatives 4, 6, and 8 would apply when metals treating would be needed, and Alternatives 3, 5, and 7 would apply when metals treating would not be needed. Alternatives 3, 5, and 7 would be similarly effective and implementable relative to one another. The only distinction evident with executing one alternative versus another would be the total present worth cost (or benefit/cost ratio). This distinction would only be significant for groups with large differences in cost between alternatives, given the level of detail of the cost analysis. The alternatives with metals treatment (4, 6, and 8) showed a similar trend. Because of the variation in site characteristics and contaminants, no alternatives are consistently more cost-effective. Additionally, Group G sites contain floating hydrocarbons at the groundwater surface. Alternative 9, bioslurping, would specifically address floating product recovery. Thus, Alternative 9 cannot be directly compared to the other groundwater alternatives.

The evaluation of applicable treatment alternatives for Groups A through I is summarized in Table 9-1. Table 9-2 provides a summary of total present worth costs, and Table 9-3 provides a summary of total scores and benefit/cost ratios for each alternative and group. Figures 9-1 and 9-2 are bar charts that show, for each group, the total score and benefit/cost ratio of each applicable alternative. Figure 9-1 applies to those groups which would not need metals treatment, and Figure 9-2 applies to those which would.

High benefit/cost ratios do not necessarily indicate an alternative would adequately address all contaminants. The institutional actions alternative consistently has a high benefit/cost ratio. This is due more to low cost than significant benefit. As stated earlier, this alternative does not adequately meet the threshold criteria and would have to be implemented with a complementary alternative. Bioslurping also has a high benefit/cost ratio (50), but the alternative primarily addresses floating product recovery. It would need to be implemented in conjunction with an alternative that would address dissolved product constituents.

Section 8.0 evaluated the sensitivity of the alternatives analysis to variation in assumptions. As stated in Section 8.1, present worth costs are very sensitive to discount rate changes; the total present worth cost can vary 250% over a discount rate range from 0 to 10 percent. The cost is moderately sensitive to changes in cleanup goal and O&M contingency, increasing 15% if O&M contingency is doubled and varying 50% over a cleanup goal range from 0.5 to 500 μg/L TCE. As the discount rate rises, the total present worth cost

Figure 9-1.
Alternatives for Groundwater Groups Requiring Metals Treatment(A, B, C, D, F, G and I)

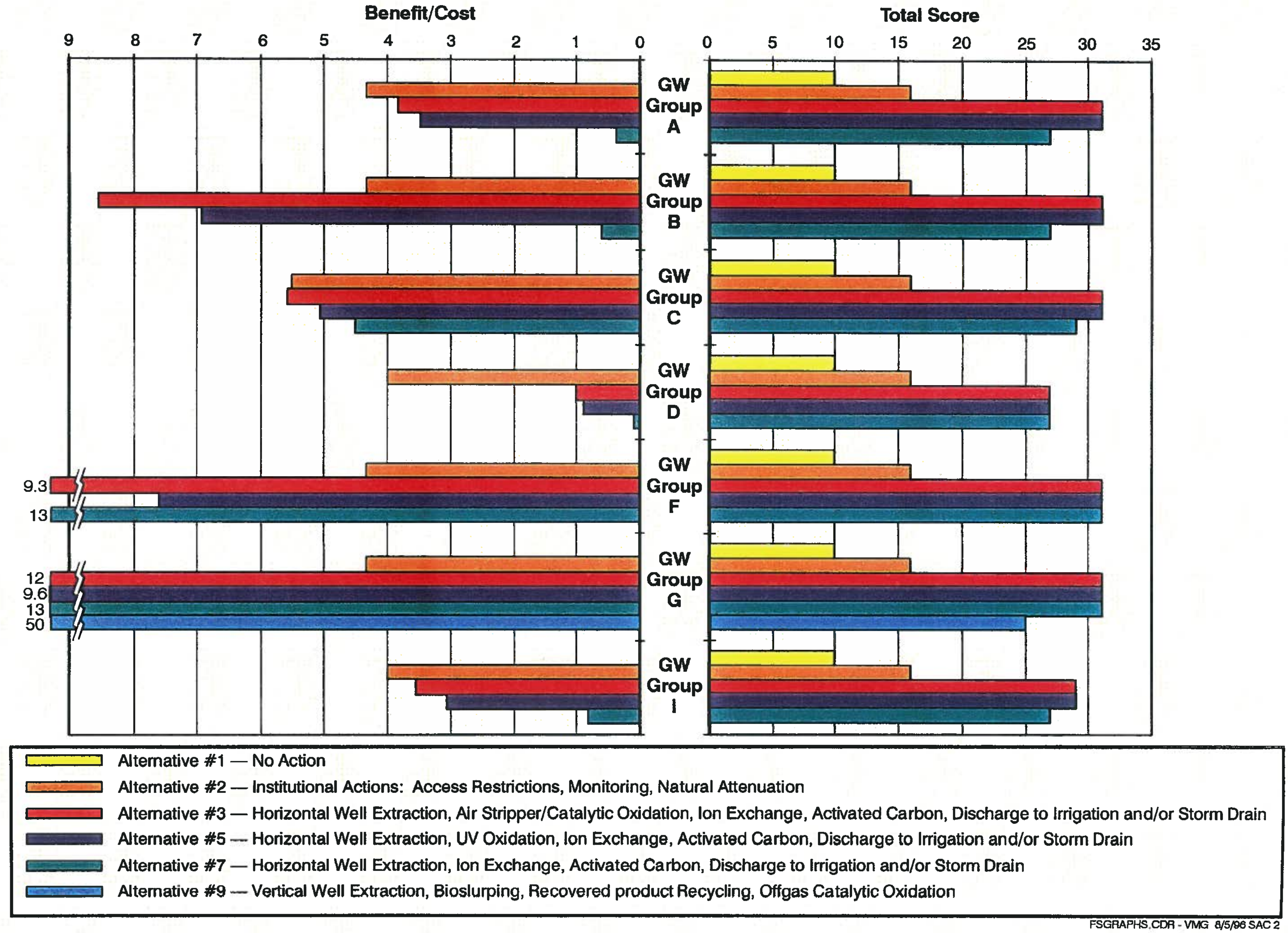

Figure 9-2.
Alternatives for Groundwater Groups Not Requiring Metals Treatment(E and H)

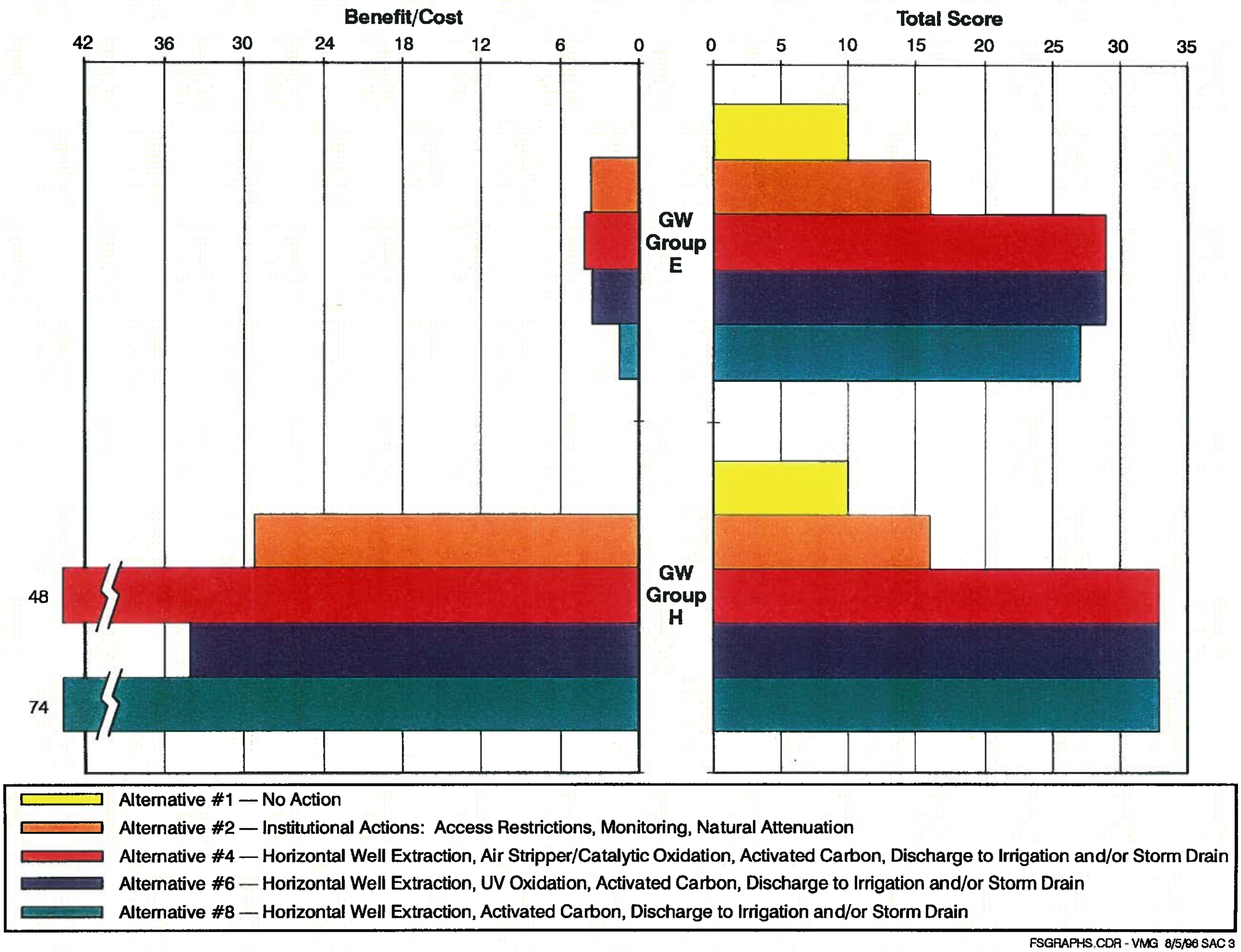

Table 9-1

Groundwater Groups Evaluation Summary (Active Treatment Alternatives)

Group	Most Cost Effective[1]	Highest Benefit[2]
A	Alternative 3 (3.8)	Alternatives 3, 5, 7 (25)
B	Alternative 3 (8.6)	Alternatives 3, 5, 7 (25)
C	Alternative 3 (5.6)	Alternatives 3, 5, 7 (25)
D	Alternative 3 (3)	Alternatives 3, 5, 7 (25)
E	Alternative 4 (4.9)	Alternatives 4, 6, 8 (25)
F	Alternative 7 (9.3)	Alternatives 3, 5, 7 (25)
G	Alternatives 7, 9 (13, 50)	Alternatives 3, 5, 7 (25)
H	Alternative 8 (74)	Alternatives 4, 6, 8 (25)
I	Alternative 3 (3.7)	Alternatives 3, 5, 7 (25)

[1] Highest Benefit/Cost Ratio is in parentheses.
[2] Highest Total of Effectiveness Criteria Scores is in parentheses.

Alternative #3: Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #4: Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #5: Horizontal Well Extraction, UV Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #6: Horizontal Well Extraction, UV Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #7: Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #8: Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #9: Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation

Table 9-2

Summary of Total Present Worth Costs[1] for Groundwater Alternatives

Group	Alternative #1	Alternative #2	Alternative #3	Alternative #4	Alternative #5	Alternative #6	Alternative #7	Alternative #8	Alternative #9
A	$0	$1.4M	$6.5M	NA	$7.1M	NA	$63M	NA	NA
B	$0	$1.4M	$2.9M	NA	$3.6M	NA	$38M	NA	NA
C	$0	$1.1M	$4.5M	NA	$4.9M	NA	$5.5M	NA	NA
D	$0	$1.5M	$27M	NA	$29M	NA	$230M	NA	NA
E	$0	$1.5M	NA	$5.1M	NA	$5.9M	NA	$15M	NA
F	$0	$1.4M	$2.7M	NA	$3.3M	NA	$2.0M	NA	NA
G	$0	$1.4M	$2.1M	NA	$2.6M	NA	$1.9M	NA	$0.34M
H	$0	$0.21M	NA	$0.52M	NA	$0.65M	NA	$0.34M	NA
I	$0	$1.5M	$6.7M	NA	$7.8M	NA	$30M	NA	NA

Alternative #1: No Action
Alternative #2: Institutional Actions: Access Restrictions, Monitoring, Natural Attenuation
Alternative #3: Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #4: Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #5: Horizontal Well Extraction, UV Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #6: Horizontal Well Extraction, UV Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #7: Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #8: Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #9: Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation

[1] in millions (M) of dollars

NA = Not Applicable

Table 9-3

Summary of Total Scores and Benefit/Cost Ratios for Groundwater[1]

Group	Alternative #1	Alternative #2	Alternative #3	Alternative #4	Alternative #5	Alternative #6	Alternative #7	Alternative #8	Alternative #9
A	10 | 0	16 | 4.3	29 | 3.8	NA	29 | 3.5	NA	27 | 0.40	NA	NA
B	10 | 0	16 | 4.3	31 | 8.6	NA	31 | 6.9	NA	27 | 0.66	NA	NA
C	10 | 0	16 | 5.5	31 | 5.6	NA	31 | 5.1	NA	29 | 4.5	NA	NA
D	10 | 0	16 | 4	27 | 0.93	NA	27 | 0.86	NA	27 | 0.11	NA	NA
E	10 | 0	16 | 4	NA	29 | 4.9	NA	29 | 4.2	NA	27 | 1.7	NA
F	10 | 0	16 | 4.3	31 | 9.3	NA	31 | 7.6	NA	31 | 13	NA	NA
G	10 | 0	16 | 4.3	31 | 12	NA	31 | 9.6	NA	31 | 13	NA	25 | 50
H	10 | 0	16 | 29	NA	33 | 48	NA	33 | 38	NA	33 | 74	NA
I	10 | 0	16 | 4	29 | 3.7	NA	29 | 3.2	NA	27 | 0.83	NA	NA

Alternative #1: No Action
Alternative #2: Institutional Actions: Access Restrictions, Monitoring, Natural Attenuation
Alternative #3: Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #4: Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #5: Horizontal Well Extraction, UV Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #6: Horizontal Well Extraction, UV Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #7: Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #8: Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain
Alternative #9: Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation

[1] The left side of each box indicates the total score and the right side of each box indicates the benefit/cost ratio.

NA = Not Applicable

decreases. The total present worth cost will rise slightly as either O&M contingency increases or cleanup goal (at a constant water flow rate) decreases. These factors have the most effect on groundwater remediation cost because the majority of the total present worth cost is derived from O&M expenses.

9.2 Summary of the Surface Water Group

In the surface water group, Group J, only Alternatives 12, 13, 14, and 15 meet the threshold criteria: Protective of Human Health and the Environment, and Compliance with Appropriate ARARs. The no action alternative and the institutional action alternatives rate 0 for one or both of the threshold criteria. Threshold criteria are minimum standards that must be met; therefore, the no action alternative and institutional actions should only be considered in concert with additional risk management or other alternatives, respectively.

Table 9-4 contains the total scores, present worth costs, and benefit/cost ratios for each surface water alternative. The highest total score was for Alternative 15, source control. Evaluation of this alternative was based on the assumptions that the groundwater and soil site selected alternatives would be completely effective in preventing migration of contaminated groundwater and surface water to Union Creek, and that the groundwater and soil sites are the only sources of surface water contamination. The no action and institutional action alternatives have the lowest total score, primarily because they would provide little or no remediation of the contamination. The active treatment alternatives (Alternatives 12, 13, and 15) scored at least 21. Alternative 14 does not involve treatment of the contaminants, but relies on preventing contamination of the surface water by slip-lining and collaring the storm sewer lines.

The highest benefit/cost ratio (31) is for slip-lining and collaring the storm sewer. No benefit/cost ratio was calculated for Alternative 15, source control, because the

Table 9-4

Summary of Total Scores, Present Worth Costs, and Benefit/Cost Ratios for Surface Water

Alternative	Total Score	Cost	Benefit/Cost Ratio
Alternative #10	10	$0	NA
Alternative #11	14	$2.6M	2.3
Alternative #12	25	$14M	1.5
Alternative #13	21	$9.1M	1.6
Alternative #14	20	$0.39M	31
Alternative #15	25	$0	NA

Alternative #10: No Action
Alternative #11: Institutional Actions: Access Restrictions, Monitoring, Natural Attenuation
Alternative #12: Collection Sump, Ion Exchange, Activated Carbon, Discharge to Union Creek
Alternative #13: Collection Sump, Activated Carbon, Discharge to Union Creek
Alternative #14: Slip-lining and Collaring Storm Sewer
Alternative #15: Source Control

NA = Not Applicable

Note: The estimated present worth cost is in millions (M) of dollars.

costs are considered for the specific upstream groundwater and soil sites. The other benefit/cost ratios range from 1.5 (Alternative 12) to 2.3 (Alternative 11).

Figure 9-3 shows the surface water alternatives' total scores and benefit/cost ratios.

As discussed in Section 8.2, surface water cleanup costs were very sensitive to changes in discount rate, and moderately sensitive to changes in cleanup time and O&M contingency. As the discount rate ranges from 0 to 10%, the total cost varies by over 100 percent. Doubled cleanup time and doubled O&M contingency increase the total cost by approximately 20 percent.

9.3 Summary of the Soil Groups

Table 9-5 summarizes the evaluation of alternatives for Groups K through R. Alternative 20 has the highest benefit (total of 5 effectiveness criteria) for all soil groups except Group O. Alternatives 21 and 22 have the highest benefit for Group O. Alternative 20 was not the most cost-effective alternative for any soils group. Alternative 17 is the most cost-effective for soil Groups K, L, M, N, O, P, and Q. Alternative 18 is the most cost-effective for Group R.

Table 9-6 shows the alternatives' total scores and benefit/cost ratios, and Table 9-7 shows the alternatives' total present worth costs. The highest total scores are generally associated with alternatives that treat contaminants and provide protection from exposure. Alternative 20 has the highest total score for Groups K, L, M, N, and R. Groups O, P, and Q have Alternatives 21 and 22 with the highest total score. In Figure 9-4, the alternatives' total scores and benefit/cost ratios are shown for each soil group in a bar chart.

Because cost generally varies more than effectiveness scores, it is the most important factor in the ranking of benefit/cost scores between alternatives within groups. In

Figure 9-3.
Alternatives for Surface Water Group J

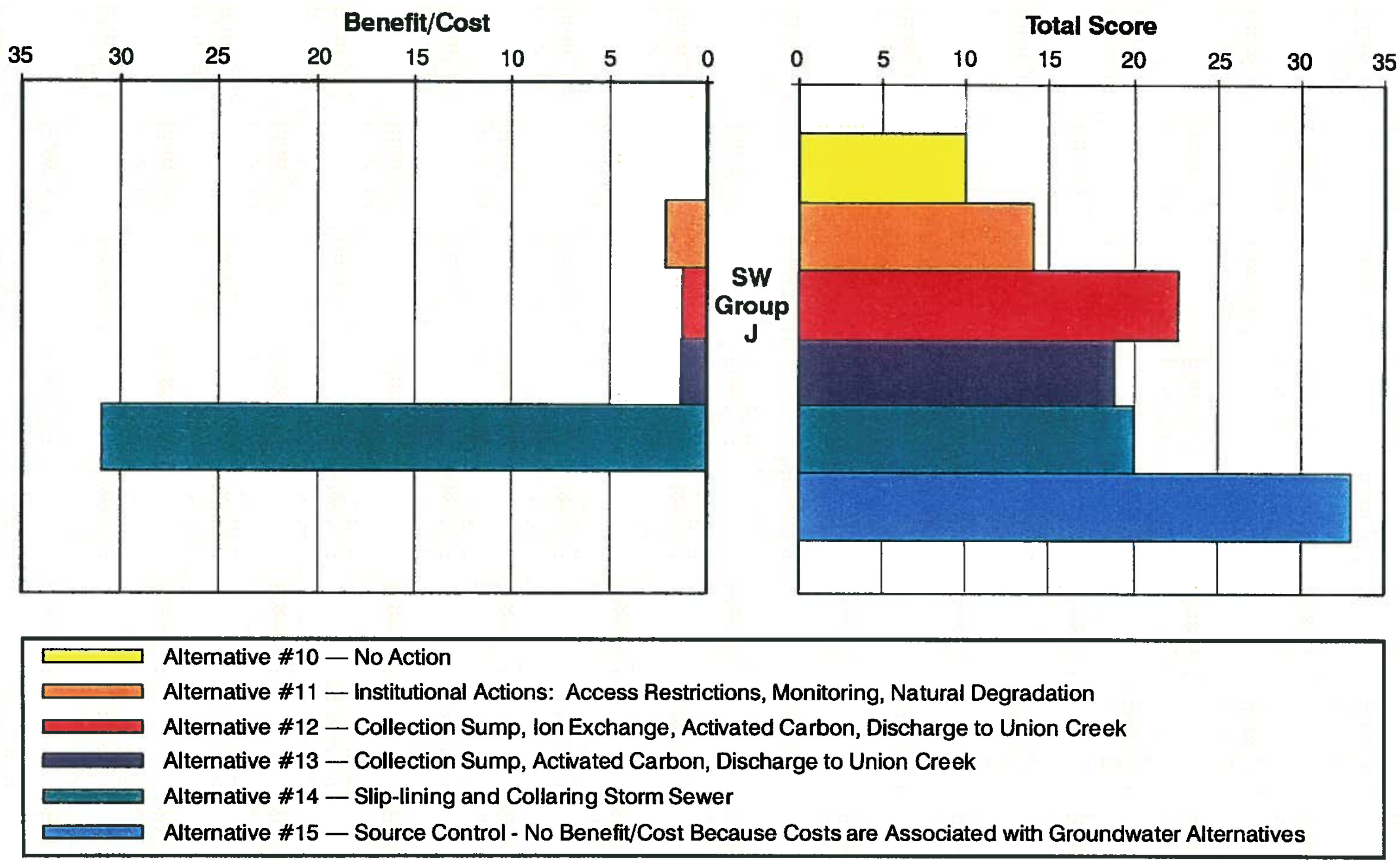

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Table 9-5

Soil Groups Evaluation Summary

Group	Most Cost Effective[1]	Highest Benefit[2]
K	Alternative 17 (82)	Alternative 20 (23)
L	Alternative 17 (33)	Alternative 20 (17)
M	Alternative 17 (69)	Alternative 20 (23)
N	Alternative 17 (160)	Alternative 20 (21)
O	Alternative 17 (140)	Alternative 21, 22 (17)
P	Alternative 17 (64)	Alternative 20 (19)
Q	Alternative 17 (120)	Alternative 20 (19)
R	Alternative 18 (43)	Alternative 20 (16)

1 Highest Benefit/Cost Ratio is shown in parentheses.
2 Highest Total of Effectiveness Criteria Scores is shown in parentheses.

Alternative #17: Institutional Actions
Alternative #18: Backhoe, Disposal at Existing Off-site Landfill
Alternative #19: Soil and Bentonite Cap
Alternative #20: Backhoe, Ex-Situ High Temperature Thermal Treatment, Disposal at Existing Off-site Landfill
Alternative #21: In-Situ Soil Vapor Extraction (SVE), Off Gas Catalytic Oxidation
Alternative #22: In-Situ Bioventing

Table 9-6

Summary of Total Scores and Benefit/Cost Ratios for Soil[1]

Group	Alternative #16	Alternative #17	Alternative #18	Alternative #19	Alternative #20	Alternative #21	Alternative #22
K	10 | 0	17 | 82	22 | 5.9	20 | 7.4	27 | 0.61	NA	NA
L	10 | 0	19 | 33	14 | 0.92	14 | 0.67	19 | 0.09	NA	NA
M	10 | 0	19 | 69	22 | 2.2	22 | 6.4	27 | 1.0	NA	NA
N	10 | 0	19 | 160	24 | 42	22 | 24	25 | 4.1	NA	NA
O	10 | 0	19 | 140	17 | 18	20 | 52	20 | 2.5	25 | 65	25 | 94
P	10 | 0	19 | 64	18 | 3.0	18 | 7.5	21 | 0.35	25 | 27	25 | 29
Q	10 | 0	19 | 120	20 | 17	22 | 39	23 | 2.1	25 | 74	25 | 89
R	10 | 0	NA	21 | 13	NA	22 | 4.4	NA	NA

[1] These total scores and benefit/cost ratios were derived from analyses of how alternatives would address soil which poses a risk to human health and ecological receptors. Total scores are indicated on the left side of the box and benefit/cost ratios are indicated on the right hand side.

Alternative #16: No Action
Alternative #17: Institutional Actions: Access Restrictions, Monitoring, Natural Degradation
Alternative #18: Backhoe, Disposal at Existing Off-site Landfill
Alternative #19: Soil and Bentonite Cap
Alternative #20: Backhoe, Ex-Situ High Temperature Thermal Treatment, Disposal at Existing Off-site Landfill
Alternative #21: In-Situ Soil Vapor Extraction (SVE), Off Gas Catalytic Oxidation
Alternative #22: In-Situ Bioventing

NA = Not Applicable

Table 9-7

Summary of Total Present Worth Costs for Soil[1]

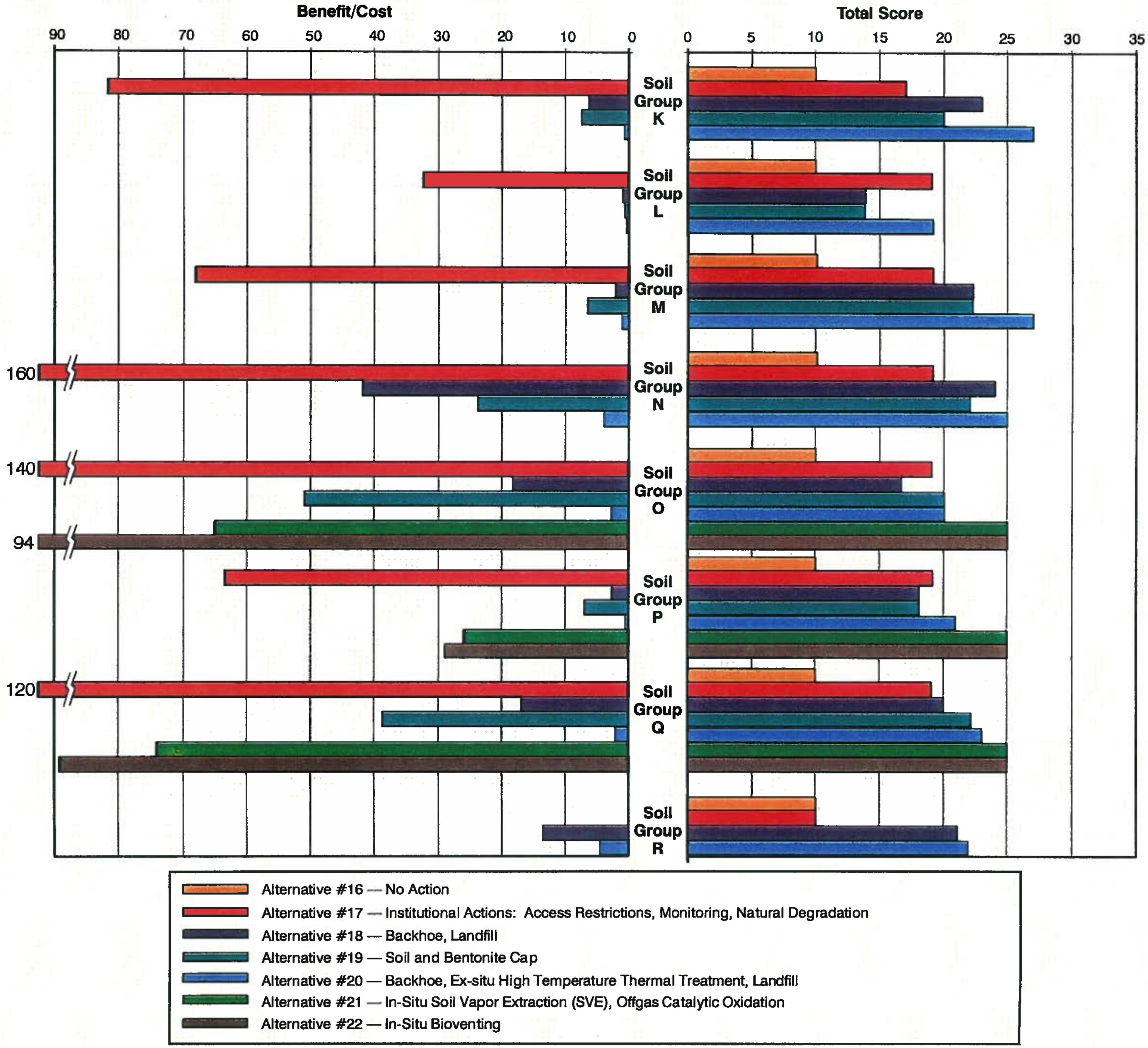
Group	Alternative #16	Alternative #17	Alternative #18	Alternative #19	Alternative #20	Alternative #21	Alternative #22
K	$0	$0.11M	$2.7M	$1.9M	$38M	NA	NA
L	$0	$0.27M	$13M	$18M	$190M	NA	NA
M	$0	$0.13M	$7.4M	$2.2M	$22M	NA	NA
N	$0	$0.057M	$0.38M	$0.58M	$5.1M	NA	NA
O	$0	$0.064M	$0.50M	$0.23M	$6.4M	$0.26M	$0.18M
P	$0	$0.14M	$4.0M	$1.6M	$55M	$0.63M	$0.58M
Q	$0	$0.073M	$0.71M	$0.31M	$9.1M	$0.23M	$0.19M
R	$0	$0.1M	$0.3M	NA	$3.6M	NA	NA

[1] Costs are in millions (M) of dollars.

Alternative #16: No Action
Alternative #17: Institutional Actions: Access Restrictions, Monitoring, Natural Degradation
Alternative #18: Backhoe, Disposal at Existing Off-site Landfill
Alternative #19: Soil and Bentonite Cap
Alternative #20: Backhoe, Ex-Situ High Temperature Thermal Treatment, Disposal at Existing Off-site Landfill
Alternative #21: In-Situ Soil Vapor Extraction (SVE), Off Gas Catalytic Oxidation
Alternative #22: In-situ Bioventing

NA = Not Applicable

Figure 9-4. Alternatives for Soil Groups (K, L, M, N, O, P, Q and R)



most groups, the highest benefit/cost ratings are associated with alternatives that provide at least some protection from contaminants at relatively little cost. Alternative 20 has the highest present worth costs for all groups while Alternative 17 consistently has the lowest present worth cost.

Alternatives 21 and 22 also have high benefit/cost ratios. However, neither of these alternatives alone can address the entire range of soil contaminants at the applicable sites. These alternatives will likely be implemented with other soil remediation alternatives.

In every soil group, Groups K through R, only Alternatives 18, 19, and 20 at least partially meet the threshold criteria, Overall Protectiveness of Human Health and the Environment, and Compliance with ARARs. Since the threshold criteria are minimum standards that must be met, Alternative 16 should not be considered without additional risk management for these groups.

Alternative 17 would be partially protective of human health and the environment and was rated 0 for compliance with ARARs because it would not likely comply with most chemical-specific ARARs. However, given its low cost relative to other alternatives, it should continue to be considered.

As discussed in Section 8.3, soil cleanup costs for Alternatives 17, 18, 19, and 20 were very sensitive to changes in cleanup requirements and moderately sensitive to changes in scope and bid contingencies. Increasing cleanup requirements to address areas with ecological risk increased the cleanup cost by as much as 64 percent. Doubling scope and bid contingencies increased the cleanup cost as much as 26 percent. The total present worth costs of the alternatives were not sensitive to changes in discount rate for these alternatives that do not have associated future costs (O&M costs).

10.0 COMBINING MEDIUM-SPECIFIC ALTERNATIVES INTO AN INTEGRATED PLAN FOR A SITE

The detailed analysis of alternatives sections (Sections 4.0 through 9.0) of this Feasibility Study (FS) examined and ranked alternatives for each impacted medium and site grouping at Travis AFB. This final section provides guidance to integrate the "medium-specific" alternatives into comprehensive "site-specific" alternatives, as well as to combine sites for remedial action.

The detailed analysis of alternatives was conducted by medium to simplify the evaluation process. For each IRP site, an integrated alternative that addresses all impacts at the site will be developed collaboratively by the U.S. Air Force, regulatory agencies, and the Restoration Advisory Board (RAB). However, there are 20 sites and 22 medium-specific alternatives. With this number, a very large number of different site alternative combinations could be developed. For example, choosing just two sites for combined remedial action out of the 20 sites in the NEWIOU results in 190 different two-site groupings. If three remedial alternatives were selected from the 22 alternatives available, 1,540 three-alternative groupings would be possible. This means that for a plausible integrated action that combined only two sites with three alternatives, up to 292,600 combinations could be developed. Considering in detail each of these combinations is unrealistic and unnecessary. A "plug in" approach that develops an integrated alternative by "plugging in" the best medium-specific alternatives into a comprehensive action at a site greatly simplifies the selection and application of individual medium alternatives.

This section describes the factors to consider in this "plug in" approach and describes how to develop the selected alternative for each site using the FS.

The FS identifies and evaluates the technologic components that could be used in a remedial action. The most cost-effective components are combined into an integrated alternative by evaluating the following key physical and logistical aspects of the sites:

- The interrelationship between each contaminated medium with other media (i.e., inter-media) at the same site;
- The potential benefits of combining sites for remedial action;
- The potential benefits of applying different medium-specific alternatives to different geographic areas of a site; and
- The potential benefits of staging action over time, starting with a focused and intensive action to remove the high concentration of contamination, followed by longer term containment of the remaining constituents.

These four factors are discussed in detail in this section. Examples are given of the interrelationships of media, site combinations, alternative combinations, and staged remediation. Table 10-1 indicates how the FS fits into the overall plan for remediating sites in the Travis IRP. The data provided in the FS are used to support the decision maker when developing the integrated alternative(s) for each site. The FS is used to present the rationale for selecting the integrated alternatives. Data from the FS is used to document improvements on the effectiveness, implementability, and lower costs achieved by integrating alternatives instead of executing stand-alone medium-specific alternatives. The last subsection, 10.5, of this section provides guidance and references the Proposed Plan/ROD process as the mechanism for developing integrated alternatives for each site.

10.1 Inter-media Relationships and the Influence on Developing Integrated Alternatives

Groundwater, soil, surface water, and sediment interact to varying degrees depending upon the location of a site, the geology, topography, and contaminant type. Not all media are connected at a site. The impacted media at each site are shown on Table 10-2; Figure 10-1 shows the types of media interaction at Travis AFB. By taking an action on one medium, the benefits on another may be so great that no additional action is needed. However, an action on one medium can also be detrimental to another. Each interaction is discussed below.

Table 10-1

Travis IRP CERCLA Process

Travis AFB IRP Task	Documentation
1. Define the Problem (Identify Sites and COCs)	Remedial Investigations (for the NOU, EIOU, and WIOU) FS - Section 1.0
2. Identify Preliminary RAOs	FS - Section 2.0
3. Identify Technologies and Screen Alternatives	FS - Section 3.0
4. Analyze Screened Alternatives in Detail	FS - Sections 4.0 - 9.0
5. Methodology for Combining Alternative(s) for Each Site	FS - Section 10.0
6. Selection of Integrated Alternatives for Sites	Proposed Plan(s)
7. CERCLA Documentation of Alternative Selection	FS Proposed Plan(s) Record of Decision(s)

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
COCs = Contaminants of Concern
EIOU = East Industrial Operable Unit
FS = Feasibility Study
IRP = Installation Restoration Program
NOU = North Operable Unit
RAO = Remedial Action Objective
WIOU = West Industrial Operable Unit

Table 10-2

Media Impacted at Each NEWIOU Site

Site	Groundwater	Surface Water	Soil	Sediment
SD001	—	✓	—	✓
FT002	—	—	✓	—
FT003	—	—	✓	—
FT004	✓	—	✓	—
FT005	✓	—	✓	—
LF006	✓	—	—	—
LF007	✓	—	✓	—
OT010	—	—	✓	—
SS015	✓	—	✓	—
SS016	✓	—	✓	—
WP017	—	—	✓	—
SS029	✓	—	✓	—
SS030	✓	—	✓	—
SD031	✓	—	—	—
ST032	✓	—	✓	—
SD033	✓	✓	—	✓
SD034	✓	—	✓	—
SS035	✓	—	✓	—
SD036	✓	—	✓	—
SD037	✓	—	✓	—

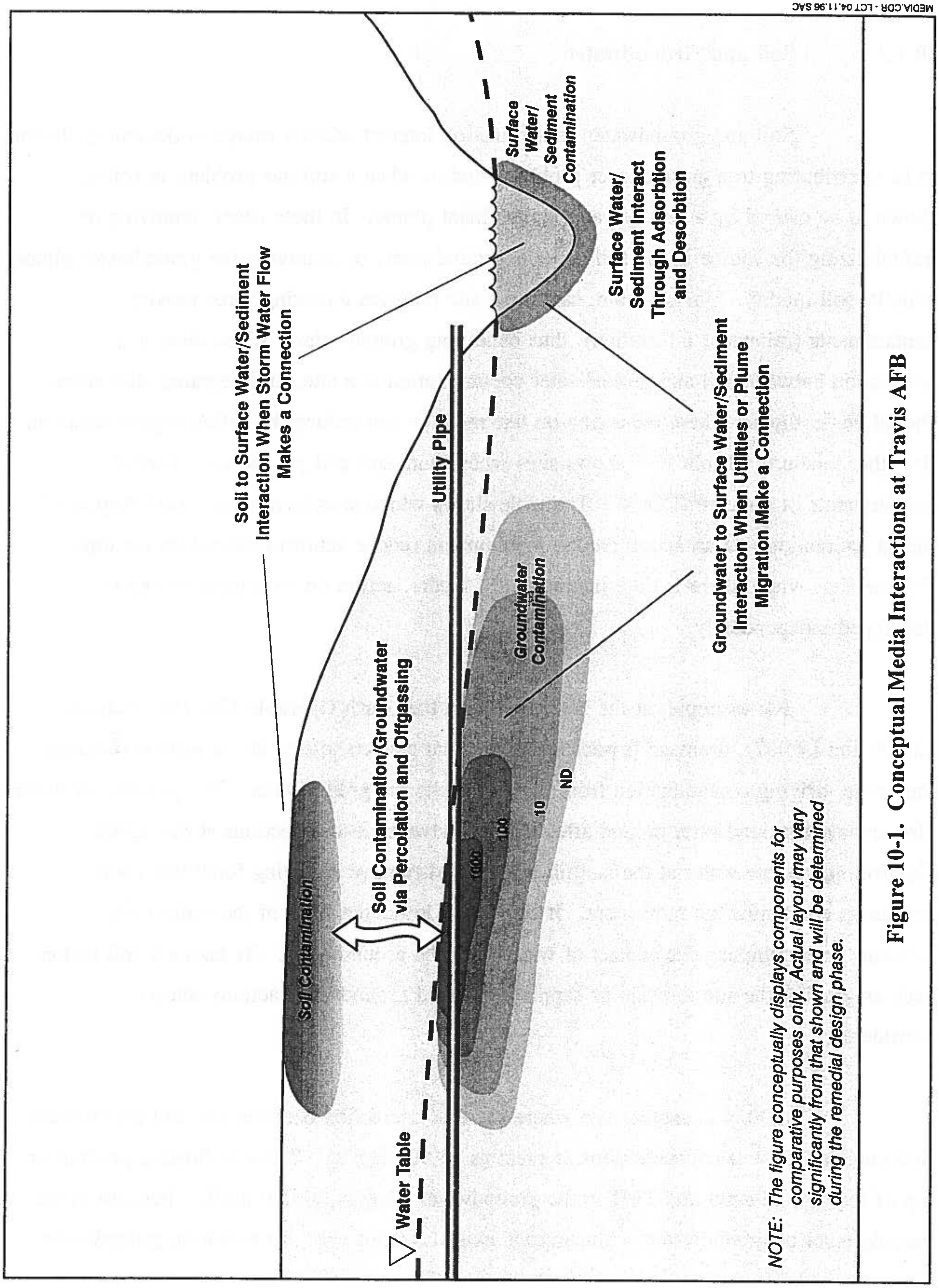


Figure 10-1. Conceptual Media Interactions at Travis AFB

10.1.1 Soil and Groundwater

Soil and groundwater contamination interact when a source in the soil is shown to be contributing to a groundwater problem, and/or when a soil gas problem in soil is shown to be caused by a groundwater contaminant plume. In these cases, removing or immobilizing the source in the soil benefits groundwater, or removing the groundwater plume benefits soil quality. For example, capping a site removes a driving force moving contaminants (rainwater infiltration), thus benefiting groundwater. When there is a connection between soil and groundwater contamination at a site, an integrated alternative should be developed where the action on one medium can reduce the action requirements on the other medium. Table 10-3 shows sites where both soil and groundwater contain contaminants of concern (COCs). The table shows which sites have such a high degree of media interaction that an action on one medium can reduce actions required on the other. For the sites where there is little interaction of media, action on each medium can be developed independently.

For example, at the landfill sites in the North Operable Unit (NOU) (Sites LF006 and LF007), drainage is poor and water that collects after a storm infiltrates through the waste, driving contamination from the waste into the groundwater. The ponding of water also creates a groundwater mound affecting groundwater flow directions at Site LF007. Controlling surface water at the landfill sites would remove a driving force that could accelerate contamination movement. It could also lower the level of the water table, reducing or eliminating the contact of waste with the groundwater. By taking a soil action, such as grading the site to drain or capping, reduced groundwater actions could be considered.

SD034 is another site where there is interaction between soil and groundwater. Soil contains TPH at concentrations as great as 15,900 mg/kg. There is floating product on top of the groundwater and TPH in the groundwater exceeds 20,000 mg/L. Because of the varying level of groundwater, a smear zone exists. In this case, an action on groundwater

Table 10-3

Sites With Potential for Cross-Media Benefits of Remedial Actions

Site	Description of Interaction/Cross-Media Impacts of Remedial Actions
FT004	Surface soil constitutes most of the areal extent of soil contamination. A small portion of the site has TPH-contaminated subsurface soil that could interact with groundwater which also contains TPH contamination. Groundwater remediation would have a minor beneficial effect on the overall volume of contaminated soil. Soil remediation would have a minor beneficial effect on contaminated groundwater.
FT005	Surface soil constitutes most of the areal extent of soil contamination. A small portion of the site has TPH-contaminated subsurface soil that could interact with groundwater which also contains TPH contamination. Groundwater remediation would have a minor beneficial effect on the overall volume of contaminated soil. Soil remediation would have a minor beneficial effect on contaminated groundwater.
LF006	The source of TCE in groundwater probably is buried waste. Actions to address buried debris could reduce the scale of groundwater remediation or possibly support a groundwater containment strategy. Actions to reduce rainwater percolation through contaminated debris resulting in the leaching of contaminants into the shallow groundwater would also support a groundwater containment strategy.
LF007	The source of contaminants in groundwater probably is buried waste. Actions to address buried debris could reduce the scale of groundwater remediation or possibly support a groundwater containment strategy. Actions to reduce rainwater percolation through contaminated debris resulting in the leaching of contaminants into the shallow groundwater would also support a groundwater containment strategy.
SS015	Surface soil constitutes most of areal extent soil contamination. A small portion of the site has TPH-contaminated subsurface soil that could interact with groundwater which also contains TPH contamination. Groundwater remediation would have a minor beneficial effect on the overall volume of contaminated soil. Soil remediation would have a minor beneficial effect on contaminated groundwater.
SS016	The overall areal extent of soil contamination is very small relative to areal extent of groundwater contamination. Some surface and subsurface TPH soil contamination is near "hot spots" of groundwater contamination. Remedial actions on soil would have a very minor beneficial effect on the overall extent of groundwater contamination. Groundwater remedial action would have a minor beneficial effect on subsurface TPH contamination and no effect on surface soil TPH and SVOC contamination.
ST032	There is TPH contamination both in subsurface soil (in the first few feet above the groundwater) and in groundwater. Groundwater remedial action could reduce the need to clean up soil. Soil remedial action would have a minor beneficial effect on groundwater.
SD034	There is TPH in both subsurface soil and groundwater. Free product exists above the groundwater. Groundwater remedial action could reduce the need for soil action and support the use of institutional actions for soil. A soil action would have a minor beneficial effect on TPH in groundwater, but no effect on other groundwater COCs, such as TCE.

Table 10-3

(Continued)

Site	Description of Interaction/Cross-Media Impacts of Remedial Actions
SS035	Surface soil contamination does not appear to interact with groundwater contamination.
SD036	TPH-contaminated subsurface soil is associated with groundwater TPH "hot spots." Groundwater remedial action could reduce the need for a soil remedial action. A soil action would have a minor beneficial effect on concentrations of TPH in groundwater, but no effect on other COCs in groundwater, such as TCE.
SD037	TPH-contaminated subsurface soil is associated with TPH in groundwater. Groundwater remedial action could reduce the need for a remedial action for TPH-contaminated soil and would support the use of institutional actions for soil. (The volume of PAH-contaminated surface soil would be unaffected by groundwater remedial action.) A soil action on the TPH-contaminated subsurface soil would have a minor benefit on TPH in groundwater, but no effect on other groundwater COCs, such as TCE.

that biovented the soil (such as 2-phase extraction) would not only remediate groundwater, but would also remediate the soil, so that no further or no other actions, other than institutional actions, would be needed for the soil at the site.

10.1.2 Groundwater Interaction with Surface Water and Sediment

A groundwater to surface water pathway exists when groundwater discharges into a surface water body such as a creek. The discharge can occur either directly through the banks or bed of the creek or through discharge into a conduit such as a ditch or culvert that leads to the creek. Contaminated groundwater impacts the quality of the surface water and can adsorb onto sediment creating an ecological concern. At Travis AFB, Sites SD001 and SD033 (Union Creek and the West Branch of Union Creek) are receptors of contamination from other sites. Sites with groundwater contaminant plumes near Sites SD001 and SD033 are shown on Figure 10-2. Figure 10-2 also indicates the locations of the storm drainage and sanitary sewer systems, since these systems can be potential conduits for contamination. The sites with a potential interaction with Union Creek and the West Branch are shown on Tables 10-4 and 10-5.

Where contaminated groundwater is in close contact with the creek or there is a open conduit connecting groundwater and surface water, an action on groundwater that prevents the migration of contamination to the creek would have a beneficial effect on the surface water and sediment quality. The benefit could remove the need for additional action to protect surface water and sediment. Actions on groundwater, as a consequence of pump-and-treat actions, that could benefit surface water include:

- Intercepting contaminants in the plume before they reach the creek; and
- Lowering the groundwater table to an elevation below the invert of the storm drain.

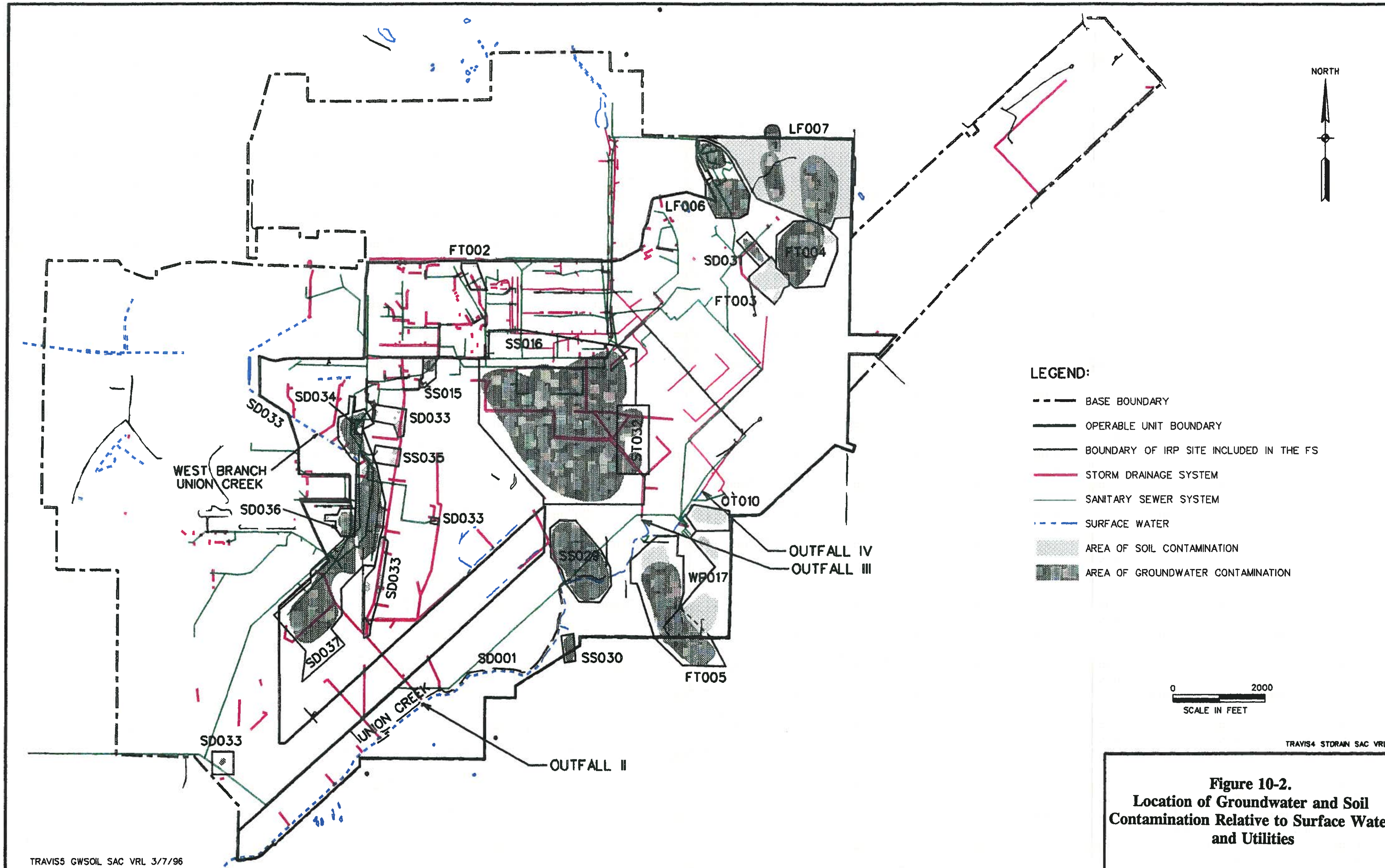


Figure 10-2.
Location of Groundwater and Soil Contamination Relative to Surface Water and Utilities

Table 10-4

Potential Interactions Between Soil and Surface Water

Site	Interaction	Explanation
FT002	Soil ⇒ Surface Water (SD033)	Transport of contaminants by erosion of disturbed contaminated soil.
FT003	Soil ⇒ Surface Water (Drainage Ditch)	Transport through erosion of disturbed contaminated soil.
FT004	Soil ⇒ Surface Water (Drainage Ditch)	Transport through erosion of disturbed contaminated soil.
FT005	Soil ⇒ Surface Water (SD001 Union Creek)	Transport through erosion of disturbed contaminated soil.
LF007	Soil ⇒ Surface Water (SD001 Union Creek)	Transport through erosion of disturbed contaminated soil.
OT010	Soil ⇒ Surface Water (SD001 Union Creek)	Transport through erosion of disturbed contaminated soil.
SS015	Soil ⇒ Surface Water (Storm Sewer System III)	Transport through erosion of disturbed contaminated soil.
SS016	Soil ⇒ Surface Water (Storm Sewer System III)	Transport through erosion of disturbed contaminated soil.
WP017	Soil ⇒ Surface Water (SD001 Union Creek)	Transport through erosion of disturbed contaminated soil.
SS035	Soil ⇒ Surface Water (SD033)	Transport through erosion of disturbed contaminated soil.
SD037	Soil ⇒ Surface Water (SD033)	Transport through erosion of disturbed contaminated soil.

Soil = Soil medium
Surface Water = Surface water medium
⇒ = Indicates direction of interaction between media

Note: Disturbance includes routine disking, construction, or remedial activities.

Table 10-5

Potential Interactions Between Groundwater and Surface Water[1]

Site	Interaction	Explanation
SS015	GW ⇒ Surface	Transport from GW plume to SD001 through underground utilities.
SS016	GW ⇒ Surface	Transport from GW plume to SD001 through underground utilities.
SS029	GW ⇒ Surface	Transport from GW plume to creek when the water table is above the elevation of the creek bed.
ST032	GW ⇒ Surface	Transport from GW plume to SD001 through underground utilities.
SD033	GW ⇒ Surface	Transport from GW plume to SD033 through underground utilities.
SD034	GW ⇒ Surface	Transport from GW plume to SD033 through underground utilities.
SS035	GW ⇒ Surface	Transport from GW plume to SD033 through underground utilities.
SD036	GW ⇒ Surface	Transport from GW plume to SD033 through underground utilities.
SD037	GW ⇒ Surface	Transport from GW plume to SD033 through underground utilities.

GW = Groundwater medium
Surface = Surface water medium
⇒ = Indicates direction of interaction between media

1 = Refer to Figure 10-2 for a display of the interaction between groundwater and surface water contamination and utilities.

At Travis AFB, Union Creek and its West Branch rely, to an extent, on groundwater discharge for water flow. Groundwater discharge into the creek is especially important during the summer to maintain habitat. Therefore, lowering of the water table near the creek and its tributaries needs to be considered. The large scale lowering of the water table, as a consequence of groundwater pump-and-treat actions, to the degree that the base flow of the creek is affected should not be done. Significantly changing the surface water/groundwater balance could negatively impact the habitat by removing an important source of water for the creek.

Taking action on surface water, such as slip-lining and collaring the conduits, would improve water quality in the creek, but the action would have little beneficial impact on groundwater quality. However, if the action on surface water removes the pathway, then the need for a groundwater action could be reduced if the plume poses no other threats to human health or the environment. The groundwater/surface water alternatives need to be selected as a paired action by considering the cost and benefit of taking an action on one medium, thereby reducing the action required on the other medium.

Soil and Surface Water/Sediment

Soil and surface water/sediment interactions may occur where contamination exists in the shallow soil, and drainage ditches or storm sewers connect the contamination area with the creek. During rain events, runoff can carry contaminants from the contaminated site to the creek, contaminating the water and the sediment. An action on the "source" site, such as removing the soil or capping, could remove the pathway and benefit the water quality of the creek.

The sites with soil contamination are shown on Figure 10-2 and are listed on Table 10-2. Table 10-4 lists sites with potential interactions between soil and surface water. The soil to surface water pathway is not an ongoing problem, but the potential exists for migration. Erosion or disturbing the contaminated areas could result in the movement of contaminated soil toward the creek. As with groundwater, any action at these sites, such as capping, excavation, and removal of the contaminated soil, or restrictions on activities that could disturb the contaminated areas, could eliminate the need to take further action at Union Creek to protect surface water and sediment quality from soil to surface water pathways.

Surface Water and Sediment Interactions

Surface water and sediment interactions can include leaching of contaminants from the sediment to the surface water, and transport of contaminated sediment by the surface water. Contaminants in surface water could also sorb to sediment. Both surface water and sediment within creeks are receptors of contaminated water or eroded soil from upstream sources, as shown in Figure 10-2. If actions are taken in the source areas, reduced action at the creek could be considered if the rate of natural degradation and desorbing of contaminants from sediment to surface water is acceptable.

10.1.3 Example of Building a Site-Wide Alternative Considering Media Interactions

An example of the decision making process for combining media alternatives into a site-wide alternative for Site SS016 is provided below. This example is only an illustration of the decision making process and does not represent a recommended option. The components of the action could be conducted at different times for the different media addressed.

The general alternatives for groundwater, soil, and surface water are:

- No Action (Alternatives 1, 10, and 16);
- Institutional Actions (including monitoring) (Alternatives 2, 11, and 17);
- Pump and Treat Actions (Alternatives 3, 4, 5, 6, 7, and 8);

- Excavation (Alternative 18);
- Capping (Alternative 19); and
- Slip-lining and collaring the storm drain (Alternative 14).

A summary of conditions at Site SS016 includes a contaminant plume that does not represent an immediate risk to human health because there is no direct exposure pathway. However, the potential exists for exposure if the area is excavated because the depth to groundwater is less than 10 feet. The potential exposure is also possible from soil contamination if the area is excavated. Because of the interaction of the media, surface water could be impacted by groundwater and also by soil contamination if the soil were eroded or disturbed by construction. Also, there is an ongoing potential for impact to surface water as the plume moves toward the south.

Each alternative may affect, to different degrees, the contamination and media interactions at Site SS016. No Action would not prevent contamination from entering the creek and there would be no ability to track the plume as it moved. Though there is no immediate risk to human health (because no person is exposed to the contamination) there would be the potential risk if the area were excavated. No Action would not prevent this risk. The same conditions are true for No Action for soil contamination.

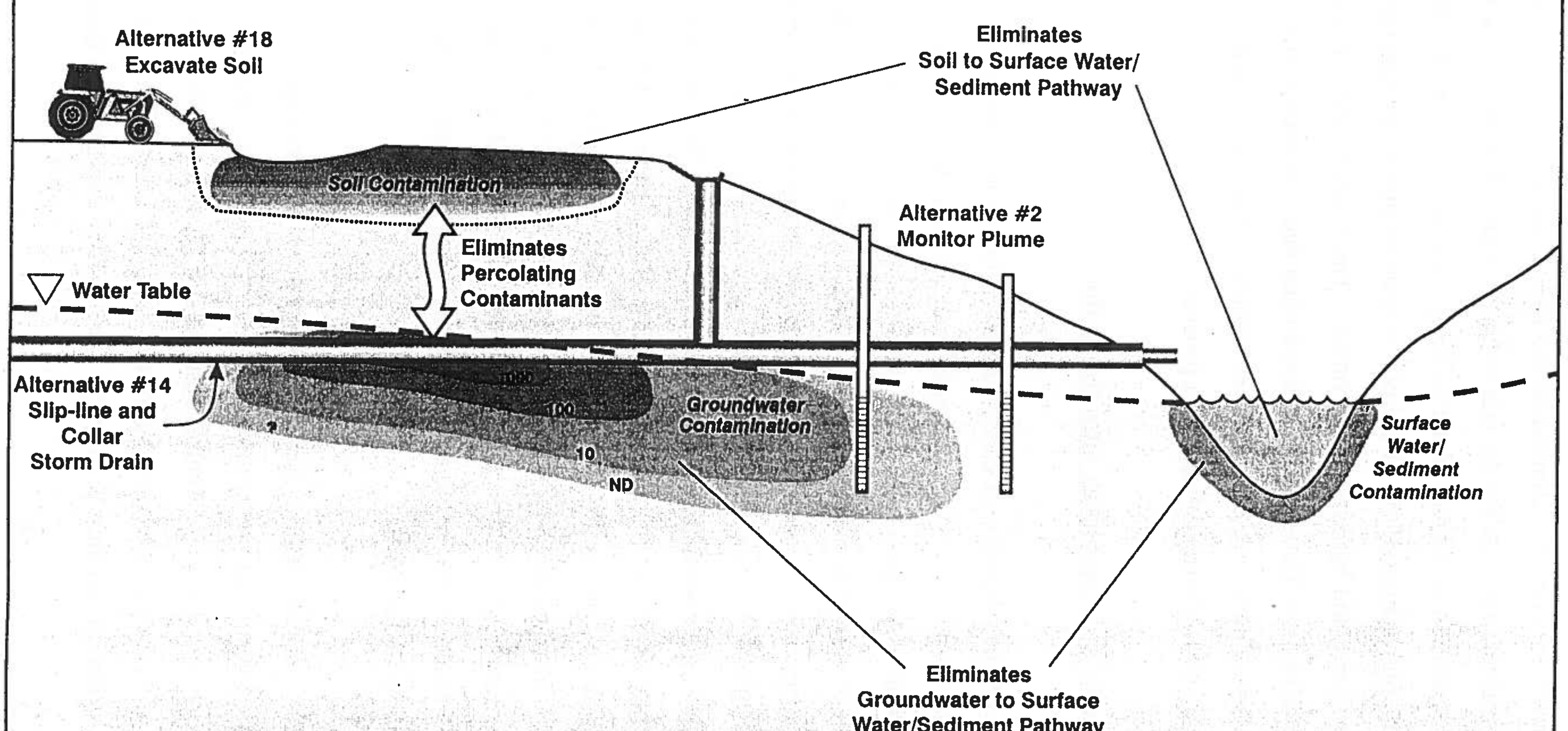
Institutional Actions would prevent the possibility of impact to human health by preventing excavation in the areas of soil and groundwater contamination without proper safety considerations. Movement of the plume could be monitored allowing for additional action if the plume migrated close to the creek bank. However, considering the potential interaction of media, Institutional Actions would not prevent current migration of contamination to Union Creek. A decision would have to be made by the Remedial Program Managers (RPMs) at this point regarding the current creek impacts and whether the current condition is acceptable. If the condition is acceptable, the monitoring performed under Institutional Actions would provide a warning if contaminant discharge increased over time, thus warranting additional action. The acceptability of Institutional Actions needs to be considered in light of the cost of the additional action.

Additional actions on groundwater to protect surface water include lowering the groundwater table, as a consequence of groundwater pump-and-treat actions, to below the storm drain invert. This action removes contaminated groundwater for treatment and prevents discharge of contaminants, such as TCE, into the storm drain. In this case, the groundwater action eliminates the need for action on the surface water itself, based on the contribution of contaminants from Site SS016. Other sites impacting the creek would have to have similar removal of pathway before No Action on the entire creek could be selected.

Actions that could be taken on soil are capping the site, preventing off site migration, or excavating the contamination, eliminating the source. Each action protects surface water. With capping, an institutional action preventing disturbance of the cap would have to be built into the alternative.

A potential action that could be taken on the surface water in lieu of a groundwater action would include slip-lining the inside of the existing storm drain and/or installing collars on the exterior of the pipes. Both options prevent the migration of contaminated water within the storm drain system to surface water bodies. External pipe collars would prevent migration through the disturbed soil associated with the pipe trench. This action would limit transport of contaminants, but would not remove them from the groundwater. By eliminating the contaminant migration pathway to the surface water, alternatives for groundwater that do not involve pump and treat become more desirable since the surface water action removes the primary threat to the environment at Site SS016, (i.e., the migration of contamination via the storm drain to surface water [Site SD001]).

Figure 10-3 presents an example of a multimedia site alternative for Site SS016 that considers media interactions. The example is not a recommended alternative, but is provided to demonstrate the thought process when developing a site-wide alternative. The



NOTE: The figure conceptually displays components for comparative purposes only. Actual layout may vary significantly from that shown and will be determined during the remedial design phase.

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Figure 10-3. Example Site Alternative Considering Media Interactions

example shows excavating the soil, eliminating the soil to surface water connection. This action is also a permanent solution for the soil contamination. The storm drain is slip-lined, eliminating the groundwater to surface water pathway, and the plume is monitored to provide an early warning of plume migration. If the plume were shown to be migrating toward the creek, additional action could be taken in the future. The example only considers interactions between media. The concepts of combining sites for action, selecting different alternatives for different parts of a contamination problem, and staging actions need to be factored into the site-wide alternative selection process.

10.2 Benefits Of Combining Sites for Action

The primary benefits of combining sites for remedial action are reduced cost and improved implementability. The most significant cost savings would result from using a centralized groundwater treatment system. A larger system would be needed, but the technology would not change from the technology selected for each individual site. The savings would be from reduced electrical hook-up needs, integrated water reuse, less capital equipment and construction needs, and streamlined operations and maintenance. The logistics of combining sites would depend upon funding cycles. The decision on which sites to combine for action should be made at the remedial design stage. Sites that would benefit the most from a combined action are sites that are in close geographic proximity and sites that are in the same hydrogeologic flow basin. Sites in proximity can share treatment plants and other infrastructure. Sites in the same basin could be managed on a basin-wide action, such as installing a series of extraction wells at the downgradient edge of the basin and intercepting plumes at that location.

Figure 10-4 shows the proximity of sites and the drainage basins. The NOU sites are in close proximity and are in one groundwater flow basin. The EIOU flight line sites are in proximity and are in the central basin. Sites FT005 and SS030 are also in different basins. Even though they are in different basins, it is possible to consider combined (non-basin wide) action due to their proximity. The WIOU sites lie on a drainage divide and

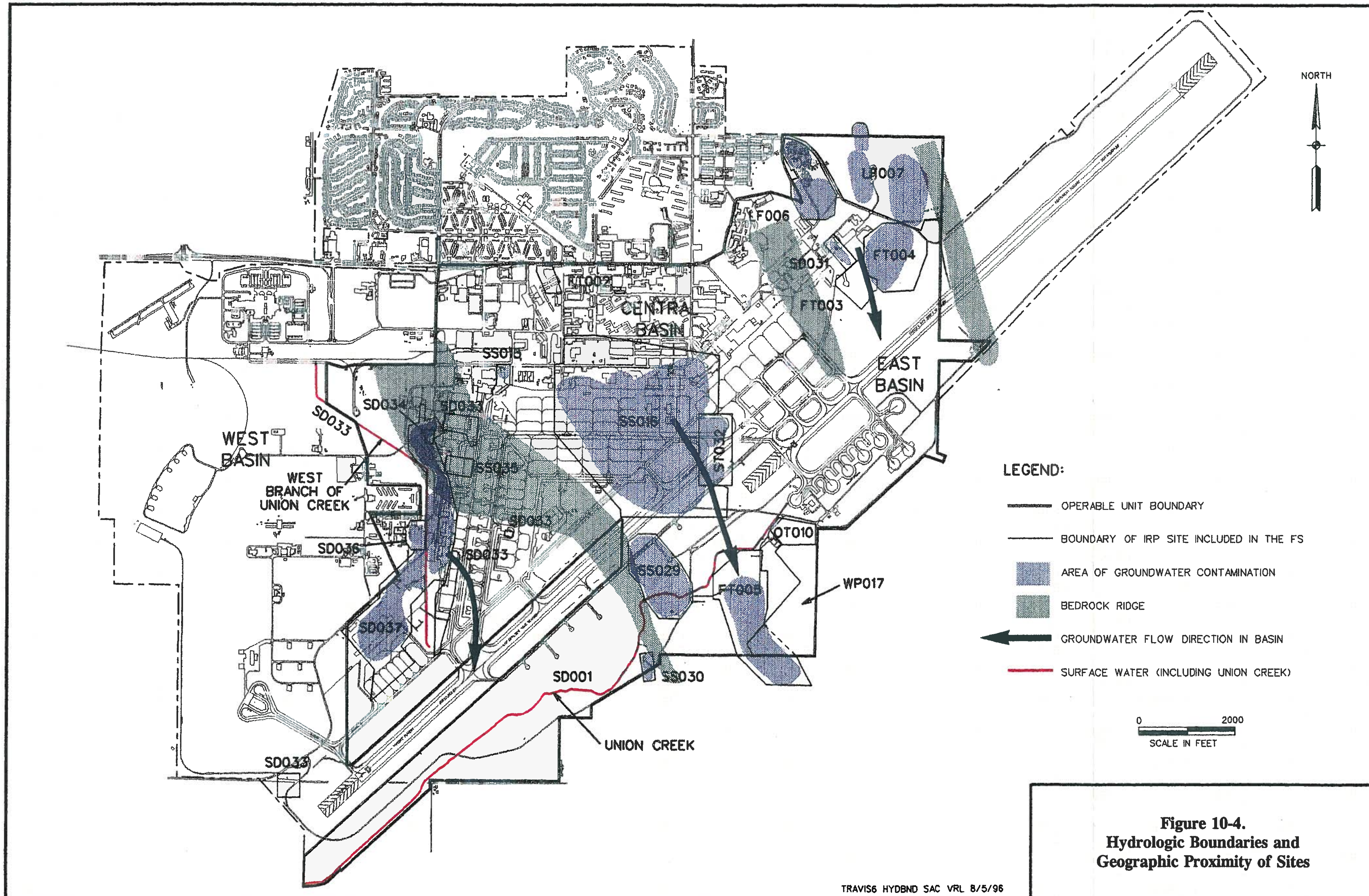

**Figure 10-4.
Hydrologic Boundaries and
Geographic Proximity of Sites**

in the west basin. Sites on the divide should not be managed in a basin-wide action since downgradient control of groundwater contamination from these sites could not be assured. However, the sites could be combined for treatment at a centralized treatment facility.

Sites FT005, SS029, and SS030 are used as an example to illustrate the benefits of combining sites and using a centralized treatment plant. The sites are shown on Figure 10-5. The example involves treating groundwater from the three sites at one centrally located treatment plant. Site SS016 is also in the same general area of these sites. However, combining this site with the others is not likely to be feasible due to the presence of the runways between Site SS016 and the plant. Also, only the southern portion of the Site SS016 plume could likely be treated at the plant. Unless the entire plume can be treated at the plant, the cost estimates for Site SS016 cannot easily be applied for cost comparison.

The site of the existing Outfall III granulated activated carbon (GAC) treatment plant is used as the location of the central plant in this example. The treatment train is assumed to be ultraviolet oxidation (UV-OX) and GAC polishing. Since the only viable water discharge alternative in this geographic area of the base is discharge to surface water, ion exchange is included in the treatment train to ensure that the effluent will meet NPDES standards. Water can enter the treatment facility either before the UV-OX system or after, depending upon the influent contaminant concentrations. This treatment train is used only as an example and is not necessarily a recommended action. Specific components of the treatment system would only be known after the remedial design is completed. For example, the need for ion exchange to treat metals concentrations to discharge standards would be determined after a bench scale treatability test is performed during the remedial design of the treatment system. While some economic benefit may be derived from making use of existing structures at the existing Outfall III GAC treatment plant, this example does not include these benefits so that the conclusions from this analysis can be more generally applied to all Travis AFB sites.

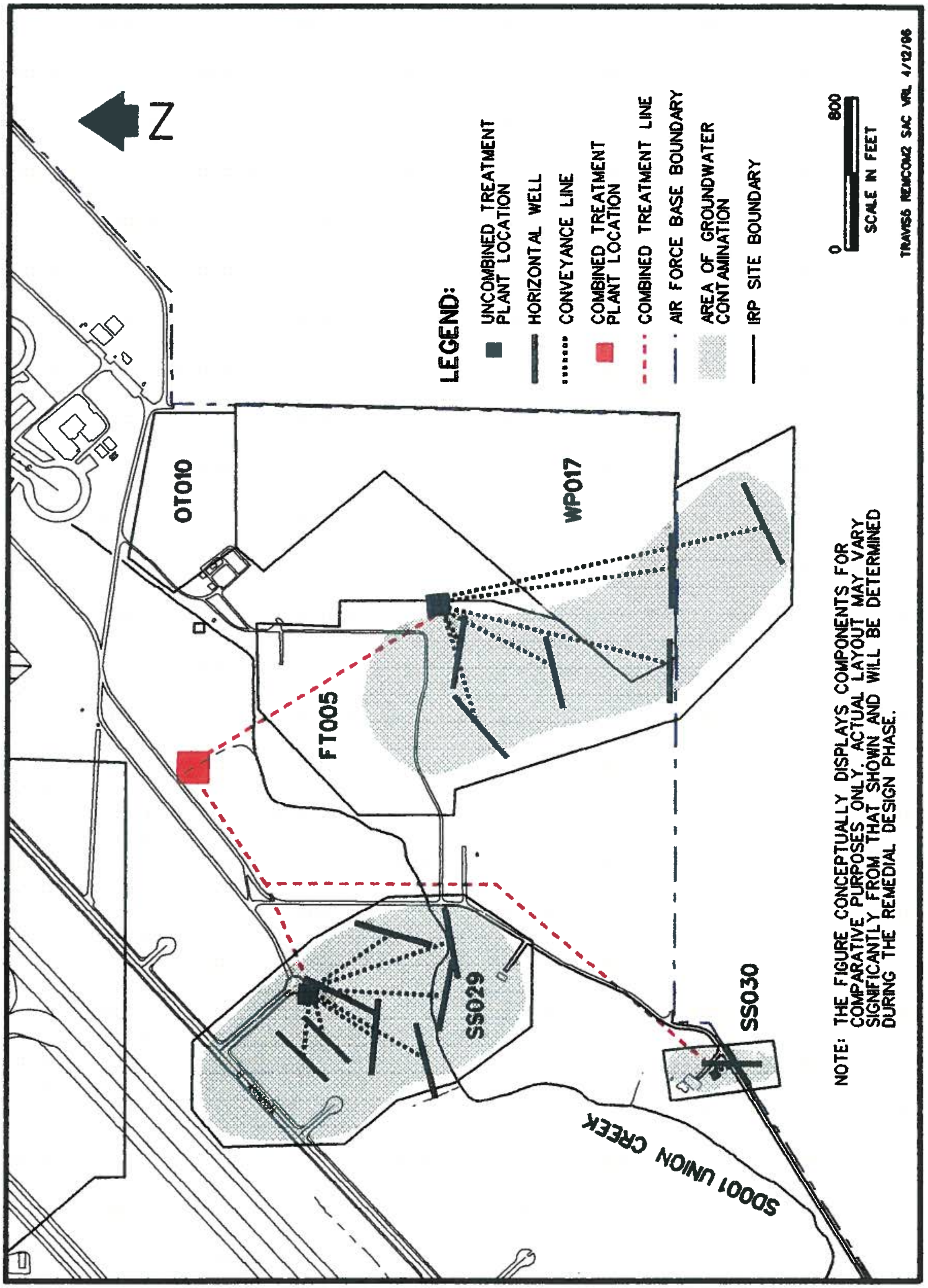

Figure 10-5. Example of Combining Sites for Remedial Action

Centralized groundwater treatment involves collecting the contaminated water from wells at the individual sites. The water is then pumped from each site to the centralized treatment facility. The water is treated and is discharged to Union Creek.

A process flow diagram of the Centralized Treatment Facility is shown in Figure 10-6. The flow rates shown on Figure 10-6 reflect the expected rates for the sites. Groundwater is extracted from wells at the individual sites. For a given site, the extracted groundwater from each well is segregated based on the contaminant concentration, as determined by periodic sampling. Water which can economically be treated with activated carbon (nominally 500 μg/L or less TCE) is routed past the UV-OX system to the carbon. Extracted groundwater which contains high concentration of TCE or compounds which are difficult to adsorb, such as vinyl chloride, are routed to the UV-OX system. The total water flow from any well at the site can be piped to either the carbon or UV-OX parts of the treatment system. The treated water is discharged to Union Creek at Outfall III. All these technical components are identical to system components identified in Alternative 5.

Since the technology of an evaluated alternative is used at the Centralized Treatment Facility, the effectiveness determined in the FS for the alternative is unlikely to be significantly affected. While the quantity and quality of water treated at the Centralized Treatment Facility would differ from that of three individual treatment facilities, the overall effectiveness of the treatment system should be similar for each of system. Total air emissions from the three plants may also differ from those from a central plant, but again, the difference is unlikely to be substantial.

Combining sites as described in this example does affect implementability and cost. Implementability, on one hand, may be slightly decreased for the Centralized Treatment Facility since the sighting requirements of a single large facility may be more difficult than for a small plant. However, dedicating land for one plant may have less mission impact than locating three plants. The effort required to obtain approvals and/or permits from the Bay Area Air Quality Management District for a central plant may also

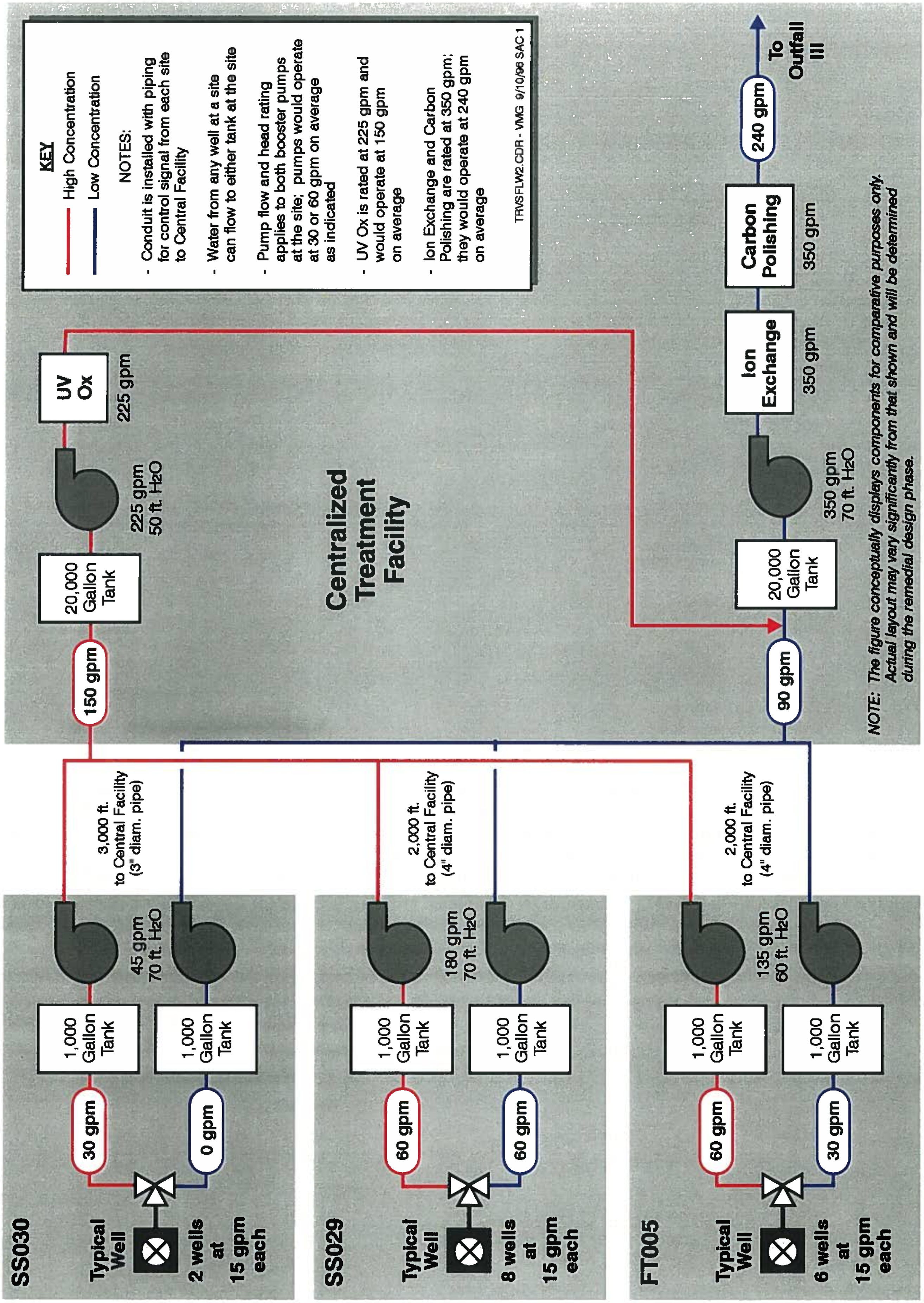

Figure 10-6. Outfall III Centralized Treatment Facility Process Flow Diagram

differ from that for separate plants. One point source emission with controls may be more desirable that three point sources. Other implementability benefits of the Centralized Treatment Facility include centralized operation and maintenance activities, safer storage of chemicals, and reduced area for staging of hazardous wastes and materials, such as spent activated carbon.

A reduction in the net present worth cost is the most tangible benefit from combining sites. Table 10-6 shows the cost of the three individual sites, a subtotal of these costs, and the costs associated with the Centralized Treatment Facility. For purposes of this comparison, Alternatives 5 and 6, which include UV oxidation and activated carbon, are used for each of the individual sites. An implicit advantage of the configuration shown in Figure 10-6 is that flows from the various wells can be optimally treated. Since contaminant concentration will vary over time, operational flexibility to select the most economical treatment method for a given stream is desirable. The cleanup times are estimated in this FS at 15, 149, and 77 years for FT005, SS029, and SS030, respectively (see Appendix C).

The cost estimate for the Centralized Treatment Facility assumes that treatment activities and operating costs associated with each site will cease once the calculated time to cleanup to 5 μg/L (MCL for TCE) for that site has been reached. The costs estimated in Table 10-6 for the Centralized Treatment Facility were derived using the same cost model, methodology, and assumptions used in estimating costs for the individual sites. The last tab in Appendix B presents the cost summary backup sheets for the Centralized Treatment Facility. The Centralized Treatment Facility results in an estimated total present worth cost savings of $1,300,000.

10.3 Multiple Alternatives for Geographical Areas of a Site

For large sites, different areas of the site may need different actions. Selecting more than one alternative for each medium may be more cost effective than choosing only one alternative per medium. An example of selecting more than one

Table 10-6

Cost Comparison for the Centralized Treatment Facility[1]

Facility	Capital Cost	Operation and Maintenance Present Worth	Total Present Worth
FT005 (Alternative 5)	$1,900,000	$3,100,000	$4,900,000
SS029 (Alternative 6)	$1,700,000	$4,200,000	$5,900,000
SS030 (Alternative 5)	$730,000	$2,600,000	$3,300,000
Subtotal	$4,300,000	$9,900,000	$14,100,000
Centralized Treatment Facility	$5,000,000	$7,800,000	$12,800,000

[1] Costs for each line item are rounded off to two significant figures. Therefore, the subtotals and totals did not necessarily add up on this table.

alternative is shown in Figure 10-7. The example considers Site LF007 (Landfill 2). The multiple alternatives could be implemented at the same time or could be implemented in phases over time.

This example shows that a focused pump and treat action can be taken on the portion of the groundwater contamination that is migrating off base. Impact to groundwater will be reduced by a combination of grading and capping. The landfill would be graded to drain so water does not pond, further reducing the soil/groundwater interaction. Part of the grading would be consolidating surface contamination to areas that would be capped. The portion of contamination that is exposed at the surface would be capped, preventing exposure and infiltration. Since the grading and capping would eliminate vernal pools, new pools would be constructed on another part of the base or enhancement of off-base vernal pools would be considered as a mitigating action. Groundwater would be monitored and risk would be minimized through institutional actions prohibiting the use of the groundwater that lies under and adjacent to the landfill, and by limiting access and land use. The combination of institutional actions, focused pump and treat action on the contaminated groundwater migrating off base, and capping and grading to reduce contaminant migration would effectively reduce risk at the site.

The benefit of this combined action is in cost savings. Capping the entire landfill and installing a complete pump and treat system (implementing Alternatives 19 and 5) would cost up to $24 million. The combined alternative shown in the example would cost approximately $11 million. These costs savings are just an example of the benefits of implementing different alternatives for different parts of the site. The cost data in Appendix B of the FS were used to qualitatively predict this savings from different combinations of alternatives.

Implementing multiple alternatives at a site for each medium should not negatively affect the conclusions of the detailed analysis of alternatives. Effectiveness of alternatives, such as institutional actions, would improve when they are coupled with capping

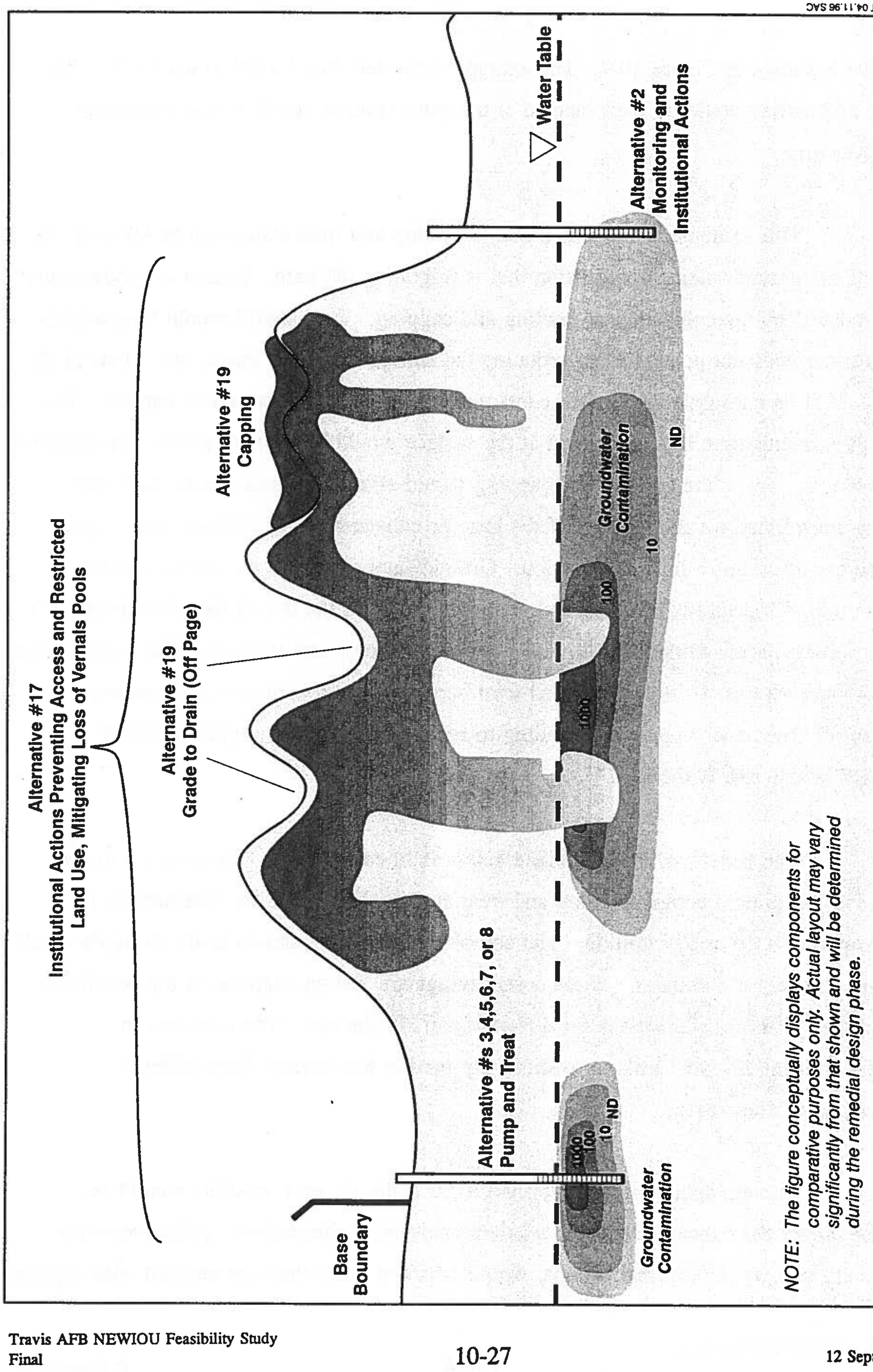

Figure 10-7. Multiple Alternatives Per Media At One Site

and focused pumping actions, and other containment strategies. The effectiveness of pump and treat alternatives would also improve because source areas would be controlled by actions taken in the soil. The implementability stays essentially the same, but the cost is reduced. The selection of multiple actions is based on applying the alternatives over smaller and appropriate areas, instead of the worst case assumption of having the alternative applied to the entire site. For all multiple alternative scenarios, it is important that the applicability of the CERCLA effectiveness and implementability results for each component of the action be verified, showing that the overall effectiveness of the multiple alternative scenario meets or exceeds the effectiveness of the single alternative scenario, with similar or increased implementability.

10.4 The Benefits of Staged Remedial Action

Staged remedial action is focused primarily on groundwater because actions taken for soil, surface water, and sediment are usually complete in a relatively short period of time, often at the conclusion of construction. Groundwater actions operate for extended periods of time and address contamination that varies in concentration geographically and over time. Staged remediation is the same as implementing multiple alternatives at a site except that the time over which the alternatives are implemented and/or operated is different for different parts of the plume. Also, the clean-up levels can be different based on potential health and ecological risks, and the success of containment of the contamination. A staged remedial action is beneficial because the efficiency of groundwater clean-up is dependent upon the contaminant concentration. Significant contaminant reduction can be achieved from areas of the plume that contain high concentrations of the target compounds or undissolved contaminants such as fuel or solvent. The cost benefit of contaminant reduction declines exponentially as concentrations decrease. In the terms of the detailed analysis of alternatives performed in Sections 4.0 through 9.0 of this FS, the cost benefit ratio of the alternative would drop over time since a reduced rate of contaminant mass removal would occur over time (less effectiveness or risk reduction) while operating costs remain relatively constant. Another benefit of staged remedial action is that actions can be coordinated with funding cycles. By staging, the Air Force can possibly implement several "hot spot" remedial actions instead of one complete action at one, lower risk site.

Staged remediation implements a short term (several years) action in areas of high contamination and a different action in areas of a plume with lower contamination. Because of the very long time to clean up low concentrations, the action taken on the low concentrations is directed on containing the contamination in areas where there is no exposure to human health or the environment.

An example of a staged remedial action is provided for Site SS016. The example is shown on Figure 10-8. This site contains groundwater contamination that covers a large geographic area. The TCE concentration for a grab sample from a borehole was 175,000 μg/L. Samples from monitoring wells in the source area indicate TCE concentrations of up to 32,000 μg/L. However, most of the geographic area of the plume has concentrations of TCE that are below 1,000 μg/l. The site also has soil contamination. The groundwater contamination may affect Union Creek.

For this site, the first stage could be a focused action to reduce TCE concentrations in the source area. Coupled with this first stage could be the excavation of the soil contamination and monitoring of the surface water. A cleanup level would be developed for the source area.

Stage two could be a larger scale groundwater removal and treatment system for the areas near the plume edge with lower concentrations than that near the plume center. As with the focused removal system for the source area, a clean-up level would be developed for this action. The level could be different than for the focused system based on the migration potential of the plume. Even though the outer edges of the SS016 plume are closer to the receptor (Union Creek), concentrations are lower thus the cleanup level could be less than the focused system to ensure containment of the plume. For sites where plumes migrate

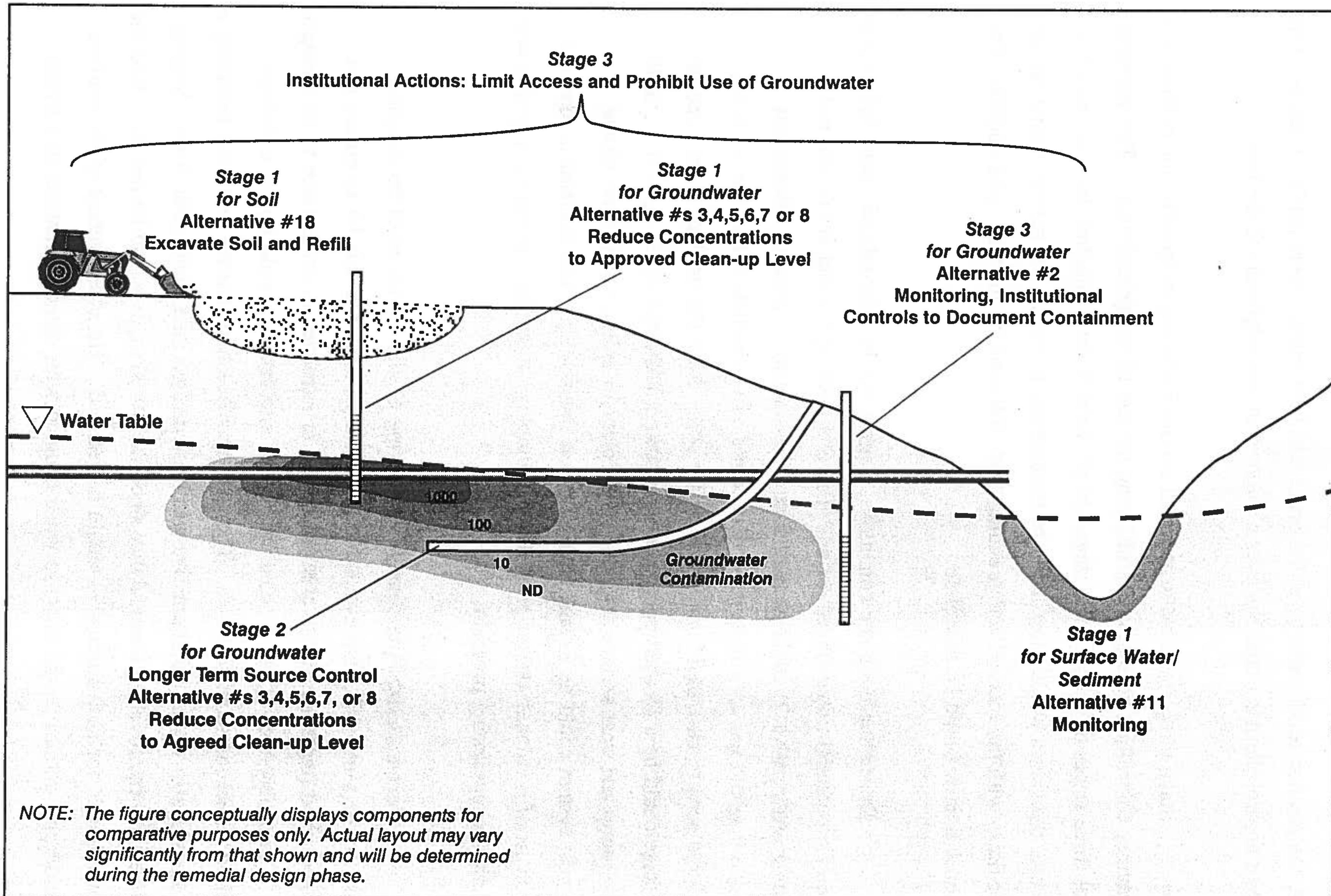

Figure 10-8. Example of a Staged Remedial Action

off base, the cleanup level could be at the maximum contaminant level (MCL) because of the diminished control the Air Force has over a plume that has migrated off the base.

Stage three could be institutional actions including monitoring the containment of the plume, controlling access, and prohibiting the use of the groundwater. This example identifies three stages of action. The stages do not have to be sequential, but they could be. In this case, the stages would most likely be concurrent, however, the actions would end at different times with the focused action ending first, followed by the wide area control. The institutional actions would be indefinite.

Depending upon site conditions, staging can be time-related. Site SS034 is an example of a potential timed staged action. There is floating product at this site and Bioslurping (Alternative 9) could be used first. Considering intermedia interactions, Alternative 9 would not only remove product, but could remediate soil at the same time, reducing the need to take additional action on the soil. After the product is removed the second stage could be a focused pump and treat system (Alternatives 3, 4, 5, 6, 7, or 8). After the pump and treat system has achieved its cleanup levels, a long term plume containment system could be installed and operated indefinitely. The containment systems could consist of a reduced rate of groundwater pumping, at strategic locations, together with a groundwater monitoring program.

As emphasized previously, any staging of alternatives must be analyzed according to the same CERCLA evaluation criteria used earlier in this FS to ensure that effectiveness and implementability criteria are met or exceeded in comparison to an unstaged action. The conclusions of the detailed analysis of alternatives should not be negatively affected by a decision to stage action. The analysis of each alternative was done assuming a worst case scenario where the alternative was implemented on a stand alone basis. Staging alternatives will improve implementability since smaller systems would be needed. Also the time commitment for each alternative would be reduced. The effectiveness of alternatives like institutional actions would improve when coupled with other alternatives in a staged plan. For example, institutional actions would be more effective when coupled with a reduction in the contaminant concentrations and the containment of a plume. Finally, the cost of each component of a staged action would be reduced because the operations period would be reduced from the clean-up time frames estimated in Appendix C.

10.5 Decision Process to Develop Integrated Alternatives for IRP Sites

Fully integrated alternatives for each site will be developed in the Proposed Plan/ROD process using a "plug in" process where the "best" alternative for each medium at each site is selected. An alternative is rated the "best" based on the results of this FS, an evaluation of appropriate alternatives for all media at each site during the Proposed Plan process, and on the concerns and interests of the regulatory agencies and the public. Regulatory agency and public interests are incorporated into the integrated alternative through the review and comment process.

The "plug in" process will begin by considering each site individually. After integrated alternatives are developed for each site, the inter-media benefits of the actions, and the benefits of combining sites for action, will be considered, and a fully integrated plan developed. The developed plan and the decisions made while implementing the "plug in" process will be documented in the Proposed Plan(s) and ROD(s).

10.5.1 Process for Combining Sites and Cross-media Benefit Analysis

Combining sites for action has the potential for saving money and improving the implementability of an action. Cross-media benefits, where an action on one medium reduces the contamination concentrations in another medium, can reduce costs by taking advantage of cross-media benefits and reducing the overall action required to protect human health and the environment. To develop a fully integrated alternative for each site, two steps are necessary: first, the results of the "plug-in" alternative selection process should be tabulated. Second, the list of alternatives should be examined for opportunities to combine sites for remedial action to reduce costs and improve overall CERCLA evaluation criteria scores. Alternatives could be drawn from the applicable site group or a different site group if relevant conclusions can be reached. Opportunities for combined action would occur where sites are located in close proximity and have the same remedial actions selected. If opportunities exist for combined action, the plan for action should be flexible, allowing combined actions.

To determine cross-media benefits, the integrated alternatives for each site should be examined for synergy between actions. Where the action taken at one site benefits another site, the action(s) selected for the benefiting site should be reduced to the extent possible, while still protecting human health and the environment. For example, at sites where the groundwater action reduces soil contamination, the level of action selected for soil should be reduced and vice versa. Reduced action is possible because of the benefits provided by the actions taken on the one site.

After the site alternatives are evaluated for the benefits of combining sites for action and reduced action possibly due to the benefits of cross-media remediation, a final fully integrated alternative for each site will be developed. The final integrated alternative, with the decision making process, will be documented in the Proposed Plan(s) and Record(s) of Decision for the NEWIOU.

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