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— COMMITTED TO PROTECTION OF THE ENVIRONMENT —

ALTERNATIVE ASSESSMENT
OF
INTERIM RESPONSE ACTIONS
FOR
OTHER CONTAMINATION SOURCES
M-1 SETTLING BASINS
SEPTEMBER 1989
CONTRACT NO. DAAA15-88-D-0022
VERSION 2.0

020

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FOR THE ROCKY MOUNTAIN ARSENAL CONTAMINATION CLEANUP,
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Prepared by:

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Prepared for:

U.S. ARMY PROGRAM MANAGER'S OFFICE
FOR ROCKY MOUNTAIN ARSENAL CONTAMINATION CLEANUP

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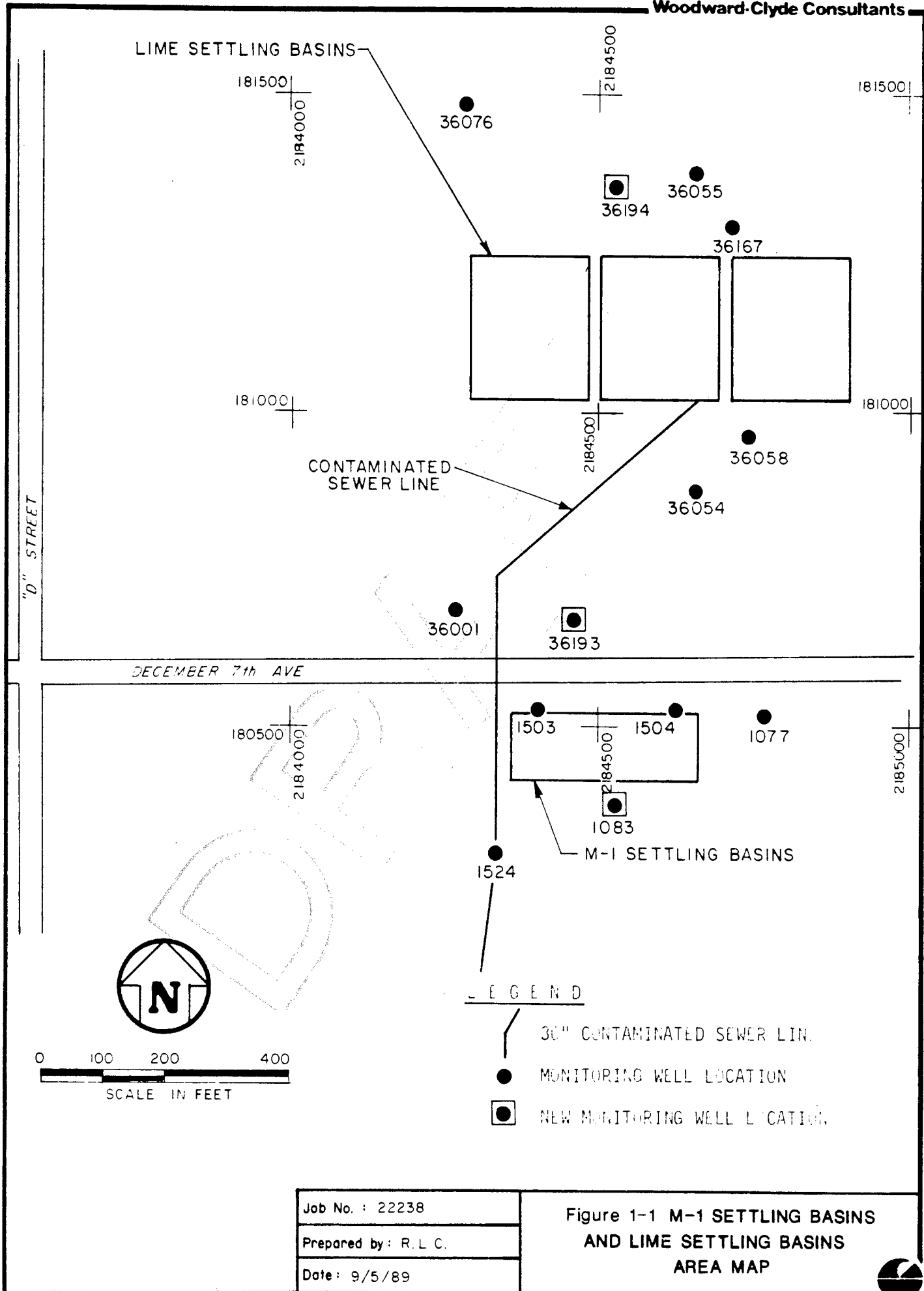
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1.1 PURPOSE OF THE INTERIM RESPONSE ACTION (IRA) ALTERNATIVE ASSESSMENT DOCUMENT

The IRA Alternative Assessment Document describes the process and results of the alternative assessment conducted for the M-1 Settling Basins at the Rocky Mountain Arsenal (RMA). The M-1 Settling Basins are located in the South Plants area of RMA (Figure 1-1). The M-1 Settling Basins appear to be a direct source of arsenic contamination to the groundwater. This evaluation is discussed in Section 2.2.2.

Technologies and alternatives have been developed which will remove or contain the potential source of groundwater contamination at this site. These alternatives will be evaluated to assess whether there is a clear and significant benefit in performing an interim response action now. The alternatives are evaluated by using existing data. Recent field studies will provide additional data, which may necessitate the reevaluation of alternatives. The final selection of the preferred remedial action will be presented in the IRA decision document.

An interim response action, as defined in this document, refers to any possible interim action including the Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA) alternatives: no action, monitoring, institutional control, containment, or any on-site or off-site treatment. Interim response action alternatives were developed by considering a range of types and degrees of treatment and associated degrees of contaminant containment. These were then evaluated against criteria that address effectiveness, implementability, cost, and regulatory requirements, to arrive at the identification of a suite of preferred interim response actions.



This Alternative Assessment Document is prepared in accordance with the Federal Facility Agreement pursuant to CERCLA Section 120. This Agreement, in Section XXII, specifies the preparation of an Alternative Assessment Document and a subsequent Decision Document that will recommend a preferred IRA for the M-1 Settling Basins.

1.2 IRA CANDIDATE SELECTION CRITERIA

The Federal Facility Agreement, in paragraph 22.1, addresses the issue of IRAs. IRAs are defined as interim response actions that have been "determined by the Organizations to be necessary and appropriate for the Site." The agreement requires the Army to assess and, if appropriate, implement necessary actions at selected sites. The M-1 Settling Basins are included in these selected sites as part of the "other contamination sources".

Subsequent to the issuance of the Federal Facilities Agreement, a decision logic that establishes evaluation criteria was developed. The three criteria established and their contributing factors are:

- (1) Is the site an active primary source?
 - Is it an active source of groundwater contamination?
 - Is it a primary groundwater contamination source?
- (2) Does the site pose a significant risk to human or biota receptors?
 - Have potential receptors been identified?
 - Have previous studies been confirmed by new data?
 - Is there any conflicting evidence?

(3) Is there a significant long-term benefit if an IRA is done now?

- Will interim action reduce risk?
- Will interim action reduce long-term costs?

The type of action taken, either long-term monitoring or interim treatment, and the timing of the action will depend on the responses to the above questions. The decision logic is shown on Figure 1-2.

If the answers to the questions on the decision flow chart are inconclusive, a conservative approach will be taken. For example, if clear risk to human or biota receptors has not been shown, then it will be assumed that some risk does exist.

At the M-1 Settling Basins, it appears clear that there is an active primary source of groundwater contamination. Although this site does not appear to pose a significant risk to human or biota receptors at this time, there may be some long-term benefit in performing an IRA now. Alternative interim response actions are discussed in this document. The benefit in performing any of these actions will be discussed in the IRA Decision Document.

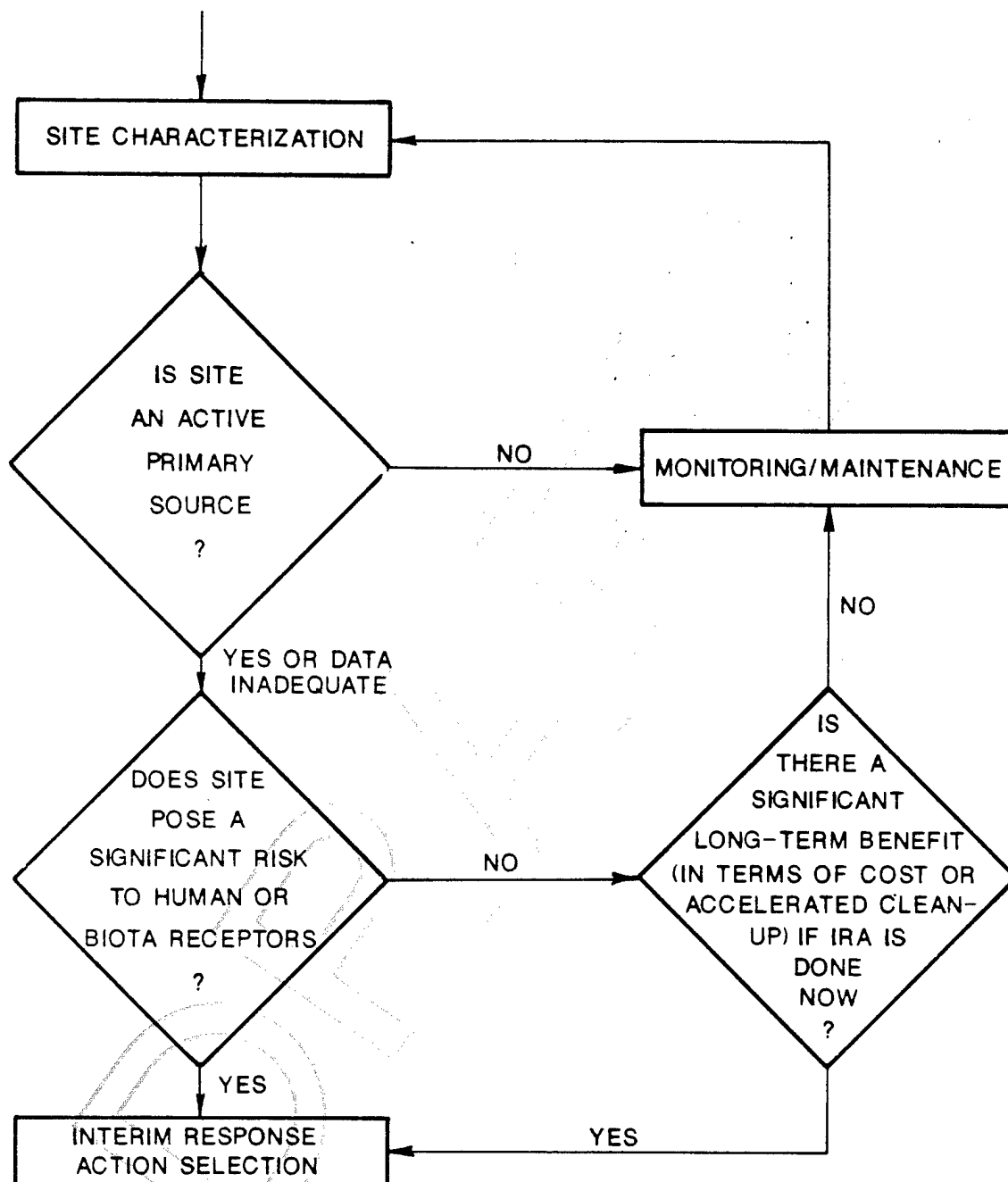
1.3 REPORT ORGANIZATION

The Alternative Assessment Document is divided into five additional text sections and a reference section.

Specifically, Section 2.0 summarizes the information and results of the current and previous investigations, a brief description of the site, extent of contamination, and a summary of the design basis. Section 3.0 identifies and provides a preliminary evaluation of remedial action technologies, as derived from the development of remedial action objectives. Section 4.0 presents the development of alternatives from the technologies and provides a detailed description of each site-specific alternative as well as the criteria used to evaluate them. Section 5.0 presents a cost estimate of each alternative treatment scenario. Section 6.0

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presents a brief summary of the results of this alternative assessment. Section 7.0 lists references cited within the text. A recommended action will be presented in the subsequent IRA Decision Document.



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Figure 1-2 - DECISION FLOW CHART FOR
INTERIM ACTION VERSUS
MONITORING/MAINTENANCE
ON HOT SPOT IRAs



2.1 SITE DESCRIPTION AND HISTORY

2.1.1 Site Description

2.1.1.1 Location

The M-1 Basins are located in the South Plants area just south of December 7th Avenue along the northern edge of the north west quarter of Section 1.0. The northwest corner of the basins is 75 feet south of the centerline of December 7 Avenue and 25 feet east of the contaminated sewer line that drained from the South Plants into the Lime Settling Basins (Figure 1-1). The elevation of the ground surface in the M-1 Basins area is approximately 5,265 feet above mean seal level (MSL). The basins and the berms surrounding them, all of which are now buried and partially built upon, occupy an area of approximately 46,200 square feet.

2.1.1.2 History

Two basins were originally constructed in 1942, but when these filled with solids, a third was constructed in 1943. All three were unlined, each measured approximately 90 feet wide (E-W), 115 feet long, and 7 feet deep, according to the as-built drawings. They were initially constructed to treat waste fluids from the lewisite disposal facility. However, lesser amounts of waste materials from alleged spills within the acetylene generation building, the thionylchloride plant, and the arsenic trichloride plant may have been routed through floor drains and the connecting piping to the basins (Ebasco Services, Inc., 1987).

The liquids discharged into the basins first passed through a set of reactor towers where calcium carbonate was added, then through a wooden trough into the M-1 Settling Basins where the arsenic precipitated out of solution. The elutriate was decanted off through an 18-inch diameter pipe to the Lime Settling Basins

(in Section 36) where final treatment occurred, and then routed into Basin A (Ebasco Services, Inc. 1987).

The basins also received a considerable amount of mercuric chloride catalyst, possibly from a spill. Various sources reported quantities such as 183,000 pounds, 500 pounds, 30,000 gallons, and \$25,000 worth (Ebasco Services, Inc., 1988).

The basins were backfilled, probably in 1947, and are now covered with soil and/or structures. The facilities that surround the M-1 Basins area were used to manufacture insecticides from 1952 until the early 1980s.

2.1.1.3 Geology

The M-1 Basins are located near the headwaters of a series of paleodrainages that originate in the upland area occupied by Section 1.0. Two significant stratigraphic units have been identified at the site. These are the Quaternary Alluvium and the Cretaceous-Tertiary Denver Formation.

The surficial materials in the M-1 Basins area consist of 10 to 15 feet of Quaternary Age alluvial soil which unconformably overlies Denver Formation bedrock. The entire area around the basins is covered with a veneer of imported soil. The soil cover over the waste material in the basins ranged from 2-to 4-feet thick.

The unconsolidated alluvial soil is composed of fine-to medium-grained subangular alluvial, eolian, and eluvial sands silts, and clays, with some minor amounts of gravel.

The Denver Formation is generally composed of finer grained materials including olive to bluish-gray to brown interbedded claystones, siltstones, and sandstones with some interbedded lignite seams. The contact between the Quaternary alluvial unit and the Denver Formation is often coincident with an eluvial clay or volcaniclastic unit, which is typically found on the tops of the hills and ridges

at RMA and is usually absent from the low-lying areas (Ebasco Services, Inc., 1989a). The elevation of the contact between the alluvial soil and the top of the Denver Formation is variable at RMA. In the M-1 Basins area, the contact was found between an elevation of approximately 5,246 feet and 5,254 feet above mean sea level (MSL) (Ebasco Services, Inc., 1989b).

2.1.1.4 Hydrology

Both the alluvial and bedrock units are known to be waterbearing units in the M-1 Basins area. Previous investigations conducted at RMA have concluded that the alluvial aquifer is unconfined and that the Denver Formation may be partially confined in some zones beyond the upper weathered zone (Ebasco Services, Inc. 1989a). The weathered portion of the Denver Formation is apparently in contact with the alluvial aquifer. Since this investigation focused primarily on evaluating impacts to the alluvial aquifer, the discussion will be limited to the characteristics of the unconfined alluvial aquifer.

In the M-1 Basins area, groundwater flow in the alluvial aquifer is apparently toward the north and possibly slightly northwest due to the influence of localized mounding of groundwater in the South Plants area. The local groundwater gradient is in the range of 0.008 to 0.011 ft/ft. Due to seasonal variations and local topography, the top of the groundwater ranges from approximately 5 to 10 feet below ground surface. The average saturated thickness of the alluvial aquifer is approximately 8 feet (Ebasco Services, Inc, 1989b).

Aquifer tests conducted on the alluvial aquifer during previous investigations at RMA indicate that the hydraulic conductivity of the unit is in the 6.0×10^{-3} cm/sec to 2.4×10^{-3} cm/sec range. By comparison, the reported hydraulic conductivity value for the Denver Formation is in the range of 5×10^{-5} cm/sec.

2.1.2 Previous Investigations

2.1.2.1 Soils

The M-1 Basins were investigated by the Army's consultant, Ebasco, in 1987 and by Shell's consultant, Morrison-Knudsen Engineers in 1988. Twenty-six soil and waste samples were taken from 6 borings within or near the M-1 Basins during the two investigations. The locations of these borings are shown on Figure 2-1. The samples were analyzed for volatiles, semivolatiles, ICP metals, arsenic, mercury, and thiodiglycol.

2.1.2.2 Groundwater

Several groundwater monitoring wells have been installed to monitor alluvial ground in the vicinity of the M-1 Basins. Well Nos. 01503 and 01504 are located in the berm immediately down gradient of the M-1 Basins, Well No. 01524 is located approximately 100 feet upgradient of the western most basin, Well No. 36001 is located approximately 200 feet northwest (downgradient) of the western most basin, and Well No. 01077 is located approximately 100 feet east of the basin area. The locations of these wells are shown on Figure 2-1. Samples from the wells were analyzed for total and dissolved arsenic, mercury, volatiles, semivolatiles, and pesticides during previous investigations. In spring 1989, Well Nos. 01503, 01504, 01524, 01077, 36001, and new Well Nos. 10183 and 36193 were sampled and analyzed for total and dissolved arsenic and mercury.

2.2 NATURE AND EXTENT OF CONTAMINATION

2.2.1 Soils

Soil samples collected and analyzed during the previous investigations indicated high concentrations of arsenic and mercury in the soil in, and around, the M-1 Basins at depths of 0.5 feet to approximately 7.0 feet. The concentration of arsenic and mercury in samples taken within the basins was variable and ranged from 0.01 percent to 11.0 percent. Concentrations of these constituents are reduced at depths below approximately 7 feet and in the soil surrounding the basins. Table 2-1 shows a summary of the contaminants found in soil samples taken during the previous studies.

2.2.2 Groundwater

Groundwater samples collected and analyzed during the previous studies suggest that a high concentration of arsenic is attached to soil particles moving with the groundwater as it leaves the M-1 Basins area. This interpretation is based on the difference in the concentration of arsenic between filtered and unfiltered groundwater samples from wells immediately downgradient of the basins. Unfiltered groundwater samples from Well Nos. 01503 and 01504 indicated up to 59,000 ug/l arsenic, while the filtered samples indicated less than 0.01 ug/l for each well.

Preliminary analytical results from groundwater sampling conducted in spring 1989 confirm that there are high levels of arsenic in the groundwater, but these results show little difference between filtered and unfiltered samples. Total and dissolved arsenic concentrations are quite similar in magnitude, and indicate a high concentration of arsenic immediately downgradient of the M-1 Settling Basins. This indicates that the M-1 Settling Basins are a direct source of groundwater contamination.

Groundwater samples from wells located upgradient and adjacent to the basins did not indicate elevated concentrations of either soluble or suspended arsenic.

Table 2-2 is a summary of the contaminants found in groundwater from wells in the M-1 Basins area during previous studies.

2.3 CONTAMINANT FATE AND TRANSPORT

The contaminants observed in the field investigation can exist in several chemical forms in the environment and can progress through several media in a number of different ways. This section presents the fate and transport of both the organics and metals detected in these field investigations.

2.3.1 Fate of the Organics

A number of organic compounds found in this study area and their physical and chemical properties are listed in Table 2-3. The fate of these organic compounds are controlled by the following processes: volatilization, hydrolysis, photolysis, oxidation, sorption, and biodegradation. Each process is discussed in the following sections.

2.3.1.1 Volatilization

The volatilization process occurs rapidly in the near-surface where contaminated soil is exposed to the air or when contaminated soil particles are moved by the wind.

2.3.1.1.1 Pesticides. If exposed to air, the organochlorine pesticides (aldrin and dieldrin) would slowly volatilize into the atmosphere because of their low vapor pressures (Table 2-3).

2.3.1.1.2 Semivolatile Chlorinated Hydrocarbons. The semivolatile chlorinated hydrocarbons are somewhat volatile (Table 2-3) and could be lost by volatilization into the atmosphere. These compounds are more volatile than the pesticides.

2.3.1.1.3 Volatile Hydrocarbons. Bicycloheptadiene and dicyclopentadiene are very volatile and easily could be lost from the surface soil into the atmosphere by volatilization.

2.3.1.2 Hydrolysis

Hydrolysis is not important with regard to the fate of the organic contaminants in the M-1 Settling Basins. The process is very slow.

2.3.1.2.1 Pesticides. Hydrolytic reactions for the pesticides are slow and dependent on pH.

2.3.1.2.2 Semivolatile Chlorinated Hydrocarbons. Hydrolytic reactions for all the chlorinated hydrocarbons are slow. For example, chloroform has a half-life of 3,500 years.

2.3.1.2.3 Volatile Hydrocarbons. If hydrolysis can occur for these compounds, the process would be very slow. In general, hydrolysis under ambient environmental conditions is highly improbable.

2.3.1.3 Photolysis

Photolysis is applicable only to contaminated soil exposed to sunlight either at the ground surface or while being transported in finely dispersed particles by the wind. This process is not significant in the fate of the organic compounds found in this study area because they are located below the ground surface.

2.3.1.4 Oxidation

In general, pesticides, chlorinated hydrocarbons, hydrocarbons, and other organic compounds are resistant to chemical oxidation in the subsurface. Chlorinated hydrocarbons, however, after volatilization into the troposphere can be attacked by hydroxide radicals.

2.3.1.5 Sorption

Aldrin and dieldrin are the only organic compounds in this area that can be absorbed either by plants growing in the area or on the surface of soil particles (especially clay particles). Sorption in nature should be the greatest in the spring and early summer when plants are starting to grow. Sorption is not considered a significant fate mechanism because there is little plant life in the M-1 Settling Basins area and because the soil does not contain large amounts of clay.

2.3.1.6 Biodegradation

In order for significant aerobic biodegradation to occur, bacteria must be in place, and oxygen and nutrient sources must be available for the bacteria to grow and degrade the organic contaminants. In order for significant anaerobic biodegradation to occur, bacteria must be in place and a nutrient source (usually nitrates) must be available. Biodegradation is always occurring, but at very slow rates because of the lack of nutrients and/or oxygen.

2.3.1.6.1 Pesticides. Chlorinated pesticides are the most stable pesticides in the environment, but they can be slowly degraded over a period of one to thirty years.

2.3.1.6.2 Semivolatile Chlorinated Hydrocarbons. Aerobic biodegradation of semivolatile chlorinated hydrocarbons occurs slowly. Initial research has indicated that anaerobic biodegradation might be faster; however, not enough work has been performed to verify this finding.

2.3.1.6.3 Volatile Hydrocarbons. Bacteria under aerobic conditions can slowly degrade hydrocarbons. However, in nature the process is usually inhibited by lack of oxygen and nutrients.

2.3.1.7 Conclusions

The major fate mechanism for organic compounds appears to be volatilization and this only occurs for those organic compounds with high vapor pressures near the ground surface that volatilize. The other fate mechanisms are slow and insignificant in regard to contaminant removal from the soil in this study area. Biodegradation is possible if sufficient oxygen and nutrients are present.

2.3.2 Transport of Organics

The transport of organics in the M-1 Settling Basins area can occur by the following mechanisms:

- transport of soluble and insoluble organics with soil by precipitation runoff,
- transport of soluble and insoluble organics with soil by wind,
- downward migration of soluble organics with precipitation through the subsurface soil into the groundwater,
- transport of soluble organics with the groundwater,
- transport of volatile organics through the unsaturated subsurface soil (vadose zone), and

- transport and adsorption of the soluble organics along the lignite seams in the Denver Formation.

The transport of the organics, including organochlorine pesticides and the volatile hydrocarbons, can be hindered by the absorption of the organics on the organic material in the soil, on the surfaces of soil particles (especially clayey particles), and in the lignite seams in the Denver Formation. The sorption of the organics is dependent on a number of factors, but in general follow the order: organic soil > clay > sand. Hexachlorocyclopentadiene has little or no affinity for surface interaction with the soil due to its volatility and solubility in water. Soil with high organic detritus would increase the sorptive nature for hexachlorocyclopentadiene but is still less as compared to the other organic compounds.

As the groundwater is remediated or the concentration of the organics in the groundwater decreases, the organics sorbed to the soil will be slowly released. This slow release of organics makes remediation of the groundwater difficult.

Tables 2-1 and 2-3 list the concentrations of a number of organic compounds in the soil found in this area, and their chemical and physical properties, respectively.

2.3.2.1 Contaminated Soil Transport by Precipitation Runoff

The transport of soluble and insoluble organics associated with soil movement due to surface runoff of rainwater or snowmelt appears to be somewhat limited because the amount of precipitation at RMA is approximately 15 inches a year. The precipitation would, in general, preferentially infiltrate the soil and reach the groundwater table.

2.3.2.2 Contaminated Soil Transport by Wind

The transport of organics associated with soil movement by the wind is another possible mechanism. During wind transport, volatilization could occur to reduce

the concentration of the organics in the soil particles. In addition, when the widely dispersed soil particles return to the ground, they would be distributed over a larger, possibly uncontaminated area. Thus, the concentration of the organics on the ground surface would be less due to volatilization and dispersion.

2.3.2.3 Organics Transport with Precipitation

Because of the limited amount of precipitation, there would not be any significant transport of soluble organics with precipitation runoff. The major transport pathway of the precipitation is downward migration through the subsurface soil into the groundwater. The depth of groundwater in this area is shallow, approximately 5 to 10 feet below the surface.

2.3.2.3.1 Pesticides. The organochlorine pesticides (aldrin and dieldrin) are not that soluble in water (Table 2-3) and therefore would not migrate any significant distance. Although the concentrations of aldrin and endrin are low in the soil (Table 2-1), this transport mechanism is possible.

2.3.2.3.2 Semivolatile Chlorinated Hydrocarbons. Hexachlorocyclopentadiene is soluble in water and its density is greater than water (Table 2-3). Therefore, it can migrate downward into the groundwater at a faster rate than the other organic compounds.

2.3.2.3.3 Volatile Hydrocarbons Similar to hexachlorocyclopentadiene, bicycloheptadiene, and dicyclopentadiene are soluble in water, but their densities are less than that of water. Because of their densities, downward migration of these compounds is dependent on their solubility to move through the vadose zone with precipitation into the groundwater.

2.3.2.4 Organics Transport with Groundwater

Once the soluble organics are in the groundwater, they will migrate downgradient with the groundwater. The migration rate will be slower than the groundwater gradient due to chemical absorption effects of the soils.

2.3.2.5 Organic Vapor Transport

Bicycloheptadiene and dicyclopentadiene are highly volatile (Table 2-3). Their vapors would accumulate and migrate through the vadose zone. Whenever the groundwater level rises, the vapors in the unsaturated soil will dissolve in the groundwater and increase the concentration of contaminants in the groundwater.

2.3.2.6 Transport of Organics Along Lignite Seams

The stratigraphy of the Denver Formation includes several lignite seams interbedded with the clay and sandstone portions of the formation. High concentrations of volatile and semivolatile organic compounds could preferentially migrate through these seams. If concentrations are low, diffusion rates are reduced and adsorption becomes a dominant mechanism. Therefore, low concentrations of volatiles and semivolatiles would tend to be adsorbed on the lignite seams. Less volatile contaminants, such as the pesticides, if they were able to migrate to the Denver Formation, would be strongly sorbed to the lignite seams.

2.3.3 Fate of the Metals

Unlike organics, metals in the soil are indestructible. There are no natural physical, chemical, or biological processes that can transform metals into harmless compounds. Some chemical processes, for example, oxidation and reduction, can be applied to harmful forms of metals to make them less toxic. However, methylation of arsenic, mercury, and lead by soil microorganisms and bacteria can occur to produce volatile methylated metals that can migrate through the unsaturated zone of the soil. These volatile organometals are chemically

and biologically different from the parent metal inorganic compounds. Methylated metals have been found in landfills, but the factors controlling the methylation process are not completely understood. Another volatile arsenic compound that could exist in this area is arsine.

Another process that can be considered is the uptake of soluble metal compounds by plants growing at RMA. Even though some of the metals, especially mercury and copper, are highly toxic to plants, interaction with less toxic metals, such as cadmium and zinc, results in a synergism which reduces toxicity and allows absorption by the plant roots.

The two processes above are possible at the M-1 Settling Basins area but would not be considered major factors in the reduction of metal contamination.

2.3.4 Transport of Metals

Existing information on metals contamination in this area does not differentiate in what form the metals exist: elemental, ionic, organometal, or sorbed to humic material or the surface of soil particles. For purposes of this study, the metals will be considered as soluble or nonsoluble. The soluble metals are those metal species that are (1) soluble in water and (2) capable of being leached out of the soil by water to migrate from the contaminant source to form a larger area of contamination. The nonsoluble metals include elemental metals, ionic species such as metal oxides, metal organic chelates, and metals sorbed on the surface of the soil (especially clayey fractions) or humic material in the soil. The nonsoluble metals are considered relatively immobile in the subsurface.

Three transport processes that could occur in this area are (1) movement of soluble and nonsoluble metals with soil transport during precipitation runoff, (2) movement of soluble and nonsoluble metals with soil by wind, and (3) movement of the soluble metals with precipitation downward through the subsurface soil into the groundwater, and further movement with the groundwater. Because, the amount of precipitation at RMA is approximately 15 inches per year, transport

of the metals associated with soil movement due to of surface runoff, in ephemeral streams, would appear to be somewhat limited.

Movement of the metals by the wind is another possible transport mechanism. The contaminated soil particles will be widely dispersed by the wind so that when the soil is returned to the ground, the concentration of metals in the soil in the area of deposition would probably be below the total threshold limit concentrations (TTLIC).

Of the three transport processes, the major migration pathway appears to be downward movement through the soil, into and with the groundwater. The groundwater fluctuates seasonally, and is sometimes in direct contact with the sludge in the M-1 Settling Basins. The upgradient groundwater is known to be contaminated and may be contributing to contaminant levels in the M-1 Settling Basins.

Once the metals are in the groundwater, they will migrate with the groundwater. Some of the metals may be absorbed by organic matter and or the surfaces of soil particles (especially clay particles).

2.4 APPLICABLE SITE STANDARDS

With the available knowledge of the nature and distribution of chemical contaminants at the site, as well as the fate and transport of these chemicals in the environment, a survey of applicable or relevant and appropriate requirements (ARARs) is necessary. These ARARs will outline any site-specific regulatory conditions which might either limit the choice of alternatives or place limits on the contaminate concentrations of process residuals. The ARARs are provided separately.

2.5 DESIGN BASIS FOR INTERIM ACTIVITY

This section summarizes the engineering constraints considered in the technology and alternative evaluation process.

The total aerial extent of the three M-1 Settling Basins is shown to be 115 feet by 300 feet on design drawings. It is assumed that the waste material in the basins is covered by two feet of soil overburden and that the waste material extends to a depth of seven feet below ground surface. The total volume of the sludge is estimated to be approximately 6,400 yd³.

Volume estimates for the sensitivity analysis consider only a maximum-volume case by assuming a 20 feet perimeter boundary of soil to be treated around the M-1 Settling Basins. In addition, for the sensitivity analysis, the depth of contamination was assumed to be 10 feet below ground surface.

Alluvial groundwater is assumed to extend from approximately 8 feet below ground surface, with some seasonal variation, into a confining clay layer which is about 15 feet below ground surface. All treatment technologies will address the contents of the basins and the overburden only. No aquifer dewatering and subsequent treatment will be necessary for the purpose of this interim response action. Any excavation activities will be performed during the dry season in late summer or early fall to reduce the potential for encountering groundwater.

Preliminary analysis of the waste material in the basins indicates that the in-place waste is approximately 47 percent water. The waste is described as a gray-to-white very wet, silty clay-like material, similar to the consistency of toothpaste. Based on previous investigations, this material is assumed on the average to be about 8 percent arsenic, 0.5 percent mercury with the balance being oxide or carbonate calcium salts as measured on a dry basis. The wet density of this material is assumed to be 1.35 tons/yd³.

The soil surrounding the basins is gravelly to silty sands, with lesser amounts of clayey sands to silty sand. The in-place density of this soil is assumed to be 1.5 tons/yd³.

A summary of the design basis is shown in Table 2-4.

TABLE 2-1
SUMMARY OF CONTAMINANTS IN SOIL AND SLUDGE

Contaminant	SOIL		SLUDGE	
	No. of Samples	Range (µg/g)	No. of Samples	Range (µg/g)
Volatile Organic Compounds/GCMS				
Methylene Chloride (CH ₂ CL ₂)	3	1.71-6.70	4	3.0-6.1
Bicycloheptadiene (BCHPD)	3	2.0 -5000	6	2.1-600
Semivolatile Organic Compounds/GCMS				
Aldrin (ALDRN)	2	2.0-30	7	1.4-4000
Dicyclopentadiene (DCPD)	2	300-2000		
Dieldrin (DLDRN)	5	0.4-100		
Hexachlorocyclopentadiene (CL ₆ CP)	1	3000		
Isodrin (ISODR)	1	10		
Metals/ICP				
Cadmium (Cd)	4	1.3-2.9	11	5.3-3900
Chromium (Cr)	3	9.9-14	3	7.4-11.6
Copper (Cu)	4	9.3-21	2	14.4-21.8
Lead (Pb)	7	20-35	12	16.4-248
Zinc (Zn)	7	46-69		
Separate Analyses				
Arsenic (As)	11	9.2-480	15	120-110,000
Mercury (Hg)	11	0.3-210	14	1.1-35,000

Sources: D.P. Associates, Inc. 1989a
Ebasco Services, Inc. 1988

TABLE 2-2

SUMMARY OF CONTAMINANTS IN GROUNDWATER

Contaminant	No. of Samples	Upgradient Range ($\mu\text{g/l}$)	No. of Samples	Downgradient Range ($\mu\text{g/l}$)
Volatile Organic Compounds/GCMS				
Benzene (C_6H_6)	4	406-3400	4	36.0-3000
Bicycloheptadiene (BCHPD)	2	18.0-74.0	4	2379-9500
Carbon Tetrachloride (CCl_4)	1	230.0		
Chlorobenzene (ClC_6H_5)	2	1,073-35,000	2	194.0-209.0
Chloroform (CHCl_3)	3	6.0-250	4	30.0-2000
Dibromochloropropane (DBCP)			21	5330.0-229,000
Methylisobutyl Ketone (MIBK)	3	10.0-7200	3	130.0-3063
Xylene (XYLEN)	1	12.0	1	7.0
Tetrachloroethene (TCLEE)	4	317.0-15,000	4	3.0-640.0
Toluene (MEC_6H_5)	4	320.0-1200	4	254.0-2600
Dichloroethene (12DCE)	1	690.0		
Trichloroethene (TRCLE)	3	331.0-1500	3	0.40-210.0
Semivolatile Organic Compounds/GCMS				
Aldrin (ALDRN)	3	0.29-3.1	2	0.75-1.58
Chlorophenylmethyl Sulfide (CPMS)	2	89.0 -140.0	1	13.4
Chlorophenylmethyl Sulfoxide (CPMSO)	1	17.0	3	21.5-32.3
Chlorophenylmethyl Sulfone (CPMSO ₂)	3	20.9-28.2	4	20.1-350.0
Dibromochloropropane (DBCP)	2	4.5-7.74		
Dicyclopentadiene (DCPD)	1	330.0	13	400.0-84,200
Dieldrin (DLDRN)	2	0.325-0.355	3	1.26-820.0
Diisopropyl methyl Phosphonate (DIMP)	1	33.5	8	3.0-6600
Dimethylmethyl Phosphonate (DMMP)	2	12.6-45		
Dithiane (DITH)	1	1.96		
Endrin (ENDRN)	2	1.40-5.9	2	0.71-1.53
Hexachlorocyclopentadiene (HCPD)	1	0.468		
Isodrin (ISODR)	1	0.252	2	2.0
Organochlorine Pesticides (GCEC)				
Dichloroethane (PPDDE)	1	0.86		
Trichloroethane (PPDDT)	2	0.790-1.5		
Organosulfur Compounds/GCFID				
Dimethyldisulfide (DMDS)	2	3.16-140		
Metals/ICP				
Copper (Cu)	1	44.8		
Zinc (Zn)	1	24.2		
Separate Analyses/AA				
Arsenic (As-total)			2	23,400-59,300
Arsenic (As-filtered)			2	0.0058-0.0063
Mercury (Hg)			1	29.0

Sources: D.P. Associates, Inc. 1986
D.P. Associates, Inc. 1989b

(11111C02-3100) (8-28-89) (RMA)

TABLE 2-3

CHEMICAL AND PHYSICAL PROPERTIES OF ORGANIC ANALYTES IN THE M-1 SETTLING BASIN AREA

Compound	Reference	Physical State (20°C, 1atm)	Density (g/ml)	Aqueous ^a Solubility (mg/l) (20-25°C)	Vapor ^b Pressure (mm Hg) (20-25°C)	Henry's Law ^c Constant (atm m ³ /mol)	Partition ^d Coefficient Log (K _{OW})	Partition ^e Coefficient Log (K _{OC})
<u>Volatile Hydrocarbons</u>								
Bicycloheptadiene	Ebasco, 1989	liquid solid	0.91	228	50	2.6x10 ⁻²	1.98	19
Dicyclopentadiene	Ebasco, 1989		0.98	19.4	1.7	1.0x10 ⁻²	3.14	2.99
<u>Semivolatiles Halogenated Organics</u>								
Hexachlorocyclopentadiene	Ebasco, 1989	liquid	1.7	1.59	0.08	6.8x10 ⁻²	5.04	4.06
<u>Organochlorine Pesticides</u>								
Aldrin	Ebasco, 1989	solid	1.75	0.021	6.6x10 ⁻⁵	5.3-7.4	4.67	
Dieldrin	Ebasco, 1989	solid		0.084	1.78x10 ⁻⁷	3.5-6.2	3.86	

Notes:

- a The geometric mean of multiple values was tabulated.
- b Where available, values reported by USEPA, 1982 were tabulated. If a USEPA value was not available, the geometric mean of reported values was presented.
- c Where available, values reported by the USEPA were tabulated. If a USEPA value was not available, the geometric mean of reported values was presented.
- d If available, the octanol/water partition coefficient reported in Ebasco, 1989 (forthcoming) was reported. If more than one value was reported, the range of reported values was tabulated.
- e If available, the organic carbon partition coefficient reported in Ebasco, 1989 (forthcoming) was reported. If more than one value was reported, the MLE value calculated by Ebasco, 1989 (forthcoming) was tabulated.

TABLE 2-4
M-1 SETTLING BASINS
DESIGN BASIS

Site Characteristics

	<u>Units</u>	<u>Estimates</u>	<u>Maximum</u>
Perimeter	Ft	830	910
Surface Area	Ft ²	34,500	46,200
Depth of Contamination	Ft	7	10
Depth of Groundwater	Ft	8-9	10
Depth of Confining Layer	Ft	18	18
Volume	Yd ³		
Sludge		6,400	6,400
Soil		2,600	10,700
Total		9,000	17,100

Sludge Characteristics

Gray-to-white, very wet silty clay like material
Density: 1.35 tons/yd³

Soil Characteristics

Gravelly-to-silty sands, with lesser amounts of clayey sand to silty sand
Density: 1.5 tons/yd³

<u>Contaminant</u>	<u>Soil Geometric Mean (ug/g)</u>	<u>Sludge Geometric Mean (ug/g)</u>
Volatile Organic Compounds/GCMS		
Methylene Chloride (CH ₂ CL ₂)	3.5	3.7
Bicycloheptadiene (BCHPD)	235	45
Semivolatile Organic Compounds/GCMS		
Aldrin (ALDRN)	8	
Dicyclopentadiene (DCPD)	1340	8
Dieldrin (DLDRN)	4	
Hexachlorocyclopentadiene (CL ₆ CP)	3000	
Isodrin (ISODR)	10	
Metals/ICP		
Cadmium (Cd)	3.6	22.9
Chromium (Cr)	11.9	9
Copper (Cu)	12.6	17.7
Lead (Pb)	26.5	42.7
Zinc (Zn)	61	35.1
Separate Analyses/AA		
Arsenic (As)	78	38300
Mercury (Hg)	6	2550



3.0

IDENTIFICATION AND EVALUATION OF INTERIM ACTION TECHNOLOGIES

This section develops the interim action objectives and identifies potential interim action technologies specific to the M-1 Settling Basins at the Rocky Mountain Arsenal (RMA). The interim action objectives are site-specific goals for treating the soil and groundwater to protect human health and the environment. As the preliminary step to identifying IRA alternatives, potentially applicable technologies for interim response actions are identified, described, and evaluated in terms of their general effectiveness. Acceptable technologies are presented in Section 4.0 for evaluation as interim alternatives.

3.1 DEVELOPMENT OF INTERIM ACTION OBJECTIVES

Interim action objectives facilitate achieving site-specific goals for protecting human health and the environment. These objectives provide a basis to measure the potential effectiveness of the interim response action alternatives presented in Section 4.0.

3.1.1 Soil and Sludge

The interim response action objectives related to contaminated soil and sludge at the M-1 Settling Basins are to:

- control migration of soil contamination to the groundwater;
- provide for overall protectiveness of human health and the environment;
- provide short-term and long-term effectiveness;
- select interim alternatives having acceptable implementation; and

- select a cost-effective interim action that, to the maximum extent practicable, meets ARARS.

3.1.2 Water

It is assumed that IRA alternatives involving excavation activities would occur when the water table is at a low point and would not interfere with the excavation. If, for any reason, this would not be possible, groundwater containing contaminants may be encountered. These contaminants appear to be originating from the South Plants area. Water treatment would only be conducted as part of a dewatering operation required for a soil/sludge treatment. The objective of this interim response action is source containment, removal, or treatment. Groundwater remediation is assumed to be beyond the scope of this IRA.

The specific interim objective for water treatment at the M-1 Settling Basins is to provide an unsaturated soil, if necessary to implement a soil treatment alternative. If some dewatering and subsequent water treatment processes do prove to be necessary, the objectives will be to:

- provide for short-term effectiveness;
- select interim alternatives with acceptable implementation; and
- select a cost-effective interim action that, to the maximum extent practicable, meets ARARS.

3.2 IDENTIFICATION AND EVALUATION OF TECHNOLOGIES

This section identifies and evaluates interim response action technologies applicable to the M-1 Settling Basins. Tables 3-1a and 3-1b list general response actions and technologies typically applied to contaminated soil and water, respectively. Each technology is evaluated as being applicable or not applicable, based on the site-specific and contaminant-specific conditions at the M-1 Settling Basins.

The technologies remaining after the initial evaluation in Tables 3-1a and 3-1b which require further description are discussed in detail in this section. Focus is placed on the technical performance, operational reliability, and implementation of each technology. Several technologies are eliminated from further consideration at this point. Tables 3-2a and 3-2b summarize this discussion and identify technologies that are used in the alternatives evaluated in Section 4.0.

CERCLA guidance (EPA 1988) suggests the selection of no more than ten or eleven alternatives. The alternatives should include a mix of institutional controls, containment, in-situ treatment, on-site treatment technologies, as well as on-site and off-site disposal. This suggested mix of technologies was applied in selecting the alternative technologies discussed in Section 4.0.

This section is organized by general response action. Technologies are introduced with respect to their applicability to address a particular general response. These general response actions include monitoring, institutional controls, containment, source collection, treatment, and disposal.

3.2.1 Monitoring

Monitoring of the M-1 Settling Basins would consist of periodic sampling of upgradient and downgradient groundwater monitoring wells. Groundwater would be analyzed for the organic and inorganic compounds that have been detected in the sludge and contaminated soil in the vicinity of the M-1 Settling Basins. The

resulting historical data base, augmented by current and future monitoring, would provide an indication of whether the M-1 Settling Basins are a continuing source of groundwater degradation in the time between the implementation of this interim response action (IRA) and the overall site remediation.

Monitoring is a feasible technology for the apparent relatively immobile compounds present at the M-1 Settling Basins and will be retained for further evaluation.

3.2.2 Institutional Controls

While not a technology, institutional controls are incorporated into the assessment as a variation of the no action alternative. Institutional controls would be applicable in the case of no-action, on-site storage or landfill, capping-in-place, or other interim alternatives which result in leaving contaminated materials on-site that could be compromised by future excavation or construction activities.

Since a fence and guard post are used to secure the arsenal, site access restrictions are in place to some extent. Additional restrictions, such as fencing around the perimeter of the M-1 Settling Basins, would be feasible. This alternative will be retained for further evaluation.

3.2.3 In-place Containment

Five technologies are identified as either source containment or associated with source containment measures:

- Capping
- Dikes and berms
- Slurry walls
- Grout curtain
- Sheet piling

3.2.3.1 Capping

Capping is a process used to cover buried waste materials to prevent their contact with the land surface and surface water. Substantive performance standards for caps must conform with 40 CFR Part 264.310, which describes Resource Conservation and Recovery Act (RCRA) Landfill Closure Requirements. As described there, a cap consists of a compacted clay layer, a synthetic geomembrane liner, a sand drainage layer, and a surface layer of vegetated topsoil, asphalt, or rock. For short-term implementation, non-conforming caps are sometimes applicable. These consist only of a compacted clay layer beneath a surface layer of either vegetated topsoil, asphalt, concrete, or rock.

Surface caps must be sloped to provide rapid surface drainage away from the contaminated areas. Collection systems may be incorporated into surface caps; however, this is generally not necessary if high concentrations of mobile contaminants are not present. The technology required to implement this alternative is commonly used for in-place closure of contaminated soils or in conjunction with confinement of contaminated groundwater.

Capping is effective in minimizing the leaching of contaminants from the soil profile above the groundwater table. However, waste materials below the water table will still be transported by groundwater migration. Supplementary groundwater control measures are generally required to remediate soil contamination below the groundwater table.

Surface-capping technology will be retained for more detailed analysis and evaluation since it is relatively economical to implement, is technically feasible and, when used in conjunction with other groundwater measures, can be effective in reducing contaminant leachate production from near-surface soils.

3.2.3.2 Dikes and Berms

Dikes and berms are well-compacted earthen ridges constructed immediately upslope from or along the perimeter of a disposal site. These structures are generally designed to provide short-term protection of critical areas by intercepting storm run-off and diverting the flow to natural or man-made drainage ways.

Dikes and berms are widely used as temporary structures (normally one year) to provide isolation of wastes until they can be removed. They are usually limited to a maximum area coverage of five acres.

This technology will be retained for more detailed analysis and evaluation because it is a cost-effective, technically feasible method of preventing surface runoff from impacting remediation operations at the M-1 Settling Basins.

3.2.3.3 Slurry Walls

A slurry wall is a vertical, low-permeability wall, typically constructed of a soil-bentonite mixture, which is placed in a trench kept open by a slurry (bentonite-water mixture). The trench is typically 2 to 3 feet wide and is usually keyed into a low-permeability basal unit. A surface capping system is generally constructed in conjunction with the slurry wall.

At this site, the relatively shallow depth of the Denver Formation, which appears to be a suitable stratum for effective containment of downward migration of contamination, is favorable for economical soil-bentonite slurry wall construction. Excavation to the depth for the desired key into the Denver Formation could be accomplished in a single stage by using a backhoe or similar excavation equipment. Slurry wall construction has been performed successfully on other projects under similar conditions and is an accepted method for groundwater or soil contamination containment.

The technology required for slurry wall construction is commonly used in containment of hazardous waste sites. Because of the shallow depth to a low-

permeability stratum and generally favorable soil conditions, this technology will be retained for more detailed analysis and evaluation. It is relatively economical to implement, is technically feasible, and may be used in conjunction with a surface capping system or other groundwater control measures as an effective measure of reducing contaminant migration.

3.2.3.4 Grout Curtain

Grout curtains are subsurface barriers created in unconsolidated materials by pressure injection. Grout curtains are generally more expensive than slurry walls and their ability to develop a continuous low-permeability barrier is questionable. It has been shown that occasionally, as a result of grout shrinkage and erratic movement of the grout through the soil pores, large voids may remain. Sandy soils present at the site could require large volumes of grout, making this alternative potentially very expensive with less control of barrier wall continuity compared to a soil-bentonite slurry wall. For these reasons, this technology is eliminated from further consideration.

3.2.3.5 Sheet Piling

Sheet piling cut-off walls may serve as a groundwater barrier to redirect groundwater flow. Such cut-off walls may be used to redirect or contain groundwater to eliminate contact with contaminated materials and/or to prevent contaminated groundwater and waste material from migrating off-site. Of the three available materials for sheet pilings (wood, precast concrete, and steel), steel is the most efficient and cost-effective groundwater barrier.

The installation of a steel sheet piling cut-off wall requires that the pilings be assembled at their edge interlocks before being driven into the ground. The piles are then driven a few feet at a time over the entire length of the wall, using either a pneumatic or steam pile driver, until the appropriate depth is obtained.

Initially, steel sheet piling cut-off walls are quite permeable; the edge interlocks must be loose to facilitate the driving process, and to allow water to pass through them easily. Eventually, fine soil particles may adhere within the seams and the wall becomes less permeable to groundwater flow. In very coarse, sandy soils the wall may never seal unless the piling seams are first grouted, which adds to the overall cost. Corrosion of the steel from chemical exposure due to soil and groundwater contaminants can be reduced by the use of galvanized steel or other steel coatings at an increased cost; however, driving operations may damage the coating material. In general, steel sheet piling cut-off walls tend to be more expensive and probably less effective than slurry walls. Therefore, the use of sheet piling cut-off walls is not considered a feasible interim action technology and is eliminated from further consideration.

3.2.4 Source Collection

Excavation of contaminated soils is a standard approach to source collection at hazardous waste sites. Excavation is a prerequisite to disposal of soils in a landfill (on-site or off-site) or treatment, and is also required for some methods of soil washing or chemical fixation. Typically, excavation depths are limited to the depth of the groundwater table. Since the depth to the water table at the site varies during the year, scheduling of the excavation operations during the low water table season would be appropriate.

Temporary excavations will typically be performed with side slopes of 1 vertical to 1 horizontal (1:1) to protect workers and equipment within the excavation in accordance with Occupational Safety and Health Administration (OSHA) requirements. This technology will be retained for further evaluation.

3.2.5 Treatment

The contaminated soils and sludges at the M-1 Settling Basins can be treated to reduce their mobility, toxicity, and volume. This treatment may be physical, chemical, biological, or a combination. This treatment can be accomplished with or without source collection methods described in the previous section. Treatment methods not requiring source collection are called in-situ methods and are described in subsection 3.2.5.1. On-site treatment methods are described in subsections 3.2.5.2 and 3.2.5.3. Off-site treatment technologies are discussed in subsection 3.2.5.4.

3.2.5.1 In-situ Treatment Technologies

Three technologies are identified as in-situ treatment measures:

- In-situ vitrification
- In-situ chemical fixation
- In-situ soil washing

3.2.5.1.1 In-situ Vitrification. In-situ vitrification is a thermal treatment process that consolidates contaminated soils into a hard, impermeable, stable glass and/or crystalline product. The process passes an electric current among four electrodes placed in the ground in a square array. Heat from the electric current melts the soil and rocks and pyrolyzes organic materials. During the process, metallic and other inorganic materials are dissolved into or encapsulated in the vitrified mass. The system reaches up to 3600°F, well above the 2000°F to 2500°F fusion temperature of soils. Since soil is not electrically conductive once the moisture has been driven off by initial heatup, a conductive mixture of flaked graphite and glass frit is placed between the electrodes as a "starter path." As the graphite is consumed, the current is transferred to the molten soil which becomes progressively more conductive. When the electric current is cut off, the molten volume cools and solidifies. Because of the intense chemical and structural changes, subsidence accompanies cooling and some backfilling and regrading are required.

The process generates considerable gases from volatile constituents in the soil and by-product gases from pyrolysis of larger organic molecules. The gases and by-products migrate to the surface of the vitrified zone where they combust in the presence of oxygen. A gas collection hood and off-gas treatment system control gas emissions.

The process has been applied at both bench- and field-scale on electroplating wastes, dioxin waste, and a waste pile of mixed containerized organic wastes. The typical field-scale energy consumption ranges from 500 to 1,000 kW per 100 tons of waste. This technology may possibly be effective and will be evaluated further.

3.2.5.1.2 In-situ Chemical Fixation. Chemical fixation technology for either metal or organic contaminants is potentially available without excavation of soils. At least one supplier has demonstrated a pilot-scale system to drill and blend waste material in place with a fixative or bonding agent. The process consists of drilling into the waste or soil with a boring rod with two liquid channels. While the rod is being lifted, bonding agents supplied by grout pumps are injected through the channels and mixed, eventually setting into a vertical cylindrical column of impermeable inorganic crystalline or cemented material.

This technique is still in the experimental stage and the test system has been designed for an organic contaminated soil. No demonstration is available for metals which are present at the M-1 Settling Basins. Therefore, this technology has not been selected for further evaluation based on the above considerations.

3.2.5.1.3 In-situ Soil Washing. In-situ soil washing has been applied at the test or pilot level for both organic and metal contaminated soils. The process consists of saturating the contaminated zones with chelate, solvent, or diluent via injection wells, and collecting the introduced fluid and entrained contaminant via a second series of wells, producing a washing circuit.

Several potential problems may be encountered with this approach. First, the chelate or solvent, by rendering the contaminants soluble, may spread the contamination if the collection system is not completely effective. Second, because of the uncertainties of distribution patterns, large quantities of solutions must be applied. Third, contact patterns and residence time are less certain than in an above-ground system. For these reasons, in-situ soil washing is not retained for further consideration.

3.2.5.2 On-site Soil and Sludge Treatment Methods

Three technologies are identified as on-site treatment measures for contaminated soil and sludge:

- Chemical fixation/stabilization
- Soil washing/solution mining
- Vitrification

3.2.5.2.1 Chemical Fixation/Stabilization. Chemical fixation/stabilization refers to treatment methods that surround or encapsulate waste components in a stable inorganic matrix. The treatment additives are selected to:

- minimize contaminant spread by agglomerating the wastes and reducing the transfer surface area;
- reduce the solubility, toxicity, or mobility of hazardous components; and
- solidify or otherwise improve the handling or structural characteristics of the waste.

Stabilization generally refers to those processes that add materials to change the pH, limit the solubility or mobility, or otherwise chemically alter the environment around the contaminant molecule. This process may solidify the

waste or contaminated soil, or may leave it either friable or close to its original consistency after treatment.

Chemical fixation involves applying additives of the type and quantity that will produce a monolithic block of high structural integrity or a friable product. This process produces a stable inorganic polymer lattice that incorporates the contaminants in the chemical structure of the lattice.

Chemical fixation/stabilization can be accomplished by various means; most are referred to in terms of the additives used to treat the waste. The two approaches discussed herein are the cement process and the pozzolanic silicate process. Both processes will require a solids-handling operation consisting of the following basic steps:

1. Excavation of contaminated soils
2. Temporary storage on a pad on-site
3. Blending with additives in a high shear mixer or pug-type mill
4. Reaction time in a solidification cell
5. Replacement into either the excavation pit or a landfill

3.2.5.2.1.1 Cement Process. The cement process is based on the addition of primarily portland cement or other cementitious materials and water, which will mechanically incorporate waste components into a rigid matrix when it cures. However, many wastes, especially organic contaminants remain leachable from the cured cement since they are not chemically bound. This process elevates the bulk pH to a level at which most metal ions are in the insoluble hydroxide or carbonate form. The actual cement matrix is a calcium-silicate hydrate.

The metal salts are not stable over a wide pH range and potentially even precipitation is acidic enough to initiate leaching. This process, when used alone, is generally not effective on some metal salts such as salts of lead, copper, and zinc. Hence, the cement process is usually used in conjunction with other processes as a final hardening agent.

3.2.5.2.1.2 Pozzolanic Silicate Process. The pozzolanic process forms a matrix from fine ground siliceous materials such as fly ash, blast furnace slag, or kiln dust with calcium oxide or gypsum and water. Silicate content is often augmented by addition of solutions of sodium or potassium silicate. As with the cement process, this process increases the weight and volume of the waste. However, depending on additive ratios, the product consistency may remain clay-like to friable rather than a cemented solid.

This system has been applied to both divalent metal contaminants and organic contaminants in field-scale remediations. This system is effective in binding heavy metals because they chemically react with the silicate materials as the initiators of the gel or setting process. The presence of oil and grease may interfere with the reaction, as do some sulfates, dichromates, and carbohydrates. Oil and grease are not expected to be factors in the treatment at the M-1 Settling Basins.

Both cement and pozzolanic processes utilize readily available materials and conventional mixing equipment. Some combinations of chemical fixation or stabilization methods will be evaluated further.

3.2.5.2.2 Soil Washing/Solution Mining. Soil washing, also referred to as solution mining when performed as a batch operation, consists of mixing contaminated soil with a chelating agent or solvent to dissolve and remove the entrapped metals and organics. In the batch process, a tank or plastic-lined pit is filled with excavated soils in a working pile or heap. The pile is sprayed and flooded with the treatment solvent or chelate and the leachate collected and recycled. The solution is recycled until the contaminant concentrations in both the soil and the treatment solution are equal, and no further extraction from the soil will occur. The solution is then diverted and solids extracted via vacuum filtration or other dewatering process. The remaining liquids are either processed for reuse or chemically or thermally destroyed. The filtrate sludge is suitable for recycling in a smelting furnace for recovery of the metal constituents and thermal destruction of any organic content. The solution process significantly reduces the volume of metal-bearing

solids to a smaller amount more economically and safely transported to an off-site recovery treatment/disposal facility.

The batch process can be carried out completely on site except for any smelter recovery step. This process has been applied to ore piles in the precious and commercial metals industry and is referred to as "heap leaching."

Soil washing can also be conducted as a continuous process by utilizing a froth flotation. In this application, the soils are screened prior to the addition of cleansing agents and water to form a slurry. This slurry is routed to parallel flotation cells. The contaminated froth is drawn off the top and the slurry is pumped to wet-scouring tanks for a final water rinse. The cleaned slurry is then dewatered by filtration, leaving a soil that can be returned to the site or disposed of as clean fill. The contamination is collected in the form of a concentrated sludge, which can be incinerated or landfilled. This process configuration is usually applied to organics-contaminated soil. This process has been conducted on a bench- and pilot-scale in Europe with excellent removal efficiencies reported on soils with concentrations of contaminants in the range of those at the M-1 Settling Basins ("Procestechnologie, Heidemij Uitvoering," Brochine, undated). This process can also be applicable for metals removal. However, the process configuration for metals removal is normally a counter current decantation process. This approach offers the possibility of addressing both metals and organics.

The waste material in the M-1 Settling Basins has been shown to have an alkaline pH. An excessive amount of acid would be required to dissolve the calcium salt and reduce the pH before the metals could be solubilized and washed from the soil, making soil washing an inefficient method of treating the M-1 Settling Basins waste. There is also the possibility that arsine gas may be formed during this process. Therefore, this process will not be considered further.

3.2.5.2.3 Vitrification. Vitrification is a thermal treatment technology used to transform the physical and chemical characteristics of a hazardous solid waste so that the organic contaminants are destroyed and treated residues contain primarily inorganic hazardous material immobilized in a vitreous mass. Vitrification can be applied in-situ, as described in Section 3.2.5.1.1, or above ground as described herein. Inorganic contaminants should remain entrained in the glass melt, while any organic compounds are oxidized at the reactor temperature of approximately 3000°F.

The reaction chamber is divided into upper and lower refractory-lined sections. The upper section accepts the waste feed via gravity and contains gases and other products of pyrolysis; the lower section contains a two-layer molten zone for both the metallic and siliceous melts. The feed is gravity fed into the reactor by conveyor. The off-gas and particulates are drawn off by an induction fan to an off-gas treatment system. This system usually consists of a cyclone, baghouse, acid gas scrubber, and if necessary, a carbon filter. Particulate and gas streams, as well as the carbon filter, can be recycled to the reactor.

There are several vitrification processes currently available; each has characteristic reaction conditions (e.g. temperature, oxygen content), and solids-handling methods. One vitrification process is commercially available in full-scale operation. However, this process has not been applied to volatile metals and the vendor currently has no plans to modify the process to treat volatile metals. Therefore, this technology will not be retained for further evaluation.

3.2.5.4 Off-site Treatment

One technology, chemical fixation/stabilization, is identified as an off-site treatment measure.

3.2.5.4.1 Off-site Chemical Fixation/Stabilization. To reiterate, chemical fixation/stabilization refers to a treatment method that surrounds or

encapsulates waste components in a stable inorganic matrix. To utilize this option off-site would involve the following basic steps:

1. Excavation of contaminated soils and sludges
2. Transportation to a treatment facility
3. Blending with additives in a high shear or pug-type mill
4. Reaction time in a solidification cell
5. Burial in an existing commercial RCRA-landfill

This process utilizes readily available materials and equipment, is technically feasible, and will be considered further.

3.2.6 Disposal

Soil, concentrated sludges, and other solid wastes may require disposal before or after treatment. This disposal can be either on site or off site at a properly permitted facility. This section evaluates technologies for the disposal of soils, sludges, and other solid waste.

3.2.6.1 On-site Disposal

Two technologies have been identified for on-site disposal of solid waste:

- Hazardous waste landfill
- Solid waste landfill

3.2.6.1.1 Hazardous Waste Landfill. Solid wastes that have been classified as hazardous under 40 CFR Part 261 are required to be disposed in a landfill which substantially complies with the requirements of 40 CFR 264, Subpart N. EPA guidelines for landfills establish both the types of sites and the design requirements for such a facility. Design requirements presently include double liners, leachate collection and treatment, capping, surface water control, and a groundwater monitoring system.

Since the site does have sufficient open-land area, this technology will be considered further as an interim action.

3.2.6.1.2 Solid Waste Landfill. The selected soil/sludge treatment technology may be effective in declassifying the material as hazardous as defined in 40 CFR Part 261. Therefore, hazardous waste storage requirements would be unnecessary. On-site solid waste disposal in a facility designed to meet EPA's solid waste landfill requirements will be considered further.

3.2.6.2 Off-site Disposal

Two alternative methods are available for off-site disposal of soils/sludges:

- Disposal in a Class I landfill
- Disposal in a Class III landfill

3.2.6.2.1 Disposal in a Class I Landfill. Contaminated soils and sludges or treated solid waste streams from treatment processes can be disposed of off-site in a commercial Class I landfill. The nearest, fully-permitted Class I facility to RMA is the USPCI Grassy Mountain landfill outside of Clive, Utah. Off-site disposal will require excavation and management of groundwater through one or more of the treatment technologies described in a previous section. Since this is a feasible technology, it will be further evaluated.

3.2.6.2.2 Disposal in a Class III Landfill. Nonhazardous solid wastes from soil/sludge treatment processes can be disposed of in a nonhazardous Class III landfill. Several of these exist in the area. Disposal at a facility with less stringent controls than Class I will require that the waste transported off site be delisted and considered nonhazardous. Since there will be some nonhazardous debris generated in these operations, this will be considered a feasible technology and will be evaluated further.

3.2.7 Dewatering and Water Treatment

As discussed in Section 3.1.2, water treatment would only be conducted as part of a dewatering operation required for a soil/sludge treatment. It has been assumed that the chosen IRA alternative can be implemented during the dry season, which would make dewatering and water treatment unnecessary. If this is impossible, the following dewatering and water treatment alternatives will be considered.

3.2.7.1 Dewatering Process

Contaminated soils/sludges can be dewatered by using one or more of the following processes:

- Pumping from wells
- Pumping from collection trenches excavated below the water table
- Excavation and filtration

3.2.7.1.1 Groundwater Well Pumping. Groundwater pumping techniques involve the active manipulation and management of groundwater to contain or remove a plume or to adjust groundwater levels to prevent the formation of a plume. At the M-1 Settling Basins, the objective is to lower the contaminated groundwater table a sufficient depth to allow for effective soil remediation. This soil remediation method may be in-situ or may require excavation. In either case, the presence of groundwater may limit the effectiveness of the chosen methods. Types of wells used in the management of contaminated groundwater include wellpoints, suction wells, ejector wells, and deep wells. The selection depends on groundwater depth as well as the hydrologic and geologic characteristics of the aquifer.

This method of groundwater control will be retained for more detailed analysis and evaluation since it is a technically feasible method of dewatering the soil beneath the M-1 Settling Basins.

3.2.7.1.2 Subsurface Drains

Subsurface drains are usually any type of buried conduit used to convey and collect aqueous discharges by gravity flow. They create a zone of influence much like an extraction well. Drains have distinct advantages over wells for use in shallow aquifers, such as at the M-1 Settling Basins. Pumping on a shallow well field in strata of low or variable hydraulic conductivity can be problematic if a continuous hydraulic boundary is necessary. Also, operation and maintenance costs are generally lower for drains with respect to wells.

The main components of a drainage system are a drain pipe for conveying flow to a wet well, a gravel pack around the drain pipe, a filter to prevent clogging (if fines are a problem), backfill, and a manhole or wet well for groundwater collection and pumping.

This method of groundwater control will be retained for more detailed analysis and evaluation since it is a technically feasible, potentially cost-effective method of dewatering the soil beneath the M-1 Settling Basins.

3.2.7.1.3 Filtration. Soils and sludges can be dewatered after excavation by using a couple of techniques. Soils are allowed to drain within a bermed area after excavation. The drained water is collected in a low-point sump for subsequent water treatment. This is effective for removing only a fraction of the associated groundwater but may be applicable for processes requiring water, for example, chemical fixation/stabilization.

If the excavated solids require a greater level of dewatering for subsequent processing, this can be accomplished by using a vacuum filter. This filtration operation can be run in a batch or continuous mode. In a continuous mode, the soil/sludge is fed through a hopper and a rotating drum equipped with a cloth filter media. A vacuum is drawn on the interior of the drum which pulls water through the cloth media. The dried soil/sludge is then separated from the cloth media either by a stationary knife or by gravity.

This type of filtration can typically produce a dried sludge with water content as low as 10 percent. This technology is feasible for alternatives that required significant dewatering prior to solids processing, and will be retained for further evaluation.

3.2.7.2 Water Treatment Processes

Historical information and data from the spring 1989 investigation indicates that groundwater in the vicinity of the M-1 Settling Basins contains many of the organic and inorganic compounds detected in the South Plant's area. Predominant classes of groundwater contaminants include arsenic, mercury, organochlorine pesticides, volatile organic compounds, and semivolatile organic compounds. Whether or not the M-1 Settling Basins contribute to this aquifer degradation does not affect the conclusion that this water, once extracted, will require treatment prior to either reinjection or disposal. The following alternatives for water treatment will be discussed in this section.

- Carbon adsorption
- Rotating biological contactor
- Fixed-bed bioreactor
- Powdered activated carbon/activated sludge
- Ultraviolet-enhanced chemical oxidation
- Chemical precipitation/flocculation
- Ion exchange
- Activated alumina

3.2.7.2.1 Carbon Adsorption. Granular activated carbon (GAC) adsorption is commonly used for removal of organics from water. The removal efficiency depends

on factors such as the polarity, solubility, and size of the molecules to be removed. The adsorption occurs in packed columns with flow rates and contact times determined by properties of the contaminants to be removed.

The carbon must be regenerated when saturated or when the effluent reaches unacceptable levels of contaminants. At these times, the bed of carbon is removed from the packed column and replaced with new material. The saturated carbon is thermally treated in a regeneration furnace for destruction of adsorbed organic compounds and reused. Poor adsorbability or higher contaminant concentrations result in frequent regenerations.

The volatile halogenated organics present in the alluvial aquifer in the vicinity of the M-1 Settling Basins (see Section 2.0) are among the least sorbable species with reference to GAC. Carbon adsorption of these compounds from the groundwater would result in breakthrough of the carbon beds by one or more species long before the carbon was saturated. This would result in frequent carbon changeout producing large volumes of waste solids for regeneration or disposal. For this reason, GAC will not be considered further.

3.2.7.2.2 Rotating Biological Contactors. Rotating biological contactors (RBC) are considered for groundwater treatment because of their relatively low energy use and simple operation. An RBC system consists of a series of disks covered with a film of active biomass that is partially submerged in the wastewater. Disk rotation alternately exposes the attached biomass to the substrate-rich wastewater and to the atmosphere. Substrate (including hazardous constituents), measured as soluble biochemical oxygen demand or chemical oxygen demand (BOD_5 or COD), is oxidized and converted to a new biomass, soluble metabolic by-products, and gaseous end products. Sequential groups of disks, called stages, are designed to meet specific effluent requirements based upon soluble BOD removal in each stage.

Important controlling factors of the RBC system are influent substrate concentration, surface hydraulic load, disk rotational speed, effective disk surface area, submerged disk depth, liquid retention time, wastewater treatment

temperature, and number of stages. Therefore, the prediction of achievable effluent concentrations from an RBC wastewater treatment system is difficult because of the number of the process operating parameters.

Studies indicate the RBC process for municipal wastewater is approximately first order with respect to BOD concentration; that is, the rate of bio-oxidation is proportional to the amount of oxidizable organic matter remaining. The design of the standard municipal RBC process is primarily based on the hydraulic loading rate (gal/day/ft²) and the organic loading (lbs BOD/day/ft²). Temperature can affect performance of the fixed-film process, as it influences substrate removal rates, oxygen saturation values (also mass transfer driving forces), and the diffusivities of oxygen and substrate. At wastewater temperatures of 13°C (55°F), changes in hydraulic or organic loading have been shown to result in significant changes in BOD removal.

The staging of RBC units is a major design element. The simulation of plug flow operation by proper staging results in a higher treatment efficiency. RBC facilities are typically designed with four or more stages operating in series depending on the substrate removal desired.

General Advantages of an RBC System:

- Simple operation and maintenance
- High resistance to shock and hydraulic loading
- Successful operation with or without air supply
- Low-sludge production with good sludge settleability and dewaterability
- Low-power consumption
- Low-heat loss

Major Disadvantages of an RBC System:

- It does not address the arsenic in the groundwater (arsenic may be toxic to biomass).
- The technology is relatively unproven for the conditions at RMA.
- Engineering costs are higher because of the process development studies required (i.e., pilot studies).

Since an RBC does not significantly reduce the arsenic concentration in the water, it would have to be used in conjunction with another treatment step design to reduce arsenic concentrations to acceptable discharge levels. Although the technology will require process development studies, it will be retained for further consideration.

3.2.7.2.3 Fixed-Bed Bioreactor. Conventional, flow-through aeration basins (lagoons and tanks) are of limited effectiveness in biodegradation of low concentration influent waters. The primary limitation consists of the inability of microorganisms to find sufficient organic substrate to feed upon in a high-volume, low-concentration system, i.e., insufficient contact between biomass and contaminants.

Fixed-bed bioreactors are adaptations of aerobic bioreactors that allow the processing of diluted wastewaters. A fixed-bed reactor consists of one or more tanks or vessels fitted with a high surface area plastic or other fill material, which is baffled or compartmentalized to reduce throughput velocity and maximize retention time. Microorganisms are seeded at a startup with nutrients and carbohydrate solution to encourage initiation of a biomass growth on the fill material surface. Feedwater undergoes intimate contact with the fill surfaces over a long enough time period to allow microbes to locate and degrade contaminant molecules. Aeration is augmented by bottom spargers or diffusers.

Fixed-bed systems are available in modular portable tank systems with built-in aerators and fill media, allowing relatively simple mobilization/ demobilization. These systems have been effective at several large-scale groundwater remediation sites. This technology will be considered further as part of an overall groundwater treatment system, though other steps will be required for arsenic removal.

3.2.7.2.4 Powdered Activated Carbon/Activated Sludge. Powdered activated carbon (PAC) addition to a conventional activated sludge wastewater treatment system can significantly improve the performance of the system because removal of recalcitrant organic compounds is improved. Biological treatment of municipal and industrial wastewater is a well-proven technology. However, process performance can be detrimentally affected by low organic loading and the presence of refractory compounds that may pass through the system. Addition of a powdered carbon can improve performance by adsorbing these components and providing a longer residence time for biological metabolism. In a biologically active, powdered activated carbon treatment (PACT) system, powdered carbon is added to a conventional activated sludge system. The powdered carbon adsorbs organic contaminants that have not been degraded biologically and is removed from the wastewater in a clarifier. The clarifier underflow is recycled back to the contactor tank, with a small side stream removed for disposal. The spent carbon sludge must be disposed of at an EPA-permitted disposal facility. The spent carbon may also be regenerated on-site using a wet air oxidation process; however, for intermediate water throughput rates (500 to 1,000 gpm), off-site disposal of the spent carbon sludge is more economical.

PACT installations are in successful operation for treatment of municipal, industrial, and mixed municipal/industrial wastes (Zimpro, Inc. 1987). Incineration and/or landfilling of the sludge is employed at a number of these installations.

Ability to vary the PAC dosage gives flexibility to the process. At RMA, the dose could vary with the flow rate or concentration to provide control over

effluent quality. This would enable adjustment of treatment to achieve removal levels necessary for compliance with POTW limitations.

The advantages of this treatment method are:

- Fast rate of adsorption
- Easy-to-control removal efficiency
- Lower carbon requirement than GAC

Disadvantages of this treatment technology are:

- High capital costs
- Problems with the handling of spent carbon sludge
- Does not remove arsenic

In general, the treatment efficiency of a PACT system approximates that of other biological treatment processes. However, the PACT approach generates a considerably larger quantity of secondary waste, i.e., sludge, to achieve comparable treatment results. Based on the availability of equivalent treatment technologies generating less waste, PACT will not be evaluated further.

3.2.7.2.5 Ultraviolet-enhanced Chemical Oxidation. In theory, organic matter in a wastewater stream can be completely destroyed by chemical or thermal oxidation. The by-products of complete oxidation of a hydrocarbon are water and carbon dioxide. Thus, it should be theoretically possible to convert even the most toxic hydrocarbons to innocuous chemicals that would not have adverse environmental effects.

There are many methods of oxidizing organic chemicals. Thermal methods are the most familiar, but they are unsuitable for diluted, high-volume liquid waste streams because of the large energy requirements for vaporizing the bulk liquid. Therefore, for most diluted liquid streams, some method of chemical oxidation is preferred to remove the objectionable components from the wastewater. The most suitable chemical oxidation processes identified for this study were

ultraviolet-enhanced oxidation by ozone or hydrogen peroxide. These processes have been shown to achieve complete destruction of target organics when operated under optimal conditions.

Ozone is a powerful oxidizing agent that has traditionally been used in wastewater treatment systems as a disinfectant and viricide. Ozone is produced when a high voltage is imposed across a discharge gap in the presence of a gas containing oxygen. Because ozone is a relatively unstable gas, it must be generated on site from air or pure oxygen. In a pure oxygen system, off-gases from the ozone contact chamber can be recycled back to the ozone generator for more efficient oxygen use. In an air system, off-gases are usually vented to the atmosphere. Ozone quickly reverts to oxygen in the environment and does not pose a significant environmental impact when used in an air-fed system.

Ultraviolet (UV) light has been shown to markedly increase the rate of oxidation in ozonation reactors treating wastewaters. This is attributed to the higher energy of the ultraviolet light excitation of the organic molecules. Unfortunately, the use of ultraviolet light enhances only the rate of oxidation, but not the efficiency. Thus, the quantity of ozone required will not be reduced appreciably by ultraviolet radiation.

Hydrogen peroxide, when exposed to UV light, readily reacts to form hydroxyl radicals. These radicals are also strong oxidants that can similarly react with organic contaminants in water. The choice of optimal oxidant and operating conditions can only be determined after a bench-scale test. However, the technology is feasible for the destruction of organics in groundwater and will be evaluated further. The selection of an oxidant (ozone or hydrogen peroxide) is addressed later in the selection process. An additional post-treatment step would be required for the metals contamination in the water because ultraviolet-enhanced chemical oxidation does not remove metals.

3.2.7.2.6 Chemical Precipitation/Flocculation. Chemical precipitation/ flocculation involves adding agents to remove the contaminants from solution, followed by sedimentation or other physical separation to remove the resulting

insoluble particles from the water. Chemicals added to remove contaminants from solution either:

- increase or decrease the system pH to a level where the contaminant is less soluble,
- react with the contaminant to form an insoluble salt, or
- shift the solubility equilibrium of the contaminant to make the existing compound insoluble.

Additionally, polymer flocculants are frequently added to help agglomerate the resulting suspended particles into "floc" or larger particles that can be more easily removed by sedimentation, filtration, centrifugation or other mechanical means.

Removal of particulates is generally accomplished by long-residence time sedimentation (settling) in a clarifier. The combination of microfiltration and recycling of the concentrate through the reagent mix portion of the system until large settleable particle size develops is also applied to metal salt systems. Both approaches often require subsequent dewatering operations for reduction of the generated sludges. Dewatering is commonly performed by pressure filtration using either a belt-filter press or a plate-and-frame filter. The final sludge cake (approximately 30 to 50 percent solids) would be landfilled with or without chemical fixation/ stabilization. This technology is technically feasible for metals removal and is retained for further evaluation.

3.2.7.2.7 Ion Exchange. Ion exchange treatment removes selected ions from water by electrochemically collecting them on a polymeric surface containing sites of opposite charge. Systems suited to water treatment generally contain one or more pressure vessels (exchangers) filled with "resin beds" consisting of beads of various polymer resins containing either cationic or anionic sites. When the water or aqueous waste has passed through the beds long enough to saturate the sites, flow is stopped and the beds "regenerated" by contacting with

a regenerate solution (acids, caustic, or other solutions as appropriate) to remove the contaminant ions. The spent regenerate is either processed for reuse, concentrated for recovery of the contaminants, or processed for disposal.

Ion exchange is a potentially feasible technology for the removal of arsenic and will be considered further. Complete removal has been reported (Lenox Institute for Research 1984). However, it should be noted that the resin bed used in the study was a combination of anion and cation exchange resins, since arsenic may exist in several oxidation states.

3.2.7.2.8 Activated Alumina. Arsenic can be adsorbed from a water stream on the surface of activated alumina. Activated alumina is essentially a highly porous form of aluminum oxide. Aluminas are available both as granules and as fine powders; hence they provide a large surface area and adsorptive capacity per unit volume (Considine 1971). This technology is currently in use with granular activated carbon for arsenic removal in the treatment system in Building 1713 at RMA (ESE 1988), therefore it will be retained for further evaluation.

3.2.7.3 Treated Water Disposal

There are three on-site methods of disposal for treated water: reinjection, percolation, and discharge to the RMA treatment plant. Discharge to a storm drain is the only available off-site disposal option.

3.2.7.3.1 Reinjection. The conventional method of injecting fluids or reinjecting extracted water into an aquifer is the use of injection wells screened at strategic depths. However, that injection water will probably be laden with suspended and microbial solids unless it has first been filtered. Filtering can add considerably to total water treatment costs. If the injected water is not filtered, injection well screens are likely to clog readily with solids and will not be dependable for long-term service. In addition, screens provide surface area for microbial growth and may plug, even with fluids that

have been filtered of solids and microbes. For these reasons, this technology will not be considered further.

3.2.7.3.2 Percolation. Discharge water can be pumped or drained over a bed of crushed rock or gravel in order to enhance its percolation through the vadose zone. The percolation bed is a simple technology that is more reliable than injection wells, since it is less susceptible to fouling resulting from microbial growth.

This technology will be retained for further evaluation.

3.2.7.3.3 Discharge to RMA Treatment Plant. Treated water can be routed to the nearest sanitary sewer that discharges to the RMA treatment plant. Discharge requirements would need to be set based on their treatment capacity and capabilities. Discharge limitations to the sanitary sewer usually entail limits on such parameters as pH, temperature, toxic metal content, combustability, and ignitability. However, the ability of the RMA treatment plant to handle additional capacity, the applicability of its unit operations to the expected effluent from a water treatment operation and the condition of the sewers are in question. This technology is not considered applicable and will not be considered further.

3.2.7.3.4 Discharge to Storm Drain. Treated water can be routed to the nearest storm drain for what amounts to surface water discharge. Surface water discharge at RMA ultimately outfalls to the south fork of the Platte River.

Surface water discharge will pose a limitation on any treated effluent water, which must be of low enough concentration to achieve NPDES outfall limits of the RMA.

However, these discharge limitations will not be any more stringent and could very likely be the same as those imposed on other disposal options (e.g., percolation beds). Therefore, this option will be retained for further evaluation.

3.3 SUMMARY OF RETAINED TECHNOLOGIES

Table 3-2 summarizes the preceding section. Several identified technologies were evaluated as not being applicable based on technical implementability. The remaining technologies formulate the alternative remediation scenarios of Section 4.0.

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Table 3-1a
Identification of Potential Technologies
M-1 Settling Basins
Soils and Sludges

Response Action	Remedial Technology	Process Description	Site Rating	Comments	Unit Cost (as shown)
=====					
Monitoring					
	Soil Boring/ Trenches	Sampling/ Analysis	NA	Sufficient amount of soil samples have been taken	
	Lysimeters	Sampling/ Analysis	A	For sampling leachate in the vadose zone	

Institutional Controls					
	Access Restrictions	Fencing	A	Will limit site access	\$10/LF

In-place Containment					
Soils	Surface Capping	Multi-layer Cap	A	Requires regrading; may crack due to desiccation	\$5-15/yd2
		Clay Cap	A	Effective if properly designed; requires regrading	\$30-50/yd2
		Synthetic Liner	A	Requires regrading; highly susceptible to deterioration if not protected	\$4-10/yd2
		Asphalt	A	Effective as erosion protection, imperviousness may degrade as a result of weathering	\$4-8/yd2
		Concrete	NA	Excessively rigid, may crack, expensive	\$20-50/yd2
	Surface Control	Soil Stabilization	A	Improves erosion resistance, may decrease infiltration	\$3-5/yd2
		Grading	A	Controls runoff and runoff; inexpensive, reduces erosion	\$0.5-1.0/yd2
		Dikes/Berms	A	Controls runoff and runoff; inexpensive	\$2-5/yd3
		Vertical Barriers	Slurry Wall	A	Proven technology; confining layer at 20 feet
	Grout Curtains		NA	Low quality control for field implementation	\$6-10/ft2
			Sheet Piling	NA	More pervios than slurry wall, installation difficult in dense or cobbly soils

Source Collection					
	Excavation	i.e. Backhoe dozer	A	Hazardous soils excavation has occurred at the arsenal already; must be health and safety equipped	\$1-3/yd3

In-situ Treatment					
		Biological	NA	Sludge composition is very high in Hg and As, which will inhibit effectiveness of biodegradation	Low <\$100/yd3

Table 3-1a (Continued)

Response Action	Remedial Technology	Process Description	Site Rating	Comments	Unit Cost (as shown)
=====					
		Vitrification	A	Bench test being performed on sludge: effectiveness for volatile metals in question	\$400-700/yd3
		Chemical Fixation	A	Effective on high concentrations of organic contamination with ground water at/or below 10 feet	
		Soil Washing	A	More effective on metals than on organics; bench testing recommended	\$45-65/yd3
		Aeration/Vacuum Extraction	NA	Recommended for volatile contamination; not recommended for OCP's	

On-site Treatment					
	Biological	Landfarming	NA	Currently testing on OCP's; metal contamination will inhibit effectiveness of biodeg.	\$25-40/yd3
		Bioreactor	NA	Agitation speeds degradation rate; metals will inhibit effectiveness	\$25-45/yd3
	Chemical	Soil Washing (Surfactant)	NA	Proven effective on organics in soil; limited metals removal	\$60-80/yd3
		Fixation	A	Typically used for metal extraction in mining; limited recovery levels;	\$60-80/yd3
		Oxidation	NA	Effective in lab studies; difficult to duplicate in field	\$100-125/yd3
		Solution Mining (Chelation)	A	More effective on metals than organics; quality control fairly high for small particle sizes	\$35-100/yd3
		Dechlorination	NA	Bench and pilot test demonstrated successful destruction of OCP's in soils and sludges; no metals treatment	\$100-150/yd3
	Physical	Separation	A	Separation Techniques may be used to remove liquids from the sludge (i.e. centrifuge)	
		Thermal Stripping	NA	Effective for volatiles and semi volatiles; will not address metals	\$150-200/yd3
		Pozzolonic Fixation	A	Will reduce contaminent mobility by reducing soil surface area	\$50-100/yd3
		Air Stripping	NA	Most effective for volatile contaminents; not recommended for OCP's	\$20-30/yd3
		Steam Stripping	NA	Most effective for volatile contaminents	\$50-70/yd3

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Table 3-1a (Continued)

Response Action	Remedial Technology	Process Description	Site Rating	Comments	Unit Cost (as shown)
Off-site Treatment	Incineration	Rotary Kiln	NA	will not address metal contamination; possible negative community reaction	\$300-500/yd3
		Fluidized Bed	NA	will not address metal contamination; possible negative community reaction	\$210-400/yd3
		Infra-Red Moving Bed	NA	will not address metal contamination; possible negative community reaction	\$250-500/yd3
On-Site Disposal	Chemical	Fixation	A	More effective on metals than organics; quality control fairly high for small soil particle sizes	
Off-site Disposal	Landfill	RCRA	A	Will provide maximum containment for the soils and sludges	
		Non-RCRA	NA	Sufficient containment for interim response	
	Landfill	Class I	A	Appropriate for smaller volumes and residual sludges from treatments	\$100-500+/yd3
		Class II	NA	Applicable for non-hazardous or delisted waste	\$1 - \$20/ton
		Class III	NA	Not an appropriate waste facility	\$1-15/yd3

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Table 3-1b
Identification of Potential Technologies
M-1 Settling Basins
Water

Response Action	Remedial Technology	Process Description	Site Rating	Comments	Unit Cost (as shown)
Monitoring	Installation Of Wells	Sampling/ Analysis	NA	Sufficient amount of monitoring wells exist on site	\$3 -7000/well
Dewatering	Extraction	Pumping Wells	A	Proven tech. at ground water control and remediation	\$5000-15000/well
	Subsurface Drains	Collection Trench	A	Applicable for shallow ground water	\$75-100/ft
	Filtration	Gravity Drain	A	Effective enough for some treatment processes; easily implemented	
		Vacuum Filter	A	Produces well-dried sludge; proven technology	
Water Treatment	Physical	Separation	NA	Only necessary if multiple liquid phases exist	cap=\$7-25,000 O&M=\$.05-.1/1k gal
		Filtration	A	A potential usage for above ground dewatering	
		Air Stripping	NA	Only applicable on volatile organics	cap=\$20-75,000 O&M=\$0.1-.25/1k ga
		Reverse Osmosis	A	Large organics could clog membrane; produces large concentrate volume	Cap=\$250-500K O&M=\$.7-2/1k gal
		Act. Carbon Adsorption	A	Applicable on PAHs, marginally on PCP; As will adsorb onto activated carbon	cap=\$50-500k O&M=\$.5-2/1k gal
		Resin/ Adsorption	NA	Effective as Carbon but more expensive; must regenerate or dispose off site	cap=\$50-500k
		Activated Alumina	A	Effective on arsenic	
	Biological	Rotating Bio. Contactor	NA	Marginally effective on OCP's expensive for remediations; does not address metals	cap=\$1.5-2.5 mil O&M=\$1-2/1000gal
		Aerated Impoundment	NA	Marginally effective on OCP's large area required; does not address metals	cap=\$20-50K O&M=\$0.2-0.4/1k gal
		Activated Sludge	NA	Marginally effective on OCP's; costly for remediation; does not address metals	
		Fixed Bed Bioreactor	NA	Fairly effective on OCP's; least costly of all bio treatment; does not address metals	cap= \$50-150,000 O&M=\$.1-.4/1k gal
		PACT/Activated Sludge	A	Effective on OCP's compounds; proven technology; expensive;	cap=\$2-4 mil O&M= \$.5-1/1k gal

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Table 3-1b (Continued)

Response Action	Remedial Technology	Process Description	Site Rating	Comments	Unit Cost (as shown)
Disposal	Chemical	Dechlorination	NA	Laboratory tested; creates hazardous waste stream	cap=NA O&M=>\$5/1K gal
		UV/Ozone	A	Proven technology on OCP's; will not treat metals	cap=\$45-300K O&M=\$.5-2/1k gal
		Chemical Precipitation	A	Not applicable on organics; but effective for As removal	cap=high<\$500k
		Ion Exchange	A	Effective at metal removal; large sludge volume is generated	CAP= O&M= \$10/1000 gal
		Electrical Precipitation	NA	Success at some metals removal; As in wrong oxidation state	
	Thermal	Solar Evaporation	NA	Excessive land space required; possible negative community reaction	cap=\$25-50k O&M=\$.05-.2/1k gal
	Off-site	RCRA Facility	NA	Costly because of large volumes potential hazard and liability for offsite hauling and treatment	cap=\$25k O&M=\$5-50/1k gal
		POTW	A	Effective if groundwater is accepted by POTW	cap=\$5k O&M=\$0.01-.1/1Kgal
	On-Site	Injection Well	A	Tendency to clog; effective if soils are highly transmissive	\$7-12000/well
		Percolation Bed	A	Current injection method at RMA	
		Pond/Lagoon	NA	Not available	\$10000/yr
		RMA Treatment Plant	A	Army currently has an on-site treatment plant at the arsenal	
		Surface Drainage	A	NPDES permit impact	
	Off-Site	POTW	NA	Discharge without treatment is not recommended; negative community acceptance	\$10000/yr
		Surface Drainage	NA	Not recommended; surface water can be negatively impacted	\$10,000
		Injection Well	NA	Tendency to clog; effective if soil is highly transmissive	\$15,000/yr
		Storm Sewer	NA	NPDES permit required	\$10-15,000/yr

Table 3-2a
Technology Screening For
M-1 Basins
Soils and Sludges

Response Action	Remedial Technology	Process Description	Retain for Alternative (yes/no)	Screening Comments
Monitoring	Soil Boring/ Trenches	Sampling/ Analysis	YES	Confirmation samples may be necessary
	Lysimeters	Sampling/ Analysis	NO	No alternates require soil moisture monitoring
Institutional Controls				
	Access Restrictions	Fencing	YES	Perimeter fencing will be constructed around the M-1 Basins; incorporated with Alternative 3
In-place Containment				
	Surface Capping	Multi-layered Cap	YES	A multi-layered cap will be constructed alone or with a slurry wall in Alternatives 4 and 5
		Clay Cap	NO	Unprotected clay may crack upon extended exposure; poor drainage
		Asphalt	NO	Asphalt alone will not be a sufficient cap, however, could be used as a protective liner for the designed cap
	Surface Control	Soil Stabilization	YES	Soil stabilization techniques may be incorporated for erosion control to cement existing soil enhancing runoff
		Grading	YES	Site grading will be incorporated to control surface drainage and divert runoff/runon to the source areas
		Dikes/Berms	YES	Will be incorporated for designs of temporary storage pads of soils as well as containment of site process treatment areas
	Vertical Barriers	Slurry Wall	YES	Alternative 4 incorporates slurry wall technology for in-place containment of the M-1 Basins
		Grout Curtains	NO	Less effective than a slurry wall
		Sheet Piling	NO	Ineffective for graveling, sandy soil; potential for migration through joints
Source Collection				
	Excavation	e.g. Backhoe	YES	Excavation techniques will be implemented
In-Situ Treatment				
		Vitrification	YES	ISV will address both metals and organics; off gas treatment required to address OCPs and metals
		Chemical Fixation	NO	Quality assurance questionable for fixation of OCPs with low TCLP levels
		Soil Washing	NO	

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Table 3-2a (Continued)

Response Action	Remedial Technology	Process Description	Retain for Alternative (yes/no)	Screening Comments
=====				
On-Site Treatment	Chemical	Fixation	YES	Fixation will bind both metals and organics; however, bench testing prior to implementation will be required
		Solution Mining (Chelation)	NO	Applicable to metal contamination; however, ability for process to achieve necessary removal efficiency is questionable
	Physical	Pozzolonic Fixation	NO	OCPs are easily leachable; only decreases surface area of solids; matrix can be broken down
		Vitrification	NO	No vendor available to vitrify volatile metals
Off-site Disposal	Landfill	Class I	YES	Retained for alternatives as an offsite technology; closest facility is in Grassy Mountain, Utah
		Class III	YES	Appropriate for nonhazardous materials (i.e., site debris)
On-Site Disposal	Landfill	RCRA Standard	YES	Will be formulated into an alternative; will provide maximum onsite containment
		Non-RCRA Standard	YES	Retained because of the possibility of requiring only a temporary action for the IRA

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Table 3-2b
Technology Screening For
M-1 Basins
Water

Response Action	Remedial Technology	Process Description	Retain for Alternative (yes/no)	Screening Comments
Monitoring	Additional Sampling	Sampling/ Analysis	YES	G.W. monitoring will continue; however no additional wells will be installed
	Installation of Wells		NO	Sufficient wells exist
Dewatering	Extraction	Pumping Wells	NO	Low yielding aquifer requires excessive number of wells
	Subsurface Drains	Collection Trench	YES	During excavation, surface trenches may be employed for dewatering prior to soil removal
	Filtration	Gravity Drain	YES	Effective enough for some treatment processes; easily implemented
		Vacuum Filter	YES	Produces well-dried sludge; proven technology
Water Treatment	Physical	Separation	YES	Sludge proven to phase separate after liquefaction
		Act. Carbon Adsorption	NO	Effective on OCPs but not on metals; could be effective if only a small volume of water is to be treated
		Activated Alumina	YES	Currently in use at RMA
		Filtration	YES	Effective for above-ground dewatering
		Reverse Osmosis	NO	May not meet effluent requirements; concentrate may require further processing
	Biological	PACT/Activated Sludge	NO	Large secondary waste stream (sludge) generated
	Chemical	UV/Ozone	YES	Effective on organics
		Chemical Precipitation	YES	Although inefficient with many startup/shutdowns and creates a large sludge volume mobile treatment units do exist and this treatment does work
		Ion Exchange	YES	Mobile treatment units exist; will require bench or pilot studies to treat to low arsenic levels
Disposal	On-Site	Injection Well	NO	Tendency to clog; effective if soils are highly transmissive; NPDES permit impact
		Percolation Bed	YES	Is available on site and is currently the alternative to water discharge
		RMA Treatment Plant	NO	Is limited to extra water capacity and is susceptible to process upsets
		Surface Drainage	YES	Will require NPDES permit modifications
	Off-Site	Surface Drainage	YES	Will require NPDES permit modifications
		Storm Drain	YES	Will require NPDES permit modifications

4.0
DEVELOPMENT AND EVALUATION OF ALTERNATIVES

This section evaluates interim response alternatives which have been developed for the M-1 Settling Basins. The alternatives are designed from one or more feasible technologies introduced in Section 3.0. The alternatives are configured to address both the contamination on-site and any waste streams generated as part of treatment. These alternatives are then evaluated with respect to:

- Effectiveness
- Implementability
- Reduction in mobility, toxicity, and volume
- Overall protectiveness of human health and the environment
- Compliance with applicable or relevant and appropriate regulations

Costs associated with the alternatives will be addressed in Section 5.0.

4.1 DEVELOPMENT OF SOIL/SLUDGE REMEDIATION ALTERNATIVES

Eight alternatives have been developed as interim response actions (IRAs) according to CERCLA guidance. The suite of alternatives includes administrative, containment, treatment and disposal options. Section 3.0 shows several feasible treatment technologies. The treatment technologies chosen for alternative development area a mix of physical, thermal, chemical, and biological technologies (where appropriate) which show reasonable implementability based on engineering judgment. The alternatives are:

<u>Alternative</u>	<u>Description</u>
1	No action
2	Monitoring
3	Institutional controls
4	Slurry wall containment with cap
5	Multi-layered cap

- | | |
|---|--|
| 6 | In-situ vitrification with off-gas control |
| 7 | Chemical fixation with on-site disposal |
| 8 | Chemical fixation with off-site disposal |

The first three alternatives do not involve containment or treatment but are included per EPA guidance document, "Guidance For Conducting Remedial Investigations and Feasibility Studies Under CERCLA," Interim Final October 1988.

The next two alternatives represent in-place containment with no treatment. These are considered viable since this is an IRA. The contamination would remain in place until such time as the overall site remediation addressed this area.

The next two alternatives represent viable on-site treatment scenarios. One is an in-situ alternative not requiring excavation, while the other requires excavation and soil/sludge treatment on site.

The final alternative consists of excavation and on-site soil/sludge treatment with final disposal at a fully-permitted commercial RCRA landfill. Each alternative is described in the following subsections.

4.1.1 Alternative 1 - No Action

This alternative assumes that no action will be taken to contain or treat contaminated soils and sludge at the M-1 Settling Basins. Additional groundwater monitoring would not be required if this alternative is selected.

4.1.2 Alternative 2 - Monitoring

This alternative assumes that the only action taken at the M-1 Settling Basins is additional groundwater monitoring. In addition, monitoring will be part of Alternatives 3 through 8.

The monitoring consists of quarterly sampling and analysis of groundwater from existing monitoring Well Nos. 01083, 01524, 01503, 01504, and 36193. The water will be analyzed for the following analytes:

- Volatile halogenated organics
- Volatile aromatic organics
- Semivolatile halogenated organics
- Total and dissolved arsenic
- Total and dissolved mercury
- ICP metals
- pH

This information will be included as part of the comprehensive monitoring program at the Rocky Mountain Arsenal (RMA). Analyses of these data will help to evaluate how much the M-1 Settling Basins are actively degrading groundwater quality in the area and will provide information necessary to develop a final response action.

In addition to groundwater monitoring, an air monitoring program will also be designed. The program will monitor ambient air for fugitive dust and organic volatilization. It is assumed that four monitoring stations will be set up on all sides of the site.

The sampling effort will include:

- Dust PM 10, for metals and fugitive particulates
- PUF (polyurethane foam), for pesticides
- Tenax/activated carbon, for volatile organic compounds

Groundwater and air sampling will occur on a quarterly basis for this alternative. Groundwater and air sampling will also be performed during the construction operations period of the containment and treatment alternatives. Quarterly groundwater monitoring will be performed following the construction

operations period of Alternatives 3 through 8, and quarterly air monitoring will be performed following the construction operations period of Alternative 3.

4.1.3 Alternative 3 - Institutional Controls

The institutional control alternative consists of constructing a fence around the site. As the design basis shows in Section 2.0, this would entail the construction of approximately 910 lineal feet of chainlink fence with controlled access points (i.e., locked gates).

4.1.4 Alternative 4 - Slurry Wall with Cap

The slurry wall and cap alternative would consist of constructing a slurry wall around the M-1 Settling Basins and a cap covering the area enclosed by the slurry wall. This alternative would enclose the source of contamination and reduce the migration of hazardous constituents. The slurry wall and cap would be designed to contain the contamination source until a final response action is selected and implemented.

4.1.4.1 Construction of 360° Slurry Wall

The slurry wall would enclose the three M-1 Settling Basins, as well as the berms surrounding the basins, and provide lateral containment of the contamination source. The enclosed area would be about 300 feet long and 115 feet wide. The size of the enclosed area would be slightly less than 1 acre. The slurry wall would be about 910 feet long and would penetrate, at a minimum, through the upper 18 feet of silty, sandy soils into the underlying clayey soils. For this feasibility study, it is assumed conservatively that the slurry wall would be keyed at a depth of 25 feet into the Denver Formation beneath the clayey soils.

4.1.4.2 Construction of a Multi-layered Cap

The cap would be designed and constructed to cover the entire area enclosed by the slurry wall (about 1 acre). The cap would consist of, from the base upwards,

an 18-inch thick compacted clayey soil layer, a 60-mil thick high-density polyethylene (HDPE) flexible membrane liner, a synthetic drainage net, a geotextile filter fabric and a 1-foot protective soil layer. The cap would be sloped from the center to the edge at about 2 or 3 percent to facilitate runoff of surface water from the cap. This cover design would reduce infiltration of surface water into the M-1 settling basins. Water infiltrating the cover would collect onto the clayey soil/flexible membrane composite layer and would be drained to the outside of the cap by gravity through the synthetic drainage net. The geotextile filter fabric would reduce the risk of the synthetic drainage net being clogged by soil particles from the overlying soil layer.

4.1.5 Alternative 5 - Multi-layered Cap

This alternative would consist of covering the M-1 Settling Basins with a cap to reduce infiltration of surface water. The extent and design of the cap would be the same as that for the slurry wall and cap alternative described above. The cap would be designed and constructed to cover the M-1 Settling Basins, about 1 acre.

4.1.6 Alternative 6 - In-situ Vitrification (ISV) with Off-gas Control

Contaminated soils and sludge would be vitrified in-situ by introducing sufficient electrical current through the soil to raise the soil temperature to its melting point. The current would be introduced by four electrodes placed in the ground in a square array. A slurry wall will be constructed around the ISV area. It is assumed that dewatering is unnecessary. The water within the boundaries of the slurry wall will be vaporized during the ISV and water from the surrounding region will not migrate through the slurry wall. The sequence of activities that would be performed in this alternative consists of the following.

- Construction of a 360° slurry wall
- In-situ vitrification in stages throughout the 1-acre site
- Regrading site

4.1.6.1 Construction of a 360° Slurry Wall

The slurry wall would be constructed as described in Section 4.1.4 with the exception that the depth of the slurry wall will only be 15 feet. In this case, the slurry wall is used to provide a temporary barrier to groundwater recharge in the vitrification area.

4.1.6.2 In-situ Vitrification

The vitrification process is initiated by the placement of four electrodes in a square array approximately 18 feet apart to a depth of approximately 7 feet. An off-gas collection hood will be installed that will route off-gases and steam under negative pressure to the off-gas control system housed on-site in a trailer. A second trailer will house the electrical switchgear that will condition the 4160-volt power obtained from the site power distribution system and deliver it to the electrodes.

The off-gas control system will cool, scrub, and filter the vapors collected from the off-gassing melt. Assuming this process drives off the 47 percent water fraction of the sludge, approximately 700,000 gallons of steam, with trace contaminants of arsenic and mercury, will be generated. This will be condensed indirectly by using a circulating glycol system. Noncondensed acid gases will be absorbed in a packed scrubber column. As a final step in the air pollution control sequence, the exhaust gases will pass through an activated carbon absorber prior to venting to the atmosphere.

The condensate will have elevated concentrations of arsenic and mercury, as well as an alkaline pH. This will require pH adjustment and precipitation of arsenic and mercury to reduce arsenic and mercury levels to accepted discharge limits. Mercury may be in a recoverable form. Actual wastewater treatment will be determined during pilot testing. Any sludge generated in the wastewater treatment will be added to unvitrified soil/sludge for subsequent vitrification. The treated effluent water will be discharged to the alluvial aquifer through a percolation bed.

The process will vitrify the soil/sludge at a rate of approximately 3 to 5 tons/hour. Once the melt is complete, the system will be dismantled and moved to the next area of the vitrification sequence, leaving the melt to cool. To process the approximately 9,000 yd³ of soil, the operation will take about 5 months.

4.1.6.3 Site Regrading

After the vitrification process is complete, some subsidence will have occurred, approximately 40 to 50 percent of the depth of melting. Imported fill will be brought in from nearby, by using standard earth-moving equipment (e.g., loader, end dump trucks, etc.) as necessary to ensure positive surface drainage away from the vitrified area.

4.1.7 Alternative 7 - Chemical Fixation With On-site Disposal

This alternative would include excavation of approximately 10,800 yd³ (9,000 yd³ plus a 20 percent bulking factor) of sludge and soils by sections or subareas to be treated, mixing of the excavated contaminated soils with one or more fixation agents, testing of the treated portions to ensure treatment effectiveness, and placement of the treated soil in an on-site landfill. This sequence would be repeated for successive subareas until the entire area to be chemically fixed is treated. Two general types of mixing methods are commonly used for the chemical fixation process: batch mixing on the surface of a workpad, or semicontinuous mixing in cement handling equipment, such as a pug mill. The semicontinuous approach is more likely to be employed for this remediation.

Chemical fixation is based on treatment methods that surround or encapsulate waste components in a stable inorganic matrix. The treatment additives are selected to accomplish one or more of the following results: reduce the mobility of contaminants by reducing the surface area exposed to leaching fluids, reduce the solubility or toxicity by chemically binding the contaminants into a crystal

or inorganic lattice, or solidify or otherwise improve the handling properties of the bulk waste.

Typical additives are sodium silicate, portland cement, fly ash, or kiln dust. The resulting material will remain friable even after curing; that is, it will not harden into a concrete mass. The exact composition and volume of fixing agents are not presently known, since these treatment specifics vary somewhat with the vendor, and the vendor has not yet been selected. For the same reason, an exact increase in volume is not known, although it is estimated that bulking factors of between 10 percent and 20 percent by volume could be expected. A bench-scale treatability test program should be conducted to determine the proper additives and additive ratios.

Chemical fixation is well-suited for the metals contamination at this site. Certain organic contaminants in the surface soil can also be immobilized by chemical fixation.

A storage pad will be constructed for storage of excavated soils prior to chemical fixation. The storage pad will have a clay liner and sump for drainage to minimize contact between contaminated and uncontaminated soil and precipitation. A second pad of similar size will be constructed nearby for storage of treated soils. The pads will be constructed with low permeability liners. Each pad will be surrounded on the perimeter with a containment berm. Contaminated soils will be run through screens to separate large fragments. The screening device will most probably be a slanted vibrating screen or series of screens with a screen size of 1/4 inch. Larger fragments may be crushed prior to fixation. Any uncrushable debris will be collected and cleaned or transported to a Class I disposal facility. After screening and crushing, the soil will be moved into and through the fixation machinery and then to the fixed materials pad. The area required for the equipment would be approximately 2,000 ft². For the purpose of cost and schedule development, it is assumed that excavation and treatment of the contaminated soils will proceed in 500 yd³ per day increments using two units. Soil excavation at the M-1 Settling Basins may require backhoes, loaders, bulldozers, and personal protective equipment.

During operations, confirmation samples from the treated soil stockpile and the excavation limits will be collected for chemical testing, for comparison to leachate and/or cleanup criteria. The fixation contractor will take performance samples of the treated material after mixing and will test for chemical stability. In addition, one sample of every ten will be tested with the proposed EPA TCLP test to indicate leachable organic and metal materials.

The chemically fixed soils and sludges will be disposed of on site in a landfill. This landfill would be constructed with a clay liner and cap as well as a synthetic liner, leachate monitoring and collection sump, and groundwater monitoring wells. The fixed soils/sludges must pass leachability tests before they are landfilled. The landfill may be evaluated during the final remediation at RMA as a possible permanent repository for the fixed materials.

4.1.7.1 Landfill Construction

A landfill would be constructed above ground in the vicinity of the M-1 Settling Basins for the containment of the chemically fixed materials. The landfill would be designed to hold about 11,900 yd³ (9,000 yd³ plus 20 percent for excavation bulking plus 10 percent for bulking from the fixation process) of contaminated materials. The bottom liner and leachate collection system would consist of, from the base upwards, an 18-inch thick compacted clayey soil layer, a 60-mil thick HDPE flexible membrane liner, a synthetic drainage net, and a geotextile filter fabric. The bottom liner would be sloped at a minimum of 2 percent toward a leachate collection sump. Liquids collecting in the leachate collection sump would be removed. The contaminated soils would be placed in the landfill in lifts and compacted to minimize settlement after placement. The first lift of soil in the landfill would be placed in a manner that would not damage the completed liner system. The total height of the soil in the landfill would be about 15 feet. Once all the contaminated materials have been placed in the landfill, a cover would be constructed to close the landfill. The cover system would consist of, from the base upwards, an 18-inch thick compacted clayey soil layer, a 60-mil thick HDPE flexible membrane liner, a synthetic drainage net,

a geotextile filter fabric and a 1-foot thick protective soil layer. Treatment of the protective soil layer, such as cement or asphalt addition, may be used to improve the erosion resistance of the soil and reduce maintenance.

4.1.7.2 Transportation to On-site Landfill

The fixed soil/sludge will be placed on dump trucks and sent to the nearby landfill described in the previous section. Assuming a chemical fixation rate of 500 yds³ per day, this operation should take approximately 17 days and involve approximately 30 to 35 daily round trips of a 15 yd³ capacity dump truck between the M-1 Settling Basins and the newly constructed landfill.

4.1.7.3 Site Regrading

After completion of the excavation operation, the site will be regraded. The site will then be revegetated for erosion control.

Site operations for the chemical fixation process with on-site landfill are as follows.

- Excavate contaminated soil, dewater if necessary, and transport to storage pad.
- Collect confirmation samples from base of final excavation.
- Screen all debris and solids 1/4-inch or greater in diameter from the soils.
- Crush oversized material to the appropriate size.

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- Collect untreatable debris, if present, and store temporarily or haul to a Class I landfill.
- Convey contaminated soils from the storage pad to the fixation processing equipment.
- Add fixation chemicals and water to the soils and mix to uniformity.
- Transfer the fixed soil to the treatment pad for temporary storage and sampling.
- Backfill the basin area with engineered fill.
- Landfill construction
- Transport of fixed soil to an on-site landfill.

4.1.8 Alternative 8 - Chemical Fixation With Off-site Disposal

Contaminated soils and sludges can be excavated and disposed of off-site in a Class I landfill. Due to the high water content of the M-1 Settling Basin sludges, this material would need to be chemically fixed before it can be placed in a landfill. This alternative can be considered a final response action. The sequence of activities that would be performed in this alternative consists of the following:

- Chemical fixation of soil/sludge
- Transportation to off-site landfill
- Site regrading

4.1.8.1 Chemical Fixation of Soil/Sludge

Soil and sludge from the M-1 Settling Basins would be chemically fixed according to the same procedures described in Section 4.1.7.

4.1.8.2 Transportation to Off-site Landfill

The dump trucks hauling contaminated soil/sludge will be decontaminated and secured prior to hauling. The soil will be sent to the USPCI Class I landfill near Clive, Utah. Hauling costs per yard of material are cited in Section 5.0. Therefore, the total volume of 11,900 yd³ was used for the cost calculations. Disposal was quoted per ton, so a density of 1.5 tons/yd³ was used to convert volume to weight.

4.1.8.3 Site Regrading

After excavation, the site will be regraded and revegetated as described in Section 4.1.7.3.

4.2 ALTERNATIVE EVALUATION CRITERIA

The interim alternatives will be evaluated based on the following criteria:

- Effectiveness
- Reduction of mobility, toxicity, and volume
- Implementability
- Overall protection of human health and the environment

- Conformance with applicable or relevant and appropriate requirements
- Cost

The definition and interpretation of these criteria are outlined in this section.

How each alternative addresses each of the evaluation criteria will be presented in greater detail in the IRA decision document. However, a summary of alternative evaluation criteria is presented in matrix form in Tables 4-1a and 4-1b.

4.2.1 Effectiveness

The effectiveness of the interim alternatives will be considered in terms of its long-term and short-term effectiveness in meeting the remedial action objectives.

Long-term effectiveness examines the effectiveness of each alternative in maintaining protection of human health and the environment after response objectives have been met. This evaluation is divided with two main criteria: magnitude of residual risk, as well as adequacy and reliability of long-term controls to manage that residual risk. Some of the questions addressed in this evaluation are as follows.

- What is the magnitude of the remaining risk?
- What type and degree of long-term management is required?
- What difficulties and uncertainties may be associated with long-term operation and maintenance?
- What are the uncertainties associated with land disposal of residuals and untreated wastes?

- Is there a clear and significant long-term benefit in implementing this alternative now?

Since this activity is an IRA, the long-term effectiveness criteria will be considered over a five-year period unless the alternative is considered to be appropriate for a final response (e.g., vitrification).

Short-term effectiveness examines the effectiveness of alternatives in protecting human health and the environment during the construction and implementation period until objectives have been met. Short-term effectiveness has three elements: community protection, worker protection, and environmental impact.

Community protection considers any risk that results from implementation of the proposed interim action. Some of the questions that identify potential community risks from a remedial process are:

- If a process failed, would it pose a significant risk to the community?
- Is the operation of this process foolproof?
- Are effective mitigation measures available to reduce community risk if the process fails, or are the mitigation measures of unknown effectiveness?

Worker protection evaluations during interim response activities consider the potential threats that may be posed to workers and the effectiveness and reliability of protective measures that could be taken. Among the worker protection issues, considerations are:

- Is the process inherently safe and does it pose no significant risk to the workers at the site?

- If risks to treatment plant operators exist, can they be effectively mitigated through proper design, operation, and maintenance, or is the effectiveness of these mitigation measures unknown?
- Does the process release hazardous substances to the work place environment?
- Are the protective equipment and operating procedures designated in the site health and safety plan adequate for the work place conditions?

The environmental criteria address the potential adverse environmental impacts that may result from the interim alternative and they evaluate how effective available mitigation measures would be in preventing or reducing the impacts. The environmental assessment considers the following questions.

- Do process emissions have potentially significant adverse environmental impact during routine operation?
- If the process emissions have adverse environmental impact during routine operation, but emissions are unlikely, are mitigation measures available and are they certain or uncertain?

4.2.2 Reduction of Mobility, Toxicity, and Volume

Reduction of waste mobility, toxicity, and volume reduces the potential of that waste to harm humans or the environment. This evaluation criterion evaluates the process effectiveness to reduce organic and metals concentrations and to reduce waste quantity. Some of the specific issues addressed in the evaluation of this criterion include the following.

- Does the process completely destroy organics?
- Does the process permanently immobilize organics?

- Does the process reduce the mobility of organics?
- Does the process significantly reduce the toxicity of organics?
- Does the treatment immobilize the metals? Does the treatment leave the metals incompletely immobilized and requiring significant waste management (i.e., hazardous waste landfill)?
- Does the treatment produce a significant reduction in hazardous waste volume?
- Does the process result in a significant increase in hazardous waste volume?

4.2.3 Implementability

The implementability criterion addresses the technical and administrative feasibility of an alternative and the availability of various services and materials required for its implementation. Some of the specific issues to be evaluated include the following questions.

- Is the process well developed with many hazardous waste or related treatment applications, or has it been demonstrated on at least one full-scale application?
- Has the process only been demonstrated at pilot scale or not at all?
- What is the commercial availability of the process?
- Does the process use conventional equipment, or are any parts proprietary and/or not commercially available?

- Is the process equipment easy to operate and maintain, or does it require significant maintenance?
- What are the monitoring requirements of each process?
- Are there minimal emissions and is only process control monitoring required?
- Are emissions easily controlled with standard equipment to assure environmental compliance?

4.2.4 Overall Protection of Human Health and the Environment

This criterion assesses whether each alternative provides adequate protection of human health and the environment. Assessment of protection draws upon other evaluation criteria, especially short-term effectiveness and compliance with ARARs and considers whether each alternative poses unacceptable short-term or cross-media impacts.

4.2.5 Conformance with Applicable or Relevant and Appropriate Requirements

One of the criteria used to evaluate each of the remedial alternatives is compliance with applicable or relevant and appropriate requirements (ARARs). Alternatives that meet all ARARs will be preferred because they ensure that remediation will be conducted in a manner that protects human health and the environment.

TABLE 4-1a

TECHNICAL EVALUATION OF ALTERNATIVES
MOTOR POOL AREA
THRESHOLD CRITERIA

Alternative	Interim Remedial Action	Overall Protectiveness of Human Health and the Environment	Compliance With ARARs
1. No Action		Not protective	There are no chemical-specific ARARs for contaminated soils which are not excavated. Thus, no action is in compliance with ARARs.
2. Monitoring		Not protective	This alternative will comply with ARARs related to monitoring.
3. Institutional	Access restriction (fencing)	Marginally protective	The institutional controls will comply with ARARs, related to access.
4. Slurry Wall with Cap	-Site preparation -Construct slurry wall -Construct cap	Somewhat protective; reduces risk by isolating material from environment; vertical and horizontal migration retarded	This alternative will be designed to comply with ARARs.
5. Multi-layered Cap	-Site preparation -Construct cap	Somewhat protective; reduces risk by isolating material from surface; infiltration barrier limits vertical migration	This alternative will comply with ARARs.
6. In-site Vitrification	-Site preparation -Construct slurry wall -Vitrify solids -Regrade site	Protective; reduces risk by immobilizing remaining contaminant	This alternative will comply with ARARs.

TABLE 4-1a
(Continued)

Alternative	Interim Action	Overall Protectiveness of Human Health and the Environment	Compliance With ARARs
7. Chemical Fixation with On-Site Disposal	- Site preparation - Construct landfill - Excavate - Dewater (if necessary) - Treat extracted water and discharge to percolation beds - Chemical fixation of both organics and metals - On-site disposal of treated soil in landfill - Regrade site	Protective; reduces risk by immobilizing metal and some organic contaminants	This alternative will comply with only some ARARs. The landfill design will not include detection monitoring.
8. Chemical Fixation and Off-Site Disposal	- Site preparation - Excavate - Dewater (if necessary) - Treat extracted water and discharge to percolation beds - Chemical fixation of both organics and metals - Transport to off-site RCRA landfill - Regrade site	Protective; reduces risk by immobilizing metal and some organic contaminant.	This alternative will comply with ARARs.

TABLE 4-1b

TECHNICAL EVALUATION OF ALTERNATIVES
M-1 SETTLING BASINS

EVALUATION CRITERIA

Alternative	Reduction of Toxicity, Mobility and Volume	Short-Term Effectiveness	Long-Term Effectiveness	Implementability	Cost
1. No Action	None	None	None	Easily implemented	Low
2. Monitoring	None	Monitoring can begin immediately; no additional impact on community or environment; sampling personnel may require personal protective equipment	Limited long-term effectiveness; potential indicator of future impact at sensitive receptors; evaluation necessary in 5 years	Easily implemented as part of existing monitoring program	Low
3. Institutional	None	Fence construction can begin immediately; no additional impacts on community or environment; construction personnel may require personal protective equipment	Long-term effectiveness limited; access control must be monitored; evaluation necessary in 5 years	Easily implemented; structural integrity necessary to restrict access	Low

TABLE 4-1b
(Continued)

Alternative	Reduction of Toxicity, Mobility and Volume	Short-Term Effectiveness	Long-Term Effectiveness	Implementability	Cost
4. Slurry Wall with Cap	Reduces mobility of contaminants to ground water	Less than one year implementation; no additional impacts on community or environment; construction personnel may require personal protective equipment; dust control measures may be necessary	Long-term effectiveness limited; monitoring required for possible migration through slurry wall; cap integrity inspection required; evaluation necessary in five years	Straight-forward construction; confining layer fairly shallow, provides sufficient anchor; several contractors available; destruction of cap necessary for further remediation action	Low
5. Multi-layered Cap	Reduces mobility of contaminants to ground water by reducing infiltration	Less than one year implementation; no additional impacts on community or environment; construction personnel may require personal protective equipment; dust control measures may be necessary	Long-term effectiveness limited; cap integrity inspection required; evaluation necessary in five years	Straight-forward construction; destruction of cap necessary for further remedial action	Low
6. In-situ Vittrification	Mobility of contaminants is greatly reduced; toxicity and volume are reduced.	One year implementation; off gassing must be controlled to minimize risk to workers and community	Expected good long-term effectiveness	Technology has gone through significant testing; off gas treatment must be monitored and vitrification must be field tested; operations require significant power; only one contractor available	High

TABLE 4-1b
(Continued)

Alternative	Reduction of Toxicity, Mobility and Volume	Short-Term Effectiveness	Long-Term Effectiveness	Implementability	Cost
7. Chemical Fixation with On-Site Disposal	Mobility of contami- nants is greatly reduced; toxicity is reduced; volume increased	Less than one year implementation; dust control measures may be necessary; workers may require personal protective equipment	Expected good long- term effectiveness	Fixation technology well-established; treatability testing required; turnkey contractors available	Medium
8. Chemical Fixation with Off-Site Disposal	Mobility of contami- nants is greatly reduced; toxicity is reduced; volume increased	Less than one year implementation; dust control measures may be necessary; workers may require personal protective equipment; possible community impact associated with transportation of fixed material	Expected good long- term effectiveness; potential liability at off-site landfill	Fixation technology well-established; treatability testing required; turnkey contractors available	High

The alternatives developed in Section 4.0 have been evaluated with respect to the threshold criteria of (1) compliance with ARARs and (2) protectiveness of human health and the environment. They have also been evaluated with respect to:

- Effectiveness
- Reduction of mobility, toxicity, or volume
- Implementability

This section discusses the costs involved with implementing each alternative. Since the Federal Facility Agreement states that the IRA decision document should select the most cost-effective alternative which meets the threshold criteria, these estimated costs will be a fundamental tool in the decision making process.

5.1 ECONOMIC ASSUMPTIONS

The cost estimates developed for the evaluated alternatives are intended to be used as comparative tools. These study estimates can be considered to have an accuracy of +50 percent to -30 percent. These estimates are divided into capital and operating and maintenance (O&M) costs. A present worth analysis is also presented to compare alternatives with different project durations.

Whenever possible, vendor quotes for capital and O&M costs are used. However, several other sources of costs have been utilized. These include generic unit costs, previous similar estimates (modified by site-specific information) and conventional cost estimating guides. All costs that are obtained from these materials will be escalated to third quarter 1989 by using the Chemical Engineering plant cost index.

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The following engineering assumptions have been used.

- For the purpose of cost comparisons, a 5-year operating life has been assumed for the IRA. This assumption may be altered by the final Record of Decision (ROD).
- Connections to electricity, natural gas, water, and sewer will be provided by RMA at no additional cost to the remediation project.
- Off-site disposal of hazardous solids will be at the USPCI Grassy Mountain landfill near Clive, Utah. Bulk waste will be shipped off site in trucks.
- An operating rate of 7,000 hours/year will be used for continuous processes utilizing mechanical equipment. This allows for approximately 20 percent downtime for maintenance and repair.
- Engineering, design, construction management and startup are assumed to be 20 to 50 percent of major purchased equipment (MPE) costs to \$5,000,000, 15 to 20 percent of MPE for equipment costs in the range of \$5,000,000 - \$10,000,000 and 5 to 10 percent of MPE for equipment costs in excess of \$10,000,000.
- A contingency of 20 percent has been applied to all capital and O&M cost estimates.
- Utility costs have been estimated by using the following rates:

Electricity*	\$0.085/kwh
Water	\$3.76/1000 gallons
Natural gas	\$3.359/1,000 ft ³
Sewer	\$1.50/1,000 gallons

* In-situ vitrification was costed at \$0.05/kwh because major user rates may be lower.

- Off-site disposal costs have been estimated by using the following rates:

Transportation	\$120/ton
Disposal	\$140/ton

- O&M costs incurred after the first year have been discounted at 5 percent.
- Treatment operations conducted by a turn-key vendor are considered under O&M costs, regardless of treatment duration.

5.2 ALTERNATIVE COSTING

5.2.1 Alternative 1 - No Action

This alternative assumes that no action will be taken to contain or treat contaminated soil/sludge at the M-1 Settling Basins. This alternative results in no capital or O&M costs; therefore, present worth costs are not included in Table 5-8.

5.2.2 Alternative 2 - Monitoring

Costing for the monitoring alternative has been divided into groundwater and air monitoring. For the groundwater monitoring plan, it is intended to only have an operations and maintenance cost. Capital costs have not been included because only existing monitoring wells are to be sampled. Air monitoring is specific to ambient air and will include monitoring stations in each direction from the M-1 Settling Basin area. For details on capital and O&M cost, refer to Table 5-1.

5.2.2.1 Capital Cost

Direct cost for the air monitoring program will include the necessary monitoring equipment and program design. Including the 20 percent contingency, the capital cost for this alternative is \$62,400. This capital cost will be included in the total for all the alternatives.

5.2.2.2 Operations and Maintenance

Groundwater and air monitoring O&M costs include quarterly sampling, analysis and reporting. The totals for groundwater and air monitoring O&M costs are \$168,000 and \$174,700 respectively, for a total of \$342,700. This total is included for each alternative for both the O&M operations and post-interim action costs.

5.2.2.3 Present Worth Value

The total present worth value of \$1,547,000 is the sum of the capital cost at \$62,000, plus the present worth value for the O&M cost of \$342,700 over five years.

5.2.3 Alternative 3 - Institutional Controls

Cost details for Alternative 3 are presented in Table 5-2. The total capital required for this alternative is \$110,000. Besides the 20 percent contingency and monitoring capital of \$62,400 the only major cost items are fencing at \$9,100 and site preparation, at \$20,000.

5.2.3.1 Operations and Maintenance

No additional operations and maintenance costs have been assumed for Alternative 3. Only the O&M cost from Alternative 2, Monitoring, is included at \$342,700.

5.2.3.2 Present Worth Value

The total present worth value for Alternative 3 is \$1,595,000, which is a total of the capital and the present worth value of the O&M cost over 5 years.

5.2.4 Alternative 4 - Containment by Slurry Wall and Cap

Cost details for Alternative 4 are presented in Table 5-3 and the capital, O&M and present worth value are summarized in Table 5-8.

5.2.4.1 Capital Cost

Some of the major cost items for the slurry wall and cap construction are: slurry wall and cap construction, \$273,600 and \$84,320, respectively; and engineering design and supervision, \$94,100. Including the 20 percent contingency, the total capital requirement is \$677,300. Construction activities are assumed to be completed in one year.

5.2.4.2 Operations and Maintenance

In the summary table, the O&M cost from Table 5-1 of \$342,700 has been included for operations period (years 0-1). During the operations period O&M costs include air and groundwater monitoring. During the post-interim action period, the cost items are groundwater monitoring and cap maintenance at \$25,000 for a total closure period O&M cost of \$193,000.

5.2.4.3 Present Worth Value

The present worth value for this alternative is \$1,655,000, which is the total of the capital and the present worth value of the operations and post-closure O&M costs.

5.2.5 Alternative 5 - Containment, Multi-layered Cap

Cost details are presented in Table 5-4 and the present worth value summary is presented in Table 5-8.

5.2.5.1 Capital Cost

Major cost items for the total capital requirement are as follows: cap construction, \$84,300 and engineering and supervision, \$39,300. The total capital requirement for this alternative is \$283,300, including a 20 percent contingency. The construction period is anticipated to be within one year.

5.2.5.2 Operations and Maintenance Cost

In addition to the O&M post-closure monitoring cost, \$25,000 is included for cap maintenance. Similar to Alternative 4, the operation period cost is \$342,700 and the post-interim action O&M cost is \$193,000.

5.2.5.3 Present Worth Value

The total present worth value for this alternative is \$1,261,000, which is a total of the capital and the present worth value of the two O&M costs over the 5 year period (see Section 5.2.4.3).

5.2.6 Alternative 6 - In-situ Vitrification

Cost details for this alternative are presented in Table 5-5 and summarized in the present worth value Table 5-8.

5.2.6.1 Capital Costs

The total capital requirement of \$470,600 is based on the slurry wall construction, and engineering and supervision. Upon completion of the slurry wall, the in-situ vitrification (ISV) process is to begin, and is expected to last less than one year (assuming one ISV unit at the site).

5.2.6.2 Operations and Maintenance

Annual O&M costs for in-situ vitrification is based on \$20 per ton for off-gas treatment operations and \$400 per ton for electrical charges. Because of the increased power requirement, a lower charge of \$0.05 per kwh was used instead of \$0.085 per kwh.

Total ISV cost is \$8,000,200 for the operations and maintenance. This includes the ISV operation, operations monitoring, and engineering and supervision. The operations period costs occur from years 0 through 1. From year 2 to 5, post-interim action monitoring costs of \$168,000 occur, which include ground-water monitoring and reporting.

5.2.6.3 Present Worth Value

The present worth value for the operations and post-interim action period O&M cost is \$8,657,000.

5.2.7 Alternative 7 - Chemical Fixation With On-site Disposal

Cost details for this alternative are presented in Table 5-6 and a present worth summarization is presented in Table 5-8.

5.2.7.1 Capital Cost

The total capital requirement is \$624,000 which is based on the liner construction, air monitoring site preparation costs and on-site landfill construction. The liner will contain excavated soils prior to treatment as well as treated soil until testing for the chemical fixation is complete.

5.2.7.2 Annual Operations and Maintenance

The total annual O&M cost of \$1,708,100 includes the chemical fixation process at \$65 yd³, soils handling, and sampling and monitoring. The chemical fixation will be completed within one year and is to occur at a rate of 500 yd³ per day (assuming one unit). Performance sampling is based on one sample per 500 yd³ of soil.

A post-interim action cost of \$193,000 will occur from years 2 to 5 and will include both air and groundwater monitoring as well as cap maintenance on the on-site landfill.

5.2.7.3 Present Worth Value

The total present worth value is \$2,902,000 which is a total of the capital, the present worth for the operating period (year 1), and the post-interim action period (years 2-5).

5.2.8 Alternative 8 - Chemical Fixation With Off-site Disposal

Cost details for this alternative are presented in Table 5-7.

5.2.8.1 Capital Cost

The total capital requirement of \$161,900 is based on air monitoring capital and site preparation which includes removing the existing structures on the basins, as well as engineering and supervision.

5.2.8.2 Operations and Maintenance

Operations and maintenance costs consist of a first year operations cost of \$8,378,400, and a post-interim action O&M of \$168,000 which will occur from years 2 through 5. First year O&M costs include the chemical fixation process at \$65/yd³, performance sampling and monitoring, transporting 17,800 tons to the USPCI Class I facility in Utah, and engineering and supervision. The chemical fixation will be completed at a rate of 500 yd³ per day (assuming one unit). Performance sampling is based on one sample per 500 yd³ of soil/sludge. Disposal and transportation costs are based on \$140/ton and \$120/ton, respectively.

5.2.8.3 Present Worth Value

A total present worth value of \$8,708,000 is the sum of the capital and an operations and post-interim action O&M present worth cost of \$8,546,000.

5.3 SENSITIVITY ANALYSIS

A sensitivity analysis has been performed to determine which alternative will be affected by changes in the design basis presented in Section 2.5. Table 5-9 summarizes this analysis and presents the total present worth value for each alternative per sensitivity parameter. A discussion of each parameter follows:

- Additional Volume of Contaminated Soil: The volume of soil/sludge to be treated was increased by assuming a larger extent of contamination. An extended boundary was added to the known boundaries of the M-1 Settling Basins, making the dimensions of the basins 140 feet by 330 feet, and the contamination was assumed to extend to 10 feet below ground surface. The containment alternatives (Alternatives 4 and 5) were only affected slightly by this change with their total present worth value increasing 3 to 5 percent. Chemical fixation with on-site disposal total present worth costs were increased 43 percent. In-situ vitrification (ISV) and chemical fixation with off-site disposal were

most affected by the volume change with total present worth cost increases of 73 percent and 78 percent, respectively.

- Double Unit Treatment Costs: Costs for three of the alternatives are dependent on the unit treatment costs. The unit treatment costs were doubled to evaluate the effect of the unit costs on the total cost for the alternatives. Doubling the unit treatment costs had an affect similar to adding additional volumes of contaminated soil. Total present worth costs for chemical fixation with on-site disposal increased 32 percent. Total present worth costs for ISV increased dramatically, 81 percent. Total present-worth costs for chemical fixation with off-site disposal only increased 11 percent because the bulk of the cost for that alternative is because of the transport and disposal of the fixed material.

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Table 5-1
Alternative 2-Groundwater and Air Monitoring: Cost Estimate
M-1 Settling Basins

ASSUMPTIONS:

- (1) Groundwater samples at \$5000/sample (includes labor, health and safety at Level B personal protective equipment, and analytical)
- (2) Quarterly groundwater sampling of 5 wells (20 samples/year)
- (3) Quarterly groundwater monitoring will continue for the duration of the IRA
- (4) For air monitoring, assume quarterly sampling of four stations on each side of the site
- (5) Air monitoring samples include dust/metals, pesticides, and volatile organics

ITEM	DESCRIPTION	UNIT	UNIT COST	AMOUNT	COST
(A) GROUNDWATER MONITORING:					

CAPITAL COSTS (NONE)					
ANNUAL OPERATIONS AND MAINTENANCE					
(1)	Sampling of Existing Monitoring Wells	ea.	\$5,000	20	\$100,000
(2)	Reporting/ Data Interpretation	ea.	\$10,000	4	\$40,000

				Subtotal	\$140,000
(3)	Contingency at 20%				28,000

				ANNUAL O&M COST	\$168,000
(B) AIR MONITORING:					

CAPITAL COST					
(1)	DUST PM 10	ea.	\$3,000	4	\$12,000
(2)	PUF	ea.	\$4,000	4	\$16,000
(3)	Sampling Pumps	ea.	\$1,000	4	\$4,000
(4)	Technical Support and Program Design	ea.	\$20,000	1	\$20,000

				Subtotal	\$52,000
(5)	Contingency at 20%				\$10,400

				TOTAL CAPITAL COST	\$62,400

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Table 5-1 (Continued)

ANNUAL OPERATIONS AND MAINTENANCE (O&M)					
(1)	DUST / metals sampling	ea.	\$1,000	16	\$16,000
(2)	PUF	ea.	\$300	16	\$4,800
(3)	Volatiles	ea.	\$300	16	\$4,800
(4)	Labor	ea.	\$20,000	4	\$80,000
(5)	Interpretation & Reporting	ea.	\$10,000	4	\$40,000

				Subtotal	\$145,600
(6)	Contingency at 20%				29,120

				ANNUAL O&M COSTS	\$174,720

Table 5-1 (Continued)

ANNUAL OPERATIONS AND MAINTENANCE (O&M)				
(1) DUST / metals sampling	ea.	\$1,000	16	\$16,000
(2) PUF	ea.	\$300	16	\$4,800
(3) Volatiles	ea.	\$300	16	\$4,800
(4) Labor	ea.	\$20,000	4	\$80,000
(5) Interpretation & Reporting	ea.	\$10,000	4	\$40,000

		Subtotal		\$145,600
(6) Contingency at 20%				29,120

		ANNUAL O&M COSTS		\$174,720

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Table 5-2
Alternative 3 - Institutional Controls: Cost Estimate
M-1 Settling Basins

ASSUMPTIONS:

- (1) Institutional controls costs include air and groundwater monitoring
- (2) Institutional controls consist of perimeter fencing (910 ft) which assumes a 10 foot boundary around the contaminated area

ITEM	DESCRIPTION	UNIT	UNIT COST	AMOUNT	COST
CAPITAL COST					
(1)	Monitoring Capital (Item B, Table 5-1)				\$62,400
(2)	Site Preparation				\$20,000
(3)	Fencing	L.F.	\$10	910	\$9,100

		Subtotal			\$91,500
(4)	Contingency at 20%				\$18,300

	TOTAL CAPITAL COST				\$109,800
ANNUAL OPERATIONS AND MAINTENANCE (years 0-5) (Items A and B, Table 5-1)					
(1)	Groundwater Monitoring				\$168,000
(2)	Air Monitoring				\$174,720

	ANNUAL O&M COSTS				\$342,720

Table 5-3
Alternative 4 - Containment: Slurry Wall and Cap: Cost Estimate
M-1 Settling Basins

ASSUMPTIONS:

- (1) Site preparation will consist of grading and filling of low-lying areas to control runoff
- (2) A slurry wall will surround the three M-1 Settling Basins. The length of the slurry wall is estimated to be 910 feet, the depth is assumed to be 25 ft.
- (3) The multilayer cap design is based on most appropriate protection for an interim action.
- (4) Monitoring costs are detailed in Table 5-1

ITEM	DESCRIPTION	UNIT	UNIT COST	AMOUNT	COST
CAPITAL COST					
(1)	Air Monitoring Capital (Item B, Table 5-1)				\$62,400
(2)	Site Preparation (includes removal of above-ground equipment)				\$50,000
(3)	Slurry Wall	ft2	\$12	22,800	\$273,600
(4)	Construct cap:				
	Clay	yd3	\$8	2,400	\$19,200
	Flexible membrane	yd2	\$5	4,800	\$25,920
	Synthetic drainage net	yd2	\$3	4,800	\$15,840
	Geotextile	yd2	\$2	4,800	\$10,560
	Protective soil layer	yd3	\$8	1,600	\$12,800
	Cap Cost				\$84,320
	Subtotal				\$470,320
(5)	Engineering and Supervision at 20%				\$94,064
	Subtotal				\$564,384
(6)	Contingency at 20%				\$112,877
	TOTAL CAPITAL COSTS				\$677,261
ANNUAL OPERATIONS AND MAINTENANCE COSTS					
A.	Construction Operations Monitoring (year 0-1) (Items A and B, Table 5-1)				\$342,720
B.	Post-Interim Action Monitoring (years 2-5)				
(1)	Groundwater Monitoring (Item A, Table 5-1)				\$168,000
(2)	Cap Maintenance				\$25,000
	ANNUAL POST-INTERIM ACTION O&M COSTS				\$193,000

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Table 5-4
Alternative 5 - Containment Multi-Layer Cap: Cost Estimate
M-1 Settling Basins

ASSUMPTIONS:

- (1) Site preparation will consist of grading and filling of low-lying areas to control runoff.
- (2) Cap design is the same as the slurry wall and cap alternative.
- (3) Monitoring costs are detailed in Table 5-1.

ITEM	DESCRIPTION	UNIT	UNIT COST	AMOUNT	COST
CAPITAL COST					
(1)	Air Monitoring Capital (Item B, Table 5-1)				\$62,400
(2)	Site Preparation (includes removal of above-ground equipment)				\$50,000
(3)	Construct Cap:				
	Clay	yd3	\$8	2,400	\$19,200
	Flexible Membrane	yd2	\$5	4,800	\$25,920
	Synthetic Drainage Net	yd2	\$3	4,800	\$15,840
	Geotextile	yd2	\$2	4,800	\$10,560
	Protective Soil Layer	yd3	\$8	1,600	\$12,800

	Cap Cost				\$84,320

	Subtotal				\$196,720
(4)	Engineering and Supervision at 20%				\$39,344

	Subtotal				\$236,064
(5)	Contingency at 20%				\$47,213

	TOTAL CAPITAL COST				\$283,277
ANNUAL OPERATIONS AND MAINTENANCE COST					
A.	Construction Operations Monitoring (year 0-1) (Items A and B, Table 5-1)				\$342,720
B.	Post-Interim Action Monitoring (years 2-5)				
(1)	Groundwater Monitoring (Item A, Table 5-1)				\$168,000
(2)	Cap Maintenance				\$25,000

	ANNUAL POST-INTERIM ACTION O&M COSTS				\$193,000

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Table 5-5
Alternative 6 - In Situ Slurry Wall and Vitrification: Cost Estimate
M-1 Settling Basins

ASSUMPTIONS:

- (1) Slurry wall constructed to 15 ft to reduce potential groundwater recharge in the vitrification area
- (2) There will be no dewatering within the slurry wall
- (3) Vitrification cost includes \$400/ton for electricity and \$20/ton for off-gas treatment. Assume treatment rate of 6 tons/hr (144 tons per day) for a project life of 105 days (assume 1 year)
- (4) Soil volume = 9,000 yd³ at 1.35 ton/yd³

ITEM	DESCRIPTION	UNIT	UNIT COST	AMOUNT	COST
CAPITAL COST					
(1)	Air Monitoring Capital (Item B, Table 5-1)				\$62,400
(2)	Site Preparation (includes removal of above-ground equipment)				\$50,000
(3)	Slurry Wall	ft ²	\$12	13,700	\$164,400
(4)	Site Restoration Includes: Backfill, grading and replanting				\$50,000
	Subtotal				\$326,800
(5)	Engineering and Supervision at 20%				\$65,360
	Subtotal				\$392,160
(6)	Contingency at 20%				\$78,432
	TOTAL CAPITAL COST				\$470,592
ANNUAL OPERATIONS AND MAINTENANCE (year 0-1)					
(1)	Construction Operations Monitoring (Items A and B, Table 5-1)				\$342,720
(2)	Mobilization/Demobilization				\$110,000
(3)	Vitrify Solids				
	soil vitrification	ton	\$400	12,150	\$4,860,000
	off-gas treatment	ton	\$20	12,150	\$243,000
	Vitrification				\$5,555,720
(4)	Engineering and Supervision at 20%				\$1,111,144
	Subtotal				\$6,666,864
(5)	Contingency at 20%				\$1,333,373
	ANNUAL O&M COSTS				\$8,000,237
ANNUAL POST-INTERIM ACTION O&M COSTS (years 2-5)					
	Groundwater Monitoring (Item A, Table 5-1)				\$168,000

Table 5-6
Alternative 7 - Chemical Fixation With On-site Disposal: Cost Estimate
M-1 Settling Basins

ASSUMPTIONS:

- (1) On-site above-ground landfill construction and filling operations will be performed within one year
- (2) Landfill bottom liner system includes leachate collection system
- (3) Landfill cover consists of a multilayer system
- (4) Landfill volume assumes a 20 percent bulking factor from excavation plus 10 percent bulking from chemical fixation
- (5) Soils will be excavated and stored on a temporary pad which will also contain the chemical fixing process equipment
- (6) Treatment will be conducted by a turnkey contractor within the first year

ITEM	DESCRIPTION	UNIT	UNIT COST	AMOUNT	COST
CAPITAL COST					
(1)	Air Monitoring Capital (Item B, Table 5-1)				\$62,400
(2)	Site Preparation (includes removal of above-ground equipment)				\$50,000
(3)	Construct Landfill				
	Landfill Construction				
	Area Preparation	yd3	\$3	2,500	\$7,500
	Clayey Soil Liner	yd3	\$8	2,500	\$20,000
	Flexible Membrane Liner	yd2	\$5	4,900	\$26,460
	Synthetic Drainage Net	yd2	\$3	4,900	\$15,680
	Geotextile Filter Fabric	yd2	\$2	4,900	\$10,780
	Cover Construction				
	Clayey Soil Liner	yd3	\$8	2,600	\$20,800
	Flexible Membrane Liner	yd2	\$5	5,200	\$28,080
	Synthetic Drainage Net	yd2	\$3	5,200	\$16,640
	Geotextile Filter Fabric	yd2	\$2	5,200	\$11,440
	Protective Soil Layer	yd3	\$8	1,700	\$13,600

	Landfill Costs				\$170,980

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Table 5-6 (Continued)

(4) Liner Construction (for temporary storage and treatment facility)				\$100,000
(5) Site Restoration				\$50,000
			Subtotal	\$433,380
(6) Engineering and Supervision at 20%				\$86,676
			Subtotal	\$520,056
(7) Contingency at 20%				\$104,011
			TOTAL CAPITAL COST	\$624,067
ANNUAL OPERATIONS AND MAINTENANCE (year 0-1)				
(1) Construction Operations Monitoring (Items A and B, Table 5-1)				\$342,720
(2) Soils Handling (backfilling included)	yd3	\$12	10,800	\$129,600
(3) Chemically Fix Soils	yd3	\$65	10,800	\$702,000
(4) Performance Sampling and Monitoring	yd3	\$500	24	\$11,880
			Subtotal	\$1,186,200
(5) Engineering and Supervision at 20%				\$237,240
			Subtotal	\$1,423,440
(6) Contingency at 20%				\$284,688
			ANNUAL O&M COSTS	\$1,708,128
ANNUAL POST-INTERIM ACTION O&M COST (years 2-5)				
(1) Groundwater Monitoring (Item A, Table 5-1)				\$168,000
(2) Cap Maintenance				\$25,000
			ANNUAL POST-INTERIM ACTION O&M COSTS	\$193,000

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Table 5-7
Alternative 8 - Chemical Fixation With Off-site Disposal: Cost Estimate
M-1 Settling Basins

ASSUMPTIONS:

- (1) Soils will be excavated and stored on a temporary pad which will also contain the chemical fixing process equipment
- (2) Treatment will be conducted by a turnkey contractor within the first year
- (3) Soils will be transported to the USPCI facility in Grassy Mountain, Utah at a cost of \$120/ton transportation and \$140/ton disposal
- (4) Soil amount = 6,400 yd³ + 20% excavation bulking + 10% chemical fixation bulking; assume 1.5 tons/yd³ for fixed materials

ITEM	DESCRIPTION	UNIT	UNIT COST	AMOUNT	COST
CAPITAL COST					
1)	Air Monitoring Capital (Item B, Table 5-1)				\$62,400
2)	Site Preparation (includes removal of above-ground equipment)				\$50,000
	Subtotal				\$112,400
3)	Engineering and Supervision at 20%				\$22,480
	Subtotal				\$134,880
4)	Contingency at 20%				\$26,976
	TOTAL CAPITAL COST				\$161,856
ANNUAL OPERATIONS AND MAINTENANCE (year 0-1)					
(1)	Construction Operations Monitoring (Items A and B, Table 5-1)				\$342,720
(2)	Soils Handling (backfilling included)	yd ³	\$12	10,800	\$129,600
(3)	Chemically Fix Soils	yd ³	\$65	10,800	\$702,000
(4)	Performance Sampling and Monitoring	yd ³	\$500	22	\$10,800
(5)	Transport to Off-site Facility	ton	\$120	17,820	\$2,138,400
(6)	Off-site Landfill Disposal Fee	ton	\$140	17,820	\$2,494,800
	Subtotal				\$5,818,320
(7)	Engineering and Supervision at 20%				\$1,163,664
	Subtotal				\$6,981,984
(8)	Contingency at 20%				\$1,396,397
	ANNUAL O&M COSTS				\$8,378,381
ANNUAL POST-INTERIM ACTION O&M COSTS (years 2-5)					
	Groundwater Monitoring (Item A, Table 5-1)				\$168,000

Table 5-8
Present Worth Summary Table
M-1 Settling Basins

Design Basis
Soil Volume = 9,000 (yd³)
Discount Factor = 5%

ALTERNATIVE	CAPITAL COSTS	ANNUAL O & M OPERATIONS	ANNUAL O & M POST-IRA	PRESENT WORTH ANNUAL O&M Opn & Post-IRA	TOTAL PRESENT WORTH VALUE (Cap. + O&M)
ALT 2 - Monitoring	\$62,000	Yrs. 0 - 5 \$343,000	NA	\$1,485,000	\$1,547,000
ALT 3 - Institutional Controls	\$110,000	Yrs. 0 - 5 \$343,000	NA	\$1,485,000	\$1,595,000
ALT 4 - Containment Slurry Wall and Cap	\$677,000	Yrs. 0 - 1 \$343,000	Yrs. 2 - 5 \$193,000	\$978,000	\$1,655,000
ALT 5 - Containment Multi-layered Cap	\$283,000	Yrs. 0 - 1 \$343,000	Yrs. 2 - 5 \$193,000	\$978,000	\$1,261,000
ALT 6 - In-situ Slurry Wall and Vitrification	\$471,000	Yrs. 0 - 1 \$8,000,000	Yrs. 2 - 5 \$168,000	\$8,186,000	\$8,657,000
ALT 7 - Treatment Chemical Fixation with On-site Disposal	\$624,000	Yrs. 0 - 1 \$1,708,000	Yrs. 2 - 5 \$193,000	\$2,278,000	\$2,902,000
ALT 8 - Treatment Chemical Fixation with Off-site Disposal	\$162,000	Yrs. 0 - 1 \$8,378,000	Yrs. 2 - 5 \$168,000	\$8,546,000	\$8,708,000

This alternative assessment document has summarized the history and extent of contamination at the M-1 Settling Basins. This information was used to develop a basis by which technologies could be evaluated. Both demonstrated and promising technologies were formulated into eight alternatives to address the contaminated soil and sludge at the site.

The eight alternatives have been evaluated based on the criteria described in Section 4.2. This section initiates the decision process by ranking the alternatives. Figure 6-1 shows the decision logic. The alternatives have been classified as one of the following:

- Preferred: Preferred alternatives meet the threshold criteria listed in Table 4-1a and meet most of the evaluation criteria listed in Table 4-1b. Preferred alternatives will be considered further in the IRA decision document.
- Marginally preferred: Marginally preferred alternatives meet the threshold criteria listed in Table 4-1a to some degree and meet some of the evaluation criteria listed in Table 4-1b. Marginally preferred alternatives will be considered further in the IRA Decision Document.
- Not preferred: Alternatives which are not preferred either do not meet the threshold criteria of Table 4-1a or meet few of the evaluation criteria of Table 4-1b. These alternatives will not be considered in the IRA Decision Document.

The eight alternatives are classified in Table 6-1. There are two preferred alternatives:

- Alternative 6 - In-situ vitrification
- Alternative 7 - Chemical fixation with on-site disposal

These alternatives are protective of human health and environment and can be designed to meet all ARARs.

There are three marginally preferred alternatives:

- Alternative 4 - Slurry wall with cap
- Alternative 5 - Multi-layered cap
- Alternative 8 - Chemical fixation with off-site disposal

Alternatives 4 and 5 are somewhat to moderately protective of human health and the environment. Alternative 8 is extremely expensive and has the potential for long-term liability.

There are three alternatives which are not preferred:

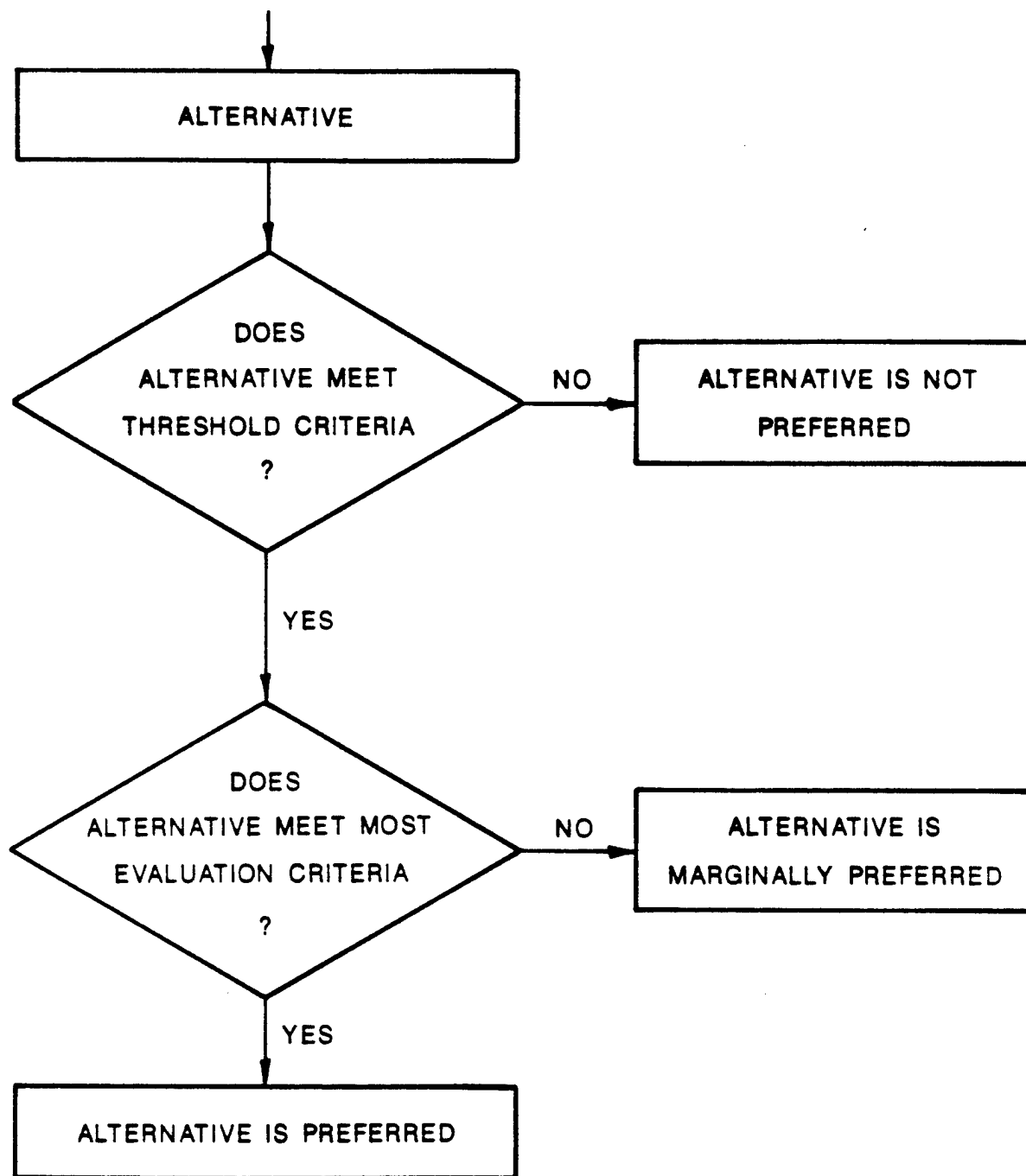
- Alternative 1 - No action
- Alternative 2 - Monitoring
- Alternative 3 - Institutional controls

Alternatives 1, 2, and 3 are not protective of human health and the environment and will not be considered further.

The preferred and marginally preferred alternatives will be evaluated and screened in greater detail in the IRA Decision Document. This document will recommend a preferred alternative for addressing contaminated soil at the M-1 Settling Basins.

TABLE 6-1
ALTERNATIVE CLASSIFICATION

Alternative	Classification	Comments
1. No Action	Not Preferred	Not protective; no reduction in mobility, toxicity, or volume. No short- or long-term effectiveness.
2. Monitoring	Not Preferred	Not protective; no reduction in mobility, toxicity, or volume; no long-term effectiveness.
3. Institutional Controls	Not Preferred	Not protective; no reduction in mobility, toxicity, or volume; no long-term effectiveness.
4. Slurry Wall With Cap	Marginally Preferred	Somewhat protective; reduces mobility, does not reduce contaminant toxicity or volume; good short-term effectiveness; poor long-term effectiveness.
5. Multi-layered Cap	Marginally Preferred	Somewhat protective; reduces mobility, does not reduce contaminant toxicity or volume; moderate short-term effectiveness; poor long-term effectiveness.
6. In-situ Vitrification	Preferred	Protective; reduces mobility, toxicity, and volume; good short- and long-term effectiveness; high cost.
7. Chemical Fixation With On-site Disposal	Preferred	Protective; reduces mobility and toxicity, increases volume; good long-term effectiveness; some short-term effects possible; treatability testing required.
8. Chemical Fixation With Off-site Disposal	Marginally Preferred	Protective; reduces mobility and toxicity, increases volume; good long-term effectiveness, but potential short-term effects possible; treatability testing required; high cost.



THRESHOLD CRITERIA: OVERALL PROTECTION OF HUMAN HEALTH
AND THE ENVIRONMENT

COMPLIANCE WITH ARARS

EVALUATION CRITERIA: REDUCTION OF TOXICITY, MOBILITY AND VOLUME
SHORT-TERM EFFECTIVENESS
LONG-TERM EFFECTIVENESS
IMPLEMENTABILITY
COST

Job No. : 22238

Prepared by: K.A.S.

Date: 9/4/89

Figure 6-1 IRA ALTERNATIVE
RANKING

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APPENDIX A
COMMENTS AND RESPONSES

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This Appendix is held open pending receipt of comments from the reviewing parties and completion of responses to those comments.