Kaiser Aluminum and Chemical Company

Mead Works

EXECUTIVE SUMMARY
CYANIDE REMOVAL INVESTIGATION

Prepared by

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Project No.: S13780.A0
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INTRODUCTION AND OBJECTIVES

The Kaiser Aluminum and Chemical Company has found that leachate from a spent potliner pile at their plant at Mead, Washington, has contaminated local ground water with iron-complexed cyanide. The source of the cyanide has been isolated to prevent further leaching and the company is taking positive steps to prevent further spread of the contaminated water into adjacent areas.

The approach being investigated for preventing the spread of the contaminated water involves the following steps:

1. Drill blocking wells and remove the contaminated ground water

2. Treat the contaminated water to remove the contaminants

3. Discharge the purified water to a surface receiving stream

4. Destroy or dispose of the concentrated contaminants

The Kaiser Aluminum and Chemical Company has contracted with CH2M HILL to identify, select, and test candidate processes for removing or destroying cyanide and fluoride, the other principal contaminant. The project objectives are to:

- Identify and select appropriate treatment technologies for removal of contaminants.

- Meet or exceed preset discharge limits for these contaminants.

- Select a process that is reasonable in cost.

CH2M HILL's primary tasks in the current contract are to conduct a literature review and select contaminant removal and destruction technologies, perform laboratory bench-scale testing to verify the selection, and develop a conceptual-level process flowsheet and cost estimate for the selected treatment scheme. These three activities have been completed.

RESULTS

Background. Prior studies performed by another contractor have suggested that blocking wells could remove 60 to 80 gallons per minute of contaminated ground water. For this study, the flow rate has been rounded up to 100 gallons per minute. The contaminated water would be treated to remove cyanide and fluoride and then would be discharged into Tharpe Lake.

Tharpe Lake is the effluent water receiving pond at the Mead Works. It receives an annual average of about 2.5 million gallons of plant wastewater per day. For purposes of this study, the estimated amount it receives is assumed to average 2 million gallons per day (1,389 gallons per minute). The concentration of contaminants in the treated water would be diluted by the large flow through Tharpe Lake.

Literature Review. CH2M HILL reviewed laboratory reports and cyanide treatment literature provided by Kaiser Aluminum and Chemical Company. In addition, CH2M HILL cited over 50 sources on cyanide and fluoride removal technology from open literature.

The literature review confirmed one key fact: iron-complexed cyanide (ferricyanide and ferrocyanide) is essentially unaffected by most processes used to destroy free cyanide or cyanide bound to other metals.

Nineteen cyanide treatment processes were identified during the literature survey. Eight of these had no effect on iron-complexed cyanide; five were of questionable utility either due to the lack of specific process information or because they were in a primitive stage of development; and six held some potential for iron-complexed cyanide removal or destruction.

Four of the six candidate processes were of limited interest because of their extreme energy consumption, lack of operating history, materials selection problems, process control difficulties, and other factors. The four uninteresting processes (and the primary reason they were not considered further) were: ultraviolet/ozone treatment (high operating cost and technical problems); solar destruction (very limited design or performance data); hot alkaline chlorination (high chlorine residual in effluent, multiple technical problems); and thermal destruction (very energy intensive, high operating cost).

The two remaining processes were selected for laboratory bench-scale cyanide removal testing. These processes were ferri- and ferrocyanide removal by selective ion exchange and chemical precipitation with iron salts.

The literature review of fluoride removal technology identified three potential precipitation processes: removal by iron salt precipitation, alum treatment, and precipitation as calcium fluoride. Five other fluoride removal schemes were considered briefly, but were dismissed.

Bench Tests. Ten cyanide precipitation tests run in laboratory glassware always showed a cyanide concentration reduction over 98.6 percent to 2-3 mg/l (ppm) from an initial value of 225 mg/l by adding iron compounds, provided well-defined test conditions were maintained. When the cyanide precipitation reaction was run in 100-gallon batches and stirred for a longer time than the laboratory glassware tests, the cyanide concentration after treatment was always less than 0.8 mg/l (800 ppb), except for one run in which test conditions were purposely altered. This amounts to a 99.6 percent removal.

This suggests that with even longer retention times, lower cyanide levels than 800 ppb could be achieved. Pilot tests with continuous flow equipment will be needed to determine whether these low levels can be attained in a full-scale continuous process.

The 100-gallon batches of iron salt-treated water were prepared as a pretreatment step for selective ion exchange column testing. The ion exchange resin whose performance was evaluated was Rohm and Haas macr0-reticular weak base anion resin IRA-35 in the sulfate form.

Seven ion exchange tests were run with iron salt-pretreated water. In all cases, the total cyanide content was reduced; however, in five of the runs, the ion exchange column became bound with carbon dioxide gas, which was slowly being released from the mildly acidic column feed. This indicates that a decarbonator will have to be included in the process design. Also, during these five runs iron oxide deposited in the ion exchange column, fouling the resin, and causing an increase in pressure drop across the column. This led to the conclusion that excess iron will need to be removed before the water is fed to the ion exchanger. In the remaining two test runs, the column feed was air sparged to remove the carbon dioxide, and excess iron was precipitated.

The first test run with air-sparged feed gave a threefold reduction in total cyanide to 0.22 mg/l (220 ppb) from an initial level (after iron salt precipitation) of 700 ppb at a column throughput rate of 8 bed volumes (BV) per hour. The second test run with air-sparged feed was made at 19 BV/hour, and the cyanide level was reduced only to 550 ppb from an initial value of 700 ppb. These ion exchange tests indicate that cyanide is more efficiently removed at low flow rates.

Fluoride removal tests were run in the laboratory to evaluate the three types of treatment under consideration. The tests with ferric chloride showed that great excesses of chemicals would be required to attain more than a nominal fluoride reduction below the 185 mg/l concentration in the raw water. Ferric chloride tests were discontinued because of the poor test results.

Fluoride precipitation with alum was also tested. Although a significant excess of alum was required to promote fluoride precipitation, fluoride concentrations under 90 mg/l could be obtained. Fluoride removal with alum was discontinued when it became apparent that lime treatment would be required to remove excess iron from ion exchange system feed. Calcium from the lime used to precipitate excess iron will combine with fluoride in the water to form a calcium fluoride precipitate.

Subsequent tests with lime produced a treated water which had fluoride concentrations ranging between 18 and 66 mg/l. Typically, the fluoride level was reduced to the 20- to 50-mg/l range in treated water. This range is somewhat higher than reported in several literature sources, and is thought to be due to the high ionic background of the water.

Process Flowsheet. The preliminary process design is based on treating 100 gallons per minute of contaminated ground water. The design criteria are based on results obtained in laboratory bench-scale tests performed by CH2M HILL. Figure 1 is the preliminary flow diagram of the process.

Contaminated water is pumped at a rate of 100 gpm into an equalization tank having a 12-hour storage capacity. The cyanide content of the contaminated raw water was assumed to be about 200 mg/l based on the composition of the sample tested in the laboratory. The raw water pH is reduced from 9.7 to about 6 and the water is fed into a rapid-mix tank to which ferrous sulfate, ferric chloride, and a polyelectrolyte are added to precipitate iron-complexed cyanide. The rapid-mix tank is followed by a stirred tank reactor and a clarifier/ thickener. Ferri- and ferrocyanide complexes are precipitated along with excess ferric hydroxide and are settled out in the clarifier/thickener. Thickened sludge is recycled to the rapid-mix tank and a slip stream is dewatered in a sludge drying bed system to produce a solid waste. The drying bed is periodically cleaned, and the solid waste is transferred to the pot liner pile for future permanent storage or transport to an off-site disposal facility.

The clarifier overflow is passed through a mixed-media pressure filter to remove any remaining cyanide-bearing suspended solids. The dissolved cyanide content of the filter effluent is expected to be 0.5 to 1 mg/l. The filter effluent is then fed into a decarbonation system in which the pH of the solution is dropped to 5.0 and air is sparged into the solution to strip carbon dioxide. The alkalinity of the contaminated water is reduced to a low level in the process. Carbon dioxide removal is necessary to avoid degassing of the solution in the ion exchanger columns.

The effluent from the decarbonation system is fed into an equalization tank and then into the fluoride removal system. Lime, calcium chloride, and a polyelectrolyte are added to the stream in a rapid-mix tank. These chemicals precipitate fluoride (as calcium fluoride) and iron (as ferrous hydroxide) in a stirred reactor downstream. The reactor effluent is fed to a clarifier/thickener in which the calcium fluoride and ferrous hydroxide are removed. The clarified effluent is passed through a mixed-media gravity filter for further suspended solids removal. The pH of the solution in the fluoride removal process is about 8.

Most of the clarifier sludge is recycled to the rapid-mix tank and the rest is dewatered in the sludge drying bed for disposal along with the cyanide sludge. The fluoride removal system is expected to reduce the fluoride content of the water from 180 mg/l to less than 50 milligrams per liter.

The gravity filter effluent is then introduced into the final cyanide removal process. This process consists of a pH adjustment tank, in which the pH is adjusted to about 6, and an ion exchange system.

The effluent from the pH adjustment tank is fed into the ion exchange system in which the cyanide content of the solution is further decreased to about 200 micrograms per liter. The ion exchange resin used in this process is selective for ferri- and ferrocyanide complexes. The effluent from the ion exchange system is mixed with the existing 2-mgd effluent from the plant and discharged.

The ion exchange resin is periodically backwashed and regenerated with fresh water, caustic, and sulfuric acid.

The regenerant wastes are dumped into an evaporation pond in which the water is totally evaporated.

Cost Estimate. The costs for the three subsystems have been developed independently to better illustrate the distribution of cost in relation to the amount of contaminant removed. The estimated capital and operating costs* are shown in Table 1.

Table 1
COST ESTIMATE

System	Capital Cost (1,000 dollars)	Operating Cost (1,000 dollars/year)
Cyanide Precipitation	980	290
Fluoride Precipitation	950	180
Cyanide Polishing (ion exchange)	2,450	320
TOTAL	4,380	790

If a 15 percent interest rate on capital and an 8 percent inflation rate for operation and maintenance costs are assumed, the 20-year annualized cost distribution for the three subsystems shown in Table 2 results. Table 2 also shows the cost per 1,000 gallons of water treated, and the cost per pound of pollutant removed, assuming the initial cyanide concentration is 200 mg/l, the cyanide content of ion exchange system feed is 0.7 mg/l, and the initial fluoride level is 185 mg/l.

The figures in the table reflect the extremely high cost of treatment required to "polish" cyanide by ion exchange prior to discharge.

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*Order-of-magnitude-type estimates are accurate to +50, -30 percent (as defined by the American Association of Cost Engineers). Costs are in September 1980 dollars. Land, taxes, legal, insurance, and startup costs are not included.

Table 2
ANNUALIZED COSTS

System	Annualized Cost ($1,000/year)	Treatment Cost	
		dollars ~~$1,000~~ Per /000 GallonS	$ Per Pound Pollutant Removed
Cyanide Precipitation	388	7.4	4.4
Fluoride Precipitation	277	5.3	4.4
Cyanide Polishing (Ion Exchange)	588	11.0	2,800
TOTAL	1,223	23.7	

CONCLUSIONS AND RECOMMENDATIONS

1. Iron-complexed cyanide is essentially unaffected by most processes which can be used to destroy free cyanide or cyanide that is bound to metals other than iron.

2. There were few reliable literature sources dealing with iron-complexed cyanide removal or destruction, especially at concentrations below about 1 mg/l or in a continuous treatment system.

3. Iron salt precipitation is the recommended method for gross iron-complexed cyanide removal.

4. Bench-scale ion exchange polishing failed to reduce the cyanide content of iron salt-treated water to a sufficiently low level for direct discharge off site without substantial dilution.

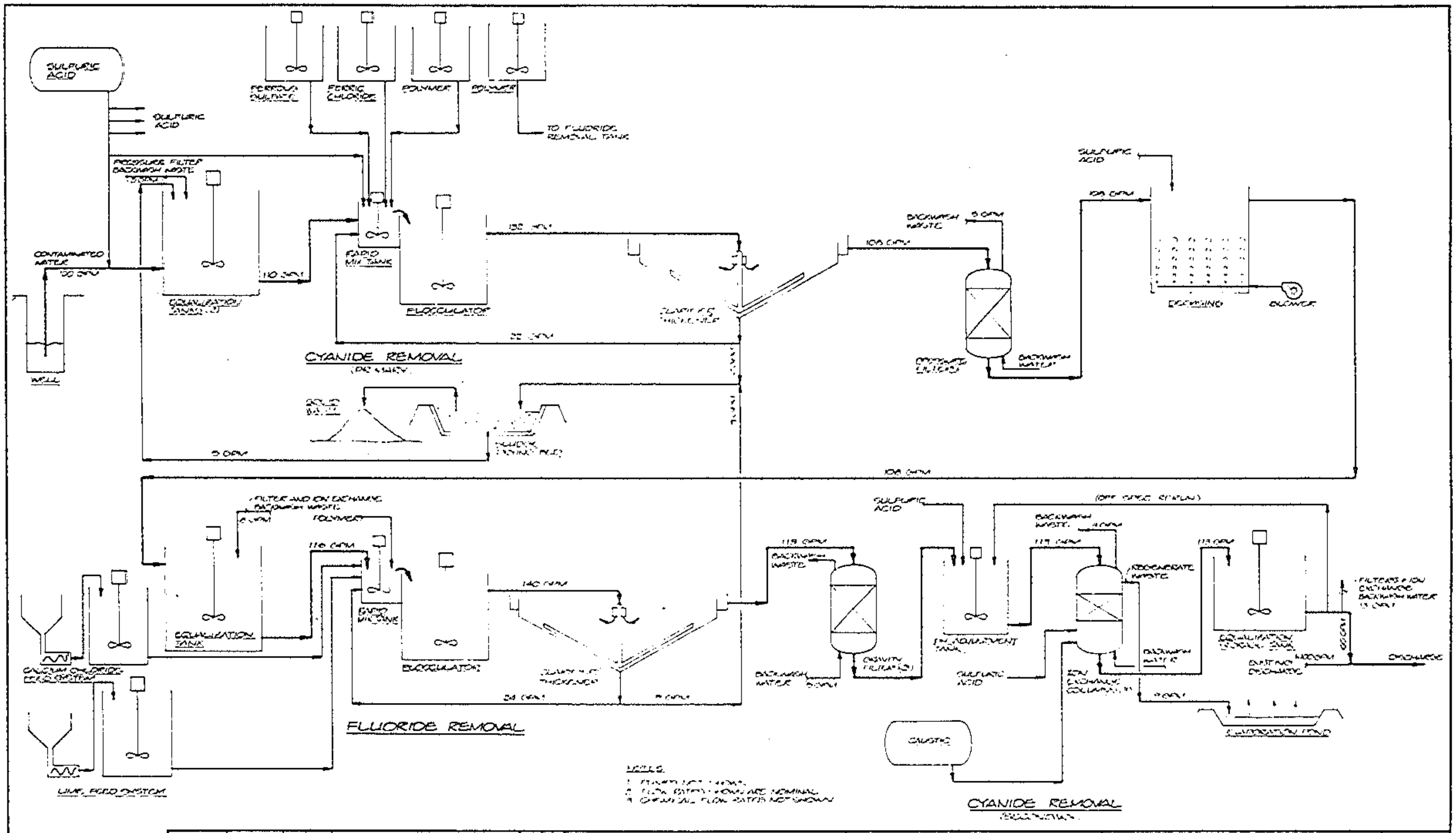
5. Calcium precipitation is the recommended method for fluoride removal.

6. Pilot plant tests are recommended to verify bench test results and to obtain design data under continuous flow conditions.

7. Some of the major uncertainties in the iron salt cyanide precipitation process are reaction rates, degree of removal under continuous flow conditions, need for sludge recycle, sludge settling and dewatering properties, and media filter removal efficiency.

8. Fluoride precipitation at Mead may be affected by the high concentrations of other ions in solution, which could indirectly affect the reaction rate and sludge properties.

9. Sun pond performance (photocatalyzed iron-cyanide dissociation and subsequent cyanide volatilization) should be investigated for at least one year as an alternative to evaporation pond disposal of ion exchange regenerant wastes.



NOTES:
1. PUMPS NOT SHOWN
2. FLOW RATES SHOWN ARE NOMINAL
3. CHEMICAL FLOW RATES NOT SHOWN

CH2M HILL

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APPD	NO	DATE	REVISION	BY	APPD

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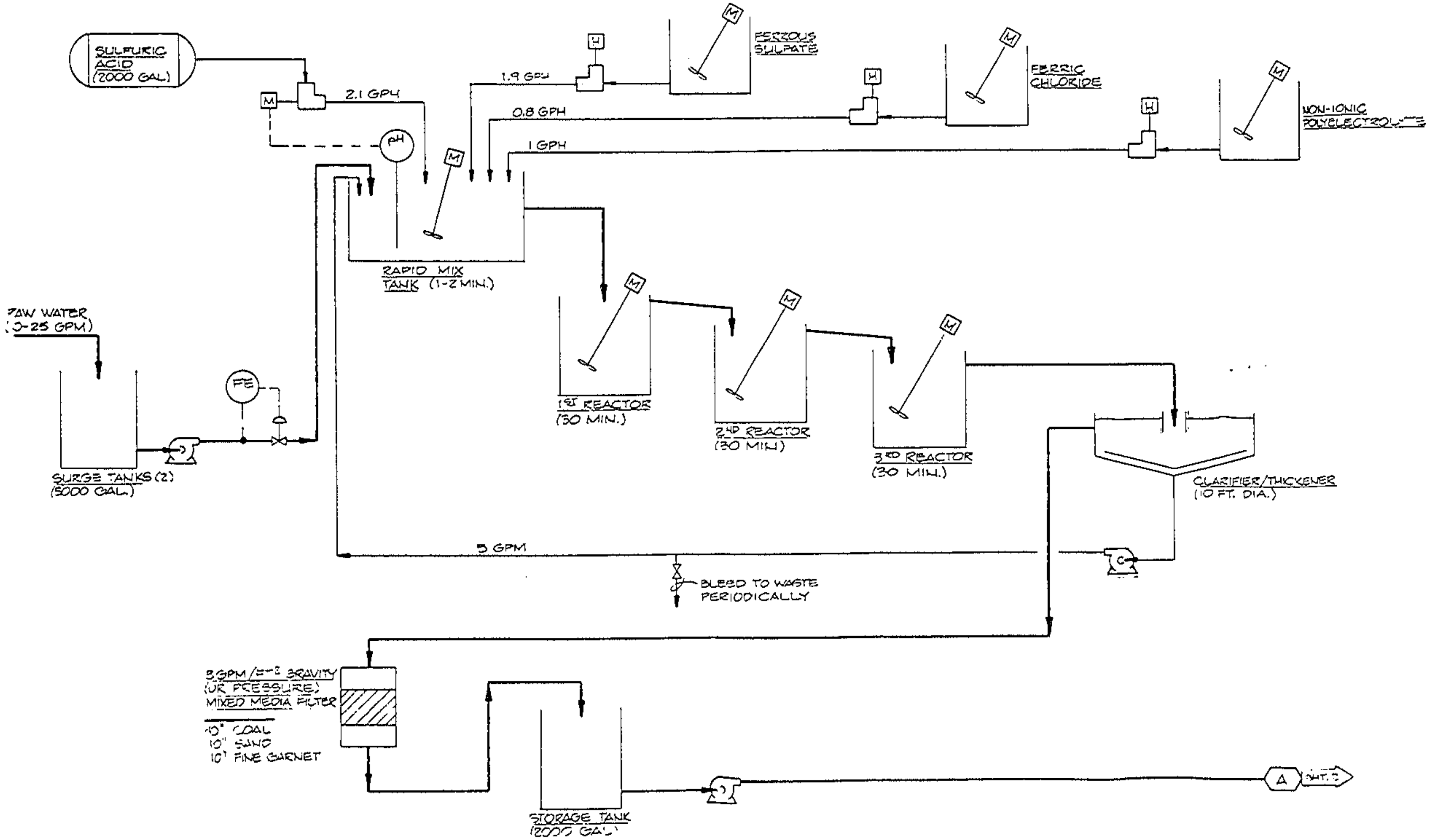
CYANIDE AND FLUORIDE REMOVAL
FIGURE 1
PROCESS FLOW DIAGRAM

SHEET 1
OF 1

PRELIMINARY



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CYANIDE PRECIPITATION
FLOW DIAGRAM

SHEET 1
JDM/CBC
SEPT. 1990

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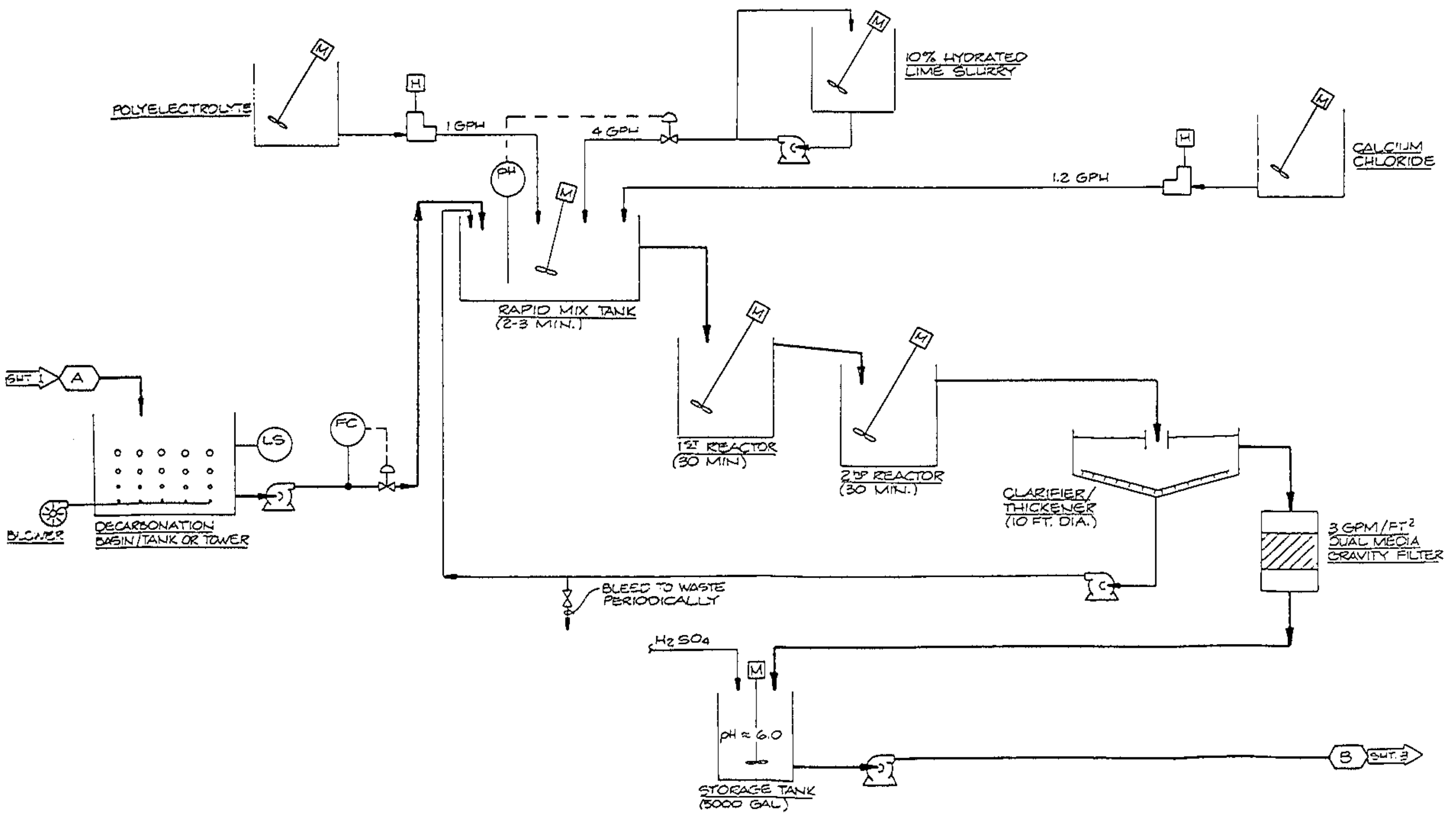

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FLUORIDE PRECIPITATION
FLOW DIAGRAM

SHEET 2
JDM/GEE
SEPT., 1980

CH2M HILL

C12780.A0

Kaiser Aluminum and
Chemical Company
Mead Works

PRELIMINARY CYANIDE AND FLUORIDE REMOVAL PILOT TEST PLAN

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Project No: S13780.A0
September 1980

PRELIMINARY CYANIDE AND FLUORIDE REMOVAL PILOT TEST PLAN

INTRODUCTION

Kaiser Aluminum and Chemical Company has found that leachate from a spent potliner pile has contaminated local ground water with iron-complexed cyanide. The source of the cyanide has been isolated to prevent further leaching, and the company is taking positive steps to prevent further spread of the contaminated water into adjacent areas.

The approach being investigated to solve the problem involves the following steps:

1. Drill blocking wells and remove contaminated ground water
2. Treat the contaminated water to remove the contaminants
3. Discharge the purified water to a surface receiving body
4. Destroy or dispose of the concentrated contaminants

CH2M HILL has surveyed cyanide and fluoride (the other principal contaminant) treatment technology and performed laboratory bench-scale treatability tests under contract to Kaiser Aluminum. The treatments consist of primary cyanide precipitation by iron salt addition, fluoride precipitation by lime and calcium chloride treatment, and final cyanide polishing by selective, weak-base anion exchange.

The laboratory results suggested current NPDES discharge permit provisions could be met with the chosen technology. However, on-site pilot tests are required to demonstrate adequate system performance and reliability and to establish a number of design parameters that cannot be readily determined in the laboratory. The proposed pilot test plant is shown schematically on Sheets 1, 2, and 3.

OBJECTIVES

The objectives of the pilot tests fall into both general and specific categories and are described below.

General:

- Verify overall cyanide and fluoride removal
- Demonstrate system reliability
- Identify practical process control parameters
- Expose unanticipated weaknesses

Specific:

Cyanide Precipitation Subsystem -

- Establish iron cyanide precipitation kinetics, including retention time and solids contacting requirements
- Measure hindered and unhindered precipitate settling rates for clarifier/thickener sizing
- Verify media filter performance
- Confirm chemical requirements
- Determine sludge dewatering properties

Fluoride Precipitation Subsystem -

- Verify calcium fluoride precipitation kinetics (ionic background effects)
- Confirm hindered and unhindered precipitate settling rates for clarifier/thickener sizing
- Determine chemical requirements
- Demonstrate calcium fluoride sludge dewatering properties

Cyanide Polishing Subsystem -

- Determine ion exchanger's cyanide selectivity
- Establish chemical requirements
- Measure rate of waste regenerant production
- Correlate cyanide selectivity with ionic background
- Explore the effect of throughput rate
- Test cyanide loss rate from a sun pond (ongoing for 1 year)
- Verify decarbonator performance

TEST PLAN

Priorities

The recommended test priorities are in the following order:

1. Cyanide precipitation kinetics and liquid-solid separation testing are most important. Laboratory testing showed that the greatest

improvements might be obtained in this system for the lowest cost per pound of cyanide removed.

2. Cyanide polishing with selective ion exchange offers much less potential for improvement than the precipitation process. More emphasis should be placed on cost reduction than on marginal improvements in technical performance.

3. Fluoride precipitation with calcium is a well-established art. Laboratory kinetics tests concurrent with pilot plant operation should provide sufficient design information. Settling, thickening, and dewatering design data may be available from literature sources. The primary need for piloting this step is to protect the ion exchanges units from iron fouling. Iron is removed concurrently with flouride.

Sequence of Tests

Consistent with the testing priorities, continuous-flow cyanide precipitation kinetics tests will be investigated first. Results of these tests directly affect the performance of the selective ion exchange polishing step. Cyanide sludge settling, thickening, and dewatering tests can be initiated concurrently with the kinetics tests.

Performance of the ion exchanger will be evaluated using feedwater compositions produced in the upstream processes. Deliberate modification of the ion exchange feedwater composition would be undertaken only if it becomes necessary to resolve conflicting results that are significant to the cost of treatment or that might compromise technical performance.

Adequate fluoride removal under the optimum conditions cited in literature could prompt a recommendation to forego extensive tests on the fluoride removal system. If poor fluoride removal were experienced, the causes would be investigated using the pilot plant and supported by laboratory tests determining whether kinetic or equilibrium limitations are governing. In any event, iron removal will be necessary to protect the ion exchange resin beds.

Data Required for Testing

The data to be taken during pilot testing consist of:

- Major flow rates (liquids and solids)
- Reagent tank liquid levels
- Chemical consumption rates (batch mix frequencies)
- Chemical compositions of the process streams
- Stream temperatures

- Time, including a log book showing the date and time significant events occurred and noting miscellaneous observations
- Ion exchange resin capacity (only if deterioration is suspected)

Chemical Analyses

Where possible, chemical testing should be performed at the Mead facility to avoid sample deterioration. This is especially important where measurements of reaction rates are involved.

Data Reduction

Test results will be evaluated both concurrently with and subsequent to test execution. It is important that a comprehensive test data evaluation immediately follow the completion of scheduled testing so that discrepancies can be identified and retesting can be performed to resolve any conflicts.

Prototype equipment sizing calculations should be made to confirm that sufficient data have been obtained and that the calculated equipment sizes and capacities are practical and realistic.

TEST PLANT EXECUTION

Location

The proposed testing will be conducted at the Kaiser Aluminum and Chemical Company Mead Works outside Spokane.

Treated Water Discharge

At an estimated pilot plant operating rate of 25 gpm, effluent containing up to 3 mg/l of total cyanide could be blended with the existing 2-million-gallon-per-day outfall before the existing 50-part-per-billion NPDES cyanide discharge limit is exceeded. Laboratory tests indicate that cyanide levels of 0.6 to 2.5 mg/l would be expected in the effluent from the cyanide precipitation subsystem. Further reductions would occur in the ion exchange section of the pilot plant.

Should the cyanide concentration of the treated water rise above 3 mg/l, two courses of action are open, depending upon the cyanide concentration:

- Reduce the discharge rate from the pilot plant until the high-cyanide-containing waste is purged (e.g., 7 mg/l cyanide could be purged by reducing the throughput to 10 gpm for about 24 hours)
- Recycle the off-spec water back to the pilot plant feed surge tank for reprocessing in the cyanide precipitation subsystem

At a pilot plant flow rate of 25 gpm, the current NPDES fluoride discharge limit of 150 pounds per day is not expected to be approached, irrespective of the degree of removal in the fluoride precipitation subsystem.

Waste Disposal

About 50,000 gallons of liquid waste will be generated during the estimated 120-day test period. Eighty-two percent arises from ion exchange regeneration, 14 percent from iron cyanide precipitation, and 4 percent from fluoride precipitation. It is proposed that this waste be impounded in an existing, large unused clarifier. The collected waste would evaporate in several years, or could be transferred to an evaporation pond, if one is built. The solids would ultimately be hauled to a dedicated land disposal site.

Pilot Plant Capacity Selection

Experience and generally accepted opinion indicate that the minimum flow rate at which continuous gravity liquid-solid separation (clarification and thickening) can be meaningfully evaluated is about 10 to 25 gallons per minute. A maximum pilot plant capacity of 25 gpm was also selected for compliance with current NPDES discharge limits for cyanide.

Schedule

The overall pilot test program is estimated to take 13 months. The testing portion requires a 4-month effort. The overall test program schedule and the testing sequence are shown in Figures 4 and 5, respectively.

It is estimated that up to 2 months could be pared from the schedule if testing of the flouride and ion exchange systems were not required. Private funding was assumed to avoid delays due to Federal procurement procedures.

Staffing

The pilot plant test program assumes around-the-clock operation. This is necessitated by the long system residence time and the long time required to build up cyanide and fluoride sludge inventories to steady-state levels. Plant operators will be needed during the 4-month test period and during the one-month shakedown run.

The test schedule has been structured for two full-time engineers, who will need frequent analytical test support from the Kaiser laboratory staff. Resin degradation testing, if required, will be performed by an off-site laboratory that specializes in this type of analysis.

COST

The estimated cost for carrying out the test plan totals $950,000 over the 13-month period. This estimate includes the following:

Installed Equipment	$700,000
Chemicals and Consumables	40,000
Engineering Services	200,000
Miscellaneous Supplies	10,000
Total	$950,000

The engineering services include pilot plant design; coordination of site preparation and equipment installation; procurement specifications, alternate source identification, and bid review; pretest shakedown; pilot plant testing; and final report preparation.

The pilot plant equipment includes the operable systems within the battery limits and assumes electricity, water, drains, and other utlities are available within close proximity of the test plant. The engineering estimate assumes fast-track procedures with maximum cooperation with construction personnel (i.e., voluminous contract documents not required.) Cost do not include: operating labor, contingency inflation, sludge drying bed, and land acquisition, sun pond, freeze protection, surveys, site preparation, and buildings.

If the scope of the pilot test plan can be reduced so that only the cyanide precipitation process is tested, the total cost could drop to about $400,000. The saving comes mostly from reduced equipment requirements.

The cost estimates advanced here are preliminary in nature and must be further refined as the plan becomes more definitive. Budget-type accuracy (+30, -15%) should be assumed.

ENGINEERING ASSESSMENT REPORT ON CYANIDE CONTAMINATION
KAISER ALUMINUM AND CHEMICAL CORPORATION
MEAD WORKS

SECOND QUARTERLY PROGRESS SUMMARY

The purpose of the Second Quarterly Progress Summary is to report progress in the compilation of background information on the cyanide release at Kaiser Aluminum's Mead Works, and describe work on the identification and development of remedial alternatives, in connection with the preparation of the Engineering Assessment Report.

In the preceding quarterly progress summary, the general approach for conducting an engineering assessment of various options for controlling the release and transport of contaminated groundwater was presented to the Department of Ecology. The description covered the following four activities:

- Characterization and documentation of the past and present situation at Mead, and preparation of a Current Status Report, under preparation by Hart Crowser
- Identification of remedial technologies that may be applicable in the current situation
- Screening and combining candidate technologies into several comprehensive remedial alternatives, and the comparative evaluation of these alternatives
- Documentation of the process in an Engineering Assessment Report

CH2M HILL is pursuing the last three activities in cooperation with Hart Crowser.

During the past 3 months, the first draft of the Current Status Report was prepared and reviewed, and a revised version is now being reviewed. The Current Status Report is estimated to be about 80 percent complete, and will provide a benchmark with which to evaluate future remedial actions at the Mead site. The report describes the discovery and investigation of the cyanide-contaminated groundwater plume extending from the vicinity of the spent potliner pile to the Little Spokane River, and chronicles the subsequent investigations and remedial actions. In light of the contaminant pathway, the majority of the report is devoted to interpreting hydrogeological interactions between source and plume, defining the contaminated plume boundaries and direction of flow, and describing progress in abating contaminant migration through a variety of remedial actions.

Work on the Engineering Assessment Report in the past 3 months has been directed toward documenting the screening of potentially applicable technologies, combining the retained technologies into remedial alternatives, and developing and evaluating the alternatives. The initial list of technologies that was used to identify potentially applicable technologies is included at the end of this progress summary, Table 2-1. The consolidated list of potentially applicable technologies which was derived from Table 2-1, is also attached as Tables 2-3, and 2-4, consisting of source-related and plume-related technologies, respectively. Descriptions of each potentially applicable technology are also included for clarification. Those technologies which were deemed applicable to Mead were compiled into sets of source-related and plume-related remedial alternatives, and these are presented in tabular form in Tables 2-5 and 2-6, respectively. The source-related remedial alternatives are also presented schematically in Figures 2-1 through 2-5. Finally, three of the remedial alternatives have a process-intensive component. These are fluid bed combustion and pyrohydrolysis, among the source-related alternatives, and cyanide precipitation from groundwater extracted from beneath the site.

Portions of the Engineering Assessment Report have been written, and report writing and evaluation of the remedial alternatives will continue into the next quarter. We appreciate your interest, and welcome any questions or comments you may have.

Initial List of Technologies

Table 2-1
TYPICAL CORRECTIVE MEASURE TECHNOLOGIES

Technology	Screening Results First Level
A. Air Pollution Controls	
o Capping	
- Synthetic membranes	
- Clay	
- Asphalt	
- Multimedia cap	
- Concrete	
- Chemical sealants/stabilizers	
o Dust Control Measures	Selected for further consideration in conjunction with waste removal technologies
- Polymers	
- Water	
B. Surface Water Controls	
o Capping (see A.)	Selected for further consideration
o Upgrade existing caps	Selected for further consideration
o Reroute, repair, or replace existing pipelines, and relocate wastewater treatment plant	Selected for further consideration
o Pipeline leak monitoring	Selected for further consideration
o Grading	Provided as a component of capping technology
- Scarification	
- Tracking	
- Contour furrowing	
o Revegetation	Considered as a component of capping technology
- Grasses	
- Legumes	
- Shrubs	
- Trees, conifers	
- Trees, hardwoods	

Table 2-1
(continued)

Technology	Screening Results First Level
o Diversion and Collection Systems	Considered as a component of capping technology
- Dikes and berms	
- Ditches and trenches	
- Terraces and benches	
- Chutes and downpipes	
- Seepage basins	
- Sedimentation basins and ponds	
- Levees	
- Addition of freeboard	
- Floodwalls	
C. Leachate and Groundwater Controls	
o Capping	Selected for further consideration
o Containment barriers	Components selected for further consideration
Function options	
- Downgradient placement	
- Upgradient placement	
- Circumferential placement	
Material and construction options (vertical barriers)	
- Soil-bentonite slurry wall	
- Cement-bentonite slurry wall	
- Vibrating beam	
- Grout curtains	
- Steel sheet piling	
Horizontal barriers (bottom sealing)	
- Block displacement	
- Grout injection	

Table 2-1
(continued)

Technology	Screening Results First Level
o Groundwater pumping (generally used with cappint and treatment) Function options - Extraction and injection - Extraction alone - Injection alone Equipment and Material Options - Well points - Deep wells - Suction wells - Ejector wells	Components selected for further consideration
o Subsurface Collection Drains - French drains - Tile drains - Pipe drains (dual media drains)	Not applicable to this site
o Groundwater Monitoring	Selected for further consideration
D. <u>Gas Mitigation Controls</u>	
o Capping (gas barriers) (see A)	Not applicable to this site
o Gas collection and/or recovery - Passive pipe vents - Passive trench vents - Active gas collection systems	Not applicable to this site

Table 2-1
(continued)

Technology	Screening Results First Level
E. Excavation and Removal of Waste and Soil	
o Excavation and removal - Backhoe - Cranes and attachments - Front-end loaders - Scrapers - Pumps - Industrial vacuums - Drum grapplers - Forklifts and attachments	Components selected for further consideration
o Grading (see B)	Considered as a component of capping
o Capping (see A)	Selected for further consideration
o Revegetation (see B)	Considered as a component of capping
F. Removal and Containment of Contaminated Sediments	
o Sediment removal Mechanical dredging - Clamshell - Dragline - Backhoe Hydraulic dredging - Plain suction - Cutterhead - Dustpan Pneumatic dredging - Airlift - Pneuma - Oozer	Site does not contain contaminated sediments; not applicable to this site

Table 2-1
(continued)

Technology	Screening Results First Level
o Sediment turbidity controls and containment	Not applicable to this site
- Curtain barriers	
- Cofferdams	
- Pneumatic barriers	
- Capping	
G. <u>In Situ Treatment</u>	
o Hydrolysis	Components selected for further consideration
o Oxidation	
o Reduction	
o Soil aeration	
o Solvent flushing	
o Neutralization	
o Polymerization	
o Sulfide precipitation	
o Bioreclamation	
o Permeable treatment beds	
o Chemical dechlorination	
o Vitrification	
H. <u>Direct Waste Treatment</u>	
o Incineration	Components selected for further consideration
- Rotary kiln	
- Fluidized bed	
- Multiple hearth	
- Molten salt	
- Cement kiln	
- In situ vitrification	
o Potliner--specific treatments	Components selected for further consideration
- Incineration by fluidized bed combustion	
- Pyrohydrolysis	
- Pyrosulfolysis	
- Carbon recovery by steam hydrolysis or hot-water leach	
- Carbon reuse as anode material	

Table 2-1
(continued)

Technology	Screening Results First Level
- Alcan membrane process	
- Alcoa aluminum sulfate/ sulfuric acid process	
- Alcan Deutschman process	
- Cyclonic smelting	
- Incineration followed by sodium carbonate addition	
o Potliner--specific recycle/resale	Components selected for further consideration
- Recycle in-plant (dry roasting)	
- Recycle in-plant (wet processing	
- Resale for steelmaking	
- Resale for mineral wool production	
- Resale for cement kiln fuel	
o Gaseous waste treatment	Considered as a component of other direct waste treatment technologies
- Activated carbon	
- Flares	
- Afterburners	
o Treatment of aqueous and liquid waste streams and groundwater	Components selected for further consideration
Biological treatment	
- Activated sludge	
- Trickling filters	
- Aerated lagoons	
- Waste stabilization ponds	
- Rotating biological disks	
- Fluidized bed bioreactors	
Chemical treatment	
- Neutralization	
- Precipitation	
- Oxidation	
- Hydrolysis	
- Reduction	
- Chemical dechlorination	
- Ultraviolet/ozonation	

Table 2-1
(continued)

Technology	Screening Results First Level
Physical treatment	
- Flow equalization	
- Flocculation	
- Sedimentation	
- Activated carbon	
- Kleensorb	
- Ion exchange	
- Reverse osmosis	
- Liquid-liquid extraction	
- Oil-water separator	
- Steam distillation	
- Air stripping	
- Steam stripping	
- Filtration	
- Dissolved air flotation	
Discharge to a publicly owned treatment works	
o Solids handling and treatment	Considered as a component of other treatment technologies
Dewatering	
- Screens, hydraulic classifiers, scalpers	
- Centrifuges	
- Gravity thickening	
- Flocculation, sedimentation	
- Belt filter presses	
- Filter presses	
- Drying or dewatering beds	
- Vacuum-assisted drying beds	
Treatment	
- Neutralization	
- Solvent	
- Oxidation	
- Reduction	
- Composting	

Table 2-1
(continued)

Technology	Screening Results First Level
o Solidification, stabilization, or fixation - Cement-based - Lime-based - Thermoplastic - Organic polymer - Self-cementing techniques - Surface encapsulation - Glassification - Solidification (i.e., fly ash, polymers, sawdust) - Grouting	Components selected for further consideration
I. <u>Land Disposal Storage</u>	
o Landfills onsite/offsite o Surface impoundments o Land application o Waste piles o Deep-well injection o Temporary storage	Components selected for further consideration
J. <u>Contaminated Water Supplies and Sewer Lines</u>	
o In situ cleaning o Removal and replacement o Alternative drinking water supplies - Cisterns or tanks - Deeper or upgradient wells - Municipal water systems - Relocation of intake o Individual treatment units	Not relevant under existing site conditions (some components previously implemented)

Sources: U.S. Environmental Protection Agency, "Guidance on Feasibility Studies Under CERCLA," EPA/540/6-85/003, June 1985.

Washington State Department of Ecology. "A Study of Hazardous Waste Management Priorities for Categories of Waste in Washington State," Ecology Document Number 86-7. July 1986.

Potentially-Applicable Technologies:

Source-Related

Table 2-3
INTERIM SCREENING OF SOURCE-RELATED TECHNOLOGIES

	Screening Criteria			
Corrective Measure Technology	Technical	Public Health, Environment, Institutional	Relative Cost	Retained for Further Consideration
1. Excavation and onsite storage	Proven technology. Relatively rapid implementation. Excavation is possible for potliner pile, but subsurface soil excavation is not feasible because of depth and slope stability considerations. Waste materials will be exposed to leaching during excavation. Dust control will be necessary to prevent wind-borne migration. Liner and cap needed in storage area to control leachate. An additional waste source area is created requiring monitoring and maintenance. A liner leak detection program is necessary to detect liner failure.	Regulatory limitations on moving the contaminated material. Must dedicate part of existing site to permanent storage of the materials. Restrictions on construction of new hazardous waste landvills over sole source aquifers probably apply.	Capital cost high. O&M cost low.	No. New source created; landfill siting over sole source aquifers may apply.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria Technical	 Public Health, Environment, Institutional	 Relative Cost	Retained for Further Consideration
2. Excavation and offsite disposal	Proven technology. Excavation is possible for potliner, but excavation of subsurface soil is not feasible because of the depth of the soil column and poor slope stability during excavation. Waste materials will be exposed to leaching during excavation. Dust control will be necessary to prevent wind-borne migration. Offsite landfills may not accept the excavated material.	Eliminates contaminants at primary source. Contaminants are not treated. Short-term public health impact from noise, odor, and dust.	High capital cost. No O&M cost.	Yes
3. Excavation and recycle in-plant (dry-roasting of potliner)	Proven technology. Relatively rapid implementation. An ongoing program with potliner generated since 1980; process established. No further capacity in existing equipment. Process is not applicable to soil, butt tailings pile, or rubble pile.	May be sanctioned under reuse provisions within RCRA.	Capital cost high. O&M cost high.	No. Already practiced on currently generated material. Impurities limit degree of recycle back to the pots.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria			Retained for Further Consideration
	Technical	Public Health, Environment, Institutional	Relative Cost	
4. Excavation and recycle in-plant (wet processing of potliner)	Proven technology. Relatively rapid implementation. An established process but process feasibility is market dependent. Currently, there is little domestic market for reclaimed product and, therefore, limited resale value. Feedstock and product variability and purity unpredictable.	Wastewater and waste solids are produced; these require treatment and disposal.	Capital cost high. O&M cost high.	No. No demand for the recovered cryolite; waste disopsal of cyanide-containing carbon slurry a deterrent.
5. Excavation and Resale (for steelmaking, mineral wool production, and/or cement kiln fuel)	Demonstrated technologies. Relatively rapid implementation. Feasibility of these processes are market dependent. Generally, there is insufficient northwest capacity to absorb the necessary quantity of waste. Uncontrolled quality of the waste piles will limit market acceptance of the waste. Product specifications still being developed by purchaser.	Probable listing as a hazardous waste will place restrictions on the sale of spent potliner from aluminum production and may eliminate this option.	O&M cost low.	No. Marketability determined by potential uers, not by Kaiser. Potential listing as a "hazardous waste" may block future resale for secondary uses.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria: Technical	Screening Criteria: Public Health, Environment, Institutional	Screening Criteria: Relative Cost	Retained for Further Consideration
6. Excavation and Incineration (FBC typ.)	Demonstrated on a limited scale. Relatively rapid implementation. Process will require onsite storage facilities and waste preparation by size reduction, preclassification, or other method. Process developed for feedstocks of type under consideration.	Regulatory classification of treatment residues needs to be verified (air, water, solids). ARARs apply. Regulatory constraints may make permitting difficult.	Capital cost high. O&M cost high.	Yes
7. Excavation and pyrohydrolysis, and burial of residues	Developing technology. Process fundamentals understood; no known demonstration or prototype plant experience. Process economic feasibility is dependent on Bayer plants available to take product as feedstock. Process economics are unfavorable in the Northwest because there are no Bayer plants in existence. Fluoride recovery is inefficient compared to other recycling processes.	Vapor phase hydrogen fluoride needs high capture efficiency. Personnel hazard potential. Regulatory constraints may preclude acceptance of the waste into the Bayer process.	Capital cost high. O&M cost high.	Yes

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria: Technical	Screening Criteria: Public Health, Environment, Institutional	Screening Criteria: Relative Cost	Retained for Further Consideration
8. Excavation, pyrosulfolysis, and burial of residues	Developing technology. Process fundamentals understood at laboratory scale only; no known demonstration or prototype plant experience. Technical feasibility is dependent on quality of feedstock and difficult agglomeration problems have occurred during testing. Uncontrolled quality in waste pile may preclude acceptability of waste in process. Fluoride is recovered during the process.	Sulfur dioxide and hydrogen fluoride air controls would probably be needed. Residue disposal is required.	Capital cost high. O&M cost high.	No. Early stage of development. Commercial-scale feasibility uncertain.
9. Excavation, Carbon Recovery by either steam hydrolysis or hot water leach, residue disposal	Commercial in Canada but not commonly used in the U.S. Recovered carbon is reusable only for carbon sidewall blocks, which are not used at Kaiser Mead plant. Only a portion of the waste can be recycled; a large amount of residues remain.	Residues require offsite disposal. A generated wastewater stream requires treatment and disposal.	Capital cost moderately high. O&M cost high.	No. Sidewall blocks from recovered carbon not used at Mead.

Table 2-3
(continued)

	Screening Criteria			
Corrective Measure Technology	Technical	Public Health, Environment, Institutional	Relative Cost	Retained for Further Consideration
10. Excavation, carbon recovery as anode material	Experimental technology. Laboratory tests indicate difficulties in obtaining a satisfactory anode at anything but low addition levels. Feasibility of process for large waste volumes is unlikely. Useful only in Soderberg plant, whereas Mead is a prebake plant.	May be sanctioned under reuse provisions within RCRA.	Capital cost low with existing Soderberg plant. O&M cost high.	No. Mead is not a Soderberg facility; reuse quantity limited; technology experimental.
11. In situ vitrification, onsite disposal	Process not proven on spent potlining wastes. Reaction may not be controllable with high carbon wastes such as spent potlining. Excessive fuming may cause formidable technical problems. Method not yet practiced commercially. Proprietary process of Battelle Pacific Northwest Laboratory.	Gaseous emissions, air controls would probably be needed. Final product may require offsite disposal.	High capital cost, high O&M cost.	No. No known commercial experience. Intended for soil, not carbonaceous wastes. Concerns about emissions, combustion, and process control and confinement.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria			Retained for Further Consideration
	Technical	Public Health, Environment, Institutional	Relative Cost	
12. Excavation, Alcan Membrane Process	Technology development discontinued. Small-scale pilot project completed, but no followup development. Economic projections are not promising: requires Bayer process for reuse of reaction products.	Gaseous emissions require treatment.	High capital cost, high O&M.	No. Early stage of development; reliance on Bayer plant; byproduct disposal.
13. Excavation, Alcoa aluminum sulfate/ sulfuric acid leach process	Unproven technology. Process fundamentals understood, but process has not been technically demonstrated. Significant technical difficulties. Economically unattractive.	Personnel hazard potential.	High capital cost. High O&M.	No. Early stage of development; cyanide volatilization.
14. Excavation, Alcan Deutschman Process	Developing technology. Process fundamentals understood at laboratory level, but not technically demonstrated at larger scale. No apparent aqueous waste stream. Uncontrolled quality in waste pile may preclude acceptability of waste in process.	Ash disposal may be a problem. Personnel hazard potential.	High capital cost; low O&M.	No. Early stage of development.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria			Retained for Further Consideration
	Technical	Public Health, Environment, Institutional	Relative Cost	
15. Excavation, cyclonic smelting furnace, Disposal of residues	Experimental process. Research has not yet been published. Process is not yet commercial. Apparent logistical and product use problems.	Unknown	Unknown	No. Early stage of development; no known process documentation.
16. Excavation, incineration followed by sodium carbonate addition	Unproven process. Experimental. Process is not commercial and little information is available to evaluate its use.	Unknown	Unknown	No. Information limited; early stage of development.
17. Grouting (rubble pile	Considered for rubble pile. Chemical or foaming cement grouts can be used to fill the void spaces in the waste. Volume of voids is high. Proportion of voids varies widely making injection control difficult. Difficult to access the steep slopes of the rubble pile.	Uncertainty about the control provided by the grout.	High capital cost. Low O&M cost.	No. Implementation difficult because of limited side access and large voids.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria			Retained for Further Consideration
	Technical	Public Health, Environment, Institutional	Relative Cost	
18. Cap	Cement, asphalt concrete, and soil caps are not 100 percent impermeable while synthetic membrane and multimedia caps may be close to 100 percent impermeable. Soil, membrane, and multimedia caps are more appropriate to flat areas or low slopes. Piles must be graded to get flatter, smoother slopes in preparation for placement of cap. Cement, asphalt, or soil caps may crack if settling occurs under new loading.	Contaminants remain onsite. Rapid implementation.	Moderate capital cost. Low O&M cost.	Yes
19. Upgrade (existing) caps	Existing asphalt caps require periodic maintenance. Further hydration potential eliminated with cap maintenance. Upgrade only undertaken to achieve RCRA performance standards.	Reopening capped area might change regulatory status of the covered areas.	Potentially moderate capital cost. Low O&M cost.	No. Existing caps meet RCRA performance standards.

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria: Technical	Screening Criteria: Public Health, Environment, Institutional	Screening Criteria: Relative Cost	Retained for Further Consideration
20. Reroute water lines/relocate Wastewater treatment plant	Technically feasible and straightforward to implement.	No significant considerations identified.	Capital cost moderately high. O&M cost unchanged from current status.	Yes
21. Pipeline leakage Monitoring program	Established methods available. Periodic leak investigation (not continuous, online) is feasible at present. Methods for pressure piping more definitive than those for gravity drainage systems. May need to coordinate with water-level measurements in monitoring well system.	No restrictions identified.	O&M cost low to moderate, depending on frequency.	Yes

Table 2-3
(continued)

Corrective Measure Technology	Screening Criteria: Technical	Screening Criteria: Public Health, Environment, Institutional	Screening Criteria: Relative Cost	Retained for Further Consideration
22. Vertical barriers	Rapid implementation. Barrier must fully penetrate the pervious subsoils and embed in an impervious soil unit. Required depth is too deep for steel sheet piles. Required depth of barrier, nature of subsoils, and quality requirements suggest a slurry wall is more appropriate than a grout curtain. A full circumference wall may be required to prevent upgradient flow of infiltration. A slurry wall would not be completely impervious and drainage would pool within the wall until the water developed sufficient head to cause flow through the more porous areas of wall.	May affect local groundwater flow	High capital cost. Low O&M cost unless the barrier is breached and reconstruction is required.	No. Coarse subsoil, depth to groundwater, and uncertain depth to impermeable material impose difficulties.

Potentially-Applicable Technologies:

Plume-Related

Table 2-4
INTERIM SCREENING OF PLUME-RELATED TECHNOLOGIES

Corrective Measure Technology	Screening Criteria: Technical	Screening Criteria: Public Health, Environment, Institutional	Screening Criteria: Relative Cost	Retained for Further Consideration
1. Extraction wells	Proven technology. Pumping may change groundwater flow patterns. Duration of pumping could be long.	Rights-of-way and access. Treated water disposal.	Capital costs are moderate. O&M cost is moderate.	Yes
2. Biological treatment	Poor results in trying to biologically treat cyanide-containing wastewater from aluminum reduction facilities. Extensive development work would be required.	Cyanide destroyed instead of concentrated.	Moderate capital cost. Low-to-moderate O&M cost.	No. Process is unsuccessful, so far, with aluminum plant wastewaters.
3. Physical treatments (reverse osmosis, ion exchange)	Liquid waste stream enriched in cyanide, posing a disposal problem. Development work may be required. Not specific to cyanide. Free cyanide would be poorly removed.	Cyanide-rich wastewater to be disposed of.	Moderate to high capital cost, moderate to high O&M cost.	No. Concentrated liquid waste stream remains, which requires disposal. Neither process feasible as a stand-alone process with Mead groundwater.

Table 2-4
(continued)

Corrective Measure Technology	Screening Criteria: Technical	Screening Criteria: Public Health, Environment, Institutional	Screening Criteria: Relative Cost	Retained for Further Consideration
4. Chemical treatment (precipitation)	Prussian blue precipitation process specific for cyanide. Difficult to reduce cyanide below 1 to 3 mg/l concentration. Demonstrated on wastewaters from aluminum reduction facilities.	Waste solids to dispose of (may be "nonhazardous").	Moderate capital cost. Moderate O&M cost.	Yes
5. Chemical treatment (oxidation)	Oxidation processes have proven ineffective with ferrocyanide.	Releases to air of ozone or chlorine may need to be controlled.	High capital cost. High O&M cost.	No. Oxidation ineffective with iron-complexed cyanide.
6. Treated wastewater discharge to local POTW	Proven technology. Will likely require installation of new onsite pump station along with force main to sanitary sewer.	Possible leakage from city-owned sanitary sewer lines. Possible leakage from holding basins in city system, such as Lidgerwood Lagoon.	Medium capital cost. Medium O&M cost.	Yes
7. Groundwater monitoring	Ongoing program with monitoring wells already in place. System appears responsive to changes in groundwater regime.		Low capital cost. Low O&M cost.	Yes

Potentially-Applicable Technology Descriptions

TECHNOLOGY DISCUSSIONS

The technologies which had potential usefulness for the Mead site were classified according to their applicability to the source or the plume operable unit.

I. SOURCE-RELATED TECHNOLOGIES

A. General

Excavation. Excavation is the process of physically digging and removing the waste sources from their existing emplacements. Use of this technology would be required in any remedial alternative involving handling of the waste sources. Generally the method of excavation is selected by a given contractor and depends on the type of equipment the contractor has available. For removal of waste deposits on the ground surface, bulldozers, front end loaders, and haul trucks would be the most likely equipment used. For below-ground excavation, this equipment, as well as a drag line, backhoe, or other equipment, might also be used. Excavation at the Mead site would require that dust from the spent potliner be controlled. This would probably be implemented by spraying the waste piles and the filled haul trucks with water during the process. Tight covers over the truck beds might also be necessary during any transport to minimize dust release.

Onsite Storage. This technology would keep the waste materials onsite but in an Ecology-approved waste storage area. Generally, this would require excavating the source materials and depositing them into a lined waste disposal area meeting RCRA performance standards and with a cover cap that meets RCRA performance criteria over the top. A closure plan would be required with a written environmental monitoring and release response plan included. Groundwater monitoring would be an essential element in the closure plan. This technology option is not retained because an additional onsite source of potential releases would be created. Restrictions on siting landfills over sole source aquifers may also apply.

Offsite Disposal in RCRA-Permitted Landfill. Although potlining wastes have not officially been designated as a RCRA Subtitle C hazardous waste, potlining has been proposed for listing several times. Because of these concerns, we have assumed that offsite disposal at a RCRA-permitted landfill would be necessary. There are two and possibly three landfills in the Northwest where spent potliner may be disposed. Implementation of this remedy would require excavation with associated dust control, hauling, waste compatibility testing, and probably capping of the excavated area after waste removal to control cyanide migration in contaminated subsurface soil. This option is retained for further consideration.

B. Infiltration Control

These technologies minimize the amount of direct rainfall, stormwater drainage, or plant pipe leakage that is allowed to percolate into the subsurface soil. Use of these technologies controls the leaching of contaminants from the waste sources and their migration into groundwater.

Grouting. Grouting would be most applicable for use on the rubble and brick pile. Grout may consist of mixtures of cement and water with admixtures of clay and chemicals to control fluidity or may consist of chemicals that form a gel or rubbery compound in the ground. The grout would be injected in a liquid state into voids in waste piles. The grout would be allowed to harden, subsequently reducing the permeability of these waste piles and preparing the piles for an impermeable cap. There is difficulty in implementing this technology with waste piles like the rubble pile, which have such large void volumes. The large voids and the variability in porosity make control of grout injection difficult, and limited equipment and personnel access to the sides of the waste piles compounds the problem. This option was not retained for further consideration.

Capping. Installing new caps over the waste sources at the site would generally be performed to RCRA (40 CFR Part 264) and Washington Department of Ecology performance standards. Various cap design options are possible, all of which would meet the required performance standards. The cap should be designed to limit liquids infiltration, promote surface drainage, minimize erosion, and accommodate possible future subsidence. A likelihood in the use of this technology is that the waste piles would likely be graded to obtain flatter and smoother surfaces for capping. Capping of cyanide sources and infiltration areas is retained for further consideration.

Upgrade Existing Caps. In this option, the existing asphalt cap over the spent potliner pile would be upgraded to conform to RCRA performance requirements. Cracks in the existing cap would be repaired with new asphalt and surface water run-on routed away from the capped area, as is now practiced. A program to monitor the integrity of the cap and to repair it as necessary would be developed. The usefulness of performing a cap upgrade for the spent potliner pile is questionable as the present cap appears to be functioning well and has recently had the cracks in it repaired. Further, this cap presently meets RCRA and Washington

Department of Ecology performance standards as identified in the Code of Federal Regulations (40 CFR Part 264) for site closure.

Reroute, Replace, or Repair Existing Water Pipelines and the Sanitary Treatment Plant. Leakage from existing pipelines in the vicinity of the spent potlining pile could potentially percolate through contaminated subsurface soil and cause continued groundwater contamination. Water lines, sanitary sewer lines, and storm drainage pipelines would be rerouted away the potliner pile, replaced, or repaired in order to remove these potential sources of leachate. Rerouting is applicable for the larger-sized storm drain pipe and several small water and sewer pipelines. Direct parallel replacement or repair by slip lining with polyethylene pipe is possible for other water, sewer, and storm drain pipe where rerouting is not possible because of their services to existing plant facilities. These options are retained for further consideration.

Pipeline Leak Monitoring. This technology calls for hydraulically testing the structural integrity of water, sewer, and storm drain pipe in the vicinity of the potlining pile. Leak testing has occurred in the past at the Mead Works. The approached used in previous testing of pressurized water lines involved:

- Identifying the pipe segment to be tested and any vital services on the line requiring special consideration.
- Identifying secondary services on the line segment to be tested and disconnecting these services or estimating their consumption.
- Closing isolation valves where possible.
- Connecting a fill line to the segment to be tested and blocking the end of the segment.
- Pumping water into the pipe segment through a water meter and periodically measuring the volume of water consumed.

Sonic (i.e., acoustic) leak detection was tested in 1982 at the Mead works and found to be infeasible.

Video testing might be used in addition to hydraulic testing to investigate leakage of sewer lines and storm drains. If pipe leaks are discovered, the leaking pipe segment would be repaired as necessary. This option is retained for further consideration.

C. Vertical Barriers

Vertical barriers would be used to isolate contaminated subsoil beneath the waste pile(s) from groundwater to control the transport of cyanide into the main plume.

Sheet Piles. Sheet piles are relatively flat and wide in cross section so that when driven side by side they form a cutoff wall. Because they are physically driven down from the surface their use is limited to a fairly shallow depth. Effective use of the sheet piles is contingent upon keying the wall into an impermeable layer of subsoil. This technology would be difficult to implement, given the 60-foot depth from surface of the first significant aquitard. This option is not further considered because it is difficult to implement to depths where it would be effective.

Slurry Wall. Slurry walls can be described as permanent "membranes" constructed in subsurface soil. In this process, a vertical wall trench is excavated by a trenching machine, a "clam shell," or by drilling a series of overlapping, large diameter vertical holes. The trench is maintained during and after excavation by backfilling with a bentonite clay mud. The mud is finally displaced by concrete and the finished subsurface installation is a concrete wall with mud-impregnated soil on the outside. Construction is by a variety of drilling and digging methods depending on the particular equipment used. Slurry walls are usually limited to a depth of less than 50 feet but walls to several hundred feet have been built. Slurry wall effectiveness is contingent upon keying the wall into an impermeable layer of subsoil. Implementation would be difficult at Mead because of the nature of the subsoil, the depth to groundwater (approximately 150 feet), and the apparent absence of an impermeable zone to key into. This option was not considered further.

Grout Curtain. A grout curtain is a barrier comprised of soil with grout filled voids. The curtain is created by drilling vertical holes and grouting successive intervals of the holes with cement based or chemical grouts. The grout holes are closely spaced in a linear array and several lines of grout holes may be used to obtain a reasonably continuous and thick zone of grouted soil. The continuity of the grouting is checked by noting grout movement into ungrouted holes and by core drilling into the grouted zone. Grout curtain installation would be difficult at Mead because of the subsoil conditions, depth to groundwater, and absence of an identified zone to key into.

D. Direct Waste Treatment

Recycle In-Plant (Dry Roasting). Crushed and ground spent potliner is combusted in a multiple-hearth furnace to burn off the carbon. The remaining high fluoride fraction is returned to the aluminum production process. The quantity of spent potliner that can be processed in this manner is limited because of impurities in the high fluoride fraction, which if introduced in too high a percentage, will contaminate the cryolite baths. This option is already practiced at Mead. Extensive additional recycling of spent potliner, especially potliner that contained dirt or had been buried, would introduce unacceptable quantities of impurities into the cryolite baths. No further consideration is given to this option, beyond current practice.

Recycle In-Plant (Wet Processing). Crushed and ground spent potliner is placed into a caustic bath and the soluble cryolite fraction is extracted. The remaining insoluble carbonaceous fraction requires disposal and would contain cyanide in soluble form. The dissolved cryolite is reprecipitated by reducing the pH, and the cryolite is separated, dried, and stored for eventual reuse. Recent surpluses of cryolite on the market have reduced demand for this product making resale difficult. This option is not considered further.

Resale for Steelmaking. Spent potliner has found limited use in the steelmaking industry in the past 2 or 3 years. Its main use is as a substitute for the fluxing agent, fluorspar. Potliner recycled in this manner must be crushed and ground to between 1/4 and 3 inches in size. It is then placed into the furnace at an appropriate time during the "heat" and burned. At present, there is only limited demand for potliner use in steelmaking. Some pilot testing has been accomplished but industry standards have not been identified nor has the material been fully accepted by the industry. Since the marketability of spent potliner to steel producers is market-driven, and not within Kaiser Aluminum's control, this option cannot be treated as an active means for disposal of spent potliner. Possible future listing of spent potliner as a hazardous waste could jeopardize resale for reuse in any offsite facility.

Resale for Mineral Wool Production. Spent potliner may be used as an alternative feed stock in the production of mineral wool because of its low melting refractory components coupled with its benefit as a supplemental fuel. This technology has been pilot tested, but industry standards have not been established. Potliner is crushed and ground to between 2 and 6 inches in size. It is then burned in a cupola with other feed stock. Fluorides and other inorganics are incorporated into the mineral wool product.

Cyanides are destroyed during combustion. The process has not been fully accepted by the mineral wool manufacturing industry and air emissions are a possibility. Spent potliner resale for reuse is purchaser-controlled, and any future listing of this material as a "hazardous waste" would make it unattractive for secondary uses. This option is not considered further.

Resale as a Fuel Supplement in a Cement Kiln. The high carbon content in spent potliner makes it suitable as a fuel supplement in a cement kiln. Cement clinker is produced by burning finely ground raw cement mix in a rotary kiln at approximately 2,700°F. Volatile components in the cement mix are driven off and partial melting occurs, leading to nodulation of the feed into round balls known as "clinkers." Test burns have shown that substitution of small amounts of spent potliner in the feed (approximately 2 to 4 percent by weight) would result in reduced fossil fuel costs with no adverse effects on cement quality, kiln operation, or equipment. Cyanide destruction was nearly complete and fluoride emissions in the stack were negligible. Additional studies are necessary, however, before cement industry acceptance can be obtained. Spent potliner resale for reuse is purchaser-controlled, and any future listing of this material as a "hazardous waste" would make it unattractive for secondary uses. This option is not retained for further consideration.

Incineration by Fluidized Bed Combustion. In this process, spent potliner is burned in a circulating fluidized bed combustor at approximately 1,400°F with the result being destruction of cyanide. Air is used for combustion and fluidizing the bed. Coarse solids are removed from the bottom of the combustion chamber while fines are recirculated in a high temperature loop that helps to control combustion temperature while keeping the bed expanded. Use of this technology at the Mead site would require processing of spent potliner prior to incineration. Material processing would include excavation followed by scrap metal removal and crushing to approximately 1/4-inch-size solids. Process offgas could contain high levels of fluorides, which would require scrubbing. Leachable fluorides in the process ash may limit the number of acceptable landfill locations where residues could be placed. This option has been under active development recently, and is retained for further consideration.

Pyrohydrolysis. In this process, spent potliner is burned in a circulating fluidized bed reactor at approximately 2,200°F resulting in nearly complete cyanide destruction. Steam is injected into the combustor, reacting with the fluorides to produce hydrogen fluoride gas. The offgas is scrubbed in an absorption tower resulting in a 25-percent hydrogen fluoride solution that may be sold on the open market. In the pyrohydrolysis process itself, coarse solids are removed from the bottom of the combustion chamber while fine solids are recirculated into the bed to control combustion temperature and to keep the bed expanded. Combustion ash contains sodium and aluminum values suitable for reuse in the Bayer process for bauxite refining. However, the great distances to the remaining Bayer plants that are still operating in this country limit the viability of this approach, and residues would be disposed of by landfilling. This option is retained for further consideration.

Pyrosulfolysis. This process is similar to that described for pyrohydrolysis except that air, sulphur dioxide, and steam are injected into a circulating fluidized bed reactor operating at approximately 1,300°F to 1,650°F. Cyanide destruction is achieved while producing hydrofluoric acid for possible resale, manufacture of aluminum fluoride or other fluoride chemicals. An ash low in cyanide and fluoride is produced that may be acceptable for landfill disposal. The process is relatively experimental, however, and has not been demonstrated at other than a laboratory testing level. This option is not considered further because of its early stage of development.

Carbon Recovery by Steam Hydrolysis or Hot-Water Leach. This process is currently being employed on a limited scale by Alcan at one plant in Canada. Spent potlining is crushed and ground to between 1/2 inch and 3/4 inch. It is then placed in either an autoclave, sparged with steam, or boiled with hot water to hydrolyze the cyanide. The resulting product is then screened to recover the treated carbon, which is returned to the plant as carbon paste for the production of carbon side wall blocks. Presently, ALCAN is recycling only a portion of their potlining and has no additional capacity. In addition, carbon side wall blocks are not used in aluminum production at the Mead works, thus limiting the usefulness of this technology for waste potliner at Kaiser Mead. This option is not considered further.

Carbon Reuse as Anode Material. This process attempts to reuse the carbon in spent potlining for anodes in Soderberg plants. Crushed and processed spent potlining is mixed with anode paste at concentrations of less than 10 percent of the total anode mass. The resulting paste is then placed inside a container on top of an operating Soderberg cell. As the anode is consumed, the paste falls down into the cell and is slowly baked hard in the process. This technology needs further study to minimize effects of sodium, fluoride, and other compounds on anode quality. At the low percentage additions of spent potliner currently being mixed into the anode paste, there is insufficient northwest plant capacity to consume the quantity of spent potliner at the Mead site.

The process is most applicable to reuse of new spent potliner currently being generated by the aluminum industry that has fewer process contaminants. Mead is a prebake plant, so carbon use in anode paste is not applicable. This option is not considered further because Mead is not a Soderberg plant, the reuse quantity is limited, and because carbon reuse as anode material is experimental.

In Situ Vitrification. In situ vitrification involves the passage of electrical current through a melt of the waste undergoing fixation. This process is proprietary to Battelle Northwest Laboratories and is usually contemplated for soils contaminated with radioactive compounds. Electrodes are placed into the material to be treated at a predetermined spacing, the area to be heated is treated with a graphite to impart electrical conductivity, and electrical current is applied. As the treated material begins to melt it becomes electrically conductive thereby accelerating the process. After the waste is completely melted, current flow is stopped and the molten mass is allowed to cool into an immobile glassy state. There is no known commercial experience with this process, and there are concerns about uncontrolled combustion, gaseous and particulate emissions containing fluoride and hydrocarbons, and contaminant within controllable zones within the spent potlining pile. This process is not considered further.

Alcan Membrane Process--There are several possible versions of this process. In the basic process, ground potlining is first digested in caustic to produce a solution of sodium fluoride (NaF) and sodium aluminate ($NaAlO_2$). Liquids are then decanted off to an evaporator to crystallize out the sodium fluoride. Solids from the decanter go to disposal. The sodium fluoride crystals from the evaporator are washed in caustic and are dissolved in boiling water. This solution is then passed through a water-splitting membrane to produce solutions of hydrogen fluoride and sodium hydroxide. The hydrogen fluoride solution can then be reacted with solid Al_2O_3-$3H_2O$ to produce aluminum fluoride (AlF_3) for resale. Cyanide present in the potliner is extracted into the caustic and discharged along with sodium aluminate from the evaporator. Cyanide can be destroyed by returning the sodium aluminate to a Bayer plant. This process has not been demonstrated beyond a pilot-scale operation and work has reportedly been discontinued at Alcan. This option is not considered further because of its reliance on a nearby Bayer plant and its early stage of development (especially the bipolar "water-splitting" membranes. Carbonaceous by-products stream disposal appears to be an unresolved issue.

Alcoa Aluminum Sulfate/Sulfuric Acid Leach Process--This process uses a two-step digestion of spent potliner in an aluminum sulfate and sulfuric acid bath to volatilize cyanide and to extract fluoride (aluminum fluoride) and sodium fluoride. Bath effluent requires treatment to remove free fluoride. Solids that require disposal are produced. The process has been only tested on a small scale and is not technically proven. Full-scale operations would require material excavation, size reduction processing, and an acid plant for hydrofluoric acid production. This option is not considered further because of its early stage of development.

Alcan Deutschman Process. Spent potliner is treated in a two-step process. Crushed and prepared potliner is heated in the presence of water or steam to hydrolyze cyanide. Solids are then reacted with sulfuric acid and either calcium hydroxide or calcium oxide to precipitate fluoride as CaF_2. Cyanide removals of over 99 percent has been achieved in pilot testing. Fluoride levels in ash may be low enough for acceptable ash disposal in nonhazardous waste landfills. Material preparation including size reduction and scrap metal removal would be required prior to treatment. Leachate from the fluoride reaction may require treatment. This technology is still experimental and has not been demonstrated in a large-scale continuous process. This option is not considered further because of its early stage of development.

Cyclonic Smelting. Spent potlining is incinerated in a cyclone smelter similar to those used at copper plants. Potliner is melted at high temperature, thereby oxidizing cyanide and driving off fluorides. This technology is still experimental and there is no currently published literature describing the process. Fluoride scrubbing of the offgas as well as material processing and size reduction would likely be required. This option is not considered further because of limited reporting of tests, and its early stage of development.

Incineration Followed by Sodium Carbonate Addition. Little information is available on this process, but it is thought to be a variation of dry roasting. The process is experimental, and has reportedly experienced some problems at this stage of development. This option is not considered further.

II. PLUME-RELATED TECHNOLOGIES

A. Groundwater Extraction

Groundwater extraction is the process of removing water from saturated subsoil for the purpose of either intercepting a contaminated plume, inhibiting plume migration, or removing water for treatment.

Extraction Wells. Extraction wells would be used to pump groundwater from the uppermost saturated zone in the deep aquifer in the vicinity of the Mead site. These wells would be located along the centerline to withdraw contaminated groundwater for surface treatment and/or disposal. It is envisioned that three extraction wells would be located at 500-foot intervals along the plume centerline, with the first placed near TH-8. Each well would produce at a rate of about 70 to 85 gpm (total 200 gpm for all three wells). It is estimated that this groundwater extraction rate would produce groundwater with cyanide above the minimum treatable concentration, but would not exceed the sewer capacity at the point of discharge.

B. Groundwater Treatment

Biological Treatment. This technology would normally involve the use of several unit processes. First, wastewater would be feed into a basin with a large population of acclimated microbes attached to rotating biological contactors. Wastewater would then flow into a clarifier where any sloughed solids would be settled and and the supernatant would overflow to other polishing treatment steps such as filtering. Solids would be removed from the clarifier and dewatered in a filter press or other suitable device. Attempts to apply biological treatment to aluminum industry wastewaters have been unsuccessful to date; consequently, this option is not considered further.

Treatment by Ion Exchange. The ion exchange process employs an anion exchange resin that has high ferrocyanide selectivity. The Rohm and Haas Company has developed several resins for this purpose. In this process, contaminated water is passed through a properly conditioned column of ion exchange resin. The resin adsorbs ferrocyanide and release the anion that was formerly bound to the resin. Once the resin is exhausted, it is regenerated by replacing the ferrocyanide ions with hydroxide ions by treatment with sodium hydroxide. A subsequent replacement of the OH^- anion with SO_4^{-2} anion from sulfuric acid completes the regeneration cycle. This process is suitable for only complex cyanide; therefore, free cyanide in the water must be complexed before it can be treated. Because the operating cycle time decreases as feedwater ferrocyanide concentrations increase, this process would be most suitable for polishing the effluent from another process, such as chemical precipitation. The effectiveness of ion exchange diminishes as the dissolved solids content of the water increases. Regeneration waste contains a high concentration of cyanide that must either be treated to destroy the cyanide or disposed of by other methods. This option is not considered further because previous testing showed that ion exchange removed little cyanide in addition to what could be precipitated.

Physical Treatment by Reverse Osmosis. Reverse osmosis is frequently used in the desalinization of brackish water and seawater. This technology utilizes a semipermeable membrane that inhibits the passage of dissolved solids but allows water to pass. Feedwater is fed under pressure into the reverse osmosis unit, where it is separated by the membrane into a waste brine stream and low-salinity product water. Product water recovery constitutes generally 30 to 85 percent of the feed. The waste brine solution must be disposed of. Reverse osmosis only concentrates the cyanide into a smaller liquid stream, it does not destroy cyanide. If this technology were used, the waste brine would contain concentrated cyanide that would require further treatment or disposal. This option is not considered further.

Chemical Treatment by Precipitation. Precipitation treatment for iron cyanides has been used in a full-scale, continuous process to reduce the cyanide concentration in aluminum plant wastewater. In precipitation treatment, ferrous and ferric salts (usually ferrous sulfate and ferric chloride, respectively) are added to the wastewater and insoluble iron cyanide compounds precipitate, reducing the total cyanide content to a level between about 1 to 3 mg/l. The process would be carried out using a conventional water treatment plant consisting of rapid mixing, reaction, gravity settling, and filtration. Treated water leaving the filter would be discharged to either a POTW or to a receiving stream, if sufficient treatment has been obtained. Sludge precipitated in the reactor and collected in the clarifier would be dewatered by conventional techniques, such as a filter press, centrifuge, or drying bed, and disposed of in a suitable landfill. This option is retained for further consideration.

Chemical Treatment by Oxidation. In an oxidation process, groundwater-containing ferrocyanide would be pumped from the ground and treated in one of several processes. Among the potential choices are hot alkaline chlorination and ultraviolet-catalyzed ozone. Neither of these processes has been used for aluminum industry wastewater at a commercial scale for a variety of technical, economic, and environmental reasons. As an example, hot alkaline chlorination uses about 1,000 mg/l of excess chlorine, but residual cyanide concentrations fall in the same range as for the chemical precipitation process. And ultraviolet/ozone treatment is hampered by the accumulation of iron oxide deposits on the optical surfaces after only a short period of operation. This option is not retained for further consideration.

C. Treated Wastewater Discharge to Local POTW

Treated wastewater produced at the onsite groundwater treatment system would be discharged to the City of Spokane

Municipal Wastewater Treatment System. A force main constructed at the plant site would be necessary to convey the treated groundwater to a preselected discharge point into the City's sanitary sewer system. This option is retained for further consideration.

D. Groundwater Monitoring

Currently, there is an ongoing groundwater monitoring program in force at the Mead works. Groundwater samples are collected from selected wells and analyzed to monitor changes in groundwater contaminant concentrations. Specific wells would be identified and sampled four times per year. Selection of the wells for sampling would be dependent on the remedial alternative to be implemented. The wells would be selected to model, as accurately as possible, the effects of remedial action that is to be implemented. It is assumed that no new wells would be constructed. This option is retained for further consideration.

DETAILED TECHNOLOGY SCREENING

The technology alternatives identified above were evaluated in moderate detail and screened on the basis of their technical, economic, and institutional feasibility, and their impacts on public health, welfare, and the environment. This screening process was intended to eliminate technologies that may prove infeasible to implement or that rely on processes that are unlikely to perform satisfactorily or reliably.

Technical criteria included evaluation of performance, reliability, and implementability as discussed below:

- Performance. Performance was assessed on the basis of effectiveness and useful life. Effectiveness was evaluated in terms of the degree to which the technology would prevent or minimize the release of hazardous substances to current or future receptors. Useful life was related to the length of time that the level of effectiveness could be maintained.

- Reliability. Reliability was assessed on the basis of operation, maintenance, and demonstrated performance. Operation and maintenance were evaluated in terms of labor availability, frequency, necessity, and equipment complexity. Demonstrated performance included consideration of proven performance, probability of failure, and pilot testing needs.

- Implementability. Implementability was based on the ease of installation and time for implementation. Ease of installation was related to constructibility of the technology, applicability to site conditions, external conditions such as the need for permits, and access to offsite disposal facilities, and equipment availability. The time for implementation was assumed to be the time to achieve beneficial results.

Technologies that were deemed to be unreliable, perform poorly, or were not fully demonstrated were excluded from further consideration during the screening process.

Public health and welfare, environmental, and institutional screening criteria are described as follows:

- Effects on Public Health and Welfare. Short-term (i.e., construction-related) and long-term health risks from exposure to contaminants were considered. Short- or long-term effects could include odor, noise, and air pollution; disruption of households, businesses, and services; use of natural resources; alteration of natural environments, transportation corridors, and urban facilities; relocation of households, businesses, and services; and aesthetic changes. For the purposes of this screening effort, these effects were evaluated on exposure or no exposure conditions only.

- Environmental Effects. Short- and long-term effects on the environment that were considered include toxic effects on plant and animal life from exposure to contamination, alteration of wildlife habitat, and effects on threatened and endangered species.

- Institutional Effects. Institutional effects evaluated were related to surface and groundwater quality standards; air quality, odor, and noise standards; land acquisition, land use, and zoning; and federal, state, local laws, or policies.

Costs were included in the evaluation only for comparison purposes and reflect judgment based on engineering experience at other sites and installations. Relative costs, designated as either low, medium, or high, were used to enable a qualitative comparison between technologies. Both capital and operation and maintenance costs were considered.

The use of relative costs is accepted by the U.S. EPA for technology screening. These estimates were developed only for the purpose of screening technologies and do not reflect the entire cost of implementing a technology. These costs are appropriate only for comparison between alternative measures applied in a particular area. Any other use of these estimates is not appropriate and would be misleading.

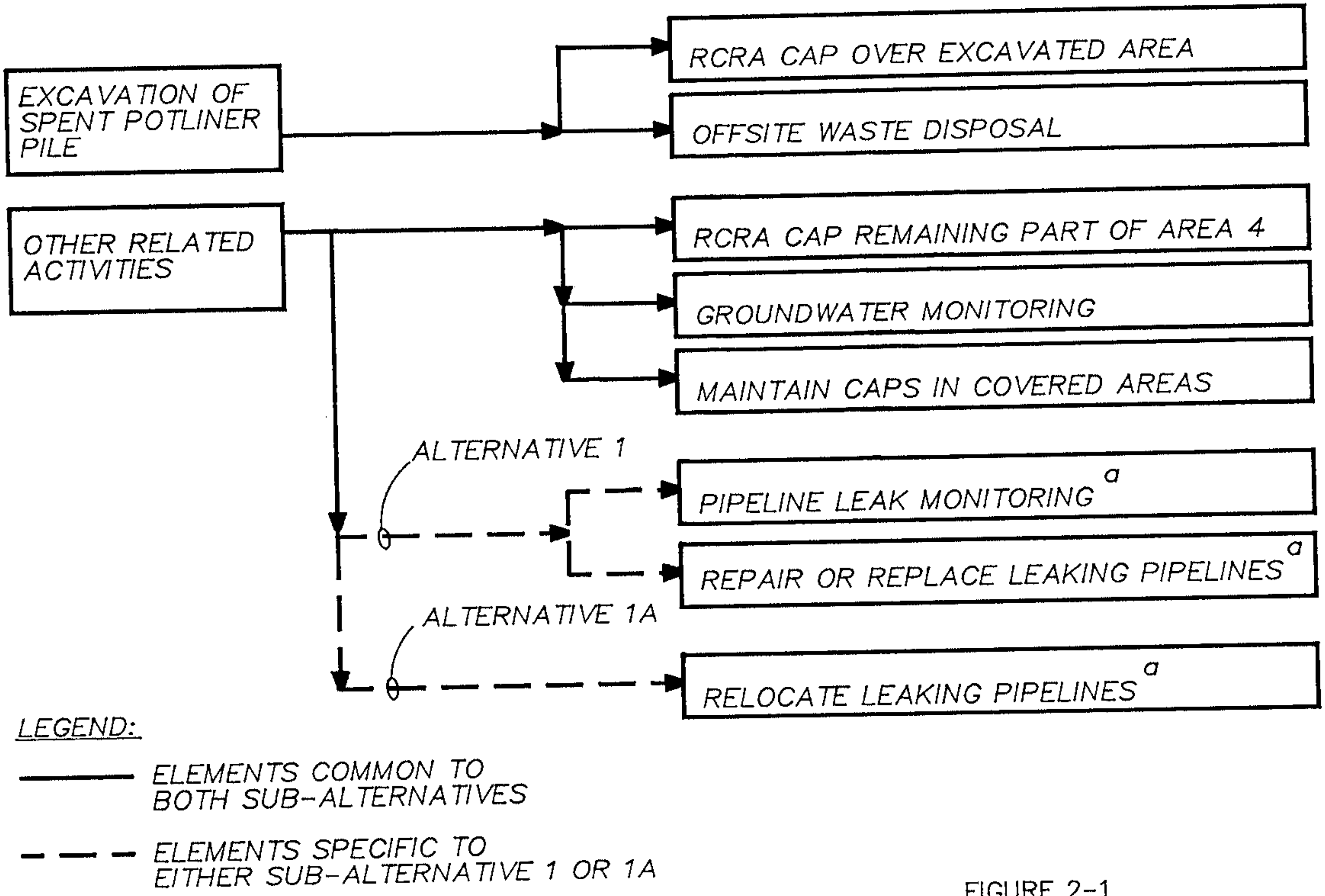
The screening criteria were used to evaluate corrective measures relative to other technologies accomplishing the same objective. Since each technology does not address all treatment objectives, the technology evaluation assumes that other technologies necessary to meet the objective are implemented concurrently. The effect of combining technologies will be considered in the detailed analyses of alternatives.

The results of the detailed screening are presented in Tables 2-3 and 2-4. Technologies considered to have some merit for use at the Mead Works are identified with a "yes" written under the "retained for further consideration" column. These technologies were combined into corrective remedial alternatives in the next section of this chapter.

Source-Related and Plume-Related Remedial Alternatives

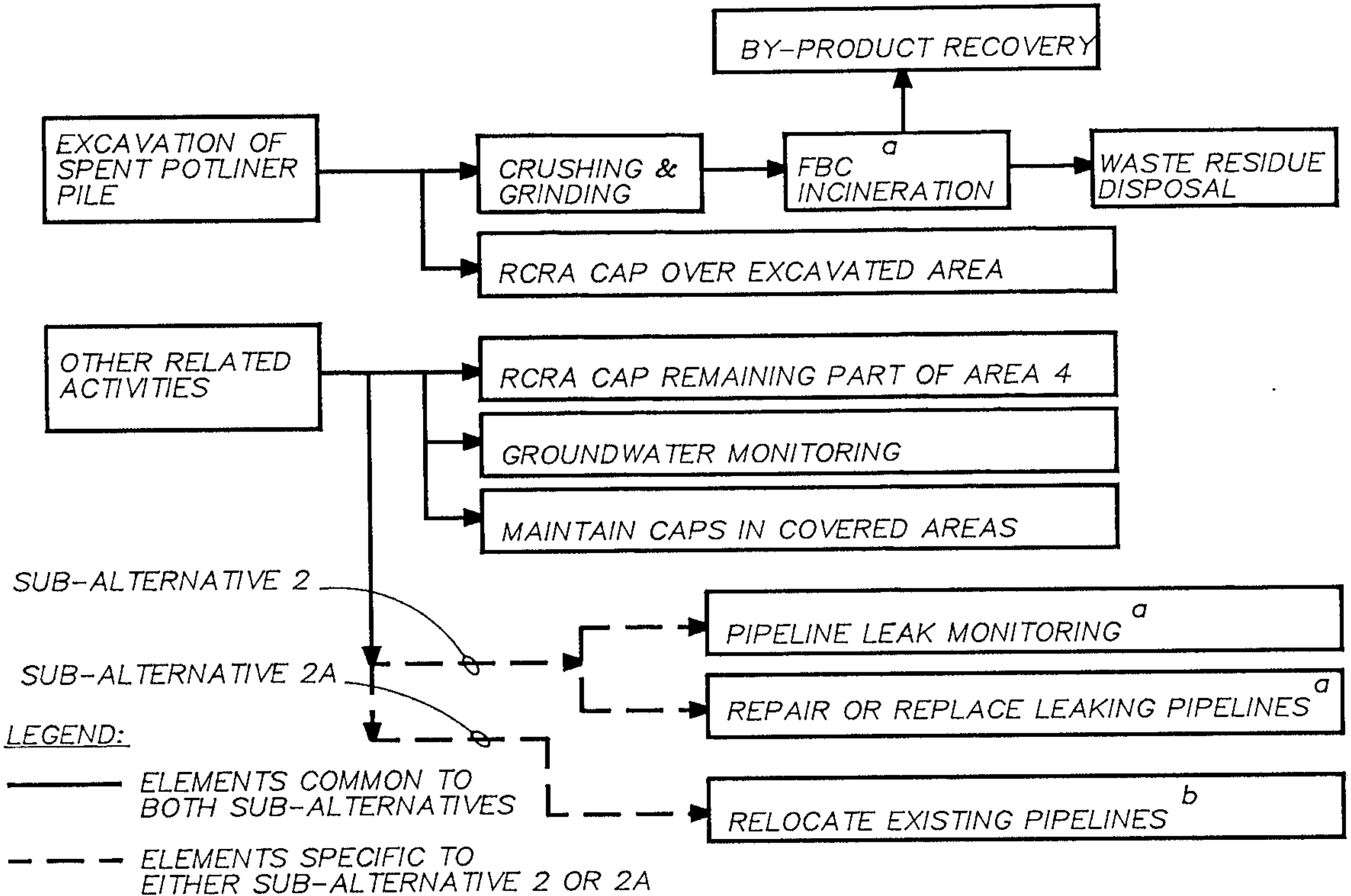
Table 2-5
POTENTIAL REMEDIAL ALTERNATIVES FOR THE SOURCE-RELATED OPERABLE UNIT AT KAISER MEAD

Technology	Alt. 1	Alt. 1A	Alt. 2	Alt. 2A	Alt. 3	Alt. 3A	Alt. 4	Alt. 4A	Alt. 5
1. Excavation	X	X	X	X	X	X			
2. Offsite Disposal	X	X			X	X			
3. Incineration			X	X					
4. Pyrohydrolysis					X	X			
5. RCRA Cover Cap	X	X	X	X	X	X	X	X	
6. Pipeline Leak Monitoring	X		X		X		X		X
7. Repair or Replace Leaking Pipelines	X		X		X		X		X
8. Relocate Leaking Water, Sanitary Sewer, Storm Drainage Pipeline, and Water Treatment Plant		X		X		X		X	
9. Groundwater Monitoring	X	X	X	X	X	X	X	X	X



[a] "PIPELINES" REFERS TO WATER, STORM DRAIN PIPING, SANITARY SEWER AND TREATMENT PLANT

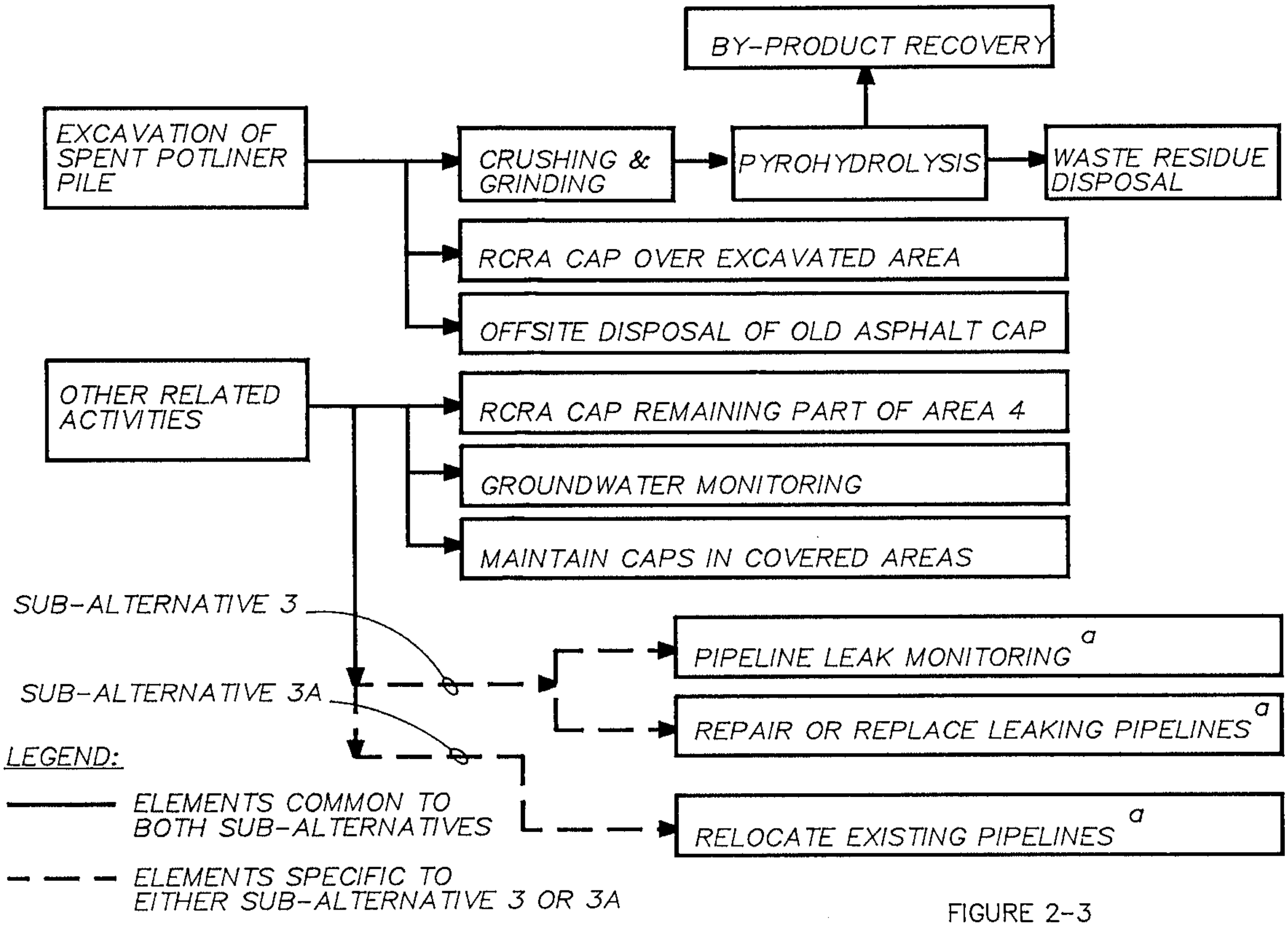
FIGURE 2-1
ALTERNATIVES 1 AND 1A:
OFFSITE DISPOSAL



[a] FBC STANDS FOR FLUIDIZED BED COMBUSTION.

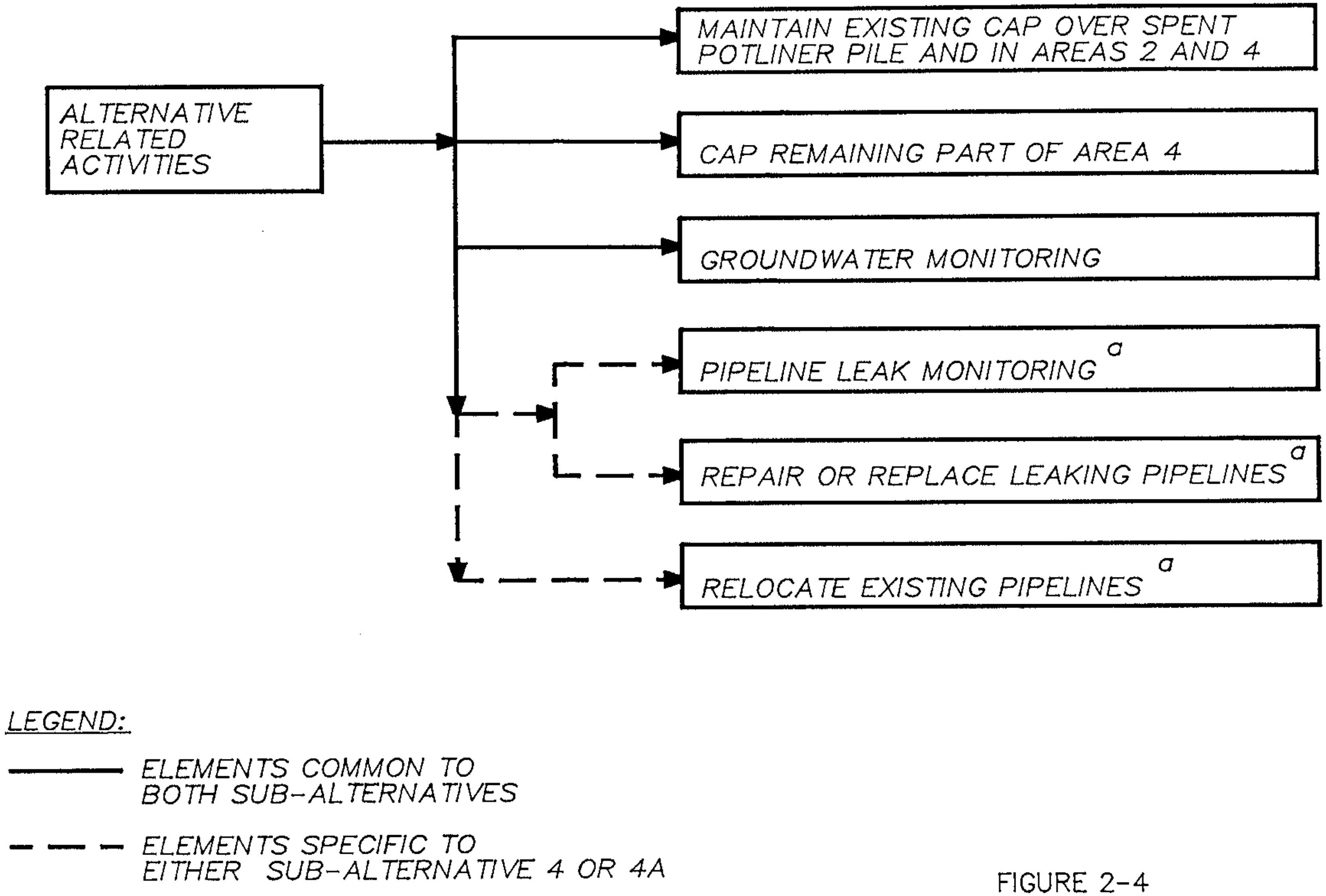
[b] "PIPELINES" REFERS TO WATER, STORM DRAIN PIPING, SANITARY SEWER AND TREATMENT PLANT.

FIGURE 2-2
ALTERNATIVES 2 AND 2A
INCINERATION



[a] "PIPELINES" REFERS TO WATER, STORM DRAIN PIPING, SANITARY SEWER AND TREATMENT PLANT.

FIGURE 2-3
ALTERNATIVES 3 AND 3A
PYROHYDROLYSIS



[a] "PIPELINES" REFERS TO WATER, STORM DRAIN PIPING, SANITARY SEWER AND TREATMENT PLANT.

FIGURE 2-4
ALTERNATIVES 4 AND 4A
SOURCE CONTROL

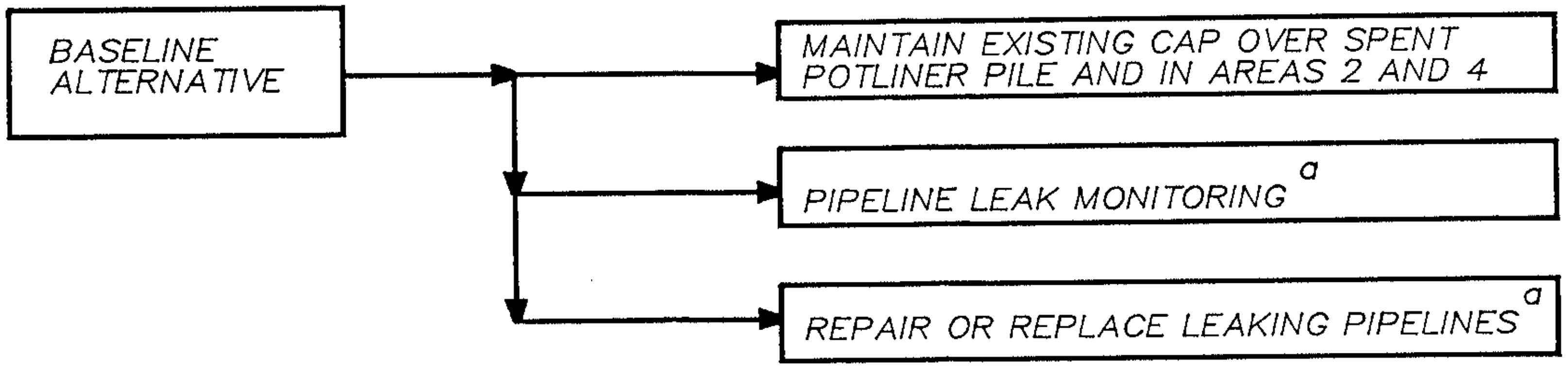


FIGURE 2-5
ALTERNATIVE 5
BASELINE

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[a] "PIPELINES" REFERS TO WATER, STORM DRAIN PIPING, SANITARY SEWER AND TREATMENT PLANT.

Table 2-6

POTENTIAL REMEDIAL ALTERNATIVES FOR THE PLUME-RELATED OPERABLE UNIT AT KAISER MEAD

Technology	Alt. 1	Alt. 2
1. Extraction Wells	X	
2. GW Treatment by Chemical Precipitation	X	
3. Treated Effluent Discharge to POTW	X	
4. Groundwater Monitoring	X	X