**EXH. RJR-32**
**DOCKETS UE-170033/UG-170034**
**2017 PSE GENERAL RATE CASE**
**WITNESS: RONALD J. ROBERTS**

**BEFORE THE**
**WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION**

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| **WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION,**<br><br>**Complainant,**<br><br>**v.**<br><br>**PUGET SOUND ENERGY,**<br><br>**Respondent.** | **Docket UE-170033**<br>**Docket UG-170034** |

**SECOND EXHIBIT (NONCONFIDENTIAL) TO THE PREFILED REBUTTAL TESTIMONY OF**

**RONALD J. ROBERTS**

**ON BEHALF OF PUGET SOUND ENERGY**

**AUGUST 9, 2017**

# Study of Alternate
# Ash Disposal Methods
# For Colstrip Units No. 1 and No. 2

February 1985

The Montana Power Company

1985 Work Order No. 10-50112

File 8680 - Second Stage Evaporation Pond

Study of Alternate

Ash Disposal Methods

For Colstrip Units No. 1 and No. 2

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## SUMMARY

1. This report presents the results and recommendations of a study of alternate ash disposal methods for Colstrip Units No. 1 and No. 2.

2. Two main methods of ash disposal were identified, wet (or pond) and dry. The wet method disposes of the ash in slurry form in an evaporation pond. The dry method utilizes mechanical means to dry the ash with the dried ash being hauled to a final disposal point.

3. The alternatives for pond disposal that were identified varied in the method and degree of seepage control provided. All options envisioned a second stage evaporation pond in the original location proposed by Bechtel.

4. The alternatives for dry disposal that were identified varied in the location of the dewatering facility and the location of the final disposal point of the dried ash. Disposal of the ash in Western Energy's mine was one of the variations considered.

5. All alternatives for disposal were reviewed for technical and economic feasibility. Pond disposal was narrowed to five alternatives and dry was narrowed to three.

6. Operational, environmental and regulatory aspects of all seven alternatives were examined. Two consulting firms were enlisted to help in the investigation. Both field and laboratory testing were performed to define design parameters and anticipated impacts of each disposal method.

7. A cost estimate of each alternative was made. Both capital and operating costs were determined, then levelized for comparison on an annual basis. Additionally, a cash flow was developed for three of the alternatives.

8. All dry disposal alternatives were ruled out on the basis of high cost. It was determined that the advantages inherent to the dry method could not offset the disadvantage of high cost.

9. It is recommended that the Company proceed with implementation of one of the pond alternatives considered. This recommendation is made on the basis that the most expensive pond alternative anticipated would still be significantly less costly than any dry disposal method considered, assuming an escalation rate of six percent over the 25-year life of the project.

10. It is also recommended that the Company proceed further with the engineering required to select a specific pond alternative prior to presentation to the State of any plans for an ash disposal system.

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# 1.0 INTRODUCTION

## 1.1 Background of Project

Since beginning operation in 1975-1976, the ash from Colstrip Units No. 1 and No. 2 has been deposited as a slurry in the first stage evaporation pond which is located about three miles northwest of the plant site. The term "ash" is used in this report to describe the solid waste material produced from the scrubber system. The material is actually a combination of fly ash and precipitated solids which result from the desulfurization process that occurs in the scrubbers. Bottom ash is not included in what is termed "ash" in this report; it is handled altogether separately. The rate of filling of the pond with ash has been monitored closely and, over the years, it has been very consistent. Using this historical data, it has been determined that the first stage pond will be full by 1989, at which time another site for the disposal of ash will be required.

The original concept for this additional disposal site called for construction of another evaporation pond immediately downstream of the existing one. In 1978, Bechtel was engaged to design a second stage evaporation pond in Section 21, T2N, R41E. The design was completed in 1980 and the major activities since that time have been 1) monitoring the fill rate in the first stage pond and 2) conducting studies of the environmental impact of a second stage pond.

In January, 1984, MPC management directed that mine disposal of ash be studied as an alternate to constructing another evaporation pond. The study began in August of 1984, culminating in this report which details the results and conclusions.

1.2 Scope of Study

The purpose of this study was to investigate alternate methods of ash disposal with the ultimate objective of making a recommendation to MPC management as to a preferred method of disposal to pursue when the first stage evaporation pond becomes full. Two types of methods were considered, wet disposal and dry disposal. Numerous options for each method exist and each option was considered to one extent or another.

Two consultants were engaged during the study - Hydrometrics, Inc. of Helena, Montana, and Conversion Systems, Inc. (CSI) of Horsham, Pennsylvania. Hydrometrics studied the environmental impacts of the various options, both wet and dry, but CSI's involvement was limited to the dry process only.

All preliminary engineering relating to site layouts, operational considerations and cost estimating was done in-house.

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## 2.0 WET DISPOSAL METHODS

### 2.1 General

Wet disposal of ash in an evaporation pond is the present disposal method used by Colstrip Units No. 1 and No. 2. Both particulate and FGD waste is removed in wet scrubbers. The scrubber effluent is an ash slurry which is pumped year-round from the scrubbers to on-site ponds. From there, the solids are dredged and pumped approximately three miles to the first stage evaporation pond (Pond E). The dredging is usually done from April through October. In Pond E, the ash settles out, then the water is decanted off and either returned to the plant or evaporated. When the pond is completely full of ash and all the water has evaporated, the surface will be covered with topsoil and revegetated.

### 2.2 Description of Alternatives

#### 2.2.1 General

All of the pond alternatives have several components in common. All of them require the construction of a dam as designed and specified by Bechtel in 1980. Included therein is some new slurry line piping, the east drain relocation, transmission line rerouting, some return line piping and miscellaneous electrical work. Also common to all the options is the installation of a city water system for the residents and businesses located immediately downstream of the second stage pond.

The differences between the various pond options are in the methods of seepage control and mitigation that would be used for each.

2.2.2 Feasible Alternatives

The following alternatives were considered to be technically and economically feasible:

A. Provide a bentonite-soil liner and an interception well system.

B. Provide a synthetic membrane liner and an interception well system.

C. Provide a bentonite-soil liner only.

D. Provide a synthetic membrane liner only.

E. Provide an interception well system only.

2.2.2.1 Pond Alternative A

This option provides a dual system of seepage control and mitigation. The pond would be lined with a mixture of the natural soil and bentonite clay. The bentonite-soil liner was assumed to be two feet thick and would ultimately cover the entire surface of the pond bottom. The exact ratio of soil to bentonite would be determined as a result of testing with the available soil to yield the permeability required to meet the maximum allowable seepage rate.

Since the pond fills relatively slowly, it was envisioned that the pond would be divided into five areas by constructing four internal dikes as shown in Figure 1. Areas 1 and 5 would be lined first since Area 1 would be the first to receive ash and Area 5 would serve as the clearwell. The other areas would be lined as the fill rate dictated. This staged filling of the pond is the same concept that is presently used in the first stage pond.

The interception well system would consist of 400 wells spaced 50 feet apart along the northwest and northeast sides of the pond (see Figure 1). This line of wells would be approximately perpendicular to the anticipated direction of groundwater flow. The wells would be pumped to remove the seepage water from the ground and return it to the second stage pond. This technique would not reduce or eliminate seepage from the pond, but would significantly restrict the lateral movement of seepage water, thereby reducing or eliminating impacts due to seepage. It was assumed that this interception system would be built in stages over three consecutive years starting with the first year of the pond's operation.

2.2.2.2 Pond Alternative B

This alternative also has a dual system for seepage control and mitigation. The pond liner would be a material such as hypalon, PVC or high density polyethylene no less than 30 mils thick. It would be installed in stages as described for Pond Alternative A.

The interception well system would be the same as described for Pond Alternative A.

2.2.2.3 Pond Alternative C

This alternative provides for a bentonite-soil liner as the only means of seepage control. The liner would be as described for Pond Alternative A.

#### 2.2.2.4 Pond Alternative D

This alternative was considered as having a synthetic membrane liner as the only means of seepage control. The liner would be as described for Pond Alternative B.

#### 2.2.2.5 Pond Alternative E

This alternative has a single method of seepage mitigation in the form of an interception well system. Other than the partial upstream blanketing included as part of the dam construction, there is no seepage control. The wells mitigate the effects of pond seepage by intercepting it and returning the water to the pond. The well system would be as described for Pond Alternative A.

### 2.2.3 Infeasible Alternatives

Certain seepage control methods were used to identify additional options for pond disposal but were eliminated from further detailed consideration because they were deemed to be technically unacceptable. Also, even if they were technically acceptable, the cost of each would be prohibitive. These infeasible options were:

F. Provide a natural soil liner.

G. Provide a grout curtain.

H. Provide a slurry wall.

2.2.3.1 Pond Alternative F

This alternative would use a natural soil liner for seepage control. The best permeability that could be expected from the natural soil would be several orders of magnitude greater than with a bentonite liner. Therefore, to get a comparable allowable seepage level out of the pond, the liner would have to be tens of feet thick which is not practical. If the liner was kept to a reasonable thickness, then the seepage would be greater than acceptable limits. For this reason, this option was not studied in further detail.

2.2.3.2 Pond Alternative G

Installing a grout curtain constituted this option. Grout curtain installation could be done easily enough, but there was considerable doubt as to a grout curtain's ability to limit seepage to acceptable limits. Since acceptable seepage could not be guaranteed, this option was not studied in further detail.

2.2.3.3 Pond Alternative H

This option included using a slurry wall for seepage control. Slurry walls are a proven technology, but the underlying geology of the area must be compatible in order to make them practical. The maximum practical depth for a slurry is about 70 to 80 feet, but in the area of a second stage pond, the depth to the first acceptable impervious stratum is about 150 feet. At this depth, a slurry wall is not at this time technically or economically feasible. For this reason, this option was dropped from further consideration.

## 2.3 Cost

### 2.3.1 General

Estimates were developed for both the initial capital cost and the annual operating cost of each feasible alternative. All estimates were done in 1985 dollars and contain a contingency of approximately 15 percent. Some capital items would be built in stages over several years, but were considered as initial capital costs. The costs of these items were estimated as if they would be constructed in their entirety in 1985.

### 2.3.2 Capital Costs

All of the feasible alternatives for pond disposal were made up of some combination of the following capital items:

1. Dam
2. City water system (for downstream residents and businesses)
3. Synthetic membrane liner
4. Bentonite-soil liner
5. Groundwater interception well system

All costs are listed in Table I.

The cost of the dam was originally estimated in 1979 by Bechtel. This cost was escalated six years at seven percent (an assumed average of escalation rates over the past six years) to get the cost into 1985 dollars. Added to this were items such as construction testing and inspection, transmission line reroutes and MPC engineering, thereby bringing the grand total to construct the dam to $13,800,000.

The cost of a city water system for the residents and businesses located immediately downstream of the second stage evaporation pond dam is included in the total cost of each alternative. The system would consist of a main line connecting to the existing Colstrip Community Services Company's system and a distribution network to the various customers. The estimate to construct this system is $250,000.

The total cost for installing a synthetic membrane liner is $8,853,000. Included therein is the cost of a 100 mil liner to cover the entire 163 acre area of the pond plus the cost of constructing four internal dikes to accommodate staged filling of the pond.

The bentonite-soil liner costs are based on a two foot thick liner with a ratio of soil to bentonite assumed to yield an acceptable permeability. These costs could change significantly if future testing were to indicate that the assumptions are not acceptable. The thickness of the liner may change, or the amount of bentonite required may change, or both. The costs presented in this report are based on the information available at this time which is not necessarily to the detail required for a final mix design for a liner of this type. The cost to construct four internal dikes is also included in the total of $9,350,000 for this liner.

The cost of the interception well system includes installation of 400 wells, piping into the evaporation pond and running in adequate power for the pumps. The system was estimated assuming a 50 foot spacing of wells which is the closest spacing that would be required. If future testing indicates that a wider spacing would be acceptable, then the cost would be less than the current estimate of $2,983,000.

### 2.3.3 Operating Costs

Operating costs for the feasible pond alternatives vary only by the inclusion or exclusion of the interception well system. Except for the interception well system, the operating cost of the pond is the same regardless of the seepage control measures used. The base cost, therefore, of operating the pond is estimated to be $248,000 per year, which includes an estimate for liner maintenance. The additional operating cost of the interception well system is $32,000 per year. All costs are shown in Table II.

## 2.4 Operational Considerations

The operation of an evaporation pond system is not highly complex. The requirements for operation are well defined for Colstrip Units No. 1 and No. 2 since this is the method of ash disposal that has been used since the initial start-up of the units. The operation is not labor intensive and can be run without a great deal of monitoring by plant operators.

### 2.4.1 Equipment

Since the material to be handled in an evaporation pond system is a slurry of water and solids, most of the equipment required consists of pumps, valves and pipelines. A dredge is required in the on-site ponds and floating pump platforms are required in the evaporation pond and in the on-site clearwell pond. Pumps are located on the dredge, on the floating platforms and in the booster pump building.

### 2.4.2 Labor

Except for the dredge, none of the components of the system require the constant attention of an operator. The dredge requires a crew of two persons per shift during the dredging season, which is usually from April through October. During the remainder of the year, only periodic checks of the system are required by plant operators. Maintenance is performed on an as-needed basis, except for periodic preventive maintenance measures. There is not enough maintenance to require a dedicated crew for the system.

### 2.4.3 Operational Scheme

The system in its entirety is only operated during warm weather months. All components of the system between the on-site ponds and the evaporation pond are shut down and drained during the coldest winter months (November-March). The only operation during these winter months is pumping of the scrubber effluent slurry from the scrubbers to the on-site pond. When dredging commences in the spring, the settled solids in the on-site ponds are pumped by the dredge to the booster pump house and then on to the evaporation pond. The slurry is discharged into an outlying area of the pond which is separated from the clearwell area of the pond by a dike. The dike allows more rapid settling of the solids, which results in clearer decant water. The decanted water is returned to the on-site ponds by the floating return pump during shifts when there is no dredging.

The discharge point of the slurry pipe at the evaporation pond must be moved from time to time to allow uniform distribution of the settled solids within the area being filled. The overflow for the decant water in the area being filled needs to be raised periodically as the area fills with solids. These tasks are required on an infrequent basis and are not highly labor intensive.

## 2.5 Environmental Considerations

### 2.5.1 Seepage Impact Analysis

Groundwater in the vicinity of the proposed Stage II evaporation pond will be impacted by seepage water from the pond. However, if seepage rates are low enough a slow movement of small quantities of seepage water in the existing groundwater system should significantly limit deterioration of groundwater quality in the vicinity of the pond. A review of the impacts of seepage from the Stage 1 evaporation pond on water resources in the area is valuable for prediction of impacts from the Stage II pond.

#### 2.5.1.1 Review of Stage I Evaporation Pond Impacts

An estimate of seepage from the Stage I pond was made by Bechtel in 1976. Using the same type of analysis used to estimate seepage from the proposed Stage II pond, a total of 79 gpm was estimated to seep from the Stage I dam and impoundment. Seepage abatement measures suggested by Bechtel (Reference 1), included blanketing highly permeable zones of the bottom of the impoundment with bentonite or a clay-cement mixture; grouting zones of potential seepage around the periphery of the pond where seepage might be expected to occur through joints and fractures; construction of a system of drains and interception wells should seepage persist. It was further estimated that a properly designed seepage control system would limit the seepage toward Armells' Creek alluvial channel to 13 gpm (Reference 1, page 80). Actual seepage control measures employed for the Stage I pond include blanketing on isolated permeable zones of the pond bottom and the installation of a sump downstream of the Stage 1 dam which is used to collect pond water from the dam drains. Water from the sump is pumped back to the pond.

A preliminary assessment of the effects of Stage I pond seepage on water resources has been made in a report by Hydrometrics (Reference 2). Since that time, additional water level and water quality data have been obtained from existing monitoring wells and from new monitoring wells drilled north of the Stage I pond.

In November 1976, start-up of the Stage I pond began. In the spring of 1977, normal operation of the pond began. Also in 1977, dividing the pond into five cells was initiated. The sequence of filling started in the northern-most area and proceeded counter clockwise around the pond. The middle cell of the pond is the decant area. At present, the two southern (and final) arms are not completely filled. The lining provided on the bottom of the pond was locally borrowed soil placed to cover the more permeable areas in the impoundment.

Water levels in a number of sub-McKay wells peripheral and downgradient of the Stage I pond, have been monitored since construction of the pond (Reference 3, Figures 13 through 16 and Appendix 4). Of the 11 wells monitored, water levels have significantly risen in wells 119, 121, 124, 205 and 208. These rises coincided with the beginning of the Stage I pond operation in early 1977. Monitoring wells further downgradient, wells 409, 411 and 413, have not had significant rises in water levels. The water level in well 412 has risen at a rate of approximately one foot per year since the start of measurements in 1978 and has shown some seasonal fluctuation. It is possible that the static water level in well 412 is responding to an influx of water seeped from the Stage I pond sump. Water from the sump may be traveling downgradient to well 412 through the ephemeral drainage alluvium. Significant water level changes occurred in 1979 in wells 211, 412 and 413. However, these wells are located in coulee bottoms and are completed in shallow sub-McKay strata which underlie the unconsolidated coulee sediment. The rise and fall in water levels in these three wells probably was due to infiltration from an unusually heavy snowpack and large runoff in the spring of 1979 (NOAA, 1979).

Chemical analyses have been conducted on sub-McKay groundwater from six monitoring wells adjacent to the Stage I pond and four wells downgradient about 400 feet (Reference 3, Appendix 3). Samples have been collected from 1976 to the present for physical parameters, common ions, nutrients and trace elements, including boron. Concentration versus time plots for specific electrical conductivity and sulfate for the wells sampled, are shown in Reference 3, Figures 17 through 27.

Significant increases in conductivity and sulfate concentration occurred in wells 119, 208 and 210. A moderate increase in conductivity and sulfate concentration has occurred in well 412. As noted earlier, water in this well may be affected by water seeped from the Stage I pond sump. Water quality changes were expected in well 208 because of its close proximity to the pond. Well 205 is also near the pond, but unexpectedly does not show an increase in either conductivity or sulfate concentration even though water levels have risen about 50 feet. The increase in sulfate concentrations and conductivities in well 119 and 210 indicates seepage water is moving south and east of the pond. Wells 119 and 210 are about 1,200 feet southeast and 1,400 feet east from the pond, respectively. Well 121 (about 2,000 feet southeast of the Stage I pond) does not show an increase in conductivity or sulfate concentration, however, it has experienced a significant rise in water levels. This increase indicates the well probably is being affected by seepage from the nearby surge pond rather than the Stage I pond. Well 121 is much closer to the surge pond and water elevations in the surge pond have been higher than the Stage I pond. This would have resulted in water movement from the surge pond toward well 121. Presently, pool elevations of the two ponds are approximately equal. When full, pool elevation of the Stage I will be about 15 feet higher than the surge pond.

Well 211, directly downgradient of the Stage I dam embankment, does not show a significant increase in water levels, nor any increase in specific conductivity or sulfate. The evaporation pond sump is slightly further downstream than well 211. Water in the sump shows a significant increase in sulfate concentration and conductivity changing from 1,700 umhos conductance and 826 mg/l sulfate in 1976 to

9,740 umhos conductance and 6,750 mg/l sulfate in 1984. The sump was not sampled from 1979 through 1982.

In November 1984, four new monitoring wells were drilled, tested and sampled. All of the wells are north and downgradient of the Stage I pond. Water quality data from samples collected from well 354D, 355D and 356D show that the conductance varies from 1,390 umhos to 2,630 umhos and sulfates vary from 368 mg/l to 985 mg/l. These low concentrations indicate that the Stage I pond has had little or no effect on water quality in groundwater north of the pond. The fourth well, 357A, was drilled into Stocker Creek alluvium and is over 1.5 miles north of the Stage I pond. Conductance of water from well 357A is 2,120 umhos and sulfate concentration is 1,120 mg/l. There is no evidence the groundwater has been impacted by the Stage I pond.

Alluvial well 352A was constructed in 1983 and was sampled three times in 1984. Well 352A is located in the ephemeral drainage where the proposed Stage II dam is to be located. The well is 33 feet deep. Water from this well has a sulfate concentration of about 3,100 mg/l and a conductivity of about 4,300 umhos/cm. Water quality in this well may be representative of the natural alluvial water or it may have been influenced by water from the Stage I pond sump.

Data from monitoring wells shows the Stage I evaporation pond probably has had no effect on either Stocker Creek or East Fork Armells Creek. Limited seepage and slow movement of groundwater has prevented any stream impacts.

There has been a limited amount of water quality data obtained from private wells east of the Stage I pond. Several of these wells were sampled in 1982 by Hydrometrics, but the sampling has not been repeated and water quality trends cannot be determined. The wells are similar in quality and are a sodium-sulfate type. There are no water quality characteristics of these wells that indicate impacts from the Stage I pond.

In summary, water level and water quality data indicate that seepage from the Stage I evaporation pond has had some effect on groundwater peripheral to the pond. However, impacts have been localized indicating the following:

1. Rates of movement of seepage water through the underlying bedrock aquifer have been very slow.

2. Fractures or joints in the aquifer system may be responsible for transmitting seepage water to some wells located away from the immediate vicinity of the pond (wells 119 and 210).

3. Water in wells 352A and 412 may be influenced by seepage water from the impoundment and from the Stage I pond sump.

2.5.1.2 <u>Anticipated Impacts of Stage II Evaporation Pond</u>

The potential long-term impact of seepage from the Stage II evaporation pond is difficult to accurately predict. The detailed stratigraphy and lithology of strata between the Stage II pond and the nearby private wells is not well known and only limited hydraulic data has been obtained from water-yielding zones in the Stage II pond area. Bedrock in the entire area is essentially flat-laying and is anisotropic; that is, there is a strong preference for horizontal rather than vertical movement of groundwater. This is quite common in Fort Union Formation sediments and results in a much lower potential for seepage water to affect deeper aquifers rather than shallow aquifers. It is clear that movement of seepage water from the pond would be slow and in a dominantly horizontal direction.

Hydrometrics performed a seepage analysis on the second stage evaporation pond using a model developed by McWhorter and Nelson. This model takes into account unsaturated flow above the groundwater table which is the actual situation which will exist for the second stage evaporation pond. Several scenarios were analyzed using different permeabilities (for different liners) and different operating schemes.

Some private wells east of the proposed Stage II pond are not deep and the sealing of the casing and water-bearing zones in the deep wells is uncertain. There is, therefore, a potential pathway for movement of pond seepage water into both deep and shallow wells. If significant seepage occurs from the Stage II pond, it is very likely that water quality impacts will eventually occur in private wells east of the pond.

The Stage II evaporation pond will be about 6,000 feet from Stocker Creek and 2,500 feet from East Fork Armells Creek. Again, due to limited seepage, long distances and slow groundwater movement, the impact of the Stage II pond on these streams will be small and it will take many years for the impact to occur. Due to the distance and direction (north) to Stocker Creek and the limited seepage, it is doubtful that pond seepage would raise the potentiometric surface sufficiently to cause any groundwater discharge at the ground surface as springs or seeps. This evaluation assumes there are no fault or fracture zones or thin highly permeable layers that would allow rapid groundwater movement northward into the Stocker Creek area.

Seepage from the Stage II pond probably will move northeast and there may be no measurable impacts to Stocker Creek.

Based on the area geology and present groundwater flow system, Stage II pond seepage would move northeast. After many years, some or all of this seepage may enter the alluvial groundwater system adjacent to East Fork Armells Creek. Some seepage water ultimately would probably be lost by evapotranspiration and some would mix with the existing East Fork Armells Creek alluvial groundwater. Due to the relatively large surface water and groundwater flow in East Fork Armells Creek, the impact of the seepage water would be small.

Seepage through the Stage II dam and abutments will be controlled by the dam design and abutment blanketing. A dam drainage and valley pump-back system will significantly reduce or eliminate impacts from dam seepage.

If groundwater interception system is used, the impacts of pond seepage would be reduced or eliminated.

### 2.5.2 Water Resources Monitoring Plan

A comprehensive water resources monitoring plan will be needed to document the performance of the Stage II evaporation pond. This would include both surface water and groundwater monitoring peripheral to the pond with water quality, streamflow and groundwater levels the primary focus of monitoring. The monitoring program should utilize, as much as possible, available monitoring wells and surface water monitoring sites.

#### 2.5.2.1 Groundwater

Groundwater monitoring would include periodic measurements of water levels and water quality. Monitoring wells must be completed in all stratigraphic units that potentially could be affected by pond seepage. The number of new monitoring wells required will depend on expected pond seepage and the method of operation of the impoundment. With a monitoring well spacing of 350 to 500 feet it would require 40 to 60 wells to monitor two stratigraphic horizons. Specific locations and depths for new wells would need to be determined in the field to insure they are accessible and will not conflict with facilities associated with the Stage II pond. Hydrological and geological results obtained from drilling the first few new monitoring wells also may influence the number and location of the remainder of the new wells.

It is recommended that new wells be constructed in a manner similar to existing monitoring wells. This would include drilling by forward rotary; casing with four- to 4-1/2-inch ID PVC pipe and slotting the pipe in the target zone on completion using a commercial plastic screen. The wells should be sealed with one or more packers set above the water yielding zone; use of bentonite or a bentonite-cuttings mixture in the annulus between the drilled hole and the casing and a surface seal of clay to prevent infiltration of surface water.

Groundwater levels should be monitored on a periodic basis. Seepage from the Stage II pond would recharge groundwater in strata adjacent to the pond and would raise water levels. Other factors, such as snowmelt, rainfall and mining, also can influence groundwater recharge so water levels are not a direct indicator of pond leakage. Water levels should be monitored on a monthly basis using a calibrated electric probe or a steel tape. Wells showing unusual water level fluctuations should be monitored more frequently and a few selected wells should be instrumented with continuous water level recorders to measure short-term fluctuations in groundwater levels.

Groundwater quality in strata peripheral to the Stage II pond can provide information on pond performance. Significant seepage from the pond would eventually cause a change in quality of groundwater beneath and peripheral to the pond. Groundwater quality monitoring should be conducted on a semiannual basis with sampling in the spring and fall. This is the same monitoring frequency as is used for wells peripheral to power plant process ponds and for the Units No. 3 and No. 4 effluent holding pond.

Chemical and physical parameters that should be monitored are listed in Table IV. These parameters have been identified as potentially important and are consistent with the parameter list used for other groundwater monitoring in the Colstrip area.

2.5.2.2 Surface Water

Surface water sampling would include periodic measurements of streamflow in lower Stocker Creek and in East Fork Armells Creek both upstream and downstream of the confluence with the ephermal drainage. Measurement stations would be installed so that potential contributions from groundwater inflow could be detected. Sampling would also include periodic measurements of water quality. Although measurements of streamflow and surface water quality may not need to be made as frequently as measurements of groundwater levels and groundwater quality, it is important to establish a baseline for surface water flow and quality. Surface water quality sampling stations already existing on East Fork Armells Creek include SW-13 located just downstream of the confluence of Stocker Creek; the PBR flume located north of the Stage II pond area and south of Stocker Creek; the NF flume located between the Stage II pond area and the surge pond; and the SF flume located between the surge pond and Colstrip. No surface water sampling sites are presently in existence on lower Stocker Creek.

#### 2.5.2.3 Quality Control and Assurance

A quality assurance (QA) and quality control (QC) plan are a necessary element of any monitoring program. A comprehensive QA/QC program will be needed for the Stage II evaporation pond program. The QA/QC procedures are designed to ensure that the amount and frequency of monitoring, the information and data gathered during monitoring and the resulting decisions are technically sound, statistically valid and properly documented.

The QC program would apply to all field and laboratory activities associated with the Stage II pond monitoring program. These activities include streamflow data collection, static water level data collection, water quality sample collection and laboratory analysis which includes a system of blanks, duplicates, standards, splits and spikes, to ensure laboratory precision and accuracy.

Quality assurance (QA) would apply to the system of periodic external checks which would provide assurance of an effective QC program. The QA program would include performance audits of field equipment, limited periodic collection and analysis of separate samples, participation in an EPA-QA program, system audits and quality assurance reports.

## 2.6 Regulatory Considerations

The Montana Department of Health and Environmental Sciences administers the Montana Water Quality Act (Title 75, Chapter 5, MCA) which requires compliance with surface water and groundwater quality standards. Design of the Stage II evaporation pond will include retention of large flood flows including the PMF (Probable Maximum Flood). There will, therefore, be no discharges to surface water from the pond.

Contamination of groundwater is also a concern and performance of the pond will need to comply with the MGWPCS (Montana Groundwater Pollution Control System) (ARM 16.20.1002 through 16.2.1025).

The Montana Groundwater Pollution Control System requires that existing quality of groundwater be maintained. Section 16.20.1011 states:

> "Any groundwater whose existing quality is higher than the established groundwater quality standards for its classification must be maintained at that high quality, unless it can be affirmatively demonstrated to the Board that a change is justifiable as a result of necessary economic or social development and will not preclude present or anticipated use of such water."

Groundwater in the Stage II pond area is Class II or Class III.

As shown in Reference 3, Exhibit 1, there are a number of private water wells located one-half mile east of the Stage II pond. Movement of seepage water to these wells is a potential regulatory problem.

The MGWPCS allows a mixing zone wherein the groundwaters do not need to meet the groundwater standards (ARM 16.20.1010). The section also states in part:

> "The size of the mixing zone will generally not extend beyond the property boundaries of the operator of the source."

If significant leakage occurs from the Stage II pond, then the short distance to nearby private wells will eventually result in changes in water quality in some of these wells.

To comply with the MGWPCS, the Stage II pond system will need to be designed, constructed and operated to prevent groundwater contamination.

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## 3.0 DRY DISPOSAL METHODS

### 3.1 General

This section will provide information on the fundamentals of stabilization/fixation as it relates to FGD dry disposal for Colstrip Units No. 1 and No. 2. Conversion Systems, Inc. was contracted to provide technical assistance in material testing, equipment selection and cost estimating for the dry disposal system method.

Two processes are used for conditioning the FGD scrubber bleed wastes for dry disposal. These are stabilization and fixation. Stabilization is used in a broad sense to mean any physical treatment designed to improve the physical handling properties of the FGD waste. In our case, this applies to the primary dewatering devices (thickeners) and secondary dewatering devices (vacuum filters). Fixation, on the other hand, is a type of stabilization which involves the addition of a reagent, causing chemical reactions with the FGD waste. In our case, lime would be added to the dry filter cake from the vacuum filters which results in cementitious-type reactions in the sludge. These reactions bond the solids together to reduce permeability and increase shear strength, thereby enhancing the physical stability and handability of the dry waste.

### 3.1.1. Stabilization

Physical stabilization is accomplished by reducing the moisture content of the FGD scrubber bleed to the point where structural properties are optimized and maximum density is obtained. However, material physically stabilized in this manner is subject to erosion, rapid saturation and leachability potential when exposed to rainfall. Since no chemical reactions are involved, the stabilization process is reversible. If the mixture is rewetted or allowed to saturate, the material will fluidize, causing a rapid decrease in strength.

The dewatering method for the proposed Colstrip Units No. 1 and No. 2 FGD dry disposal system, would include two 100 percent thickeners (75 feet in diameter) that would receive the five percent solids slurry from the scrubber underflow tanks. The thickeners would dewater the FGD slurry to a solids content of 30 to 40 percent and discharge the resultant waste to the thickener surge tank. The surge tank's primary purpose is to provide the secondary dewatering process a constant percent-solids waste stream by averaging out inconsistent thickener performance. The secondary dewatering process would consist of three 100 percent vacuum filters (12 feet diameter by 18 feet long), which would receive the FGD waste from the thickener surge tank. The vacuum filters would produce a filter cake with a solids content of 75 percent which is adequate for dry handling and further fixation processing.

3.1.2 Fixation

Fixation processes employ mechanisms that take advantage of the chemical interactions between the FGD waste and additives. These processes further stabilize the FGD waste with chemical reactions similar to those involved in cement chemistry, i.e., the hardening of concrete. With this process, a period of time is required for initial curing of the material before it is placed in the disposal site. A properly "fixed" material behaves much the same as a silty clay when initially placed in the final disposal site. After compacting, the curing process continues for 60 to 90 days at which time the material exhibits the properties of a low-strength concrete-like material. Unlike a physically stabilized sludge, a "fixed" sludge shows no tendency to reslurry when exposed to water.

The fixation process for the proposed Colstrip Unit No. 1 and No. 2 FGD dry disposal system would include a lime silo, pulverizer, related lime weighing and conveying systems and a pug mill for mixing the pulverized lime with the filter cake discharge from the vacuum filters. The material discharged from the pug mill would be placed into piles outside the facility using a radial stacker. Each pile would contain 24 hours worth of generated FGD waste and each pile would be left undisturbed for a period of three to six days for initial curing to take place. Due to the exothermic reaction of the curing process, internal heat generated in the pile would act as a freeze protection device during the winter months. After initial curing, a front-end loader would place the material in trucks for transportation to the final disposal site.

Based on testing conducted by Conversion Systems, Inc., the properties of the compacted-cured material are as follows:

| | Fixed 2% CaO | Fixed 3% CaO |
|---|---|---|
| - Solids Content (%) | 78.5 | 79.2 |
| - Wet Density (#/ft.$^3$) | 107.4 | 108.3 |
| - Unconfined Compressive Strength (psi) | 74 | 178 |
| - Permeability Coeff. (cm/sec) After 1 Month | $2.42 \times 10^{-7}$ | $7.22 \times 10^{-7}$ |

Refer to Figure 2 for a flow diagram of the dry disposal system.

### 3.2 Description of Alternatives

Three alternatives were investigated based on facility location and final disposal site selection.

#### 3.2.1 Dry Alternative A

This alternative would locate the complete dry disposal processing facility on the west side of Ponds A and B at the plantsite (Figure 3) with truck hauling of the waste to the Area D mine by Western Energy.

The location of the processing facility was chosen for its close proximity to Ponds A and B to minimize the pumping and piping requirements of thickener overflows and filtrate water which would be disposed of in these ponds. Western Energy would utilize off-road haulers (40-ton end dumps) to transport the waste an average of five miles to the Area D mine area.

### 3.2.2 Dry Alternative B

This alternative would locate the facility in the same location as described in Dry Alternative A, but with truck hauling to a landfill (second stage evaporation pond area) by a contractor.

This alternative would require the contractor to utilize highway trucks for the three-mile haul to the landfill.

### 3.2.3 Dry Alternative C

This alternative would divide the processing facility, locating the thickeners on the west side of Ponds A and B and pumping the underflow to the remainder of the facility located at the landfill with truck hauling of the fixed ash to designated portions of the landfill by a contractor.

This alternative allows a much shorter hauling distance, but additional equipment is required for pumping the underflow and disposing of filtrate water.

### 3.2.4 Infeasible Alternatives

Other alternatives were considered, such as using an overland conveyor to replace some of the truck hauling, locating the facility closer to the Area D mine and installing a moveable radial stacker that would be associated with the overland conveyor for total elimination of truck hauling. Each of these alternatives, though, were judged either unacceptable from an engineering or economic standpoint.

## 3.3 Cost

### 3.3.1 General

Estimates of initial capital costs and operating costs were made for each feasible alternative. All estimates were done in 1985 dollars and contain a contingency of approximately 15 percent. Portions of the estimates were done in-house while other portions were provided by CSI, Western Energy and General Constructors of Butte.

### 3.3.2 Capital Costs

The capital costs differ between the alternatives due to the location of the drying facility. Locating the facility at the remote landfill increases capital costs because of the requirement of additional pumping, piping and other equipment. The cost of the dewatering system as designed by CSI, however, remains the same regardless of its location. CSI's estimate for the main facility is $11,890,000. Itemized lists of the capital costs for all options are shown on Table VA and Table VB.

### 3.3.3 Operating Costs

The operation of the dry disposal system is complex and labor intensive, therefore the operating costs are quite high. As shown on Table II, the largest components of the total operating cost for any of the alternatives are labor, lime and truck hauling. The operating costs for the three feasible options differ only by the difference in truck hauling costs. All operating costs are subject to escalation over the 25-year life of the project. Levelized annual costs and a cash flow analysis for the dry disposal options are provided in Section 4.0 of this report.

## 3.4 Operational Considerations

The primary goals for the design of the dry disposal system is to achieve as much operational flexibility and system reliability as possible. The operating factors considered in the design of this system are:

- Winter Time Operation
- Truck Hauling Flexibility
- Landfill Operation
- System Redundancy

3.4.1 Winter Time Operation

With the extreme winter conditions experienced in Colstrip, disposal of the FGD waste material was considered an important factor in the design of the system. To alleviate possible freezing of the exposed piles of FGD waste material, it was determined that the addition of lime in the process would provide enough internal heat in the piles to prevent freezing, except for a frozen crust layer estimated to be six inches thick which a front-end loader should be able to penetrate.

3.4.2 Truck Hauling Flexibility

The design of the system incorporates fixation processing which allows for the accumulation of FGD waste material in curing piles. This concept provides the flexibility for truck hauling one shift per day, five days per week. If the FGD waste was not "fixed", trucks would be loaded directly from the vacuum filter discharge conveyor.

### 3.4.3 Landfill Operation

The landfill, shown in Figure 4, is designed to place the dry FGD material into designated five-acre sections. Each section will be filled to the recommended elevation before a new section is prepared to receive material. After a new section is prepared, the previous section is reclaimed and vegetated. This approach exposes only the active section of the landfill to rainfall, thus simplifying the collection and disposal of runoff from the active section.

### 3.4.4 System Redundancy

The dry disposal system has built-in redundancy since the existing pond disposal method can be used if the dry system is unavailable. Redundant equipment is provided, however, for the high maintenance items such as full-size spares of the vacuum filter and pug mills.

## 3.5 Environmental Considerations

### 3.5.1 General

Review of alternative ash disposal methods, regulatory framework and hydrology of potential disposal areas shows that each disposal area and disposal technique has environmental considerations that must be evaluated. Disposal into mined areas (Areas A and D) and disposal into a Stage II landfill area have many similar environmental concerns, but also have some differences.

The major environmental consideration in disposal of ash into mined lands in Area A or Area D is the long-term impact on groundwater quality. Recent data from Conversion Systems, Inc. (Ref. 4) shows fixing the ash reduces the concentration of sulfate ion in the leachate. The higher pH and much lower permeability of fixed ash also would reduce the amount of leachate from the ash. The use of lime in the ash causes a sulfo-pozzolanic reaction similar to that in concrete. Ruggiano and Poulson (1980) also show the fixed ash can improve the quality of leachate from landfilled ash.

Another concern in disposal of ash into mined areas is the potential impact of ash on the post-mining surface water drainage system. After regrading of the mined area, erosion by surface water runoff could affect ash layers and result in ash redeposition in downstream portions of the reconstructed drainages. Fixed ash, however, is reported to have unconfined compressive strength ranging from 50 to 250 psi (pounds per square inch). This would reduce erosion of the ash by runoff. (Ruggiano and Poulson, 1980.)

An additional concern in ash disposal is burial of the ash sufficiently deep to prevent adverse affects on post-mining vegetation. The ash is a less desirable growing medium than spoils and will require burial to some depth.

The volume of ash is equal to about 1.4 percent of the overburden that would be removed during mining in Area A or Area D. This small volume of ash will have little affect on post-mining topography in the mined area.

Disposal of ash into the Stage II landfill could potentially affect groundwater quality. Major considerations are percolation of water drained from the ash and movement into the underlying groundwater. Similarly, infiltration of water into the ash surface could occur and result in percolation through the ash and movement of soluble salts downward into the underlying groundwater. Another concern in the Stage II landfill area would be the quality of runoff water from stored ash. The ash, if directly in contact with flowing water, will erode and will subsequently be redeposited. Design of the Stage II area must consider stabilization of the deposited ash surface to prevent erosion.

The following sections describe potential impacts of the various alternate methods of ash disposal.

### 3.5.2 Mine Area Disposal

Disposal of ash into mined lands in Area A or Area D would all be into spoils and could be by one of the following alternatives:

1. Disposal in pit bottoms;

2. Disposal in the vee-notch between spoil ridges;

3. Disposal in a layer above the water table.

Permeability of reclaimed spoils is a combination of the primary permeability of replaced materials and secondary permeability of spoils caused by disaggregation of consolidated bedrock materials into rubble during excavation and replacement in mine cuts. Spoils in Area A or Area D will be placed by dragline. Van Voast (1974) and Van Voast and Hedges (1975) suggest that coarse rubble observed at the base of dragline spoils has a greater permeability than the remainder of replaced spoils. Vertical permeability also will be increased due to disruption of the horizontal layers. These changes in permeability of spoils will result in water levels being lower after mining is completed. Recharge of groundwater after mining in Area A or Area D will be limited and reestablishment of a groundwater system in mined areas will take a very long time.

3.5.2.1 Pit Bottom Disposal

In Area D, the bottom of the pit in the southern and central portions of the mine area is expected to contain water. It is only in the latter years of mining in the northern portion of Area D that dry pit bottoms are expected. Any disposal of ash into pit bottoms, therefore, must be assumed to be into wet bottoms. Direct contact of the ash with water in pit bottoms would significantly increase the salinity in the post-mining groundwater. A study in North Dakota by Groenewold and Manz (1982) concluded that placement of ash into wet pit bottoms was the poorest alternative examined and that it could cause significant salinity in post-mining groundwater. It is expected that the regulatory agencies would not allow disposal of ash into wet pit bottoms. In Area A there a few small sections where pit bottoms are expected to be dry; however, in general, pit bottoms in Area A will be wet and a post-mining groundwater system will develop. It is concluded that disposal of fly ash in the pit bottoms in either Area A or Area D would not be desirable due to the salinity of the ash that would be in contact with post-mining groundwater.

### 3.5.2.2 Vee-Notch Disposal

Disposal of ash into the vee-notch between spoil ridges involves placement of ash as a relatively continuous ribbon in the vee-notch then covering the ash with the material from the upper portions of the spoil ridges. This could affect water quality by percolation of precipitation through the ash layer prior to regrading of the spoils and percolation of precipitation through the ash layers after mining and reclamation are completed. During the period the vee-notch is open (approximately one to two years), some precipitation undoubtedly would accumulate in the bottom of the vee and percolate into the ash. It is probable that the bottoms of the vee-notches would not be exposed for sufficient time to allow any significant amount of recharge to percolate downward beneath the vee-notches. In North Dakota, Groenewold and Manz (1982) showed that there was some movement of salinity downward beneath ash disposed of in vee-notches, but the salinity did not percolate a significant distance below the ash.

After mining is completed, there may be some vertical recharge in the spoils causing percolation of water downward through the spoils and through the ash. Since the ash is a small percentage of the spoils, its contribution to post-mining groundwater salinity would be small.

Estimation of post-mining groundwater quality in the resaturated spoils is important in evaluation of ash disposal alternatives in mined areas. Disturbance of the hydrogeologic system caused by mining influences spoils hydrogeochemical processes by:

1. Altering groundwater levels and flow patterns;

2. Increasing the surface area of disturbed overburden sediments and releasing sodium, magnesium, potassium and chloride and other ions from fresh surfaces;

3. Increasing pore volume; and

4. Increasing oxygen trapped in the intersticies.

The principle result of these processes is an increase in dissolved substances in the groundwater. Placement of fixed ash into the spoils could slightly change the quality of post-mining groundwater.

Present methods available to predict post-mining water quality in reclaimed spoils are inexact. Attempts to predict post-mining groundwater quality have been made by Van Voast and others (1978), Moran and others (1978), Palmer and Cherry

(1979) and Hounslow and others (1979). Palmer and Cherry (1979) state that an accurate scientific method for prediction of the long-term chemical quality of groundwater in reclaimed spoils is limited. Van Voast and others (1978) compared saturated paste extract analyses with the reclaimed spoils water quality at the Big Sky and Decker Coal which are south and southeast, respectively, of Colstrip. This study indicated that a correlation exists between cation concentrations in groundwater in spoils and those in the saturated paste extracts. This study also included leaching tests to determine the amount of available soluble salts in the spoils. Leachate hydrochemistry was shown to be similar to overburden saturated paste extract hydrochemistry (Reference 5, Figure 9). Results of these leaching experiments (Reference 5, Figure 10) also showed specific conductance of the leachate decreased rapidly and eventually approached the specific conductance of the initial input water. The saturated paste extract analyses are, therefore, important in predicting probable groundwater chemistry after the reclaimed spoils are saturated.

The Van Voast technique, therefore, is a potential method for predicting post-mining groundwater quality where fixed ash is placed in the spoils. For Area D, the overburden saturated paste electric conductivity (EC) is 2,150 umhos/cm (micromhos per centimeter) at 25°C. Using a conversion factor of 0.65, the TDS (total dissolved solids) concentration of the extract is estimated to be about 1,400 mg/l. Assuming ash saturated paste extract would have a maximum TDS approximately equal to the present Stage I evaporation pond decant water, the effect of ash on post-mining groundwater can be estimated. The sulfo-pozzolanic reaction probably will reduce the water solubility of the fixed ash.

Using the weighted effects of spoils (98.6 percent and 1,400 mg/l) and ash (1.4 percent and 9,500 mg/l TDS), the predicted post-mining groundwater quality in Area D is estimated to have a maximum TDS concentration of 1,511 mg/l. This would be a maximum of eight percent higher than spoils water quality without ash emplacement. This simple model of post-mine water quality has not been specifically tested with fixed ash material. Ash permeability has been tested and results show 5 x 10-5 cm/sec for unfixed ash and 7 x 10-7 cm/sec for ash with three percent lime added (Reference 4). The low permeability of ash, particularly with lime added, would reduce the impact of ash on post-mining groundwater quality. Vertical percolation of groundwater may preferentially be through the more permeable spoils, rather than through the fixed ash. Overall, ash disposed in the vee-notch may have little impact on post-mining groundwater quality.

Another factor to be considered in disposal of ash in the vee-notch is potential effects on surface water. After mining is completed, some regrading of the mined area is required and a post-mining surface water drainage system is constructed. Ash in vee-notches is not deeply buried and considerable planning will be required to avoid cutting into the ash with post-mining regrading. After mining, the ash must have the required depth of burial in the regraded land surface and cannot be exposed at the land surface or in reconstructed drainageways.

3.5.2.3 Layer Above Water Table

Placement of ash in a layer above the post-mining water table should have groundwater quality impacts similar to that described for disposal into the vee-notch. After mining and reclamation, long-term vertical percolation of water through spoils and fixed ash could result in slightly more dissolved solids in the post-mining groundwater system than if ash were not placed in the spoils. This increase in salinity is predicted to be small due to the small percentage of ash in the spoils and should be of the same magnitude as predicted for the vee-notch disposal alternative.

A subalternative to this disposal option is to place a thick layer of ash above the water table in short segments of mine cuts. This would concentrate the ash and would significantly reduce the area underlain by ash in the reclaimed land surface. The reduced area of ash should reduce the potential for interaction with infiltrating water and should reduce the potential impact on groundwater quality.

3.5.3 Stage II Landfill Area Disposal

The disposal concept in the Stage II landfill area is to fill the basin with "fixed" ash; that is, ash containing about three percent added lime. Fixed ash has a low permeability and percolation of water through the landfill would be very slow. A test of fixed ash by CSI showed a permeability of compacted material of 7 x 10-7 cm/sec. This permeability would be lower than the average soil permeability in the landfill area.

Design of the landfill includes a sloping surface that would prevent ponding of surface water and a soil/vegetation cover that would result in significant evapotranspiration. This concept, therefore, minimizes infiltration and reduces the potential for changes in groundwater quality. If it is assumed that ten percent of the annual precipitation of

16 inches over the 160-acre disposal site infiltrates into the ash and continues downward to the water table, a net groundwater flux of about 13 gpm would result. Quality of the leachate is difficult to predict and would be affected by ion exchange, absorption, precipitation, dissolution and other physical-chemical processes. The quality of percolating groundwater would be equal to or better than decant water in the Stage I pond (about 9,500 mg/l TDS) due to the fixation process that reduces solubility of compounds in the ash. The following data were obtained from "EPA Leachate Analysis" of fixed ash (Reference 4).

| Constituent | Concentration (mg/l) |
|---|---|
| Arsenic | < .01 |
| Barium | 0.20 |
| Cadmium | < .01 |
| Chromium | < .05 |
| Lead | < .05 |
| Mercury | < .001 |
| Selenium | < .01 |
| Silver | < .05 |
| Chloride | 6 |
| Sulfate | 1,177 |

These data show the leachate is not hazardous and these concentrations are less than the maximum inorganic contaminant levels allowed in drinking water in Montana (ARM 16.20.203).

Runoff from the Stage II landfill drainage basin occurs only in response to severe rainfall events or to rapid melting of a deep snowpack. These events seldom occur and, as a result, streamflow is very uncommon in the drainage. The quality of runoff water would be affected by ash only if runoff water were in direct contact wit the ash. The low permeability and compressive strength of the "fixed" ash would resist the dissolution of soluble salts and runoff water quality probably would not be significantly degraded by local areas of contact with the ash. The landfill would be designed to minimize contact between runoff water and ash. Also, catchments will be constructed in order to intercept streamflow and prevent runoff water from leaving the landfill area. Ultimately, a single catchment will be used when the entire landfill has been reclaimed (Figure 4).

Overall available data suggest that disposal of dry ash by landfilling will result in good protection of the quality of surface water and groundwater in the landfill area. Additional detailed work would be needed to more precisely evaluate the influence of ash and to provide a basis for landfill site design.

## 3.6 Regulatory Considerations

Future disposal of ash from Colstrip Units No. 1 and No. 2 at any site must comply with all applicable state and federal laws and regulations. Laws and regulations applicable to ash disposal will be a function of the site selected, technique used for disposal and methods of placement and handling of ash in the disposal area. Of major concern is the potential impact of ash on water resources. Each of the potential disposal areas, that is Area A and Area D and the Stage II landfill area, have different physical characteristics and different regulatory concerns. The specific method use for ash disposal, such as placement between spoil ridges, placement in the pit bottom after mining is completed, placement at some intermediate level in spoils or placement in a landfill is an important factor in planning and designing an operation so it will comply with applicable laws and regulations.

In Montana, there is a complex regulatory framework to protect environmental resources including surface water and groundwater. Colstrip Units No. 1 and No. 2 received a construction permit from the Montana Department of Health and Environmental Sciences on April 23, 1973. This permit contained no stipulations and granted The Montana Power

Company permission to operate Colstrip Units No. 1 and No. 2, including the ash disposal facilities.

Review of applicable laws and regulations shows the following agencies may have regulatory authority over activities associated with ash disposal.

1. Montana Department of Health and Environmental Sciences, Water Quality Bureau, Solid Waste Management Bureau.

2. Montana Department of State Lands

3. Montana Department of Natural Resources and Conservation

The Solid Waste Management Bureau of Montana Department of Health and Environmental Sciences (MDHES) regulates disposal of solid wastes through the Montana Solid Waste Management Act (Title 75, Chapter 10, MCA) and through the Solid Waste Management Rules (ARM 16.14.501 through 16.14.608) and through the Hazardous Waste Management Rules (ARM 16.44.101 through 16.44.901) pursuant to that act.

The Solid Waste Management Act states that there is no prohibition on a person disposing of his own solid waste upon land owned or leased by that person as long as it does not create a nuisance or public health hazard. In this act, the term "person" includes a firm, company or corporation. The Resources Conservation and Recovery Act (RCRA), administered in part in Montana by the Montana Solid Waste Management Bureau, is designed to control certain hazardous wastes. Ash wastes generated by steam power plant from use of fossil fuels are presently exempted from this Act in Section 40 CFR 261.4(B)(4).

The Montana Department of Health and Environmental Sciences also administers the Montana Water Quality Act (Title 75, Chapter 5, MCA), the Surface Water Quality Standards (ARM 16.20.601 through 16.20.643) and the Montana Groundwater Pollution Control System (ARM 16.20.1001 through 16.20.1025).

The DHES Surface Water Quality Standards are designed to protect the quality of surface waters in Montana. The present ash disposal design concept does not involve a discharge to surface water. Any runoff from disposal areas will be prevented or will be impounded to avoid any discharge to surface water.

The Montana Groundwater Pollution Control System (MGWPCS) requires that existing quality of groundwater be maintained. Section 16.20.1011 states:

"Any groundwater whose existing quality is higher than the established groundwater quality standard for its classification must be maintained at that high quality, unless it can be affirmatively demonstrated to the board that a change is justifiable as a result of necessary economic or social development and will not preclude present or anticipated use of such water."

Groundwater in the Stage II landfill area and in Areas A and D are either Class II or Class III. The groundwater standards provide a specific exemption for mined areas under ARM-16.20.1011 (3) which states:

"Changes in groundwater quality whether or not applicable groundwater quality standards for dissolved substances are violated, resulting from nonpoint source pollutants from lands or operations where all reasonable land, soil and water conservation practices have been applied do not constitute degradation."

The DHES presently considers mined lands to be nonpoint sources where water quality standards are not applicable providing all reasonable land, soil and water conservation practices have been applied. This exemption may include disposal of ash wastes into mined lands even though the ash may slightly increase the salinity of post-mining groundwaters. The performance provisions of the MGWPCS most probably apply to storage of dry ash in the Stage II landfill area.

Mining Area A has an approved operating permit from the Montana Department of State Lands and Area D is expected to receive a permit within a few months. To dispose of ash into these areas will require a modification of the operating permit and the modification will have to be in compliance with all provisions of the Strip and Underground Mine Reclamation Act (Title 82, Cha. 4, MCA) and the regulation pursuant to that Act (ARM 26.4.1001-1015 and 1101-1125). This regulation contains extensive sections on water resources, including both surface water, groundwater and water quality including:

ARM 26.4.314 Plan for Protection of the Hydrologic Balance

ARM 26.4.505 Burial and Treatment of Waste Materials

ARM 26.4.506 Prevention of Leaching

ARM 26.4.643 Groundwater Protection

ARM 26.4.645 Groundwater and Monitoring

In general, these regulations require that groundwater quantity and quality be protected in mined areas and that the area be restored to provide long-term protection of both surface water and groundwater resources. It is very probable that DSL will require a reevaluation of the surface water and groundwater aspects of the permit issued for Area A or D before authorizing disposal of ash into a mined area. The use of a mined area for disposal of ash is unprecedented in Montana and reaction of the regulatory agency to such a proposal cannot accurately be predicted. The agency has sufficient regulatory discretion to either permit or to disallow the use of a mined area for disposal of ash. It is probable that the agency will require an evaluation of the impact on surface water and groundwater from the disposal of ash, particularly, the long-term impact on groundwater quality in the post-mining groundwater system.

Another section of the Strip and Underground Mine Regulation (26.4.505 - Burial and Treatment of Waste Materials) states:

> "Acid-forming, toxic-forming, combustible or any other waste materials identified by the department that are exposed, used or produced during mining shall be covered with a minimum of eight feet of the best available nontoxic and noncombustible material."

DSL may require that any ash used in the vee-notch or other location in the mine spoils be covered with a minimum of eight feet of spoils. The DSL regulation (ARM 26.4.509) further states:

> "Backfilled materials shall be selectively placed and compacted wherever necessary to prevent leaching of acid-forming or toxic-forming materials into surface or subsurface waters in accordance with Subchapter 6 and wherever necessary to ensure the stability of the backfilled materials."

Thus, the regulatory authority of DSL probably extends to placement of ash into mined areas. DSL may consider disposal of ash into mined area, a minor amendment of the operating permit and a relatively simple Environmental Analysis (EA) may satisfy the requirements of the Montana Environmental Policy Act (MEPA). DSL also may determine that a Preliminary

Environmental Review (PER) is necessary for the permit amendment.

The Montana Department of Natural Resources and Conservation administers the Major Facilities Siting Act (Title 75, Cha. 20, MCA) that regulates facilities associated with power generation plants. The ash ponds for Colstrip Units No. 1 and No. 2 were permitted by the Montana Department of Health and Environmental Science prior to enactment of the Major Facilities Siting Act.

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## 4.0 COMPARISON OF ALTERNATIVES

### 4.1 Cost Analysis

To compare the cost of all feasible alternatives over the entire life of the project, a levelized annual cost analysis was performed. Each alternative has capital costs and operating costs associated with it. These costs were put into levelized annual costs using the following economic factors obtained from the Resources Planning Department:

- Life of Project = 25 years
- Escalation Rate = 6 Percent
- Present Worth Rate = 12.55 Percent
- Levelized Fixed Charge Rate for Capital Costs = 17.37 Percent
- Levelizing Factor for Annual Operating Costs = 1.6638

These factors were applied to the costs detailed in Sections 2.3 and 3.3 of this report and the results are listed in Tables VI A and VI B. This analysis indicates that all methods of dry disposal of ash are more expensive than any of the pond alternatives. Even though the capital costs for the dry methods are about half of what they are for the pond methods, the levelized annual operating costs are almost an order of magnitude higher. The net effect is to make the dry disposal alternatives too expensive over the life of the project.

A sensitivity analysis was performed to determine if the cost analysis results would change with lower escalation rates. The dry disposal options are less expensive at lower escalation rates, becoming equal in cost to the pond options at a rate of about 2.5 percent. This rate was deemed too low to be realistic, therefore, the results obtained at six percent escalation are the basis for the recommendations contained in this report.

A cash flow analysis was also done for selected dry and pond alternatives to determine if the disadvantage of overall high cost of the dry methods could be offset by favorable cash flow since the capital costs were much lower. Tables VII A, VII B and VII C show the results. The least expensive dry disposal method still has no advantage over the pond method. This is due to the fact that a large portion of the capital cost for the pond options can be deferred about ten years by staging the construction of the main dam. This is done by filling the outlying pond areas to their ultimate elevation first and not filling immediately adjacent to the main dam until those areas are filled.

In summary, it is apparent that any of the pond alternatives are less expensive than any of dry alternatives over the 25-year life of this project.

## 4.3 Advantages/Disadvantages

As each of the main disposal methods, dry and pond, were studied, advantages and disadvantages of each were identified. The differences listed in the comparison below are generic to the main methods, i.e., not to any of the specific alternatives of either. The impacts of several of the differences (e.g., permitting) are difficult to quantity and are quite subjective.

### POND DISPOSAL

#### Advantages

1. Lower levelized annual cost.
2. Much easier to operate.
3. Precedent exists in first stage pond.
4. Pond concept already permitted under permit obtained by Colstrip Units No. 1 and No. 2.

Disadvantages

1. Socially/politically unpopular.
2. Greater potential for groundwater impacts.

DRY DISPOSAL

Advantages

1. Socially/politically more acceptable.
2. Less potential for groundwater impacts.

Disadvantages

1. Higher levelized annual cost.
2. Operation is complex and labor intensive.
3. No precedent exists in Montana.
4. Concept not covered by existing permits for Colstrip Units No. 1 and No. 2.

### 4.2 Conclusions

The choice of which of the two main disposal methods the Company should pursue was made fairly simple due to the magnitude of the cost differential between them. The pond method is less expensive on a levelized annual basis by a margin ranging from $283,000 per year to as much as $1,907,000 per year. This difference amounts to millions of dollars over the 25-year life of the project. It was determined, therefore, that this cost advantage of the pond method far outweighed the disadvantages associated with it. Only if the levelized annual costs were nearly equal, would there be a need to assign an importance level to each advantage and disadvantage and make an evaluation based on such weighting.

Selection of the preferred pond alternative is not so clear. There are significant cost differentials between certain options and the impact of the regulatory process must be considered for each one.

When the permit for Colstrip Units No. 1 and No. 2 was obtained, the Company committed to the installation of groundwater interception wells if the need became evident in the future through monitoring of groundwater quality. When the effluent holding pond for Colstrip Units No. 3 and No. 4 was constructed, the State not only required the same type of commitment from the project owner's, but also required the immediate construction of a perimeter slurry wall and a partial underdrain system as additional seepage control measures. With this type of everchanging precedents being set, it cannot be accurately determined exactly what the

State would require in the way of seepage control and mitigation measures.

After reviewing the technical, economic, environmental and regulatory aspects of this project, it is recommended that the Company proceed with implementation of one of the feasible pond alternatives discussed herein. Additional engineering should be done in order to select a particular pond alternative before presentation to the State of any proposal. The cost of any pond option will be less than for any of the dry disposal options available, assuming an escalation rate of six percent over the life of the project.

240310

REFERENCES


1. Bechtel Corporation, "Evaporation Pond Design Report for The Montana Power Company" Revised May 1976.

2. Hydrometrics, "Assessment of the Influence of Units 1 and 2 Fly Ash Disposal Pond On Groundwater Resources Near Colstrip, Montana," May 1983.

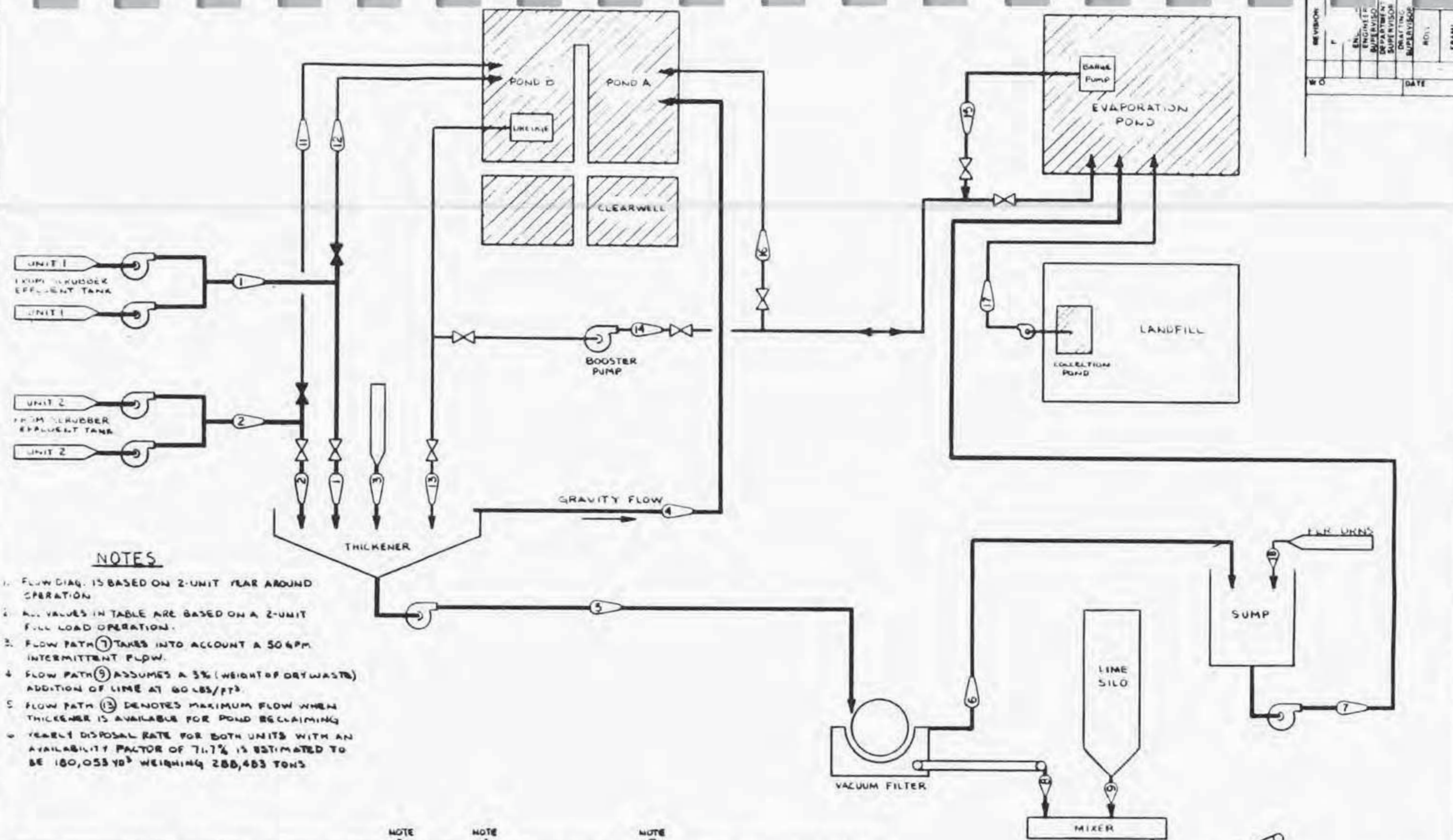
3. Hydrometrics, "Assessment of the Influence of the Units 1 and 2 Proposed Stage II Evaporation Pond on Groundwater Resources Near Colstrip, Montana," March 1985.

4. Conversion Systems, Inc., "Preliminary Design and Conceptual Engineering Report," December 1984.

5. Hydrometrics, "Assessment of Alternatives for Disposal of Dried Ash From Colstrip Power Generation Units 1 and 2," January 1985.


COLSTRIP #1 & #2
Proposed Second Stage
Evaporation Pond
REFERENCE DRAWINGS
DWG. NO.
THE MONTANA POWER COMPANY
DRAWN
DESIGNED
APPROVED
SCALE
PROJECT NO.
SIZE
SHEET
A
REVISION
DRAFTER
DESIGN ENGR
ENGR. SUPV
DEPT HEAD
DFTG. SUPV
ROLL
FRAME
DATE
BURLINGTON NORTHERN RAILROAD
STATE HIGHWAY
WATER LINE (EXISTING)
LINE OF GROUNDWATER
INTERCEPTION WELLS
AREA 1
AREA 2
AREA 3
AREA 4
AREA 5
SECOND STAGE
EVAPORATION
POND
3270
EXISTING
FIRST STAGE
EVAPORATION

Figure 1




## NOTES

1. FLOW DIAG. IS BASED ON 2-UNIT YEAR AROUND OPERATION.
2. ALL VALUES IN TABLE ARE BASED ON A 2-UNIT FULL LOAD OPERATION.
3. FLOW PATH (7) TAKES INTO ACCOUNT A 50 GPM INTERMITTENT FLOW.
4. FLOW PATH (9) ASSUMES A 3% (WEIGHT OF DRY WASTE) ADDITION OF LIME AT 60 LBS/FT³.
5. FLOW PATH (13) DENOTES MAXIMUM FLOW WHEN THICKENER IS AVAILABLE FOR POND RECLAIMING.
6. YEARLY DISPOSAL RATE FOR BOTH UNITS WITH AN AVAILABILITY FACTOR OF 71.7% IS ESTIMATED TO BE 180,053 YD³ WEIGHING 288,483 TONS.

| STREAM NUMBERS | 1 | 2 | 3 | 4 | 5 | 6 | 7 (NOTE 3) | 8 | 9 (NOTE 4) | 10 | 11 | 12 | 13 (NOTE 5) | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PRIMARY FLOW | | | | | | | | | | SECONDARY FLOW | | | | | | | |
| WATER LBS/MIN | 13,439 | 13,439 | | 24,808 | 2070 | 1783 | 2261 | 287 | 0 | 287 | 13,439 | 13,439 | 2605 | 27,910 | 24,793 | 24,793 | 2479 | 413 |
| DISSOLVED SOLIDS | 272 | 272 | | 482 | 62 | 62 | 62 | 0 | 0 | 0 | 272 | 272 | 73 | 779 | 480 | 480 | 48 | 8 |
| SUSPEND. SOLIDS | 574 | 574 | | 0 | 1148 | 0 | 0 | 1148 | 34 | 1182 | 574 | 574 | 1148 | 12,295 | 0 | 0 | 0 | 0 |
| TOTAL | 14,285 | 14,285 | | 25,290 | 3280 | 1845 | 2323 | 1435 | 34 | 1531 | 14,285 | 14,285 | 3826 | 40,984 | 25,273 | 25,273 | 2527 | 421 |
| % SUSPENDED SOLIDS | 4.0 | 4.0 | | 0 | 35 | 0 | 0 | 80 | 100 | 81 | 4.0 | 4.0 | 30 | 30 | 0 | 0 | 0 | 0 |
| TOTAL FLOW GPM | 1655 | 1655 | | 3002 | 308 | 217 | 275 | 92 | N/A | N/A | 1655 | 1655 | 374 | 4100 | 3000 | 3000 | 300 | 50 |
| TOTAL VOL. FT³/MIN | 221 | 221 | | 401 | 41 | 29 | 37 | 12.3 | .6 | 12.9 | 221 | 221 | 50 | 548 | 401 | 401 | 40 | 6.7 |
| SPECIFIC GRAVITY | 1.036 | 1.036 | | 1.01 | 1.28 | 1.02 | 1.01 | 1.88 | .96 | 1.91 | 1.036 | 1.036 | 1.23 | 1.2 | 1.01 | 1.01 | 1.01 | 1.01 |

REFERENCE DRAWINGS | DRAWING NO.

THE MONTANA POWER COMPANY

**FLOW DIAGRAM**
**FGD SOLID WASTE DISPOSAL**
REMOTE SITE LOCATION

DRAWN | DESIGNED RWH | APPROVED
SCALE NONE | PROJECT NO. | SIZE B | SEQ | SHEET

Figure 2

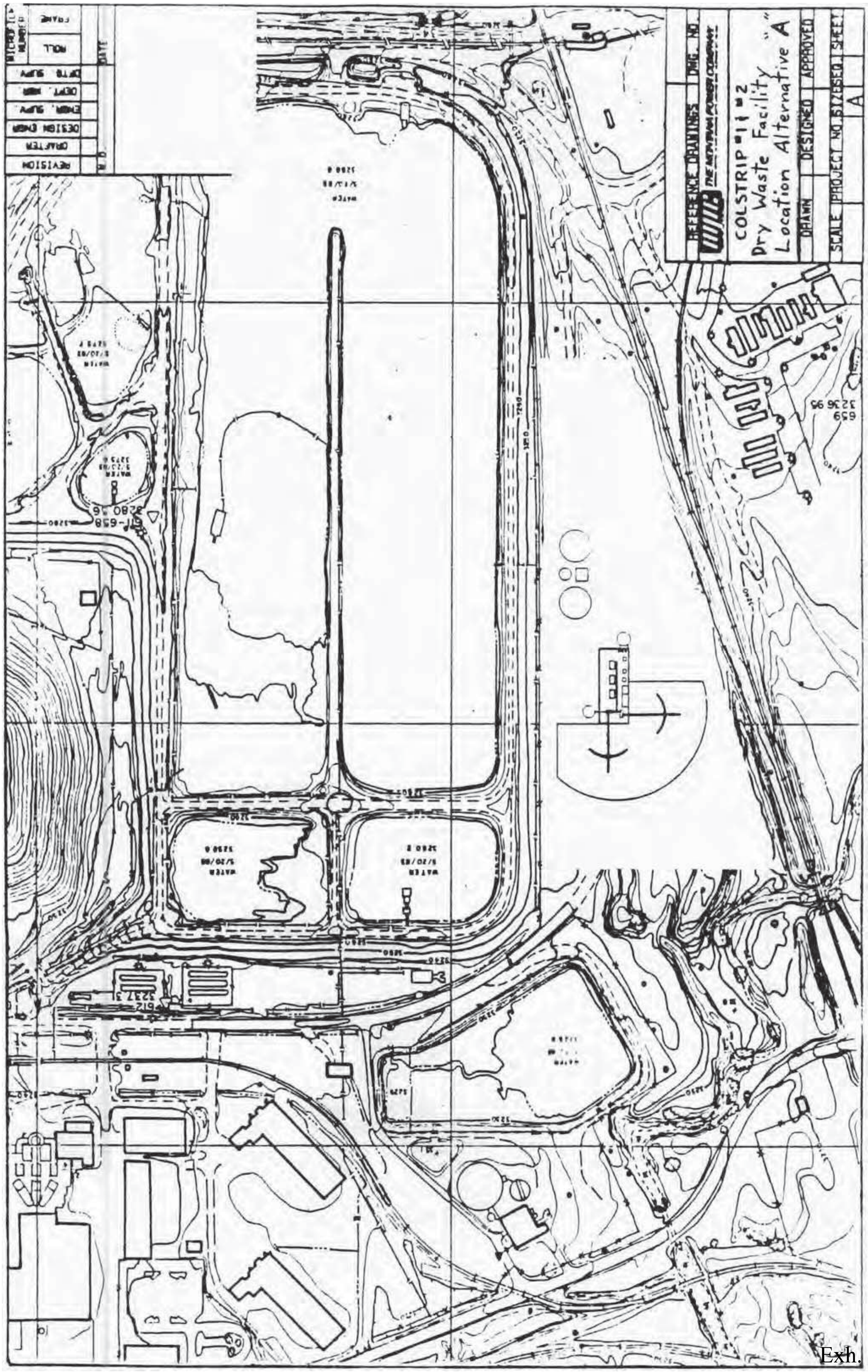

REFERENCE DRAWINGS
DWG. NO.
THE MONTANA POWER COMPANY
Dry Waste Facility
Location Alternative "A"
DRAWN
DESIGNED
APPROVED
SCALE
PROJECT NO.
SIZE
SHEET
A
WATER

Figure 3

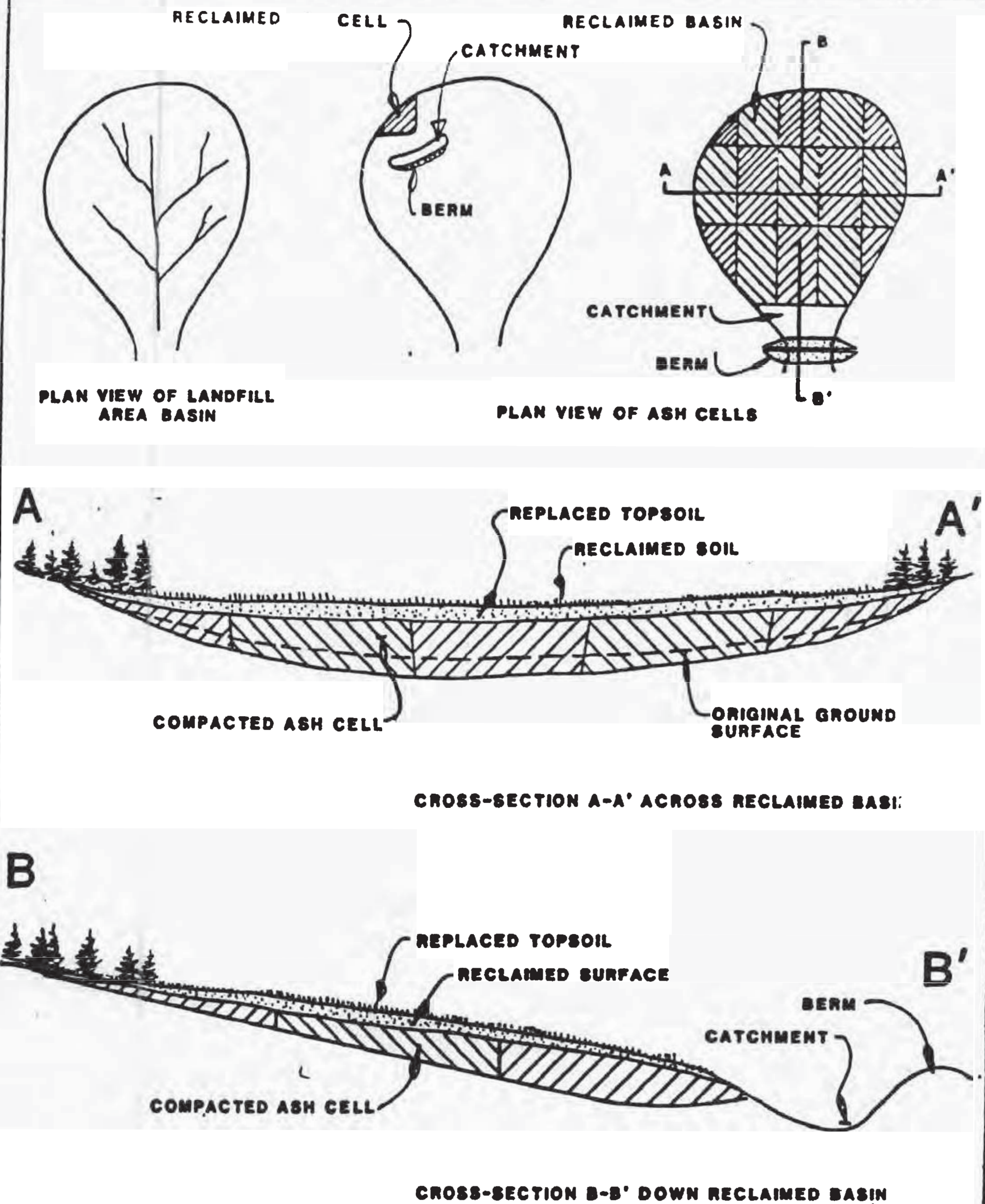



FIGURE 4 CONCEPTUAL DISPOSAL OF DRY ASH IN STAGE 2 LANDFILL AREA

TABLE I

CAPITAL COSTS FOR POND DISPOSAL

| | | |
|---|---|---|
| I. | Stage II Evaporation Pond Dam | $ 13,800,000 |
| II. | Seepage Control Measures | |
| | A. PVC Membrane (100 mill) | $ 8,853,000 |
| | B. Bentonite - Soil Liner (two feet) | 9,350,000 |
| III. | Seepage Mitigation Measures | |
| | A. Groundwater Interception Well System | $ 2,983,000 |
| | B. Installation of City Water System | 250,000 |
| IV. | Methods of Pond Disposal | |
| | A. Method A | |
| | 1. Dam | $ 13,800,000 |
| | 2. Bentonite - Soil Liner | 9,350,000 |
| | 3. Groundwater Interception System | 2,983,000 |
| | 4. City Water System | 250,000 |
| | Total | $ 26,383,000 |
| | B. Method B | |
| | 1. Dam | $ 13,800,000 |
| | 2. PVC Membrane | 8,853,000 |
| | 3. Groundwater Interception System | 2,983,000 |
| | 4. City Water System | 250,000 |
| | Total | $ 25,886,000 |
| | C. Method C | |
| | 1. Dam | $ 13,800,000 |
| | 2. Bentonite - Soil Liner | 9,350,000 |
| | 3. City Water System | 250,000 |
| | Total | $ 23,400,000 |
| | D. Method D | |
| | 1. Dam | $ 13,800,000 |
| | 2. PVC Membrane Liner | 8,853,000 |
| | 3. City Water System | 250,000 |
| | Total | $ 22,903,000 |
| | E. Method E | |
| | 1. Dam | $ 13,800,000 |
| | 2. Groundwater Interception System | 2,983,000 |
| | 3. City Water System | 250,000 |
| | Total | $ 17,033,000 |

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TABLE II

ANNUAL OPERATING AND MAINTENANCE COSTS

| | | |
|---|---|---|
| I. | Pond Disposal | |
| A. | O&M Labor (all options) | $ 228,000 |
| B. | Power (all options) | 20,000 |
| | Subtotal | $ 248,000 |
| C. | Interception Well System O&M | $ 32,000 |
| II. | Dry Disposal | |
| A. | O&M Labor | $ 500,000 |
| B. | Maintenance | 130,000 |
| C. | Lime | 397,000 |
| D. | Power | 55,500 |
| | Subtotal | $ 1,082,500 |
| E. | Truck Haul | |
| | 1. From plant site to mine (Option A) | $ 1,356,000 |
| | 2. From plant site to landfill (Option B) | 1,082,000 |
| | 3. From remote facility to landfill (Option C) | 721,000 |

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TABLE III

SUMMARY OF SEEPAGE CALCULATIONS

| Liner Permeability (1) cm/sec | Evaporation Rate (2) % of Inflow | Net Quantity of Water Delivered to Pond GPM | Mean Percolation Rate Through Pond Bottom (3) GPM | Pond Seepage (4) GPM | Method of Analysis For Evaluation Percolation Rate (5) | Method of Analysis for Calculating Transient Water Levels in Aquifer and Flux Across Property Boundary (6) |
|---|---|---|---|---|---|---|
| 10-5 | 33 | 183 | 161 | 12.9 | McWhorter and Nelson | USGS-2D |
| 10-7 | 33 | 183 | 117 | 10.9 | McWhorter and Nelson | USGS-2D |
| 10-11 | 33 | 183 | 5-15 | Nil | Estimated | |

Notes: (1) 10-5 cm/sec permeability corresponds to an unlined pond or cell; permeability of the accumulating ash is 10-5 cm/sec.
10-7 cm/sec permeability corresponds to a 2-foot thick bentonite-soil liner.
10-11 cm/sec permeability corresponds to a 30-mil thick synthetic membrane liner.

(2) Gross quantity of water delivered to pond is 441.1 AFT (274 GPM); net quantity of water available for seepage from the pond is 441 AFT (274 GPM) minus evaporation.

(3) Mean percolation rate for 26 years. Bechtel (1979) estimates a total of 110 gpm will seep through the dam structure and abutments, and this water will be returned to the pond via downstream horizontal drain and relief well.

(4) Calculated at a distance of 2700 feet downgradient (Northeast) from the center of the pond grid and for a width of 4000 feet (see Figures 16, 17, and 18).

(5) McWhorter and Nelson, 1979, computerized by Waste and Land Systems, Inc., 1980. Synthetic membrane liner percolation rate estimated from manufacturer's information.

(6) U. S. Geological Survey, 1984.

TABLE IV

COMMON PHYSICAL AND CHEMICAL PARAMETERS ANALYZED IN WATER SAMPLED FROM THE COLSTRIP AREA

I. Physical Parameters

A. Specific Conductance (SC)
B. Total Dissolved Solids (TDS)
C. Sodium Adsorption Ratio (SAR)

II. Common Ions

A. Total Hardness as $CAC0_3$
B. Calcium (Ca)
C. Magnesium (Mg)
D. Sodium (Na)
E. Potassium (K)
F. Alkalinity as $CaC0_3$
G. Bicarbonate ($HCO_3$)
H. Sulfate ($SO_4$)
I. Chloride (Cl)
J. Fluoride (F)

III. Nutrients

A. Nitrate + Nitrite as N
B. Ortho-Phosphate ($PO_4$-P)

IV. Trace Elements

A. Aluminum (Al)
B. Boron (B)
C. Cadmium (Cd)
D. Copper (Cu)
E. Iron (Fe)
F. Lead (Pb)
G. Manganese (Mn)
H. Mercury (Hg)
I. Selenium (Se)
J. Vanadium (V)
K. Zinc (Zn)

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TABLE V-A

CAPITAL COSTS OF DRY WASTE DISPOSAL
PLANT SITE OPTION

This option allows dewatering equipment to be located at the plant site, with hauling to the mine area as the primary disposal with hauling to the landfill as an alternate.

| | | |
|---|---|---|
| I. | Primary Dewatering System as Estimated by CSI | |
| | A. Design, Supply, Erection and Start-up | $ 10,900,000 |
| | B. Adders for Design Change | 400,000 |
| | C. Adder for Std. Foundation | 590,000 |
| | Total | $ 11,890,000 |
| II. | Additional System Requirements | |
| | A. Site Development | $ 307,000 |
| | B. External Piping to Process Facility | 137,800 |
| | C. Additional Equipment-Mech/Elect | 198,600 |
| | D. Additional Civil/Structural | 54,000 |
| | Total | $ 697,400 |
| III. | Total System Cost | $ 12,587,400 |

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TABLE V-B

CAPITAL COSTS OF DRY WASTE DISPOSAL
REMOTE OPTION

This option locates the thickeners at the plant site and the remainder of the processing equipment at the landfill area. With this option, only the landfill will be used for disposal.

| | | |
|---|---|---|
| I. | Primary Dewatering System as Estimated by CSI | |
| A. | Design, Supply, Erection and Start-up | $ 10,900,000 |
| B. | Adders for Design Change | 400,000 |
| C. | Adder for Standard Foundation | 590,000 |
| | Total | $ 11,890,000 |
| II. | Additional System Requirements | |
| A. | Site Development | $ 212,000 |
| B. | External Piping to Process Facility | 554,700 |
| C. | Additional Equip-Mech/Elect | 333,100 |
| D. | Booster Pumphouse-Civil | 96,000 |
| E. | Maintenance Bldg-Civil | 280,000 |
| F. | Additional Civil/Structural | 55,000 |
| | Total | $ 1,530,800 |
| III. | Total System Cost | $ 13,420,800 |

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** 01-Apr-85 ***

TABLE VI-A

COSTS FOR POND DISPOSAL METHODS

| Option | Capital Cost | Levelized Capital Cost | Operating Cost | Levelized Operating Cost * | Total Levelized Annual Expenditures |
|---|---|---|---|---|---|
| A | $26,383,000 | $4,582,727 | $280,000 | $465,864 | $5,048,591 |
| B | $25,886,000 | $4,496,398 | $280,000 | $465,864 | $4,962,262 |
| C | $23,400,000 | $4,064,580 | $248,000 | $412,622 | $4,477,202 |
| D | $22,903,000 | $3,978,251 | $248,000 | $412,622 | $4,390,874 |
| E | $17,033,000 | $2,958,632 | $280,000 | $465,864 | $3,424,496 |

A = Bentonite-soil Liner + Interception Wells
B = Membrane Liner + Interception Wells
C = Bentonite-soil Liner only
D = Membrane Liner only
E = Interception Wells only

TABLE VI-B

COSTS FOR DRY DISPOSAL METHODS

| Option | Capital Cost | Levelized Capital Cost | Operating Cost | Levelized Operating Cost * | Total Levelized Annual Expenditures |
|---|---|---|---|---|---|
| A | $12,587,400 | $2,186,431 | $2,438,500 | $4,057,176 | $6,243,608 |
| B | $12,587,400 | $2,186,431 | $2,164,500 | $3,601,295 | $5,787,726 |
| C | $13,420,800 | $2,331,193 | $1,803,500 | $3,000,663 | $5,331,856 |

A = Plant Site Option - Haul to Mine
B = Plant Site Option - Haul to Landfill
C = Remote Option - Short Haul to Landfill

* Escalation = 6 %

## TABLE VII-A

CASH FLOW FOR POND OPTION B

| Year | Capital Cost * | Operating Cost* | Total Expenditure |
|---|---|---|---|
| 1987(1) | $ 5,500,000 | $ 0 | $ 5,500,000 |
| 1988(2) | 12,408,000 | 0 | 12,408,000 |
| 1989(3) | 1,255,000 | 354,000 | 1,609,000 |
| 1990(4) | 1,330,000 | 375,000 | 1,706,000 |
| 1991(5) | 1,410,000 | 397,000 | 1,807,000 |
| 1992(6) | 1,027,000 | 422,000 | 1,449,000 |
| 1993(7) | 1,739,000 | 447,000 | 2,186,000 |
| 1994(8) | 0 | 473,000 | 473,000 |
| 1995(9) | 0 | 501,000 | 501,000 |
| 1996(10) | 8,169,000 | 531,000 | 8,700,000 |
| 1997(11) | 0 | 563,000 | 563,000 |
| 1998(12) | 0 | 597,000 | 597,000 |
| 1999(13) | 0 | 633,000 | 633,000 |
| 2000(14) | 0 | 670,000 | 670,000 |
| | | escalate each year @ 6% | escalate each year @ 6% |
| 2013(27) | 0 | 1,429,000 | 1,429,000 |

## TABLE VII-B

CASH FLOW FOR POND OPTION D

| Year | Capital Cost * | Operating Cost* | Total Expenditure |
|---|---|---|---|
| 1987(1) | $ 5,500,000 | $ 0 | $ 5,500,000 |
| 1988(2) | 12,408,000 | 0 | 12,408,000 |
| 1989(3) | 0 | 313,000 | 313,000 |
| 1990(4) | 0 | 332,000 | 332,000 |
| 1991(5) | 0 | 352,000 | 352,000 |
| 1992(6) | 1,027,000 | 373,000 | 1,400,000 |
| 1993(7) | 1,739,000 | 395,000 | 2,134,000 |
| 1994(8) | 0 | 419,000 | 419,000 |
| 1995(9) | 0 | 444,000 | 444,000 |
| 1996(10) | 8,169,000 | 471,000 | 8,640,000 |
| 1997(11) | 0 | 499,000 | 499,000 |
| 1998(12) | 0 | 529,000 | 529,000 |
| 1999(13) | 0 | 561,000 | 561,000 |
| 2000(14) | 0 | 594,000 | 594,000 |
| | | escalate each year @ 6% | escalate each year @ 6% |
| 2013(27) | 0 | 1,268,000 | 1,268,000 |

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TABLE VII-C

CASH FLOW FOR DRY OPTION C

| Year | Capital Cost * | Operating Cost* | Total Expenditure |
|---|---|---|---|
| 1986(1) | $ 530,000 | $ 0 | $ 530,000 |
| 1987(2) | 4,720,000 | 0 | 4,720,000 |
| 1988(3) | 10,385,000 | 535,000 | 10,920,000 |
| 1989(4) | 0 | 2,277,000 | 2,277,000 |
| 1990(5) | 0 | 2,413,000 | 2,413,000 |
| | | escalate each year @ 6% | escalate each year @ 6% |
| 2013(28) | 0 | 8,697,000 | 8,697,000 |

*Amounts are the expenditures in the year shown.

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