ENVIRONMENTAL ASSESSMENT

OF THE

DAWN MINING COMPANY

PROPOSED BELOW-GRADE TAILINGS MANAGEMENT PLAN

FORD, WASHINGTON

AUGUST, 1980

PROJECT WM-33

PREPARED BY THE

U. S. NUCLEAR REGULATORY COMMISSION

WASHINGTON, D.C.

FOR THE DEPARTMENT OF SOCIAL AND HEALTH SERVICES

STATE OF WASHINGTON

TO DOCUMENT TECHNICAL ASSISTANCE

BEING PROVIDED IN CONNECTION

WITH THE LICENSING OF THE

PROPOSED TAILINGS MANAGEMENT PLAN

SUMMARY AND CONCLUSIONS

This evaluation has been prepared by the staff of the U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, in response to a request for technical assistance from the state of Washington, Department of Social and Health Services (DSHS) regarding a licensing action related to the Dawn Mining Company uranium mill near Ford, Washington.

The licensing action of DSHS would authorize the construction of a fully lined, below-grade tailings impoundment adjacent to the existing above-grade impoundment. The proposed pit has been designed by Dawn Mining Company to meet their increased tailings storage demands. The major features of the proposed impoundment and the significant environmental impacts to be expected, assuming full implementation of recommendations made by the NRC staff (see pages ii-v), are as follows:

1. The proposed 28-acre tailings impoundment will consist of a specially excavated pit dug into sand and gravel deposits immediately south of the existing impoundments. The pit will be nominally 70 feet (21 m) deep with side slopes of 3 horizontal and 1 vertical. A 5-foot high perimeter dike will be constructed to provide necessary freeboard. The sides and bottom of the pit will be lined with 30 mil reinforced Hypalon to prevent seepage. Excess excavated materials will be stockpiled adjacent to the perimeter dike for future use during site reclamation.

   The design of the proposed impoundment has been reviewed by the NRC staff and, subject to implementation of NRC recommendations and resolution of the issues raised therein, meets the requirements of Regulatory Guide 3.11, "Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills."

2. A reclamation and long-term stabilization plan has been formulated. As presently outlined, the company will cap the entire tailings disposal facility with a two-foot thick compacted clay layer, overlain further by an eight-foot layer of sands and gravels derived from the present project excavations. The side slopes of the above-grade perimeter dike will be moderated to one vertical on five horizontal. The proposed below-grade mode of tailings disposal, together with implementation of the staff's recommendation for a rock cover on exposed slopes of the final cover, provides high assurance of long-term stability and isolation of the tailings. By eliminating the adverse effects of surface wind and water erosion through proper reclamation cover treatment, the need for ongoing active maintenance of the reclaimed tailings can be eliminated. By placement of the tailings below grade, the potential for dispersion of tailings by natural forces, such as floods or earthquakes, is made minimal.

3. The 30-mil, reinforced Hypalon liner will essentially eliminate seepage from the impoundment during its operational lifetime, so long as liner integrity is maintained. After use of the impoundment is terminated (approximately 10 to 13 years), the tailings will be dewatered for from

one to three years through decanting, evaporation, and use of the underdrain system. Following dewatering, if disruption of the liner does occur over the long term, the clay layer in the cap and the site climatic condition of net evaporation will reduce available water for percolation and seepage to a minimum.

Based upon its evaluation, as documented in this report, the NRC staff recommends that the following steps be required of the applicant to assure that the proposed operation is conducted in a way that assures public health and safety and protection of the environment. These general recommendations and specific conditions should be incorporated into the proposed amendment as license conditions:

1. The final tailings cover should be stabilized by rock or stone mulch. The rock should be applied over exposed slopes and be of a size sufficiently large so as not to be susceptible to dislocation from human or animal activity at the site. Such covers are known to be effective in eliminating both wind and water sheet erosion. Due to the nature of the sand and gravel cap materials, the lack of a topsoil layer, and the low summer season precipitation, it is doubtful that a vegetative cover will be self-sustaining over the entire tailings disposal area and over the very long-term period of concern. Without a permanent stabilizing cover, there can be no reasonable expectation that significant erosion can be eliminated. A revised reclamation plan incorporating a rock cover should be submitted by Dawn for DSHS review. It should include details on the size and placing of the rock and an evaluation that shows that the integrity of the proposed cover, particularly in those areas over which runoff will flow, will not be compromised by long-term erosional forces. A detailed reclamation plan for the existing above-grade tailings areas should also be submitted for DSHS review.

2. The assumed shear strength values used in the impoundment slope stability analyses are not consistent with correlations for corrected blow count values. Consequently, prior to any approval of Dawn's proposal, Dawn should be required to submit for review a revised stability analysis using blow counts adjusted for overburden stress to arrive at a more correct value for the angle of internal friction. Alternatively, the results of shear strength testing such as direct shear tests could be used to indicate the reasonableness of the value that was used in the applicant's analyses.

3. Detailed specifications must be provided for the proposed riprap inner slope wave protection. The riprap should have a minimum average grain size (D_{50}) of 10 inches (25 cm), it should be well graded, and it should meet filter criteria with the bedding sand.

4. Because one end of the proposed impoundment is underlain by basalt and the remainder underlain by a deep deposit of stiff clay, the total settlement of the clay could manifest itself as differential settlement across the site. Field or laboratory data must be provided to indicate if the

compressibility of the underlying deep deposits of clay is sufficiently low so that the loading imposed by the difference in unit weights, between that of the tailings and the in situ density of the sands, will not cause excessive differential settlement. If this cannot be demonstrated, the design of the liner system should be revised to preclude rupture of the liner due to differential settlement.

5. Using filter design criteria as detailed in Reference 12, an independent analysis of the underdrain system by the NRC staff indicates that for both the bedding and the drain pipe filter, criteria governing segregation of grain sizes have not been met. Filter criteria must be met to assure an effective and reliable system.

6. To enable a complete water balance to be performed, operational procedures should be defined to indicate how decanting will be accomplished after the initial period of 2.75 years. The procedures should indicate the method of handling the decant water and the disposal thereof. If evaporation and recycle cannot adequately handle this excess water, then modifications to the mill circuit or tailings management plan would be necessary.

7. To ensure that construction adequately satisfies the design criteria in NRC Regulatory Guide 3.11, a set of construction specifications should be prepared and submitted to the state of Washington for review and approval, prior to approval by the state of construction operations.

   The NRC staff recommends that based on the reported grain size distribution of materials to be used for construction of the perimeter embankment, compaction specifications detailed in Reference 3 should be modified. The embankment should be compacted to an average of 85 percent but not less than 80 percent relative density as determined by ASTM D-2049.

8. The state of Washington should be notified by Dawn at least six weeks prior to the following key stages of the impoundment construction to provide adequate time to arrange onsite inspections, by a geotechnical engineer, of the following critical stages:

   a. Near completion of pit excavation.

   b. During liner placement.

   c. Near completion of the perimeter dike foundation preparation.

   d. At an early stage of perimeter dike fill placement.

9. Within six months after completion of the impoundment construction, Dawn should submit a construction report to the state of Washington for review. The report should include, but not be limited to, the following information:

   a. Earthwork and liner quality control and specification compliance test results.

b. As-built drawings.

c. Photos of site before, during, and after construction.

d. A discussion of unexpected conditions and problems encountered in construction and the methods employed to resolve the problems.

10. Before engaging in any project-related activity not evaluated by the NRC or the state of Washington, the applicant should prepare and record an environmental evaluation of such activity. When the evaluation indicates that such activity may result in a significant adverse environmental impact that was not evaluated, or that is greater than that evaluated in this environmental assessment, the applicant should provide a written evaluation of such activity and obtain prior approval of the state of Washington for the activity.

11. In order to preclude the occurrence of large releases in the event of a failure of the tailings pipeline, the NRC staff recommends that an audible or visible alarm in the mill control room or other occupied office, which activates automatically upon a drop in pipeline pressure, be installed at the Dawn site. The pressure monitor should be located at the discharge point of the pipeline.

12. The mill operator should conduct a comprehensive effluent and environmental radiological monitoring program. The program should be designed and implemented so as to provide sufficient data to enable reliable evaluations of compliance with 40 CFR Part 190. The program should meet the minimum specifications and guidelines presented in USNRC Regulatory Guide 4.14, "Radiological Effluent and Environmental Monitoring at Uranium Mills," and implement a quality assurance program that satisfies the criteria specified in USNRC Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment." All results should be reported to the state of Washington for review at six-month intervals.

13. The mill operator should conduct and document an annual land use survey of all areas within 2.5 miles (4 km) of the mill to maintain current information as to the location of nearby residences or other inhabited structures, use of land for grazing, crop or vegetable growing, etc. This program should provide all land use data necessary for evaluations of compliance with 40 CFR Part 190. Results should be reported to the state of Washington for review within 30 days of survey completion.

14. The mill operator should assure, through periodic inspection and/or testing, that all effluent control devices are maintained in good working order. All such devices must be in use when operations are underway. Yellowcake emission control devices should be checked not less than every 4 hours, when operations are underway, to assure that they are operating effectively. Such inspections and/or testing as are conducted should be

documented, and should be in conformance with a written plan for such inspections and/or testing which has been approved by the state of Washington. Results should be reported to the state in connection with the overall environmental and effluent monitoring program specified above.

15. Dawn should implement an interim stabilization program, with specific written operating procedures, that minimizes the blowing of airborne particulates from all exposed tailings beach areas by any of several effective dust-suppression alternatives incorporating physical methods, such as keeping the surfaces wet through tailings discharge and/or water sprinkling, covering with wood chips, or covering with other dust-reduction materials. The effectiveness of the control method(s) or interim cover used should be evaluated weekly by means of a documented tailings area inspection.

16. The licensee should be required to maintain a financial surety arrangement to ensure reclamation of the tailings area.

17. To assure that the liner system is properly installed and maintained, Dawn should be required to develop and submit for DSHS review, a quality assurance program covering all aspects of liner installation.

18. Although it is the NRC's position that the tailings management method discussed in this assessment represents the most environmentally sound and reasonable alternative now available, any licensing action authorizing this tailings management plan should be subject to revision in accordance with the conclusions of the final generic environmental impact statement on uranium milling and any related rulemaking.

19. There should be a daily, documented inspection of the tailings distribution and retention systems to monitor the stability of embankments, and to determine that tailings operations are being conducted as planned and called for in written procedures.

TABLE OF CONTENTS

Page

1. INTRODUCTION

The Department of Social and Health Services of the state of Washington requested technical assistance from the U.S. Nuclear Regulatory Commission (NRC) in the environmental review of Dawn Mining Company's proposed below-grade uranium mill tailings management plan. As concluded at meetings with the state of Washington on February 28 and 29, 1980, technical assistance was requested in the following areas:

1. Tailings Management Alternatives
2. Reclamation and Long-Term Stability of the Tailings Retention System
3. Impacts to Surface Water and Groundwater
4. Radiological Assessment
5. Environmental Impacts of Accidents

1.1 THE APPLICANT'S PROPOSAL

Dawn Mining Company has proposed the construction of a new tailings disposal system at their mill near Ford, Washington, approximately 25 miles (40 km) northwest of Spokane (Figure 1.1). At the present, time Dawn is depositing tailings in an above-grade impoundment to the southwest of the mill. The proposed tailings retention system is to consist of a specially excavated 28-acre, 70-foot (21 m) deep pit constructed immediately south of the present above-grade tailings area. The pit would have side slopes of three horizontal to one vertical and would be completely lined with 30-mil reinforced Hypalon. The proposal is designed to meet Dawn's foreseeable tailings capacity needs over the next ten years assuming no change in the current ore processing rate.

1.2 CONTENTS OF REPORT

The bases and conclusions of the NRC staff's review and assessment of the Dawn Mining Company's proposed below-grade tailings impoundment are presented in this report. The major components of the report are as follows: (1) summary and recommended licensing conditions, (2) description of the site environment and the proposed impoundment, (3) evaluation of the proposed design in comparison with NRC's performance objectives for tailings management, (4) radiological impact assessment and evaluations of compliance with 10 CFR Part 20 and 40 CFR Part 19 , (5) review of the geotechnical and hydrologic aspects of operational stability of the proposed tailings system, (6) environmental impacts of accidents, and (7) alternative methods for tailings management.

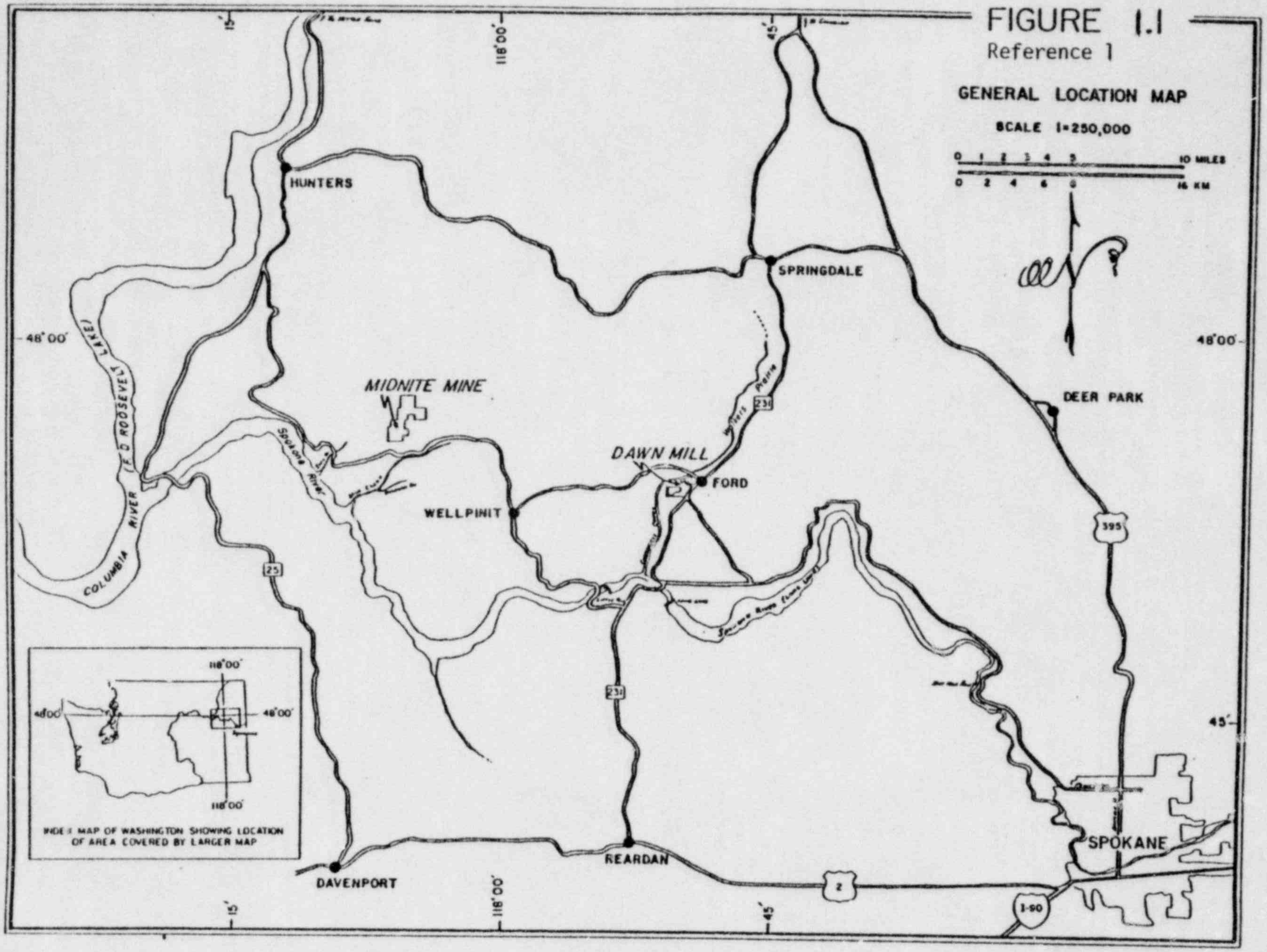


FIGURE 1.1
Reference 1

2. DESCRIPTION OF SITE CHARACTERISTICS

2.1 TOPOGRAPHY

The Dawn mill complex is located in Walker's Prairie, a northeast trending valley about two miles (3.2 km) wide and 15 miles (24 km) long. The valley is bordered along the northwest by rimrock cliffs of plateau basalts and along the southeast by rounded granitic hills.

The valley floor is a flat plain of glacial out-wash deposits. The site of the proposed tailings area is a relatively level terrace of the Chamokane Creek and averages approximately 1,740 feet in elevation. The creek is located about one-half mile (0.8 km) northwest of the site and has cut through the terrace to form a relatively steep scarp approximately 100 feet (30.5 m) high.

It is indicated in the EIS that the only significant accretionary/avulsionary action in the area is downcutting by Chamokane Creek. It may be questioned, whether the accretionary/avulsionary forces are presently at work at the same rate as was the case several thousand years ago. It is noted that Chamokane Creek cascades over a series of scenic small falls dropping about 50 feet (15.3 m) in a span of 500 feet (153 m). This cascade is known as Chamokane Falls. Chamokane Falls likely represents a stable base level that would govern the present rate of downcutting of Chamokane Creek. The resistant rock at Chamokane Falls should enhance the long-term stability of the site.

2.2 GEOLOGY

2.2.1 Regional Geology

About 30 million years ago, following periods of structural deformation (mountain building), widespread granitic intrusions, scattered volcanic activity and major block faulting, great rifts opened in central and southwestern Washington and flood basalts filled the lowlands and built thicknesses of up to 10,000 feet (3,050 m). A few of the uppermost flows lapped into the highland valleys in the vicinity of the Dawn mill site. After a period of quiescence and erosion, the great continental glaciers began their movements about 1 million years ago, climaxing the local geologic history. Meltwaters carried huge loads of rock flour, sands and gravels southwestwards across the basalt plateau. In the Ford area, a layer of coarse gravel 20 feet (6 m) thick was deposited by the last meltwaters some 20,000 years ago.

2.2.2 Site Geology

Based on local boring records, the mill area is underlain by a granitic basement buried beneath thin remnants of Columbia River basalt and a thick accumulation of glacio-fluvial clays, sands, and bouldery gravels. Figure 2.1 is an interpretive geologic profile of the materials underlying and adjacent to the millsite. At the proposed tailings area, the upper layers of sands and gravels are, for the most part, underlain by stiff clays at depths generally greater

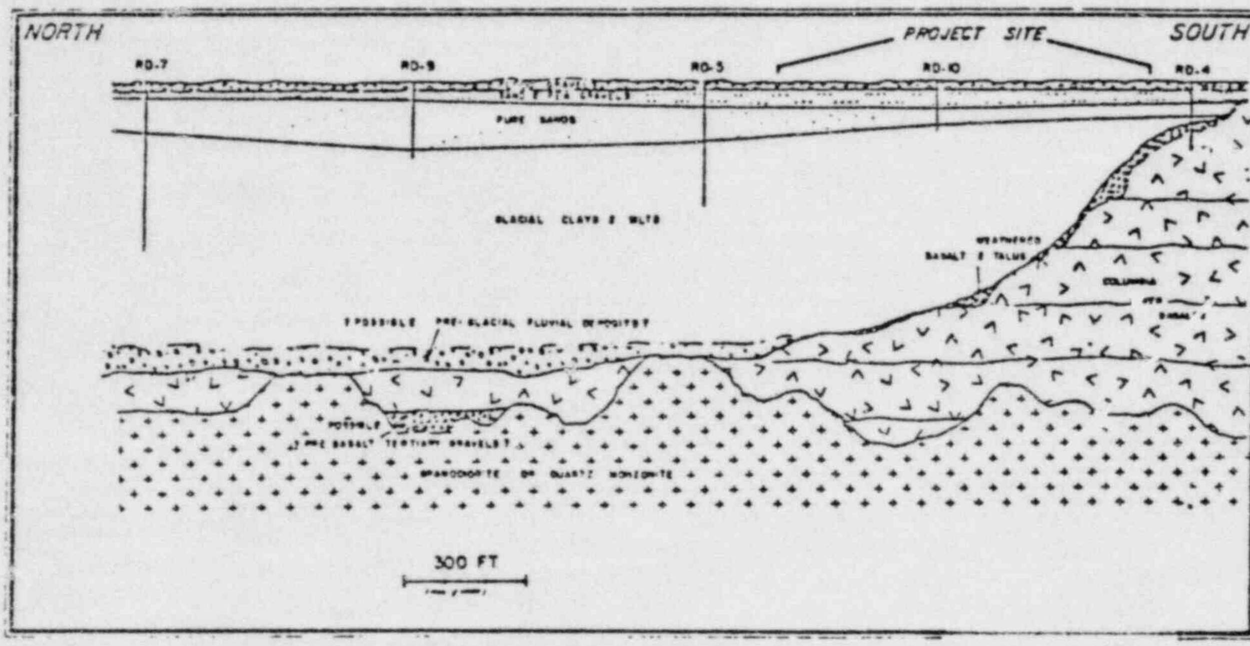


Figure 2.1. Interpretive Geologic Profile (Source: Reference 1)

than 100 feet (30.5 m). The surface of the clay layer dips moderately towards the nearby Chamokane Creek. Deeply weathered basalt bedrock underlies the upper sands in the easternmost part of the proposed tailings area at depths likely to be encountered during the pit excavation.

2.2.3 Seismicity

Within a 100-mile (160-km) radius of the project area, approximately 100 seismic events occurred between 1897 and 1973, with the greatest intensities reported as VI on the modified Mercalli scale or magnitude 4.8 on the Richter scale. This information is based on applicable data reported in the "Draft Environmental Statement, Sherwood Uranium Project, Spokane Indian Reservation" (Ref. 5). A few of the most severe earthquakes with epicenters from 100 to 400 miles (160 km to 640 km) away from the project area have produced significant local ground movement, but none in recorded history have extensively damaged structures in the Spokane area.

Based on the region's seismic history, the probability of a major damaging earthquake occurring at or near the proposed site is slight. Algermissen and Perkins (Ref. 2) indicate that in this area there is a 90 percent probability that a horizontal acceleration in rock of 4 percent gravity (0.04 g) would not be exceeded within 50 years.

In the Golder Report (Ref. 3) it is stated that a pseudostatic earthquake coefficient of 0.05 g was utilized for design of the embankments. Data given in Bolt, 1977, (Ref. 4) indicates that for earthquakes of intensity VI on the modified Mercalli scale, maximum accelerations ranging from 0.005 g up to 0.066 g may be expected. In consideration of the fact that the earthquakes noted are within an area of 100 miles (160 km) from the site and the fact that the site is located over a deep deposit of soil overlying bedrock, it is considered likely that the peak acceleration at this site would be less than 0.066 g. Consequently, the use of a coefficient of 0.05 g is considered to be realistic.

2.3 Groundwater

The groundwater/surface water relationship in Walker's Prairie is complex, being comprised of several significant geohydrologic horizons. At the project site the uppermost groundwater zone occurs within and at the base of the highly permeable gravel/sand section composing the uppermost 100 feet (30.5 m) of the valley fill. This water is perched on a dense, silty, blue/gray clay which serves as a barrier for vertical infiltration. The clay surface dips gently westward, inducing groundwater migration in that direction. Flows at this interface are reported to be modest.

Drill holes at the site of the proposed tailings impoundment for purposes of subsoil investigation encountered groundwater in only one boring. The static water level in the hole was at a depth of 93.3 feet (28.46 m) below the surface on October 17, 1979 (Ref. 3). Based on Dawn Mining Company data as noted in Reference 3, fluctuations in the groundwater table of up to 15 feet (4.6 m) have been indicated in response to intense rainfall. Even with this fluctuation, normal groundwater levels would still be expected to remain beneath the maximum depth of excavation of the pit for the proposed tailings impoundment.

2.4 Hydrology

The design storm procedures outlined in the "Design of Small Dams" by the U.S. Bureau of Reclamation (Ref. 6) were used by the staff to compute the 36-hour, Probable Maximum Precipitation (PMP) General Storm, and the subsequent Probable Maximum Flood (PMF). The flood depth was derived in accordance with the PMF series specified in the USNRC Regulatory Guide 3.11 (Ref. 7). The PMF series analysis assumes that the impoundment must accept flood waters equivalent to 40 percent of the PMF followed in 3 to 5 days by the PMF, all of which was preceded or followed by a 100-year storm. The PMP was estimated to be 8.33 inches (21.2 cm) for the Dawn mill site. The computations are presented in Appendix D, Section I.

The USNRC PMF series yields equivalent storm depths of 3.4 inches (8.6 cm), 8.4 inches (21.2 cm), and 4.4 inches (11.2 cm) for the 0.40 PMP, PMP and the 100-year storms respectively resulting in a total of 16.2 inches (41.0 cm) of precipitation. The PMF series thereby contributes in excess of 34 acre-feet of storm water to the impoundment. The proposed tailings pond at the Dawn mill site will have an approximate drainage area of 25.5 acres (10.3 ha), as it is surrounded by perimeter dikes. Because there is no tributary runoff, the design PMF is equal to the PMP.

The applicant utilized the U.S. Weather Bureau PMP computations of 1967 to generate a 72-hour PMP of 12 inches (30.5 cm). However, instead of computing the 100-year storm depth and integrating this value into the USNRC PMF design procedure, the applicant apparently estimated the 100-year cumulative seasonal precipitation (October to March) of 25 inches (63.5 cm) for the project site. The total PMF precipitation depth reported was the summation of the PMP and the 100-year seasonal precipitation resulting in 37 inches (94.0 cm). The applicant estimated an inflow volume of 78.6 acre-feet of water into the impoundment.

Although the applicant did not follow the PMF series procedure as outlined in USNRC Regulatory Guide 3.11, the extreme conservatism resulted in a total design precipitation of 2.25 times greater than a more traditional PMF series analysis.

2.5 Meteorology

The Dawn mill site is located between the flatlands of the Columbia Basin to the west and the foothills of the Rocky Mountains to the east. The project site is situated such that there are no climatological records available for nearby locations. Therefore, the climatological data is based on the Spokane (25 miles (40 km) to the southeast), Wellpinit (10 miles (16 km) to west-southwest), and Chewelah (35 miles (56 km) to the north-northeast) weather stations.

The annual precipitation measured at the surrounding weather stations ranges from 16.5 inches (41.9 cm) to 19.3 inches (49.0 cm). Approximately 70 percent of this total falls between the first of October and the end of March. During the October-March period, about half of the precipitation falls as snow. Throughout the remainder of the review presented in this report, precipitation is conservatively estimated to be 20 inches (50.8 cm) per year for the Dawn project site.

The mean annual temperature for the area is about 47°F (8°C). The mean temperature during the winter months is about 28°F (-2°C) while the summer months average 66°F (19°C). Most of the air masses which reacn the area consist of maritime polar air brought in by prevailing westerly and south-westerly circulations. Occasionally, the area is overridden by dry continental polar air masses from the northeast, resulting in high temperature/low humidity periods in the summer and/or subzero temperatures in the winter.

Annual high temperatures of 100°F (38°C) have been recorded at the Dawn project site. Temperatures around 85°F (29°C) are common during June, July, and August. Annual low temperatures average approximately -7°F (-22°C). However, extreme low temperatures have been recorded from -20°F (-29°C) to -40°F (-40°C).

Records from Spokane indicate that prevailing winds blow from the southwest and south-southwest. However, during the winter months the air flow is commonly reversed, with winds out of the northeast. The average annual windspeed is 8.5 mph (see Table 2.1).

The mean annual lake evaporation in the project area is approximately 38 inches (96.5 cm) per year. Class A pan evaporation is about 53 inches (135 cm) per year. An estimated monthly evaporation rate in inches per month is presented in Appendix D, Section III. It is estimated that the net annual evaporation is about 18 inches (46 cm) per year.

Table 2.1 Joint frequency of annual average wind speed and direction for Spokane, Washington, 1967-1971 (2.2% calm is distributed in the table)

Direction	Speed, mph						
	0-3	4-6	7-10	11-16	17-21	>21	Total
N	0.5%	1.5%	0.9%	0.2%	0.0%	0.0%	3.1%
NNE	0.5	1.7	1.2	0.3	0.0	0.0	3.7
NE	0.8	3.0	3.5	0.6	0.1	0.0	8.0
ENE	0.8	3.6	4.4	0.7	0.1	0.0	9.6
E	1.0	2.6	1.4	0.2	0.0	0.0	5.2
ESE	0.5	1.5	0.9	0.1	0.0	0.0	3.0
SE	0.6	1.7	1.7	0.3	0.0	0.0	4.3
SSE	0.6	2.2	4.6	0.9	0.1	0.0	8.4
S	0.9	3.4	5.7	2.8	0.4	0.0	13.2
SSW	0.5	1.6	4.3	4.4	1.2	0.1	12.1
SW	0.6	2.0	4.6	4.8	1.8	0.6	14.4
WSW	0.6	1.7	2.8	2.0	0.7	0.2	8.0
W	0.4	1.2	1.0	0.6	0.2	0.0	3.4
WNW	0.3	0.6	0.4	0.2	0.1	0.0	1.6
NW	0.2	0.4	0.3	0.1	0.0	0.0	1.0
NNW	0.2	0.4	0.3	0.1	0.0	0.0	1.0
	9.0%	29.1%	38.0%	18.3%	4.7%	0.9%	100.0%

From "Wind Distribution of Pasquill Stability Classes--Spokane, Washington, 1967-1971," National Climatic Center, Asheville, North Carolina.

3. DESCRIPTION AND EVALUATION OF THE PROPOSED TAILINGS MANAGEMENT PLAN

3.1 DESCRIPTION OF PROPOSED TAILINGS MANAGEMENT PLAN

3.1.1 General Description

At the present time, there are three above-grade tailings disposal areas at the Dawn site. Figure 3.1 shows a plan map of the existing tailings disposal areas and the proposed excavation site for the below-grade impoundment. Tailings are presently being deposited in area 3, areas 1 and 2 being full and covered with woodchips. It is anticipated that the present tailings disposal capacity at area 3 will be exceeded in a short period of time, and, therefore, an additional disposal system has been designed. The proposed tailings impoundment will consist of a specially excavated pit dug into the sand and gravel deposits to the south of the present tailings impoundment. Figures 3.2 and 3.3 show a plan view and cross-sections through the proposed pit. The pit will be nominally 70 feet (21 m) deep. The side slopes of the pit will be excavated on a slope of 3 horizontal to 1 vertical (3h:1v). A section through the pit showing details of the pit and the embankment is shown in Figure 3.4. Along the side of the pit adjacent to the existing tailings disposal facility, a 50-foot (15-m) wide bench will be left to improve the overall stability. The other sides of the pit will be bounded by a 5-foot (1.5-m) high and 30-foot (9-m) wide perimeter dike constructed with materials removed from the excavation. Excess materials removed from the excavation will be stockpiled adjacent to the perimeter dike and other existing dikes for future use during reclamation.

The sides and bottom of the pit will be lined with 30-mil reinforced Hypalon to prevent seepage. An internal subdrain system will be placed on the bottom of the pit above the liner to accelerate removal of water from the tailings once the tailings disposal facility has been filled.

3.1.2 General Disposal Operations

Tailings will leave the mill as a 30 to 50-percent solid slurry and will be pumped through a 6-inch PVC pipeline one-half mile to the proposed tailings disposal facility (Ref. 1). Tailings components are derived from several points in the mill circuit, but the principal exit point for the leached solid residues is from the Number 4 thickener underflow.

Tailings slurry will flow into the disposal facility at a rate of approximately 0.95 acre-feet per day (Ref. 1). Based on a 365-day per year operation, nearly 347 acre-feet of slurry will be deposited into the disposal facility annually. The pond will be allowed to fill with no decantation of the solution until the pond reaches the maximum operating level of from elevation 1,738 feet to elevation 1,740 feet. Since a Hypalon liner will be installed to control seepage, the only loss from the disposal facility will be to evaporation processes.

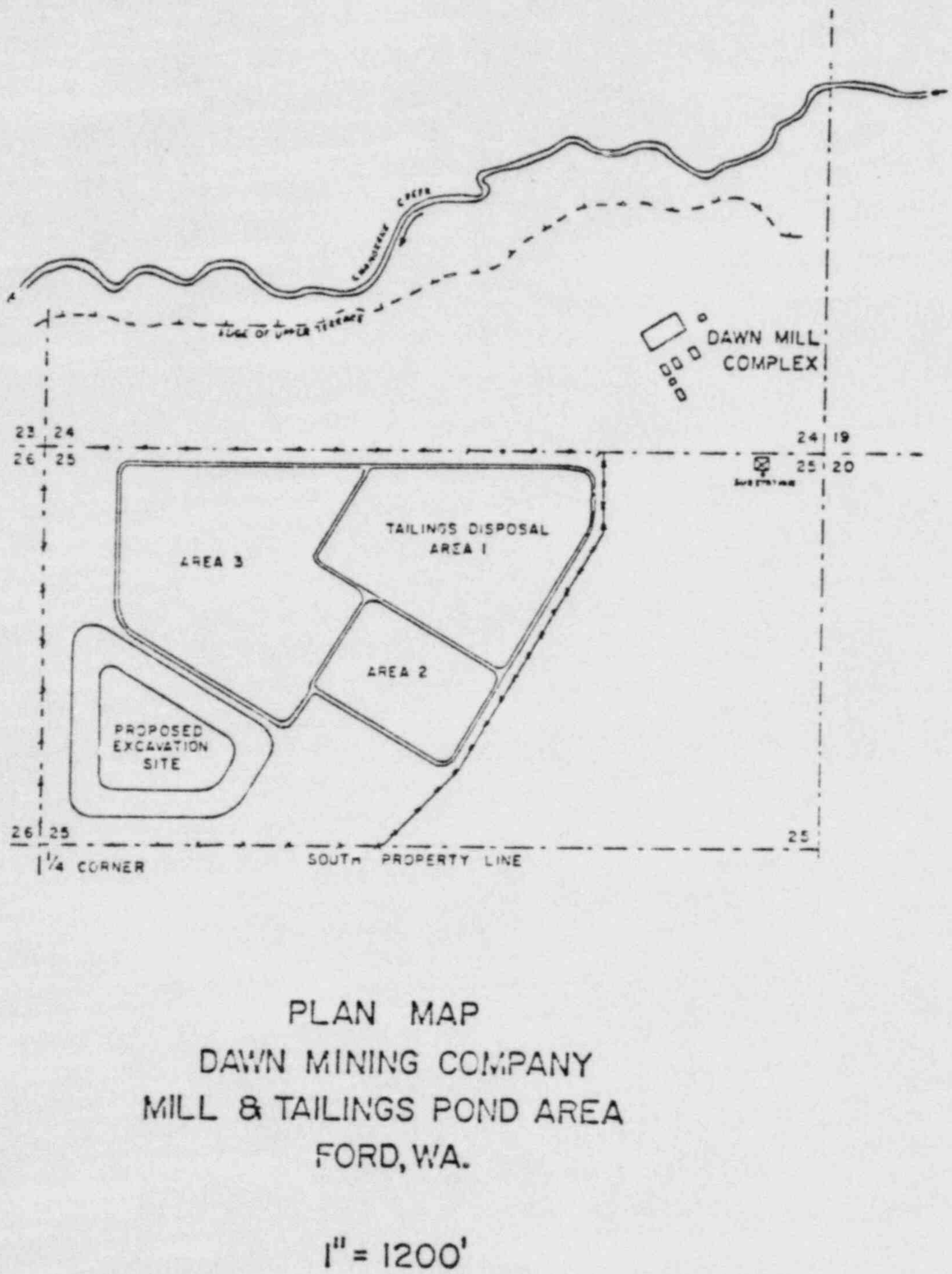


Figure 3.1. Plan Map (Source: Reference 1)

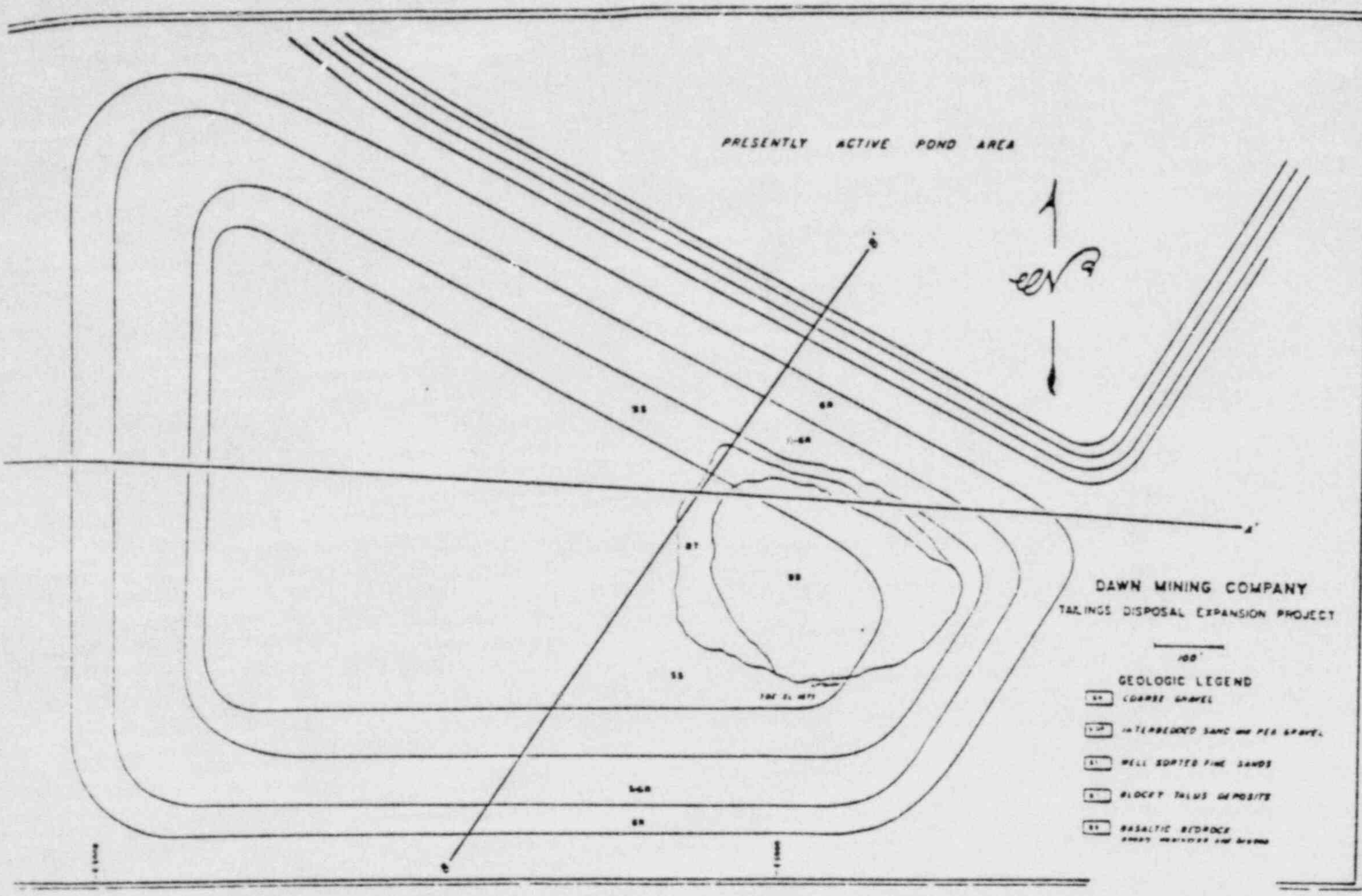


Figure 3.2. Tailings Disposal Expansion Project (Source: Reference 1)

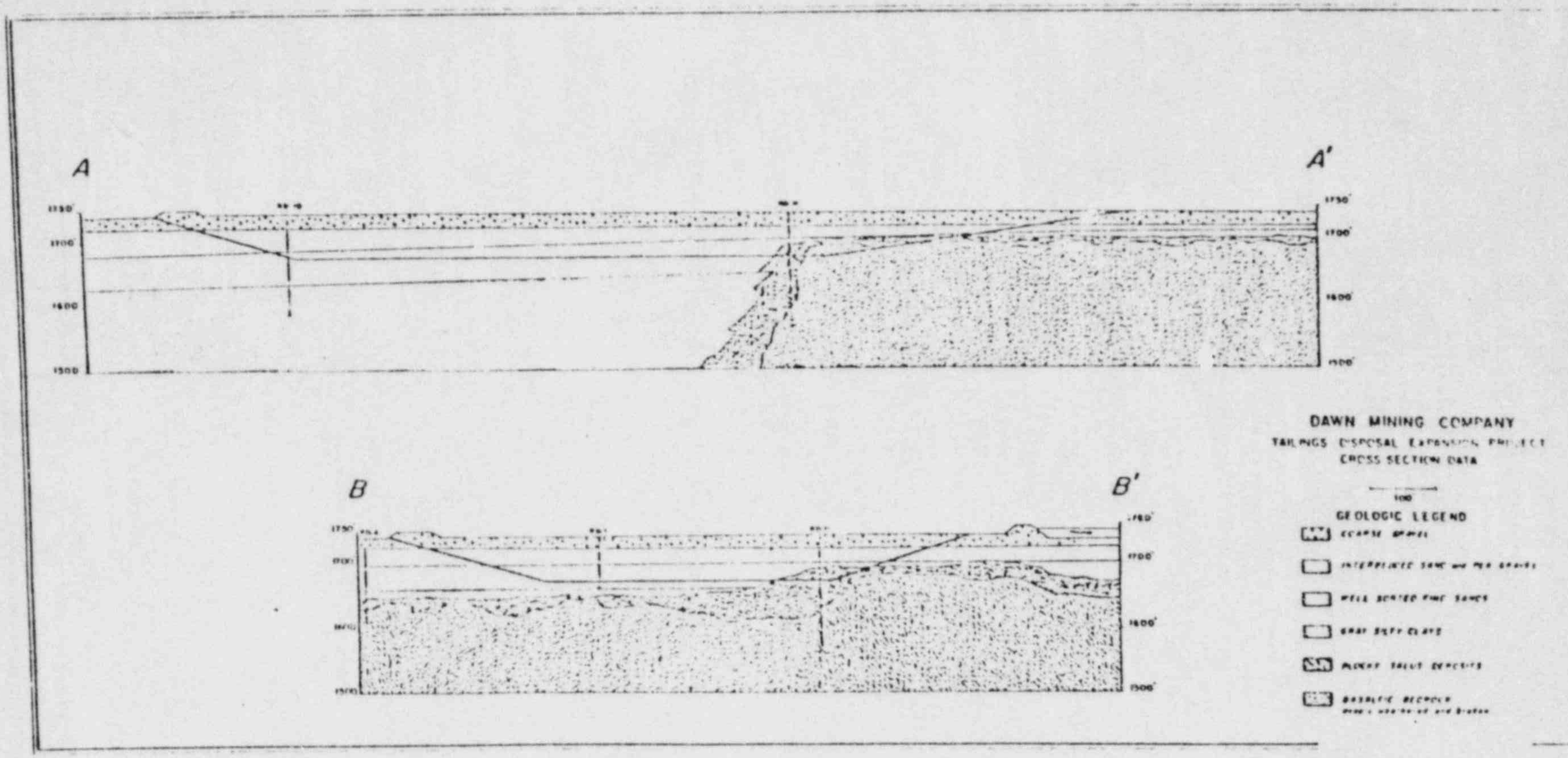


Figure 3.3. Cross-Sections of Proposed Pit (Source: Reference 1)

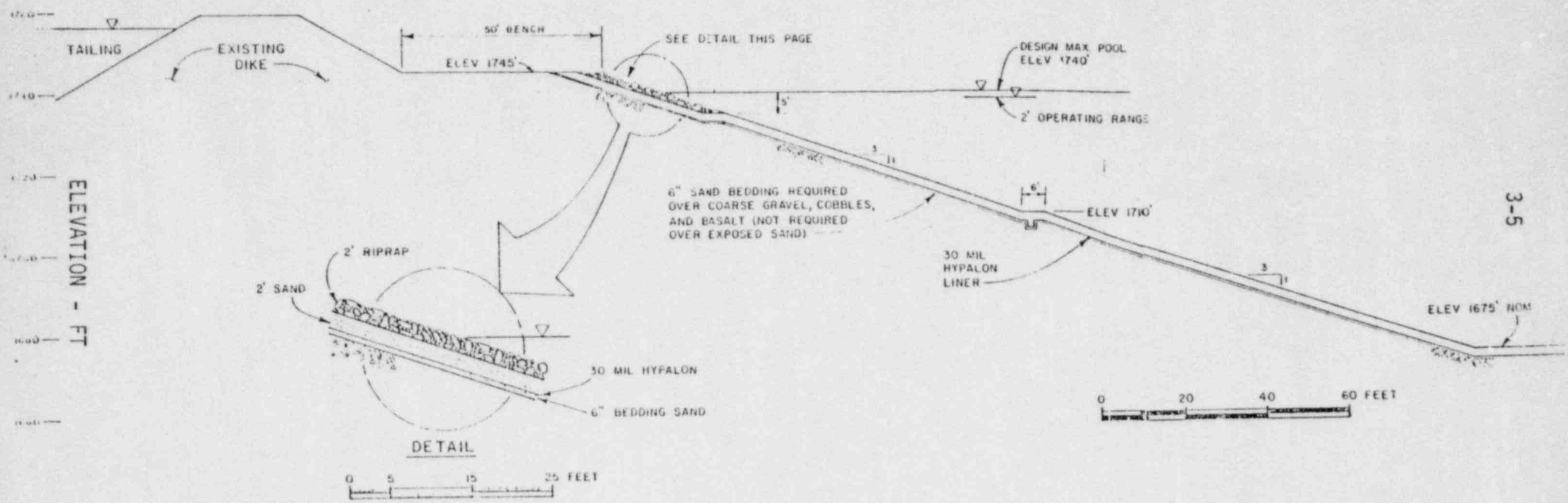


Figure 3.4. Typical Section of North Side of Pit (Source: Reference 3)

Throughout operations, a minimum freeboard of 5 feet (1.5 m) will be maintained to manage inflow of precipitation and associated wave runup. A complete freeboard analysis is discussed in Section 3.2.1.6.2 of this report.

3.1.3 Embankment and Pit

The general layout of the pit is shown in Figure 3.5. As shown in Figure 3.4, the slopes of the pit will typically be 3h:1v and the upper 10 feet (3 m) (vertical distance) of the slope will be covered with riprap to protect against wave action.

The 5-foot (1.5-m) high perimeter dike will be constructed from the near surface coarse gravel, sand, and cobble material at the site and will also be lined with Hypalon and riprapped (Ref. 3). The applicant has reported that materials will be compacted to at least 95 percent of the maximum density as specified by the modified compaction test, ASTM D1557 and that the soil will be placed in lifts of 12 inches (30.5 cm) or less, loose thickness. Slopes of all constructed dikes will be no steeper than 3h:1v.

3.1.4 Underdrain System and Liner

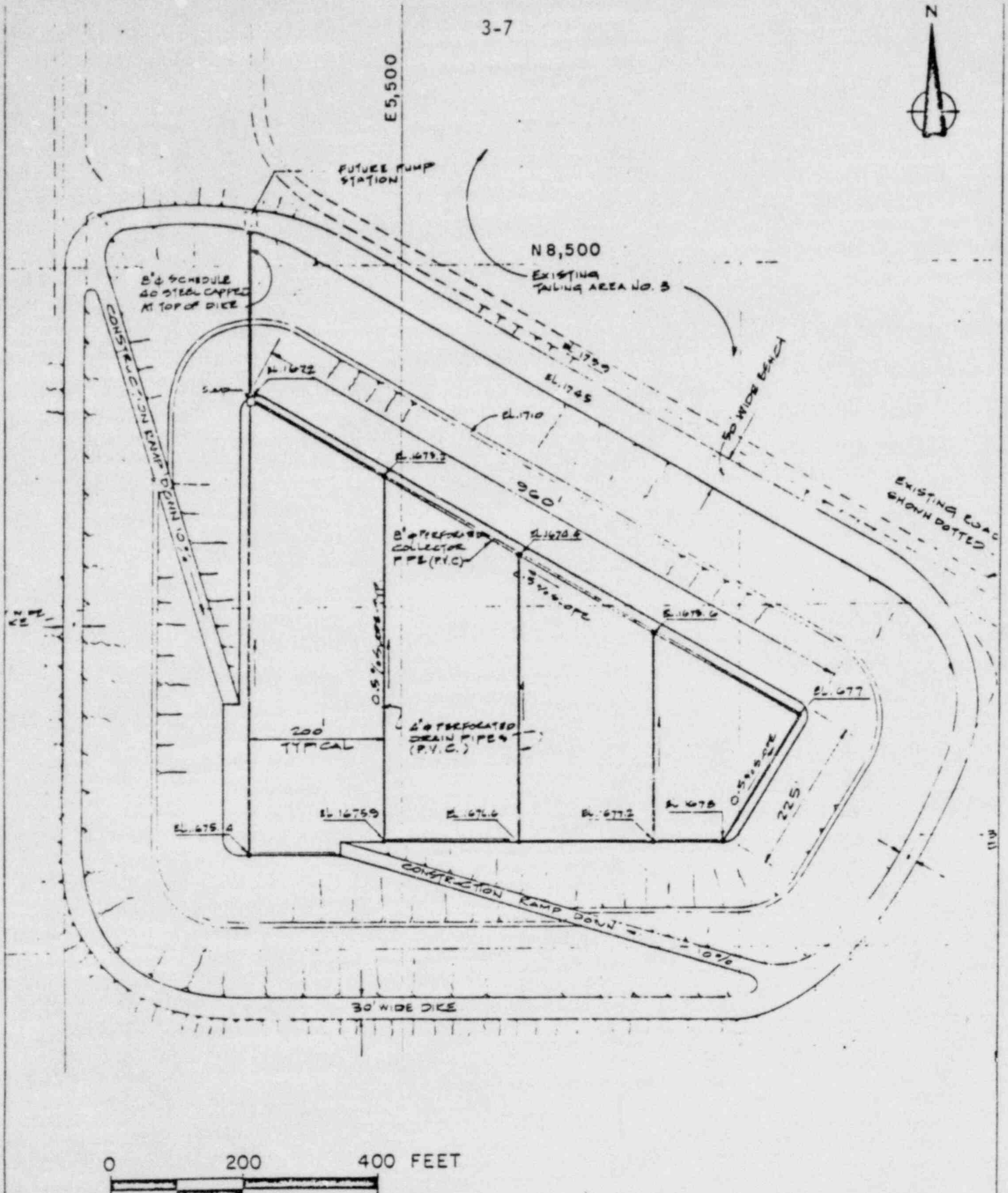
To eliminate seepage from the impoundment, a 30-mil Hypalon liner will be placed on the bottom and along the sides of the pit. Details of placement of the liner are shown in Figure 3.4. Six inches of bedding sand will be placed underneath the liner to prevent punctures from any underlying irregularities. Two feet of sand will be placed on top of the liner for protection. Along the upper edges of the impoundment, two feet of riprap will be placed to provide slope protection for the bedding sand from wave action.

An internal subdrain system will be placed above the liner to accelerate removal of water from the impoundment. The layout of the underdrain dewatering system is shown in Figure 3.5. Cross-sections of the drains are shown in Figure 3.6. The drains consist of slotted drain pipe surrounded by filter material and covered by the cover sand protecting the liner. Calculations presented in the Geotechnical Design Report by Golder Associates (Ref. 3) indicate that the drains will be capable of carrying water in excess of the full quantity of water delivered to the tailings through the slurry pipeline.

3.1.5 Proposed Reclamation and Long-Term Stability Plan

Dawn Mining Company has proposed the following program for reclamation and long-term stabilization of the tailings disposal facilities:

a. Tailings will be allowed to dewater for a period of one to three years to allow heavy equipment to work on the tailings surface. Interim measures (sprinkling, spraying with chemicals, or wood chip cover) will be taken to control dusting.

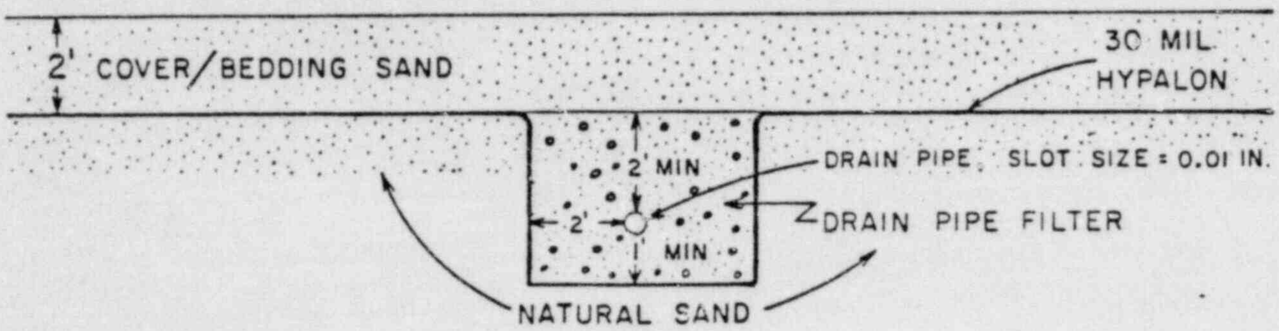


REFERENCE: KILBORN/NUS INC
NO. 7419-13-004
DATE: 14 SEPT. 79

Figure 3.5. Plot Plan and Layout of Pit and Subdrain System (Source: Reference 3)

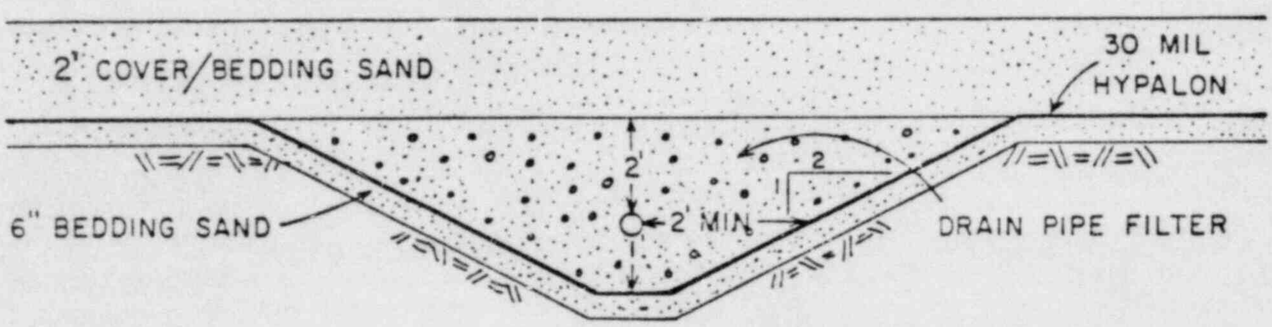
CASE I.

FOUNDATION IS PREDOMINANTLY FINE TO MEDIUM SAND



CASE 2.

FOUNDATION IS PREDOMINANTLY GRAVEL, COBBLES OR ROCK



NOTE:

CASE 2 TRENCH HAS TO BE EXCAVATED IN ROCK OR COARSE GRANULAR SOILS, THEREFORE SIDE SLOPES WILL HAVE TO BE FLATTENED TO 2h:lv SO SAND BEDDING CAN BE PLACED UNDER HYPALON

Figure 3.6. Drainpipe Insta lation Details (Source: Reference 3)

b. The tailings surface will be graded.

c. A layer of clay two feet (0.6 m) thick will be placed and compacted over the tailings surface.

d. An additional layer of fill 8 feet (2.4 m) thick consisting of sand and gravel will be placed overlying the clay.

e. No topsoil will be added to this cover since the area surrounding the project site has minimum natural "A" horizon soil development.

f. The cover over the tailings will be graded and contoured so as to eliminate the possibility of ponding of precipitation over the area. In addition, the side slopes of the capped layer will be reduced to a slope of 5h:1v by the addition of fill materials along the periphery.

g. The entire area will be seeded and fertilized to stabilize the cover. It is stated in Dawn's EIS (Ref. 1) that natural reforestation will ensue fairly rapidly as evidenced by the trees presently growing on the abandoned tailings berm around the areas presently in operation.

h. Revegetation effort will be monitored for success and remedial measures will be taken to ensure coverage of the area.

3.2 EVALUATION OF PROPOSED TAILINGS MANAGEMENT PLAN

3.2.1 Operational Stability

3.2.1.1 Slope Stability

A failure of the pit side slopes could permanently damage the Hypalon liner and a failure of the north slope in particular could also cause a failure of the existing above-grade impoundment and a subsequent release of tailings. In order to evaluate the safety of the proposed impoundment against this type of event, independent slope stability analyses were conducted by the staff utilizing computer program STABL2 (Ref. 33). A total of ten potential failure surfaces were generated and the lowest factor of safety observed for those trial failure surfaces was 1.95. All other values were greater than 2. Results of these computations and the cross-section utilized is shown in Appendix C. The shear strength parameters used in these analyses were the same as those used by Dawn's consultant, Golder Associates (Ref. 3).

The phreatic surface utilized in the staff's stability analyses was the same as that used by Golder Associates. As discussed in the previous section describing the groundwater conditions at the site, this phreatic surface is considered to be realistic and, even under fluctuations due to heavy rains, the phreatic surface will not rise above the bottom of the pit.

As computed in the Golder analysis and the NRC staff's independent analysis, the factors of safety for the stability of the pit walls are greater than the value of 1.5 required by USNRC Regulatory Guide 3.11. However, the shear strengths used by the applicant in arriving at these factors of safety were not based on Standard Penetration testing results adjusted for overburden stress and thus were slightly nonconservative. Consequently, prior to any approval of Dawn's proposal, Dawn should be required to submit for review a revised stability analysis using blow counts adjusted for overburden stress to arrive at a more correct value for the angle of internal friction. Alternatively, the results of shear strength testing such as direct shear tests could be used to indicate the reasonableness of the value that was used in the applicant's analyses.

3.2.1.2 Settlement

Dawn conducted settlement analyses to indicate the potential for differential settlement due to differences in the subsoil conditions from one end of the pit to the other. One end is underlain by basalt whereas the remainder of the disposal area is underlain by a stiff clay.

The results of the NRC staff's independent check of settlement calculations submitted by Dawn compared favorably with the computed results indicated by Golder Associates in Reference 8.

However, none of the computations presented by Dawn takes into account the deep layer of glacial clays underlying the site. Because one end of the site is underlain by basalt with little or no clay present there, the total settlement of clay could manifest itself as differential settlement across the site.

Considering the difference between the unit weight of the tailings and that of the existing sand, the total excess load that will be applied is approximately 0.30 tons per square foot. If the clay is highly overconsolidated, it is expected that this low additional loading would cause little or no settlement. However, there is no data presented indicating the compressibility of the clay. Therefore, Dawn should be required to submit additional laboratory or field data to show that the compressibility of the clay is low enough to result in negligible elastic and plastic settlements.

3.2.1.3 Liquefaction Potential

Dawn has stated that because the water table is low, because the fine sands are relatively dense, and because the earthquake potential at the site is slight, liquefaction is considered unlikely at this site. Generally, liquefaction is of concern only for loose soils when the water table is near the surface. Consequently, because of the very low water table and the fact that overlying soils are coarse grained, the NRC staff agrees that the liquefaction potential at the site is low and does not need to be addressed further.

3.2.1.4 Slope Protection

In reference 3 it is stated that basalt from the disposal pit in combination with the coarse-grained, near-surface materials of the site may be used for the riprap slope protection to be placed from the crest of the perimeter dike to 3 feet (0.9 m) below the lowest operating pool level. The only specification regarding riprap size is that cobbles, boulders, or rock fragments up to 12 to 18 inches (30 to 45 cm) in diameter would be satisfactory for use in the riprap. Sherard, et al., (Ref. 9, Table 8.1:1) indicates that for wave heights less than or equal to 2 feet (0.6 m), the minimum average rock size (D_{50}) should be 10 inches (25 cm). Furthermore, filter criteria should be met between the riprap and the sand bedding material. Therefore, Dawn should be required to submit more detailed specifications for the riprap indicating that a minimum average grain size (D_{50}) of 10 inches (25 cm) will be met, that the riprap will be well graded, and that filter criteria will be met between the sand bedding material and riprap.

3.2.1.5 Underdrain System and Liner

The underdrain system shown in Figure 3.6 indicates various zones of sand and bedding material and tailings in contact with one another. The grain size distribution curves for these materials shown in Reference 3 were stated to have been designed on the basis of Corps of Engineers criteria. However, using the criteria detailed in the Pit Slope Manual (Ref. 12), an independent analysis by NRC staff indicated that for both the bedding and the drain pipe filter, criteria governing segregation of grain sizes have not been met. Although failure of the underdrain system does not present an environmental or safety hazard, all filter criteria should be met if an effective system is to be ensured.

The liner integrity against shear stresses on the impoundment slopes was evaluated by the applicant and a check by NRC staff showed that an adequate factor of safety will be provided by the strength of the Hypalon.

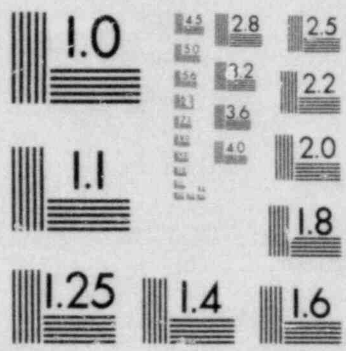
3.2.1.6 Hydrologic Considerations

3.2.1.6.1 Water Balance Analysis

An independent water balance analysis was conducted by the NRC staff to ensure that the applicant's tailings pond management scheme will function as proposed. In performing this analysis, the assumptions that were made are as follows:

- Annual precipitation is approximately 20 inches (51 cm) per annum.
- The total evaporation rate is 38 inches (96 cm) per year (Ref. 1). Monthly evaporation rates are depicted in Appendix D, Section III.
- Seepage will not occur out of the pit.
- The slurry inflow into the pond is 0.95 acre-feet per day, (Ref. 8). It was assumed the mill will operate 365 days per year.

IMAGE EVALUATION
TEST TARGET (MT-3)



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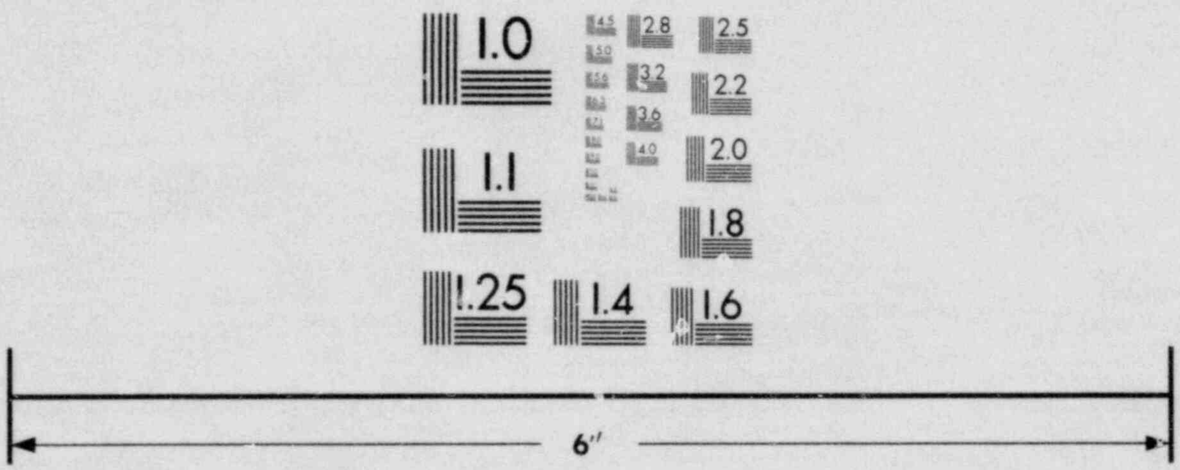
MICROCOPY RESOLUTION TEST CHART

IMAGE EVALUATION TEST TARGET (MT-3)



MICROCOPY RESOLUTION TEST CHART

- The pond will accept all slurry discharges until filled, after which decanting will be required.

- The maximum operating level of the tailings pond is elevation 1740.

Since the applicant has not provided either a stage-volume curve or a stage-surface area curve to perform the water balance analysis, curves were constructed based on information presented in Reference 8. Both the stage-volume and stage-surface area curves are shown in Appendix D.

The water balance analysis was performed in a conservative manner. The analysis began in January, at a time when pond evaporation would be a minimum. The result depicted in Appendix D indicates that the applicant can discharge slurry into the pond approximately 2.75 years before decanting operations are required. This value agrees with the applicant's analysis presented in Reference 8.

Further analysis of the tailings pond management scheme, in terms of the water inflow-outflow characteristics, cannot be evaluated because decanting operation details have not yet been provided. Also, a more accurate estimate of the percentage of slurry solid would be needed to further refine the water balance analysis. The applicant reports that, presently, from 30-50 percent of the slurry are solids (Ref. 1). While this presents no problem from an environmental and safety standpoint, these details must be provided in the near future for evaluation if operations are to continue in a timely manner. If evaporation and recycle cannot adequately handle this excess water then modifications to the mill circuit or tailings management plan would be necessary.

3.2.1.6.2 Freeboard

The applicant has estimated that the PMF will contribute 37 inches (94 cm) of water to the 25.5 acre drainage basin resulting in a volume of approximately 78.6 acre-feet. The NRC staff's hydrological analysis, as presented in Section 2.4, indicates that the PMF series will contribute 16.2 inches (41.0 cm) of precipitation or $\sim$ 34 acre feet. Based upon an approximate impoundment fetch length of 1200 feet (365 m) and an estimated maximum wind velocity of 100 mph (160 km/hr), the maximum wave height and subsequent embankment runup is calculated by the NRC staff to be approximately 2 feet (0.6 m) (Ref. 9, 14).

The maximum pond operating level has been established at elevation 1740 and the design impoundment crest at elevation 1745. The resultant operating freeboard is 5 feet (1.52 m). Combining the conservative PMF depth calculated by Dawn with the potential wave height results in a required freeboard of 5.08 feet (1.55 m) which is necessary to retain any potential overtopping of the embankment crest.

The upper 10 feet (3.0 m) of the embankment (that is, elevation 1735 to 1745) will be riprapped to ensure embankment protection from wave action as shown in Figure 3.4. Consequently, wind and wave damage should be minimal. Because of the wave protection and the extreme conservatism with which the PMF was estimated by the applicant, the NRC staff recommends that the proposed 5 feet (1.52 m) of freeboard be considered adequate.

3.2.1.7 Construction

Recommendations for details of the embankment and pit construction and placement of materials are presented in Reference 3. However, no official construction specifications have been drawn up. The NRC staff recommends that a set of construction specifications be prepared and submitted to the state of Washington for approval prior to startup of construction operations. With regard to the impoundment construction, the following recommendations are offered:

a. Compaction criteria of 95 percent of the maximum dry density as determined by the Modified Compaction Test, ASTM D1557 is specified. Based on the grain size distribution curves in Reference 3, it is anticipated that the dike material will have 5 percent or less of material passing the number 200 sieve. Therefore, it is the recommendation of the NRC staff that the embankment be compacted to an average of 85 percent but not less than 80 percent relative density as determined by ASTM D2049.

b. Inspection of the facility is recommended during key stages of construction. These should include:

   1. Near completion of pit excavation.

   2. During liner placement.

   3. Near completion of perimeter dike foundation preparation.

   4. At an early stage of perimeter dike fill placement.

c. A construction report should be submitted to the state of Washington for review after completion of the facility and should include quality control and specification compliance test results.

3.2.2 Seepage Control

The staff has investigated the resistance of the reinforced Hypalon liner, proposed by Dawn, to the materials in the tailings discharge and finds that, provided that the liner, bedding material, and sand cover are properly installed and maintained, the liner system should retain its integrity during the operational life of the pit and beyond. Therefore, no degradation of the groundwater will occur.

To assure that the liner system is properly installed and maintained, Dawn should be required to develop and submit for review a quality assurance program covering all aspects of liner installation.

3.2.3 Long-Term Stability and Reclamation Plan

3.2.3.1 Technical Criteria

An evaluation of the long-term stability of the uranium mill tailings disposal plan was performed. The reclamation plan of the proposed disposal site must be incorporated into the reclamation plan for the entire tailings disposal area and cannot be reviewed completely on the basis of existing information. Nevertheless, the following evaluation indicates the adequacy of the proposed plan from the viewpoint of long-term stability. The long-term stability and proposed reclamation plan was evaluated in accordance with the list of failure modes presented in Table 3.1. Because of the subsurface disposal plan proposed, several of the potential failure mechanisms indicated in Table 3.1 have minor or no consequence with regard to the long-term stability.

3.2.3.2 Evaluation of Proposed Reclamation Plan

The staff notes that the information developed in the Final Generic Environmental Impact Statement on Uranium Milling being prepared by NRC could modify or change reclamation requirements. The generic statement will contain the results of ongoing research to assess the environmental impacts of uranium mill tailings ponds and piles, and will suggest means for mitigating any adverse impacts. Any licensing action approving the below grade disposal plan should be subject to revisions based on the conclusions of the Final Generic Environmental Impact Statement on Uranium Milling and any related rulemaking.

The applicant must also be required to maintain surety arrangements to cover the costs of reclaiming the tailings disposal areas.

3.2.3.2.1 Failure Modes Associated with Impoundment Elements

The cap will consist of 10 feet (3 m) of cover. The first 2 feet (0.6 m) immediately above the tailings surface will be comprised of a clay layer which will be placed and compacted. An 8-foot (2.4 m) thick layer of sand and gravel will be placed over the clay. The cover over the tailings will be graded and contoured to facilitate drainage away from the impoundment area and thus minimize sheet or gully erosion. Cover will be placed at a maximum slope of 5h:1v. Due to the materials being used to comprise the cap, the effects due to the differential settlement and chemical attack are anticipated to be minimal.

The entire disposal area floor and sideslope surface will be lined with a fabric-reinforced, 30-mil, synthetic rubber Hypalon liner. The liner membrane will extend up the dike to a level 5 feet (1.5 m) above the original ground surface. A 2-foot (0.6 m) thick cover layer of stabilized sand will be placed over the membrane. After use of the below grade tailings pit is terminated, the tailings will be dewatered for from one to three years through decanting, evaporation, and use of the underdrain system. Assuming proper placement of the liner and satisfactory dewatering of the tailings, all free water in the tailings should be removed in this period. Differential settlement or other adverse affects on the liner are anticipated to be minimal. However, i disruption of the liner does occur over long-term periods, the contoured clay layer in the cap and the climatic condition of net evaporation will reduce available water for percolation and seepage to a minimum.

Table 3.1 Complete list of failure modes considered in assessment of long-term stability. (Ref. 13)

A. Failure Modes Associated with Impoundment Elements

1. CAP

   a) Differential settlement
   b) Gullying
   c) Water sheet erosion
   d) Wind erosion
   e) Flooding
   f) Chemical attack
   g) Shrinkage

2. LINERS

   a) Differential settlement
   b) Subsidence of subsoil and rock
   c) Chemical attack
   d) Physical penetration

3. EMBANKMENT

   a) Differential settlement
   b) Slope failure
   c) Gullying
   d) Water sheet erosion
   e) Wind erosion
   f) Flooding
   g) Weathering and chemical attack

4. REVEGETATION

   a) Fire
   b) Climatic Change

5. WATER DIVERSION STRUCTURES

   a) Slope failure
   b) Obstruction

B. Failure Modes Associated with Natural Phenomena

1. Earthquakes
2. Floods
3. Windstorms
4. Tornados
5. Glaciation
6. Fire and pestilence

The applicant reports that the reclaimed area will be seeded and fertilized to stabilize the cover. However, due to the nature of the sand and gravel cap materials, the lack of a topsoil layer, and the low summer season precipitation, reforestation and revegetation of the cap will likely be difficult. Vegetative development may require the area to be maintained for an extended period of time. In addition, it is not known if continued growth can be assured over the long term on exposed slopes without routine maintenance. Therefore, placement of a rock cover on exposed slopes of the reclaimed area should be required.

3.2.3.2.2 Failure Modes Associated with Natural Phenomena

Since the pit is constructed below the ground surface, the potential for dispersion of the tailings due to earthquake and/or liquefaction is considered to be minimal.

The Dawn mill site lies within the drainage basin of the Chamokane Creek, the principal surface stream of Walker's Prairie basin. Although the tailings disposal site is located near the creek, the disposal site has been located upon a terrace approximately 100 feet (30 m) above the creek elevation. Since all the tailings will be disposed of below the natural ground level and covered with a 10-foot cap, adverse effects due to the flooding over long-term periods are considered to be minimal.

The effects of wind storms, tornados, glaciation, fire and pestilence were shown to be negligible in the long-term report by Nelson and Shepherd (Ref. 13).

3.2.3.2.3 Reduction of Gamma Radiation and Emanation of Radon From the Reclaimed Area

The reclamation cover proposed by Dawn was calculated by the staff to meet the tailings objectives requiring reduction of direct gamma radiation from the impoundment to essentially background and reduction of radon emanation from the impoundment area to $\sim$ twice the emanation rate in the surrounding environs.

4. RADIOLOGICAL ASSESSMENT

4.1 INTRODUCTION

This section presents the NRC staff's assessment of the incremental radiological impacts resulting from operation of the Dawn uranium mill with the proposed new below-grade tailings impoundment. Because the new impoundment is to be completely lined with an impervious synthetic membrane, no significant seepage of tailings liquids from the new impoundment is anticipated. Therefore, the proposed action which is assessed herein, that is, construction and operation of a fully lined below-grade tailings impoundment, will not result in any additional releases of radioactive materials via seepage or any other liquid pathway. Consequently, liquid pathways are not considered within this section. Impacts and problems associated with continuing seepage from the present above-grade impoundments will be addressed in detail in connection with the presently pending license renewal. Accordingly, this assessment addresses only airborne radioactive effluents from the Dawn project.

Major components of the staff's evaluation documented here have included detailed assessments of the following: (1) annual releases of airborne radioactive materials from the mill and all tailings storage areas; (2) resulting incremental radioactivity concentrations in air and in other environmental media; and (3) resulting incremental radiation dose commitments to individuals and populations. The calculated results are compared to natural background radiation exposures and applicable regulatory limits. All potential airborne exposure pathways likely to contribute a significant fraction of total exposures have been included in the analysis. Dose commitments resulting from all releases, both with and without the new impoundment, are presented and discussed.

As a predictive calculational analysis, the results of this evaluation are dependent upon, and sensitive to, values chosen for the many necessary input parameters. Changes in input parameter values used in this assessment would necessarily result in changes to the calculated results. Significant modifications to the Dawn facility's design or mode of operation, which would affect the assumptions made here concerning effluent releases, would necessitate a revised analysis to confirm or revise the conclusions drawn here. Additionally, as a complex predictive mathematical analysis, results presented here have inherent levels of uncertainty which are difficult to quantify. Such results must be adequately supported by empirical data obtained through site-specific effluent and environmental monitoring programs before a high degree of confidence can be established.

4.2 ESTIMATED RADIOACTIVITY RELEASES

This assessment is based on an evaluation of radioactivity releases from the various components of the entire Dawn facility during the final year of operation of the new below-grade tailings impoundment. Incremental annual dose commitments due to releases from operation of the new impoundment will be highest during this year. The basic information, data, and assumptions used to estimate radioactivity releases are summarized in Table 4.1. The estimated release rates by facility component are presented in Table 4.2. Further, more-detailed information pertaining to the evaluation of radioactivity releases is provided in Appendices A and B.

Release rates presented in Table 4.2 are based on the assumption that the presently active impoundment will be covered with wood chips after the new impoundment becomes operational, thus reducing potential particulate releases from this source by 97 percent (wood chips have been applied to the abandoned impoundment areas by the mill operator already). It is also assumed that particulate emissions from the new impoundment will be controlled by water cover, chemical stabilization, or other means, such that 80 percent of potential releases will be abated. On this basis, and with the mill itself still in operation, the new impoundment contributes the following fractions of total facility emissions: less than 4 percent of total uranium; 27 to 28 percent of total thorium, radium, and lead; and 11 percent of total radon.

4.3 EXPOSURE PATHWAYS

Potential environmental pathways by which people could be exposed to radioactive materials resulting from the project are presented schematically in Figure 4.1. The pathways of concern for the airborne effluents include inhalation of radioactive materials in the air, external exposure to radioactive materials in the air or deposited on ground surfaces, and ingestion of contaminated food products (that is, vegetables and meat).

There will be no planned or routine releases of radioactive waste materials directly into surface waters. The proposed tailings area floor and side slopes will be completely lined with a synthetic membrane liner and, therefore, no seepage to groundwater is anticipated. There is, however, seepage of radioactive liquids from the existing above-grade tailings impoundment and the existing groundwater situation will be evaluated in detail in connection with the pending license renewal for the entire facility.

4.4 RADIATION DOSE COMMITMENTS TO INDIVIDUALS

The radiation dose at a reference point depends on the distance and direction of the point with respect to the sources. The dose decreases with distance as the radioactive particulates are dispersed and depleted by deposition, and their concentration decreases. The direction of the reference point with respect to the mill is important because the average concentration of particulates is higher downwind. Prevailing winds in the site vicinity are out of the SSW and SW sectors (see Table 2.1).

The residence closest to the Dawn site is 0.42 miles (0.68 km) southeast of the mill and the nearest residence in the prevailing wind directing is 0.81 miles (1.3 km) ENE of the mill. In addition, the applicant has reported the presence of a nearby vegetable garden (0.5 km ESE) and a nearby workshop (0.6 km NNE). The staff understands that private residences are also located near, but not at, these latter two locations.

Table 4.1 Principal parameter values used in the radiological assessment of the Dawn Mining Company uranium project

Parameter	Value(s)*
A. General Data	
Average ore grade, % U_3O_8	0.153
Ore concentration, pCi/g U-238 and daughters	432.0
Ore processing rate, MT/d	430.0
Days/yr operational	346
B. Ore Storage Pile(s)	
Actual area, acres	13.6
Annual average dust loss rate, g/m^2-yr	42.0
Dust/ore activity ratio	2.5
Reduction factor for chemical spraying and wetting, %	50.0
Release rate for truck dumping and ore pad activities, %	7.5×10^{-3}
Specific Rn-222 flux from ore piles, $\frac{pCi/m^2\text{-sec}}{pCi/gm\ Ra\text{-}226}$	1.0
C. Hoppers and Feeders	
Release rate for ore feeding, %	0.01
Dust/ore activity ratio	2.5
Reduction factor for dust control, %	50%
Fraction of Rn-222 equilibrium ore content released, %	20.0
D. Crushing and Grinding	
Release rate for crushing and grinding, %	0.01
Efficiency of particulate loss control, %	99.0
Dust/ore activity ratio	2.5
Fraction of Rn-222 equilibrium oil content released, %	20.0
E. Fine Ore Storage	
Release rate for fine ore activities, %	0.015
Efficiency of particulate loss control, %	80.0
Dust/ore activity ratio	2.5
Fraction of Rn-222 equilibrium ore content released, %	20.0

Table 4.1 (Continued)

Parameter	Value(s)*
F. Yellowcake Drying and Packaging	
Yellowcake production rate, MT/year	206.3
Release rate of yellowcake product to atmosphere, %	4.85×10^{-3}
Yellowcake fraction of U-238, %	90.8
Yellowcake fraction of Th-230, %	0.5
Yellowcake fraction of Pb-210, %	0.1
Yellowcake fraction of Ra-226, %	0.1
Yellowcake purity, %	79.0
E. Tailings Impoundment System	
General parameters	
Fraction U to tailings, %	9.2
Fraction Th to tailings, %	95.0
Fraction Ra and Pb to tailings, %	99.8
Annual average dust loss rate, g/m^2-yr	420.0
Dust/tails activity ratio	2.5
Dusting reduction factor for water cover, moisture, and chemical agents, %	80.0
Specific Rn-222 flux from exposed beach, $\frac{pCi/m^2\text{-sec Rn-222}}{pCi/g\text{ Ra-226}}$	1.0
Abandoned tailings impoundment	
Total area, acres	59.2
Area exposed to dusting, %	1.0-3.0
Tailings activities, pCi/gm	
U-238	62.1
Th-230	641.2
Ra-226	673.6
Pb-210	673.6
Present Tailings Impoundment	
Total area, acres	47.0
Area exposed to dusting, %	90.0
Reduction factor of dust loss by chemical stabilization and wetting, %	80.0
Tailings activities, pCi/gm	
U-238	62.1
Th-230	641.2
Ra-226	673.6
Pb-210	673.6

Table 4.1 (Continued)

Parameter	Value(s)*
Future tailings impoundment	
Total area, acres	27.2
Reduction factor of dust loss by water cover, chemical stabilization, %	80.0
Tailings activities, pCi/gm	
U-238	39.8
Th-230	410.4
Ra-226	431.2
Pb-210	431.2

*Parameter values presented here are those selected by the NRC staff for use in its radiological impact assessment of the Dawn Mining Company uranium mill project. In instances where available data have been insufficient and/or not specific, reasonably conservative estimates have been made.

Table 4.2 Estimated annual releases of radioactive materials resulting from the Dawn Mining Company uranium project*

Release source	Annual releases, Curie/year**				
	U-238	Th-230	Ra-226	Pb-210	Rn-222
Ore storage	7.30E-03	7.30E-03	7.30E-03	7.30E-03	7.48E+02
Hopper and feeders	8.00E-03	8.00E-03	8.00E-03	8.00E-03	1.28E+01
Grinding and crushing	1.60E-04	1.60E-04	1.60E-04	1.60E-04	1.28E+01
Fine ore storage	4.80E-03	4.80E-03	4.80E-03	4.80E-03	1.28E+01
Yellowcake stacks	2.23E-03	1.12E-05	2.23E-06	2.23E-06	0.0
Tailings impoundments					
Abandoned pile	1.56E-04	1.61E-03	1.69E-03	1.69E-03	5.11E+03
Present pile	3.71E-04	3.83E-03	4.03E-03	4.03E-03	4.05E+03
Future pile	9.20E-04	9.48E-03	9.96E-03	9.96E-03	1.23E+03

*Releases are based on the projected operations for the final year of mill operation (1990).

**Releases of all other isotopes in the U-238 decay series are also included in the radiological impact analysis. These releases are assumed to be identical to those presented here for parent isotopes. For instance, the release rate of U-234 is taken to be identical to that for U-238. Release rates of Pb-210 and Po-210 are assumed equal to that given for Ra-226.

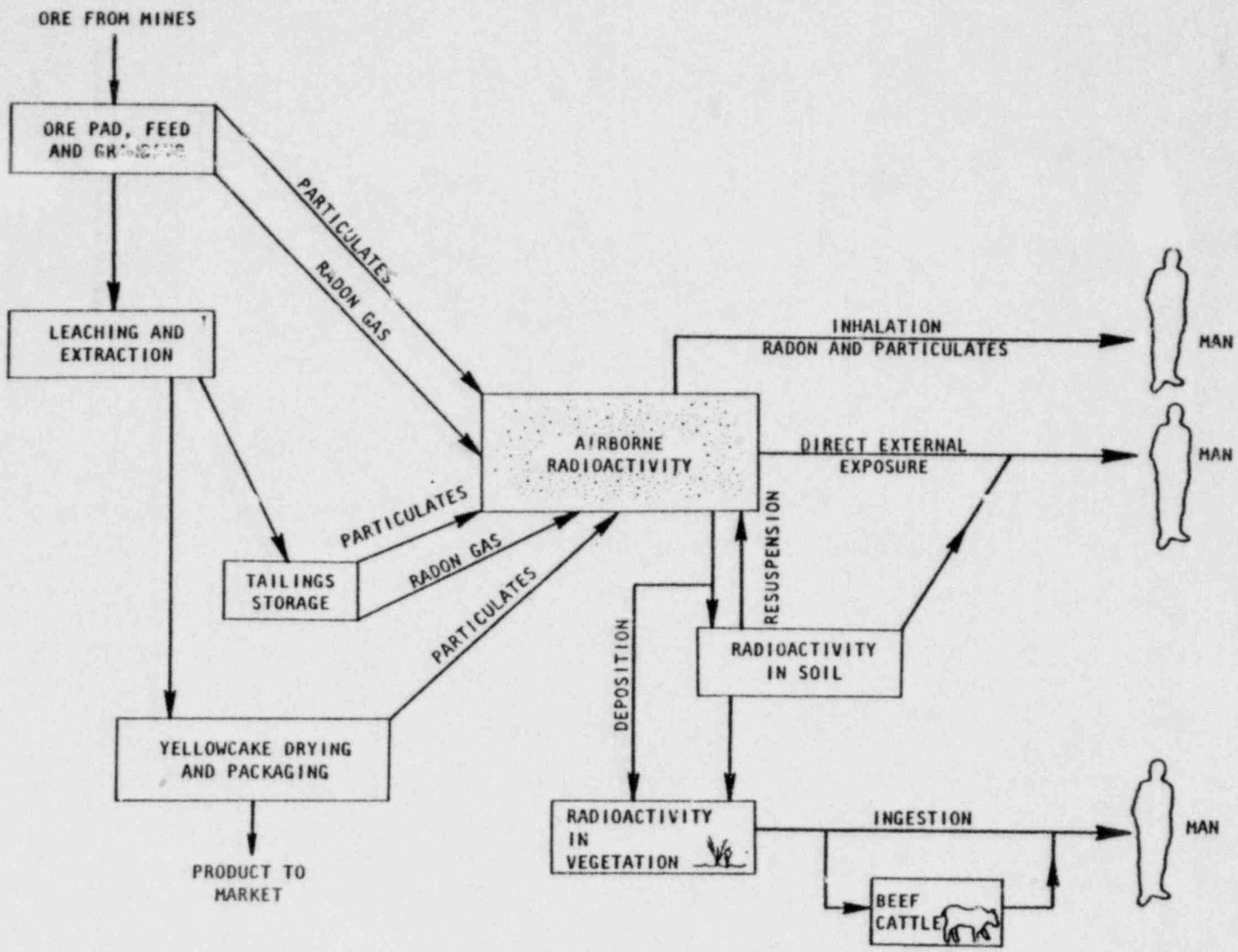


Fig. 4.1 Sources of Radioactive Effluents from the Mill and Exposure Pathways to Man

Table 4.3 presents the calculated annual dose commitments received by people living at these locations, as well as those at Ford, the nearest town. For each of these locations, it was assumed that individuals would have access to and consume as part of their normal diet, beef fed by grazing in an area centered approximately 0.6 km NE of the mill. Also, the milk pathway was conservatively assumed to exist at each location although it is not known whether or not that is the case.

4.5 RADIATION DOSE COMMITMENTS TO POPULATIONS

The annual 100-year environmental dose commitments received by the (regional) population within 50 miles (80 km) of the site are presented in Table 4.4. The projected population distribution data (Table 4.5), based on the year 1990, were used to do the estimation.

Releases of radon gas yield radiological impacts which occur over a range of thousands of miles from a release source. Impacts of radon releases from the facility that occur within 50 miles (20 km) of the site have been included in the tabulation of the regional population dose commitments (Table 4.4). Transcontinental radon-222 impacts have also been evaluated. Table 4.6 includes total environmental dose commitments received by both regional and extra-regional populations. A grand total of 100-year environmental dose commitments received by all populations is also presented.

4.6 EVALUATION OF COMPLIANCE WITH REGULATORY LIMITS

Dose commitments to individuals at the locations noted in Section 4.4 were calculated for the purpose of evaluating compliance with the limits specified by the U.S. Environmental Protection Agency's (EPA) 40 CFR Part 190, "Radiation Protection Standards for Normal Operations of the Uranium Fuel Cycle," which will be effective for uranium milling operations in December 1980. Under 40 CFR Part 190, total doses to any organ of an offsite individual are limited to 25 millirems/year, excluding contributions from radon-222 and its radioactive daughters. Table 4.7 provides a comparison of the calculated dose commitments to individuals with the 40 CFR Part 190 limits. Doses in this table are lower than total doses (Table 4.3) because contributions from radon-222 and its daughters have been omitted.

As indicated in Table 4.7, maximum individual doses at the "nearest residence" and "nearest residence in the prevailing wind direction" locations are computed to be within EPA limits. However, maximum individual doses computed for the "garden" and workshop" locations are above the 25 mrem per year limit. It is not clear to the staff whether or not individuals actually live at or near the garden or workshop, or whether or not, and to what extent, the various food ingestion pathways assumed here actually exist. From the analysis performed, however, it can be concluded that construction and operation of the new impoundment will have very little bearing on the issue of overall site compliance with 40 CFR Part 190.

Under 10 CFR Part 20, air concentrations in unrestricted areas are limited to maximum permissible concentrations (MPCs). Table 4.8 presents the results of

Table 4.3 Annual Dose Commitments to Individuals in the Vicinity of the Dawn Mining Company Uranium Mill (mrem/years)

Location	Exposure Pathway[a]	Whole Body		Bone		Lung		Bronchial Epithelium	
		Present[d]	Expanded[e]	Present	Expanded	Present	Expanded	Present	Expanded
Nearest resident, 0.7 km SE	Inhalation[b]	0.07	0.08	1.97	2.29	3.25	3.54	316.	340.
	External ground	1.57	1.76	1.57	1.76	1.57	1.76	1.57	1.76
	External cloud	0.46	0.52	0.46	0.52	0.46	0.52	0.46	0.52
	Ingestion								
	Vegetable	0.26	0.38	2.98	4.46	0.26	0.38	0.26	0.38
	Meat[c]	0.42	0.46	5.20	5.75	0.42	0.46	0.42	0.46
	Milk	0.06	0.09	0.65	0.97	0.06	0.09	0.06	0.09
	Total	2.84	3.29	12.8	15.8	6.02	6.75	319.	343.
Nearest resident in prevailing wind direction, 1.3 km ENE	Inhalation[b]	0.10	0.11	2.84	3.10	4.77	5.01	155.	167.
	External ground	1.73	1.88	1.73	1.88	1.73	1.88	1.73	1.88
	External cloud	0.55	0.61	0.55	0.61	0.55	0.61	0.55	0.61
	Ingestion								
	Vegetable	0.31	0.41	3.74	4.88	0.31	0.41	0.31	0.41
	Meat[c]	0.42	0.46	5.20	5.75	0.42	0.46	0.42	0.46
	Milk	0.08	0.10	0.81	1.06	0.08	0.10	0.08	0.10
	Total	3.19	3.57	14.9	17.3	7.86	8.47	158.	170.
Garden 0.5 km ESE	Inhalation[b]	0.25	0.27	7.37	7.98	12.1	12.6	506.	534.
	External ground	4.72	5.08	4.72	5.08	4.72	5.08	4.72	5.08
	External cloud	0.60	0.68	0.60	0.68	0.60	0.68	0.60	0.68
	Ingestion								
	Vegetable	0.92	1.16	11.0	13.8	0.92	1.16	0.92	1.16
	Meat[c]	0.42	0.46	5.20	5.75	0.42	0.46	0.42	0.46
	Milk	0.23	0.29	2.39	3.00	0.23	0.29	0.23	0.29
	Total	7.14	7.94	31.3	36.3	19.0	20.3	513.	542.
Fence Post Workshop 0.6 km NNE	Inhalation[b]	0.65	0.68	19.9	20.6	32.9	33.5	260.	280
	External ground	10.7	11.1	10.7	11.1	10.7	11.1	10.7	11.1
	External cloud	0.33	0.38	0.33	0.38	0.33	0.38	0.33	0.38
	Ingestion								
	Vegetable	2.20	2.47	26.3	29.5	2.20	2.47	2.20	2.47
	Meat[c]	0.42	0.46	5.20	5.75	0.42	0.46	0.42	0.46
	Milk	0.54	0.61	5.73	6.42	0.54	0.61	0.54	0.61
	Total	14.8	15.7	68.2	73.8	47.1	48.5	274.	295.
Nearest town, Ford, 2.3 km E	Inhalation[b]	0.02	0.02	0.61	0.69	1.00	1.08	64.2	70.6
	External ground	0.43	0.47	0.43	0.47	0.43	0.47	0.43	0.47
	External cloud	0.39	0.44	0.39	0.44	0.39	0.44	0.39	0.44
	Ingestion								
	Vegetable	0.07	0.10	0.82	1.17	0.07	0.10	0.07	0.10
	Meat[c]	0.42	0.46	5.20	5.75	0.42	0.46	0.42	0.46
	Milk	0.02	0.02	0.18	0.25	0.02	0.02	0.02	0.02
	Total	1.35	1.51	7.63	8.77	2.33	2.57	65.5	72.1

[a] Doses are integrated over a 50-year period from one year of inhalation or ingestion.

[b] Doses to the whole body, lungs, and bone are those resulting from the inhalation of particulates of U-238, U-234, Th-230, Ra-226, Pb-210, and Po-210. Doses to the bronchial epithelium are those resulting from the inhalation of radon daughters.

[c] Ingestion doses result from the consumption of the meat of cattle grazing 0.6 km NE of the mill.

[d] Without new impoundment.

[e] With new impoundment.

Table 4.4 Annual environmental dose commitments to regional population within 50-mile radius resulting from the operation of the Dawn Mining Company uranium mill

	Annual Environmental Dose Commitments (EDC), person-rem/year*							
	Whole Body		Bone		Lung		Bronchial epithelium**	
Exposure Pathway	Present†	Expanded††	Present	Expanded	Present	Expanded	Present	Expanded
Inhalation	0.18	0.21	5.72	6.38	3.23	3.47	307.0	346.0
External from ground	0.69	0.90	0.69	0.90	0.69	0.90	0.69	0.90
External from cloud	4.78	5.37	4.78	5.37	4.78	5.37	4.78	5.37
Vegetable ingestion	4.27	5.32	76.1	91.5	4.27	5.32	4.27	5.32
Meat ingestion	0.15	0.18	2.91	3.46	0.15	0.18	0.15	0.18
Milk ingestion	0.23	0.31	3.05	3.91	0.23	0.31	0.23	0.31
Total	10.3	12.3	93.3	112.0	13.4	15.6	317.0	358.0
Estimated population dose from natural background	53,849	53,849	70,650	70,650	54,280	54,280	241,242	241,242
Ratio of total annual regional population dose to that from natural background***	0.0002	0.0002	0.0013	0.0016	0.0002	0.0003	0.0013	0.0015

*Doses to the whole body, lung, and bone are those resulting from the releases of particulates of U-238, U-234, Th-230, Ra-226, and Pb-210.

**Inhalation doses to the bronchial epithelium are those resulting from the inhalation of radon daughters.

***Background doses are based on the regional population size of 430,790 and background radiation doses presented in Reference 32.

†Without new impoundment.

††With new impoundment.

Table 4.5 Projected 1990 Population Distribution--50-Mile Radius of the Dawn Mining Company Mill

KILOMETERS	N 0.0	NNE 22.5	NE 45.0	ENE 67.5	E 90.0	ESE 112.5	SE 135.0	SSE 157.5	S 180.0	SSW 202.5	SW 225.0	WSW 247.5	W 270.0	WNW 292.5	NW 315.0	NNW 337.5
1.0- 2.0	3	3	10	10	3	6	5	5	10	5	5	0	0	5	10	10
2.0- 3.0	5	3	16	16	5	10	10	10	10	10	5	5	10	5	10	5
3.0- 4.0	5	10	16	21	5	26	16	16	21	10	5	5	10	5	5	5
4.0- 5.0	5	16	16	16	5	31	21	21	21	10	5	5	16	10	10	5
5.0-10.0	52	52	31	26	52	52	31	31	21	52	16	16	21	10	10	10
10.0-20.0	52	105	52	210	105	52	52	31	52	52	21	52	441	52	21	21
20.0-30.0	105	278	52	970	970	1259	210	52	540	52	21	52	52	21	37	10
30.0-40.0	53	53	53	319	6482	9668	15193	14044	159	159	53	21	53	32	159	11
40.0-50.0	2242	11	11	319	3299	36614	187655	8050	159	159	1699	53	27	21	11	11
50.0-60.0	106	11	11	319	319	93360	10407	7551	159	53	212	382	27	11	11	11
60.0-70.0	106	11	377	2273	106	3186	1062	262	159	32	552	159	106	11	11	11
70.0-80.0	5236	11	11	1989	2210	2989	658	212	584	32	53	1179	212	11	11	11
1.0-80.0	7970	564	656	6488	135[illegible]	147253	215320	30285	1895	626	2647	1929	975	194	306	121

TOTAL 1-80 KM POPULATION IS 430790 PERSONS

Table 4.6 Annual environmental dose commitments to continental populations from the operation of the Dawn Mining Company uranium mill

	Total Environmental Dose Commitments (EDC), Person-rem/year							
	Whole body		Bone		Lung		Bronchial epithelium	
	Present†	Expanded††	Present	Expanded	Present	Expanded	Present	Expanded
EDC's received by the population within 80 km of the mill	10.3	12.3	93.3	112.	13.4	15.6	317.	358.
EDC's received by the population beyond 80 km of the mill	102.	116.	1387.	1564.	22.3	25.5	478.	538.
Total EDC's received by the continental populations	112.	128.	1480.	1675.	35.7	41.0	795.	896.
Fraction of background*	3.06E-06**	3.49E-06	4.04E-05	4.57E-05	9.74E-07	1.12E-06	4.34E-06	4.89E-06

*Background values estimated on the basis of year 1990 continental population of 366.4 million people, each person receiving 100 millirem/year to the whole body, bone, and lung and 500 millirem/year to the bronchial epithelium.

**The notation 3.06E-06 denotes 3.06×10^{-6}.

†Without new impoundment.

††With new impoundment.

Table 4.7 Comparison of annual dose commitments to individuals with EPA radiation protection standards (40 CFR 190)*

Location	Exposure Pathway	Calculated annual dose commitment (mrem/year)					
		Whole body		Bone		Lung	
		Present	Expanded	Present	Expanded	Present	Expanded
Nearest resident 0.7 km SE	Inhalation	0.07	0.08	1.97	2.29	3.26	3.54
	External exposure	0.04	0.04	0.04	0.04	0.04	0.04
	Ingestion						
	Vegetable	0.25	0.38	2.98	4.46	0.25	0.38
	Meat**	0.42	0.46	5.20	5.75	0.42	0.46
	Milk	0.09	0.09	0.65	0.97	0.09	0.09
	Total	0.87	1.05	10.8	13.5	4.06	4.51
	EPA limit	25.0	25.0	25.0	25.0	25.0	25.0
	Fractional limit	0.03	0.04	0.43	0.54	0.16	0.18
Nearest resident in the prevailing wind 1.3 km ENE	Inhalation	0.09	0.10	2.83	3.09	4.76	5.00
	External exposure	0.04	0.05	0.04	0.05	0.04	0.05
	Ingestion						
	Vegetable	0.31	0.41	3.73	4.87	0.31	0.41
	Meat**	0.42	0.46	5.20	5.75	0.42	0.46
	Milk	0.08	0.10	0.82	1.06	0.08	0.10
	Total	0.94	1.12	12.6	14.8	5.61	6.02
	EPA limit	25.0	25.0	25.0	25.0	25.0	25.0
	Fraction of limit	0.04	0.04	0.50	0.59	0.22	0.24
Garden 0.5 km ESE	Inhalation	0.25	0.27	7.37	7.98	12.1	12.6
	External exposure	0.12	0.13	0.12	0.13	0.12	0.13
	Ingestion						
	Vegetable	0.92	1.16	11.4	13.8	0.92	1.16
	Meat**	0.42	0.46	5.20	5.75	0.42	0.46
	Milk	0.23	0.29	2.39	3.00	0.23	0.29
	Total	1.94	2.31	26.5	30.7	13.8	14.6
	EPA limit	25.0	25.0	25.0	25.0	25.0	25.0
	Fraction of limit	0.08	0.09	1.06	1.23	0.55	0.58
Fence Post Workshop 0.6Km NNE	Inhalation	0.66	0.68	19.9	20.6	3.29	33.5
	External exposure	0.29	0.30	0.29	0.30	0.29	0.30
	Ingestion						
	Vegetable	2.20	2.47	26.3	29.5	2.20	2.47
	Meat**	0.42	0.46	5.20	5.75	0.42	0.46
	Milk	0.35	0.61	5.73	6.42	0.55	0.61
	Total	4.12	4.52	57.4	62.6	36.4	37.3
	EPA limit	25.0	25.0	25.0	25.0	25.0	25.0
	Fraction of limit	0.16	0.18	2.30	2.50	1.46	1.49
Nearest town, Ford, 2.3 KmE	Inhalation	0.02	0.02	0.59	0.68	1.[illegible]	1.08
	External exposure	0.01	0.01	0.01	0.01	0.01	0.01
	Ingestion						
	Vegetable	0.07	0.10	0.82	1.16	0.07	0.10
	Meat**	0.42	0.46	5.20	5.75	0.42	0.46
	Milk	0.02	0.02	0.18	0.25	0.02	0.02
	Total	0.54	0.61	6.80	7.85	1.52	1.67
	EPA limit	25.0	25.0	25.0	25.0	25.0	25.0
	Fraction of limit	0.02	0.02	0.27	0.31	0.06	0.07

*40 CFR Part 190 specifically excludes any doses and dose commitments arising from the releases of radon and daughters.

**Meat ingestion doses result from consumption of meat from cattle grazed 0.6 km NE of the mill site.

†Without new impoundment.

††With new impoundment.

the staff's evaluation of compliance with 10 CFR Part 20 for calculated annual average air concentrations for selected restricted area boundary locations. As indicated by the results presented in Table 4.8, there does not appear to be any problem in meeting the MPC limits specified in 10 CFR Part 20. In addition to the locations evaluated in Table 4.8, other locations along the restricted area boundary were evaluated but were found to have lower computed average air concentrations. In all cases, the incremental air concentration increases due to releases from the new impoundment were inconsequential.

4.7 OCCUPATIONAL RADIATION EXPOSURE

Uranium mills are designed, built, and operated to minimize exposure of both the mill workers and the general public to radiation. Occupational exposures for workers are required to be monitored and kept below regulatory limits. In addition, protection measures to reduce occupational exposures are periodically reviewed and revised in accordance with the requirement to make such exposures as low as is reasonably achievable.

The scope of this NRC staff review has not included a review of the inplant radiological safety program proposed for the mill. However, occupational exposures can be characterized in general terms. Special studies at selected mills have shown that the exposures of mill workers to airborne radioactivity are normally below 25 percent of the maximum permissible concentrations given in Appendix B of 10 CFR Part 20 and that external exposures are normally less than 25 percent of 10 CFR Part 20 limits (Refs. 21 and 22). A recent review (Ref. 22) of mill exposure data by the NRC staff has indicated that only a few uranium mill employees may have exceeded, over a one-year period, 15 to 20 percent of the permissible exposure to ore dust, 25 percent of the permissible exposure to yellowcake, or 10 percent of the permissible exposure to radon concentrations. Except for a few individuals, the combined exposure of an average worker to these radioactive components over a one-year period probably does not exceed 25 percent of the total permissible exposure.

With respect to the operation of the new tailings impoundment, such operation will yield marginal increases in onsite ambient air concentrations of radon and radioactive particulates. However, such increases will be generally insignificant in comparison to existing air concentrations and will not present a problem in maintaining occupational exposures within acceptable limits.

4.8 RADIOLOGICAL IMPACT ON BIOTA OTHER THAN MAN

Although no guidelines concerning acceptable limits of radiation exposure have been established for the protection of species other than man, it is generally agreed that the limits for humans are also conservative for those species (Refs. 23-30). Doses from gaseous effluents to terrestrial biota (such as birds and mammals) are quite similar to those calculated for man and arise from the same dispersion pathways and considerations. Because the effluents of the mill will be monitored and maintained within safe radiological protection limits for man, no adverse radiological impact is expected for resident biota.

The staff considers that operation of the new impoundment will not significantly increase either the magnitude or variety of radiological impacts to biota resulting from operation of the Dawn facility as a whole.

Table 4.8 Comparisons of air concentrations during mill generation with 10 CFR Part 20 limits for unrestricted areas

	Total air concentrations, pCi/m³, of radionuclides											
	U-238		U-234		Th-230		Ra-226		Pb-210		W L* Concentration	
10 CFR Part 20 limits**	5.00E-00		4.00E+00		8.00E-02		2.00E+00		4.00E+00		3.33E-02	
Predicted values:	Present	Expanded	Present	Expanded	Present	Expanded	Present	Expanded	Present	Expanded	Present	Expanded
Restricted area boundary (0.3 km NE)	3.43E-02***	3.43E-02	3.43E-02	3.43E-02	3.42E-02	3.45E-02	3.42E-02	3.45E-02	3.42E-02	3.45E-02	1.55E-03	1.69E-03
Fraction of limit	6.86E-03	6.86E-03	8.58E-03	8.58E-03	4.28E-01	4.32E-02	1.71E-02	1.73E-02	8.55E-03	8.62E-03	4.65E-02	5.08E-02
Restricted area boundary (0.1 km N)	2.34E-02	2.34E-02	2.34E-02	2.34E-02	2.36E-02	2.40E-02	2.36E-02	2.40E-02	2.36E-02	2.40E-02	1.74E-03	1.90E-03
Fraction of limit	4.67E-03	4.67E-03	5.84E-03	5.84E-03	2.95E-01	3.00E-01	1.18E-02	1.20E-02	5.90E-03	6.00E-03	5.23E-02	5.69E-02
Restricted area boundary (0.2 km W)	1.52E-02	1.52E-02	1.52E-02	1.52E-02	1.55E-02	1.60E-02	1.56E-02	1.61E-02	1.55E-02	1.60E-02	2.35E-03	2.53E-03
Fraction of limit	3.04E-03	3.04E-03	3.80E-03	3.80E-03	1.94E-01	2.00E-01	7.80E-03	8.03E-03	3.88E-03	4.01E-03	7.06E-02	7.61E-02

*WL denotes "working level." A one-WL concentration is defined to be any combination of air concentrations of the short lived Rn-222 daughters Po-218, Pb-214, Bi-214, and Po-214 that, in one liter of air, will yield a total of 1.3×10^5 Mev of alpha particle energy in their complete decay to Pb-210. Predicted values given for outdoor air are those calculated on the basis of actual ingrowth from released Rn-222.

**Values given are from 10 CFR Part 20, Appendix B, Table II, Column 1.

***The notation 3.43E-02 denotes 3.43×10^{-2}.

4.9 SUMMARY OF RADIOLOGICAL IMPACTS AND CONCLUSIONS

On the basis of this predictive analysis, which is based on reasonably conservative assumptions, it appears likely that the Dawn facility can operate in compliance with 40 CFR Part 190 if there are no private residences in the immediate areas of the mill complex (for example, at the "garden" and "fence post workshop" locations). A definite determination of actual residences must be made in the immediate future. In addition, the dose estimates reported herein must be verified by empirical data obtained through detailed effluent and environmental monitoring programs such as are specified in USNRC Regulatory Guide 4.14, "Radiological Effluent and Environmental Monitoring at Uranium Mills" (issued as Revision 1, April 25, 1980). Therefore, it is recommended that such a monitoring program be instituted promptly, if not already in place. The monitoring program should be comprehensive in scope and should be capable of providing conclusive evaluations of 40 CFR Part 190 compliance; a quality assurance program satisfying the guidelines of USNRC Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment," (issued as Revision 1, February 1979) should be implemented. Because 40 CFR Part 190 compliance is so obviously and strongly coupled with land use and demography in the immediate site area, the mill operator should be required by license condition to conduct an annual survey of land use (grazing, inhabited structures, wells, etc.) in the area within about 2.5 miles (4 km) of the mill, and submit a written report to the state. In view of the uncertainty of the present land use characteristics, and the imminent effective date of 40 CFR 190, the first such survey should be conducted immediately.

Also, because compliance with 40 CFR Part 190 must be assured, and because all radioactive emissions should be kept as low as practicable in any event, the mill operator should be required by license condition to keep all effluent control equipment in good working order and in use at all times during mill operation. This is particularly necessary with respect to yellowcake emission control devices since uncontrolled yellowcake emissions can yield high exposures, relative to the 25 mrem per year limit, in very short time periods, especially in the presence of unfavorable meteorology. Frequent checks of yellowcake stack emission control devices should be required.

The staff's analysis of 40 CFR Part 190 compliance has assumed that the presently active tailings impoundment will be decommissioned and promptly treated so as to reach a high degree of control (97 percent) of potential particulate emissions from that source. Should that not be the case, the staff's evaluation indicates 40 CFR Part 190 compliance would be doubtful. Therefore, the mill operator should be required by license condition to take appropriate actions to control particulate dusting from the present impoundment by any available means to levels which are as low as practicable. Exposed tailings beaches should be kept moist, treated with chemical stabilizers, or covered with wood chips at all times so as to prevent the unnecessary blowing of particulate tailings debris. Similar control should be exercised with respect to the abandoned tailings areas and the new impoundment so as to keep releases of particulates from these sources as low as practicable.

5. ENVIRONMENTAL EFFECTS OF ACCIDENTS

The occurrence of accidents can be minimized through proper design, construction, and operation as well as a quality assurance program designed to establish and maintain safe operations. The applicant has submitted an environmental impact statement and plans for the design and construction of a below-grade pit. These submittals have been reviewed by the NRC staff to ensure that there is a basis for safe operation. Moreover, the state of Washington will maintain surveillance over the plant by conducting periodic inspections of the facility and by requiring reports of effluent releases and deviations from normal operations.

Notwithstanding the above safeguards, accidents involving the release of radioactive materials or harmful chemicals have occurred in uranium milling operations. Therefore, in this assessment, accidents which might occur during operation of the proposed impoundment have been postulated and their potential environmental impacts evaluated.

Inadvertent release of the tailings solution to the environment could result from an overflow, a rupture in the tailings distribution piping, or a failure of the pit side slopes resulting in liner damage and/or failure of the existing impoundment (deep-seated failure of the north slope). Failure of the side slopes could be attributed to a destructive earthquake or structural failure. Release of tailings due to a failure in the embankment around the pit will be essentially precluded since the operating level of ponded tailings will be at the natural ground level.

The below-grade pit could overflow only if the pit was left unattended for several weeks. The required 5-foot (1.5-m) freeboard of the pit is more than adequate to contain the design flood (see Section 3.2.1.6.2).

An analysis by the applicant's consultants concluded that the side slopes would be stable under both static and earthquake conditions, meeting the minimum factors of safety prescribed in NRC Regulatory Guide 3.11 (Ref. 7). Before issuing concurrence with the results, the NRC staff has recommended submittal of additional analyses (see Section 3.2.1.1). However, no approval for the pit will be considered until this issue is resolved and it is shown that the design meets the criteria prescribed in NRC R.G. 3.11. Even if a side slope failure occurred, however, the majority of tailings released from the existing impoundment would probably flow into the excavated pit. As the pit is filled with tailings from normal operations, the weight of the tailings against the side slope should preclude any possiblity of a slope failure.

Based on the above discussions, the only probable failure that would result in significant offsite releases would be a break in the tailings distribution piping resulting in a release of slurry.

It is not possible to predict the probability of a pipeline failure specific to the Dawn mill with a reasonable degree of accuracy. Even if the frequency of such an event were known accurately, it would be difficult to predict the magnitude of the release of tailings slurry or solution. However, tailings releases have occurred in the past, and the data from these releases may provide a conservative indication of the expected consequences of dam and pipeline failure. A summary of incidents recorded for the period 1959-1979 is presented in Table 5.1.

Based on these historical data, the average release from tailings dam failure or flooding for ten incidents was approximately 1.4×10^7 gal (5.5×10^7 L) of liquids and 3.0×10^7 lb (1.5×10^7 kg) of solids. Pipeline failures resulted in an average release of about 9.2×10^5 gal (3.5×10^6 L) of liquids and 1.8×10^7 lb (8.2×10^6 kg) of solids.

Six out of ten releases involving dam failure or flooding reached the watercourse, and five out of seven releases from pipeline failures reached the watercourse. However, most failures in the tailings distribution piping would result in release of the slurry to the tailings pond and not to the environment. Since many of these dikes and pipeline distribution systems were poorly constructed and current impoundments have more stringent design requirements, the probability and magnitude of past releases should overestimate any future accidental releases.

The average concentrations of radionuclides in the tailings solution, as measured by the applicant, are compared with applicable standards in Table 5.2. In addition, dissolved minerals from the ore are found in the solution.

Any large release of tailings slurry from that portion of the tailings pipeline that is not within the tailings impoundment area, would likely reach the Chamokane Creek to the north or west. In order to preclude the occurrence of large releases from the pipeline, Dawn should be required to install an audible or visible alarm in the mill control room or office which activates automatically upon a drop in pipeline pressure. The pressure monitor should be located at the discharge point of the pipeline.

Should any release of tailings occur, it is recommended that appropriate officials of the state of Washington be informed immediately of the approximate time of the accident and be provided with estimates of the quantities of liquids and solids released.

Table 5.1. Summary of Accidental Tailings Slurry Releases, 1959-1979[a]

Mill	Year	Cause	Solids Released, lb (kg)	Liquids Released, gal (L)	Reached Watercourse
Union Carbide-Green River	1959	Flash flood	3×10^7 (14×10^6)	3×10^6 (1.2×10^7)[b]	Yes
Kerr-McGee-Shiprock	1960	Dam failure	2×10^6 (9×10^5)[b]	2×10^5 (9.1×10^5)	Yes
Union Carbide-Maybell	1961	Dam failure	1×10^6 (5×10^5)	1×10^5 (4×10^5)b	No
Mines Development, Inc.-Edgemont	1962	Dam failure	4×10^5 (2×10^5)	5×10^4 (2×10^5)b	Yes
Atlas-Zinc Minerals-Mexican Hat	1962	Pipeline failure	7×10^5 (3×10^5)	5×10^4 (2×10^5)	Yes
Utah Construction-Riverton	1963	Flooding	2×10^8 (1×10^8)[b]	2×10^7 (8.7×10^7)	Yes
VCA-Shiprock, N. M.	1966	Pipeline failure	1×10^5 (6.4×10^4)[b]	2×10^4 (6.1×10^4)	Small amount
Atlas-Moab	1967	Pipeline failure	4×10^6 (2×10^6)[b]	4×10^5 (1.7×10^6)	Yes
Climax-Grand Junction	1967	Dam failure	$2\text{-}30 \times 10^6$ ($1\text{-}14 \times 10^6$)[b]	$0.3\text{-}3 \times 10^6$ ($1\text{-}11 \times 10^6$)	Yes
Atlas-Moab	1968	Pipeline failure	2×10^5 (1×10^5)[b]	3×10^4 (1.3×10^5)	Yes
Petrotomics-Shirley Basin	1971	Dam failure	2×10^4 (9×10^3)[b]	2×10^3 (8×10^3)	No
Western Nuclear-Jeffrey City	1971	Pipeline/dam failure[c]	No quantitative information		No
UNC-Homestake Partners, Grants	1977	Pipeline failure	1×10^8 (4.5×10^7)	2.2×10^6 (8.3×10^6)	No
Western Nuclear-Jeffrey City	1977	Dam failure[d]	1.8×10^7 (8.2×10^6)[d]	2×10^6 (7.6×10^6)	No
UNC-Church Rock, New Mexico	1977	Pipeline failure	2.5×10^3 (1.1×10^3)	4×10^3 (1.5×10^4)	Yes[e]
UNC-Church Rock, New Mexico	1979	Dam failure	2.2×10^6 (9.98×10^5)	1×10^8 (3.8×10^6)	Yes

[a]From: "Environmental Survey of the Uranium Fuel Cycle," WASH-1248, U.S. Atomic Energy Commission, Fuels and Materials, Directorate of Licensing, April 1974. Updated (last four entries) through 1979 by the staff.

[b]Assuming equal weights of solids and liquids released, and density of the liquids to be approximately 1.1 kg/L (2.4 lb/gal).

[c]Occurred at the Split Rock mill in March 1971. A tailings line broke, causing the dike to fail. The accident went undetected for two hours and tailings flowed into a natural basin adjacent to the tailings pond, on WNI property.

[d]Occurred at the Split Rock mill in April 1977: assuming equal weights of solids and liquids released, and density of the liquids to be approximately 4 kg/L ([illegible] lb/gal).

[e]Approximately 80% of solids and 20% of liquids.

Table 5.2 Measured concentrations of radionuclides in the Dawn Mining Company tailings solution

Radionuclide	Concentration* μCi/mL	Maximum permissible concentration for unrestricted areas,** μCi/mL
U (nat)	0.5×10^{-5}	3.0×10^{-5}
Th-230	150×10^{-6}	2.0×10^{-6}
Ra-226	40×10^{-8}	3.0×10^{-8}

*Reference 16.

**Rules and Regulations, Title 10, Chapter I, Code of Federal Regulations, Part 20, Standards for Protection Against Radiation, U.S. Nuclear Regulatory Commission.

6.0 TAILINGS MANAGEMENT ALTERNATIVES

6.1 INTRODUCTION

Engineering techniques for controlling pollutants from tailings storage, both during operational and postoperational stages of a milling project, have been demonstrated. The unique characteristics of each mill facility must be identified and the appropriate environmental controls must be applied.

A set of tailings management performance objectives has been developed by the NRC staff against which each alternative is judged to ensure that potential public health hazards that otherwise could occur are avoided or minimized. The performance objectives are as follows:

Siting and Design

1. Locate the tailings isolation area remote from people such that population exposures would be reduced to the maximum extent reasonably achievable.

2. Locate the tailings isolation area such that disruption and dispersion by natural forces is eliminated or reduced to the maximum extent reasonably achievable.

3. Design the isolation area such that seepage of toxic materials into the groundwater system would be eliminated or reduced to the maximum extent reasonably achievable.

Operations

4. Eliminate the blowing of tailings to unrestricted areas during normal operating conditions.

Post-reclamation

5. Reduce direct gamma radiation from the impoundment area to essentially background.

6. Reduce the radon emanation rate from the impoundment area to about twice the emanation rate in the surrounding environs.

7. Eliminate the need for an ongoing monitoring and maintenance program following successful reclamation.

8. Provide surety arrangements to assure that sufficient funds are available to complete the full reclamation plan.

In the case of the Dawn Mining Company mill, the number of alternatives in engineering techniques is constrained by the fact that the mill has been operating for about 20 years and by the fact that accumulated tailings have already affected the environment.

6.2 ALTERNATIVES

6.2.1 Siting

The NRC staff does not require detailed evaluation of alternative sites for future tailings disposal at an existing mill provided that the onsite location proposed by a licensee adequately satisfies the staff's performance objectives. The use of an alternative site would not greatly reduce the environmental impacts at the present site and in addition would create more environmental impacts at a new site. In addition, locating a new tailings impoundment at the existing mill site avoids the proliferation of tailings disposal areas.

6.2.2 Design

The onsite alternatives for expansion of the tailings disposal facilities that have been evaluated by the applicant include the following:

I. Vertical additions to present impoundment dikes.

II. Construction of a new dike impoundment adjacent to existing facilities.

III. Excavation of a subgrade storage pit.

The above tailings management alternatives were evaluated by the NRC staff with respect to the performance objectives listed in Section 6.1 as well as with respect to their relative economic and environmental costs and relative levels of resource utilization.

Alternative I represents the technology that has been in general use in the uranium milling industry in the past. The technology is now being phased out for the reasons listed in the following paragraph.

The option of continued use of the impoundment was rejected for the following reasons: (1) there is uncontrolled seepage contamination migrating from the existing impoundment (2) above-grade disposal to even higher elevations would be more susceptible to blowing of particulates during operation; (3) continued disposal in the existing impoundment would result in additional seepage contamination and result in a higher above-grade mound after reclamation, thereby increasing its susceptibility to natural erosive effects over the long term. Therefore, this alternative would not satisfy the staff's performance objectives 3, 4, and 7.

Although Alternative I is initially the least expensive of the alternatives, it is probable that long-term maintenance and protection would make it the most expensive.

Alternative I meets very few of the staff's performance objectives and for these reasons must, therefore, be rejected regardless of cost.

Alternative II would require a new aboveground area and construction similar to that of Alternative I except that greater protection against ground and surface water seepage would likely be employed in a new design. This alternative would be much more susceptible to long-term erosion and dispersion of dry tailings during operation than pit disposal. Thus, this alternative does not satisfy performance objectives 2, 4, and 7 as well as Alternative III would.

Alternative III represents a more modern view on the technology of tailings disposal. The tailings are placed in a pit well below grade and safety is assured for any ordinary climatic or geological event. Seepage to surface waters is eliminated, and if, as in this case, an impermeable liner is used, penetration of pollutants to groundwater are also severely restricted. Dusting is minimized by the wind-sheltered locations of the tailings, well below ground level. On reclamation, the tailings can be covered with a thick earth and clay cover, and the final contours can blend into the natural surface contours, minimizing erosion. Thus, long-term stability would be more readily achieved, and ongoing monitoring and maintenance would be unnecessary. In addition, the material excavated from the pit can be used in reclamation of the proposed and existing tailings areas. This would eliminate the need to strip mine the materials from another source.

The prime option for the proposed tailings disposal facility as viewed by the NRC staff is placement below grade in a specially excavated, lined pit. Site conditions for which below-grade disposal might not be the most environmentally sound approach, such as a high quality groundwater formation near the surface or sound bedrock near the surface, are not present at the Dawn site. Therefore, the NRC staff agrees with the applicant's rejection of the above-grade alternatives and their decision to excavate a fully lined, below-grade pit.

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APPENDIX A CALCULATION OF SOURCE TERM

Introduction

The radiological assessment for the operation of the Dawn Mining Company uranium mill was performed using the MILDOS computer code. The input to the computer code consists of site-specific data and staff estimates of the radioactive effluents from the mill and tailings management systems. These source term calculations for the tailings impoundment are described in Appendix B. Source terms are defined as the estimated quantity of radioactivity released in a specific period of time.

The mill sources addressed in this appendix are:

1. The ore pad and its related activities.
2. Mill hoppers and feeders.
3. Grinders and crushers.
4. Fine ore storage and transfer of [illegible]
5. Yellowcake drying and packaging.

Some general parameter values which are necessary to these calculations are:

1. The annual ore processing rate is 148,500 MT/year.
2. The ratio of radioactivity in the ore dust to that of the bulk ore is 2.5.
3. The bulk ore activity for U-238, Th-230, Ra-226, and Pb-210 is 432 pCi/gm.

Ore Pad Activities

Particulate emissions from the ore pad are the result of:

1. Truck delivery of ore.
2. Ore pad handling by front-end loaders and other equipment.
3. Windblown emission.

Radon gas emissions are estimated on a specific Rn-222 flux (Ref. A.1) of

$$1.0 \ \frac{\text{pCi/m}^2\text{-sec Rn-222}}{\text{pCi/gm Ra-226}}$$

1. Truck Unloading

The release rate is estimated by the staff to be (Ref. A.2):

$$0.1 \text{ lb/ton} = 0.1/2000 = 5 \times 10^{-5} \text{ release fraction}$$

The particulate release is then:

$$148{,}500 \text{ MT/year} \times 10^{6} \text{ gm/MT} \times 2.5 \times 10^{-12} \text{ Ci/pCi}$$

$$\times\, 5 \times 10^{-5} \times 432 \text{ pCi/gm} = 8.04 \times 10^{-3} \text{ Ci/year}$$

2. Handling

The release rate is estimated to be (Ref. A.2):

$0.05 \text{ lb/ton} = 0.05/2000 = 2.5 \times 10^{-5}$ release fraction.

The particulate release is then:

$148{,}500 \text{ MT/year} \times 10^{6} \text{ gm/MT} \times 2.5 \times 10^{-12} \text{ Ci/pCi}$

$\times 2.5 \times 10^{-5} \times 432 \text{ pCi/gm} = 4.01 \times 10^{-3} \text{ Ci/year}$

3. Windblown Emission

The dusting rate for the ore pad is 42 gm/m^2-year (Ref. A.1)

The particulate release is then:

$42 \text{ gm/m}^2\text{-year} \times 432 \text{ pCi/gm} \times 2.5 \times 5.5 \times 10^{4} \text{ m}^2$

$\times 10^{-12} \text{ Ci/pCi} = 2.49 \times 10^{-3} \text{ Ci/year}$

4. Radon-222 Release from Ore Pad

The staff estimates radon release to be

$$1.0 \frac{\text{pCi/m}^2\text{-sec Rn-222}}{\text{pCi/gm Ra-226}} \times 432 \text{ pCi/gm} \times 3.156 \times 10^{7} \text{ sec/year}$$

$\times 10^{-12} \text{ Ci/pCi} \times 5.5 \times 10^{4} \text{ m}^2 = 748 \text{ Ci/year}$

Total ore pad emissions for U-238, Th-230, Ra-226, Pb-210 (secular equilibrium):

8.04×10^{-3} Ci/year

4.01×10^{-3} Ci/year

$\underline{2.49 \times 10^{-3}}$ Ci/year

1.45×10^{-3} Ci/year × 50 percent reduction (Ref. A.3)

$= 7.30 \times 10^{-3}$ Ci/year

Total ore pad radon emission is 748 Ci/year.

Hoppers and Feeders

The release rate is estimated to be (Ref. A.2):

$0.2 \text{ lb/ton} = 0.2/2000 = 10^{-4}$ release fraction.

The particulate release is then:

$148{,}500$ MT/year × 10^6 gm/MT × 2.5 × 432 pCi/gm × 10^{-4}

× 10^{-12} Ci/pCi = 1.60×10^{-2} Ci/year.

Dust suppression techniques such as chemical spraying and wetting on the ore pad would reduce dust in the transfer of ore to the grinding stage. Thus, the particulate release for U-238, Th-230, Ra-226, and Pb-210 is estimated to be:

1.60×10^{-2} Ci/year × 50% (Ref. A.3) = 8.00×10^{-3} Ci/year.

The radon release in based on a staff estimate that 20 percent of the secular equilibrium content of radon escapes at this stage of the ore processing. This estimate also accounts for radon released from other sources such as the leaching, CCD, and other circuits in the mill, which are not specifically addressed.

The radon release is computed as:

$148{,}500$ MT/year × 10^6 gm/MT × 10^{-12} Ci/pCi × 20% × 432 pCi/gm = 12.8 Ci/year

Grinding and Crushing

The release rate is estimated to be (Ref. A.2):

0.2 lb/ton = 0.2/2000 ≈ 10^{-4} release fraction.

The particulate release is then:

$148{,}500$ MT/year × 10^6 gm/MT × 432 pCi/gm × 2.5×10^{-4}

× 10^{-12} Ci/pCi = 1.60×10^{-2} Ci/year.

This emission point has an emission control device (bag house), which the applicant estimates (Ref. A.4) at 99.5 percent efficiency. The staff selected a 99 percent efficiency to account for downtime and other routine losses of efficiency.

Thus, the particulate souce term is then:

1.60×10^{-2} Ci/year × 1% = 1.60×10^{-4} Ci/year.

The staff estimates that the radon source term will be approximately the same as that for the hopper and feeder:

12.8 Ci/year

for the same reasons as mentioned before.

Fine Ore Storage

The staff estimates loss from loading in, loading out, and transfers of ore to and from the fine ore storage area. The release rate for each of these three activities is estimated (Ref. A.2) to be 0.1 lb/ton each.

Thus,

$$3 \times 0.1 \text{ lb/ton} = 0.3/2000 = 1.5 \times 10^{-4} \text{ release fraction.}$$

The particulate source term for U-238, Th-230, Ra-226, and Pb-210 is estimated to be:

$$148{,}500 \text{ MT/year} \times 10^6 \text{ gm/MT} \times 2.5 \times 1.5 \times 10^{-4} \times 432 \text{ pCi/gm} = 2.41 \times 10^{-2} \text{ Ci/year.}$$

The applicant estimates (Ref. A.4) efficiency of emission control to be 80 percent, so the particulate source term reduces to:

$$2.41 \times 10^{-2} \text{ Ci/year} \times 20\% = 4.80 \times 10^{-3} \text{ Ci/year.}$$

Again, the radon source term is estimated to be 12.8 Ci/year for the same reasons given for the feeding and crushing processes.

Yellowcake Drying and Packaging

The yellowcake production rate is computed as follows:

$$148{,}500 \text{ MT/year} \times 0.153\% \times 90.8\% = 206.3 \text{ MT/year,}$$

where 0.153% is the ore grade (average),
and 90.8% is the recovery rate.

The applicant estimates 8712 hours/year operating time, which gives the hourly production rate of

$$\frac{260.3 \text{ MT/year}}{8712 \text{ hours/year}} = 0.024 \text{ MT/hour.}$$

The applicant reports the following hourly emission rate of 6.79×10^{-4} kg/hour for the dryer and of 4.85×10^{-4} kg/hour for packaging. The total yellowcake drying and packaging is 1.164×10^{-3} kg/hr. The release rate is then

$$\frac{1.164 \times 10^{-3} \text{ kg/hr}}{0.024 \times 10^{3} \text{ kg/hr}} = 4.85 \times 10^{-5} \text{ release fraction.}$$

Thus,

$$206.3 \text{ MT/year} \times 4.85 \times 10^{-5} = 10^{-2} \text{ MT/year yellowcake released.}$$

The U-238 particulate source term is:

10^{-2} MT/year x 10^6 gm/MT x 3.33 x 10^{-7} Ci/gm U-238 x 0.85

x 0.79 = 2.23 x 10^{-3} Ci/year,

where 0.85 is the percent of uranium in U_3O_8

0.79 is the reported purity of yellowcake.

The Generic Environmental Impact Statement on Uranium Milling (NUREG-0706) (Ref. A.5) reports that the activity of Th-230 in yellowcake is 0.5 percent that of U-238 and that activity of Ra-226 and Pb-210 are each 0.1 percent that of U-238.

The Th-230 source term is 2.23 x 10^{-3} Ci/year x 0.5% = 1.12 x 10^{-5} Ci/year.

The Pb-210 and Ra-226 source terms are 2.23 x 10^{-3} Ci/year x 0.1% =

2.23 x 10^{-6} Ci/year.

Radon release from yellowcake operations is assumed to be negligible.

Summary

Except for the yellowcake source terms, the U-238, U-234, Th-230, Ra-226, and Pb-210 quantities are considered to be in secular equilibrium. In general, radioactive emissions which are not explicitly calculated are assumed to be equal to the next higher-up parent in the decay chain.

The MILDOS code also accounts for mechanisms such as ingrowth of radon daughters, resuspension, deposition, all of which are further explained in Appendix B.

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APPENDIX B DETAILED RADIOLOGICAL ASSESSMENT

Supplemental information is provided below which describes the models, data, and assumptions utilized by the staff in performing its radiological impact assessment of the Dawn Mining Company Uranium Project. The primary calculational tool employed by the staff in performing this assessment is MILDOS (Ref. B.1), an NRC-modified version of the UDAD (Uranium Dispersion and Dosimetry) computer code originated at Argonne National Laboratory (Ref. B.2).

B.1 ANNUAL RADIOACTIVE MATERIAL RELEASES

Estimated annual activity releases for the Dawn Mining Company Uranium Project are provided in Table 4.2. They are based on the data and assumptions given in Table 4.1 and described elsewhere in Section 4, with the exception of the annual average dusting rate for exposed tailings sands. This dusting rate is calculated in accordance with the following equation:

$$M = \frac{3.156 \times 10^7}{0.5} \sum_s R_s F_s \qquad \text{(B-1)}$$

where F_s is the annual average frequency of occurrence of wind speed group s, dimensionless;

R_s is the dusting rate for tailings sands at the average wind speed for wind speed group s, for particles $\leq$ 20 μm diameter, g/m²-sec;

M is the annual dust loss per unit area, g/m²-yr;

3.156×10^7 is the number of seconds per year; and

0.5 is the fraction of the total dust loss constituted by particles $\leq$ 20 μm diameter, dimensionless (Ref. B.1).

The values of R_s and F_s utilized by the staff are as given in Table B.1.

Table B.1 Parameter values for calculation of annual dusting rate for exposed tailings sands

Wind Speed Group, knots	Average Wind Speed, mph	Dusting Rate (R_s), g/m²-sec*	Frequency of Occurrence (F_s)**
0-3	1.5	0	0
4-6	5.5	0	0
7-10	10.0	3.92×10^{-7}	0.38011
11-16	15.5	9.68×10^{-6}	0.18314
17-21	21.5	5.71×10^{-5}	0.04671
>21	28.0	2.08×10^{-4}	0.00993

*Dusting rate as a function of wind speed is computed by the MILDOS code (Ref. B.1).

**Wind speed frequencies obtained from annual joint frequency data presented in Table B.2.

Table B.2 Joint relative frequency meteorologic?' data

MPH	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTALS
STABILITY CLASS 1																	
1.5	.0134	.0013	.0202	.0176	.0108	.0039	.0039	.0026	.0160	.0082	.0039	.0013	.0013	.0082	.0026	.0013	.1165
5.5	.0274	.0068	.0205	.0068	.0137	.0205	.0205	.0137	.0411	0.0000	.0205	.0068	.0068	0.0000	.0137	.0068	.2256
10.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ALL	.0408	.0081	.0407	.0244	.0245	.0244	.0244	.0163	.0571	.0082	.0244	.0081	.0081	.0082	.0163	.0081	.3421
STABILITY CLASS 2																	
1.5	.0391	.0459	.0632	.0626	.0987	.0609	.0875	.0462	.1060	.0530	.0840	.0688	.0389	.0586	.0443	.0081	.9658
5.5	.1233	.1164	.2192	.1986	.2260	.1438	.0890	.1233	.2329	.1164	.2055	.1712	.1164	.0685	.0616	.0342	2.2463
10.0	.0479	.0822	.1027	.1712	.0685	.0411	.0342	.0274	.1301	.1233	.1986	.0890	.0548	.0068	.0274	.0137	1.2189
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0[illegible]000	0.0000
ALL	.2103	.244[illegible]	.3851	.4324	.3932	.2458	.2107	.1969	.4690	.2927	.4881	.3290	.2101	.1339	.1333	[illegible]460	4.4310
STABILITY CLASS 3																	
1.5	.0257	.0250	.0508	.0659	.0385	.0251	.0113	.0329	.[illegible]207	.0167	.0323	.0329	.0250	.0169	.0097	.0228	[illegible]522
5.5	.1781	.1507	.3356	.3767	.4041	.1575	.1644	.1849	.2603	.1027	.1644	.1849	.1507	.1096	.1027	.0685	[illegible]58
10.0	.2329	.2534	.7945	1.0410	.4178	.2466	.2671	.4178	.6643	.753[illegible]	.6301	.5548	.2397	.0890	.0753	.0959	6[illegible]
15.5	0.0000	.0137	.0548	.0479	.0205	.0068	0.0000	0.0000	.0479	.1096	.1986	.0959	.0068	0.0000	0.0000	.0068	.6093
21.5	.0068	0.0000	0.0000	.0068	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]068	.0068	0.0000	0.0000	0.0000	0.0000	.0068	.0272
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0068	0.0000	0.0000	0.0000	0.0000	0.0000	.0068
ALL	.4435	.4428	1.2357	1.5383	.8809	.4360	.4428	.6356	.9932	.9892	1.0390	.8685	.4222	.2155	.1877	.1940	10.9649
STABILITY CLASS 4																	
1.5	.1228	.1007	.1692	.2487	.3005	.1365	.1637	.1355	.2383	.0973	.0938	.1104	.0583	.0521	.0356	.0501	2.1095
5.5	.5000	.4931	.9314	1.0547	.8219	.4863	.5822	.5958	.9999	.5616	.5000	.4109	.3150	.1507	.1164	.1164	8.6363
10.0	.4109	.6438	1.9245	2.3423	.6369	.5616	1.0753	2.5272	3.4929	2.6163	2.5409	1.3835	.5068	.1644	.1712	.0959	21.0944
15.5	.1849	.3082	.4931	.5890	.1918	.1027	.3219	.9314	2.7601	4.3216	4.5613	1.9040	.6164	.2329	.0548	.1301	17.7042
21.5	.0205	.0205	.0822	.0890	.0205	0.0000	.0068	.1233	.[illegible]904	1.1438	1.7944	.7054	.1918	.0274	0.000[illegible]	.0274	4.6434
28.0	0.0000	0.0000	.0068	0.0000	0.0000	0.0000	0.0000	.0068	.0411	.1164	.5411	.2192	.0548	0.0000	0.000[illegible]	0.0000	.9862
ALL	1.2391	1.5663	3.6072	4.3237	1.9716	1.2871	2.1499	4.3200	[illegible].9227	8.8570	10.0315	4.7[illegible]34	1.7391	.6275	.378	.4199	55.1740
STABILITY CLASS 5																	
1.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5.5	.2671	.4383	.6849	.8972	.5205	.3493	.3972	.6095	.6849	.2466	.4109	.2877	.2397	.1096	.0479	.0548	6.2461
10.0	.1918	.1986	.6917	.8424	.2603	.0479	.3561	1.6300	1.4451	.7945	1.2259	.8150	.1986	.0959	.0753	.0548	8.9239
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ALL	.4589	.6369	1.3766	1.7396	.7808	.3972	.7533	2.2395	2.1300	1.0411	1.6368	1.1027	.4383	.2055	.1232	.1096	15.1700
STABILITY CLASS 6																	
1.5	.3363	.3773	.4443	.4162	.5124	.2654	.2989	.3193	.5181	.2936	.3829	.4256	.3122	.2104	.0878	.1073	5.3080
5.5	.4452	.5068	.8424	1.0205	.6164	.3424	.4589	.6438	1.1712	.5274	.6986	.6164	.3904	.1370	.1096	.0822	8.6092
10.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]	0.0000
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000[illegible]	0.000[illegible]	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00[illegible]0	0.000[illegible]	0.00[illegible]0
ALL	.7815	.8841	1.2867	1.4367	1.1288	.6078	.7578	.9631	1.6893	.8210	1.08[illegible]	1.0420	.7026	.3474	.1974	.189[illegible]	13.9[illegible]72
ALL	[illegible].1741	3.7827	7.9320	9.4951	5.1798	2.9983	4.3389	8.3714	13.2613	12.0092	14.3013	8.0837	3.5204	1.5380	1.03[illegible]9	.9771	9[illegible].9992

The calculated value of the annual dusting rate, M is 420 g/m^2-yr. Annual curie releases from the tailings piles are then given by the following relationship:

$$S = MA(1-f_c)\, f_t\, (C)\, (2.5 \times 10^{-12}) \qquad \text{(B-2)}$$

where A is the assumed beach area of the pile, m^2;

f_c is the fraction of the dusting rate controlled by mitigating actions, dimensionless;

f_t is the fraction of the ore content of the particular nuclide present in the tails;

S is the annual release for the particular beach area, Ci/yr;

C is the assumed raw ore activity, pCi/g;

2.5 is the dust to tails activity ratio; and

10^{-12} is Ci/pCi.

The tailings placed in the above grade impoundment has a raw ore activity of 675 pCi/gm. The future impoundment would store tailings corresponding to a lower ore activity of 432 pCi/gm.

The present impoundment (47 acres) will be used until the end of 1981, when it will be permitted to dry. When sufficient drying has been achieved, wood chips and/or chemical stabilization will be applied until full reclamation is begun. During the drying period, chemical stabilizers and/or surficial water spraying will be used to reduce dusting.

The future impoundment (26 acres) will be below grade and for the most part covered by liquid. The staff has assigned an 80 percent reduction factor of dusting by the methods of water cover, chemical stabilization and water spraying during operation. Upon application of wood chip cover, the staff assumes that this will effectively eliminate particulate effluents from tailings.

Dust losses from the ore storage piles were estimated by assuming they would be about 10 percent of those from an equivalent area of tailings beach. Calculated dust losses were reduced by 50 percent to account for dust loss control measures required by the staff.

B.2 ATMOSPHERIC TRANSPORT

The staff analysis of offsite air concentrations of radioactive materials has been based on five years of meteorological data collected at Spokane, Washington, over the period 1967 through 1971 (Ref. B.3). The collected meteorological data are entered into the MILDOS code as input, in the form of a joint frequency distribution by stability class, wind speed group, and direction. The joint frequency data employed by the staff for this analysis are presented in Table B.2.

The dispersion model employed by the MILDOS code is the basic straight-line Gaussian plume model (Ref. B.1). Ground-level, sector-average concentrations are computed using this model and are corrected for decay and ingrowth in transit (for Rn-222 and daughters) and for depletion due to deposition losses (for particulate material). Area sources are treated using a virtual point source technique. Resuspension into the air of particulate material initially deposited on ground surfaces is treated using a resuspension factor which depends on the age of the deposited material and its particle size (Ref. B.1). For the isotopes of concern here, the total air concentration including resuspension is about 1.6 times the ordinary air concentration.

The assumed particle size distribution, particle density, and deposition velocities for each source are presented in Table B.3.

Table B.3 Physical characteristics assumed for particulate material releases

Activity Source	Diameter μm	Density g/cm^3	Deposition Velocity cm/sec	AMAD* μm
Activity Source				
Crusher dusts	1.0	2.4	1.0	1.55
Yellowcake dusts	1.0	8.9	1.0	2.98
Tailings, ore pile dusts	5.0 (30%)	2.4	1.0	7.75
Tailings, ore pile dusts	35.0 (70%)	2.4	8.8	54.2
Ingrown Rn daughters	0	1.0	0.3	0.3

*Aerodynamic equivalent diameter, used in calculating inhalation doses (Ref. B.1).

B.3 CONCENTRATIONS IN ENVIRONMENTAL MEDIA

Information provided below describes the methods and data used by the staff to determine the concentrations of radioactive materials in the environmental media of concern in the vicinity of the site. These include concentrations in the air (for inhalation and direct external exposure), on the ground (for direct external exposure), and in meat and vegetables (for ingestion exposure). Concentration values are computed explicitly by the MILDOS code for U-238, Th-230, Ra-226, Rn-222 (air only), and Pb-210. Concentrations of Th-234, Pa-234, and U-234, are assumed to be equal to that of U-238. Concentrations of Bi-210 and Po-210 are assumed to be equal to that of Pb-210.

B.3.1 <u>Air Concentrations</u>

Ordinary, direct air concentrations are computed by the MILDOS code for each receptor location, from each activity source, by particle size (for particulates). Direct air concentrations computed by MILDOS include depletion by deposition (particulates) or the effects of ingrowth and decay in transit (radon and daughters). In order to compute inhalation doses, the total air concentration of each isotope at each location, as a function of particle size, is computed as the sum of the direct air concentration and the resuspended air concentration:

$$C_{aip}(t) = C_{aipd} + C_{aipr}(t), \qquad \text{(B-3)}$$

where $C_{aip}(t)$ is the total air concentration of isotope i, particle size p, at time t, pCi/m³;

C_{aipd} is the direct air concentration of isotope i, particle size p, for the time constant, pCi/m³; and

$C_{aipr}(t)$ is the resuspended air concentration of isotope i, particle size p, at time t, pCi/m³.

The resuspended air concentration is computed using a time-dependent resuspension factor, $R_p(t)$, defined by

$$R_p(t) = (1/V_p)10^{-5}\, e^{-\lambda_R t} \text{ (for } t \le 1.82 \text{ yr)} \qquad \text{(B-4a)}$$

$$R_p(t) = (1/V_p)10^{-9} \qquad \text{(for } t > 1.83 \text{ yr)} \qquad \text{(B-4b)}$$

where $R_p(t)$ is the ratio of the resuspended air concentration to the ground concentration, for a ground concentration of age t years, of particle size p, m^{-1};

V_p is the deposition velocity of particle size p, cm/sec;

λ_R is the assumed decay constant of the resuspension factor (equivalent to a 50-day half-life), 5.06 yr;

10^{-5} is the initial value of the resuspension factor (for particles with a deposition velocity of 1 cm/sec), m^{-1};

10^{-9} is the terminal value of the resuspension factor (for particles with a deposition velocity of 1 cm/sec), m^{-1}; and

1.82 is the time required to reach the terminal resuspension factor, years.

The basic formulation of the above expression for the resuspension factor, the initial and final values, and the assigned decay constant derive from experimental observations (Rev. B.3). The inverse relationship to deposition velocity eliminates mass balance problems involving resuspension of more than 100 percent of the initial ground deposition for the 35 μm particle size (see Table B.3). Based on this formulation, the resuspended air concentration is given by:

$$C_{aipr}(t) = 0.01\ C_{aipd}\ 10^{-5} \left[\frac{1 - \exp[-(\lambda_i^* + \lambda_R)(t - a)]}{(\lambda_i^* + \lambda_R)} \cdots \right. \qquad (B-5)$$

$$\left. + 10^{-4}\delta(t) \frac{\exp[-\lambda_i^*(t - a)] - \exp(-\lambda_i^* t)}{\lambda_i^*} \right] (3.156 \times 10^7)$$

where a is equal to (t - 1.82) if t < 1.82 and is equal to zero otherwise, years;

$\delta(t)$ is zero if t < 1.82 and is unity otherwise, dimensionless;

λ_i^* is the effective decay constant for isotope i on soil, $year^{-1}$;

.01 is the deposition velocity for the particle size for which the initial resuspension factor value is 10^{-5} per meter, m/sec;

3.156×10^7 is sec/year.

Total air concentrations are computed using equations B-5 and B-3 for all particulate effluents. Radon daughters which grow in from released radon are not depleted due to deposition losses and are therefore not assumed to resuspend.

B.3.2 Ground Concentrations

Radionuclide ground concentrations are computed from the calculated airborne particulate concentrations arising directly from onsite sources (not including air concentrations resulting from resuspension). Resuspended particulate concentrations are not considered for evaluating ground concentrations. The direct deposition rate of radionuclide i is calculated, using the following relationship:

$$D_{di} = \sum_p C_{adip} V_p, \qquad (B-6a)$$

where C_{adip} is the direct air concentration of radionuclide i, particle size p, pCi/m^3;

D_{di} is the resulting direct deposition rate of radionuclide i, pCi/m^2-sec;

V_p is the deposition velocity of particle size p, m/sec (see Ref. B.4).

The concentration of radionuclide i on a ground surface due to constant deposition at the rate D_{di} over time interval t is obtained from

$$C_{gi}(t) = D_{di} \left[\frac{1 - \exp -(\lambda_i + \lambda_e)t}{\lambda_i + \lambda_e} \right], \qquad (B-6b)$$

where $C_{gi}(t)$ is the ground surface concentration of radionuclide i at time t, pCi/m^2;

t is the time interval over which deposition has occurred, sec;

λ_e is the assumed rate constant for environmental loss, sec^{-1};

λ_i is the radioactive decay constant for radionuclide i, sec^{-1}.

The environmental loss constant, λ_e, corresponds to an assumed half-time for loss of environmental availability of 50 years, (Ref. B.3). This parameter accounts for downward migration in soil and loss of availability due to chemical binding. It is assumed to apply to all radionuclides deposited on the ground.

Ground concentrations are explicitly computed only for uranium-238, thorium-230, radium-226, and lead-210. For all other radionuclides, the ground concentration is assumed equal to that of the first parent radionuclide for which the ground concentration is explicitly calculated. For lead-210, ingrowth from deposited radium-226 can be significant. The concentration of lead-210 on the ground due to radium-226 deposition is calculated by the staff, using the standard Bateman formulation and assuming that radium-226 decays directly to lead-210. If i = 6 for radium-226 and i = 12 for lead-210 (Ref. B.1), the following equation is obtained:

$$C_{g12}(Pb \leftarrow Ra) = \frac{\lambda_{12} D_{d6}}{\lambda_6^*} \left[\frac{1 - \exp(-\lambda_{12}^* t)}{\lambda_{12}^*} + \frac{\exp(-\lambda_6^* t) - \exp(-\lambda_{12}^* t)}{\lambda_6^* - \lambda_{12}^*} \right], \quad \text{(B-7)}$$

where $C_{g12}(Pb \leftarrow Ra)$ is the incremental lead-210 ground concentration resulting from radium-226 deposition, pCi/m^2;

λ_n^* is the effective rate constant for loss by radioactive decay and migration of a ground-deposited radionuclide and is equal to $\lambda_n + \lambda_e$, sec^{-1}.

B.3.3 Vegetation Concentrations

Vegetation concentrations are derived from ground concentrations and total deposition rates. Total deposition rates are given by the following summation:

$$D_i = \sum_p C_{aip} V_p, \quad \text{(B-8a)}$$

where D_i is the total deposition rate, including deposition of resuspended activity, of radionuclide i, pCi/m^2-sec.

Concentrations of released particulate materials can be environmentally transferred to the edible portions of vegetables, or to hay or pasture grass consumed by animals, by two mechanisms--direct foliar retention and root uptake. Five categories of vegetation are treated by the staff. They are edible above-ground vegetables, potatoes, other edible below-ground vegetables, pasture grass, and hay. Vegetation concentrations are computed using the following equation:

$$C_{vi} = D_i E_r E_v \left[\frac{1 - \exp(-\lambda_w t_v)}{Y_v \lambda_w} \right] + C_{gi}(B_{vi}/P) \quad , \qquad \text{(B-8b)}$$

where B_{vi} is the soil-to-plant transfer factor for isotope i, vegetation type v, dimensionless;

C_{vip} is the resulting concentration of isotope i, particle size p, in vegetation v, pCi/kg;

E_v is the fraction of the foliar deposition reaching edible portions of vegetation v, dimensionless;

F_r is the fraction of the total deposition retained on plant surfaces, 0.2, dimensionless;

P is the assumed areal soil density for surface mixing, 240 kg/m^2;

t_v is the assumed duration of exposure while growing for vegetation v, sec;

Y_v is the assumed yield density of vegetation v, kg/m^2;

λ_w is the decay constant accounting for weathering losses (equivalent to a 14-day half-life), 5.73 x 10^{-7} per second.

The value of E_y is assumed to be 1.0 for all above-ground vegetation, and 0.1 for all below-ground vegetables (Ref. B.7). The value of t_v is taken to be 60 days, except for pasture grass, where a value of 30 days is assumed. The yield density, Y_v, is taken to be 2.0 kg/m^2 except for pasture grass, where a value of 0.75 kg/m^2 is applied. Values of the soil to plant transfer coefficients, B_{vi}, are provided in Table B.4.

B.3.4 Meat and Milk Concentrations

Radioactive materials can be deposited on grasses, hay, or silage which is eaten by meat animals, which are in turn eaten by man. It has been assumed that meat animals obtain their entire feed requirement by grazing eight months per year, and by eating nonlocally grown stored feed for approximately 10 weeks. The equation used to estimate meat concentrations is:

Table B.4 Environmental transfer coefficients

Material	U	Th	Ra	Pb
Plant/Soil (B_{vi})				
Edible above ground	2.5×10^{-3}	4.2×10^{-3}	1.4×10^{-2}	4.0×10^{-3}
Potatoes	2.5×10^{-3}	4.2×10^{-3}	3.0×10^{-3}	4.0×10^{-3}
Other below ground	2.5×10^{-3}	4.2×10^{-3}	1.4×10^{-2}	4.0×10^{-3}
Pasture grass	2.5×10^{-3}	4.2×10^{-3}	1.8×10^{-2}	2.8×10^{-2}
Stored feed (hay)	2.5×10^{-3}	4.2×10^{-3}	8.2×10^{-2}	3.6×10^{-2}
Beef/Feed (F_{bi})				
pCi/kg per pCi/day	3.4×10^{-4}	2.0×10^{-4}	5.1×10^{4}	7.1×10^{-4}

Source: U.S. Nuclear Regulatory Commission, "Calculational Models for Estimating Radiation Doses to Man from Airborne Radioactive Materials Resulting from Uranium Operations," Task RH 802-4, May 1979.

$$C_{bi} = Q\, F_{bi}\, (0.67\, C_{pgi} + 0.20\, C_{hi}) \qquad \text{(B-9a)}$$

where C_{pgi} is the concentration of isotope i in pasture grass, pCi/kg;

C_{hi} is the concentration of isotope i in hay (or other stored feed), pCi/kg;

C_{bi} is the resulting concentration of isotope i in meat, pCi/kg;

F_{bi} is the feed to meat transfer factor for isotope i, pCi/kg per pCi/day (see Table B.4);

Q is the assumed feed ingestion rate, 50 kg/day;

0.67 is the fraction of the total annual feed requirement assumed to be satisfied by pasture grass; and

0.20 is the fraction of the total annual feed requirement assumed to be satisfied by locally grown stored feed (hay).

The above grazing assumptions are also reflected in the following equation for milk concentrations:

$$C_{mi} = Q\, F_{mi}\, (0.67\, C_{pgi} + 0.20\, C_{hi}) \qquad \text{(B-9b)}$$

where C_{mi} is the average concentration of iostope i in milk, pCi/ℓ; and

F_{mi} is the feed to milk activity transfer factor for isotope i, pCi/ℓ per pCi/day ingested (see Table B.4).

Table B.5 Inhalation dose conversion factors (mrem/year/pCi/m^3)

Organ	U-238	U-234	U-230	Ra-226	Pb-210	Po-210
Particle Size = 0.3 µm						
Whole body					7.46E+00	1.29E+00
Bone					2.32E+02	5.24E+00
Kidney					1.93E+02	3.87E+01
Liver					5.91E+01	1.15E+01
Mass average lung					6.27E+01	2.66E+02
Particle Size = 1.0 µm						
Whole body	9.82E+00	1.12E+01	1.37E+02	3.58E+01	4.66E+00	5.95E-01
Bone	1.66E+02	1.81E+02	4.90E+03	3.58E+02	1.45E+02	2.43E+00
Kidney	3.78E+01	4.30E+01	1.37E+03	1.26E+00	1.21E+02	1.79E+01
Liver	0.	0.	2.82E+02	4.47E-02	3.69E+01	5.34E+00
Mass average lung	1.07E+03	1.21E+03	2.37E+03	4.88E+03	5.69E+02	3.13E+02
Particle Size = 1.0 µm						
Whole body	4.32E+00	4.92E+00	1.66E+02	3.09E+01	4.36E+00	4.71E-01
Bone	7.92E+01	7.95E+01	5.95E+03	3.09E+02	1.35E+02	1.92E+00
Kidney	1.66E+01	1.89E+01	1.67E+03	1.09E+00	1.13E+02	1.42E+01
Liver	0.	0.	3.43E+02	3.87E-02	3.45E+01	4.22E+00
Mass average lung	1.58E+02	1.80E+02	3.22E+03	6.61E+03	7.72E+03	4.20E+02
Particle Size = 5.0 µm						
Whole body	1.16E+00	1.32E+00	1.01E+02	4.00E+01	4.84E+00	7.10E-01
Bone	1.96E+01	2.14E+01	3.60E+03	4.00E+02	1.50E+02	2.89E+00
Kidney	4.47E+00	5.10E+00	1.00E+03	1.41E+00	1.25E+02	2.13E+01
Liver	0.	0.	2.07E+02	4.97E-02	3.83E+01	6.36E+00
Mass average lung	1.24E+03	1.42E+03	1.38E+03	2.84E+03	3.30E+02	1.88E+02
Particle Size = 35.0 µm						
Whole body	7.92E-01	9.02E-01	5.77E+01	3.90E+01	4.43E+00	7.28E-01
Bone	1.34E+01	1.46E+01	2.07E+03	3.90E+02	1.38E+02	2.96E+00
Kidney	3.05E+00	3.47E+00	5.73E+02	1.38E+00	1.15E+02	2.19E+01
Liver	0.	0.	1.19E+02	4.85E-02	3.51E+01	6.52E+00
Mass average lung	3.33E+02	3.80E+02	3.71E+02	7.64E+02	8.70E+01	5.75E+01

Doses to the bronchial epithelium from Rn-222 and short-lived daughters were computed based on the assumption of indoor exposure at 100% occupancy. The dose conversion factor for bronchial epithelium exposure from Rn-222 derives as follows:

1) 1 pCi/m^3 Rn-222 = 5 x 10^{-6} Working Level (WL).*

2) Continuous exposure to 1 WL = 25 cumulative working level months (WLM) per year.

3) 1 WLM = 5000 mrem (Ref. B.8).

Therefore:

$$(1 \text{ pCi/m}^3 \text{ Rn-222}) \times (5 \times 10^{-6} \frac{\text{WL}}{\text{pCi/m}^3}) \times (25 \frac{\text{WLM}}{\text{WL}}) \times (5000 \frac{\text{mrem}}{\text{WLM}}) = 0.625 \text{ mrem}$$

and the Rn-222 bronchial epithelium dose conversion factor is taken to be 0.625 mrem/yr per pCi/m^3.

B.4.2 External Doses

External doses from air and ground concentrations are computed using the dose conversion factors provided in Table B.6 (Ref. B.1). Doses are computed based on 100 percent occupancy at the particular location. Indoor exposure is assumed to occur 14 hrs/day at a dose rate of 70% of the outdoor dose rate.

Table B.6 Dose conversion factors for external exposure

Dose factors for doses from air concentrations, mrem/yr per pCi/m^3

Isotope	Skin	Whole Body
U-238	1.05 E-05	1.57 E-06
Th-234	6.63 E-05	5.24 E-05
Pa(m)-234	8.57 E-05	6.64 E-05
U-234	1.36 E-05	2.49 E-06
Th-230	1.29 E-09	3.59 E-06
Ra-226	6.00 E-05	4.90 E-05
Rn-222	3.46 E-10	2.83 E-06
Po-218	8.18 E-07	6.34 E-07
Pb-214	2.06 E-03	1.67 E-03
Bi-214	1.36 E-02	1.16 E-02
Po-214	9.89 E-07	7.66 E-07
Pb-210	4.17 E-05	1.43 E-05

Dose factors for doses from ground concentrations, mrem/yr per pCi/m^2

Isotope	Skin	Whole Body
U-238	2.13 E-06	3.17 E-07
Th-234	2.10 E-06	1.66 E-06
Pa(m)-234	1.60 E-06	1.24 E-06
U-234	2.60 E-06	4.78 E-07
Th-230	2.20 E-06	6.12 E-07
Ra-226	1.16 E-06	9.47 E-07
Rn-222	6.15 E-08	5.03 E-08
Po-218	1.42 E-08	1.10 E-08
Pb-214	3.89 E-05	3.16 E-05
Bi-214	2.18 E-04	1.85 E-04
Po-214	1.72 E-08	1.33 E-08
Pb-210	6.65 E-06	2.27 E-06

*One WL concentration is defined as any combination of short-lived radioactive decay products on Rn-222 in one liter of air that will release 1.3 x 10^5 MeV of alpha particle energy during radioactive decay to Pb-210.

B.4.3 Ingestion Doses

Ingestion doses are computed for vegetables and meat (beef and lamb) on the basis of concentrations obtained using Equations B-8 and B-9, ingestion rates given in Table B.7, and dose conversion factors given in Table B.8 (Refs. B.1, B.9). Vegetable ingestion doses were computed assuming an average 50 percent activity reduction due to food preparation (Ref. B.4). Ingestion doses to children and teenagers were computed but found to be equivalent to or less than doses to adults.

Table B.7 Assumed food ingestion rates,* kg/yr

	Infant	Child	Teen	Adult
I. Vegetables (total):	-	48	76	105
a) Edible above ground	-	17	29	40
b) Potatoes	-	27	42	60
c) Other below ground	-	3.4	5.0	5.0
II. Meat (beef, fresh pork, and lamb)	-	28	45	78
III. Milk (liters/yr)	208	208	246	130

*All data taken from Reference B.6. Ingestion rates are averages for typical rural farm households. No allowance is credited for portions of year when locally or homegrown food may not be available.

Table B.8 Ingestion dose conversion factors (mrem/pCi ingested)

Age Group	Organ	Isotope							
		U-238	U-234	Th-234	Th-230	Ra-226	Pb-210	Bi-210	Po-210
Infant	Whole body	3.33 E-04	3.80 E-04	2.00 E-08	1.06 E-04	1.07 E-02	2.38 E-03	3.58 E-07	7.41 E-04
	Bone	4.47 E-03	4.88 E-03	6.92 E-07	3.80 E-03	9.44 E-02	5.28 E-02	4.16 E-06	3.10 E-03
	Liver	0	0	3.77 E-08	1.90 E-04	4.76 E-05	1.42 E-02	2.68 E-05	5.93 E-03
	Kidney	9.28 E-04	1.06 E-03	1.39 E-07	9.12 E-04	8.71 E-04	4.33 E-02	2.08 E-04	1.26 E-02
Child	Whole body	1.94 E-04	2.21 E-04	9.88 E-09	9.91 E-05	9.87 E-03	2.09 E-03	1.69 E-07	3.67 E-04
	Bone	3.27 E-03	3.57 E-03	3.42 E-07	3.55 E-03	8.76 E-02	4.75 E-02	1.97 E-06	1.52 E-03
	Liver	0	0	1.51 E-08	1.78 E-04	1.84 E-05	1.22 E-02	1.02 E-05	2.43 E-03
	Kidney	5.24 E-04	5.98 E-04	8.01 E-08	8.67 E-08	4.88 E-04	3.67 E-02	1.15 E-04	7.56 E-03
Teenager	Whole body	6.49 E-05	7.39 E-05	3.31 E-09	6.00 E-05	5.00 E-03	7.01 E-04	5.66 E-08	1.23 E-04
	Bone	1.09 E-03	1.19 E-03	1.14 E-07	2.16 E-03	4.09 E-02	1.81 E-02	6.59 E-07	5.09 E-04
	Liver	0	0	6.68 E-09	1.23 E-04	8.13 E-06	5.44 E-03	4.51 E-06	1.07 E-03
	Kidney	2.50 E-04	2.85 E-04	3.81 E-08	5.99 E-04	2.32 E-04	1.72 E-02	5.48 E-05	3.60 E-03
Adult	Whole body	4.54 E-05	5.17 E-05	2.13 E-09	5.70 E-05	4.60 E-03	5.44 E-04	3.96 E-08	8.59 E-05
	Bone	7.67 E-04	8.36 E-04	8.01 E-08	2.06 E-03	4.60 E-02	1.53 E-02	4.61 E-07	3.56 E-04
	Liver	0	0	4.71 E-09	1.17 E-04	5.74 E-06	4.37 E-03	3.18 E-06	7.56 E-04
	Kidney	1.75 E-04	1.99 E-04	2.67 E-08	5.65 E-04	1.63 E-04	1.23 E-02	3.83 E-05	2.52 E-03

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B.2. M. Momeni, et al., "Uranium Dispersion and Dosimetry (UDAD) Code," Argonne National Laboratory Report, ANL/ES-72, NUREG/CR-0553, May 1979.

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B.4. "Draft Generic Environmental Impact Statement on Uranium Milling," U.S. Nuclear Regulatory Commission, NUREG-0511, April 1979.

B.5. D. C. Kocher, "Nuclear Decay Data for Radionuclides Occurring in Routine Releases from Nuclear Fuel Cycle Facilities," Report ORNL/NUREG/TM-102, Oak Ridge National Laboratory, August 1977.

B.6. J. F. Fletcher and W. L. Dotson (compilers), "HERMES - A Digital Computer Code for Estimating Regional Radiological Effects from the Nuclear Power Industry," Hanford Engineering Development Laboratory, HEDL-TME-71-168, December 1971.

B.7. D. R. Kalkwarf, "Solubility Classification of Airborne Products from Uranium Ores and Tailings Piles," Report NUREG/CR-0530; PNL-2830, Pacific Northwest Laboratory, January 1979.

B.8. National Academy of Sciences - National Research Council, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," Report on the Advisory Committee on Biological Effects of Ionizing Radiation (BEIR), U.S. Government Printing Office, 1972.

B.9. G. R. Hoenes and J. K. Soldat, "Age-Specific Radiation Dose Conversion Factors for a One-Year Chronic Intake," Battelle Pacific Northwest Laboratories, U.S. Nuclear Regulatory Commission Report NUREG-0172, November 1977.

APPENDIX C

Stability Computations

APPENDIX C

Slope Stability Analysis

DAWN MINING COMPANY

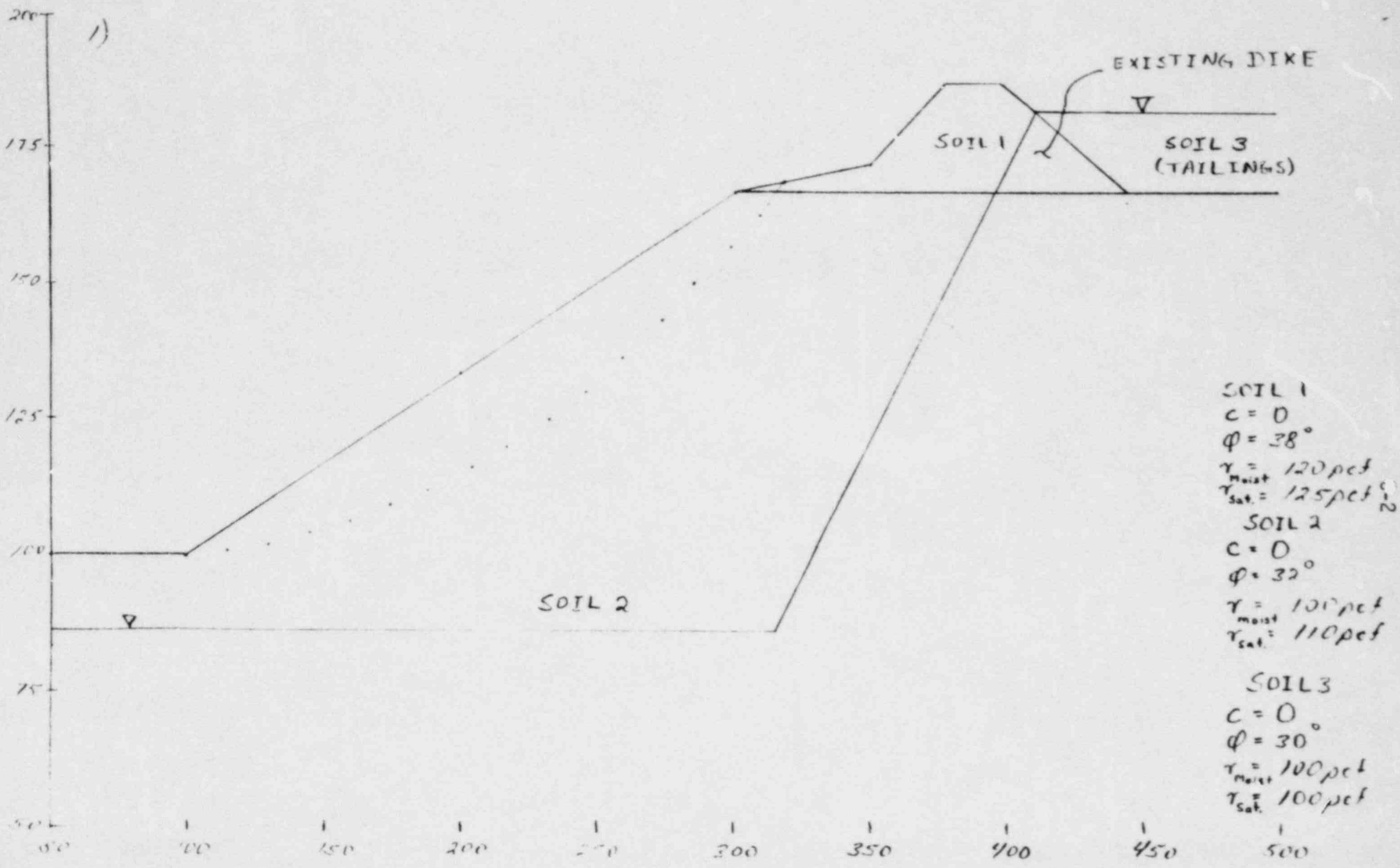
This analysis utilized the program STABL2. A total of 10 potential failure surfaces were generated from each of three initiation points. The three initiation points included: 1) the toe of the proposed pit, 2) the crest of the proposed dike, and 3) a point midway between these two points on the pit slope. The left termination point was taken as the crest of the proposed facility and the right termination point as a point on the existing tailing surface. Minimum elevation of surface development was taken as 75', a distance of 25' below the bottom of the proposed pit. Length of segments defining the surfaces was taken as 15'. Limits for surface initiation angles were randomly chosen by the computer.

Factors of Safety (for the ten most critical of the trial failure surfaces examined)

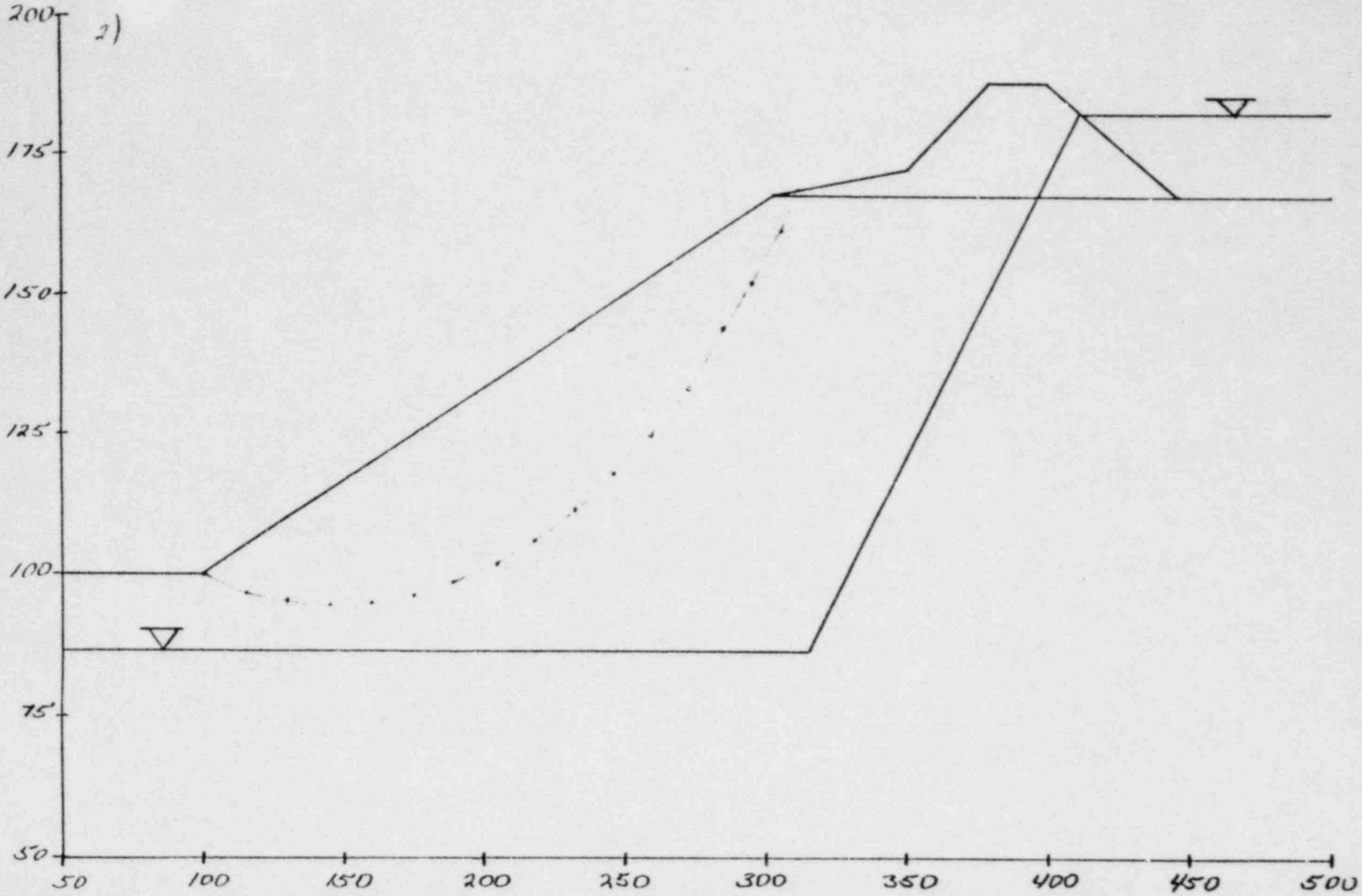
1. 1.950	6. 2.207
2. 2.016	7. 2.211
3. 2.102	8. 2.215
4. 2.166	9. 2.217
5. 2.168	10. 2.245*

*Note: Initiation point coordinates: x = 200.5, y = 133.5 (located on pit slope) F.S. = 2.25.

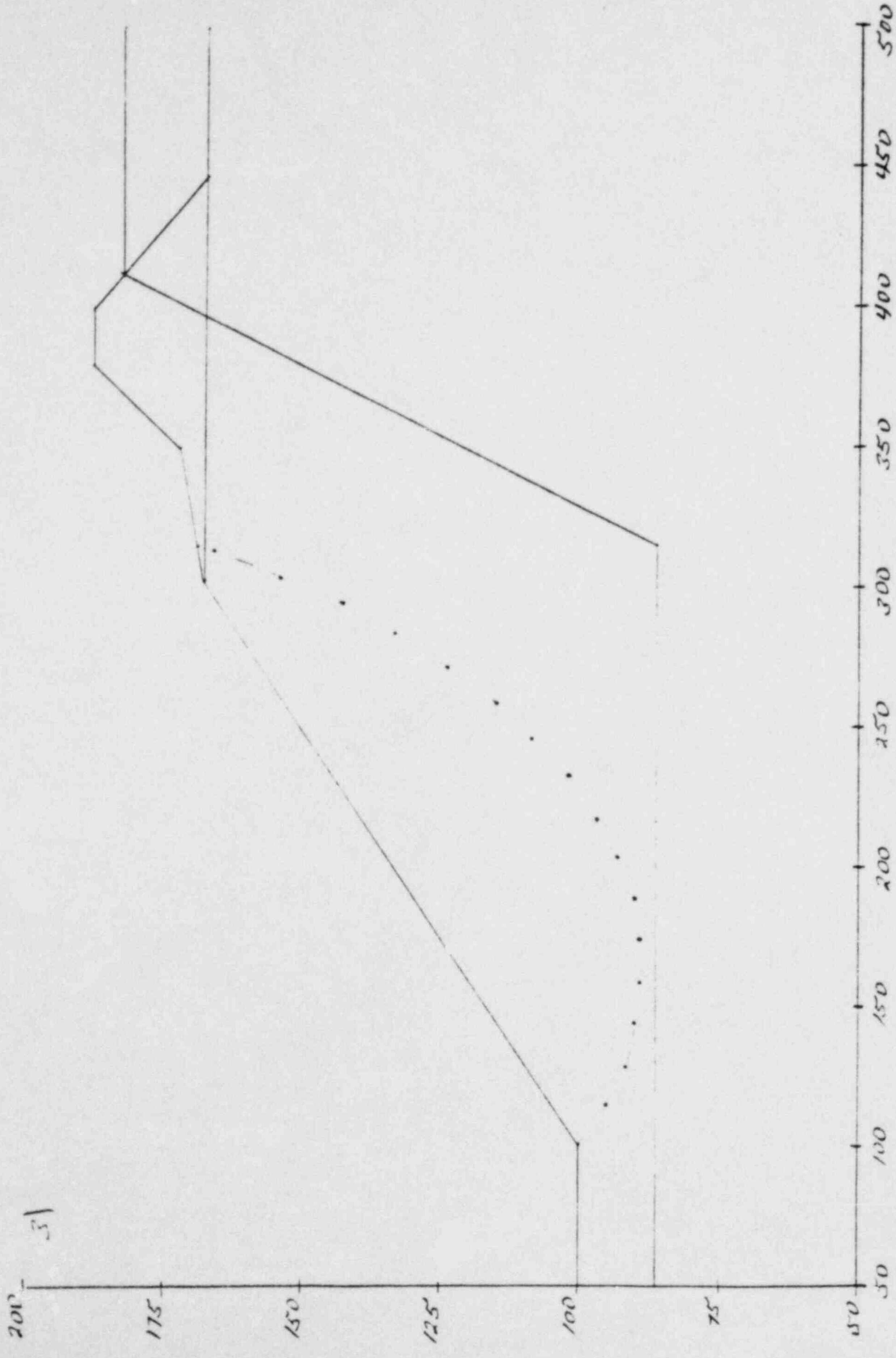
Initiation point coordinates for the remaining 9 failure surfaces: x = 100.0, y = 100.0 (located at the toe of the proposed pit) $F.S._{avg}$ = 2.14.



FACTOR OF SAFETY = 1.950 DAWN MINING COMPANY Scale 1" = 50'



FACTOR OF SAFETY = 2.016



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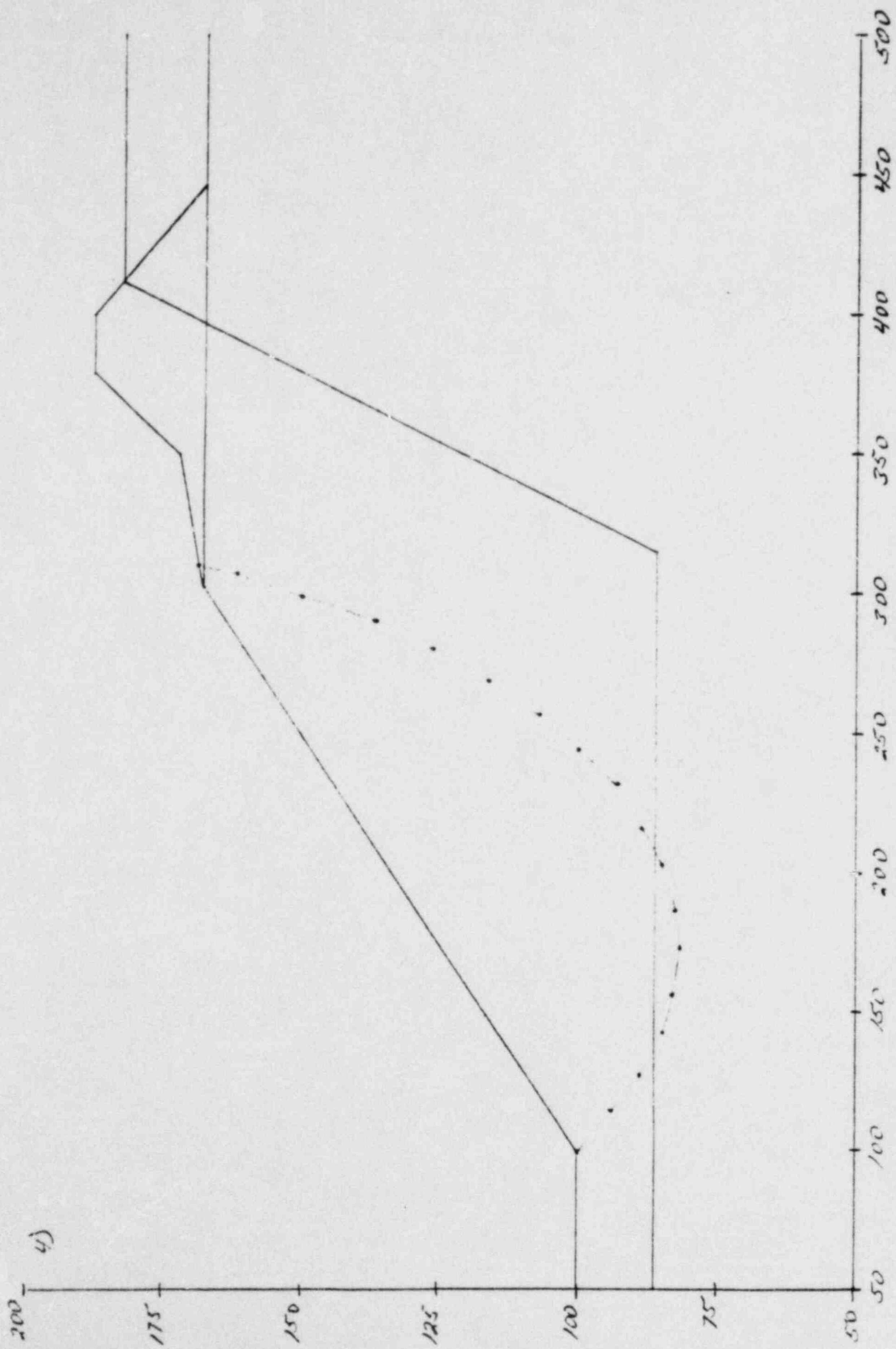

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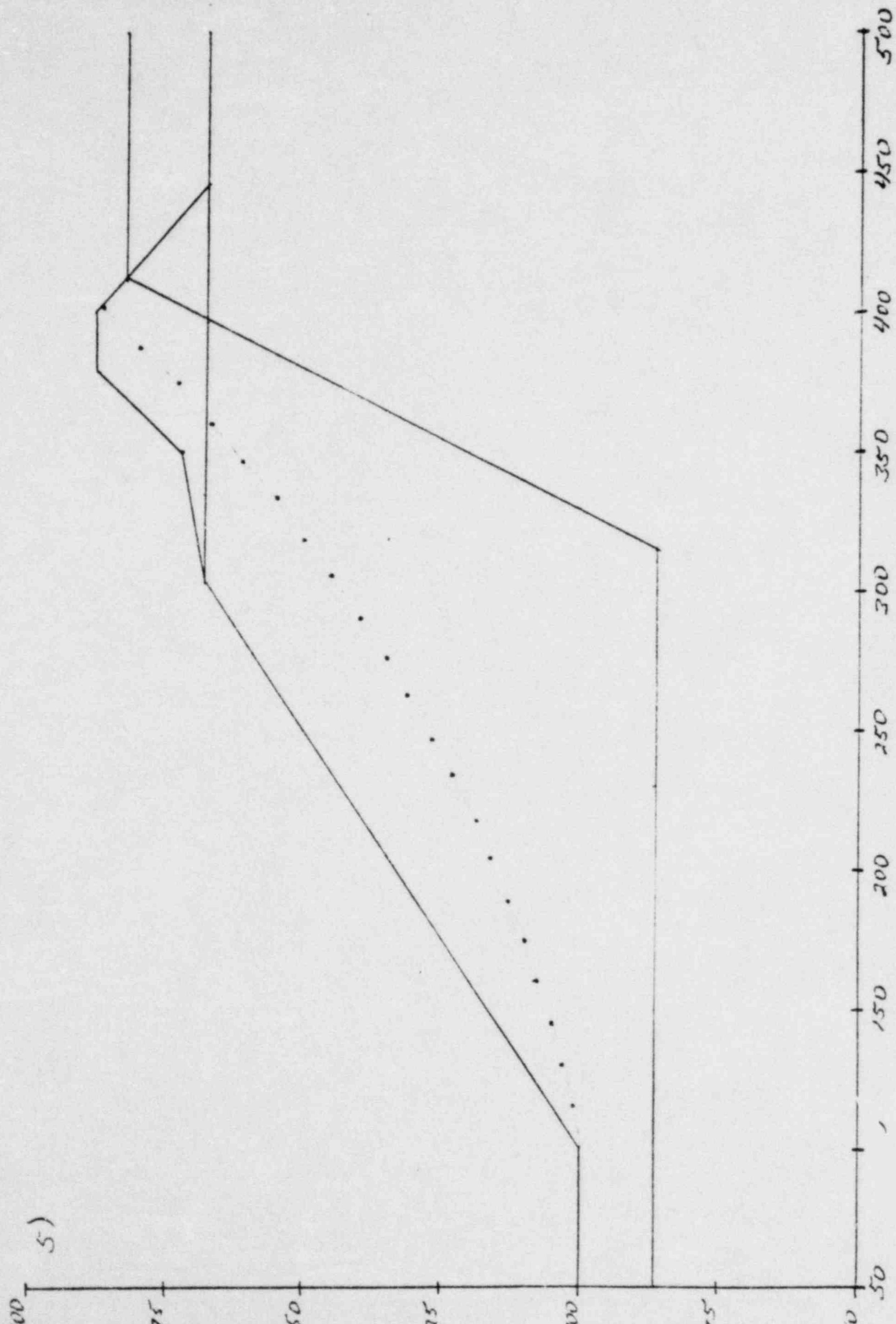

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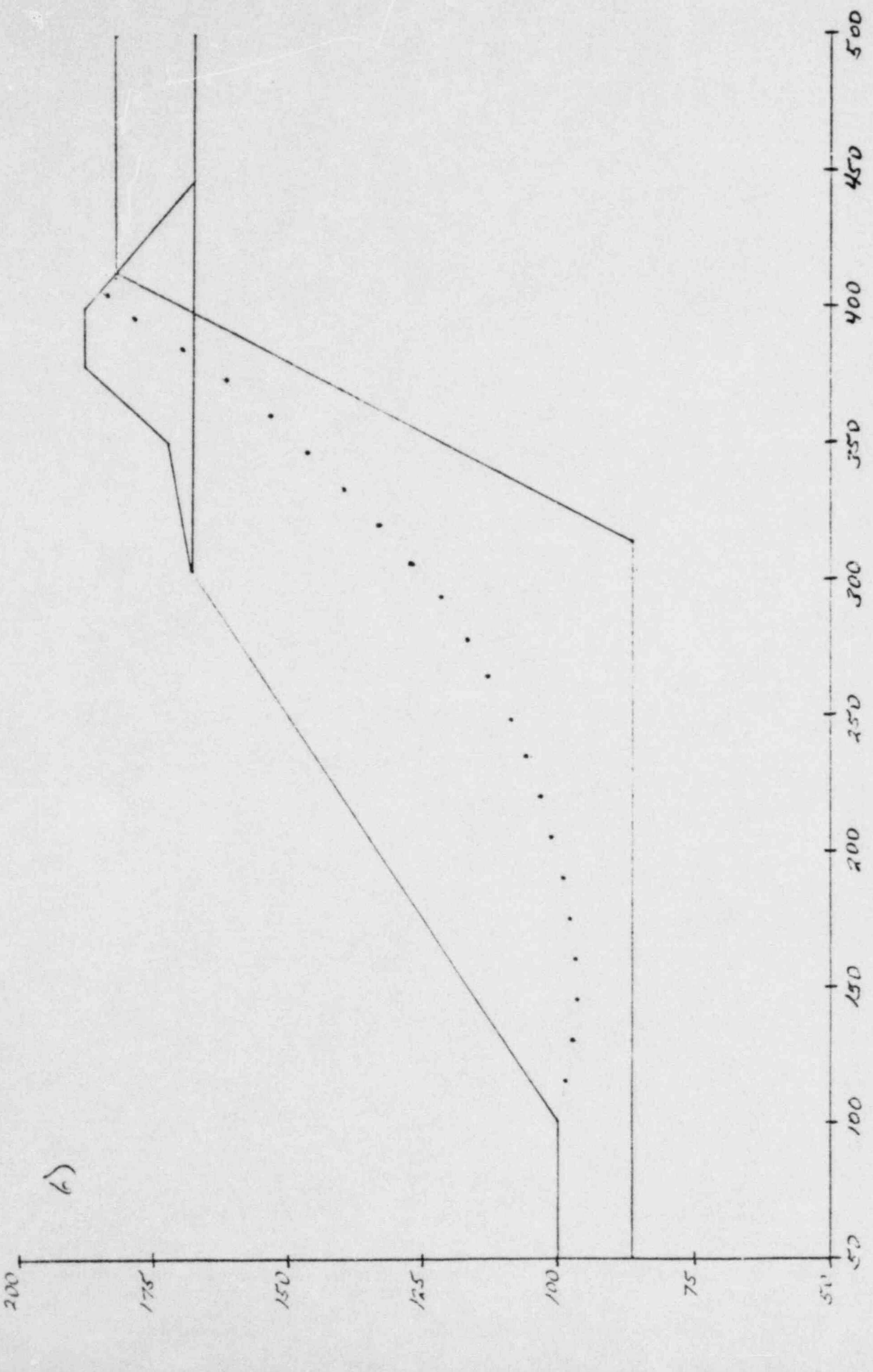

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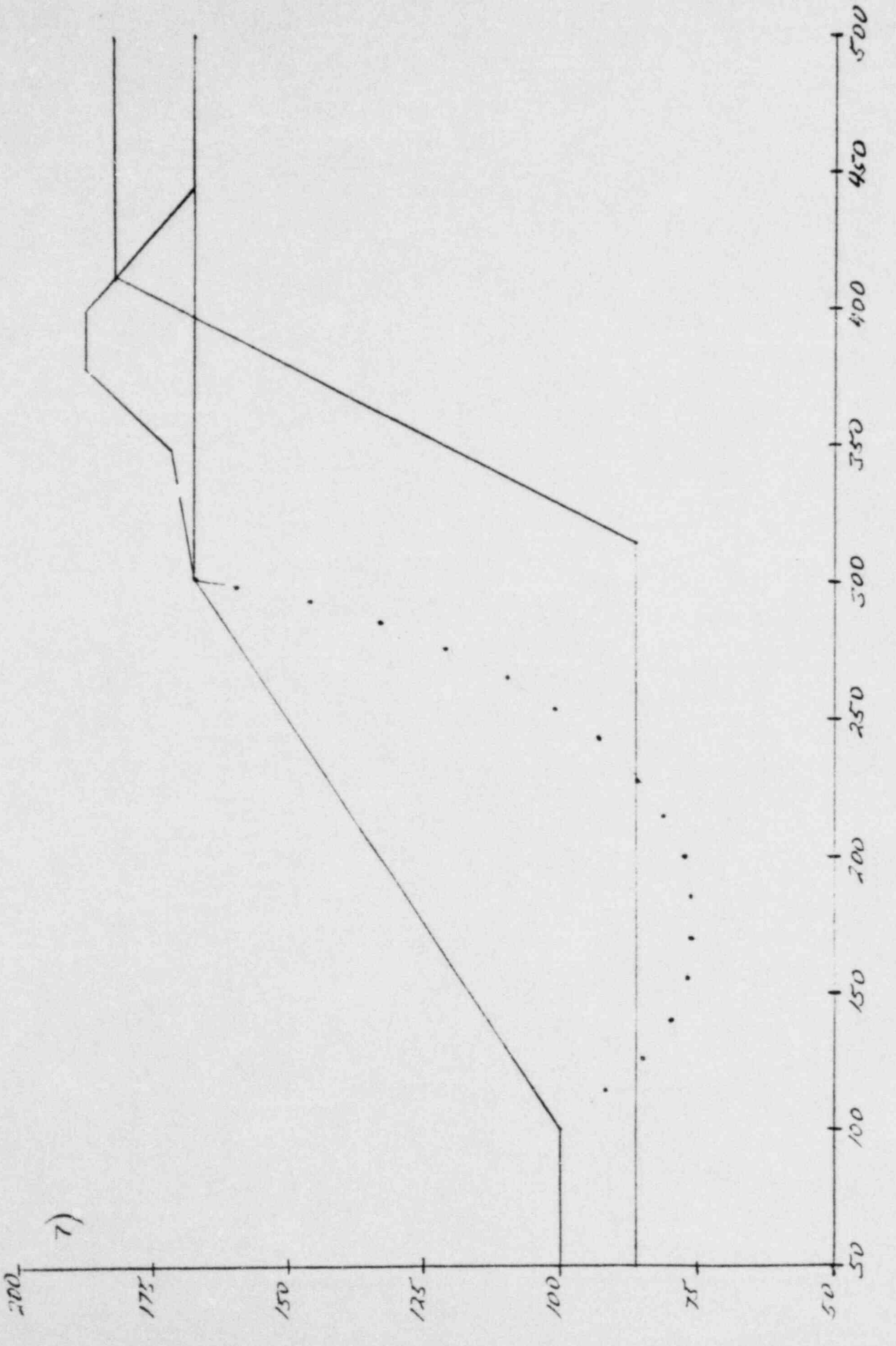

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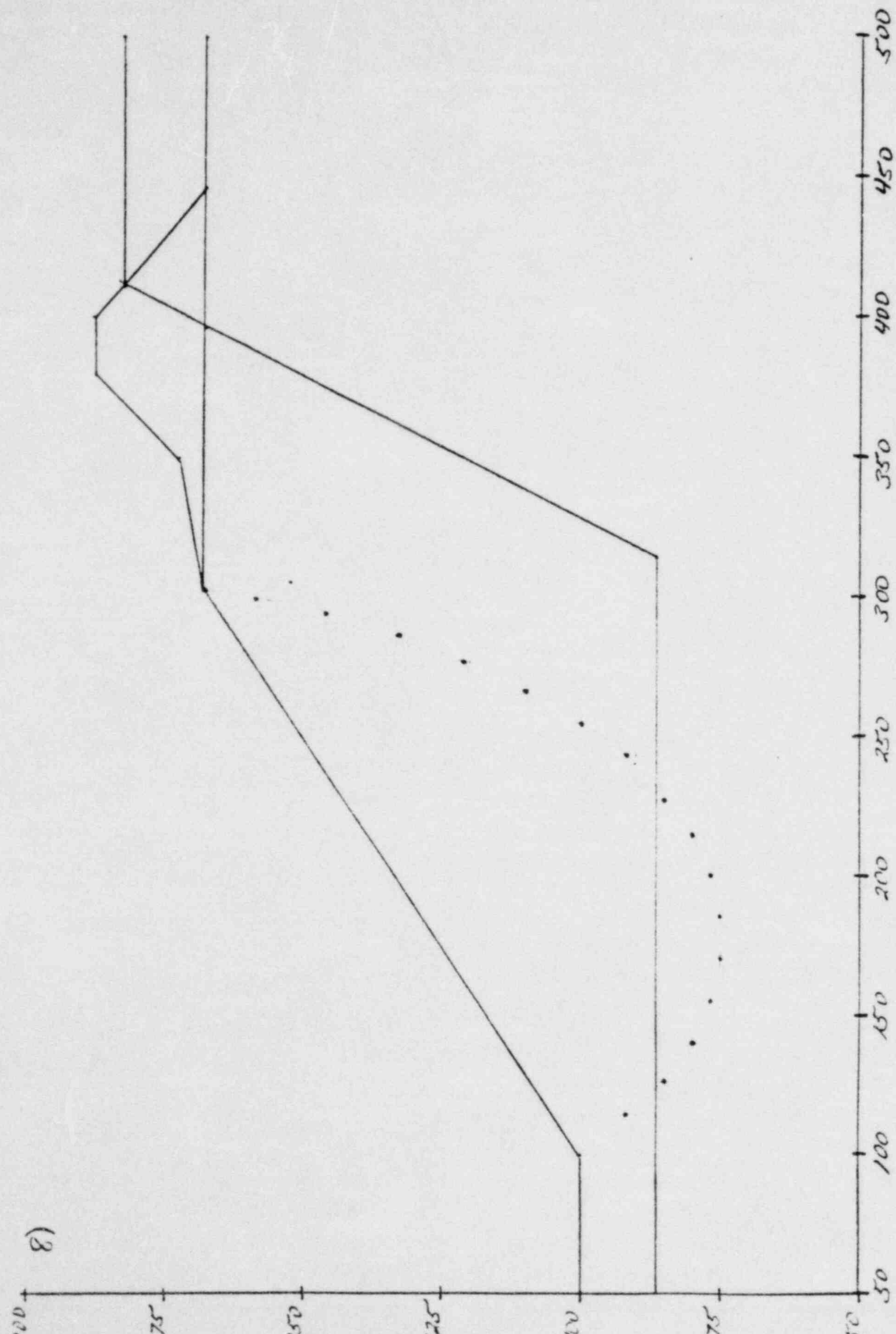
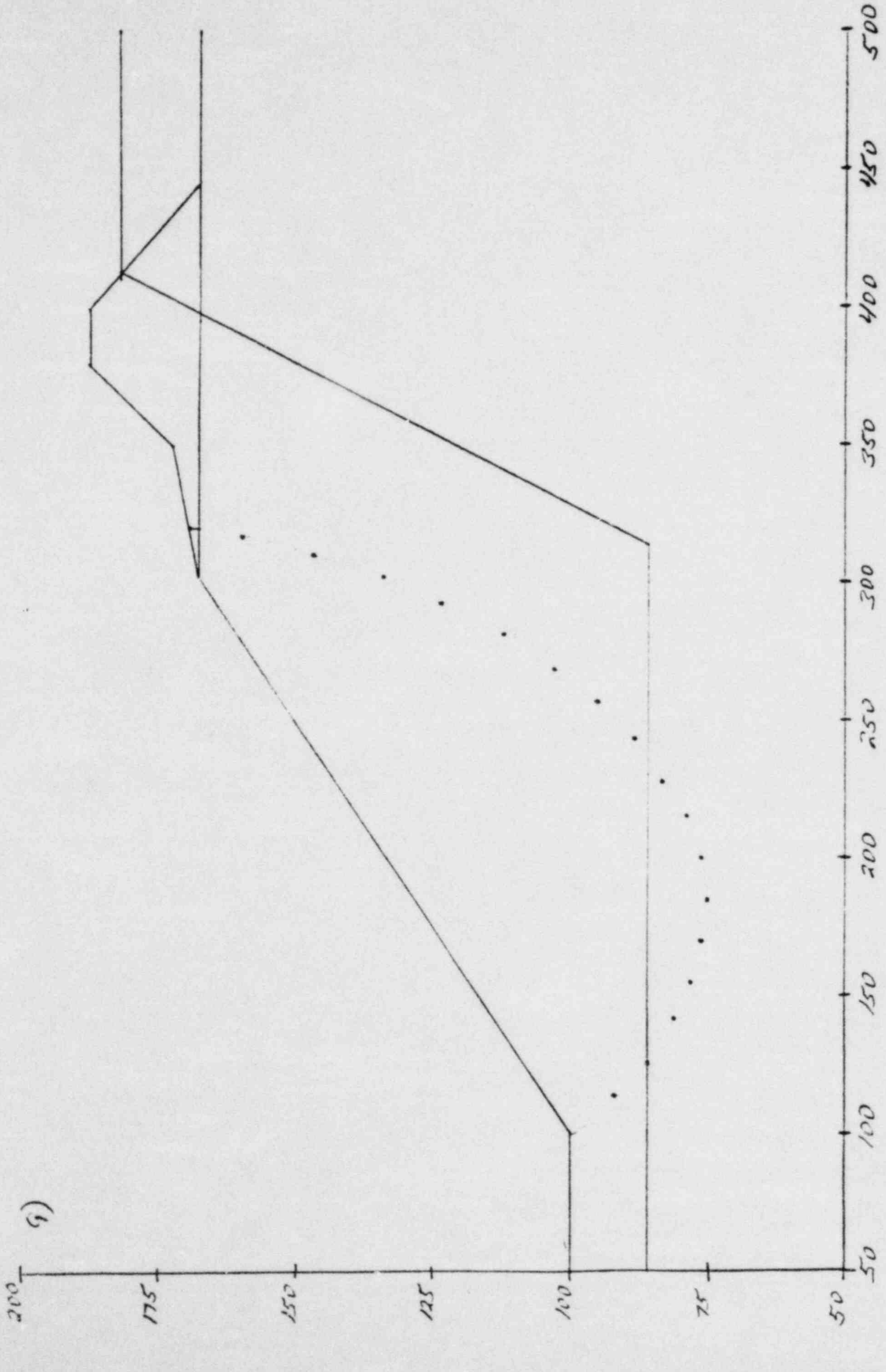
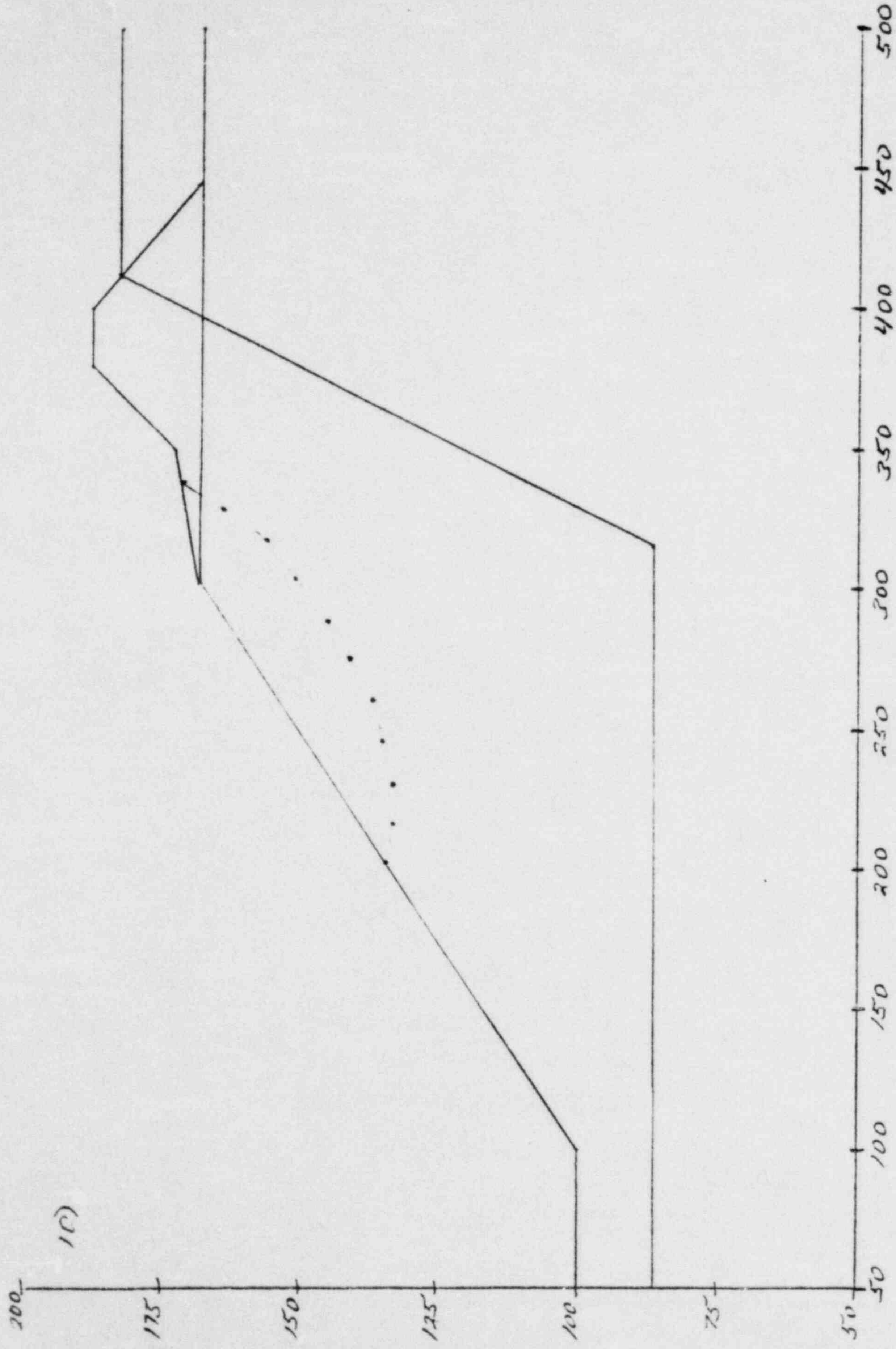


FACTOR OF SAFETY = 2.215



FACTOR OF SAFETY = 2.217



FACTOR OF SAFETY= 2.245

APPENDIX D

Hydrologic Computations

PMP 72 hour General Storm

1 sq mile = 640 acres

1 mile = 5280 ft

I. Probable maximum 6-hour point value

General Storm West of the 105° meridian (Zone B) = 3.5"

SPOKANE

For extending the 6-hr general storm value to a period of (36 hr) we multiply 3.5" times the corresponding values given in Table No. 1

1. a. A = 25.5 acres

   A = 0.040 square miles

   b. Length of longest water course

   L ≅ 1200' = 0.23 miles

   c. Difference in elevation from the highest point in the basin to the basin outlet

   Δh = 1745' - 1670' = 75'

2. General Design Hazard — PMP

3. Six hour general storm extended to a period of 36 hr

   Zone B, West of 105° meridian

   D = 2 hour time increments

   Rainfall = 3.5" (No area reduction ratio is applied)

4. General Soil Conditions.

   a. Antecedent moisture conditions AMC: II

   b. General Soil classification: D

   c. SCS number = 95

5. Triangular Hydrograph Information

a. $L = 0.23$ miles

$\Delta h = 75'$

b. Tc = Time of concentration

$$Tc = \left[\frac{11.9\ L^3}{H}\right]^{0.385} = 0.090\ hr.$$

No correction is needed for Tc because CN is > 80

$D = 2$ hr.

$$Tp = \frac{D}{2} + 0.6\ Tc = 1.05\ hr.$$

$Tb = 2.67\ Tp = 2.80$ hr

$Tr = Tb - Tp = 2.80 - 1.05 = 1.75$ hr

$$qi = \frac{484\ A\ Q}{Tp}$$

For Q = 1" of rainfall

$$qi = \frac{484 \times 0.040 \times 1}{1.05} = 18.44\ cfs$$

$qi \cong 19$ cfs

6 hr. General Storm - P.M.P (extended to 36 hr)

1 Duration (hrs)	2 % 6 hr Rainfall	3 Cumulative Rainfall (in)	4 Incremental Rainfall (in)	5 Design Rainfall (in)	6 Adj Design Rainfall (in)	7 P.M.P Cum. Des Rainfall (in)
0	-	-	-	-	-	-
2	0.48	1.68	1.68	0.24	0.24	0.24
4	0.77	2.70	1.02	0.28	0.28	0.52
6	1.00	3.50	0.80	0.28	0.28	0.80
8	1.18	4.13	0.63	0.35	0.35	1.15
10	1.36	4.76	0.63	0.39	0.39	1.54
12	1.53	5.36	0.60	0.45	0.45	1.99
14	1.66	5.81	0.45	0.60	0.60	2.59
16	1.77	6.20	0.39	0.63	0.63	3.22
18	1.87	6.55	0.35	0.80	0.80	4.02
20	1.95	6.83	0.28	1.68	1.68	5.70
22	2.03	7.11	0.28	1.02	1.02	6.72
24	2.10	7.35	0.24	0.63	0.63	7.35
26	2.16	7.56	0.21	0.21	0.21	7.56
28	2.22	7.77	0.21	0.21	0.21	7.77
30	2.28	7.98	0.21	0.21	0.21	7.98
32	2.32	8.12	0.14	0.14	0.14	8.12
34	2.35	8.23	0.11	0.11	0.11	8.23
36	2.38	8.33	0.10	0.10	0.10	8.33

1	8	9	10	11	12	13	14
Durations (hrs)	Q Cumulative Runoff (in)	Increm. Runoff (in)	q_i (cfs)	q_p (cfs)	Begin Hydrograph hrs	Peak Hydrograph hrs	End Hydrograph hrs
0	-		-	-	-	-	-
2	0.04	0.04	19	0.76	0	1.05	2.80
4	0.19	0.15	19	2.85	2	3.05	4.80
6	0.40	0.21	19	3.99	4	5.05	6.80
8	0.70	0.30	19	5.70	6	7.05	8.80
10	1.05	0.35	19	6.65	8	9.05	10.80
12	1.49	0.44	19	8.36	10	11.05	12.80
14	2.08	0.59	19	11.21	12	13.05	14.80
16	2.66	0.58	19	11.02	14	15.05	16.80
18	3.45	0.79	19	15.01	16	17.05	18.80
20	5.12	1.67	19	31.73	18	19.05	20.80
22	6.13	1.01	19	19.19	20	21.05	22.80
24	6.75	0.62	19	11.78	22	23.05	24.80
26	6.95	0.20	19	3.80	24	25.05	26.80
28	7.18	0.23	19	4.37	26	27.05	28.80
30	7.40	0.22	19	4.18	28	29.05	30.80
32	7.53	0.13	19	2.47	30	31.05	32.80
34	7.64	0.11	19	2.09	32	33.05	34.80
36	7.73	0.09	19	1.71	34	35.05	36.80

II. a) Elevation-area Curve

From Appendix 2 . Dawn Mining Company Report

Top Surface Area = 1'055.000 ft^2 = 24.22 Acr Elev. = 1740 ft.

Bottom Surf. Area = 366.300 ft^2 = 8.41 Acr Elev = 1675 ft.

See Figure No 1

b) Elevation - Volume Curve

Elevation (ft)	Surface Area (Acre)	Average Volume (Acre-ft)
1675	8.41	0
1680	9.00	43.53
1685	9.55	89.91
1690	10.20	139.29
1695	10.80	191.79
1700	11.60	247.79
1705	12.30	307.54
1710	13.15	371.17
1715	14.20	434.80
1720	15.40	508.80
1725	17.00	589.80
1730	18.80	679.30
1735	21.30	779.55
1740	24.22	893.35

See Figure No 2

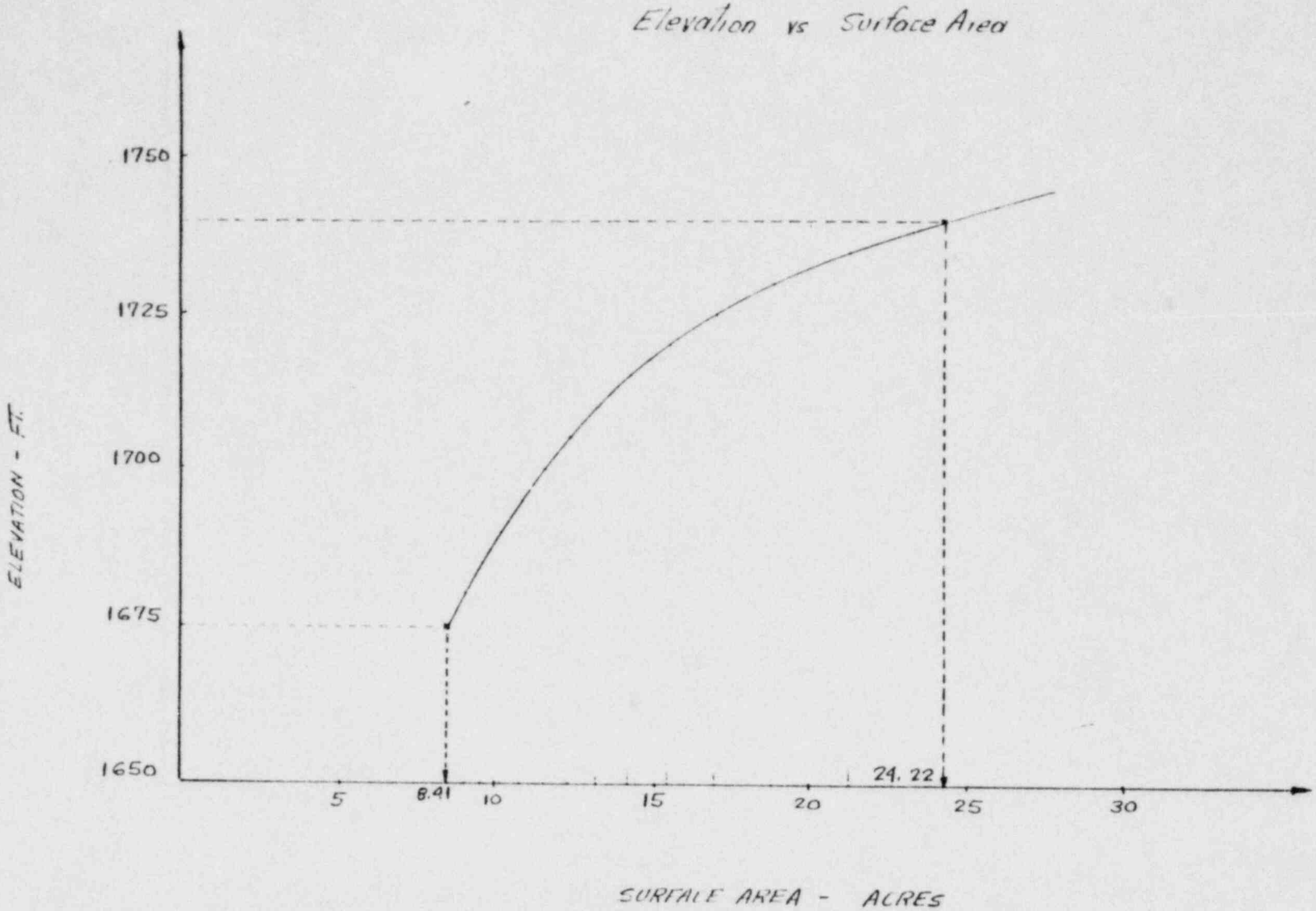

Elevation vs Surface Area
1750
1725
1700
1675
1650
ELEVATION - FT.
5
8.41
10
15
20
24. 22
25
30
SURFACE AREA - ACRES

FIGURE No 1

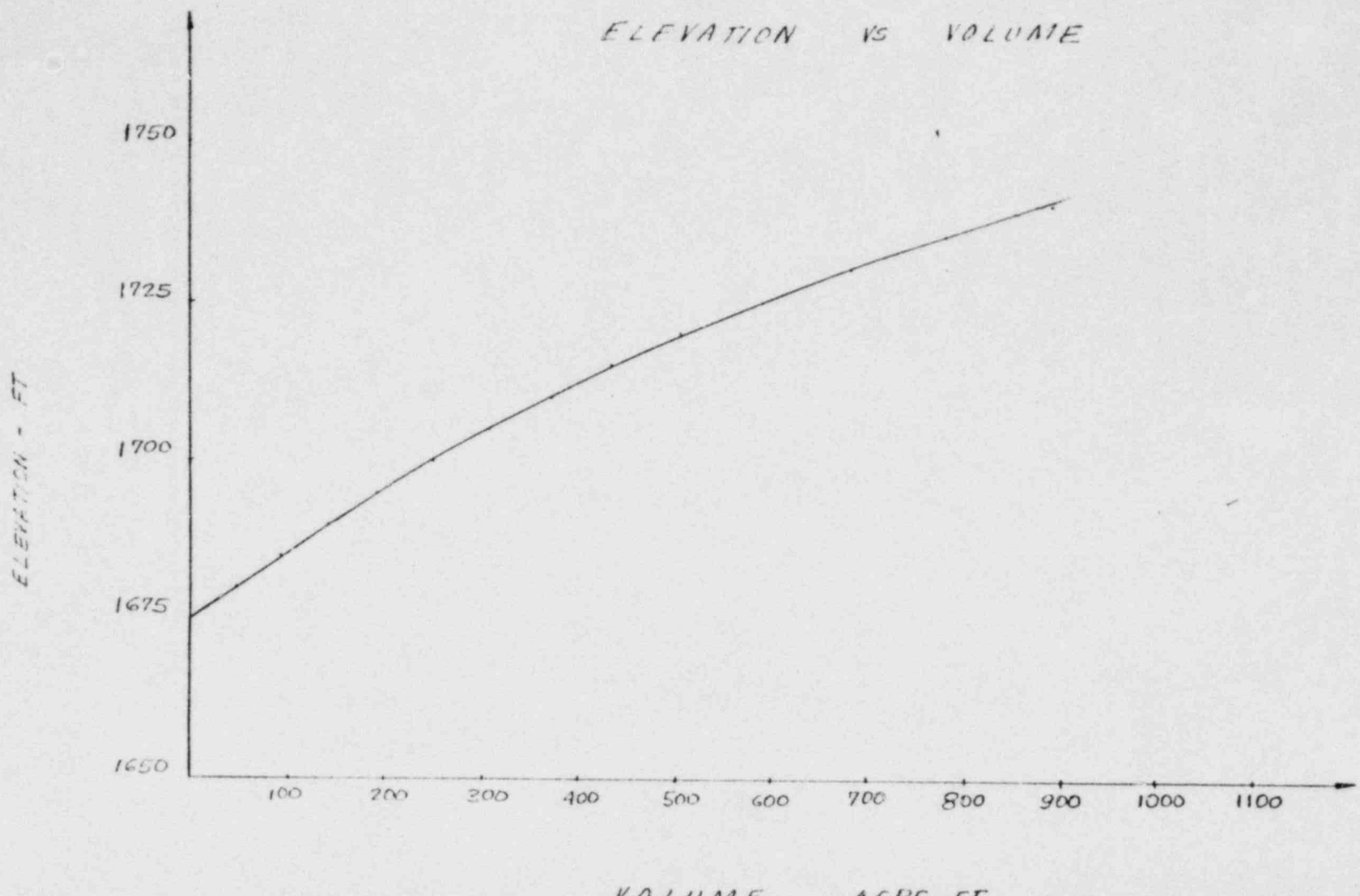

ELEVATION VS VOLUME
ELEVATION - FT
1750
1725
1700
1675
1650
100
200
300
400
500
600
700
800
900
1000
1100
VOLUME - ACRE-FT.

FIGURE No 2

III. Inflow - Outflow Water Balance

Normal tailings inflow = 0.95 acre-feet / day
Mean annual lake evaporation = 38" / year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Avg T°F	26.8	31.7	39.0	48.0	56.1	62.5	70.6	68.5	60.3	49.0	36.1	30.8
Av. Evap (in)	–	0.15"	1.44"	3.04"	4.48"	5.62"	7.07"	6.69"	5.29"	3.23"	0.95"	–
Av. Precip (in)	2.10"	1.65"	1.54"	0.97"	1.36"	1.29"	0.39"	0.54"	0.87"	1.59"	1.95"	2.25"
Tailings inf (Ac.ft)	29.45	26.6	29.45	28.5	29.45	28.5	29.45	29.45	28.5	29.45	28.5	29.45

		T. Inflow Acr. ft	Precip. Acre-ft	Evap. Acre-ft	Outflow Acre-ft.
1981	JAN	29.45	1.59	–	29.45
	FEB	56.05	1.26	0.11	57.20
	MAR	86.65	1.22	1.14	86.73
	APR	115.23	0.80	2.50	113.53
	MAY	142.98	1.16	3.82	140.32
	JUN	168.82	1.13	4.94	165.01
	JUL	194.46	0.35	6.39	188.42
	AUG	217.87	0.50	6.23	212.14
	SEP	240.64	0.83	5.02	236.45
	OCT	265.90	1.57	3.18	264.29
	NOV	292.79	1.97	0.96	293.80
	DEC	323.25	2.35	–	325.60

		Acre-ft			
		T. inflow	Precip	Evap	Outflow
1982	JAN	355.05	2.26	–	357.31
	FEB	383.91	1.84	0.17	385.58
	MAR	415.03	1.78	1.66	415.15
	APR	443.65	1.16	3.63	441.18
	MAY	470.63	1.68	5.52	466.79
	JUN	495.29	1.63	7.11	489.81
	JUL	519.26	0.51	9.19	510.58
	AUG	540.03	0.72	8.93	531.82
	SEP	560.32	1.19	7.17	554.34
	OCT	583.79	2.24	4.54	581.49
	NOV	609.99	2.83	1.38	611.44
	DEC	640.89	3.38	–	644.27
1983	JAN	673.72	3.27	–	676.99
	FEB	703.59	2.67	0.24	706.02
	MAR	735.47	2.59	2.42	735.64
	APR	764.14	1.69	5.30	760.53
	MAY	789.98	2.44	8.05	784.37
	JUN	812.87	2.38	10.38	804.87
	JUL	834.32	0.74	13.38	821.68
	AUG	851.13	1.04	12.90	839.27
	SEP	867.77	1.71	10.29	859.19
	OCT	888.64	3.19	6.49	885.34 ✓ o.k.