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# Surface-to-Underground Access Study for the Prospective Yucca Mountain Nuclear Waste Repository

A. W. Dennis and Dravo Engineers

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Sandia National Laboratories
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# SURFACE-TO-UNDERGROUND ACCESS STUDY FOR THE PROSPECTIVE YUCCA MOUNTAIN NUCLEAR WASTE REPOSITORY

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## ABSTRACT

The Nevada Nuclear Waste Storage Investigations (NNWSI) project has as one of its principal objectives the conceptual design of the buildings and facilities that will be required at a repository for commercially generated radioactive waste. A 10% ramp access and a shaft-and-drift access were investigated to determine the better access method for waste transfer. The ramp access was determined to be preferable from both an operational and a cost standpoint. A 10% ramp, a 20% ramp, a shaft-and-drift, and a shaft-only access were investigated to determine the best access method for mining operations. The 10% ramp, 20% ramp, and shaft-only access were determined to be equally acceptable for mining operations. The shaft-and-drift access has been eliminated from further consideration because of its higher cost in relation to the other mining access options.

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## SUMMARY

Repository access has been addressed by Sandia National Laboratories and by Dravo Engineers, Inc., to determine the optimum access method for the prospective nuclear waste repository at Yucca Mountain, Nye County, Nevada. For the purpose of this report, repository access is defined as the connection between the surface waste receiving facilities and the underground waste emplacement areas, and the connection between the surface mine facilities and the underground mine construction areas. This study was conducted in two parts: first, Dravo Engineers, Inc., developed preliminary designs and associated cost estimates for several access methods, and then Sandia National Laboratories evaluated each of these designs, giving consideration to the proposed repository operating procedures, expected exposure of workers to penetrating radiation, and the estimated costs.

As a result of this study, a ramp is recommended for moving waste from the surface to the underground. This ramp would originate at the surface waste handling facilities site and would terminate at the underground repository entry point. The ramps would be driven on a maximum grade of 10% (1 ft vertical drop for every 10 ft of horizontal travel). The recommendation to use a ramp access is equally valid for waste emplacement in vertical or horizontal boreholes.

The surface facilities for mining operations can be co-located with the waste handling facilities, or they can be placed at a separate location. Three of the sites considered, two with co-located facilities and one with separate sites for

surface facilities, were suitable for either a ramp access or a shaft-and-drift access. In all three cases, the estimated capital and operating costs were lower for the ramp access. A fourth mining facility site, located within the repository boundary, was also considered. Direct shaft access is feasible from this site.

A 10% ramp from the mining facility sites co-located with the waste handling facility sites, a 20% ramp from the mining facility site located to the west of the waste handling facility sites, and a direct shaft access from a mining facility site within the repository boundary are all reasonable candidates for mining operations access. It is recommended that the mining access method be selected during the conceptual design phase of this program. At that time, the incremental costs of developing a second site for mining operations and the desired repository entry point will be determined. When this information is available, the optimum entry method (ramp or shaft) for mining operations can be identified.

# 1. INTRODUCTION

Sandia National Laboratories, under the direction of the Department of Energy (DOE) and in cooperation with Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and the United States Geological Survey, is engaged in the conceptual design of a repository for commercially generated radioactive waste. This repository design is being developed as part of the Geologic Repository Program of the DOE as directed by the Nuclear Waste Policy Act of 1982. If constructed, this project would provide a repository on federally owned land at Yucca Mountain, Nye County, Nevada.

Repository access has been addressed by Dravo Engineers, Inc., and by Sandia National Laboratories to determine the optimum access method. For the purpose of this report, repository access is defined as the connection between the surface waste receiving facilities and the underground waste emplacement areas, and the connection between the surface mine support facilities and the underground mine construction areas. This study was conducted in two parts: first, Dravo Engineers, Inc., developed preliminary designs and associated cost estimates for several access methods, and then Sandia National Laboratories evaluated each of these designs, giving consideration to the proposed repository operating procedures and expected exposure of workers to radiation.

For waste transfer operations, a ramp access and a shaft-and-drift access were considered from each of two surface sites (a total of four options). For mining operations, a ramp access and a shaft-and-drift access were considered from each

of three surface sites for both the vertical and the horizontal waste emplacement methods (an additional 12 options). Also, for mining operations, a shaft-only access was considered from a single surface site for both waste emplacement methods (two additional options). In all, four preliminary designs were considered for waste transfer operations, and 14 preliminary designs were considered for mining operations. These designs and the detailed capital and operating cost estimates for each access design considered were prepared by Dravo Engineers, Inc.

The contents of this report can be summarized as follows: Section 2 describes surface facility sites and the access methods considered. Section 3 gives the estimated capital and daily operating costs for each site and access method. Section 4 discusses the evaluation factors used for waste emplacement access recommendation, and Section 5 discusses the evaluation factors used for mining operations access recommendations. Section 6 contains the access method recommendations which Sandia reached based on this information.

The data and repository configurations discussed in this report are based on data and assumptions made in 1983 when the work was performed. Although more recent analyses have resulted in a different reference configuration for a repository design at the Yucca Mountain site, the conclusions reached here are still valid.

# 2.0 UNDERGROUND REPOSITORY ACCESS METHODS

## 2.1 Repository Access Methods--Waste Handling Operations

### 2.1.1 Design Criteria and Assumptions

The preliminary comparison of methods for waste handling operations was based on the following design criteria provided by Sandia National Laboratories:

- Waste transfer hoisting system shall be capable of transporting a 50-ton payload from surface-to-underground repository at a rate of at least 10 per day.

- A design grade of 10% shall be used for ramp access.

- An operating period of five days per week, two shifts per day, 250 days per calendar year shall be used for waste emplacement operations.

- The repository underground entry point is assumed to be located at coordinates N762,860 and E564,050 and an elevation of 2,910 ft (Reference 1).

- The location of the waste handling access portal must be adjacent to the surface waste handling facilities.

### 2.1.2 Site Considerations and Selection

The following items were considered in the site selections for waste handling facilities:

- The selected site shall permit rail and highway access at reasonable approach grades.

- The topography of the site shall be reasonably flat.

- The route of the surface-to-underground access shall be relatively free of fractures and faults, based on existing maps.

These items were used in the selection of candidate sites. The candidate sites were evaluated by a Dravo technical review committee, and two sites were selected that met the necessary criteria; they are identified as Site 1 and Site 2 (Figures 2.1 and 2.2). (Note: all figures for Section 2 are grouped at the end of the section.)

### 2.1.3 Comparison of Shaft-and-Drift and Ramp Access

The shaft-and-drift and a ramp were identified as viable repository access methods. A shaft provides vertical access to the repository horizon and may require a horizontal drift to connect the shaft to the underground repository entry point. A ramp provides access through an inclined opening directly to the underground repository entry point. For the purposes of this study, the two

methods have been compared on a capital and operating cost basis. Rock competence, maintenance, equipment transfer, ventilation requirements, and emergency egress were also considered (Table 2.1).

Table 2.1

Comparison of Shaft-and-Drift Method and Ramp Method for Waste Handling Operations

| Shaft-and-Drift | Ramp |
|---|---|
| 1. Rock in the shaft that varies in in competency can be effectively supported using minor changes in design of the concrete lining. The drift, however, must contain sufficiently competent rock to permit ground control with normal rockbolting techniques and a minimum of concrete lining, due to the large expense involved for full lining. | Rock in the ramp must be sufficiently competent to permit control of the ground with normal rockbolting techniques and a minimum of concrete lining, due to the large expense involved for full lining. |
| 2. A concrete-lined shaft requires minimal maintenance. A drift requires continuing maintenance unless it is fully lined. | A ramp requires continuing maintenance, unless it is fully lined. |
| 3. Large mobile equipment must be disassembled and lowered into the mine. | Large mobile equipment can be moved underground without disassembly. |
| 4. Ventilation requirements are minimal in the shaft itself. (If diesel equipment is in the drift, ventilation requirements will be higher.) | Ventilation requirements are higher if diesel equipment is used for transport. |
| 5. If designated as a mine escapeway, emergency egress is usually via a separate, independent hoisting system or a ladder travelway. | If designated as a mine escapeway, emergency egress can be by foot or vehicle. |

### 2.1.4 Shaft-and-Drift Method of Entry

The shaft-and-drift combination for repository access consists of a vertical shaft extending from the waste handling facilities to the repository horizon and a horizontal drift connecting the shaft to the entry point of the repository. A general arrangement of the shaft-and-drift access method is shown in Figure 2.3. One shaft-and-drift combination is proposed for each surface waste handling facility location (Sites 1 and 2); these are referred to as Cases A-1 and A-2 and are schematically shown in Figures 2.1 and 2.2. The shaft depth is 870 ft in each case; the connecting drift is 6,800 ft long for Case A-1 and 7,400 ft long for Case A-2, Table 2.2.

Table 2.2

Waste Handling Operations
Comparison of Alternate Cases
For Repository Access
Using Shaft-and-Drift Methods

| CASE NO. | ACCESS METHOD | SITE | DESCRIPTION |
|---|---|---|---|
| A-1 | Shaft-and-Drift | 1 | 22' dia by 870' Shaft<br>20' by 15' by 6,800' Drift |
| A-2 | Shaft-and-Drift | 2 | 22' dia by 870' Shaft<br>20' by 15' by 7,400' Drift |

Shaft Size--The major factors in determining shaft diameter are the size and weight of the facility cask. The weight to be lowered (cask plus the conveyance) determines the hoist rope size, which in turn sizes the hoist drum. A diameter of 22 ft was selected for the shaft to allow for sufficient clearance between the

conveyances and the shaft walls. The shaft cross section and general arrangement are shown in Figure 2.3.

Hoist System and Headframe--A multi-rope friction-type hoist was selected because of the cask weight of 50 tons. This type of hoise is commonly used in the industry for high load situations. The shaft conveyance will be designed to operate on rope guides. Fixed guides will be provided at the shaft collar (surface) and the underground station to stabilize the cask loading/unloading process. A counterweight will be used to offset the conveyance weight, thus reducing hoist power requirements. Friction hoists are commonly mounted in headframe structures for simplicity and ease of operations and maintenance. The relationships of the headframe-mounted hoist, the headframe, and the shaft are shown in Figure 2.3.

For cost-estimating purposes, the required hoisting system configuration was determined using a Dravo computer program. The hoisting design data which resulted from these calculations are presented in Table 2.3.

The reinforced concrete headframe is designed to be an integral part of the waste handling system. It includes the inside-mounted friction hoist, man-elevator, stairwell, equipment lifting bay and hatches, and a bridge crane for equipment installation and servicing. Approximate dimensions are 36 ft by 45 ft by 152 ft, sufficient to allow all hoisting functions to be performed and to provide required clearances. The headframe design also allows for the installation of the necessary shaft sinking equipment to allow shaft sinking to proceed with a minimum of schedule interference from permanent equipment installation and facility construction.

Table 2.3

Summary of Hoisting Design Data For Waste Emplacement Used for Cost Estimates

| | |
|---|---|
| Hoist Type | Friction hoist |
| Hoist Wheel Diameter | 120 in. |
| Cage Weight | 86,000 lb |
| Payload (Cage) | 100,000 lb |
| Counterweight | 136,000 lb |
| Number of Ropes | 8 |
| Hoisting Rope | 1.5 in. diameter |
| Rope Type | 6 x 19 round strand/ fiber core |
| Rope Breaking Strength | 190,000 lb single rope |
| Weight of Rope | 3.7 lb/ft |
| Acceleration | 0.5 $fps^2$ |
| Deceleration | 0.5 $fps^2$ |
| Creep Speed | 1.0 fps |
| Creep Time | 4 sec |
| Hoisting Speed | 120 fpm |
| Static Safety Factor (Required) | 6.55 |
| Static Safety Factor (Actual) | 7.00 |
| Dynamic Safety Factor (Desired) | 4 |
| Dynamic Safety Factor (Actual) | 5.18 |
| Rope Tension on the Loaded Side ($T_1$) | 217,080 lb for multiple (8) ropes |
| Rope Tension on the Unloaded Side ($T_2$) | 167,080 lb for multiple (8) ropes |
| $T_1/T_2$ | 1.30 |
| Tread Pressure | 267 psi |
| Motor Horsepower | 250 |
| Hoist Distance | 720 ft |
| Hoisting Time (Including Creep) | 384 sec |

The shaft extends 150 ft below the underground station. The underground station elevation is 20 ft above the repository entry elevation to provide a nominal drainage grade along the drift that connects the shaft station to the repository.

Connecting Drift--Shaft to Repository--The connecting drift from the shaft to the repository entry point must

- Allow for efficient movement of a waste transport vehicle.
- Provide sufficient ventilation for operation of the waste transport vehicles.

Similar criteria were used to size the drifts in the repository (Reference 1). The 20-ft-wide by 15-ft-high arched drift used in the repository will also be used in this study. The cross section of this drift is shown in Figure 2.4; this is the same cross section as the ramp discussed in Section 2.1.5 of this report. The drift lengths determined for estimating purposes are shown in Table 2.2. An arch is commonly used in volcanic formations (such as the tuffs in this project). If the shape is changed to rectangular, for example, the cost estimates will not be seriously affected.

Excavation Techniques--For the purposes of cost estimating, the shafts, ramps, and drifts are assumed to be conventionally excavated using drill and blast techniques. Conventional techniques are being used at this time because mechanical devices have not yet been fully developed and proven which can reliably and competitively excavate the hard (15,000 psi), silica-rich tuffs at the repository site. These tuffs cause high rates of machine wear. Mechanized mining techniques, however, warrant further study for use at the Nevada Test Site Waste Repository because new developments are continually being made by manufacturers.

The roadbed will be concreted to provide a uniform transport surface. Ground support will be provided by rockbolts, wire mesh, and shotcrete, all standard methods used for this type of excavation. Because of anticipated fractured ground conditions, it is estimated that 25% of the drift length will require additional steel sets, lagging, and concrete for ground support.

### 2.1.5 Ramp Method of Entry

The ramp method of repository entry consists of an inclined opening (the ramp)

extending from the waste handling facilities directly to the underground entry point of the repository. A general-arrangement layout drawing of the ramp method is shown in Figure 2.4. One ramp is proposed for each surface waste handling facility location (Sites 1 and 2); these are referred to as Cases A-3 and A-4. Table 2-4 provides the description for each of the two cases, which are schematically shown in Figures 2.5 and 2.6.

Table 2.4

Waste Handling Operations
Comparison of Alternate Cases
For Repository Access
Using Ramp Methods

| Number | Access Method | Site | Description |
|---|---|---|---|
| A-3 | 10% Ramp | 1 | 20' by 15' by 7,400' horizontal distance at 10% grade |
| A-4 | 10% Ramp | 2 | 20' by 15' by 7,400' horizontal distance at 10% grade |

The design criteria, the physical relationships between the surface and underground, and the flexibility of trackless equipment over track vehicles determined that trackless haulage should be used in the ramp design.

Ramp Grade

The specific ramp design factors used for this project were obtained from Reference 8 and are as follows:

- Maximum grade in the repository openings is 10%.

- Equipment to transport the facility casks will be designed to operate on a 10% grade.

Given these design parameters, Dravo designed a 10% grade ramp from both surface locations to the repository. The resulting ramps are both 7,437 ft long and cover a vertical depth of 740 ft (Figure 2.4).

The size of the ramp was determined by the same procedure used to size the drift; namely, the functional criteria and previous design work were reviewed to arrive at the same 20-ft-wide by 15-ft-high arched cross section used in the repository drifts. Figure 2.4 shows this cross section, as well as the layout of the ramp. Conventional drill and blast excavation methods will be used as a basis for cost estimating.

The roadbed will be concreted to provide a uniform transport surface. Ground support will be provided by rockbolts, wire mesh, and shotcrete, all standard methods used for this type of excavation. Due to anticipated fractured and faulted ground conditions, it is estimated that 25% of the ramp length will require additional steel sets, lagging, and concrete for ground support.

## 2.2 Repository Access Methods--Mining Operations

### 2.2.1 Design Criteria and Assumptions

The preliminary comparison of access methods used for the mining operations of the repository was developed in Reference 1.

The major design criteria for the access opening are summarized as follows:

- The number of miners to be transported in and out of the underground area is 56 per shift for the horizontal emplacement

method and 184 per shift for the vertical emplacement method. An additional 50 people per shift must be moved in and out of the underground area for waste handling operations.

- Three shifts per day, five days per week, 250 days per year for a period of 20 years will be required for mining operations.

- Mined rock is produced at a rate of 1,500 tons/day for horizontal emplacement and 10,000 tons/day for the vertical emplacement method.

- Supplies must be moved into the underground area as required to support mining operations.

- The repository underground entry point is assumed to be located at coordinates N762,700 and E564,070, and at an elevation of 2,910 ft (Reference 1).

### 2.2.2 Site Considerations and Selection

The following items were considered in the site selection for the mining facilities:

- The selected site shall permit highway access at a reasonable approach grade.

- The topography of the area shall be reasonably flat.

- The route of the surface to underground access shall be relatively free of fractures and faults, based on existing maps.

- The site shall be close to the projected boundary of the underground repository area.

- The site for mining support facilities shall be close to the site for waste handling facilities.

- The mine development rock disposal distance shall be reasonable.

These items were reviewed and used in the selection of potential sites for the mine support facilities. The sites were evaluated by a Dravo technical review committee and four sites met the necessary criteria. They have been identified as Sites 1, 2, 3, and 4 (see Figures 2.7, 2.8, 2.9 and 2.10).

Site 1 is co-located with waste handling Site 1; Site 2 is co-located with waste handling Site 2; Site 3 is located west of Site 1 closer to the repository boundary; and Site 4 is located within the projected boundary of the repository above the entry point.

### 2.2.3 Comparison of Shaft-and-Drift and Ramp Access

A shaft provides vertical access to the repository horizon and may require a horizontal drift to connect the shaft and the underground repository entry point. A ramp provides access through an inclined opening directly to the

repository entry point. For the purposes of this study, the two methods have been compared on a capital and operating cost basis. Rock competence, maintenance, equipment access, development rock removal, ventilation, emergency egress, and efficiency of men and materials transport were also considered (Table 2.5).

### 2.2.4 Shaft-and-Drift Method of Entry

The shaft-and-drift combination for repository access consists of a vertical shaft extending from the mine support facilities to the repository horizon and a horizontal drift connecting the shaft to the entry point of the repository. General-arrangement drawings of the shaft-and-drift access method are shown in Figures 2.11 and 2.12. Four potential surface sites were selected for this study. Two shaft-and-drift combinations, one for vertical emplacement and one for horizontal emplacement were studied for Sites 1, 2, and 3, and a shaft-only access was studied for Site 4. These are Cases B-1 through B-8. They are shown in Figures 2.7 through 2.10. Table 2.6 provides the description for each of these cases.

Shaft Size--The major factors in determining the diameter of the shaft are the number of personnel to be transported underground and the amount of material to be hoisted daily. The cage (conveyance), in addition to hoisting personnel, must be large enough to lower supplies such as explosives, rockbolts, and vehicle parts. The size of the skips (rock conveyances) is based on the number of tons of broken rock to be hoisted daily. Preliminary layouts were prepared by Dravo mining and mechanical engineers for the 10,000 tons/day (TPD) and 1,500 TPD

Table 2.5

Comparison of Shaft-Drift Method and Ramp Method for Mining Operations

| Shaft-and-Drift | Ramp |
|---|---|
| 1. Rock in the shaft that varies in in competency can be effectively supported using minor changes in design of the concrete lining. The drift, however, must contain sufficiently competent rock to permit ground control with normal rockbolting techniques and a minimum of concrete lining, due to the large expense involved for full lining. | Rock in the ramp must be sufficiently competent to permit control of the ground with normal rockbolting techniques and a minimum of concrete lining, due to the large expense involved for full lining. |
| 2. A concrete-lined shaft requires minimal maintenance. A drift requires continuing maintenance unless it is fully lined. | A ramp requires continuing maintenance, unless it is fully lined. |
| 3. Large mobile equipment must be disassembled and lowered into the mine. | Large mobile equipment can be moved underground without disassembly. |
| 4. A hoisting system is required to remove the broken development rock from the mine. | Conveyors can be used to remove the broken development rock from the mine. |
| 5. Ventilation requirements are minimal in the shaft itself. (If diesel equipment is in the drift, ventilation requirements will be higher.) | Ventilation requirements are higher if diesel equipment is used for transport. |
| 6. If designated as a mine escapeway, emergency egress is usually via a separate, independent hoisting system or a ladder travelway. | If designated as a mine escapeway, emergency egress can be by foot or vehicle. |
| 7. More efficient handling of men and materials to underground is due to the direct vertical route and fast hoisting systems. | Less efficient handling of men and materials to underground is due to the slow speed of wheeled transport vehicles. Efficiency is increased somewhat by a steeper ramp with a hoisting system. |

Table 2.6

Mining Operations
Comparison of Alternate Cases
For Repository Access

| Case Number | Access Method | Surface Site | Emplacement Method | Description |
|---|---|---|---|---|
| B-1 | Shaft-and-Drift | 1 | Vertical | 25' dia by 1,030' Shaft<br>20' by 15' by 6,850' Drift |
| B-2 | Shaft-and-Drift | 1 | Horizontal | 20' dia by 830' Shaft<br>20' by 15' by 6,850' Drift |
| B-3 | Shaft-and-Drift | 2 | Vertical | 25' dia by 1,030' Shaft<br>20' by 15' by 7,400' Drift |
| B-4 | Shaft-and-Drift | 2 | Horizontal | 20' dia by 830' Shaft<br>20' by 15' by 7,400' Drift |
| B-5 | Shaft-and-Drift | 3 | Vertical | 25' dia by 1,200' Shaft<br>20' by 15' by 4,550' Drift |
| B-6 | Shaft-and-Drift | 3 | Horizontal | 20' dia by 1,000' Shaft<br>20' by 15' by 4,550' Drift |
| B-7 | Shaft Only | 4 | Vertical | 25' dia by 1,400' Shaft |
| B-8 | Shaft Only | 4 | Horizontal | 20' dia by 1,200' Shaft |

requirements. Allowing for sufficient clearances between the conveyances, shaft steel, and the shaft walls, a shaft diameter of 25 ft was selected for the vertical emplacement method (10,000 TPD), and a shaft diameter of 20 ft was selected for the horizontal emplacement method (1,500 TPD). Cross sections of these shafts are shown in Figures 2.13 and 2.14.

Hoist System and Headframe--Conventional double-drum hoists were selected for all cases of shaft access for mining operations. These hoists are all ground mounted and have a separate headframe structure. They are commonly used in industry for most smaller tonnage operations. The cage is attached to a single hoist rope and

will be designed to operate on fixed guides in the shaft. A counterweight will be attached to offset the conveyance weight. The skips will operate in balance (one acting as a counterweight), each attached to its own hoist drum by a hoist rope. They will be designed to operate on rope guides. Fixed guides will be used at the shaft collar (surface) and at the shaft level to stabilize the loading/dumping processes.

The relationships of the headframe, the shaft, and the ground-mounted hoist are shown in Figures 2.11 and 2.12.

For cost-estimating purposes, the required hoisting system configuration was determined using a Dravo computer program. The hoisting design data which resulted from these calculations are presented in Table 2.7 for each production rate.

For the horizontal emplacement (1,500 TPD) case, the shaft extends 110 ft below the station level to provide the necessary clearance below the skip when it is in the loading position (Figure 2.9). For the vertical emplacement (10,000 TPD) case, the shaft extends 310 ft below the station level to provide the necessary clearance below the skip in the loading position and to allow for the installation of a surge bin between the station level and the loading pocket. The capacity of the bin is equal to one shift's production and is consistent with standard mining practice (Figure 2.12).

Connecting Drift-Shaft to Repository--The connecting drift from the shaft to the repository entry point must

- Allow for efficient movement of development muck to the shaft for skip loading at the rates established for each emplacement method.

- Act as a mine service entry for movement of men and materials.

Similar criteria were used to size the development drifts in the repository (Reference 1). This size was reviewed by Dravo mining engineers to confirm that all the criteria were met for the connecting drift. Based on these findings, the 20-ft-wide by 15-ft-high arched drift was used for comparison purposes in this study. The drift lengths determined for estimating purposes are shown in Table 2.8. The roadbed will be concreted to provide a uniform transport surface. Ground support will be provided by rockbolts, wire mesh, and shotcrete, all standard methods used for this type of excavation. Because of anticipated fractured ground conditions, it is estimated that 25% of the drift length will require additional steel sets, lagging, and concrete for ground support.

### 2.2.5 Ramp Method of Entry

The ramp method of repository entry consists of an inclined opening (the ramp) extending from the waste handling facilities directly to the underground entry point of the repository. General-arrangement drawings of the ramp method are shown in Figures 2.15 and 2.16. Ramp entries are evaluated for Sites 1, 2, and 3. These are referred to as Cases B-9 through B-14 and are described in Table 2.8. These cases are schematically shown in Figures 2.17, 2.18, and 2.19.

Table 2.7

Summary of Hoisting Design Data For Mining Operations Used For Cost Estimates

| | Vertical Emplacement | Horizontal Emplacement |
|---|---|---|
| Hoist Type | Double Drum | Double Drum |
| Hoist Drum Diameter - Skip | 150 in. | 100 in. |
| Hoist Drum Diameter - Cage | 177 in. | 140 in. |
| Skip Weight (Each) | 9.7 tons | 4.2 tons |
| Cage Weight | 15.75 tons | 9.6 tons |
| Payload - Skip (Each) | 14 tons | 6 tons |
| Payload - Cage | 22.5 tons | 12 tons |
| Counterweight | 27 tons | 15.6 tons |
| Hoisting Rope - Skip | 1 7/8 in. diameter | 1 1/4 in. diameter |
| Hoisting Rope - Cage & Counterweight | 2 1/4 in. diameter | 1 3/4 in. diameter |
| Rope Type | 6 x 19 round strand wire core | 6 x 19 round strand wire core |
| Hoist Distance | 1,265 ft | 1,150 ft |
| Acceleration - Skip | 2.5 $fps^2$ | 2.5 $fps^2$ |
| Acceleration - Cage | 2.0 $fps^2$ | 2.5 $fps^2$ |
| Deceleration - Skip | 2.5 $fps^2$ | 2.5 $fps^2$ |
| Deceleration - Cage | 2.0 $fps^2$ | 2.0 $fps^2$ |
| Creep Speed - Skip | 2 fps | 2 fps |
| Creep Speed - Cage | 2 fps | 2 fps |
| Creep Time - Skip | 5 sec | 5 sec |
| Creep Time - Cage | 5 sec | 5 sec |
| Hoisting Speed - Skip | 1,260 fpm | 1,200 fpm |
| Hoisting Speed - Cage | 1,005 fpm | 1,080 fpm |
| Static Safety Factor (Actual) - Skip | 5.76 | 6.01 |
| Static Safety Factor (Actual) - Cage | 5.64 | 5.82 |
| Dynamic Safety Factor (Actual) - Skip | 4.39 | 4.22 |
| Dynamic Safety Factor (Actual) - Cage | 4.63 | 4.24 |

Table 2.7 (Continued)

| | Vertical Emplacement | Horizontal Emplacement |
|---|---|---|
| Motor Horsepower - Skip | 1,250 | 550 |
| Motor Horsepower - Cage | 550 | 300 |
| Hoisting Time (Including Creep) - Skip | 78 sec | 84 sec |
| Hoisting Time (Including Creep) - Cage | 108 sec | 97 sec |

Table 2.8

Mining Operations
Comparison of Alternate Cases
For Repository Access
Using Ramp Methods

| Case Number | Access Method | Site | Emplacement Method | Description |
|---|---|---|---|---|
| B-9 | 10% Ramp | 1 | Vertical | 20' by 15' by 7,400' horizontal distance at 10% grade |
| B-10 | 10% Ramp | 1 | Horizontal | 20' by 15' by 7,400' horizontal distance at 10% grade |
| B-11 | 10% Ramp | 2 | Vertical | 20' by 15' by 7,400' horizontal distance at 10% grade |
| B-12 | 10% Ramp | 2 | Horizontal | 20' by 15' by 7,400' horizontal distance at 10% grade |
| B-13 | 20% Ramp | 3 | Vertical | 20' by 15' by 4,550' horizontal distance at 20% grade |
| B-14 | 20% Ramp | 3 | Horizontal | 20' by 15' by 4,550' horizontal distance at 20% grade |

Ramp Grades--Cases B-9 through B-12 have a similar geometry with a ramp length of 7,437 feet on a 10% grade, covering a vertical depth of 740 feet from the mine support facilities (Sites 1 or 2) to the underground repository entry point. The designs are the same for vertical and horizontal canister emplacement methods

with one exception, the size of the conveyor belt. Cases B-13 and B-14 have a ramp length of 4,640 feet on a 20% grade, covering a vertical depth of 910 feet from the mine support facilities (Site 3) to the underground repository entry point. Different size conveyor belts are also used at this site for each emplacement option.

Transport Method--Two methods to transport men and materials are used: (1) a hoisting system and track vehicle, and (2) trackless haulage by rubber-tired vehicles.

Dravo determined that tractless haulage with rubber-tired personnel and material-transport vehicles should be used on the 10% grade ramp (Cases B-9 through B-12), and a hoist and track haulage system be used on the 20% grade ramp design (Cases B-13 and B-14).

The size of the ramp was determined by the same procedure used to size the drift. Figure 2.15 shows the ramp cross section as well as the ramp layout.

The roadbed of the 10% ramp will be concreted to provide a uniform transport surface. Ground support will be provided by rockbolts, wire mesh, and shotcrete, all standard methods used for this type of excavation. Because of anticipated fractured and faulted ground conditions, it has been estimated that 25% of the ramp length will require additional steel sets, lagging, and concrete for ground support.

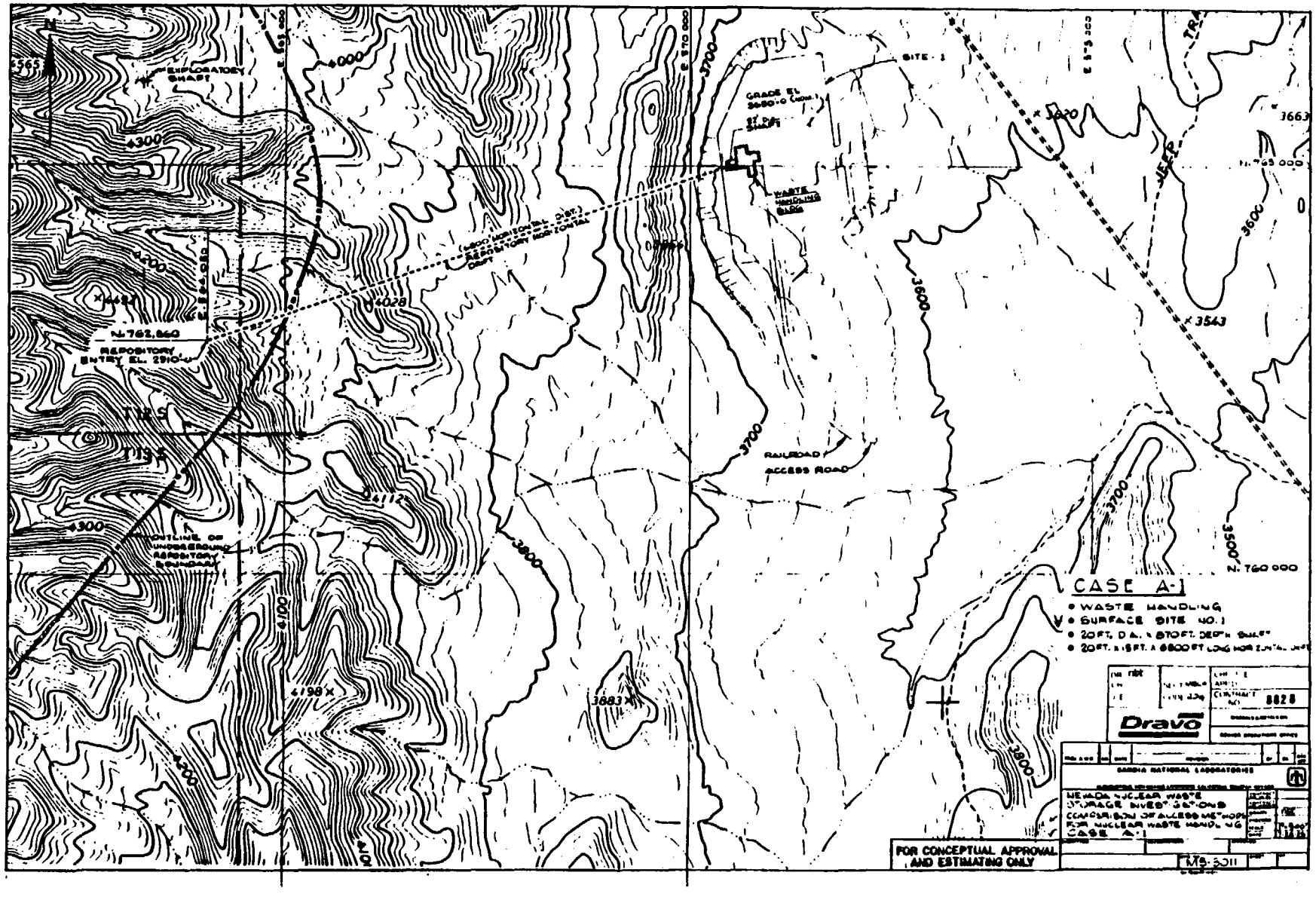

EXPLORATORY SHAFT
REPOSITORY ENTRY EL. 2910
N. 762,860
OUTLINE OF UNDERGROUND REPOSITORY BOUNDARY
WASTE HANDLING BLDG
RAILROAD ACCESS ROAD
SITE 1
JEEP TRAIL
N. 760 000
CASE A-1
• WASTE HANDLING
• SURFACE SITE NO. 1
FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY
Dravo
SANDIA NATIONAL LABORATORIES
NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS
COMPARISON OF ALLEGED METHODS FOR NUCLEAR WASTE HANDLING
CASE A-1
MB-5011

FIGURE 2.1

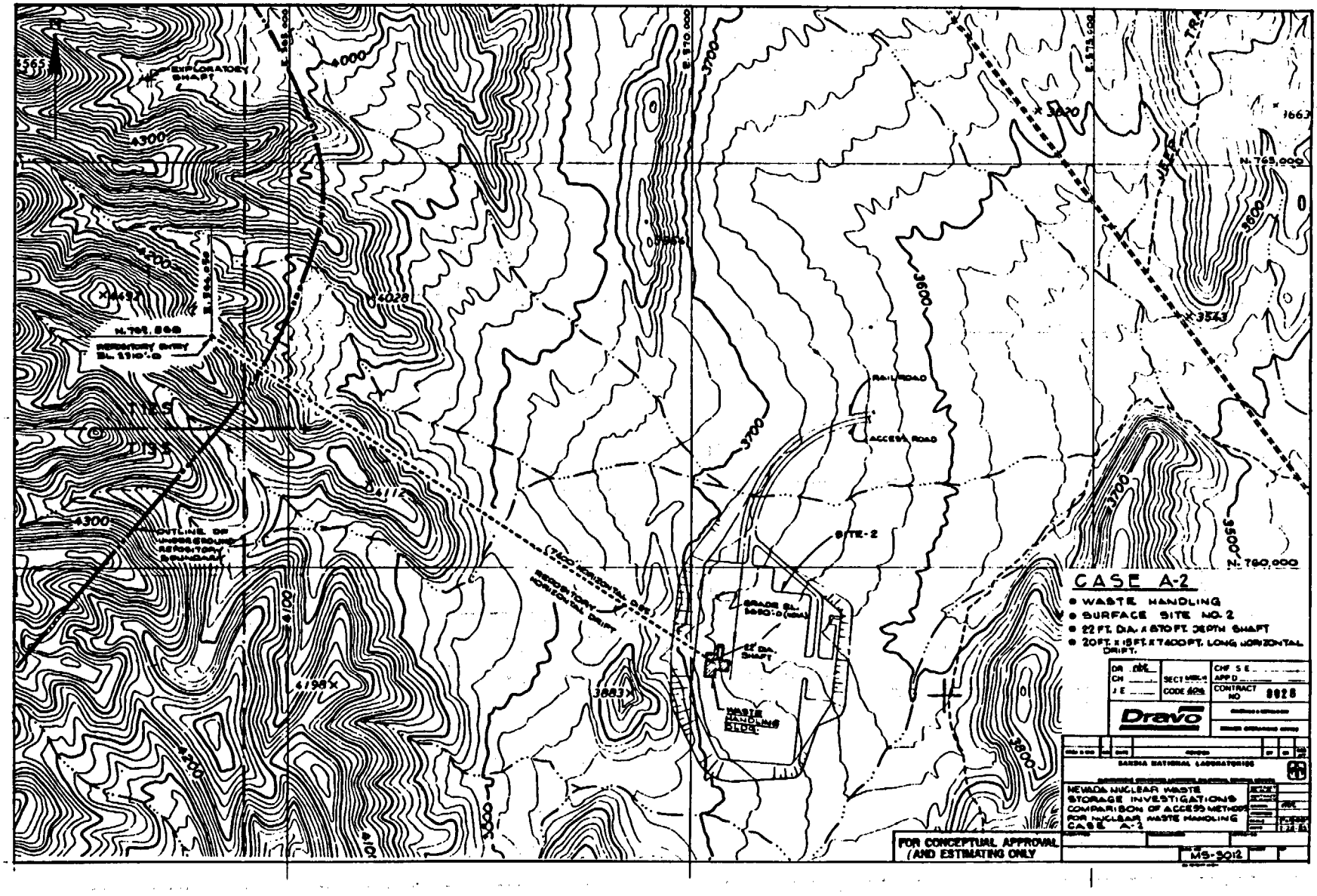

CASE A-2
• WASTE HANDLING
• SURFACE SITE NO. 2
• 22 FT. DIA. x 870 FT. DEPTH SHAFT
• 20 FT. x 15 FT. x 7400 FT. LONG HORIZONTAL DRIFT.
FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY
NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS
COMPARISON OF ACCESS METHODS FOR NUCLEAR WASTE HANDLING
CASE A-2
SANDIA NATIONAL LABORATORIES
Dravo
MS-3012
EXPLORATORY SHAFT
REPOSITORY ENTRY
OUTLINE OF UNDERGROUND REPOSITORY BOUNDARY
RAILROAD
ACCESS ROAD
SITE-2
22' DIA. SHAFT
WASTE HANDLING BLDG.
N. 765,000
N. 760,000
E. 570,000
E. 575,000
4300
4200
4100
4000
3900
3800
3700
3600
3500
4112
4028
4198
3883
3543
1663

FIGURE 2.2

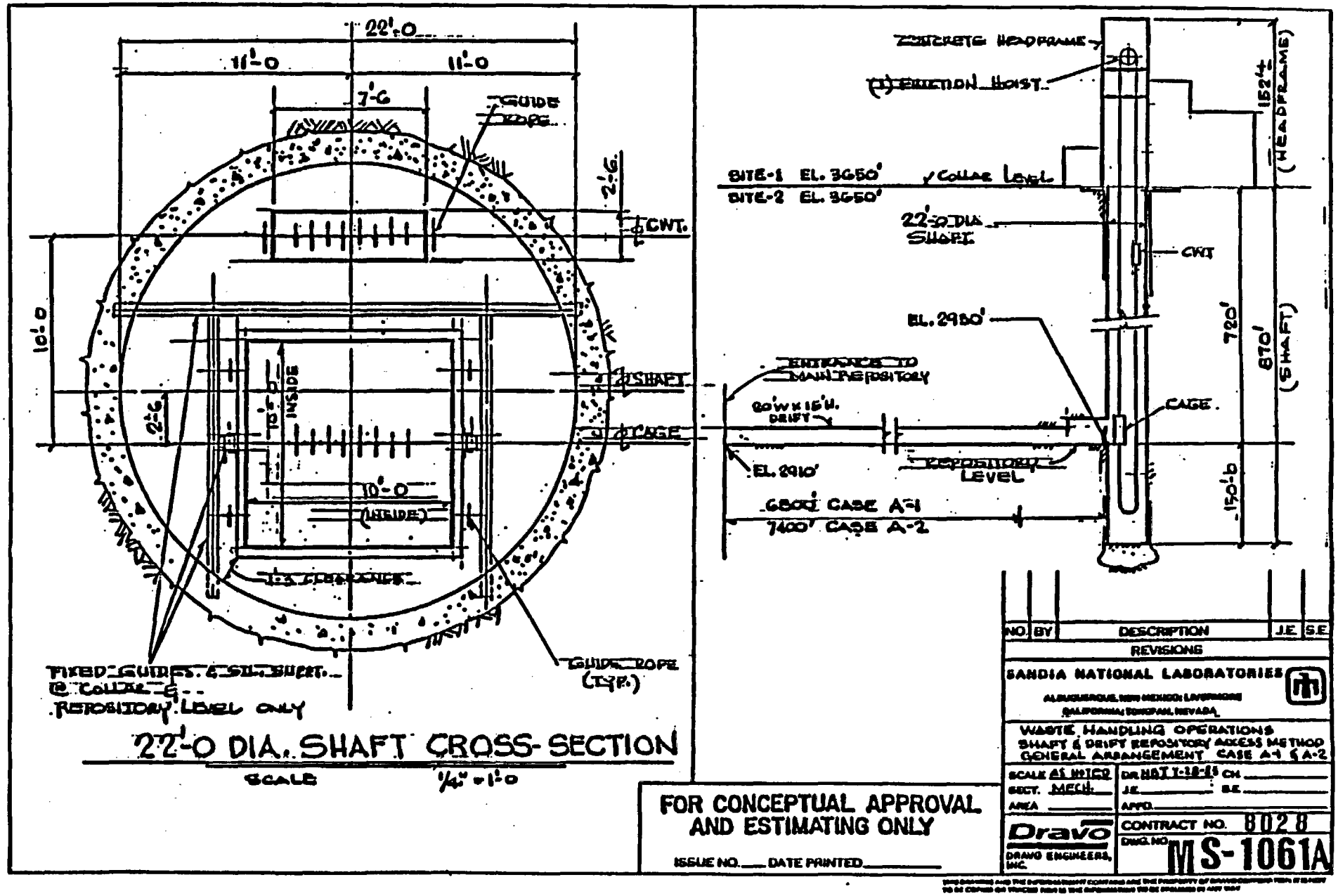

22'-0
11'-0
11'-0
7'-6
GUIDE ROPE
2'-6
CWT.
10'-0
SHAFT
CAGE
2'-6
10'-0 INSIDE
10'-0 (INSIDE)
1'-3 CLEARANCE
FIXED GUIDES & SH. SUPPT. @ COLLAR & REPOSITORY LEVEL ONLY
GUIDE ROPE (TYP.)
22'-0 DIA. SHAFT CROSS-SECTION
SCALE 1/4" = 1'-0
CONCRETE HEADFRAME
(1) ERECTION HOIST
SITE-1 EL. 3650'
SITE-2 EL. 3650'
COLLAR LEVEL
22'-0 DIA SHAFT
CWT
EL. 2980'
ENTRANCE TO MAIN REPOSITORY
20'W x 15'H. DRIFT
EL. 2910'
REPOSITORY LEVEL
6800' CASE A-1
7400' CASE A-2
CAGE
152'-4 (HEADFRAME)
720'
870' (SHAFT)
150'-0
NO. BY DESCRIPTION J.E. S.E.
REVISIONS
SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO; LIVERMORE, CALIFORNIA; TONOPAH, NEVADA
WASTE HANDLING OPERATIONS
SHAFT & DRIFT REPOSITORY ACCESS METHOD
GENERAL ARRANGEMENT CASE A-1 & A-2
SCALE AS NOTED
SECT. MECH.
AREA
DR. HAT 1-18-85 CH.
J.E. S.E.
APPD.
Dravo
DRAVO ENGINEERS, INC.
CONTRACT NO. 8028
DWG. NO. MS-1061A
FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY
ISSUE NO. DATE PRINTED

FIGURE 2.3

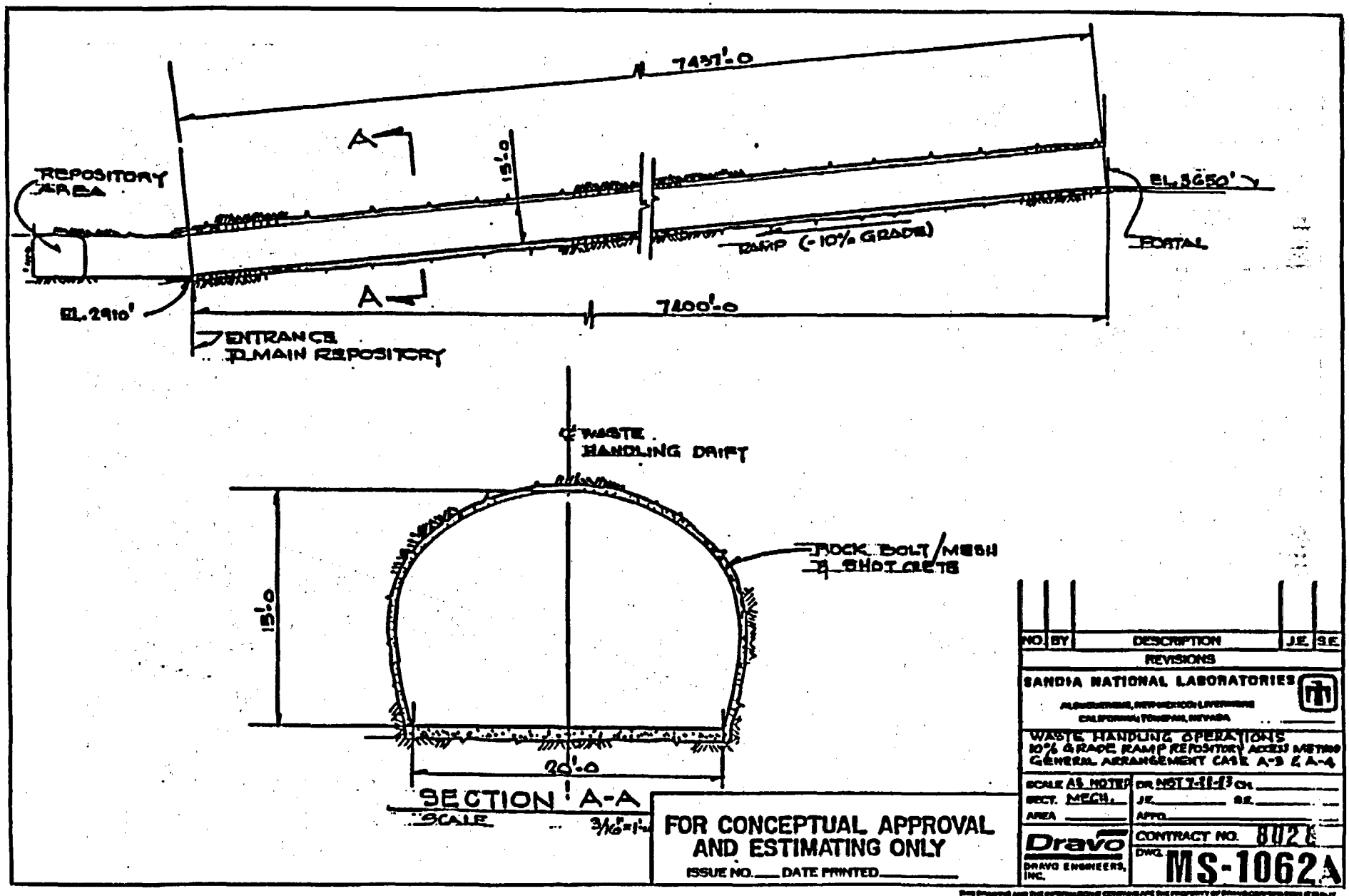

7437'-0
A
15'-0
REPOSITORY AREA
EL. 3650'
RAMP (-10% GRADE)
PORTAL
EL. 2910'
A
7400'-0
ENTRANCE TO MAIN REPOSITORY
℄ WASTE HANDLING DRIFT
ROCK BOLT/MESH & SHOTCRETE
15'-0
20'-0
SECTION A-A
SCALE 3/16"=1'-0
FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY
ISSUE NO. DATE PRINTED
NO. BY DESCRIPTION J.E. S.E.
REVISIONS
SANDIA NATIONAL LABORATORIES
WASTE HANDLING OPERATIONS
10% GRADE RAMP REPOSITORY ACCESS METHOD
GENERAL ARRANGEMENT CASE A-3 & A-4
SCALE AS NOTED
DR. NST 7-11-83
SECT. MECH.
AREA
J.E.
S.E.
APPD.
Dravo
DRAVO ENGINEERS, INC.
CONTRACT NO. 8026
DWG. MS-1062A

FIGURE 2.4

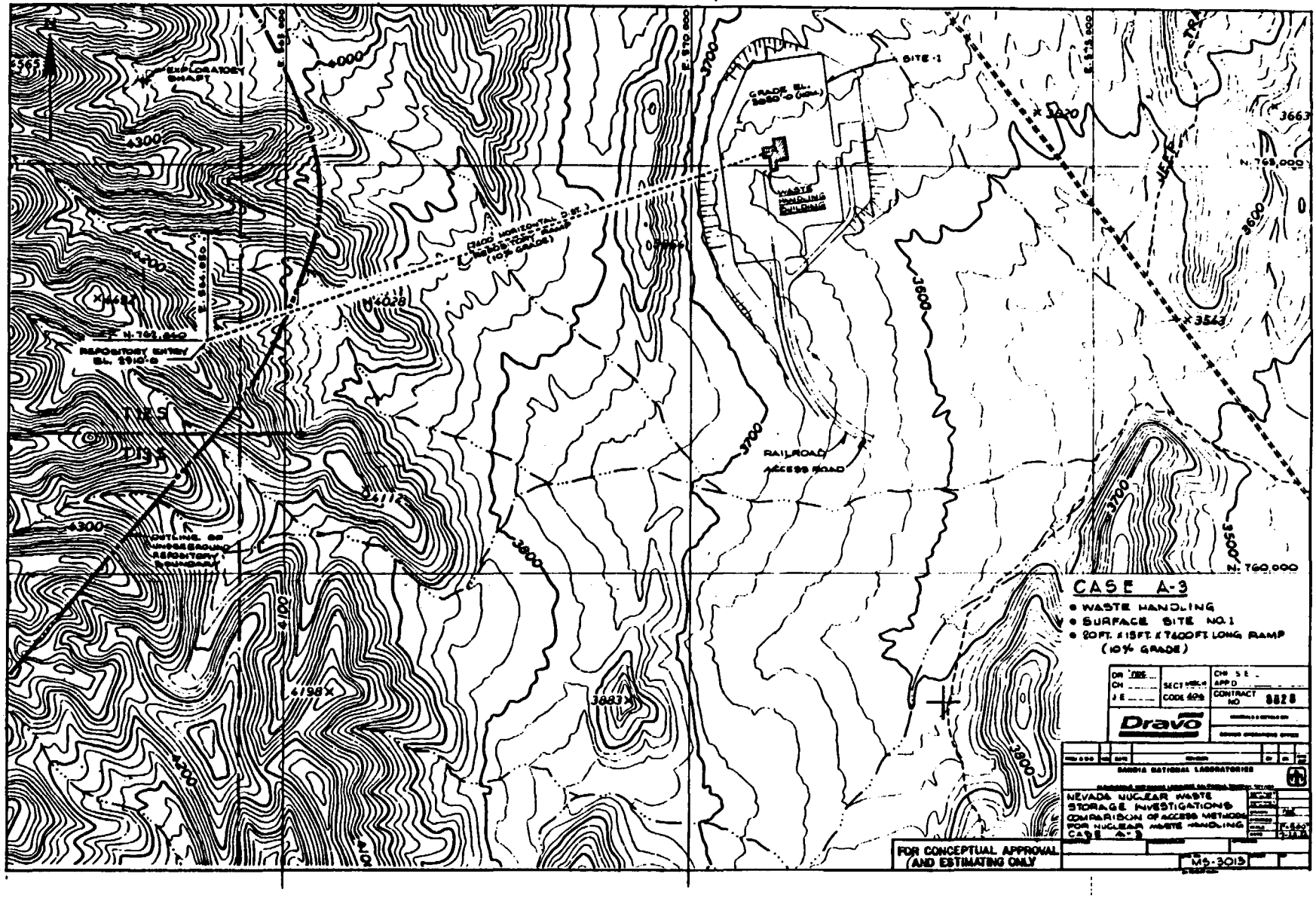

CASE A-3
• WASTE HANDLING
• SURFACE SITE NO. 1
• 20 FT. x 15 FT. x 7600 FT. LONG RAMP
(10% GRADE)
FOR CONCEPTUAL APPROVAL
AND ESTIMATING ONLY
NEVADA NUCLEAR WASTE
STORAGE INVESTIGATIONS
COMPARISON OF ACCESS METHODS
FOR NUCLEAR WASTE HANDLING
CASE A-3
SANDIA NATIONAL LABORATORIES
Dravo
CONTRACT NO 8828
MS-3013
EXPLORATORY SHAFT
REPOSITORY ENTRY
EL. 2910'-0
N. 769,000
N. 760,000
SITE 1
WASTE HANDLING BUILDING
RAILROAD
ACCESS ROAD
OUTLINE OF UNDERGROUND REPOSITORY BOUNDARY
4300
4000
4100
3700
3600
3500
3800
3663
3543
4020
4112
4198
3883

FIGURE 2.5

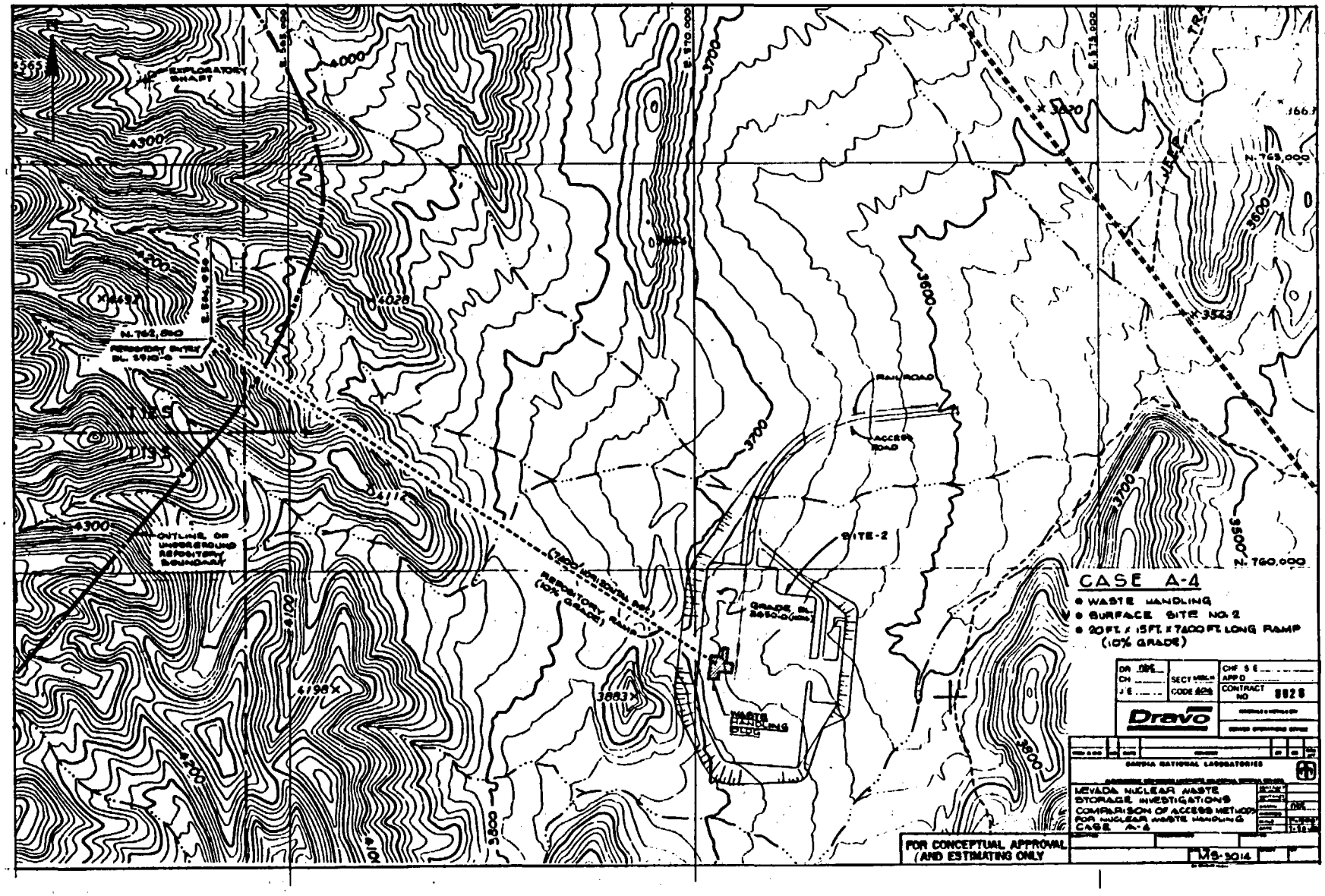

CASE A-4
• WASTE HANDLING
• SURFACE SITE NO. 2
• 20 FT. x 15 FT. x 7400 FT. LONG RAMP (10% GRADE)
FOR CONCEPTUAL APPROVAL (AND ESTIMATING ONLY)
NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS
COMPARISON OF ACCESS METHODS FOR NUCLEAR WASTE HANDLING
CASE A-4
SANDIA NATIONAL LABORATORIES
Bravo
SITE-2
RAILROAD
ACCESS ROAD
WASTE HANDLING BLDG
EXPLORATORY SHAFT
REPOSITORY ENTRY
OUTLINE OF UNDERGROUND REPOSITORY BOUNDARY
REPOSITORY RAMP (10% GRADE)
N. 765,000
N. 760,000
N. 762,000
3600
3700
3800
4000
4300
4700
4200
4100
4198
3883
3573
3420
4411
4028
4631
4300

FIGURE 2.6

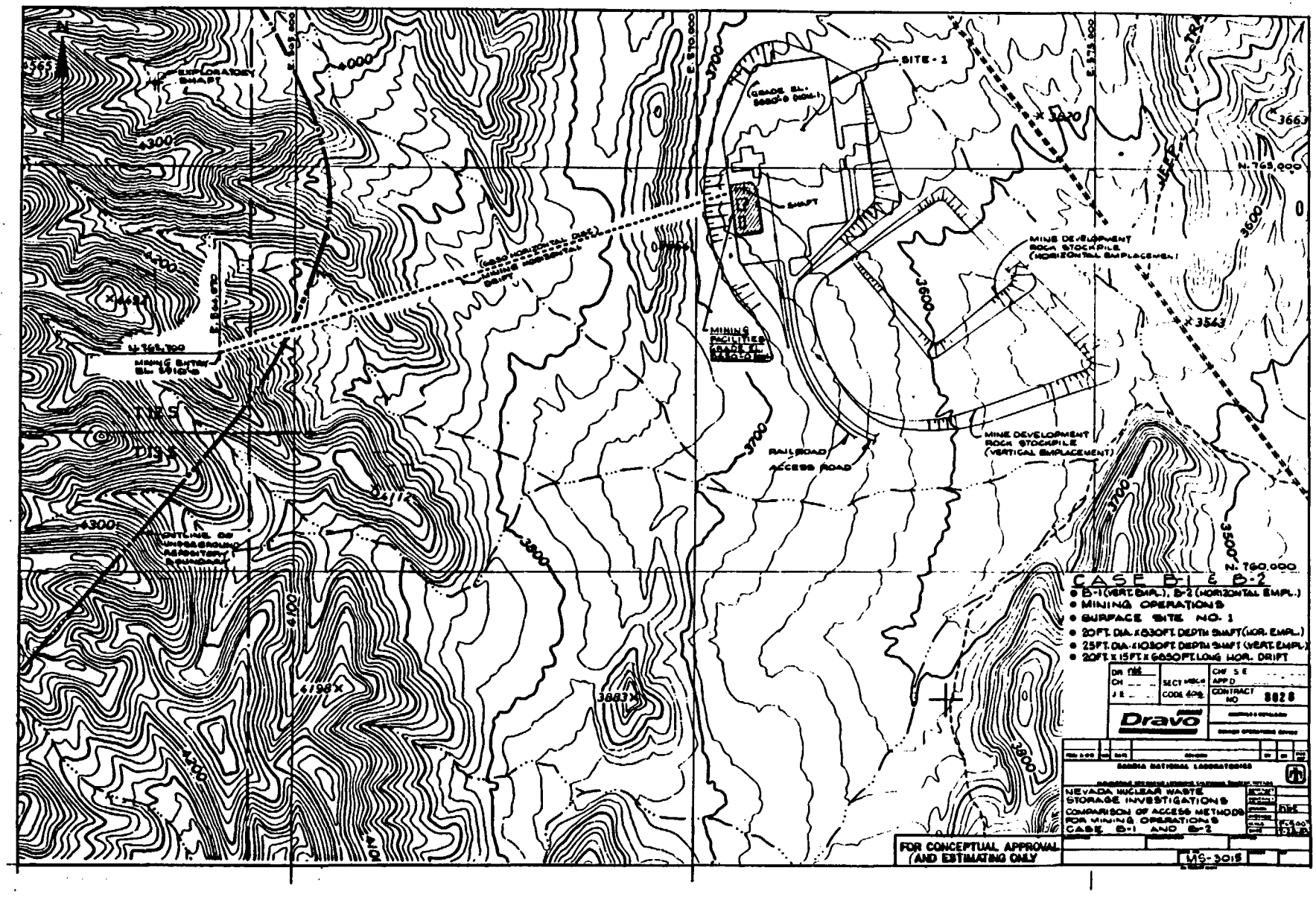

CASE B-1 & B-2
• B-1 (VERT. EMPL.), B-2 (HORIZONTAL EMPL.)
• MINING OPERATIONS
• SURFACE SITE NO. 1
• 20 FT. DIA. x 830 FT. DEPTH SHAFT (HOR. EMPL.)
• 25 FT. DIA. x 1030 FT. DEPTH SHAFT (VERT. EMPL.)
• 20 FT. x 15 FT. x 6650 FT. LONG HOR. DRIFT
FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY
NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS
COMPARISON OF ACCESS METHODS FOR MINING OPERATIONS
CASE B-1 AND B-2
SANDIA NATIONAL LABORATORIES
Dravo
CONTRACT NO 8828
MS-3015
SITE - 1
EXPLORATORY SHAFT
MINING BATTERY
MINING FACILITIES
SHAFT
MINE DEVELOPMENT ROCK STOCKPILE (HORIZONTAL EMPLACEMENT)
MINE DEVELOPMENT ROCK STOCKPILE (VERTICAL EMPLACEMENT)
RAILROAD ACCESS ROAD
N. 765,000
N. 760,000
E. 570,000
E. 575,000
E. 580,000
4000
4300
4100
3700
3600
3500
3800
3820
3543
3667
4412
4198
3883

FIGURE 2.7

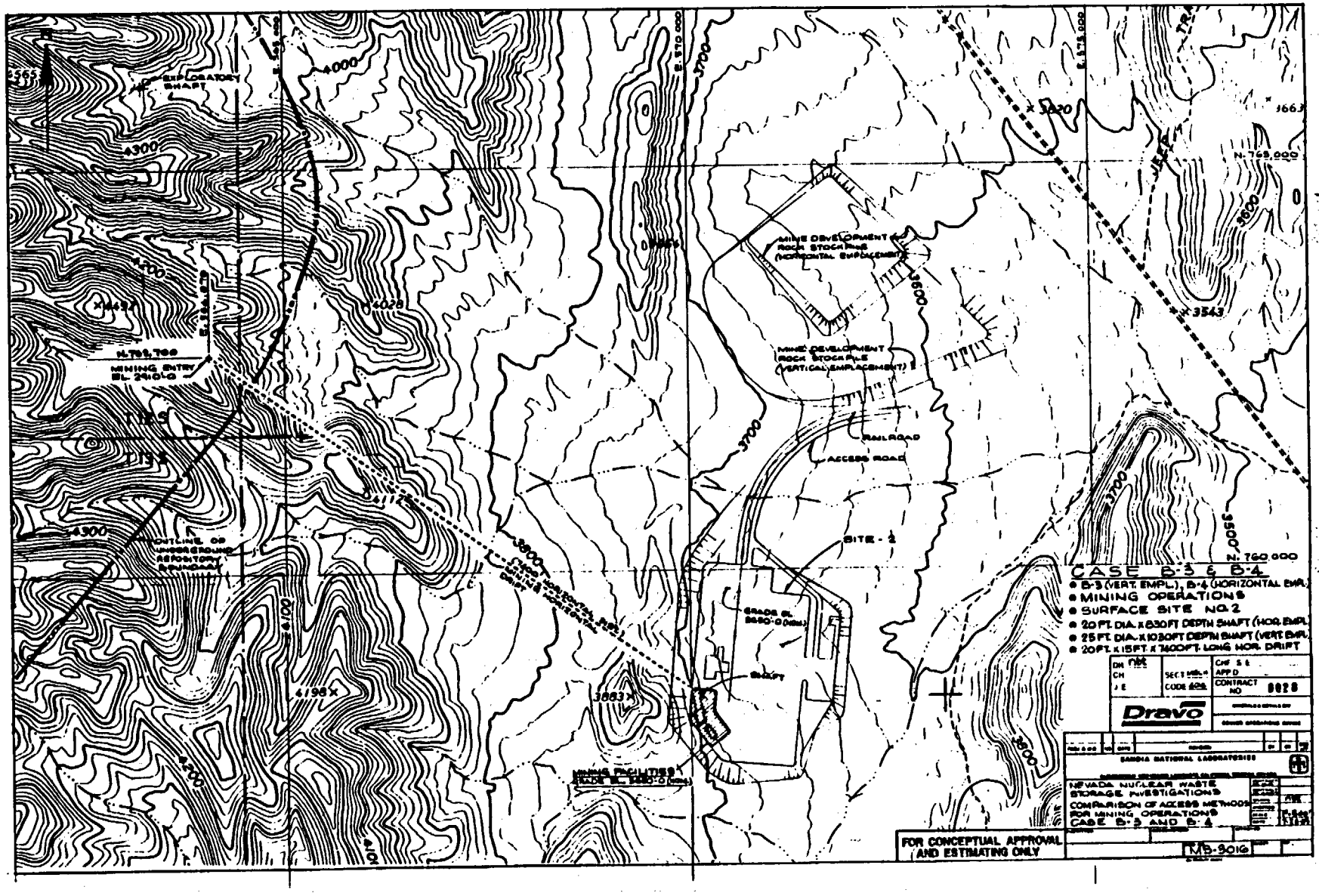

CASE B-3 & B-4
B-3 (VERT. EMPL.), B-4 (HORIZONTAL EMPL.)
MINING OPERATIONS
SURFACE SITE NO. 2
20 FT. DIA. X 830 FT DEPTH SHAFT (HOR. EMPL.)
25 FT. DIA. X 1030 FT DEPTH SHAFT (VERT. EMPL.)
20 FT. X 15 FT. X 7400 FT. LONG HOR. DRIFT
NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS
COMPARISON OF ACCESS METHODS FOR MINING OPERATIONS
CASE B-3 AND B-4
FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY
MINE DEVELOPMENT ROCK STOCKPILE (HORIZONTAL EMPLACEMENT)
MINE DEVELOPMENT ROCK STOCKPILE (VERTICAL EMPLACEMENT)
RAILROAD
ACCESS ROAD
SITE - 2
SHAFT
MINING FACILITIES
MINING ENTRY EL. 2410.0
OUTLINE OF UNDERGROUND EXPLORATORY ROUNDS
EXPLORATORY SHAFT
N. 769,000
N. 760,000
SANDIA NATIONAL LABORATORIES
Dravo
MB-9016

FIGURE 2.8

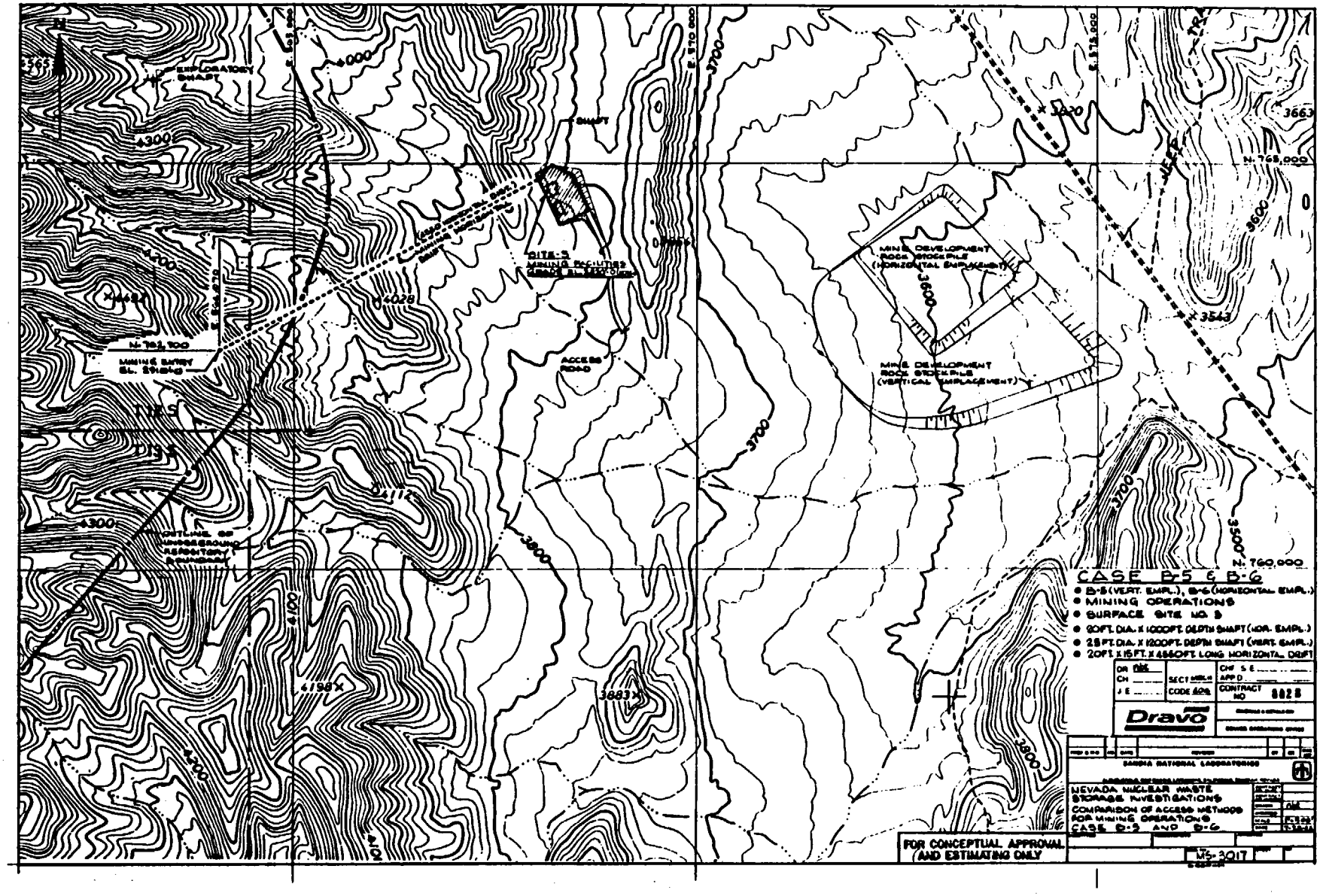

CASE B-5 & B-6
B-5 (VERT. EMPL.), B-6 (HORIZONTAL EMPL.)
MINING OPERATIONS
SURFACE SITE NO. 3
20FT. DIA. X 1000FT. DEPTH SHAFT (HOR. EMPL.)
25FT. DIA. X 1200FT. DEPTH SHAFT (VERT. EMPL.)
20FT. X 15FT. X 4860FT. LONG HORIZONTAL DRIFT
Dravo
SANDIA NATIONAL LABORATORIES
NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS
COMPARISON OF ACCESS METHODS FOR MINING OPERATIONS
CASE B-5 AND B-6
FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY
MINE DEVELOPMENT ROCK STOCKPILE (HORIZONTAL EMPLACEMENT)
MINE DEVELOPMENT ROCK STOCKPILE (VERTICAL EMPLACEMENT)
SITE 3 MINING FACILITIES
ACCESS ROAD
SHAFT
MINING ENTRY
OUTLINE OF UNDERGROUND REPOSITORY BOUNDARY
N. 765,000
N. 760,000
N. 755,000
E. 570,000
E. 575,000
3700
3600
3500
3800
4000
4300
4100
4200
4400
3663
3543
3820
4028
4112
4198
3883

FIGURE 2.9

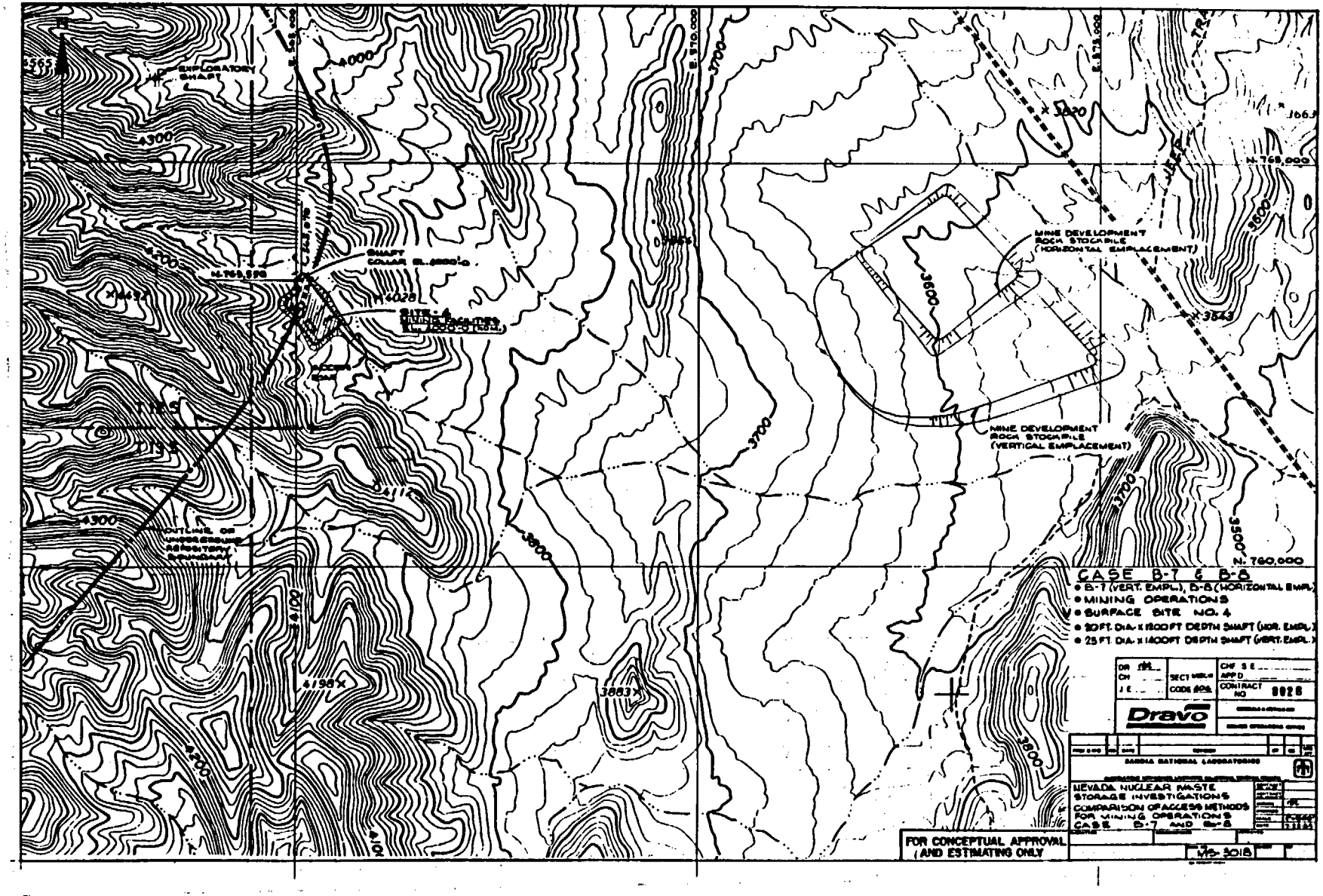
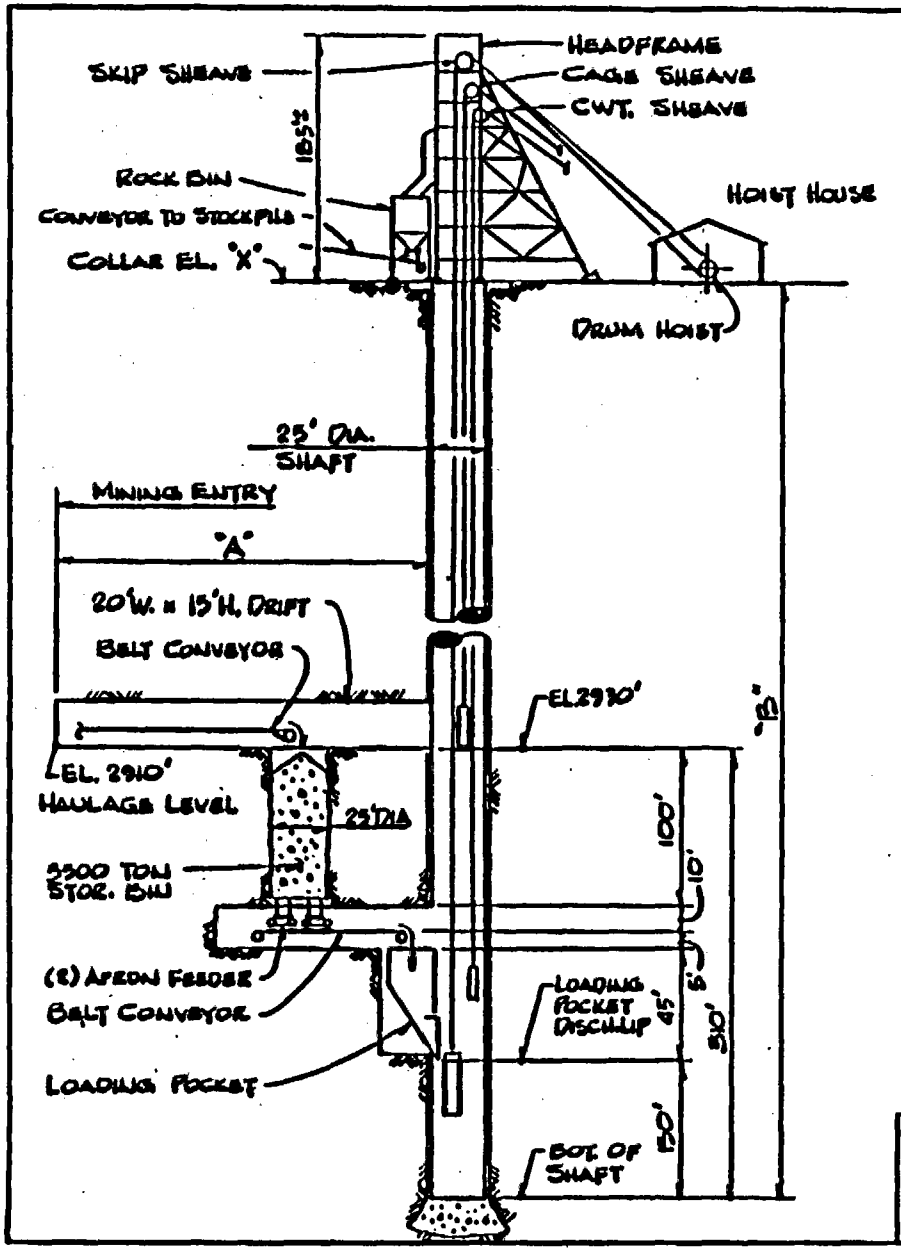

EXPLORATORY SHAFT
SHAFT COLLAR
SITE 4
MINE DEVELOPMENT ROCK STOCKPILE (HORIZONTAL EMPLACEMENT)
MINE DEVELOPMENT ROCK STOCKPILE (VERTICAL EMPLACEMENT)
OUTLINE OF UNDERGROUND RESEARCH BOUNDARY
N. 768,000
N. 760,000
E. 570,000
E. 575,000
4000
4300
4200
4100
3700
3600
3500
3800
4198
3883
3820
3643
CASE B-7 & B-8
• B-7 (VERT. EMPL.), B-8 (HORIZONTAL EMPL.)
• MINING OPERATIONS
• SURFACE SITE NO. 4
• 20 FT. DIA. x 1800 FT DEPTH SHAFT (HOR. EMPL.)
• 25 FT. DIA. x 1400 FT DEPTH SHAFT (VERT. EMPL.)
Dravo
SANDIA NATIONAL LABORATORIES
NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS
COMPARISON OF ACCESS METHODS FOR MINING OPERATIONS
CASE B-7 AND B-8
FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY

FIGURE 2.10




| CASE No. | ACCESS METHOD | SURFACE LOCATION | EMPLACEMENT METHOD | COLLAR EL. "X" | "A" | "B" |
|---|---|---|---|---|---|---|
| B-1 | SHAFT & DRIFT | No. 1 | VERTICAL | 3610' | 6850' | 1030' |
| B-3 | SHAFT & DRIFT | No. 2 | VERTICAL | 3650' | 7400' | 1030' |
| B-5 | SHAFT & DRIFT | No. 3 | VERTICAL | 3820' | 4550' | 1200' |
| B-7 | SHAFT ONLY | No. 4 | VERTICAL | 4000' | — | 1400' |

FOR REFERENCE DRAWING
SHAFT CROSS SECTION
SEE MS-1050E

| NO | BY | DESCRIPTION | J.E. | S.E. |
|---|---|---|---|---|

REVISIONS

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO; LIVERMORE, CALIFORNIA; TONOPAH, NEVADA

MINING OPERATIONS
SHAFT & DRIFT MINING ACCESS METHOD
GEN. ARRGT. CASES D-1, D-3, D-5 & D-7

SCALE N.T.S. DR. STRAND 8-1-81 CH.
SECT. MECH. J.E. S.E.
AREA APPD.

Dravo DRAVO ENGINEERS, INC.

CONTRACT NO. 8028
DWG MS-1050D

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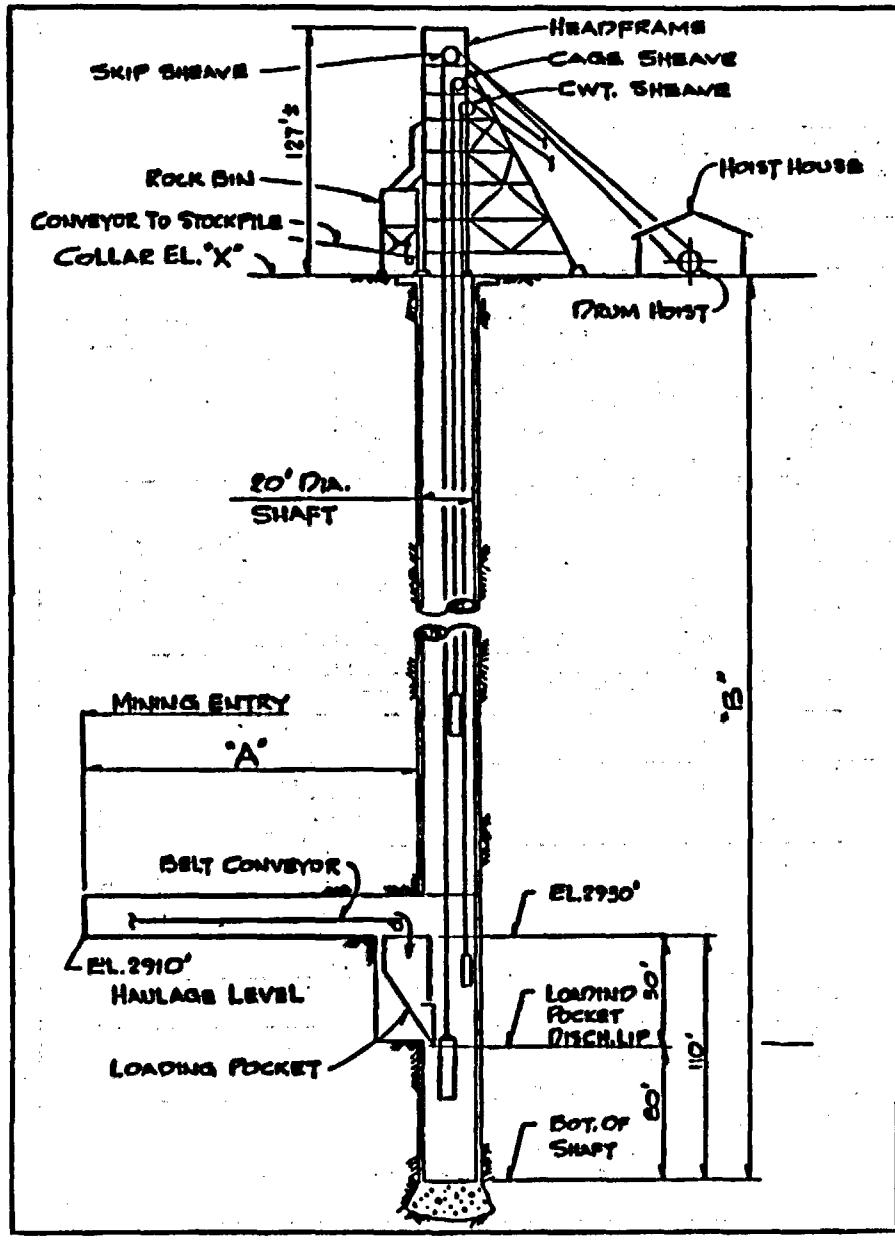
FIGURE 2.11




| CASE No. | ACCESS METHOD | SURFACE LOCATION | EMPLACEMENT METHOD | COLLAR EL. "X" | "A" | "B" |
|---|---|---|---|---|---|---|
| B-2 | SHAFT & DRIFT | No. 1 | HORIZONTAL | 3650' | 6850' | 850' |
| B-4 | SHAFT & DRIFT | No. 2 | HORIZONTAL | 3650' | 7400' | 850' |
| B-6 | SHAFT & DRIFT | No. 3 | HORIZONTAL | 3820' | 4550' | 1000' |
| B-8 | SHAFT ONLY | No. 4 | HORIZONTAL | 4000' | — | 1200' |

FOR REFERENCE DRAWING
SHAFT CROSS SECTION
SEE MS-1051 E

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ISSUE NO.____ DATE PRINTED_____

| NO. | BY | DESCRIPTION | J.E. | S.E. |
|---|---|---|---|---|

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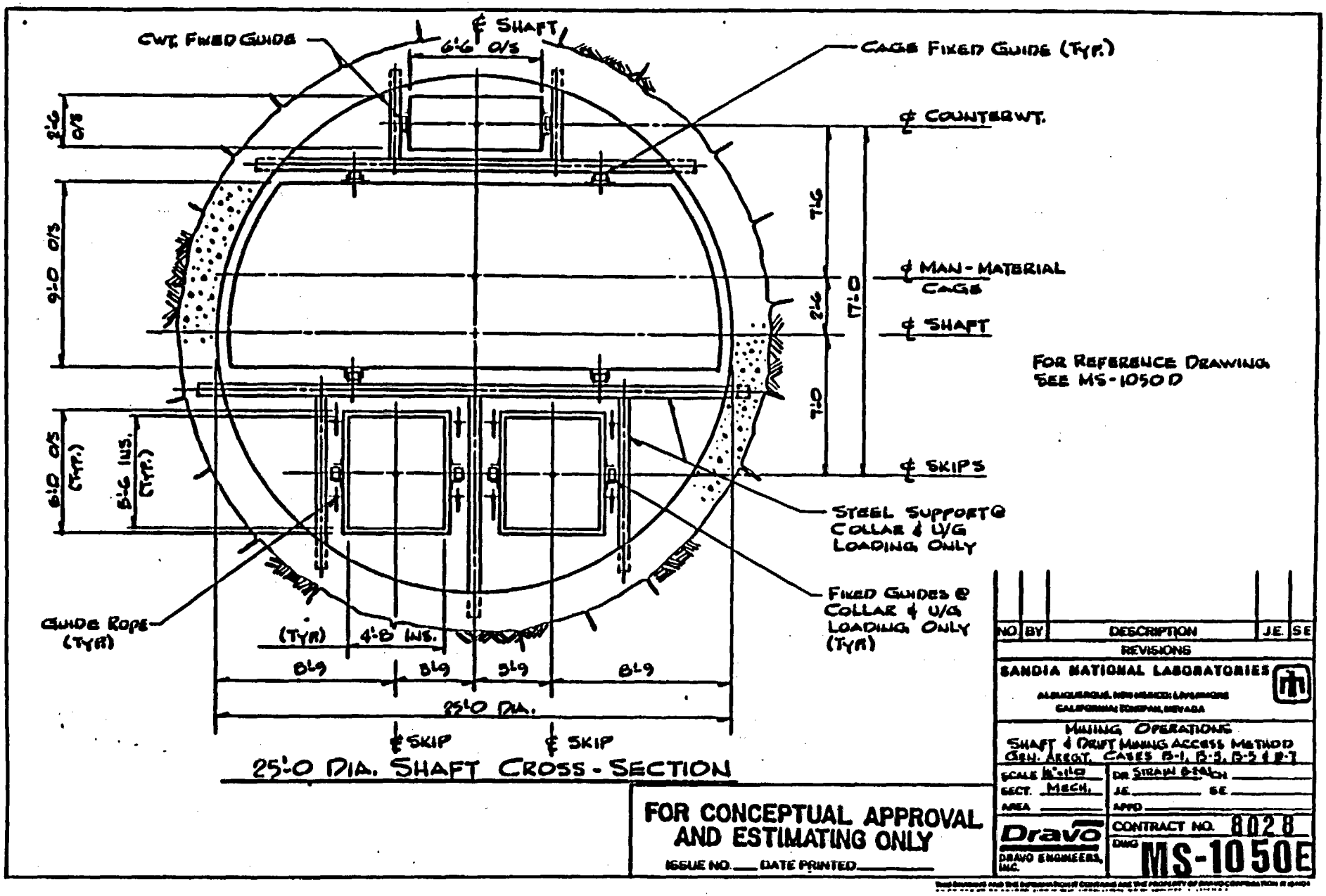
SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO; LIVERMORE CALIFORNIA; TONOPAH, NEVADA

MINING OPERATIONS
SHAFT & DRIFT MINING ACCESS METHOD
GEN. ARRGT. CASES B-2, B-4, B-6 & B-8

SCALE N.T.S.
SECT. MECH
AREA
DR. STRAN 8/81 CH.
J.E. S.E.
APPD.
CONTRACT NO. 8023
DWG. MS-1051 E

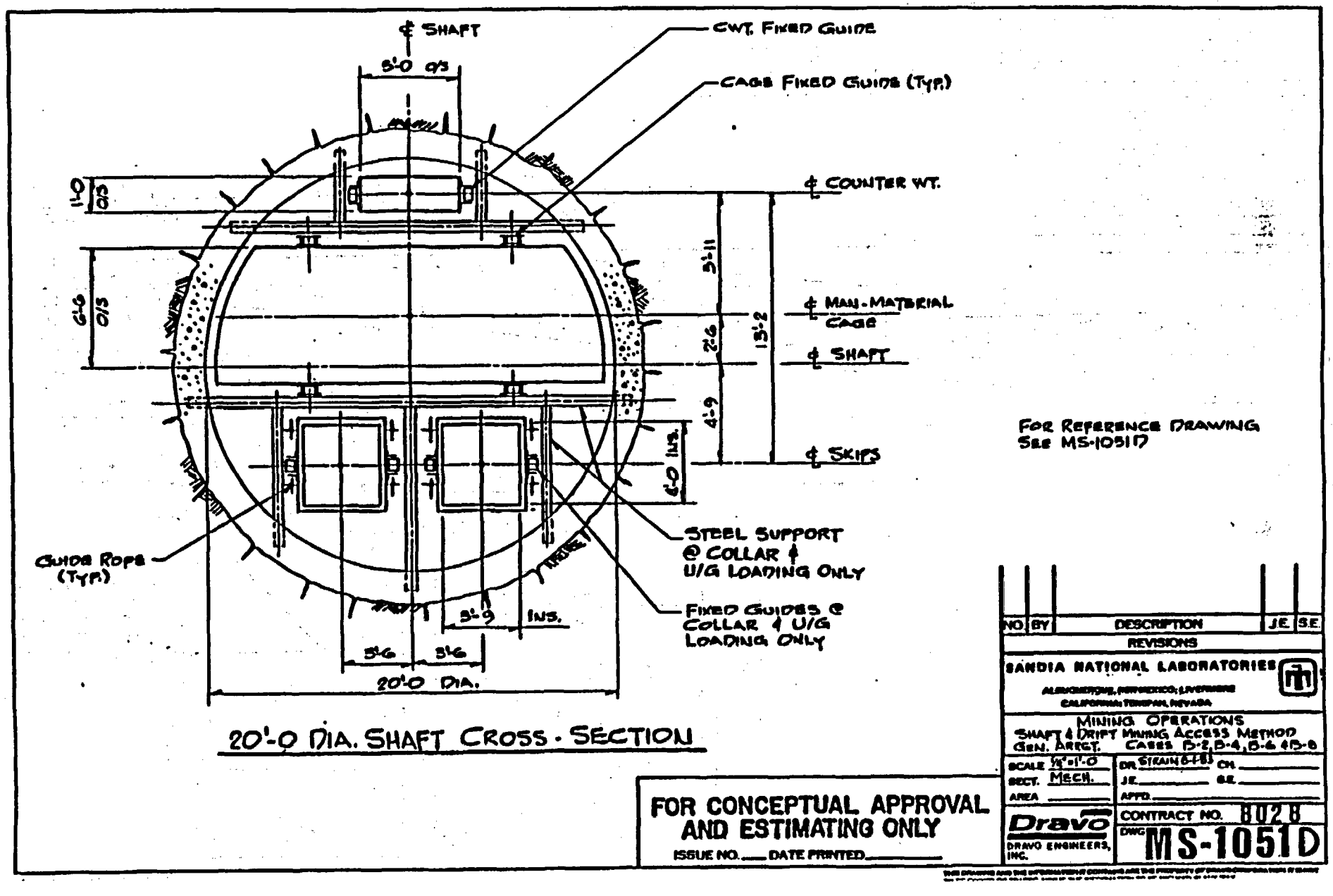
Bravo
BRAVO ENGINEERS, INC.

FIGURE 2.12




25'-0 DIA. SHAFT CROSS-SECTION

FIGURE 2.13




20'-0 DIA. SHAFT CROSS-SECTION

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ISSUE NO.____ DATE PRINTED_____

FIGURE 2.14

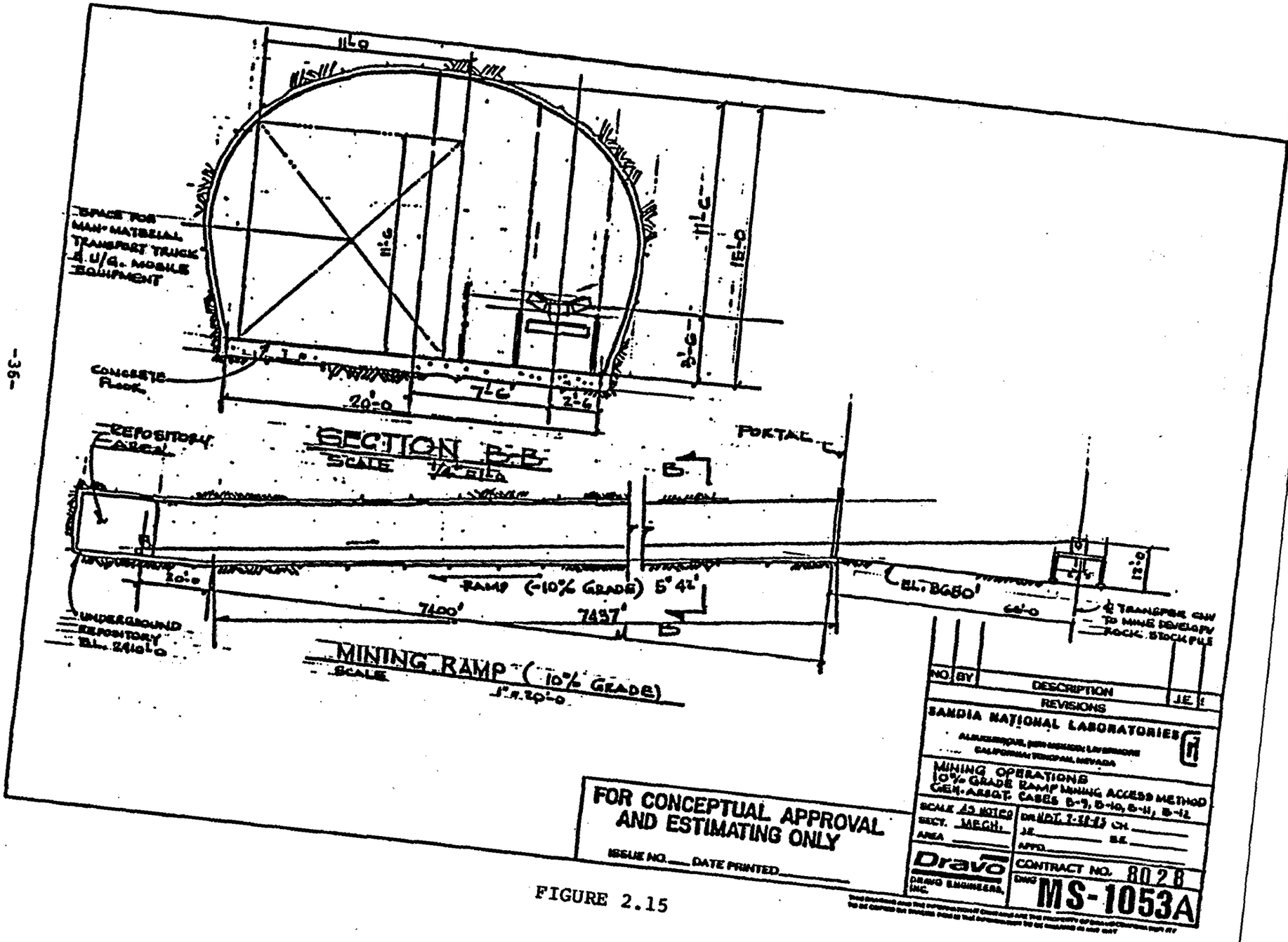
SPACE FOR MAN-MATERIAL TRANSPORT TRUCK & U/G. MOBILE EQUIPMENT
CONCRETE FLOOR
SECTION B-B
SCALE 1/4" = 1'-0
REPOSITORY AREA
PORTAL
RAMP (-10% GRADE) 5° 42'
EL. 8680'
UNDERGROUND REPOSITORY EL. 2410'-0
MINING RAMP (10% GRADE)
SCALE 1" = 20'-0
TRANSFER CAR TO MINE DEVELOPM ROCK STOCKPILE
NO. BY DESCRIPTION J.E.
REVISIONS
SANDIA NATIONAL LABORATORIES
MINING OPERATIONS
10% GRADE RAMP MINING ACCESS METHOD
GEN. ARRGT. CASES B-9, B-10, B-11, B-12
SCALE AS NOTED
SECT. MECH.
AREA
DR. OCT. 7-11-83
CONTRACT NO. 8028
DRAVO ENGINEERS, INC.
MS-1053A
FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY
ISSUE NO. DATE PRINTED

FIGURE 2.15

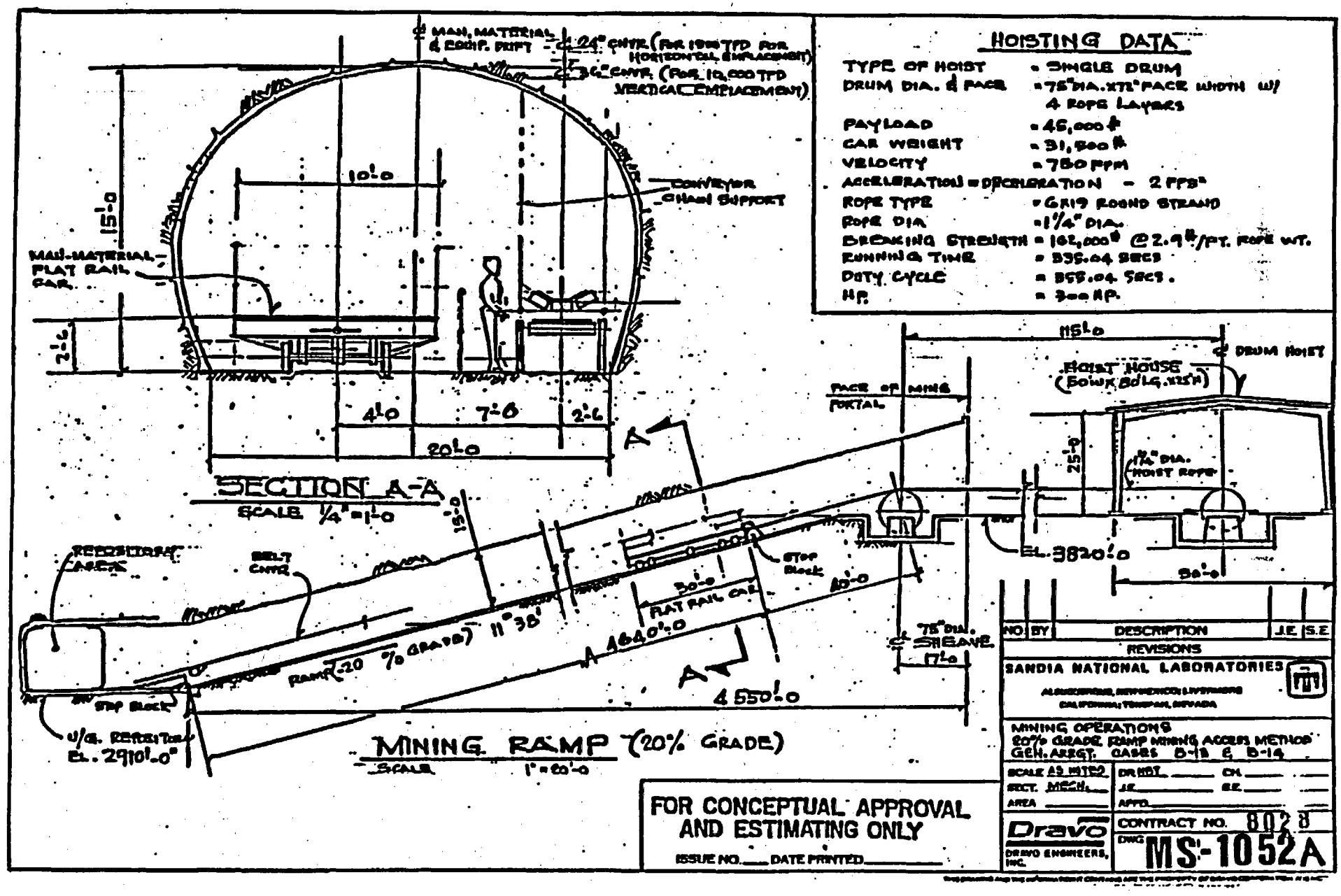
HOISTING DATA
TYPE OF HOIST = SINGLE DRUM
DRUM DIA. & FACE = 75" DIA. X 72" FACE WIDTH W/ 4 ROPE LAYERS
PAYLOAD = 46,000 #
CAR WEIGHT = 31,500 #
VELOCITY = 750 FPM
ACCELERATION = DECELERATION - 2 FPS²
ROPE TYPE = 6X19 ROUND STRAND
ROPE DIA = 1 1/4" DIA.
BREAKING STRENGTH = 162,000# @ 2.9#/FT. ROPE WT.
RUNNING TIME = 535.04 SECS
DUTY CYCLE = 555.04 SECS.
HP. = 300 HP.
SECTION A-A
SCALE 1/4" = 1'-0
MINING RAMP (20% GRADE)
SCALE 1" = 20'-0
FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY
ISSUE NO. DATE PRINTED
SANDIA NATIONAL LABORATORIES
MINING OPERATIONS
20% GRADE RAMP MINING ACCESS METHOD
GEN. ARRGT. CASES B-13 & B-14
CONTRACT NO. 8028
DWG MS-1052A
DRAVO ENGINEERS, INC.
MAN, MATERIAL & EQUIP. DRIFT
CONVEYOR CHAIN SUPPORT
MAN-MATERIAL FLAT RAIL CAR
BELT CONV.
STOP BLOCK
FLAT RAIL CAR
RAMP (20 % GRADE)
4640'-0
4550'-0
U/G. REFERENCE EL. 2910'-0"
FACE OF MINE PORTAL
HOIST HOUSE
DRUM HOIST
1 1/4" DIA. HOIST ROPE
EL. 3820'-0
75" DIA. SHEAVE
NO. BY DESCRIPTION J.E. S.E.
REVISIONS

FIGURE 2.16

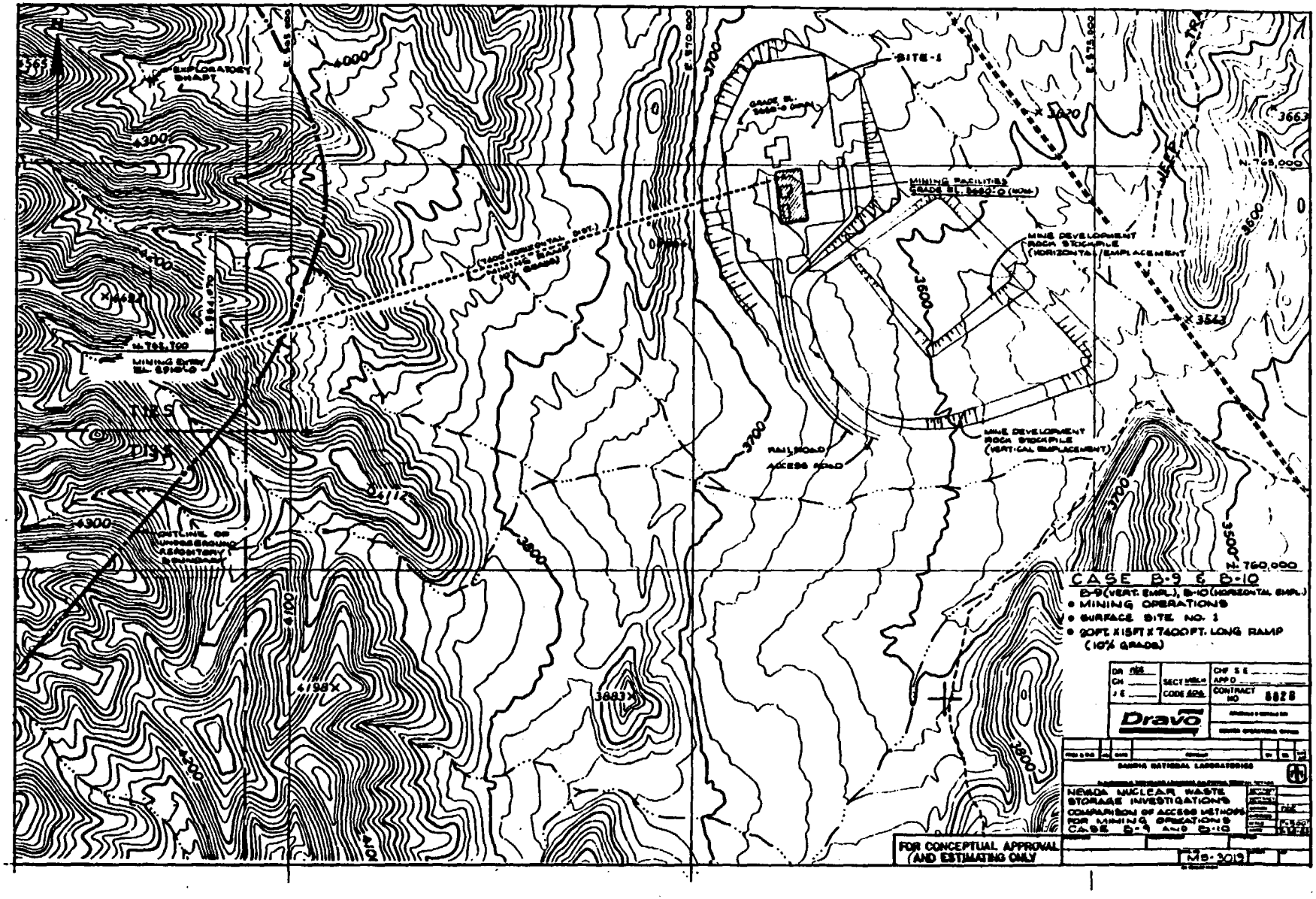
CASE B-9 & B-10
B-9 (VERT. EMPL.), B-10 (HORIZONTAL EMPL.)
• MINING OPERATIONS
• SURFACE SITE NO. 1
• 20FT. X 15FT X 7400FT. LONG RAMP (10% GRADE)
SITE-1
MINING FACILITIES
MINE DEVELOPMENT ROCK STOCKPILE (HORIZONTAL EMPLACEMENT)
MINE DEVELOPMENT ROCK STOCKPILE (VERTICAL EMPLACEMENT)
RAILROAD ACCESS ROAD
EXPLORATORY SHAFT
MINING SHAFT
FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY
NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS
COMPARISON OF ACCESS METHODS FOR MINING OPERATIONS
CASE B-9 AND B-10
Dravo
CONTRACT NO 8828
MS-3019

FIGURE 2.17

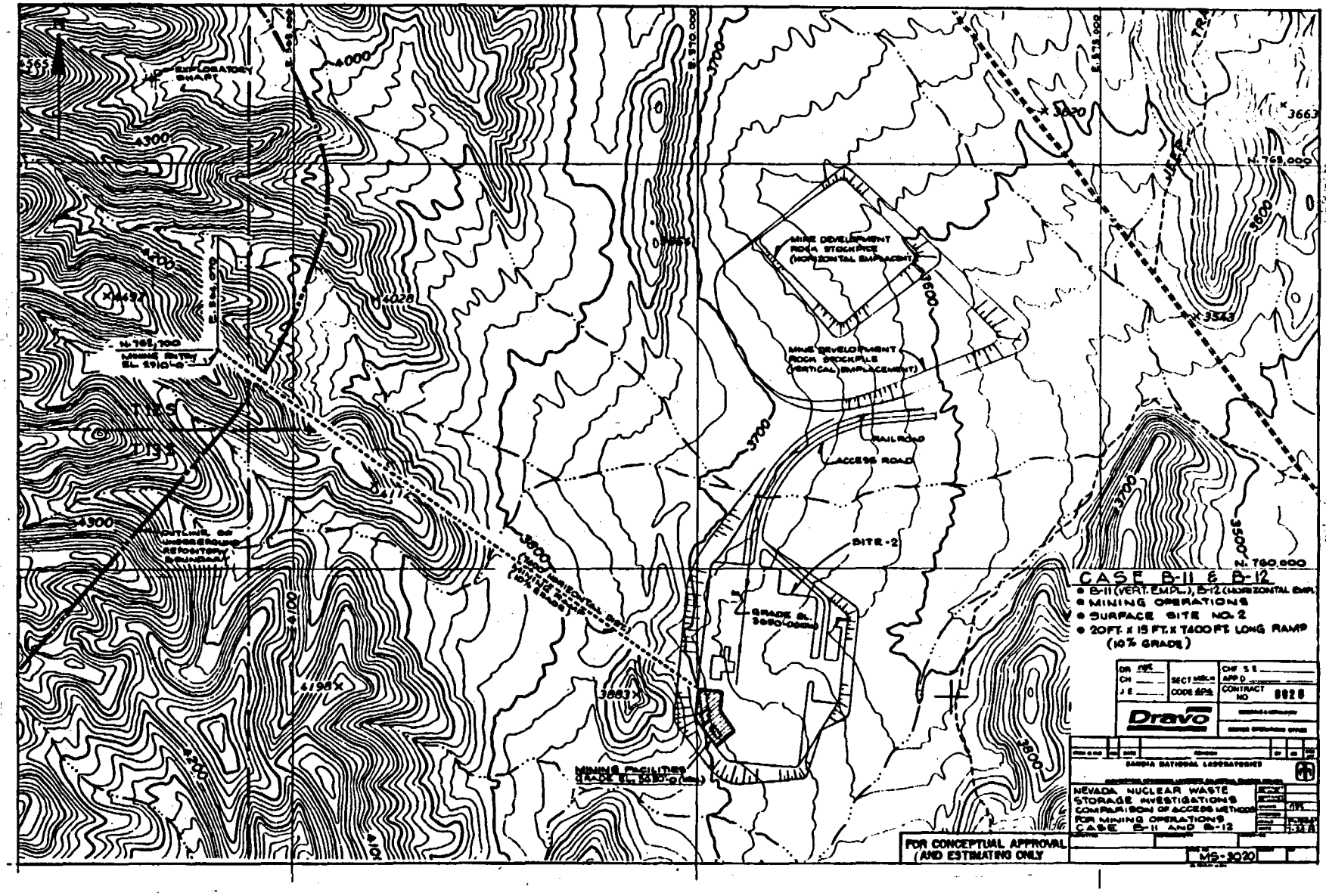
EXPLORATORY SHAFT
MINE DEVELOPMENT ROCK STOCKPILE (HORIZONTAL EMPLACEMENT)
MINE DEVELOPMENT ROCK STOCKPILE (VERTICAL EMPLACEMENT)
RAILROAD
ACCESS ROAD
SITE-2
GRADE EL. 3950'-0"(MIN)
MINING FACILITIES (GRADE EL. 3950'-0"(MIN))
MINING ENTRY EL. 3910'-0"
OUTLINE OF UNDERGROUND REPOSITORY BOUNDARY
N. 769,000
N. 768,700
N. 760,000
E. 568,000
E. 570,000
E. 572,000
4000
4300
4400
4020
3700
3600
3500
3800
4100
4200
3663
3343
3020
4197
3883
CASE B-11 & B-12
• B-11 (VERT. EMPL.), B-12 (HORIZONTAL EMPL.)
• MINING OPERATIONS
• SURFACE SITE NO. 2
• 20FT. x 15 FT. x 7400 FT. LONG RAMP (10% GRADE)
DR
CH
J.E.
SECT. MGR.
CODE SPEC.
CHF S.E.
APP'D
CONTRACT NO.
0028
Dravo
SANDIA NATIONAL LABORATORIES
NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS
COMPARISON OF ACCESS METHODS FOR MINING OPERATIONS
CASE B-11 AND B-12
FOR CONCEPTUAL APPROVAL (AND ESTIMATING ONLY)
MS-3020

FIGURE 2.18

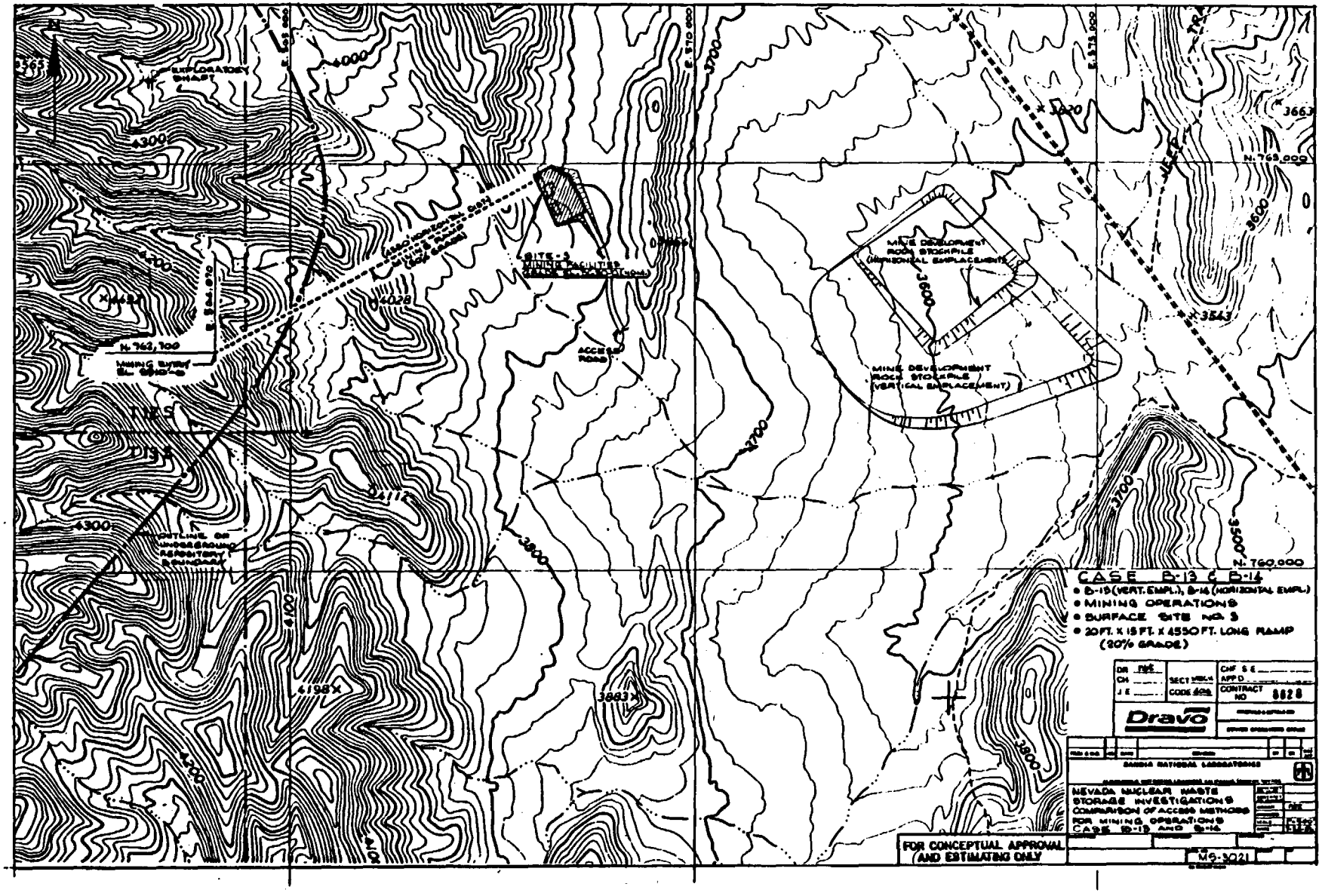
CASE B-13 & B-14
• B-13 (VERT. EMPL.), B-14 (HORIZONTAL EMPL.)
• MINING OPERATIONS
• SURFACE SITE NO. 3
• 20 FT. X 15 FT. X 4550 FT. LONG RAMP (20% GRADE)
FOR CONCEPTUAL APPROVAL AND ESTIMATING ONLY
NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS
COMPARISON OF ACCESS METHODS FOR MINING OPERATIONS
CASE B-13 AND B-14
SANDIA NATIONAL LABORATORIES
Dravo
MS-3021
N. 765,000
N. 760,000
N. 762,100
SITE-3 MINING FACILITIES
MINE DEVELOPMENT ROCK STOCKPILE (HORIZONTAL EMPLACEMENT)
MINE DEVELOPMENT ROCK STOCKPILE (VERTICAL EMPLACEMENT)
ACCESS ROAD
EXPLORATORY SHAFT
OUTLINE OF UNDERGROUND REPOSITORY BOUNDARY
MINING SURVEY

FIGURE 2.19

# 3.0 COST ESTIMATES FOR UNDERGROUND ACCESS

## 3.1 General

The cost estimate is based on the criteria, assumptions, data, and drawings contained in this report. Two separate estimating techniques are used for the capital costs and the average annual operating costs; each method is described in the following sections. The engineering drawings, Figures 2.1 through 2.19, have been developed and checked to a level necessary for preliminary estimating only. The drawings serve as the basis for the estimate.

## 3.2 Capital Cost Methodology

Ramp and Shaft Excavation--The majority of excavation costs for the comparative study were based on detailed estimate curves from the 1974 study "Analysis of Large-Scale, Non-Coal Underground Mining Methods," Reference 2. This study was prepared by Dravo for the U.S. Bureau of Mines (USBM) under contract No. S0122059. Shaft-sinking and ramp-excavation curves were escalated to first quarter 1983 dollars using the construction cost index from the Engineering News Record. Adjustment for size was made by prorating the face areas for both shafts and ramps. Ramp grades were adjusted by interpolation.

Figure 3.1 shows the updated curves by excavation and lining cost vs. depth for various diameters of concrete-lined, conventionally sunk circular shafts. (NOTE: all figures and tables for Section 3 are grouped at the end of the section.) Figure 3.2 shows the updated curves for excavation and support costs

vs. vertical distance (depth) for 10% and 20% grade ramps of a nominal 256 $ft^2$ cross section. For each case estimated, the depth or distance was plotted on the pertinent cost curve, and the construction cost was determined from this intersection point.

The curves represent estimated costs for

- Shafts--conventional excavation and concrete lining.

- Ramps--conventional excavation, rockbolt ground support.

- Shafts and Ramps--labor and fringes, construction equipment, permanent material (concrete shaft lining, rockbolts), consumable construction materials, and contractor overhead and profit.

Labor Rates--Labor rates used for other cost categories not included in the cost curves were obtained from Reference 1. These are based on contractors' union rates currently being paid at the Nevada Test Site. Forty percent was added to the base rate for fringe benefits, including vacation, sick leave, insurance costs, and workmen's compensation.

Drift Estimates--The cost per foot of excavation was derived by estimating the crew size required for excavation, including maintenance, support, and supervisory personnel. From this, the total cost per shift was developed. The cost per shift of each machine used to excavate the drift and the material costs of explosives, rockbolts, mesh, drill steel, bits, hoses,

fittings, and installed utility lines were estimated. Additionally, the costs of shotcreting, installing a concrete floor, and muck hoisting were added. Contractor overhead and profit were added to the total direct costs. Construction activity cycle times were calculated separately to obtain an average advance rate of 5.28 ft per shift. This was used in conjunction with the cost per shift to calculate the cost per foot of drift.

Ground Support Estimates--The cost of additional ground support used in weaker rock zones is based on 30-lb/ft steel arch sets on 4-ft centers with 14-gauge steel lagging between the sets. The space between the lagging and rock is nominally 1 ft and is pumped full of concrete. The material cost is derived from recently obtained quotes by Dravo, and the manpower and time for construction are based on Dravo experience. These costs were assembled in a manner similar to the drift estimates to arrive at a unit cost per foot of ground support. The estimated costs apply to both the ramp and the drift from the shaft to the repository, the face section being the same.

Independent Estimate Check of Cost Curves--The curves (Figure 3.1) used to estimate the costs for the various shafts were checked against recent shaft bids and shaft-sinking contracts and were found to be within the allowances for this study.

A check of the cost curves (Figure 3.2) used for estimating the cost of 10% and 20% ramps was made using the drift-estimating techniques described above. The only major variable was in the mucking phase because the headings have the same face area. A larger load-haul-dump unit was used for

the ramp estimate than for the drift estimate because the ramp would open to the surface and offer easy access for large equipment. Haul speeds also varied because of the grade of the ramp. The adjusted cost curves were 21% and 13% higher than the calculated check costs for the 10% and 20% ramps, respectively.

Equipment and Permanent Material--The principal reference for equipment is the equipment list contained on the detailed estimate sheets; all major permanently installed equipment for all cases is shown in Tables 3.1 through 3.13.

Telephone quotations were received for most major items of hoisting equipment. Other equipment and materials were priced from Dravo's historical data files. The estimated cost of equipment and materials represents first quarter 1983 prices. No escalation has been added.

Capital Cost Estimate Tabulations--The detailed capital cost estimates for each case studied are presented in Tables 3.1 to 3.13. Each table includes estimates for excavation and permanent equipment installation. The A series cases are for waste handling access methods; the B series cases are for mining operations access methods for both horizontal and vertical canister emplacement.

Accuracy-- In Dravo's judgement, the accuracy of the capital cost estimate is ±30%. The estimating methods used are a combination of budgetary estimating (provided by the cost curves) and semidetailed estimating (cycle

time estimates and vendor phone quotes for specific equipment) techniques. The costs are within the accuracies necessary to perform the cost comparisons required in this report.

Construction Time--Advance rates used in comparing shafts and ramps were taken from curves obtained from the same USBM report (Reference 2) as the cost curves. Construction times are based on a three-shift-per-day operation, 6 days per week and assume all excavation begins from surface. The original curves were interpolated for the 10% and 20% ramp grades, and were adjusted for the size of the ramp heading and shaft diameters.

Drift development times from the shaft to the repository were calculated based on the cycle times used to prepare the cost estimate. The cycle time to excavate one round in the 20-ft by 15-ft drift was derived by summing estimated times, based on Dravo experience, for each of the mining phases that make up the excavation cycle. Consideration was given to quantities of muck removed, number of 14-ft-long holes to be drilled in the round to yield an estimated 12-ft break, the number of rockbolts to be installed, haul distance for the muck, and the additional concrete steel sets for ground support. Some operations, such as piping or shotcreting, are done concurrently with the excavation cycle.

The construction times for each of the cases are summarized in Table 3.23.

## 3.3 Average Annual Operating Cost Methodology

The operating costs of permanently installed equipment and facilities including hoists, conveyances, and conveyors have been estimated. These costs include labor, materials, and equipment for maintenance and operations. The estimates have been prepared on a cost-per-operating-day basis. Only the direct costs have been considered; overhead costs (such as staff supervision and accounting) are not included. The detailed operating cost estimates on a daily basis for each case studied are presented in Tables 3.14 to 3.22.

Categories of directly associated operating costs were determined for each case to make the estimates comparable. These categories include hoist operations, inspection and maintenance, work force travel time, supply transport, and conveyor operations. Each of these cost catagories was subdivided into the functional areas of labor, supplies, and equipment operation; then a separate estimate was prepared for each detailed area. The estimating procedure is as follows:

Labor--The operating and maintenance personnel requirements were determined on a daily basis for each operating cost area for each case. These manpower requirements were based on Dravo experience for that particular operating cost category.

Labor rates were obtained from Reference 1. These labor rates are based on contractors' union rates currently being paid at the Nevada Test Site. Forty percent was added to the base rate for fringe benefits, including vacation, sick leave, insurance costs, and workmen's compensation.

The labor cost per day for each category was calculated using the estimated manhours and labor rates. This procedure was used for all categories except conveyor operations.

The labor costs for conveyor maintenance operation were determined from the "Capital and Operating Cost Handbook," USBM Report No. OFR 10-78. The costs were updated to the first quarter 1983 using the Construction Cost Index from the Engineering News Record. The cost curves in this handbook are on a daily basis.

The cost for transporting the miners and repository workers to and from underground is separately estimated for all ramp and shaft cases and is included under the mining access methods (the B series cases).

Supplies and Equipment Operations--Supplies and equipment operating costs for hoisting and conveying were derived from the "Capital and Operating Cost Handbook," USBM Report No. OFR 10-78 updated to 1983 using the Construction Cost Index from the Engineering News Record. The cost curves in this handbook are on a daily basis. Conveyor supplies consist of power only; conveyor equipment operation consists of repair parts and lubrication. Hoisting supplies consist of power- and steel-related items (such as ropes and material for conveyance repairs). Hoist equipment operations consist of repair parts and lubrication.

Equipment operating costs for men and supply transport vehicles were based on reasonable hourly operating costs from Dravo's historical files for

similar type equipment. These hourly costs were multiplied by the number of daily operating hours to arrive at an estimated cost per day for these categories.

Accuracy--In Dravo's judgement, the accuracy of the operating cost estimate is ±30%. The estimating methods used are a combination of budgetary estimating (provided by the operating cost curves) and semidetailed estimating (man-hour and cycle times) techniques. The costs are within the accuracies necessary to perform the cost comparisons required in this report. Dravo has made the costs as comparable as possible between the various cases; however, they are intended as a guide only, not as an absolute cost (for shaft operations for example) because many other related costs have not been, and cannot be, included until more detailed operating plans are determined.

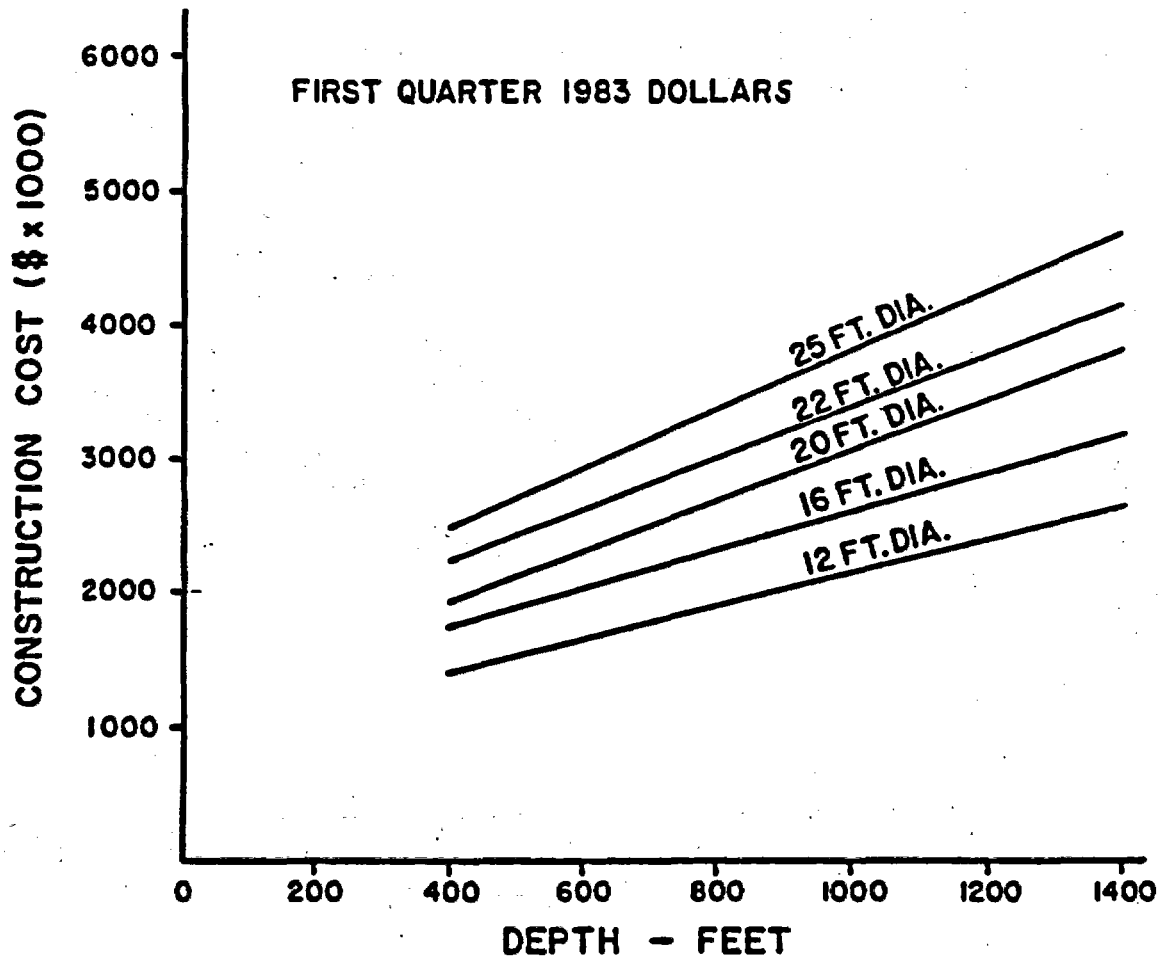


FIGURE 3.1. EXCAVATION AND LINING COST FOR VARIOUS DIAMETERS OF CONCRETE LINED CONVENTIONALLY SUNK CIRCULAR SHAFTS

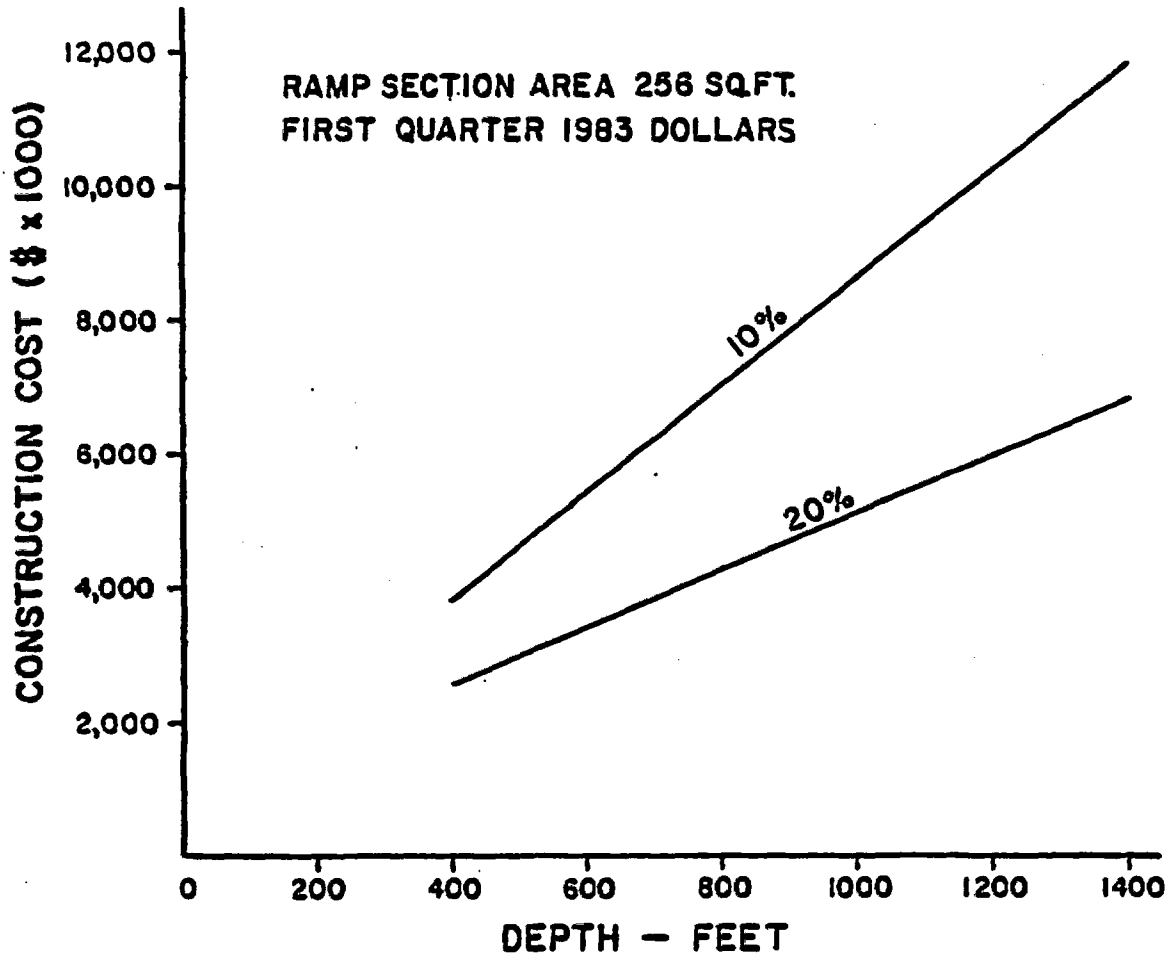


FIGURE 3.2. EXCAVATION AND SUPPORT COST VS VERTICAL DISTANCE FOR CONVENTIONALLY DRIVEN RAMPS AT 10% AND 20% GRADES

TABLE 3.1
CAPITAL COST ESTIMATE
CASES A-1 AND A-2
WASTE HANDLING
SHAFT AND DRIFT ACCESS

| ITEM | DESCRIPTION | UNIT A-1 | UNIT A-2 | UNIT COST A-1 | UNIT COST A-2 | AMOUNT A-1 | AMOUNT A-2 |
|---|---|---|---|---|---|---|---|
| **Excavation** | | | | | | | |
| Shaft* | 22' Ø, concrete lined (12"), includes collar, not equipped. | 870' | 870' | $3517.24/ft | $3517.24/ft. | 3,060,000 | 3,060,000 |
| Repository Drift | 20'W, 15'H, rock bolt/mesh, concrete floor (8"), shotcrete walls, roof. | 6800' | 7400' | $1114/ft. | $1114/ft. | 7,575,200 | 8,243,600 |
| Drift Ground Support | 25% of drift, added support steel | 1700' | 1850' | $ 585/ft. | $ 585/ft. | 994,500 | 1,082,250 |
| TOTAL EXCAVATION | | | | | | 11,629,700 | 12,385,850 |
| **Permanent Equipment** | | | | | | | |
| Headframe | 36'W, 45'L, 152'H, concrete | 1587 cu. yd. | 1587 cu yd | $ 250 cu. yd. | $ 250 cu. yd. | 396,750 | 396,750 |
| Hoist | 120" wheel Ø, 250 hp DC drive, friction | 1 hoist | 1 hoist | $ 982,000 | $ 982,000 | 982,000 | 982,000 |
| Cage (waste handling) | 10'W, 10'L, 40'H, 50 ton capacity, weight 86,000 lb. | 1 cage | 1 cage | $ 197,800 | $ 197,800 | 197,800 | 197,800 |
| Counterweight (CWT) | 136,000 lb., lead | 1 CWT | 1 CWT | $ 0.45/lb. | $ 0.45/lb. | 61,200 | 61,200 |
| Hoisting and Tail Ropes | 1½" Ø, 6 x 19 round strand | 8 @ 2009' | 8 @ 2009' | $ 8/ft. | $ 8/ft. | 128,576 | 128,576 |
| Guide Ropes | 1-5/8" Ø 6 x 19 round strand | 6 @ 965' | 6 @ 965' | $ 8/ft. | $ 8/ft. | 46,320 | 46,320 |
| Cheeseweight (for guide ropes) | 18,000 lb., lead | 6 ea. | 6 ea. | $ 0.45/lb. | $ 0.45/lb. | 48,600 | 48,600 |
| Shaft Equipment | Fixed guides, support steel buntons | 19 tons | 19 tons | $ 1900/ton | $ 1900/ton | 36,100 | 36,100 |
| Headframe Equipment | shaft catch gear, arrestors, | 1 lot | 1 lot | $ 33,500 | $ 33,500 | 33,500 | 33,500 |
| TOTAL PERMANENT EQUIPMENT | | | | | | 1,930,846 | 1,930,846 |
| TOTAL CAPITAL COST | | | | | | $13,560,546 | $14,316,696 |

* Shaft Costs from Fig. 3.1. Unit Costs shown were calculated for comparitive purposes only.

TABLE 3.2
CAPITAL COST ESTIMATE
CASES A-3 AND A-4
WASTE HANDLING
10% GRADE RAMP

| ITEM | DESCRIPTION | UNIT A-3 | UNIT A-4 | UNIT COST A-3 | UNIT COST A-4 | AMOUNT A-3 | AMOUNT A-4 |
|---|---|---|---|---|---|---|---|
| Excavation | | | | | | | |
| Ramp* | Waste handling - repository, 10% grade, rockbolt/mesh, 20' x 20' drift. | 7437' | 7437' | $ 860.56/ft | $ 860.56/ft | 6,400,000 | 6,400,000 |
| Ramp Walls and Roof | Shotcrete | 7437' | 7437' | $ 100/ft. | $ 100/ft. | 743,700 | 743,700 |
| Ramp Floor | Concrete (8"), 20' W | 7437' | 7437' | $ 59.55/ft. | $ 59.55/ft. | 442,873 | 442,873 |
| Ramp Ground Support | 25% of ramp, added ground support, steel sets, lagging, concrete. | 1859' | 1859' | $ 585/ft. | $ 585/ft. | 1,087,515 | 1,087,515 |
| TOTAL CAPITAL COST | | | | | | $ 8,674,088 | $ 8,674,088 |

* Ramp Costs from Fig. 3.2. Unit costs shown were calculated for comparitive purposes only.

TABLE 3.3
CAPITAL COST ESTIMATE
CASE B1 (VERTICAL EMPLACEMENT)
SHAFT
10,000 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT | UNIT COST | AMOUNT |
|---|---|---|---|---|
| Excavation | | | | |
| Shaft* | 25' Ø concrete lined (12"), includes collar and loading pocket, not equipped | 1030' | $3669.90/ft. | 3,780,000 |
| Repository Drift | 20'W, 15'H, rock bolt/mesh, concrete floor (8"), shotcrete walls, roof. | 6850' | $1114/ft. | 7,630,900 |
| Drift Ground Support | 25% of drift, added support steel | 1713' | $ 585/ft. | 1,002,105 |
| Underground Storage Bin | Excavation with 3500 ton cap, 25'Ø 100'H | 50,000 cu. ft. | $3.5/cu. ft. | 175,000 |
| TOTAL EXCAVATION | | | | 12,588,005 |
| Permanent Equipment | | | | |
| Headframe | Structural Steel, 185'H, compartment with 250 ton integral bin. | 288 tons steel | $ 1900/ton | 547,200 |
| Hoist House | Prefab building with roofing, siding, HVAC, interior finish, 60'W, 100'L, 25'H | 6000 sq. ft. | $ 36/sq. ft. | 216,000 |
| Hoist Foundation | Concrete, 30' x 40' x 8' | 2 @ 355 cu. yd. | $ 200 cu. yd. | 142,000 |
| Skip Loading Pocket | 200 cu. ft., hopper, twin loading chutes, gates, support structural steel | 65 tons steel | $ 1900/ton | 123,500 |
| Wire Rope | 1-7/8" Ø for production hoist | 2 @ 1350 ft. | $ 11/ft. | 29,700 |
| Guide Ropes | 1-3/4" Ø for production hoist | 8 @ 1110 ft. | $ 8/ft. | 71,040 |
| Sheaves | 12'-6" Ø for production hoist | 2 ea. | $ 31,522 | 63,044 |
| Wire Rope | 2¼" Ø for service hoist | 3230 ft. | $ 14/ft. | 45,220 |
| Production Hoist | Double drum, double clutch, 1250 hp DC drive; will hoist 2 skips, 200 cu. ft. capacity each. | 1 ea. | $1,850,000 | 1,850,000 |
| Service Hoist | Double drum, 550 hp DC drive, for men and material | 1 ea. | $1,200,000 | 1,200,000 |
| Skips | Bottom dump, 200 cu. ft. capacity | 2 ea. | $ 54,915 | 109,830 |
| Dump Scrolls | 6 tons/pair | 2 pair | $ 1600/ton | 19,200 |
| Cage | Double deck, for men and material | 31,500 lb. | $ 2.28/lb. | 71,820 |
| Belt Conveyor | Underground, loading pocket feed, 36"W | 100'LG. | $ 216/ft. | 21,600 |

| | | | | |
|---|---|---|---|---|
| Apron Feeder | Underground, 48"W, 10'L, includes drive | 2 ea. | $ 35,000 | 70,000 |
| Cage Counterweight | Lead | 54,000 lb. | $ 0.45/lb. | 24,300 |
| Cage Guides | Steel (.025 T/Ft.) | 26 tons | $ 1900/ton | 49,400 |
| Guide Rope Cheeseweights | Lead | (8) 20,000 lb. | $ 0.45/lb. | 72,000 |
| TOTAL PERMANENT EQUIPMENT | | | | 4,725,854 |
| TOTAL CAPITAL COST | | | | $17,313,859 |

* Shaft Costs from Fig. 3.1. Unit costs shown were calculated for comparitive purposes only.

TABLE 3.4
CAPITAL COST ESTIMATE
CASE B2 (HORIZONTAL EMPLACEMENT)
SHAFT AND HOIST
1500 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT | UNIT COST | AMOUNT |
|---|---|---|---|---|
| Excavation | | | | |
| Shaft* | 20' Ø, concrete lined (12") includes collar and loading pocket, not equipped. | 830' | $3313.25/ft. | 2,750,000 |
| Repository Drift | 20'W, 15'H, rock bolt/mesh, concrete floor (8"), shotcrete walls, roof. | 6850' | $1114/ft. | 7,630,900 |
| Drift Ground Support | 25% of drift, added support steel | 1713' | $ 585/ft. | 1,002,105 |
| TOTAL EXCAVATION | | | | 11,383,005 |
| Permanent Equipment | | | | |
| Headframe | Structural steel, 127'H, includes 250-ton bins | 184 tons steel | $ 1900/ton | 349,600 |
| Hoist House | Prefab building with roofing, siding, HVAC, 60'W, 80'L, 25'H | 4800 sq. ft. | $ 36/sq. ft. | 172,800 |
| Hoist Foundation | Concrete, 30' x 25' x 6' | 2 @ 166.5 cu. yd. | $ 200/cu.yd. | 66,600 |
| Skip Loading Pocket | 100 cu. ft., hopper, twin loading chutes, cylinder operated gates, support structural steel | 45 tons | $ 1900/ton | 85,500 |
| Wire Rope | 1¼" Ø for production hoist | 2 @ 1080 ft. | $ 8/ft. | 17,280 |
| Guide ropes | 1-3/4" Ø for production hoist | 8 @ 922 ft. | $ 8/ft. | 59,008 |
| Sheaves | 8'-4" Ø for production hoist | 2 ea. | $25,218 | 50,436 |
| Sheaves | 11'-8" Ø for cage hoist and counterweight | 2 ea. | $25,218 | 50,436 |
| Production Hoist | Double drum, clutch, 550 hp DC drive; will hoist 2 skips, 100 cu. ft. capacity each | 1 ea. | $1,536,184 | 1,536,184 |
| Wire Rope | 1-3/4" Ø for cage and counterweight | 2 @ 1010 ft. | $ 8/ft. | 16,160 |
| Cage Hoist | Double drum, 300 hp DC drive, for men and material | 1 ea. | $882,960 | 882,960 |
| Skips | Bottom dump, 100 cu. ft. capacity | 2 ea. | $41,186 | 82,372 |
| Dump Scrolls | 3.5 ton per pair | 2 pair | $ 1600/ton | 11,200 |

| | | | | |
|---|---|---|---|---|
| Cage | Double deck, for men and material, steel | 25 tons | $ 1600/ton | 40,000 |
| Shaft Equipment | Support steel, buntons, 760 ft. (.048 T/ft) | 36 tons | $ 1900/ton | 68,400 |
| Cage Counterweights | Lead | 32,600 lb. | $ 0.45/lb. | 14,670 |
| Cheeseweights | Lead | 8 @ 15,000 lb. | $ 0.45/lb. | 54,000 |
| TOTAL PERMANENT EQUIPMENT | | | | 3,557,606 |
| TOTAL CAPITAL COST | | | | $14,940,611 |

* Shaft costs from Fig. 3.1. Unit costs shown were calculated for comparitive purposes only.

TABLE 3.5
CAPITAL COST ESTIMATE
CASE B3 (VERTICAL EMPLACEMENT)
SHAFT
10,000 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT | UNIT COST | AMOUNT |
|---|---|---|---|---|
| Excavation | | | | |
| Shaft* | 25' Ø concrete lined (12"), includes collar and loading pocket, not equipped | 1030' | $3669.90/ft. | 3,780,000 |
| Repository Drift | 20'W, 15'H, rock bolt/mesh, concrete floor (8"), shotcrete walls, roof. | 7400' | $1114/ft. | 8,243,600 |
| Drift Ground Support | 25% of drift, added support steel | 1850' | $ 585/ft. | 1,082,250 |
| Underground Storage Bin | Excavation with 3500 Ton Cap, 25' Ø 100'H | 50,000 cu. ft. | $ 3.5/cu. ft. | 175,000 |
| TOTAL EXCAVATION | | | | 13,280,850 |
| Permanent Equipment | | | | |
| Headframe | Structural Steel, 185'H, compartment with 250 ton integral bin. | 288 tons steel | $ 1900/ton | 547,200 |
| Hoist House | Prefab building with roofing, siding, HVAC, interior finish, 60'W, 100'L, 25'H | 6000 sq. ft. | $ 36/sq. ft. | 216,000 |
| Hoist Foundation | Concrete, 30' x 40' x 8' | 2 @ 355 cu. yd. | $ 200 cu. yd. | 142,000 |
| Skip Loading Pocket | 200 cu. ft., hopper, twin loading chutes, gates, support structural steel | 65 tons steel | $ 1900/ton | 123,500 |
| Wire Rope | 1-7/8" Ø for production hoist | 2 @ 1350 ft. | $ 11/ft. | 29,700 |
| Guide Ropes | 1-3/4" Ø for production hoist | 8 @ 1110 ft. | $ 8/ft. | 71,040 |
| Sheaves | 12'-6" Ø for production hoist | 2 ea. | $ 31,522 | 63,044 |
| Wire Rope | 2¼" Ø for service hoist | 3230 ft. | $ 14/ft. | 45,220 |
| Production Hoist | Double drum, double clutch, 1250 hp DC drive; will hoist 2 skips, 200 cu. ft. capacity each. | 1 ea. | $1,850,000 | 1,850,000 |
| Service Hoist | Double drum, 550 hp DC drive, for men and material | 1 ea. | $1,200,000 | 1,200,000 |
| Skips | Bottom dump, 200 cu. ft. capacity | 2 ea. | $ 54,915 | 109,830 |
| Dump Scrolls | 6 tons/pair | 2 pair | $ 1600/ton | 19,200 |
| Cage | Double deck, for men and material | 31,500 lb. | $ 2.28/lb. | 71,820 |
| Belt Conveyor | Underground, loading pocket feed, 36"W | 100'LG. | $ 216/ft. | 21,600 |

| | | | | |
|---|---|---|---|---|
| Apron Feeder | Underground, 48"W, 10'L, includes drive | 2 ea. | $ 35,000 | 70,000 |
| Cage Counterweight | Lead | 54,000 lb. | $ 0.45/lb. | 24,300 |
| Cage Guides | Steel (.025 T/Ft.) | 26 tons | $ 1900/ton | 49,400 |
| Guide Rope Cheeseweights | Lead | (8) 20,000 lb. | $ 0.45/lb. | 72,000 |
| **TOTAL PERMANENT EQUIPMENT** | | | | 4,725,854 |
| **TOTAL CAPITAL COST** | | | | $18,006,704 |

* Shaft costs from Fig. 3.1. Unit costs shown were calculated for comparitive purposes only.

TABLE 3.6
CAPITAL COST ESTIMATE
CASE B4 (HORIZONTAL EMPLACEMENT)
SHAFT AND HOIST
1500 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT | UNIT COST | AMOUNT |
|---|---|---|---|---|
| Excavation | | | | |
| Shaft* | 20' Ø, concrete lined (12") includes collar and loading pocket, not equipped. | 830' | $3313.25/ft. | 2,750,000 |
| Repository Drift | 20'W, 15'H, rock bolt/mesh, concrete floor (8"), shotcrete walls, roof. | 7400' | $1114/ft. | 8,243,600 |
| Drift Ground Support | 25% of drift, added support steel | 1850' | $ 585/ft. | 1,082,250 |
| TOTAL EXCAVATION | | | | 12,075,850 |
| Permanent Equipment | | | | |
| Headframe | Structural steel, 127'H, includes 250-ton bins | 184 tons steel | $ 1900/ton | 349,600 |
| Hoist House | Prefab building with roofing, siding, HVAC, 60'W, 80'L, 25'H | 4800 sq. ft. | $ 36/sq. ft. | 172,800 |
| Hoist Foundation | Concrete, 30' x 25' x 6' | 2 @ 166.5 cu. yd. | $ 200/cu.yd. | 66,600 |
| Skip Loading Pocket | 100 cu. ft., hopper, twin loading chutes, cylinder operated gates, support structural steel | 45 tons | $ 1900/ton | 85,500 |
| Wire Rope | 1¼" Ø for production hoist | 2 @ 1080 ft. | $ 8/ft. | 17,280 |
| Guide ropes | 1-3/4" Ø for production hoist | 8 @ 922 ft. | $ 8/ft. | 59,008 |
| Sheaves | 8'-4" Ø for production hoist | 2 ea. | $25,218 | 50,436 |
| Sheaves | 11'-8" Ø for cage hoist and counterweight | 2 ea. | $25,218 | 50,436 |
| Production Hoist | Double drum, clutch, 550 hp DC drive; will hoist 2 skips, 100 cu. ft. capacity each | 1 ea. | $1,536,184 | 1,536,184 |
| Wire Rope | 1-3/4" Ø for cage and counterweight | 2 @ 1010 ft. | $ 8/ft. | 16,160 |
| Cage Hoist | Double drum, 300 hp DC drive, for men and material | 1 ea. | $882,960 | 882,960 |
| Skips | Bottom dump, 100 cu. ft. capacity | 2 ea. | $41,186 | 82,372 |
| Dump Scrolls | 3.5 ton per pair | 2 pair | $ 1600/ton | 11,200 |

| | | | | |
|---|---|---|---|---|
| Cage | Double deck, for men and material, steel | 25 tons | $ 1600/ton | 40,000 |
| Shaft Equipment | Support steel, buntons, 760 ft. (.048 T/ft) | 36 tons | $ 1900/ton | 68,400 |
| Cage Counterweights | Lead | 32,600 lb. | $ 0.45/lb. | 14,670 |
| Cheeseweights | Lead | 8 @ 15,000 lb. | $ 0.45/lb. | 54,000 |
| **TOTAL PERMANENT EQUIPMENT** | | | | 3,557,606 |
| **TOTAL CAPITAL COST** | | | | $15,633,456 |

* Shaft costs from Fig. 3.1. Unit costs shown were calculated for comparitive purposes only.

TABLE 3.7
CAPITAL COST ESTIMATE
CASE B5 (VERTICAL EMPLACEMENT)
SHAFT
10,000 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT | UNIT COST | AMOUNT |
|---|---|---|---|---|
| Excavation | | | | |
| Shaft* | 25' Ø concrete lined (12"), includes collar and loading pocket, not equipped | 1200' | $3466.67/ft. | 4,160,000 |
| Repository Drift | 20'W, 15'H, rock bolt/mesh, concrete floor (8"), shotcrete walls, roof. | 4550' | $1114/ft. | 5,068,700 |
| Drift Ground Support | 25% of drift, added support steel | 1138' | $ 585/ft. | 665,730 |
| Underground Storage Bin | Excavation with 3500 ton cap, 25' Ø 100'H | 50,000 cu. ft. | $ 3.5/cu. ft. | 175,000 |
| TOTAL EXCAVATION | | | | 10,069,430 |
| Permanent Equipment | | | | |
| Headframe | Structural Steel, 185'H, compartment with 250 ton integral bin. | 288 tons steel | $ 1900/ton | 547,200 |
| Hoist House | Prefab building with roofing, siding, HVAC, interior finish, 60'W, 100'L, 25'H | 6000 sq. ft. | $ 36/sq. ft. | 216,000 |
| Hoist Foundation | Concrete, 30' x 40' x 8' | 2 @ 355 cu. yd. | $ 200/yd. | 142,000 |
| Skip Loading Pocket | 200 cu. ft., hopper, twin loading chutes, gates, support structural steel | 65 tons steel | $ 1900/ton | 123,500 |
| Wire Rope | 1-7/8" Ø for production hoist | 2 @ 1520 ft. | $ 11/ft. | 33,440 |
| Guide Ropes | 1-3/4" Ø for production hoist | 8 @ 1280 ft. | $ 8/ft. | 81,920 |
| Sheaves | 12'-6" Ø for production hoist | 2 ea. | $ 31,522 | 63,044 |
| Wire Rope | 2¼" Ø for service hoist | 3400 ft. | $ 14/ft. | 47,600 |
| Production Hoist | Double drum, double clutch, 1250 hp DC drive; will hoist 2 skips, 200 cu. ft. capacity each. | 1 ea. | $1,850,000 | 1,850,000 |
| Service Hoist | Double drum, 550 hp DC drive, for men and material | 1 ea. | $1,200,000 | 1,200,000 |
| Skips | Bottom dump, 200 cu. ft. capacity | 2 ea. | $ 54,915 | 109,830 |
| Dump Scrolls | 6 tons/pair | 2 pair | $ 1600/ton | 19,200 |
| Cage | Double deck, for men and material | 31,500 lb. | $ 2.28/lb. | 71,820 |
| Belt Conveyor | Underground, loading pocket feed, 36"W | 100'LG. | $ 216/ft. | 21,600 |

| | | | | |
|---|---|---|---|---|
| Apron Feeder | Underground, 48"W, 10'L, includes drive | 2 ea. | $ 35,000 | 70,000 |
| Cage Counterweight | Lead | 54,000 lb. | $ 0.45/lb. | 24,300 |
| Cage Guides | Steel (.025 T/Ft.) | 30 tons | $ 1900/ton | 57,000 |
| Guide Rope Cheeseweights | Lead | (8) 20,000 lb. | $ 0.45/lb. | 72,000 |
| **TOTAL PERMANENT EQUIPMENT** | | | | 4,750,454 |
| **TOTAL CAPITAL COST** | | | | $14,819,884 |

* Shaft costs from Fig. 3.1. Unit costs shown were calculated for comparitive purposes only.

TABLE 3.8
CAPITAL COST ESTIMATE
CASE B6 (HORIZONTAL EMPLACEMENT)
SHAFT AND HOIST
1500 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT | UNIT COST | AMOUNT |
|---|---|---|---|---|
| Excavation | | | | |
| Shaft* | 20' Ø, concrete lined (12") includes collar and loading pocket, not equipped. | 1000' | $3030.00/ft. | 3,030,000 |
| Repository Drift | 20'W, 15'H, rock bolt/mesh, concrete floor (8"), shotcrete walls, roof. | 4550' | $1114/ft. | 5,068,700 |
| Drift Ground Support | 25% of drift, added support steel | 1138' | $ 585/ft. | 665,730 |
| TOTAL EXCAVATION | | | | 8,764,430 |
| Permanent Equipment | | | | |
| Headframe | Structural steel, 127'H, includes 250-ton bins | 184 tons steel | $ 1900/ton | 349,600 |
| Hoist House | Prefab building with roofing, siding, HVAC, 60'W, 80'L, 25'H | 4800 sq. ft. | $ 36/sq. ft. | 172,800 |
| Hoist Foundation | Concrete, 30' x 25' x 6' | 2 @ 166.5 cu. yd. | $ 200/cu.yd. | 66,600 |
| Skip Loading Pocket | 100 cu. ft., hopper, twin loading chutes, cylinder operated gates, support structural steel | 45 tons | $ 1900/ton | 85,500 |
| Wire Rope | 1¼" Ø for production hoist | 2 @ 1250 ft. | $ 8/ft. | 20,000 |
| Guide ropes | 1-3/4" Ø for production hoist | 8 @ 1092 ft. | $ 8/ft. | 69,888 |
| Sheaves | 8'-4" Ø for production hoist | 2 ea. | $25,218 | 50,436 |
| Sheaves | 11'-8" Ø for cage hoist and counterweight | 2 ea. | $25,218 | 50,436 |
| Production Hoist | Double drum, clutch, 550 hp DC drive; will hoist 2 skips, 100 cu. ft. capacity each | 1 ea. | $1,536,184 | 1,536,184 |
| Wire Rope | 1-3/4" Ø for cage and counterweight | 2 @ 1180 ft. | $ 8/ft. | 18,880 |
| Cage Hoist | Double drum, 300 hp DC drive, for men and material | 1 ea. | $882,960 | 882,960 |
| Skips | Bottom dump, 100 cu. ft. capacity | 2 ea. | $41,186 | 82,372 |
| Dump Scrolls | 3.5 ton per pair | 2 pair | $ 1600/ton | 11,200 |

| | | | | |
|---|---|---|---|---|
| Cage | Double deck, for men and material, steel | 25 tons | $ 1600/ton | 40,000 |
| Shaft Equipment | Support steel, buntons, 930 ft. (.048 T/ft) | 45 tons | $ 1900/ton | 85,500 |
| Cage Counterweights | Lead | 32,600 lb. | $ 0.45/lb. | 14,670 |
| Cheeseweights | Lead | 8 @ 15,000 lb. | $ 0.45/lb. | 54,000 |
| **TOTAL PERMANENT EQUIPMENT** | | | | 3,591,026 |
| **TOTAL CAPITAL COST** | | | | $12,355,456 |

* Shaft costs from Fig. 3.1. Unit costs shown were calculated for comparitive purposes only.

TABLE 3.9
CAPITAL COST ESTIMATE
CASE B7 (VERTICAL EMPLACEMENT)
SHAFT
10,000 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT | UNIT COST | AMOUNT |
|---|---|---|---|---|
| **Excavation** | | | | |
| Shaft* | 25' Ø concrete lined (12"), includes collar and loading pocket, not equipped | 1400' | $3330.71/ft. | 4,663,000 |
| Underground Stroage Bin | Excavation with 3500 ton cap, 25' Ø 100'H | 50,000 cu. ft. | $ 3.5/cu. ft. | 175,000 |
| Conveyor Drift | 20'W, 15'H, 100'L | 30,000 cu. ft. | $ 3.5/cu. ft. | 105,000 |
| **TOTAL EXCAVATION** | | | | 4,943,000 |
| **Permanent Equipment** | | | | |
| Headframe | Structural Steel, 185'H, compartment with 250 ton integral bin. | 288 tons steel | $ 1900/ton | 547,200 |
| Hoist House | Prefab building with roofing, siding, HVAC, interior finish, 60'W, 100'L, 25'H | 6000 sq. ft. | $ 36/sq. ft. | 216,000 |
| Hoist Foundation | Concrete, 30' x 40' x 8' | 2 @ 355 cu. yd. | $ 200 cu. yd. | 142,000 |
| Skip Loading Pocket | 200 cu. ft., hopper, twin loading chutes, gates, support structural steel | 65 tons steel | $ 1900/ton | 123,500 |
| Wire Rope | 1-7/8" Ø for production hoist | 2 @ 1720 ft. | $ 11/ft. | 37,840 |
| Guide Ropes | 1-3/4" Ø for production hoist | 8 @ 1480 ft. | $ 8/ft. | 94,720 |
| Sheaves | 12'-6" Ø for production hoist | 2 ea. | $ 31,522 | 63,044 |
| Wire Rope | 2¼" Ø for service hoist | 3600 ft. | $ 14/ft. | 50,400 |
| Production Hoist | Double drum, double clutch, 1250 hp DC drive; will hoist 2 skips, 200 cu. ft. capacity each. | 1 ea. | $1,850,000 | 1,850,000 |
| Service Hoist | Double drum, 550 hp DC drive, for men and material | 1 ea. | $1,200,000 | 1,200,000 |
| Skips | Bottom dump, 200 cu. ft. capacity | 2 ea. | $ 54,915 | 109,830 |
| Dump Scrolls | 6 tons/pair | 2 pair | $ 1600/ton | 19,200 |
| Cage | Double deck, for men and material | 31,500 lb. | $ 2.28/lb. | 71,820 |
| Belt Conveyor | Underground, loading pocket feed, 36"W | 100'LG. | $ 216/ft. | 21,600 |

| | | | | |
|---|---|---|---|---|
| Apron Feeder | Underground, 48"W, 10'L, includes drive | 2 ea. | $ 35,000 | 70,000 |
| Cage Counterweight | Lead | 54,000 lb. | $ 0.45/lb. | 24,300 |
| Cage Guides | Steel | 35 tons | $ 1900/ton | 66,500 |
| Guide Rope Cheeseweights | Lead | (8) 20,000 lb. | $ 0.45/lb. | 72,000 |
| **TOTAL PERMANENT EQUIPMENT** | | | | 4,779,954 |
| **TOTAL CAPITAL COST** | | | | $9,722,954* |

* Shaft costs from Fig. 3.1. Unit costs shown were calculated for comparitive purposes only.

TABLE 3.10
CAPITAL COST ESTIMATE
CASE B8 (HORIZONTAL EMPLACEMENT)
SHAFT AND HOIST
1500 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT | UNIT COST | AMOUNT |
|---|---|---|---|---|
| Excavation | | | | |
| Shaft* | 20' Ø, concrete lined (12") includes collar and loading pocket, not equipped. | 1200' | $2868.33/ft. | 3,442,000 |
| TOTAL EXCAVATION | | | | 3,442,000 |
| Permanent Equipment | | | | |
| Headframe | Structural steel, 127'H, includes 250-ton bins | 184 tons steel | $ 1900/ton installed | 349,600 |
| Hoist House | Prefab building with roofing, siding, HVAC, 60'W, 80'L, 25'H | 4800 sq. ft. | $ 36/sq. ft. | 172,800 |
| Hoist Foundation | Concrete, 30' x 25' x 6' | 2 @ 166.5 cu. yd. | $ 200/cu.yd. | 66,600 |
| Skip Loading Pocket | 100 cu. ft., hopper, twin loading chutes, cylinder operated gates, support structural steel | 45 tons | $ 1900/ton | 85,500 |
| Wire Rope | 1¼" Ø for production hoist | 2 @ 1450' | $ 8/ft. | 23,200 |
| Guide ropes | 1-3/4" Ø for production hoist | 8 @ 1292' | $ 8/ft. | 82,688 |
| Sheaves | 8'-4" Ø for production hoist | 2 ea. | $25,218 | 50,436 |
| Sheaves | 11'-8" Ø for cage hoist and counterweight | 2 ea. | $25,218 | 50,436 |
| Production Hoist | Double drum, clutch, 550 hp DC drive; will hoist 2 skips, 100 cu. ft. capacity each | 1 ea. | $1,536,184 | 1,536,184 |
| Wire Rope | 1-3/4" Ø for cage and counterweight | 2 @ 1380 ft. | $ 8/ft. | 22,080 |
| Cage Hoist | Double drum, 300 hp DC drive, for men and material | 1 ea. | $882,960 | 882,960 |
| Skips | Bottom dump, 100 cu. ft. capacity | 2 ea. | $41,186 | 82,372 |
| Dump Scrolls | 3.5 ton per pair | 2 pair | $ 1600/ton | 11,200 |
| Cage | Double deck, for men and material, steel | 25 tons | $ 1600/ton | 40,000 |
| Shaft Equipment | Support steel, buntons, 1130' | 54 tons | $ 1900/ton | 102,600 |

| | | | | |
|---|---|---|---|---|
| Cage Counterweights | Lead | 32,600 lb. | $ 0.45/lb. | 14,670 |
| Cheeseweights | Lead | 8 @ 15,000 lb. | $ 0.45/lb. | 54,000 |
| **TOTAL PERMANENT EQUIPMENT** | | | | 3,627,326 |
| **TOTAL CAPITAL COST** | | | | $7,069,326 |

* Shaft costs from Fig. 3.1. Unit costs shown were calculated for comparitive purposes only.

TABLE 3.11
CAPITAL COST ESTIMATE
CASES B-9 AND B-10 (VERTICAL & HORIZONTAL EMPLACEMENT)
10% RAMP
10,000 & 1500 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT B-9 | UNIT B-10 | UNIT COST B-9 | UNIT COST B-10 | AMOUNT B-9 | AMOUNT B-10 |
|---|---|---|---|---|---|---|---|
| Excavation | | | | | | | |
| Ramp* | Mining, 10% Grade, Rock Bolt/ Mesh, 20'W. x 15'H. | 7437' | 7437' | 860.56/ft. | $860.56/ft. | 6,400,000 | 6,400,000 |
| Ramp Floor | Conc. 8" Thk. x 20'W. | 7437' | 7437' | $59.55/ft. | $59.55/ft. | 442,873 | 442,873 |
| Ramp Walls & Roof | Shotcrete | 7437' | 7437' | $100/ft. | $100/ft. | 743,700 | 743,700 |
| Ramp Ground Support | 25% of Ramp, Added Ground Support Steel Sets, Lagging and Concrete | 1859' | 1859' | $585/ft. | $585/ft. | 1,087,515 | 1,087,515 |
| TOTAL EXCAVATION | | | | | | 8,674,088 | 8,674,088 |
| Permanent Equipment | | | | | | | |
| Belt Conveyor | 24"W., 1500 TPD (Horiz. Emplacement) | | 7437' | | $144/ft. | | 1,070,928 |
| Belt Conveyor | 36" W., 10,000 TPD (Vert. Emplacement) | 7437' | | $216/ft. | | 1,606,392 | |
| TOTAL PERMANENT EQUIPMENT | | | | | | 1,606,392 | 1,070,928 |
| TOTAL CAPITAL COST | | | | | | $10,280,480 | $ 9,745,016 |

* Ramp costs from Fig. 3.2. Unit costs shown were calculated for comparitive purposes only.

TABLE 3.12
CAPITAL COST ESTIMATE
CASES B-11 AND B-12 (VERTICAL & HORIZONTAL EMPLACEMENT)
10% RAMP
10,000 & 1500 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT B-11 | UNIT B-12 | UNIT COST B-11 | UNIT COST B-12 | AMOUNT B-11 | AMOUNT B-12 |
|---|---|---|---|---|---|---|---|
| Excavation | | | | | | | |
| Ramp* | Mining, 10% Grade, Rock Bolt/ Mesh, 20'W. x 15'H. | 7437' | 7437' | 850.56/ft. | $850.56/ft. | 6,400,000 | 6,400,000 |
| Ramp Floor | Conc. 8" Thk. x 20'W. | 7437' | 7437' | $59.55/ft. | $59.55/ft. | 442,873 | 442,873 |
| Ramp Walls & Roof | Shotcrete | 7437' | 7437' | $100/ft. | $100/ft. | 743,700 | 743,700 |
| Ramp Ground Support | 25% of Ramp, Added Ground Support Steel Sets, Lagging and Concrete | 1859' | 1859' | $585/ft. | $585/ft. | 1,087,515 | 1,087,515 |
| TOTAL EXCAVATION | | | | | | 8,674,088 | 8,674,088 |
| Permanent Equipment | | | | | | | |
| Belt Conveyor | 24"W., 1500 TPD (Horiz. Emplacement) | | 7437' | | $144/ft. | | 1,070,928 |
| Belt Conveyor | 36" W., 10,000 TPD (Vert. Emplacement) | 7437' | | $216/ft. | | 1,606,392 | |
| TOTAL PERMANENT EQUIPMENT | | | | | | 1,606,392 | 1,070,928 |
| TOTAL CAPITAL COST | | | | | | $10,280,480 | $ 9,745,016 |

* Ramp costs from Fig. 3.2. Unit costs shown were calculated for comparitive purposes only.

TABLE 3.13
CAPITAL COST ESTIMATE
CASES B13 & B14 (VERTICAL AND HORIZONTAL EMPLACEMENT)
20% RAMP
10,000 & 1500 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT B-13 | UNIT B-14 | UNIT COST B-13 | UNIT COST B-14 | AMOUNT B-13 | AMOUNT B-14 |
|---|---|---|---|---|---|---|---|
| Excavation | | | | | | | |
| Ramp* | Mining, 20% grade, rock bolt/mesh, 20'W, 15'H | 4640' | 4640' | $948.28/ft. | $948.28/ft. | 4,400,000 | 4,400,000 |
| Ramp Walls and Roof | Shotcrete, 20'W, 15'H | 4640' | 4640' | $ 100/ft. | $ 100/ft. | 464,000 | 464,000 |
| Ramp Ground Support | 25% of ramp, added ground support, steel sets, lagging, concrete | 1160' | 1160' | $ 585/ft. | $ 585/ft. | 678,600 | 678,600 |
| TOTAL EXCAVATION | | | | | | 5,542,600 | 5,542,600 |
| Permanent Equipment | | | | | | | |
| Belt Conveyor | 24" Wide, 1500 TPD Muck | | 4711'LG. | | $144/ft. | | 678,384 |
| Belt Conveyor | 36" Wide, 10,000 TPD Muck TPD Muck | 4711' lg. | | $ 216/ft. | | 1,017,576 | |
| Flat Rail Car | 10'W x 30'L w/Safety Mech. for men and material transport | 1 ea. | 1 ea. | $32,600 | $32,600 | 32,600 | 32,600 |
| Rail | 85#, @ 28.3#/ft. | 9280' | 9280' | $42.50/ft. | $42.50/ft. | 394,400 | 394,400 |
| Wire Rope | Hoisting, 1¼"Ø, 6 x 19 Round Strand | 4821' | 4821' | $ 8/ft. | $ 8/ft. | 38,568 | 38,568 |
| Drum Hoist | Single Drum w/300 HP DC Drive for Hoist Men and Material | 1 ea. | 1 ea. | $780,000 | $780,000 | 780,000 | 780,000 |
| Sheave | 75" Dia. | 1 ea. | 1 ea. | $25,000 | $25,000 | 25,000 | 25,000 |
| Hoist House | Prefab. Bldg. W/Roof, siding, HVAC, and Int. Fin. 50'W. x 80'L. x 25'H. | 4000 $ft^2$ | 4000 $ft^2$ | $ 36/$ft^2$ | $ 36/$ft^2$ | 144,000 | 144,000 |
| Hoist Foundation | Conc., 30' x 25' x 6' | 166.5 $yd^3$ | 166.5 $yd^3$ | $200/$yd^3$ | $200/$yd^3$ | 33,300 | 33,300 |
| TOTAL PERMANENT EQUIPMENT | | | | | | 2,465,444 | 2,126,252 |
| TOTAL CAPITAL COST | | | | | | $ 8,008,044 | $ 7,668,852 |

* Ramp costs from Fig. 3.2. Unit costs shown were calculated for comparitive purposes only.

TABLE 3.14
OPERATING COST ESTIMATE
CASES A-1 AND A-2
WASTE HANDLING
SHAFT AND DRIFT ACCESS

| ITEM | DESCRIPTION | UNIT | UNIT COST | AMOUNT/DAY |
|---|---|---|---|---|
| Hoist Operations | | | | |
| | Labor | 32 hr. | $ 22.50/hr | 720.00 |
| | Supplies | 1 lot | $ 213.00 | 213.00 |
| | Equipment Operation | 1 lot | $ 84.00 | 84.00 |
| TOTAL HOIST OPERATIONS | | | | 1017.00 |
| Inspection/Maintenance | | | | |
| | Labor | 14.4 hr. | $ 22.36/hr | 322.00 |
| TOTAL OPERATING COST | | | | $ 1339.00 |

TABLE 3.15
OPERATING COST ESTIMATE
CASES A-3 AND A-4
WASTE HANDLING
10% GRADE RAMP

| ITEM | DESCRIPTION | UNIT | UNIT COST | AMOUNT/DAY |
|---|---|---|---|---|
| Inspection/Maintenance | | | | |
| | Labor | 8 hr. | $ 21.00/hr. | 168.00 |
| Operations | | | | |
| | Labor | 16 hr. | $ 21.00/hr. | 366.00 |
| TOTAL OPERATING COST | | | | $ 504.00 |

TABLE 3.16
OPERATING COST ESTIMATE
CASES B-1, B-3 and B-5 (VERTICAL EMPLACEMENT)
SHAFT
10,000 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT B-1 | UNIT B-3 | UNIT B-5 | UNIT COST B-1 | UNIT COST B-3 | UNIT COST B-5 | AMOUNT/DAY B-1 | AMOUNT/DAY B-3 | AMOUNT/DAY B-5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Travel Time | | | | | | | | | | |
| | Labor | 156.28 hr | 165.28 hr | 117.57 hr | $21.00/hr | $21.00/hr | $21.00/hr | 3,282.00 | 3,471.00 | 2,469.00 |
| Man Vehicle | | | | | | | | | | |
| | Labor | 2.82 hr | 3.05 hr | 1.85 hr | $21.00/hr | $21.00/hr | $21.00/hr | 59.00 | 64.00 | 39.00 |
| | Equipment Operations | 2.82 hr | 3.05 hr | 1.85 hr | $30.00/hr | $30.00/hr | $30.00/hr | 85.00 | 92.00 | 56.00 |
| TOTAL MAN VEHICLE | | | | | | | | 144.00 | 156.00 | 95.00 |
| Supply Transport | | | | | | | | | | |
| | Labor | 24 hr | 24 hr | 24 hr | $21.00/hr | $21.00/hr | $21.00/hr | 504.00 | 504.00 | 504.00 |
| | Equipment Operations | 24 hr | 24 hr | 24 hr | $30.00/hr | 30.00/hr | $30.00/hr | 720.00 | 720.00 | 720.00 |
| TOTAL SUPPLY TRANSPORT | | | | | | | | 1,224.00 | 1,224.00 | 1,224.00 |
| Inspection/Maintenance | | | | | | | | | | |
| | Labor | 11.20 hr | 11.20 hr | 11.20 hr | $21.85/hr | $21.85/hr | $21.85/hr | 245.00 | 245.00 | 245.00 |
| Belt Conveyor Operations | | | | | | | | | | |
| | Labor | 13.33 hr | 14.08 hr | 10.37 hr | $24.00/hr | $24.00/hr | $24.00/hr | 320.00 | 338.00 | 249.00 |
| | Supplies | 1 lot | 1 lot | 1 lot | $249 | $267 | $182 | 249.00 | 267.00 | 182.00 |
| | Equipment Operations | 1 lot | 1 lot | 1 lot | $18 | $19 | $14 | 18.00 | 19.00 | 14.00 |
| TOTAL BELT CONVEYOR OPERATIONS | | | | | | | | 587.00 | 624.00 | 445.00 |
| Hoist Operations | | | | | | | | | | |
| | Labor | 120 hr | 120 hr | 120 hr | $24.00/hr | $24.00/hr | $24.00/hr | 2,880.00 | 2,880.00 | 2,880.00 |
| | Supplies | 1 lot | 1 lot | 1 lot | $2136 | $2136 | $2136 | 2,136.00 | 2,136.00 | 2,136.00 |
| | Equipment Operations | 1 lot | 1 lot | 1 lot | $356 | $356 | $356 | 356.00 | 356.00 | 356.00 |
| TOTAL HOIST OPERATIONS | | | | | | | | 5,372.00 | 5,372.00 | 5,372.00 |
| TOTAL OPERATING COST | | | | | | | | $10,854.00 | $11,092.00 | $9,850.00 |

TABLE 3.17

OPERATING COST ESTIMATE
CASES B-2, B-4 AND B-6 (HORIZONTAL EMPLACEMENT)
SHAFT AND HOIST
1500 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT B-2 | UNIT B-4 | UNIT B-6 | UNIT COST B-2 | UNIT COST B-4 | UNIT COST B-6 | AMOUNT/DAY B-2 | AMOUNT/DAY B-4 | AMOUNT/DAY B-6 |
|---|---|---|---|---|---|---|---|---|---|---|
| Travel Time | | | | | | | | | | |
| | Labor | 64.23 hr | 67.95 hr | 48.33 hr | $21.00/hr | $21.00/hr | $21.00/hr | 1,349.00 | 1,427.00 | 1,015.00 |
| Man Vehicle | | | | | | | | | | |
| | Labor | 1.16 hr | 1.25 hr | .76 hr | $21.00/hr | $21.00/hr | $21.00/hr | 24.00 | 26.00 | 16.00 |
| | Equipment Operations | 1.16 hr | 1.25 hr | .76 hr | $30.00/hr | $30.00/hr | $30.00/hr | 35.00 | 38.00 | 23.00 |
| TOTAL MAN VEHICLE | | | | | | | | 59.00 | 64.00 | 39.00 |
| Supply Transport | | | | | | | | | | |
| | Labor | 24 hr | 24 hr | 24 hr | $21.00/hr | $21.00/hr | $21.00/hr | 504.00 | 504.00 | 504.00 |
| | Equipment Operations | 24 hr | 24 hr | 24 hr | $30.00/hr | $30.00/hr | $30.00/hr | 720.00 | 720.00 | 720.00 |
| TOTAL SUPPLY TRANSPORT | | | | | | | | 1,224.00 | 1,224.00 | 1,224.00 |
| Maintenance/Inspection | | | | | | | | | | |
| | Labor | 11.20 hr | 11.20 hr | 11.20 hr | $21.85/hr | $21.85/hr | $21.85/hr | 245.00 | 245.00 | 245.00 |
| Belt Conveyor Operations | | | | | | | | | | |
| | Labor | 3.12 hr | 3.70 hr | 2.58 hr | $24.00/hr | $24.00/hr | $24.00/hr | 75.00 | 89.00 | 62.00 |
| | Supplies | 1 lot | 1 lot | 1 lot | $50 | $51 | $33 | 50.00 | 51.00 | 33.00 |
| | Equipment Operations | 1 lot | 1 lot | 1 lot | $4 | $5 | $4 | 4.00 | 5.00 | 4.00 |
| TOTAL BELT CONVEYOR OPERATIONS | | | | | | | | 129.00 | 145.00 | 99.00 |
| Hoist Operations | | | | | | | | | | |
| | Labor | 120 hr | 120 hr | 120 hr | $24.00/hr | $24.00/hr | $24.00/hr | 2,880.00 | 2,880.00 | 2,880.00 |
| | Supplies | 1 lot | 1 lot | 1 lot | $623 | $623 | $623 | 623.00 | 623.00 | 623.00 |
| | Equipment Operations | 1 lot | 1 lot | 1 lot | $142 | $142 | $142 | 142.00 | 142.00 | 142.00 |
| TOTAL HOIST OPERATIONS | | | | | | | | 3,645.00 | 3,645.00 | 3,645.00 |
| TOTAL OPERATING COST | | | | | | | | $6,651.00 | $6,750.00 | $6,267.00 |

TABLE 3.18
OPERATING COST ESTIMATE
CASE B-7 (VERTICAL EMPLACEMENT SHAFT)
10,000 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT | UNIT COST | AMOUNT/DAY |
|---|---|---|---|---|
| Travel Time | | | | |
| | Labor | 43.47 hr | $ 21.00/hr. | 913.00 |
| Supply Transport | | | | |
| | Labor | 12 hr. | $ 21.00/hr. | 252.00 |
| | Equipment Operations | 12 hr. | $ 30.00/hr. | 360.00 |
| TOTAL SUPPLY TRANSPORT | | | | 612.00 |
| Inspection/Maintenance | | | | |
| | Labor | 3.20 hr | $ 24.00/hr. | 77.00 |
| Hoist Operations | | | | |
| | Labor | 120 hr | $ 24.00/hr. | 2,880.00 |
| | Supplies | 1 lot | $ 2,136 | 2,136.00 |
| | Equipment Operations | 1 lot | $ 356 | 356.00 |
| TOTAL HOIST OPERATIONS | | | | 5372.00 |
| TOTAL OPERATING COST | | | | $ 6974.00 |

TABLE 3.19
OPERATING COST ESTIMATE
CASE B-8 (HORIZONTAL EMPLACEMENT)
SHAFT AND HOIST
1500 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT | UNIT COST | AMOUNT/DAY |
|---|---|---|---|---|
| Travel Time | | | | |
| | Labor | 17.85 | $21.00/hr. | 375.00 |
| Supply Transport | | | | |
| | Labor | 12 hr. | $ 21.00/hr. | 252.00 |
| | Equipment Operations | 12 hr. | $ 30.00/hr. | 360.00 |
| TOTAL SUPPLY TRANSPORT | | | | 612.00 |
| Inspection/Maintenance | | | | |
| | Labor | 3.20 hr. | $ 24.00/hr. | 77.00 |
| Hoist Operations | | | | |
| | Labor | 120 hr. | $ 24.00/hr. | 2,880.00 |
| | Supplies | 1 lot | $ 623.00 | 623.00 |
| | Equipment Operations | 1 lot | $ 142.00 | 142.00 |
| TOTAL HOIST OPERATIONS | | | | 3,645.00 |
| TOTAL OPERATING COST | | | | $4,709.00 |

TABLE 3.20
OPERATING COST ESTIMATE
CASES B-9 AND B-10 (VERTICAL & HORIZONTAL EMPLACEMENT)
10% RAMP
10,000 & 1500 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT B-9 | UNIT B-10 | UNIT COST B-9 | UNIT COST B-10 | AMOUNT/DAY B-9 | AMOUNT/DAY B-10 |
|---|---|---|---|---|---|---|---|
| Travel Time | | | | | | | |
| | Labor | 365.55 hr | 150.23 hr | $21.00/hr | $21.00/hr | 7677.00 | 3155.00 |
| Man Vehicle | | | | | | | |
| | Labor | 9.14 hr | 3.76 hr | $21.00/hr | $21.00/hr | 192.00 | 79.00 |
| | Equipment Operations | 9.14 hr | 3.76 hr | $30.00/hr | $30.00/hr | 274.00 | 113.00 |
| TOTAL MAN VEHICLE | | | | | | 466.00 | 192.00 |
| Supply Transport | | | | | | | |
| | Labor | 48 hr | 24 hr | $21.00/hr | $21.00/hr | 1,008.00 | 504.00 |
| | Equipment Operations | 48 hr | 24 hr | $30.00/hr | $30.00/hr | 1,440.00 | 720.00 |
| TOTAL SUPPLY TRANSPORT | | | | | | 2,448.00 | 1,224.00 |
| Inspection/Maintenance | | | | | | | |
| | Labor | 8 hr | 8 hr | $21.00/hr | $21.00/hr | 168.00 | 168.00 |
| Belt Conveyor Operations | | | | | | | |
| | Labor | 20.66 hr | 5.45 hr | $24.00/hr | $24.00/hr | 496.00 | 131.00 |
| | Supplies | 1 lot | 1 lot | $839 | $167 | 839.00 | 167.00 |
| | Equipment Operaions | 1 lot | 1 lot | $29 | $8 | 29.00 | 8.00 |
| TOTAL BELT CONVEYOR OPERATIONS | | | | | | 1,364.00 | 306.00 |
| TOTAL OPERATING COST | | | | | | $ 12,123.00 | $ 5,045.00 |

TABLE 3.21
OPERATING COST ESTIMATE
CASES B-11 AND B-12 (VERTICAL & HORIZONTAL EMPLACEMENT)
10% RAMP
10,000 & 1500 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT B-11 | UNIT B-12 | UNIT COST B-11 | UNIT COST B-12 | AMOUNT/DAY B-11 | AMOUNT/DAY B-12 |
|---|---|---|---|---|---|---|---|
| Travel Time | | | | | | | |
| | Labor | 365.55 hr | 150.23 hr | $21.00/hr | $21.00/hr | 7677.00 | 3155.00 |
| Man Vehicle | | | | | | | |
| | Labor | 9.14 hr | 3.76 hr | $21.00/hr | $21.00/hr | 192.00 | 79.00 |
| | Equipment Operations | 9.14 hr | 3.76 hr | $30.00/hr | $30.00/hr | 274.00 | 113.00 |
| TOTAL MAN VEHICLE | | | | | | 466.00 | 192.00 |
| Supply Transport | | | | | | | |
| | Labor | 48 hr | 24 hr | $21.00/hr | $21.00/hr | 1,008.00 | 504.00 |
| | Equipment Operations | 48 hr | 24 hr | $30.00/hr | $30.00/hr | 1,440.00 | 720.00 |
| TOTAL SUPPLY TRANSPORT | | | | | | 2,448.00 | 1,224.00 |
| Inspection/Maintenance | | | | | | | |
| | Labor | 8 hr | 8 hr | $21.00/hr | $21.00/hr | 168.00 | 168.00 |
| Belt Conveyor Operations | | | | | | | |
| | Labor | 20.66 hr | 5.45 hr | $24.00/hr | $24.00/hr | 496.00 | 131.00 |
| | Supplies | 1 lot | 1 lot | $839 | $167 | 839.00 | 167.00 |
| | Equipment Operaions | 1 lot | 1 lot | $29 | $8 | 29.00 | 8.00 |
| TOTAL BELT CONVEYOR OPERATIONS | | | | | | 1,364.00 | 306.00 |
| TOTAL OPERATING COST | | | | | | $ 12,123.00 | $ 5,045.00 |

TABLE 3.22
OPERATING COST ESTIMATE
CASES B-13 AND B-14 (VERTICAL AND HORIZONTAL EMPLACEMENT)
20% RAMP
10,000 AND 1500 TPD MUCK HANDLING

| ITEM | DESCRIPTION | UNIT B-13 | UNIT B-14 | UNIT COST B-13 | UNIT COST B-14 | AMOUNT B-13 | AMOUNT B-14 |
|---|---|---|---|---|---|---|---|
| Travel Time | | | | | | | |
| | Labor | 123.57 hr | 50.80 hr | $ 21.00/hr | $ 21.00/hr | 2,595.00 | 1,067.00 |
| Hoisting Operation | | | | | | | |
| | Labor | 48 hr | 48 hr | $ 22.50/hr | $ 22.50/hr | 1,080.00 | 1,080.00 |
| | Supplies | 1 lot | 1 lot | $1068 | $312 | 1,068.00 | 312.00 |
| | Equipment Operations | 1 lot | 1 lot | $ 178 | $ 71 | 178.00 | 71.00 |
| TOTAL HOISTING OPERATIONS | | | | | | 2,326.00 | 1,463.00 |
| Inspection/Maintenance | | | | | | | |
| | Labor | 8 hr | 8 hr | $ 21.00/hr | $21.00/hr | 168.00 | 168.00 |
| Belt Conveyor Operations | | | | | | | |
| | Labor | 19.95 hr | 4.95 hr | $ 24.00/hr | $ 24.00/hr | 479.00 | 119.00 |
| | Supplies | 1 lot | 1 lot | $ 954 | $ 173 | 954.00 | 173.00 |
| | Equipment Operations | 1 lot | 1 lot | $ 28 | $ 8 | 28.00 | 8.00 |
| TOTAL BELT CONVEYOR OPERATIONS | | | | | | 1,461.00 | 300.00 |
| TOTAL OPERATING COST | | | | | | $ 6,550.00 | $ 2,998.00 |

TABLE 3.23

SUMMARY OF CONSTRUCTION TIME FOR EACH ACCESS METHOD

SCHEDULE - WEEKS

| Waste Handling Access | Shaft | Drift | Total | Ramp |
|---|---|---|---|---|
| Case A1 | 43 | 88 | 131 | - |
| Case A2 | 43 | 96 | 139 | - |
| Case A3 | - | - | - | 114 |
| Case A4 | - | - | - | 114 |
| **Mining Operations Access** | | | | |
| Case B1 | 40 | 88 | 128 | - |
| Case B2 | 49 | 88 | 137 | - |
| Case B3 | 40 | 96 | 136 | - |
| Case B4 | 49 | 96 | 145 | - |
| Case B5 | 53 | 59 | 112 | - |
| Case B6 | 44 | 59 | 103 | - |
| Case B7 | 58 | - | 58 | - |
| Case B8 | 49 | - | 49 | - |
| Case B9 | - | - | - | 114 |
| Case B10 | - | - | - | 114 |
| Case B11 | - | - | - | 114 |
| Case B12 | - | - | - | 114 |
| Case B13 | - | - | - | 72 |
| Case B14 | - | - | - | 72 |

# 4.0 EVALUATION OF SELECTION FACTORS FOR WASTE EMPLACEMENT ACCESS

The selection of a ramp access over a shaft-and-drift access is based on the evaluation of seven factors.

- Radiological Safety
- Industrial Safety
- Worker Radiation Exposure
- Repository Sealing
- Capital and Operating Costs
- Operational Analysis
- Waste Emplacement Equipment Requirements

The subjective safety and sealing evaluations were based on the experience of Sandia National Laboratories staff. The worker radiation exposure evaluation is based on the results of a joint study by Sandia National Laboratories and Los Alamos Technical Associates (Reference 3). The repository capital and operating costs associated with underground access have been presented in Sections 2 and 3 of this report. The operating procedures associated with underground access are discussed in Reference 4. The operational analysis and equipment requirements are evaluated based on the time estimates developed in the worker exposure study (Reference 3), the waste emplacement procedures (Reference 4), and the expected waste emplacement rate (Reference 5).

## 4.1 Radiological Safety

Radiological safety evaluation is concerned with any accident which might result in the release of radioactive materials. The following accident scenarios are assumed to be the maximum credible accident for each access method under consideration.

- Ramp Access--The waste package will be transported to the underground repository area on a rubber-tired, self-powered transporter (Reference 6). The maximum accident is a transporter brake failure, followed by impact into another vehicle and/or the ramp wall, and a diesel fuel fire (Reference 7).

- Shaft-and-Drift Access--The waste will be transported by hoist cage from the surface to the underground station. The maximum credible accident is a cable failure which results in a cage drop with impact at the bottom of the shaft (Reference 8). A more likely, but less severe accident would be failure of the hoist drum brake, resulting in a runaway cage. The hoist will be counterweighted; thus, whenever a cask is being transported, the hoist system will be in an approximately balanced condition and the maximum hoist cage velocity will be limited by the hoisting system.

Of the two considered accidents, transporter brake failure is considered the more likely because the cage will be supported by eight independent steel hoisting ropes, with a combined dynamic safety factor of 4 (Table 2.3). However, the maximum free-fall impact velocity for the cage drop is substantially higher than

the maximum impact velocity expected in the case of a transport vehicle brake failure accident. In the case of a cage drop, the cage is guided during free-fall (870 ft), whereas, in the case of vehicle brake failure, loss-of-control and impact into a vehicle or the wall is expected at relatively low speeds.

Based on full-scale cask impact tests and scale-model cask drop tests conducted by Sandia National Laboratories (Reference 9), there is a very low probability for radioactive material release in either of these accidents. However, the transport vehicle brake failure accident is judged the least likely to adversely affect radiological safety.

## 4.2 Industrial Safety

Industrial safety is concerned with any accident not involving radioactive materials which could result in a worker injury or fatality. The maximum credible industrial accident for ramp access, transport vehicle brake failure, is the same as discussed in Section 4.1. In this case, the possibility of injury to the waste transporter driver and any passengers is the item of concern. The maximum credible accident associated with shaft-and-drift access is a handling accident during the loading/unloading of the waste transfer cask from the hoist cage, and during the loading/unloading of the transfer cask from the cask transporter (Reference 4).

The weight of the waste transfer cask (approximately 60,000 lb) is such that any handling accident could result in serious injuries. Likewise, a brake failure and runaway vehicle accident on a ramp could also result in serious injuries.

The probability of occurrence for either of these accidents is highly dependent upon the equipment used and the probability of equipment failure. Because the equipment and method of equipment operation can be selected and controlled during repository design and operations, industrial safety can be controlled and made equal for these access methods.

## 4.3 Worker Radiation Exposure

The operational procedures for surface-to-underground waste transfer are presented in Reference 4. These procedures and radiation dose maps for waste transfer casks were used to calculate the worker exposure for surface-to-underground transfer of spent fuel and high-level waste (Reference 3). The results of these calculations are summarized in Table 4.1.

Table 4.1

Worker Radiation Exposure

| Access Method | Total Number of Radiation Workers Involved | Total Exposure Man Rem/Yr |
|---|---|---|
| Ramp | 6 | 2.7 |
| Shaft-and-Drift | 8 | 3.3 |

The ramp access results in the lowest total exposure of workers to penetrating radiation and is therefore the preferred option.

## 4.4 Repository Sealing

The need for, and extent of, repository sealing is currently being determined (Reference 10). Sealing requirements have not been finalized, but it now appears that either a ramp or a shaft-and-drift access could be sealed in an equally acceptable manner. Therefore, from a repository sealing aspect, either access method is acceptable. If any significant advantages (repository sealing advantages) are identified which favor either method, this factor will be reevaluated.

## 4.5 Capital and Operating Costs

The capital and operating cost estimates do not include such items as the cost of facility casks, transporters, and special cask handling equipment. The costs discussed are limited to mining costs and costs associated with the operation and maintenance of the ramps, drifts, and hoists. Equipment requirements are discussed in Section 4.7, and the relative capital and operating costs of these equipment items are assumed to be directly proportional to the number of pieces of equipment required.

Two surface sites for waste receiving facilities were considered in this study. Each meets the general site criteria discussed in Section 2. These sites, their corresponding repository horizon access points, the conceptual design layout for ramp access, and the conceptual design layout for shaft-and-drift access are shown in Figures 2.1, 2.2, 2.5, and 2.6 of Section 2. The estimated capital and daily operating costs for each of these design options are presented in detail in Tables 3.1, 3.2, 3.14, and 3.15 of Section 3 and are summarized in Table 4.2.

Table 4.2

Cost Summary for Repository Waste Handling Access Options

| Site | Access | Capital Cost | Daily Operating Cost |
|---|---|---|---|
| 1 | 10% Ramp | $ 8,674,000 | $ 500 |
| 1 | Shaft-and-Drift | 13,561,000 | 1,340 |
| 2 | 10% Ramp | 8,674,000 | 500 |
| 2 | Shaft-and-Drift | 14,317,000 | 1,340 |

The capital and operating costs for ramp access are lower than those for shaft-and-drift access for both Sites 1 and 2; therefore, the ramp access is desirable from a cost standpoint.

## 4.6 Operational Analysis

The operational analysis is concerned with the operational time required to transfer the waste packages from the surface waste handling facilities to the repository underground entry point. The locations assumed for the surface facilities and underground entry point are identified in Section 2, Figures 2.1 and 2.2. The time required to perform each of the operational steps in the surface-to-underground waste transfer operation was estimated as part of the repository worker radiation exposure study (Reference 3). A summary of these operations times is presented in Table 4.3. An operational time of 245 min will be required to transfer a waste package using a shaft-and-drift access, and 140 min of operational time will be required to transfer a package using a ramp access.

Table 4.3
Operational Analysis of Time Required
for Surface-to-Underground Transfer
of Canistered Waste

SHAFT ACCESS FROM SURFACE STORAGE
TO EMPLACEMENT HORIZON

| Operation--Shaft-and-Drift Access | Operations Time (min) Ind. | Cum. |
|---|---|---|
| 1.0 WASTE PACKAGE LOADING: | | |
| 1.1 Move facility cask on transfer cart to transfer station | 20 | |
| 1.2 Align facility cask and attach to port | 10 | |
| 1.3 Remove port cover | 10 | |
| 1.4 Remove facility cask lid | 10 | |
| 1.5 Load waste package | 20 | |
| 1.6 Replace facility cask lid | 10 | |
| 1.7 Replace port cover | 10 | |
| 1.8 Detach cask from port | 10 | |
| 1.9 Release facility cask | 10 | |
| 1.10 Move facility cask on transfer cart to shaft | 10 | |
| | 120 | 120 |
| 2.0 FACILITY CASK SHAFT ACCESS: | | |
| 2.1 Hoist at surface | P* | |
| 2.2 Engage "chair" system | 10 | |
| 2.3 Load facility cask on hoist | 20 | |
| 2.4 Disengage "chair" system | 5 | |
| 2.5 Lower to emplacement horizon | 5 | |
| 2.6 Engage "chair" system | 5 | |
| 2.7 Unload facility cask from hoist | 20 | |
| 2.8 Move facility cask on transfer cart to transfer station | 10 | |
| 2.9 Remove facility cask from transfer cart, load empty facility cask on transfer cart, and return cart to hoist and surface | P | |
| | 75 | 195 |
| 3.0 TRANSPORTER AT EMPLACEMENT HORIZON: | | |
| 3.1 Move transporter to transfer station | 10 | |
| 3.2 Load facility cask on transporter | 20 | |
| 3.3 Move facility cask to emplacement horizon access point | 20 | |
| | 50 | 245 |

* P = Parallel operation

Table 4.3 (Continued)

RAMP ACCESS FROM SURFACE STORAGE
TO EMPLACEMENT HORIZON

| Operation Description--Ramp Access | Operations Time (min) Ind. | Cum. |
|---|---|---|
| 4.0 WASTE PACKAGE LOADING: | | |
| 4.1 Move transporter with facility cask to transfer station | 20 | |
| 4.2 Align facility cask and attach to port | 10 | |
| 4.3 Remove port cover | 10 | |
| 4.4 Remove facility cask lid | 10 | |
| 4.5 Load waste package | 20 | |
| 4.6 Replace facility cask lid | 10 | |
| 4.7 Replace port cover | 10 | |
| 4.8 Detach transporter facility cask from port | 10 | |
| 4.9 Release transporter | 10 | |
| 4.10 Proceed to ramp | 10 | |
| | 120 | 120 |
| 5.0 TRANSPORTER RAMP ACCESS: | | |
| 5.1 Move facility cask down ramp to emplacement horizon access point | 20 | |
| | 20 | 140 |

An operational analysis of the information contained in Table 4.3 reveals that the transfer of the waste package from the surface surge storage facility to the facility transfer cask requires 90 min of operational time for both shaft-and-drift access (operations 1.2 through 1.9) and ramp access (operations 4.2 through 4.9). A single surface-to-underground transfer operation requires 75 min of hoist operational time for shaft access (operations 2.1 through 2.9) and 40 min of ramp operational time (operation 5.1 and similar transporter return time not identified in Table 4.3). Thus, if a single waste transfer station is used, the maximum delivery rate of waste package to the underground access point is one every 90 min for both access options. This 90-min time is governed by the time required to load the waste package into the facility cask. However, if two waste transfer stations are used, the delivery rate to the underground access point is dependent on the access method. For shaft-and-drift access, the delivery rate is controlled by the hoist cycle time of 75 min. For ramp access, the delivery rate is controlled by the facility cask loading time and the number of loading operations that can be conducted in parallel. Ramp access, therefore, has a maximum delivery rate of one waste package every 45 min to the underground access point if two waste transfer stations are used.

The minimum operational time required to deliver a given number of waste packages to the underground access point using parallel operations can be computed as follows:.

Let:

N = the total number of waste packages to be transferred,

C = the transfer time for a single package, and

A = the minimum incremental transfer time for each additional package.

Then the minimum operational time (t) required for the transfer of N waste packages from surface surge storage to the underground access point can be determined from the relationship

$$t = A(N-1) + C.$$

If two waste transfer stations are used, the constants in the above equation become:

Shaft-and-Drift Access

C = 245 minutes

A = 75 minutes,

Ramp Access

C = 140 minutes

A = 45 minutes.

The quantity of canistered waste--spent fuel, commercial high-level waste (CHLW) defense high-level waste (DHLW), transuranic (TRU) waste, and spent fuel hardware--which is expected to be transferred from the surface facilities to the underground area is listed in Table 4.4. Using this information and assuming that (1) two waste transfer stations are used and (2) that the repository operates 1500 hours per year (6 hours of operational time per shift, 5 days/week, and 50 weeks/year); approximately 11 waste packages must be transferred per operational day if the Table 4.4 lower-bound estimate is used, and 17 packages must be transferred per day if the Table 4.4 upper-bound estimate is used. The required operational time in hours and the number of shifts required per operational day are listed in Table 4.5.

Table 4.4

Annual Emplacement Rate for Canistered Waste*

| Type of Waste Canister | Predicted Annual Emplacement Rate (Canisters/Year) Lower-Bound | Upper-Bound |
|---|---|---|
| PWR Spent Fuel Canisters | 336 | 672 |
| BWR Spent Fuel Canisters | 173 | 346 |
| CHLW Canisters | 660 | 660 |
| DHLW Type Canisters | | |
| (a) DHLW | 500 | 500 |
| (b) Cladding Waste | 484 | 484 |
| (c) TRU Waste | 460 | 1380 |
| (d) Spent Fuel Hardware | 83 | - |
| TOTAL CANISTERS | 2696 | 4042 |

*Based on Table 1 of Reference 5.

Table 4.5

Required Daily Operations Times

| Access Method | Required Operations Times Lower-Bound Hours/Shifts | Upper-Bound Hours/Shifts |
|---|---|---|
| Ramp Access | 9.8/2 | 14.3/3 |
| Shaft-and-Drift Access | 16.6/3 | 24.1/4+ |

The ramp access is preferred because it requires the minimum operations times for both upper- and lower-bound waste emplacement estimates.

## 4.7 Waste Emplacement Equipment Requirements

The number of facility casks needed to transfer waste canisters from the surface surge storage area to the underground repository will be used as a measure of the equipment requirements for the each access method. A minimum of four different casks are needed to accommodate the spent fuel and high-level wastes. The requirement for the different casks is based on radiation shielding requirements and different waste canister outside diameters (Reference 5). The waste canister outside diameters (O.D.) are:

PWR spent fuel canister--50 cm O.D.

BWR spent fuel canister--57 cm O.D.

CHLW canister--32 cm O.D.

DHLW and other
waste in canisters--61 cm O. D.

The total operational time required to complete one waste emplacement cycle--that is, the time required to load the waste canister into the transfer cask, move the cask to the waste emplacement location, emplace the waste, and return the cask to the waste loading station--was determined based on the operations time estimates in Reference 3. These cycle times are shown in Table 4.6 Vertical waste emplacement is the reference waste emplacement method (Reference 11) and will be utilized in estimating equipment requirements for both access methods.

Table 4.6

Cycle Times for Transfer Casks

| Access Method | Cycle Time: Horizontal Waste Emplacement | Cycle Time: Vertical Waste Emplacement |
|---|---|---|
| Ramp | 270 min | 300 min |
| Shaft-and-Drift | 415 min | 445 min |

The maximum number of emplacement cycles per transfer cask per year (C) can be estimated using the expression:

$$C = \frac{\text{(operation time/shift) (shifts/operating day) (operating days/year)}}{\text{(cycle time for casks)}}$$

The operating time/shift is 360 min (6 hr). The number of shifts/day is two for the lower-bound emplacement rate and three for the upper-bound emplacement rate. The number of operating days per year is 250. The cycle times for casks are 300 min for ramp access and 445 min for shaft-and-drift access. The maximum number of emplacement cycles available per cask per year is stated in Table 4.7.

Table 4.7

Maximum Emplacement Cycles/Cask/Year

| Access Method | Lower-Bound Emplacement Rate | Upper-Bound Emplacement Rate |
|---|---|---|
| Ramp | 600 | 900 |
| Shaft-and-Drift | 404 | 606 |

The minimum number of transfer casks required for both the upper-bound and lower-bound rates for each type of waste can be calculated by dividing the annual emplacement rate for each type of waste canister, Table 4.4, by the corresponding maximum number of emplacement cycles per cask per year, Table 4.7, and rounding to the next highest integer. The minimum number of transfer casks required for each of the different waste canisters are shown in Table 4.8.

Table 4.8

Minimum Number of Transfer Casks Required

| Type of Waste Canister | Lower-Bound | | Upper-Bound | |
|---|---|---|---|---|
| | Ramp | Shaft-and-Drift | Ramp | Shaft-and-Drift |
| PWR Spent Fuel | 1 | 1 | 1 | 2 |
| BWR Spent Fuel | 1 | 1 | 1 | 1 |
| CHLW | 2 | 2 | 1 | 2 |
| DHLW and Other Waste in Canisters | 3 | 4 | 3 | 4 |
| Total Casks | 7 | 8 | 6 | 9 |

The ramp access requires fewer casks than the shaft-and-drift access, and it is considered the preferred option.

## 5.0 EVALUATION OF MINING ACCESS SELECTION FACTORS

Three selection factors were considered in evaluating the seven mining access options--ramp access and shaft-and-drift access from three surface sites and direct-shaft access from one surface site. Each of these seven access options was evaluated for waste emplaced in vertical boreholes in the emplacement drift floor and for waste emplaced in long horizontal boreholes in the emplacement drift walls (Reference 11). In all, 14 cases were considered. The selection criteria used to evaluate the mining access options are:

- Industrial Safety
- Repository Sealing
- Capital and Operating Costs

The mining access studies were prepared by Dravo Engineerings, Inc., and are presented in detail in Sections 2 and 3. The shaft-and-drift access method was eliminated from consideration because its cost was higher than ramp access cost for all cases considered. A clear choice between ramp access and direct-shaft access could not be made with the available information. The incremental facility costs associated with establishing separate sites for waste receiving and mining activities were not determined as part of this study. Without these site-associated costs, the most economical mining access method could not be identified.

## 5.1 Industrial Safety

All access methods were determined to be acceptable insofar as industrial safety is concerned. Ramp access, shaft-and-drift access, and direct-shaft access are all employed by the mining industry to provide underground access for personnel, supplies, equipment, and muck-handling systems. All access methods were, therefore, judged equally acceptable from an industrial safety standpoint.

## 5.2 Repository Sealing

The repository sealing needs associated with mining operations access are the same as those associated with waste emplacement access (Section 4.4). As with waste emplacement access, all mining access options are considered equally acceptable at this time.

## 5.3 Capital and Operating Costs

Four surface sites were considered for mining operations. The locations of the mining operation sites, the conceptual design of shafts-and-drifts with 1500 ton-per-day (horizontal waste emplacement) and 10,000 ton-per-day (vertical waste emplacement) capacities, and the conceptual design of ramps with grades of 10% and 20% are shown in Figures 2.7 through 2.19 in Section 2. Both shaft-and-drift access and ramp access were considered from Sites 1, 2, and 3. Because Site 4 is located directly above the repository access point, shaft-only access was considered from Site 4. In all cases, separate estimates were prepared for the men, material, and muck-handling requirements for the vertical and the horizontal waste emplacement configurations.

The shaft used for the horizontal waste emplacement option is 20 ft in diameter and has a 1500 ton-per-day muck-handling capacity. The shaft used for the vertical waste emplacement option is 25 ft in diameter and has a 10,000 ton-per-day muck-handling capacity. The muck conveyors in the ramps will be either 24 or 36 in. wide and will have capacities of 1500 or 10,000 tons per day, respectively.

In the discussion that follows, Sites 1, 2, and 3 are evaluated first; Site 4 is then considered. The estimated capital and operating costs for these mining access options were obtained from Tables 3.3 through 3.13 and 3.16 through 3.22 in Section 3. A summary of the estimated capital and daily operating costs for mining access operations from Sites 1, 2, and 3 is presented in Table 5.1.

Table 5.1

Cost Summary for Repository Mining Access Options

| Site | Access | Emplacement | Capital Cost | Daily Operating Cost |
|---|---|---|---|---|
| 1 | 10% Ramp | Vertical | $ 10,280,000 | $ 12,120 |
| 1 | Shaft-and-Drift | Vertical | 17,314,000 | 10,850 |
| 1 | 10% Ramp | Horizontal | 9,745,000 | 5,050 |
| 1 | Shaft-and-Drift | Horizontal | 14,941,000 | 6,650 |
| 2 | 10% Ramp | Vertical | 10,280,000 | 12,120 |
| 2 | Shaft-and-Drift | Vertical | 18,007,000 | 11,090 |
| 2 | 10% Ramp | Horizontal | 9,745,000 | 5,050 |

Table 5.1 (Continued)

Cost Summary for Repository Mining Access Options

| Site | Access | Emplacement | Capital Cost | Daily Operating Cost |
|---|---|---|---|---|
| 2 | Shaft-and-Drift | Horizontal | 15,633,000 | 6,750 |
| 3 | 20% Ramp | Vertical | 8,008,000 | 6,550 |
| 3 | Shaft-and-Drift | Vertical | 14,820,000 | 9,850 |
| 3 | 20% Ramp | Horizontal | 7,669,000 | 3,000 |
| 3 | Shaft-and-Drift | Horizontal | 12,355,000 | 6,270 |

In all the cases above, the capital cost of a ramp is less than a shaft-and-drift. Also, the operating cost is less for the ramp option in all cases except the vertical waste emplacement ramp option from Sites 1 and 2. (The reason for the higher estimated operating cost of the ramp option from Sites 1 and 2 will be discussed later.) The shaft-and-drift options are dropped from further consideration at this time because of their generally higher cost. Also, the capital and operating costs for the ramp option from Sites 1 and 2 are equal and, henceforth, only Site 1 will be discussed. The reader should note that Site 2 is still viable.

A summary of the estimated capital and daily operating costs for ramp access from Sites 1 and 3 is shown in Table 5.2.

Table 5.2

Capital and Operating Cost Summary for Ramp Access
From Sites 1 and 3--Mining Operations

| Site | Emplacement | Capital Cost | Daily Operating Cost |
|---|---|---|---|
| 1 | Vertical | $10,280,000 | $ 12,120 |
| 3 | Vertical | 8,008,000 | 6,550 |
| 1 | Horizontal | 9,745,000 | 5,050 |
| 3 | Horizontal | 7,669,000 | 3,000 |

The first inclination is to favor Site 3 since both capital and operating costs are lower than they are for Site 1. However, mining operation Sites 1 and 2 are co-located with surface waste receiving Sites 1 and 2, while mining operations Site 3 is to the the west of the surface waste receiving sites. The development of a separate site for mining operations carries with it incremental additions of both capital and operating costs. These additional costs, which are not addressed in this study, must be considered prior to making a final selection. Capital costs for a separate mining operations site (Site 3 or Site 4) will increase the total capital costs because of the additional facility requirements; for example:

1. An access road suitable for heavy (80,000 lb GVW) truck traffic. All mine supplies will be hauled by truck.

2. Extension of the commercial and emergency electrical power distribution, including additional substations and switching equipment.

3. Extension of water lines and either an independent sewage treatment facility or a sewage line from the surface waste receiving facilities site.

4. Extension of communication systems.

5. Fuel oil storage facilities or a fuel oil transfer line from the surface waste receiving facilities site.

6. Duplication of service facilities such as the medical aid facilities, the fire protection facilities, and some warehouse facilities.

It should be noted that an unimproved road, electrical power lines, and a water line currently pass through Site 3.

Operating costs will also be increased by utilizing two separate sites for waste handling and mining operations. Additional security, maintenance, and administrative personnel will be required. Additional vehicles will be required for transportation of personnel and supplies between sites. Additional maintenance costs will be incurred on the added highway and the extended utility systems.

The maximum capital cost difference between Sites 1 and 3 is $2,210,000 (vertical emplacement method) and is within the ±30% accuracy bounds on the estimates. The additional capital costs which would be incurred if a separate site were developed for mining operations have not been estimated. However, it is expected

that the total project capital cost will increase slightly if a separate site is developed for mining operations.

The operating cost for mining operations at Site 1 is approximately $5,600 per day higher than for Site 3 if the vertical waste emplacement option is employed and $2,000 per day higher if the horizontal waste emplacement option is employed. A labor cost of $168 per day (direct salary plus 40% for fringe benefits) was used in Section 3 to estimate the labor portion of the operating costs. Using this same cost ($168/day), the above operating cost differential is equivalent to employing 33 additional personnel for the vertical emplacement mode or 12 additional personnel for the horizontal emplacement mode, based on the staffing estimate for a single site (Reference 12). The addition of 10 to 15 employees appears reasonable for two-site operations. Hence, for the horizontal emplacement option, no economic advantage would be gained by developing a separate site for mining activities insofar as operating costs are concerned. However, there does appear to be an economic advantage to developing a separate site if the vertical emplacement option is used.

The operating cost estimate for Site 1 will now be compared with Site 3 to determine if cost reductions can be achieved. The estimated daily operating costs for Site 1 and Site 3, vertical emplacement, are presented in detail in Tables 3.20 and 3.22. These costs are summarized in Table 5.3.

Table 5.3

Daily Operating Costs for Sites 1 and 3 Ramp Access
Vertical Waste Emplacement Option--Mining Operations

| Item | Site 1 | Site 3 |
|---|---|---|
| Personnel Transport Costs | $ 8,140 | $ 2,600 |
| Supply Transport Costs | 2,450 | 2,320 |
| Inspection and Maintenance | 170 | 170 |
| Conveyor Operations | 1,360 | 1,460 |
| | $ 12,120 | $ 6,550 |

The cost of transporting the miners to and from the underground assembly point is the only major difference in operating costs between these sites. There are two components in the calculation of the Site 1 personnel transport cost. The first is the direct labor cost; the miners are paid on a portal-to-portal basis. Hence, the time spent in transit is a direct-operation cost which must be accounted for in the facility operating cost estimate. The second component is the cost of the trucks used to transport the miners and the salary of the truck drivers. In the operational cost estimates for ramp access from Sites 1 and 2, a speed of 5 mph was used to estimate the required travel time. At Site 3, a rail-guided, hoist-controlled vehicle is used to transport the miners. This vehicle was assumed to operate at a speed of 10 mph. The differences in transport speed, transport distance, and transport vehicles make labor transport costs for Site 1 more than three times those for Site 3. The transport operations on the 10% ramp (Site 1) are now being studied to determine if a rail-guided, rubber-tired, self-propelled vehicle with an average speed of

10 mph can be used for men and materials transport. If such a vehicle can be obtained, the operating costs for Site 1 can be reduced by as much as $4,000 per day. If the additional costs for operating separate sites for waste handling operations and mining operations are considered, this reduction in operating costs is sufficient to make the ramp access from Site 1 economically attractive when compared to ramp access from Site 3.

One additional mining access alternative must be considered, direct-shaft access from Site 4. Site 4 is located inside the repository boundary; hence, the shaft yields direct-vertical access to the repository horizon assembly point. The shaft access has the advantage of rapid surface-to-underground transport. One-way-trip time on the 10% ramp at a speed of 10 mph is 8 1/2 min. One-way-trip time using a shaft hoisting system is less than 2 min. However, the access to the repository horizon must be located directly below the surface entry point. If the access point is desired below a location where the surface topography is unsuitable for surface facility construction, the surface mining support facilities must be offset, and the shaft-and-drift system must be used.

The estimated capital and operating costs for Site 4 do not make it more attractive than Site 3. These costs are summarized in Table 5.4.

The capital and operating costs for the vertical waste emplacement option are lower for Site 3 than they are for Site 4. However, for the horizontal waste emplacement option, the capital costs for Site 4 are lower than those for Site 3,

Table 5.4

Capital and Daily Operating Cost Summary
For Sites 3 and 4--Mining Operations

| Access | Site | Emplacement | Capital Cost | Daily Operating Cost |
|---|---|---|---|---|
| Ramp | 3 | Vertical | $ 8,010,000 | $ 6,550 |
| Shaft | 4 | Vertical | 9,720,000 | 6,970 |
| Ramp | 3 | Horizontal | 7,670,000 | 3,000 |
| Shaft | 4 | Horizontal | 7,070,000 | 4,710 |

while the operating costs are lower for Site 3 than they are for Site 4. The lower Site 3 operating costs are sufficient to offset the difference in capital costs between Sites 3 and 4 in less than 2 yr. Therefore, if cost considerations alone are used, Site 3 would be considered preferable to Site 4.

# 6.0 ACCESS RECOMMENDATIONS

The rugged topography of Yucca Mountain overlies most of the potential repository boundaries, essentially forcing the location of surface facilities to more suitable terrain adjacent to the boundaries. Criteria have been developed and a study is underway to evaluate potential sites for surface facilities on the more suitable eastern margins of Yucca Mountain. The alluvial slopes southwest of the repository boundary on Bureau of Land Management land were precluded from consideration as a result of land use agreements with the U.S. Air Force, which controls the Nellis Air Force Range, and on which part of the repository boundary is located (Reference 13).

Both a single site and separate sites for surface waste handling facilities and mine support facilities were considered. The surface waste handling facilities require both rail and highway access, while the mine support facilities require only highway access. Thus, the surface waste handling facilities must be located in an area accessible by rail, maximum 3% grade, while the mine support facilities can be located in areas where the highway grades approach 10% for short distances. The sites considered for surface facilities in this study meet these maximum grade requirements.

The underground repository horizon access method recommendations were made independently for the waste handling operations and the mining operations.

## 6.1 Access for Waste Emplacement Operations

A ramp is recommended for moving waste from the surface to the underground. This ramp will originate at the surface waste handling facilities site and will terminate at the underground repository entry point. The ramp would be driven on a maximum grade of 10% (1 ft vertical drop for every 10 ft of horizontal travel). The recommendation to utilize the ramp access is based on the evaluation of operational considerations discussed in Section 4. The recommendation to use ramp access is equally valid for waste emplacement in vertical or horizontal boreholes (Reference 11). This recommendation is also acceptable for all surface waste handling facility sites currently under consideration.

## 6.2 Access for Mining Operations

The surface facilities for mining operations can be co-located with the waste handling facilities, or they can be placed at a separate location. Three of the sites considered, two with co-located facilities and one with separate sites for surface facilities, were suitable for either a ramp access or a shaft-and-drift access. In all three cases, the ramp access was preferable to the shaft-and-drift because of lower capital and operating costs. A fourth mining facility site, located within the repository boundary, was also considered. Direct shaft access is feasible from this site.

A 10% ramp from the mining facility sites co-located with the waste handling facility sites, a 20% ramp from the mining facility site located to the west of the waste handling facility sites, and a direct shaft access from a mining facility site within the repository boundary are all reasonable candidates for mining operations access. Each of these options is discussed in Section 5.

It is recommended that the mining access method be selected during the conceptual design phase of this project. At that time, the incremental costs of developing a second site for mining operations and the desired repository entry point will be determined. When this information is available, the optimum entry method for mining operations can be identified.

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