

**ATTACHMENT G2
APPENDIX B**

SHAFT SEALING CONSTRUCTION PROCEDURES

**SHAFT SEALING SYSTEM
COMPLIANCE SUBMITTAL DESIGN REPORT**

Waste Isolation Pilot Plant
Hazardous Waste Permit
November 30, 2010

(This page intentionally blank)

**ATTACHMENT G2
APPENDIX B**

SHAFT SEALING CONSTRUCTION PROCEDURES

**SHAFT SEALING SYSTEM
COMPLIANCE SUBMITTAL DESIGN REPORT**

Appendix B Abstract

This appendix describes equipment and procedures used to construct the shaft seals as specified in Permit Attachment G2. Existing or reasonably modified construction equipment is specified, standard mining practices are applied, and a general schedule is provided at the end of this appendix. This appendix describes the following activities:

- pre-sealing activities for the sub-surface and surface,
- construction and operation of a multi-deck stage,
- installation of special concrete (sumps, shaft station monoliths, and concrete plugs),
- installation of compacted clay columns,
- emplacement and dynamic compaction of WIPP salt,
- installation of neat asphalt and asphaltic mastic mix,
- grouting of concrete plugs and the country rock behind existing shaft liners,
- removal of portions of the existing shaft liners, and
- emplacement of compacted earthen fill.

(This page intentionally blank)

TABLE OF CONTENTS

B1.	Introduction	1
B2.	Project Mobilization	2
B2.1	Subsurface.....	2
B2.2	Surface	2
B2.3	Installation of Utilities	3
B3.	Multi-Deck Stage	4
B4.	Placement of Sealing Materials	5
B4.1	Concrete	6
B4.1.1	Shaft Station Monolith.....	6
B4.1.2	Concrete-Asphalt Waterstops	7
B4.1.3	Concrete Plugs	7
B4.2	Clay	7
B4.2.1	Salado and Rustler Compacted Clay Column	7
B4.3	Asphalt.....	8
B4.3.1	Concrete-Asphalt Waterstops	8
B4.3.2	Asphaltic Mastic Mix Column	10
B4.4	Compacted Salt Column	11
B4.5	Grout.....	13
B4.6	Compacted Earthen Fill.....	14
B4.6.1	Lower Section.....	14
B4.6.2	Upper Section.....	15
B4.7	Schedule.....	15
B5.	References.....	43

FIGURES

Figure	Title
Figure G2B-1	Multi-Deck Stage Illustrating Dynamic Compaction
Figure G2B-2	Multi-Deck Stage Illustrating Excavation for Asphalt Waterstop
Figure G2B-3	Typical Fibercrete at Top of Asphalt
Figure G2B-4	Drop Pattern for 6-m-Diameter Shaft Using a 1.2-m-Diameter Tamper
Figure G2B-5	Plan and Section Views of Downward Spin Pattern of Grout Holes
Figure G2B-6	Plan and Section Views of Upward Spin Pattern of Grout Holes

1 **B1. Introduction**

2 This appendix describes construction specifications for placement of shaft seal materials.
3 Flexibility is incorporated in construction specifications to facilitate placement of several different
4 material types. Engineering materials used to seal the full length of the shaft include earthen fill,
5 compacted clay, tamped crushed salt, asphalt, concrete, and a combination of concrete and
6 asphalt in concrete-asphalt waterstops. Appendix A of Permit Attachment G2 provides details of
7 the materials. A full-length shaft seal of this type has never before been constructed; however,
8 application of available technology and equipment, standard construction practices, and
9 common materials provides confidence that the system can be placed to satisfy the design
10 requirements.

11 A primary feature of the construction specification is development of a work platform from which
12 seal materials are placed. Although the proposed multi-deck stage (galloway) proposed here is
13 engineered specifically for shaft sealing operations, it is similar to stages used for construction
14 of shafts. Inherently flexible, the multi-deck stage facilitates several construction methods
15 required for the various materials specified for the shaft seal system. It provides an assembly of
16 a slickline and header for transport of flowable materials from the surface to the placement
17 horizon. A crane device is attached to the base of the stage to facilitate compaction, and an
18 avenue through the stage provides a means to transport bulk material. It is understood that
19 procedures specified here may change during the tens of years preceding construction as a
20 result of equipment development, additional testing, or design changes. Further, it is
21 acknowledged that the construction methods specified are not the only methods that could
22 place the seal materials successfully.

23 A few assumptions are made for purposes of evaluating construction activities. These
24 assumptions are not binding, but are included to assist discussion of general operational
25 scenarios. For example, four multi-deck stages are specified, one for each shaft. This
26 specification is based on shaft-sinking experience, which indicates that because of the wear
27 encountered, it is advisable to replace rather than rebuild stages. However, much of the
28 equipment on the multi-deck stage is reused. For scheduling purposes, it is assumed that
29 sealing operations are conducted in two of the four shafts simultaneously. The Air Intake and
30 Exhaust Shafts are sealed first, and the Waste and Salt Handling Shafts are sealed last. With
31 this approach, shaft sealing will require about six and a half years, excluding related work
32 undertaken by the WIPP Management and Operating Contractor (**MOC**). Sealing the shafts
33 sequentially would require approximately eleven and a half years. To facilitate discussion of
34 scheduling and responsibilities, it is assumed that sealing operations will be conducted by a
35 contractor other than the MOC.

36 Years from now, when actual construction begins, it is probable that alternatives may be
37 favored. Therefore, construction procedures note alternative methods in recognition that
38 changes are likely and that the construction strategy is sufficiently robust to accommodate
39 alternatives. This appendix contains both general and very specific information. It begins with a
40 discussion of general mobilization in Section 2. Details of the multi-deck construction stage are
41 provided in Section 3. Section 4 contains descriptions of the construction activities. Information
42 presented here is supplemented by several engineering drawings and sketches contained in
43 Permit Attachment G2, Appendix E. The topical information and the level of provided detail
44 substantiate the theory that reliable shaft seal construction is possible using available
45 technology and materials.

1 **B2. Project Mobilization**

2 The duty descriptions that follow are for discussion purposes. The discussions do not
3 presuppose contractual arrangements, but simply identify tasks necessary for shaft seal
4 construction.

5 **B2.1 Subsurface**

6 Prior to initiation of sealing activities, the MOC will remove installations and equipment on the
7 repository level. A determination of items removed will be made before construction begins.
8 Such removal would include, but is not limited to, gates and fences at the shaft; equipment such
9 as winches, ventilation fans, pipelines; and communication and power cables. Additionally, the
10 following items will be removed from the shafts:

- 11 • cables, counterweights, and sheaves;
- 12 • existing waterlines; and
- 13 • electrical cables not required for sealing operations.

14 The following equipment will be stored near the shaft on the repository level by the Sealing
15 Contractor prior to initiation of sealing activities:

- 16 • a concrete header, hopper, and pump;
- 17 • a concrete pump line to distribute concrete; and
- 18 • an auxiliary mine fan and sufficient flexible ventilation tubing to reach work areas
19 required for installation of the shaft station concrete monolith.

20 The subsurface will be prepared adequately for placement of the shaft station monolith.
21 Determination of other preparatory requirements may be necessary at the time of construction.

22 **B2.2 Surface**

23 The MOC will remove surface facilities such as headframes, hoists, and buildings to provide
24 clear space for the Sealing Contractor. Utilities required for sealing activities (e.g., air
25 compressors, water, electrical power and communication lines) will be preserved. The Sealing
26 Contractor will establish a site office and facilities required to support the construction crews,
27 including a change house, lamp room, warehouse, maintenance shop, and security provisions.
28 Locations will be selected and foundations constructed for headframes, multi-deck stage
29 winches, man/equipment hoist, and exhaust fan. A drawing in Permit Attachment G2, Appendix
30 E (Sketch E-4) depicts a typical headframe and associated surface facilities. The hoist and
31 winches will be enclosed in suitable buildings; utilities and ventilation ducting will be extended to
32 the shaft collar. The large ventilation fan located near the collar is designed to exhaust air
33 through the rigid ventilation duct, resulting in the movement of fresh air down the shaft. Air flow
34 will be sufficient to support eight workers to the depth of the repository level. The following
35 facilities will be procured and positioned near the shaft collar:

- 36 • a concrete batch plant capable of weighing, batching, and mixing the concrete to
37 design specifications;

- 1 • a crushing and screening plant to process WIPP salt and local soil;
- 2 • an insulated and heated pug mill, asphalt pump, asphalt storage tank, and other
- 3 auxiliary equipment; and
- 4 • pads, silos, and structures to protect sealing materials from the weather.

5 The Sealing Contractor will construct a temporary structural steel bulkhead over the shaft at the
6 surface. The bulkhead will be sufficiently strong to support the weight of the multi-deck stage,
7 which will be constructed on it. When the multi-deck stage is completed, the headframe will be
8 erected. The headframe (depicted in Permit Attachment G2, Appendix E, Sketch E-3) will be
9 built around the multi-deck stage, and a mobile crane will be required during fabrication. When
10 the headframe is completed, cables for hoisting and lowering the multi-deck stage will be
11 installed. Cables will run from the three winches, over the sheaves in the headframe, down and
12 under the sheaves on the multi-deck stage, and up to anchors in the headframe. The headframe
13 will be sufficiently high to permit the multi-deck stage to be hoisted until the lowest component is
14 3.05 m (10 ft) above surface. This will facilitate slinging equipment below the multi-deck stage
15 and lowering it to the work surface, as well as activities required at the collar during asphalt
16 emplacement.

17 The multi-deck stage will be lowered to clear the collar, allowing the installation of compressed-
18 air-activated steel shaft collar doors, which will serve as a safety device, permitting safe access
19 to the man cage and bucket, while preventing objects from falling down the shaft. Following
20 installation of these doors, workers will utilize the multi-deck stage to traverse the shaft from the
21 collar to the repository horizon, inspecting it for safety hazards and making any necessary
22 repairs. After this inspection, the multi-deck stage will return to the surface.

23 **B2.3 Installation of Utilities**

24 In preparation for placement of shaft seal materials, requisite utilities will be outfitted for
25 operations. The multi-deck stage will descend from the collar to the repository horizon. As
26 added assurance against unwanted water, a gathering system similar to the one currently in
27 place at the bottom of the concrete liner will be installed and moved upward as seal
28 emplacement proceeds. Water collected will be hoisted to the surface for disposal. Additionally,
29 any significant inflow will be located and minimized by grouting. After installation of the water
30 gathering system, the following utilities will be installed from surface to the repository horizon by
31 securely fastening them to the shaft wall:

- 32 • 5.1-cm steel waterline with automatic shut-off valves every 60 m;
- 33 • 10.2-cm steel compressed-air line;
- 34 • power, signal, and communications cables;
- 35 • 15.2 cm steel slickline and header; and
- 36 • a rigid, cylindrical, ventilation duct, which would range from 107 cm in diameter in the
37 three largest shafts to 91 cm in diameter in the Salt Handling Shaft.

1 **B3. Multi-Deck Stage**

2 The multi-deck stage (galloway) provides a work platform from which all sealing operations
3 except placement of asphalt are conducted. The concept of using a multi-deck stage is derived
4 from similar equipment commonly employed during shaft sinking operations. Plan and section
5 views of conceptual multi-deck stages are shown in Permit Attachment G2, Appendix E,
6 Sketches E-1 and E-2. The construction decks specified here are modified from typical shaft
7 sinking configurations in two important ways to facilitate construction. Conceptual illustrations of
8 these two modifications are displayed in Figures G2B-1 and G2B-2. Figure G2B-1 illustrates the
9 multi-deck performing dynamic compaction of salt. Figure G2B-2 illustrates the multi-deck stage
10 configured for excavation of the kerf required for the asphalt waterstop in Salado salt.

11 A device called a polar crane mounted below the lower deck can be configured for either
12 dynamic compaction or salt excavation. The crane can rotate 360° horizontally by actuating its
13 geared track drive. Its maximum rotational speed will be approximately two revolutions per
14 minute. The crane can be controlled manually or by computer (computerized control will swiftly
15 position the tamper in the numerous drop positions required for dynamic compaction). When
16 excavation for the concrete-asphalt waterstops is required, the tamper, electromagnet, and
17 cable used for dynamic compaction will be removed, and a custom salt undercutter will be
18 mounted on the polar crane trolley. Geared drives on the crane, trolley, and undercutter will
19 supply the force required for excavation. In addition to the special features noted above and
20 shown in Figures G2B-1 and G2B-2, the multi-deck stage has the following equipment and
21 capabilities:

- 22 • Maximum hoisting/lowering speed is approximately 4.6 m (15 ft) per minute.
- 23 • A cable, electromagnet, and tamper will be attached to the polar crane during dynamic
24 compaction. The cylindrical tamper consists of A-36 carbon steel plates bolted
25 together with high-tensile-strength steel bolts. It is hoisted and dropped by the polar
26 crane using the electromagnet. The tamper will be mechanically secured to the polar
27 crane before personnel are allowed under it.
- 28 • Range-finding lasers will facilitate the accurate positioning of the multi-deck stage
29 above the work surface and allow the operator to determine when the surface is
30 sufficiently level. The distance indicated by each laser will be displayed on a monitor at
31 the crane control station.
- 32 • Flood lights and remotely controlled closed-circuit television equipment will enable the
33 crane operator to view operations below the multi-deck stage on a monitor.
- 34 • Fold-out floor extensions that accommodate the variance in shaft diameter between
35 the unlined and lined portions of the shaft will be provided for safety.
- 36 • A cutout in each deck, combined with a removable section of the polar crane track, will
37 permit stage movement without removal of the rigid ventilation duct (which is fastened
38 to the shaft wall).

1 The multi-deck stage is equipped with many of the features found on conventional shaft sinking
2 stages, such as:

- 3 • three independent hoisting/lowering cables,
- 4 • man and material conveyances capable of passing through the multi-deck stage and
5 accessing the working surface below,
- 6 • a jib crane that can be used to service the working surface below,
- 7 • removable safety screens and railings, and
- 8 • centering devices.

9 Three sets of double locking devices are provided to secure the multi-deck stage to the shaft
10 wall. A suitable factor of safety for these locking devices is judged to be 4. The area of the grips
11 securing the deck is calculated from static principles:

$$12 \quad FS = \mu(Co)(A)/W \quad (B-1)$$

13 where:

- 14 FS = factor of safety
- 15 μ = steel/salt friction coefficient = 0.15 (see Table 20.1 in McClintock and Aragon, 1966;
16 and Van Sambeek, 1988)
- 17 Co = compressive strength of WIPP salt, which varies from 172 kg/cm² to 262 kg/cm² (Van
18 Sambeek, 1988)
- 19 W = total vertical weight
- 20 A = total gripper pad surface area.

21 Manipulating the equation to solve for required area, applying a factor of safety of 4, selecting
22 the heaviest work stage (753,832 kg) and the minimum compressive strength value for salt
23 (assuming that the locking pressure equals the minimum compressive strength of salt), the
24 following gripper surface area (A) is:

$$25 \quad A = 4(753,832 \text{ kg})/0.15(172 \text{ kg/cm}^2) = 11,416.5 \text{ cm}^2, \text{ and each of the six gripper}$$

26 pads would be 1902.8 cm².

27 As designed, each gripper pad area is 2167.2 cm², resulting in a factor of safety (FS) of 4.56.
28 Additionally, although tension in the hoisting cables is relaxed while the multi-deck stage is in
29 the locked configuration, the cables are still available to hold the work-deck, should the locking
30 devices fail.

31 **B4. Placement of Sealing Materials**

32 Construction activities include placement of materials in three basic ways: (1) by slickline (e.g.,
33 concrete and asphalt), (2) by compaction (e.g., salt and earthen fill), and (3) by physical
34 placement (e.g., clay blocks). Materials will be placed at various elevations using identical
35 procedures. Because placement procedures generally are identical regardless of elevation, they

1 will be described only once. Where differences occur, they will be identified and described. In
2 general, placement of shaft seal elements is described from bottom to top.

3 **B4.1 Concrete**

4 Concrete is used as a seal material for several different components, such as the existing
5 sumps in the Salt Handling Shaft and the Waste Shaft, the shaft station monoliths, concrete
6 plugs, and concrete-asphalt waterstops. Existing sumps are shown in Permit Attachment G2,
7 Appendix E, Drawings SNL-007, Sheets 6 and 21. Shaft station monoliths are shown in
8 Drawings SNL-007, Sheets 6, 11, 16, and 21. Concrete plugs are depicted on Drawings SNL-
9 007, Sheets 4, 5, 9, 10, 14, 15, 19, and 20. Lower, middle, and upper concrete-asphalt
10 waterstops are shown in Drawing SNL-007, Sheet 22. Construction material for all concrete
11 members will be Salado Mass Concrete (SMC).

12 As specified, all SMC will be mixed on surface to produce a product possessing the
13 characteristics defined in Permit Attachment G2, Appendix A. Concrete will be transferred to its
14 placement location within the shaft via slickline and header. The slickline (shown in Figure G2B-
15 1) is a steel pipe fastened to the shaft wall. Vertical drops as great as 656 m to the repository
16 horizon are required. Such concrete transport and construction are common in mining
17 applications. For example, a large copper mine in Arizona is placing concrete at a depth of 797
18 m using this procedure. A header attached to the bottom of the slickline is designed to absorb
19 kinetic energy generated by the falling material. The header, a steel pipe slightly larger in
20 diameter than the slickline and made of thicker steel, diverts the flow 45°, absorbing most of the
21 impact. Because the drop generates considerable force, the header will be securely supported
22 by a reinforced steel shelf bolted to the shaft wall. A flexible hose, in sections approximately 3 m
23 long and joined by quick-connect fittings, will be attached to the header.

24 **B4.1.1 Shaft Station Monolith**

25 Construction of the shaft station monoliths is preceded by filling two existing sumps with SMC.
26 Initially, sufficient hose will be used to convey the concrete to the bottom of the sump. The
27 discharge will remain below the concrete surface during placement to minimize air entrainment.
28 Sections of hose will be withdrawn and removed as the SMC rises to the floor of the repository
29 horizon in a continuous pour. Subsequent to filling the sump, arrangements will be made to
30 place the concrete monolith.

31 A small mine fan will be located above the rigid suction-duct inlet to ensure a fresh air base.
32 Masonry block forms will be constructed at the extremities of the shaft station monolith in the
33 drifts leading from the station. Temporary forms, partially filling the opening, will be erected at
34 the shafts to facilitate the placement of the outermost concrete. These temporary forms will
35 permit access necessary to ensure adequate concrete placement. SMC will be transported via
36 the slickline to the header, which will discharge into a hopper feeding the concrete pump, and
37 the pump will be attached to the pumpcrete line. The pumpcrete line, suspended in cable slings
38 near the back of the drifts, will be extended to the outer forms. A flexible hose, attached to the
39 end of the pumpcrete line, will be used by workers to direct emplacement. The pumpcrete line
40 will be withdrawn as emplacement proceeds toward the shaft.

41 When the concrete has reached the top of the temporary forms, they will be extended to seal
42 the openings completely, and two 5-cm-diameter polyvinyl chloride (PVC) pipes will be
43 incorporated in the upper portion of each form. Both pipes will be situated in a vertical plane

1 oriented on the long axis of the heading and inclined away from the station at approximately 70°
2 to the horizontal. The upper end of the top pipe will extend to just below the back, and the upper
3 end of the lower pipe will be located just below that of the top pipe. SMC will be injected through
4 the lower pipe until return is obtained from the upper pipe, ensuring that the heading has been
5 filled to the back. The header will then be moved to a position in the shaft above the designed
6 elevation at the top of the shaft station monolith and supported by a bracket bolted to the shaft
7 wall. After the outer concrete has achieved stability, the temporary interior forms may be
8 removed. Equipment no longer required will be slung below the multi-deck stage and hoisted to
9 surface for storage and later use. The station and shaft will be filled to design elevation with
10 concrete via the slickline, header, and flexible hose. The slickline is cleaned with spherical,
11 neoprene swabs ("pigs") that are pumped through the slickline, header, and hose.

12 **B4.1.2 Concrete-Asphalt Waterstops**

13 Lower, middle, and upper concrete-asphalt waterstops in a given shaft are identical and consist
14 of two SMC sections separated by an asphalt waterstop. Before the bottom member of the
15 lower concrete component is placed, the multi-deck stage will be raised into the headframe; the
16 polar crane will be mounted below the lower deck; and the salt undercutter will be mounted on
17 the crane trolley. The multi-deck stage will then return to the elevation of the concrete
18 component. Two undercutter bars will be used to make the necessary excavations for upper,
19 middle, and lower asphalt-concrete waterstops and the concrete plug above the Salado
20 Formation. Notches for the plugs will be excavated using a short, rigid cutter bar (length less
21 than half the radius). The kerf for the asphalt waterstop will be excavated using a long cutter bar
22 that can excavate the walls to a depth of one shaft radius. These operations will be conducted
23 as required as seal placement proceeds upward.

24 The lower concrete member (and all subsequent concrete entities) will be placed via the
25 slickline, header, and flexible hose, using the procedure outlined for the shaft station monolith.
26 Construction of vertical shaft seals provides the ideal situation for minimizing interface
27 permeability between the rock and seal materials. Concrete will flow under its own weight to
28 provide intimate contact. A tight cohesive interface was demonstrated for concrete in the small-
29 scale seal performance tests (SSSPTs). The SSSPT concrete plugs were nearly impermeable
30 without grouting. However, interface grouting is usually performed in similar construction, and it
31 will be done here in the appropriate locations.

32 **B4.1.3 Concrete Plugs**

33 An SMC plug, keyed into the shaft wall, is situated a few meters above the upper Salado
34 contact in the Rustler Formation. A final SMC plug is located a few meters below surface in the
35 Dewey Lake Redbeds. This plug is emplaced within the existing shaft liner using the same
36 construction technique employed for the concrete-asphalt waterstops.

37 **B4.2 Clay**

38 **B4.2.1 Salado and Rustler Compacted Clay Column**

39 Blocks of sodium bentonite clay, precompacted to a density of 1.8 to 2.0 g/cm³, will be the
40 sealing material. This density has been achieved at the WIPP using a compaction pressure of
41 492.2 kg/cm² in a machine designed to produce adobe blocks (Knowles and Howard, 1996).
42 Blocks are envisioned as cubes, 20.8 cm on the edge, weighing approximately 18 kg, a

1 reasonable weight for workers to handle. The bentonite blocks will be compacted at the WIPP in
2 a new custom block-compacting machine and will be stored in controlled humidity to prevent
3 desiccation cracking. Blocks will be transported from surface in the man cage, which will be
4 sized to fit through the circular "bucket hole" in the multi-deck stage. The conveyance will be
5 stacked with blocks to a height of approximately 1.8 m.

6 Installation will consist of manually stacking individual blocks so that all interfaces are in contact.
7 Block surfaces will be moistened with a spray of potable water as the blocks are placed to
8 initiate a minor amount of swelling, which will ensure a tight fit and a decrease in permeability.
9 Peripheral blocks will be trimmed to fit irregularities in the shaft wall and placed as close to the
10 wall as possible. Trimmed material will be manually removed with a vacuum. Dry bentonite will
11 be manually tamped into remaining voids in each layer of blocks. This procedure will be
12 repeated throughout the clay column. The multi-deck stage will, in all cases, be raised and
13 utilities removed to the surface as emplacement of sealing materials proceeds upward.

14 Dynamic compaction construction is an alternative method of clay emplacement that could be
15 considered in the detailed design. Dynamic compaction materials being considered are:

- 16 • sodium bentonite/fine silica sand, and
- 17 • highly compressed bentonite pellets.

18 Boonsinsuk et al. (1991) developed and tested a dynamic (drop hammer) method for a relatively
19 large diameter (0.5-m) hole, simulated with a steel cylinder, that gave very good results on 1 : 1
20 dry mass mixtures of sodium bentonite and sand, at a moisture content of 17% to 19%. The
21 alternatives have the advantages of simplifying emplacement.

22 **B4.3 Asphalt**

23 Asphalt, produced as a distillate of petroleum, is selected as the seal material because of its
24 longevity, extremely low permeability, history of successful use as a shaft lining material, and its
25 ability to heal if deformed. Shielded from ultraviolet radiation and mixed with hydrated lime to
26 inhibit microbial degradation, the longevity of the asphalt will be great. Emplaced by tremie line
27 at the temperature specified, the material will be fluid and self-leveling, ensuring complete
28 contact with the salt.

29 Construction of an asphalt column using heated asphalt will introduce heat to the surrounding
30 salt. The thermal shock and heat dissipation through the salt has not been studied in detail.
31 Performance of the asphalt column may be enhanced by the introduction of the heat that results
32 from acceleration of creep and healing of microfractures. If, upon further study, the
33 thermomechanical effects are deemed undesirable or if an alternative construction method is
34 preferred at a later date, asphalt can readily be placed as blocks. Asphalt can "cold flow" to fill
35 gaps, or the seams between blocks can be filled with low-viscosity material.

36 **B4.3.1 Concrete-Asphalt Waterstops**

37 Electrically insulated, steel grated flooring will be constructed over the shaft at the surface. A
38 second, similar flooring will be built in the shaft 3 m below the first. These floors will be used
39 only during the emplacement of asphalt and asphaltic mastic mix (AMM) and will be removed at
40 all other times. A 12.7-cm ID/14-cm OD, 4130 steel pipe (tremie line) in 3-m lengths will be
41 electrically equipped for impedance heating, then insulated and suspended in the shaft from

1 slips (pipe holding devices) situated on the upper floor. The tremie line cross-sectional area is
2 smallest at the shoulder of the top thread, where tensional yield is 50,000 kg; the line weight is
3 20.8 kg/m. Heavier weights are routinely suspended in this manner in the petroleum and mining
4 industries.

5 Neat, AR-4000-graded petroleum-based asphalt cement will be the sealing material for asphalt
6 waterstops. Neat asphalt from the refinery will be delivered to the WIPP at approximately 80°C
7 in conventional, insulated refinery trucks and pumped into a heated and insulated storage tank
8 located near the shaft. The multi-deck stage will be hoisted into the headframe and
9 mechanically secured for safety. Asphalt, heated to 180°C ±5°, will be pumped down the shaft
10 to the fill elevation through the heated tremie line. Viscosity of the neat asphalt for the
11 waterstops will be sufficiently low to allow limited penetration of the DRZ. Installation of asphalt
12 in each of the concrete-waterstops is identical.

13 As the pipe is lowered, workers on the lower deck will attach the wiring required for heating
14 circuits and apply insulation. Workers on the top deck will install flanged and electrically
15 insulated couplings as required (the opening in the slip bowl will be large enough to permit the
16 passage of these couplings). Properly equipping and lowering the pipe should progress at the
17 rate of one section every 10 minutes. The lower asphalt waterstop requires approximately 607
18 m of pipe for a casing weight of 12,700 kg. Additionally, electrical wire and insulation will weigh
19 about 7250 kg for a total equipped tremie line weight of 20,000 kg. Therefore, the safety factor
20 for the tremie line is 50,000 kg/20,000 kg, or 2.5.

21 To minimize air entrainment, the lower end of the tremie line will be immersed as much as 1 m
22 during hot asphalt emplacement. Therefore, the lower 3 m of casing will be left bare (to simplify
23 cleaning when emplacement has been completed).

24 Initially the tremie line will be lowered until it contacts the concrete plug (immediately underlying
25 the excavation for the waterstop) and then raised approximately 0.3 m. Asphalt emplacement
26 will proceed as follows:

- 27 • The impedance heating system will be energized, heating the tremie line to 180°C ±5°,
28 and the asphalt in the storage tank will be heated to approximately 180°C ±5°.
- 29 • Heated, neat asphalt will be pumped down the tremie line at a rate approximating
30 13 L/min. This low rate will ensure that the asphalt flows across the plug from the
31 insertion point, completely filling the excavation and shaft to the design elevation.
- 32 • The tremie line will be raised 3 m and cleaned by pumping a neoprene swab through it
33 with air pressure. Impedance heating will be stopped, and the line will be allowed to
34 cool. When cool, the line will be hoisted, stripped, cleaned, disassembled, and stored
35 for future use.

36 Sealing operations will be suspended until the air temperature at the top of the asphalt has
37 fallen to approximately 50°C for the comfort of the workers when they resume activity at the fill
38 horizon. Temperature will be determined by lowering a remotely read thermometer to an
39 elevation approximately 3 m above the asphalt at the center of the shaft. The temperature of the
40 asphalt at the center of the shaft will be 50°C in about a month, but active ventilation should
41 permit work to resume in about two weeks (see calculations in Appendix D of *Waste Isolation*

1 *Pilot Plant Shaft Sealing System Compliance Submittal Design Report (“Compliance Submittal*
2 *Design Report”)* (Sandia, 1996)).

3 When sufficient cooling has occurred, workers will descend in the multi-deck stage and cover
4 the hot asphalt with an insulating and structural material such as fiber-reinforced shotcrete, as
5 illustrated in Figure G2B-3. To accomplish this, they will spray cementitious shotcrete containing
6 fibrillated polypropylene fibers (for added tensional strength), attaining a minimum thickness of
7 approximately 0.6 m.

8 **B4.3.2 Asphaltic Mastic Mix Column**

9 Asphaltic mastic mix (AMM) for the column will be prepared on surface in a pug mill. Viscosity of
10 the AMM can be tailored to provide desired properties such as limited migration into large
11 fractures.

12 • AMM will be prepared by mixing the ingredients in the pug mill, which has been heated
13 to $180^{\circ}\text{C} \pm 5^{\circ}$. The mix will be pumped from the pug mill through the tremie line to the
14 emplacement depth. AMM is self-leveling at this temperature, and its hydrostatic head
15 will ensure intimate contact with the shaft walls.

16 • Pumping rate will be approximately 200 L/min for efficiency, because of the larger
17 volume (approximately 1,224,700 L in the Air Intake Shaft). To facilitate efficient
18 emplacement and avoid air entrainment, the tremie line will not be shortened until the
19 mix has filled 6 vertical meters of the shaft. Back pressure (approximately 0.84 kg/cm^2)
20 resulting from 6 m of AMM above the discharge point will be easily overcome from
21 surface by the hydraulic head.

22 After 6 vertical meters of AMM have been placed:

23 • Impedance heating current will be turned off and locked out (the hot line will drain
24 completely).

25 • To prevent excessive back pressure resulting from AMM above the insertion point, the
26 line will be disconnected from the pump and hoisted hot. Two sections will be stripped,
27 removed, cleaned with a “pig,” and stacked near the shaft.

28 • Electrical feed will be adjusted (because of the decreased resistance of the shortened
29 line).

30 • The tremie line will be reconnected to the pump.

31 • The impedance heating system will be energized.

32 • When the temperature of the line has stabilized at $180^{\circ}\text{C} \pm 5^{\circ}$, pumping will resume.

33 This procedure will be followed until the entire column, including the volume computed to
34 counteract 0.9 m of vertical shrinkage (calculations in Appendix D of the Compliance Submittal
35 Design Report (Sandia, 1996)), has been placed. The line will be disconnected from the pump
36 and cleaned by pumping “pigs” through it with air pressure. It will then be hoisted, stripped,
37 removed in 3-m sections, and stacked on surface for reuse.

1 Sealing operations will be suspended following removal of the tremie line, and ventilation will be
2 continuous to speed cooling. The column will shrink vertically but maintain contact with the shaft
3 walls as it cools. When the air temperature at 3 m above the asphalt has cooled sufficiently,
4 workers will descend on the multi-deck stage and cover the hot asphalt with fibercrete as
5 described for the concrete-asphalt waterstop (Permit Attachment G2, Appendix B, Section
6 B4.3.1) and illustrated in Figure G2B-3.

7 Note: Near the top of the Salado Formation, portions of the concrete liner key, chemical seal
8 rings, and concrete and steel shaft liners will be removed. Liner removal will occur before
9 emplacement of AMM. For safety, exposed rock will be secured with horizontal, radial rock bolts
10 and cyclone steel mesh. A range-finding device, fastened to the shaft wall approximately 3 m
11 above the proposed top of the asphaltic column, will indicate when the hot AMM reaches the
12 desired elevation. A remotely read thermometer, affixed to the shaft wall approximately 2 m
13 above the proposed top of the column, will show when the air temperature has fallen sufficiently
14 to resume operations. The intake of the rigid ventilation duct will be positioned approximately
15 3 m above the proposed top of the column, and ventilation will be continuous throughout
16 emplacement and cooling of the asphaltic column. After the multi-deck stage has been hoisted
17 into the headframe and mechanically secured for safety, emplacement of AMM will proceed.

18 **B4.4 Compacted Salt Column**

19 Crushed, mine-run salt, dynamically compacted against intact Salado salt, is the major long-
20 term shaft seal element. As-mined WIPP salt will be crushed and screened to a maximum
21 particle dimension of 5 mm. The salt will be transferred from surface to the fill elevation via the
22 slickline and header. A flexible hose attached to the header will be used to emplace the salt,
23 and a calculated weight of water will be added. After the salt has been nominally leveled, it will
24 be dynamically compacted. Dynamic compaction consists of compacting material by dropping a
25 tamper on it and delivering a specified amount of energy. The application of three times
26 Modified Procter Energy (MPE) to each lift (one MPE equals 2,700,000 Joules/m³) will result in
27 compacting the salt to 90% of the density of in-place rock salt.

28 Approximately 170 vertical meters of salt will be dynamically compacted. Dynamic compaction
29 was validated in a large-scale demonstration at Sandia National Laboratories during 1995. As-
30 mined WIPP salt was dynamically compacted to 90% density of in-place rock salt in a cylindrical
31 steel chamber simulating the Salt Handling Shaft (Ahrens and Hansen, 1995). Depth of
32 compaction is greater than that achieved by most other methods, allowing the emplacement of
33 thicker lifts. For example, dropping the 4.69 metric ton tamper 18 m (as specified below) results
34 in a compaction depth of approximately 4.6 m, allowing emplacement of lifts 1.5-m high. Most
35 other compaction methods are limited to lifts of 0.3 m or less. Lift thickness will be increased
36 and drop height decreased for the initial lift above the concrete plug at the base of the salt
37 column to ensure that the concrete is not damaged. Drop height for the second and third lifts will
38 be decreased as well. Although the tamper impact is thereby reduced, three MPE will be
39 delivered to the entire salt column.

40 If lifts are 1.5-m thick, the third lift below the surface will receive additional densification during
41 compaction of overlying lifts, and this phenomenon will proceed up the shaft. Construction will
42 begin by hoisting the multi-deck stage to the surface and attaching the cable, electromagnet,
43 and tamper to the hoist on the polar crane. The multi-deck assembly will be lowered to the
44 placement elevation, and moisture content of the crushed and screened salt will be calibrated.
45 Then the salt will be conveyed at a measured rate via a weighbelt conveyor to a vibrator-

1 equipped hopper overlying the 15.2-cm ID slickline. The salt will pass down the slickline and exit
2 a flexible hose connected to the header. A worker will direct the discharge so that the upper
3 surface of the lift is nominally level and suitable for dynamic compaction. A second worker will
4 add potable water, in the form of a fine spray, to the salt as it exits the hose. Water volume will
5 be electronically controlled and coordinated with the weight of the salt to achieve the desired
6 moisture content.

7 The initial lift above the SMC will be 4.6 m, and drop height will be 6 m. This increased lift
8 thickness and reduced drop height are specified to protect the underlying SMC plug from
9 damage and/or displacement from tamper impact. Compaction depth for a drop height of 6 m is
10 approximately 3.7 m. Ultimately, the tamper will be dropped six times in each position, resulting
11 in a total of 132 drops per lift in the larger shafts. The drop pattern is shown in Figure G2B-4. A
12 salt lift 1.5 m high will then be placed and leveled. Following compaction of the initial lift, the
13 multi-deck stage will be positioned so the base of the hoisted tamper is 10 m above the surface
14 of the salt.

15 The multi-deck stage will then be secured to the shaft walls by activating hydraulically powered
16 locking devices. Hydraulic pressure will be maintained on these units when they are in the
17 locked position; in addition, a mechanical pawl and ratchet on each pair will prevent loosening.
18 The safety factor for the locking devices has been calculated to be approximately 4.5. After
19 locking, tension in the hoisting cables will be relaxed, and centering rams will be activated to
20 level the decks. Prior to positioning the stage, tension will be applied to the hoisting cables; the
21 centering rams will be retracted; and the locking devices will be disengaged.

22 The work deck will be hoisted until the base of the retracted tamper is 23 m above the surface of
23 the salt, where it will be locked into position and leveled as described above. This procedure,
24 repeated throughout the salt column, allows emplacement and compaction of three lifts (1.5-m
25 thick) per multi-deck stage move. Depth of compaction for a drop height of 18 m is
26 approximately 4.6 m. Therefore the third lift below the fill surface will receive a total of 9 MPE
27 ($274,560 \text{ m kg/m}^3$), matching the energy applied in the successful, large-scale demonstration.

28 The compactive effect expands laterally as it proceeds downward from the base of the tamper
29 and will effectively compact the salt into irregularities in the shaft wall, as demonstrated in the
30 large-scale demonstration. Although other techniques could be used, dynamic compaction was
31 selected because it is simple, can be used in the WIPP shafts, and has been demonstrated
32 (Hansen and Ahrens, 1996).

33 The tamper will be dropped from the hoisted position by turning off the power to the
34 electromagnet. Immediately upon release, the crane operator will "chase" the tamper by
35 lowering the electromagnet at twice hoisting speed; the magnet will engage the tamper, allowing
36 it to be hoisted for the subsequent drop. Initially, the tamper will be dropped in positions that
37 avoid impact craters caused by preceding drops. The surface will then be leveled manually and
38 the tamper dropped in positions omitted during the previous drop series.

39 Experience gained during the large-scale salt compaction demonstration indicated that a
40 considerable volume of dust is generated during the emplacement of the salt, but not during
41 dynamic compaction. However, because the intake of the rigid vent duct is below the multi-deck
42 stage, workers below the stage will wear respirators during emplacement. They will be the only
43 workers affected by dust during dynamic compaction.

1 The Air Intake Shaft will require 22 drop positions (Figure G2B-4). Application of one MPE
2 requires six drops in each position, for a total of 132 drops per lift. Three MPE, a total of 396
3 drops per lift, will be applied to all salt. After each compaction cycle, the salt surface will be
4 leveled manually and the tamper will be dropped in positions omitted in the preceding drop
5 series. Two lifts, each 1.8 m high, will then be sequentially placed, leveled, and compacted with
6 two MPE, using a 6-m drop height.

7 Dynamic compaction ensures a tight interface. Salt compacted during the large-scale dynamic
8 compaction demonstration adhered so tenaciously to the smooth interior walls of the steel
9 compaction chamber that grinders with stiff wire wheels were required for its removal.

10 **B4.5 Grout**

11 Ultrafine sulfate-resistant cementitious grout (Ahrens et al., 1996) is selected as the sealing
12 material. Specifically developed for use at the WIPP, and successfully demonstrated in an in
13 situ test, the hardened grout has a permeability of $1 \times 10^{-21} \text{ m}^2$. It has the ability to penetrate
14 fractures smaller than 6 microns and is being used for the following purposes:

- 15 • to seal many of the microfractures in the DRZ and ensure a tight interface between
16 SMC and the enclosing rock, and
- 17 • to solidify fractured rock behind existing concrete shaft liners, prior to removal of the
18 liner (for worker safety).

19 The interface between concrete plugs in the Salado Formation (and one in the Rustler
20 Formation, a short distance above the Salado) will be grouted. A 45° downward-opening cone of
21 reverse circulation diamond drill holes will be collared in the top of the plugs, drilled in a spin
22 pattern (see Figure G2B-5), and stage grouted with ultrafine cementitious grout at 3.5 kg/cm²
23 below lithostatic pressure. Stage grouting consists of:

- 24 • drilling and grouting primary holes, one at a time;
- 25 • drilling and grouting secondary holes, one at a time, on either side of the primary holes
26 that accepted grout; and
- 27 • (if necessary) drilling and grouting tertiary holes on either side of secondary holes that
28 accepted grout.

29 Note: For safety, all liner removal tasks will be accomplished from the bottom deck. In areas
30 where the steel liner is removed, it will be cut into manageable pieces with a cutting torch and
31 hoisted to the surface for disposal. Mechanical methods will be employed to clean and roughen
32 the existing concrete shaft liner before placing the Dewey Lake SMC plug in the shafts.

33 The work sequence will start 3 m below the lower elevation of liner removal. A 45° upward-
34 opening cone of grout injection holes, drilled in a "spin" pattern (Figure G2B-6), will be drilled to
35 a depth subtending one shaft radius on a horizontal plane. These holes will be stage grouted as
36 described in Section 4.5. Noncoring, reverse circulation, diamond drill equipment will be used to
37 avoid plugging fractures with fine-grained diamond drill cuttings. Ultrafine cementitious grout will
38 be mixed on the surface, transferred via the slickline to the upper deck of the multi-deck stage,
39 and injected at 3.5 kg/cm² gage below lithostatic pressure to avoid hydrofracturing the rock.

1 Grout will be transferred in batches, and after each transfer, a “pig” will be pumped through the
2 slickline and header to clean them. Grouting will proceed upward from the lowest fan to the
3 highest. Recent studies conducted in the Air Intake Shaft (Dale and Hurtado, 1996) show that
4 this hole depth exceeds that required for complete penetration of the Disturbed Rock Zone
5 (DRZ). Maximum horizontal spacing at the ends of the holes will be 3 m.

6 The multi-deck stage will then be raised 3 m and a second fan, identical to the first, will be
7 drilled and grouted. This procedure will continue, with grout fans 3 m apart vertically, until the
8 highest fan, located 3 m above the highest point of liner removal, has been drilled and grouted.
9 Ultrafine cementitious grout was observed to penetrate more than 2 m in the underground
10 grouting experiment conducted at the WIPP in Room L-3 (Ahrens and Onofrei, 1996).

11 When grouting is completed, the multi-deck stage will be lowered to the bottom of the liner
12 removal section and a hole will be made through the concrete liner. This hole, approximately 30
13 cm in diameter, will serve as “free-face” to which the liner will be broken. Similar establishment
14 and utilization of free face is a common practice in hard rock mining (e.g., the central drill hole in
15 a series drilled into the rock to be blasted is left empty and used as free-face to which
16 explosives in adjacent holes break the rock). Radial, horizontal percussion holes will be drilled
17 on a 30-cm grid (or less, if required), covering the liner to be removed. Hydraulic wedges,
18 activated in these holes, will then break out the liner, starting adjacent to the free face and
19 progressing away from it, from the bottom up. Broken fragments of the concrete liner will fall to
20 the fill surface below.

21 A mucking “claw,” suspended from the trolley of the polar crane, will collect the broken concrete
22 and place it in the bucket for removal to the surface. As many as three buckets can be used to
23 speed this work.

24 **B4.6 Compacted Earthen Fill**

25 Local soil, screened to a maximum particle dimension of 13 mm, will be placed and compacted
26 to inhibit the migration of surficial water into the shaft cross section. Such movement is further
27 decreased by a 12-m high SMC plug at the top of the Dewey Lake Redbeds.

28 **B4.6.1 Lower Section**

29 Emplacement of the compacted earthen fill will proceed as follows:

- 30 • Moisture content of the screened soil will be determined.
- 31 • The soil will then be transferred via the slickline, header, and flexible hose from
32 surface to the fill elevation. The moisture content optimal for compaction will be
33 achieved using the same procedure as described for compacted salt (Permit
34 Attachment G2, Appendix B, Section B4.4). The soil will be emplaced in lifts 1.2 m high
35 (depth of compaction is approximately 3.7 m) and dynamically compacted using a drop
36 height of 18.3 m.
- 37 • The fill will be dynamically compacted until its hydraulic conductivity to water is
38 nominally equivalent to that of the surrounding formation.

1 This procedure will continue until the lower section has been emplaced and compacted. Care
2 will be exercised at the top of the column to ensure that all soil receives sufficient compaction.

3 **B4.6.2 Upper Section**

4 The upper section contains insufficient room to employ dynamic compaction. Therefore the
5 screened soil, emplaced as described above, will be compacted by vibratory-impact sheepsfoot
6 roller, vibratory sheepsfoot roller, or a walk-behind vibratory-plate compactor. Because of the
7 limited compaction depth of this equipment, lifts will be 0.3 m high. The top of the fill will be
8 coordinated with the MOC to accommodate plans for decommissioning surface facilities and
9 placing markers.

10 **B4.7 Schedule**

11 Preliminary construction schedules are included on the following pages. The first schedule is a
12 concise outline of the total construction schedule. It is followed by individual schedules for each
13 shaft. The first schedule in each shaft series is a truncated schedule showing the major
14 milestones. The truncated schedules are followed by detailed construction schedules for each
15 shaft. These schedules indicate that it will take approximately six and a half years to complete
16 the shaft sealing operations, assuming two shafts are simultaneously sealed.

17

1
2

(This page intentionally blank)

1

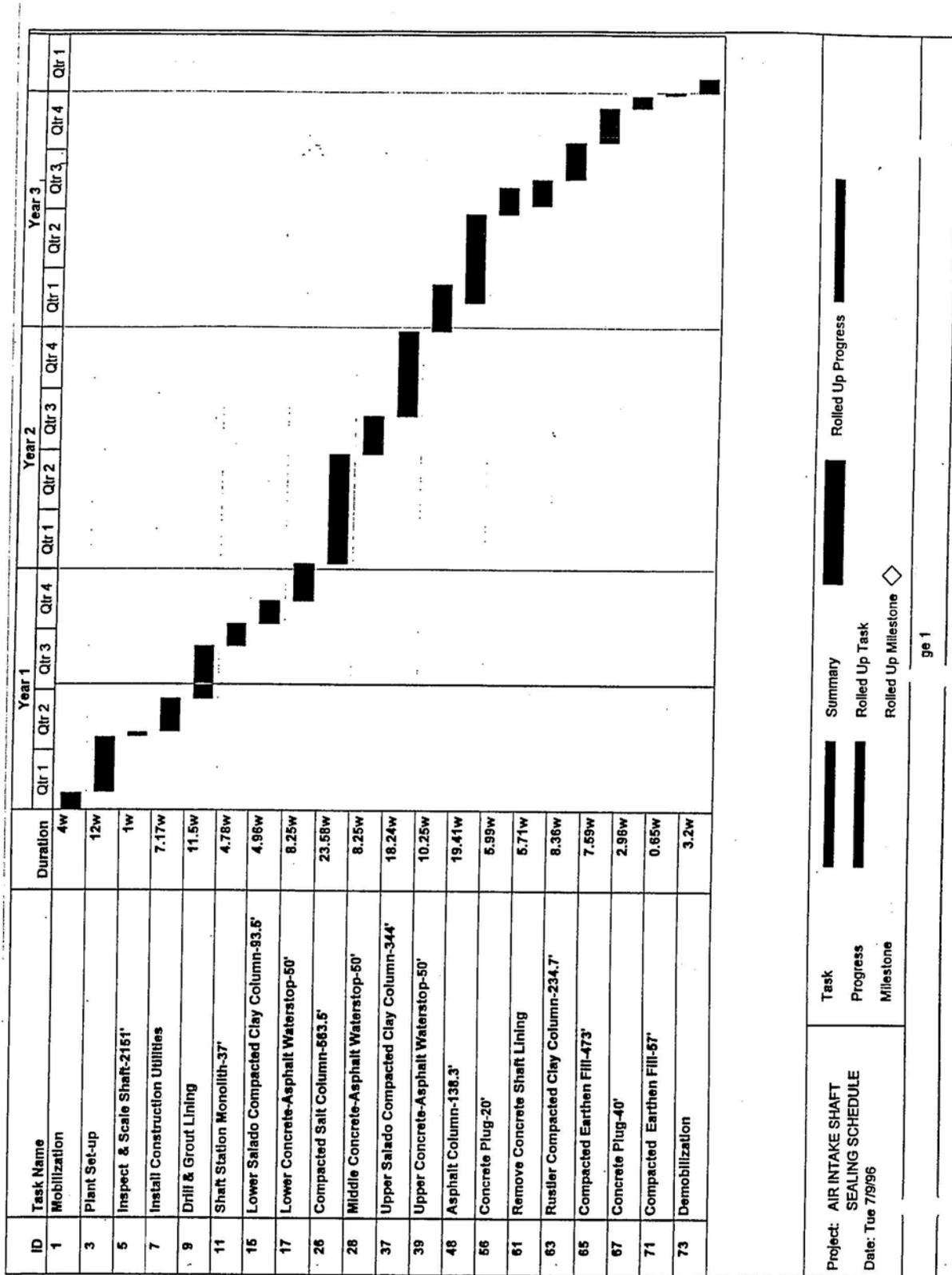
SEALING SCHEDULE - ALL SHAFTS

2

1

SEALING SCHEDULE - AIR INTAKE SHAFT

2



ID	Task Name	Duration	Year 1				Year 2				Year 3						
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4			
1	Mobilization	4w	■														
2	Mobilize	4w	■														
3	Plant Set-up	12w	■	■													
4	Plant Set-up	12w	■	■													
5	Inspect & Scale Shaft-2161'	1w		■													
6	Inspect & Scale Shaft	1w		■													
7	Install Construction Utilities	7.17w		■	■												
8	Install Utilities	7.17w		■	■												
9	Drill & Grout Lining	11.5w			■	■											
10	Drill & Grout Lining	11.5w			■	■											
11	Shaft Station Monolith-37"	4.78w				■	■										
12	Construct Bulkheads	0.8w					■										
13	Pour Concrete (37' high)	0.98w						■									
14	Cure Concrete	3w							■								
15	Lower Salado Compacted Clay Column-93.5'	4.96w							■	■							
16	Emplace Bentonite Blocks (93.5' high)	4.96w							■	■							
17	Lower Concrete-Asphalt Waterstop-50'	8.26w								■	■	■					
18	Excavate for Lower Plug	1.67w									■						
19	Pour Concrete-Lower Plug (23' high typ.)	0.28w										■					
20	Excavate Waterstop	0.63w											■				
21	Place Asphalt (4' high typ.)	0.72w												■			
22	Cool-down Asphalt	1w													■		

Project: AIR INTAKE SHAFT
 SEALING SCHEDULE
 Date: Tue 7/9/96

Task
 Progress
 Milestone

Summary
 Rolled Up Task
 Rolled Up Milestone

Rolled Up Progress

ID	Task Name	Duration	Year 1				Year 2				Year 3			
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4
23	Excavate for Upper Plug	1.67W												
24	Pour Concrete-Upper Plug (23' high typ.)	0.28W												
25	Cure Concrete	2W												
26	Compacted Salt Column-583.5'	23.58W												
27	Emplace & Compact Crushed/Screened Salt	23.58W												
28	Middle Concrete-Asphalt Waterstop-50'	8.25W												
29	Excavate for Lower Plug	1.67W												
30	Pour Concrete-Lower Plug	0.28W												
31	Excavate Waterstop	0.63W												
32	Place Asphalt	0.72W												
33	Cool-down Asphalt	1W												
34	Excavate for Upper Plug	1.67W												
35	Pour Concrete-Upper Plug	0.28W												
36	Cure Concrete	2W												
37	Upper Salado Compacted Clay Column-344'	18.24W												
38	Emplace Bentonite Blocks	18.24W												
39	Upper Concrete-Asphalt Waterstop-50'	10.25W												
40	Excavate for Lower Plug	1.67W												
41	Pour Concrete-Lower Plug	0.28W												
42	Excavate Waterstop	0.63W												
43	Place Asphalt	0.72W												
44	Cool-down Asphalt	1W												

Project: AIR INTAKE SHAFT SEALING SCHEDULE	Task	Summary	Rolled Up Progress
Date: Tue 7/9/96	Progress	Rolled Up Task	
	Milestone	Rolled Up Milestone	

1
2

ID	Task Name	Duration	Year 1				Year 2				Year 3			
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4
45	Excavate for Upper Plug	1.67w												
46	Pour Concrete-Upper Plug	0.28w												
47	Cure Concrete	4w												
48	Asphalt Column-138.3'	19.41w												
49	Remove Lining in Key	3.76w												
50	Remove Chemical Seal Rings	0.6w												
51	Mobilize to Emplace Asphalt	0.3w												
52	Asphalt in Salt Section	3.62w												
53	Asphalt in Lower Lined Section	1.93w												
54	Complete Asphalt Emplacement	2.77w												
55	Cool-down Asphalt	6.43w												
56	Concrete Plug-20'	5.99w												
57	Remove Concrete Lining & Rock	1.65w												
58	Remove Liner Plate	0.13w												
59	Pour Concrete(20' high)	0.21w												
60	Cure Concrete	4w												
61	Remove Concrete Shaft Lining	5.71w												
62	Remove 86' of lining-4 zones	5.71w												
63	Rustler Compacted Clay Column-234.7'	8.36w												
64	Emplace & Compact Bentonite(234.7' high)	8.36w												
65	Compacted Earthen Fill-473'	7.59w												
66	Emplace & Compact Earthen Fill(473' high)	7.59w												

Project: AIR INTAKE SHAFT SEALING SCHEDULE
 Date: Tue 7/9/98

Task Progress Milestone

Summary Rolled Up Task Rolled Up Milestone

Rolled Up Progress

1
2

ID	Task Name	Duration	Year 1				Year 2				Year 3							
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4				
67	Concrete Plug-40'	2.96w																
68	Clean Existing Surface	0.6w																
69	Pour Concrete(40' high)	0.36w																
70	Cure Concrete	2w																
71	Compacted Earthen Fill-57'	0.85w																
72	Emplace & Compact Earthen Fill (57' high)	0.65w																
73	Demobilization	3.2w																
74	Demob	3.2w																

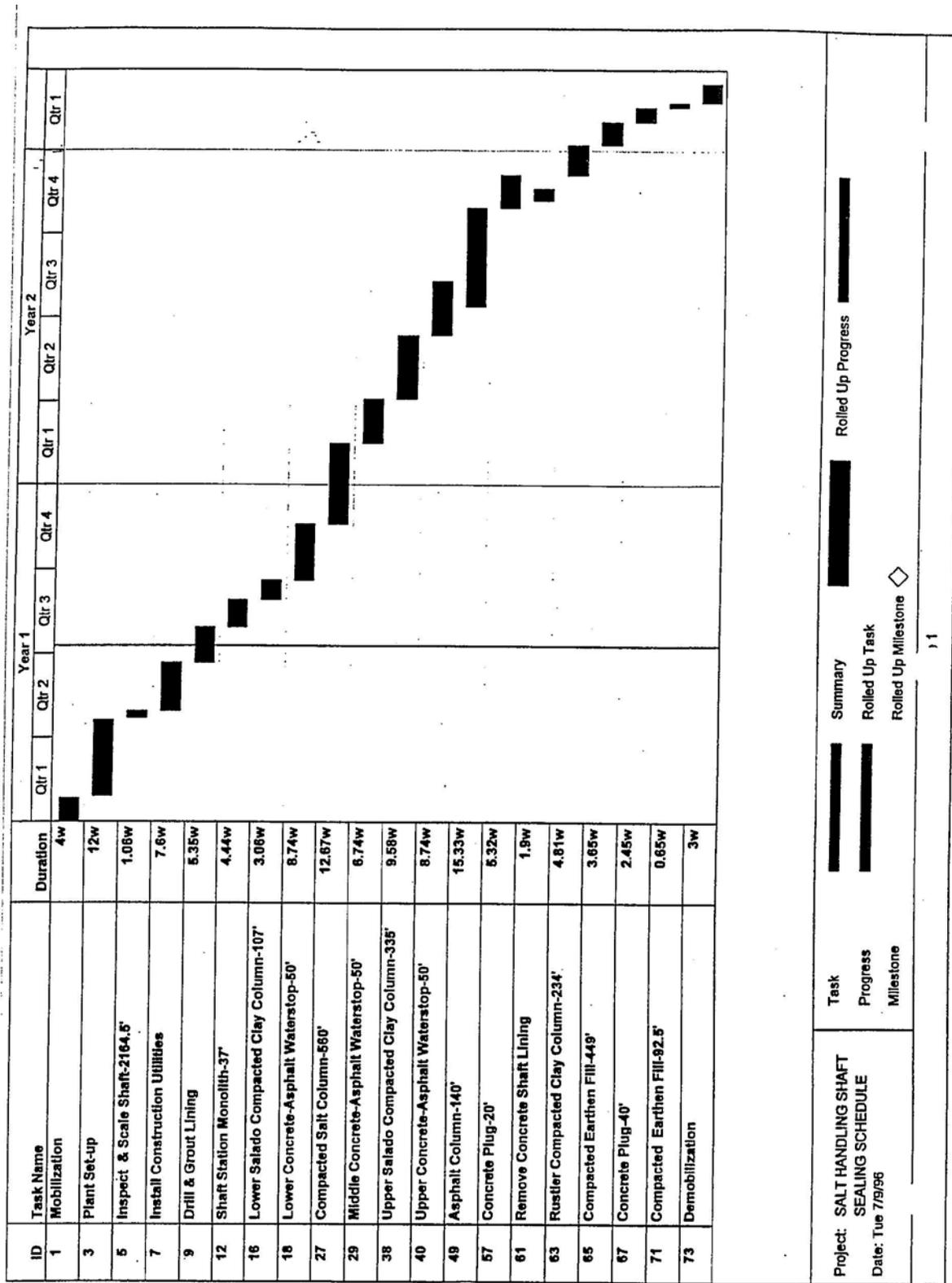
Project: AIR INTAKE SHAFT SEALING SCHEDULE	Task	Summary	Rollled Up Progress
Date: Tue 7/9/96	Progress	Rollled Up Task	
	Milestone	Rollled Up Milestone	◇

1
2

1

SEALING SCHEDULE - SALT HANDLING SHAFT

2



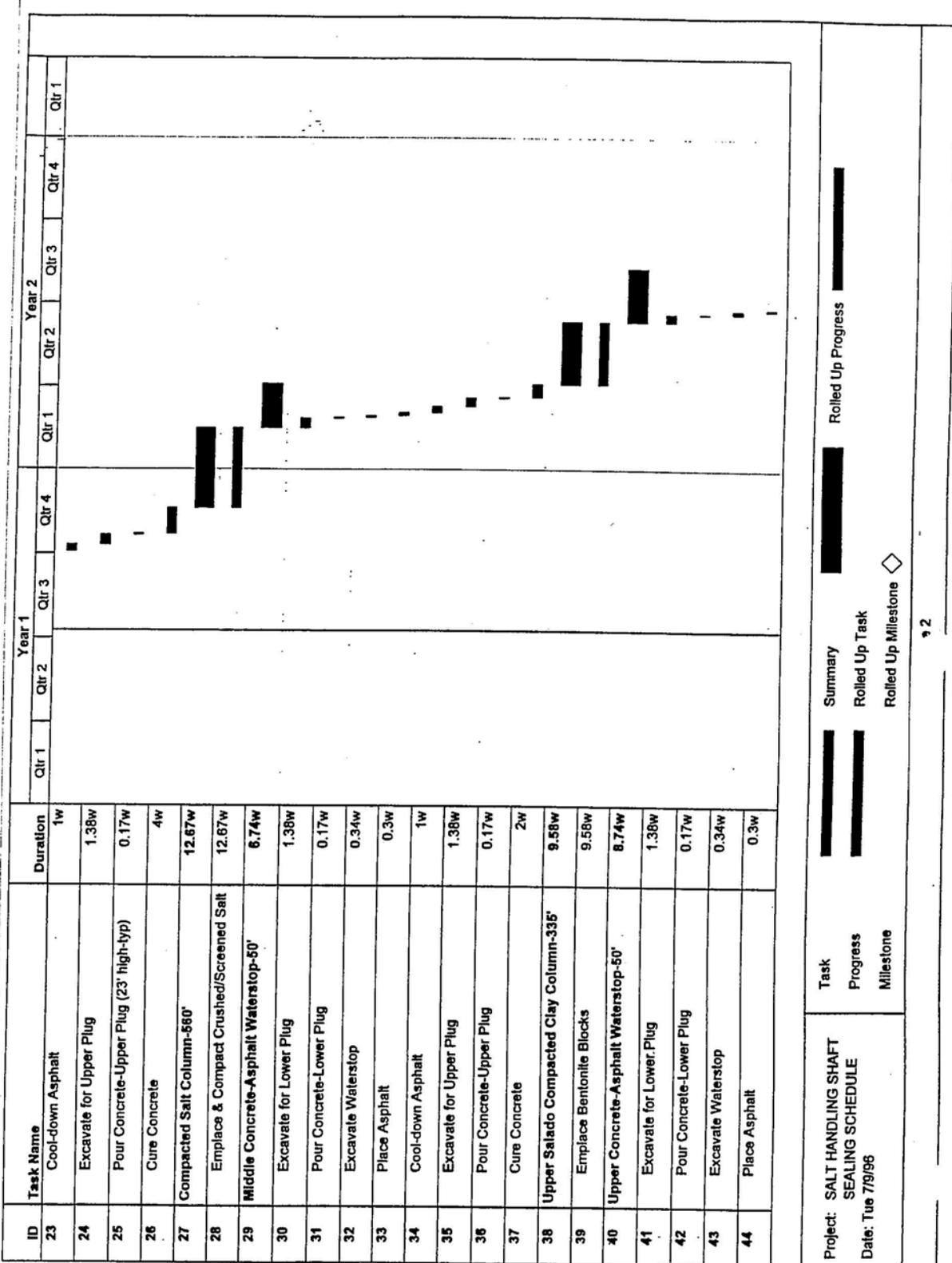
1
2

ID	Task Name	Duration	Year 1				Year 2						
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4			
1	Mobilization	4w	■										
2	Mobilize	4w	■										
3	Plant Set-up	12w		■									
4	Plant Set-up	12w		■									
5	Inspect & Scale Shaft-2164.5'	1.06w			■								
6	Inspect & Scale Shaft	1.06w			■								
7	Install Construction Utilities	7.6w		■									
8	Install Utilities	7.6w		■									
9	Drill & Grout Lining	5.35w			■								
10	Drill Grout Holes	2.14w			■								
11	Grout Lining	3.21w			■								
12	Shaft Station Monolith-37'	4.44w				■							
13	Construct Bulkheads	0.8w				■							
14	Pour Concrete (37' high)	0.64w				■							
15	Cure Concrete	3w				■							
16	Lower Salado Compacted Clay Column-107'	3.06w					■						
17	Emplace Bentonite Blocks (107.0' high)	3.06w					■						
18	Lower Concrete-Asphalt Waterstop-50'	8.74w						■					
19	Excavate for Lower Plug	1.36w						■					
20	Pour Concrete-Lower Plug (23' high-tyt)	0.17w						■					
21	Excavate Waterstop	0.34w						■					
22	Place Asphalt (4' high-tyt)	0.3w						■					

1
2

■ Task
■ Progress
◇ Milestone
■ Summary
■ Rolled Up Task
◇ Rolled Up Milestone
■ Rolled Up Progress

Project: SALT HANDLING SHAFT
 SEALING SCHEDULE
 Date: Tue 7/9/96



1
2

ID	Task Name	Duration	Year 1				Year 2						
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4			
45	Cool-down Asphalt	1w											
46	Excavate for Upper Plug	1.38w											
47	Pour Concrete-Upper Plug	0.17w											
48	Cure Concrete	4w											
49	Asphalt Column-140'	15.33w											
50	Remove Lining in Key	2.02w											
51	Remove Chemical Seal Rings	0.4w											
52	Mobilize to emplace asphalt	2w											
53	Asphalt in Salt Section	2.73w											
54	Asphalt in Lower Lined Section	0.25w											
55	Complete Asphalt Emplacement	1.5w											
56	Cool-down Asphalt	6.43w											
57	Concrete Plug-20'	5.32w											
58	Remove Concrete Lining & Rock	1.11w											
59	Pour Concrete (20' high)	0.21w											
60	Cure Concrete	4w											
61	Remove Concrete Shaft Lining	1.9w											
62	Remove 72' of lining-4 zones	1.9w											
63	Rustler Compacted Clay Column-234'	4.81w											
64	Emplace & Compact Bentonite (234' high)	4.81w											
65	Compacted Earthen Fill-449'	3.65w											
66	Emplace & Compact Earthen Fill (449' high)	3.65w											

Task	Summary	Rolled Up Progress
Progress	Rolled Up Task	
Milestone	Rolled Up Milestone	

Project: SALT HANDLING SHAFT SEALING SCHEDULE
 Date: Tue 7/9/96

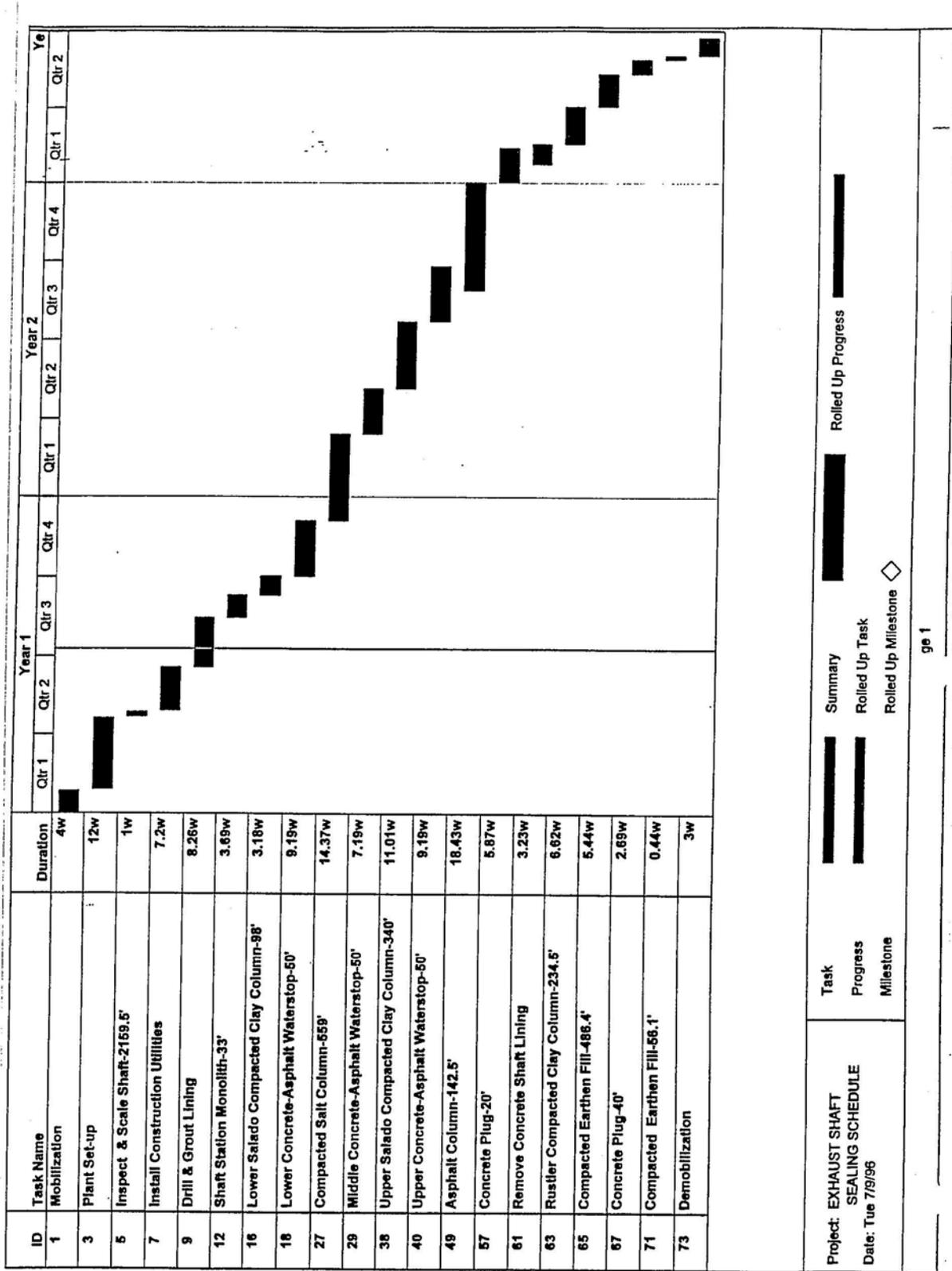
Page 3

1
2

1

SEALING SCHEDULE - EXHAUST SHAFT

2



ID	Task Name	Duration	Year 1				Year 2				Year			
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2		
1	Mobilization	4w	■											
2	Mobilize	4w	■											
3	Plant Set-up	12w	■	■										
4	Plant Set-up	12w	■	■										
5	Inspect & Scale Shaft-2159.5'	1w		■										
6	Inspect & Scale Shaft	1w		■										
7	Install Construction Utilities	7.2w		■	■									
8	Install Utilities	7.2w		■	■									
9	Drill & Grout Lining	8.26w			■	■								
10	Drill Grout Holes	3.3w			■									
11	Grout Lining	4.96w			■	■								
12	Shaft Station Monolith-33'	3.69w				■	■							
13	Construct Bulkheads	0.4w					■							
14	Pour Concrete (33' high)	0.29w					■							
15	Cure Concrete	3w					■							
16	Lower Salado Compacted Clay Column-98'	3.18w					■	■						
17	Emplace Bentonite Blocks (98' high)	3.18w					■	■						
18	Lower Concrete-Asphalt Waterstop-50'	9.19w						■	■	■				
19	Excavate for Lower Plug	1.45w							■					
20	Pour Concrete-Lower Plug (23' high-ty)	0.22w								■				
21	Excavate Waterstop	0.47w									■			
22	Place Asphalt (4' high-ty)	0.38w										■		

Task
 Progress
 Milestone

Summary
 Rolled Up Task
 Rolled Up Milestone

Rolled Up Progress
 Rolled Up Milestone

Project: EXHAUST SHAFT
 SEALING SCHEDULE
 Date: Tue 7/9/96

1
2

ID	Task Name	Duration	Year 1				Year 2				Year				
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2			
23	Cool-down Asphalt	1w													
24	Excavate for Upper Plug	1.45w													
25	Pour Concrete-Upper Plug (23' high-tp)	0.22w													
26	Cure Concrete	4w													
27	Compacted Salt Column-559'	14.37w													
28	Emplace & Compact Crushed/Screened Salt	14.37w													
29	Middle Concrete-Asphalt Waterstop-50'	7.19w													
30	Excavate for Lower Plug	1.45w													
31	Pour Concrete-Lower Plug	0.22w													
32	Excavate Waterstop	0.47w													
33	Place Asphalt	0.38w													
34	Cool-down Asphalt	1w													
35	Excavate for Upper Plug	1.45w													
36	Pour Concrete-Upper Plug	0.22w													
37	Cure Concrete	2w													
38	Upper Salado Compacted Clay Column-340'	11.01w													
39	Emplace Bentonite Blocks(340' high)	11.01w													
40	Upper Concrete-Asphalt Waterstop-50'	9.19w													
41	Excavate for Lower Plug	1.45w													
42	Pour Concrete-Lower Plug	0.22w													
43	Excavate Waterstop	0.47w													
44	Place Asphalt	0.38w													

Project: EXHAUST SHAFT SEALING SCHEDULE	Task	Summary	Rolled Up Progress
Date: Tue 7/9/96	Progress	Rolled Up Task	
	Milestone	Rolled Up Milestone	

1
2

ID	Task Name	Duration	Year 1				Year 2						
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4			
45	Cool-down Asphalt	1w											
46	Excavate for Upper Plug	1.45w											
47	Pour Concrete-Upper Plug	0.22w											
48	Cure Concrete	4w											
49	Asphalt Column-142.5'	18.43w											
50	Remove Lining In Key	3.15w											
51	Remove Chemical Seal Rings	0.5w											
52	Mobilize to Emplace Asphalt	2w											
53	Asphalt in Salt Section	2.64w											
54	Asphalt in Lower Lined Section	1.44w											
55	Complete Asphalt Emplacement	2.27w											
56	Cool-down Asphalt	6.43w											
57	Concrete Plug-20'	5.87w											
58	Remove Concrete Lining & Rock	1.7w											
59	Pour Concrete (20' high)	0.17w											
60	Cure Concrete	4w											
61	Remove Concrete Shaft Lining	3.23w											
62	Remove 84' of lining-4 zones	3.23w											
63	Rustler Compacted Clay Column-234.5'	6.62w											
64	Emplace & Compact Bentonite(234.5' high)	6.62w											
65	Compacted Earthen Fill-486.4'	5.44w											
66	Emplace & Compact Earthen Fill(486.4' high)	5.44w											

1
2

█ Summary
█ Rolled Up Progress
█ Task
█ Progress
█ Milestone
█ Rolled Up Task
◇ Rolled Up Milestone

Project: EXHAUST SHAFT
 SEALING SCHEDULE
 Date: Tue 7/9/96

ID	Task Name	Duration	Year 1				Year 2				Year			
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2		
67	Concrete Plug-40'	2.69w												
68	Clean Existing Surface	0.47w												
69	Pour Concrete	0.22w												
70	Cure Concrete	2w												
71	Compacted Earthen Fill-56.1'	0.44w												
72	Emplace & Compact Earthen Fill (56.1'high)	0.44w												
73	Demobilization	3w												
74	Demob	3w												

Project: EXHAUST SHAFT SEALING SCHEDULE Date: Tue 7/9/96	Task Progress Milestone	Summary Rolled Up Task Rolled Up Milestone	Rolled Up Progress
--	-------------------------------	--	--------------------

1
2

1

SEALING SCHEDULE - WASTE SHAFT

2

ID	Task Name	Duration	Year 1				Year 2				Year 3				Year 4	
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2
1	Mobilization	4w	■													
2	Mobilize	4w	■													
3	Plant Set-up	12w	■	■												
4	Plant Set-up	12w	■	■												
5	Inspect & Scale Shaft-2159.5'	1w		■												
6	Inspect & Scale Shaft	1w		■												
7	Install Construction Utilities	7.2w		■	■											
8	Install Utilities	7.2w		■	■											
9	Drill & Grout Lining	11.21w			■	■										
10	Drill Grout Holes	4.48w			■											
11	Grout Lining	6.73w			■											
12	Shaft Station Monolith-37'	5.17w			■											
13	Construct Bulkheads	1w			■											
14	Pour Concrete (37' high)	1.17w			■											
15	Cure Concrete	3w			■											
16	Lower Salado Compacted Clay Column-86'	5.01w			■											
17	Emplace Bentonite Blocks (96' high)	5.01w			■											
18	Lower Concrete-Asphalt Waterstop-50'	12.57w			■	■										
19	Excavate for Lower Plug	2.72w			■											
20	Pour Concrete-Lower Plug (23' high-tp)	0.27w			■											
21	Excavate Waterstop	0.84w			■											
22	Place Asphalt (4' high-tp)	0.75w			■											

1
2

Project: WASTE HANDLING SHAFT SEALING SCHEDULE
 Date: Tue 7/9/96

Task Progress Milestone

Summary Rolled Up Task Rolled Up Milestone

Legend: ■ Task Progress ■ Milestone

ID	Task Name	Duration	Year 1				Year 2				Year 3				Year 4		
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	
23	Cool-down Asphalt	1w															
24	Excavate for Upper Plug	2.72w															
25	Pour Concrete-Upper Plug (23' high-tp)	0.27w															
26	Cure Concrete	4w															
27	Compacted Salt Column-555.5'	22.87w															
28	Emplace & Compact Crushed/Screened Salt	22.87w															
29	Middle Concrete-Asphalt Waterstop-50'	10.57w															
30	Excavate for Lower Plug	2.72w															
31	Pour Concrete-Lower Plug	0.27w															
32	Excavate Waterstop	0.84w															
33	Place Asphalt	0.75w															
34	Cool-down Asphalt	1w															
35	Excavate for Upper Plug	2.72w															
36	Pour Concrete-Upper Plug	0.27w															
37	Cure Concrete	2w															
38	Upper Salado Compacted Clay Column-351.5'	17.86w															
39	Emplace Bentonite Blocks(351.5' high)	17.86w															
40	Upper Concrete-Asphalt Waterstop-50'	12.57w															
41	Excavate for Lower Plug	2.72w															
42	Pour Concrete-Lower Plug	0.27w															
43	Excavate Waterstop	0.84w															
44	Place Asphalt	0.75w															

1
2

Project: WASTE HANDLING SHAFT
 SEALING SCHEDULE
 Date: Tue 7/9/96

Task
 Progress
 Milestone

Summary
 Rolled Up Task
 Rolled Up Milestone

Roll Up Progress

ID	Task Name	Duration	Year 1				Year 2				Year 3				Ye		
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	
45	Cool-down Asphalt	1w															
46	Excavate for Upper Plug	2.72w															
47	Pour Concrete-Upper Plug	0.27w															
48	Cure Concrete	4w															
49	Asphalt Column-142.3'	20.71w															
50	Remove Lining in Key	3.8w															
51	Remove Chemical Seal Rings	0.6w															
52	Mobilize to emplace asphalt	0.3w															
53	Asphalt in Salt Section	4.01w															
54	Asphalt in Lower Lined Section	2.33w															
55	Complete Asphalt Emplacement	3.24w															
56	Cool-down Asphalt	6.43w															
57	Concrete Plug-20'	6.98w															
58	Remove Concrete Lining & Rock	1.73w															
59	Pour Concrete (20' high)	0.25w															
60	Cure Concrete	4w															
61	Remove Concrete Shaft Lining	5.07w															
62	Remove 64' of lining-4 zones	5.07w															
63	Rustler Compacted Clay Column-234.7'	10.99w															
64	Emplace & Compact Bentonite (234.7' high)	10.99w															
65	Compacted Earthen Fill-447'	8.25w															
66	Emplace & Compact Earthen Fill (447' high)	8.25w															

1
2

Task
 Progress
 Milestone

Summary
 Rolled Up Task
 Rolled Up Milestone

Rolled Up Progress

ID	Task Name	Duration	Year 1				Year 2				Year 3				Ye	
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2
67	Concrete Plug-40'	3.04w														
68	Clean Existing Surface	0.64w														
69	Pour Concrete	0.4w														
70	Cure Concrete	2w														
71	Compacted Earthen Fill-61.5'	1.14w														
72	Emplace & Compact Earthen Fill (61.5' high)	1.14w														
73	Demobilization	3.5w														
74	Demob	3.5w														

Task	Summary	Rolled Up Progress
Progress	Rolled Up Task	
Milestone	Rolled Up Milestone	

4

1
2

1 **B5. References**

2 Ahrens, E.H., and F.D. Hansen. 1995. *Large-Scale Dynamic Compaction Demonstration Using*
3 *WIPP Salt: Fielding and Preliminary Results*. SAND95-1941. Albuquerque, NM: Sandia National
4 Laboratories. (Copy on file in the Sandia WIPP Central Files, Sandia National Laboratories,
5 Albuquerque, NM [SWCF] as WPO31104.)

6 Ahrens, E.H., and M. Onofrei. 1996. "Ultrafine Cement Grout for Sealing Underground Nuclear
7 Waste Repositories," *2nd North American Rock Mechanics Symposium (NARMS 96), Montreal,*
8 *Quebec, June 19-21, 1996*. SAND96-0195C. Albuquerque, NM: Sandia National Laboratories.
9 (Copy on file in the SWCF as WPO31251.)

10 Ahrens, E.H., T.F. Dale, and R.S. Van Pelt. 1996. *Data Report on the Waste Isolation Pilot Plant*
11 *Small-Scale Seal Performance Test, Series F Grouting Experiment*. SAND93-1000.
12 Albuquerque, NM: Sandia National Laboratories. (Copy on file in the SWCF as WPO37355.)

13 Boonsinsuk, P., B.C. Pulles, B.H. Kjartanson, and D.A. Dixon. 1991. "Prediction of Compactive
14 Effort for a Bentonite-Sand Mixture," *44th Canadian Geotechnical Conference, Preprint Volume,*
15 *Calgary, Alberta, September 29-October 2, 1991*. Paper No. 64. Waterloo, Ontario: Canadian
16 Geotechnical Society. Pt. 2, 64/1 through 64/12. (Copy on file in the SWCF.)

17 Dale, T., and L.D. Hurtado. 1996. "WIPP Air-Intake Shaft Disturbed-Rock Zone Study," *4th*
18 *International Conference on the Mechanical Behavior of Salt, Montreal, Quebec, June 17-18,*
19 *1996*. SAND96-1327C. Albuquerque, NM: Sandia National Laboratories. (Copy on file in the
20 SWCF.)

21 Hansen, F.D., and E.H. Ahrens. 1996. "Large-Scale Dynamic Compaction of Natural Salt," *4th*
22 *International Conference on the Mechanical Behavior of Salt, Montreal, Quebec, June 17-18,*
23 *1996*. SAND96-0792C. Albuquerque, NM: Sandia National Laboratories. (Copy on file in the
24 SWCF as WPO39544.)

25 Knowles, M.K., and C.L. Howard. 1996. "Field and Laboratory Testing of Seal Materials
26 Proposed for the Waste Isolation Pilot Plant," *Proceedings of the Waste Management 1996*
27 *Symposium, Tucson, AZ, February 25-29, 1996*. SAND95-2082C. Albuquerque, NM: Sandia
28 National Laboratories. (Copy on file in the SWCF as WPO30945.)

29 McClintock, F.A., and A.S. Aragon. 1996. *Mechanical Behavior of Materials*. Reading MA:
30 Addison-Wesley.

31 Sandia (Repository Isolation Systems Department 6121). 1996. *Waste Isolation Pilot Plant Shaft*
32 *Sealing System Compliance Submittal Design Report*. SAND96-1326/1&2. Albuquerque, NM:
33 Sandia National Laboratories.

34 Van Sambeek, L.L. 1988. *Considerations for the Use of Quarried Salt Blocks in Seal*
35 *Components at the WIPP*. Topical Report RSI-0340. Rapid City, SD: RE/SPEC Inc. (Copy on
36 file in the SWCF as WPO9233.)

37

1
2

(This page intentionally blank)

1

FIGURES

2

(This page intentionally blank)

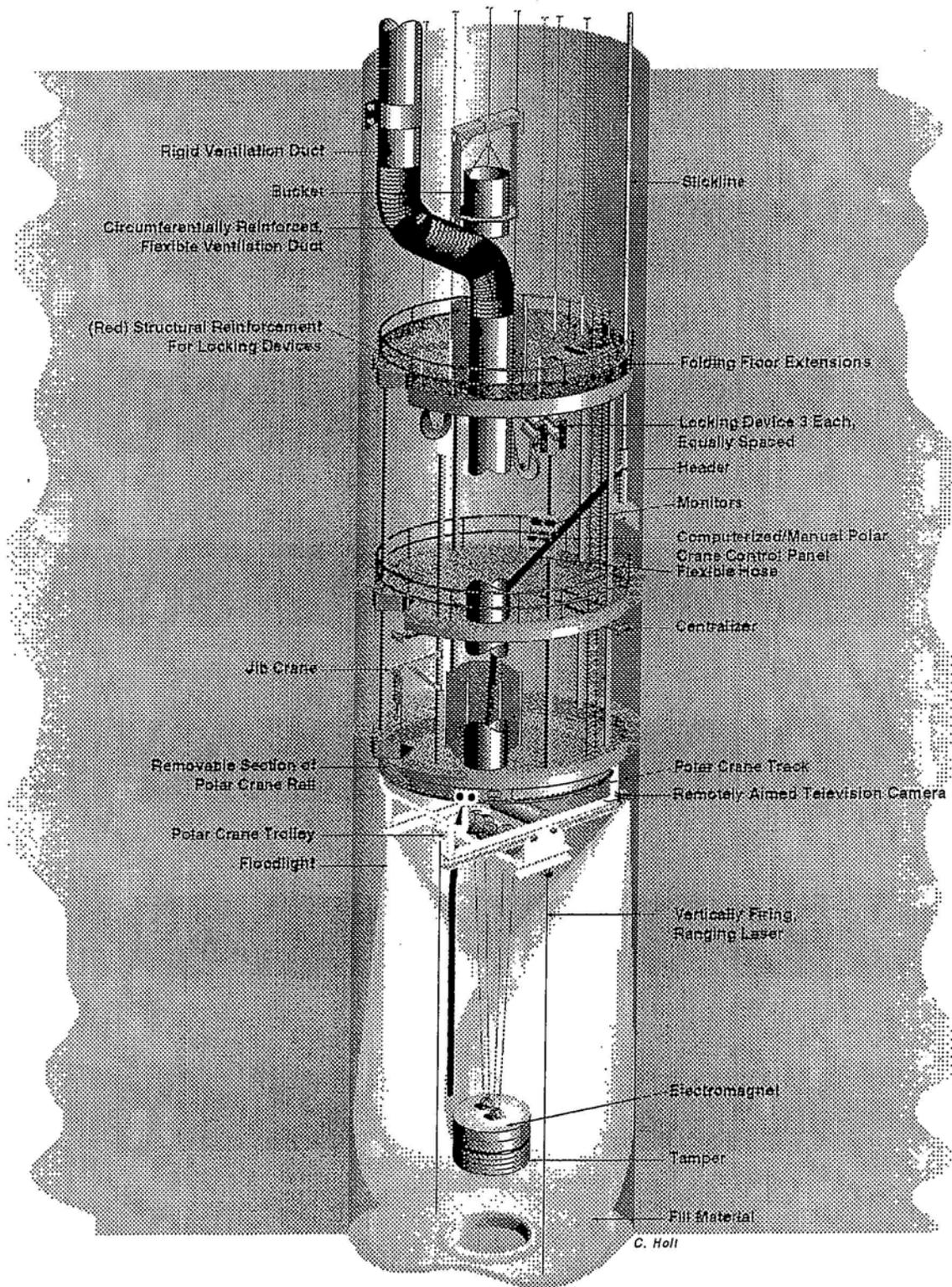


Figure G2B-1
Multi-Deck Stage Illustrating Dynamic Compaction

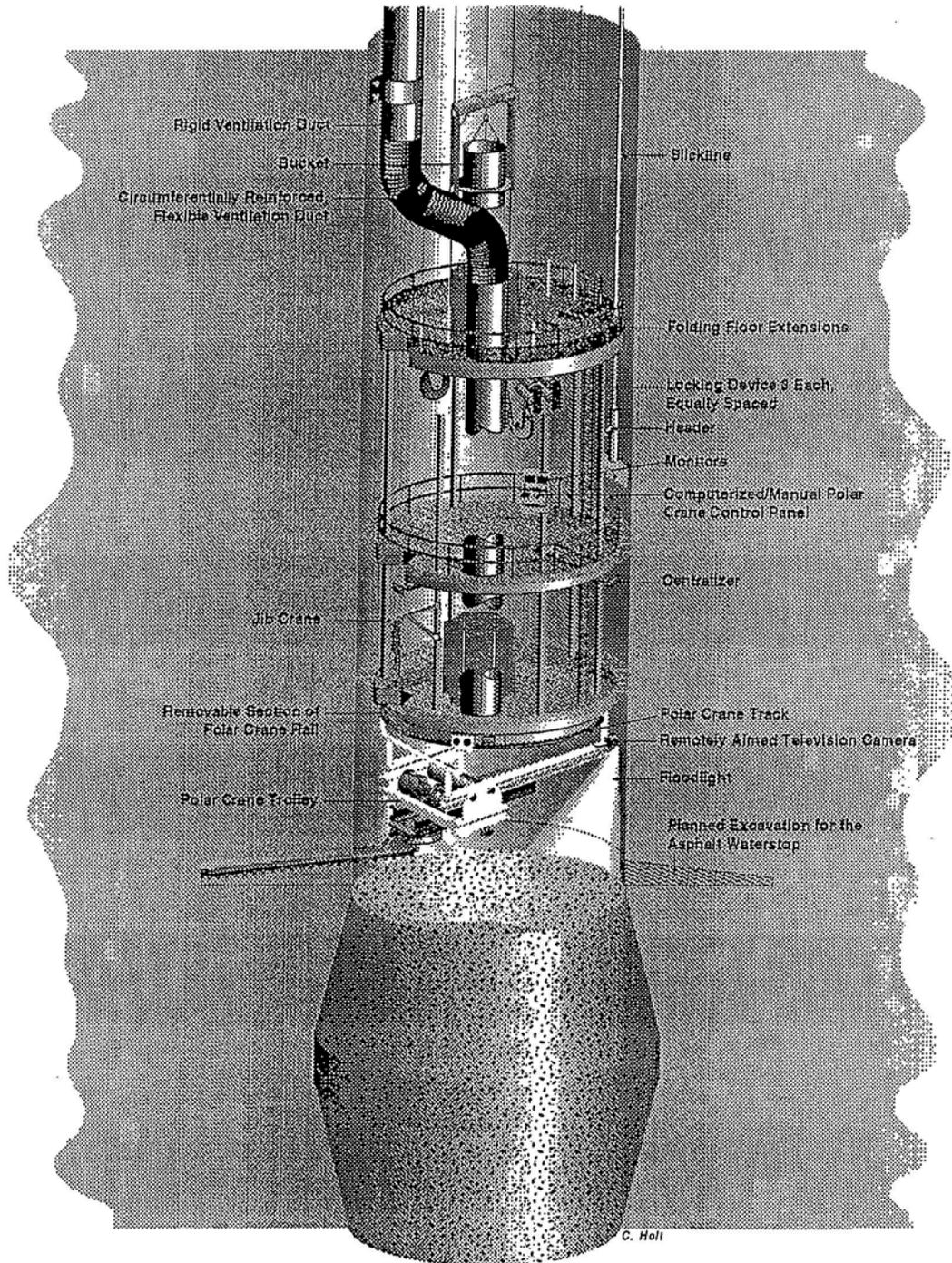
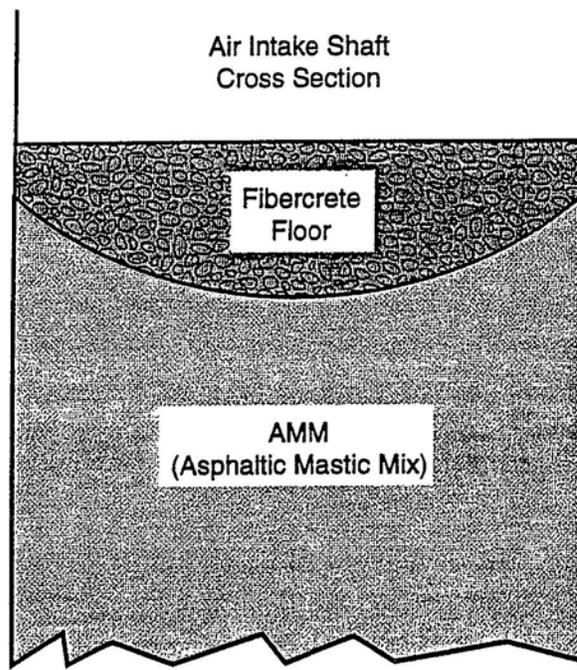
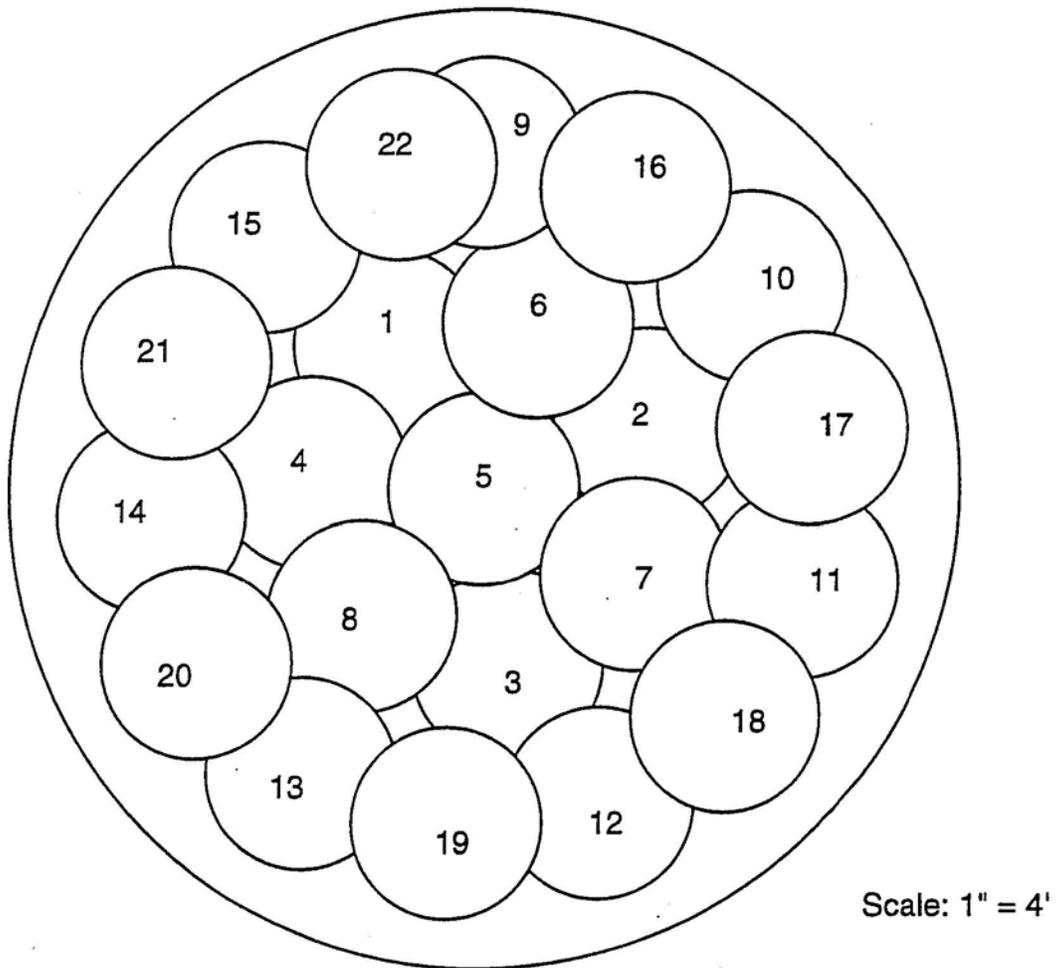


Figure G2B-2
Multi-Deck Stage Illustrating Excavation for Asphalt Waterstop



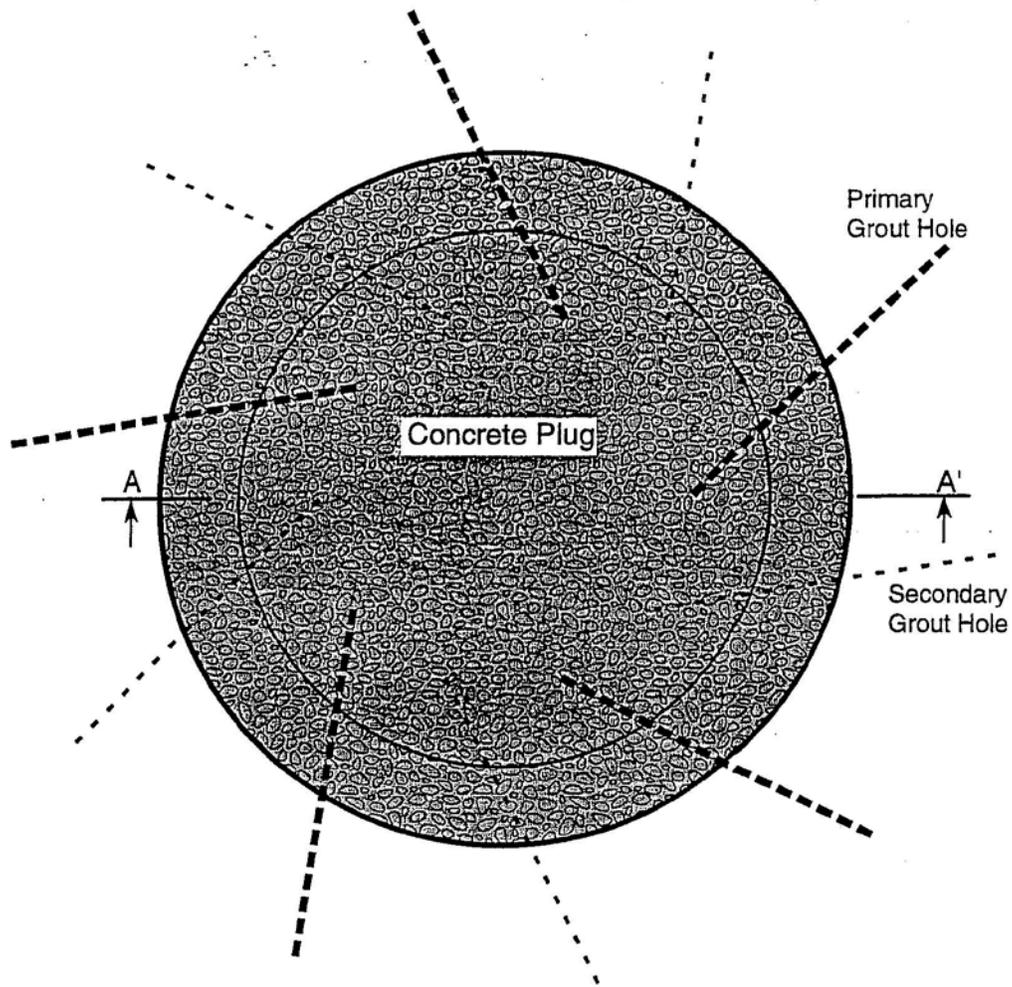
TRI-6121-375-0

Figure G2B-3
Typical Fibercrete at Top of Asphalt

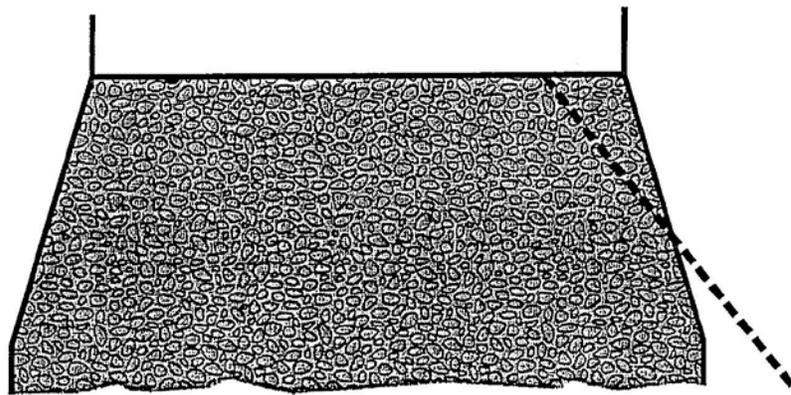


TRI-6121-376-0

Figure G2B-4
Drop Pattern for 6-m-Diameter Shaft Using a 1.2-m-Diameter Tamper



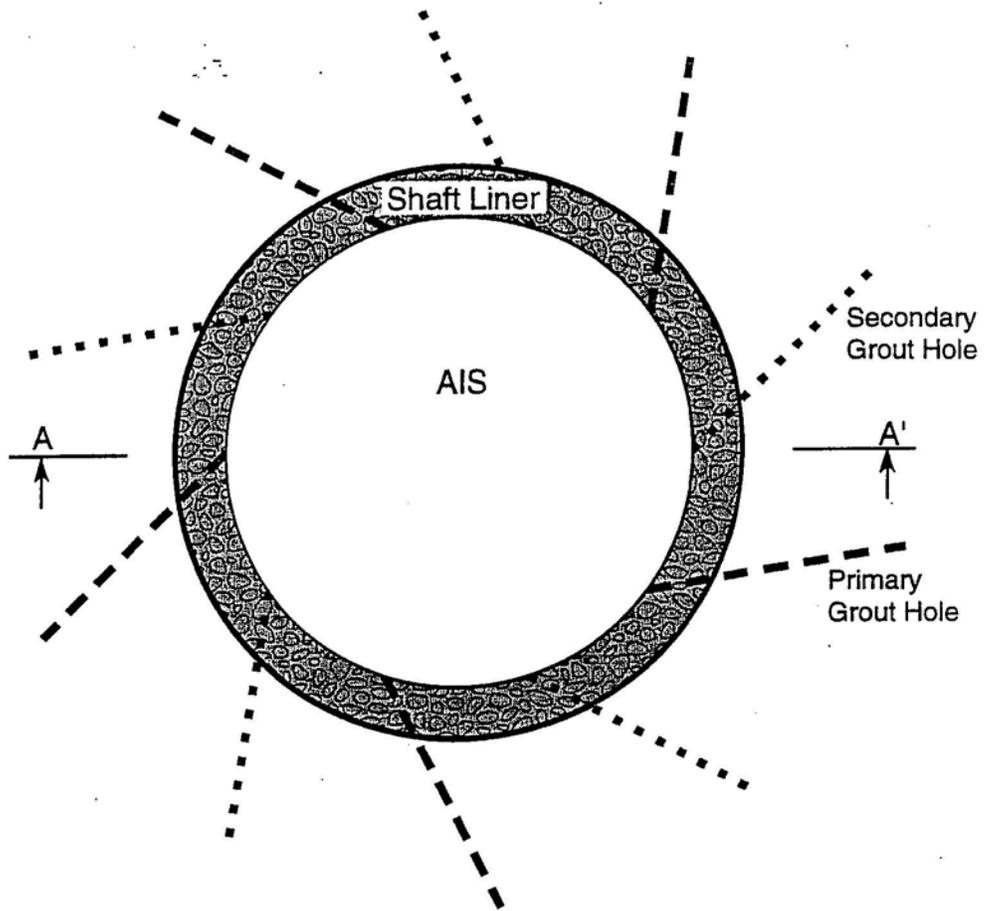
Plan View of Grout Holes in Spin Pattern



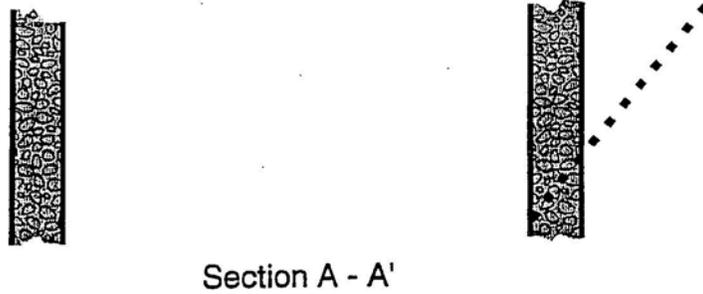
Section A - A'

TRI-6121-373-0

Figure G2B-5
Plan and Section Views of Downward Spin Pattern of Grout Holes



Plan View of Grout Holes in Spin Pattern



TRI-6121-374-0

Figure G2B-6
Plan and Section Views of Upward Spin Pattern of Grout Holes