Department of Energy
Office of Civilian Radioactive Waste Management
Office of Repository Development
1551 Hillshire Drive
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QA: N/A
Project No. WM-00011

JUL 28 2004

OVERNIGHT MAIL

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TRANSMITTAL OF REPORT EXTREME WIND/TORNADO/TORNADO MISSILE HAZARD ANALYSIS (REDACTED)

Reference: Ltr, Ziegler to Chief, High-Level Waste Branch (NRC), dtd 7/24/03 (Transmittal of Information Addressing KTI Agreement Item Preclosure Safety [PRE] 3.02)

This letter transmits as an enclosure the report, *Extreme Wind/Tornado/Tornado Missile Hazard Analysis* (Redacted), as requested by your staff. The full version (Official Use Only) of this report was previously transmitted to you by the referenced letter.

The enclosed redacted report can be made publicly available via the U.S. Nuclear Regulatory Commission's Public Document Room and the Agency-wide Documents Access and Management System (ADAMS). However, requests for a copy of this document from a third party should be referred to the Office of Repository Development, Freedom of Information/Privacy Act Officer.

There are no new regulatory commitments in the body or enclosure to this letter. Please direct any questions concerning this letter and its enclosure to Timothy C. Gunter at (702) 794-1343 or e-mail at timothy_gunter@ymp.gov, or Diane Quenell at (702) 794-5004 or e-mail diane_quenell@ymp.gov.

Joseph D. Ziegler, Director
Office of License Application and Strategy

OLA&S:TCG-1705

Enclosure:
Extreme Wind/Tornado/Tornado Missile Hazard Analysis, CAL-WHS-MD-000002, Revision 00B (Redacted)

NMSS07

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OCRWM	DESIGN CALCULATION OR ANALYSIS COVER SHEET	1. QA: QA 2. Page 1 of 35

3. System	4. Document Identifier
Waste Handling	CAL-WHS-MD-000002 REV 00B

5. Title
Extreme Wind/Tornado/Tornado Missile Hazard Analysis

6. Group
Preclosure Safety Analysis

7. Document Status Designation

☒ Preliminary ☐ Final ☐ Cancelled

8. Notes/Comments

Attachments	Total Number of Pages
Attachment I	4

RECORD OF REVISIONS

9. No.	10. Reason For Revision	11. Total # of Pgs.	12. Last Pg. #	13. Originator (Print/Sign/Date)	14. Checker (Print/Sign/Date)	15. QER (Print/Sign/Date)	16. Approved/Accepted (Print/Sign)	17. Date
00A	Initial issue.	30	I-3 of I-3	S.F. Alex Deng	Douglas D. Orvis	Steve Schuermann	Dennis Richardson	03/31/03
00B	Incorporating DOE review comments.	31	I-4 of I-4	S.F. Alex Deng [signature] 07/03/03	Douglas D. Orvis [signature] 7/3/03	Steve Schuermann [signature] 7/11/03	Dennis Richardson [signature] 7/10/03	

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ENCLOSURE

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ACRONYMS

DCT	Disposal Container Transporter
DOE	U.S. Department of Energy
DTF	dry transfer facility
HLW	high-level radioactive waste
HSM	horizontal storage module
ITS	important to safety
MGR	monitored geologic repository
NRC	U.S. Nuclear Regulatory Commission
NTS	Nevada Test Site
PC	Performance Category
RRF	Remediation/Repair Facility
SCT	Storage Cask Transporter
SNF	spent nuclear fuel
SSC	system, structure, or component
SSCs	systems, structures, and components
WPT	Waste Package Transporter

1. PURPOSE

As determined from *MGR External Events Hazards Analysis* (CRWMS M&O 2000a, Sections 6.3.3.10 and 6.3.3.44), hazards from extreme winds and tornadoes are applicable to the monitored geologic repository (MGR) during the preclosure period. Thus, the purpose of this analysis is twofold: the first is to provide the design input to account for the extreme winds and tornadoes for the systems, structures, and components (SSCs) that are important to safety (ITS); the second is to provide an analysis in response to the U.S. Nuclear Regulatory Commission (NRC) and U.S. Department of Energy (DOE) Agreement PRE.03.02, which reads as follows:

> Provide an analysis, including (1) selection of the design basis tornado, together with the supporting technical basis; (2) selection of credible tornado missile characteristics for the waste package and other structures, systems, and components, together with the technical bases; and (3) analysis of the effects of impact of the design basis tornado missiles or justification for excluding such tornado missiles as credible hazards.

To fulfill the purpose of the analysis, the following tasks are performed and the results are documented in this analysis:

- Establish the design basis wind speeds for the extreme wind and tornado and the corresponding missile spectrum for the Yucca Mountain Repository Project site (addresses Point 1 of PRE.03.02).
- Perform tornado and tornado missile screening analysis, based on probability and missile to exclude tornado missile as for certain SSCs ITS (addresses Point 3 of PRE.03.02).
- Establish the extreme wind or tornado missile spectrum for design bases of the SSCs ITS that were not excluded as credible hazards by the screening analysis (addresses Point 2 of PRE.03.02).
- Establish minimum thickness of concrete missile barriers as design bases to prevent effects of impact on by the design-basis missile spectrum (addresses Point 3 of PRE.03.02).

This analysis does not present design information to demonstrate that missile barriers are included in the design but does present the for tornado missile barriers that will tornado missile impact on

This analysis supports the development of risk-informed, performance-based design basis in accordance with 10 CFR Part 63 but also incorporates NRC precedents established for regulation of nuclear power plants.

This analysis is also an extension of a previous analysis of a similar title (CRWMS M&O 1999) in that tornado missile screening and tornado missile spectrum selection are performed in this analysis. Additional justification for establishing the MGR design basis tornado wind speed of is also provided in this analysis.

The intended use of this analysis is to establish the design basis wind speeds of the extreme wind and tornadoes and the corresponding missile spectrum.

This analysis is based on preliminary design information and shall not be used to support drawings and specifications for fabrication, procurement, or construction.

2. QUALITY ASSURANCE

As determined from Section 2.2.2 of *Quality Assurance Requirements and Description* (DOE 2003), this analysis is subject to the MGR quality assurance program requirements for classifying items important to radiological safety and waste isolation. This analysis is developed in accordance with procedures AP-3.13Q, *Design Control,* and AP-3.12Q, *Design Calculations and Analyses,* and, when revised using License Application design information, will provide input to the design of SSCs included on the *Q-List* (YMP 2001). Input data are identified and tracked in accordance with AP-3.15Q, *Managing Technical Product Inputs.*

3. USE OF SOFTWARE

No software is used for this analysis.

4. INPUTS

4.1 TECHNICAL INFORMATION AND PARAMETERS

4.1.1 Extreme Winds

Technical information related to MGR site-specific extreme winds and tornadoes was obtained from *Engineering Design Climatology and Regional Meteorological Conditions Report* (CRWMS M&O 1997; DTN: MO9811DEDCRMCR.000) and *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities* (DOE-STD-1020-2002, Table 3-2).

4.1.2 Tornadoes

Tornado related technical information was obtained from Regulatory Guide 1.76, *Design Basis Tornado for Nuclear Power Plants* and from NUREG/CR-4461, *Tornado Climatology of the Contiguous United States* (Ramsdell and Andrews 1986).

4.1.3 Tornado Missile Impact Parameter (Ψ)

The parameter is defined as the probability of tornado . A range of Ψ values is obtained from NUREG/CR-4710, *Shutdown Decay Heat Removal Analysis of a Combustion Engineering 2-Loop Pressurized Water Reactor, Case Study* (Cramond et al. 1987, Appendix G).

4.1.4 Tornado Missile Spectrum

The tornado missile spectrum is obtained from NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants* (NRC 1987, Section 3.5.1.4).

4.2 CRITERIA

Event frequency Category 2 screening criteria of 1E-6 per year is used for probability screening in this analysis. This is based on:

1. 10 CFR 63.2 which states, "Other event sequences that have at least one chance in 10,000 of occurring before permanent closure are referred to as Category 2 event sequences." This probability may be expressed as 1E-4.

2. Stating the frequency-screening threshold operationally in terms of frequency requires knowledge of the duration of the period before permanent closure. For this analysis, the frequency-screening threshold is conservatively set to 1E-6 per year, which generously allows emplacement and other handling operations to last up to 100 years before permanent closure (i.e., dividing 1E-4 by 100 years resulting in 1E-6 per year).

4.3 CODES, REGULATIONS AND STANDARDS

10 CFR Part 63. 2002. Energy: Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada.

10 CFR Part 71. 1987. Energy: Packaging and Transportation of Radioactive Material. Readily available.

ASCE 7-98. 2000. *Minimum Design Loads for Buildings and Other Structures.* Revision of ANSI/ASCE 7-95.

DOE-STD-1020-2002. 2002. *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities.*

5. ASSUMPTIONS

5.1 The number of tornado missiles used in this analysis is assumed to be This number is based on NUREG/CR-4710, which was used in the tornado missile impact analysis for the St. Lucie Nuclear Power Plant (Cramond et al. 1987). This number is believed to be conservative because in general there are more objects at a typical nuclear power plant sites than at the MGR site such as etc. Also there are no at the MGR site. During construction phase (i.e., when one dry transfer facility (DTF) building is completed and in operation and the second DTF or any other buildings are under construction), there could potentially be the MGR site that could become . These could include etc. The assumed number of is still believed to be conservative and representative of most of the objects at the MGR site including the materials of construction. This assumption is used in Sections 6.4.3 and 7.2.

5.2 The Waste Package Transporter (WPT) traveling speed is assumed to be . This assumption is based on the of an operator. The maximum travel speed for the WPT is (CRWMS M&O 2000b). However an operator may need to WPT in order to operate the WPT. This assumption is used in Section 6.4.6.

5.3 The maximum number of trips per year for the WPT to travel from the DTF to the subsurface is estimated to be This assumption is based on the number of waste packages in the waste stream loading schedule (CRWMS M&O 2000c, Table 1; CRWMS M&O 2000d, Attachment III) for commercial and DOE spent nuclear fuel (SNF). The maximum number of waste packages loaded with the commercial SNF (CSNF) waste packages in any one year is (during the calendar year of 2015) which comprises about 67 percent of the total loading (CRWMS M&O 2000d, Attachment III). The percentage of waste packages for loading the DOE high-level radioactive waste (HLW) and SNF is about of the commercial waste packages, i.e., 120 [=365.5(0.33)] (CRWMS M&O 2000c, Table 1). Thus the total maximum loading in any one year for both CSNF and DOE HLW is about waste packages (=365.5 + 120). Therefore, the assumed one trip per one waste package, is conservative. This assumption is used in Section 6.4.6.

5.4 The Disposal Container Transporter (DCT) traveling speed is assumed to be based on using a conservative lower end speed value for this type of transporter, which has a maximum speed of (CRWMS M&O 2000b). This assumption is used in Section 6.4.6. At the completion of this analysis, the name of the DCT had been changed. Future revision of this analysis will reflect the correct current or future name of the DCT but the function and traveling speed of DCT are not expected to change. This assumption is used in Section 6.4.6.

5.5 The number of round trips per year for the DCT to travel from the DTF to the Remediation/Repair Facility (RRF) building is estimated to be (CRWMS M&O 2000e, Section 2.1). This assumption is used in Section 6.4.6.

5.6 The Storage Cask Transporter (SCT) traveling speed is approximately (McDaniel 2002, Section 3.2.1). This assumption is used in Section 6.4.6.

5.7 The number of round trips for the SCT to travel from the DTF to the waste aging area is estimated to be This assumption is based on (1) loading of for aging at the North Portal Pad (selected design per McDaniel 2002, Section 3.2.1.4); and (2) loading per waste package (McDaniel 2002, Section 3.2.1.4), for example, dividing resulting in This makes the total number of trips to be represents the loading for aging for the entire period of repository operation (McDaniel 2002, Section 3.2.1.4), which is very conservative to be used on a yearly basis. This assumption is used in Section 6.4.6.

5.8 At the MGR site, a normalized mean missile impact parameter (Ψ) value of missile frequency is assumed for . This assumption is based on normalized value for in NRC tornado intensity Regions I and II as presented in NUREG/CR-4710 (Cramond et al. 1987, Table 4-1a). This value is representative and conservative for the buildings at the MGR site, which are in NRC Region III. This assumption is used in Section 6.4.1.

5.9 At the MGR site, a normalized mean Ψ value of is assumed for This assumption is based on a normalized value for high exposure targets with a weighting factor of is presented in NUREG/CR-4710 (Cramond et al. 1987, Table 4-1b). This value is representative and conservative for , (for example, equipment at the MGR site). This assumption is used in Section 6.4.2.

5.10 The of the DTF building are , shown in Attachment I, Figures I-1 and I-2. Two DTF buildings are used in this analysis as shown in Attachment I, Figure I-3 (Williams 2002, Figure II-9). This assumption is used in Section 6.4.4.1 to calculate the target area of the DTF.

5.11 The location of the DTF is assumed to be at about the same location as are the shown in Attachment I, Figure I-3 (Williams 2002, Figure II-9). This assumption is used in Section 6.4.6.1 to determine the for different transporters.

5.12 The from the DTF to the North Portal is by measurement, based on the measured from one of the DTFs to the North Portal shown in Attachment I, Figure I-3 (Williams 2002, Figure II-9). This assumption is used in Section 6.4.6.1.

5.13 The from the DTF to the RRF is by measurement, based on the measured from one of the DTFs to the RRF shown in Attachment I, Figure I-3 (Williams 2002, Figure II-9). This assumption is used in Section 6.4.6.2.

5.14 The from the DTF to the waste aging area is . by measurement, based on the measured from one of the DTFs to the waste aging pad area shown in Attachment I, Figure I-3 (Williams 2002, Figure II-9) . This assumption is used in Section 6.4.6.3.

5.15 The DTF building is assumed to have five surfaces (four sides and roof) for the tornado missile target area calculation. This assumption is conservative since no missiles can strike the ground floor, and the This receiving area is not considered as (Assumption 5.17). However for conservatism, the wall on the in the target area calculations. The same assumption (i.e., excluding the ground floor and any protected surface) is used for calculating the target areas of RRF and horizontal storage module (HSM). This assumption is used in Section 6.4.4.1.

5.16 The storage module shown in Transnuclear West (2002, Table 1.2-2) is assumed to be representative of the HSM to be used at the aging facility at the MGR site. There are of such storage modules (McDaniel 2002, Section 3.2.1.4). This assumption is used in Section 6.4.4.1.

5.17 Structures and equipment that handle or store intact transportation casks, licensed to 10 CFR Part 71, are assumed to tornado missile impact based on: (1) 10 CFR Part 71 provides necessary and sufficient design bases to prevent release of radionuclides from a transport cask exposed to normal and abnormal transport environments including natural phenomenon; and (2) the metallic structure of a cask is tornado missiles per NUREG-0800 (NRC 1987, Section 3.5.3, II.B.6). This assumption is used in Section 6.4.4.1.

6. ANALYSIS

The analyses presented in this report focus on (1) the basis for selecting the design basis wind speeds for extreme wind and tornado; (2) the calculations of tornado missile probability screening; and (3) the basis for selecting the missile spectrum for designing the SSCs that are ITS; details on each are provided in Section 6.1.

6.1 EXTREME WINDS

The typical method to show design compliance for SSCs that have to withstand the effects of extreme winds is provided in Sections 2.3.1 and 3.3.1 of the *Standard Review Plan for Nuclear Power Plants* (NRC 1987). The Standard Review Plan states that the 100-year return period "fastest mile of wind" including vertical velocity distribution and gust factor should be used and be based on the standard published by the American National Standards Institute (ANSI) with suitable corrections for local conditions. The current standard published by ASCE is ASCE 7-98, *Minimum Design Loads for Building and other Structures,* which is a revision of ANSI/ASCE 7-95 published earlier by ANSI. The basic wind speed defined in this document is a 3-second gust with an annual probability of 0.02 of being equaled or exceeded (50-year mean recurrence interval).

Wind speed data have been collected near the MGR site (CRWMS M&O 1997). These data include observed maximum daily one-second gust and one-minute wind speed at 9 locations for the period 1993-1996. The magnitude of the 50-year and 100-year return wind speeds was also estimated from these site-specific data. These site-specific data are shown in Table 1 and correspond to the location with the highest value in the meteorological monitoring network. Note that the 1-second gust wind data shown in Table 1 are a conservative estimate of the 3-second gust defined in ASCE 7-98. However, the source of the data presented in Table 1 (CRWMS M&O 1997) is not qualified data based on AP-3.15Q, *Managing Technical Product Inputs.*

Table 1. Maximum Estimated and Observed Wind Speeds Near to Yucca Mountain, Nevada

	Wind Speed, m/sec [mph]	
	50-year, 1 second gust	100-year, 1 minute
Observed	40.22 [90]	33.16 [74]
Estimated	54.11 [121]	48.47 [109]

Source: CRWMS M&O 1997
Note: m = meters, mph = miles per hour, sec = seconds

An alternative data source is DOE-STD-1020-2002, which is a qualified data source based on AP-3.15Q. Table 3-2 of DOE-STD-1020-2002 provides recommended peak gust wind speeds for straight winds for different structure, system, or component (SSC) Performance Category (PC) groups for the DOE facilities. Based on Table 3-2 of DOE-STD-1020-2002, a wind speed of 117 miles per hour is specified for the Nevada Test Site (NTS) for PC-3. PC-3 is applicable for non-reactor nuclear facilities.

Design Basis Extreme Wind Speed—Based on the discussions presented above, a wind speed of 121 miles per hour (shown in Table 1) is selected as the design basis wind speed for the MGR site for the design of SSCs and is conservative relative to the 117 miles per hour in DOE-STD-1020-2002.

6.2 TORNADO

6.2.1 Tornado Data

The intensity of a tornado is normally measured by the Fujita-scale as shown in Table 2. The Fujita-scale rates the intensity of a tornado based on the damage caused, not by its size. Meteorologists often classify the F0 and F1 scale as weak tornadoes, the F2 and F3 scale as strong tornadoes, and the F4 and F5 scale as violent tornadoes. As indicated in Table 2, light object missiles are generated in the F2 scale, progressing to large missiles generated in the F4 scale and beyond.

Table 2. The Fujita Scale of Tornado Intensity

F-Scale Number	Intensity Descriptor	Wind Speed (mph)	Level of Damage
F0	Gale tornado	40-72	Chimneys damaged; tree branches broken off; shallow-rooted trees pushed over; sign boards damaged.
F1	Moderate tornado	73-112	Roof surfaces peeled off; mobile homes pushed off foundations or overturned; moving autos pushed off road.
F2	Significant tornado	113-157	Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
F3	Severe tornado	158-206	Roofs and some walls torn off well constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.

Table 2. The Fujita Scale of Tornado Intensity (continued)

F4	Devastating tornado	207-260	Well-constructed houses leveled; weak foundation structures relocated; cars thrown and large missiles generated.
F5	Incredible tornado	261-318	Strong frame houses lifted off foundation and carried considerable distance to disintegrate; trees debarked; automobile-sized projectiles hurtle through the air in excess of 100 yards; other incredible phenomena expected.
F6	Inconceivable tornado	319-379	Not provided.

Source: NOAA 2003. Notes: mph = miles per hour

Data about tornado occurrences in the Great Basin area of Nevada, Utah, Arizona, and portions of California from October 1986 through November 1996 were compiled in *Engineering Design Climatology and Regional Meteorological Conditions Report* (CRWMS M&O 1997). That report cites an earlier survey that indicated that there were no tornadoes reported on the NTS between 1916 and 1969 and only four within a 150-mile radius of the NTS. Only 12 tornadoes were reported in the entire state of Nevada between 1959 and 1973.

Out of a total of 73 reported tornadoes in the Great Basin areas in the October 1986 to November 1996 period: 15 tornadoes were in the F1 category with a wind speed greater that 32 meters per second (73 miles per hour), but less than or equal to 50 meters per second (113 miles per hour); four were in the F2 category with a wind speed greater that 50 meters per second, but less than or equal to 70 meters per second (157 miles per hour) (CRWMS M&O 1997). No F2 tornadoes were reported in the State of Nevada (CRWMS M&O 1997). The other 54 reported tornadoes were in the F0 category with speeds up to 32 meters per second (72 miles per hour). The tornado reported closest to Yucca Mountain was in Amargosa Valley, approximately 50 kilometers from Yucca Mountain. This F0 tornado occurred on July 16, 1987 (CRWMS M&O 1997).

In 1986, the NRC issued new guidance on tornado strike and intensity probabilities in NUREG/CR-4461 (Ramsdell and Andrews 1986). The new guidance was based on 30 years of data contained in the National Severe Storms Forecast Center tornado database from the period of January 1, 1954 through December 31, 1983. The report contains tornado characteristics including the number of occurrences, frequencies of occurrence, and average dimensions for the contiguous United States including the 5-degree and 1-degree latitude and longitude boxes. Table 3 provides a summary on the number and Fujita-scale of reported tornadoes pertaining to the MGR site.

Table 3 indicates that for the 30 years reporting period, there was no recorded tornado of any intensity for the 1-degree box containing the MGR site. For the 5-degree box, which covers part of California, a total of 25 tornadoes was reported, of which 17 were classified by intensity. The worst case was three of the F2 tornadoes. The number of unclassified tornadoes is included in the total number used to determine the point strike probabilities.

Table 3. Number of Tornadoes From 1954 to 1983 Pertaining to Monitored Geologic Repository Site

Description	F0	F1	F2	F3	F4	F5	F6	Unclassified [a]
1-degree box containing MGR site	0	0	0	0	0	0	0	0
5-degree box containing MGR site	8	6	3	0	0	0	0	8
Nevada State	6	3	0	0	0	0	0	11

Source: NUREG/CR-4461, Ramsdell and Andrews 1986.
NOTE: [a] "unclassified" refers to tornadoes observed but with insufficient data to permit classifying by Fujita scale.

The historical information previously reported shows that there has not been a high intensity tornado at the MGR site.

DOE-STD-1020-2002, Table 3-2, provides recommendations for selecting wind speeds corresponding to straight winds and tornadoes for the DOE facilities. Based on DOE-STD-1020-2002, Table 3-2, no tornado is specified for the NTS in any of the SSC PC groups, which indicates that tornado is not of a concern for the NTS. Since the NTS is contiguous to the Yucca Mountain site, this provides additional assurance that tornadoes are not a significant hazard to the MGR.

6.2.2 Tornado Design Basis Wind Speed

As discussed in Section 6.2.1, the only tornado reported close to Yucca Mountain was a F0 tornado, which occurred on July 16, 1987. It corresponds to a highest wind speed of 72 miles per hour based as shown in Table 2. Although historically no high intensity tornado has occurred at the MGR site, a conservative approach is used for the selection of a design basis tornado wind speed as described in the following discussion.

In NUREG/CR-4461 (Ramsdell and Andrews 1986), the maximum tornado wind speed for a given probability of occurrence is determined as follows:

$$P_{occur} = P_s P_i \quad \text{(Eq. 1)}$$

where

P_{occur} = the probability of tornado occurrence per year for intensity i
P_s = tornado point strike probability per year
P_i = tornado intensity probability

A Weibull probability distribution was developed in NUREG/CR-4461 to correlate the tornado wind speed and P_i for the eastern and western regions of the United States (Ramsdell and Andrews 1986, Figure 27). This guidance provides an approach for the MGR to use the intensity distribution of reported tornadoes west of the Rocky Mountains and so results in a higher proportion of severe tornadoes than have been observed near the MGR site. Also in

NUREG/CR-4461, a P_s value of 4.22E-6 per year was established (based on the expected area) for the 5-degree box containing the MGR site (Ramsdell and Andrews 1986, p. D-13 of Appendix D). The critical value of P_i is derived for a specified P_{occur}. Thus if 1E-6 per year is used as P_{occur} for MGR, the value of P_i correlates to a maximum tornado wind speed of 189 miles per hour using the Weibull distribution (Ramsdell and Andrews 1986, Figure 33). This is also based on the upper 90 percent confidence level of the point strike probability for the 5-degree box.

Using the same approach, Table 4 lists the wind speeds provided for 1E-5, 1E-6, and 1E-7 per year probabilities of occurrence for the 5-degree box containing Yucca Mountain. Table 4 shows both the nominal (expected) values (Ramsell and Andrews 1986, Figures 31 and 32), and the value associated with the upper end of the 90 percent confidence interval for strike probabilities (Ramsdell and Andrews 1986, Figures 30, 33, and 34). Statistically, this latter value is interpreted as the maximum value in a range that has a 90 percent chance of containing the true strike probability based on Table 4 and the threshold limit for credibility of 1E-6 per year. Thus the maximum wind speed value corresponding to 1E-6 per year selected for the MGR is 189 miles per hour.

Table 4. Tornado Wind Speed (miles per hour) for 5-degree Box Containing Yucca Mountain, Nevada

	Strike Probability of Occurrence per Year (Poccur)		
	1E-5	1E-6	1E-7
Nominal Wind Speed[a]	NP	131	NP
Upper 90% Wind Speed[a]	151	189	189

NOTES: [a]Wind speed is the sum of the translational and rotational components.
NP = Not Provided.
Source: NUREG/CR-446 (Ramsdell and Andrews 1986, Figures 30 through 34).

6.2.3 Design Basis Tornado Wind Speed for Monitored Geologic Repository Site

Based on the discussion presented in Section 6.2.2, the design basis tornado wind speed for MGR is selected as 189 miles per hour (shown in Table 4), which corresponds to a frequency of occurrence of 1E-6 per year. For a 189 miles per hour wind speed, the corresponding pressure drop is 0.81 pounds per square inch and the rate of pressure drop is 0.3 pounds per square inch per second (CRWMS M&O 1999).

6.3 TORNADO MISSILE SCREENING METHODOLOGY

Tornado missile screening utilizes the methodology documented in NUREG/CR-4710 (Cramond et al. 1987), which is based on the point strike probabilities of the tornado and tornado missiles. The details of the screening calculations are provided in Section 6.3.1.

6.3.1 Tornado Missile Impact Probability (P_{mi})

P_{mi}, the annual probability of a tornado missile impacting a given target on the MGR site is calculated by Equation 2.

$$P_{mi} = (P_s)(P_{ms}) \quad \text{(Eq. 2)}$$

where

P_s = tornado point strike probability per year

P_{ms} = conditional probability of tornado missile striking a particular target given a tornado strike at the MGR site.

The approach for calculating P_s is taken from NUREG/CR-4461 (Ramsdell and Andrews 1986). The approach for calculating P_{ms} is taken from NUREG/CR-4710 (Cramond et al. 1987). The calculations for the MGR site are presented in the following sections.

6.3.2 Tornado Point Strike Probability (P_s)

NUREG/CR-4461 (Ramsdell and Andrews 1986) provides a formula to calculate the tornado wind (not missile) point strike probability as follows:

$$P_s = A_t / [(A_r)(N_y)] \quad \text{(Eq. 3)}$$

where

P_s is the annual tornado point strike probability of any intensity

A_t is the total area affected by tornadoes

A_r is the area of the region (e.g., the 5-degree box)

N_y is the number of years in the period of record for which the tornado area was determined.

In NUREG/CR-4461, N_y is 30 years corresponding to the period of 1954 through 1983 (Ramsdell and Andrews 1986).

As discussed in NUREG/CR-4461 (Ramsdell and Andrews 1986), the parameter A_t is the product of the number of tornado events and a measure of the area affected by each tornado, termed the "event area." The event area could be an "expected area" or "average area." The expected area is calculated from a distribution, typically a lognormal distribution, which tends to result in a mean (or expected) value that is a large event area. The average area is the arithmetic average of observed or estimated areas of actual occurrences, and therefore, is computed from a small sample. When the form of the distribution is known, the expected value is a better estimate of the true mean than the arithmetic average. However when the number of reported tornadoes becomes too small, the expected values may also be in error even if the form of the distribution is correct. Based on the small number of tornadoes reported for the MGR site as discussed in Section 6.2.1, the average area is the better choice for calculating the tornado strike probability for MGR site application.

In NUREG/CR-4461 (Ramsdell and Andrews 1986), a 5-degree box centered on 37.5 degree latitude north and 117.5 degree longitude west contains the MGR site. Therefore the tornado point strike probabilities for the 5-degree box are selected to represent the MGR site. For this 5-degree box, a P_s value of 5.59E-7 per year, based on an average tornado area, is provided in NUREG/CR-4461 (Ramsdell and Andrews 1986, p. D-13 in Appendix D). This P_s value is used as the tornado strike probability for the MGR site and is considered appropriate for a risk-informed screening of tornado missiles as described in Section 6.5.

6.3.3 Tornado Missile Strike Probability (P_{ms})

The methodology for calculating the P_{ms} for structures and components is described in NUREG/CR-4710 (Cramond et al. 1987, Appendix G). This methodology has been used by some nuclear power utilities (e.g., Calvert Cliffs, Oconee, St. Lucie) to calculate the missile strike probabilities in their probabilistic risk assessments. Based on NUREG/CR-4710 (Cramond et al. 1987), the P_{ms} is defined as follows:

$$P_{ms} = A\, N_m\, \Psi \qquad \text{(Eq. 4)}$$

where

A = the area of the target (s) in question (in ft^2)

N_m = the number of candidate missiles

Ψ = the missile impact parameter, defined as the probability of impact/missile/unit target area/tornado point strike frequency

As described in NUREG/CR-4710 (Cramond et al. 1987), Ψ values are normalized based on the following variables:

- Size of targets
- Relative Fujita-scale distribution in the region surrounding the site
- Type and location of missiles
- Arrangement of buildings and location of missile targets.

The Ψ values were normalized for the previously listed variables using data from two nuclear power plants (Cramond et al. 1987). When normalizing the data for two plants in NRC tornado intensity Regions I and II (Regulatory Guide 1.76), it was found that the relative Fujita-scale distribution between regions does not have a significant effect on the Ψ values. The MGR is in Region III, thus Ψ values derived for Regions I and II are conservative for application to the MGR site.

6.4 MISSILE IMPACT PROBABILITY (P_{mi}) CALCULATIONS FOR MONITORED GEOLOGIC REPOSITORY SITE

Utilizing the methodology presented in NUREG/CR-4710 (Cramond et al. 1987), the missile impact probability calculations for the MGR site are performed in the following sections.

6.4.1 Ψ Value for Large Structures

The large structures refer to buildings in the that would be exposed to tornado missiles. NUREG/CR-4710 (Cramond et al. 1987, Table 4-1a) provides a normalized mean Ψ value of 1.23E-10/missile/unit target area/tornado point strike frequency for large structures (Assumption 5.8). This normalized mean value will be used for building structures at the MGR site.

6.4.2 Ψ Value for Small Targets

The small targets refer to the equipment in the that would be exposed to tornado missiles. Three normalized mean Ψ values for different degree of exposures have been derived for small targets (approximately 100 to 1000 ft^2) in NUREG/CR-4710 (Cramond et al. 1987, Table 4-1b). They are:.

- High exposure: per missile per square foot of target area per tornado point strike frequency.
- Medium exposure: per missile per square foot of target area per tornado point strike frequency.
- Low exposure: per missile per square foot of target area per tornado point strike frequency.

The exposure is defined as the exposure area of the targets relative to the population and location of the missiles, which would normally be based on the site survey and judgement. NUREG/CR-4710 (Cramond et al. 1987, p. G-37) uses weighting factors of 0.1 for high, 0.4 for medium and 0.5 for low exposures. The weighted sum of high, medium, and low exposures is 2.84E-10.

For the purposes of this analysis, a conservative high exposure value of 2.42E-9 with a weighting factor of 1.0 will be used (Assumption 5.9).

6.4.3 Number of Missiles (N_m)

The number of candidate missiles (those missiles which could to the components of interest) is typically determined by a detailed survey and walk down of the areas surrounding the site. Such data are not currently available for the MGR site. Therefore, representative information is derived from NUREG-4710, which provides the following distribution of missiles based on judgement and used in the St. Lucie probabilistic risk assessment (Cramond et al. 1987, p. G-37):

Probability Weighting	Number of Missiles (N_m)
0.2	
0.6	
0.2	

Therefore, the St. Lucie probabilistic risk assessment used the weighted average = (0.2)(5000) + (0.6)(25,000) + (0.2)(60,000) = 28,000.

Since the types and numbers of objects surrounding the MGR site cannot be determined at this time, the largest number of missiles with probability of used. This is considered to be conservative since there are more missiles surrounding the eastern nuclear power plant sites than expected at the MGR site (Assumption 5.1).

6.4.4 Target Areas

The target areas for missile impact are defined as the total of the structure or component.

6.4.4.1 Large Structures

The structures refer to buildings in the at the MGR site that would be exposed to tornado missiles and house the Only structures that or SNF or HLW will be considered in this analysis. Thus, the two DTFs and the RRF are considered in this analysis.

Additionally, the located in the are also considered as structures. The is designed to for aging purposes and is made of There are a total of (Assumption 5.16). In the aging facility, the in In the row layout, are protected with a and are protected with a (Transnuclear West 2002, Table 1.2-2). For the purpose of missile impact probability analysis, the row is considered to be . This is conservative relative to assuming that

For calculating the target area of a DTF, only the the operations of the are considered. These sections form a However in the target area calculations the is not included because missiles cannot strike it. The to a missile strike because the are intact and no are performed in this section of a DTF (Assumptions 5.15 and 5.17). However for conservatism, the wall on the is included in the target area calculations. Thus,

Target area of DTF = length x width + 2 x length x height + 2 x width x height

=

(Attachment I)

sum of the lengths of the waste package load out and buffer area and the closure area and the transfer area =

For the the target area is calculated with four surfaces excluding the ground floor and the side Thus, Target area of RRF = length x width + 2 x length x height + width x height

=

(BSC 2003a and BSC 2003b)

For calculating the target area of the HSM, three sides of a box are considered excluding the ground floor and the two sides with . Thus,

Target area of one HSM = length x width + 2 x length x height

=

(Transnuclear West 2002, Table 1.2-2)

6.4.4.2 Small Targets

The small targets refer to the equipment in the at the MGR site that would be exposed to tornado missiles and contain the Equipment that does not contain will not be considered in this analysis regardless of its size. For this analysis, the WPT, the DCT, and the SCT are considered. The WPT carries the from the DTF to the subsurface. The DCT carries from DTF to the RRF building. The SCT carries from DTF to the waste aging area. The target areas of these transporters are calculated using the cylindrical surface areas. Thus,

WPT = π x diameter x height = (BSC 2001)

DCT = π x diameter x height = (BSC 2003c)

SCT = π x diameter x height = (BSC 2003d)

6.4.5 P_{ms} Values for Monitored Geologic Repository Site

Utilizing the values of Ψ, N_m, and target areas for and presented in the previous sections, the P_{ms} values can be calculated using Equation 4. Table 5 provides a summary of the P_{ms} results. The unit is probability/tornado point strike frequency.

Table 5. Calculated P_{ms} Values for Monitored Geologic Repository Site

	A	N_m	Ψ	P_{ms}[c]
DTF				
RRF				
HSM				
WPT				
DCT				
SCT				

NOTES: [a]P_{ms} value is for one DTF. [b]P_{ms} value is for 100 HSMs. [c]P_{ms} value calculated by Equation 4.

6.4.6 Equipment Exposure Time Probability (P_{expt})

The equipment exposure time is the of equipment, when and the . During this exposure time in the the equipment is if a tornado were to

The exposure time probability is calculated as follows:

6.4.6.1 WPT

1. Distance that a WPT travels between a

   D_{exp} = (Assumptions 5.11 and 5.12)

2. WPT traveling speed, S_{wpt} = (Assumption 5.2)
3. WPT exposure time per trip = D_{exp} / S_{wpt} = = per trip
4. Total number of trips = (Assumption 5.3)
5. Probability of Exposure Time P_{expt}=
   (probability of being in the when tornado strikes)

6.4.6.2 DCT

1. Distance that a DCT travels between a DTF to the RRF building,

   D_{exp} = (Assumption 5.13)

2. DCT traveling speed, S_{dct} = (Assumption 5.4)
3. DCT exposure time per trip = D_{exp} / S_{dct} = per trip
4. Total number of round trips = (Assumption 5.5)

5. Probability of Exposure Time P_{expt}=

A DCT needs to make , and
building, after remediation is completed.

6.4.6.3 SCT

1. Distance that a SCT travels between a DTF building to waste aging area,

   D_{exp} = (Assumption 5.14)

2. SCT traveling speed, S_{sct} = (Assumption 5.6)

3. SCT exposure time per trip = D_{exp} / S_{sct} =

4. Total number of round trips = (Assumption 5.7)

5. Probability of Exposure Time P_{expt}=

SCT needs to make and
area is completed.

6.4.7 Tornado Missile Impact Probability (P_{mi})

6.4.7.1 Large Structures

The missile impact probability (P_{mi}) can be calculated for large structures by multiplying P_{ms} by P_s per Equation 2. P_{mi} is the annual probability of a tornado missile of any size (generated by any tornado) striking each . P_s is the annual probability of a tornado strike for any point in the 5-degree box. The P_s value used is , which is based on NUREG/CR-4461 (Ramsdell and Andrews 1986) (see Section 6.3.2) and is applicable for MGR site in a five-degree box.

Knowing the P_{ms} values as presented in Section 6.4.5 (Table 5) and the P_s value, the P_{mi} values can be calculated for the large structures. The results are shown in Table 6.

Table 6. P_{mi} Values for Large Structures

	Ps	Pms	Pmi
DTF			
RRF			
HSM			

NOTE: [a]P_{mi} value is for one DTF.

The results in Table 6 indicate that for each of the large structures, the P_{mi} values are less than per year. However, the probability for any of these structures to be struck by a tornado missile is the sum of the probability of each of these structures. Thus the collective P_{mi} value is per year, which includes the probability for a tornado missile impacting

. The value of per year is used for tornado missile screening as discussed in Section 6.5.

6.4.7.2 Small Targets

The missile impact probability can be calculated for small targets or equipment by multiplying P_{ms} by P_s and P_{expt} (equipment exposure time probability) per Equation 5.

$$P_{mi} = P_{ms} (P_s) (P_{expt}) \qquad \text{(Eq. 5)}$$

Knowing the P_{ms} values as presented in Section 6.4.5 (Table 5) and the P_s (Section 6.3.2) and P_{expt} values (Section 6.4.6), the P_{mi} values can be calculated for small targets. The results are shown in Table 7.

Table 7. P_{mi} Values for Small Targets

	Ps	Pms	Pexpt	Pmi
WPT				
DCT				
SCT				

The results in Table 7 indicate that for the small targets, the P_{mi} values are much less than the threshold screening value of per year.

6.5 TORNADO MISSILE SCREENING BASED ON IMPACT PROBABILITY

Tornado missile impact probability screening is based on treating the tornado strike as the initiating event and generation of missiles and missile strike on an SSC as part of an event sequence. Then, the joint probability of the tornado strike and the probability of a missile striking an SSC give the annual probability of an event sequence. The screening criteria of per year (Section 4.2) is used to determine the credibility of a missile striking an SSC.

The probability of missile generation and the probability of striking a given target area are combined in the parameter Ψ. The Ψ value used in calculating the missile strike probability is normalized based on the information for various parameters related to Ψ. This information was collected at nuclear power plant sites in the eastern region of the United States (Cramond et al. 1987), which is conservative in the application for the MGR site. The final normalized Ψ values are to the tornado F-scale distribution (Cramond et al 1987, p. G-35). However, the final normalized Ψ values are for the MGR site because the contribution of large F-scale tornadoes just does on the data presented in NUREG/CR-4461 (Ramsdell and Andrews 1986) for the 5-degree box containing MGR site.

6.5.1 Large Structures

The results presented in Tables 6 and 7 show that the P_{mi} values are less than per year for structures containing . Thus the structures, i.e., can be screened out from tornado missile strikes if each of these structures is treated from the missile strike. However the probability for a tornado missile to strike any of the structures is the sum of the probabilities for all of the structures, including the , as listed in Table 6. This results in a collective probability of per year. Therefore, collectively, the structures are from the possibility of a tornado missile strike. As a result, the structures will be designed to withstand tornado missile strike from missiles as defined in Section 8 and the waste packages inside these structures will be protected from missiles.

6.5.2 Small Targets

Based on the results presented in Section 6.4.7, which show that the P_{mi} values are less than per year for the equipment containing (e.g., can be from tornado missile strikes. Because the will not be operated at the same time, each can be treated as independent and thus no summation of the strike probabilities is necessary as is done for the structures. Even if the strike probabilities from the were summed, the overall probability would still be much less than per year. As a result, the inside the equipment can be screened out from credible tornado missile strikes.

7. SENSITIVITY ANALYSIS

The of the tornado missile probability screening are the following:

- Missile impact parameter (Ψ)
- Number of missiles (N_m)
- Equipment exposure time probability (P_{expt})
- Tornado point strike probability (P_s).

The sensitivity evaluation on each of these parameters is presented in Section 7.1.

7.1 MISSILE IMPACT PARAMETER (Ψ)

As discussed in Section 6.4.2, a high exposure value of of target area frequency with a weighting factor of is used to calculate the missile impact probability for small targets. Using weighting factors other than 1.0 for high exposure and applying Ψ values for medium and low exposures would result in a Ψ value of (Section 6.4.2) which would be almost ten times less than the value of used in the impact probability calculations. Thus the value of is very conservative for calculating the missile impact probability for and no further change in Ψ value will be considered.

7.2 NUMBER OF MISSILES

Generally, for nuclear power plants, the number of missiles is estimated from the the plant site by a site walkdown. The sources of missiles include etc. Because the major buildings at the MGR site (e.g., DTFs, RRF) do not currently exist, it is very difficult to estimate the number of missiles that could be generated by tornadoes. During the , when one DTF building is completed and in operation and the second DTF or any other buildings are under construction, there could,

The number of missiles used in this analysis is based on NUREG/CR-4710 (Cramond et al. 1987), which was used in the tornado missile impact analysis for the St. Lucie Nuclear Power Plant. This number is believed to be conservative (Assumption 5.1). If the number of missiles is increased to , then the P_{mi} values will be increased by a factor of . Based on the results presented in Section 6.4, still would result in the screening out of tornado impact for the structures independently and the equipment such as

7.3 EQUIPMENT EXPOSURE TIME PROBABILITY

The parameters used to calculate the exposure time are distance, speed and number of trips per year. The values of distance and speed are not expected to change much. For the number of trips, is conservative based on the waste stream loading schedule (Assumption 5.3). If this number is increased by , for example, then the exposure time will be increased by a factor of which results in a . change in the P_{mi} values for WPT.

For DCT, the value of per year (Assumption 5.5) is based on *Waste Package Remediation System Description Document* (CRWMS M&O 2000e, Section 2.1). A reasonable increase would be more; for example, a factor of This . results in a minimal change in the P_{mi} values for DCT.

7.4 TORNADO POINT STRIKE PROBABILITY

In NUREG/CR-4461 (Ramsdell and Andrews 1986), there are two values of tornado point strike probability (P_s). The value of per year is based on the tornado expected area and is used in this analysis to determine the maximum tornado wind speed. The value of per year is based on the tornado average area and is used in this analysis for tornado missile probability screening. For maximum wind speed determination, it is more conservative to use the expected area value. For missile probability screening, as discussed in Section 6.3.2, the tornado average area is used because there were no tornadoes reported in the MGR site. For this sensitivity study, the P_s value of per year corresponding to the expected area is used to calculate the missile impact probability (P_{mi}) using Equation 5. The results are presented in the Table 8.

Table 8. P_{mi} Values Using the Tornado Strike Probability (P_s) Value of

Large Structures	DTF	RRF	HSM
Small Targets	WPT	DCT	SCT

The results in Table 8 indicate that none of the large structures, when treated can be screened out from the tornado missile strike when a P_s value of per year is used, which corresponds to a tornado expected area. In this case, the probability that any one of these structures is struck by a missile is the sum of the probabilities for 1 the _; for example, per year. The small targets can still be screened out from the tornado missile strike when a P_s value of per year is used.

8. TORNADO MISSILE SPECTRUM FOR MONITORED GEOLOGIC REPOSITORY SYSTEM, STRUCTURE, OR COMPONENT DESIGN

The results of the screening process presented throughout Sections 6 and 7 indicate that the cannot be screened out from the tornado missile strike when the strike probability of all of the are summed even when the tornado average area is used. Thus, tornado missiles need to be specified for designing the structures that are , at the MGR site. This section provides the tornado missile spectrum and the basis for their selection. The typical method for demonstrating compliance with the design of structures that have to withstand the effects of tornado-generated missiles is provided in NUREG-0800, Section 3.5.3, Barrier Design Procedures, and Section 3.5.1.4, Missiles Generated by Natural Phenomena. Section 3.5.1.4 requires that the applicant has postulated missiles that include at least three objects (NRC 1987):

1. A massive high kinetic energy missile that deforms on impact

2. A rigid missile to test penetration resistance

3. A small rigid missile of a size sufficient to just pass through any openings in protective barriers.

Section 3.5.1.4 of NUREG-0800 also identifies two missile spectra that will satisfy this requirement (NRC 1987):

1. missiles include an The impact speed required is of the maximum horizontal wind speed of the design basis tornado. The first nissiles are assumed to impact at normal incidence. The last missile is assumed to impinge upon barrier openings in the most directions.

2. missiles may be used as an alternative to missiles. missiles and their associated horizontal speeds are provided in Table 9.

Table 9. Missiles

Missile	Mass (kg)	Dimensions (m)	Velocity (m/sec)
A.			
B.			
C.			
D.			
E.			
F.			

Sources: NRC 1987, Section 3.5.1.4, associated with Region III
Note: kg = kilogram, m = meter, sec = second, Sch. = schedule.

Vertical velocities of of the postulated horizontal velocities are used in both spectra except for the small missile in in . These missiles should have the same velocity in all directions. Missiles A, B, C, and E, listed in Table 9, are to be considered at all elevations, whereas missiles D and F are to be considered at elevations up to of the facility structures.

of concrete or steel should be provided to prevent penetrations and in the case of in case of missile impact. The minimum barrier thickness should , than the values shown in Table 10 (NRC 1987, Section 3.5.3).

Table 10. Minimum Acceptable Barrier Thickness Requirements for Local Damage Prediction Against Tornado Generated Missiles

Region III		
Concrete Strength (psi)	*Wall Thickness* (inches)	*Roof Thickness* (inches)

Source: NRC 1987, Section 3.5.3.
Note: psi = pounds per square inch

9. CONCLUSIONS

Based on the results presented throughout Sections 6, 7, and 8, it is concluded that:

9.1 The design basis extreme wind speed is 121 miles per hour, which is a 50-year return 1-second gust wind. It is based on the historical data collected at the MGR site during the years of 1993 through 1996, and the DOE-STD-1020-2002 design basis wind for PC-3 facilities at the NTS.

9.2 The design basis tornado wind speed for MGR site is 189 miles per hour, which corresponds to a frequency of occurrence of 10^{-6} per year. It is based on regulations and precedents in Regulatory Guide 1.76 for nuclear reactors and the updated data in NUREG/CR-4461 (Ramsdell and Andrews 1986) for a 5-degree box containing the MGR site. For the 189 miles per hour wind speed, the corresponding pressure drop is 0.81 pounds per square inch and the rate of pressure drop is 0.3 pounds per square inch per second (CRWMS M&O 1999). Both, the design basis extreme wind speed of 121 miles per hour and the design basis tornado speed of 189 miles per hour are considered in the design of the SSCs that are ITS.

9.3 Tornado missiles for buildings based on a risk-informed application of tornado missile impact probability calculations using the parameter values corresponding to a 5-degree box for the MGR site.

9.4 Tornado missiles for equipment based on a risk-informed application of tornado missile impact probability calculations using the parameter values corresponding to a 5-degree box for the MGR site and to a tornado probability based on either the tornado expected area or the tornado average area. As a result, the waste packages tornado missile strikes.

9.5 Tornado missile specified in the NUREG-0800 (NRC 1987, Section 3.5.1.4) will be used for designing the structures that are ITS at the MGR site. missiles are selected because, as stated in Section 3.5.1.4 of NUREG-0800, these are selected by the National Bureau of Standards as representative of construction site missiles. Since the MGR site will be under concurrent operations and construction for both the surface and subsurface facilities during a part of the preclosure period, missiles are selected as being appropriate design basis for the MGR site. Further, the accepted thickness for tornado missile barriers specified in NUREG-0800 is based on missiles (NRC 1987, Section 3.5.3).

9.6 The design bases of structures that are ITS should provide the wall and roof thickness that of concrete missile barriers presented in Table 10 (or) to prevent effects of impact on SSCs ITS by design-basis missiles (. The thickness specified for missiles specified in NUREG-0800 (NRC 1987, Section 3.5.3) is based on the missile speeds corresponding to tornado Region I, which than those for Region III, presented in Table 9. Therefore the presented in Table 10 are conservative design bases for the missiles recommended in 9.5. Waste packages and other radioactive waste forms inside these structures will be protected from missiles, and there is no need to assess the effects of impact of design-basis tornado missiles as initiators of radiological event sequences.

The results presented in this analysis indicate that the outputs are reasonable compared to the identified inputs and that the results are suitable for the intended use.

10. REFERENCES

10.1 DOCUMENTS CITED

BSC (Bechtel SAIC Company) 2001. *Repository Design, Waste Package Transporter.* DWG-WES-ME-000002 REV A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20020102.0326.

BSC 2003a. *Remediation/Repair Facility General Arrangement, Roof Plan, Option B.* SR-ME-SK-130-xxx-00A. Las Vegas, Nevada: Bechtel SAIC Company.

BSC 2003b. *Remediation/Repair Facility General Arrangement.* SR-ME-SK-130-901-00A. Las Vegas, Nevada: Bechtel SAIC Company.

BSC 2003c. *Disposal Container Transporter, Mechanical Equipment Envelope.* SR-ME-SK-1501-601-00A. Las Vegas, Nevada: Bechtel SAIC Company.

BSC 2003d. *Waste Aging Facility Mechanical Flow Diagram.* 170-MHO-HMAO-00303-000-00A. Las Vegas, Nevada: Bechtel SAIC Company.

Cramond, W.R.; Ericson, D.M., Jr.; and Sanders, G.A. 1987. *Shutdown Decay Heat Removal Analysis of a Combustion Engineering 2-Loop Pressurized Water Reactor, Case Study.* NUREG/CR-4710. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 253026.

CRWMS M&O 1997. *Engineering Design Climatology and Regional Meteorological Conditions Report.* B00000000-01717-5707-00066 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980304.0028.

CRWMS M&O 1999. *MGR Design Basis Extreme Wind/Tornado Analysis.* ANL-MGR-SE-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991215.0461.

CRWMS M&O 2000a. *MGR External Events Hazards Analysis.* ANL-MGR-SE-000004 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000310.0069.

CRWMS M&O 2000b. *Subsurface Transporter Safety Systems Analysis.* ANL-WER-ME-000001 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000829.0005.

CRWMS M&O 2000c. *Waste Package Design Sensitivity Report.* TDR-EBS-MD-000008 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000518.0179.

CRWMS M&O 2000d. *Waste Packages and Source Terms for the Commercial 1999 Design Basis Waste Streams.* CAL-MGR-MD-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000214.0479.

CRWMS M&O 2000e. *Waste Package Remediation System Description Document.* SDD-WPR-SE-000001 REV 01 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000807.0090.

DOE (U.S. Department of Energy) 2003. *Quality Assurance Requirements and Description.* DOE/RW-0333P, Rev. 13. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: DOC.20030422.0003.

McDaniel, P. 2002. *Design Evolution Study–Aging Options.* TDR-MGR-MD-000011 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20020429.0316.

NOAA (National Oceanic & Atmospheric Administration) 2003. "Fast Facts About Tornadoes." Washington D.C.: U.S. Department of Commerce. Accessed March 11, 2003. TIC: 253966. http://www.noaa.gov

NRC (U.S. Nuclear Regulatory Commission) 1987. *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants.* NUREG-0800. LWR Edition. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 203894.

Ramsdell, J.V. and Andrews, G.L. 1986. *Tornado Climatology of the Contiguous United States.* NUREG/CR-4461. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.20010727.0159.

Transnuclear West 2002. *NUHOMS-MP-187 Transportation Package Safety Analysis Report.* Docket No. 71-9255, Rev. 16. Hawthorne, New York: Transnuclear.

Williams, N.H. 2002. "Transmittal of Deliverable #SFC1020M3, Monitored Geologic Repository (MGR) Site Development Plan (SDP) - Contract No. DE-AC28-01RW12101." Letter from N.H. Williams (BSC) to J.D. Ziegler (DOE/YMSCO), NS:deh 1021024768, October 21, 2002, with enclosures. ACC: MOL.20021113.0373.

YMP (Yucca Mountain Site Characterization Project) 2001. *Q-List.* YMP/90-55Q, Rev. 7. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.20010409.0366.

10.2 CODES, REGULATIONS, STANDARDS, AND PROCEDURES

10 CFR 63. 2002. Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. Readily available.

10 CFR 71. 1987. Energy: Packaging and Transportation of Radioactive Material. Readily available.

ASCE 7-98. 2000. *Minimum Design Loads for Buildings and Other Structures.* Revision of ANSI/ASCE 7-95. Reston, Virginia: American Society of Civil Engineers. TIC: 247427.

AP-3.12Q, Rev. 2, ICN 0. *Design Calculations and Analyses.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: DOC. 20030403.0003.

AP-3.13Q, Rev. 3, ICN 1. *Design Control.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20020925.04444.

AP-3.15Q, Rev. 4, ICN 1. *Managing Technical Product Inputs.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: DOC.20030512.0006.

DOE-STD-1020-2002. 2002. *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities.* Washington, D.C.: U.S. Department of Energy. TIC: 253058.

Regulatory Guide 1.76, Rev. 0. 1974. *Design Basis Tornado for Nuclear Power Plants.* Washington, D.C.: U.S. Atomic Energy Commission. TIC: 2717.

10.3 DATA

MO9811DEDCRMCR.000. Data Reported in the Engineering Design Climatology and Regional Meteorology Conditions Report. Submittal date: 11/12/98.

ATTACHMENT I

DRY TRANSFER FACILITY FLOOR PLAN

DRY TRANSFER FACILITY SECTION VIEW

NORTH PORTAL WASTE HANDLING FACILITIES

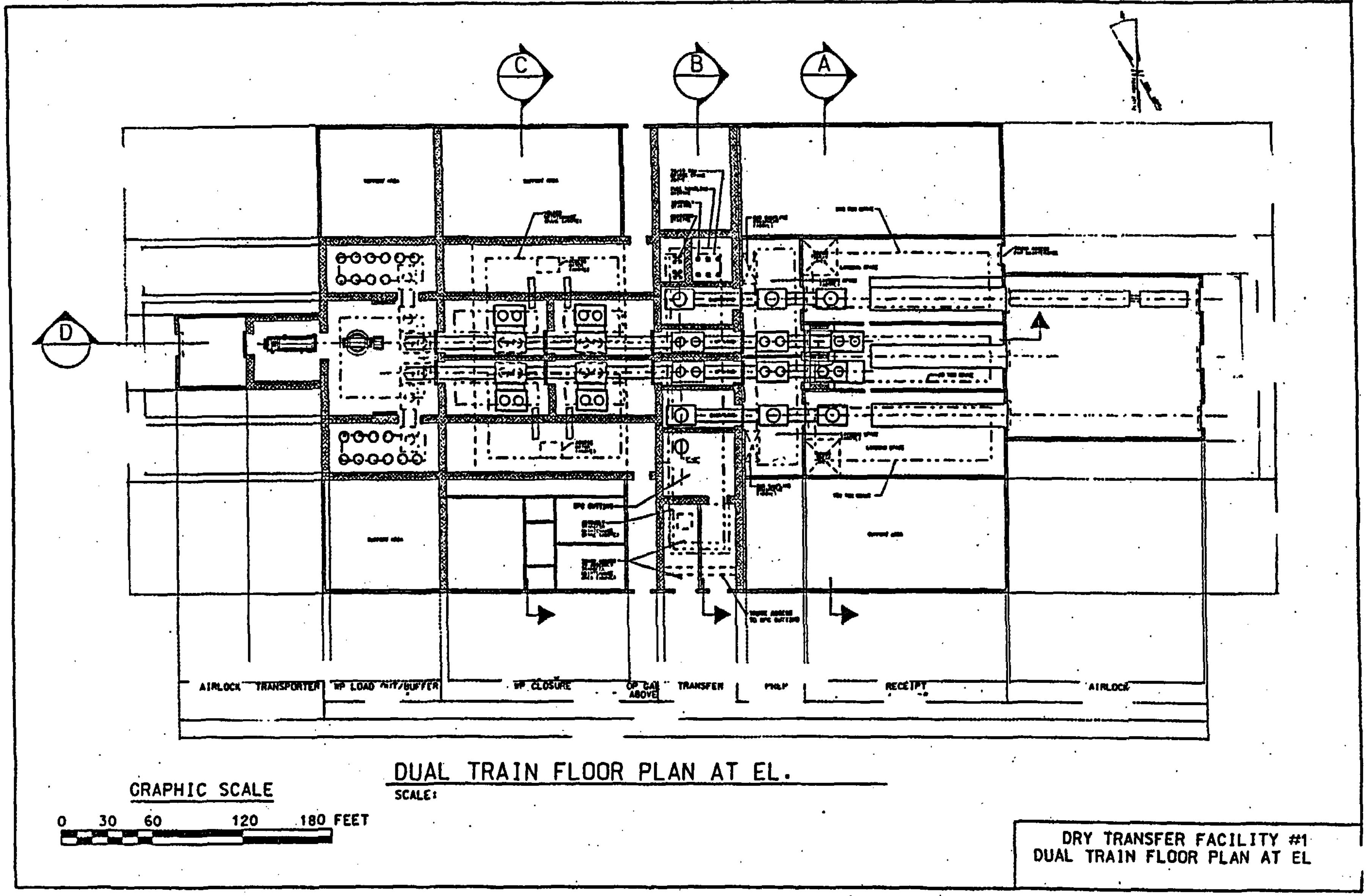


Figure I-1. Dry Transfer Facility Floor Plan

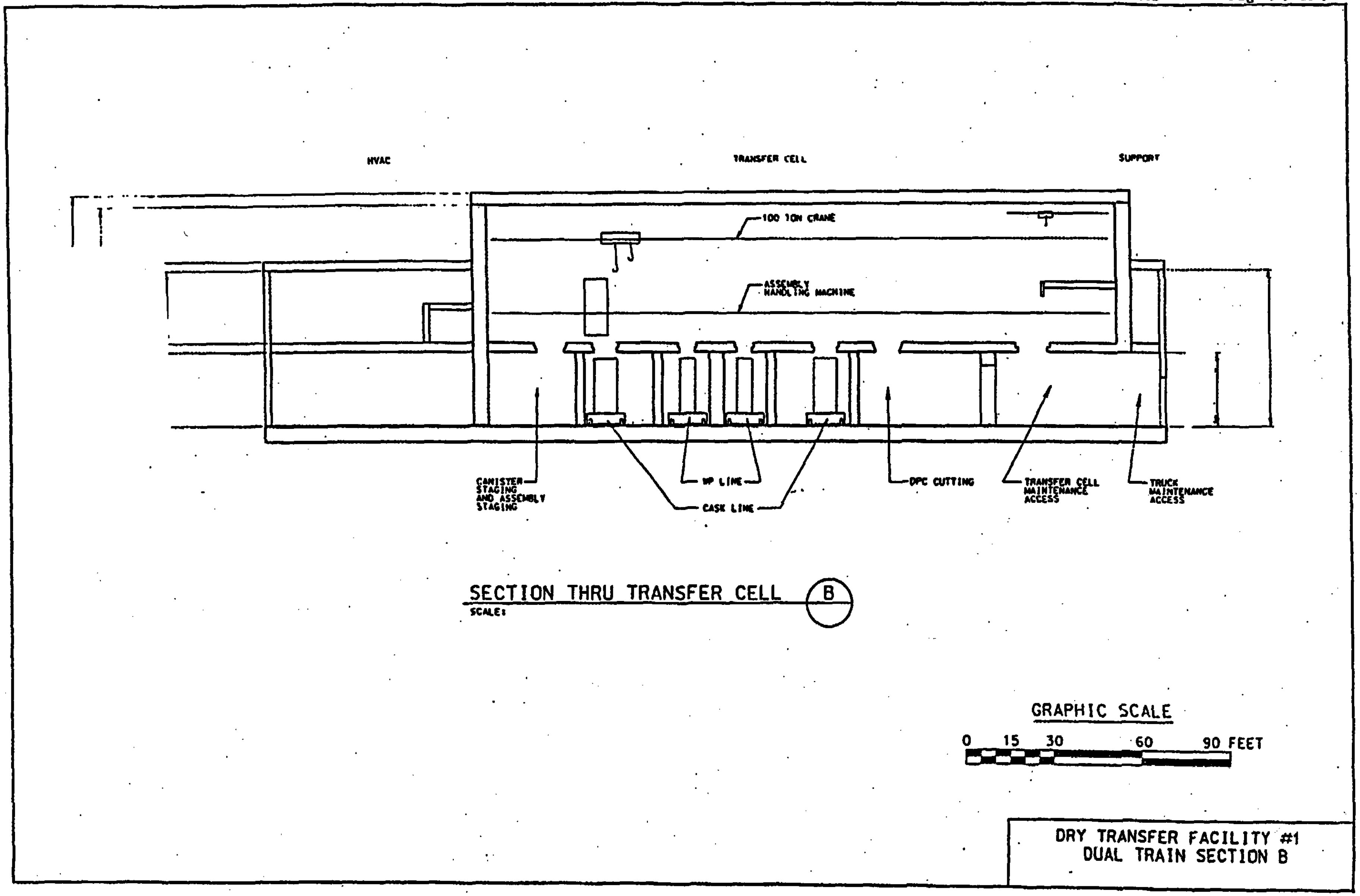
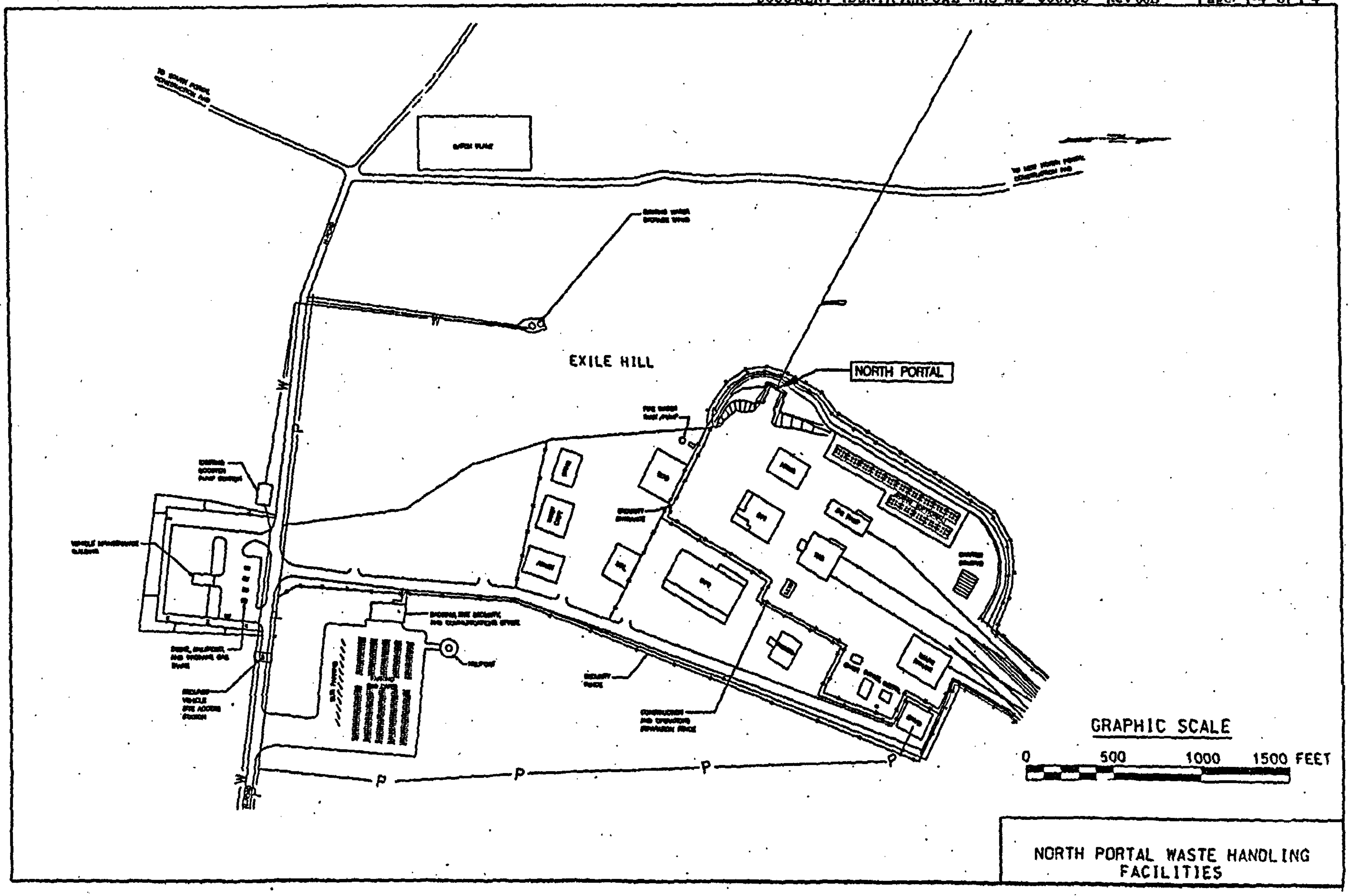


Figure I-2. Dry Transfer Facility Section View



Source: Williams 2002, Figure II-9

Figure I-3. North Portal Waste Handling Facilities