Initial Site-Specific De-Inventory Report for Zion

RPT-3022658-001

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REVISION LOG

Rev.	Date	Affected Pages	Revision Description
000	10/25/19	N/A	Initial Issue
001	5/14/23	Disclaimer	Updated disclaimer per DOE GC recommendations
		Acronyms	Added several acronyms
		ES	• Deleted first paragraph • Clarified some text • Corrected order of routes (ranked) • Corrected route titles as used in the report • Corrected impact of senstivity analyses • Updated here and throughout the report to "Security Plan" • Updated here and throughout the report to "Emergency Response Plan" • Corrected cost value from section 7.
		Section 1	• Editorial changes made to clarify text

Rev.	Date	Affected Pages	Revision Description
			• Added “Possible” to Figure 1-2 caption • Change from transportation cask to dry shielded canister
		Section 2	• Updated status of sites’ decommissioning activities (including the licensing and ownership status) • Updated Figures 2-2, 2-4, 2-9, 2-11, and 2-12 • Updated the cask/canister licensing information • Clarified some of the canister operations • Added Figure 2-23 (revising subsequent figure numbers) • Updated a citation title in Section 2.2 • Changed from Exelon to Constellation Energy, clarified use of a gantry system, and clarified details on some of the required equipment • Added further GTCC LLW information
		Section 3	• Added some information on prior shipments from the site, including barge shipments
		Section 4	• New introductory text has been added to identify the temporal nature of the information in this section • Two new paragraphs provided by the Department of Energy’s General Counsel have been added • Clarified entities and persons in bulleted list • Updated names for various positions
		Section 5	Minor grammatical updates
		Section 6	• Clarified areas involved with this actvity • Minor grammatical updates • Clarified some of the cask specific operations and updated Table 6-2 per the MAGNATRAN SAR for maintenance program • Added new footnote to clarify NRC route approval is not typically required for DOE shipments • Table 6-4 clarified crane size • Updated Table 6-4 for some of the ancillary equipment • Deleted text related to the superceded DOE Manual 460.2 • Deleted paragraph related to NRC oversight • Deleted material in section 6.6 related to the QAP

Rev.	Date	Affected Pages	Revision Description
		Section 7	• Made some grammatical updates • Updated some of the equipment needs and corrected year of ANSI N14.5 utilized • Revised Section 7.6 title
		Section 8	• Revised section title (removed “”Safety”) • Clarifications made to the text • Clarified protection of Safeguards Information • Clarified some terms and revised nearby waterway • Renamed sections 8.4, 8.11, 8.12, 8.13 • Deleted text related to the superceded DOE Manual 460.2A and associated bullets in Sections 8.11, 8.12 & 8.13 • Added new bullets to Sections 8.11, 8.12 & 8.13 covering in-transit protection
		Section 9	• Modified section and sub-section titles • Minor grammatical updates made • Section 9.1 revised to reflect requirements associated with emergency response information that is commonly incorporated into an Emergency Response Plan • Updated information required for an emergency contact telephone number • Provided some clarifying remarks on the example index of an ERP and corrected some items in the index
		Section 10	• Minor updates to items 1, 3 and 4 • Removed last paragraph
		Section 11	Update to references and added several new references

DISCLAIMER

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List of Acronyms

AAR	Association of American Railroads
AEA	Atomic Energy Act
ALARA	As Low As Reasonably Achievable
ANSI	American National Standards Institute
ASNT	American Society for Nondestructive Testing
BNSF	Burlington Northern Santa Fe Railway
BOL	Bill of Lading
CAD	Computer Aided Drawing
CFR	Code of Federal Regulations
CHA	Chain Hoist Assembly
CN	Canadian National
CO	Crane Operator
CoC	Certificate of Compliance
ComEd	CommonWealth Edison
COSS	Cask Operations Shift Supervisor
COTP	Captain of the Port
CRCPD	Conference of Radiation Control Program Directors, Inc.
DHS	Department of Homeland Security
DOE	Department of Energy
DOT	Department of Transportation
DSC	Dry Shielded Canister
EO	Tractor/JCB Driver and Equipment Operator
ERP	Emergency Response Plan
FA	Fuel Assembly
FRA	Federal Railroad Administration
FSAR	Final Safety Analysis Report
FSO	Facility Security Officer
FSP	Facility Security Plan
ft	feet
GCUS	Geographical Center of the 48 Contiguous United States
GPS	Global Positioning System
GTCC	Greater Than Class C
GWd	GigaWatt-day
HAZMAT	Hazardous Material
HBU	High Burnup Fuel
HHT	Heavy Haul Truck/Trailer
HLW	High-Level Radioactive Waste
HRCQ	Highway Route Controlled Quantity
HSM	Horizontal Storage Module
HTUA	High Threat Urban Areas
IL	Illinois
in	inch
ISFSI	Independent Spent Fuel Storage Installation
ISR	Independent Safety Review
kW	Kilowatt

lbs	Pounds
LLC	Limited Liability Corporation
LLEA	Local Law Enforcement Agency
LLW	Low-Level Radioactive Waste
LP	Low Pressure
LPRC	Low-Profile Rail Cart
MCC	Movement Control Center
mph	miles per hour
MSLD	Mass Spectrometer Leak Detection
MTC	MAGNASTOR Transfer Cask
MTHM	Metric Tons Heavy Metal
MTSA	Maritime Transportation Security Act
MUA	Multi-Attribute Utility Analysis
NOAA	National Oceanic and Atmospheric Administration
NOPB	New Orleans Public Belt Railroad
NRC	U.S. Nuclear Regulatory Commission
NRHM	Non-Radioactive Hazardous Materials
NUTECH	Nuclear Technology Inc.
NWPA	Nuclear Waste Policy Act
OJT	On the Job Training
OM	Operations Manager
OSHA	Occupational Safety and Health Administration
PHMSA	Pipeline and Hazardous Materials Safety Administration
PIH	Poisonous Inhalation Hazard
PPE	Personal Protective Equipment
PW	Procedure Writer
PWR	Pressurized Water Reactor
QA	Quality Assurance
QAP	Quality Assurance Program
QC	Quality Control
QS	QA/QC Specialist
RAM	Radioactive Material
RCT	Radiation Control Technician
RM	Rigger/Cask Operations Technician/Mechanic
RP	Radiation Protection
RSAT	Risk and Security Assessment Team
RSSM	Rail Security Sensitive Materials
RWC	Radioactive Waste Container
RWP	Radiation Work Permit
SAR	Safety Analysis Report
SFA	Spent Fuel Assembly
SG	Steam Generator
SME	Subject Matter Expert
SNF	Spent Nuclear Fuel
SP	Security Personnel
START	Stakeholder Tool for Assessing Radioactive Transportation
STB	Surface Transportation Board

TC	Transport and Waste Management Coordinator
TIH	Toxic Inhalation Hazards
TPE	Training Program Evaluation
TS	Technical Specification
TSC	Transportable Storage Canister
TSA	Transportation Security Administration
TWIC	Transportation Worker Identification Credential
UP	Union Pacific
U.S.	United States
USCG	U.S. Coast Guard
USG	U.S. Gypsum Corp. railroad
VCT	Vertical Cask Transporter
VDS	Vacuum Drying System

Executive Summary

The purpose of this report is to assist the United States (U.S.) Department of Energy (DOE) in laying the groundwork for implementing an integrated nuclear waste management system. This includes preparing for future large-scale transport of Spent Nuclear Fuel (SNF), High-Level Radioactive Waste (HLW), and Greater Than Class C (GTCC) Low-Level Radioactive Waste (LLW). This report addresses the tasks, equipment, and interfaces necessary for the complete de-inventory of the Zion Nuclear Power Station (Zion) independent spent fuel storage installation (ISFSI) site located in the town of Zion, IL, approximately 42 miles north of Chicago, IL. As such, this report is intended to provide information useful for planning options within an integrated nuclear waste management system.

Multiple modes of transport of the existing SNF and GTCC LLW were considered as part of this report (i.e., heavy haul truck (HHT), rail, and barge). Barge-to-rail, HHT-to-rail, and direct rail access were evaluated as viable modes of transport by this assessment. To assess the identified routes and modes, a Multi-Attribute Utility Analysis (MUA) was performed. In addition to subject matter expert (SME) input, data from the DOE's Stakeholder Tool for Assessing Radioactive Transportation (START) program was utilized to support the evaluation of the routes in the MUA. The MUA identified a favored route and mode(s) of transport for shipping the existing SNF and GTCC LLW from Zion to a Class I railroad and then to the hypothetical destination near the geographical center of the 48 contiguous United States (GCUS).

The MUA established a ranking of five possible routes from the Zion site, listed here in order of decreasing favorability as analyzed by the MUA:

1) Union Pacific (UP) only Rail around Chicago direct to GCUS (i.e., referred to as "A. UP Direct Around Chicago" route in the MUA).
2) UP Alternate Rail through Sterling and Springfield avoiding Chicago (i.e., referred to as "C. UP Alternate Rail through Springfield avoiding Chicago" route in the MUA).
3) UP Alternate Rail through Sterling and Springfield (i.e., referred to as "B. UP Alternate Rail through Springfield" route in the MUA).
4) Barge only avoiding Chicago going through Peoria to GCUS (i.e., referred to as "D. Barge Only" route in the MUA).
5) Heavy Haul Truck (HHT) Minimum Distance to GCUS (i.e., referred to as "E. Heavy Haul Truck Only" route in the MUA).

Sensitivity analyses were performed on the MUA results to examine the impact on the rankings of the routes created by changes in the weighting of metrics used to evaluate those routes (e.g., cost of rental equipment, ease of permitting, etc.) and by suppressing the evaluation range of some specific metrics (e.g., cumulative worker exposure). The sensitivity analyses showed a robustly consistent set of rankings, with only the two highest ranked routes switching positions under a couple of the sensitivity analyses and the ranking of the last three ranked routes remaining consistent throughout the sensitivity analyses. The two scenarios where the top two ranked routes switched positions occurred when (1) the safety and security and (2) the security, safety, and public acceptability metrics were removed from consideration.

Using the primary MUA result, a concept of operations and recommended budget and spending plan are detailed for the removal of existing SNF and GTCC LLW from the Zion site using the highest rated shipment route: by rail on the UP around Chicago, IL to the GCUS. The total estimated budget for the entire Zion campaign organized over 53 calendar weeks is $17.8M (2022).

Also documented in this assessment are aspects of a Security Plan and associated procedures and an Emergency Response Plan and associated preparedness for the prospective shipments. Finally, the recommended next steps are identified for the process of initiating the removal of the existing SNF and GTCC LLW from the Zion site.

1.0 INTRODUCTION

This report provides an assessment of the tasks, equipment, and interfaces that would be necessary to remove the SNF and GTCC LLW from the Zion ISFSI located in the town of Zion, IL, approximately 42 miles north of Chicago, IL. The objective of this removal activity would be to transport the existing SNF and GTCC LLW to a Class I railroad, where it could then be transported to a future consolidated interim storage facility or geological repository. A railroad hub in the central U.S. with connections to all other major rail carriers was used as the route endpoint for the purposes of this study, because it could serve as a connection point to storage or disposal facilities located in any region of the U.S. The use of GCUS as a hypothetical destination is not to imply that this location is being considered for a future consolidated interim storage facility, geological repository, or a transportation hub but was used, for purposes of this report, as a basis for scheduling and costing estimates assessed in this report.

In performing this assessment, the results are expected to support the laying of groundwork for implementing an integrated nuclear waste management system for the U.S. DOE. This includes preparing for future large-scale transport of SNF, HLW, and GTCC LLW. This assessment specifically examines the removal of the existing SNF and GTCC LLW contained within the Zion ISFSI using Orano's and our teaming partners' experiences in the shipping of like and similar materials. For the purposes of this assessment, it is assumed that DOE would be responsible for a federal consolidated interim storage facility or geological repository to which the material would be shipped and would be the shipper of record; it is also assumed that the shipments would be regulated by the U.S. Nuclear Regulatory Commission (NRC) and the Department of Transportation (DOT) like comparable commercial shipments.

To lay the foundation of the assessment, the report begins by examining the pertinent site information in **Section 2.0**, including a description of the site and its characteristics, the characteristics of the existing SNF and the GTCC LLW to be shipped from the site, a description of the NAC MAGNASTOR System used to store this material onsite and the associated transportation packaging system, the NAC MAGNATRAN. The site information is vital to establishing whether sufficient space exists to perform transfer activities and to assessing and identifying the potential need for site infrastructure modifications (e.g., fence line modifications to optimize/streamline transfer operations and/or loading activities) and/or hardware requirements (e.g., need for an intermodal transport cradle/frame) to facilitate the shipment of these NAC MAGNATRANs from the Zion ISFSI. Although accessing the site was not within the scope of this activity, sufficient sources of information existed for an informed assessment of the site to be performed, but ultimately a formal inspection would be necessary to verify assumed site criteria. Identification of the characteristics of the existing SNF and the GTCC LLW at the Zion ISFSI provide the information necessary to verify compliance with the transportation licenses via their NRC Certificates of Compliance (CoCs). Similarly, the description of the NAC MAGNATRANs to be shipped are also verified to be compliant with their CoCs, allowing, if necessary, provisions to be designated to bring them into compliance or identification of exemptions requiring approval from the regulator.

After the pertinent site information was assessed, a transportation route analysis was performed, as described in **Section 3.0**, identifying transportation routes from the Zion ISFSI to a Class I railroad, which would then be used for subsequent shipment to a repository or interim storage facility. Multiple modes of transport of the existing SNF and GTCC LLW were considered (i.e., HHT, rail, and barge). From the Zion ISFSI site itself, all three modes were evaluated to be viable options for shipment of the existing SNF and GTCC LLW. **Figure 1-1** depicts the major steps of the potential transfer scenarios considered. As shown in this figure, the direct to rail scenario appears to be the least complicated approach, with the minimum number of times the NAC MAGNATRANs are handled, whereas the barge scenario appears to be more complicated, with additional handling activities. The result of the assessment of the transportation routes is a listing of multiple viable routes with various attributes, both positive and negative, that require evaluation to identify the optimal and/or favored route to transport the existing SNF and GTCC LLW from the Zion site.

An MUA was selected as the means to assess the various routes and modes and identify a ranking of these routes. Due to the large number of potential routes and associated modes initially identified, performing the MUA would be burdensome, so initial screening criteria were established to allow for less attractive routes to be screened from further consideration based on attributes associated with a particular mode of transport (i.e., screening is performed only between routes associated with a particular mode of transport). These screening criteria were applied in **Section 3.5** to reduce the number of identified routes from greater than 20 to a manageable number of five. After the participating entities were identified in **Section 4.0**, these five routes (using all three common modes from the site: HHT, barge, and direct loading on to rail) were evaluated using the MUA to rank the routes for shipping the existing SNF and GTCC LLW from Zion to the hypothetical destination of GCUS by Class I rail in **Section 5.0**. **Figure 1-2** identifies the routes evaluated in the MUA.

Based on the results from the MUA, a concept of operations and recommended budget and spending plan are detailed for the highest ranked shipment route in **Section 6.0** and **Section 7.0**, respectively. This assessment also includes information on a Security Plan and associated procedures in **Section 8.0** and an Emergency Response Plan and associated preparedness for the prospective shipments in **Section 9.0**. Finally, **Section 10.0** identifies the recommended next steps to initiate removal of existing SNF and GTCC LLW from Zion.

The routes are described in further detail through-out this report. These figures were produced using results from START software[1]. The colored lines indicate the routes analyzed by the MUA as explained in the figure.

Figure 1-1: Flow of Operations Assessed for Loading a Consist per Mode of Transport from Zion ISFSI

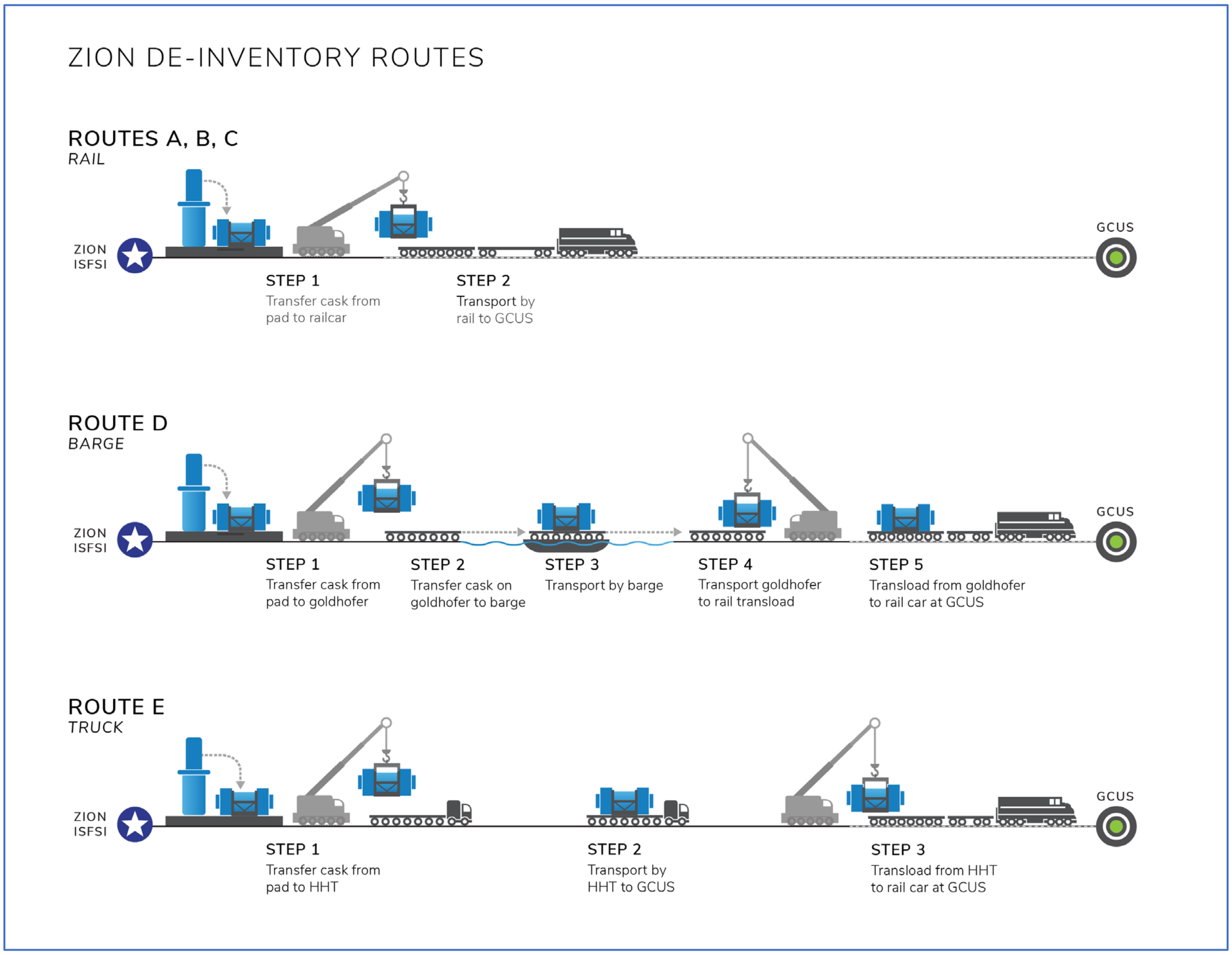
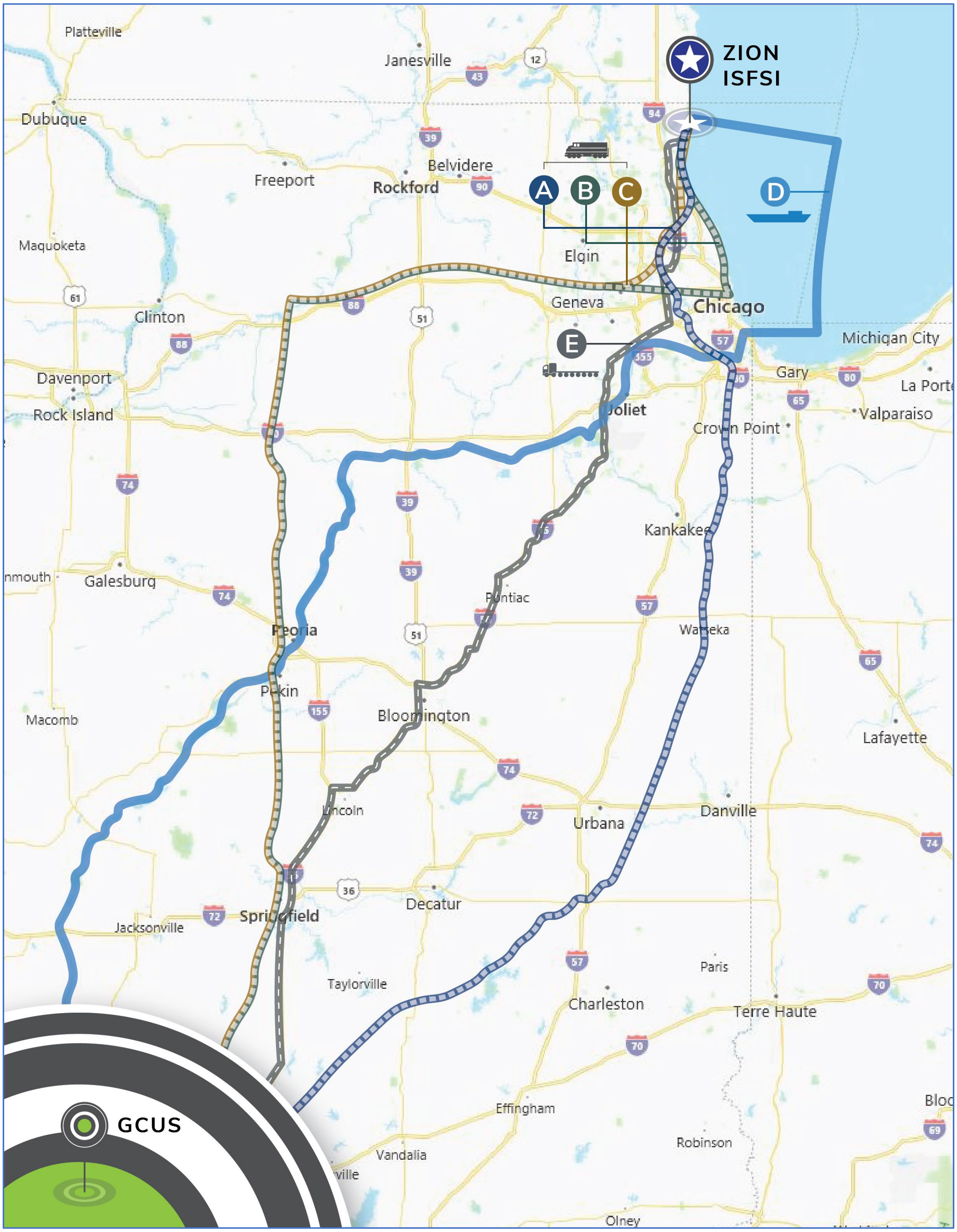


Figure 1-2: Possible Routes Evaluated By The MUA For Shipment Of SNF and GTCC LLW From Zion ISFSI



2.0 PERTINENT SITE INFORMATION

2.1 Description of Site/Characteristics

The Zion Nuclear Power Station (Zion) site, owned by ZionSolutions, LLC, is located in the northern quarter of Illinois in the city of Zion, approximately 42 miles north of Chicago, Illinois and 42 miles south of Milwaukee, Wisconsin on the western shore of Lake Michigan as shown in **Figure 2-1**. The site is bordered on the north and south by the Illinois Beach State Park, on the east by Lake Michigan, and on the west by private industry property and the Union Pacific Railroad.

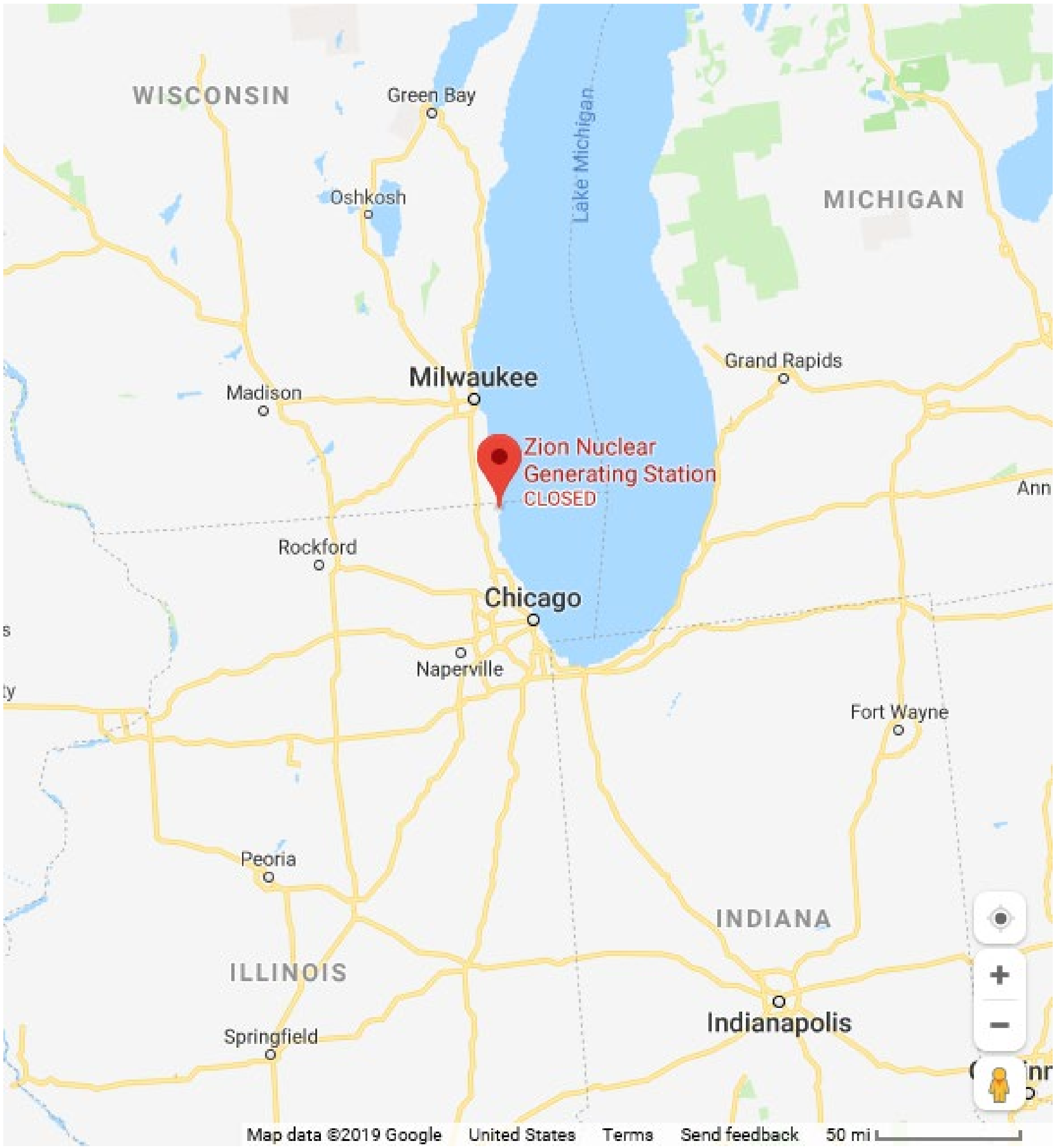
The owner-controlled site, shown in **Figure 2-2** and **Figure 2-3,** consists of approximately 331 acres. Within the owner-controlled area was the approximately 87-acre, security restricted, fence-enclosed area of the former nuclear facility. The site is covered mainly by sandy soil with patches of peat and muck in the marshy western portions of the site. The topography of the site and its immediate elevation is relatively flat, with elevations ranging from about 580 to 600 feet above sea level. The approximate mean lake elevation of Lake Michigan is 580 feet above sea level. The general area near the site is beach front and underdeveloped lowlands. Farther from the site, the terrain remains relatively flat. Along the routes to the interstate highways, elevations range from about 600 to 740 feet above sea level. The slopes of all grades along the routes are 2 percent or less[2][3]. The center of the community of Zion is approximately 1.6 miles from the plant location on the site. There is considerable commercial and residential development in the nearby area.

The Zion site consisted of two (Units 1 and 2) Westinghouse 4-loop Pressurized Water Reactors (PWR). Unit 1, a 1,085 megawatt (electric) nuclear power plant (10 CFR Part 50 Facility Operating License DPR-39, Docket No. 50-295) began commercial operation on December 31, 1973. Unit 2, also a 1,085 megawatt (electric) nuclear power plant (10 CFR Part 50 Facility Operating License DPR-48, Docket No. 50-304) began commercial operation on September 9, 1974. Zion was originally operated by CommonWealth Edison (ComEd) until it was permanently shut down on February 13, 1998. On March 9, 1998, both units were placed in a SAFSTOR condition (a period of safe storage of the stabilized and defueled facility). In 2000, the license was transferred from ComEd to Exelon Generation Company (EGC), LLC. The reactors at the Zion site remained in a SAFSTOR condition until September of 2010, when the operating licenses were transferred from EGC to Zion*Solutions* and active decommissioning activities began using the DECON approach. Zion*Solutions* is the current licensee and the submitter of the License Termination Plan (LTP). The LTP describes the process used to meet the requirements for terminating the 10 CFR Part 50 license and to release the site for unrestricted use, excluding the Independent Spent Fuel Storage Installation (ISFSI) area. The ISFSI was built under the general license provision of 10 CFR 72, Subpart K. Subpart K grants a general license to holders of 10 CFR 50 licensees to construct and operate an ISFSI on a site licensed under 10 CFR 50[4]. Construction of the ISFSI was completed in April 2013 and is shown in **Figure 2-4.** Spent fuel and GTCC waste transfer operations began in December 2013 and were completed in January 2015. The spent nuclear fuel will remain in storage under amended 10 CFR Part 50 licenses and the associated 10 CFR Part 72 license (Docket No. 72-1037) until the fuel is transferred to a permanent repository.

There is a pending NRC order approving the transfer of the Zion Nuclear Power Station licenses from ZionSolutions, LLC to Exelon Generation Company, LLC[43]. On November 26, 2019, the NRC issued an Order approving the license transfer and draft conforming administrative license amendments[44]. The transfer order was intended to be implemented upon the completion of decommissioning activities at the Zion site and was effective for one year from its date of issuance. Four extension requests have since been submitted for extension of the order effective date and to allow additional time for decommissioning activities and NRC review completion. The current date for completion of transfer is November 26, 2023[40]. Approximately 1,000 rail cars (ABC and gondola cars) removed material from the site, including the outbound movement of the steam generators by barge. All on-site above grade nuclear facility structures have been demolished and removed from the site and the Final Status Survey Reports are under review by the NRC. The ISFSI as well as the ComEd switchyard to the west of the plant will remain after the decommissioning is completed. Once decommissioning is completed, the 10 CFR Part 50 license will be reduced to the area around the ISFSI, approximately 5 acres, and the site will be transferred back to EGC.[3] Effective February 2, 2022, Exelon Generation LLC separated from the Exelon Corporation and renamed as Constellation Energy Corporation[41].

The Zion site is directly served by Union Pacific (UP) railroad via an approximately 1.3-mile on-site rail spur leading from the main line to the on-site ISFSI. The rail spur was refurbished for decommissioning. At the end of the decommissioning, the rail spurs to units 1 and 2 were removed. The remaining rail to the ISFSI is fully functional, however the condition of the rail spur will need evaluation to ensure the track condition is acceptable at the time of the shipments. The site also has an on-site road system with access to I-94 which is 9 miles west of the site and runs in a general north-south direction. The Zion site has no current barge slip or pier facility. A barge area used during plant construction was abandoned and the land was donated to the Illinois Beach State Park. However, the barge pilings remain and could be used to refurbish the former barge area. Zion*Solutions* shipped the turbine and generators by barge with the barges grounded on the beach to allow for loading. After this one-time operation was completed, the beach was restored to its natural state.

Figure 2-1: Zion Site Location[39]



Note: Google Maps uses the description "Zion Nuclear Generating Station" to reference the Zion Nuclear Power Station".

Figure 2-2: Zion Site[39]

Figure 2-3: Zion Owner Controlled Area[3]

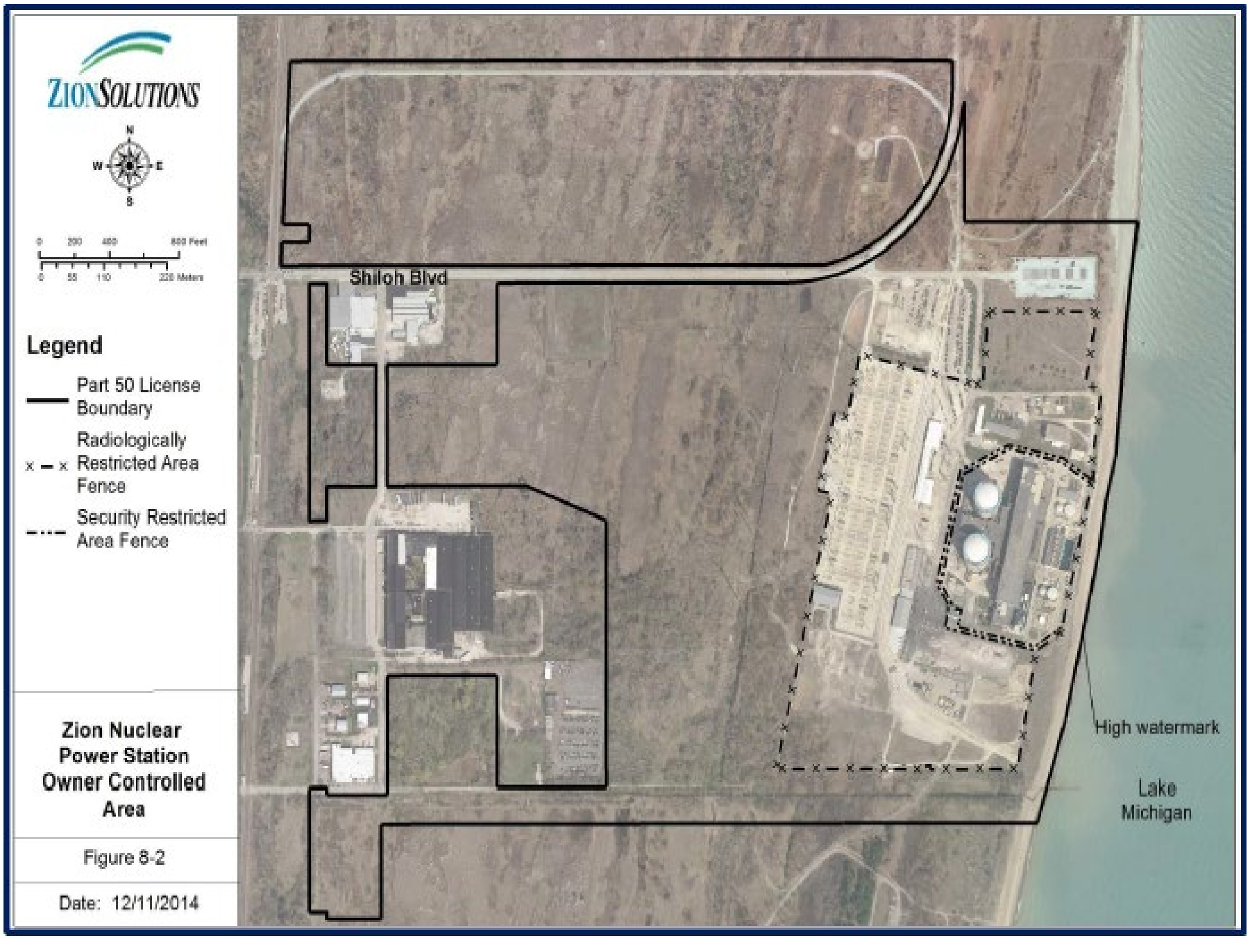


Figure 2-4: Zion ISFSI Location[39]

The storage system used at Zion is the NAC MAGNASTOR dry cask storage system (Docket No. 72-1031), which consists of a transportable storage canister (TSC) Type 1 Model TSC4 with a spent fuel assembly (SFA) fuel basket, a vertical concrete cask (VCC) Model CC4, and a MAGNASTOR transfer cask (MTC) Model MTC2. The TSCs can be loaded into a NAC MAGNATRAN transportation cask (Docket No. 71-9356) to enable transporting the contents from the Zion site. Refer to **Section 2.2** and **Section 2.3** below for information regarding the details of the SNF and GTCC to be shipped and for canister and transport packaging details.

All the SNF and GTCC LLW was removed from the spent fuel pool and moved to the on-site ISFSI. The intact fuel assemblies were loaded into the TSCs, which were then loaded into VCCs and moved to the ISFSI Storage Pad. Decommissioning began in October of 2010, and transfer of spent fuel and greater than Class C Waste to the on-site ISFSI began in 2014 and was completed in 2015.[5] The total inventory of the Zion SNF and GTCC LLW stored in NAC-MAGNASTOR Systems is presented in **Table 2-1**.

Table 2-1: SNF and GTCC TSC Inventory Summary for Zion Site[6][7][8]

MAGNASTOR TSC4 Canisters		# SNF Assemblies (PWR) +2 DFCs of Fuel Debris	# Damaged Fuel Cans	# Damaged SNF Assemblies
SNF	GTCC LLW			
61	4	2,228	98	57

The 61 NAC MAGNASTOR canisters of spent nuclear fuel are registered to MAGNASTOR Certificate of Compliance 1031, Amendment 6, dated December 21, 2016[9]. It is expected that the Zion MAGNASTOR canisters will be re-registered to CoC No. 1031, Amendment 12[42] and Final Safety Analysis Report (FSAR) Revision 12 following NRC approval in 2023. Use of the ISFSI for storage and handling of spent fuel is granted upon compliance with the conditions of the General License issued under 10 CFR 72, Subpart K, and the Zion 10 CFR 72.212 Evaluation Report.[5]

The MAGNASTOR dry cask storage system and the ISFSI provide long-term on-site storage of Zion SNF and GTCC waste as shown in **Figure 2-5**, **Figure 2-6**, and **Figure 2-7**. The ISFSI, approximately 5 acres,[10] has been constructed in the southwest corner of the Zion site, immediately south of the switch yard and set back several hundred yards from the lake frontage. The spent nuclear fuel and GTCC waste will remain in storage at the ISFSI under the amended Part 50 license and the associated 10 CFR Part 72 license until the fuel and waste are transferred. Several services, such as the City of Zion water and sanitary sewer services, and ComEd electrical service will remain in operation to support the ISFSI monitoring and security operations[3]. The ISFSI concrete storage pad area is divided into two sections, each approximately 150 ft long x 50 ft wide, separated by an access aisle, approximately 35 ft wide. The northern most storage pad section consists of 4 rows of 8 VCCs each for a total of 32 VCCs. The southern most storage pad section consists of 3 rows of 8 VCCs each and 1 row of 9 VCCs for a total of 33 VCCs. All 65 VCCs are loaded and the ISFSI is surrounded by two security fences. The ISFSI Monitoring Building is part of the inner security fence boundary around the VCCs. The outer security fence surrounds both of the VCC storage pads and the Monitoring Building. A warehouse building north of the ISFSI pad will be part of the licensed ISFSI area once decommissioning is complete and the license transfer has occurred. A paved road, 35 ft wide, runs approximately 350 ft from the VCC storage pad access aisle through the ISFSI access gate to the rail spur.

Figure 2-8 shows the configuration of the loaded VCCs on the ISFSI pad.

Figure 2-5: Zion ISFSI[39]

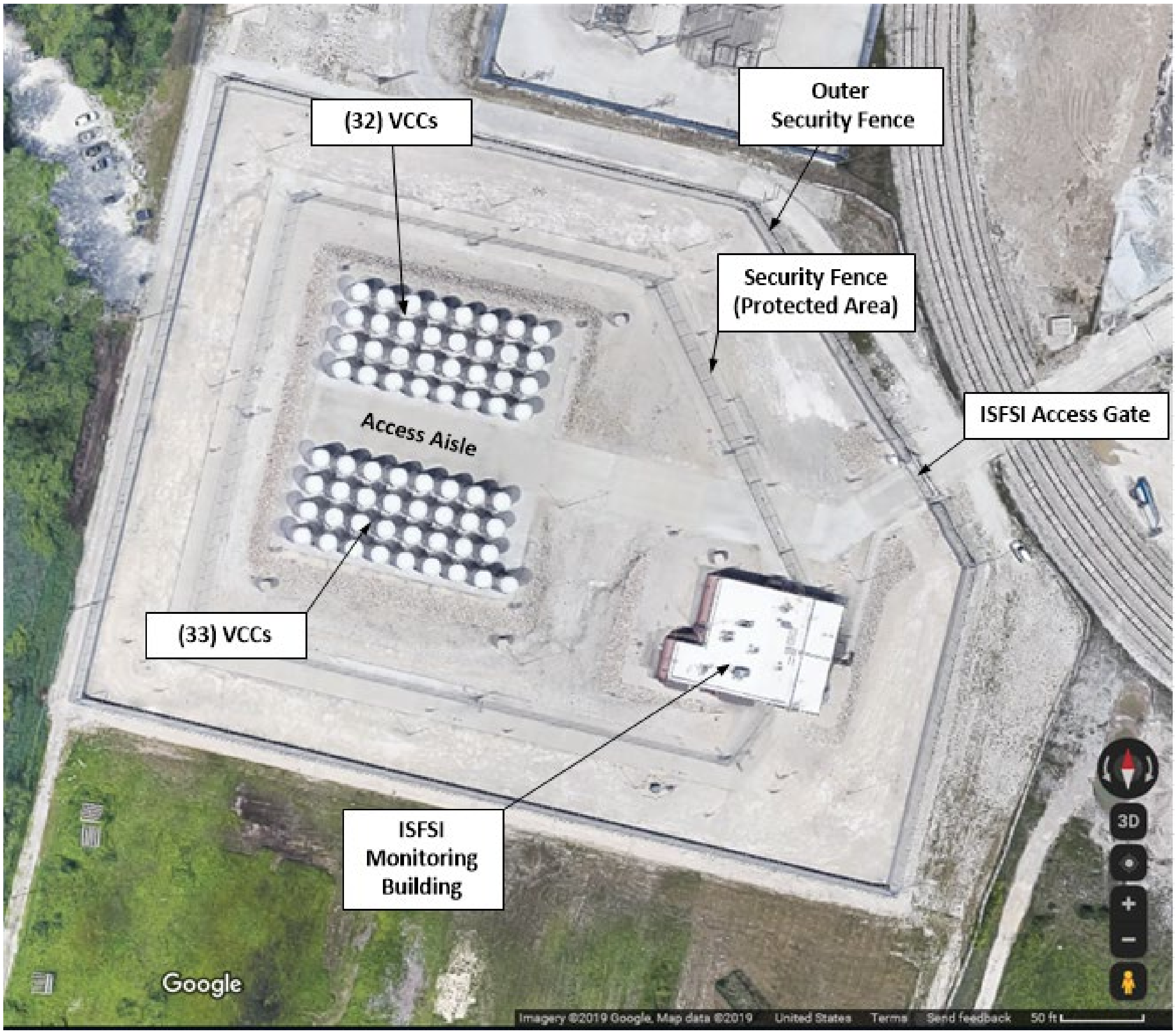


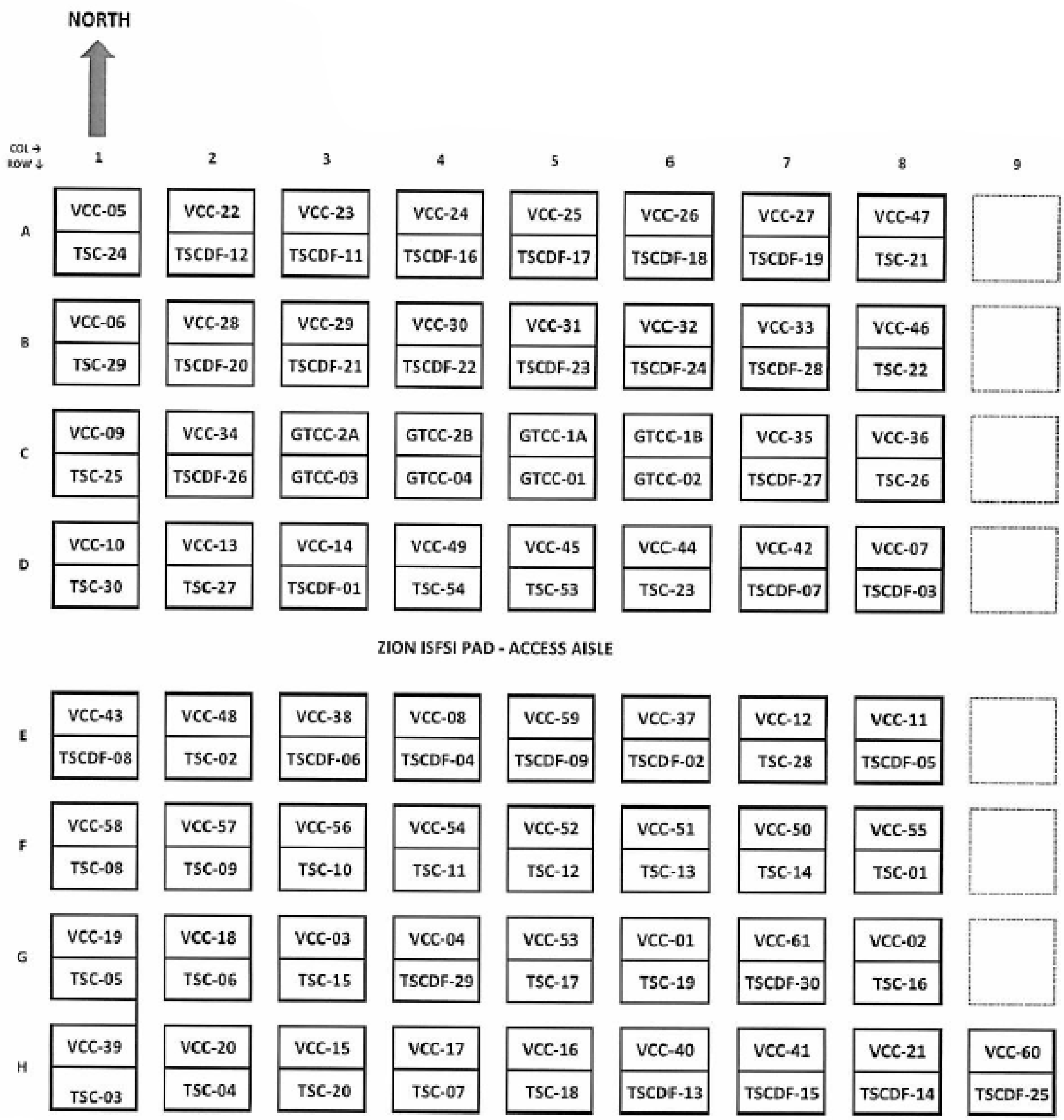
Figure 2-6: Zion ISFSI West View

Photo courtesy of Zion

Figure 2-7: Zion VCCs[6]

Photo courtesy of EnergySolutions

Figure 2-8: Zion ISFSI Pad Configuration[6]



Site Infrastructure

Figure 2-9 provides an aerial view of the Zion site, including the former reactor site, ISFSI, on-site rail spur, former VCC staging area, and ComEd switchyard. On-site land activities such as vehicle parking and equipment/container laydown, storage, staging and waste loading occurred during decommissioning similar to when the facility was operational. Structures such as the switchyard, the ISFSI, the microwave tower, and the sewage lift station, as well as roadways and rail lines, will remain in place at license termination as requested by Exelon[3]. The site is essentially a level property located on Lake Michigan beachfront and bordered by the Illinois Beach State Park on the north and south.

The on-site rail spur, partially shown in **Figure 2-9** and completely shown in **Figure 2-13**, is approximately 1.45 miles long from the UP mainline (point of switch) to the northeast corner of the Zion site near the shoreline. The on-site rail spur was originally installed during the construction of Zion in the early 1970's and was part of the operation of the facility. The distance of the on-site rail spur from the UP mainline (point of switch) to the area directly adjacent to the ISFSI is approximately 1.3 miles. **Figure 2-10** shows the track running adjacent to the entrance of the ISFSI. The on-site rail spur was modified and refurbished to support shipment of low-level radioactive waste from the site to support decommissioning activities. This refurbishment included installing concrete ties with Pandrol clips on the curves as shown in **Figure 2-15**. A 4-inch ballast lift was also performed over the length of the spur. On the east-west portion of the spur every other wooden tie was replaced. There is sufficient track in the proper configuration to load the entire train consist. The loading configuration is 8 cars, composed of 5 cask cars, 2 buffers, and 1 security car. It is not anticipated that the two locomotives will stay with the rest of the cars while it is being loaded; however, there is room on this track to add them to the 8 cars. When the train is pulled it will be in the configuration of locomotive-locomotive-buffer-cask-cask-cask-cask-cask-buffer-security car. Depending on clearance approvals, additional buffers may be necessary between the cask cars.

The Zion site currently has no barge facility. During construction of the Zion site, barges were used to move materials and components to the site. The barge facility was located at the northern end of the site on the Lake Michigan shore and has been abandoned. The land on which the barge facility was located was donated to the Illinois Beach State Park. However, the barge pilings, as shown in **Figure 2-11,** remain and could be reused to refurbish the barge facility[8]. Alternatively, an area closer to the beach from the ISFSI could be used to ground a barge to support roll-on/roll-off operations. This would provide a closer HHT on-site movement but may require construction of an appropriate road or use of crane mats to stabilize the ground between the ISFSI and the beach for loading purposes. The shoreline freezes and would not allow shipping during winter months. There is also an active storm water drain pipe in this area.

Some onsite roads have been refurbished and a reinforced heavy haul path was constructed to support the transfer of VCCs to the ISFSI in 2014[3]. An evaluation of the onsite roads to support transport cask movement to a potential barge location or for movement to off-site roads would be required.

A proposed haul path of approximately 350 ft from the ISFSI pad to the rail track running adjacent to the ISFSI is shown in **Figure 2-12**. This is the location where it is recommended to transload the casks onto rail cars for the outbound train movement from the site to the GCUS.

Figure 2-9: Aerial View of Zion Site[39]

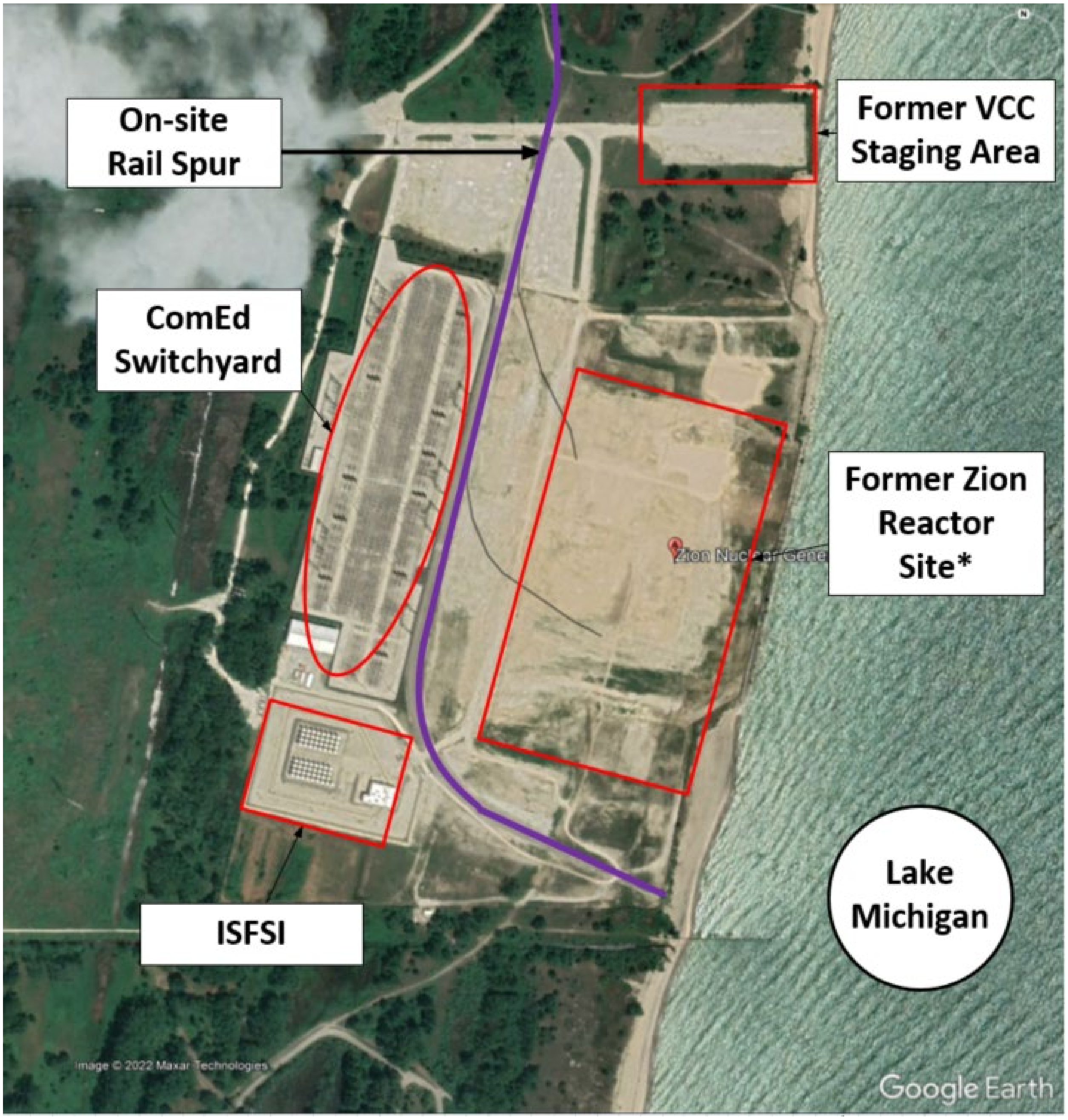


Figure 2-10: On-Site Rail Spur Adjacent to ISFSI[6]

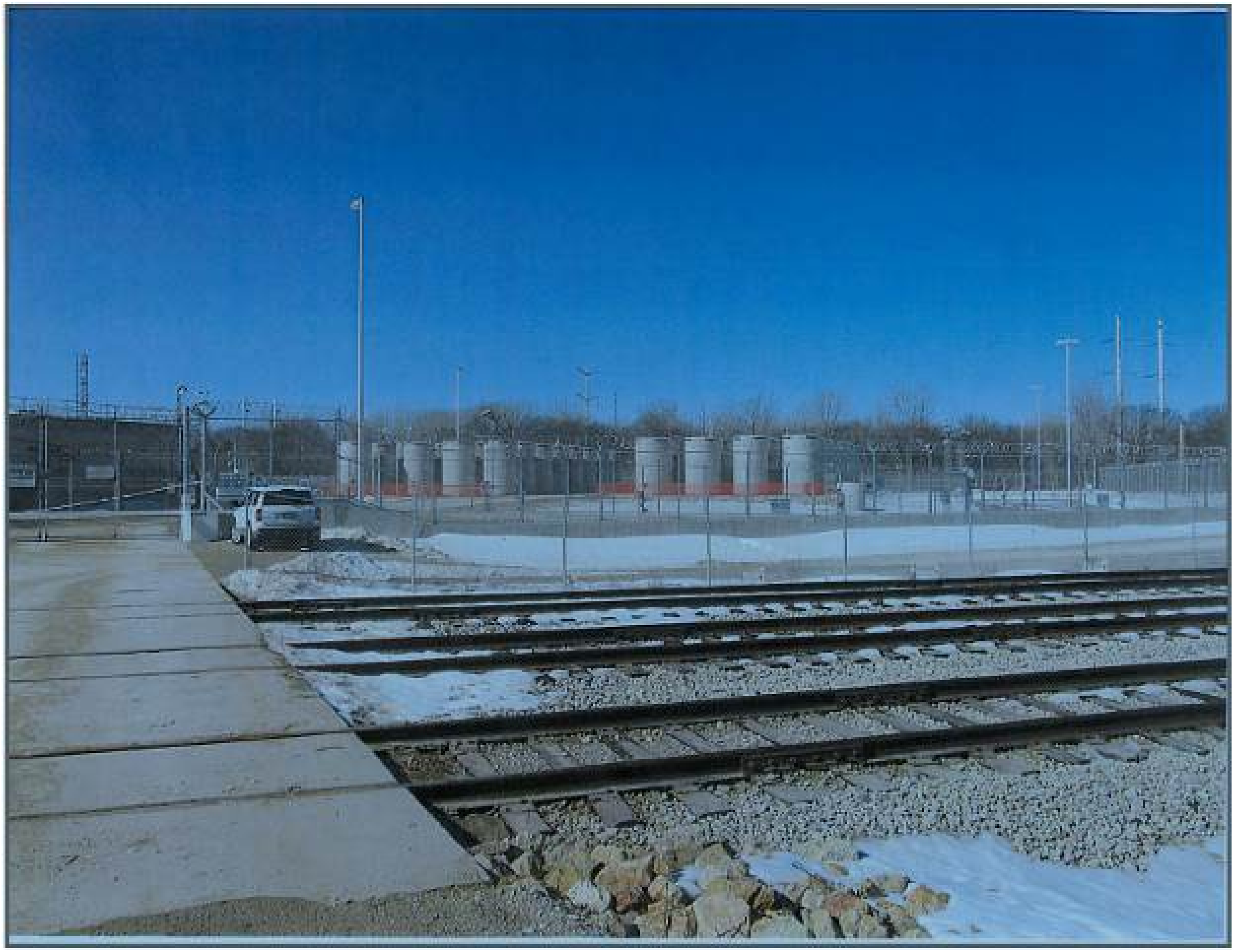


Photo courtesy of Zion

Figure 2-11: Barge Pilings at North End of Zion Site[39]

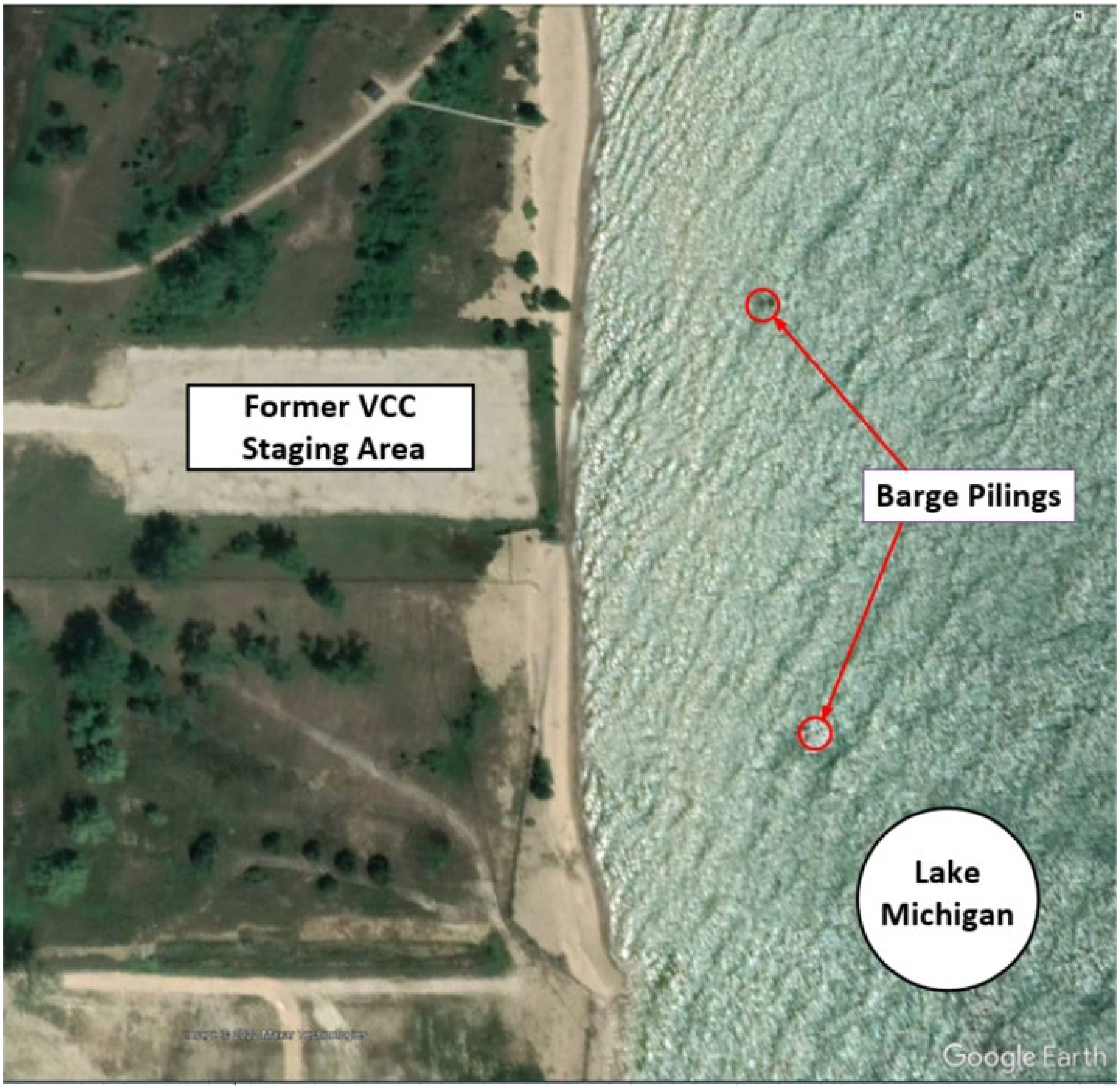
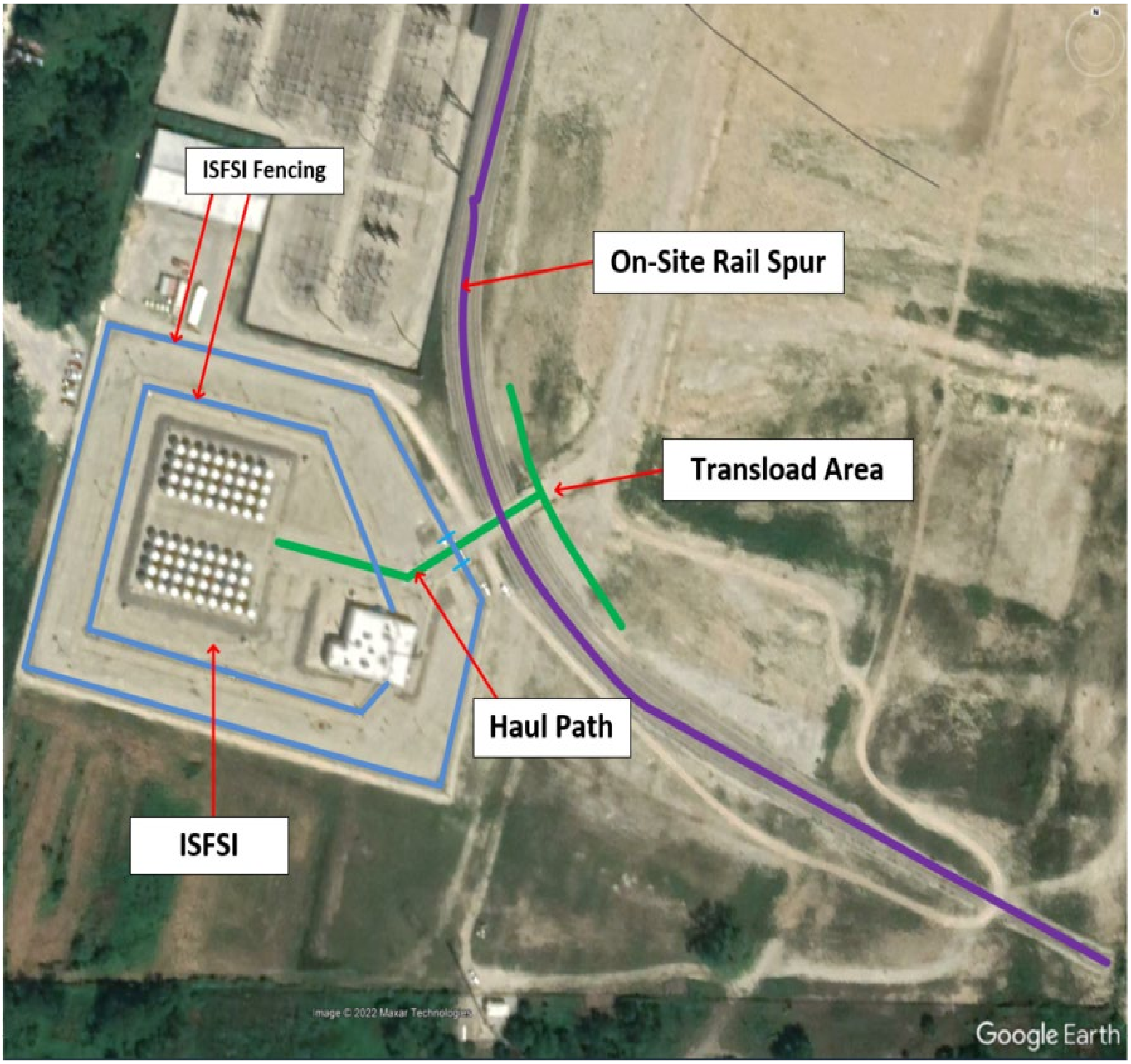


Figure 2-12: ISFSI Haul Path to Track Spur Adjacent to ISFSI[39]



Near-site Transportation Infrastructure

Zion has an on-site rail spur that provides access to the UP mainline west of the Zion site as shown in **Figure 2-13**. The UP mainline and on-site rail spur point of switch is about 0.1 mile west of the Zion site boundary and 0.1 mile north of the commuter rail station from the town of Zion. The spur begins a 90-degree curve to the south over a length of about 750 feet and merges with the eastern-most of the two UP mainline tracks. **Figure 2-14** shows the rail spur entering the Zion site and **Figure 2-15** shows the junction of the Zion on-site rail spur with the UP rail line. **Figure 2-15** also shows the concrete rail ties that were used in the reconstructing the curves of the on-site rail spur. The UP rail line in the vicinity of the Zion site is designated as track class 4. The UP mainline is used mainly for commuter trains but freight shipments are allowed with proper scheduling to avoid interfering with the commuter trains[2]. In 2016, eight steam generators were shipped by rail from the Zion site to Clive, Utah for disposal. The steam generators ranged in weight from 444,000 to 462,200 lb. and were shipped on 360-ton, 53-foot deck, 12-axle QTTX flat cars[5].

The Zion site is located 9 road-miles east of 1-94, the Tri-State Tollway, a north-south highway. There is a network of primary and secondary highways and section line roads in the adjacent area which provide a variety of high-capacity routes to and from the site and the immediate vicinity. Zion has used heavy haul trucks to ship radioactive waste off-site for disposal. For example, in 2011, Zion*Solutions* shipped the Zion Unit 2 reactor head 1,500 miles from the Zion site to Clive, Utah for disposal. The reactor head was approximately 17 feet in diameter and weighed 225,000 lbs. A heavy haul truck was used for this shipment because the Zion Unit 2 reactor head was too wide for shipment by rail[5].

As mentioned previously, a barge facility was built to support construction of Zion and used to receive heavy equipment. It was subsequently dismantled, and the prior barge site is now a part of the Illinois State Park and as a result there is currently no barge access at the site. The barge pilings remain and there are other areas along the owner property adjacent to the lake that may be suitable for grounding a barge. The site recommended for loading barges on this site is on the beach directly across from the end of the rail track, in alignment with the ISFSI. This location offers a shorter on-site HHT movement from the ISFSI to the barge. All barge traffic north of the Chicago area is limited to the summer months due to waves or ice on the lake[5].

The NAC MAGNATRAN transportation casks will be moved to the on-site rail transload location. Refer to **Section 6.1.3** for specific details of the canister transfer and cask preparation operations for the NAC MAGNASTOR and NAC MAGNATRAN systems.

Figure 2-13: Rail Interface at Zion[39]

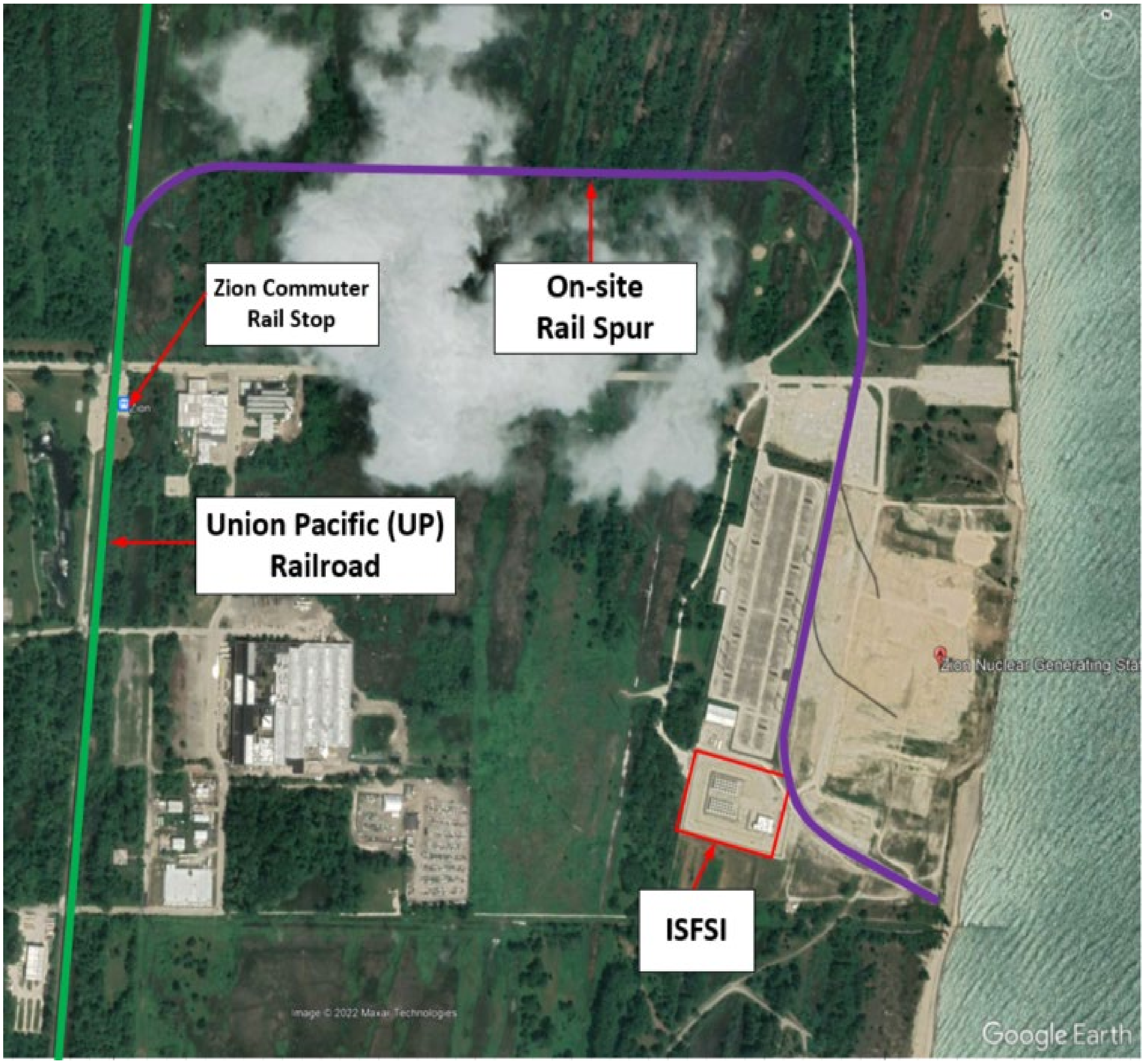


Figure 2-14: On-Site Rail Spur Entering Zion Site[6]

Photo courtesy of Federal Railroad Administration

Figure 2-15: Junction of Zion On-Site Rail Spur with Union Pacific Railroad Showing Concrete Rail Ties (2013)[6]

NAC MAGNASTOR Storage System Details

As part of the Zion decommissioning process, the complete inventory of Zion SNF was removed from the spent fuel pool and moved to the ISFSI for long-term onsite storage in NAC MAGNASTOR systems. The intact low burnup (≤ 45GWd/MTU) fuel assemblies were loaded into thirty-two (32) standard MAGNASTOR PWR Transportable Storage Canisters (TSC4 [indicating a two-piece closure lid, 5 inch stainless steel and 4 inch carbon steel plate]), which were then loaded into MAGNASTOR concrete storage casks (VCCs) (Type CC4 indicating removable VCC lifting lugs) and moved to the ISFSI storage pad. Damaged and high burnup (HBU) (> 45 GWd/MTU) fuel assemblies and the two items of fuel debris (e.g., skeleton assembly Y48B and rod basket ZFRSB1) were loaded into Damaged Fuel Cans (DFCs) located in the four corner damaged fuel locations of the Damaged Fuel (DF) MAGNASTOR PWR TSC. A total of twenty-nine (29) DF TSCs were loaded and placed into storage at the ISFSI in VCCs. Details of the SNF contents can be found in **Section 2.2**.

The MAGNASTOR system for storage of PWR SNF is comprised of the following components: Fuel TSCs (for intact fuel assemblies only), DF TSCs (for up to four damaged and/or HBU fuel assemblies, and up to 37 undamaged low burnup fuel assemblies), VCCs, and a MAGNASTOR Transfer Cask (MTC). The TSCs can be loaded into a corresponding MAGNATRAN transport cask system (NRC CoC No. 71-9356) to enable transport of the contents from the Zion site. The Zion MAGNASTOR storage systems include 32 Type 1 TSCs (173-inch internal cavity length) and 29 Type 1 DF TSCs. The TSCs used at Zion are identified as TSC4 indicating a two-part closure lid in lieu of a solid closure lid. The MAGNASTOR VCCs used at Zion are identified as CC4 indicating a standard VCC with removable lifting lugs.

In addition to the 61 MAGNASTOR systems loaded with SNF, four (4) GTCC LLW MAGNASTOR systems were loaded with irradiated reactor internals and limited quantities of special nuclear material in the two reactor containments and stored at the ISFSI. The special nuclear material is contained in two of the GTCC LLW TSCs as follows: Unit 1 GTCC-01 contains 4 Unit 1 Reactor Vessel Specimen Program (RVSP) Capsules S, V, W and Z, and Unit 2 GTCC-01 contains 22 Unit 1 and Unit 2 Movable Incore Detectors (MIDs). There is no process waste in the GTCC canisters (i.e., no Tri-Nuc filters or F/D resin). The GTCC LLW TSC is identical to the fuel and DF TSCs except they have a specially designed GTCC LLW basket to reduce the systems external dose. The maximum weight of the loaded GTCC LLW TSCs is 98,000 pounds.

The VCCs, shown in **Figure 2-16**, **Figure 2-17**, and **Figure 2-18** were fabricated onsite and loaded with welded-closed TSCs within the Zion Fuel Building. There are 65 of these storage casks at the Zion ISFSI (61 containing fuel and DF TSCs, and 4 containing GTCC LLW TSCs), with details as follows:

- The Zion MAGNASTOR VCC casks are 232.4 inches high with lifting lugs installed and 219 inches high with bolted lifting lugs removed, and an external diameter of 136 inches[11].
- The reinforced concrete and steel liner walls of the VCC are 28.25 inches thick and consist of a 1.75-inch-thick inner steel liner surrounded by 26.5 inches of reinforced concrete[12].
- The approximate weights of the MAGNASTOR VCC casks are 210,000 pounds empty and 318,500 pounds loaded with a MAGNASTOR DF TSC[13]. VCCs loaded with MAGNASTOR fuel TSCs weigh 315,000 pounds and are bounded by the VCCs containing DF TSCs.
- The VCC lid, which incorporates concrete neutron shielding, weighs approximately 4,500 pounds and is secured to the cask liner with 6 5/8-inch stainless steel bolts. Three of the six lid bolt holes in the lid are provided threaded for attaching 7/8-9UNC-2B hoist rings for lifting[14].
- The VCCs were loaded and moved out of the Zion Fuel Building using a Low-Profile Rail Cart (LPRC). Once out of the Fuel Building a Vertical Cask Transporter (VCT) was moved to access the VCC on the LPRC for movement to the ISFSI pad (see **Figure 2-17** and **Figure 2-18**). Once in place at the ISFSI designated storage position, the VCC was set down and detached from the VCT and the VCC lifting lugs were removed for the next VCC movement.

The MAGNASTOR Fuel and DF TSCs, used to confine the SNF and shown in **Figure 2-19**, are dual-cerified Type 304/304L stainless steel and provide confinement of the contents. Each TSC is individually helium leak tested to leak tight criteria prior to acceptance in accordance with ANSI N14.5[15]. The basket assembly for the damaged and canned HBU fuel is shown in **Figure 2-20**. Details of the MAGNASTOR TSCs are as follows:

- The Zion MAGNASTOR TSCs are 184.75 inches high with an outer diameter of 72.0 inches[16].
- The maximum loaded weight of the Zion MAGNASTOR SNF TSCs is 101,000 pounds including 62,160 pounds for contents.
- The maximum loaded weight of the Zion MAGNASTOR DF TSCs is 104,000 pounds including 61,184 pounds for contents.
- The maximum loaded weight for the MAGNASTOR GTCC LLW TSC is 98,000 pounds including 55,000 pounds for contents.
- The Zion MAGNASTOR TSC closure lid includes six threaded holes (2-4 ½ UNC-2B) to install swivel hoist rings and redundant sling sets or alternate TSC lifting system, which are used for lifting the loaded Zion MAGNASTOR TSC[17]. The closure lid also is provided with three threaded holes (1-8 UNC-2B) for lifting of the closure lid only and would not be used for the TSC transfer operations.

To enable transferring a Zion MAGNASTOR fuel, DF or GTCC LLW TSC from a VCC to a MAGNATRAN transportation cask, an MTC2[18], shown in **Figure 2-21** and **Figure 2-22**, will be used. Details of the MTC2 are as follows:

- The MTC2 stainless steel transfer cask is 192.8 inches high (including the height of the three retaining block assemblies) and a nominal diameter of 88 inches and is hereafter referred to as the MTC.
- The inner and outer stainless-steel shells of the MTC encase the neutron (NS-4-FR) and lead shielding layers[19].
- The inner cavity of the MTC has a nominal diameter of 73 inches and a cavity height of 185.8 inches to accommodate the Zion TSC overall length of 184.8 inches[18].
- The approximate weight of the empty MTC is 106,000 pounds and the dry loaded weights are 212,250 pounds (PWR Fuel TSC), 216,750 pounds (PWR DF TSC) and 204,000 pounds (GTCC LLW TSC)[19].
- The top of the MTC has three sets of retaining blocks that are moved into an engaged position to prevent a TSC from being raised out of the MTC during TSC transfer operations[19].
- Attached to the bottom of the MTC is a set of hydraulically operated shield doors to permit passage of a TSC from the VCC into the MTC and from the MTC to the MAGNATRAN transport cask.
- The MTC includes one pair of lifting trunnions oriented in the opening direction of the shield doors and provide for single-failure-proof (via high design safety factors) lifting with an MTC Lift Yoke.
- Following completion of NAC equipment demobilization, one of the two MTCs used at Zion was moved to the Kewaunee fuel load project and the other provided to another MAGNASTOR system user.

Figure 2-16: MAGNASTOR Vertical Concrete Cask[14]

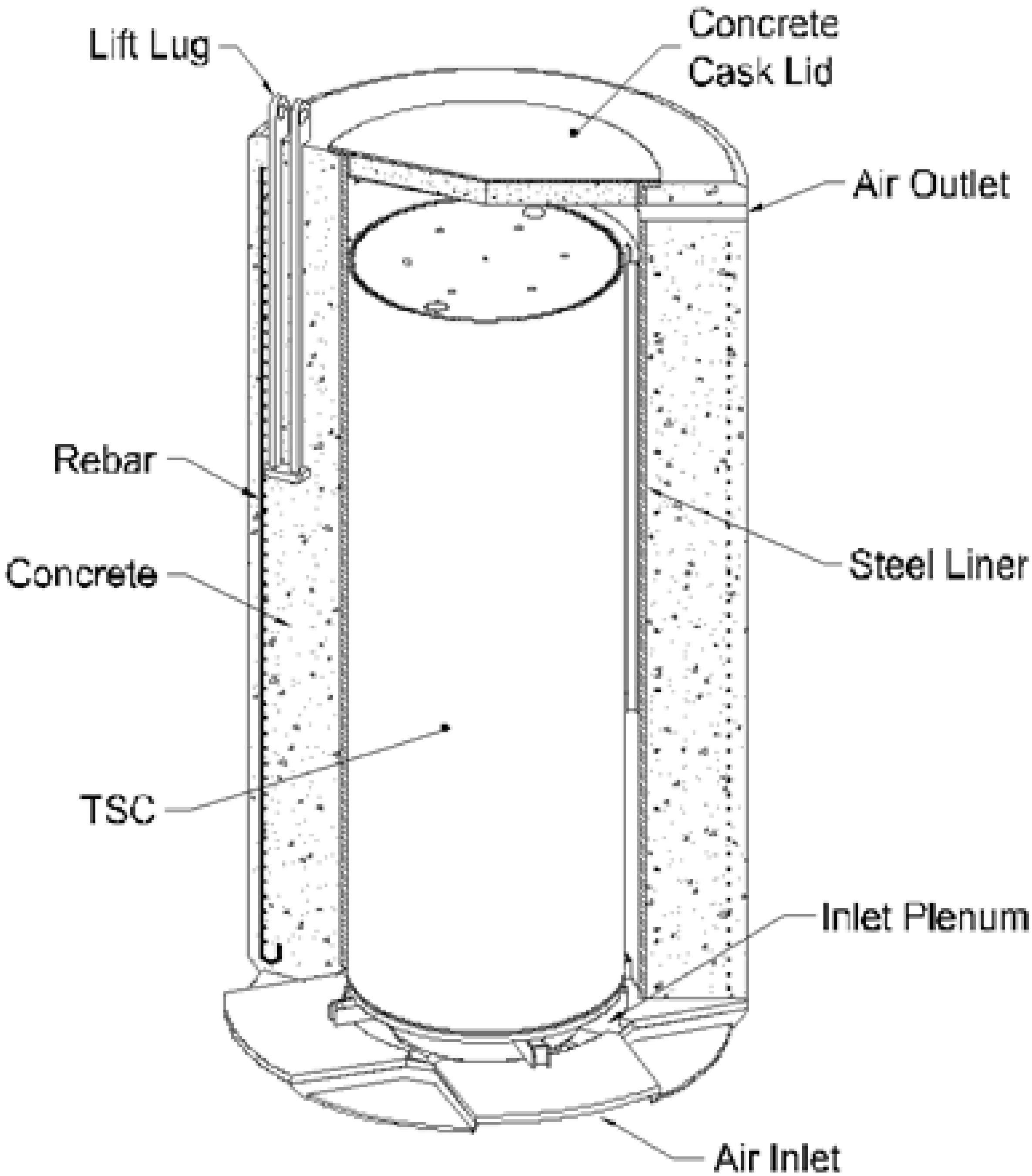


Figure 2-17: MAGNASTOR Vertical Zion VCC Engaged to VCT and Being Removed from LPRC

Figure 2-18: MAGNASTOR Loaded Zion VCC Transferred to the ISFSI by VCT[20]

Figure 2-19: MAGNASTOR Transportable Storage Canister (TSC)[14][18]

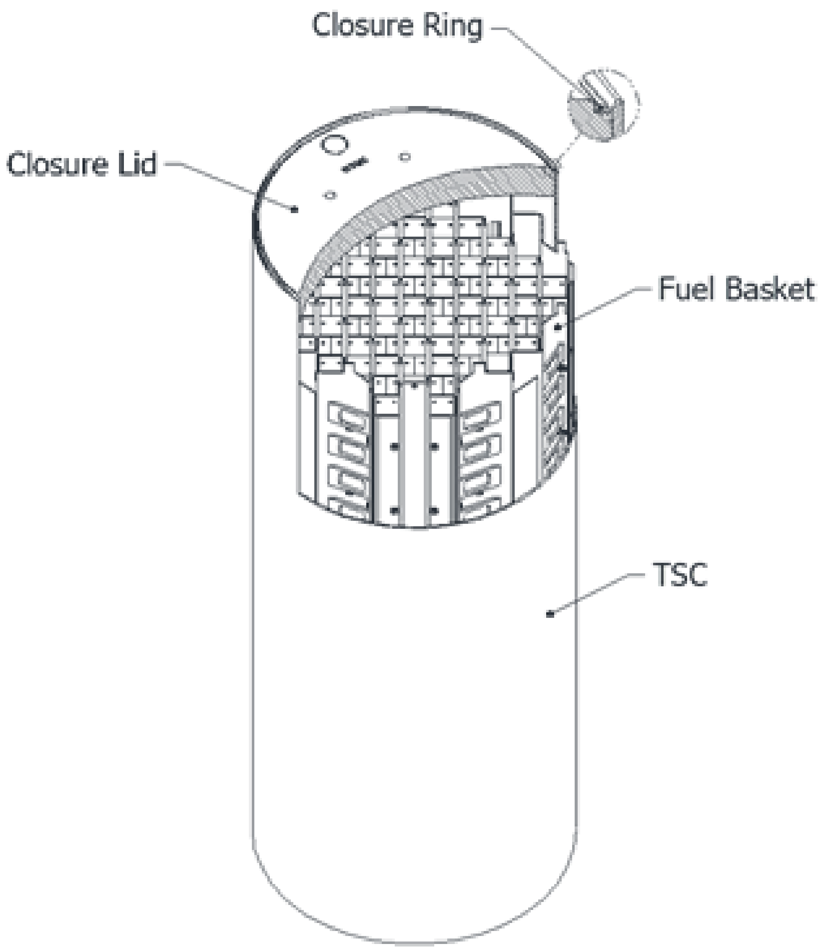


Figure 2-20: MAGNASTOR DF TSC Fuel Basket[14][15]

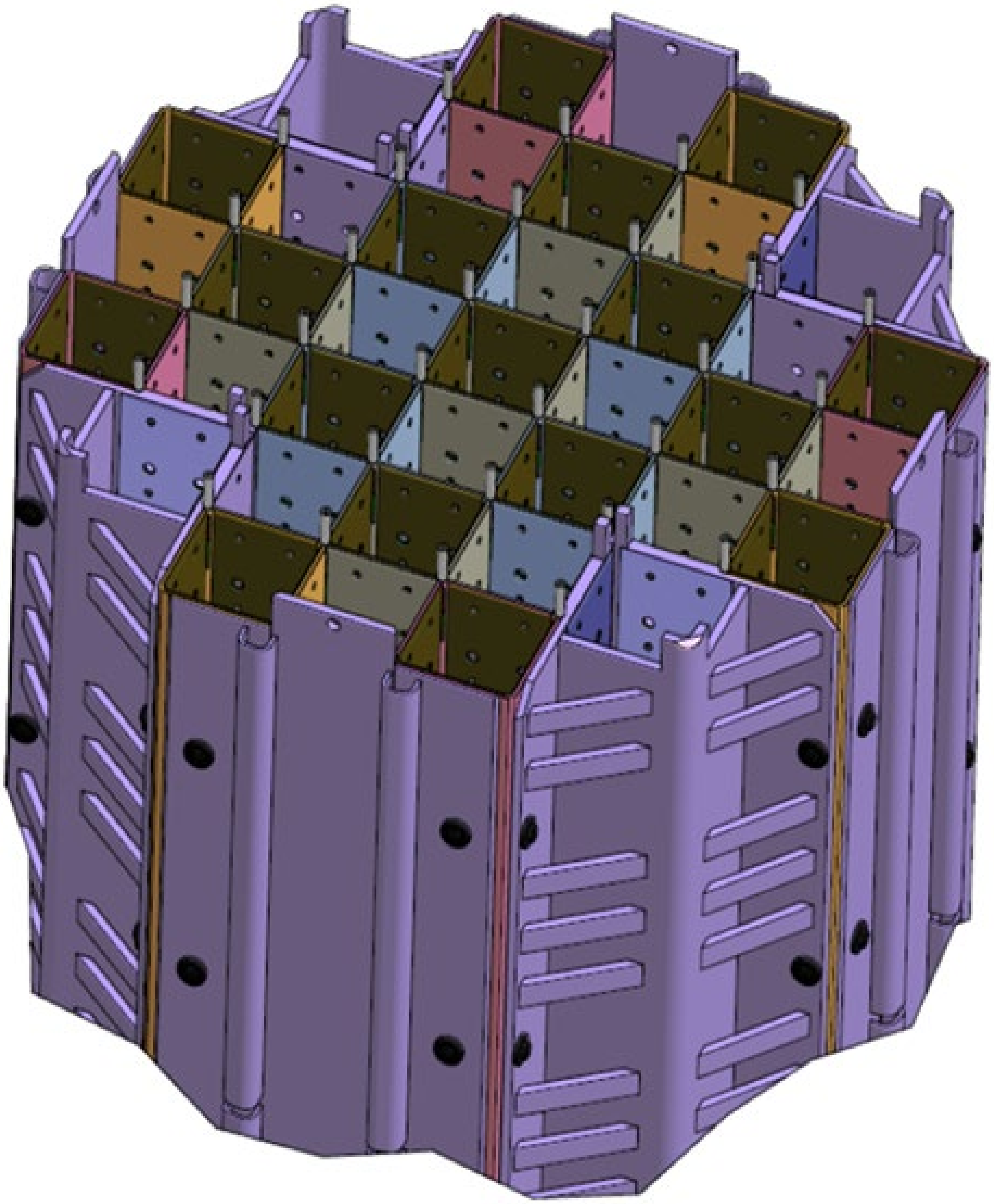


Figure 2-21: MAGNASTOR Transfer Cask (MTC)[14][19] and Transfer Adapter

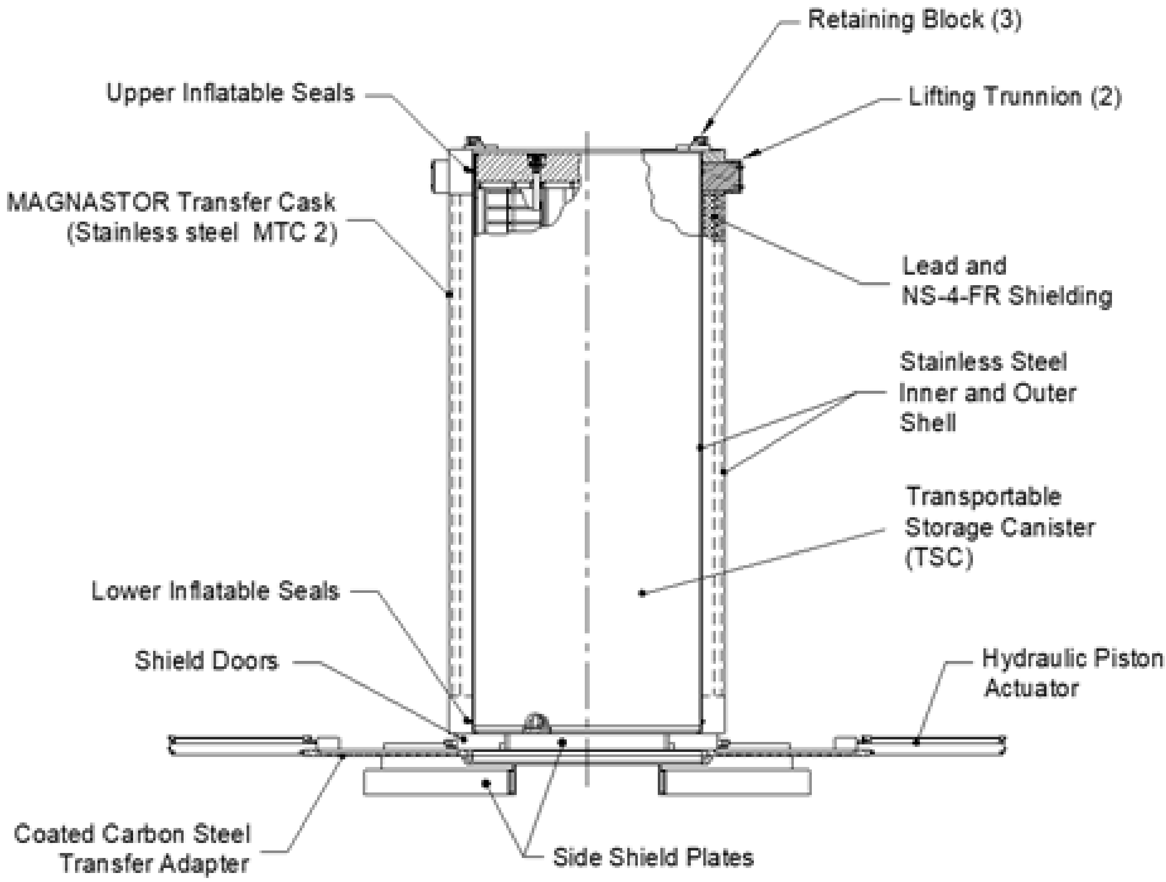


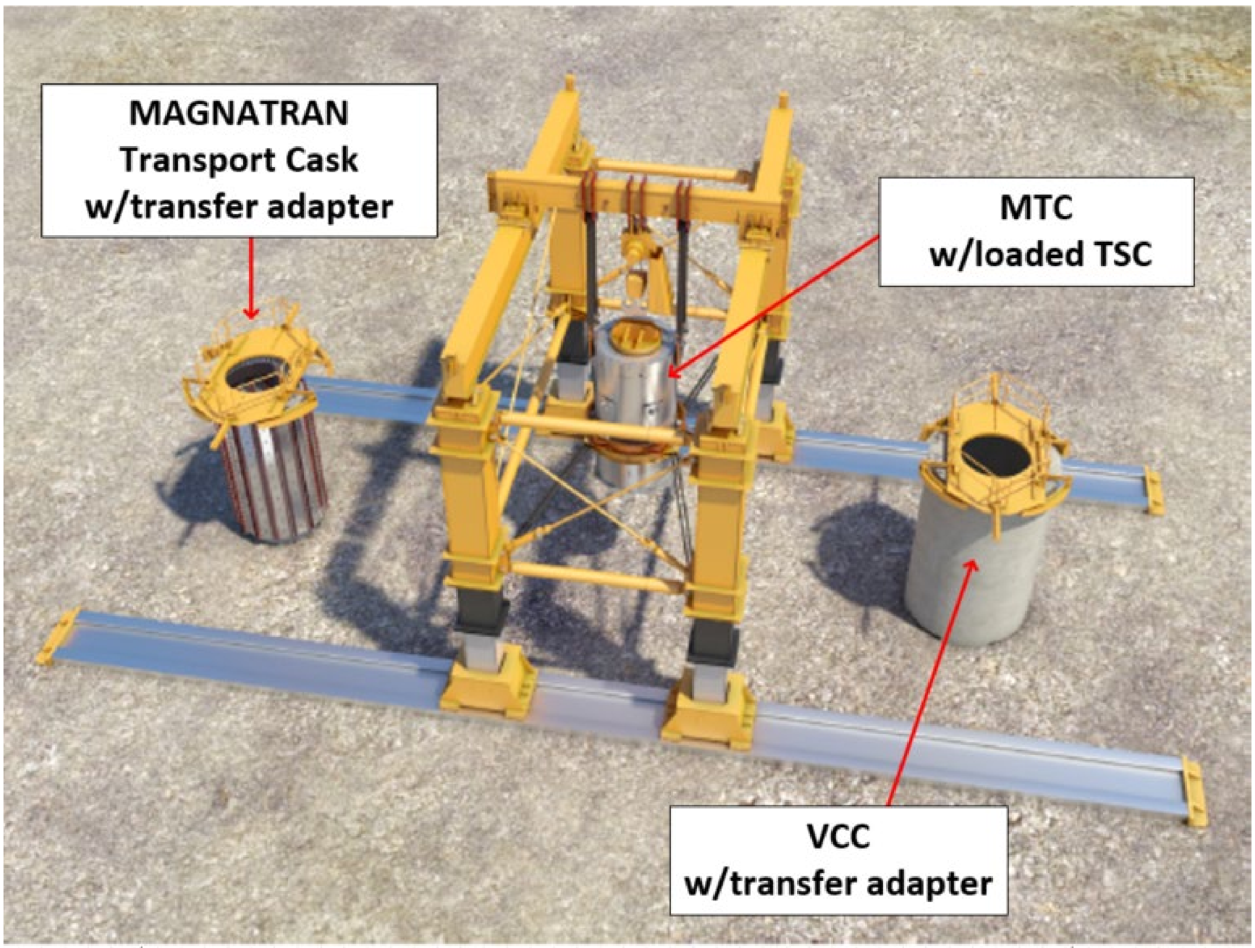
Figure 2-22: MAGNASTOR Transfer Cask (MTC)[19] Transfer of Zion TSC into VCC with MTC Restraints Installed

Transport Equipment

At the current time, there is insufficient space on the Zion ISFSI pad to perform the set-up and positioning of equipment to perform the MAGNASTOR TSC transfer operations in a safe and efficient manner. It is recommended that an evaluation of the available pad area for a TSC Handling, and Transfer Facility be conducted directly adjacent to the designated rail transload location. It is estimated that a TSC Handling and Transfer Facility pad of approximately 25 x 35 feet level with the ground be designed and constructed to support on-site transport operations. The loaded VCCs would be brought to the TSC Handling and Transfer Facility using a VCT. The empty MAGNATRAN transportation cask would be off-loaded from the rail car and set down vertically on the TSC Handling and Transfer Facility pad.

The transfer and loading of the MAGNASTOR TSCs would be performed in a vertical orientation with the VCC and MAGNATRAN positioned adjacent to each other at the TSC Handling and Transfer Facility. The empty MTC with its transfer adaptor is positioned on top of the VCC for retrieval of the TSC and the TSC is then withdrawn from the VCC into the MTC. The loaded MTC is moved and set down on top of the MAGNATRAN transport cask and the TSC lowered into the transport cask. A TSC Handling and Transfer Facility may require a seismic support structure in accordance with MAGNASTOR CoC No. 1031 Technical Specification (TS), Appendix A, 4.4 if the load handling system does not remain engaged to the MTC when in the stack-up position on top of the VCC or MAGNATRAN transport cask. As an alternative to the seismic support structure at the TSC Handling and Transfer Facility, a mobile or fixed crane system, or a qualified gantry system such as NAC's Modular Portable Cask Transfer Facility as shown in **Figure 2-23** could be used to engage to a Secure-Lift Yoke and Integrated Chain Hoist that would be used to efficiently transfer and load the Zion TSCs into the MAGNATRAN transportation casks while maintaining support for the MTC while set down on the VCC or MAGNATRAN transportation cask. The Modular Portable Cask Transfer Facility satisfies the MAGNASTOR CoC No. 1031 TSs Appendix A, Section 4.4, "TSC Handling and Transfer Facility" requirements. These operational alternatives are discussed in further detail in **Section 6.0**.

Figure 2-23: NAC Modular Portable Cask Transfer Facility



During Zion TSC transfer and loading operations, a loaded VCC can be brought from its' storage on the Zion ISFSI pad to the designated transfer/unloading position on the pad using the VCT. After the VCC is positioned, the rail car conveying an empty MAGNATRAN transportation cask is positioned adjacent to the TSC Handling and Transfer Facility and the MAGNATRAN is prepared for off-loading, uprighted and set down on the TSC Handling and Transfer Facility pad adjacent to the VCC. If operationally preferred, the MAGNATRAN on its intermodal transport cradle can be lifted off of the rail car and set on the ground and the uprighting performed.

At the completion of the MAGNATRAN transportation cask loading with a Zion TSC and preparation of the package for transport, the MAGNATRAN cask is down ended onto the intermodal transport cradle located on the rail car. The empty VCC is repositioned on the pad or the empty VCC storage area using the VCT and the next VCC is retrieved for pickup of the next loaded VCC designated for unloading.

2.2 Characteristics of SNF and GTCC LLW to be Shipped

The transfer of the complete inventory of SNF intended to be shipped from the Zion site to the Zion ISFSI was completed on January 8, 2015, and is contained in sixty-one (61) MAGNASTOR PWR Fuel and DF TSCs loaded in Vertical Concrete Casks (VCCs). There is a total of 2,226 SNF assemblies and two DFCs containing fuel debris with a total of 1,018.52 Metric Tons of Heavy Metal (MTHM), which are stored at the Zion ISFSI[19]. Four (4) MAGNASTOR GTCC LLW systems were also loaded and are co-located with the SNF systems at the Zion ISFSI.

The Zion SNF is a Westinghouse 15 x 15 assembly configuration and was supplied by Westinghouse in one of three designs. In all cases, the fuel assemblies are 159.975 inches long without insert and 164.935 inches long with insert and a cross-section of 8.426 inches. **Table 2-2** provides information on the Zion fuel designs. **Table 2-3** provides the discharge date for the Zion SNF in storage and **Table 2-4** provides the ranges of burnups for the Zion fuel inventory.

Table 2-2: Zion Fuel Design Information[5][21]

Design	No. of Assemblies at Zion ISFSI
WE 15x15 Vantage 5 (W1515WV5)	194
WE 15x15 OFA (W1515WO)	920
WE 15x15 WL (W1515WL)	1,112
Fuel Debris DFC	2
Total	2,228

Table 2-3 and **Table 2-4** provide data associated with the fuel assemblies loaded in the Zion ISFSI. The fuel was discharged from the reactor vessel between 1976 and 1997. The lowest burnup is 14.2 GWd/MTHM and the highest burnup is 55.4 GWd/MTHM. The median burnup is 33.1 GWd/MTHM. There are 36 fuel assemblies having a burnup greater than 45 GWd/MTHM (i.e., high burnup). An additional assembly with a burnup of 44.945 GWd/MTHM was also treated as high burnup. More details on the SNF are contained within the Nuclear Power Plant Infrastructure Evaluations for Removal of Spent Nuclear Fuel[6], the NAC MAGNASTOR FSAR[12], and NRC MAGNASTOR CoC[22].

Table 2-3: Zion Fuel Discharge Data[5][7][8]

Year[1]	SNF Assemblies
1976	49
1977	106
1978	129
1979	139
1980	59
1981	128
1982	52
1983	129
1984	68
1985	149
1986	60
1987	80
1988	148
1989	76
1990	72
1992	160
1993	76
1995	160
1996	193
1997	193
Total	2,228

1. Note: Year indicates when the assemblies were discharged

Table 2-4: Zion Fuel Burnup Data[7][8][21]

Burnup (GWd/MTHM)	SNF Burnup
10 - 15	16
15 - 20	137
20 - 25	124
25 - 30	287
30 - 35	900
35 - 40	507
40 - 45	219
45 – 50 (HBU)	32
50 – 55 (HBU)	2
55 – 60 (HBU)	2
Total	**2,228**

The SNF and associated non-fuel hardware loaded into the MAGNASTOR Systems currently in storage at Zion are listed in **Table 2-5**. A total of 2,226 Zion SNF assemblies and 2 DFCs of fuel debris were loaded into 61 MAGNASTOR Systems including 32 standard PWR fuel TSCs and 29 damaged fuel (DF) PWR TSCs.

Table 2-5: Zion TSC Fuel Loading Details[7][8][21][23]

Fuel Load Sequence No.	MAGNASTOR VCC / TSC Serial Number	TSC Contents [2, 3]	Heat Load[1] (kW)	Date Loaded onto ISFSI
1	VCC-41 / TSCDF-15	37 SNF FAs + 4 DFCs (+ 7 BPRA + 9 RCCA + 8 TPD + 7 BPRA)	10.58	1/9/14
2	VCC-40 / TSCDF-13	37 SNF FAs + 4 DFCs (+ 8 BPRA + 9 RCCA + 9 TPD + 7 WABA)	10.57	1/17/14
3	VCC-21 / TSCDF-14	37 SNF FAs + 4 DFCs (+ 7 BPRA + + 12 TPD + 5 WABA + 9 RCCA)	10.47	1/25/14

Fuel Load Sequence No.	MAGNASTOR VCC / TSC Serial Number	TSC Contents [2, 3]	Heat Load[1] (kW)	Date Loaded onto ISFSI
4	VCC-39 / TSC-03	37 SNF FAs (+ 8 BPRA + 11 WABA + 10 TPN + 8 RCCA)	11.72	2/15/14
5	VCC-20 / TSC-04	37 SNF FAs (+ 13 BPRA + 12 TPD + 12 WABA)	11.99	2/25/14
6	VCC-19 / TSC-05	36 SNF FAs (+ 9 BPRA + 13 WABA + 5 TPD)	15.14	3/5/14
7	VCC-18 / TSC-06	36 SNF FAs (+ 2 BPRA + 14 WABA + 5 TPD + 1 HFRA + 1 RCCA)	15.35	3/13/14
8	VCC-23 / TSCDF-11	37 SNF FAs + 4 DFC (+ 9 TPD + 9 RCCA + 1 BPRA + 14 WABA)	16.72	3/26/14
9	VCC-22 / TSCDF-12	37 SNF FAs + 4 DFCs (+ 5 BPRA + 9 RCCA + 9 TPD + 10 WABA)	15.82	4/5/14
10	VCC-24 / TSCDF-16	36 SNF FAs + 1 DFC of Fuel Debis (ZFRSB1) + 3 DFCs (+ 7 BPRA + 9 RCCA + 10 WABA + 6 TPD)	16.68	4/10/14
11	VCC-25 / TSCDF-17	37 SNF FAs + 4 DFC (+ 12 TPD + 9 RCCA + 4 BPRA + 5 WABA)	15.76	4/19/14
12	VCC-26 / TSCDF-18	37 SNF FAs + 4 DFC (+ 7 TPD + 9 RCCA + 3 BPRA +11 WABA)	16.65	4/24/14
13	VCC-27 / TSCDF-19	37 SNF FAs + 4 DFCs (+ 9 BPRA + WABA + 6 TPD + 9 RCCA)	15.32	4/30/14
14	VCC-28 / TSCDF-20	36 SNF FAs + 1 DFC of Fuel Debis (Y48B) + 3 DFCs (+ 5 BPRA + 7 TPD + 10 WABA + 9 RCCA)	17.83	5/4/14

Fuel Load Sequence No.	MAGNASTOR VCC / TSC Serial Number	TSC Contents [2, 3]	Heat Load[1] (kW)	Date Loaded onto ISFSI
15	VCC-29 / TSCDF-21	37 SNF FAs + 4 DFCs (+ 5 BPRA + 7 TPD + 8 WABA + 9 RCCA)	18.1	5/8/14
16	VCC-30 / TSCDF-22	36 SNF FAs + 4 DFCs (+ 5 BPRA + 10 TPD + 10 WABA + 1 NSA-Sec)	18.18	5/13/14
17	VCC-31 / TSCDF-23	37 SNF FAs + 4 DFCs (+ 3 BPRA + 7 TPD + 10 WABA + 9 RCCA)	18.23	5/17/14
18	VCC-32 / TSCDF-24	36 SNF FAs + 4 DFCs (+ 6 BPRA + 10 TPD + 8 WABA + 2 RCCA)	18.2	5/22/14
19	VCC-33 / TSCDF-28	37 SNF FAs + 4 DFCs (+ 5 BPRA + 6 TPD + 10 WABA + 9 RCCA)	18.1	5/27/14
20	VCC-34 / TSCDF-26	36 SNF FAs + 4 DFCs (+ 6 BPRA + 11 TPD + 12 WABA + 1 RCCA)	17.29	5/31/14
21	VCC-35 / TSCDF-27	36 SNF FAs + 4 DFCs (+ 3 BPRA + 6 TPD + 16 WABA + + 1 NSA-Sec)	17.9	6/2/14
22	VCC-17 / TSC-07	37 SNF FAs (+ 11 BPRA + 15 WABA + 13 TPD)	11.96	6/8/14
23	VCC-01 / TSC-19	36 SNF FAs (+ 5 BPRA + 1 NSA-Sec + 5 TPD + 17 WABA)	14.6	6/14/14
24	VCC-02 / TSC-16	36 SNF FAs (+ 2 BPRA + 9 TPD + 11 WABA)	14.95	6/19/14
25	VCC-16 / TSC-18	37 SNF FAs (+ 9 BPRA + 10 WABA + 14 TPD + 3 RCCA)	11.67	6/25/14

Fuel Load Sequence No.	MAGNASTOR VCC / TSC Serial Number	TSC Contents [2, 3]	Heat Load[1] (kW)	Date Loaded onto ISFSI
26	VCC-15 / TSC-20	37 SNF FAs (+ 14 BPRA + 7 WABA + 14 TPD + 2 RCCA)	11.71	7/12/14
27	VCC-03 / TSC-15	36 SNF FAs (+ 4 BPRA + 5 TPD + 19 WABA + 1 NSA-Sec)	14.53	7/19/14
28	VCC-04 / TSCDF-29	37 SNF FAs + 4 DFCs (+ 3 BPRA + 9 TPD + 12 WABA + 9 RCCA)	14.82	7/25/14
29	VCC-61 / TSCDF-30	37 SNF FAs + 4 DFCs (+ 4 BPRA + 11 TPD + 9 WABA + 9 RCCA)	14.8	7/30/14
30	VCC-60 / TSCDF-25	37 SNF FAs (+ 13 BPRA + 9 TPD + 6 WABA + 9 RCCA)	10.6	8/7/14
31	VCC-58 / TSC-08	36 SNF FAs (+ 3 BPRA + 4 TPD + 16 WABA + 1 HFRA)	15.3	8/13/14
32	VCC-57 / TSC-09	36 SNF FAs (+ 1 BPRA + 7 TPD + 13 WABA)	17.4	8/19/14
33	VCC-56 / TSC-10	37 SNF FAs (+ 5 BPRA + 6 TPD + 9 WABA + 5 RCCA + NSA-Pri)	18.36	8/24/14
34	VCC-54 / TSC-11	37 SNF FAs (+ 5 BPRA + 5 TPD + 9 WABA + 1 RCCA + 1 NSA-Sec)	18.02	8/30/14
35	VCC-53 / TSC-17	36 SNF FAs (+ 3 BPRA + 5 TPD + 18 WABA + 1 HFRA)	14.47	9/4/14
36	VCC-52 / TSC-12	37 SNF FAs (+ 6 BPRA + 7 TPD + 9 WABA + 1 RCCA + 1 NSA-Sec)	17.9	9/9/14
37	VCC-51 / TSC-13	37 SNF FAs (+ 4 BPRA + 8 TPD + 12 WABA + 1 NSA-Sec)	17.33	9/15/14

Fuel Load Sequence No.	MAGNASTOR VCC / TSC Serial Number	TSC Contents [2, 3]	Heat Load[1] (kW)	Date Loaded onto ISFSI
38	VCC-50 / TSC-14	37 SNF FAs (+ 5 BPRA + 5 TPD + 9 WABA + 1 RCCA + 1 NSA-Pri)	18.02	9/21/14
39	VCC-55 / TSC-01	36 SNF FAs (+ 3 BPRA + 6 TPD + 10 WABA + 5 HFRA + 1 NSA-Sec)	15.14	9/25/14
40	VCC-48 / TSC-02	33 SNF FAs	15.04	9/30/14
41	VCC-47 / TSC-21	37 SNF FAs (+ 4 BPRA + 9 TPD + 13 WABA + 1 RCCA + 1 NSA-Sec)	16.33	10/6/14
42	VCC-46 / TSC-22	37 SNF FAs (+ 4 BPRA + 11 TPD + 14 WABA)	15.9	10/11/14
43	VCC-36 / TSC-26	37 SNF FAs (+ 2 BPRA + 7 TPD + 20 WABA + 1 NSA-Pri)	16.2	10/16/14
44	VCC-05 / TSC-24	35 SNF FAs (+ 5 BPRA + 12 TPD + 3 WABA)	15.71	10/21/14
45	VCC-06 / TSC-29	35 SNF FAs (+ 8 TPD + 12 WABA)	14.9	10/25/14
46	VCC-07 / TSCDF-03	37 SNF FAs + 4 DFCs (+ 5 BPRA + 10 TPD + 8 WABA + 9 RCCA)	15.18	10/31/14
47	VCC-08 / TSCDF-04	36 SNF FAs + 4 DFCs (+ 3 BPRA + 9 TPD + 10 WABA + 3 RCCA + 1 NSA-Sec)	17.86	11/4/14
48	VCC-09 / TSC-25	33 SNF FAs (+ 7 TPD + 12 WABA + 1 RCCA)	13.89	11/9/14
49	VCC-10 / TSC-30	37 SNF FAs (+ 11 TPD + 17 WABA + 2 BPRA)	15.48	11/16/14

Fuel Load Sequence No.	MAGNASTOR VCC / TSC Serial Number	TSC Contents [2, 3]	Heat Load[1] (kW)	Date Loaded onto ISFSI
50	VCC-11 / TSCDF-05	37 SNF FAs + 4 DFCs (+ 6 BPRA + 8 TPD + 10 WABA + 9 RCCA)	14.9	11/21/14
51	VCC-12 / TSC-28	36 SNF FAs (+ 3 TPD + 17 WABA + 3 BPRA + 2 RCCA)	17.12	11/25/14
52	VCC-13 / TSC-27	37 SNF FAs (+ 6 TPD + 20 WABA + 2 BPRA)	15.84	11/30/14
53	VCC-14 / TSCDF-01	37 SNF FAs + 4 DFCs (+ 8 BPRA + 5 TPD + 9 WABA + 9 RCCA)	15.59	12/4/14
54	VCC-37 / TSCDF-02	36 SNF FAs (+ 4 BPRA + 4 TPD + 11 WABA + 1 RCCA)	16.74	12/9/14
55	VCC-38 / TSCDF-06	36 SNF FAs + 2 DFCs (+ 6 BPRA + 8 TPD + 10 WABA)	17.47	12/13/14
56	VCC-42 / TSCDF-07	37 SNF FAs (+ 3 BPRA + 11 TPD + 17 WABA)	15.12	12/17/14
57	VCC-43 / TSCDF-08	37 SNF FAs + 4 DFCs (+ 7 BPRA + 9 TPD + 7 WABA + 9 RCCA)	14.87	12/22/14
58	VCC-44 / TSC-23	37 SNF FAs (+ 7 TPD +18 WABA + 6 BPRA + 1 RCCA)	15.29	12/26/14
59	VCC-45 / TSC-53	37 SNF FAs (+ 13 TPD +13 WABA + 1 BPRA + 1 RCCA + 1 NSA-Pri)	16.15	12/30/14
60	VCC-49 / TSC-54	37 SNF FAs (+ 5 BPRA + 7 TPD + 18 WABA + 2 RCCA)	15.66	1/4/15
61	VCC-59 / TSCDF-09	37 SNF FAs + 2 DFC (+ 7 BPRA + 13 TPD + 6 WABA + 9 RCCA)	16.52	1/8/15

Notes
1 Heat load values are for the entire system based on Zion data at time of loading
2 Content abbreviations FA – Fuel Assemblies (Max. Assembly 1475#); DFC – Damaged Fuel Can (123#); BPRA – Burnable Poison Rod Assembly (20#); RCCA – Reactor Core Control Assembly (165#); NSA – Neutron Source Assembly (10#); TP – Thimble Plug (10#); WABA – Wet Annulus Burnup Assembly (23#)
3 Ninety-eight DFCs loaded in TSCDF canisters.

The Zion GTCC LLW loaded into four (4) MAGNASTOR GTCC LLW TSCs are listed in **Table 2-6**. A total of 99,099 pounds of GTCC LLW were loaded from the Zion Unit 1 and Unit 2 reactor internals. The GTCC LLW TSCs are approved for transport in the MAGNATRAN transport cask system. The GTCC LLW loaded consists of irradiated reactor internals and limited quantities of special nuclear material in the two reactor containments and stored at the ISFSI. The special nuclear material is contained in two of the GTCC LLW TSCs as follows: Unit 1 GTCC-01 contains 4 Unit 1 Reactor Vessel Specimen Program (RVSP) Capsules S, V, W and Z, and Unit 2 GTCC-01 contains 22 Unit 1 and Unit 2 Movable Incore Detectors (MIDs). There is no process waste in the GTCC canisters (i.e., no Tri-Nuc filters or F/D resin). The entire contents of the GTCC canisters were fully de-watered during the vacuum drying process.

Table 2-6: GTCC LLW Canister Loading[21]

Package No	GTCC Weight (lbs)	Total TSC Weight (lbs)	Activity Inventory[1] (Ci)	Heat Load
U1 GTCC-01	25,291	55,908	FE-55 – 7,601 Co-60 – 59,692 Ni-63 – 51,961	Approx. 1 kW
U1 GTCC-02	25,271	55,262	Fe-55 – 9,222 Co-60 – 51,304 Ni-63 – 64,888	Approx. 1 kW
U2 GTCC-01	23,495	51,904	FE-55 – 7,966 Co-60 – 56,908 Ni-63 – 54,089	Approx. 1 kW
U2 GTCC-02	22,042	50,541	Fe-55 – 7,254 Co-60 – 40,176 Ni-63 – 49,845	Approx. 1 kW

Note:
1 Activity Datum U1 GTCC LLW - 2/1/2015; U2 GTCC LLW – 8/1/2014

2.3 Description of Canisters/Overpacks to be Shipped

The inventory of MAGNASTOR TSCs at the Zion ISFSI to be evaluated for shipment in MAGNATRAN transport casks includes the 61 MAGNASTOR Fuel and DF TSCs listed in **Table 2-5**, and the 4 GTCC LLW TSCs listed in **Table 2-6**[11]. The MAGNASTOR TSCs at Zion site are certified for transportation of in the MAGNATRAN transport cask under Certificate of Compliance (CoC) No. 71-9356[23] as follows: Undamaged Fuel TSCs per 5.(b)(1)(i) and 5.(b)(2)(i); Damaged and High Burnup TSCs per 5.(b)(1)(ii) and 5.(b)(2)(ii); and GTCC LLW per 5.(b)(1)(iv) and 5.(b)(2)(iv). The characteristics of the MAGNATRAN contents are as authorized in the CoC [9] and as summarized below in **Table 2-7**. At the current time, a majority of the SNF assemblies loaded into MAGNASTOR fuel and DF TSCs is transportable under the current MAGNATRAN CoC. However, there may be some higher enriched and underloaded assemblies that require additional cooling time to meet **Table 2-8, Table 2-9, Table 2-10**, and **Table 2-11** for undamaged and damaged fuel assemblies. These assembly specific calculations and evaluations will be required to be performed to ensure all SNF assemblies satisfy all applicable MAGNATRAN CoC requirements prior to loading. These evaluations would be completed as part of the MAGNSTOR and MAGNATRAN FSAR, SAR and applicable CoC reviews. The GTCC LLW TSCs are evaluated to be currently authorized for transport.

Table 2-7: Description of Zion 15x15 PWR TSC Contents for Transport[23]

Characteristic	Fuel Assembly 15 x15
Base Fuel Type[1]	W
Max Initial Enrichment (wt. % 235U) [2]	5.0
Min Initial Enrichment (wt. % 235U) [2]	1.3
Number of Fuel Rods [3]	204
Max Assembly Average Burnup (MWd/MTU) [4]	60,000
Min Cool Time (years)	4
Max Weight per Storage Location (lbs.)	See Note 6
Max Decay Heat per Fuel Location (Watts) [5]	622 / 595

Notes:

1 Indicates assembly vendor/type reference for fuel input data. Fuel acceptability for loading is not restricted to the indicated vendor provided that the fuel assembly meets the load limits. Abbreviations are as follows: Westinghouse (W, WE)

2 All reported enrichment values are nominal pre-irradiation fabrication values. PWR fuel is loaded using burnup credit. Maximum enrichment is a function of minimum burnup. Maximum initial enrichment represents the peak fuel rod enrichment for variably-enriched fuel assemblies.

3 Assemblies may contain nonfuel hardware and/or fuel replacement rods.

4 All fuel with burnup >45,000 MWd/MTU is placed into DFCs. (Note: it is NAC's intent to delete this requirement for high burnup fuel (HBU) as NRC gains additional information on the integrity of HBU fuel assemblies).

5 Maximum uniform heat load per storage location. For PWR baskets with Type 2 thermal conductivity neutron absorbers (MMC) is 622 watts per storage location (590.5 watts for maximum assembly average burnup >45,000 MWd/MTU), and for PWR baskets with Type 1 thermal conductivity neutron absorbers (Boral) the maximum heat load is 595 watts per storage location (565 watts for maximum assembly average burnup >45,000 MWd/MTU). The heat load includes the contribution from the nonfuel hardware.

6 Maximum weight per storage location is 1,765 lbs. (including nonfuel hardware and spacers) with a maximum contents weight of 62,160 lbs. for the PWR basket and 61,184 lbs. for the DF basket.

The maximum initial enrichment for undamaged Zion SNF FAs proposed for transport in the MAGNATRAN shall be verified to meet the requirements of **Table 2-8** for 15 year minimum cooled fuel and **Table 2-9** for underloaded 20 year minimum cooled fuel.

Table 2-8: Maximum Initial Enrichment – 37-Assembly Undamaged Zion Fuel[23]

Assembly ID	^{10}B Absorber (g/cm^2)	Zero (0) Burnup Maximum Enrichment (wt %)	Max Initial Enrichment (wt % ^{235}U) = C_4 × Burnup (GWd/MTU) + C_5					
			Burnup (GWd/MTU) < 18		18 ≤ Burnup (GWd/MTU) ≤ 30		Burnup (GWd/MTU) < 30	
			C_4	C_5	C_4	C_5	C_4	C_5
WE15	0.036	1.9	0.0494	1.74	0.0683	1.72	0.0742	1.67

Table 2-9: Maximum Initial Enrichment – Undamaged Zion Fuel Configuration[23]

Number of Assemblies Loaded	^{10}B Absorber (g/cm^2)	Zero (0) Burnup Maximum Enrichment (wt. % ^{235}U)	Max Initial Enrichment (wt % ^{235}U) = C_4 × Burnup (GWd/MTU) + C_5					
			Burnup (GWd/MTU) < 18		18 ≤ Burnup (GWd/MTU) ≤ 30		Burnup (GWd/MTU) > 30	
			C_4	C_5	C_4	C_5	C_4	C_5
36	0.036	2.0	0.0497	1.93	0.0681	1.99	0.0747	2.00
35		2.1	0.0507	1.97	0.0673	2.08	0.0730	2.12
33		2.2	0.0504	2.12	0.0664	2.29	0.0745	2.32

Similarly, the maximum initial enrichment for damaged Zion SNF FAs proposed for transport in the MAGNATRAN shall be verified to meet the requirements of **Table 2-10** for 15 year minimum cooled fuel and **Table 2-11** for underloaded 20 year minimum cooled fuel.

Table 2-10: Maximum Initial Enrichment – 37-Assembly Damaged Zion Fuel[23]

Assembly ID	^{10}B Absorber (g/cm^3	Zero (0) Burnup Max. Enr. (wt %)	Max Initial Enrichment (wt % ^{235}U) = C_4 × Burnup (GWd/MTU) + C_5							
			Burnup (GWd/MTU) < 18		18 ≤ Burnup (GWd/MTU) ≤ 30		30 < Burnup (GWd/MTU) ≤ 50		50 < Burnup (GWd/MTU)	
			C_4	C_5	C_4	C_5	C_4	C_5	C_4	C_5
WE15	0.036	1.6	0.0482	1.43	0.0692	1.27	0.0738	1.08	0.0738	0.767

Table 2-11: Maximum Initial Enrichment-Damaged Zion Fuel Configuration[23]

Number of Assemblies	^{10}B Absorber (g/cm^2)	Zero (0) Burnup Max. Enr. (wt %)	Max Initial Enrichment (wt % ^{235}U) = C_4 × Burnup (GWd/MTU) + C_5							
			Burnup (GWd/MTU) < 18		18 ≤ Burnup (GWd/MTU) ≤ 30		30 < Burnup (GWd/MTU) ≤ 50		50 < Burnup (GWd/MTU)	
			C_4	C_5	C_4	C_5	C_4	C_5	C_4	C_5
36	0.036	1.6	0.0483	1.53	0.0721	1.35	0.0750	1.17	0.0750	0.851
35		1.7	0.0532	1.51	0.0722	1.45	0.0778	1.14	0.0778	1.14
33		1.7	0.0524	1.60	0.0734	1.52	0.0791	1.22	0.0791	1.22

The requirements for additional cool time for damaged and HBU Zion SFAs are presented in **Table 2-12.**

Table 2-12: Additional Cool Time Required for Damaged and High Burnup Zion W 15x15 Fuel Contents[23]

Max Assembly Average Burnup (GWd/MTU)	Min initial Assembly Average Enrichment (wt% 235U)	WE 15 x 15 Delta Cool Time (years)
35	2.1	2.5
	2.3	0.8
40	2.5	3.3
	2.7	1.2
	2.9	0.0
45	2.7	4.5
	2.9	2.7
	3.1	0.7
	3.3	0.0
50	2.7	4.8
	2.9	3.5
	3.1	1.2
	3.3	0.0
55	3.1	4.0
	3.3	1.9
	3.5	0.0
60	3.1	5.0
	3.3	4.9
	3.5	2.9
	3.7	0.8
	3.9	0.0

Additional cooling times and requirements for Zion SFA hardware are presented in **Table 2-13, Table 2-14**, and **Table 2-15**.

Table 2-13: Description of Zion Nonfuel Hardware TSC Contents Cooling Times for Transport in MAGNATRAN[23]

Additional WE 15x15 Fuel Assembly Cool Time Required to Load Nonfuel Hardware			
Core (Assembly)	Additional Cool Time (Years)		
	BPRA/HFRA	GTPD/NSA	RCC
W 15x15	1.3	0.1	6.9

Table 2-14: Description of Zion Nonfuel Hardware TSC Contents Burnup and Cooling Times for Transport in MAGNATRAN[23]

Nonfuel Hardware Max Burnup and Required Cool Times (Years)		
Hardware	Maximum Burnup (GWd/MTU)	Minimum Cool Time (Years) [1] WE 15x15
BPRA	70	8.0
GTPD/NSA	180	8.0

1 Minimum cool time for Zion nonfuel hardware should be met by 2023 for newest assembly.

Table 2-15: Description of Zion Nonfuel Hardware TSC ^{60}Co Activity for Transport in MAGNATRAN[23]

Nonfuel Hardware Max ^{60}Co Activity (Ci)	
Hardware	WE 15x15
BPRA	901.0
GTPD/NSA	73.1

The MAGNATRAN transport cask is designed to be compatible with all MAGNASTOR TSCs currently deployed at six ISFSIs in the U.S. including Constellation Energy's Zion and Three-Mile Island sites, Duke Power's Catawba and McGuire Stations, Dominion's Kewaunee, and Arizona Public Service's (APS) Palo Verde Nuclear Generating Station (PVNGS). Primarily based on their lengths, two categories of PWR and two categories of BWR fuel assemblies have been evaluated in the safety analysis for transport. Two lengths of TSCs are designed to transport the two categories of PWR and BWR fuel assemblies. The MAGNASTOR TSCs at Zion site are the short length (Type 1) PWR design. The weights of the Zion MAGNASTOR system and MAGNATRAN transport packaging components are shown in **Table 2-16** and the overall characteristics and dimensions are shown in **Table 2-17**.

Table 2-16: NAC MAGNASTOR Storage and MAGNATRAN Transport Cask Weights[13][19]

MAGNASTOR and MAGNATRAN Component Description	Zion Fuel TSC and MAGNATRAN Weights (pounds)	Zion DF TSC and MAGNATRAN Weights (pounds)	Zion GTCC LLW MAGNATRAN Weights (pounds)
TSC Empty Weight (w/basket, w/o fuel/GTCC LLW or closure lid)	29,000	33,500	33,000
TSC Closure Lid	10,500	10,500	10,500
TSC Contents	62,160	61,184	55,000
Loaded/Closed Canister	101,000	104,500	98,000
VCC (empty w/lid)	210,000	210,000	210,000
VCC Lid	4,500	4,500	4,500
VCC Loaded	315,000	318,500	312,500
MTC (empty)	106,000	106,000	106,000
MTC w/TSC	207,000	210,500	204,000

MAGNASTOR and MAGNATRAN Component Description	Zion Fuel TSC and MAGNATRAN Weights (pounds)	Zion DF TSC and MAGNATRAN Weights (pounds)	Zion GTCC LLW MAGNATRAN Weights (pounds)
MAGNASTOR Transfer Adapter	12,850	12,850	12,850
MTC Lift Yoke	5,500	5,500	5,500
Loaded MTC Under-the-Hook Weight [1]	212,500	216,000	209,500
MAGNATRAN TSC Content Weight (Maximum)	101,000	104,500	98,000
MAGNATRAN Transport Spacer for TSC4	1,000	1,000	1,000
MAGNATRAN Top Impact Limiter (Balsa)	8,000	8,000	8,000
MAGNATRAN Bottom Impact Limiter (Balsa)	8,000	8,000	8,000
MAGNATRAN Lid (w/Closure Bolts)	10,500	10,500	10,500
MAGNATRAN Cask Body	180,500	180,500	180,500
MAGNATRAN with Lid and Closure Bolts	191,000	191,000	191,000
MAGNATRAN with Lids + Spacer	192,000	192,000	192,000
Loaded MAGNATRAN with Zion TSC Contents	293,000	296,500	290,000
MAGNATRAN Lift Yoke (nominal estimated weight)	10,000	10,000	10,000
Loaded MAGNATRAN Under-the-Hook Weight (dry) [2]	303,000	306,500	300,000
MAGNATRAN Package Transport Ready Weight (Zion) [3]	309,000	312,500	306,000
Intermodal Transport Cradle (estimated weight) [4]	46,200	46,200	46,200

1. MAGNASTOR Transfer Cask (MTC) Under-the-hook weight: MAGNASTOR MTC with loaded Zion DF TSC and MTC Lift Yoke.
2. MAGNATRAN Under-the hook weight: MAGNATRAN loaded with Zion MAGNASTOR TSC contents, Closure Lid, MAGNATRAN transport cavity spacer, and MAGNATRAN lift yoke.
3. MAGNATRAN Package – Transport-ready weight: loaded cask with impact limiters, Zion MAGNASTOR TSCs containing Zion SNF, etc.
4. Intermodal Transport Cradle weight based on Atlas Railcar Project conceptual design[24]

Table 2-17: MAGNATRAN Transport Cask Design Characteristics and Component Dimensions[19]

Design Characteristic	Value	Material
MAGNATRAN Overall Length without Impact Limiters	214 in.	--
MAGNATRAN Overall Length with Impact Limiters	322 in.	--

Design Characteristic	Value	Material
MAGNATRAN Body Maximum Cross-Section Diameter • Across corners of neutron shield plates • Across tips of cooling fins	 99.5 in. 110 in.	--
MAGNATRAN Upper Forging Diameter	86.7 in.	--
MAGNATRAN Bottom Forging Diameter	86.7 in.	--
Impact Limiter Diameter	128 in.	--
MAGNATRAN Limiter Height	66.1 in.	--
MAGNATRAN Cavity Length	192.5 in.	--
Cask Cavity Diameter	72.5 in.	--
Cask Capacity (No. of PWR SNF assemblies) • PWR Fuel • PWR DF	 37 37 (incl. up to 4 DFC)	 -- --
Inner Shell Thickness	1.75 in.	Type 304 Stainless Steel
Gamma Shield Thickness	3.2 in.	Chemical-Copper Lead
Outer Shell Thickness	2.25 in.	Type 304 Stainless Steel
Top Forging – Radial Thickness at Cavity Diameter	7.22 in.	Type 304 Stainless Steel
Bottom Thickness (total) • Bottom Inner Forging • Bottom Plate	13.65 in. 5.0 in. 8.65 in.	 Type 304 Stainless Steel Type 304 Stainless Steel
Neutron Shield Assembly - Thickness • Neutron Shielding • Outer and Inner Shell • Bottom / Top End Plates	 5.5 in. 0.125 in. 0.25 in.	 NS-4-FR, Solid Synthetic Polymer Type 304 Stainless Steel Type 304 Stainless Steel
Lifting Trunnions • Trunnion Diameter • Trunnion Shaft Length • Trunnion Bushing Diameter • Trunnion Cap Diameter • Trunnion Cap Thickness • Bolts (9) • Torque • Trunnion Weight (handling) • Rotation Trunnion Diameter • Rotation Trunnion Available Shaft Length • Rotation Trunnion Support	 6.25 in. 3.75 in. 7.5 in. 8.0 in. 0.378 in. 1-1/8 8 UN-3A 120 ± 20 ft.-lbs. 115 lbs. 6.0 in. 2.5 in. 15.0 x 11.6 x thickness of 6.67 / 7.9 in.	 Type 17-4 PH Stainless Steel (bolted) Nitronic 60 Stainless Steel 304 Stainless Steel SB-637, GR N07718, Nickel Alloy Steel Type 17-4 PH SS (pinned to Trunnion Support) XM-19 Stainless Steel

Design Characteristic	Value	Material
MAGNATRAN Lid Assembly • Total Thickness • Overall Lid Diameter • Recessed Lid Diameter • Top Lid Section Diameter • Lid Rim at Bolt Circle • Bolts (48) • Torque • Inner O-Ring • Outer O-Ring • Leak Test Port Plug Torque	7.75 in. 81.96 in. 72.0 in. 73.7 in. 2.25 in. 2 - 8 UN – 2A 4600 ± 200 ft.-lbs. Metal EPDM 1	17-4 PH Stainless Steel Nickel Alloy SB637, Grade N07718 Helicoflex H-311676 Parker 0.275 E740-75 120 ± 5 in.-lbs.
Vent Coverplate • Body thickness • Diameter • Bolts (4) • Torque • Inner O-Ring • Outer O-Ring • Leak Test Port Plug Torque	1.25 in. 5.25 1/2 - 13 UNC 160 ± 20 in-lbs. Metal EPDM 1	Type 304 Stainless Steel SA-193, GR B6, Type 410 SS Helicoflex U42412-2500SEB Parker 2-234 E740-75 120 ± 5 in.-lbs.

Figure 2-24 shows a representation of a MAGNATRAN cask[18] on an intermodal transport cradle secured to a 12-axle railcar. **Figure 2-25** shows a picture of a NAC-STC transport package, similar in dimensions to a MAGNATRAN transport cask, loaded on an HHT with front tie-down being installed for transport in China.

Figure 2-24: MAGNATRAN on Transport Frame Mounted on 12-Axle Railcar

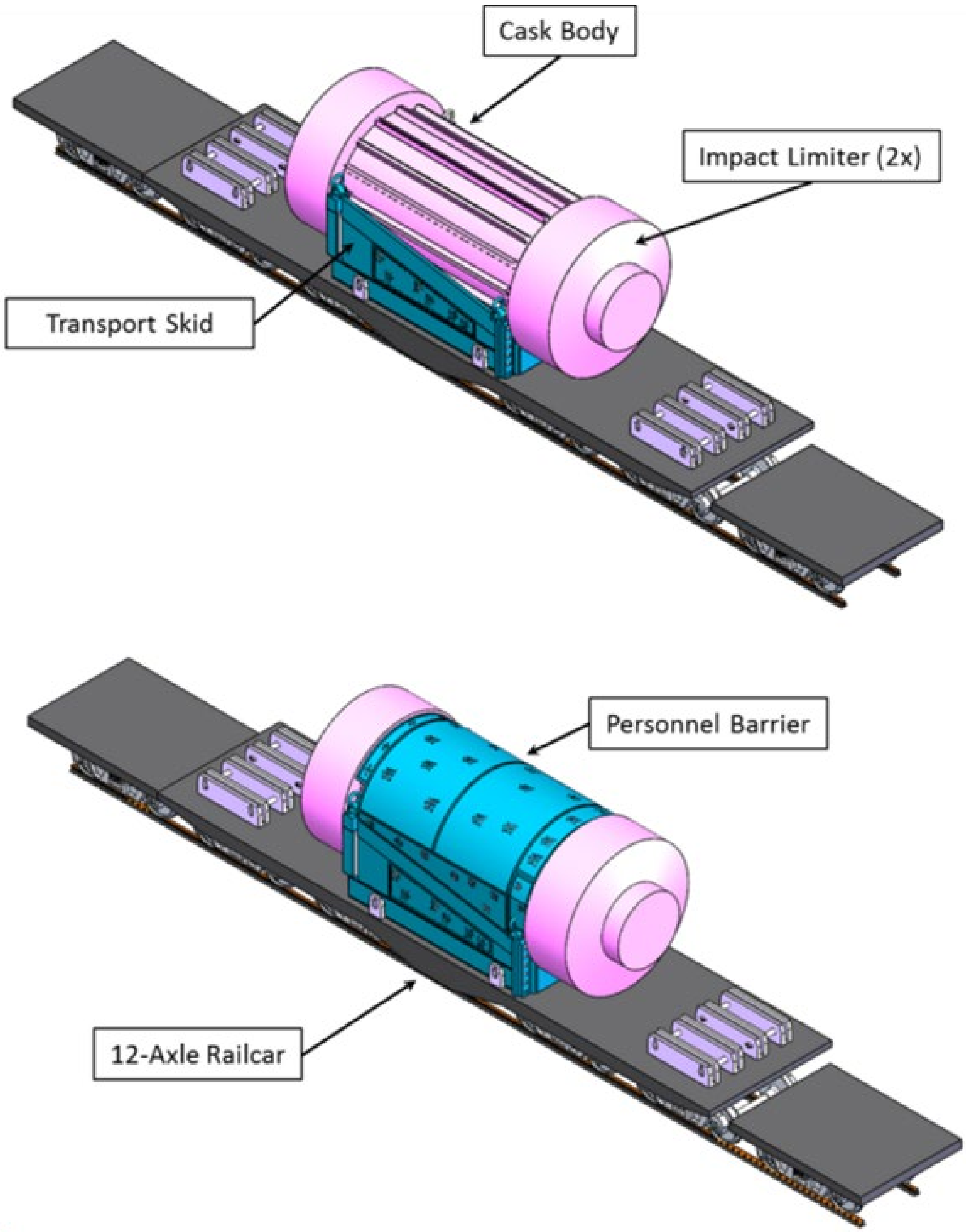
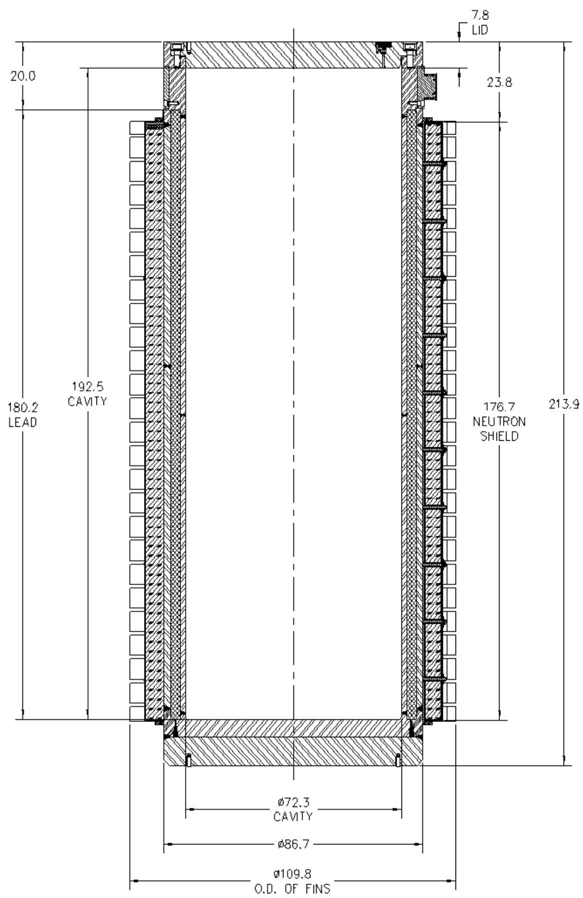


Figure 2-25: MAGNATRAN Package Front Tiedown Installation

The transport operations from Zion site are expected to be by rail using the intermodal transport cradle tied down to the rail car. The overall transport weight and dimensions for each MAGNATRAN package, including margins and transport cradle, is estimated to be: 360,000 pounds, 27 feet long, 10 feet 8 inches wide, and 11 feet high (measured from base of the cradle). It is important to note that the 128-inch load width, which is driven by the impact limiters, will not exceed the 128-inch width limit imposed by the AAR for unrestricted interchange service.

The MAGNATRAN packages at Zion site will be loaded with TSCs containing SNF. The major components of the package are shown in **Figure 2-26** and include the cask body, bolted lifting trunnions, rear rotation trunnions, transport lid, and vent port and coverplate. The MAGNASTOR Zion TSC consists of the canister shell, a spent fuel basket (standard or DF), a closure lid with vent and drain ports and redundant port coverplates (not accessible during transfer and loading of the MAGNASTOR TSC into the MAGNATRAN), and closure ring providing a redundant confinement boundary to the closure lid to shell weld, as shown in **Figure 2-19**. The closure lid lifting holes are designed for the safe handling and transfer of the loaded TSC to and from the VCC, and to the MAGNATRAN transport cask for off-site transport. The MAGNASTOR TSCs are constructed of stainless steel and after loading, are welded closed, vacuum dried, backfilled with high-purity helium, and the closure lid vent and drain inner port coverplates are leak tested prior to the installation and welding of the outer vent and drain port coverplates. During storage operations, the TSCs provide for confinement of the radioactive contents.

Figure 2-26: MAGNATRAN Section Views[18]

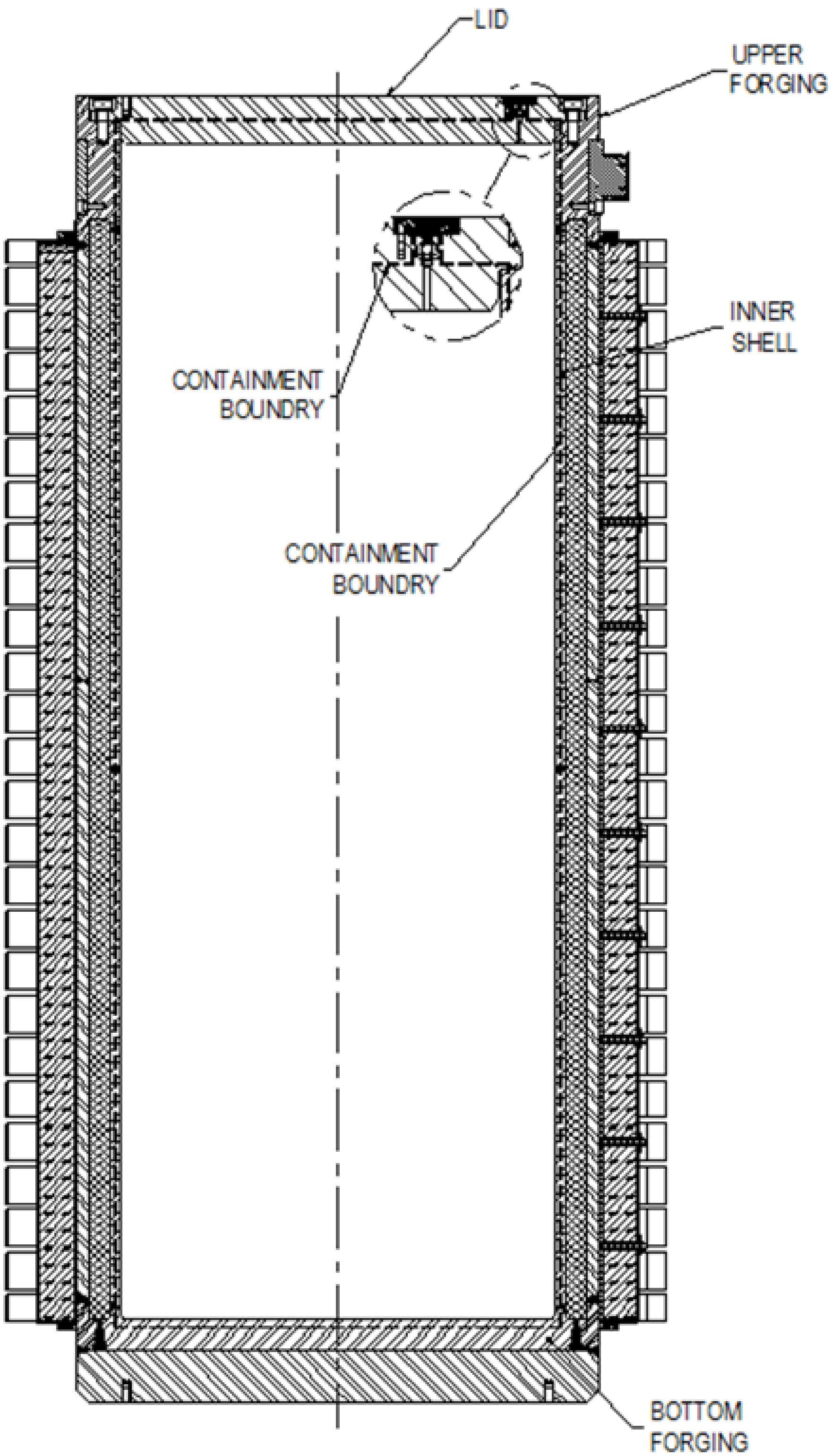


Following the transfer of the Zion MAGNASTOR TSCs from the VCC into the MAGNATRAN transport cask, the transport lid with a cask cavity spacer bolted to the lid's underside is installed with a new inner metallic (containment) and a reusable outer Ethylene Propylene Diene Monomer (EPDM) O-ring seal. The MAGNATRAN cavity is then evacuated and backfilled with high-purity helium and the transport lid and new vent port coverplate inner metallic containment boundary O-ring seals are leak tested using a helium Mass Spectrometer Leak Detection (MSLD) system to leak-tight criteria in accordance with ANSI N14.5-1997[21]. After loading of the Zion MAGNASTOR TSC in the MAGNATRAN transport cask and transport lid closure helium leak testing, the MAGNATRAN transport cask provides the transport containment boundary under normal and accident conditions of transport.

The MAGNATRAN transportation package containment boundary, shown in **Figure 2-27**, includes the MAGNASTOR inner shell, upper forging, bottom inner forging, transport lid, vent port coverplate, and transport lid and vent port coverplate metallic O-ring seals. The MAGNATRAN metallic containment seals are each individually inspected, replaced, and leakage tested prior to each loaded transport.

During fabrication, the MAGNATRAN cask containment boundary weldment including the inner shell, bottom inner forging, upper forging and inner lid are hydrostatically tested per the American Society of Mechanical Engineers (ASME) Code, Section III, NB-6000 followed by helium leak testing to confirm a total leakage rate of $\leq 2.0 \times 10^{-7}$ cm^3/sec, helium (leak-tight in accordance with ANSI N14.5-1997[21]). Following completion of the hydrostatic test of the MAGNATRAN cask, the transport lid and vent port cover containment components and metallic O-ring seals are fabrication leakage rate tested to confirm that the individual leakage rates are $\leq 2.0 \times 10^{-7}$ cm^3/sec, helium, in accordance with ANSI N14.5-1997 as specified in the MAGNATRAN SAR Containment Evaluation.

Figure 2-27: MAGNATRAN Containment Boundary[18]



The first operational sequence for the transfer of the Zion MAGNASTOR TSCs from the VCCs to the MAGNATRAN transport cask is the receipt and off-loading of the empty MAGNATRAN transport cask from the railcar mounted transport frame. At Zion site, a Vertical Cask Transporter (VCT) with additional lift links for attachment to the MAGNATRAN lifting trunnions will be used to transport the empty MAGNATRAN transport cask to the TSC Handling and Transfer Facility at the rail transload location.

After performance of the receipt inspection of the MAGNATRAN and removal of the front and rear impact limiters, the MAGNATRAN lifting trunnions will be bolted and torqued to the upper forging. The MAGNATRAN lift yoke will then be engaged to a mobile crane of sufficient lift capacity and the cask will be uprighted on its rear trunnions, removed from the transport frame, set down, and moved to a suitable position at the TSC Handling and Transfer Facility using the VCT. At Zion site, there is not sufficient space on the MAGNASTOR ISFSI pad to use as the TSC Handling and Transfer Facility. Therefore, a separate TSC Handling, and Transfer Facility pad of approximately 25 x 35 feet will be required to be designed and constructed. An appropriate cask work platform or scaffolding will be established around the VCC and transport cask areas to provide personnel access to the cask lid area. It is expected that the TSC Handling, and Transfer Facility will be constructed immediately adjacent to the on-site rail line at the designated transload location.

The MAGNATRAN transport lid bolts are removed, and the lid is removed using the four-legged transport lid lifting sling set and hoist rings, and temporarily stored while protecting the lid O-rings and seating surfaces. The transport lid inner metallic O-ring is removed, the O-ring groove will be cleaned and inspected, and a new seal installed on the lid prior to re-installation of the lid after TSC loading.

The MAGNATRAN transfer shield ring, designed to protect the cask's O-ring sealing surface and provide additional shielding, is installed, and bolted in place in the transport lid recess of the cask. A MAGNASTOR/MAGNATRAN transfer adapter is then lifted and placed on the transfer shield ring and bolted in place. A Foreign Material Exclusion (FME) cover is then placed over the MAGNATRAN cask cavity to protect from foreign material entry and the cask is ready for TSC transfer. *Note: It is not expected that TSC loading operations into the MAGNATRAN transport cask will be performed during inclement weather as it is imperative to keep water, rain, snow, and ice from entering the cask cavity. The cask cavity is required to be dry of free water prior to transport to prevent a cask cavity overpressure.*

Once the MAGNATRAN is in position, the VCT is used to retrieve the MAGNASTOR VCC to be unloaded. The VCC would be positioned adjacent to the transport cask and appropriate scaffolding, and work platforms or man-lifts provided to access the top of the concrete cask. The VCC lid bolts would be removed and a four-legged VCC lid lift ring used to remove and temporarily store the VCC lid. The TSC lift adapter plate is installed on the TSC Closure Lid and bolted in place. *Note: Alternatively, a qualified gantry crane system can be established over each side of the split ISFSI pad that would be capable of positioning a MTC on each VCC for retrieval of the stored TSC without the need to move the VCC. The MTC would then be moved to a suitable position on the MAGNATRAN transport cask for downloading of the TSC into the cask.*

Figure 2-28 presents the next operational sequence and equipment requirements for retrieving a loaded MAGNASTOR TSC from a VCC. Following VCC lid removal, the MAGNASTOR transfer adapter is installed on top of the VCC. The TSC lift adapter plate is bolted to the

MAGNASTOR TSC closure lid using the six bolt holes provided in the TSC closure lid. The MTC, with the retaining blocks in the engaged position, is then placed on top of the adapter plate using the Secure-Lift Yoke and Chain Hoist combined with a qualified mobile crane. The Secure-Lift Yoke and Hoist would eliminate the need for a TSC Handling and Transfer Facility (TSC HTF) as required per the MAGNASTOR CoC Technical Specifications to restrain or maintain the MTC on top of the VCC or the MAGNATRAN cask during the TSC transfer operations, as the Secure-Lift Yoke would maintain operational and stability control of the MTC throughout the TSC transfer operation. *Note: A qualified gantry system would meet the CoC Technical Specification requirements of Appendix A, TS 4.4 for a TSC Handling and Transfer Facility.*

Additional details on the Secure-Lift Yoke and Hoist design and operational features are provided in **Section 6.1.3**. The MTC shield doors are opened using the adapter plate auxiliary hydraulic system. Once the Secure-Lift Yoke and Hoist is in place to restrain and maintain the stability of the MTC using a mobile crane atop the VCC, the air-powered hoist is engaged to the TSC lift adapter plate and engaged with the hydraulically actuated engagement pins to the hoist hook. The hoist is then activated to lift the TSC from the VCC into the MTC annulus. The shield doors are closed and the TSC is set down on the shield doors. The shield doors are then secured with lock pins.

Figure 2-29 shows the next operational sequence where the TSC is transferred into the MAGNATRAN cask cavity. When ready to perform the transfer operation, the FME cover is removed from the top of the MAGNATRAN cask, and the internal cavity inspected for any foreign materials. The MTC containing a loaded TSC is then lowered in place atop the adapter plate using the Secure-Lift Yoke and Hoist, and the MTC shield door connector is engaged to the hydraulic actuators. The MTC door lock pins are then removed, the Secure-Lift Hoist is then re-engaged to the TSC lift adapter plate using the lift adapter plates' hydraulic cylinders. The Secure-Lift Hoist is activated to lift the MAGNASTOR TSC off the shield doors, the doors opened with the auxiliary hydraulic system, and the TSC slowly lowered into the MAGNATRAN cavity to rest on the transport casks bottom inner forging. The Secure-Lift Yoke and Hoist remains attached to the MTC and TSC throughout the operational sequence. The actual Secure-Lift Yoke and Hoist in operation is shown in **Figure 2-30.**

Figure 2-28: MAGNATRAN VCC Unloading Transfer Operation with TSC Partially Removed[13][18]

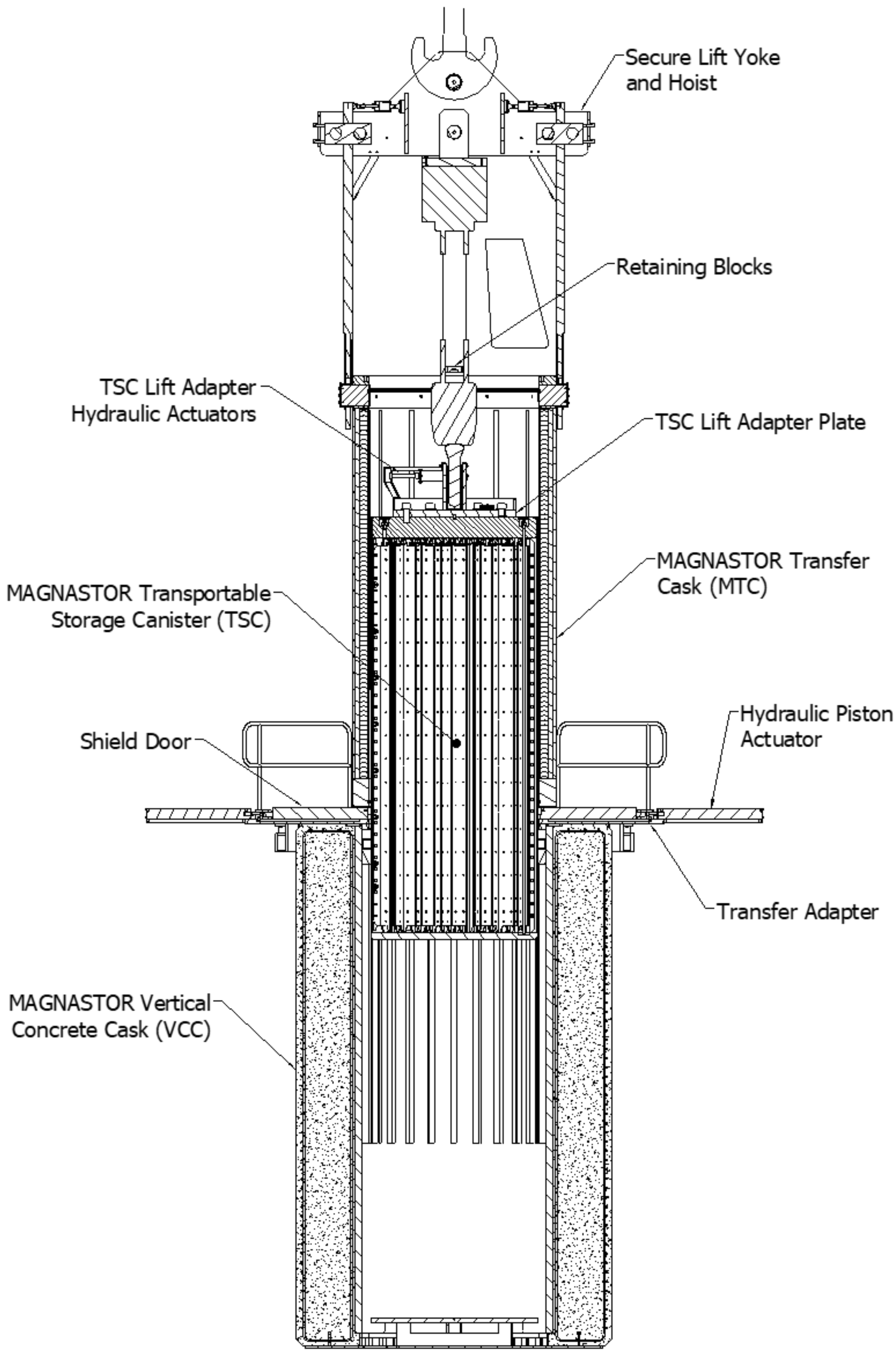


Figure 2-29: MAGNATRAN Transfer Operation with MAGASTOR TSC Partially Inserted[18]

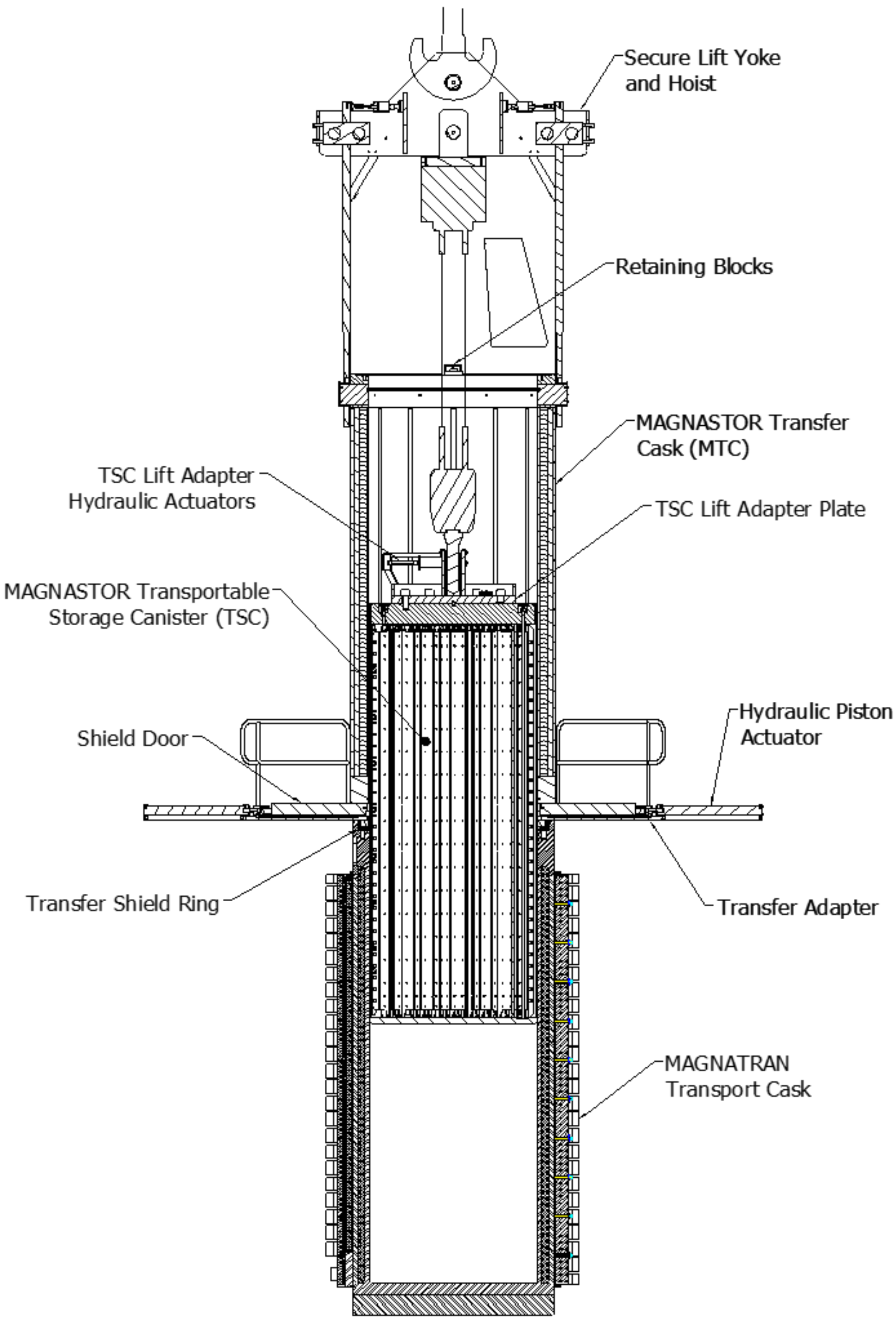
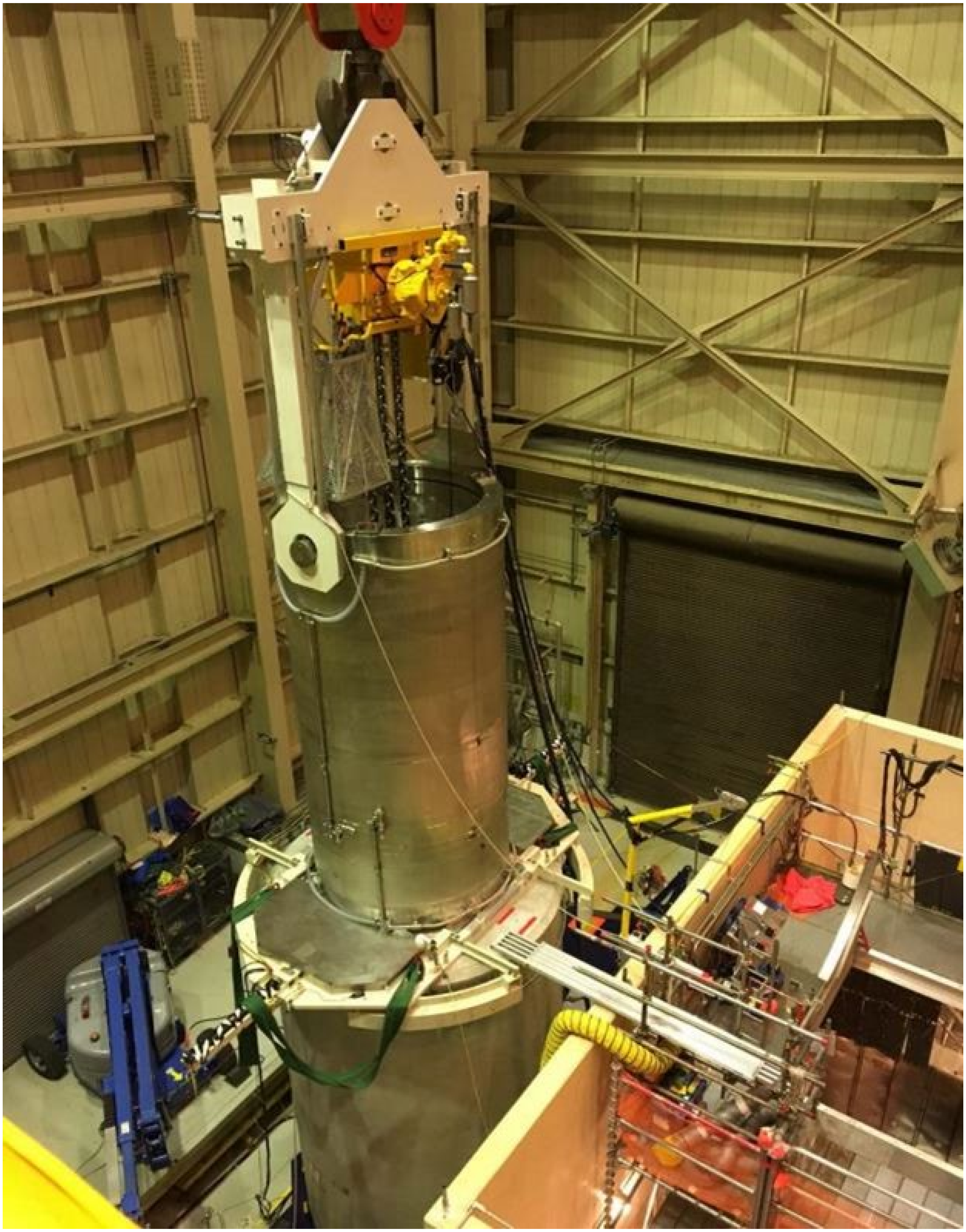


Figure 2-30: MAGNATRAN Transfer Cask (MTC2)[18] with Transfer Adapter on VCC for TSC Transfer with Secure-Lift Yoke and Chain Hoist



As shown in **Figure 2-27**, the MAGNATRAN cask includes a vent port in the transport lid. The vent consists of a ½-inch quick disconnect fitting with a seal and a cover plate with an inner metallic O-ring and outer EPDM seal that is secured with 4 ½-inch diameter bolts. The MAGNATRAN transport lid contains an inner metallic O-ring and outer EPDM seal and is secured to the cask body with 48 2-inch diameter bolts. The lid also includes a test port that is used to leak test the MAGNATRAN transport lid containment seal integrity. **Figure 2-27** shows the MAGNATRAN containment boundary.

The unloading of a MAGNASTOR TSC from a VCC and transfer to a MAGNATRAN transport cask, and preparation of the MAGNATRAN cask for transport, will include the following high-level activities (additional operational details are described in **Section 6.1.3** and MAGNATRAN SAR[18] and MAGNASTOR FSAR[12]):

1. At receipt of the empty MAGNATRAN onsite, perform radiation and removable contamination surveys and record results in accordance with 10 CFR 20.1906 to ensure removable contamination levels comply with 10 CFR 71.87(i) and radiation levels comply with 10 CFR 71.47. Inspect MAGNATRAN packaging including impact limiters and radial neutron shields for possible transport damage and record inspection results on cask receiving/loading report. Clean the packaging exterior to ensure that surfaces are cleaned of chloride-containing salts and other corrosive agents.
2. Prepare the MAGNATRAN packaging for loading by removing the personnel barrier, front and rear impact limiters (**Figure 2-31**) releasing front tie-downs and cleaning the cask exterior of road dirt.
3. Remove the two trunnion plugs held in place by 4 1x1/8x8-inch socket head cap screws and install the two lifting trunnions and torque the 9 1x1/8x8-inch socket head cap screws torqued to 120 ± 20 ft.-lbs. Ensure trunnion bushings and trunnion caps are installed on the lifting trunnions.
4. Install the MAGNATRAN Lift Yoke to a suitable crane and engage the yoke arms to the lifting trunnions. Use the MAGNATRAN lift yoke to upright the cask by rotating on the rear trunnions and position it on an approved pad adjacent to the rail tracks. Using the VCT engage the MAGNATRAN lifting links to the two front trunnions and lift and move the cask to the TSC Handling and Transfer Facility and set cask down in designated loading area. Set up appropriate scaffolding and man-lifts to provide access to the top of the cask.
5. Remove 48 transport lid bolts in sequence indicated on the lid and store. Using transport lid lift slings and hoist rings, remove the transport lid and store. Visually inspect lid bolts. Store inner lid and inner lid bolts to prevent damage to O-ring grooves/surfaces and threads. Prior to inner lid re-installation the inner lid metallic O-rings will be replaced and outer EDPM O-rings inspected and replaced, if required.
6. Install MAGNATRAN transfer shield ring to protect cask body sealing surfaces and bolt to cask body.
7. Install MAGNASTOR transfer adapter to the top of the cask and bolt the adapter to the transfer shield ring. Connect auxiliary hydraulic system to the two hydraulic cylinders on the transfer adapter. Position the connector assemblies in the engage position extender to engage the MTC shield door connectors.

Figure 2-31: MAGNATRAN Package Impact Limiter Removal / Installation

8. Install FME cover over the open MAGNATRAN cavity to prevent intrusion of foreign materials and to protect from weather.

9. Prepare Zion site MAGNASTOR VCC for movement to the TSC Handling and Transfer Facility location by performing radiation survey and disconnecting temperature monitoring system. Remove the eight hex head cap screws from each lift lug embedment and install the two lifting-lug sets to the embedments using the eight VCC lifting-lug bolts and washers. Torque the bolts to 115 ± 10 ft.-lbs.

10. Position the VCT adjacent to the ISFSI pad and the VCC to be moved.

11. Position VCT above the VCC to be moved and engage the lifting lugs to the VCT VCC lifting links.
12. Move the VCT with Zion MAGNASTOR VCC to TSC Handling and Transfer Facility (see **Figure 2-32**) and set down VCC. Disengage the VCT from the lifting lugs and move the VCT from the area. Position appropriate scaffolding and/or man-lifts to allow access to the top of the VCC.
13. Remove six VCC lid bolts and install lifting slings and hoist rings to three lifting holes identified on the lid. Using a suitable crane, remove and store VCC lid and lid bolts.
14. Remove closure lid lifting hole shield plugs if installed, and using a suitable crane, lift and position the TSC lift adapter plate (approximate weight 3,400 lbs.) (see **Figure 2-35**) on the top of the closure lid. Install and torque the 6 2½-inch bolts and washers.
15. Prepare MTC for receipt of the TSC by performing pre-use inspection and engaging retaining blocks to engaged position.
16. Install transfer adapter plate on top of the VCC. Connect auxiliary hydraulic actuating system to the transfer adapter door hydraulic cylinders and position them in the engage position to connect to the shield door connectors.
17. Remove FME cover from the top of the MAGNATRAN cask, opening the cask cavity for receipt of the loaded Zion MAGNASTOR TSC.
18. Engage the Secure-Lift Yoke and Chain Hoist (see **Figure 2-33**, **Figure 2-34**, and **Figure 2-35**) to a suitable crane or gantry with 200% load capacity over the load to be handled. Connect air-powered hoist system to a suitable air compressor (minimum of 500 CFM capacity) and engage the lift yoke arms to the MTC's lifting trunnions. Lift and set the MTC down on top of VCC transfer adapter plate engaging the shield door male connectors to the hydraulic cylinder female connectors. Remove the shield door lock pins.
19. Using the transfer adapter hydraulic system, open the MTC shield doors allowing access to the TSC lift adapter plate.
20. Lower the chain hoist sister hook to engage the TSC lift adapter plate. Engage the lift adapter hydraulic cylinders to engage the two lift adapter plate pins to the sister hook using suitable camera and video system
21. Using the Secure-Lift Yoke Chain Hoist, lift the TSC from the VCC cavity until the top of the TSC is within a ½ inch of the base of the retaining blocks. Stop hoist, and using transfer adapter plate auxiliary hydraulic system, close the shield doors. Install the shield door lock pins. Note: Per the Operating Procedures in the MAGNATRAN SAR, there is a maximum time limit of 41 hours from the lifting of the TSC off the VCC pedestal (Step 21) to placement of the MAGNATRAN package in a horizontal position on the intermodal transport frame (Step 39).
22. Using the Secure-Lift Yoke, lift the MTC from the top of the VCC and position the MTC on top of the adapter plate on the MAGNATRAN cask. Engage the shield door connectors.
23. Using the chain hoist attached to the TSC lift adapter plate to lift TSC off the MTC shield doors approximately a ½ inch to prevent contact with the retaining blocks, remove the shield door lock pins and open the shield door hydraulics to open the shield doors.

Figure 2-32: MAGNASTOR VCC Engaged to Self-Propelled VCT

24. Using the chain hoist, slowly lower the TSC into the MAGNATRAN cask cavity. Once the TSC is fully down, disengage the TSC lift adapter plate from the hoist sister hook and withdraw the hoist to the full up position.
25. When the chain hoist is clear, close shield doors, install door lock pins, and remove the MTC from the top of the MAGNATRAN cask and set down in a safe area in preparation for the next TSC transfer/loading sequence.
26. Remove the TSC lift adapter plate from the TSC closure lid and store. Unbolt the transfer adapter from the transfer shield ring and remove the transfer adapter. Unbolt and remove the transfer shield ring and store.
27. Ensure all equipment is removed from the top of the MAGNATRAN cask and TSC.
28. Clean the transport lid metallic seal groove and install a new inner containment boundary metallic O-ring seal and retention clips.
29. Using MAGNATRAN transport lid lifting slings and crane, install the transport lid including the cask cavity spacer (approximate weight 1,000 lbs.) bolted to the underside of the lid to properly limit Zion TSC movement during transport. *[Note: MAGNATRAN transport casks provided for Zion TSC transports will be supplied with cavity spacer installed. Empty MAGNATRAN transports can be performed with cavity spacer installed.]*
30. Install 48 lid bolts and tighten to hand tight. Torque all bolts to 4,600 ± 200 ft.-lbs. in accordance with the torquing sequence marked on the lid in three passes until all bolts are verified at final torque.
31. Remove vent port coverplate and connect vacuum pumping and helium backfill system to the vent port quick disconnect valve.
32. Operate vacuum pump until a final vacuum of ≤ 3 torr is reached and then turn off vacuum pump.
33. Backfill MAGNATRAN cask cavity with high-purity helium to a pressure of 1 atm and disconnect the vacuum and helium backfill system from the vent port.
34. Clean vent port coverplate metallic seal groove and install new inner containment boundary metallic O-ring seal and retention clips. Visually inspect outer EPDM O-ring for damage and replace if required.
35. Install vent port coverplate and torque to 160 ± 20 in.-lbs.
36. Remove vent port test plug, connect helium MSLD system to the port and evacuate the inter-seal volume to a pressure of < 0.1 torr to allow performance of the maintenance leakage rate test. Test is acceptable if detected leakage rate is ≤ 2 x 10-7 cm3/s, helium with a minimum test system sensitivity of ≤ 1 x 10-7 cm3/s, helium. If test is acceptable, re-install the vent port coverplate test plug with new O-ring.
37. Remove transport lid inter-seal test port plug, connect helium MSLD system to the port, and evacuate the inter-seal volume to a pressure of < 0.1 torr to allow performance of the maintenance leakage rate test. Test is acceptable if detected leakage rate is ≤ 2 x 10-7 cm3/s, helium with a minimum test system sensitivity of ≤ 1 x 10-7 cm3/s, helium. If test is acceptable, re-install the inner lid inter-seal test port plug with new O-ring.

Figure 2-33: MAGNASTOR Transfer Cask[19] Engaged to Secure-Lift Yoke

Figure 2-34: Secure-Lift Yoke and Chain Hoist

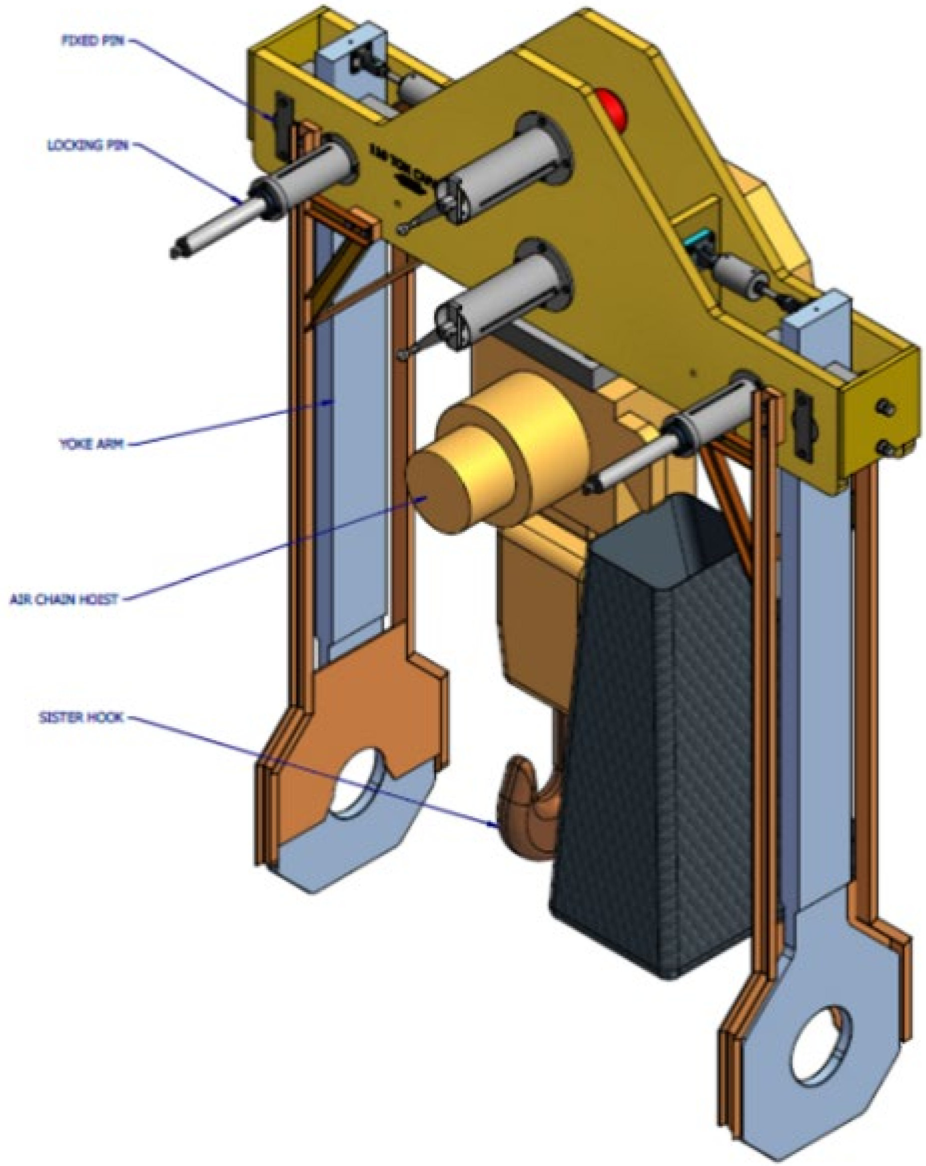


Figure 2-35: MAGNASTOR Secure-Lift Yoke and Chain Hoist with TSC Lift Adapter Plate

38. Using the VCT lift loaded MAGNATRAN cask and move to a position adjacent to the railcar and set down on approved pad. Disengage the VCT from the lifting trunnions and engage to MAGNATRAN lift yoke connected to a suitable crane.
39. Lift the MAGNATRAN and position the rear rotation trunnions over the rear saddle on the intermodal transport frame positioned on the railcar, lower the cask to engage the rear trunnions supports, and rotate the cask from vertical to horizontal orientation. *[As noted, following Step 21, the positioning of the loaded MAGNATRAN cask in a horizontal position on the transport frame is required to be completed in 41 hours in accordance with the current CoC.]*
40. Install front tie down over cask upper forging.
41. Install top and bottom impact limiters and install tamper indication device (TID) between adjacent upper impact limiter retaining rods to detect tampering during transport.
42. Perform final radiation and contamination surveys. Apply fissile material labels on the package.
43. Install personnel barrier and padlock barrier access portal.
44. Affix applicable placards to transport vehicle.
45. Complete all shipping documentation and provide special instruction to carrier/shipper for an Exclusive Use Shipment. The MAGNATRAN is now authorized for transport off-site (See **Figure 2-36**).
46. At site's convenience, the empty VCC can be prepared for return to the ISFSI by removing the transfer adapter, reinstalling and bolting the VCC lid, and lifting and transporting the VCC back to the pad using the VCT.

Note: The MAGNATRAN transport cask systems provided to perform MAGNASTOR TSC transports from Zion will be in full compliance with the maintenance program as specified in Chapter 8 of the MAGNATRAN Safety Analysis Report (SAR), which specifies the required maintenance program for the cask (see MAGNATRAN Maintenance Schedule Table in **Table 6-2** in **Section 6.1.3)**. NAC or the cask supplier would certify that the cask is compliant with the current annual maintenance program, which would include dye penetrant [penetrant testing (PT)] examination of the lifting trunnions and replacement of quick disconnects.

Figure 2-36: NAC-STC Package Ready for Transport

(Note: NAC-STC shown as no MAGNATRAN casks have been fabricated to date)

Equipment and Auxiliary System Requirements:

To perform the above sequence of operations, many ancillary devices, equipment, and systems will be required. These ancillary equipment and systems, along with a description of their purposes and availability are listed below. The listing will also address responsibility for providing the equipment and components and provides a cross reference to the applicable CoC requirement. It is recommended that a separate list of other miscellaneous equipment and services not covered by the listing below be assembled as discussed in **Section 10.0**.

Vertical Cask Transporter:

A VCT will be required to lift and move the loaded VCCs at the ISFSI to and from the TSC Handling and Transfer Facility for TSC transfer operations. The VCT can also be used to vertically transport the empty or loaded MAGNATRAN transport cask and the empty MTC. The VCT used at Zion, Kewaunee, and Three-Mile Island was designed and manufactured by Lift Systems Inc.

The self-powered VCT is shown in **Figure 2-32** transporting a VCC by the lift lugs. The loaded VCC is brought from the ISFSI to the TSC Handling and Transfer Facility where it is set down for unloading of the TSC. The VCT is a specially designed heavy-lifting device to lift the VCC by engaging the transporters’ lifting components to the VCC’s lifting lugs. The lift height of the base of the loaded VCC during lifting and transport operations is limited to ≤24 inches by the CoC’s Technical Specifications, Appendix A, Paragraph 4.3.1(h).

The VCT is designed to have the following critical physical capabilities and attributes:

- Minimum rated capacity of 180 tons. Tare weight of 167,000 lbs.
- Fully loaded weight of 527,000 lbs. with a MAGNASTOR VCC weighing a maximum of 318,500 lbs or MAGNATRAN transport cask weighing a maximum of 310,000 lbs.
- VCT to interface with a MAGNASTOR VCC with an overall height of 232.4 inches with lifting lugs installed.
- VCT to interface with an MTC with the following characteristics: empty weight of 55 tons; overall height of 192.2 inches; nominal outer diameter of 88 inches; approximately 100 inches across trunnion pair each having a diameter of 10 inches (including bushing); and 10.5-inch end caps.
- The VCT's header beam, lift links, and lift link pins to be designed in accordance with ANSI N14.6.
- VCT maximum width to be 19 feet.
- VCT maximum length between ends of front and rear tow eyes to be 24 feet, 4 inches.
- VCT fuel tank capacity shall be limited to a maximum of 50 gallons.
- VCT travel speed under full load to be 0.5 mph on level ground.
- VCT able to operate under full load with a maximum grade of 10%.
- VCT able to maneuver under full load with a roadway side to side slope of up to 4%.
- VCT limits average ground bearing pressure under full load to less than 50 psi.
- VCT under full load to have full autorotation capability.
- VCT is provided with an Automatic Wedgelock System (e.g., a redundant drop prevention system replacing manual pins).
- VCT is provided with a Computer Assisted Remote Lifting (CARL) control system including radio remote controls.
- VCT is provided with a mechanical stop to prevent a loaded VCC from exceeding a 24-inch lift height.
- VCT can be provided with a mechanical stop to prevent a loaded MAGNATRAN transport cask exceeding 10-inch lift height.

MAGNASTOR Transfer Cask (MTC) and Retaining Blocks:

The MTC is designed, fabricated, and tested to meet the requirements of ANSI N14.6[22] as a special lifting device. The standard MTC is fabricated from carbon steel and is designed to be compatible with longer length BWR and PWR SNF assemblies. The stainless steel MTC is specifically designed to accommodate the shorter MAGNASTOR TSC for Westinghouse length fuel assemblies used at Zion. The MTC is provided with two lifting trunnions located near the top of the cask. There are threaded holes provided in the top and bottom rings (forgings) of the MTC and in each shield door for attachment of handling lugs for use in receipt, up-righting, and handling of an empty cask or shield door. The MTC provides biological shielding and structural protection for a loaded TSC and is used to lift and move the TSC between workstations. The MTC is also used to shield the vertical transfer of a TSC into or out of a VCC or a MAGNATRAN transport cask.

The MTC design incorporates three retaining blocks, pin-locked in place, to prevent a loaded TSC from being inadvertently lifted through its top opening. The MTC has retractable bottom shield doors. During TSC loading and handling operations, the shield doors are closed and secured. After placement of the MTC on the Transfer Adapter on the VCC or the MAGNATRAN transport cask, the locking pins are removed, and the doors are retracted using hydraulic cylinders and an auxiliary hydraulic supply system.

The MTC used at Zion and Three-Mile Island was supplied by NAC and was subsequently used for MAGNASTOR storage operations at Kewaunee Nuclear Station. It is available for future de-inventory projects containing MAGNASTOR storage systems such as Zion. Duke Power's Catawba and McGuire Nuclear Stations, which also use MAGNASTOR, own their MTCs. **Figure 2-30** shows an example of a stainless steel MTC engaged to a secure-life yoke.

MTC Transfer Adapter:

The MTC Transfer Adapter (**Figure 2-28** and **Figure 2-29**) is used to hydraulically operate the MTC shield doors. The Transfer Adapter also incorporates shields and rails to reduce the dose to operational personnel during the TSC transfer operations. The adapter incorporates two hydraulic cylinders mounted on each end of the plate that extend female connectors used to engage the male connectors on the shield doors. The hydraulic cylinders are operated by a separate auxiliary hydraulic system including hydraulic pump, hoses, and valves. The operational sequence proposed herein is based on the use of two MTC Transfer Adapters so that the TSC can be transferred directly from the VCC to the MAGNATRAN cask without the need to reposition the transfer adapter. It is expected that two transfer adapters would be available for the Zion de-inventory project.

Secure-Lift Yoke and Integrated Chain Hoist Assembly:

The MTC Secure-Lift Yoke is designed for the lifting and movement of the loaded MTC from the top of the VCC positioned at the ISFSI TSC Handling and Transfer Facility while engaged to a suitable mobile crane or NAC's Modular Portable Cask Transfer Facility using a single pin engagement. The Modular Portable Cask Transfer Facility satisfies the MAGNASTOR CoC No. 1031 TSs Appendix A, Section 4.4, "TSC Handling and Transfer Facility" requirements." The MTC Secure-Lift Yoke will then move the loaded MTC to a transfer position on the top of the MAGNATRAN cask fitted with an MTC Transfer Adapter. MTC Secure-Lift Yoke remains engaged to the MTC from time of engagement to the MTC lifting trunnions, through MTC transfer and placement on the VCC/adapter plate, lifting of the TSC into the MTC with the Chain Hoist Assembly (CHA), and during movement to the MAGNATRAN and lowering of the TSC into the cask cavity. The MTC Secure-Lift Yoke is designed for single-failure-proof handling of the MTC and TSC through use of high design safety factors in accordance with ANSI N14.6[22] and NUREG 0612[25]. The maximum design rated load for the Secure-Lift Yoke is 115 tons.

The Secure-Lift Yoke arms and strongback are constructed of high-strength alloy steel and the lift arms are pneumatically actuated. The MTC Secure-Lift Yoke can withstand seismic loadings imparted by the mobile cask handling crane and will provide for the attachment point of the TSC Chain Hoist System as described below. The MTC Secure-Lift Yoke arms will be engaged and disengaged pneumatically using remote control operation, and the MTC Secure-Lift Yoke arms will be locked in the closed orientation during MTC handling, lifting, and TSC transfer operations.

The TSC Chain Hoist System is designed to transfer (i.e., raise and lower) a loaded TSC from the VCC to the MTC, and from the MTC to the MAGNATRAN transport cask cavity. The MTC will be positioned on the top a transfer adapter plate which will be positioned on the top of the VCC to provide the interface for mating of the MTC to the VCC and MAGNATRAN cask, and for operation of the MTC shield doors prior to TSC transfer. The MTC will be lifted, positioned and maintained in the required position and orientation on top of the VCC and MAGNATRAN cask throughout the TSC transfer operation by the MTC Secure-Lift Yoke. The total height of the Secure-Lift Yoke above the pad surface to the centerline of the yoke's engagement pin to the mobile crane hook is approximately 45 feet.

The CHA will be connected to the 110-ton Secure-Lift Yoke by means of a clevis adapter and connecting pin. The lower attachment point of the hoist system is a sister hook that will be connected to the TSC lift adapter plate installed and bolted to the TSC. The engagement of the CHA hook to the TSC lift adapter plate by dual-pin assemblies will be actuated using remotely operated hydraulic cylinders.

The CHA will be built upon a 110-ton air-operated chain hoist and will comply with the requirements of ASME B30.16[26] and will have an established maximum critical lift (MCL) of 55 tons in accordance with the requirements of ASME NUM-1[27], Type 1B for a critical lift chain hoist. *[Note: the CHA is not considered a single-failure-proof load handling device as delineated in Section 5.1.6 of NUREG-0612. Additional analyses at the designated TSC transfer locations and licensing actions may be required for its use.]*

TSC Lift Adapter Plate:

The TSC Lift Adapter Plate is designed to interface with the Secure-Lift Yoke and Chain Hoist Assembly and is a single-failure-proof device through the use of high design safety factors in accordance with ANSI N14.6[20] and NUREG 0612[25]. The TSC lift adapter plate is bolted to the TSC closure lid to allow the remote engagement of the chain hoist sister hook using two hydraulically operated engagement pins.

The Secure-Lift Yoke and Chain Hoist Assembly on a storage stand with the TSC lift adapter plate shown in the foreground is provided in **Figure 2-35**. A view of the Secure-Lift Yoke and Chain Hoist is provided in **Figure 2-34** and the actual components are shown in **Figure 2-35**.

Mobile Diesel-Powered Air Compressor:

A diesel-powered air compressor with a rated capacity of approximately 900 CFM is required to properly operate the Secure-Lift Yoke and Chain Hoist system. The air compressor will need to be located close to the TSC Handling and Transfer Facility. There are currently no diesel air compressors at Zion. NAC has a single KAESER Mobilair 260 T air compressor meeting project requirements available for lease. Similar diesel-driven air compressors are available for lease or purchase as redundant air supplies from air compressor suppliers.

Auxiliary Hydraulic System for Transfer Adapter:

An electrically powered, high-pressure hydraulic pump, hoses, valves, and connectors are required to operate the hydraulic cylinders mounted on the transfer adapters to open and close the MTC shield doors to allow the TSC to be lowered into or lifted from the VCC or the MAGNATRAN transport cask. The auxiliary hydraulic system is installed after the transfer adapter is placed on the VCC and transport cask. A single hydraulic system with a second set of supply and return hoses could operate two separate transfer adapter plate hydraulic cylinder sets. This equipment will be available for lease from NAC.

Auxiliary Lifting Rigs:

A number of slings and rigging attachments are required to handle various MAGNASTOR and MAGNATRAN components and to safely operate the system. The lifting sling systems are designed to meet the requirements of ANSI N14.6[20] and ASME B30.9[28], as applicable, and to comply with the guidance provided in NUREG-0612[25] for handling heavy loads. Sling sets for critical loads are designed to provide a load rated capacity of at least 600% of the load being lifted. Each sling set for critical loads is load tested to 300% of the design lifting capacity prior to delivery. Redundant sling sets are designed to 300% of the load and tested to 150%. Following ISFSI loading operations, a complete set of new lifting rigs including associated hoist rings and turnbuckles for both MAGNASTOR and MAGNATRAN components will need to be procured and tested prior to the start of the Zion de-inventory campaign.

The following auxiliary lifting rigs are used to operate the system for transfer and loading operations at Zion:

- MTC Transfer Adapter Lifting Rig: this lifting rig is used to place and remove the Transfer Adapter assembly onto the VCC or MAGNATRAN using a four-point lift. The four-legged sling set is attached to the four lifting lugs or hoist rings on the Transfer Adapter using shackles.
- MAGNASTOR VCC Lid Lifting Rig: this lifting rig is used to install and remove the VCC lid using a three-point lift. The three-legged sling is attached to the VCC lid by three hoist rings.
- MAGNATRAN Transport Lid Lifting Rig: this lifting rig is used to install and remove the transport cask lid using a four-point lift. The four-legged sling is attached to the cask lid by four hoist rings.
- MAGNATRAN Impact Limiter Lifting Rig: this lifting rig is used to remove and install the impact limiters to the front and rear of the MAGNATRAN cask. The four-legged sling is attached to the four lifting lugs welded to the top of the impact limiter using shackles.
- MAGNATRAN Personnel Barrier Lifting Rig: this lifting rig is used to remove and install the personnel barrier on the intermodal transport frame which prevents personnel contact with the center section of the transport cask between the front and rear impact limiters.

Helium Mass Spectrometer Leak Detection (MSLD) System:

Prior to any transport of the loaded MAGNATRAN transport cask, the inner metallic containment boundary seals of the transport lid and vent port coverplate will require replacement and maintenance leakage rate testing to leak-tight criteria in accordance with ANSI N14.5-1997[23] as specified in the MAGNATRAN SAR[18] using a helium MSLD system including a calibrated leak. Additional equipment required for helium-evacuated envelope leakage testing would include high purity helium ($\geq$ 99.1%), appropriate tubing, valves, calibrated pressure and vacuum gauges of the appropriate sensitivity and connectors to mate with the vent and transport lid port leak test connection.

Replacement O-Ring Seals:

Following replacement of the transport lid and vent port coverplate metallic O-ring seals, a helium leakage rate test is required to be performed on each containment closure component using a helium MSLD. The maintenance leakage rate testing of the MAGNATRAN package transport lid and vent port coverplate containment O-ring seals is to confirm a leakage rate of $\leq 2.0 \times 10^{-7}$ cm^3/sec, helium at a minimum test sensitivity of $\leq 1.0 \times 10^{-7}$ cm^3/sec, helium. The testing requirements and procedural guidance are specified in Chapter 7, Section 7.1.2 of the MAGNATRAN SAR[18]. There is no MSLD currently available at Zion and a new system will be required to be leased or procured and specialized connectors for connection to the MAGNATRAN containment leakage transport lid and vent port coverplate test ports will need to be leased or procured.

Vacuum Pumping and Helium Backfill System:

Following loading of the Zion MAGNASTOR TSC into the MAGNATRAN and installation and torquing of the transport lid, the cask cavity is evacuated to ≤ 3 torr using a vacuum pumping system connected to the MAGNATRAN transport lid vent port quick disconnect coupling. This allows backfilling of the cask cavity to 1 atm. with high-purity helium. The vacuum pump skid generally includes a high-efficiency, large-capacity vacuum pump, pressure and vacuum gauges, isolation valves, and high vacuum piping and hoses for connecting the vacuum pumping system to the TSC vent port opening. The potentially contaminated exhaust of the vacuum pump will require routing to a portable HEPA system. If contamination is detected during evacuation of the MAGNATRAN cavity loaded with a Zion MAGNASTOR TSC, the source of the contamination will be required to be determined prior to final preparations for shipment of the package. (*Note: The MAGNASTOR TSCs may have residual removable contamination because of in-pool loading as allowed by MAGNASTOR TS LCO 3.3.1*). The high-purity helium supply is connected directly to the vacuum-pumping skid to allow helium backfill after isolation of the vacuum pump without the need to disconnect and reconnect piping and uses the same vacuum/pressure gauges. A supply of helium bottles and a bottle rack will need to be supplied and stored at the TSC Handling and Transfer Facility location. A Vacuum Drying System (VDS) and Helium Backfill System are not currently available at Zion. A NAC system will be available at the time of the de-inventory project for lease.

Cranes:

A number (minimum of two) of overhead lifting devices of sufficient capacity would be required for the operations. This must meet the requirements of the MAGNASTOR CoC No. 1031 TSs Appendix A, Section 4.4, "TSC Handling and Transfer Facility" located at a Transfer Station. It is expected that the areas adjacent to the two ISFSI pads provide enough space to locate the TSC Handling and Transfer Facility. At the TSC Handling and Transfer Facility pad, a TSC Handling, and Transfer Facility will be required to meet the criteria specified in Section 4.4 of the Appendix A TSs. The use of any stationary or mobile crane or gantry to lift and handle the loaded MAGNASTOR TSC must meet the requirements of this TS. If determined to be acceptable for use, the Secure-Lift Yoke and Integrated Chain Hoist System can be used to lift and transfer the TSCs from the VCCs to the MAGNATRAN casks at Zion. One large-capacity crane would be required for vertical lifting and movement of the MTC using the Secure-Lift Yoke and Integrated Chain Hoist System and also for the upending and down-ending of the MAGNATRAN from and to the intermodal transport frame located on the railcar or on the ground, and subsequently lifted horizontally and loaded onto the railcar. Cranes and handling equipment would be required to meet the requirements of MAGNASTOR CoC Technical Specification 4.4 for a qualified TSC Handling and Transfer Facility. If determined to be optimum, two large capacity cranes may be provided with one in service at the TSC Handling and Transfer Facility and the second used for off-loading empty MAGNATRAN transport casks and lifting and rotation loaded MAGNATRAN transport cask at the rail siding pad location. A smaller crane(s) would be required for lifting ancillary items, such as the VCC lid, transfer adapters, MAGNATRAN transport lid, transport impact limiters, and personnel barrier.

Manlifts:

A minimum of one manlift capable of accessing the top of the MTC when in stack-up position on the VCC or the MAGNATRAN cask will be required. Minimum lift height would be approximately 35 feet.

Impact Limiters:

The MAGNATRAN transport cask will arrive with two impact limiters, one each bolted to the cask lid and bottom forging according to the requirements of the SAR. The impact limiters would be fabricated as part of the transport cask procurement and fabrication. Each impact limiter assembly is provided with a set of two stainless steel Anti-Rotation Angles (3 x 3 x ¼) welded to the impact limiter shell. The anti-rotation angles allow the limiters to be stored in a vertical orientation after removal from the cask.

Intermodal Transport Frame and Tie-down Straps/Restraints:

An intermodal transport skid/shipping frame, associated tie-down straps, and restraints would need to be fabricated for each of the MAGNTRAN casks. These devices will be specific for the MAGNATRAN cask and do not currently exist or may be based on a universal transport cradle design developed under DOE auspices. The same equipment would be used for HHT, rail, and barge transport. The equipment will be designed to allow for horizontal handling for intermodal transfer between transport modes with impact limiters and personnel barriers installed.

Personnel Barrier:

As required by the MAGNATRAN CoC, a personnel barrier would be placed around the loaded package. The barrier, which attaches to the transport frame, spans the distance between the impact limiters and matches the outer diameter of the impact limiters. It is expected that personnel barrier designs and supply would be part of the design and supply of the intermodal transport frames.

Hydraulic Bolt Torquing Equipment and Standard Tools:

To properly install and torque the 48 MAGNATRAN transport lid bolts to the required torque of 4,600 ± 200 ft-lb, a hydraulic torquing device(s) capable of torques up to 5,000 ft.-lbs. will be required. A set of standard tools and equipment will be required to remove and install other MAGNATRAN components, MAGNASTOR VCC components, cask cradle tie-downs, etc. A final listing of required fittings, connectors, and tools will be prepared as part of the final preparation for project performance.

MAGNATRAN Lift Yoke:

A MAGNATRAN Lifting Yoke will be required for rotation and vertical handling of the MAGNATRAN cask to and from the intermodal transport frame. The MAGNATRAN Lift Yoke is designed for single-failure-proof handling of the MAGNATRAN using high design safety factors in accordance with ANSI N14.6[20] and NUREG 0612[25]. No MAGNATRAN Lift Yokes have been fabricated to date for use. The MAGNATRAN Lifting Yoke would be supplied as part of the MAGNATRAN cask supply package and would be procured and fabricated as part of the cask fabrication project.

Horizontal Intermodal Transport Frame Lift Beam:

The horizontal intermodal transport cradle lift beam would be used to lift and move an empty or loaded transport frame containing an empty or loaded MAGNATRAN package with impact limiters and personnel barrier installed at the loading site if determined to be the optimal operational approach. A design for the intermodal transport frame and the horizontal frame lift beam has been developed by others and is expected to be suitable for use with the MAGNATRAN transport cask system.

MAGNATRAN Transport Cask Cavity Spacer:

A MAGNATRAN cask cavity spacer, in accordance with the approved SAR License Drawing[29], will be required for each MAGNATRAN cask transporting Zion MAGNASTOR TSCs. The cask cavity spacer is 7.0 inches in height and 70.7 inches in diameter and weighs approximately 1,000 lbs. Each spacer will be required to be bolted to the underside of the transport lid prior to delivery of the cask to Zion.

Equipment Availability Onsite:

Based on the demobilization of essentially all cask-loading equipment from Zion upon completion of the fuel loading campaign in 2015 and subsequent demolition/decommissioning of all buildings and facilities, it is expected that essentially all the identified equipment and systems will be required to be procured or leased from NAC or others, as described above.

Note: The MTC, transfer adapter, lifting yokes and chain hoists, mobile and fixed lifting and handling equipment, lifting rig sets, and other auxiliary equipment and systems will be required to be maintained, inspected, and load and/or functionally tested as required by the MAGNASTOR and MAGNATRAN Operations Manuals, SAR and FSAR, and component specific maintenance manuals, as appropriate, prior to use at Zion.

3.0 TRANSPORTATION ROUTE ANALYSIS

This section describes the available routes investigated to transport the loaded transportation casks from Zion for delivery to the closest Class I railroad and the subsequent movement to GCUS. Although there is ample rail infrastructure at the site to conduct on-site transloading of the casks onto rail cars, all potential transportation modes were considered for outbound movement of the loaded casks. A number of routes were identified and, as discussed in **Section 3.5,** the options available were down-selected using specified criteria, resulting in a total of five scenarios to consider further using the MUA process, as covered in detail in **Section 5.0,** including three direct rail, one HHT-to-rail, and one barge-to-rail.

3.1. Heavy Haul Trucking Routes

Zion is located in Zion, Illinois at 100 Shiloh Blvd in Northeast Illinois, approximately 42 miles north of Chicago, Illinois. The access road leads to Interstate 94. Both interstate highways and county routes are close to the site. Depending on which loading site is selected, navigation north and south from the site on Interstate 94 is possible. Alternate routes are available using county roads, such as Route 137. There are no state designated heavy haul, restricted, Hazardous Materials (HAZMAT), Highway Route Controlled Quantity (HRCQ) of Class 7 radioactive materials (RAM), or non-radioactive hazardous materials (NRHM) truck routes near Zion or along reasonable HHT routes to the GCUS.

The private paved roads on the Zion site appear to be in good condition. There is good access to and from the ISFSI via an existing road. Some of these roads have recently been refurbished and a reinforced heavy-haul path was constructed to support the transfer of VCCs to the ISFSI in 2014[6]. HHT ingress and egress to the site is via Shiloh Blvd which can be accessed by both an Interstate and county route, as described above.

HHT was used in the past to remove radioactive waste from Zion to the EnergySolutions disposal site in Clive, UT. During decommissioning, Zion*Solutions* removed the Unit 2 reactor head by HHT due to its oversized dimensions which were too large to be cleared for shipment by rail. The reactor head was 17 feet in diameter. The heavy haul truck travelled 1,500 miles from Zion to the low-level radioactive waste disposal facility in Clive, Utah.

Although not entirely practical, HHT direct routes from Zion to GCUS were investigated. It is unlikely that the repository will be located at GCUS and the HHT movement is inconsistent with the study parameters of moving the casks from the ISFSI to a Class I railroad. START identified the HHT route as only 336 miles with a transit time of 5 hours. Due to the speed and permit restrictions and based on practical experience moving dimensional cargo over-the-road, it is unlikely that this cargo would be able to move this distance within the START identified time frame, even though the route is primarily on interstate highways once the HHT leaves the access road at Zion.

There is no on-site HHT road leading from the ISFSI to the recommended barge location, which is located on-site across from the ISFSI, at the east end of the rail track leading to the beach. The prior existing barge facility which was on-site at the time the plant was built, is no longer in place and there is no road in place to reach the waterfront. In the event of a barge focused transportation campaign, the surface of the existing roads or the terrain would have to be evaluated for establishing a stable road surface to reach the barge site.

Two potential private rail tracks were identified for possible use as off-site transload areas for loading the train consist purely as options in the event there was a problem with the Zion rail track, which is not anticipated at this time as it has recently been refurbished. To investigate all modes available for shipment, the two closest rail tracks were identified and are reflected in **Table 3-1** below.

Table 3-1: Nearest Rail Tracks Outside of Zion Site

Track Location	Siding Length (ft)	HHT Mileage to Track	Site Description	Challenges/Considerations
315 E. Sea Horse Dr Waukegan,IL 60085	694’	8.0	Private facility: cement terminal	Served by CN, 8 miles from Zion, an active rail shipper, limited amount of track, congested area next to marina & yacht club.
401 E. Greenwood Ave Waukegan,IL 60085	16,035.22’	11.9	Private facility: NRG Waukegan Generating Station	Active receiver of unit trains of coal. Extensive rail infrastructure with several tracks that are long enough to load the entire train consist and which likely could be isolated to avoid interference with rail operations for the site

START[1] was utilized to create truck routes to the two rail served sites identified within close proximity to the Zion site. Only one of these locations is considered a viable option for establishing an off-site transload location.

Routes were configured to utilize interstate highways wherever available to avoid using two-lane country or local roads and potentially alleviate road congestion during tourist seasons.

Although the NRG site is an excellent option for establishing an off-site location for a transload, the fact remains that Zion has sufficient useable rail in the appropriate configurations to allow for conducting an efficient transloading campaign entirely on the Zion property. This would eliminate the need for HHT permits and any lease or related expense to use another company’s private rail infrastructure to load the trains.

3.2. Rail Routes

As described in **Section 2.0**, the Zion site is directly rail served by the UP Railroad, which is a Class I railroad. It is the only railroad which directly serves the Zion site.

There are no other freight railroads located in the immediate vicinity with access to the Zion site. A commuter railroad runs along the UP line just outside Zion property and the public metro station is located approximately 0.8 miles from the entrance to the site at 631 Shiloh Avenue. This metro line is called Metra Rail and the station is called the Zion Metra Station East. It uses the same UP mainline that would be used to transport the loaded cask cars from the site. There will be some restrictions for the loaded cask train departing the site which will involve coordinating the train departures around the commuter train schedule once the shipping campaign begins.

The mainline switch is still in place along with six other three switches on the property. The rail siding has a long lead connecting the UP mainline to the multiple tracks within the perimeter of the active portions of the old plant. There are two substantial curves in the track coming off the mainline track. For safety reasons, the UP informed the most recent shipper from the site, Zion*Solutions*, that it would not travel over the track to switch cars due to the extreme curvature of the track as shown in **Figure 3-1**. This condition still exists today.

During decommissioning, ZionSolutions successfully shipped approximately 1,000 ABC and gondola rail cars from the site to Clive, UT for disposal. A UP direct route was used.

Figure 3-1: Point of Switch and Curvatures

Therefore, to have rail service, Zion personnel/contractors were required to push the loaded railcars from the loading site in the plant to the point of switch where UP would back into the track and couple to the awaiting loaded cars to pull them from the site. Additionally, UP would push the empty cars into the site just past the point of switch and Zion personnel used a track mobile to come out to the waiting cars and pull them into the plant where they would load them. The degree of the two curves on the siding coming from the UP mainline to the plant is 12 degrees, 0 minutes, 0 seconds and 11 degrees, 30 minutes, 27 seconds. UP will not traverse any track on a private siding that is greater than a 12-degree curve. The goal is for the UP to operate only over private track it deems safe. This condition has not affected rail service at the plant. It only means the shipper must place the loaded cars on the track close to the mainline, so the UP does not have to travel over the track (or pull cars into the plant itself).

There is approximately 7,413.11 feet of usable track on three parallel tracks running from Shiloh Road to the end of the track closest to the beach/waterfront.

No other railroads have access to the site nor are operating within close proximity to Zion. No short lines near the plant have suitable established transload locations.

Table 3-2 lists the railroads in the geographic area.

Table 3-2: Class I and Class II Railroads Near Zion[1]

Railroad	Railroad Class	Notes
Union Pacific Railroad	Class I	Direct access to Zion, switch and track is active and in place
Canadian National Railroad	Class I	Not close enough to provide options for transload
Canadian Pacific Railway	Class I	Not close enough to provide options for transload
BNSF	Class I	Not close enough to provide options for transload
WSOR	Class II	No sidings in the area, established bulk transload facilities in WI ranging from 49 to 135 miles from the site. No machinery or dimensional transloads a thit time.

In the past, there were two additional tracks that led to the two cooling towers/reactor buildings. Those tracks have been removed.

In addition to the recently shipped LLW, the plant has used rail transportation to ship other dimensional cargo from the site, such as the eight steam generators which moved in 2016 for disposal, also to Clive, UT. According to the shutdown sites report, these units weighed between 444,000 and 462,200 lbs. each and moved on 12-axle rail cars.

Over 7,100 feet of private rail track is located on the Zion property. The rail track was actively used during decommissioning and has been upgraded and maintained. Multiple switches on site are operable and at least three tracks have run-around capabilities.

The existing rail tracks have been used in the recent past from 2011 through 2018 by Zion*Solutions* for outbound movements of LLW shipments. As stated above, approximately 1,000 carloads were shipped from the site. The rail track was refurbished including the installation of concrete ties in the curves and the replacement of a portion of the wood ties along the east-west portion of the track[6]. Three parallel tracks from switches near Shiloh Road run along the perimeter of the old plant and are perpendicular to the ISFSI pads.

Several of these tracks provide adequate locations for on-site transloading. Because the selected track, shown in **Figure 3-2**, is closest to the ISFSI, on-site transport effort and time is minimized.

Figure 3-2: On-Site Train Loading Location

Several direct rail routes were considered from the Zion site to GCUS as identified in **Table 3-3**. One of these three routes is the UP direct around Chicago to GCUS. This route travels the Milwaukee Sub to the Villa Grove Sub to the Pana Sub and ending at GCUS. START identified this route as having a total of 336 miles with total rail transit time of 8.62 hours. This is a standard, direct route from the origin to the GCUS and it can accommodate dimensional cargo. The loaded train configuration has been cleared on this route.

An alternative direct rail route involved a route from Zion to GCUS via Chicago, IL, to Springfield, IL. START determined this route was 384 miles with a total transit time of approximately 12.88 hours. This route is not as direct as the recommended route and is not a standard route over which HAZMAT or dimensional traffic would move from this origin to GCUS.

Another alternative rail direct route involved a route from Zion to GCUS via Springfield, IL. START determined this route was 364 miles with a total transit time of approximately 11.85 hours. This route is not as direct as the recommended route. This is not a standard route over which HAZMAT or dimensional traffic would normally move from this origin to GCUS.

Table 3-3: Potential Rail Routes to GCUS

Route Identification	Total Distance (Miles)	Total Travel Time (min/hrs)	Route Description	Challenges/Considerations
UP rail only around Chicago	336	517 / 9	Developed using START from expert rail route knowledge. Rail lines UP only.	Benefits include only one Class I carrier over the entire route, least transit time and most direct route. Route A.
UP rail through Chicago / Springfield	384	773 / 13	Developed using START and Minimum Travel Time forcing to Springfield as optional rail.	This route was developed using START from expert rail knowledge for an alternate UP route going into Chicago through Springfield as an alternate option for Route A.
UP rail through Springfield	364	711 / 12	Developed using START from expert rail route knowledge for alternate UP routes.	This route was developed using START from expert rail knowledge for an alternate UP route to avoid going into Chicago by heading west of Chicago through Springfield. This is a second alternate route which avoids going directly into Chicago versus Route A.

Other identified rail direct routes involved additional rail carriers, additional rail miles, a circuitous route, increased transit time, more railroad interchanges, and additional costs for movement of the train to GCUS. The routes are identified in the above table.

3.3. Barge

Zion is located on Lake Michigan. There is no existing barge slip; however, barges were used during the construction of the plant. The barge area has since been abandoned with only the pilings remaining. The land where the previous barge dock had been located was donated and converted into an Illinois State-owned Park. The site is located on a beach as shown at the end of Route 1 on **Figure 3-3**. A physical site and marine survey must be conducted to ensure there are no submersed barriers to reaching the beach or obstacles on the beach to prevent landing the barge.

Figure 3-3: Zion Potential Barge Loading Sites

The site also contains a beach location considered for grounding a barge for potential outbound barge movements from the site. This location is the shortest on-site haul from the ISFSI to a potential barge site and is shown at the end of Route 2 on **Figure 3-3**. A survey would be required to determine if the soil is compact enough to construct or modify the ground conditions for establishing an acceptable road from the ISFSI to the beach area to conduct a barge loading campaign if this option is selected for movement of the casks from the site. During decommissioning, Zion*Solutions* grounded a barge on the beach to load the turbine and generators which were shipped to another plant in for reuse. This precedent indicates at least at the time of the shipment that ground conditions were acceptable and stable for outbound barge shipments from the beach area.

Weather conditions on Lake Michigan must be considered for any barge movement, as ice, snow, wind, thunderstorms and tides are factors. Although Lake Michigan and the other Great Lakes are considered to be essentially nontidal, Lake Michigan, like all bodies of water, does experience tidal fluctuations caused by the gravitational pull of the sun and moon which occur in a semi-diurnal (twice daily) pattern. These minor variations are masked by the greater fluctuations in lake levels produced by wind and barometric pressure changes including seiches (standing waves oscillating in a body of water). According to NOAA, Zion, IL is (1) one of the snowiest places in IL with an average of 41"/year, (2) tornadoes are common in IL with 63% occurring between March and May, (3) a total of 61 historical tornado events with recorded magnitude of 2 or above were in or near Zion, IL and, (4) the chance of earthquake damage in Zion, IL is lower than the IL average and is much lower than the national average. The risk of tornado damage in Zion is lower than the IL average, but is higher than the national average.

As the ISFSI is above the grade of the beach, removing the fence, performing grading, and laying crane mats as a foundation would allow for a smooth surface for the goldhofer[1] to transport the casks from the ISFSI to the barge in a safe manner. "Goldhofer" is a manufacturer of a commonly used hydraulic platform trailer. There are two common types of these trailers. The first type is self-propelled (an engine is mounted on the end of the trailer, and it has drive-axles) and is generically called SPMT (self-propeller modular trailers). The second is not self-propelled (a heavy-duty tractor generally with four axles that is counterweighted unless it is used with a gooseneck attachment) and is towed by a prime mover for tractor force.

The type of goldhofer to be used will be determined at the time of shipment when the ground survey is conducted. The selection will be based on several operating factors and in accordance with the ground conditions at the time of the campaign (wet, dry, how compact, etc.). There are many types of goldhofer configurations which could effectively be used for this operation, but an off-road configuration would be recommended due to the beach-like conditions over which the unit will travel. The most maneuverable would be an electronic steered, self-powered self-propelled trailer. These trailers have the greatest turning degree capabilities. A second option would be a mechanical trailer (commonly known as a THP) and is mechanically steered and is designed to be towed by a prime mover (but, may be attached to a self-propelled PST trailer). The third option would be a powered unit that is self-propelled and connected to a THP trailer (commonly called a PST trailer). The first and third types are designed to operate without a prime mover.

The beach access road appears to be sloping toward the beach. A detailed survey would be required to confirm the beach access road's condition, grade, and possible use for access to the beach. There may be a possibility of using the rail track as a foundation for a temporary roadbed leading to the beach. Engineering evaluation would be required to determine if this is a viable option to reach the barge location.

All prior barge shipments delivering dimensional components to Zion via the original barge area were successful and without incident. The one outbound barge shipment Zion*Solutions* conducted

[1] In this report, a goldhofer equates to a heavy-duty, self-propelled trailer/module.

during decommissioning using the beach was also successful and the beach was restored after the shipment. Because of the option for grounding the barge and the prior successful barge shipments and the direct barge access on the property, other off-site barge loading locations were not considered as part of this evaluation.

One START barge route evaluated included movement from Zion around Chicago through the Little Calumet River via the sanitary shipping and drainage canal connecting with the Illinois River to a location in the vicinity of GCUS. Here the casks could be unloaded from barge and transloaded onto rail with only a short HHT movement to reach the transload track for the final rail movement to the GCUS. An unloading area was identified for grounding the barge within very close proximity to GCUS. On this route the barge would maintain a distance of approximately 20 feet from the shoreline to the mouth of the river. Traveling south the barge will encounter 11 locks traversing the Upper Mississippi River. START identified the total water distance to be 473 miles and transit time to be 68 hours or 2.83 days.

A second START generated barge route evaluated movement from Zion traveling through Chicago. This route also followed the above water route through the sanitary shipping and drainage canal to the Illinois River and the Mississippi River and to the same location in the vicinity of GCUS. Here the casks could be transloaded from barge to rail for the final movement to the GCUS. Traveling South from Zion the barge will encounter 11 locks on the way to the Upper Mississippi River. START identified the total water distance of 463 miles and transit time of 63 hours or 2.63 days. See **Table 3-4** for potential barge routes.

Table 3-4: Potential Barge Routes

Route Identification	Total Distance (Miles)	Total Travel Time (min/hrs)	Route Description	Challenges / Considerations
Barge from Zion ISFSI along Lake Michigan avoiding Chicago to Illinois River to the Mississippi River	473	1632 / 68	From Zion ISFSI along Lake Michigan avoiding Chicago to Illinois River to the Mississippi River	11 locks are found along the route.
Barge from Zion ISFSI along Lake Michigan to Illinois River to the Mississippi River	463	1512 / 63	From Zion ISFSI along Lake Michigan to Illinois River to the Mississippi River	11 locks are found along the route

3.4. Barge Unloading Locations

Several options for potential barge unloading locations were identified in the vicinity of GCUS. The majority of the barge slips in this area are privately owned. Interference with ongoing operations would therefore need to be coordinated with the owners and current users of these sites. Permission must also be obtained from the owner of the private slips. **Table 3-5** lists the potential barge unloading locations that provide close proximity to rail loading tracks near the barge site.

The most feasible docking location near the GCUS is shown in **Figure 3-4**. Additional lifts which will add cost and time are required for a barge shipment from the site to the identified locations for loading onto rail.

Table 3-5: Possible Barge Unloading Sites at GCUS

Rail Transload Facility	Distance from Barge	Comments / Details
Intersection of Hog Haven Road & rail yard Sauget, IL 62201	1,333 ft	Portion of track inside rail yard Not secured by a fence Congested
Gavion 10 Pitzman Ave Sauget, IL 62201	2,392 ft	1,490 ft of private track
Lawn & Garden Midwest 3414 Hog Haven Road Sauget, IL 62201	1.09 miles	3,392ft of track
Eastman Chemical Plant /Solutia 500 Monsanto Avenue Sauget, IL 62201	2.1 miles	Secure

Note: the use of any existing barge slip or dock should be evaluated and a marine survey conducted to determine if submerged conditions would present complications to the operation. If a pier is used, its condition to hold the combined weight of the cask, cradle, and goldhofer would need to be evaluated. A pier or dock was not considered in either the loading or unloading operations for this barge campaign.

Figure 3-4: Hog Haven Rd Barge Off-Load in the Vicinity of GCUS

3.5. Down-Selected Transportation Routes

Considering the large number of potential transportation routes identified in the previous sections, a set of screening criteria was developed and applied to down-select a small group of options considered to be viable for further investigation. To preserve options for all three possible modes of transportation from the Zion site, this down-select was based on comparing routes containing the same modes of transport (i.e., truck routes were not screened based on characteristics of barge routes) and results in one or more routes identified for each mode of transport to be evaluated by the MUA. The criteria utilized are as follows:

1. The time and/or distance to be traveled by the conveyance/barge would be significantly more than alternate viable routes without significant/substantial benefit.
2. Clearance limits on routes (e.g., through tunnels, around curves, or through heavily forested roads) are not met without significant/substantial upgrading.
3. Route includes substantial distances with steep grades.
4. Bridges/overpasses to be used would not sustain weight of conveyance without significant/substantial upgrading.
5. Natural features make barge landings, overpack loading, etc. difficult to perform without significant/substantial upgrading or infrastructure development.
6. No available loading facility or insufficient track for performing loading of a full consist.
7. Transload and/or port facility does not permit receipt of Class 7 materials.

8. Number of interchanges between carriers.
9. Avoidance of high-density transit areas (i.e., regions with significant rail traffic) that would require interruption of traffic if shipment were to transit region.
10. Characteristics of HHT that would require preapproval for Highway Route Controlled Quantity (HRCQ) shipments.[2]

Some of the potential transportation routes had unique characteristics that did not correlate with any of the 10 listed criteria above. These characteristics greatly reduced the viability of the transportation route; therefore, an 11th category, "Other", was added to the screening criteria so that the unique criterion could be captured. The above criteria was applied to a number of potential routes for screening before being assessed in the MUA process. After applying the above screening criteria (see **Table 3-6**), a total of five possible routes were identified and are included for further evaluation in the MUA (**Section 5.0**):

1. UP only Rail around Chicago direct to GCUS (i.e., referred to as "A. UP Direct Around Chicago" route in the MUA; **Figure 3-5**).
2. UP Alternate Rail through Sterling and Springfield (i.e., referred to as "B. UP Alternate" route in the MUA; **Figure 3-6**).
3. UP Alternate Rail through Sterling and Springfield avoiding Chicago (i.e., referred to as "C. UP Alternate Rail Around Chicago" route in the MUA; **Figure 3-7**).
4. Barge only avoiding Chicago going through Peoria to GCUS (i.e., referred to as "D. Barge Only" route in the MUA; **Figure 3-8**).
5. Heavy Haul Truck (HHT) Minimum Distance to GCUS (i.e., referred to as "E. HHT Only" route in the MUA; **Figure 3-9**).

Table 3-6: Routes Versus Screening Criteria

Route	1	2	3	4	5	6	7	8	9	10	Other
HHT to BNSF Transload in Chicago									X		
CN Only rail through Champaign, Aurora, and Effingham	X										
HHT Minimum Distance generated from START (Route E.)											

[2] For routes where HRCQ applies, screening may occur due to the more restrictive requirements of NRC approval of such a route and its associated requirements for armed security, disabling devices, secure communication, HAZMAT bill of laden, safe haven identification, safe-secure shipments, emergency response planning, etc.

Route	1	2	3	4	5	6	7	8	9	10	Other
UP to Interchange to BNSF through La Crosse, Dubuque, and Quincy	X							X			
UP Interchange to BNSF in Chicago through Galesburg, and Quincy								X			
HHT Minimum Population generated from START	X										Route is not linear
Barge from Zion ISFSI along Lake Michigan to Illinois River to the Mississippi River									X		
HHT to La Crosse transload	X										
HHT to sites South of Zion Site	X										
HHT to sites North of Zion Site	X										
Barge only through Preoria, avoiding Chicago (Route D.)											
HHT to 315 E SEA HORSE DR WAUKEGAN, IL, 60085						X					
UP only through Sterling and Springfield, avoiding Chicago (Route C.)											
HHT to 401 E GREENWOOD AVE WAUKEGAN, IL, 60087						X					
Barge transload in Chicago, Il UP to GCUS							X				Not optimal as direct rail is an option
Direct Rail using UP and BNSF via Joilet								X			
Direct Rail using UP, BNSF, and CN via Galesburg	X							X			
UP Rail through Sterling and Springfield (Route B.)											
UP Direct around Chicago (Route A.)											
Direct Rail (START generated minimum distance) using UP, BNSF, and CN via Chicago								X			

Route	1	2	3	4	5	6	7	8	9	10	Other
Direct Rail using UP, ans BNSF via Davenport	X										
Direct Rail using UP, and BNSF via Aurora and Quincy								X			
Direct Rail using UP, CSXT, CN, and NS via Decatur	X							X			
Direct Rail using UP, CSXT, and BNSF via Tinley Park and Kankakee	X							X			

Note: The highlighted rows indicate routes that have not been screened out and will be further analyzed in the MUA in **Section 5.0**.

Screening Criteria Legend:

1. The time and/or distance to be traveled by the conveyance/barge will be significantly in excess
2. Clearance limits on routes
3. Sustained travel on routes with steep grades
4. Bridge(s)/overpass(s) weight limitation
5. Natural features make barge landings, overpack loading, etc., difficult
6. No available loading facility or insufficient track for performing loading of a full consist
7. Transloading and/or port facility does not permit receipt of Class 7 materials
8. Number of interchanges between carriers
9. Avoidance of high-density transit areas
10. Characteristics of HHT Requiring Preapproval for HRCQ

Figure 3-5: Route A. UP Direct Around Chicago

Figure 3-6: B. UP Alternate

Figure 3-7: C. UP Alternate Rail Around Chicago

Figure 3-8: D. Barge Only

Figure 3-9: E. HHT Only

4.0 PARTICIPATING ENTITIES

This section identifies participating entities/persons this report assumed would be involved in the overall plan for the Zion site and summarizes some aspects of their potential roles. By providing this information, which is current as of the date of this report but can be out of date with new events (e.g., elections), an initial means for identifying these entities/persons in the future is considered to be provided.

Various federal agencies would have regulatory authority over the types of shipments of SNF and GTCC contemplated by this report. This report assumes that DOE would be responsible for a federal consolidated interim storage facility or geological repository to which the material would be shipped from the nuclear power plant site and that DOE would be the shipper. DOE has broad authority under the Atomic Energy Act of 1954, as amended (AEA), to regulate activities involving radioactive materials undertaken by DOE or on its behalf, including transportation of radioactive materials. However, in most cases not involving national security, DOE typically uses commercial carriers for its shipments and does not exercise its AEA authority. The DOT and the NRC jointly regulate commercial transportation of radioactive materials in the United States. Most DOE radioactive materials shipments are typically transported by commercial carriers and are subject to regulation by DOT and NRC, as appropriate.

Assuming DOE would use commercial carriers to conduct the shipments, regulatory authority over the shipments can be summarized as follows. In general, DOT would regulate the areas identified in the Memorandum of Understanding between the NRC and the DOT,[3] including package and conveyance radiological controls, routing, hazard communication, and carrier training. Assuming DOE takes custody of the material at the nuclear power plant site, DOE would have authority to regulate other aspects of the shipments (e.g., physical security), except as otherwise required by law.[4] Even where DOE does exercise its AEA authority over its shipments, DOE's general policy is that all DOE shipments must be conducted in a manner that achieves an equivalent level of safety and security to that required by DOT and NRC for comparable commercial shipments. For purposes of this report, it is assumed that the shipments to de-inventory the site would be conducted like typical commercial shipments in accordance with DOT and NRC regulatory requirements.[5]

[3] Memorandum of Understanding, Transportation of Radioactive Materials, 44 Fed. Reg. 38690 (July 2, 1979).

[4] For example, one such exception is the requirement in Section 180(a) of the Nuclear Waste Policy Act of 1982, as amended (NWPA), which requires DOE to use casks certified by the NRC for NWPA shipments. In addition, Section 180(b) of the NWPA requires DOE to follow the NRC regulations on providing advance notification of shipments to jurisdictions through which the shipments will be transported. For further discussion, see letter from Chairman Richard A. Meserve, Nuclear Regulatory Commission, to Senator Richard J. Durbin (May 10, 2002), https://www.nrc.gov/docs/ML0210/ML021060662.pdf.

[5] Although this report assumes that DOE would be the responsible entity for a consolidated interim storage facility or geological repository, this report also recognizes that if a separate management and disposal organization were to be responsible for such a facility some aspects of the regulatory regime for the shipments could differ from that which would apply if DOE were the responsible entity.

In addition to the federal agencies described above, participating entities and persons expected to be involved in the de-inventory of the site would include:

- Utility employees;
- Subcontractors: crane suppliers, riggers, etc.;
- Transportation personnel: truck operator, rail carrier, private escorts for dimensional loads, State Police and Local Law Enforcement Agency (LLEA);
- Cask supplier;
- Lift personnel;
- Security personnel;
- Communication personnel associated with participating entities (e.g., local authorities, escorts, etc.) needed for advance notification of shipments as required by 10 CFR 73.37, 10 CFR 71.97, and as recommended in NUREG-0561 Revision 2[46];
- TRANSCOM or similar satellite and associated continuous in-transit communication service provider(s); and
- Transportation emergency responders.

The participating entities/persons can be categorized into the functional groups identified in **Table 4-1**. Please note that an evaluation of tribal entities that might be impacted during de-inventory operations was performed. None were identified within the transportation routes analyzed for the report. This will need to be evaluated further once destination facilities are identified.

Table 4-1: Participating Entity Functional Identification

Function Group	Entity/Persons
Site	Site Management
	Safety
	Quality
	Document Control
	Security
	Craft Support
	Support Functions
Transportation	Transportation Supervision
	Equipment Operator (driver)
	Security

Function Group	Entity/Persons
	Shipment Response/Tracking
	Support Functions
Rail Transload Facility	Operations Supervisor
	Security
	Craft Support
	Shipment Response/Tracking
	Quality
DOTAuthorities	DOE
	State
	Local
	Federal Railroad Administration (FRA)
	U.S. Transportation Security Administration (TSA)*
	USCG
	NRC
	DOT
	Pipeline and Hazardous Materials Safety Administration (PHMSA)

*TSA operates under the direction of the Department of Homeland Security and acts on their behalf.

Per NRC's regulation 10 CFR 71.97 "Advance notification of shipment of irradiated reactor fuel and nuclear waste," the following would be required:

> (a) As specified in paragraphs (b), (c), and (d) of this section, each licensee shall provide advance notification to the governor of a State, or the governor's designee, of the shipment of licensed material, within or across the boundary of the State, before the transport, or delivery to a carrier, for transport, of licensed material outside the confines of the licensee's plant or other place of use or storage.
>
> (b) As specified in paragraphs (b), (c), and (d) of this section, after June 11, 2013, each licensee shall provide advance notification to the Tribal official of participating Tribes referenced in paragraph (c)(3)(iii) of this section, or the

official's designee, of the shipment of licensed material, within or across the boundary of the Tribe's reservation, before the transport, or delivery to a carrier, for transport, of licensed material outside the confines of the licensee's plant or other place of use or storage.

(c) Procedures for submitting advance notification. (1) The notification must be made in writing to:

(i) The office of each appropriate governor or governor's designee;

(ii) The office of each appropriate Tribal official or Tribal official's designee; and

(iii) The Director, Division of Security Policy, Office of Nuclear Security and Incident Response."

Similarly, NRC regulations in 10 CFR 73.37 and guidance in NUREG-0561 address the provision of advance notification of shipments to States and Tribes as well as other aspects of shipment coordination and communication with participating entities. Therefore, notification of governing authorities is required to coordinate transport in an actual de-inventory campaign. For transport of radioactive material[6], the government agencies listed in **Table 4-1** ("Authorities") issue regulations concerning the packaging and transport of radioactive materials.

Listed below is contact information for some of the relevant state (Illinois) government authorities, a U.S. Coast Guard point of contact for the area, and transportation services for the various modes of transport anticipated. During the development of this report, most information was obtained through public domain. In preparation for an actual de-inventory campaign, this contact information would need to be updated with current information closer to the time of shipments, as coordination and communication with appropriate participating entities would be instrumental in the execution of the shipments.

Illinois – Office of the Governor

Listed below is the contact information for the Illinois Governor's Office.

https://www2.illinois.gov/services/GOV/JB Pritzker
Office of the Governor
207 State House
Springfield, IL 62706
Phone: 217-782-6830 or 217-782-6831

Illinois – Governor's Designee for Notification of SNF Shipments

Listed below is the contact information for the Governor's designee for notification of SNF shipments.

Governor's Designee for Notification of SNF Shipments:
Captain W. Thomas Sands
Illinois State Police
Illinois Emergency Management Agency
IEMA Main Office (217) 782-2700
24-hour Response (800) 782-7860

TTY 888-614-2381
2200 South Dirksen Parkway
Springfield, IL 62703

Illinois – Department of Transportation (IDOT)

Listed below is the contact information for the Illinois DOT.

http://www.idot.illinois.gov/about-idot/ Illinois Department of Transportation
Hanley Building
2300 S. Dirksen Parkway
Springfield, IL 62764
(217) 782-7820 or TTY (866) 273-3681
(800) 452-IDOT (4368) - IDOT General Hotline

The Transport Permits Unit issues permits for oversize/overweight loads to travel on state and federal highways. For more information, contact:

Illinois Department of Transportation,
Bureau of Operations, Permit Office,
2300 South Dirksen Parkway
Springfield, IL 62764
Telephone: (217) 785-1477, if calling from Springfield area or out of state; (800) 252-8636 if calling from an Illinois number but outside of Springfield area
Email: dot.permitoffice@illinois.gov

Site Management Provider

ISFSI Manager Gerard van Noordennen - ZionSolutions (TBD)

HHT-Crane & Rigging Providers

Prior highway shipments by heavy-haul vehicles from the site were moved using Barnhart Crane and Rigging on an 18-axle goldhofer.

Barnhart Crane & Rigging
23462 S. Youngs Road
Channahon, IL 60410
Phone: (815) 431-0078
Fax: (815) 431-0776

Railroad Transportation Contacts

Union Pacific Railroad
10 West Clayton Street
Waukegan, IL 60085

Barge Operators

Barge shipment from Zion is not highly ranked for this project; if used, refer to the contacts below:

Bos Smith
Stevens Towing Company
4176 Highway 165
Yonges Island, SC 29449
843-889-2254

Cask Supplier

Listed below is the contact information for suppliers of the transport casks and related equipment discussed in this report.

NAC International
http://www.nacintl.com/
NAC Atlanta Corporate Headquarters
3930 East Jones Bridge Road
Peachtree Corners, Georgia 30092
Tel 770-447-1144
Fax 770-447-1797

5.0 MULTI-ATTRIBUTE UTILITY ANALYSIS

As noted in **Section 3.0**, there are several modes and routes for shipping NAC TSC4s from the Zion ISFSI to a railcar on a Class I railroad that can take the NAC TSC4s to their penultimate or ultimate destination (e.g., a consolidated interim storage site or a repository, respectively). The diversity of these routes reflects the multiple viable approaches to shipping the NAC TSC4s (i.e., by direct rail, HHT, or barge), and the access of Zion to these modes of transport. Furthermore, these routes potentially have both positive attributes (e.g., safe and secure transport) and negative attributes (e.g., expense) meriting an assessment approach that can evaluate these attributes in a combined manner that may distinguish one route from another and/or rank and prioritize routes.

The MUA is a structured methodology designed to handle the trade-offs among multiple objectives (i.e., attributes). The MUA provides a transparent, rational, and defensible analysis that is easy to explain and communicate. MUA methods have been used for decades to provide logically consistent analyses of options (i.e., modes and routes) that are intended to achieve more than one objective, where no single option dominates the others on all those objectives. Utility theory is a systematic approach for quantifying an individual's or team of individuals' ratings/preferences (*note: when "preference" is used together with "route" there is a specific connotation not intended to be covered in this analysis, thus "rating," "ranking," or "priority" will be used in its stead when associated with a route*). It is used to assign a numerical value on some measure of interest (e.g., metric of an attribute) and rescale it onto a normalized (0 to 1) scale with 0 representing the worst rating/option and 1 the best rating/option. This allows the direct comparison of many diverse objectives. The result is a rank-ordered evaluation of options that reflects the decision makers' preferences.

The MUA has been selected as the assessment approach for purposes of this report to evaluate the viable modes and routes (options) for moving the NAC TSC4s containing SNF and GTCC LLW from the Zion ISFSI. In this section, an MUA using a value model, which identifies preferences of attributes, relative importance of meeting an attribute, and/or tradeoffs between attributes, will be used to establish a prioritized list of modes and routes from the Zion ISFSI.

5.1. Description of MUA Applied to the Zion ISFSI

MUA is a straightforward concept. The three primary steps typically followed to frame the analysis are: (1) identify a set of objectives/attributes that an 'ideal' option will achieve; (2) define a set of performance measures (i.e., metrics) that provide a clear definition of each objective/attribute; and (3) identify or define alternative options that should be considered. Once alternative options (routes and modes), objectives (attributes), and performance measures (metrics) have been clearly defined, the preferences for the performance measures are subsequently established from a pairwise comparison between one another to establish a relative weight for each performance measure. The rating for each route per metric is established by performing another pairwise comparison between the performance measures for each route against one another. The rating of each route can then be established by using a value model to create a single metric that can be used to compare each route against one another and provide a ranking of the routes.

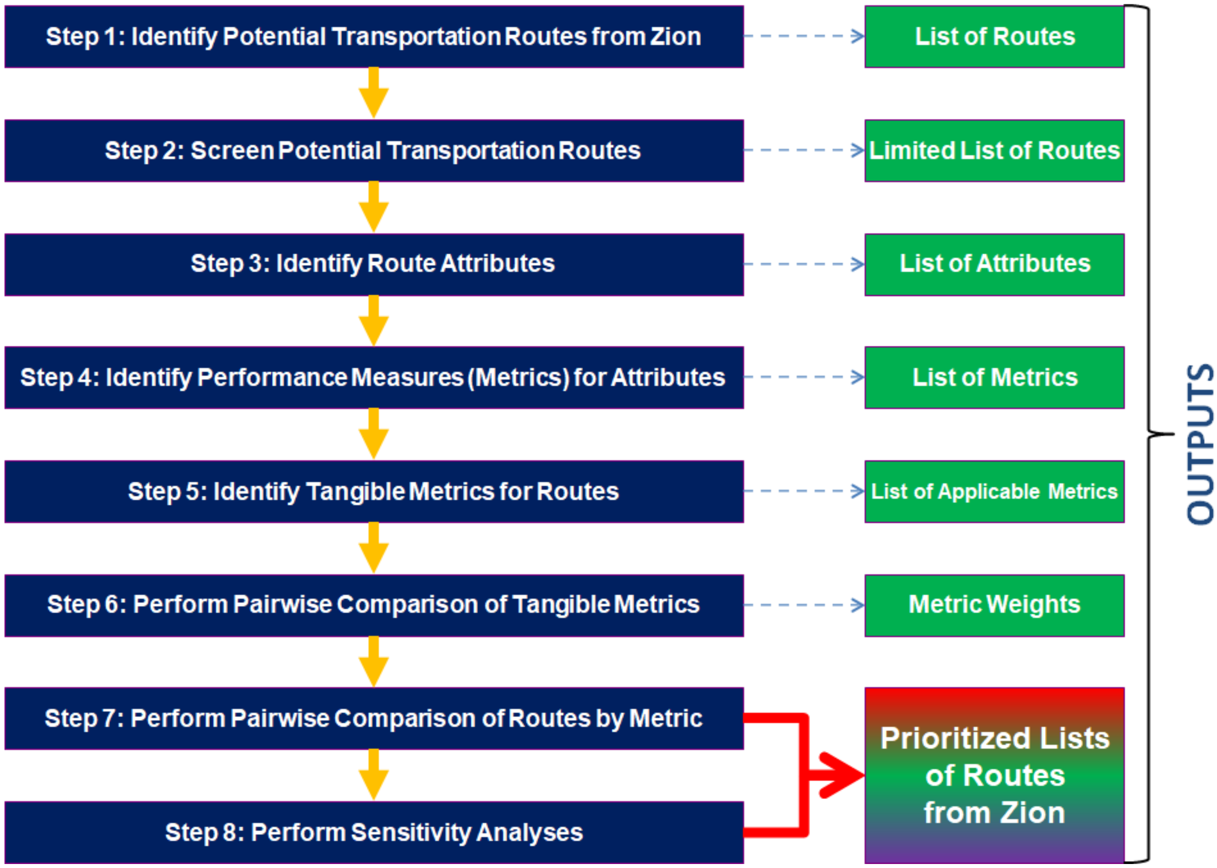
The main steps of the MUA applied to the routes from the Zion ISFSI are identified in **Figure 5-1** and are as follows:

1) Identify the potential modes and routes for transporting the NAC TSC4s from the Zion ISFSI, see **Section 3.0**.

2) Due to the larger number of potential routes identified in Step 1 from the Zion ISFSI, a set of screening criteria was developed to reduce the number of routes per mode to a limited group for further evaluation; see **Section 3.5** (if this step were not performed, then the pairwise evaluations of the routes by metric would be too cumbersome to be practical due to the number of evaluations that would need to be performed).
3) Identify the general attributes associated with the routes and the activity of shipping the NAC TSC4s from the Zion ISFSI; see **Section 5.3.1**.
4) For each identified attribute, identify the metrics that describe performance measures, which could contrast one mode and route from another; see **Section 5.3.1**.
5) Considering the limited list of routes to be evaluated, examined each attribute's metrics, and identified the ones that could tangibly differ between two or more of these modes and routes; see **Section 5.3.1**.
6) Each team member performed a pairwise comparison between each of the tangible metrics, which was subsequently quantified and resulted in a relative ranking of the metrics based on individual ratings and were also combined to establish a weight for each of the tangible metrics based on an equivalent team rating; see **Section 5.3.2** (the individual rankings also provided the basis for the sensitivity analyses).
7) The collective team performed another pairwise comparison between the tangible metrics for each route (to ensure the SMEs' preferences were incorporated and not diluted by the ratings of other individuals), and the results were quantified and evaluated to establish a relative ranking of each of the routes based on SME ratings; see **Section 5.3.3**.
8) Finally, sensitivity analyses were performed to examine the sensitivity of the ranking to different weighting of the tangible metrics; this includes evaluating the metric weights at the minimum and maximum values identified by the individual members of the team; see **Section 5.5.**

Details of the analyses and the results produced from each of these steps are described in the following portion of this section of the report.

Figure 5-1: Overview of MUA Applied to Zion ISFSI



5.2. Description of Evaluated Routes

As noted in **Section 3.0**, there are numerous possible routes from the Zion ISFSI (Step 1). The general sequences of the transportation operations for these routes fall into the following categories:

- Transfer directly to onsite rail siding (onsite rail)
- Transport by HHT directly to GCUS to an existing rail transload facility (HHT to rail)
- Transport by on-site HHT to a barge, barge transport to a port, and transfer to a railcar (HHT to barge to rail)

Due to the numerous possible routes identified in **Section 3.0**, a set of screening criteria was used to reduce these routes to a number that can be reasonably evaluated by the MUA (Step 2). If the routes were not reduced by performing this screening activity, then the MUA could take an inordinate amount of time to perform and the pairwise comparison may not be able to distinguish between many of the routes due to the compression of results between the favored routes relative to the evaluated metrics. That is, if the difference between a favored route and another route that clearly has some disadvantages is identified at an extremity of the evaluation range, then the MUA will show a distinct difference between these two routes. However, if there are other favored routes with only slight differences between one another, these differences may be difficult to distinguish from one another as the large differences will have compressed the slight differences identified between two or more favored routes and thereby prevent distinguishing between them in the overall evaluation.

The following screening criteria were used per mode of transport (i.e., routes having the same mode of transport were only contrasted against one another for screening purposes) to reduce the routes to the five routes identified in **Section 3.5**:[6]

1) The time and/or distance to be traveled by the conveyance/barge would be significantly more than alternate viable routes without significant/substantial benefit.
2) Clearance limits on routes (e.g., through tunnels, around curves, or through heavily forested roads) are not met without significant/substantial upgrading.
3) Sustained travel on routes with steep grades.
4) Bridge(s)/overpass(s) to be utilized would not sustain weight of conveyance without significant/substantial upgrading.
5) Natural features make barge landings, overpack loading, etc. difficult to perform without significant/substantial upgrading or infrastructure development.
6) No available loading facility or insufficient track for performing loading of a full consist.
7) Transloading and/or port facility does not permit receipt of Class 7 materials.
8) Number of interchanges between rail carriers.
9) Avoidance of high-density transit areas (i.e., regions with significant rail traffic) that would require interruption of traffic if shipment were to transit region.
10) Characteristics of HHT that would require preapproval for HRCQ shipments.
11) Other (as specified in Table 3-6).

The reasons for the screening of potential routes identified in **Section 3.0** are documented in **Table 3-6**. The routes unscreened and remaining to be evaluated by the MUA are as follows:

1) Rail directly from the Zion site on the SPCSL line to GCUS on UP rail lines via Waukegan, IL, Lake Bluff, IL, Valley, IL, Bryn Mawr, IL, Proviso, IL, Argo, IL, Blue Island, IL, Dolton Junction, IL, Yard Center, IL, Villa Grove, IL, Findlay Junction, IL, Mitchell, IL, and Gateway Yard, IL (i.e., referred to as "A. UP only Rail around Chicago" route in the MUA).
2) Rail directly from the Zion site on the UP line to GCUS via Lake Forest, IL, Highland Park, IL, Evanston, IL, Chicago, IL, Oak Park, IL, Elmhurst, IL, Wheaton, IL, Elburn, IL, Dekalb, IL, Ashton, IL, Nelson, IL, Bradford, IL, Bartonville, IL, Athens, IL, Springfield,

[6] Several of these screening criteria use the term "significant." This term is frequently justified through a relative comparison between identified routes (e.g., one route may be identified as requiring a single bridge to be upgraded, whereas another route may require several bridges to be upgraded). In a few cases, the opinions of the SMEs were used to screen a route using this term or not to screen a route based on, for example, historical experiences.

IL, Girard, IL, Godfrey, IL, and Granite City, IL (i.e., referred to as "B. UP Alternate Rail through Springfield" route in the MUA).

3) Rail directly from the Zion site on the UP line to GCUS via Deerfield, IL, Des Plaines, IL, Bensenville, IL, Elmhurst, IL, Wheaton, IL, Elburn, IL, Dekalb, IL, Ashton, IL, Nelson, IL, Bradford, IL, Bartonville, IL, Athens, IL, Springfield, IL, Girard, IL, Godfrey, IL, Granite City, IL (i.e., referred to as "C. UP Alternate Rail through Springfield avoiding Chicago" route in the MUA).
4) Barge from Zion ISFSI on to Lake Michigan then down the Little Calumet River through the sanitary shipping and drainage canal and then down the Mississippi River to GCUS (i.e., referred to as "D. Barge Only" route in the MUA).
5) HHT from the Zion ISFSI to a transload site in GCUS via Lincoln, IL, Springfield, IL and Bloomington, IL taking IL-120 to I-94 to I-294 and then to I-55 into the GCUS (i.e., referred to as "E. HHT Only" route in the MUA).

5.3. Evaluation of Routes

To evaluate each of these five routes, attributes used to define an 'ideal' route and associated shipping activities were identified, and for each attribute, metrics were identified that describe the performance measures and allow for the quantification of the assessment through pairwise comparisons. With these five routes in mind, the metrics were evaluated to identify those that are tangibly different between two or more routes. These tangibly different metrics were then pairwise compared against one another to identify a level of importance for each metric (i.e., a metric hierarchy) and provide a range of values against which sensitivity analyses were performed. An additional pairwise comparison was performed between the tangible metrics for each route, and using the metric hierarchy, a hierarchy for the routes was established. Finally, sensitivity analyses were performed to examine the impact changes to the weighting of the metrics had on the route hierarchy.

5.3.1. Identification of Attributes and Metrics

The attributes identified that can characterize the 'ideal' route are identified in **Table 5-1** (Step 3). These attributes were established based on solicitation of the members of the de-inventory team, past de-inventory studies[47][48][49][50][51][52], and also based on the large body of past MUA activities having been performed on nuclear waste management evaluations[53][54][55][56].

For each attribute, one or more performance measures (metrics) was established (Step 4). These metrics provide a means for estimating how well each route performs against each attribute, defined in terms that can be evaluated by technical experts and compared meaningfully by decision makers. **Table 5-1** also lists the identified metrics per attribute.

To minimize the number of evaluations performed in the next set of MUA activities, the team was surveyed to establish which metrics identify a potentially tangible difference between one or more of the remaining five routes (Step 5). **Table 5-1** shows the results of this survey and some subsequent team discussions. Those metrics identified as having the potential to differentiate between one or more of the routes are identified in **Table 5-1** with a "Y" (yes). Comments are provided in the last column of the table to indicate how the "applicable metric" assessment was performed/concluded. The results of this assessment identified at least one metric for each attribute, except for the Waste Generation attributes, for which no tangible differences in the waste productions were identified between the routes (e.g., the waste generated during the de-inventory activities, such as personnel protection equipment, is considered to essentially result in the same quantity and type of waste and hence, will not identify a tangible difference between the evaluated routes). A total of 23 metrics will be evaluated for each route and contrasted against the other routes.

Table 5-1: Attributes and Associated Metrics

Attribute	Metric	Y/N	Comments
Cost[7]	ISFSI Rental Equipment Costs (e.g., mobile cranes)	Y	Mobile cranes may be required for barge, but could instead use goldhofer and stands. Mobile cranes needed for loading on to railcar and HHT trailer for direct rail and HHT routes.
	ISFSI Hardware Procurement Costs (e.g., transfer cask)	N	Hardware is expected to be relatively the same for all routes, with stands for barging being negligible exception.
	Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)	Y	Improvements, such as preparing a barge transfer site, upgrading of on-site heavy haul paths to the rail line and barge loading site may be necessary and may pose measurable differences.
	Labor and Permitting Costs	Y	Labor and permitting costs are expected to vary by route, as on-site transfer to rail is expected to be minimal, offsite transfer by HHT to be more burdensome, and barge somewhere in-between.
	Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)	Y	The different modes of transport from the site of HHT or barge will result in different shipment costs and different transload costs.
	Cost of Rail Transport (e.g., costs associated with use of multiple railroads in route)	Y	Rail routes take different length routes and will have different numbers of interchanges.
	Total Overall Costs	N	The above broken down elements of the total cost are expected to cover this metric and hence, this metric is not expected to provide any significance to this assessment.

[7] Casks, railcars, and associated equipment are assumed to be government furnished equipment and therefore the cost of this equipment is not included in this assessment.

Attribute	Metric	Y/N	Comments
Environmental Impact	Gaseous Effluent Release	N	Although vehicle and barge emissions will be different between the routes, there are no radiological releases associated with the routes and hence, this metric is not going to provide a tangible difference between the routes.
	Liquid Effluent Release	N	No liquid effluent release is associated with any route from this site.
	Route Aesthetic Changes Needed (e.g., tree trimming)	N	Aesthetic changes not needed to support the routes to be evaluated.
	Route Impact to or Proximity to Historical, Archaeological, and/or Cultural Features	N	Evaluated routes are not expected to impact historical, archaeological, or cultural features.
	Route Environment Characteristics (e.g., terrain, grade, tunnels, etc.)	N	Evaluated routes are not expected to traverse steep grades and/or utilize tunnels that may pose a challenge to the shipments of the material from the Zion site.
	Impact of Weather to Route (e.g., limited availability of route or instability of weather)	Y	Weather (e.g., snow, ice, fog) may impact when shipments from Zion can be made depending on mode of shipment.
	Number of Water Areas Nearby Route (e.g., number of bridges crossed)	Y	According to START[1] the number of water crossings shows some differences between the routes.
	Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)	Y	START[1] identified distinguishable differences for number of environmentally sensitive areas traversed between the evaluated routes.
Institutional Considerations	Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churches)	Y	Based on results from START[1], the routes show significant differences between the number of these mass gathering places along the routes.
	Number of Tribal Lands Crossed	N	Based on results from START[1], the routes show no tribal lands are crossed by the routes.
	Public Acceptability of Route	Y	This subjective metric will be evaluated as done in the previous evaluations based on our experts opinions and will consider nearby features of the routes.
Permitting	Ease of Permit Procurement	Y	As the HHT route travels through many different jurisidctions, it will be the hardest to procure permits for, with Barge and Rail providing only minor differences.
	Number of Permits	Y	Number of permits for HHT are considered to be greater then the other routes, thus this metric was evaluated.
	Insurability of Route	N	All routes to be indemnified by DOE (Price Anderson Act).

Attribute	Metric	Y/N	Comments
Resource Requirements	Number of Personnel involved in Transfer	Y	As the barge route will require on-site transfer to the barge site and then at the conclusion of the barge route will require off-loading from the barge and subsequent transload to rail, whereas the rail routes did not require any transloading and the HHT only required transload upon arrival at GCUS, this metric was identified as showing differences between the routes.
	Quantity of Hardware Needed	N	Hardware is expected to be relatively the same for all routes, with stands for barging being negligible exception.
	Availability of Specialty Equipment (e.g., rigging, transfer cask)	N	Speciality equipment such as a transfer cask, rigging, and a heavy haul truck (goldhofer) will be required for each route. Barges and tugs will only be needed for barge routes, but their inclusion will be captured in the transport to rail costs identified above.
Safety	Cumulative Worker Exposure (proportional to handling time & number of workers)	Y	Some routes will involve greater cumulative worker exposure as a result of an additional transload activity (for barge routes) and/or the longer transient duration or cumulative duration for the shipment of single casks by HHT.
	Cumulative Population Dose along Route (proportional to population density)	Y	According to START[1], the population exposed along a route may vary significantly between various routes (noting all exposures will meet regulatory limits and be negligibly small).
	Risks Associated with Number of Lifting Activities	Y	Risks associated with lifting activities will vary between modes of transportation.
	Average Accident Frequency on Route	Y	According to START[1], the average accident frequency along a route may vary significantly between various routes (noting the frequencies are very small overall).
	Hazards (Occupational Safety and Health Administration (OSHA) & Radiological) associated with Route Duration	N	The OSHA risks are expected to be negligible and comparable for each of the routes and any difference will be covered by the worker exposure and transit duration metrics.
	Number of Fire Stations & Trained Personnel Nearby Route	Y	According to START[1], the number of fire stations and trained personnel nearby a route may vary significantly between various routes.
Schedule	Transit Duration per Conveyance and Consist	Y	START[1] identified distinguishable duration differences between the evaluated routes.

Attribute	Metric	Y/N	Comments
	Ease of Access to Transload Site (e.g., consider usage of existing site)	N	Based on current usage the transload sites for HHT and barge are not expected to pose a constraint to operations.
	Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)	Y	Potential differences may be expected between, for example, improving the heavy haul path to the barge.
	Immediacy of Ability to Perform Transfer (e.g., ability to train crew)	N	The team decided there was no tangible difference between the routes as all routes were deemed equally immediately ready for performing a transfer with some potential requirements to coordinate with other site activities, such as train or barge arrival with a load of coal.
	Size of conveyance (# of casks per shipment)	Y	HHT routes will be limited to one cask per shipment versus the 5 assumed per shipment for barge and rail.
Security/ Vulnerability	Security Vulnerability of Route	Y	Some routes may transit urban areas viewed as a higher risk, where as other routes may remain in mostly lower risk rural areas.
	Availability of Security Escort for Route	N	Security escort is assumed to always be available.
	Number of Police Stations Nearby Route	Y	START[1] identified distinguishable differences for the number of police stations nearby route metric between the evaluated routes.
Waste Generation	Quantity of Radiological Waste Produced from Normal Ops	N	A minimum amount of rad waste is expected and will likely be nearly the same for all routes.
	Quantity of Non-Radiological Waste Produced from Normal Ops	N	A minimum amount of non-rad waste is expected and will likely be nearly the same for all routes.

5.3.2. Evaluation of Individual Metrics

With the tangible metrics established in **Section 5.3.1**, a pairwise comparison between these metrics was performed by each of the 12 members of the Orano-led team to establish a relative weighting of the metrics and a range for the metric weight over which a sensitivity analyses were performed (Step 6). In a pairwise comparison, each metric is evaluated for its favorability against the other metrics. This exercise was performed by each of the 12 individuals of the Orano-led team to ensure a reasonable cross-section of preference samples was taken from the collective team, which allowed for an average metric weighting to be established and a prioritized list of metrics identified.

An example of the pairwise comparison performed by an individual is shown in **Figure 5-2**. In this example, the "Transport to Rail Class I Costs" metric (e.g., costs associated with transload activities and rental costs for a HHT, trailer, and/or barge) is pairwise compared against the other metrics on a favorability scale. For example, the "Transport to Rail Class I Costs" metric is rated mildly favorable against the "Transit Duration per Conveyance and Consist," but is rated strongly unfavorable against "Cumulative Worker Exposure." These ratings are interpreted to mean that there is a slight benefit seen to reducing the monies spent on the transport to rail at the expense of increasing the duration of the transit per conveyance and consist (e.g., renting a tug that may operate at a lower speed but costs less than a tug operating at a higher speed, then this evaluator would slightly favor utilizing the slower tug even though that may increase the transit duration). However, if there were an improvement to the transport to Rail Class I that resulted in an increased cost but could be performed to improve (reduce) the cumulative worker exposure along the route (e.g., utilization of a goldhofer trailer to eliminate some worker operations for barge activities), then this will be a strongly favored/encouraged outcome.

Figure 5-2: Example of a Portion of a Pairwise Comparison for Metrics Assessment

Column A Metrics	Column A Strongly Favorable	Column A More Favorable	Column A Mildly Favorable	Neither Favorable (neutral)	Column B Mildly Favorable	Column B More Favorable	Column B Strongly Favorable	Column B Metrics
Transport to Rail Class I Costs				x				Cost of Rail Transport
Transport to Rail Class I Costs			x					Impact of Weather to Route
Transport to Rail Class I Costs			x					Number of Water Areas Nearby Route
Transport to Rail Class I Costs		x						Number of Sensitive Environmental Areas Nearby Route
Transport to Rail Class I Costs		x						Number of Non-Easily-Mobilizable Populations
Transport to Rail Class I Costs				x				Public Acceptability of Route
Transport to Rail Class I Costs				x				Ease of Permit Procurement
Transport to Rail Class I Costs				x				Number of Permits
Transport to Rail Class I Costs					x			Number of Personnel involved in Transfer
Transport to Rail Class I Costs							x	Cumulative Worker Exposure
Transport to Rail Class I Costs						x		Cumulative Population Dose along Route
Transport to Rail Class I Costs					x			Risks Associated with Number of Lifting Activities
Transport to Rail Class I Costs				x				Average Accident Frequency on Route
Transport to Rail Class I Costs			x					Number of Fire Stations & Trained Personnel Nearby Route
Transport to Rail Class I Costs			x					Transit Duration per Conveyance and Consist
Transport to Rail Class I Costs				x				Duration for Infrastructure Improvement
Transport to Rail Class I Costs				x				Size of conveyance
Transport to Rail Class I Costs				x				Security Vulnerability of Route
Transport to Rail Class I Costs					x			Number of Police Stations Nearby Route

With 23 tangible metrics to be evaluated, 253 pairwise evaluations had to be performed by each individual. **Attachment A** shows the entire pairwise evaluation for these metrics. Note, if the original 40 metrics were evaluated, then 780 pairwise evaluations will have had to have been performed to establish the weight for the metrics (burdensome).

The favorability scale, shown in **Figure 5-2** (e.g., "Strongly Favorable"), allows for quantification of the comparison when weights are assigned to the scale. In this MUA, the relative weighting is assessed as follows:

- Strongly favorable as 11 (+5).
- More favorable as 9 (+3).
- Mildly favorable as 7 (+1).
- Neutral is rated as 6 (0).
- Mildly unfavorable as 5 (-1).
- More unfavorable as 3 (-3).
- Strongly unfavorable as 1 (-5).

Using this weight scheme, **Figure 5-3** shows the results for the relative weighting of the tangible metrics as established from the evaluation of twelve individual pairwise comparisons. **Table 5-2** shows the numerical values associated with these tangible metrics. Three sets of data are shown in this figure and four sets of data are shown in this table:

1) The "Minimum" value as established from the eleven individual assessments.
2) The "Average Weight" value, which is an average of normalized results from each of the individual assessments (i.e., each individual's assessment is equally weighted, and the results combined).

$$\bar{R}_m = \sum_{p=1}^{P} \left\{ \frac{\sum_{i=1}^{7} N_{m,p}^{i}\, W_i}{\sum_{m=1}^{M}\left[\sum_{i=1}^{7} N_{m,p}^{i}\, W_i\right]} \right\} / \mathrm{P}$$

where R = average relative weight, N = number of times rank selected, W = weight of rank (see above), M = number of metrics to be evaluated, P = number of evaluators, m. = metric, i = rank (e.g., "strongly favorable"), p = person evaluating metrics.

3) The "Biased Weight" value, which is an average of the unnormalized results from each of the individual assessments (i.e., the raw scores are used to establish overall average values, so if an individual scored significant differences between the metrics, then these results could skew the overall average in favor of this individual's assessment).

$$\bar{B}_m = \left\{ \frac{\sum_{p=1}^{P}\left(\sum_{i=1}^{7} N_{m,p}^{i}\, W_i\right)}{P} \right\} \Bigg/ \sum_{m=1}^{M} \left\{ \frac{\sum_{p=1}^{P}\left(\sum_{i=1}^{7} N_{m,p}^{i}\, W_i\right)}{P} \right\}$$

where B = averaged biased relative weight.

4) The "Maximum" value as established from the twelve individual assessments.

Results from all twelve of the individual assessments are shown in **Attachment B**.

As shown in **Figure 5-3** and **Table 5-2**, the tangible metrics with the highest preferences (based on average weighting method) are Cumulative Population Dose, Cumulative Worker Exposure, and Risk Associated with Number of Lifting Activities which rated at about 5.96%, 5.79%, and 5.53% of the total weight, respectively. The tangible metrics with the least preferences (based on average weighting method) are Number of Water Areas Nearby Route, Ease of Permit Procurement, and Labor and Permitting Costs which rated at about 3.43%, 3.60%, and 3.62% of the total weight, respectively. The preferences/ranking and weights of all the tangible metrics in descending order (based on average weighting method) are shown in **Table 5-2**.

These results also show negligible differences between the average weighting method and the biased weighting method, which indicates a fairly uniform assessment by the 12 individuals. However, at the extremities of the individual assessments (i.e., the minimum and maximum values), there are some significant findings including:

- The Average Accident Frequency on Route metric, which ranked 5th overall, was ranked 1st highest overall by an individual at 7.77% (as seen in **Figure 5-3**) indicating a wide range of importance levels for this metric between the individual evaluators. This metric also was ranked fairly low by another individual at 3.95% giving it the one of the largest ranges between maximum and minimum.
- The Security Vulnerability of Route metric, which ranked 4th overall, had the third highest favorable ranking by an individual at 7.51%, but was also ranked fairly low by another individual at 3.62% (having the second highest range between the minimum and maximum).
- Overall, the safety and security metrics ranked near the top in preference for everyone's assessment.
- The metrics with the least difference between minimum and maximum values were the Cost of Rail Transport metric and the Transport to Rail Class I Costs metric, which ranked towards the middle of importance of all the metrics and hence, showing a fairly robust rating.

Finally, the minimum and maximum values listed in **Table 5-2** provide ranges of values to be used in the sensitivity analyses performed in **Section 5.5**.

Figure 5-3: Weighting of the Tangible Metrics Based on Pairwise Comparisons

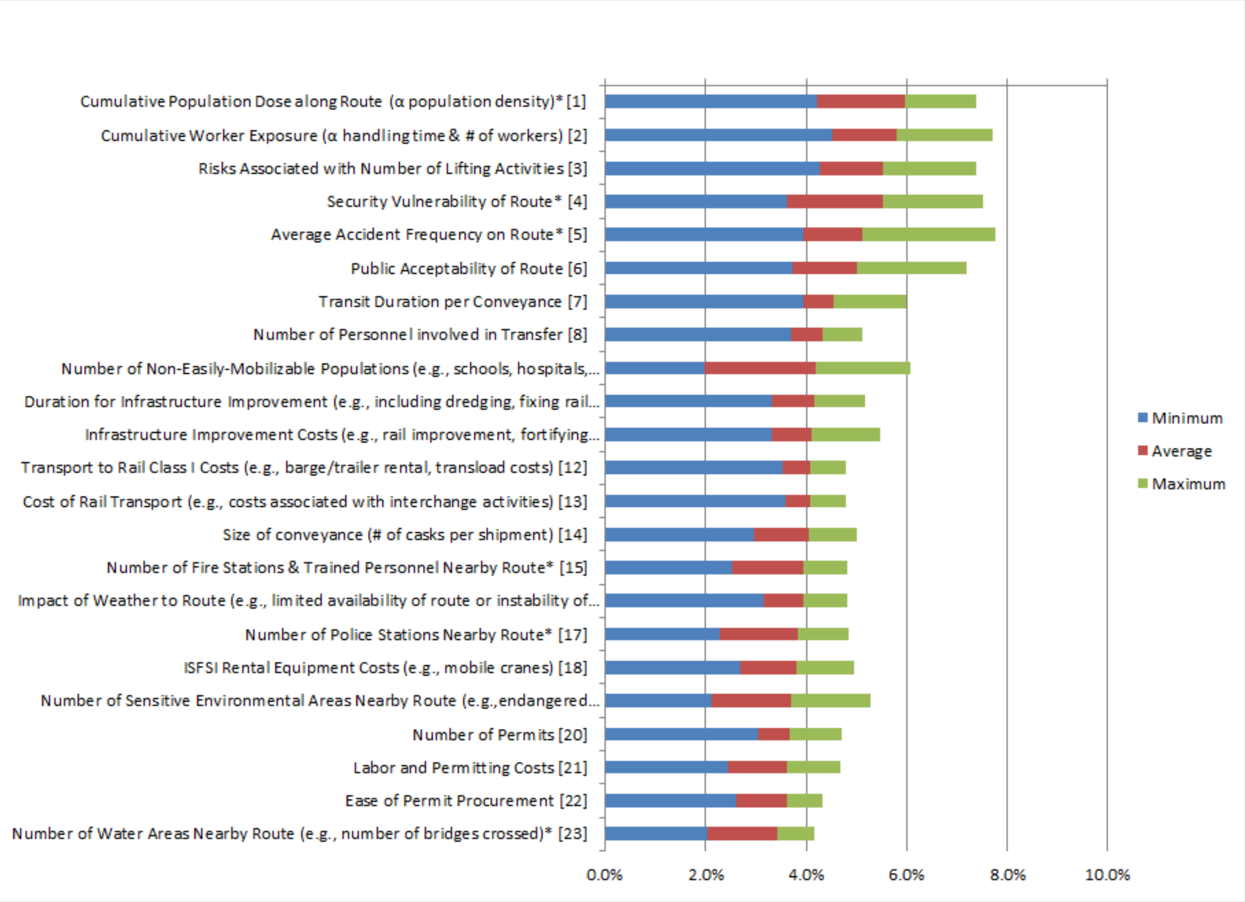


Table 5-2: Weighting of Tangible Metrics

Rank	Minimum	Average Weight	Biased Weight	Maximum	Metric
1	4.22%	5.96%	5.96%	7.38%	Cumulative Population Dose along Route
2	4.51%	5.79%	5.79%	7.71%	Cumulative Worker Exposure
3	4.28%	5.53%	5.53%	7.38%	Risks Associated with Number of Lifting Activities
4	3.62%	5.52%	5.52%	7.51%	Security Vulnerability of Route
5	3.95%	5.13%	5.13%	7.77%	Average Accident Frequency on Route
6	3.72%	5.00%	5.00%	7.18%	Public Acceptability of Route

Rank	Minimum	Average Weight	Biased Weight	Maximum	Metric
7	3.95%	4.55%	4.55%	5.99%	Transit Duration per Conveyance
8	3.69%	4.34%	4.34%	5.11%	Number of Personnel involved in Transfer
9	1.98%	4.17%	4.17%	6.06%	Number of Non-Easily-Mobilizable Populations
10	3.33%	4.15%	4.15%	5.17%	Duration for Infrastructure Improvement
11	3.33%	4.10%	4.10%	5.47%	Infrastructure Improvement Costs
12	3.52%	4.09%	4.09%	4.78%	Transport to Rail Class I Costs
13	3.59%	4.08%	4.08%	4.78%	Cost of Rail Transport
14	2.96%	4.05%	4.05%	5.01%	Size of conveyance
15	2.54%	3.96%	3.96%	4.81%	Number of Fire Stations & Trained Personnel Nearby Route
16	3.16%	3.95%	3.95%	4.81%	Impact of Weather to Route
17	2.27%	3.82%	3.82%	4.84%	Number of Police Stations Nearby Route
18	2.70%	3.79%	3.79%	4.94%	ISFSI Rental Equipment Costs
19	2.11%	3.70%	3.70%	5.27%	Number of Sensitive Environmental Areas Nearby Route
20	3.03%	3.67%	3.67%	4.71%	Number of Permits
21	2.44%	3.62%	3.62%	4.68%	Labor and Permitting Costs
22	2.60%	3.60%	3.60%	4.31%	Ease of Permit Procurement
23	2.04%	3.43%	3.43%	4.15%	Number of Water Areas Nearby Route

5.3.3. Route Assessments

With the ranking/preference of the tangible metrics calculated, another pairwise comparison was performed to compare the tangible metrics for a route against those of each of the other routes

(Step 7). Unlike the pairwise comparison performed for the tangible metrics, which were performed by multiple individuals, this pairwise comparison was performed by the collective team to ensure the responses from SMEs were properly weighted against responses from the other team members when a metric(s) (e.g., cost) was addressed in that SME's discipline(s). In this manner, for example, in the ranking of a safety-related metric, the safety SME's preference was afforded greater influence than were the preferences of the other individuals on the team if there was a difference.

An alternative approach would have been to let each SME separately perform a pairwise comparison on only the metrics within the SME's discipline(s). However, by having a team assessment, productive discussions can take place on each metric, which may change, challenge, concur, etc., on the evaluation of the metric. Furthermore, by acting as a team, the rationale for the pairwise comparisons preferences can be established, and this will lend itself to ensuring a fairly consistent basis in the selection of the preferences (e.g., this may temper extreme assessments in cases where differences in rankings of a metric may not be that significant on a relative basis).

Before performing this pairwise comparison between the tangible metrics for a route against those of each of the other routes, some cursory/preliminary data is required for each of the routes to inform this assessment. **Section 3.0** contains some of this information, but a summary of the cursory/preliminary data used to perform this comparison by metric is provided here.

5.3.3.1 On-Site Rental Equipment Costs

For the on-site rental equipment costs, the majority of the rental costs for on-site equipment would be the same for each route (e.g., mobile crane and trailer), however for the barge routes goldhofers are recommended. The goldhofers would be able to transport the NAC TSC4 canister loaded in a transportation cask to the barge from the ISFSI. The goldhofers would then drive on to the deck of the barge and be aligned with stands designed to hold the transportation casks during the barging portion of the trip. Once aligned, the goldhofers would lower their deck in a manner that would leave the transportation casks sitting in their stands (with their weight no longer supported by the goldhofers) and then drive off the barge. The use of goldhofers would eliminate the need for mobile cranes at the barge landing site, however the rental rate of goldhofers is considered to be higher than mobile cranes. Thus, the barge routes are considered to have the higher on-site rental equipment costs relative to the other routes.

5.3.3.2 Infrastructure Improvement Costs

For the infrastructure improvement costs, the only significant on-site improvement needed would be for the haul path to the barge loading site. Other infrastructure improvements considered for the Zion site included: the need to dredge the barge site, extension/improvement of the on-site rail spur, development of transload sites, and improvements of the HHT routes. However, the barge site was deemed not to require dredging as noted in **Section 3.3**. The on-site rail spur was assessed to be in functional condition as noted in **Section 3.2** and hence, also required no improvements. The on-site transload locations to be utilized for each route were identified to each be in need of development/improvement and hence, no discernable differences in the costs were identified. Finally, each of the HHT and rail routes will require clearance assessments of the off-site routes prior to their use to verify this assessment, considering this assessment is temporal. The net result is the team's assessment determined barge routes are considered to have higher infrastructure improvement costs relative to the other routes.

5.3.3.3 Labor and Permitting Costs

For the labor and permitting costs, the HHT routes are expected to have higher costs relative to the on-site rail and on-site barge costs. The HHT routes are expected to have higher permitting costs relative to the evaluated rail and barge routes, as local permits for the HHT are required whereas no local permits are necessarily needed for the rail and barge routes. Furthermore, labor costs for the HHT routes are expected to be higher per cask as HHT would only move one cask per trip, whereas rail and barge would move 5 casks per trip. In addition, HHT and barge would require off-site transload activities to rail, which the rail routes would not require. Thus, the HHT routes would have the highest labor and permitting costs followed by barge routes and with rail routes having the least labor and permitting costs relative to HHT and barge.

5.3.3.4 Transport to Rail Class I Costs

For the transport to rail costs (not including on-site costs), each of the five routes were evaluated by the team to have a cost benefit or cost penalty relative to the other routes based primarily on composite costs associated with rental of barges, tugs, and HHTs and number of transload activities. For rail routes, no transport to rail costs were identified beyond those already covered by the on-site rental costs. For barge routes, the costs are associated with: (1) the rental of a barge and tugs to ship five transportation casks at a time placed on specialty racks on the barge or left on the trailer (rolled on) and (2) the rental of a crane(s) to move the transportation cask from the trailer onto a stand on a barge (if applicable) or to move the transportation cask from the barge or trailer (rolled off) to a railcar. For HHT routes, the costs are associated with: (1) an HHT to move one transportation cask from the ISFSI to the rail transload facility at GCUS and (2) the rental of a crane to move the transportation cask from the HHT to railcar at the transload site at GCUS. In addition to these rental costs, costs associated with the distance required to be covered by the route and the five separate shipments required to be performed for this route would impact this assessment. Based on this assessment, the HHT route was considered to have the highest transport to rail costs followed by the barge route and the rail routes were deemed to have equivalent (negligible) costs and were favored over the other routes for this metric.

5.3.3.5 Cost of Rail Transport

For the cost of rail transport, the barge and HHT routes with essentially no rail (they are directly off-loaded to rail in GCUS) are favored over the rail routes. Since the rail routes follow the nearly the same paths, these routes all evaluate neutrally against one another.

5.3.3.6 Impact of Weather to Route

The impact of weather in this area of the country is considered to be either directly impacting on the routes (e.g., ice/snow covered roads or rough waters) or indirectly impacting on the routes (e.g., vacationer traffic on the roads and waterways). For example, the barge routes traversing significant distances of the Mississippi River and along Lake Michigan likely would be subject to more impact by personal boat traffic during the summer than the HHT route traveling south from the Zion site. The barge route also traverses the potentially heavily utilized Mississippi River (especially by commercial traffic) that can be impacted by the weather (e.g., by high waters). However, considering Lake Michigan and the Mississippi River are large bodies of water, these potential impacts by the weather to the barge route are expected to be minimal. The weather impact can also have an adverse impact on the HHT and barge routes, primarily due to snow and ice. Hence, the barge and HHT routes are considered to be at a disadvantage relative to the rail routes.

5.3.3.7 Number of Water Areas Nearby Route

Using data produced from the START program[1], each route could be evaluated for the number of water crossings the route traverses. Based on these results (see **Attachment D**), the number of water crossings ranged from 0 to 56, with the caveat that the route with 0 water crossings was the barge route which is continuously on the water. The route with the least number of water crossings is the HHT route (23 crossings) followed by the two rail routes through Springfield (46 crossings), and the rail route around Chicago (56 crossings).

5.3.3.8 Number of Sensitive Environmental Areas Nearby Route

Using data produced from the START program[1], each route could be evaluated for the quantity (square miles) of environmentally sensitive areas crossed. Based on these results (see **Attachment D**), the quantity of environmentally sensitive areas crossed by each route ranged from 6 to 25 square miles[8] which is small compared to the total land crossed by the entire route. Nevertheless, according to START[1], some routes do have advantages over other routes: the rail routes impact the least amount of environmentally sensitive areas (5.7 to 6.5 mi^2); the HHT route has the next least impact (9.1 mi^2); and the barge route has the highest impact (25.4 mi^2).

5.3.3.9 Number of Non-Easily-Mobilizable Populations

Using data produced from the START program[1], each route could be evaluated for the number of non-easily-mobilizable populations, such as those found at schools, hospitals, malls, stadiums, churches, and retirement homes along the routes. Based on these results (see **Attachment D**), the number of non-easily-mobilizable populations along each route was lowest for the barge route followed by the HHT route and then the rail routes around Chicago and through Springfield and the rail route through Springfield avoiding Chicago producing the highest number.

5.3.3.10 Public Acceptability of Route

The public acceptability of the five routes to be evaluated varied between each of the routes. The rail routes were judged to be favorable over the barge and HHT routes due to the lack of off-site activities (e.g., HHT and transloading), utilizing rail lines with regular commercial service, and not utilizing public waterways and crossing their associated environmentally sensitive areas. The barge route was judged to be mildly favorable over the HHT route as the barge travels on a route with a lower population density with a lower accident likelihood that is partially countered by travel on public waterways and their associated environmentally sensitive areas. The rail routes around Chicago and avoiding Chicago were favored over the rail route through Springfield due principally to the shorter routes and the avoidance of Chicago by these routes.

[8] START establishes the square miles of sensitive environmental areas crossed by a route by determining the number of miles a route crosses through these areas and assuming 800 meters on either side of the route, as a buffer region, then multiplying these values together to establish the number of square miles of sensitive environmental area.

5.3.3.11 Ease of Permit Procurement

The rail and barge routes from the Zion ISFSI either do not require permits or the permits were deemed relatively easy to obtain compared to the HHT route, which would require multiple local permits through jurisdictions potentially not receptive to these types of shipments.

5.3.3.12 Number of Permits

As noted in the prior section, the rail and barge routes from the Zion ISFSI do not require permits whereas the HHT route would require multiple local permits to travel through those jurisdictions.

5.3.3.13 Number of Personnel Involved in Transfers

The number of personnel involved in the transfers of the NAC TSC4 from the Zion ISFSI is expected to be the same for each of the rail routes and approximately the same for the HHT, while the barge route is expected to require slightly more personnel to perform the transload activities from the barge to the HHT and then to the rail.

5.3.3.14 Cumulative Worker Exposure

The cumulative worker exposure metric assessment relies heavily on the number of handling events (e.g., transloads) involving the transportation casks and, to a lesser degree, on the distance traveled for each route. These handling events are outlined below and result in the rail routes (equivalent of two on-site transload activities) and the HHT route (equivalent of one on-site transload activity and one off-site transload activity) having an advantage over the barge route (equivalent of one to two on-site transload activities and one to two off-site transload activities). Worker exposure levels would also not approach regulatory limits as the shielding afforded by the transportation casks and the remote operations involved with these handling activities would result in low exposure levels. Furthermore, the larger fraction of the cumulative worker exposure would occur within the Zion ISFSI where the transfer operations to move the NAC TSC4 canisters from the MAGNASTOR VCC to the MAGNATRAN take place and apply to each route.

- Transfer to on-site rail (two lifts):
    - Lift of the MAGNATRAN (loaded with the NAC TSC4) in its cradle onto the on-site trailer
    - Lift of the MAGNATRAN from on-site trailer to cask railcar
- Transfer to on-site barge to rail (two to four lifts):
    - Lift of the MAGNATRAN (loaded with the NAC TSC4) in its cradle onto the on-site trailer/goldhofer
    - Two options for loading onto barge:
        - Lowering of goldhofer that has been rolled onto barge to allow beams holding transportation cask and cradle to rest on stands and subsequently roll off goldhofer from barge (*Note: this lowering activity may not be necessary if the goldhofer is to be left loaded with the transportation cask and cradle on the barge)*
        - Use a crane to lift the transportation cask from the on-site trailer/goldhofer and place it onto the stands on the barge.

  - Lift of transportation cask and cradle located on beams off stand onto HHT or roll goldhofer off of barge loaded with transportation cask
  - Lift of transportation cask and cradle off of goldhofer/HHT and on to cask railcar.
- Transfer to HHT then to rail (two lifts):
  - Lift of the MAGNATRAN (loaded with the NAC TSC4) in its cradle onto the HHT trailer.
  - Lift of transportation cask and cradle from HHT trailer to cask railcar at transload site (*Note: a single lift is assumed at the HHT-to-rail transload site*).

Based on these assessments and the duration of transport on each of the individual routes, the rail routes and the HHT route are essentially equivalent to one another, and they are favored over the barge route.

5.3.3.15 Cumulative Population Dose Along Route

The cumulative population dose along each route is expected to be negligible (comparable to background) due to the significant amount of shielding afforded by the transportation casks and their canisters, the age of the SNF, and the minimal duration of exposure during each transport operation. Furthermore, doses to individual members of the public during normal transportation activities is expected to be below background levels. Nevertheless, the relative differences in preferences established for the assessment of this metric are based primarily on the total exposed population established from data provided by START[1] along each route as shown in **Table 5-3**. Those routes with the lowest total exposed populations are favored over the other routes, as they would result in the lowest cumulative dose to the population.

Table 5-3: Route Averaged Population Density Along Each Route

ID	Route Description	Average Population Density (Persons/Square Mile)[1]	Total Exposed Population Estimate[2] (Thousands)
A	UP Only Rail around Chicago	964	219
B	UP Alternate Rail through Springfield	1986	493
C	UP Alternate Rail through Springfield avoiding Chicago	1015	226
D	Barge Only	600	69
E	HHT Only	765	163

[1] Data established by START[1] and established by totaling the population located within an 800-m buffer of either side of the route and dividing by the area of the buffer.

[2] Data established from START[1] and established by multiplying the cumulative population density by the route distance and the buffer width on each side of the route (for a total width of 1,600 m).

5.3.3.16 Risks Associated with Number of Lifting Activities

Risks associated with lifting activities are dependent on the number of lifts made of a transportation cask, which have been identified in **Section 5.3.3.14**, and the continuous nature of the operation of those lifts (e.g., do a set of lifts occur sequentially separated by hours, days, or weeks). Based on this assessment, the rail routes are deemed strongly favorable over the barge route due to the number of lifts and over the HHT route due to the discontinuous nature of the lifts that occur as a result of the shipment of a single transportation cask at a time resulting in a day or several days between successive lift activities. These risks are minimized by the protection afforded the transportation casks by the impact limiters, the design of the lifting equipment (includes multiple safety factors and avoidance of single-failure points), and the robustness of the transportation cask systems. Hence, although this parameter provides some preference to rail routes, the overall risk associated with a lifting device is deemed negligible.

5.3.3.17 Average Accident Frequency on Route

Using data produced from START[1], each route could be evaluated for the annual frequency of the average accident rate (accidents per mile per year) for all of the modes of transport used on the route. However, the accident rates for the different modes of transport have different definitions for what constitutes an "accident" and hence, this data can only be used to compare routes which use the same mode of transport from the Zion site. So only the three routes that rail could be pairwise compared using the data from START[1]. As shown in **Table 5-4**, the rail route around Chicago has an accident rate approximately 2 times lower than the other two rail routes and hence, this route was deemed mildly favorable over the other two routes. For comparisons between the other routes, the rail only routes were judged to have the lowest overall accident rates compared to all the other routes, followed by the barge only route and the HHT only route.

Table 5-4: Average Accident Frequency Over Each Route[1]

Accident Rate (per mi / yr)*	Route				
	UP only Rail around Chicago	UP Alternate Rail through Springfield	UP Alternate Rail through Springfield avoiding Chicago	Barge Only	Heavy Haul Truck Only
Average Accident Rate	0.000001	0.000002	0.000002	**	**
Factor Increase Over Lowest Rate	1 x	2 x	2 x	N/A	N/A

* Note that the values listed in this table were produced by the START program[1] and in the assessment of this metric only the relative comparison values ("Factor Increase Over Lowest Rate") were utilized.

** Values for these routes from the START program[1] are not listed here because these accident rates could not be compared to one another due to different definitions of "accident" between the different modes of transport.

5.3.3.18 Number of Fire Stations & Trained Personnel Nearby Route

Using data produced from START[1], each route could be evaluated for the number of fire departments per square mile. Based on these results (see **Attachment D**), the number of fire departments ranged from 0.03 to 0.17 per square mile. The route with the highest fire departments per square mile is the UP rail route through Springfield (0.17 per square mile) followed closely by the other two rail routes (0.14 and 0.13 per square mile), followed by the HHT route (0.05 per square mile) and finally the barge route (0.03 per square mile).

5.3.3.19 Transit Duration per Conveyance and Consist

The transit duration for each route was roughly estimated during the team meeting and arrived at the following estimates:

1) Rail from Zion to GCUS by UP only Rail around Chicago
   a) Loading Cask: load NAC TSC4 canister into MAGNATRAN cask, load MAGNATRAN cask on to on-site trailer/goldhofer, and attach truck/tug to on-site trailer/goldhofer (1 to 3 days per cask)
   b) Transload: prepare and load MAGNATRAN onto cask railcar, secure, and prepare cask for shipment (1 day per cask)
   c) Complete Rail Consist (e.g., add buffer cars, locomotives, and escort car) (~1 day)
   d) Thus, approximately **<u>11 to 21 days</u>** for 5 MAGNATRAN casks to load onto a full consist
   e) Total Rail Transit Duration from START[1]: 9 hours
2) Rail from Zion to GCUS by UP alternate Rail through Springfield
   a) Same as previous rail route: thus, approximately **<u>11 to 21 days</u>** for 5 MAGNATRAN casks to load onto a full consist
   b) Total Rail Transit Duration from START[1]: 13 hours
3) Rail from Zion to GCUS by UP alternate Rail through Springfield avoiding Chicago
   a) Same as previous rail route: thus, approximately **<u>11 to 21 days</u>** for 5 MAGNATRAN casks to load onto a full consist
   b) Total Rail Transit Duration from[1]: 12 hours
4) Barge Only to GCUS
   a) Loading Cask: load NAC TSC4 canister into MAGNATRAN cask, load MAGNATRAN cask on to on-site trailer/goldhofer, and attach truck/tug to on-site trailer/goldhofer (1 to 3 days per cask)
   b) Transload: transport to barge and either roll-on on-site trailer/goldhofer or lift MAGNATRAN onto stands and then secure and prepare cask for shipment (1 day per cask)
   c) Barge Preparation: pre-barge briefings for procedures, quality, and safety reviews; assemble crew (1 to 2 days for 5 casks)
   d) Barging: transport 473 miles to GCUS (68 hrs per START[1] or 2 ¾ days for 5 casks)
   e) Unloading Barge: transload operations from barge to rail (2½ days for 5 casks)

f) Thus, approximately **<u>16 to 27 days</u>** for 5 casks to load onto cask railcar

g) Total Barge Transit Duration from START[1]: 68 hours (accounted for above)

5) Heavy Haul Truck Only to GCUS

a) Loading Cask: load NAC TSC4 canister into MAGNATRAN cask, load MAGNATRAN cask on to on-site trailer/goldhofer, and attach truck/tug to on-site trailer/goldhofer (1 to 3 days per cask)

b) Trucking: transport 336 miles to GCUS (5 hrs per START[1], but will assume 1 day per cask)

c) Unloading HHT: prepare and load MAGNATRAN onto cask railcar, secure, and prepare cask for shipment (1 day per cask)

d) Complete Rail Consist (e.g., add buffer cars, locomotives, and escort car) (~1 day).

e) Thus, approximately **<u>16 to 26 days</u>** for 5 casks to load onto cask railcar

f) Total HHT Transit Duration from START[1]: 5 hours (accounted for above)

[1] As noted in these handling times, there are also the total route transit durations on the HHTs, barges, and rails. START[1] provides these distances and total transit times and **Table 5-5** provides a breakdown by route.

Table 5-5: Route Transit Durations[1]

Distance (miles)	Route				
	UP only Rail around Chicago	UP Alternate Rail through Springfield	UP Alternate Rail through Springfield avoiding Chicago	Barge Only	Heavy Haul Truck Only
HHT	0	0	0	0	336
Barge	0	0	0	473	0
Rail	336	384	364	0	0
Total Duration (hrs)	9	13	12	68	5

Note: the times provided are based on one, one-way trip and assume travel at posted speed limits, which is not realistic, but expected speeds would still result in HHT transport durations of less than one day since the distances are fairly short. The values shown above do not account for the multiple trips that would be required by HHT to and from the site and do not account for time spent in locks.

Using the data in **Table 5-5** from START[1] (note some of these times seem counter intuitive and hence were not solely used to establish the comparisons) and the above handling times, the pairwise comparisons were performed between the various routes.

5.3.3.20 Duration for Infrastructure Improvement

Infrastructure improvements were only identified as necessary for the barge route which requires a heavy haul path built to the barge site. The duration of this infrastructure improvement is not expected to significantly impact de-inventory activities but could pose a minor burden on the barge route that the other routes do not have.

5.3.3.21 Size of Coveyance

The rail and barge routes would be able to move 5 transportation casks per shipment/conveyance, whereas the HHT route would be able to move only 1 transportation cask per shipment. Hence, in the evaluation of this metric, the rail and barge routes are favored over the HHT route.

5.3.3.22 Security Vulnerability of Route

For the metric on security vulnerability of the route, all routes were capable of being secured; however, some minor advantages of one route over another were identified and these advantages are related to a combination of duration of the shipment, distance traversing urban versus rural regions, number of high threat urban areas on the route, number of transload activities, and the lower vulnerability associated with barge routes over HHT routes. The shortest rail route direct from the site with no off-site transload activities was judged to be the most favored security route over the other routes (but only mildly favored). Similarly, the other rail routes were favored over or neutral to the barge route from a security perspective. The HHT route was deemed the least secure of the assessed routes as it required off-site transload at GCUS and its cumulative duration created by individual shipments of transportation casks was the highest.

5.3.3.23 Number of Police Stations Nearby Route

Using data produced from START[1], each route could be evaluated for the number of police stations per square mile along the route. Based on these results (see **Attachment D**), the number of police stations ranged from 0.03 to 0.13 per square mile. The route with the highest police stations per square mile is the UP rail route through Springfield (0.13 per square mile) followed closely by the other two rail routes (0.12 and 0.11 per square mile), followed by the barge route (0.05 per square mile) and finally the HHT route (0.03 per square mile).

5.4. Route Rankings

Using the metric information identified for the routes listed in the previous section, the Orano-led team held conference calls to perform a pairwise comparison of each of the tangible metrics for each of the routes identified in **Section 5.2** (Step 7). This team evaluation, unlike the individual assessments performed for the tangible metrics, ensured SMEs' preferences and knowledge could appropriately influence the results for the SMEs' metrics used to compare the routes, while at the same time allowing those knowledgeable of the routes to provide beneficial inputs and all team members the opportunity to provide feedback to the discussion related to the evaluation of the route and **Figure 5-4** provides an example of the pairwise comparison performed by the de-inventory team for the metric related to the Public Acceptability of route (as denoted on the far-left column). "Column A Routes" (2nd column on left) are subsequently compared against "Column B Routes" (last column on right) for the Public Acceptability of route metric. The favorability scale listed in this figure is the same as identified for the pairwise comparison of the tangible metrics (see **Figure 5-2**). As an example, the fourth row of the evaluation (excluding the header row) shows that the “A. UP only Rail around Chicago” route is more favorable when compared to the “E. Heavy Haul Truck Only” to GCUS route for the metric related to the Public Acceptability of route, which is reflective of the information provided in **Section 5.3.3.10**.

With 23 tangible metrics and 5 routes to be evaluated, the team performed 230 pairwise evaluations. **Attachment C** shows the entire pairwise evaluation for these metrics.

Using the same weighting scheme as described in **Section 5.3.2** and the relative weighting of the tangible metrics identified in **Table 5-2**, **Figure 5-5** shows the resulting relative weighting of the routes in order of the highest rated (A. UP only Rail around Chicago) to the least rated (D. Barge Only). **Table 5-7** shows the numerical values associated with each of the routes for multiple different weighting schemes:

1) The “Unweighted” results, which are based on each metric having an equal weight.
2) The “Average Weight” results, which are based on the metric weights associated with the “Average Weights” from **Table 5-2**.
3) The “Biased Weight” results, which are based on the metric weights associated with the “Biased Weights” from **Table 5-2.**
4) The “No Safety or Security Metric” results, which are based on zeroing out the weights associated with the safety and security metrics and re-normalizing the “Average Weights” from **Table 5-2**.
5) The “No Public Acceptability Metric” results, which are based on zeroing out the weight for the Public Acceptability of Route metric and re-normalizing the “Average Weights” from **Table 5-2**.
6) The “No Safety, Security, or Public Acceptability Metric” results, which are based on zeroing out the weights for the safety, security, and public acceptability metrics and re-normalizing the “Average Weights” from **Table 5-2**.

Figure 5-4: Example of a Portion of a Pairwise Comparison for Routes Assessment

Metric	Column A Routes	Column A Strongly Favorable	Column A More Favorable	Column A Mildly Favorable	Neither Favorable (neutral)	Column B Mildly Favorable	Column B More Favorable	Column B Strongly Favorable	Column B Routes
Public Acceptability of Route	A. UP only Rail around Chicago	x							B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago		x						D. Barge Only
	A. UP only Rail around Chicago		x						E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield						x		C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield			x					D. Barge Only
	B. UP Alternate Rail through Springfield			x					E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago		x						D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago		x						E. Heavy Haul TruckOnly
	D. Barge Only			x					E. Heavy Haul TruckOnly

As shown in **Figure 5-5** and **Table 5-7**, the routes with the highest ratings (based on average weighting method) are: UP only Rail around Chicago and UP Alternate Rail through Springfield avoiding Chicago. The route with the least favored rating (based on average weighting method) is the Barge Only to GCUS. The top two routes are almost 4% favored over the last two routes, indicating some definitive preference of these two routes with direct loading of rail on the Zion site.

Figure 5-5: Resulting List of Prioritized Routes from the ZION ISFSI Site

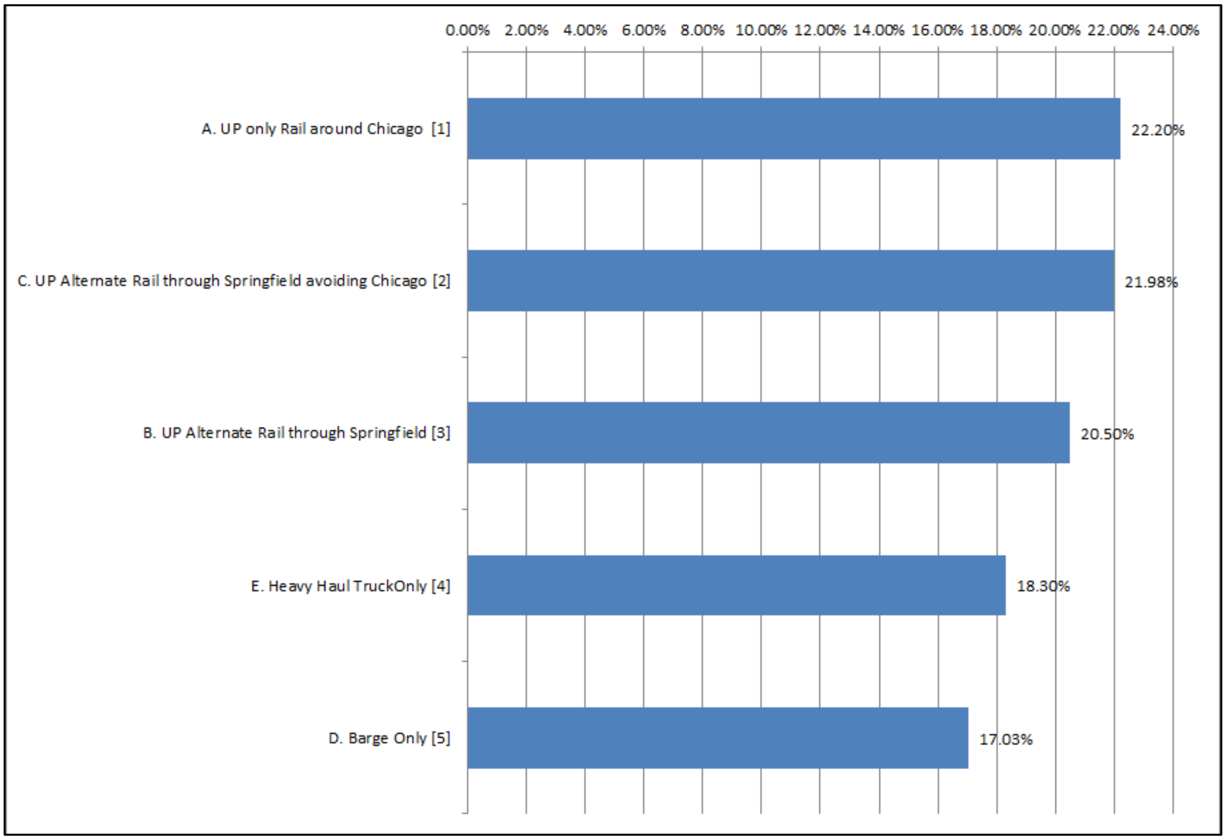


Figure 5-6 shows the impact each tangible metric had on the overall scoring of each route. There is no single dominant metric identified in this figure. However, this figure does show the two most favored routes (direct rail from the site) received significantly greater contributions from the following tangible metrics: public acceptability of routes and risks associated with number of lifting activities. Whereas the barge from the site routes received significant contributions from the following tangible metrics: cumulative population dose along route, number of non-easily mobilizable populations, and cost of rail transport. The HHT routes received significant contributions from the following tangible metrics: cumulative worker exposure and number of water areas nearby route.

Since the safety and security metrics will be established by regulation to be acceptable, these metrics may not be needed to distinguish routes from one another; hence, an alternative weighting scheme was examined to establish the impact of using no security or safety metrics. As shown in **Table 5-7**, the two highest-scored routes change position when the safety and security metrics are removed from the evaluation with and without removal of the public acceptability metric. However, the removal of only the public acceptability metric results in no change to the ranking of the routes. Additional analyses and sensitivity results were performed on these metrics to examine their impact on the rankings in **Section 5.5**.

Table 5-7 shows the sensitivity of the rankings, in general, to the alternative weighting schemes. To further examine the impact to the ranking/scores of the routes to changes in the weighting of the metrics, a sensitivity analysis was performed using the range of the metrics identified in **Table 5-2** (Step 8).

Table 5-8, **Table 5-9**, **Table 5-10**, **Table 5-11**, and **Table 5-12** present the results of the sensitivity of the route rankings to the minimization of the weighting of a metric, using the minimum metric weights from **Table 5-2**. For example, under the metric column labeled "Average Accident Frequency on Route" in **Table 5-11**, results are presented using a weight of 3.95% for the "Average Accident Frequency on Route" (instead of the 5.12% in **Table 5-2**) with the other metrics proportionally re-normalized. The results indicate no change occurs to the overall ranking. **Figure 5-7** summarizes the minimum, average, and maximum results presented in **Table 5-8**, **Table 5-9**, **Table 5-10**, **Table 5-11**, and **Table 5-12** for the minimization of individual metrics. As can be seen from these results, the UP only rail around Chicago route from Zion to GCUS remains robustly ranked as the most favored route for the removal of the SNF from the Zion ISFSI (at this time).

Table 5-13, **Table 5-14**, **Table 5-15**, **Table 5-16**, and **Table 5-17** present the results of the sensitivity of the route rankings to the maximization of the weighting of a metric, using the maximum metric weights from **Table 5-2**. For example, under the metric column labeled "Public Acceptability of Route" in **Table 5-14**, results are presented using a weight of 7.18% for the "Public Acceptability of Route" (instead of the 5.00%), with the other metrics proportionally re-normalized. The results indicate that there is no change in the ranking of the routes. **Figure 5-8** summarizes the minimum, average, and maximum results presented in **Table 5-13**, **Table 5-14**, **Table 5-15**, **Table 5-16**, and **Table 5-17** for the maximization of individual metrics. As can be seen from these results, the top ranked routes remain robustly ranked as the most favored routes for the removal of the SNF and GTCC LLW from the Zion ISFSI.A final assessment of the results was performed by taking the results for each individual from the pairwise comparison on the metrics and using them to establish a route ranking per individual. These results also established, for each individual, the same results in the ranking as seen in the above results (i.e., the rail routes with direct shipment from the Zion ISFSI as the favored routes) for the removal of the SNF and GTCC LLW from the Zion ISFSI.

As a result of the MUA and its sensitivity analyses, the prioritized list of routes from the Zion ISFSI is found in **Table 5-6**.

Table 5-6: Prioritized List of Routes from Zion ISFSI

Rank	Prioritized Route
1	A. UP only Rail around Chicago
2	C. UP Alternate Rail through Springfield avoiding Chicago
3	B. UP Alternate rail through Springfield
4	E. Heavy Haul Truck Only
5	D. Barge Only

Figure 5-6: Impact of Each Tangible Metric on Each Route's "Score"

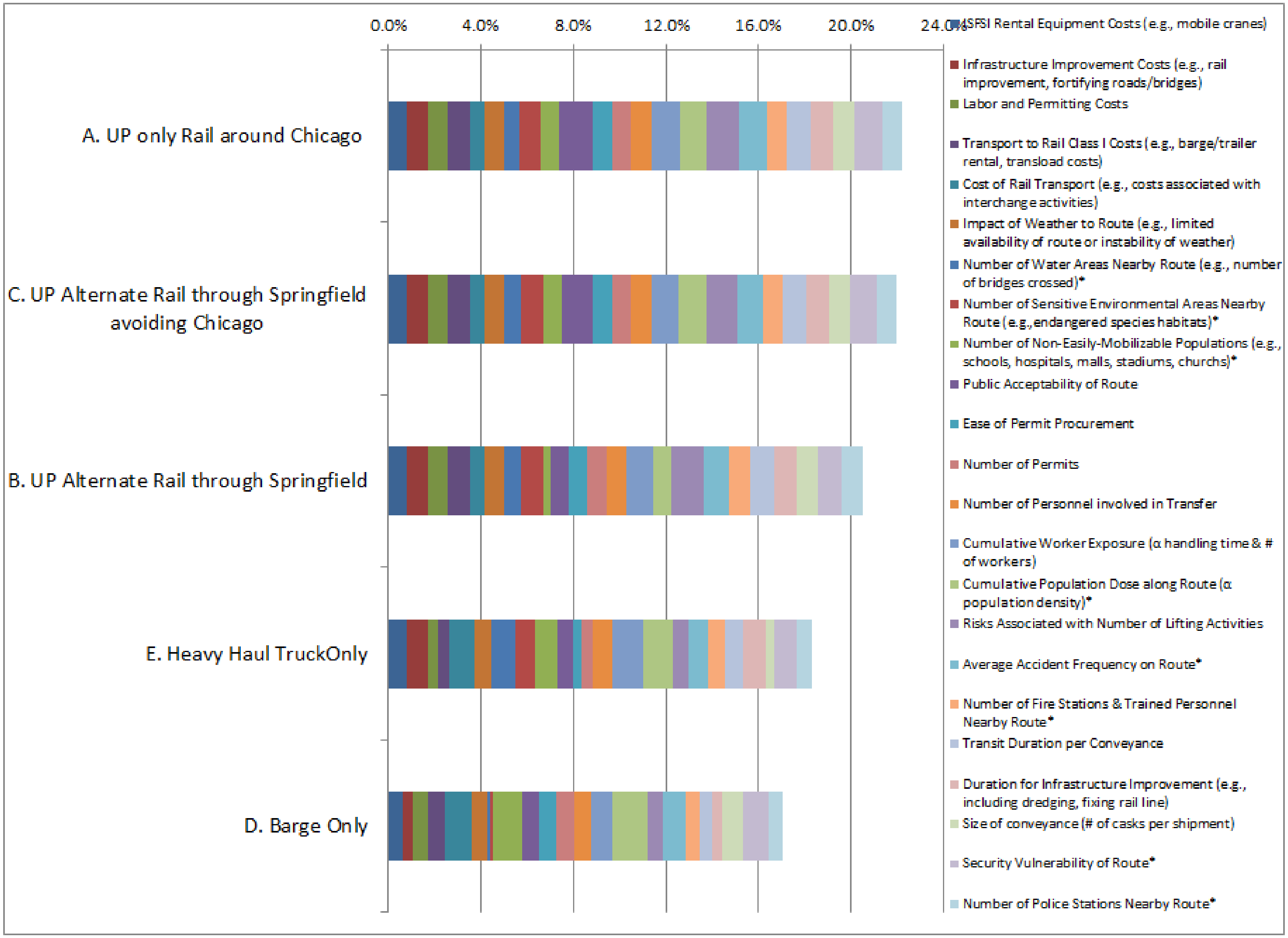


Table 5-7: Weighting of Routes

Nominal Results:	Unweighted		Average Weight		Biased Weight		No Safety or Security Metric		No Public Acceptability Metric		No Safety, Security, or Public Acceptability Metric	
Route	Rank	Result	Rank	Result	Rank	Result	Rank	Result	Rank	Result	Rank	Result
A. UP only Rail around Chicago	1	22.14%	1	22.20%	1	22.20%	2	22.23%	1	21.83%	2	21.65%
B. UP Alternate rail through Springfield	3	20.72%	3	20.50%	3	20.50%	3	20.56%	3	20.79%	3	21.03%
C. UP Alternate Rail through Springfield avoiding Chicago	2	21.99%	2	21.98%	2	21.98%	1	22.24%	2	21.69%	1	21.79%
D. Barge Only	5	16.81%	5	17.03%	5	17.03%	5	16.49%	5	17.13%	5	16.62%
E. Heavy Haul Truck Only	4	18.33%	4	18.30%	4	18.30%	4	18.47%	4	18.56%	4	18.91%

Table 5-8: Weighting of Routes at Minimum Metric Value (Part 1 of 5)

Metric Minimized:	On-Site Rental Equipment Costs		Infrastructure Improvement Costs		Labor and Permitting Costs		Transport to Rail Class I Costs		Cost of Rail Transport	
Route	Rank	Result	Rank	Result	Rank	Result	Rank	Result	Rank	Result
A. UP only Rail around Chicago	1	22.21%	1	22.20%	1	22.19%	1	22.19%	1	22.24%
B. UP Alternate rail through Springfield	3	20.49%	3	20.48%	3	20.46%	3	20.48%	3	20.52%
C. UP Alternate Rail through Springfield avoiding Chicago	2	21.99%	2	21.98%	2	21.96%	2	21.97%	2	22.01%
D. Barge Only	5	17.03%	5	17.08%	5	17.01%	5	17.02%	5	16.97%
E. Heavy Haul Truck Only	4	18.27%	4	18.27%	4	18.38%	4	18.34%	4	18.25%

Table 5-9: Weighting of Routes at Minimum Metric Value (Part 2 of 5)

Metric Minimized:	Impact of Weather to Route		Number of Water Areas Nearby Route		Number of Sensitive Environmental Areas Nearby Route		Number of Non-Easily-Mobilizable Populations		Public Acceptability of Route	
Route	Rank	Result	Rank	Result	Rank	Result	Rank	Result	Rank	Result
A. UP only Rail around Chicago	1	22.20%	1	22.23%	1	22.15%	1	22.27%	1	22.11%
B. UP Alternate rail through Springfield	3	20.49%	3	20.47%	3	20.42%	3	20.77%	3	20.57%
C. UP Alternate Rail through Springfield avoiding Chicago	2	21.98%	2	21.97%	2	21.93%	2	22.04%	2	21.91%
D. Barge Only	5	17.02%	5	17.22%	5	17.25%	5	16.73%	5	17.05%
E. Heavy Haul Truck Only	4	18.30%	4	18.11%	4	18.24%	4	18.19%	4	18.36%

Table 5-10: Weighting of Routes at Minimum Metric Value (Part 3 of 5)

Metric Minimized:	Ease of Permit Procurement		Number of Permits		Number of Personnel involved in Transfer		Cumulative Worker Exposure		Cumulative Population Dose along Route	
Route	Rank	Result	Rank	Result	Rank	Result	Rank	Result	Rank	Result
A. UP only Rail around Chicago	1	22.20%	1	22.20%	1	22.21%	1	22.22%	1	22.24%
B. UP Alternate rail through Springfield	3	20.48%	3	20.48%	3	20.49%	3	20.50%	3	20.62%
C. UP Alternate Rail through Springfield avoiding Chicago	2	21.97%	2	21.98%	2	21.99%	2	22.01%	2	22.01%
D. Barge Only	5	16.99%	5	17.00%	5	17.03%	5	17.03%	5	16.88%
E. Heavy Haul Truck Only	4	18.37%	4	18.34%	4	18.28%	4	18.24%	4	18.24%

Table 5-11: Weighting of Routes at Minimum Metric Value (Part 4 of 5)

Metric Minimized:	Risks Associated with Number of Lifting Activities		Average Accident Frequency on Route		Number of Fire Stations & Trained Personnel Nearby Route		Transit Duration per Conveyance		Duration for Infrastructure Improvement	
Route	Rank	Result	Rank	Result	Rank	Result	Rank	Result	Rank	Result
A. UP only Rail around Chicago	1	22.16%	1	22.19%	1	22.21%	1	22.19%	1	22.20%
B. UP Alternate rail through Springfield	3	20.44%	3	20.49%	3	20.46%	3	20.48%	3	20.48%
C. UP Alternate Rail through Springfield avoiding Chicago	2	21.94%	2	21.99%	2	21.98%	2	21.97%	2	21.98%
D. Barge Only	5	17.08%	5	17.01%	5	17.04%	5	17.06%	5	17.08%
E. Heavy Haul Truck Only	4	18.37%	4	18.32%	4	18.31%	4	18.30%	4	18.26%

Table 5-12: Weighting of Routes at Minimum Metric Value (Part 5 of 5)

Metric Minimized:	Size of Conveyance		Security Vulnerability of Route		Number of Police Stations nearby Route	
Route	Rank	Result	Rank	Result	Rank	Result
A. UP only Rail around Chicago	1	22.20%	1	22.19%	1	22.21%
B. UP Alternate rail through Springfield	3	20.47%	3	20.52%	3	20.45%
C. UP Alternate Rail through Springfield avoiding Chicago	2	21.97%	2	21.99%	2	21.98%
D. Barge Only	5	16.97%	5	16.97%	5	17.04%
E. Heavy Haul Truck Only	4	18.39%	4	18.33%	4	18.31%

Table 5-13: Weighting of Routes at Maximized Metric Value (Part 1 of 5)

Metric Minimized:	On-Site Rental Equipment Costs		Infrastructure Improvement Costs		Labor and Permitting Costs		Transport to Rail Class I Costs		Cost of Rail Transport	
Route	Rank	Result	Rank	Result	Rank	Result	Rank	Result	Rank	Result
A. UP only Rail around Chicago	1	22.18%	1	22.20%	1	22.21%	1	22.21%	1	22.15%
B. UP Alternate rail through Springfield	3	20.50%	3	20.52%	3	20.53%	3	20.52%	3	20.46%
C. UP Alternate Rail through Springfield avoiding Chicago	2	21.97%	2	21.99%	2	21.99%	2	21.99%	2	21.93%
D. Barge Only	5	17.02%	5	16.93%	5	17.04%	5	17.03%	5	17.10%
E. Heavy Haul Truck Only	4	18.33%	4	18.36%	4	18.23%	4	18.25%	4	18.36%

Table 5-14: Weighting of Routes at Maximized Metric Value (Part 2 of 5)

Metric Minimized:	Impact of Weather to Route		Number of Water Areas Nearby Route		Number of Sensitive Environmental Areas Nearby Route		Number of Non-Easily-Mobilizable Populations		Public Acceptability of Route	
Route	Rank	Result	Rank	Result	Rank	Result	Rank	Result	Rank	Result
A. UP only Rail around Chicago	1	22.20%	1	22.18%	1	22.24%	1	22.14%	1	22.35%
B. UP Alternate rail through Springfield	3	20.51%	3	20.51%	3	20.57%	3	20.27%	3	20.38%
C. UP Alternate Rail through Springfield avoiding Chicago	2	21.98%	2	21.98%	2	22.03%	2	21.93%	2	22.10%
D. Barge Only	5	17.03%	5	16.93%	5	16.81%	5	17.27%	5	16.98%
E. Heavy Haul Truck Only	4	18.29%	4	18.39%	4	18.35%	4	18.39%	4	18.19%

Table 5-15: Weighting of Routes at Maximized Metric Value (Part 3 of 5)

Metric Minimized:	Ease of Permit Procurement		Number of Permits		Number of Personnel involved in Transfer		Cumulative Worker Exposure		Cumulative Population Dose along Route	
Route	Rank	Result	Rank	Result	Rank	Result	Rank	Result	Rank	Result
A. UP only Rail around Chicago	1	22.20%	1	22.20%	1	22.19%	1	22.17%	1	22.17%
B. UP Alternate rail through Springfield	3	20.51%	3	20.52%	3	20.50%	3	20.49%	3	20.40%
C. UP Alternate Rail through Springfield avoiding Chicago	2	21.98%	2	21.99%	2	21.97%	2	21.94%	2	21.95%
D. Barge Only	5	17.05%	5	17.06%	5	17.02%	5	17.02%	5	17.14%
E. Heavy Haul Truck Only	4	18.25%	4	18.23%	4	18.32%	4	18.38%	4	18.35%

Table 5-16: Weighting of Routes at Maximum Metric Value (Part 4 of 5)

Metric Minimized:	Risks Associated with Number of Lifting Activities		Average Accident Frequency on Route		Number of Fire Stations & Trained Personnel Nearby Route		Transit Duration per Conveyance		Duration for Infrastructure Improvement	
Route	Rank	Result	Rank	Result	Rank	Result	Rank	Result	Rank	Result
A. UP only Rail around Chicago	1	22.25%	1	22.23%	1	22.20%	1	22.22%	1	22.20%
B. UP Alternate rail through Springfield	3	20.58%	3	20.51%	3	20.52%	3	20.54%	3	20.52%
C. UP Alternate Rail through Springfield avoiding Chicago	2	22.03%	2	21.95%	2	21.98%	2	22.00%	2	21.99%
D. Barge Only	5	16.94%	5	17.06%	5	17.02%	5	16.95%	5	16.95%
E. Heavy Haul Truck Only	4	18.19%	4	18.26%	4	18.29%	4	18.30%	4	18.34%

Table 5-17: Weighting of Routes at Maximized Metric Value (Part 5 of 5)

Metric Minimized:	Size of Conveyance		Security Vulnerability of Route		Number of Police Stations nearby Route	
Route	Rank	Result	Rank	Result	Rank	Result
A. UP only Rail around Chicago	1	22.20%	1	22.21%	1	22.19%
B. UP Alternate rail through Springfield	3	20.52%	3	20.47%	3	20.53%
C. UP Alternate Rail through Springfield avoiding Chicago	2	21.98%	2	21.97%	2	21.98%
D. Barge Only	5	17.08%	5	17.08%	5	17.01%
E. Heavy Haul Truck Only	4	18.22%	4	18.27%	4	18.29%

Figure 5-7: Minimum, Average, and Maximum Results from Sensitivity Analysis for Minimization of Each Metric

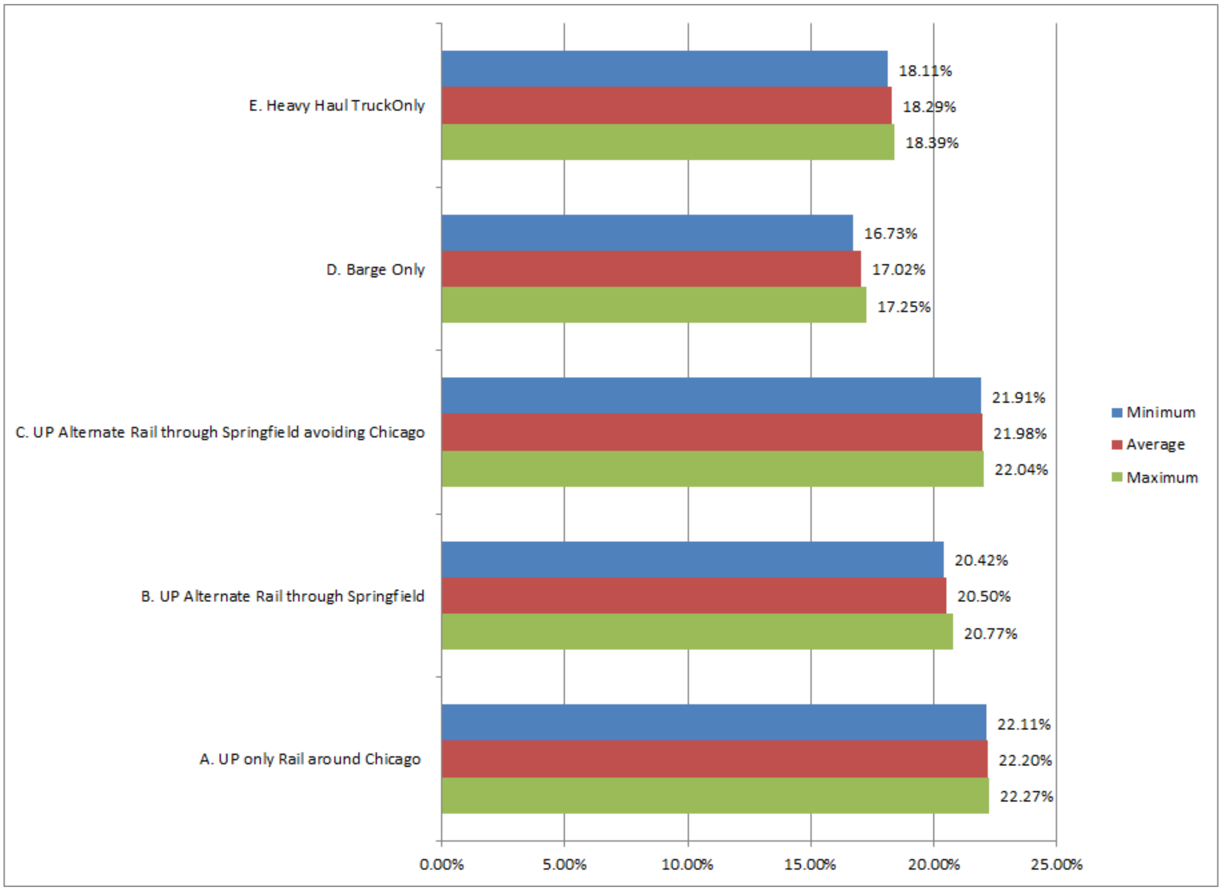
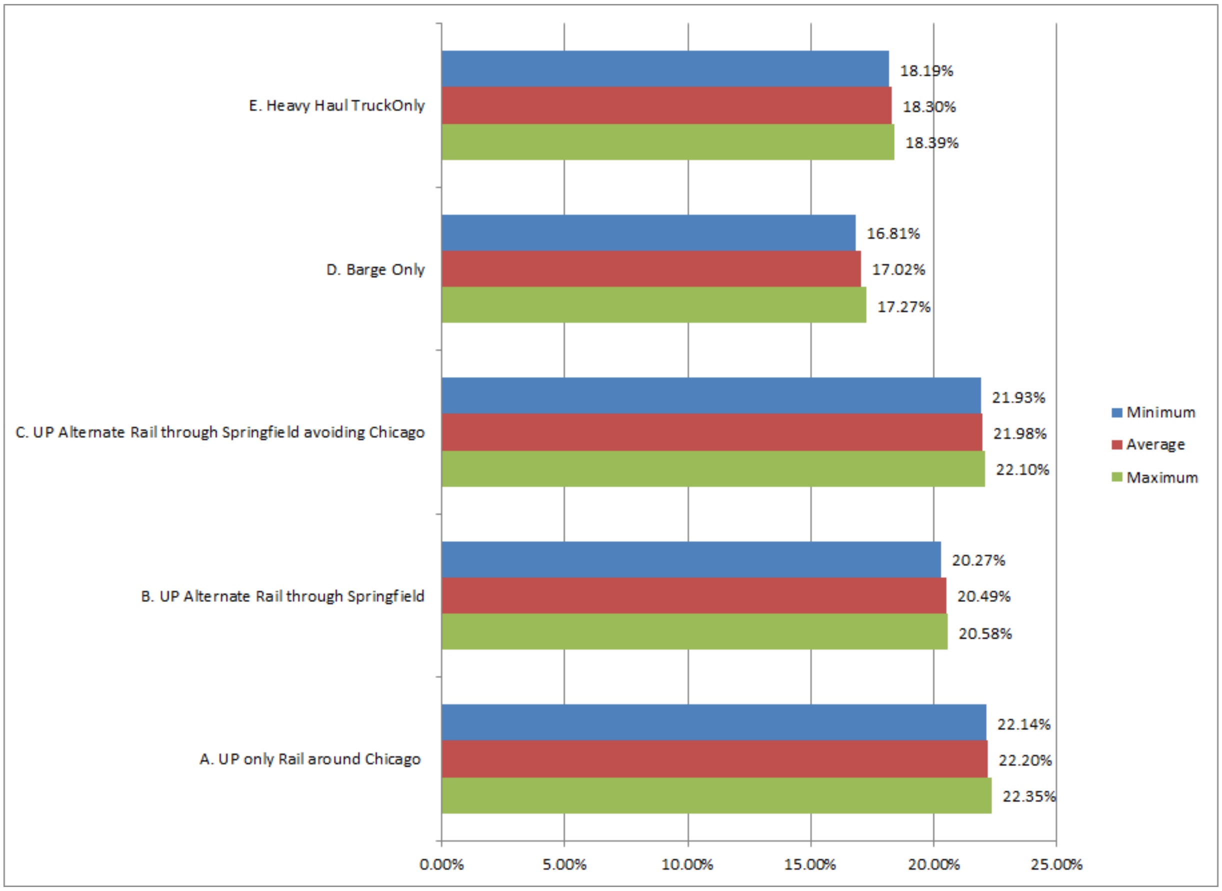


Figure 5-8: Minimum, Average, and Maximum Results from Sensitivity Analysis for Maximization of Each Metric



5.5. Additional Sensitivity Analyses

Additional sensitivity analyses have been performed to examine in more detail the impact of the results of some of the sensitivity analyses performed in **Table 5-7**. The purpose of the MUA is to use objective input, backed by numerical data generated from START[1] and evidence from other sources of information (e.g., pictures), to provide a quantitative ranking of the favorability of route scenarios. Sometimes, however, the subjective opinions of team members can span a larger range then may be necessary to distinguish between routes and may over emphasize the difference between routes. For example, as noted in **Section 5.3.3.15** the dose along the route to individuals is expected to be below background levels (i.e., essentially negligible), but nevertheless cumulative population doses along the routes were still ranked from being neutral to more favorable against one another, when in fact they should have at most spanned from neutral to mildly favorable over one another. Additional sensitivity analyses were performed which examined the impact of suppressing the range of assessments for metrics whose material results are acceptable (e.g., through regulatory requirements). Additionally, more detailed analyses of the sensitivity results presented in **Table 5-7** are provided in this section for additional assessment and one final assessment to remove potential redundancy in some of the metrics is examined.

5.5.1. Suppression of Evaluation Span for Select Metrics

As noted in **Section 5.3.3**, there are several metrics used in the MUA that realistically only vary slightly between each route, as the results will always be acceptable for regulatory reasons. The purpose of this sensitivity analyses is to examine the impact to the route rankings as a result of limiting the span select metrics can be evaluated over. These select metrics include:

- Cumulative Worker Exposure
- Cumulative Population Dose along Route
- Risks Associated with Number of Lifting Activities
- Average Accident Frequency on Route
- Number of Fire Stations & Trained Personnel Nearby Route
- Security Vulnerability of Route
- Number of Police Stations Nearby Route

These specific safety and security metrics were selected for evaluation of span suppression as a result of each of them being regulated (e.g., by the NRC) to an acceptable level. Regardless of the route selected, these identified metrics should only vary marginally, so suppressing the span of the pairwise comparison by route from between mildly favorable to mildly unfavorable, as shown in **Figure 5-9**, was examined. Since five of these seven metrics were ranked, by average, as the top five metrics from the pairwise comparison by individual team members, the suppression of the span of the pairwise comparison likely will impact the route rankings.

Figure 5-9: Example of Suppression of Span for Cumulative Worker Exposure

Metric	Column A Routes	Column A Strongly Favorable	Column A More Favorable	Column A Mildly Favorable	Neither Favorable (neutral)	Column B Mildly Favorable	Column B More Favorable	Column B Strongly Favorable	Column B Routes
Cumulative Population Dose along Route (α population density)*	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago				x				D. Barge Only
	A. UP only Rail around Chicago				x				E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield					x			D. Barge Only
	B. UP Alternate Rail through Springfield					x			E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago				x				D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago				x				E. Heavy Haul TruckOnly
	D. Barge Only				x				E. Heavy Haul TruckOnly

In **Figure 5-9**, assessments originally identified as “Strongly Favorable” or “More Favorable” were suppressed to “Mildly Favorable” and those originally identified as “Mildly Favorable” were moved to “Neither Favorable (neutral)” to examine the impact of suppressing the span of the pairwise comparison by route for metrics whose parameters are regulated to acceptable levels.

Figure 5-10 and Table 5-18 shows the modified rankings with the security and safety metrics evaluation range suppressed. Figure 5-11 shows the contribution each tangible metric makes to the scoring for each route.

compares the results from the original assessment and the modified results using the suppressed span. These results show the top two routes changing position, but the other routes retaining their original rank. Hence the rail routes from the Zion site remain the highest ranked routes, which is consistent with the results identified by the other sensitivity analyses included in this report.

Figure 5-10: Resulting List of Prioritized Routes from the Zion ISFSI for the Suppression of Span for Safety and Security Metrics

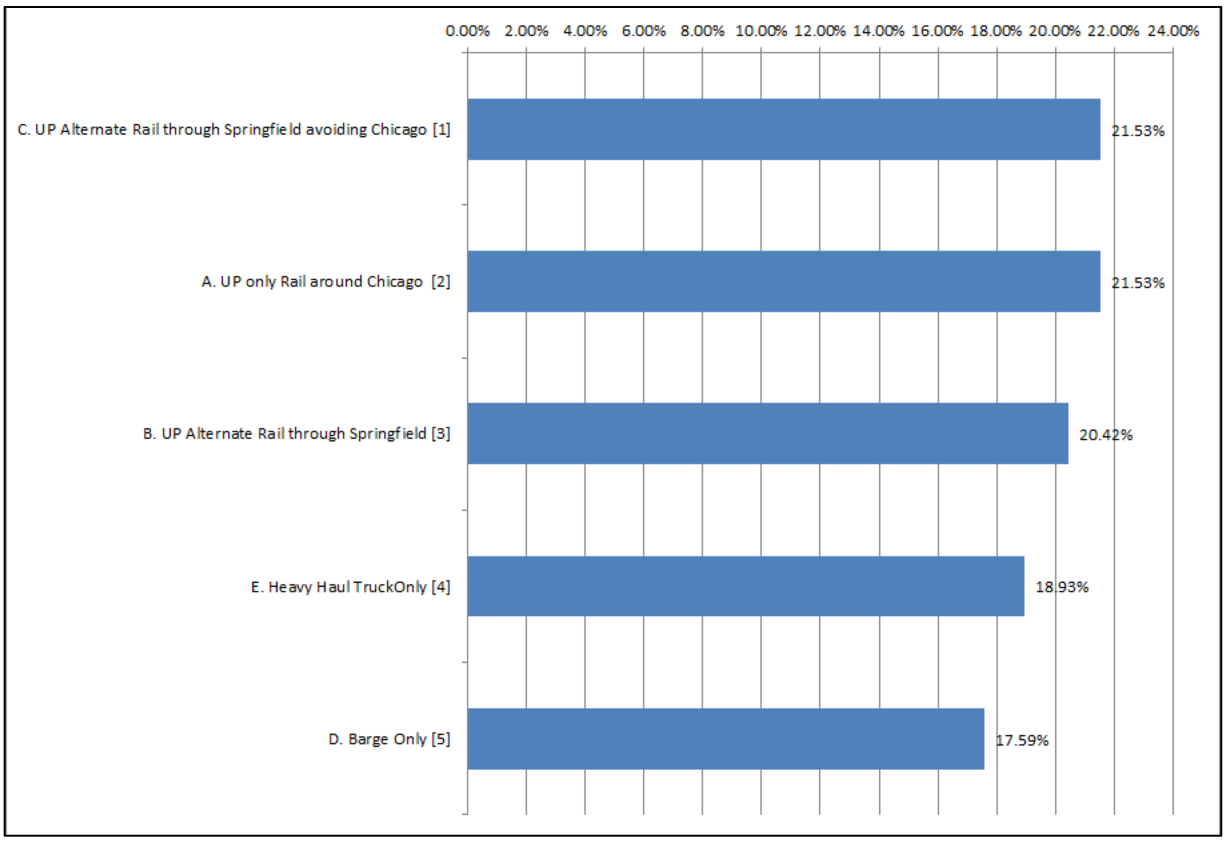


Figure 5-11: Impact of Each Tangible Metric on each Route's Scoring for the Suppression of Span for Safety and Security Metrics

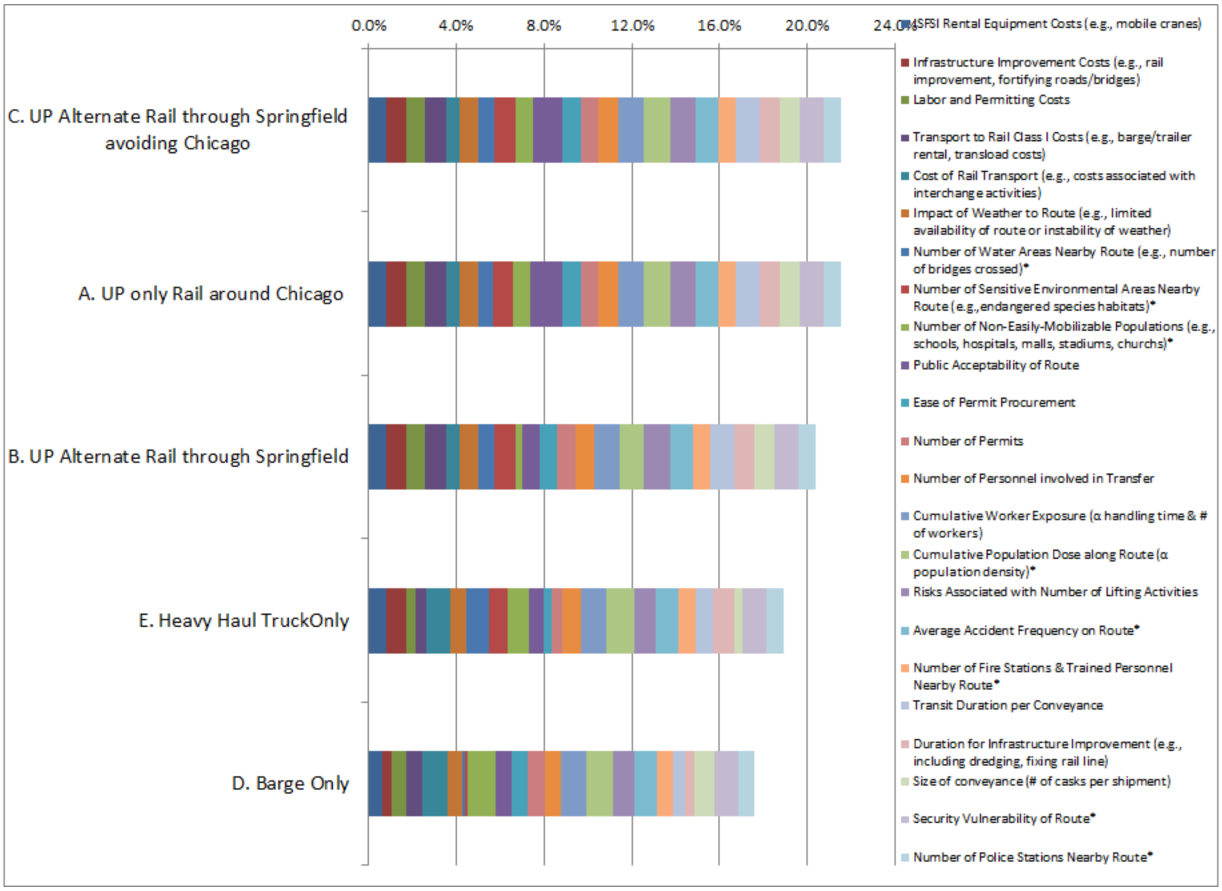


Table 5-18: Comparison of Original MUA Results to the Suppressed Span MUA Results

Suppression Results		Routes	Original Results	
Rank	Avg		Rank	Avg
2	21.53%	A. UP only Rail around Chicago	1	22.20%
3	20.42%	B. UP Alternate rail through Springfield	3	20.50%
1	21.53%	C. UP Alternate Rail through Springfield avoiding Chicago	2	21.98%
5	17.59%	D. Barge Only	5	17.03%
4	18.93%	E. Heavy Haul Truck Only	4	18.30%

5.5.2. Details of Select Sensitivity Results

Additional details of some select sensitivity results shown in **Section 5.4** are presented in this section to allow for additional assessment of the results. The specific sensitivity analyses for which additional details are provided include the impact of the removal of:

- The safety metrics including:
  - The cumulative worker exposure metric
  - The cumulative population dose along route metric
  - The risks associated with the number of lifting activities metric
  - The average accident frequency on route metric
- The security metric
- The public acceptability metric
- The public acceptability and security metrics at the same time

Results shown in **Figure 5-12** and **Table 5-19** for the removal of the safety metrics show the rankings remain the same as were established from the average weights with the rail routes from Zion to GCUS remaining the top ranked routes. Results shown in **Figure 5-13** and **Table 5-20** for the removal of the security metric again show no change from the original rankings. Results shown in **Figure 5-14** and **Table 5-21** for the removal of the public acceptability metric also show no change from the original rankings, however the top three ranked routes (all direct rail from the site) are within 1% of one another. The final sensitivity analysis performed involved removing both the public acceptability and security metrics at the same time. **Figure 5-15** and **Table 5-22** show the results of this assessment again with no change from the original ranking, however the difference between the top two routes is almost less than 0.1%, which means they are essentially equivalent.

Overall, the rail routes from Zion to GCUS are consistently the highest-ranked routes for transloading the transportation casks. However, this site does require additional assessment prior to final selection and some of the particular issues requiring resolution include but are not limited to the rail line at the on-site transload site remaining viable for use and the rail routes meeting the required clearances.

Figure 5-12: Impact of Removing the Safety Metrics

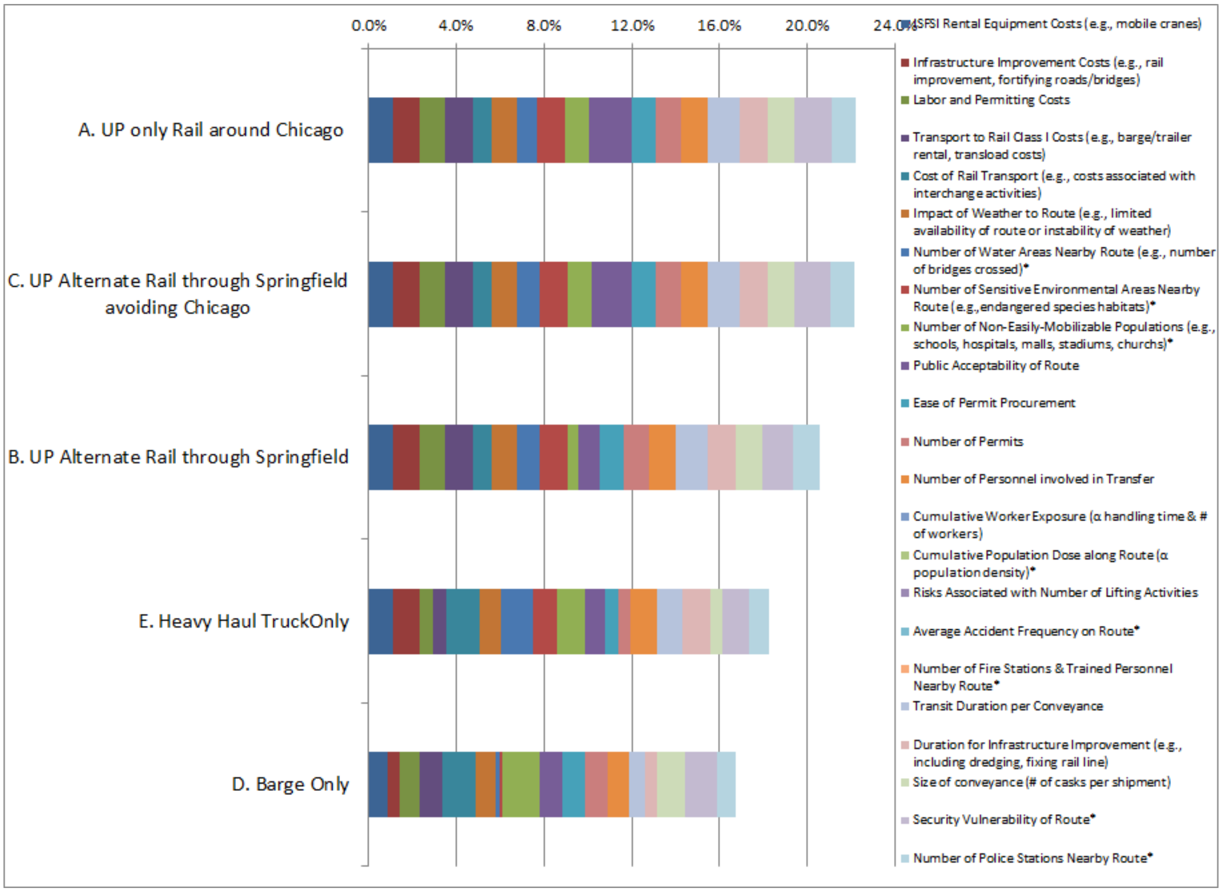


Table 5-19: Results from the Deletion of the Safety Metrics

No Safety Metrics Results		Routes	Original Results	
Rank	Avg		Rank	Avg
1	22.22%	A. UP only Rail around Chicago	1	22.20%
3	20.60%	B. UP Alternate rail through Springfield	3	20.50%
2	22.17%	C. UP Alternate Rail through Springfield avoiding Chicago	2	21.98%
5	16.72%	D. Barge Only	5	17.03%
4	18.29%	E. Heavy Haul Truck Only	4	18.30%

Figure 5-13: Impact of Removing the Security Metric

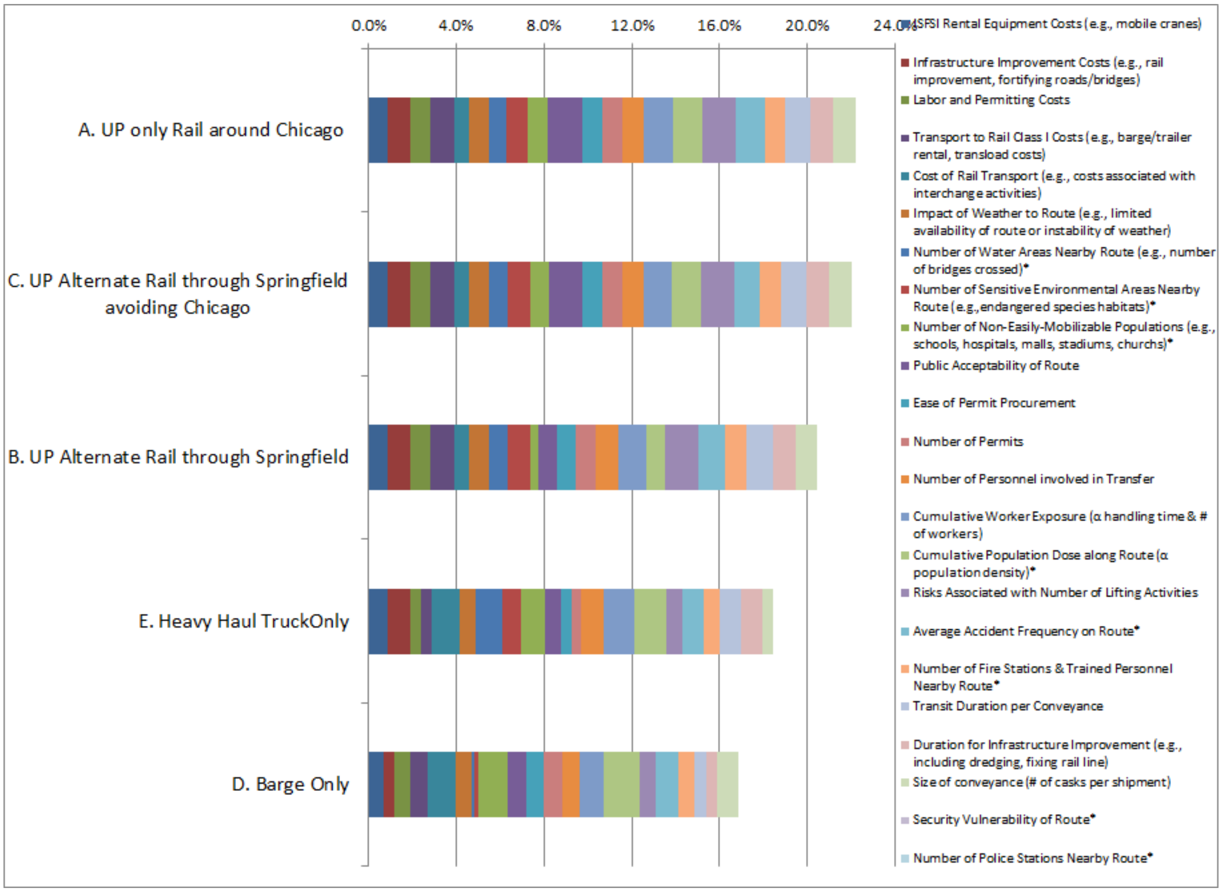


Table 5-20: Results from the Deletion of the Security Metric

No Security Metrics Results		Routes	Original Results	
Rank	Avg		Rank	Avg
1	22.20%	A. UP only Rail around Chicago	1	22.20%
3	20.46%	B. UP Alternate rail through Springfield	3	20.50%
2	22.01%	C. UP Alternate Rail through Springfield avoiding Chicago	2	21.98%
5	16.89%	D. Barge Only	5	17.03%
4	18.43%	E. Heavy Haul Truck Only	4	18.30%

Figure 5-14: Impact of Removing the Public Acceptability Metric

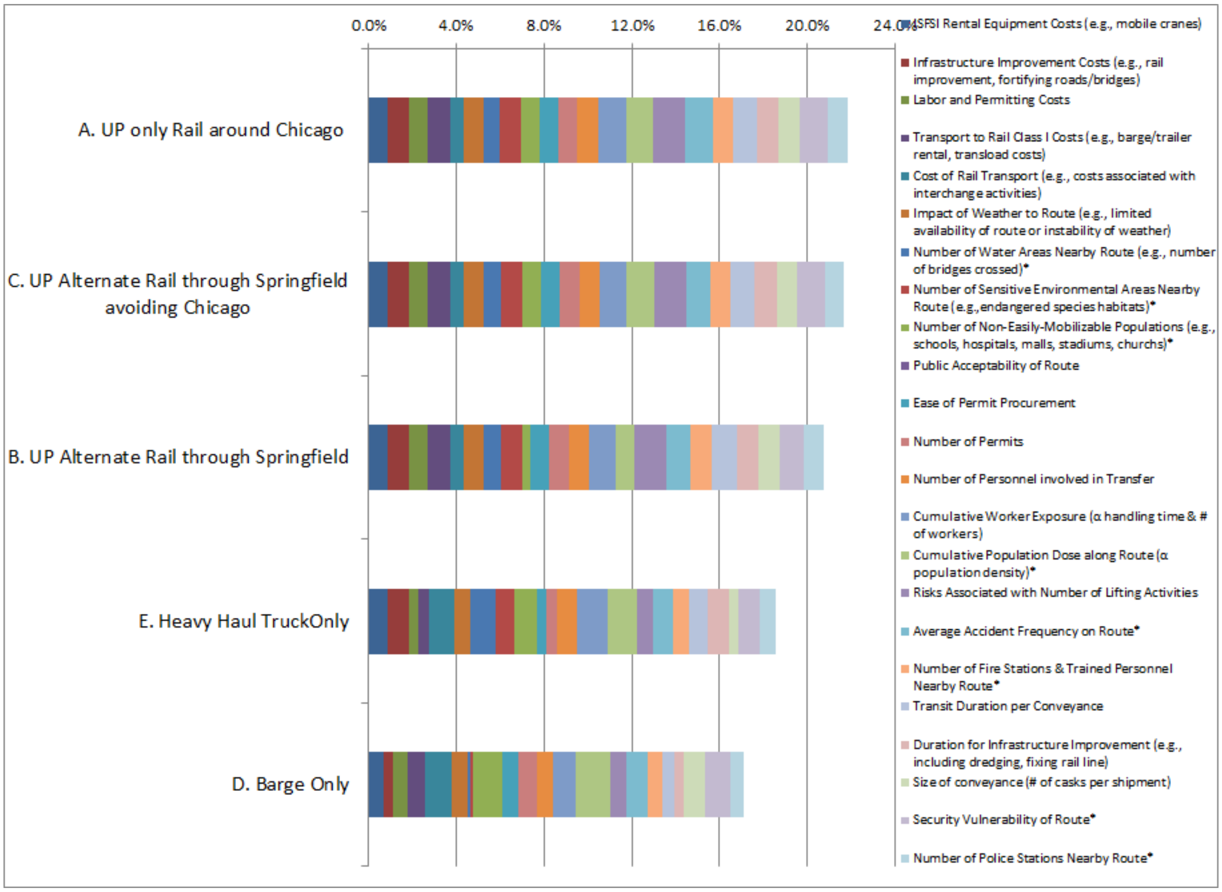


Table 5-21: Results from the Deletion of the Public Acceptability Metric

No Public Acceptability Metric Results			Original Results	
Rank	Avg	Routes	Rank	Avg
1	21.83%	A. UP only Rail around Chicago	1	22.20%
3	20.79%	B. UP Alternate rail through Springfield	3	20.50%
2	21.69%	C. UP Alternate Rail through Springfield avoiding Chicago	2	21.98%
5	17.13%	D. Barge Only	5	17.03%
4	18.56%	E. Heavy Haul Truck Only	4	18.30%

Figure 5-15: Impact of Removing the Public Acceptability and Security Metrics

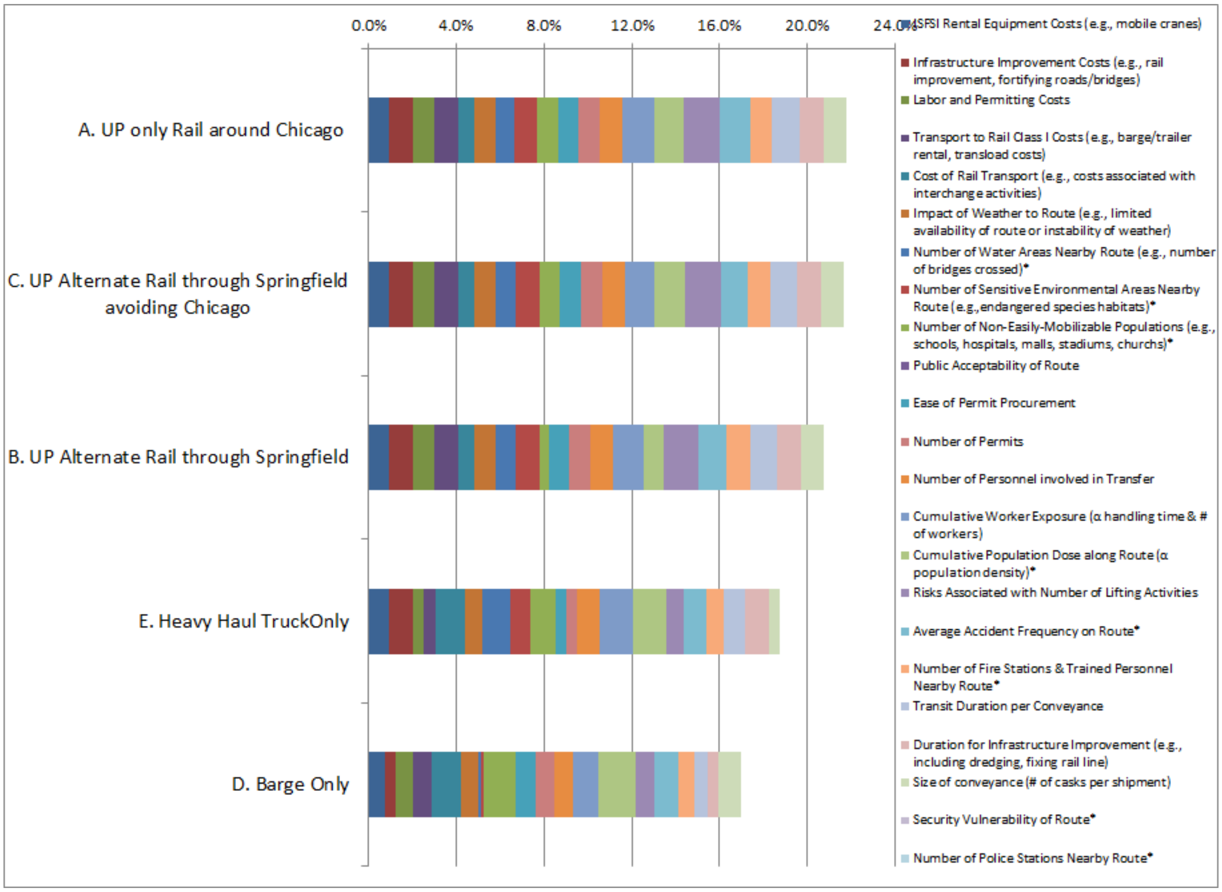


Table 5-22: Results from the Deletion of the Public Acceptability and Security Metrics

No Public Acceptability & Security Metrics Results			Original Results	
Rank	Avg	Routes	Rank	Avg
1	21.80%	A. UP only Rail around Chicago	1	22.20%
3	20.78%	B. UP Alternate rail through Springfield	3	20.50%
2	21.69%	C. UP Alternate Rail through Springfield avoiding Chicago	2	21.98%
5	17.01%	D. Barge Only	5	17.03%
4	18.73%	E. Heavy Haul Truck Only	4	18.30%

5.5.3. Evaluation of Removal of Potential Redundant Metrics

In the assessment of the routes in **Section 5.3.3**, some of the evaluated metrics utilized the same data and hence, potentially results in double-accounting that could unfairly favor a route or routes over an other route or routes. In this section, these metrics are identified and re-evaluated to prevent potential double-accounting.

The metrics using, at least partially, the same data for assessment includes:

- *Labor and Permitting Costs*, Ease of Permit Procurement, and Number of Permits
- Number of Personnel involved in Transfer and *Cumulative Worker Exposure*
- *Cumulative Population Dose along Route*, Number of Fire Stations & Trained Personnel Nearby Route, and Number of Police Stations Nearby Route
- *Transit Duration* and Size of Conveyance

To examine the impact of these potentially double-accounting metrics, the metrics in the above list that are in italics are kept for evaluation while the remaining metrics are first all evaluated as neutral and second having their weights zeroed out. **Figure 5-16** and **Table 5-23** provide the results for the case where all the non-italized metrics are neutralized (i.e., the non-italized metrics were moved to the "Neither Favorable (neutral)" position in the pair-wise comparison) and shows no change to the original ranking, however it does decrease the separation between all the routes indicating the higher ranked routes received a boost from this double-accounting. **Figure 5-17** and **Table 5-24** provide the results for the case where all the non-italized metrics are removed from the evaluation and again shows no change to the original ranking and in fact, actually increase the difference between the first two routes and the remaining routes indicating these removed metrics actually suppressed the difference between the higher and lower ranked routes.

In conclusion, the potential duplication of data usage in the evaluation of the matrix in this case actually suppressed the difference between the higher ranked and the lower ranked routes due to the dilution of the weighting by these additional metrics. In the end, the direct rail routes from the Zion ISFSI site are robustly the highest ranked routes.

Figure 5-16: Impact of Neutralizing Potentially Redundant Metrics

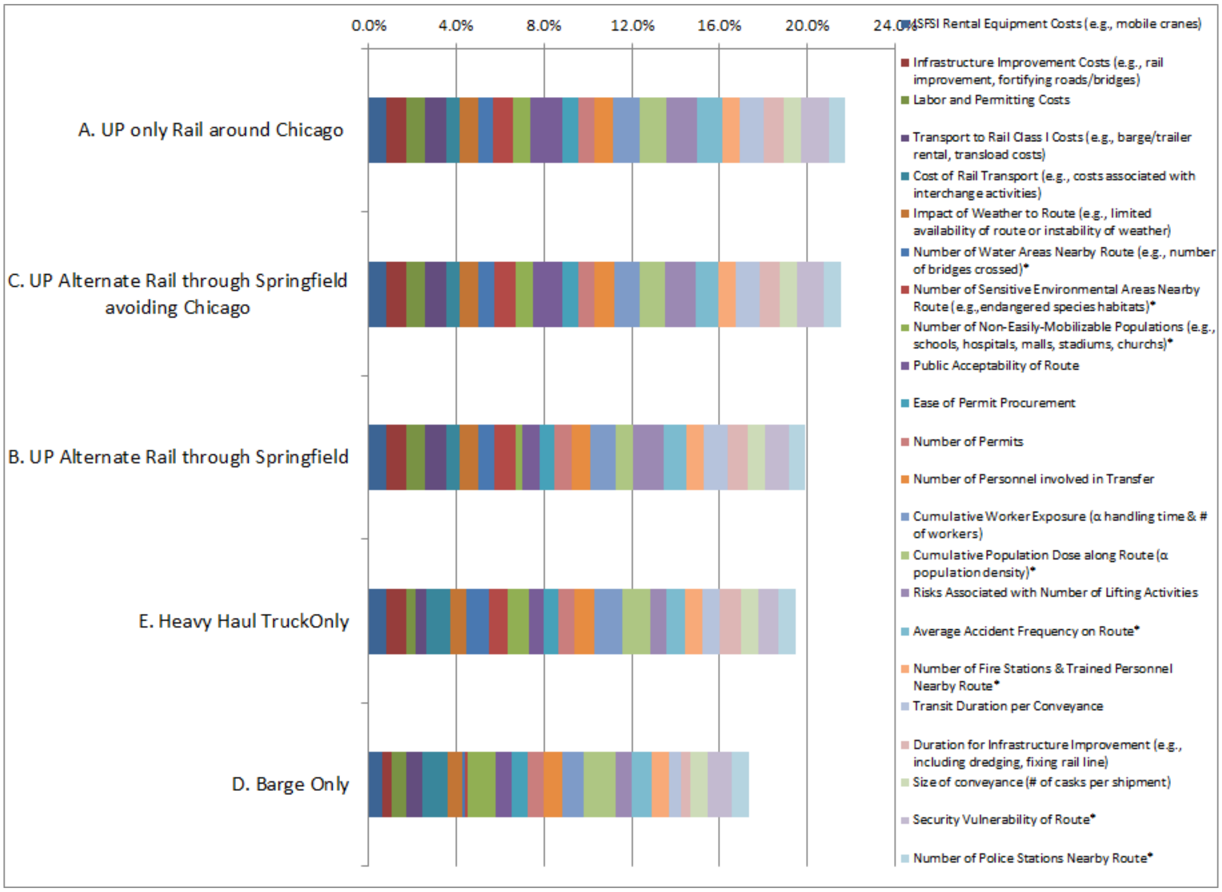


Table 5-23: Results from the Impact of Neutralizing Potentially Redundant Metrics

Neutralized Redundant Metrics Results			Original Results	
Rank	Avg	Routes	Rank	Avg
1	21.75%	A. UP only Rail around Chicago	1	22.20%
3	19.92%	B. UP Alternate rail through Springfield	3	20.50%
2	21.53%	C. UP Alternate Rail through Springfield avoiding Chicago	2	21.98%
5	17.33%	D. Barge Only	5	17.03%
4	19.47%	E. Heavy Haul Truck Only	4	18.30%

Figure 5-17: Impact of Removing Potentially Redundant Metrics

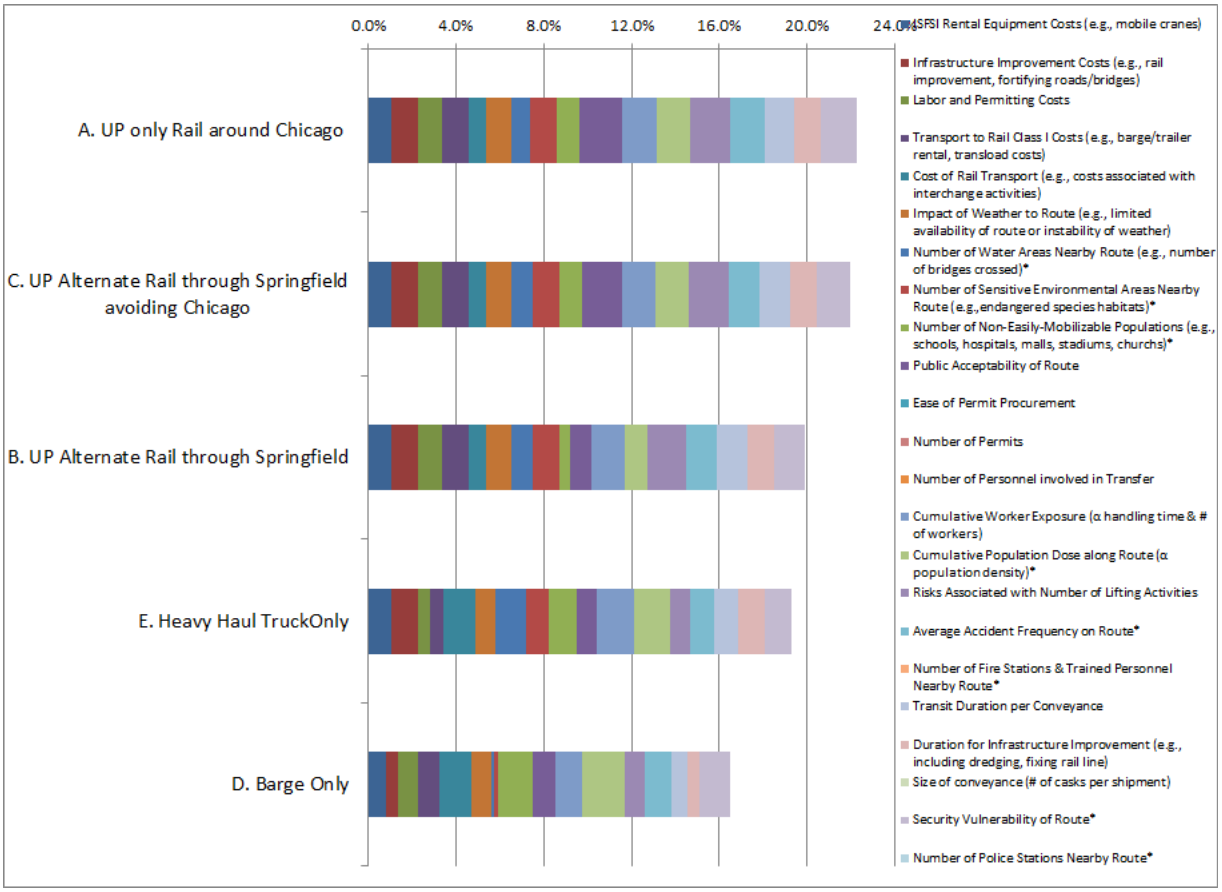


Table 5-24: Results from the Impact of Removing Potentially Redundant Metrics

Removal of Redundant Metrics Results			Original Results	
Rank	Avg	Routes	Rank	Avg
1	22.29%	A. UP only Rail around Chicago	1	22.20%
3	19.89%	B. UP Alternate rail through Springfield	3	20.50%
2	22.00%	C. UP Alternate Rail through Springfield avoiding Chicago	2	21.98%
5	16.52%	D. Barge Only	5	17.03%
4	19.31%	E. Heavy Haul Truck Only	4	18.30%

6.0 CONCEPT OF OPERATIONS FOR RECOMMENDED APPROACH

6.1 Overview of Operations and Assumptions for NAC MAGNATRAN Transport Cask System

The operations associated with the de-inventory of Zion fuel stored in MAGNASTOR systems at Zion would consist of lease or purchase of transportation casks, onsite transport equipment, auxiliary equipment and ancillary systems including mobile crane(s) and lifting equipment, construction of TSC Handling and Transfer Facility, development/confirmation of training program materials, training of operating personnel and supervisors, preparation and approval of site operating procedure for both systems, facility operational readiness review, dry run operations, de-inventory activities, transportation operations, and demobilization of equipment from the site. Due to the complexity of these operations, the sequence of activities is divided into five groups:

(1) Mobilization operations: procurement/lease and delivery of required equipment to the site; construction of TSC Handling and Transfer Facility adjacent to onsite rail tracks

(2) Operational readiness: operating procedure preparation and approval, training program development, operator training, equipment checkouts, dry run(s), and operational readiness review(s)

(3) Site operations: performance of Transportable Storage Canisters (TSCs) transfer operations from MAGNASTOR storage casks to the MAGNATRAN transport casks for offsite transports

(4) Rail transport loading operations and completion of required radioactive shipment paperwork

(5) Demobilization of equipment and personnel from the Zion site

Based on the number of TSCs to be loaded and shipped from the Zion ISFSI (i.e., 61 TSCs with SNF and 4 TSCs with GTCC LLW), it is recommended to load and ship five transport casks for each offsite transport campaign by rail transport with a total of ten transport cask systems committed to the de-inventory shipping campaign to allow near continuous loading operations while the previous shipment is in route for unloading and return transport. It is assumed that shipment of the empty casks from GCUS will be transported on a “special train” and the duration will be the same as for a loaded cask shipment.

The following assumptions were used in planning this MAGNASTOR TSC transfer, loading, and offsite shipment campaign:

- Ten MAGNATRAN transportation casks, including impact limiters, MAGNASTOR cask cavity spacers, and intermodal transport cradles with integral tie-downs and personnel barrier would be used for the de-inventory campaign located on a two special train consist system.
- A TSC Handling and Transfer Facility will be located at a new pad located to the east of both MAGNASTOR ISFSI pads. The unloading, transfer, and loading of the TSCs would be performed in a vertical orientation at the new TSC Handling and Transfer Facility pad.

- The TSC Handling and Transfer Facility will use a mobile crane meeting the requirements of the MAGNASTOR Technical Specification Appendix A, Section 4.4 and the Secure-Lift Yoke and Chain Hoist Assembly.
- The intermodal transport cradle mounted on the rail or positioned on the pad surface will be used to upright the MAGNATRAN transport casks using the MAGNATRAN vertical lift yoke. A horizontal lift beam would be required to lift the loaded intermodal transport cradles off pad surface for placement on the railcar if transport cradle is on the ground.
- The MAGNATRAN intermodal transport cradle could also be transferred with the MAGNATRAN transport cask positioned on the cradle with the impact limiters and personnel barrier installed from the ground to the railcar or directly downloaded on the cradle positioned on the railcar.
- The MAGNATRAN packages would be provided with CoCs with the USNRC CoC No. 9356 maintenance program as specified in Table 8.2.1 “Maintenance and Inspection Program Schedule” and Chapter 8.2 of the MAGNATRAN SAR (see **Table 6-2**).
- New sets of inner metallic O-ring seals and outer EPDM O-rings will be required to be installed for the transport lid and vent port coverplate. After replacement and re-installation following TSC loading, the transport lid and vent port coverplate would require helium leakage testing to ANSI N14.5 leak-tight criteria using a helium MSLD. Additional sets of containment seals will be required in case of seal leakage test failure.
- All the required transfer and auxiliary equipment detailed in **Section 2.3** would be required to be procured and fabricated, and/or leased to support the loading and shipping campaign.
- A mobile crane would be required to lift and upend the MAGNATRAN transport cask, lift the MTC and position it on the VCC, to remove the TSC from the VCC and load the TSC into the MAGNATRAN transport cask, to lift and down-end the MAGNATRAN cask on the intermodal transport cradle positioned on the railcar. Alternatively, a qualified gantry system may be used for the TSC transfer operations. Mobile cranes or gantry systems which lift SNF or loads over SNF are required to meet MAGNASTOR CoC TS Appendix A, Section 4.4 requirements.
- Fuel and GTCC LLW loaded in the TSCs are assumed to be transportable per the CoC content conditions and 10 CFR Part 71 dose and thermal limits are met.

6.1.1 Pre-Mobilization/Mobilization

Table 6-1 lists the activities required to prepare for and remove SNF and GTCC LLW from the Zion ISFSI.

Table 6-1: Activities to Prepare for and Remove SNF and GTCC LLW from Zion ISFSI in MAGNATRAN Systems

Task		Task Activity Description
Programmatic Activities to Prepare for Transport Operations from the Shutdown Zion ISFSI Site		
1	Assemble Project Organization	Assemble management teams; identify decommissioned site existing infrastructure, constraints, and transportation resource needs; and develop interface procedures.
2	Acquire MAGNATRAN transportation cask systems, Hardware, Railcars, and Transport Services	Develop specifications, solicit bids, issue contracts, and initiate preparations for shipping campaigns; includes procurement of MAGNATRAN transport packagings including impact limiters, personnel barriers, intermodal transport cradles, MAGNATRAN Cask Lift Yoke and Horizontal Lift Beam (if required); revisions to MAGNATRAN CoC, if required; procurement of AAR Standard S-2043 railcars; and procurement of off-site rail transportation services.
3	Acquire/Lease Required Auxiliary Equipment including Refurbished MAGNASTOR, Transfer Adapter, Suitable HHT(s) and Prime Mover(s), onsite Transfer Trailer and Remaining Required Auxiliary Equipment	The Zion site does not have any major components or auxiliary systems available following completion of the MAGNASTOR loading campaign. Essentially all equipment will need to be acquired/refurbished/leased and shipped to site for setup and checkout prior to start of the training program and performance of the dry run(s). In addition, there is limited staffing at the Zion decommissioned site, so outside contractor crews will need to be assembled, trained, and evaluated to perform all transfer operations.
4	Construct and prepare TSC Handling and Transfer Facility Area Pad and Equipment in accordance with the Requirements of the MAGNASTOR CoC TSs	A pad of approximately 25 feet x 35 feet on the east side between the two Zion ISFSI pads adjacent to the onsite rail line will be required to be designed and constructed. The pad will be used for the placement of the TSC Handling and Transfer Facility and positioning of the required auxiliary equipment.
5	Conduct Preliminary Logistics Analysis and Planning	Determine fleet size, transport requirements, and modes of transport for decommissioned site.
6	Coordinate with Stakeholders	Coordinates with carriers and makes notifications to federal, state, and applicable tribal nations.

Task		Task Activity Description
7	Develop Campaign Plans/Procedures (e.g., prepare, review, and approve all required site operating procedures for the TSC unloading from the VCCs and transfer/loading into the MAGNATRAN casks, preparation and testing of the casks, and procedures for all the major and auxiliary components and systems.	Develop plans, policies, and procedures for onsite operational interfaces and acceptance, support operations, and in-transit security operations. Initial drafts of the VCC handling, MTC handling, VCC/MTC stack up, and TSC unloading operations can be prepared from procedures initially prepared during the original loading campaign. Similar procedures will be required for the auxiliary equipment including VCT operations, transfer adapter hydraulic system operation, etc. New site procedures will be required for the handling of the MAGNATRAN transport casks, TSC Handling and Transfer Facility operations, proper tie-down and securing of the packages to the railcar/intermodal transport cradle, evacuation and backfilling of the cask cavity with helium, helium leakage testing of the cask containment boundary seals, etc. All approved procedures will require review and approval by Zion Independent Safety Review (ISR).
Operational Activities to Prepare, Accept, and Transport from Zion		
8	Conduct Readiness Activities (e.g., In-Processing, Badging, Training, and Dry Run(s) of All Personnel, Procedures, and Operations)	Assemble and train onsite operations interface team including readiness reviews, tabletop exercises, and dry-run operations. All new de-inventory project personnel including supervisors, riggers/cask technicians, radiation protection (RP), and Quality Assurance (QA)/Quality Control (QC) personnel would need to be trained and qualified to perform the operating procedures in accordance with Zion's Systemic Approach to Training (SAT) Programs. Training would require classroom, on-the-job training (OJT) (operating required equipment), and formal Training Program Evaluation (TPE) effectiveness. All de-inventory project personnel would require training commensurate with their responsibilities and work scope on the project.
9	Load for Off-site Transport	Unload MAGNASTOR VCCs and transfer TSCs to MAGNATRAN transport casks, install loaded casks onto intermodal transport cradles and railcars, install impact limiters and personnel barriers, release for transport.
10	Prepare and Assemble Required Documentation and Shipping Papers for Transport of the Zion SNF and GTCC contents	Plans and procedures will be required to establish the requirements of documentation of TSC contents for each TSC including SNF assembly location and history, preparation of required shipping documentation meeting DOT and NRC requirements and establishing requirements for receipt and return to storage requirements at an Interim Storage Facility, or final disposal at geologic disposal.
11	Accept for Off-site Transport	Accept loaded MAGNATRAN transport casks and shipment paperwork for exclusive use offsite transportation and shipment to the designated destination.

6.1.2 Operational Readiness

Prior to the performance of an Operational Readiness Review and Assessment, the assembled de-inventory project team would be required to be trained and competence confirmed in all required planned site operations and contingencies. All equipment would have been delivered, assembled, and proper operation verified. Required procedures and project instructions would have been approved and issued. When all preliminary activities have been completed, the Operational Readiness Review and Assessment would be performed. This is a process used to verify facility, equipment, processes, procedures, and other critical activities have been planned and executed safely. It also ensures that the project team and procedures comply with the applicable regulations, permits, authorizations, and agreements that are in effect for the shipment to meet regulatory, contract, and stakeholder requirements prior to commencing operations as part of a de-inventory of the Zion ISFSI. The following subsection will discuss the operational readiness required to ensure operations at Zion are ready to commence and can be performed in a safe and regulatory compliant manner.

A review of the MAGNASTOR FSAR and MAGNATRAN transportation cask SAR, and the applicable CoCs would need to be performed. This would verify that the contents of the MAGNASTOR TSCs met the required content conditions and quantities listed in the storage CoC and Approved Contents, and the MAGNATRAN transportation cask CoC. The contents (form and quantity) of the MAGNASTOR TSCs would require verification for compliance with the current revision of the MAGNATRAN transport cask CoC at the time of shipment.

Operations management would ensure readiness from a quality, safety, and operational perspective. Management assessments of these processes determine readiness. This assessment would include verification of the roles and responsibilities between the different organizations involved with and performing the work. Communications between the stakeholders, review and approval of procedures, and interfacing with regulators must occur to ensure the processes to execute work have been reviewed and all agree on readiness to start work. Based on the assumption in this report that DOE shipments would follow the same requirements as a commercial shipper of SNF, the NRC would be involved in the initial routing approval.[9] Once route approval is granted, advanced notification would be provided prior to each shipment since the campaign is longer in duration than one train movement.

As required by the MAGNASTOR TSs, a training program would be required to be implemented for all project personnel with the extent of training required for each individual/project position as specified in the TSs. The training program would require a qualified trainer to oversee and conduct the training on the MAGNASTOR system with operationally qualified personnel to perform the OJT and TPE portions of the training program. The training program would include the following requirements and elements:

[9] NRC route approval is not typically required for DOE shipments; however, for purposes of this report, it is assumed that the shipments would be conducted like comparable commercial shipments.

Classroom Training:

- Module 1 – MAGNASTOR and MAGNATRAN Systems Overview
- Module 2 – MAGNASTOR Transfer Cask and Transfer Adapter Operations
- Module 3 – MAGNASTOR VCC Handling and Movement
- Module 4 – Onsite VCT Operations
- Module 5 – TSC Unloading Operations from MAGNASTOR VCC
- Module 6 – MAGNATRAN Transport Cask Handling and Loading Operations
- Module 7 – MAGNATRAN Transport Cask Intermodal Transport Cradle Tie-Down and Transloading Operations
- Module 8 – Preparation of MAGNATRAN Transport Cask for Transport
- Module 9 – MAGNATRAN Transport Cask Containment O-Ring Helium Leakage Testing
- Module 10 – Use of Measuring and Test Equipment (M&TE)
- Module 11 – Radiological Concerns and ALARA Planning
- Module 12 – Regulatory Requirements
- Module 13 – Supervisor Training
- Module 14 – Contingency Zion Procedures

OJT:

- OJT-1 – Perform Pre-Use Inspections (VCC, MTC, MAGNATRAN casks, Lift Yoke(s), and other support equipment)
- OJT-2 – Perform Periodic Inspections (VCC, MTC, MAGNATRAN casks, Lift Yoke(s), and other support equipment)
- OJT-3 – Prepare a MAGNASTOR VCC and MTC for Stack-up and TSC Transfer
- OJT-4 – Off-Load Empty MAGNATRAN Transport Cask from Intermodal Transport Cradle/Railcar
- OJT-5 – Perform MTC Stack-up and TSC Unloading from VCC
- OJT-6 – Perform MAGNATRAN Transport Cask and MTC Stack-up for TSC Transfer
- OJT-7 – TSC Loading into MAGNATRAN Transport Cask
- OJT-8 – Movement of VCC to/from ISFSI to TSC Handling and Transfer Facility
- OJT-9 – MAGNATRAN Transport Cask Lid Installation and Torquing, and Cavity Evacuation, Backfill, and Helium Leakage Testing
- OJT-10 – Perform Loaded MAGNATRAN Package Down-ending on Railcar and Preparation for Transport
- OJT-11 – Onsite VCT Operations

At the completion of the classroom training and OJT elements, operations supervisors would perform TPE for each applicable project personnel to confirm the adequate knowledge and effectiveness of the training prior to final training certification.

Operational dry runs with a TSC mock-up to perform the transport cask loading operation would be conducted using the actual equipment properly positioned and manipulated up to the point of withdrawing a TSC to confirm procedures, training, and equipment interfaces, fit-up and function. A MAGNASTOR TSC mock-up modified to full length with struts can be used in the MTC to dry run the TSC transfer from the MTC to the MAGNATRAN transport cask.

Communication and interfacing with the applicable stakeholders would be needed to ensure readiness. This would include, but would not be limited to, Zion, DOE, State, and local authorities. In addition, the NRC onsite and Region III inspectors would observe and provide regulatory oversight throughout the entire preparation, construction, operating procedure and approval process, and training/dry run program. Some entities would need to be involved in all aspects of the project, i.e., planning, development of concepts, training, readiness approval, and performing oversight on any dry run operations. This would include reviewing procedures and possibly performing audits/assessments to ensure operational readiness. As additional readiness verification, an independent team of dry cask storage and transport experts would review applicable operational procedures and equipment design/function prior to initiation of the transfer program. As a last step prior to start of operations, a final dry run would be performed as specified in the MAGNASTOR CoC TSs training program and witnessed by DOE, NRC, and stakeholders. Additionally, and as applicable, these entities would be involved in event response planning and mitigation, including contingency Zion emergency event training, to ensure that any event is well managed and mitigated prior to the first shipment of the campaign. This would encompass approvals to start work, training, and interaction with State and local authorities. It is assumed that Zion, NRC, and DOE would participate as observer/regulator/participant for each shipment.

Transportation-related Operational Readiness Items

Equipment Readiness Determined through Review of the Following:

- Document insurance requirements of the contract are in place.
- Transportation equipment certifications are current and would be for the duration of the Zion transportation cycle.
- All vehicles have required registrations.
- All vehicles have current inspections.
- Radiological packaging meets all current requirements.
- Packages are correctly identified (i.e., all required markings and placards are displayed properly, and are available at the site prior to beginning the operation).
- Copies of inspections are provided for equipment to be used to handle and transport the transport casks.
- Copies of all procedures associated with the transportation of the transport casks are provided.
- Proper documentation that the required Security Plan is in place and has been approved.

Transportation Personnel Readiness:

- Key personnel and their qualifications are identified.
- Required background checks are current and requirements of coverage of drug and alcohol programs are met.
- Copies of the training materials are provided and required trainings are current for all employees involved.
- All personnel are in possession of and working from the correct procedures and Radiation Work Permits (RWPs) and copies are provided.
- All private security personnel have required weapons certifications to cover the Zion transportation cycle.
- Transportation personnel would be monitored for radiological exposure, if required.
- Proper equipment and personnel are available to monitor workers and equipment for contamination, if required.

Transportation Readiness Notifications:

- Proper notifications have been made to the Tribes, NRC, State and local governments, DOT, and DOE, as applicable, and copies are provided. Any water-served or adjacent facility is required to have an active and updated Security Plan, which must be reviewed and approved by the USCG.
    - If a plan exists, it should be confirmed by the shipper and updated as to the actual operations designed to take place on the site during the campaign.
- All required permits to transport SNF are prepared and/or in place.
- Proper notification requirements are being met for the receiving facility.
- Scheduled meetings and briefings that would be conducted for all phases of the shipments are identified.

6.1.3 Site Operations for MAGNASTOR / MAGNATRAN System

Each MAGNASTOR TSC transfer sequence will encompass the following major evolutions:

- Removal of the MAGNATRAN personnel barrier, impact limiters, and cask tie-downs
- Up-righting the empty MAGNATRAN transport cask from the transport cradle
- Movement and positioning of the vertical MAGNATRAN transport cask using a VCT at the TSC Handling and Transfer Facility
- Removal of the MAGNATRAN transport cask lid with integral cavity spacer
- Placement of the MAGNATRAN transport cask transfer shield ring and MTC transfer adapter on the MAGNATRAN transport cask
- Loaded VCC retrieval and movement to the TSC Handling and Transfer Facility using VCT

- Removal of the VCC lid and installation of the MTC transfer adapter
- VCC/MTC stack-up and TSC extraction into the MTC using the mobile crane or alternate TSC lifting system
- Lifting and movement of the loaded MTC from the VCC to the MAGNATRAN transport cask
- Transfer of the loaded TSC into the MAGNATRAN transport cask using the mobile crane or alternate TSC lifting system
- Removal of the MTC, TSC lift adapter plate, MTC transfer adapter, and adapter ring from the MAGNATRAN transport cask
- Installation of lid including bolted cavity spacer with new metallic containment O-ring seal
- Installation and torquing of the transport lid bolts
- Evacuation and helium backfill of MAGNATRAN transport cask cavity
- Installation of vent port coverplate with new metallic containment O-ring seal
- Performance of the transport lid and vent port coverplate containment O-ring helium leakage tests
- Down-ending of the loaded MAGNATRAN transport cask on the intermodal transport cradle on the railcar using a mobile crane and MAGNATRAN lift yoke
- Installation of cask tie-downs, personnel barrier, and impact limiters
- Performance of pre-shipment dose and contamination surveys
- Movement of empty VCC to storage area for later disposal.

Auxiliary equipment associated with the transfer would need to be staged, inspected, and prepared for the transfer operation. Based on review of the ISFSI at Zion and as noted in **Section 2.3**, it is planned to locate the TSC Handling and Transfer Facility at a new pad constructed on the east end of the two current ISFSI pads adjacent to the rail siding. At the TSC Handling and Transfer Facility pad equipment will be located to support and restrain the MTC during TSC transfer and loading operations. A mobile crane of sufficient capacity utilized to lift and handle the loaded MTC and MAGNATRAN transport cask must meet the requirements of MAGNASTOR TS 4.4, "TSC Handling and Transfer Facility".

Prior to the start of any MAGNASTOR TSC transfer operation or MAGNATRAN transport cask-handling evolution, a pre-job brief with the operations staff will be conducted to review procedures, verify training of staff, discuss any safety/quality-related concerns and practices, RWP requirements, dose and dose rate expectations, planned RP coverage, As Low As Reasonably Achievable (ALARA) practices, and verify adequate personnel and equipment resources are available to successfully support and complete the planned evolution(s). All work performed would be conducted by procedure, as required by the conduct of operations practices. Stop work authority would be implemented into the working culture to ensure safety and quality of any operation is achieved. Operations management would verify that the MAGNATRAN transport cask has a certification of conformance with all required cask maintenance and testing as specified in **Table 6-2**.

Prior to commencing MAGNASTOR TSC Transfer operations, the primary and auxiliary equipment and services would be configured and positioned as follows:

- Disconnect the temperature monitoring equipment from the VCC to be unloaded.
- Install the two VCC lifting lugs and torque attachment bolts.
- Position the primary mobile crane such that it would be able to reach the MAGNASTOR VCC and MAGNATRAN transport cask TSC transfer stations adjacent to the railcar location.
- Locate the secondary mobile crane intended to be used for lifting the MTC transfer adapters, transfer shield ring, and VCC and transport cask lids adjacent to the TSC Handling and Transfer Facility. If a gantry system is used, a secondary crane is not required and the primary crane is utilized for conducting the described secondary crane lifts.
- Position the transfer adapter(s), shield ring(s), air compressor, rigging, vacuum pump, leak test system, and helium supply at the TSC Handling and Transfer Facility. Also position lift yokes and temporary storage stands for the placement of the VCC lid and MAGNATRAN transport cask lid on the pad or directly adjacent to the pad.

Once the transfer equipment is staged and ready, operations would be initiated to off-load an empty MAGNATRAN transport cask from the railcar. First, the empty cask would be visually inspected for any transport or handling damage and then surveyed to determine if there is any radiation/contamination. The personnel barrier would be removed and stored using the secondary mobile crane. Next, the front and rear impact limiters would be unbolted, removed, and stored in a protected area to prevent any damage to the stainless-steel shells. The cask front tie-downs would be removed and stored. The two trunnion plugs are removed, and the two lifting trunnions inspected, installed, and bolted into position. Any road dirt and previous labels would be removed from the cask's surfaces. The primary mobile crane would then be connected to the MAGNATRAN transport cask lift yoke and the lift yoke engaged to the two lifting trunnions. The crane and lift yoke would then upend the MAGNATRAN transport cask by lifting from the front to rear while maintaining the crane and yoke above the centerline of the front trunnions while rotating the cask on its rear trunnions.

Alternatively, at the discretion of site operations management and handling equipment available, a horizontal lift beam could be used to off-load the MAGNATRAN transport cask on the intermodal transport cradle with the impact limiters and tie-downs still installed. Once positioned at ground level, the detailed up-righting operations described above will be performed to prepare and upright the MAGNATRAN transport cask in preparation for movement to the TSC Handling and Transfer Facility. Once in a vertical orientation, the MAGNATRAN transport cask would be lifted using the crane or VCT and placed in position at the TSC Handling and Transfer Facility. Appropriate work platforms to access the cask lid area would be positioned around the cask.

Once the MAGNATRAN transport cask is in position at the TSC Handling and Transfer Facility a complete visual inspection of the cask surfaces and components would be performed to verify the correct assembly of the cask. Using the man-lift and/or work platforms, personnel would access the top of the cask to inspect the transport lid, lid bolts, and vent port coverplate, bolting, and leak test port plugs.

The vent port coverplate bolts (captured) and coverplate would be removed to access the cask cavity and a pressure and gas sampling system connected to measure cask cavity pressure and cavity gas radioactivity levels (as determined by site). The cask cavity would then be vented to the atmosphere through a HEPA filter set (also used during evacuation of the cask cavity following TSC loading connected to the exhaust of the vacuum pump). The vent port coverplate and bolts would be inspected for damage, corrective actions taken as required, and stored to prevent loss or damage. Prior to re-installation, a new metallic containment O-ring would be installed in the vent port coverplate. The transport lid bolts would then be de-torqued in the numbered sequence of the bolts as stamped on the cask lid. The transport lid bolts would be inspected for any damage and damaged bolts replaced with authorized spares and stored to prevent loss or damage. The transport lid lifting rig set would then be attached to the four lift designated holes using swivel hoist rings connected to the secondary mobile crane. The lid is lifted, removed, and stored in a location to protect the O-ring grooves. Prior to lid re-installation, the transport lid metallic containment O-ring seal will be replaced.

Following the lid removal, a visual inspection of the lid containment boundary seating surface and cask cavity is performed to observe for any foreign material or damage. *Note: When operations are not in process involving the MAGNATRAN transport cask, the top of the cask cavity shall be covered with an FME and inclement weather cover.* When TSC transfer operations are scheduled to begin, the transfer shield ring is lifted, installed in the lid recess / seating surface, and bolted in place. The transfer shield ring is provided to interface with the MTC transfer adapter plate and to provide additional shielding during the loading of the TSC into the MAGNATRAN transport cask. The MTC transfer adapter is positioned on the transfer shield ring and bolted in place. The adapter plate is connected to the shield door auxiliary hydraulic system and the female connectors are positioned to the engagement position.

The VCC is lifted and removed from the ISFSI pad using the VCT attached to the two sets of lifting lugs and driven to the TSC Handling and Transfer Facility, positioned adjacent to the MAGNATRAN transport cask and disconnected from the VCT. The lifting lugs are removed and stored. The secondary mobile crane is then positioned for removal of the VCC lid and installation of the second MTC transfer adapter on the top of the VCC. Once the VCC lid is removed, the radiation dose from the TSC and the VCC/TSC annulus would increase significantly. After this point in the operation and through the extraction of the TSC from the VCC, radiation streaming is to be expected and may be significant. ALARA considerations will need to be accounted for during these operations, and radiation levels monitored and controlled. Following VCC lid removal, the MTC transfer adapter with its shield ring is positioned on the VCC. If installed, the threaded hole plugs in the lifting holes on the MAGNASTOR TSC closure lid are then removed. The TSC lift adapter plate is installed in the six lifting threaded holes on the MAGNASTOR TSC closure lid. The primary mobile crane or gantry connected to the Secure-Lift Yoke would then be used to lift and place the empty MTC with retaining blocks in the engaged position on the transfer adapter positioned on the top of the VCC.

The shield door lock pins are removed allowing for the opening of the shield doors using the auxiliary hydraulic unit, followed by the lowering and engagement of the chain hoist sister hook to the TSC Lift Adapter Plate using the hydraulically operated engagement pins. The next operational sequence is the lifting of the MAGNASTOR TSC from the VCC into the MTC. The TSC is lifted with the chain hoist into the MTC cavity until the top of the MAGNASTOR TSC is just below the retaining blocks. The retaining blocks are designed to prevent the unauthorized extraction of a loaded TSC from the MTC. The retaining blocks are structurally designed to take the entire weight of the loaded MAGNASTOR TSC and MTC without failure. However, caution should be used to ensure that the top of the TSC does not engage the retaining blocks. Once the MAGNASTOR TSC is in the MTC cavity, the auxiliary hydraulic system is used to close the shield doors and the MAGNASTOR TSC is lowered to rest on the doors.

During the TSC transfer operation, radiation dose rates are expected to be high at the MTC-to-adapter-plate interface and through gaps in the shield door to MTC openings. Also, once the MAGNASTOR TSC is in the MTC, dose rates on the MTC surfaces will be higher than the dose rates from a loaded VCC. It should be noted that there may be residual removable contamination on the exterior surfaces of the MAGNASTOR TSC as allowed by MAGNASTOR TS Limiting Condition of Operation (LCO) 3.3.2, which allows up to 10,000 dpm/100 cm^2 from beta and gamma sources, and 100 dpm/100 cm^2 from alpha sources. The residual removable contamination is expected to be significantly lower because of using clean demineralized water in the MTC/TSC annulus during in-pool and annulus cooling operations. Although the TS establishes maximum limits, a significant majority of the MAGNASTOR TSCs had less than 1,000 dpm/100 cm^2 beta/gamma contamination in surveys performed during TSC closure and transfer to VCC for storage. However, contamination control practices will be required to be observed during MAGNASTOR TSC handling and transfer operations to the MAGNATRAN transport cask. It is expected that interior surfaces of the MAGNATRAN transport cask and MTC may potentially pick up minimal contamination during the MAGNASTOR TSC transfer and loading operations. The potential contamination of the interior of the MAGNATRAN transport cask cavity would not exceed the allowable contamination limits specified for an empty radioactive return shipment per 49 CFR 173.428.

Once the shield doors are closed and the door lock pins installed, the crane or gantry would then be used to lift the loaded MTC from the top of the VCC and position it on the MTC transfer adapter on top of the MAGNATRAN transport cask using the Secure-Lift Yoke and ensuring the transfer adapter's female connectors engage with the male connectors of the shield doors. The chain hoist is then used to lift the TSC off the shield doors, the shield door lock pins are removed, and the shield doors hydraulically opened. The TSC is slowly lowered into the MAGNATRAN transport cask cavity with the chain hoist. During the MAGNASTOR TSC transfer operation, radiation dose rates are expected to be high at the MTC openings and MTC-to-MAGNATRAN interfaces. Once the TSC is fully down in the MAGNATRAN cavity, the hydraulic system is used to disconnect the chain hoist system's sister hook from the TSC lift adapter plate. The MTC shield doors are then closed, the door locks installed, and the crane or gantry and Secure-Lift Yoke is used to lift the MTC off the MAGNATRAN cask. The MTC is then set down and disengaged from the MTC lift yoke and staged for the next MAGNASTOR TSC unloading sequence from the next loaded VCC.

Operators would then access the top of the MAGNATRAN transport cask to remove the TSC Lift Adapter Plate from the TSC closure lid. Next, the MTC transfer adapter is removed using the secondary crane. A visual inspection of the cask seal seating surface is performed and any dirt or debris is removed using a soft cloth. Verification is performed to ensure that the transport lid has the cask cavity spacer installed. If the cask cavity spacer is not installed to the underside of the lid, position the spacer under the lid and install the four bolts and lock washers and torque to 300 ± 20 in-lbs. As the transport cask cavity spacer is bolted to the transport lid, there is not a requirement to remove the spacer for empty cask return shipment. The cask transport lid and cask cavity spacer installed with a new metallic containment O-ring seal is lifted using the secondary crane and transport lid sling set, installed in the lid recess, and aligned to the lid bolt holes. Once the lid is fully seated, the 48 lid bolts lubricated with Never-Seez or equivalent are installed, and using the bolt torquing device, the lid bolts are torqued in the indicated numbered sequence stamped on the lid in three passes to a final torque of 4,600 ± 200 ft-lbs.

After the transport lid is secured, a vacuum pumping and helium backfill system would be connected to the vent port and the cask cavity evacuated to a vacuum pressure of ≤ 3 torr. Without breaking the connection to the vent port, the cask cavity is then backfilled with high-purity helium (≥ 99.9%) to 1 atm (absolute) pressure. The vacuum pumping and helium backfill system is then disconnected from the vent port quick disconnect fitting. The vent port sealing surface is then inspected and cleaned, as necessary, the vent recess is flushed with helium gas, and the vent port coverplate installed with a new metallic containment O-ring seal. The four coverplate bolts lubricated with Never-Seez or equivalent are torqued to a final torque of 120 ± 20 in-lb.

Final helium leakage testing of the transport lid cask containment boundaries (e.g., transport lid seals and vent port coverplate seals) is then performed using a helium MSLD system to confirm that each containment boundary closure is leak-tight in accordance with ANSI N14.5-1997 to a leakage rate of ≤ 2 x 10^{-7} cm^3/s, helium with a minimum sensitivity of 1 x 10^{-7} cm^3/s, helium. Following successful leakage testing, the MSLD will be removed from each component and the leak test port plugs will be re-installed with a new metallic O-ring seal and tightened to the designated torque of 120 ± 5 in-lbs. The MAGNATRAN transport cask containment boundary provided by the lid closures are now verified as properly closed and leakage tested.

Following final leakage testing, decontamination of the cask external surfaces would be performed. A visual inspection of the front and rear trunnions for general condition and lubrication would be performed, with corrective actions as required. Using the VCT connected to the MAGNATRAN trunnions the loaded cask removed from the TSC Handling and Transfer Facility. The cask would need to be transported to the rail siding adjacent to the railcar provided with an intermodal transport cradle (or the intermodal transport cradle positioned on the ground). The mobile crane would then lift the MAGNATRAN transport cask over the intermodal transport cradle and lowered until the rear trunnions are seated into the cradle's rear supports and fully engaged. Taking precaution to maintain the lift yoke and crane over the centerline of the lifting trunnions, slowly lower and rotate the MAGNATRAN cask into a horizontal position on the intermodal transport cradle. (*Note that the rear trunnions are off-set from the cask centerline to assist in correct down-ending*).

Once the cask is in the horizontal position, the front trunnions are removed and replaced by the trunnion plugs. Next, final removable contamination surveys are taken for areas to be covered by the front and rear impact limiters. The cask tie-down assembly is installed between the top of the neutron shield and the trunnion plugs and engaged to restrain the cask in a vertical direction. Using the secondary mobile crane and the impact limiter sling set, the front/upper impact limiter is lifted and installed to the lid end of the cask. While maintaining the impact limiter weight on the crane, the 16-impact limiter retaining rods are installed and torqued to 35 ± 2 ft-lb. The 16 impact limiter nuts are installed and torqued to 35 ± 2 ft-lb followed by the impact limiter jam nuts torqued to 75 ± 5 ft-lb., and installed safety wire between adjacent impact limiter rods. To provide evidence of tampering during transport, a security seal wire and TID is installed between two of the front impact limiter rods. The crane and sling set are then disengaged from the front impact limiter, and the impact limiter installation operation is repeated for the rear/lower impact limiter. Finally, the personnel barrier is installed over the center of the cask enclosing the open area between the front and rear impact limiters and bolted to the intermodal transport cradle. The personnel barrier and access panel are locked to prevent unauthorized access to the cask surfaces.

If required, the intermodal transport cradle horizontal lift beam is used to lift and place the loaded intermodal transport cradle containing the assembled MAGNATRAN package on the railcar.

Final radiation surveys are then performed with dose rates taken at the cask surface, 1 meter from the cask surface and 2 meters from the vertical plane of the transport conveyance. The maximum dose rate at 1 meter from the cask is defined as the transport index (TI). All dose rates and contamination surveys must comply with applicable DOT and NRC regulations. The appropriate Criticality Safety Index (CSI) assigned to the package contents should be determined in accordance with the CoC and indicated on the Fissile Material labels applied to the package. Appropriate placards are applied to the transport vehicle in accordance with DOT regulations. The final shipping documentation is then completed by the transport specialist including instructions to the carrier regarding the required Exclusive Use Shipment.

The VCC lid is reinstalled on the VCC and the empty VCC is moved to a temporary storage pad for later disposal or return to the ISFSI pad once space permits. The VCC may have minor contamination and activation to prevent immediate disposal but is expected to allow waste processing in a short period.

Table 6-2: MAGNATRAN Maintenance Program Schedule

Maintenance Program Schedule	
Task/Activity	**Frequency**
Visual inspection of cavity	Prior to loading
Visual inspection of O-rings	Prior to loading
Visual inspection of neutron shield shell segments for structural or penetration damage	Prior to loading
Visual inspection of cask lid bolts and lid port coverplate bolts	Prior to installation (each use)
Visual and proper function inspection of cask	Prior to and during each use
Visual inspection of lifting trunnions and rotation trunnions	Prior to and during each use
Liquid penetrant inspection of lifting trunnion and rotation trunnion weld surfaces	Annually during use
Periodic leakage rate test of cask lid and lid port coverplate containment O-rings	Annually during use
Periodic Gamma and Neutron Shield Effectiveness Tests	Every 5 years during operation and use
Pre-shipment leakage rate test of cask lid and lid port coverplate containment O-rings	Prior to each loaded transport
Maintenance leakage rate test of containment system	After replacement or repair of containment boundary components
Replacement of lid and lid port coverplate metallic O-rings	Prior to each loaded transport
Visual inspection of impact limiters for structural or penetration damage	Prior to each loaded transport
Inspection of quick disconnect for proper function	Each cask use
Liquid penetrant inspection of impact limiter shell weld surfaces	Every five years or as required by visual inspection results during

Maintenance Program Schedule	
	operation and use
Replacement of non-containment O-ring	Annually, or as required by inspection during operations
Liquid penetrant inspection of neutron shield shell assemblies weld surfaces	Every five years or as required by visual inspection results during operation and use
Replacement of quick disconnect	Every two years or as required by performance during operations
Replacement of non-containment O-ring	Annually, or as required by inspection during operations
Replacement of lid port coverplate bolts	Every 20 years, or as required due to thread damage
Replacement of cask lid bolts	Every 20 years or after 350 applications of the specified torque, or as required due to thread damage

6.1.4 Transport Operations

Special Permit Requirements

The following permits for transporting the loaded transportation casks from the Zion ISFSI would have to be obtained by the shipper:

- A formal clearance submission would be made to the originating Class I rail carrier. For the purposes of this project, the goal is to deliver the overpacks from the Zion site to the Class I rail carrier, Union Pacific Railroad, which would clear the entire route with all participating railroads.
- For the purposes of this report, it is assumed that DOE would be the shipper and that the shipments would be conducted by commercial carriers like comparable commercial shipments. Although typically not required for DOE shipments, for purposes of this report, it is assumed that DOE would file an application with the NRC for an approved rail route from the Zion site to the identified destination. DOE Order 460.2B[57] provides information on the management of DOE materials transportation and packaging.

Note: a formal clearance submission is required for all dimensional shipments on all railroads involved in the full route. With loading taking place at the recommended on-site track location within Zion, the shipment will originate on a Class I carrier. The clearance will be submitted to Union Pacific Railroad which will clear the entire route to the final destination, which in this case is to the GCUS.

Each Class I rail carrier has a formal procedure for clearance submissions, and all are electronically filed. Some require a fee to accompany clearance submissions, and some do not. The following components must be present in each clearance submission:

1) Identification of the origin, the destination, the standard transportation commodity code, the shipper, receiver, and associated serving carriers, and the route (including interchange locations for the requested route).
2) Identification of the specific railcar to be used for the shipment.
3) All dimensions of the loaded unit on the railcar, which depict a profile of the loaded unit and car together. These should also include:
    a. A diagram of offsets, ballasts, or any other loading configuration specifics important to the railcar.
    b. Center of gravity measurements and total weight of the unit plus the railcar.
4) A diagram of the unit with actual placement on the selected railcar.

The more specific the information provided in the clearance submission, the better the chance of clearance acceptance. The above submission requirements are considered a minimum. Some railroads require additional information for clearance acceptance. The AAR Open Top Rules (OTLR) delineate what must be submitted for acceptance at interchange between carriers.

Note: requirements may be relaxed if movement is restricted to only one railroad and is not subject to interchange with another carrier. This also applies to loading and securement configurations. However, with Hazardous Material (HAZMAT), the relaxation of these requirements is not expected nor anticipated, principally for safety reasons.

Furthermore, it is recommended that more than 6 months are allotted for the railroad clearance submission process in the event the intended routes have not been approved for previous shipments and the approval process takes longer than anticipated. This recommendation is based on extensive experience in obtaining superload permits for movements of similar weight and dimensions and HAZMAT (Class 7). Once the route is approved, it would be valid and effective for 7 years for rail routes. The NRC would approve routes for a period of 5 years for combination routes (truck-to-rail siding, transloading, and rail to final destination). The minimum amount of time to submit routes to the NRC for approval is 90 days; however, they would prefer 6 months.

Once the rail route is cleared by all involved railroads, the clearance is valid for 6 months to one year, depending on the individual railroads involved and should the campaign take longer than 6 months, the clearance must be resubmitted. The clearance ensures that the loaded dimensions and weights of the transportation cask and railcar (in this case the train) would traverse the railroad route without any impediment. It would need to be resubmitted after 6 months to ensure no changes have taken place on the rail route that would affect the ability for the dimensional load to pass the route safely without striking anything (tunnels, bridges, trestles, signals, silos, or any structure that may be close to the track), including taking into consideration other dimensional traffic moving in the same lane.

Any time condition change or are altered on an approved route, the shipper must notify the NRC and submit an amendment.

Road permits would be required for movement of the cranes and other equipment to Zion for use in loading the transportation casks. The permits will also dictate the requirement for private escorts (not the security team) and State Police escorts for both the mobilization and demobilization efforts of the equipment. These escorts are in addition to those required by the regulations for LLEA for safety and security purposes.

Coordination with Mode of Transport

This section provides a description of activities necessary to coordinate with the various parties involved in preparation for the transport and transload activities. The actions necessary to prepare for and remove the SNF from Zion are listed as tasks in **Table 6-3**. These identified actions assume that DOE, or another management and disposal organization would be responsible for shipping and operating the consolidated interim storage facility or repository. Based on these tasks, the characteristics of the site's inventories of SNF, the onsite conditions, the near-site transportation infrastructure and experience, time sequences of activities, and time durations were developed to prepare for and remove the loaded transportation casks.

Table 6-3: Activities to Prepare for and Remove SNF and GTCC LLW from Zion ISFSI

Task		Task Activity Description
Programmatic Activities to Prepare for Transport Operations from a Shutdown Site		
1	Assemble Project Organization	Assemble management teams, identify shutdown site existing infrastructure, constraints, and transportation resource needs and develop interface procedures.
2	Acquire Casks, Railcars, Ancillary Equipment and Transport Services	Develop specifications, solicit bids, issue contracts, and initiate preparations for shipping campaigns. Includes procurement of transportation casks and revisions to CoC as may be needed, procurement of AAR Standard S-2043 railcars, and procurement of off-site transportation services.
3	Conduct Preliminary Logistics Analysis and Planning	Determine fleet size, transport requirements, and modes of transport for shutdown site.
4	Coordinate with Stakeholders	Assess and select routes and modes of transport and support training of transportation emergency response personnel.
5	Develop Campaign Plans	Develop plans, policies, and procedures for at-site operational interfaces and acceptance, support operations, and in-transit security operations.
Operational Activities to Prepare, Accept, and Transport from a Shutdown Site		
6	Conduct Readiness Activities	Assemble and train on-site operations interface team and shutdown site workers. Includes readiness reviews, tabletop exercises and dry run operations.
7	Load for On-site Transport from the ISFSI to the transload track	Load and prepare casks and place on railcar for off-site transportation.
8	Accept for On-site Transport	Accept loaded casks and shopment paperwork foe exclusive use shipment on railcar for transportation.
9	Transport	Ship loaded casks on outbound train.

Additional Coordination Efforts

Description of Activities Necessary to Coordinate with Heavy-Haul Providers:

- All diagrams, including dimensions, center of gravity, and weights must be obtained, preferably in Computer Aided Drawing (CAD) format and provided to both the heavy-haul truckers and riggers for use in planning the HHT movement (and securement on the trailer) and the lift and rigging arrangements, if required.
- Any lift diagrams or transport diagrams from the manufacturer should be provided to the riggers for use in planning the lift and rigging arrangements at the ISFSI.
- This information is used by the rigger to develop accurate engineering drawings of the transportation cask and cradle combination on the specific piece of equipment being used for the movement (e.g., railcar and crane equipment).
- The drawings developed would be provided to the team, including coordination with the crane company and riggers.
- Load securement information, including weights of the components in transport configuration, plus the weights of the trailers, would be used to determine and verify vehicle axle weights to meet all safety requirements for the short haul from the ISFSI to the rail transload track located on the Zion site at the rail track close to the ISFSI.
- The local utilities must be brought into the work plan for overhead and underground clearances, if any are impacted. While there are overhead wires in the vicinity, they do not appear to be over the rail track or within reach of the crane's boom at the rail transload site. The location of any obstructions will be identified and documented in the formal truck and transload site surveys.
- The transportation plan does not require State of IL DOT inspections, securements, routing issues (obstructions, bridge reinforcement, weight restrictions, etc.), for the on-site movement from the ISFSI to the on-site transload track as all movement will be conducted on private property. Any safety concerns identified along the haul path should be documented and included in safety briefings.

Description of Activities Necessary to Coordinate with Crane Company and Rigging Providers:

- All diagrams including dimensions, center of gravity, and weights must be collected (preferably in CAD format) to be provided to the crane company for use in planning the proper lift plan. This includes crane selection for the job based on the conditions of the site and rigging plans and configurations.
- Any manufacturing lift and transport diagrams, especially regarding restrictions on pick points or special rigging required for lifts, should be collected and distributed to the crane company. This information will be used for plan development, including crane selection.
- Crane company/riggers would physically survey the items to be lifted (casks), ground conditions, and other requirements (e.g., turn radius for crane and ancillary equipment) in addition to any specialized rigging provided by the site specific to the transportation casks being lifted. This is a joint effort between the crane company experts/engineers and transload operator/licensee/shipper. Coordination among the parties would ensure all aspects of the lift and securement plan are considered and planned.

- A timeline would be established for mobilization of all required equipment including all standard rigging tools, forklifts, etc., to make sure all equipment is in place and tested prior to the start of the operation and test lift.

Description of Activities Necessary to Coordinate with Transload Site Railroad (in this case the same as the Class I railroad):

The private rail siding located on the Zion property is served by the Union Pacific Railroad. Meeting with the railroad 6 months prior to beginning the loading operation would allow for coordinating and planning with the railroad to set expectations for service level requirements and crew staffing. Special considerations and possibly budget concerns would need to be addressed by the railroad to ensure it has the available crews to run a dedicated train and is willing to do so. Knowing how many trains will be handled and with what frequency will be important to the railroad for budgeting and crew planning purposes. Other items to discuss would be security requirements for the crew entering the site, describing the intended operations, planning for the placement, inspection of the loaded train, and all other operations including establishing the mechanics for pulling the released train from the site and obtaining the transit schedule for delivery to the GCUS.

- Develop Security Plan for the rail transload site and notify serving carrier, UP, of the plan in place and provide a contact name and number for the site. Provide proper notification that the transload site will be designated as a "rail secure area".
    - The recommended transload site is located within the Zion owned property. It likely has not been designated as a rail secure site with the railroad at this point, due to the commodities shipped from the site. Therefore, in order to ship SNF from the site, it must be declared a “rail secure area” in accordance with regulations.
    - Although not required, plan to institute the same precautions and planning as is used in Toxic Inhalation Hazards (TIH)/Poisonous Inhalation Hazards (PIH) handling and reporting for added measure of security at the rail transload site. This provides notice to the railroad of the level of preparation and operations planning for the campaign.
- Determine if railroad police are available and will be present during the manned interchange and any other stops along the rail route on the way to the final destination. They can provide extra observation in rail yards to deter rail fans, which typically "chase" dimensional shipments along the rail route and other trespassers in the yards.
- Hold initial meetings with the Class I carrier to explain the movement, provide estimated number of trains to ship, discuss the dedicated train requirement, and begin rate negotiations for the trains.
- Mention current safety and security measures for the site to ensure the railroad is aware of special considerations and operating procedures in case they have no familiarity with these requirements:
    - Note and discuss safety features that will be added to the site: fence, lights, defined perimeter, etc., as required for the individual site.
    - Discuss requirements of crew entry into the site (Transportation Worker Identification Credential (TWIC) cards, training, etc.)

- Confirm the physical location where the UP crew will pick up the loaded cask train and conduct the manned interchange. Currently operating procedures are for the railroad to pull cars staged approximately 120’ from the point of switch, on the Zion property. If curvature issues are rectified, the railroad may decide to enter further into the property.
- Discuss manned interchanges with the railroad and record keeping requirements.
- Discuss normal times of operation for the established plant and any extensions in hours the plant has granted to the shipper for the transload campaign. Coordinating operations hours and access to the plant. This is important for planning release of the loaded train and consideration of the current rail operations on the division in conjunction with normal operating parameters at the plant.
- Open communications with all rail carriers in the route to ensure a smooth transition at all interchange points. In this case, only one Class I railroad is involved in the route to the GCUS.
- Hold initial meetings with the railroad’s local trainmaster and safety manager to discuss intended operations and parameters for operations, even though the transload is taking place on a private and secure site.
- Communicate to the railroads that all requirements have been exceeded for the intended site and operations.

Transportation-related Operational Readiness Items

Equipment Readiness is Determined through Review of the Following:

- Insurance requirements of the contract are in place.
- Transportation equipment certifications are current and would be for the duration of the transportation cycle.
- All vehicles have required registrations.
- All vehicles have current inspections.
- Radiological packaging meets all current requirements.
- Packages are correctly identified; all required markings and placards are properly displayed and are available at the site prior to beginning the operation.
- Inspections for equipment to be utilized to handle and transport the transportation casks have been conducted and copies provided.
- Proper documentation is provided to the serving railroad to indicate the site has been designated as a "rail secure area". The railroads do not approve the plan, but the serving carrier must be informed a plan exists and a contact name must be provided.

Transportation Personnel Readiness:

- Identify key personnel and their qualifications.
- Ensure required background checks are current and requirements of coverage of drug and alcohol programs are met.

- Provide copies of the training materials and ensure required trainings are current for all employees involved.
- Provide copies and ensure that all personnel are in possession of and working from the correct procedures and RWP.
- Ensure all private security personnel have required weapons certifications to cover the transportation cycle.
- Ensure the transportation personnel would be monitored for radiological exposure, if required.
- Ensure proper equipment and personnel are available to monitor workers for contamination, if required.

Transportation Readiness Notifications:

- Provide copies and ensure proper notifications have been made to the Tribes, NRC, State and local governments, DOT, USCG, and DOE as applicable. The USCG would need to be notified because the transload site is located immediately on a navigable waterway, very close to the water's edge, and it should be aware of the transportation activities taking place on site.
- It is recommended that any water-served or adjacent facility should have an active Security Plan in place while campaign activities are taking place, and in compliance with the regulations, the security team must be on the site once the transportation casks begin to arrive.
- The USCG must review and approve the MTSA plan or updated plan if one already exists for the transload site.
- Provide copies of and ensure all required permits to transport SNF are prepared and/or in place.
- Ensure proper notification requirements are being met for the disposal/storage facility.
- Identify scheduled meetings and briefings that would be conducted for all phases of the shipments.

Transport Operations

Once the transportation cask is loaded and secured onto the intermodal transport cradle at the TSC Handling and Transfer Facility adjacent to the railcar at the Zion ISFSI, the loaded intermodal transport cradle containing a loaded MAGNATRAN transport cask with impact limiters installed will be horizontally lifted and set on the waiting railcar into the designated fixed alignment devices installed on the railcar deck and secured to ensure proper centering and alignment of the cask to the railcar.

Hours of operation will be in accordance with site procedures. For purposes of this report, the assumption is that two casks per day will move from the ISFSI to the rail transload site.

Prior to any transportation or lift operations, a pre-job briefing with the operations staff, including security escorts and staff that will be tracking the shipment, would be performed. This briefing would be conducted to review procedures, verify training of staff, discuss any safety/quality-related concerns and practices, and verify adequate resources are available to support the activity including verification that prerequisite conditions are met. This would include, but not be limited to all transportation cask inspections and testing completed, routes having been inspected and approved, and receipt of management approval to ship.

Performing the Loading of Railcars

The loading will be performed at the rail transloading track where the train is already staged. The receiving fixtures would already have been welded to the railcar decks in preparation for loading. This enhances the accuracy of the loading, as the fixture placement on the railcars will be carefully measured to ensure the center of gravity of the unit rests exactly on the centerline of the railcar for maximum stability and to confirm with the approved clearance window for the rail shipment.

Performance of a visual inspection of the installed transportation casks, cradle, and personnel barrier assures that it is assembled correctly and in an unimpaired physical condition. The visual inspection includes checking for cracks on the intermodal cradle main beam web-to-flange-welds, the beam webs, plus checking the tie-down structure for any signs of distortion or failure.

Before the rigging is removed from the cradle as the crew has confirmed correct placement on the car, the rigging is removed from the cask, and the boom of the crane will swing away from the loaded railcar.

In the event of using the Atlas rail car for these shipments it is noted that the fixtures have previously been attached to the rail car. The crew would then proceed to secure the cask to the cradle/skid within the parameters of the specially designed securement system, ensuring compliance with the AAR OTLR. Specifically, all restraint values would meet the stated requirements of 7.5G x 2G x 2G[30][31], the requirement from the DOT and what is required for load securement in the transportation cask SAR.

Once the transportation cask is secured to the railcar and internal inspections of the transportation cask and the loaded train is completed, the Rail Transload Facility Supervisor would request the railroad inspection. Once the inspector measures and approves the cars for shipment, the Rail Transload crew would air test the train if air brakes were on the train and perform a visual inspection of the train's safety devices. The appropriate party would issue the electronic bill of lading (BOL) to the serving railroad. The UP crew will physically enter the site to pull the train, but it will limit how far into the site it will travel due to the severe track curvature on plant property. Currently, the UP crew enters the site approximately 120' from the point of switch to attach the waiting cars to the locomotives to be pulled from the site.

The Rail Transload Crew would then attach the GPS/Impact Recorders (or other telemetric units or similar approved devices) to the loaded train to provide 24/7 on-demand GPS location information using the most current monitoring sensor technology available at the time. It is acknowledged that other telemetric and tracing devices may be used by the shipper. The device would also record any impacts (from switching, etc.) that occur at more than 4 miles/hour. Impact recorders are not required by regulation or the railroads but are commonly used by dimensional shippers for high-value and sensitive machinery to record any impacts (switching) and forces exerted on the loaded cars during transportation. Simultaneously, the Transload Facility Supervisor electronically releases the loaded train to the railroad.

Once these steps have been completed, the shipment is considered ready for transport. Additional steps to be performed prior to release of the shipment include but are not limited to preparation of transportation-related documentation BOLs, permits, and other transportation-related documents to ensure compliance with regulations, notifications of States and Tribes and regulatory agencies as required and in accordance with regulations. Communication with the MCC and security team will be coordinated and tested prior to the train being released from Zion.

Once the serving railroad notifies the rail transload facility of the intended switch time, the train will be prepared for movement from the private loading track. Due to rail line restrictions limiting how far it will come onto the site to retrieve the loaded train, the Rail Transload Manager will move the train into position using a track mobile to the specific location on the Zion site where the manned interchange will take place between the UP and the Rail Transload Manager. Upon arrival of the UP-train crew onto the site, the Rail Transload Supervisor will unlock the gate and allow entry of the train crew into the site. The crew will enter the site but only to 150' beyond the point of switch to pull loaded train or place the empty train. All switching between the loading site near the ISFSI and the "pick up" point will be performed by plant/contractor personnel. This will be a documented and manned release of the loaded train from the transload facility to the UP train crew. The chocks would be removed, and the locomotive would attach to the loaded train and pull it from the facility. The Rail Transload Supervisor would unlock the gate and allow the train to exit the transload facility property with the Rail Transload Security Team (armed security escorts) in the escort car.

The railroad and Transload Facility Manager would document the manned interchange in writing.

The UP train will leave the facility and proceed to the GCUS directly with no other interchanges or stops in the journey before arrival at GCUS. An estimated transit schedule would also be provided to the shipper for the train movement. The ability to monitor and trace the train would be limited to need-to-know personnel.

Upon arrival at the GCUS, the UP crew would document the manned interchange, deliver the loaded train to the designated track, and then disengage its locomotive. Advance notification would be provided to the GCUS location to coordinate the manned and documented interchange for placement.

6.1.5 Demobilization

Once the de-inventory project operations have been completed, demobilization would commence. This is the process of removing all the equipment and materials used during the operation at the Zion ISFSI and returning it to its proper owner in accordance with rental / lease agreements. This includes returning any leased property to the proper owner in the agreed upon condition in accordance with the lease, which may include leaving added pads, fences, and lighting in place.

As the TSC exterior surfaces are potentially contaminated as discussed earlier, large components, such as the transfer trailer, MTC, transfer adapters, lift yokes, chain hoists, VCT, etc. would be decontaminated as needed, approved for free release, and returned to the owner(s) for storage. Specialized equipment (e.g., the vacuum and leak test systems) would be decontaminated, as feasible, and returned to the owner.

Railcars would be shipped directly from the disposal or storage site at the completion of the project in accordance with the release criteria established by DOE. The train would be returned to its storage track until it is needed for the next shipment. The transport packaging, transport cradles, lift yokes, and the like would be decontaminated, placed in an assembled condition, and returned to DOE for storage and maintenance.

Demobilization of ancillary equipment from each site would be accomplished in the same manner as it was mobilized. Forklifts, man lifts, diesel air compressor(s) and any large pieces of equipment would be surveyed and loaded onto flat beds and drop deck trailers for transport back to origin. It is customary for the leasing company to pick up the equipment once it is formally released by the contractor. Rigging, tools, and smaller articles would be surveyed and loaded into containers and flatbed trailers for transport back to the owner. Security-associated equipment, such as fences and lighting, would be broken down, surveyed, and returned to the suppliers, as appropriate. If personnel trailers, porta-johns, and storage trailers are utilized, utilities would be disconnected, and the units returned to the leasing companies. Cranes would need to be broken down and transported, as required, by the road permits to reach their next destination or be returned to the owner's storage yard. Any standard rigging rented with the crane would also be inspected for condition, documented, properly packaged to prevent damage, and returned to the owner or leaser.

The empty MAGNASTOR VCCs would remain onsite for disposition by Zion as potentially contaminated and activated materials. In addition, the ISFSI site, after all removal of all NAC storage systems, would be decommissioned in accordance with NRC and site regulatory requirements.

In the event any of this equipment is purchased, it would be surveyed and loaded onto trailers or containers for movement to its storage facility. This process takes approximately one week to complete. The train would be returned intact to its storage location and would likely move in regular train service which may take a few weeks depending on the distance and route dictated for the movement.

6.2 Resource Requirements / Staffing

At the Zion site:

- Operations Manager (OM)
- Cask Operations Shift Supervisor (COSS)
- Training Specialist
- Procedure Writers
- RP Specialist– in charge of the radiation monitoring and surveys.
- Transport and Waste Management Coordinator (TC) - provides supervision of the waste management aspects of the program and of the transport. The TC is in charge of the preparation of the shipping papers, verification of the proper labeling and placarding of the transport and tracking and response coordination. Position may be seconded by a Transport Analyst.
- Crane Operators.
- RP Technicians
- Riggers
- Rail Transload Supervisor
- Rail Transload Security Team

- Cask Operations Technicians/Mechanics
- VCT Driver and Equipment Operators
- QA/QC Specialist
- Security Personnel

6.3 List of Ancillary Equipment

Table 6-4, **Table 6-5**, and **Table 6-6** identify the ancillary equipment needed to perform operations at the Zion site.

Table 6-4: Additional Equipment for Zion Site Transfer

Additional Equipment for Zion Transfer	
Primary Mobile Crane (375-ton)	Required for vertical lifting and movement of the MTC, the vertical lifting and movement of the MAGNATRAN cask, the upending and downending of the MAGNATRAN transport cask from and to the intermodal transport cradle/frame located on the railcar.
Secondary Mobile Crane (150-ton)	Required for lifting ancillary items, such as VCC lid, transfer adapters, transport cask lid, transport impact limiters, and personnel barriers. [Note: If a gantrysystem is employed at the TSC Handling and Transfer Facility the Secondary Mobile Crane is not required and the stated lifts are conducted with the Primary Mobile Crane.]
Man lift or pre-assembled scaffolding	Capable of accessing the top of the MAGNASTOR VCC or MAGNATRAN cask will be required for removal and re-installation of the VCC lid and MAGNATRAN transport lid bolts, handling of the Transfer Adapters, Transfer Shield Ring and associated lifting slings, installation and removal of the TSC lift adapter plate bolts, conducting inspections and cleaning of sealing surfaces, cover plate removal and installation, conducting helium fill and sealed leakage tests and other activities as needed.
Lifting Rigs	See **Section 2.3** for details.
Standard rigging and supplies	See **Section 2.3** for details.
Standard tools	These include personal protective equipment (PPE), communications equipment, wrenches, etc.

Table 6-5: Rail Transport

Rail Transport	
Standard tools	These include PPE, communications equipment, wrenches, etc.
Large forklift	Used to move heavy equipment onsite, pick up and relocate heavy objects, and reposition train if required.
Man lift	Used to inspect and measure the loaded railcars to ensure compliance with the clearance window and to safely extend reach of humans for any required reason.
Welding machines	Use for welding and securement.
Standard rigging and supplies	For use in lifting the overpack and cradle combination.

Table 6-6: Rail Equipment (per Consist)

Rail Equipment (per consist)	
Locomotive(s)	Dedicated for the train movement and at least two required per AAR S-2043.
Buffer cars	Used to provide buffer between loaded overpack cars and all other cars.
Load (cask) cars	Heavy duty flat cars.
Escort car	Houses the armed security team and will meet the portion of AAR S-2043 applicable to escort cars.
Redundant radio equipment	Used for communication between the security team and the monitoring control center, LLEA, and other required parties. This communication system is in addition to the normal radio communication of the railroad crew with dispatch.
GPS/impact recorder units	One per loaded overpack car. While GPS (telemetric devices) are required for SNF movements, combination units are commonly used by shippers on sensitive and high-value dimensional shipments to indicate both locations of the cars/train and to document all forces exerted on the load car while moving. These are not required by regulation or the railroad, but are an additional means of ensuring safety and security in the handling of the units during transportation.

6.4 Sequence of Operations / Schedule

The operations would be sequenced as described in **Section 6.1**.

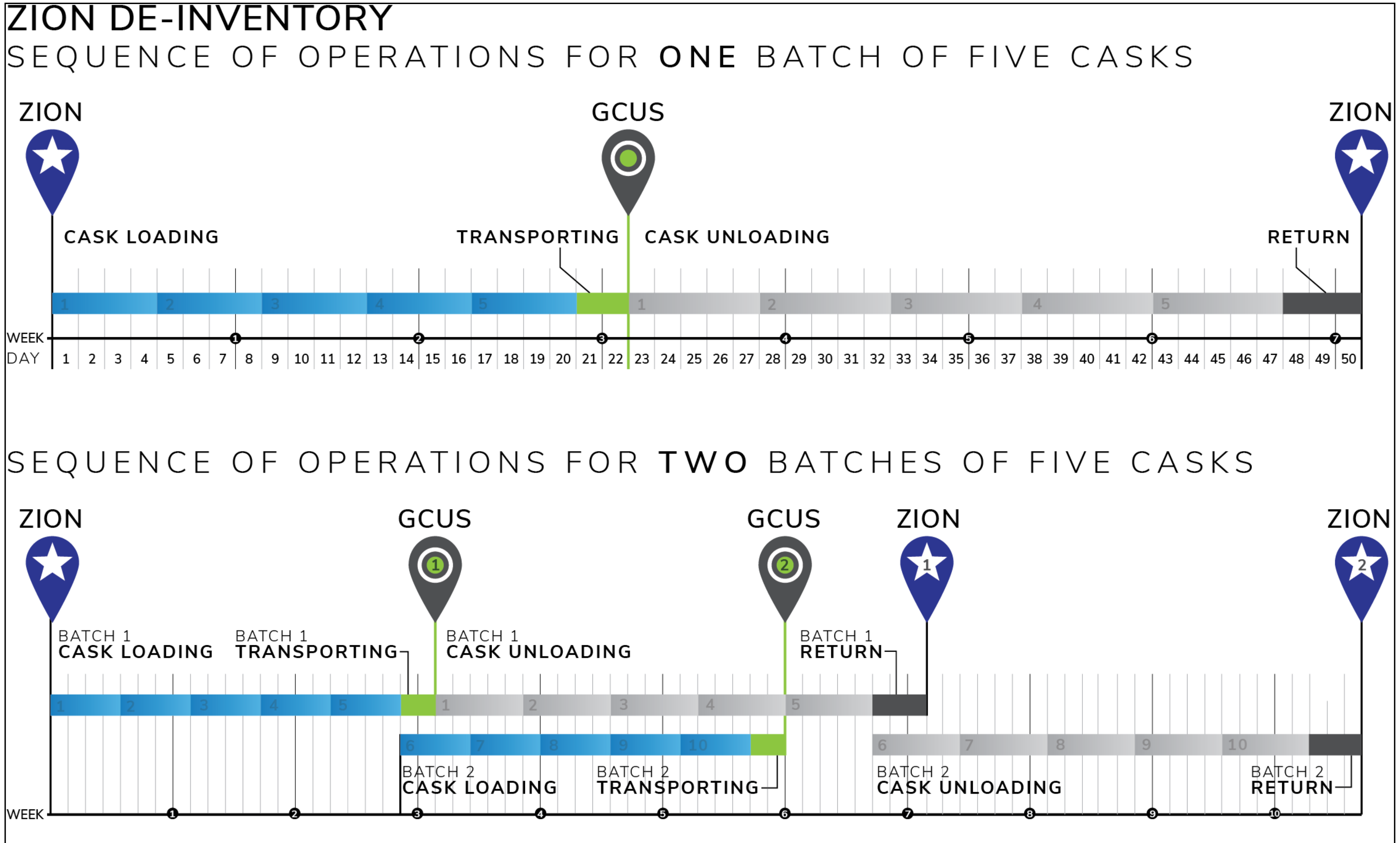
For the onsite loading sequence, it is estimated that two 10-hour days per loading will be required to move the MAGNASTOR VCC, off-load the transport casks, retrieve the TSC from the VCC storage cask into the MTC, load the TSC into the MAGNATRAN transport cask, close and prepare the casks for transport (e.g., evacuation, helium backfill, leakage testing), move the MAGNATRAN cask to the rail siding, lift and down-end the loaded MAGNATRAN cask on the transport cradle on the railcar, and release for transport. Therefore, for a 5-cask train, approximately two weeks will be required.

The sequence of operation timeline, **Figure 6-1**, outlines the operations associated with the facility at the Zion site through railcar loading. Note that some operations could be done concurrently (equipment staging and some inspections) to reduce time, but this was not considered in the development of this timeline. Transfer operations at the Zion site would include the transport casks handling operations to transfer the casks and preparation for shipment. The transit times listed in **Figure 6-1** are provisional and may change as route details and operations are better defined. Cask loading and rail transport of the 5 cask consist from the Zion site to the rail siding, conducting the down-ending the MAGNATRAN casks to the railcars, and securing the cask/intermodal transport cradles to the railcars and preparation of the train will take approximately 10 days. The total evolution from the initial transfer of a TSC from a storage cask to a transport cask to the return of the empty casks to the Zion ISFSI takes approximately 30 days.

For the resources estimate, the timeline of the operations can be broken down into 13 individual round trip shipments of 5 MAGNATRAN packages over a period of 390 days or 13 total shipments using two consists of 5 MAGNATRAN casks over a period of 210 days.

Table 6-7 estimates the resource requirements needed to support this de-inventory campaign. An additional 8 weeks of planning and preparation is added before the start of the first campaign.

Figure 6-1: Sequence of Operations



ASSUMPTIONS:

1. 5 empty MAGNATRAN casks on railcars ready for off-loading
2. 1 Vertical Cask Transporter (VCT) used to move VCC from ISFSI to TSC Transfer Station
3. 7-day work week of 8 hours per day
4. No concurrent work only work on one system at a time
5. Rail spur is adjacent to the TSC Transfer Station

Table 6-7: Operations Timeline with Required Resources

	Major steps for a 65 TSC campaign	Resources required [in full-time equivalent (FTE)]*											Estimated Duration (in work days)
		OM	COSS	TS	PW	RP	TC	CO	RM	EO	QS	SP	
1	Detailed operations planning, campaign preparation, equipment mobilization, procedure preparation and approval, training program, pre-loading review(s) and dry run(s)	1	2	1	2	2	1	2	6	2	1	3	56 days prior to start 1st campaign
2	Onsite transfer of the SNF and GTCC canisters and preparation of 5 packages	1	2	1	1	3	1	2	6	2	1	3	15 days per 5-cask campaign
3	Shipment to destination by rail	0.5			1		2						1 week per 5-cask campaign
4	Unloading	0.5	1		1	1	2	1	4	1	1	2	1.5 weeks per 5-cask campaign
5	Return transport of empty casks by	0.5			1		2						1 week per 5-cask campaign

***Key:**

OM: Operations Manager
COSS: Cask Operations Shift Supervisor
TS: Training Specialist
PW: Procedure Writer
RP: Radiation Protection
CO: Crane Operator
TC: Transport and Waste Management Coordinator
RM: Rigger/Cask Operations Technician/Mechanic
EO: VCT Driver and Equipment Operator
QS: QA/QC Specialist
SP: Security Personnel

6.5 As Low As Reasonably Achievable (ALARA) Planning

Specific requirements are provided in 10 CFR 72.126, “Criteria for radiological protection,” that address radiological control measures for work with dry cask storage of SNF. Infrastructure requirements that would be required for transitioning from essentially a static, monitoring condition of the storage of SNF to an active worksite that involves handling and loading operations would be considerable. Stranded sites that are no longer staffed with trained and qualified health physics personnel would be dependent upon either loaned labor from the utility, if those resources are still available, and/or contract health physics staff. In addition, portable survey instruments, portable Continuous Air Monitors (CAMs), and area radiation monitors must be provided along with the means to maintain them, calibrate, and response check for usage. Infrastructure must also be provided to facilitate safe operations at the site. Temporary offices, electric power for lights, equipment and instrumentation, potable water, and limited decontamination facilities must be in place prior to start of operations at the Zion ISFSI. Considerations must be made to provide for the following:

- Effluent monitoring and control
- Airborne and direct radiation monitoring capabilities
- Personnel and equipment access control
- Radioactive material control
- Decontamination capabilities for personnel and equipment
- ALARA equipment such as temporary shielding for low exposure waiting areas, video surveillance equipment, and other remote or robotic equipment may be appropriate

In accordance with the requirements stated in 10 CFR Part 20 and 10 CFR Part 72, sufficient controls must be in place to protect the workers and the public from radiation. Therefore, at a minimum, the following requirements must be satisfied prior to commencement of radiological work activities at the site:

- Approved radiological control procedures in place
- A sufficient number of trained and qualified RP Technicians are mobilized and ready to support operations at the pad (estimated at one supervisor and two RP Techs per shift)
- Sufficient quantity of radiation control equipment and consumable supplies on hand to support the planned work activities (PPE, signage for posting, radwaste controls, etc.)
- Qualified RP/ALARA supervision assigned for oversight of radiological work activities
- Personnel dosimetry for monitoring worker doses including Thermoluminescent Dosimeters (TLDs) and electronic dosimeters available for issue
- A bioassay program in place for worker monitoring (in vivo and in vitro as necessary)
- Health Physics instrumentation calibrated and suited for the types of surveys and measurements required in place
- Detailed work plans developed that would be used for RWP preparation and ALARA evaluation
- In addition to the RP Technicians, workers that are supporting operation have been trained and qualified to the applicable Rad Worker Program requirements

6.6 Quality Assurance Requirements

All quality-affecting activities associated with cask handling operations including transportation would be controlled under an NRC-approved Quality Assurance Plan (QAP) meeting the requirements of 10 CFR Part 50, Appendix B (within owner-controlled area); 10 CFR Part 71, Subpart H (as related to transportation); and 10 CFR Part 72, Subpart G (within the ISFSI site), as applicable to the scope of work.

Fabrication of important safety components and support equipment for the MAGNASTOR / MAGNATRAN Systems would be controlled under the licensee's QAP or by a qualified supplier's QAP that has been approved for this scope of work. Component classification guidance is taken from Regulatory Guide 7.10[32] and NUREG/CR-6407[33] to establish a graded approach to QA. These QAPs are used to establish the quality category of components, subassemblies, and piece parts according to each item's relative importance to safety.

7.0 BUDGET AND SPENDING PLAN

The total estimated budget for the whole Zion campaign organized over 53 calendar weeks is $17.8M. This amount is based on the assumptions and estimates listed below. The estimates provided here are centerline estimates based on the current knowledge of the sites and of the operations needed. They are based on operations being performed at the time the data was gathered for this report (2022). This section provides a breakdown of the estimated campaign costs for the de-inventory of the Zion site, by activity, and to the extent cost information is currently available. This report does not specify the party or parties responsible for the costs estimated herein.

The following assumptions were made to assess the costs in this report:

- Two sets of 5 MAGNATRAN transport casks, 5 pairs of impact limiters, 5 personnel barriers, 5 transport cradles are provided by the cask vendor. Ancillary equipment to prepare the transport cask for transportation (tooling, lifting yoke, spreader bar, leak test equipment, VDS, etc.) will be supplied by the cask vendor. No estimate is provided here.
- The cask railcars, escort car, buffer cars, locomotives, etc. are provided by DOE. No estimate is provided here.
- The site-specific physical road survey and the complete de-inventory study which includes communication with the site and official stakeholders are not included here.
- It is assumed that no covered building would be used at the designed transload location. No cost for a new building construction is considered here.
- Train delivery to the final destination and return shipment of the empties by train on Class I railroad are not included. For scheduling purpose, the destination is considered to be GCUS.
- Assumptions are made based on the current status of the origin site and current understanding of the operation. Some pieces of equipment are not designed yet, and no reasonable assumption can be made at this point.
- No additional on-site fencing and lighting is considered.
- A total of 13 iterations of 7 working weeks each will be necessary to complete the de-inventory. In addition, another iteration of 8 weeks is added and will happen before the first shipment for campaign readiness, procedure writing, dry run, testing and training purpose.
- Pre-loading canisters inspection activities are not included in the cost estimates
- Does not account for potential impact of additional specific local regulatory requirements, if applicable, and assumed labor performed by vendor-approved specialists.

7.1. Fees and Permits

No truck permit is expected to be necessary for these moves other than the one that may be required for the mobilization of the transfer equipment (that are already included in the mobilization cost) as there is no highway transport of the casks.

No physical off-site road survey would be expected.

An estimated amount of $50,000 for the NRC route approval processing, preparation of the Security Plan, route survey and the clearance are to be expected. In addition to these costs, States may require the payment of fees for the transport of SNF or HLW through the States. These costs are currently unknown.

7.2. Campaign Operation Management

The Campaign Operation Management would require a crew to be dedicated to the preparation, planning, and supervision of the operation, as described in **Section 6.0**. The Operation Management Team would be composed of a Project Manager, Plant Manager/Coordinator supported by a Scheduler and some engineering staff.

The estimated cost for the Management crew for the 53-week campaign is $1.8 million. In addition to the site physical road and rail survey, the management crew would also oversee the planning phase leading to a complete de-inventory study including communication with the site and official stakeholders. This is not captured here.

7.3. Equipment for the Loading Operations

The estimated costs for the mobilization of the equipment on site, the lease of one 375-ton crane, a 150-ton crane and operators for 53 weeks at the shipper site one large forklift, two-man lifts or scaffolding, miscellaneous supplies, air compressor(s), a VCT and the mobilization/demobilization of the equipment would be approximately $4.4 million for the duration of the Zion campaign.

Additional equipment is also necessary for the transfer of the MTC. No lease cost is included here as it is assumed here that this equipment would be borrowed from another site. The mobilization and demobilization costs of this equipment is estimated to be $0.9M.

7.4. Site modifications

The design and construction of a new TSC transfer pad to support the operation as described in **Section 6.0** is estimated $1.0M. The estimate does not include any TSC Handling and Transfer Facility or gantry system structures. No cost for a new building is considered here.

7.5. In-Transit Security

The security at the shipping site and at the receiving site would be ensured by the crew already in place at the site and is therefore not included in this estimate.

The in-transit security composed of the security crew is estimated at $500,000 during the campaign for the movement to the Class I railroad and for the security at the transload location.

7.6. Cask Transportation Services at Transshipment Site

The Cask Transportation Services team would consist of a Transport coordinator located on site that would coordinate the transport operations with truck drivers and rail operators, support the shipper in the preparation of shipping documentation, marking, labeling, and placarding. The Transport Coordinator will also notify the required regulatory body in accordance with the applicable regulation. The Transport Coordinator will be supported by a Transport Analyst. They will consolidate the communication between the shipper site, consignee site, truck drivers, and different stakeholders involved during the transportation phases. The team will also oversee the coordination for the return of the empty casks as detailed in **Section 6.0**.

A 375-ton crane, a large forklift and a man basket as detailed in **Section 6.0** will have to be mobilized and leased for the duration of the campaign.

The transportation costs include the rail transport of the casks loaded on railcars from the origin site to the location where the short line meets the class I railroad.

The estimated costs for the cask transportation services are $4.3 million for the entire campaign.

7.7. Onsite Operations

The shipping site operations would be composed of the crew listed in **Section 6.4**. The estimate for the whole crew for the onsite operation is $5.0 million for the entire campaign.

7.8. Breakdown of the Costs by Activity

This section provides a breakdown of the estimated $17.8 million cost of de-inventorying the Zion site, by activity, and to the extent cost information is currently available.

- Equipment (e.g., transportation casks, railcars, cranes, movers, etc.): >$4.0 million (cost of casks and railcars is currently unknown)
- Transportation services and security: $6.0 million
- Management and labor: $6.8 million
- Infrastructure: $1.0 million

7.9. Additional Cost Estimates to Support De-Inventory Activities

Additional costs estimated in this section that are associated with some of the activities involving the shipment of the casks from the transload site to GCUS and include: consist transportation services (loaded and unloaded) costs; emergency response center operation costs; railcar maintenance services costs; and transportation cask maintenance and compliance costs. Estimates for these costs are provided in the following sub-sections; however, these costs have several significant conditions associated with them including:

- The shipment of the consist occurs in the current quarter of the calendar year (2nd quarter of 2022), as rates are temporal.
- The transportation casks meet the 10 CFR Part 71 regulatory limits (e.g., thermal, structural, and radiological) at the time of shipment.
- The maintenance and compliance activities assumed in the cost estimate for the transportation casks are representative of the yet to be built casks systems utilized in this report (i.e., the NAC MAGNATRAN) and are similar to one another.
- The maintenance activities projected for the railcars are representative of DOE's in-progress railcar design of the Atlas cask car and will be built to ship the transportation casks identified in this report.

- The transportation cask systems and railcars are assumed to be leased to DOE and maintained at vendor operated facilities.
- The emergency response center is assumed to have been designed for the handling of multiple near-simultaneous rail shipments of SNF and estimated costs are for personal assigned full time to the monitoring of shipments only from the Zion ISFSI and the portion of the facility and communication equipment needed to support the shipments from the Zion ISFSI.

Due to the potential significant impact of these stated conditions on the following identified costs, the values are presented in ranges that provide a rough order of magnitude for the associated costs. Development of more precise values requires resolution to the above conditions, consideration of economies of scale and synergies associated with the de-inventory of multiple sites at the same or nearly same time, understanding of ownership of equipment (e.g., railcars and casks), and a comprehensive breakdown of activities.

7.9.1. Estimate of Transportation Costs

For the rail movement of a single rail consist from the loading site to the GCUS site, the costs would be comparable to the current market rates for radioactive materials rail shipments and would be broken down into the following categories:

- Freight Costs per Consist
- Special Train Movement Costs (Empty casks return shipment done on merchandise train)
- Current Fuel Surcharge Costs (this surcharge adjusts on a monthly basis)

7.9.2. Estimate of Emergency Response Center Operation Costs

The operating costs for an Emergency Response Center are based on the following additional assumptions:

- A team of 5 transport analysts to ensure a 24/7 on-duty presence and to allow an individual to attend the required periodic trainings.
- One manager with the dual role of resource manager and technical expert on emergency response.
- The crew will support the emergency response and will provide the resources to support the day-to-day transport operations with the support of a transport coordinator located on site.
- The crew will be in charge of the coordination and necessary notifications. They will coordinate with the transport vendors (railroads, trucking companies, etc.), the DOE, and the shipping and receiving sites. They will also act as the interface with the first responders and their contact information will be indicated on the shipping documentations.
- The entire crew will be trained to the DOT, NRC, DOE, and shipper’s requirements. The crew will have the necessary DOE clearances, access to the safeguards information, and appropriate training. Additional emergency training such as Federal Emergency Management Agency training would also be useful.

The costs for an Emergency Response Center should be considered independent of the number of shipments and includes the costs for an office and associated communication equipment.

7.9.3 Estimate of Railcar Maintenance Services Costs

To develop an estimate for railcar maintenance services costs, a combination of experience from an existing fleet of railcars used to ship low level waste in the U.S. and activities involving the design and potential building of AAR S-2043 compliant cask and buffer railcars for SNF shipment was utilized. For the purpose of estimating these costs, they are assumed for a single consist, made up of the aforementioned two buffer cars, five cask cars, and one escort car and dedicated to the de-inventory of the Zion ISFSI, as opposed to costs associated with maintaining a fleet of rail cars for the de-inventory of multiple sites. In addition, these additional costs would apply:

- Routine railcar maintenance is assumed provided by the handling railroads and depending on the costs, will be invoiced to the car owner (major and emergency maintenance) or covered by the shipping rate (minor/regular maintenance).
- Buffer car (4 axles) maintenance costs.
- Cask car (12 axles) maintenance costs.
- Escort car (4 axles) maintenance costs.
- Costs associated with administering a fleet maintenance program.

The above costs associated with the maintenance of a fleet of rail cars encompass activities associated with the physical inspection, periodic regular servicing, and minor routine maintenance and repair activities. Administrative costs for maintaining the program and covering taxes and insurance would have to be included in the above costs. However, these costs are estimated to only cover the cars in use for the de-inventory of the Zion ISFSI, rather than the costs associated with establishing and maintaining a facility and fleet for the larger inventory of rail cars needed for a national campaign. A separate assessment would need to be performed to establish if it is more prudent to lease the needed support services from an existing qualified supplier rather than establishing a dedicated facility to service, maintain, and store this fleet of rail cars considering:

- Administrative costs for such a support facility.
- Taxes can vary significantly by site for such a support facility, which could be placed in a large number of jurisdictions due to the number of potential de-inventory sites.
- Similarly, construction and maintenance costs for such a facility can vary widely depending on the suitable site selected.
- Staffing costs for such a facility would also vary by site selected.

As noted above, routine maintenance activities for railcars are generally provided by the railroad and a portion is covered in freight rates.

7.9.4 Estimate of Transportation Cask Maintenance and Compliance Costs

To estimate the costs associated with the maintenance of a transportation cask, the following additional assumptions would need to be made:

- One single shop is assumed to be used to perform the maintenance for all the transport casks (including those from different cask vendors if applicable).
- Costs associated with the transport to or from this shop are not included, as its location has not yet been established (although an economic argument could be made to locate this facility near the receiver site to minimize the transport costs).
- The shop where maintenance activities are to take place must have approval from the State to perform radiological work and dispose of the radioactive wastes potentially generated by the maintenance activities, noting the shop will need to open potentially contaminated transportation casks that may result in the release of some contamination.
- The shop must provide facilities for the storage of transportation casks, potentially for long periods of time.
- The shop must also allow for the training of personnel on cask maintenance operations.
- The shop must provide a covered building to allow maintenance operations to occur under any weather conditions and at any time of the year.
- The shop must be able to receive and store railcars (preferred) and/or HHT and ideally be connected by a rail spur to a major railroad.
- The shop must be equipped with a crane capable of lifting a transportation cask and the associated cradle/skid from a railcar or HHT.
    - Conservatively, the lifting capacity of this crane would need to be approximately 375 tons, although the transportation casks brought to this facility will be empty (i.e., will not include a canister with SNF).
    - From a nuclear safety standpoint, no critical load lift is necessary and hence, the crane does not need to be designed as single failure-proof.
    - The crane hook and height of the crane must be compatible with the lifting of yokes and associated rigging supplied by cask vendors.
- Some details of the transportation cask maintenance program will be different between cask vendors; however, the bulk of the maintenance costs are assumed to involve the following larger scale common activities:
    - External decontamination of the casks
    - Internal decontamination of the casks
    - Replacement of sealing gaskets
    - Periodic maintenance and leak testing of the containment boundary
    - Load tests
    - Maintenance of spare parts
    - Maintenance of the leak testing tools
    - Maintenance of cask leak testing equipment
    - Maintenance of the vacuum drying systems

  - Maintenance of lifting and support equipment (yokes, trunnions, skids, etc.)

- Leak testing will be performed according to American National Standards Institute (ANSI) N14.5-1997, unless specified otherwise in a Safety Analysis Report, by an American Society for Nondestructive Testing (ASNT) Level II cask operator.
- The maintenance program will be approved by an ASNT Level III reviewer and performed in accordance to the specifications identified in each transportation cask's Safety Analysis Report.
- The single shop will require a radiation protection plan that will be implemented and maintained.
- The size of the facility and the staff are assumed to limit maintenance to only one cask at a time.
- The staff at this single shop will be composed of 2 trained operators, some engineering support, a ½ time ASNT Level II cask operator, and a part time ASNT level III procedure writer/reviewer.

8.0 SECURITY PLAN AND PROCEDURES

A Security Plan would encompass strategies and procedures in compliance with 49 CFR Part 172 to ensure the safety and the security of the material, employees, and the public during loading, transloading activities, and movement associated with the transportation of the SNF and GTCC LLW from the Zion ISFSI to the final destination.

The transportation activities covered by the plan would include all aspects of the shipment from loading the transportation casks at the Zion ISFSI, preparing them for movement on the transport trailer to the on-site rail transload track to the train movement to the hypothetical destination of the GCUS.

Multiple entities have jurisdiction over commercial shipments of SNF in the U.S. including the NRC, USCG, and the DOT. The DOT's PHMSA issues the Hazardous Materials Regulations in 49 CFR Parts 171-180 and represents the DOT in international organizations. The relevant regulations addressing the security of SNF during transportation include: 49 CFR Parts 172-177; 10 CFR 73.20, 73.37 and 73.72 (advanced notification); and 49 CFR Part 172, Subpart I.

The basic statute regulating HAZMAT transportation in commerce in the U.S. is 49 U.S. Code 5101 et seq., which identifies "hazardous materials" by commodity, or a group of commodities. It identifies regulations for the safe movement of HAZMAT, including safety and security for movements within the U.S. Several agencies have jurisdiction over different aspects of commercial transportation of HAZMAT depending on the mode of transport and other circumstances of the shipment. These agencies include the PHMSA, Federal Motor Carrier Safety Administration, FRA, Federal Aviation Administration, and USCG. Together these entities cover all aspects of commercial transportation of HAZMAT, which includes the movement of SNF, by road, rail, air, or water with an emphasis on safely moving this material.

Given the geographic proximity of both the ISFSI and transload site to navigable waters, the MTSA is assumed to apply to the Zion water-served site, even though the recommended mode of transportation is direct rail. Any site, whether private or public, that is on or adjacent to water and handling or storing HAZMAT will be governed by the USCG regulations, in coordination with other agency regulations. It is assumed and recommended that MTSA provisions apply to both the ISFSI and transload site. As such, additional security precautions should be implemented, including development, in consultation with the USCG, a facility security plan if one does not already exist for the site. Likewise, when movement of SNF is occurring on-site, the USCG should be notified to monitor and patrol the navigable waters adjacent to the facility to provide a secure maritime area and limit access to the site by water. The COTP has the authority to establish the area as either a Safety Zone or Security Zone during loading operations, regardless of the mode of transportation.

In addition to the maritime security measures for the rail-served transload site, the railroad will be notified the site is being declared a "rail secure area" (due to the transload operation), as required by regulation. This means all provisions of the Security Plan will be adhered to and enforced and effectively, a layered security approach will be established to govern the site for ISFSI transload operation, the HHT-to-rail movement, and the rail transload operations.

While maintaining security protocols relevant to the control of sensitive information regarding the movement of the SNF and its associated procedures, all relevant parties to the transportation activity will receive a copy of the Security Plan, and complete applicable training. All personnel will be required to return a signed copy of the Security Plan review signature sheet to the designated site administrator as part of documentation control.

8.1. Security Plan Requirements

Security plans for the transportation of hazardous materials in commerce are addressed in 49 CFR Part 172, Subpart I, which mandates a Security Plan must be in writing and contain an assessment of security risks for transportation of hazardous materials identified in 49 CFR 172.800, which includes highway route controlled quantities (HRCQ) of radioactive materials and must address the identified risks including security while the material is enroute. The Security Plan must also provide protection of the ISFSI facility and transload activities incidental to the transportation, including loading and unloading operations. This document assumes the provisions of the MTSA of 2002 are applicable. No formal determination has yet been made by the USCG or the NRC as to its applicability in this situation, but it is common to notify the USCG when HAZMAT is stored or being transported on a water-served site.

As delineated in 49 CFR 172.802, a Security Plan must also include the following elements:

- Personnel security: Measures to confirm information provided by job applicants hired for positions that involve access to, and handling of, the HAZMAT covered by the Security Plan;
- Unauthorized access: Measures to address the assessed risk that unauthorized persons may gain access to the HAZMAT or transport conveyances being prepared for transportation of the HAZMAT;
- En-route security: Measures to address the assessed security risks of shipments of HAZMAT covered by the Security Plan en route from origin to destination, including shipments stored incidental to movement;
- Security Plan Owner: Identification, by job title, of the senior management official responsible for overall development and implementation of the Security Plan;
- Security duties: Duties and responsibilities for each position or department tasked with implementing any portion of the plan and the process of notifying employees when specific elements must be implemented;
- Training: Description of the training required by HAZMAT employees in accordance with 49 CFR 172.704 (a)(4) and (a)(5); and
- Risk Assessment with details addressing:
    - An assessment of transportation security risks for shipments of the specific HAZMAT listed in 49 CFR 172.800 (includes radioactive materials).
    - Site-specific or location-specific risks associated with facilities at which the HAZMAT is prepared for transportation, stored, or unloaded incidental to movement (e.g., rail transload facility).
    - Appropriate measures to address the assessed risks.

The Security Plan, including the transportation security risk assessment, must be in writing and retained for as long as it remains in effect. It must be reviewed, at a minimum, on an annual basis and updated as necessary to reflect changing circumstances. Each person required to develop or implement a portion of the Security Plan must maintain a copy of the plan (written or electronic) that is accessible at their principal place of business and must make the plan available upon request, at a reasonable time and location, to an authorized official of the DOT or the Department of Homeland Security (DHS). The most recent version of the Security Plan, or portions thereof, must be available to the employees who are responsible for implementing it, consistent with personnel security clearance, or background investigation restrictions and a demonstrated need to know. When the Security Plan is updated or revised, all employees responsible for implementing it must be notified and all copies of the plan must be maintained as of the date of the most recent revision.

8.2. Scope

Key transportation, security, and Federal and State agency officials involved in the transport will need to be identified. The truck and rail transfer sites where the SNF will be loaded or unloaded will also need to be identified. Security professionals will conduct the security and risk analysis from point of origin (Zion) to the final destination. In addition, a physical route analysis will be conducted to determine any potential logistical issues that may exist or that could pose a risk to security during all phases of the operation. Security professionals involved will identify requirements for compliance as part of the action plan and define and establish procedures for the operation, including contingency plans.

8.3. Identifying and Selecting the Principal Parties (Administrative Team)

The following should be considered for the identification and selection of the principal parties involved in the development of the Security Plan:

- The Security Contractor would chair the Administrative Team for the entire process or until an alternate is determined.
- Once the requirements of each transload site and the destination of the SNF and GTCC LLW is determined, contact should be made with all parties involved in the operation, including the rail and truck operators that will be involved with the transfer.
- Per 10 CFR 73.37 (b)(1)(viii), the initial contact with logistical partners should be made at a high level of the organizations in order to ensure the protection of Safeguards Information.
- Initial meetings should bring together the licensee, security, and risk assessment contractor or designee, high level logistical partners in truck, rail and other vendors (e.g., crane and rigging companies and monitoring partners), DHS, DOT, USCG, NRC, and other Federal and State officials, as needed.
- The meeting should address the concerns of each representative group, identify any groups that may not be present or need to be included, and come away with a framework for managing the project and how communications will be handled at all phases of the operation.
- The purpose of this meeting is to establish the Administrative Team as a partnership dedicated to working together to ensure the safety and security of the SNF and GTCC LLW in transportation and identify any areas of concern.

8.4. Select the Rail/Truck Transload Site to be Used

The following should be considered for the selecting and/or utilizing a secure, existing transload site:

- If an existing transload site is identified, it is preferred that it be a fully enclosed and secure commercial installation or that it can be easily secured. If the site must be established, these measures must be considered to enclose the site in an effort to create a secure perimeter around the loading location. This will include fencing and lighting around the perimeter of the property, installing security cameras and limiting egress and ingress to secure gates with locks at both the rail and truck entrances.
- Establish direct contacts at the site(s) for logistics and security.
- Ensure that all persons on site with direct knowledge or access to the transfer location have background checks. Security clearances may also be considered, but are not required.
- Assuming MTSA jurisdiction over the site and transload locations, TWIC identification cards would be mandatory for workers. TWIC cards are issued by TSA and involve background and fingerprint checks.

8.5. Identifying and Selecting the Risk and Security Assessment Team

Identification and selection of the Risk and Security Assessment Team (RSAT) should consider the following:

- Once the routes are proposed and agreed to by the Administrative Team, a RSAT shall be formed to conduct a security risk assessment of the routes and transfer sites.
- The RSAT will be selected and approved by the Administrative Team.
- The RSAT will be comprised of security and risk professionals from licensee, security contractor, and any Federal and State agency that wishes to participate.

The RSAT will perform the security risk assessment of the surrounding transportation infrastructure. This includes, but is not limited to, bridges, tunnels, overpasses, proximity to population centers or landmarks, direct route access to the installation, identification of potential bottlenecks, narrow roads, interstate highways, proximity to hospitals, schools, civic centers, shipping channels, and highly populated areas. The assessment should include a 10-mile area on either side of the center of the proposed transportation route. Contingency routes should be identified and assessed throughout the transportation route.

Each step in the proposed route should be geographically divided and the results submitted to the Administrative Team for evaluation. If the RSAT uncovers any major concerns during the Security Risk Assessment, the next portion of the route geographically should be placed on hold until the issue is resolved in the event the transportation route must be changed. If no major concerns are uncovered, the RSAT can continue with the next geographical portion of the trip. During the assessment, agreements need to be made with all state agencies in the state(s) that is included in the assessment before finalizing the assessment.

8.6. Evaluating the Security and Risk Assessment

Upon completion of each geographical portion of the risk assessment, the assessment will be submitted to the Administrative Team for review, evaluation, and approval. All identified risks will be evaluated and resolved, or a contingency developed prior to approval of that portion of the transportation route.

8.7. Developing a Hazardous Materials Security Plan

The following should be considered while developing a HAZMAT Security Plan:

- Existing Security Plans for the site, railroads, trucking companies and transload sites, should be incorporated into the overall plan, especially to develop a concise hand-off of security responsibilities at each transfer.
- The Security Plan hand-off of responsibility at each site will be reviewed by the RSAT and evaluated and approved by the Administrative Team, DHS, DOT, USCG, the licensee, and each individual state authority for each state that will be crossed.
- Strict chain-of-custody protocols will be established and all physical transfers will be "manned" and documented[34].
- Any additional Security Plan that will be needed at the rail/truck transfer sites will be developed using the "Risk Management Framework For Hazardous Materials Transportation"[35] and the "Enhancing Security of Hazardous Materials Shipments Against Acts of Terrorism or Sabotage"[34].

8.8. Develop Security and Communication Protocols

Security and communication protocols will be developed as follows by the Administrative Team:

- All personnel identified above will have background checks completed prior to being included in any communications.
- The level of security required for operations personnel such as railroad personnel, truck drivers, riggers, flag men, security personnel, and others once the project is operational.
- What type of communications can and cannot be used during the entire project.
- What level of distribution will be allowed and how that will be administered and monitored.
- Develop and approve all distribution lists and approved contacts.

8.9. Development of Security Plan and Protocols for Marine Facilities

The following will be considered in the development of a Security Plan and associated protocols for a marine facility site (Zion and the on-site transload track).

When a site handling hazardous materials, including SNF, is located near or on the water, additional maritime security precautions should be considered. While no determination has been made on its applicability, the MTSA describes prudent security measures for maritime facilities.

A Facility Security Plan (FSP) should be developed that identifies procedures and processes for transportation activities on site. The FSP is implemented by a Facility Security Officer (FSO) and submitted to the COTP for the Sector in which the site is located. The RSAT will conduct a security assessment up to the entrance of the marine facility. A review of the FSP in effect inside the marine facility will be conducted with the permission of the USCG COTP. An Area Maritime Security Plan should be developed that identifies procedures for handling the maritime domain surrounding the facility during a transportation activity. Included in the Area Maritime Security Plan would be buffer zones where commercial or pleasures vessels would not be permitted during a transportation activity (transloading operation) at the site.

8.10. Railroad Security Requirements

The following are railroad security-related requirements:

- The TSA published rules regarding the rail transportation of certain HAZMAT, which became effective on December 26, 2008[36] and are still in effect. The materials subject to these rules include explosive, TIH, PIH, and HRCQ. TSA refers to these commodities collectively as Rail Security-Sensitive Materials (RSSM). As a result of these rules, the carrier will only be able to accept or deliver RSSM from Rail Secure Areas.
- There are additional requirements for delivery/acceptance of RSSM in designated High Threat Urban Areas (HTUA), but none of the geographical locations involved in this assessment fall into designated HTUA.
- Shipments of RSSM will be subject to chain-of-custody requirements which apply:
    - To all shippers of these materials and
    - To receivers only located in HTUA
- Personnel must be physically present for attended hand-offs of the railcars to document the transfer by recording the following information:
    - Each railcar’s initial and number
    - The individual attending the transfer
    - The location of the transfer
    - The date and time of the transfer
- Additionally, for any location in a HTUA that receives RSSM by rail, security personnel must be present 24 hours a day, 7 days per week. For any location that has notified the railroad that an RSSM railcar is available for shipment (released).
- Security personnel must be present 24 hours a day, 7 days per week from the time notification was provided to the railroad until the transfer has been completed and appropriately documented by both the shipper and railroad.
- A facility that is directly served by a railroad will be required to provide the following information to the carrier:
    - Acknowledgement that the facility has an appropriately designated Rail Secure Area,
    - The facility has designed and implemented procedures to ensure compliance with TSA chain-of-custody requirements effective as of February 15, 2009[45] (the requirements remain the same for rail-served sites handling HAZMAT),

  - If the facility has not established a Rail Secure Area or put chain-of-custody procedures in place, declare when it expects to complete these requirements and what interim measures are in place to ensure compliance in the meantime,
  - Without compliance with these measures, the railroad may refuse to perform switching services at the facility until the requirements are met, and
  - Proper and current contact information must be supplied, including company name, street address, phone number, and primary point of contact.
- There is no requirement to submit the Security Plan to the railroad for review or approval, but the shipper must inform the serving railroad that the plan exists.
- All of the above will apply to the SNF rail transload facility.

8.11. Provisions for Protection of In-Transit Road Shipments

Specific provisions for protection of in-transit road shipments of SNF are found in 10 CFR 73.37(c):

- Transportation vehicles must be accompanied by at least two individuals
  - One serving as an armed escort
  - A second armed member of the LLEA in a mobile unit or
  - Led by a separate vehicle occupied by at least one armed escort and trailed by a third vehicle occupied by at least one armed escort
- All armed escort are equipped with a minimum of two weapons (as permitted by law); however, this requirement does not apply to LLEA personnel who are performing escort duties.
- Transport and escort vehicles are equipped with redundant communication abilities that provide 2-way communications between the transport vehicle, the escort vehicle(s), the MCC, LLEA, and one another. To ensure that 2-way communication is possible at all times, alternate communications should not be subject to the same failure modes as the primary communication.
  - Escorts must have the ability to call for assistance when necessary
  - Escorts must be provided with a way to quickly develop new LLEA contacts and obtain new route information when unexpected detours become necessary
  - Escorts must be provided a way to coordinate the movement of transport and escort vehicles when more than one transport vehicle is used in the shipment
  - Escorts must be able to reach the emergency phone number provided on the approved route
- The transport vehicle must be equipped with NRC-approved features that permit immobilization of the cab or cargo-carrying portion of the vehicle with the purpose being to render the vehicle inoperable or incapable of movement under its own power. It must take at least 30 minutes to reverse the immobility once engaged.

- The transport vehicle driver must be trained with, and capable of implementing, the transport vehicle immobilization, communications, and other security procedures.
- Shipments must be continuously and actively monitored by a telemetric position monitoring system or an alternate tracking system reporting to a MCC.

The MCC shall:

- Provide positive confirmation of the location, status, and control over the shipment
- Implement preplanned procedures in response to deviations from the authorized routes, or
- Notification of actual, attempted, or suspicious activities related to the theft loss or diversion of a shipment.

These procedures must include contact information for the appropriate LLEA along the shipment route.

8.12. Provisions for Protection of In-Transit Rail Shipments

The following provisions are required for protection of in-transit rail shipments in accordance with 10 CFR 73.37(d):

- Loaded cars must be accompanied by two armed escorts.
- At least one escort is stationed on the train, permitting observation of the shipment car while in motion (generally, in an escort or security car).
- Each armed escort shall be equipped with a minimum of two weapons (as permitted by law, but does not apply to LLEA personnel performing guard duties)..
- The train operator(s) and each escort are equipped with redundant communication capabilities that provide 2-way communications between the transport, the escort vehicle(s), the MCC, local law enforcement agencies, and one another.
- To ensure that 2-way communication is possible at all times, alternate communications should not be subject to the same failure modes as the primary communication device.
- Rail shipments must be monitored by a telemetric position monitoring system or an alternate tracking system reporting to the licensee, third-party, or railroad MCC.
- The MCC shall provide positive confirmation of the location of the shipment and its status.
- The MCC shall implement preplanned procedures in response to deviations from the authorized route or to a notification of actual, attempted, or suspicious activities related to the theft, diversion, or radiological sabotage of a shipment.
- These procedures shall include, but not be limited to, the identification of and contact information for the appropriate LLEA along the shipment route.

8.13. Provisions for Protection of In-Transit Barge Shipments

Specific provisions for protection of in-transit barge shipments are found in 10 CFR 73.37(e) and include:

- A shipment vessel while docked at a U.S. port is protected by:

  - Two armed escorts stationed on board the shipment vessel, or stationed on the dock at a location that will permit observation of the shipment vessel; or
  - A member of a LLEA, equipped with normal local law enforcement agency radio communications, who is stationed on board the shipment vessel, or on the dock at a location that will permit observation of the shipment vessel.
- As permitted by law, all armed escorts are equipped with a minimum of two weapons. This requirement does not apply to LLEA personnel who are performing escort duties.
- A shipment vessel, while within U.S. territorial waters, shall be accompanied by an individual, who may be an officer of the shipment vessel's crew, who will assure that the shipment is unloaded only as authorized by the licensee.
- Each armed escort is equipped with redundant communication abilities that provide 2-way communications between the vessel, the movement control center, local law enforcement agencies, and one another. To ensure that 2-way communication is possible at all times, alternate communications should not be subject to the same failure modes as the primary communication.

Because the on-site loading facility from the Zion ISFSI to HHT is located on Lake Michigan, the following will apply, even though no transportation on the waterways is expected to occur:

- U.S. waters extend to 3 nautical miles from the U.S. land territory, except for small offshore islands.
- Security between 3 and 12 nautical miles from the coast falls under the responsibility of the USCG.
- If a U.S. port is used for transport, the licensee shall coordinate with both the USCG and local port authorities during a transport (or transload) operation to ensure that all parties are appropriately informed and to ensure the physical protection thereof[37].
- If an established port facility is used, protocols of that MTSA plan will be enforced to protect the shipment from any threat presented from the rail transfer site being located on water or adjacent to the water and provide protection against theft, diversion, or radiologic sabotage while located adjacent or next to the water.

Items requiring action for protection of transload sites (HHT to rail) near navigable waterways include:

- MTSA plan to be developed and implemented on the rail transfer site or updated for the loading activities if one already exists.
- Property to be fenced.
- Property to be lighted.
- Perimeter and fence line to be surveilled by a closed-circuit camera system.
- All personnel on a water-served site must obtain a TWIC.
- All personnel who are on duty will have the capability to delay or impede such acts as listed for the Security Plan and can request assistance promptly from LLEA responses forces and USCG.

- All provisions applicable to U.S. ports may apply to a private water-served site, including coordinating with USCG and local port authorities.

No HAZMAT vessels will be docked at the Zion site and therefore, the escort requirements in 10 CFR 73.37(e) will not apply to the shipment campaign.

9.0 EMERGENCY RESPONSE PLAN AND PREPAREDNESS

The purpose of the Emergency Response Plan (ERP) is to establish notification protocols and provide response guidance in the event of a reportable incident involving an HHT, rail , or barge shipment transporting HAZMAT. The ERP includes all pertinent contact and contingency information including specific contact names and phone numbers, as well as procedures in the event of an incident. These procedures encompass the requirements for providing and maintaining emergency information during transportation and at facilities where HAZMAT is loaded, stored, or otherwise handled during every phase of transportation. [1]

Emergency response information is required to be immediately available for use at all times when HAZMAT is present. It is also required to be immediately available to any Federal, State, or local government agency representative who responds to an incident or is investigating an incident (per 49 CFR 172.600(c)(1)&(2))[45].

9.1. General Guidance for an Emergency Response Plan

As required by 49 CFR 172.602, emergency response information must be provided that can be used in the mitigation of an incident involving hazardous materials and, as a minimum, must contain the following information:

- The basic description and technical name of the hazardous material;
- Immediate hazards to health;
- Risks of fire or explosion;
- Immediate precautions to be taken in the event of an accident or incident;
- Immediate methods for handling fires;
- Initial methods for handling spills or leaks in the absence of fire; and
- Preliminary first aid measures.

This information must be written in English and available for use away from the package and provided in an approved format such as shipping papers or a document containing all the relevant information that will be found in shipping papers[38].

This emergency response information is usually incorporated into an ERP. The ERP will include the emergency contact telephone number (per 49 CFR172.604) and this number:

- Must be monitored at all times the HAZMAT is in transportation, including storage incidental to transportation.
- Must be monitored by a "person who is either knowledgeable of the hazardous material being shipped and has comprehensive emergency response and incident mitigation information for that material or has immediate access to a person who possesses such knowledge and information."
- Must be entered on the shipping paper(s) immediately following the description of the hazardous material.

- Must be entered on the shipping paper(s) in a prominent, readily identifiable, and clearly visible manner.
- Must be the number of the person offering the hazardous material for transportation when that person is also the emergency response information provider, or the number of an agency or organization capable of and accepting responsibility for providing the detailed information.

All HAZMAT rail shippers are registered with CHEMTREC, or a similar company, to provide the above requirements. Shipper must make sure to provide CHEMTREC with current information on the material before it is offered for transportation.

As stated above, the purpose of the ERP is to establish notification and response guidance in the event of a reportable transportation incident involving a HHT or rail shipment that is transporting hazardous material. The plan would include information in compliance with 49 CFR 172.600 to 172.606 (i.e., Subpart G) and other federal, state, and local requirements and regulations and is intended to provide direction by identifying immediate measures to contain the situation and ensure safety and security until the LLEA and emergency response professionals arrive on the scene.

The emergency response procedures apply to persons who offer, accept, transfer, or otherwise handle HAZMAT during transportation. In this case, the procedures will apply to site operations at Zion, on-site HHT transport beginning with all transfer operations conducted at Zion to transfer the overpacks from the ISFSI to the transfer trailer for the on-site transport to the on-site rail siding (loop track). This includes all transload operations to place the overpacks onto the railcars, movement of the dedicated train from the rail transload facility along the entire route from CSEC to the final destination.

The security personnel accompanying the train will remain with the train for the entire train movement.

Each entity involved in each facet of the transportation operation will develop its own emergency response information and procedures commonly included in an ERP. The plan will be disseminated to the appropriate employees and the information will become part of the overall ecurity Plan for the licensee. Each entity on the project will have separate and individual procedures respective to its role, but they will be coordinated for the project to delineate hand-off procedures (interfaces) to clearly define responsibilities for each phase and participant. Note that the limitations of information dissemination as identified by 10 CFR 71.11 must be considered before sharing information concerning safety, security, and emergency response.

An example of the index for such a plan and the information to be included is listed below. This example index comes from a proprietary ERP (containing safeguards information) from a trucking company that is actively transporting HAZMAT. It is only intended to be an example of the potential contents of an ERP.

Section 1: Purpose & Scope
Section 2: Commitments, Company procedures, Title 49 CFR related material
Section 3: References – 49 CFR Part 172 (Subpart G), Hazardous Material Regulations First Notifications, Emergency Response Guidebook (latest edition issued by DOT), Condition Reports, Assistance with Radioactive Material Transportation

Incidents, Conference of Radiation Control Program Directors, Inc. (CRCPD) "CRCPD Notes," current edition

Section 4: General - Definitions of relevant terms: Emergency, Hazardous Material, Minor and Major Incident, Reportable Quantity, Responsibilities identified for the following employees: Manager of Compliance, Director of Radiation Safety, Transload Facility Drivers, Driver Incident packet with checklists, schematics, etc.

Section 5: Notification - Notification of Transportation Incidents, Minor and Reportable Incident Notification - definitions, Emergency Contact Phone Numbers for all Company (transload, etc.) employees including 24/7 contact numbers, Emergency Response Agencies for the jurisdictions in which the SNF is traveling, with requirements for notification and frequency, Emergency Contact Responsibilities

Section 6: Attachments -Incident Log, Checklist of notifications with internal and external notification contacts and contact numbers, Notifications and conditions for contacting the National Response Center and State Agencies, Blank incident logs indicating identifying incidents and resultant injuries, with room for documenting any damage, mode contact information is listed along with vehicle details and road location (for road), and any resulting drug tests.

9.2. Zion Site-Specific Considerations for the Emergency Response Plan

The MUA identified the highest ranked route for transporting the SNF and GTCC LLW from Zion to be a direct rail route, where the transportation casks would be directly loaded onto railcars. Since the Zion site is located on or adjacent to a U.S. waterway (Lake Michigan), it is assumed that MTSA requirements apply, in addition to the Rail Secure Area designation. These two sources of provisions would present a layered security approach for the operations involved in the loading campaign. As a result, some additional fencing would be required to enclose the rail transload area (the portion of the track where the train would be loaded).

The USCG is responsible for reviewing and approving the MTSA plan for operations conducted on any water-served site, including activities at the ISFSI and rail transload site, as it pertains to safety and security of the sites from the coastline. The respective COTPs from the Ninth USCG District would be involved in the assessment of the plan. This may include a request from the site for the USCG to establish a barrier or security zone around Zion while the on-site truck transport and rail transloading operations are conducted. The required notification would be given in writing to the serving railroad, UP, stating that the area meets the requirements of a "rail secure area" and contact information will be supplied to the railroad. There is no requirement, as stated earlier, for the railroad to approve the Security Plan.

Since Zion is located on Lake Michigan, weather forecasting should be consulted for loading and unloading operations to make sure any adverse weather events do not impact or interfere with the loading campaign. NOAA reports that the risk of tornado damage in Zion is lower than the IL average, but is higher than the national average. Snowfall is also higher in Zion than the rest of IL, with an average of 41"/year.

At this time, no formal determination has been made as to the applicability/jurisdiction of MTSA on the Zion site. Compliance with MTSA is recommended as a conservative approach to implementing a multi-tiered security plan.

The site Security Plan for Zion, as required by 10 CFR Part 73, is comprehensive and encompasses various protection measures for the vital areas of the site, including the ISFSI. This plan will include compliance with 10 CFR 73.55(e)(ii), which requires the licensee to identify areas from which a waterborne vehicle must be restricted and in coordination with local, State, and federal agencies having jurisdiction over waterway approaches, provide periodic surveillance and observation of waterway approaches and adjacent areas. Hence, any MTSA requirements for the site are presumed to become part of the overall Security Plan for the site.

10.0 RECOMMENDED NEXT STEPS

Based on the results of this study, the following recommendations are provided to support implementation of a future de-inventory program. These recommendations are listed in approximate order of when to be addressed (earliest to latest):

1. Conduct an engineering survey of the onsite path from the ISFSI to the loading area and evaluate the need for improvements to ensure acceptable conditions of transport exist. Consider the extent of the concrete roadway needed to be added/upgraded at the site to handle anticipated transportation activities, as well as grading improvements need on steep paths.
2. Prepare a listing of all miscellaneous equipment and services required to safely and efficiently perform the MAGNASTOR TSC transfers into the NAC MAGNATRAN transport cask and prepare the casks for off-site transport. Such equipment would include required measuring and test equipment (MT&E) and calibration services, radiological instrumentation and services, radioactive material control supplies, additional lighting to support operations, standard tooling, hydraulic torquing equipment, etc. The listing should also include identification of responsible party for procurement and maintenance of identified equipment.
3. The NAC MAGNASTOR TSCs and MAGNATRAN transport casks will need to be evaluated prior to transport to ensure 10 CFR Part 71 requirements are met. At a minimum, this will need to involve a comparison of the fabrication records against the CoC requirements and verification that the canister integrity has been maintained. It is recommended to allocate 2-3 years for this activity, which could involve a need to revise the CoC. In general, a complete transportability study consisting of a comparison of each transport cask and its contents in a transport configuration to the 10 CFR Part 71 CoC at the time the transport will be performed by the NRC licensee with the support of the transport cask CoC holder prior to transportation of each canister to be offered for transport.
4. Establish planned shipment date from the Zion ISFSI and verify:
    a. The CoC for the MAGNATRAN transport cask is still valid. NAC has confirmed that it fully intends to submit a timely renewal application for the MAGNATRAN 10 CFR Part 71 Certificate of Compliance, as required.
    b. The contents, as loaded in the MAGNASTOR TSCs are compliant to the applicable CoC requirements (e.g., dose and thermal transport limits are satisfied). MAGNASTOR CoC is valid to February 4, 2029 and NAC fully intends to submit a timely CoC renewal application to request a 40 year period of extended operation.
    c. Ability for permitting the transportation activities along the selected route(s).
5. Establish equipment needs for transportation:
    a. Procurement of the appropriate number of MAGNATRAN transport casks, associated impact limiters, cavity spacers, transport cradles, personnel barriers, and MTC and MAGNATRAN vertical lifting yokes, and horizontal lift beam.

b. Regarding the procurement of the ten required MAGNATRAN, and associated impact limiters, cavity spacers, transport cradles, personnel barriers, and vertical lifting yoke and horizontal lift beam, the following delivery times are estimated based on imposition of the 'Buy American' clause:

   i. If all MAGNATRAN transport cask casks are purchased from one US fabricator at one time and have not been previously procured for other de-inventory projects):

   - First two casks, 24 months after receipt of order
   - Next two casks, 28 months after receipt of order
   - Next two casks, 32 months after receipt of order
   - Next two casks, 36 months after receipt of order
   - Next two casks, 40 months after receipt of order.

These cask dates bound the supply dates for impact limiters, lifting equipment, auxiliary equipment, etc.

   ii. If foreign fabricators were allowed to be considered, dates would be shortened by at least two months for each delivery.

c. Design, procure and construct additional equipment and auxiliaries including TSC Handling and Transfer Facility pad, and Gantry Crane and Chain Hoist System (if used), MTC lift yoke, vacuum, leak test and helium backfill system, pressure drop test system, etc. Limiting schedule delivery date would be for the design and construction of the gantry crane and chain hoist system at 24 months, and TSC Handling and Transfer Facility pad at 18 months.

6. Establish the Zion ISFSI site operations related details, including electrical power requirements for performing operations and verify availability at the Zion ISFSI.
7. Determine the maximum height a MAGNATRAN transport cask can be lifted without impact limiters based on use of crane equipment meeting the requirements of MAGNASTOR CoC Technical Specification Section 4.4. However, if MAGNATRAN transport cask and MTC are lifted and handled utilizing single-failure-proof lifting and handling equipment in accordance with ANSI N14.6 and NUREG-0612, then there should not be an issue regarding MTC or MAGNATRAN lifting heights without requiring a drop analysis.
8. Establish if the TSC Handling and Transfer Facility pad can be placed on or adjacent to the current rail line outside the ISFSI perimeter fencing.
9. Establish the most efficient location for the upending and down-ending of the MAGNATRAN transport cask (e.g., on the railcar or on the ground).
10. Examine potential for optimizing (time, exposure, cost. etc.) the design of the transfer activities through the use of a gantry crane and chain hoist system.
11. Consult with appropriate regulatory authorities on the applicability of the MTSA and its requirements for ISFSI.

12. Due to the potential significant impacts of the conditions and assumptions used to determine the estimated costs associated with activities involving the rail shipment of transportation casks from the transload site to the GCUS site (i.e., cask consist transportation services costs, emergency response center operation costs, railcar maintenance services freight costs, and transportation cask maintenance and compliance costs), the development of more precise costs requires resolution to, or clarification of, the identified conditions and assumptions given in **Section 7.0**, as well as consideration of economies of scale and synergies associated with the de-inventory of multiple sites at the same or nearly same time, understanding of equipment (e.g., railcars and casks) ownership impact, and the need for a comprehensive breakdown of activities involved in these costs.

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Attachment A: Full Pairwise Comparison for the Tangible Metrics

Place a single "X" per line where you believe the importance of the metric in column A falls against the metric in column B.

Column A Metrics	Column A Strongly Favorable	Column A More Favorable	Column A Mildly Favorable	Neither Favorable (neutral)	Column B Mildly Favorable	Column B More Favorable	Column B Strongly Favorable	Column B Metrics
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Labor and Permitting Costs
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Cost of Rail Transport (e.g., costs associated with interchange activities)
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Impact of Weather to Route (e.g., limited availability of route or instability of weather)
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Number of Water Areas Nearby Route (e.g., number of bridges crossed)*
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Public Acceptability of Route
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Ease of Permit Procurement
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Number of Permits
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Number of Personnel involved in Transfer
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Cumulative Worker Exposure (α handling time & # of workers)
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Cumulative Population Dose along Route (α population density)*
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Risks Associated with Number of Lifting Activities
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Average Accident Frequency on Route*
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Number of Fire Stations & Trained Personnel Nearby Route*
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Transit Duration per Conveyance
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Size of conveyance (# of casks per shipment)
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Security Vulnerability of Route*
ISFSI Rental Equipment Costs (e.g., mobile cranes)								Number of Police Stations Nearby Route*
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Labor and Permitting Costs
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Cost of Rail Transport (e.g., costs associated with interchange activities)
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Impact of Weather to Route (e.g., limited availability of route or instability of weather)
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Number of Water Areas Nearby Route (e.g., number of bridges crossed)*
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Public Acceptability of Route
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Ease of Permit Procurement
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Number of Permits
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Number of Personnel involved in Transfer
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Cumulative Worker Exposure (α handling time & # of workers)
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Cumulative Population Dose along Route (α population density)*
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Risks Associated with Number of Lifting Activities
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Average Accident Frequency on Route*
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Number of Fire Stations & Trained Personnel Nearby Route*
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Transit Duration per Conveyance
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Size of conveyance (# of casks per shipment)
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Security Vulnerability of Route*
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)								Number of Police Stations Nearby Route*
Labor and Permitting Costs								Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)
Labor and Permitting Costs								Cost of Rail Transport (e.g., costs associated with interchange activities)
Labor and Permitting Costs								Impact of Weather to Route (e.g., limited availability of route or instability of weather)
Labor and Permitting Costs								Number of Water Areas Nearby Route (e.g., number of bridges crossed)*
Labor and Permitting Costs								Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*
Labor and Permitting Costs								Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*
Labor and Permitting Costs								Public Acceptability of Route
Labor and Permitting Costs								Ease of Permit Procurement
Labor and Permitting Costs								Number of Permits
Labor and Permitting Costs								Number of Personnel involved in Transfer
Labor and Permitting Costs								Cumulative Worker Exposure (α handling time & # of workers)
Labor and Permitting Costs								Cumulative Population Dose along Route (α population density)*
Labor and Permitting Costs								Risks Associated with Number of Lifting Activities
Labor and Permitting Costs								Average Accident Frequency on Route*
Labor and Permitting Costs								Number of Fire Stations & Trained Personnel Nearby Route*
Labor and Permitting Costs								Transit Duration per Conveyance
Labor and Permitting Costs								Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
Labor and Permitting Costs								Size of conveyance (# of casks per shipment)
Labor and Permitting Costs								Security Vulnerability of Route*
Labor and Permitting Costs								Number of Police Stations Nearby Route*

Place a single "X" per line where you believe the importance of the metric in column A falls against the metric in column B.

Column A Metrics	Column A Strongly Favorable	Column A More Favorable	Column A Mildly Favorable	Neither Favorable (neutral)	Column B Mildly Favorable	Column B More Favorable	Column B Strongly Favorable	Column B Metrics
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Cost of Rail Transport (e.g., costs associated with interchange activities)
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Impact of Weather to Route (e.g., limited availability of route or instability of weather)
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Number of Water Areas Nearby Route (e.g., number of bridges crossed)*
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Public Acceptability of Route
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Ease of Permit Procurement
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Number of Permits
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Number of Personnel involved in Transfer
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Cumulative Worker Exposure (α handling time & # of workers)
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Cumulative Population Dose along Route (α population density)*
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Risks Associated with Number of Lifting Activities
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Average Accident Frequency on Route*
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Number of Fire Stations & Trained Personnel Nearby Route*
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Transit Duration per Conveyance
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Size of conveyance (# of casks per shipment)
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Security Vulnerability of Route*
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)								Number of Police Stations Nearby Route*
Cost of Rail Transport (e.g., costs associated with interchange activities)								Impact of Weather to Route (e.g., limited availability of route or instability of weather)
Cost of Rail Transport (e.g., costs associated with interchange activities)								Number of Water Areas Nearby Route (e.g., number of bridges crossed)*
Cost of Rail Transport (e.g., costs associated with interchange activities)								Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*
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Cost of Rail Transport (e.g., costs associated with interchange activities)								Number of Permits
Cost of Rail Transport (e.g., costs associated with interchange activities)								Number of Personnel involved in Transfer
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Impact of Weather to Route (e.g., limited availability of route or instability of weather)								Average Accident Frequency on Route*
Impact of Weather to Route (e.g., limited availability of route or instability of weather)								Number of Fire Stations & Trained Personnel Nearby Route*
Impact of Weather to Route (e.g., limited availability of route or instability of weather)								Transit Duration per Conveyance
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Impact of Weather to Route (e.g., limited availability of route or instability of weather)								Security Vulnerability of Route*
Impact of Weather to Route (e.g., limited availability of route or instability of weather)								Number of Police Stations Nearby Route*

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Number of Water Areas Nearby Route (e.g., number of bridges crossed)*								Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*
Number of Water Areas Nearby Route (e.g., number of bridges crossed)*								Public Acceptability of Route
Number of Water Areas Nearby Route (e.g., number of bridges crossed)*								Ease of Permit Procurement
Number of Water Areas Nearby Route (e.g., number of bridges crossed)*								Number of Permits
Number of Water Areas Nearby Route (e.g., number of bridges crossed)*								Number of Personnel involved in Transfer
Number of Water Areas Nearby Route (e.g., number of bridges crossed)*								Cumulative Worker Exposure (α handling time & # of workers)
Number of Water Areas Nearby Route (e.g., number of bridges crossed)*								Cumulative Population Dose along Route (α population density)*
Number of Water Areas Nearby Route (e.g., number of bridges crossed)*								Risks Associated with Number of Lifting Activities
Number of Water Areas Nearby Route (e.g., number of bridges crossed)*								Average Accident Frequency on Route*
Number of Water Areas Nearby Route (e.g., number of bridges crossed)*								Number of Fire Stations & Trained Personnel Nearby Route*
Number of Water Areas Nearby Route (e.g., number of bridges crossed)*								Transit Duration per Conveyance
Number of Water Areas Nearby Route (e.g., number of bridges crossed)*								Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
Number of Water Areas Nearby Route (e.g., number of bridges crossed)*								Size of conveyance (# of casks per shipment)
Number of Water Areas Nearby Route (e.g., number of bridges crossed)*								Security Vulnerability of Route*
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Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*								Public Acceptability of Route
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Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*								Number of Permits
Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*								Number of Personnel involved in Transfer
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Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*								Cumulative Population Dose along Route (α population density)*
Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*								Risks Associated with Number of Lifting Activities
Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*								Average Accident Frequency on Route*
Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*								Number of Fire Stations & Trained Personnel Nearby Route*
Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*								Transit Duration per Conveyance
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Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*								Size of conveyance (# of casks per shipment)
Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*								Security Vulnerability of Route*
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Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*								Public Acceptability of Route
Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*								Ease of Permit Procurement
Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*								Number of Permits
Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*								Number of Personnel involved in Transfer
Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*								Cumulative Worker Exposure (α handling time & # of workers)
Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*								Cumulative Population Dose along Route (α population density)*
Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*								Risks Associated with Number of Lifting Activities
Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*								Average Accident Frequency on Route*
Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*								Number of Fire Stations & Trained Personnel Nearby Route*
Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*								Transit Duration per Conveyance
Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*								Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*								Size of conveyance (# of casks per shipment)
Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*								Security Vulnerability of Route*
Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*								Number of Police Stations Nearby Route*
Public Acceptability of Route								Ease of Permit Procurement
Public Acceptability of Route								Number of Permits
Public Acceptability of Route								Number of Personnel involved in Transfer
Public Acceptability of Route								Cumulative Worker Exposure (α handling time & # of workers)
Public Acceptability of Route								Cumulative Population Dose along Route (α population density)*
Public Acceptability of Route								Risks Associated with Number of Lifting Activities
Public Acceptability of Route								Average Accident Frequency on Route*
Public Acceptability of Route								Number of Fire Stations & Trained Personnel Nearby Route*
Public Acceptability of Route								Transit Duration per Conveyance
Public Acceptability of Route								Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
Public Acceptability of Route								Size of conveyance (# of casks per shipment)
Public Acceptability of Route								Security Vulnerability of Route*
Public Acceptability of Route								Number of Police Stations Nearby Route*

Place a single "X" per line where you believe the importance of the metric in column A falls against the metric in column B.

Column A Metrics	Column A Strongly Favorable	Column A More Favorable	Column A Mildly Favorable	Neither Favorable (neutral)	Column B Mildly Favorable	Column B More Favorable	Column B Strongly Favorable	Column B Metrics
Ease of Permit Procurement								Number of Permits
Ease of Permit Procurement								Number of Personnel involved in Transfer
Ease of Permit Procurement								Cumulative Worker Exposure (α handling time & # of workers)
Ease of Permit Procurement								Cumulative Population Dose along Route (α population density)*
Ease of Permit Procurement								Risks Associated with Number of Lifting Activities
Ease of Permit Procurement								Average Accident Frequency on Route*
Ease of Permit Procurement								Number of Fire Stations & Trained Personnel Nearby Route*
Ease of Permit Procurement								Transit Duration per Conveyance
Ease of Permit Procurement								Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
Ease of Permit Procurement								Size of conveyance (# of casks per shipment)
Ease of Permit Procurement								Security Vulnerability of Route*
Ease of Permit Procurement								Number of Police Stations Nearby Route*
Number of Permits								Number of Personnel involved in Transfer
Number of Permits								Cumulative Worker Exposure (α handling time & # of workers)
Number of Permits								Cumulative Population Dose along Route (α population density)*
Number of Permits								Risks Associated with Number of Lifting Activities
Number of Permits								Average Accident Frequency on Route*
Number of Permits								Number of Fire Stations & Trained Personnel Nearby Route*
Number of Permits								Transit Duration per Conveyance
Number of Permits								Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
Number of Permits								Size of conveyance (# of casks per shipment)
Number of Permits								Security Vulnerability of Route*
Number of Permits								Number of Police Stations Nearby Route*
Number of Personnel involved in Transfer								Cumulative Worker Exposure (α handling time & # of workers)
Number of Personnel involved in Transfer								Cumulative Population Dose along Route (α population density)*
Number of Personnel involved in Transfer								Risks Associated with Number of Lifting Activities
Number of Personnel involved in Transfer								Average Accident Frequency on Route*
Number of Personnel involved in Transfer								Number of Fire Stations & Trained Personnel Nearby Route*
Number of Personnel involved in Transfer								Transit Duration per Conveyance
Number of Personnel involved in Transfer								Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
Number of Personnel involved in Transfer								Size of conveyance (# of casks per shipment)
Number of Personnel involved in Transfer								Security Vulnerability of Route*
Number of Personnel involved in Transfer								Number of Police Stations Nearby Route*
Cumulative Worker Exposure (α handling time & # of workers)								Cumulative Population Dose along Route (α population density)*
Cumulative Worker Exposure (α handling time & # of workers)								Risks Associated with Number of Lifting Activities
Cumulative Worker Exposure (α handling time & # of workers)								Average Accident Frequency on Route*
Cumulative Worker Exposure (α handling time & # of workers)								Number of Fire Stations & Trained Personnel Nearby Route*
Cumulative Worker Exposure (α handling time & # of workers)								Transit Duration per Conveyance
Cumulative Worker Exposure (α handling time & # of workers)								Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
Cumulative Worker Exposure (α handling time & # of workers)								Size of conveyance (# of casks per shipment)
Cumulative Worker Exposure (α handling time & # of workers)								Security Vulnerability of Route*
Cumulative Worker Exposure (α handling time & # of workers)								Number of Police Stations Nearby Route*
Cumulative Population Dose along Route (α population density)*								Risks Associated with Number of Lifting Activities
Cumulative Population Dose along Route (α population density)*								Average Accident Frequency on Route*
Cumulative Population Dose along Route (α population density)*								Number of Fire Stations & Trained Personnel Nearby Route*
Cumulative Population Dose along Route (α population density)*								Transit Duration per Conveyance
Cumulative Population Dose along Route (α population density)*								Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
Cumulative Population Dose along Route (α population density)*								Size of conveyance (# of casks per shipment)
Cumulative Population Dose along Route (α population density)*								Security Vulnerability of Route*
Cumulative Population Dose along Route (α population density)*								Number of Police Stations Nearby Route*
Risks Associated with Number of Lifting Activities								Average Accident Frequency on Route*
Risks Associated with Number of Lifting Activities								Number of Fire Stations & Trained Personnel Nearby Route*
Risks Associated with Number of Lifting Activities								Transit Duration per Conveyance
Risks Associated with Number of Lifting Activities								Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
Risks Associated with Number of Lifting Activities								Size of conveyance (# of casks per shipment)
Risks Associated with Number of Lifting Activities								Security Vulnerability of Route*
Risks Associated with Number of Lifting Activities								Number of Police Stations Nearby Route*

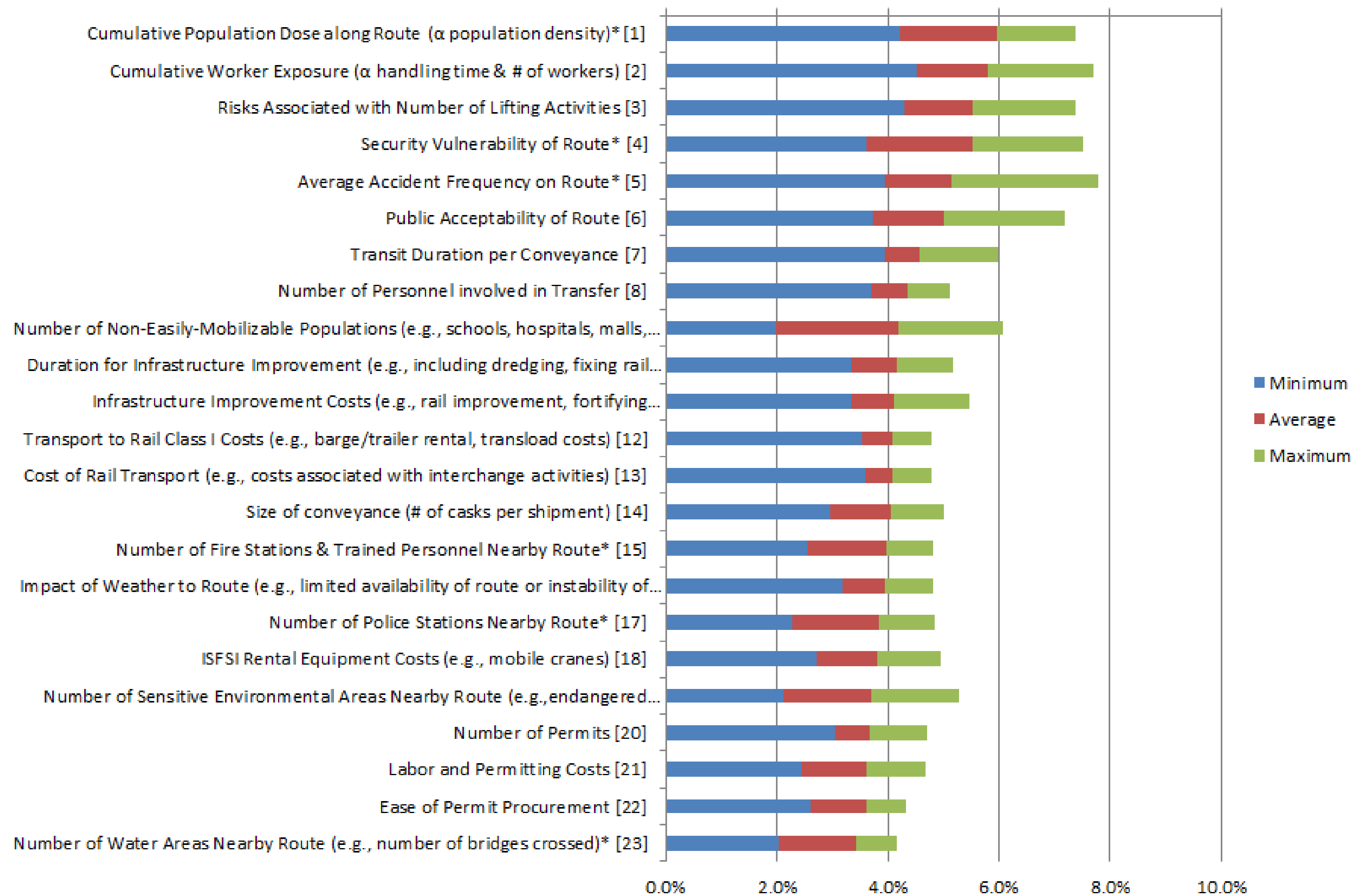
Place a single "X" per line where you believe the importance of the metric in column A falls against the metric in column B.

Column A Metrics	Column A Strongly Favorable	Column A More Favorable	Column A Mildly Favorable	Neither Favorable (neutral)	Column B Mildly Favorable	Column B More Favorable	Column B Strongly Favorable	Column B Metrics
Average Accident Frequency on Route*								Number of Fire Stations & Trained Personnel Nearby Route*
Average Accident Frequency on Route*								Transit Duration per Conveyance
Average Accident Frequency on Route*								Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
Average Accident Frequency on Route*								Size of conveyance (# of casks per shipment)
Average Accident Frequency on Route*								Security Vulnerability of Route*
Average Accident Frequency on Route*								Number of Police Stations Nearby Route*
Number of Fire Stations & Trained Personnel Nearby Route*								Transit Duration per Conveyance
Number of Fire Stations & Trained Personnel Nearby Route*								Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
Number of Fire Stations & Trained Personnel Nearby Route*								Size of conveyance (# of casks per shipment)
Number of Fire Stations & Trained Personnel Nearby Route*								Security Vulnerability of Route*
Number of Fire Stations & Trained Personnel Nearby Route*								Number of Police Stations Nearby Route*
Transit Duration per Conveyance								Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
Transit Duration per Conveyance								Size of conveyance (# of casks per shipment)
Transit Duration per Conveyance								Security Vulnerability of Route*
Transit Duration per Conveyance								Number of Police Stations Nearby Route*
Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)								Size of conveyance (# of casks per shipment)
Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)								Security Vulnerability of Route*
Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)								Number of Police Stations Nearby Route*
Size of conveyance (# of casks per shipment)								Security Vulnerability of Route*
Size of conveyance (# of casks per shipment)								Number of Police Stations Nearby Route*
Security Vulnerability of Route*								Number of Police Stations Nearby Route*

Attachment B: Results from the Twelve Individual's Pairwise Comparison for the Tangible Metrics

	Rater																											
	1		2		3		4		5		6		7		8		9		10		11		12		Average			
Metric	%	Ranking	%	Ranking	%	Ranking	%	Ranking	%	Ranking	%	Ranking	%	Ranking	%	Ranking	%	Ranking	%	Ranking	%	Ranking	%	Ranking	%	Ranking	Average	Metric
ISFSI Rental Equipment Costs (e.g., mobile cranes)	4.28%	12	3.36%	21	2.70%	22	3.92%	19	3.56%	18	3.26%	23	3.62%	19	3.39%	22	4.94%	6	4.18%	11	3.62%	16	4.68%	4	3.8%	18	16.1	ISFSI Rental Equipment Costs (e.g., mobile cranes)
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)	4.48%	10	3.75%	13	3.49%	15	3.92%	19	4.08%	14	3.59%	21	3.89%	15	3.33%	23	5.47%	4	4.41%	8	4.08%	13	4.68%	4	4.1%	11	13.3	Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)
Labor and Permitting Costs	3.13%	19	3.62%	18	2.44%	23	3.92%	19	3.06%	21	3.52%	22	3.69%	18	3.49%	21	4.35%	14	3.92%	16	3.62%	16	4.68%	4	3.6%	21	17.6	Labor and Permitting Costs
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)	4.31%	11	3.66%	16	3.72%	12	3.92%	19	4.35%	12	3.79%	18	3.99%	13	3.52%	20	4.78%	10	4.35%	9	4.02%	14	4.64%	7	4.1%	12	13.4	Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)
Cost of Rail Transport (e.g., costs associated with interchange activities)	4.12%	14	3.66%	16	3.66%	13	3.92%	19	4.22%	13	4.31%	7	3.99%	13	3.59%	19	4.78%	10	4.25%	10	3.92%	15	4.55%	8	4.1%	13	13.1	Cost of Rail Transport (e.g., costs associated with interchange activities)
Impact of Weather to Route (e.g., limited availability of route or instability of weather)	3.16%	17	4.15%	10	3.43%	16	4.25%	12	4.48%	11	3.99%	15	4.28%	9	4.35%	9	4.81%	8	3.26%	21	3.29%	18	3.95%	9	3.9%	16	12.9	Impact of Weather to Route (e.g., limited availability of route or instability of weather)
Number of Water Areas Nearby Route (e.g., number of bridges crossed)*	3.13%	19	3.72%	14	3.13%	21	4.15%	13	2.90%	22	3.72%	19	4.15%	11	3.89%	16	2.04%	22	3.23%	22	3.13%	21	3.95%	9	3.4%	23	17.4	Number of Water Areas Nearby Route (e.g., number of bridges crossed)*
Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*	4.18%	13	3.82%	11	3.66%	13	4.38%	10	2.73%	23	3.72%	19	4.35%	7	5.27%	4	2.11%	21	3.10%	23	3.13%	21	3.95%	9	3.7%	19	14.5	Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*
Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*	5.67%	4	6.06%	3	4.05%	9	4.84%	1	4.87%	8	3.85%	16	4.41%	5	3.85%	17	1.98%	23	3.33%	20	3.23%	19	3.95%	9	4.2%	9	11.2	Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*
Public Acceptability of Route	6.16%	3	4.87%	7	7.18%	4	4.81%	3	5.63%	3	3.85%	16	3.72%	17	5.99%	1	3.82%	16	4.12%	12	5.93%	3	3.95%	9	5.0%	6	7.8	Public Acceptability of Route
Ease of Permit Procurement	2.60%	23	3.23%	22	3.29%	18	3.99%	17	3.39%	19	4.31%	7	3.62%	19	4.12%	14	3.82%	16	3.89%	17	3.03%	23	3.95%	9	3.6%	22	17.0	Ease of Permit Procurement
Number of Permits	3.16%	17	3.03%	23	3.19%	20	3.99%	17	3.23%	20	4.71%	4	3.59%	22	4.12%	14	3.75%	18	4.12%	12	3.23%	19	3.95%	9	3.7%	20	16.3	Number of Permits
Number of Personnel involved in Transfer	3.92%	15	3.69%	15	4.02%	10	4.31%	11	5.01%	7	4.41%	6	4.41%	5	4.18%	13	4.28%	15	4.74%	5	5.11%	7	3.95%	9	4.3%	8	9.8	Number of Personnel involved in Transfer
Cumulative Worker Exposure (α handling time & # of workers)	4.97%	7	6.36%	1	7.08%	5	4.81%	3	5.80%	2	4.51%	5	6.16%	3	4.51%	8	4.68%	12	7.71%	1	6.52%	1	6.36%	1	5.8%	2	4.1	Cumulative Worker Exposure (α handling time & # of workers)
Cumulative Population Dose along Route (α population density)*	6.79%	1	6.16%	2	7.38%	1	4.81%	3	5.96%	1	4.22%	9	6.09%	4	4.91%	5	6.98%	2	6.46%	2	5.37%	4	6.36%	1	6.0%	1	2.9	Cumulative Population Dose along Route (α population density)*
Risks Associated with Number of Lifting Activities	5.43%	5	5.83%	5	7.38%	1	4.78%	8	5.14%	6	6.13%	2	6.29%	1	4.28%	11	4.81%	8	5.53%	3	5.99%	2	4.78%	3	5.5%	3	4.6	Risks Associated with Number of Lifting Activities
Average Accident Frequency on Route*	4.97%	7	5.40%	6	4.08%	7	4.81%	3	5.30%	5	4.02%	14	6.29%	1	5.80%	3	7.77%	1	4.05%	15	5.07%	8	3.95%	9	5.1%	5	6.6	Average Accident Frequency on Route*
Number of Fire Stations & Trained Personnel Nearby Route*	3.00%	21	4.58%	8	4.28%	6	4.81%	3	3.69%	17	4.05%	13	4.18%	10	4.64%	6	2.54%	19	3.52%	19	4.22%	10	3.95%	9	4.0%	15	11.8	Number of Fire Stations & Trained Personnel Nearby Route*
Transit Duration per Conveyance	4.78%	9	4.18%	9	4.08%	7	4.02%	14	4.74%	9	5.99%	3	4.08%	12	4.35%	9	5.73%	3	4.51%	6	4.22%	10	3.95%	9	4.6%	7	8.3	Transit Duration per Conveyance
Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)	5.07%	6	3.46%	20	3.33%	17	4.02%	14	3.95%	15	4.15%	11	4.31%	8	3.82%	18	4.41%	13	4.12%	12	5.17%	6	3.95%	9	4.1%	10	12.4	Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)
Size of conveyance (# of casks per shipment)	2.96%	22	3.79%	12	3.29%	18	4.02%	14	4.61%	10	4.22%	9	3.89%	15	4.22%	12	5.01%	5	4.51%	6	4.12%	12	3.95%	9	4.0%	14	12.0	Size of conveyance (# of casks per shipment)
Security Vulnerability of Route*	6.52%	2	6.06%	3	7.35%	3	4.78%	8	5.47%	4	7.51%	1	3.62%	19	5.83%	2	4.87%	7	4.94%	4	5.34%	5	3.95%	9	5.5%	4	5.6	Security Vulnerability of Route*
Number of Police Stations Nearby Route*	3.19%	16	3.56%	19	3.79%	11	4.84%	1	3.82%	16	4.15%	11	3.36%	23	4.55%	7	2.27%	20	3.75%	18	4.64%	9	3.95%	9	3.8%	17	13.3	Number of Police Stations Nearby Route*

Purple	Lowest Ranked
Red	Highest Ranked


Cumulative Population Dose along Route (α population density)* [1]
Cumulative Worker Exposure (α handling time & # of workers) [2]
Risks Associated with Number of Lifting Activities [3]
Security Vulnerability of Route* [4]
Average Accident Frequency on Route* [5]
Public Acceptability of Route [6]
Transit Duration per Conveyance [7]
Number of Personnel involved in Transfer [8]
Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls,...
Duration for Infrastructure Improvement (e.g., including dredging, fixing rail...
Infrastructure Improvement Costs (e.g., rail improvement, fortifying...
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs) [12]
Cost of Rail Transport (e.g., costs associated with interchange activities) [13]
Size of conveyance (# of casks per shipment) [14]
Number of Fire Stations & Trained Personnel Nearby Route* [15]
Impact of Weather to Route (e.g., limited availability of route or instability of...
Number of Police Stations Nearby Route* [17]
ISFSI Rental Equipment Costs (e.g., mobile cranes) [18]
Number of Sensitive Environmental Areas Nearby Route (e.g., endangered...
Number of Permits [20]
Labor and Permitting Costs [21]
Ease of Permit Procurement [22]
Number of Water Areas Nearby Route (e.g., number of bridges crossed)* [23]
0.0%
2.0%
4.0%
6.0%
8.0%
10.0%
Minimum
Average
Maximum

Attachment C: Full Pairwise Comparison for the Routes

Place a single "X" per line where you believe the importance of the metric for the route in column A falls against the same metric for the route in column B.

Metric	Column A Routes	Column A Strongly Favorable	Column A More Favorable	Column A Mildly Favorable	Neither Favorable (neutral)	Column B Mildly Favorable	Column B More Favorable	Column B Strongly Favorable	Column B Routes
ISFSI Rental Equipment Costs (e.g., mobile cranes)	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago			x					D. Barge Only
	A. UP only Rail around Chicago				x				E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield			x					D. Barge Only
	B. UP Alternate Rail through Springfield				x				E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago			x					D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago				x				E. Heavy Haul TruckOnly
	D. Barge Only					x			E. Heavy Haul TruckOnly
Infrastructure Improvement Costs (e.g., rail improvement, fortifying roads/bridges)	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago		x						D. Barge Only
	A. UP only Rail around Chicago				x				E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield		x						D. Barge Only
	B. UP Alternate Rail through Springfield				x				E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago		x						D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago				x				E. Heavy Haul TruckOnly
	D. Barge Only						x		E. Heavy Haul TruckOnly
Labor and Permitting Costs	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago			x					D. Barge Only
	A. UP only Rail around Chicago		x						E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield			x					D. Barge Only
	B. UP Alternate Rail through Springfield		x						E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago			x					D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago		x						E. Heavy Haul TruckOnly
	D. Barge Only			x					E. Heavy Haul TruckOnly
Transport to Rail Class I Costs (e.g., barge/trailer rental, transload costs)	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago			x					D. Barge Only
	A. UP only Rail around Chicago		x						E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield			x					D. Barge Only
	B. UP Alternate Rail through Springfield		x						E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago			x					D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago		x						E. Heavy Haul TruckOnly
	D. Barge Only			x					E. Heavy Haul TruckOnly

Metric	Column A Routes	Column A Strongly Favorable	Column A More Favorable	Column A Mildly Favorable	Neither Favorable (neutral)	Column B Mildly Favorable	Column B More Favorable	Column B Strongly Favorable	Column B Routes
Cost of Rail Transport (e.g., costs associated with interchange activities)	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago						x		D. Barge Only
	A. UP only Rail around Chicago						x		E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield						x		D. Barge Only
	B. UP Alternate Rail through Springfield						x		E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago						x		D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago						x		E. Heavy Haul TruckOnly
	D. Barge Only				x				E. Heavy Haul TruckOnly
Impact of Weather to Route (e.g., limited availability of route or instability of weather)	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago			x					D. Barge Only
	A. UP only Rail around Chicago			x					E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield			x					D. Barge Only
	B. UP Alternate Rail through Springfield			x					E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago			x					D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago			x					E. Heavy Haul TruckOnly
	D. Barge Only				x				E. Heavy Haul TruckOnly
Number of Water Areas Nearby Route (e.g., number of bridges crossed)*	A. UP only Rail around Chicago					x			B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago					x			C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago	x							D. Barge Only
	A. UP only Rail around Chicago						x		E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield	x							D. Barge Only
	B. UP Alternate Rail through Springfield						x		E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago	x							D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago						x		E. Heavy Haul TruckOnly
	D. Barge Only							x	E. Heavy Haul TruckOnly
Number of Sensitive Environmental Areas Nearby Route (e.g.,endangered species habitats)*	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago	x							D. Barge Only
	A. UP only Rail around Chicago			x					E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield	x							D. Barge Only
	B. UP Alternate Rail through Springfield			x					E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago	x							D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago			x					E. Heavy Haul TruckOnly
	D. Barge Only							x	E. Heavy Haul TruckOnly

Metric	Column A Routes	Column A Strongly Favorable	Column A More Favorable	Column A Mildly Favorable	Neither Favorable (neutral)	Column B Mildly Favorable	Column B More Favorable	Column B Strongly Favorable	Column B Routes
Number of Non-Easily-Mobilizable Populations (e.g., schools, hospitals, malls, stadiums, churchs)*	A. UP only Rail around Chicago		x						B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago						x		D. Barge Only
	A. UP only Rail around Chicago					x			E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield						x		C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield							x	D. Barge Only
	B. UP Alternate Rail through Springfield						x		E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago						x		D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago					x			E. Heavy Haul TruckOnly
	D. Barge Only			x					E. Heavy Haul TruckOnly
Public Acceptability of Route	A. UP only Rail around Chicago	x							B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago		x						D. Barge Only
	A. UP only Rail around Chicago		x						E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield						x		C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield			x					D. Barge Only
	B. UP Alternate Rail through Springfield			x					E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago		x						D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago		x						E. Heavy Haul TruckOnly
	D. Barge Only			x					E. Heavy Haul TruckOnly
Ease of Permit Procurement	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago				x				D. Barge Only
	A. UP only Rail around Chicago		x						E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield				x				D. Barge Only
	B. UP Alternate Rail through Springfield		x						E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago				x				D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago		x						E. Heavy Haul TruckOnly
	D. Barge Only			x					E. Heavy Haul TruckOnly
Number of Permits	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago				x				D. Barge Only
	A. UP only Rail around Chicago		x						E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield				x				D. Barge Only
	B. UP Alternate Rail through Springfield		x						E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago				x				D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago		x						E. Heavy Haul TruckOnly
	D. Barge Only			x					E. Heavy Haul TruckOnly

Metric	Column A Routes	Column A Strongly Favorable	Column A More Favorable	Column A Mildly Favorable	Neither Favorable (neutral)	Column B Mildly Favorable	Column B More Favorable	Column B Strongly Favorable	Column B Routes
Number of Personnel involved in Transfer	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago			x					D. Barge Only
	A. UP only Rail around Chicago				x				E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield			x					D. Barge Only
	B. UP Alternate Rail through Springfield				x				E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago			x					D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago				x				E. Heavy Haul TruckOnly
	D. Barge Only					x			E. Heavy Haul TruckOnly
Cumulative Worker Exposure (α handling time & # of workers)	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago			x					D. Barge Only
	A. UP only Rail around Chicago				x				E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield			x					D. Barge Only
	B. UP Alternate Rail through Springfield					x			E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago			x					D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago					x			E. Heavy Haul TruckOnly
	D. Barge Only					x			E. Heavy Haul TruckOnly
Cumulative Population Dose along Route (α population density)*	A. UP only Rail around Chicago			x					B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago					x			D. Barge Only
	A. UP only Rail around Chicago				x				E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield					x			C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield						x		D. Barge Only
	B. UP Alternate Rail through Springfield						x		E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago					x			D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago				x				E. Heavy Haul TruckOnly
	D. Barge Only			x					E. Heavy Haul TruckOnly
Risks Associated with Number of Lifting Activities	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago		x						D. Barge Only
	A. UP only Rail around Chicago		x						E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield		x						D. Barge Only
	B. UP Alternate Rail through Springfield		x						E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago		x						D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago		x						E. Heavy Haul TruckOnly
	D. Barge Only				x				E. Heavy Haul TruckOnly

Metric	Column A Routes	Column A Strongly Favorable	Column A More Favorable	Column A Mildly Favorable	Neither Favorable (neutral)	Column B Mildly Favorable	Column B More Favorable	Column B Strongly Favorable	Column B Routes
Average Accident Frequency on Route*	A. UP only Rail around Chicago			x					B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago			x					C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago			x					D. Barge Only
	A. UP only Rail around Chicago			x					E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield			x					D. Barge Only
	B. UP Alternate Rail through Springfield			x					E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago			x					D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago			x					E. Heavy Haul TruckOnly
	D. Barge Only			x					E. Heavy Haul TruckOnly
Number of Fire Stations & Trained Personnel Nearby Route*	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago			x					D. Barge Only
	A. UP only Rail around Chicago			x					E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield		x						D. Barge Only
	B. UP Alternate Rail through Springfield			x					E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago			x					D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago			x					E. Heavy Haul TruckOnly
	D. Barge Only				x				E. Heavy Haul TruckOnly
Transit Duration per Conveyance	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago		x						D. Barge Only
	A. UP only Rail around Chicago			x					E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield		x						D. Barge Only
	B. UP Alternate Rail through Springfield			x					E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago		x						D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago			x					E. Heavy Haul TruckOnly
	D. Barge Only					x			E. Heavy Haul TruckOnly
Duration for Infrastructure Improvement (e.g., including dredging, fixing rail line)	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago		x						D. Barge Only
	A. UP only Rail around Chicago				x				E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield		x						D. Barge Only
	B. UP Alternate Rail through Springfield				x				E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago		x						D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago				x				E. Heavy Haul TruckOnly
	D. Barge Only						x		E. Heavy Haul TruckOnly

Metric	Column A Routes	Column A Strongly Favorable	Column A More Favorable	Column A Mildly Favorable	Neither Favorable (neutral)	Column B Mildly Favorable	Column B More Favorable	Column B Strongly Favorable	Column B Routes
Size of conveyance (# of casks per shipment)	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago				x				D. Barge Only
	A. UP only Rail around Chicago		x						E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield				x				D. Barge Only
	B. UP Alternate Rail through Springfield		x						E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago				x				D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago		x						E. Heavy Haul TruckOnly
	D. Barge Only		x						E. Heavy Haul TruckOnly
Security Vulnerability of Route*	A. UP only Rail around Chicago			x					B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago			x					C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago				x				D. Barge Only
	A. UP only Rail around Chicago			x					E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield					x			C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield				x				D. Barge Only
	B. UP Alternate Rail through Springfield			x					E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago			x					D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago			x					E. Heavy Haul TruckOnly
	D. Barge Only			x					E. Heavy Haul TruckOnly
Number of Police Stations Nearby Route*	A. UP only Rail around Chicago				x				B. UP Alternate Rail through Springfield
	A. UP only Rail around Chicago				x				C. UP Alternate Rail through Springfield avoiding Chicago
	A. UP only Rail around Chicago			x					D. Barge Only
	A. UP only Rail around Chicago			x					E. Heavy Haul TruckOnly
	B. UP Alternate Rail through Springfield				x				C. UP Alternate Rail through Springfield avoiding Chicago
	B. UP Alternate Rail through Springfield		x						D. Barge Only
	B. UP Alternate Rail through Springfield			x					E. Heavy Haul TruckOnly
	C. UP Alternate Rail through Springfield avoiding Chicago			x					D. Barge Only
	C. UP Alternate Rail through Springfield avoiding Chicago			x					E. Heavy Haul TruckOnly
	D. Barge Only				x				E. Heavy Haul TruckOnly

Attachment D: Route Information from START for Zion

Route	HHT Distance (mi.)	Barge Distance (mi.)	Rail Distance (mi.)
A. Rail around Chicago direct to GCUS	0	0	336
B. Rail through Sterling and Springfield	0	0	384
C. Rail through Sterling and Springfield avoiding Chicago	0	0	364
D. Barge only avoiding Chicago going through Peoria	0	473	0
E. HHT Minimum Distance	336	0	0
F. Rail around Chicago through Champagne	0	0	340

Parameter	Route > Metric \/	A. UP rail (Around Chicago)	B. UP rail (Chicago, /Springfield)	C. UP rail (Springfield)	D. Barge only (around Chicago/ Peoria)	E. HHT only through Springfield	F. Start Generated Route
Total Dist. (mi)		336	384	364	473	336	340
Travel Time (hr/min)	Duration	9 hrs. 517 min	13 hrs. 773 min	12 hrs. 711 min.	68 hrs. 4051 min.	5 hrs. 304 min.	8 hrs. 500 min.
Accident Likelihood (per mile/year)	Accidents	0.000001	0.000002	0.000002	0.194686	0.309769	0.000001
Water Crossings	Acceptability	56	46	46	0	23	34
Average Track Class		3.6	3.0	3.1	N/A	N/A	3.6
Average Rail Traffic Density		4.0	3.0	3.3	N/A	N/A	4
Average Pop Density (/ mi^2)		964.1	1,985.9	1014.7	599.8	764.5	1,418
Total Population	Pop Dose	218,679	493,285	225,555	69,212	163,201	319,553
Mass Gathering Places	Pop Dose	148	427	164	78	62	252

Parameter	**Route >** **Metric** \/	A. UP rail (Around Chicago)	B. UP rail (Chicago, /Springfield)	C. UP rail (Springfield)	D. Barge only (around Chicago/ Peoria)	E. HHT only through Springfield	F. Start Generated Route
Tribal Lands (per mi^2)	Acceptability	0	0	0	0	0	0
Sensitive Environ. Area (/ mi^2)	Acceptability	5.83	5.71	6.48	25.43	9.13	6.6
Locks		N/A	N/A	N/A	8	N/A	N/A
Tunnels		0	0	0	0	0	0
Emergency Response Capability (/ mi^2)		0.28	0.33	0.27	0.08	0.08	0.35
Fire Departments (per mi^2)		0.14	0.17	0.13	0.03	0.05	0.19
Police (per mi^2)		0.12	0.13	0.11	0.05	0.03	0.15
Hospitals (per mi^2)		0.02	0.03	0.02	0	0	0.01

Parameter	**Route > Metric** V	A. UP rail (Around Chicago)	B. UP rail (Chicago, /Springfield)	C. UP rail (Springfield)	D. Barge only (around Chicago/ Peoria)	E. HHT only through Springfield	F. Start Generated Route
Educational Institutions (total)		123	255	120	32	60	175
Grammar Schools		120	241	114	30	56	168
Higher Education		3	14	6	2	4	7
Special Age Groups (total)		83	185	85	25	37	119
Day Care		60	153	60	21	27	95
Nursing Homes		23	32	25	4	10	24

Parameter	**Route > Metric** \/	A. UP rail (Around Chicago)	B. UP rail (Chicago, /Springfield)	C. UP rail (Springfield)	D. Barge only (around Chicago/ Peoria)	E. HHT only through Springfield	F. Start Generated Route
Railroad Crossings (total at grade)		520	680	520	0	19	455
Signs		40	75	76	0	0	7
Signals		82	38	38	0	0	42
No signs or signals		0	0	0	0	0	0
Both signs / signals		0	0	0	0	0	0
Unknown signs/signal		398	567	406	0	19	406