BMI/OTSP-07(S)
Distribution Category UC-820

BMI/OTSP--07(S)

DE90 005952

**Supplement to
MRS Systems Study,
Task F:
Transportation Impacts of a
Monitored Retrievable Storage Facility**

Technical Report

January 1990

**Office of Transportation Systems and Planning
Battelle Nuclear Systems Group
505 King Avenue
Columbus, Ohio 43201-2693**

This document is
PUBLICLY RELEASABLE

Larry E. Williams
Authorizing Official

Date: 11/21/2005

The content of this report was effective as of August 1989. This report was prepared by Battelle Nuclear Systems Group, Columbus, OH, under Contract No. DE-AC02-83CH10139 with the U.S. Department of Energy.

MASTER
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ACKNOWLEDGEMENTS

This report was prepared with the contributions and cooperation of a number of individuals. The main authors at Battelle Nuclear Systems Group were Diane Cattran, Helen Latham, John Mountain, and James Finley. Other contributors included Dave Kerr, Lee Ann Brentlinger, Larry Smith, Spyridon Tzemos, and Pamela Sutherland. The report was edited by Beatrice Weaver and Lynn Copley-Graves.

The authors would like to thank Christopher Kouts of the U.S. Department of Energy Office of Systems Integration and Regulations, Jeffrey B. Roberts and Judith Holm of the Chicago Transportation Program Office, and Mike Conroy from Weston for their direction and insightful reviews of this report.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ABSTRACT

The passage of the Nuclear Waste Policy Amendments Act of 1987 (NWPAA) modified the basis from which the Office of Civilian Radioactive Waste Management (OCRWM) had derived and developed the configuration of major elements of the waste system (repository, monitored retrievable storage, and transportation). While the key aspects of the Nuclear Waste Policy Act of 1982 remain unaltered, NWPAA provisions focusing site characterization solely at Yucca Mountain, authorizing a monitored retrievable storage (MRS) facility with specific linkages to the repository, and establishing an MRS Review Commission make it prudent for OCRWM to update its analysis of the role of the MRS in the overall waste system configuration.

This supplement provides an analysis of the operational considerations of a monitored retrievable storage facility and is based on the report entitled MRS Systems Study, Task F: Transportation Impacts of a Monitored Retrievable Storage (MRS) Facility (BMI/OTSP-07).

FOREWORD

The National Waste Terminal Storage Program was established in 1976 by the U.S. Energy Research and Development Administration. In September 1983, this program became the Civilian Radioactive Waste Management Program. Its purpose is to develop technology and provide facilities for safe, environmentally acceptable, permanent disposal of high-level waste (HLW). HLW includes wastes from both commercial and defense sources, such as spent (used) fuel from nuclear power reactors, accumulations of wastes from production of nuclear weapons, and solidified wastes from fuel processing.

The information in this report pertains to the monitored retrievable storage system studies of the Office of Systems Integration and Regulations of the Office of Civilian Radioactive Waste Management.

TABLE OF CONTENTS

	<u>Page</u>
1.0 INTRODUCTION	1
2.0 BACKGROUND	3
3.0 OPERATIONAL CONSIDERATIONS	5
3.1 ROUTING AND MODAL SPLIT	5
3.2 EMERGENCY RESPONSE	8
3.3 INSPECTION AND ENFORCEMENT	9
3.4 PRENOTIFICATION	9
3.5 DOSE	10
3.6 COSTS	11
3.7 OTHER OPERATIONAL PARAMETERS	11
4.0 MAPS AND CHARTS FOR SELECTED OPERATIONAL PARAMETERS	17
5.0 REFERENCES	45

LIST OF TABLES

	<u>Page</u>
Table 3-1. Transportation Operational Considerations of a Monitored Retrievable Storage Facility	6
Table 3-2. Transportation Dose and Costs for the Four MRS Cases	10
Table 3-3. Transportation Measurements for the Four MRS Cases	13
Table 3-4. Number of Rail Interchanges for the Four MRS Cases	15
Table 4-1. Number of Shipments and Average Per-Shipment MTU From MRS	18

LIST OF FIGURES

Figure 4-1. Shipment-Miles With No MRS for Each 77.5-MTU Spent Fuel Shipment	20
Figure 4-2. Shipment-Miles With Eastern MRS Without Western Strategy for Each 77.5-MTU Spent Fuel Shipment (Store Only)	21
Figure 4-3. Shipment-Miles With Eastern MRS With Western Strategy for Each 77.5-MTU Spent Fuel Shipment (Store Only)	22
Figure 4-4. Shipment-Miles With Western MRS for Each 77.5-MTU Spent Fuel Shipment (Store Only)	23
Figure 4-5. Shipment-Miles With No MRS for Each 126-MTU Spent Fuel Shipment (Consolidate and Canister)	24
Figure 4-6. Shipment-Miles With Eastern MRS Without Western Strategy for Each 126-MTU Spent Fuel Shipment (Consolidate and Canister)	25
Figure 4-7. Shipment-Miles With Eastern MRS With Western Strategy for Each 126-MTU Spent Fuel Shipment (Consolidate and Canister)	26
Figure 4-8. Shipment-Miles With Western MRS for Each 126-MTU Spent Fuel Shipment (Consolidate and Canister)	27
Figure 4-9. Shipment-Miles With No MRS for Each 42.8-MTU Spent Fuel Shipment (Containerize Intact Spent Fuel)	28
Figure 4-10. Shipment-Miles With Eastern MRS Without Western Strategy for Each 42.8-MTU Spent Fuel Shipment (Containerize Intact Spent Fuel)	29

LIST OF FIGURES
(Continued)

	<u>Page</u>
Figure 4-11. Shipment-Miles With Western MRS for Each 42.8-MTU Spent Fuel Shipment (Containerize Intact Spent Fuel)	30
Figure 4-12. Shipment-Miles With No MRS for Each 56.1-MTU Spent Fuel Shipment (Consolidate and Containerize)	31
Figure 4-13. Shipment-Miles With Eastern MRS Without Western Strategy for Each 56.1-MTU Spent Fuel Shipment (Consolidate and Containerize)	32
Figure 4-14. Shipment-Miles With Western MRS for Each 56.1-MTU Spent Fuel Shipment (Consolidate and Containerize)	33
Figure 4-15. No MRS: Rail and Truck Shipping Distances and Number of Shipments	34
Figure 4-16. Eastern MRS (Store Only) Without Western Strategy: Rail and Truck Shipping Distances and Number of Shipments	35
Figure 4-17. Eastern MRS (Store Only) With Western Strategy: Rail and Truck Shipping Distances and Number of Shipments	36
Figure 4-18. Western MRS (Store Only): Rail and Truck Shipping Distances and Number of Shipments	37
Figure 4-19. Eastern MRS (Consolidate and Canister) Without Western Strategy: Rail and Truck Shipping Distances and Number of Shipments	38
Figure 4-20. Eastern MRS (Consolidate and Canister) With Western Strategy: Rail and Truck Shipping Distances and Number of Shipments	39
Figure 4-21. Western MRS (Consolidate and Canister): Rail and Truck Shipping Distances and Number of Shipments	40
Figure 4-22. Eastern MRS (Containerize Intact Spent Fuel) Without Western Strategy: Rail and Truck Shipping Distances and Number of Shipments	41
Figure 4-23. Western MRS (Containerize Intact Spent Fuel): Rail and Truck Shipping Distances and Number of Shipments	42
Figure 4-24. Eastern MRS (Consolidate and Containerize) Without Western Strategy: Rail and Truck Shipping Distances and Number of Shipments	43
Figure 4-25. Western MRS (Consolidate and Containerize): Rail and Truck Shipping Distances and Number of Shipments	44

1.0 INTRODUCTION

This supplement provides an analysis of the operational considerations of a monitored retrievable storage facility and is based on the report entitled MRS Systems Study, Task F: Transportation Impacts of a Monitored Retrievable Storage (MRS) Facility (BMI/OTSP-07). That report assumed that all from-MRS shipments would be by dedicated train. Its major findings were

- Two MRS cases result in lower spent fuel transportation costs compared to the no-MRS system. They are an Eastern MRS storage-only system with a Western strategy¹ and an Eastern MRS consolidate-and-canister system with or without a Western strategy.
- In all other MRS cases, the spent fuel transportation costs are higher than for the no-MRS system.
- Costs are less to ship high-level waste (mostly defense) directly to the repository than to ship it through an Eastern or Western MRS.
- The radiation dose to the public from transporting spent fuel, which already is very low, can be reduced an additional 30 to 45 percent with an Eastern MRS.
- An MRS that consolidates and canisters fuel has less transportation cost and radiological dose than an MRS that stores only.

This supplement refers to text and tables in the Task F report to analyze 12 transportation operational considerations as they are affected by the following MRS cases:

- No MRS
- Eastern MRS with a Western strategy
- Eastern MRS without a Western strategy
- Western MRS.

The 12 transportation operational considerations are routing and modal split, emergency response, inspection and enforcement, prenotification, dose, transportation costs, number of shipments, shipment-miles, MTU-miles, cask-miles, cask-days in transit, and number of rail interchanges.

---

¹ A Western strategy is defined in the Task F report as having reactors west of 100 degrees longitude ship most spent fuel directly to the repository. Although Task F assumes concurrent startup dates for the MRS and the repository, the Western strategy does not begin until 5 years after startup. Therefore, any shipments from Western reactors during the first 5 years are assumed to be transported to the MRS. The 12 Western reactors are listed on page 4 of the Task F report.

Included in this supplement are a background section (Chapter 2), a discussion of the 12 transportation operational considerations for the four MRS cases (Chapter 3), and maps and charts that show the number of shipments, shipment-miles, and differences between rail and truck modes for the various cases (Chapter 4). Chapter 5 lists the references cited within.

2.0 BACKGROUND

The U.S. Department of Energy's original MRS proposal identified improvements and benefits that would result from having an MRS in the transportation system (DOE, 1987, p. 24). That proposal stated, for example, that an MRS would introduce greater certainty into transportation planning and significantly reduce the number of shipments to the repository. The distances over which spent fuel would be shipped by less efficient truck casks would be reduced, as would the number of cross-country shipping routes. Early identification of transportation routes to the MRS site would increase the time available to work with State and local governments, Indian Tribes, and the general public in resolving route-specific planning issues and planning for emergency preparedness.

The Nuclear Waste Policy Act of 1982 (NWPA) as amended in 1987 established an MRS Review Commission to determine the need for an MRS and specified that the Secretary of Energy may not select an MRS site until a repository site is recommended to the President.¹ Linking the MRS to the repository schedule removes some of the advantages originally envisioned for the MRS. Further, any delays in site characterization or the licensing process at the Yucca Mountain site will delay the MRS siting. The Task F report assumes concurrent startup dates for the MRS and the repository, as does the material in this supplement.

---

¹ A negotiator-selected MRS site is not limited to the repository development schedule.

3.0 OPERATIONAL CONSIDERATIONS

This chapter discusses 12 operational considerations as they relate to four MRS cases: no MRS, an Eastern MRS with a Western strategy, an Eastern MRS without a Western strategy, and a Western MRS. The 12 operational considerations are considered in the following order in Sections 3.1 through 3.7: routing and modal split, emergency response, inspection and enforcement, prenotification, dose, transportation costs, number of shipments, shipment-miles, MTU-miles, cask miles, cask-days in transit, and number of rail interchanges. This information is summarized in Table 3-1. The following discussion provides additional details on these operational considerations.

3.1 ROUTING AND MODAL SPLIT

Because of related elements, including alternative route designation, emergency response planning, prenotification, inspection and enforcement, and infrastructure needs, routing will be a major operational consideration regardless of whether there is an MRS or where it is ultimately located. Routing is "probably the single most important and complex institutional issue in shipping because it is a primary concern of citizens and public officials," according to a report entitled Analysis of Institutional Issues and Lessons Learned from Recent Spent Nuclear Fuel Shipping Campaigns (OTSP, 1988).

The number of rail and truck routes that could be considered in the East versus the West is impacted by the MRS location and strategy. If there is no MRS, there would be more long-distance shipments by truck than by train to the repository. Having more trucks on cross-country shipments, given that most of the reactors are in the East, would tend to heighten waste transportation visibility in Western corridor States and increase required interactions with States, Tribes, and local governments. With regard to routing and modal split, the Western MRS case would be very similar to the no-MRS case.

With an MRS in the East, the number of local jurisdictions traversed in the East would probably remain similar to the no-MRS case. However, the number of jurisdictions traversed in the West would be reduced because of the use of dedicated train shipments on the MRS-to-repository leg. An MRS would be more likely to ship more casks in each shipment, thereby reducing the number of long-haul trains from East to West. This would increase the proportion of the waste being moved by train, decrease routing options for the MRS-to-repository leg, and simplify planning.

With an MRS in the East with a Western strategy, truck use would be regional, be confined mostly to the Eastern states, and cover shorter distances. There would be a single rail route from an Eastern MRS to the repository. With a Western strategy, waste from Western reactors would go directly to the repository.

An Eastern MRS without a Western strategy would have some of those advantages (e.g., dedicated trains from the MRS to the repository), but there

Table 3-1. Transportation Operational Considerations of a Monitored Retrievable Storage Facility (Page 1 of 2)

Eastern MRS				
	No MRS	With Western Strategy	Without Western Strategy	Western MRS
Routing/Modal Split	• More cross-country shipments • More trucks on cross-country shipments; greater visibility and complex logistics • No impact on from-reactor modal split	• Single rail route from MRS to repository • More short shipments in Eastern region; increased routing complexities • Fewer and larger cross-country shipments • Fewer State border crossings • Greater proportion of waste can be moved by train • Federal jurisdiction clearer with use of rail (i.e., no parallel to HM-164 for highway) • Shorter distances mean truck shipments possibly less visible and complex • No impact on from-reactor modal split • Additional shipments caused by MRS to repository leg	• Single rail route from MRS to repository • More long shipments from West to Eastern MRS; increased routing complexities • Long cross-country shipments from Western reactors • Additional State border crossings compared to Western strategy • No benefit to Western States of controlled "national" route • Dedicated train use for MRS to repository • Greater proportion of waste can be moved by train in West • Federal jurisdiction clearer with use of rail (i.e., no parallel to HM-164 for highway) • Fewer long-distance shipments by truck means possibly less visible and complex • No impact on from-reactor modal split • Additional shipments caused by MRS to repository leg	• Single rail route from MRS to repository likely • More cross-country shipments • Additional shipments caused by MRS to repository leg • No benefit to Western States of controlled "national" route • More trucks on cross-country shipments; greater visibility and complex logistics • No impact on from-reactor modal split
Emergency Response	• Largest number of miles traveled increases accident potential • More cross-country routes may require more interactions with States and Tribes to address planning and training requirements	• Fewer cross-country routes may require fewer interactions with States and Tribes	• More cross-country routes than with Western strategy may require more interactions with States and Tribes	• More cross-country routes may require more interactions with States and Tribes
Inspection and Enforcement	• More potential routes could require more inspection and enforcement interactions due to more State border crossings	• Fewer potential routes could require fewer inspection and enforcement interactions due to fewer State border crossings	• More cross-country potential routes than with Western strategy could require more inspection and enforcement interactions due to more State border crossings, although use of trains could reduce	• More potential routes could require more inspection and enforcement interactions due to more State border crossings
Prenotification	• Possibly more notifications required due to more State border crossings	• Possibly fewer notifications required due to fewer State border crossings	• Possibly more notifications required than with Western strategy due to more State border crossings	• Possibly more notifications required due to more State border crossings
Dose	• In any case, dose is very low • Larger radiological dose to population along routes	• In any case, dose is very low • Smallest radiological dose to population along route	• In any case, dose is very low • Radiological dose to population along route larger than with Western strategy	• In any case, dose is very low • Radiological dose to population along routes equal to or slightly less than no-MRS case

Table 3-1. Transportation Operational Considerations of a Monitored Retrievable Storage Facility (Page 2 of 2)

	Eastern MRS			
	No MRS	With Western Strategy	Without Western Strategy	Western MRS
Transportation Costs	• Middle case in transportation costs • Less costly than a Western MRS • More costly than an Eastern MRS that consolidates and canisters with or without a Western strategy	• MRS in East, with or without a Western strategy, that consolidates and canisters is least expensive • MRS in East with a Western strategy that stores only is significantly less expensive than the other two MRS cases	• MRS in East, with or without a Western strategy, that consolidates and canisters is least expensive • MRS in East without Western strategy that stores only is about equal to or slightly more costly than no MRS or MRS with Western strategy	• Western MRS is more costly than the no-MRS system
Number of Shipments	• Slightly fewer number of shipments than any MRS case	• Little difference in number of shipments between Eastern, with or without Western strategy, and Western MRS	• Little difference in number of shipments between Eastern, with or without Western strategy, and Western MRS	• Little difference in number of shipments between Eastern and Western MRS
Shipment-miles	• Largest number of shipment-miles	• Eastern MRS that stores only or consolidates and canisters has lowest number of shipment-miles	• Eastern MRS without Western strategy results in more shipment-miles than with Western strategy but fewer than no MRS or Western MRS	• Mid-case: more shipment-miles than Eastern MRS but fewer than no MRS
MTU-miles	• Fewest number of MTU-miles	• Fewer MTU-miles than Eastern MRS without a Western strategy and more MTU-miles than Western MRS	• Most MTU-miles	• Mid-case: fewer MTU-miles than Eastern but more than no-MRS case
Cask-miles	• Largest number of cask-miles	• Significantly fewest cask-miles	• Fewer cask-miles than no MRS or Western MRS cases	• Mid-case: slightly fewer cask-miles than no MRS, more than Eastern MRS
Cask-days in Transit	• More days in transit than all cases, except with Western MRS that containerizes intact spent fuel or consolidates and containerizes	• Significantly fewer days in transit than any other case	• Fewer days in transit than no MRS or Western MRS cases	• Significantly more days in transit than either Eastern MRS case. Fewer days than no-MRS case when MRS stores only or consolidates and canisters
Rail Interchanges	• Middle case in number of rail interchanges	• Fewest number of rail interchanges	• Highest number of rail interchanges when it stores only, but is second lowest when consolidates and canisters	• Second highest in number of rail interchanges

would be several other considerations. A greater proportion of the waste could be moved to the West by train, meaning there would be fewer long-distance truck shipments. However, there would be more long shipments from reactors in the West to the Eastern MRS, increased routing complexities, and additional border crossings, which could lead to additional stops for inspection (see discussion in Section 3.3).

Different operational concerns relate to rail use. The absence of Federal routing criteria and no requirement to involve States in designating routes can cause public concern.¹ Mainline rail routes usually go through population centers, while trucks move on the outerbelts of interstate highways. There are concerns about infrastructure conditions (e.g., track, bridges, and tunnels) and the effects of severe weather on those facilities, especially in the West. Also, there are questions about where rail interchange points will be located and the potential for delays at such points.

Whether to move the waste by truck or train is an important transportation decision that is affected by the MRS cases, both logistically and in terms of cost. The presence or absence of an MRS in a waste disposal system has essentially no impact on from-reactor modal split. For from-MRS shipments, it would be clearly advantageous to ship by train if the MRS is in the East, thus effectively eliminating the need for cross-country truck shipments. Train shipments from an MRS in the East would travel along one clearly defined route, simplifying emergency response planning, inspection, and prenotification.²

3.2 EMERGENCY RESPONSE

Emergency planning and preparedness are major transportation-related concerns of State, Tribal, and local governments for a waste management system with or without an MRS. Section 180(c) of the NWPA, as amended, authorizes DOE to provide technical assistance and funding to States to train local and Tribal public safety officials in jurisdictions through which the waste is transported for both routine operations and emergency response. Emergency response is closely related to the issue of routing because the number and length of routes affects the number of interactions needed with States, Tribes, and local officials to address planning and training requirements.

In the no-MRS case, more cross-country routes may require more interactions with States and Tribes to address planning and training requirements.

---

¹ There is no Federal counterpart for rail transportation to HM-164 for highway routing. HM-164 provides that motor carriers select from "preferred" highway routes defined as including interstates or beltways and State-designated alternative highway routes selected in accordance with a DOT or equivalent routing analysis that adequately considers overall risk to the public.

² Figures 4-15 through 4-25 compare the transportation mode and distance in terms of total number of shipments for the repository lifetime for the various MRS locations and packaging configurations.

The same statement can be made for the Western MRS case because most reactors are in the East and would require cross-country shipments to a Western MRS. The significantly larger number of miles traveled (shipment-miles) for the no-MRS case could increase the number of communities and jurisdictions involved and possibly increase the training requirements to a level higher than any other case.

With an MRS in the East with a Western strategy, there would be fewer cross-country shipments and routes, hence fewer interactions with States, Tribes, and local governments. The number of shipment-miles is also related to emergency response because it affects accident potential (i.e., the larger the number of shipment-miles, the greater the accident potential).

3.3 INSPECTION AND ENFORCEMENT

Inspection and enforcement are considerations that increase in complexity as more State borders and jurisdictions are crossed, thereby increasing the potential for multiple inspections. It appears that the case requiring the fewest inspection and enforcement interactions as a result of the fewest State border crossings would be the Eastern MRS with a Western strategy. An Eastern MRS with a Western strategy could have the fewest routes because of the use of a single cross-country rail route on the MRS-to-repository leg, and therefore could require the fewest inspection and enforcement interactions.

For the no-MRS case, more potential long shipments could require more inspection and enforcement interactions as a result of more State border crossings. The Western-MRS case would also have longer, mostly cross-country shipments requiring more complex interactions. An Eastern MRS without a Western strategy would require more inspection and enforcement interactions than an Eastern MRS with a Western strategy because of the increased number of State border crossings, although the use of larger dedicated train shipments for the cross-country routes could simplify some inspection and enforcement interactions.

3.4 PRENOTIFICATION

Prenotification also increases in complexity with an increase in the number of State border crossings required. The current DOE policy is to prenotify designated representatives of States and Tribes prior to nuclear waste shipments, and the NHPA as amended requires DOE to follow U.S. Nuclear Regulatory Commission (NRC) rules regarding State and local government prenotification for the civilian program.

As in inspection and enforcement, it appears that the case that would require the fewest prenotifications as a result of the fewest State border crossings would be the Eastern MRS with a Western strategy. An Eastern MRS with a Western strategy could have fewer routes because of the use of a single cross-country rail route on the MRS-to-repository leg, and therefore could require fewer prenotifications.

For the no-MRS case, more potential routes and smaller shipments could require more prenotification interactions because there are more State border

crossings. The Western MRS would be similar to the no-MRS case. An Eastern MRS without a Western strategy would have more cross-country routes and require more prenotification interactions than an Eastern MRS with a Western strategy as a result of more State border crossings, although the use of larger shipments for the cross-country routes could simplify the prenotification interactions.

3.5 DOSE

The Task F report findings (Brentlinger et al., 1989) indicate that any additional dose to the population along routes during the projected 24-year shipment of spent fuel to the MRS or repository would be quite low--a few millirem per person--regardless of the MRS case considered. However, the largest radiological dose to the population along the routes would occur if there were no MRS. Every MRS case results in a lower dose, particularly the Eastern-MRS cases, as shown in Table 3-2. If the MRS is sited in the East with a Western strategy, the dose is reduced by nearly half compared to the no-MRS case.

Table 3-2. Transportation Dose and Costs for the Four MRS Cases*

	No MRS	Eastern MRS With Western Strategy	Eastern MRS Without Western Strategy	Western MRS
Dose (Person-rem)	2,600	1,500	1,600	2,500
Costs (\$ million)	832	741	835	896

* Store-only case. Consolidate-and-canister case numbers are somewhat lower. See Tables 12 and 13 of the Task F report.

Table 12 of the Task F report indicates that the total transportation dose for all spent fuel transportation cases considered would vary from 1,400 to 2,600 person-rem.¹ The population living along the transportation routes would receive that total. Since hundreds of thousands of people live along the transportation routes, the dose to an individual would be quite low. For perspective, the average dose from natural background radiation to each individual in the United States is about 0.1 rem per year. Natural background radiation is estimated to cause 5,000 latent-cancer fatalities per year. By contrast, the dose from transporting spent fuel directly to the repository might result in about 0.02 additional latent-cancer fatality per year.

¹ A rem is a measurement of the effects of a dose of radiation on human tissue. A millirem is one-thousandth of a rem.

3.6 COSTS

The Task F report indicates that transportation costs¹ would vary significantly depending upon whether there is an MRS in the system, what its functions are, where it is located, and whether there is a Western strategy.

Transportation costs for the no-MRS case rank in the middle among the four cases. The no-MRS transportation costs would be less than any other case except an MRS in the East that consolidates and canisters the waste, or an MRS in the East with a Western strategy that stores the waste (see Table 12 of the Task F report). The Eastern MRS with a Western strategy that consolidates and canisters is about 25 percent less costly than the no-MRS case.

A Western MRS is the most costly for two MRS packaging function cases, i.e., when it stores only (see Table 3-2) or consolidates and canisters. The Western MRS is less costly than an Eastern MRS when it consolidates and containerizes or containerizes intact spent fuel.

Between the Eastern MRS cases, the less costly is an Eastern MRS with a Western strategy. Slightly more costly is an Eastern MRS without a Western strategy.

3.7 OTHER OPERATIONAL PARAMETERS

Other operational parameters, such as number of shipments, shipment-miles, MTU-miles, cask-miles, cask-days in transit, and number of rail interchanges, are measures of transportation activity and can affect public attitudes toward transportation risk.² The perception is that risk increases with the number of shipments, the quantity of waste being moved, the number of days the waste is in transit, or the number of interchanges that occur. The public perception of risk could be reduced by reducing those factors. These terms are defined as follows:

- Shipment. The movement of one or more casks as a unit from an origination to a destination. For example, three casks moving in a train from a reactor to the repository would be considered as one shipment.
- Number of shipments. A simple count of shipments, regardless of the number or size of casks in each shipment or the mode of transport.

---

1 Transportation costs include the cost of hauling the waste, plus capital, maintenance, inspection, and security.

2 Non-radiological accident risk was not specifically addressed in the Task F report. The report addresses only the potential radiological dose to the population along the route.

- Shipment-mile. The number of shipments from each facility multiplied by the one-way distance to an MRS or repository. Three shipments each moving 150 miles would incur a total of 450 shipment-miles.
- MTU-mile. The quantity of fuel (metric tons uranium) shipped from each facility multiplied by the one-way distance to an MRS or repository. Three casks each carrying 10 MTU of spent fuel and moving 150 miles would incur a total of 4,500 MTU-miles.
- Cask-mile. The quantity of fuel shipped from each facility multiplied by the one-way distance from the facility to an MRS or repository. Three casks each moving 150 miles would incur a total of 450 cask-miles.
- Cask-day in transit. The number of days a loaded cask takes to move from a facility to an MRS or repository. Three casks each taking 5 days from origin to destination would incur a total of 15 cask-days in transit.
- Rail interchanges. The number of rail interchanges is the number of times that a railroad accepts a shipment from a reactor, an MRS, or another railroad for transportation to a destination.

From an operational perspective, all of these measurements are reflections of some aspect of transportation activity. The various elements that affect cost and risk depend on a variety of factors working in conjunction. There is some value, however, in disaggregating some of these factors into simple, single-factor weighted measures of transportation activity.

Number of shipments is the simplest indicator of nuclear waste transportation activity. It is an unweighted count of total shipments. Some cost elements, notably rail hauling cost, are largely dependent on the number of miles a shipment travels, so a distance-weighted factor (shipment-miles) is a rough indicator of hauling cost. (Hauling cost is only one cost parameter. Others include capital, maintenance, inspection, and security.)

Dose is more dependent on the total number of casks moving than on the number of shipments. Therefore, a factor indicating the number of miles traveled by all the casks (cask-miles) is a rough indicator of dose. Dose is dependent on exposure time as well as on the cask-miles traveled. Some cost elements, for example, cask capital cost and cask maintenance cost, depend on how long a cask is used. Therefore, measures of the time involved in cask trips and shipments are also of interest. These are given by cask-days in transit.

Having a measure of shipping activity that does not depend on shipping modes allows overall comparison of the various MRS locations. MTU-miles is such an indicator.

Several summary evaluations can be drawn from the Task F report. The number of cask-miles and shipment-miles is identical for truck transport because one cask per shipment is assumed. For rail transport from reactors,

the number of cask-miles is three times the number of shipment-miles because three rail casks per shipment are assumed. Similarly, for rail transport from an MRS, the number of cask-miles is five times the number of shipment-miles since five rail casks per shipment are assumed.

The no-MRS and generic Western-MRS systems result in similar estimates of total volume of transportation activity in all but one measurement--MTU-miles. The similarities can be seen in Table 3-3. However, comparison of transportation activity for the no-MRS and Eastern-MRS/Western strategy cases reveals a more noticeable difference. In this comparison, the store-only MRS function is assumed. Results show about a 3 percent increase in the total number of shipments for the Eastern MRS system. While the number of from-reactor shipments is equal in both cases, use of the Eastern MRS as an intermediate point en route to the repository means additional shipments are required to haul the spent fuel cross country to the presumed repository site at Yucca Mountain. However, by using an Eastern MRS with a Western strategy, most cross-country truck transport is eliminated and the number of cross-country shipments is decreased.

Table 3-3. Transportation Measurements for the Four MRS Cases*

	No MRS	Eastern MRS with Western Strategy	Eastern MRS Without Western Strategy	Western MRS
Number of Shipments	23,836	24,635	24,649	24,649
Shipment-Miles (x1000)	54,235	20,151	25,951	49,847
MTU-Miles (x1000)	148,685	216,617	242,403	173,591
Cask-Miles (x1000)	60,685	30,893	37,777	57,464
Cask-Days in Transit	65,627	34,913	42,033	65,139

* Store-only function. See Table 14 in the Task F report for other functions.

Compared with the no-MRS case, the number of shipments increases somewhat with an Eastern MRS, but the number of shipment-miles decreases by about 63 percent and the number of cask-miles decreases by about 50 percent. This decrease reflects the elimination of cross-country truck transport and the use of larger capacity casks with more casks per shipment in the from-MRS hauling of spent fuel. Table 3-3 also shows that MTU-miles increase by roughly 63 percent with an Eastern MRS/Western strategy system versus the no-MRS case. The Eastern MRS/Western strategy has the fewest number of cask-days in transit.

Measurement of miles in cask-miles, shipment-miles, and MTU-miles does not specifically indicate whether the mileage is accumulated along a single

route or multiple routes. In addition, these measurements do not specify the number of States involved in the shipping program or the population characteristics or number of stops along the routes. Discussions of the advantages of a frequently traveled rail route through a minimum number of States with a minimum number of stops (which is one argument for the Eastern MRS versus no MRS) can be in part supported by estimates of reduced cask-miles and shipment-miles, but go beyond the information provided by these measurements. Additional details about each of these measurements are provided below.¹

- Number of shipments. The Task F report (see Table 3-3, above) estimates that there will be slightly fewer spent fuel shipments without an MRS than with either an Eastern or Western MRS. There is little difference in the number of shipments between an Eastern MRS, with or without a Western strategy, and a Western MRS.
- Shipment-miles. With an MRS in the system, the number of shipment-miles decreases because larger rail casks can be used and multiple casks can be combined into single shipments, resulting in more waste being carried per shipment-mile. The fewest shipment-miles result when there is an Eastern MRS with a Western strategy, significantly fewer than an Eastern MRS without a Western strategy. A Western MRS results in fewer shipment-miles than the no-MRS case, but considerably more than either of the Eastern-MRS cases. Because shipment-miles is a rough indicator of hauling cost, the Eastern MRS with a Western strategy has the lowest hauling cost.
- MTU-miles. The no-MRS case results in the fewest MTU-miles, followed by a Western MRS and the Eastern MRS with a Western strategy. The Eastern MRS without a Western strategy ranks highest in MTU-miles.
- Cask-miles. An Eastern MRS with a Western strategy would result in significantly fewer cask-miles than the no-MRS case, which would cause the highest number of cask-miles. An Eastern MRS without a Western strategy would have somewhat more cask-miles than the Eastern MRS with a Western strategy and significantly fewer cask-miles than the Western-MRS case. The Western MRS would result in slightly fewer cask-miles than the no-MRS case, but more than either of the Eastern MRS cases. Cask-miles is a rough indicator of dose, and the Eastern MRS with Western strategy has the lowest number of cask-miles (see Table 3-3) and the smallest radiological dose (see Table 3-2).
- Cask-days in transit. Both the no-MRS case and the Western-MRS case would result in very similar numbers of cask-days in transit, and the numbers would be considerably higher than the

---

¹ Figures 4-1 through 4-25 show the number of shipments, shipment-miles, and differences between rail and truck modes for the four MRS cases.

number for either of the Eastern-MRS cases. As indicated in Table 14 of the Task F report, the lowest number of cask-days in transit would occur if there were an Eastern MRS with a Western strategy that consolidates and canisters. The number for that case would be more than 50 percent less than the no-MRS case. The no-MRS case results in more cask-days in transit than any other case except for a Western MRS that containerizes intact spent fuel or consolidates and containerizes.

- Number of rail interchanges. Most rail shipments will require interchanges between railroads because the reactors, MRS, and repository will likely be served by different railroads. These interchanges are potential sources of delay and public concern. The addition of an MRS to the transportation system would require additional spent fuel to be handled by rail (because it would be transferred from trucks to trains at the MRS) but would also allow larger rail casks and more casks per shipment to be used between the MRS and the repository than could be used between the reactors and the repository in the no-MRS case. On balance, the total number of rail interchanges would generally be reduced if an MRS is used, even when the additional spent fuel transferred from trucks at the MRS is considered. Table 3-4 shows the approximate number of rail interchanges of the Task F configuration.

Table 3-4. Number of Rail Interchanges for the Four MRS Cases

	No MRS	Eastern MRS With Western Strategy	Eastern MRS Without Western Strategy	Western MRS
Store only	4,347	4,278	4,445	4,365
Consolidate & canister	4,347	3,417	3,506	3,739

Note: This table includes all rail shipments from MRS, including those that arrive at the MRS by truck. Assumptions can be found in the Task F report; in particular, modal service at each reactor (Table 6), cask capacities (Tables 9 and 10), spent fuel acceptance schedule and total MTU shipped (Tables 2, 3, and 4).

Compared to the no-MRS case, the number of railroad interchanges required for shipments is the same or fewer if an MRS is added to the system. An Eastern MRS with or without a Western strategy that consolidates and canisters fuel would reduce the number of railroad interchanges by about 20 percent, while a Western MRS with consolidation and canistering would reduce the number of railroad interchanges by about 15 percent.

4.0 MAPS AND CHARTS FOR SELECTED OPERATIONAL PARAMETERS

Figures 4-1 through 4-25 provide visual representations of the number of shipments, shipment-miles, and differences between rail and truck modes for the various location/packaging configurations.

The maps in Figures 4-1 through 4-14 show the number and length of shipments required to move a specified amount of spent fuel (the equivalent of one MRS shipment) for the four MRS cases. The maps allow comparison of the no-MRS case, the Eastern MRS, the Eastern MRS with a Western strategy, and the Western MRS for each of the four MRS packaging functions. The four packaging functions are store only, consolidate and canister, containerize intact spent fuel, and consolidate and containerize. They appear in the following order:

- No MRS (Figure 4-1)
- Eastern MRS without Western strategy (store only) (Figure 4-2)
- Eastern MRS with Western strategy (store only) (Figure 4-3)
- Western MRS (store only) (Figure 4-4)
- No MRS (consolidate and canister) (Figure 4-5)
- Eastern MRS without Western strategy (consolidate and canister) (Figure 4-6)
- Eastern MRS with Western strategy (consolidate and canister) (Figure 4-7)
- Western MRS (consolidate and canister) (Figure 4-8)
- No MRS (containerize intact spent fuel) (Figure 4-9)
- Eastern MRS without Western strategy (containerize intact spent fuel) (Figure 4-10)
- Western MRS (containerize intact spent fuel) (Figure 4-11)
- No MRS (consolidate and containerize) (Figure 4-12)
- Eastern MRS without Western strategy (consolidate and containerize) (Figure 4-13)
- Western MRS (consolidate and containerize) (Figure 4-14).

The following assumptions were used in preparing the generic maps in Figures 4-1 through 4-14:

- Spent fuel shipments only
- Generic Eastern and Western MRS locations
- Task F report cask and mileage assumptions.

The data for Figures 4-1 through 4-14 were derived from information presented in Tables 2, 3, 4, 17, and 18 of the Task F report. The maps show the total shipment-miles obtained in transporting the same amount of spent fuel from reactors to the repository under several MRS location options for each packaging function.

The amount of fuel transported in each case is equivalent to an average MRS-to-repository shipment and calculated by dividing the total amount of fuel transported from the MRS by the number of MRS-to-repository shipments. Table 4-1 shows the average per-shipment MTU from the MRS that can be calculated as a function of total MTU and number of shipments.

Table 4-1. Number of Shipments and Average Per-Shipment MTU From MRS

Packaging Configuration	Number of Shipments (Given total 63,000 MTU)	Average Per-Shipment MTU
Consolidate and Canister	500	126
Store Only	813	77.5
Consolidate and Containerize	1,123	56.1
Containerize Intact Spent Fuel	1,472	42.8

The total MTU carried in one shipment from an MRS to the repository is a convenient basis for comparing the no-MRS case to the Eastern MRS, Eastern MRS/Western strategy, and Western MRS cases. The total MTU carried from the MRS is the same for all of the cases except for the Eastern MRS with a Western strategy (Figures 4-3 and 4-7). With the Eastern MRS/Western strategy, there are fewer total shipments from the MRS because some shipments go directly from the reactors to the repository. For example, with the consolidate and canister function at the MRS, there would be 500 from-MRS shipments when all reactors ship to the MRS. With the Eastern MRS/Western strategy most of the Western reactor fuel would go directly to the repository so that there would be fewer from-MRS shipments. There would be the same total number of from-reactor shipments; therefore, the number of from-reactor shipments (from Eastern reactors to MRS plus from Western reactors to repository) per MRS shipment is greater with the Western strategy.

Because the basis for each figure is one MRS shipment, the same number of metric tons of uranium are shipped from the reactors to the MRS (77.5 MTU in Figures 4-2 and 4-3 or 126 MTU in Figures 4-6 and 4-7). However, the population of reactors is different because in the Western strategy very little fuel is shipped from the Western reactors to the MRS. The elimination of Western reactors from the population of reactors shipping to the MRS results in a greater proportion of rail-served reactors shipping to the MRS.

Since rail cask capacity is about 7 times greater than the truck cask capacity, fewer from-reactor shipments are needed to meet the fixed from-MRS shipment size. As a result, Figure 4-2 shows 30 from-reactor shipments to carry 77.5 MTU to the MRS, while Figure 4-3 shows only 28 shipments to carry the same 77.5 MTU. Similarly, the number of from-reactor to MRS shipments drops from 48 in Figure 4-6 to 46 in Figure 4-7.

Two cases are not shown in these maps--an Eastern MRS with a Western strategy that containerizes intact spent fuel and an Eastern MRS with a Western strategy that consolidates and containerizes spent fuel. These are not shown because the Task F report assumes that the repository would not duplicate a containerization capability already at an MRS. Therefore, fuel from the Western reactors would be processed through the MRS.

Figures 4-15 through 4-25 are charts depicting the number of shipments and distances by mode (rail and truck) for the 11 MRS packaging function/location cases used throughout the Task F report. These are as follows:

- No MRS (Figure 4-15)
- Eastern MRS store only (Figure 4-16)
- Eastern MRS with Western strategy store only (Figure 4-17)
- Western MRS store only (Figure 4-18)
- Eastern MRS consolidate and canister (Figure 4-19)
- Eastern MRS with Western strategy consolidate and canister (Figure 4-20)
- Western MRS consolidate and canister (Figure 4-21)
- Eastern MRS containerize intact spent fuel (Figure 4-22)
- Western MRS containerize intact spent fuel (Figure 4-23)
- Eastern MRS consolidate and containerize (Figure 4-24)
- Western MRS consolidate and containerize (Figure 4-25).

These charts represent the assumed 24-year life of the shipping campaign to the first repository. In general, for the no-MRS and Western-MRS cases, there are more long-distance shipments for both truck and rail, while for the Eastern-MRS cases there are more short-distance shipments.

Figure 4-1. Shipment-Miles With No MRS for Each 77.5-MTU Spent Fuel Shipment

Notes: Assume consolidate and canister MRS packing function.
 Assume generic Eastern MRS location.

**Figure 4-2. Shipment-Miles With Eastern MRS Without Western Strategy
 for Each 77.5-MTU Spent Fuel Shipment
 – Store Only**

Notes: Assume consolidate and canister MRS packing function.
Assume generic Eastern MRS location.

**Figure 4-3. Shipment-Miles With Eastern MRS With Western Strategy
for Each 77.5-MTU Spent Fuel Shipment
– Store Only**

Note: Assume generic Western MRS location.

Figure 4-4. Shipment-Miles With Western MRS for Each 77.5-MTU Spent Fuel Shipment – Store Only

Figure 4-5. Shipment-Miles With No MRS for Each 126-MTU Spent Fuel Shipment
– Consolidate and Canister

Notes: Assume consolidate and canister MRS packing function.
Assume generic Eastern MRS location.

**Figure 4-6. Shipment-Miles With Eastern MRS Without Western Strategy
for Each 126-MTU Spent Fuel Shipment
– Consolidate and Canister**

Notes: Assume consolidate and canister MRS packing function.
 Assume generic Eastern MRS location.

**Figure 4-7. Shipment-Miles With Eastern MRS With Western Strategy
 for Each 126-MTU Spent Fuel Shipment
 – Consolidate and Canister**

Note: Assume generic Western MRS location.

Figure 4-8. Shipment-Miles With Western MRS for Each 126-MTU Spent Fuel Shipment – Consolidate and Canister

Figure 4-9. Shipment-Miles With No MRS for Each 42.8-MTU Spent Fuel Shipment – Containerize Intact Spent Fuel

Notes: Assume consolidate and canister MRS packing function.
 Assume generic Eastern MRS location.

**Figure 4-10. Shipment-Miles With Eastern MRS Without Western Strategy
 for Each 42.8-MTU Spent Fuel Shipment
 – Containerize Intact Spent Fuel**

Note: Assume generic Western MRS location.

Figure 4-11. Shipment-Miles With Western MRS for Each 42.8-MTU Spent Fuel Shipment – Containerize Intact Spent Fuel

Figure 4-12. Shipment-Miles With No MRS for Each 56.1-MTU Spent Fuel Shipment – Consolidate and Containerize

Notes: Assume consolidate and canister MRS packing function.
 Assume generic Eastern MRS location.

**Figure 4-13. Shipment-Miles With Eastern MRS Without Western Strategy
 for Each 56.1-MTU Spent Fuel Shipment
 – Consolidate and Containerize**

Note: Assume generic Western MRS location.

Figure 4-14. Shipment-Miles With Western MRS for Each 56.1-MTU Spent Fuel Shipment – Consolidate and Containerize

Figure 4-15. No MRS: Rail and Truck Shipping Distances and Number of Shipments

Figure 4-16. Eastern MRS (Store Only) Without Western Strategy: Rail and Truck Shipping Distances and Number of Shipments

Figure 4-17. Eastern MRS (Store Only) With Western Strategy: Rail and Truck Shipping Distances and Number of Shipments

* Early Western reactor shipments to MRS, prior to repository acceptance of spent fuel directly from reactors. (See footnote on page 1 of this supplement.)

Figure 4-18. Western MRS (Store Only): Rail and Truck Shipping Distances and Number of Shipments

Figure 4-19. Eastern MRS (Consolidate and Canister) Without Western Strategy: Rail and Truck Shipping Distances and Number of Shipments

Figure 4-20. Eastern MRS (Consolidate and Canister) With Western Strategy: Rail and Truck Shipping Distances and Number

* Early Western reactor shipments to MRS, prior to repository acceptance of spent fuel directly from reactors. (See footnote on page 1 of this supplement.)

Figure 4-21. Western MRS (Consolidate and Canister): Rail and Truck Shipping Distances and Number of Shipments

Figure 4-22. Eastern MRS (Containerize Intact Spent Fuel) Without Western Strategy: Rail and Truck Shipping Distances and Number of Shipments

Figure 4-23. Western MRS (Containerize Intact Spent Fuel): Rail and Truck Shipping Distances and Number of Shipments

Figure 4-24. Eastern MRS (Consolidate and Containerize) Without Western Strategy: Rail and Truck Shipping Distances and Number of Shipments

Figure 4-25. Western MRS (Consolidate and Containerize): Rail and Truck Shipping Distances and Number of Shipments

5.0 REFERENCES

Brentlinger, L. A., S. Gupta, A. M. Plummer, L. A. Smith, and S. Tzemos, 1989. MRS Systems Study, Task F: Transportation Impacts of a Monitored Retrievable Storage Facility, BMI/OTSP-07, Office of Transportation Systems and Planning, Battelle, Columbus, OH.

Office of Transportation Systems and Planning, 1988. Analysis of Institutional Issues and Lessons Learned From Recent Spent Nuclear Fuel Shipping Campaigns (1983-1987), BMI/OTSP-03, Battelle, Columbus, OH.

OTSP, see Office of Transportation Systems and Planning.

Task F Report, see Brentlinger et al., 1989.

U.S. Department of Energy, 1987. Monitored Retrievable Storage Submission to Congress; Vol. 1, The Proposal, DOE/RW-0035/1, Washington, DC, p. 24.