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RISK ANALYSIS FOR SPENT NUCLEAR FUEL TRANSPORTATION THROUGH ESMERALDA COUNTY
Highway Route

UNLV/TRC/RR-95/10

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EXECUTIVE SUMMARY

This report documents activities and findings of a transportation risk analysis conducted by the University of Nevada, Las Vegas (UNLV) Transportation Research Center (TRC) for Esmeralda County under subcontract to Intertech Services Corporation. The objective of this study was to perform a risk analysis for the potential transport of Spent Nuclear Fuel (SNF) by highway through Esmeralda County. Specifically, for the risk analysis, the current version of RADTRAN, a computerized risk assessment tool, has been used to evaluate the radiological impacts for shipments of radioactive materials along the highway routes through Esmeralda County. The analyses were performed using data reflecting local conditions with respect to population and highway operating characteristics.

The Department of Energy (DOE, 1984) had conducted a preliminary cost and risk analysis for transporting spent fuel and high level wastes to candidate repository sites nationwide, using RADTRAN II. One of the objectives of this TRC study for Esmeralda County was to compare the results of the DOE study with estimates of risk for Esmeralda County using RADTRAN IV, the current version of the code. To facilitate a comparative analysis it was necessary to update the DOE analysis. For this purpose, the DOE study was replicated using RADTRAN IV, but with the same input parameters as in the 1984 DOE study. For the Esmeralda County analysis, the same input parameters used by DOE were adopted except the population density and the transportation system characteristics, which are specific to the County.

Key input parameters identified during the course of the study include the demographic and the transportation system characteristics. An evaluation of data revealed differences in these parameters between the data used by the DOE and those representative of Esmeralda County. The transportation system characteristics, primarily accident data, differed for the DOE and the County. Esmeralda County had a higher accident rate when compared to nationwide average figures. Also, the nationwide transportation system characteristics are different when compared to that of the county. The type of roads used for the shipments across the nation will include major interstate freeways with four or more lanes. However, the potential highway route considered in Esmeralda County is a two lane highway.

The population density within an 800m corridor of the route in Esmeralda County was obtained from the 1990 Bureau of Census data. A GIS environment was used for processing this data. The variation in population density along the proposed route was estimated using ARC/INFO, a specific GIS program. The demographic characteristics of the County were found to be different from those of the country as a whole. Consequently the fraction of travel (an input parameter dependent on the population density distribution) in each of the population zones (rural, suburban and urban) would be different for the County when compared to the nationwide data. For example, the fraction/percent travel in the rural zone was 98.1 percent for Esmeralda County, whereas it was 83.7 percent for the DOE analysis.

The scenarios considered for analysis were identified based on the accident rates on the highway system in Esmeralda County. Two cases identified for analysis were: a) Average Accident Rate; and b) Worst Case (highest accident rate). These two scenarios are adequate to analyze the risks, and could be considered to represent the average and upper bound of risks based on accident rates. The accident rates per vehicle kilometer travelled were estimated using accident and traffic data obtained from the Nevada Department of Transportation.

Three available output options of RADTRAN were evaluated: a) Aggregate Analysis, b) Route Specific Analysis and c) Unit Risk Factors. The DOE (1984) report documented results in terms of unit risk factors in each of the three population zones. Hence, this approach, along with the route specific analysis was adopted to conduct the study for Esmeralda County. The output obtained in terms of the unit risk factors was compared with that of the DOE study. Also, total risk was calculated from the unit risk factors based on the procedure outlined in the RADTRAN IV User Guide (1992). Thus, a comparison was obtained for the two scenarios for the highway mode with that of the DOE study.

Preliminary findings show that the rural segments of Esmeralda County are exposed to greater risks than the nation as a whole for highway shipments of SNF. This could be attributed to the differences in the demographic and transportation system characteristics of Esmeralda County as compared to national average. In the incident free scenario, while the total (unit) risk is not affected, the distribution of risk is different for Esmeralda County when compared to results presented by the DOE for a nationwide analysis. The rural zones account for a higher proportion of risks in Esmeralda County. In the Accident Scenario, Esmeralda County is expected to experience risks significantly higher than those reported in the 1984 DOE study.

Some policy, strategic planning, design and operations related issues that could be addressed by the County for risk management have been listed in the conclusions and recommendations section of this report. These include importance of stops, location and duration of stops, and infrastructure characteristics. Crew and stops account for the most significant component of risks (expressed in terms person-rems of exposure). Design and operational considerations include a detailed evaluation of enhancing safety on the two-lane highways that could be used for SNF shipments.

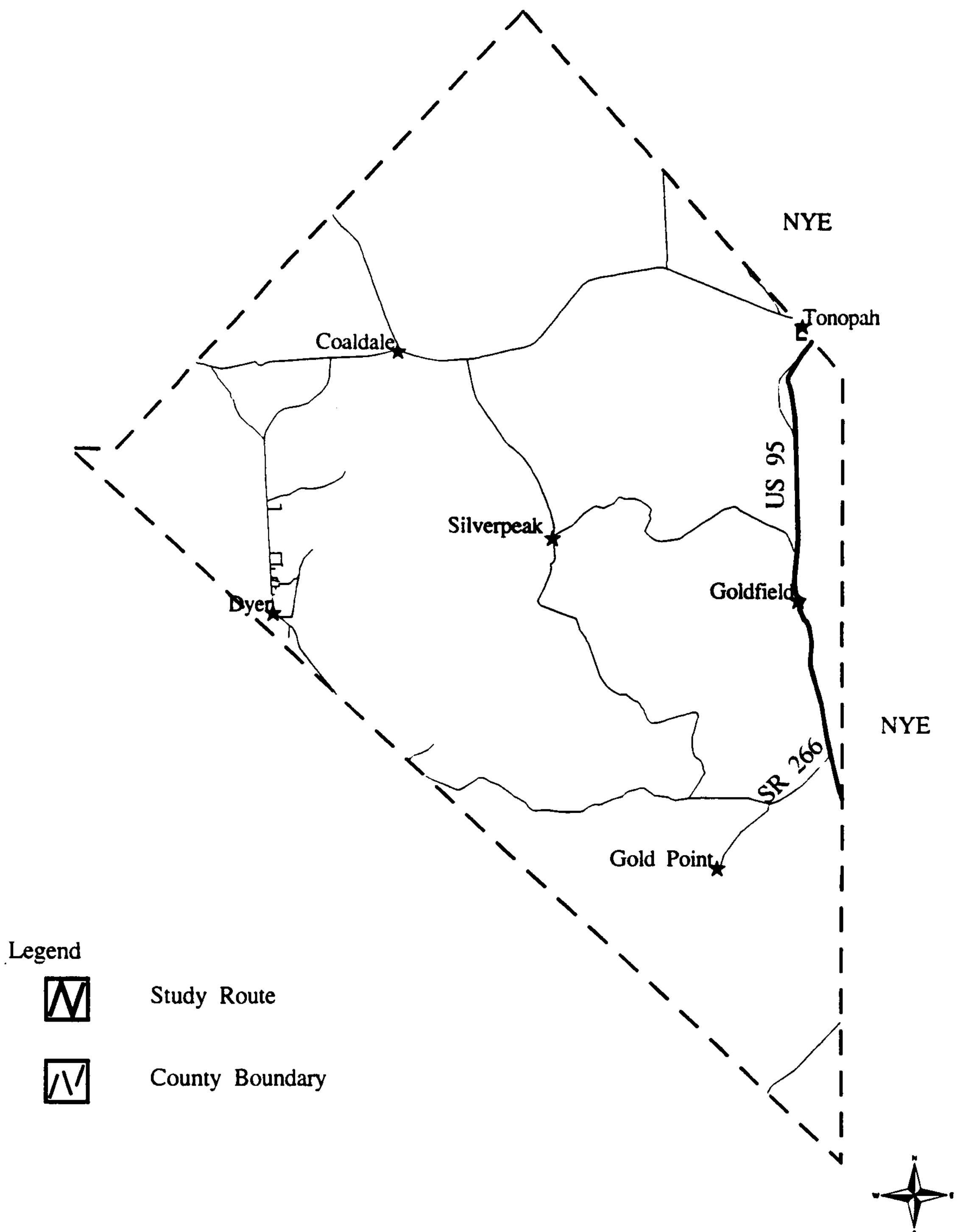
1 INTRODUCTION

The Nuclear Waste Policy Act, enacted by the United States Congress in 1982 reflects concerns related to the storage and disposal of spent nuclear fuel (SNF) and other high level radioactive wastes (HLRW). This act and its amendment directed the U.S. Department of Energy to study Yucca Mountain, Nevada, for its suitability as the nation's first deep geologic repository for SNF and HLRW. SNF and HLRW materials are currently stored on site at about 80 locations (power plants and DOE facilities) throughout the United States. If Yucca Mountain were to be selected as the site for such a repository, radioactive materials would have to be transported to Yucca Mountain. The possible modes of transportation for such shipments are highway or rail, or a combination of the two. Some of the potential higher access routes to Yucca Mountain would traverse Esmeralda County. Such shipments pose potential hazards and risks to the general population and the environment. A comprehensive transportation plan should include an assessment of the potential risks to the population, infrastructure, and environment arising from such shipments.

Intertech Services Corporation contracted with the University of Nevada, Las Vegas (UNLV) Transportation Research Center (TRC) to conduct a preliminary assessment of risks related to the shipment of radioactive materials by highway through Esmeralda County. Potential access routes to Yucca Mountain include sections of US 95 which form the highway route through Esmeralda County. The objective of this project was to conduct a preliminary analysis of potential risks of transporting radioactive materials by highway through Esmeralda County using RADTRAN IV, an existing risk assessment code, developed by Sandia National Laboratories. Specifically, the goal of the study was to incorporate local characteristics such as population densities, accident rates and hourly traffic volumes, in the risk assessment model and also to compare risks of transporting radioactive materials estimated for conditions specific to the County with risks estimated by the Department of Energy for shipments across the United States. The DOE study was conducted by using an older version of the code, namely RADTRAN II, which was the current version at the time that study was conducted. The DOE analysis was replicated with RADTRAN IV, in order to make the results comparable to that being done for Esmeralda County. This report documents the methodology, data, results and analysis that were used during the course of this study.

The highway section in Esmeralda County, that was considered for this study comprises segments of US 95, from the northern border of Nye County and Esmeralda County near Tonopah to the southern border of near SR 266 and US 95 intersection as highlighted in Figure 1. The total length of this highway section is approximately 70.210 km (43.88 miles). Principal population center along this route includes Goldfield. This segment of highway is part of a possible route (Route B) identified by the State of Nevada for transporting highway route controlled quantities of radioactive waste.

Figure 1. Key Highway Routes In Esmeralda County



2 BACKGROUND

RADTRAN is a probabilistic risk assessment code developed by the Sandia National Laboratory for radioactive materials transportation analysis. It was developed for the U.S. Department of Energy (DOE) to facilitate assessment of health and economic risks related to the transport of radioactive materials by various transportation modes. RADTRAN could be viewed as a simple set of formulae and parameters which model physical reality to obtain an estimate of health effects. But on closer examination, RADTRAN incorporates a host of assumptions regarding numerous socioeconomic and demographic characteristics which greatly affect the predicted risk estimate. The RADTRAN code comprises two main components: incident-free scenario and accident scenario. Both of these take into account on-link, off-link, and shipment factors (Neuhauser and Kanipe, 1992). On-link characteristics describe various aspects related to the actual transport link, whereas off-link characteristics describe aspects proximate to the transport link, but not physically on the link. The first component estimates radiation dosage associated with an incident free (or normal) scenario during the transport of radioactive material. The second component estimates accident risks, in terms of health and economic effects, associated with incident exposure.

RADTRAN can be used to estimate potential risk in terms of the amount of probable radiation dosage (in person-rems) that crew members, handlers, passengers, and others would be subjected to during the transport of radioactive materials. Compared to previous versions of the model, RADTRAN IV incorporates advances in the handling of route-related data and in the treatment of multiple-isotope materials. In both cases methods used formerly may still be used. Input data may continue to be in aggregate form, and the user also may continue to use RADTRAN IV to generate unit risk factors. However, "route-specific" analysis also may be performed. That is, a route may be subdivided into segments with independent, user-assigned values for population density and other route specific parameters.

In some cases, one may wish to evaluate several alternatives that differ only in route characteristics and/or numbers of shipments traversing particular segments of a network of potential routes. Unit-risk factors are often useful in analyses of this type. This is the third technique available in RADTRAN and may be the best suited for the calculation of risks for a major shipping campaign involving many identical shipments. As the DOE output was documented in terms of unit-risks, this technique was adopted for the project along with the route-specific analysis methodology. In RADTRAN IV the required degree of specificity may be introduced into an analysis with user defined parameter values. Since the vast majority of the parameters are user-definable, the user has a great deal of flexibility in performing analyses.

2.1 1984 DOE Study Using RADTRAN II

A preliminary cost and risk analysis for transporting spent nuclear fuel and high-level wastes to candidate repository sites was conducted by the DOE (1984) using RADTRAN II, which was the current version of the code at the time of the study. The DOE report discusses the relative costs and risks of transporting nuclear wastes to nine potential candidate repository sites. Transportation related impacts of the "once through" fuel cycle, in which SNF is sent directly to the repository, are evaluated. The input data and the output documented in the DOE report were used as a basis of DOE's risk estimates for comparative analyses.

2.2 1986 DOE Study Using RADTRAN III

As an element of an environmental impact assessment study, DOE used RADTRAN III to conduct an analysis of transporting irradiated nuclear fuel to a potential federal repository. The RADTRAN code was used to calculate radiation exposures and the health effects under normal or incident-free transport, and over all credible accident conditions. The model was also used to calculate the economic consequences of transportation accidents, though these costs were not included in the Department's Environmental Assessment for the proposed Yucca Mountain repository. The input used for this study was the default input data provided by the model, which may not have necessarily reflected actual local characteristics or accounted for spatial variations in the same.

2.3 Other Efforts Using RADTRAN

Carr (1992) created a data base to help evaluate the safety of existing railroads if used to transport high-level nuclear waste over time. The data base was in the form of Geographic Information Systems (GIS) maps. This information was used to execute RADTRAN IV and thus evaluate safety of transporting nuclear waste by rail. Souleyrette et al. (1992) conducted a study at UNLV TRC, using RADTRAN for the Canadian Repository program. In that case study, RADTRAN was used to compare risks for different shipment modes. These modes include shipment by truck, truck plus rail and barge plus rail. Sathisan, Madhavapeddi and Lim (1994) conducted RADTRAN-based risk assessments for rail shipments in Lincoln, Nevada. Another RADTRAN-based study by Sathisan and Madhavapeddi (1994a,b) was conducted for highway shipments in Lincoln, Nevada.

3 METHODOLOGY

Prior to using RADTRAN for risk assessment, it was necessary to make key assumptions and definitions. These include defining the boundaries of the study area: Esmeralda County; defining the mode of transport: highway; specifying the material transported: spent nuclear fuel; and identifying the transport network and its alignment: the highway route comprising segments of US 95 through Esmeralda County. Next, specific data required as inputs for the analysis were identified. In particular, the need for local data was clearly identified when it was ascertained that default did not accurately or appropriately represent the local characteristics. Some of the data were obtained based on historical information. Other inputs required additional effort such as the use of Geographic Information System (GIS) to derive the data. Two of the input variables that required the use of GIS were population density and link distance. Various approaches were used to define links and to obtain population density. These are described in the subsequent sections. Next, key differences between the input and output of the DOE study and those relevant to Esmeralda County were outlined. In this analysis, it is assumed that the minimum stop time per trip is zero.

3.1 DOE vs Esmeralda Analysis

The DOE (1984) risk analysis using RADTRAN II was updated using RADTRAN IV. This was done for both modes of transport: rail and highway. The risks for Esmeralda County were computed only for highway mode in terms of route specific and unit risk factors to facilitate comparison with the results obtained by DOE. Key inputs that are different relate to population and transportation system characteristics which are representative of the local data. These differences can be illustrated by the Fraction of Travel in each of the three population zones as shown in Table 1. The analytical scenarios for were obtained for the Route Specific Analysis to be conducted based on the variation of accident rates, population densities, traffic volumes, and lengths of links. All the other input parameters are the DOE default data that were used, including the number of accident severity categories and the fraction of accidents in rural, suburban and urban zones, for each severity category. Thus, the local data were given precedence with regard to certain key inputs to help facilitate an accurate estimation of risks.

Table 1. Fraction of Travel by Population Zone

Category	Local	DOE
Rural	0.981	0.837
Suburban	0.019	0.152
Urban	-	0.011

The principal steps used to conduct the study were as follows: (1) Update of DOE study with RADTRAN IV using Unit Risk analysis; (2) Route Specific Analysis; and (3) Unit Risk analysis in Esmeralda County. Local data were used for the inputs related to demographic and transportation system characteristics in steps 2 and 3.

3.2 Definition of Links

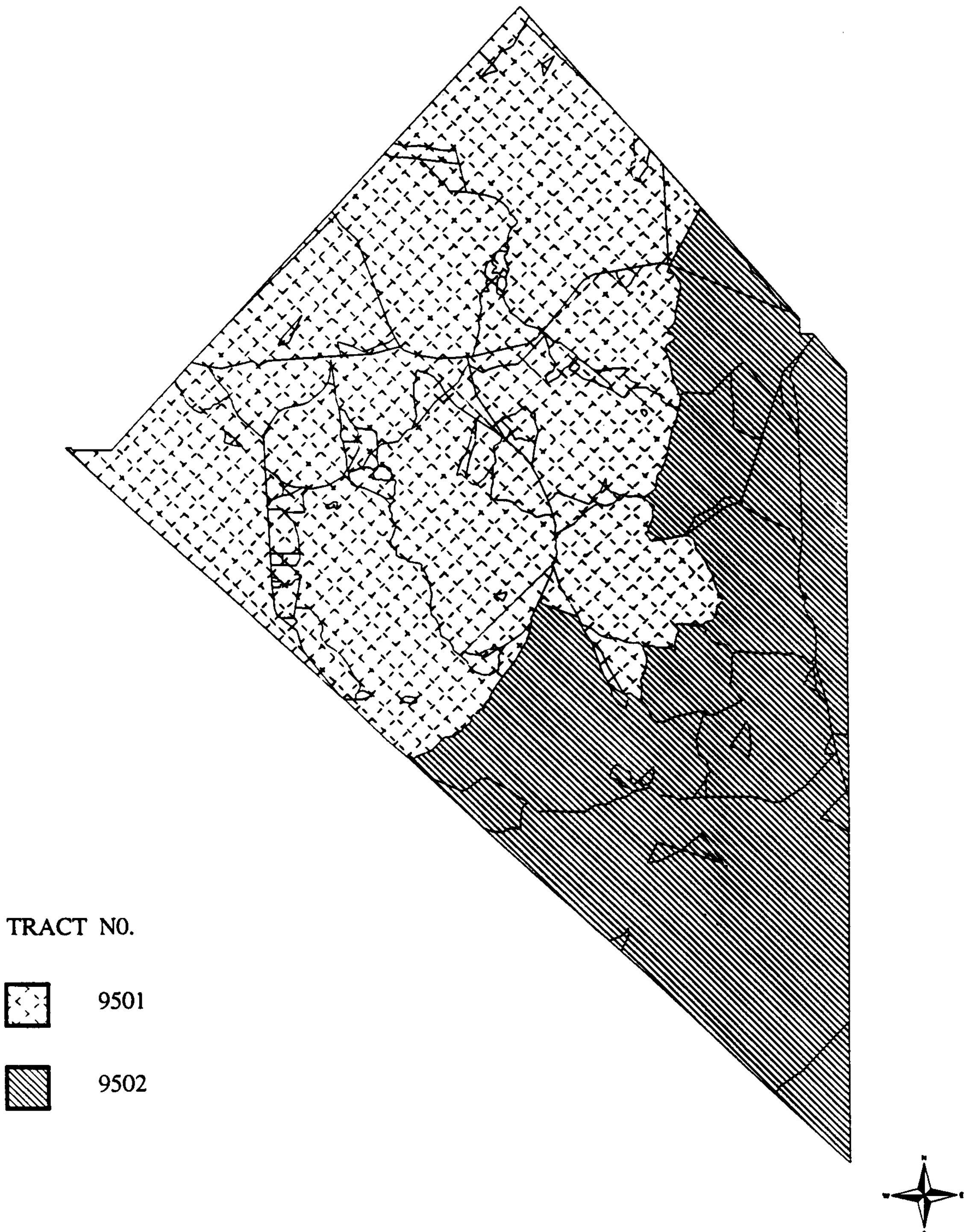
In order to perform the route specific analysis RADTRAN requires that links along the transportation route be defined. This is integral to the program's operation and for various "exposure" analysis. It is important to define links in such a manner that each link is homogenous as far as its key attributes are concerned. A key variable that needs to be accounted for in this process is the distribution of population proximate to the highway route. Therefore, a methodology based on population distribution was considered. Another parameter which had to be considered for this was the accident rate. Historical data (1987 to 1993) on traffic operations and safety on the highways under consideration were used to evaluate accident rates. These data were obtained from the Nevada Department of Transportation (NDOT). The methodology adopted for defining links by taking into consideration both the population density and the accident rates is outlined in the following sections. This is critical to the analysis and accounted for a significant portion of work on the project.

3.3 Population Density

The potential exposure to population during radioactive materials transport would be affected by the distribution of population along the highway route. This distribution (or population density) need not be uniform along the length of the route in the county. On the contrary, one would expect to find a non-uniform population density distribution: population centers with high population densities and other stretches with relatively low population densities. Therefore, an approach would be to define links based on changes in population density. One of the first steps to develop such a procedure is to determine the actual population distribution. For this purpose, information obtained from the decennial census conducted by the Bureau of Census would be a logical starting point. Since Esmeralda County has had a nominal fluctuation in total population, the data obtained from the 1990 census provides a reasonably good estimate of the population and its distribution in Esmeralda County. The County is divided into three tracts, which are further subdivided into smaller census units, blocks. Figure 2 shows the census tract division.

Population information was obtained at a block level (from TIGER files developed from the census). This was incorporated in a GIS environment (ARC/INFO) which facilitated various analyses. RADTRAN requires population density as an input and not actual population values along a link. GIS procedures were developed to obtain estimates of population density. Several alternate mechanisms were evaluated to quantify the actual distribution of population in Esmeralda County. Among these were

Figure 2. Esmeralda County: Census Tracts and Blocks



techniques that estimated population densities based on county level, tract level and block level data. However, each of these were found to be lacking in accurately reflecting existing conditions. Thus in consultation with the County advisor for the project, the following procedure was developed to facilitate estimation of population densities along transport links.

A key assumption made was that the population would be located proximate to the roads and not uniformly distributed within each block. Thus the primary road network within each block was identified and buffered using 800 meters (0.5 mile) buffer distance, assuming that people live within that distance from any roadway (see Figure 3). The buffered area within each block was calculated and this area was used to estimate population density. For the region around Goldfield, a special procedure was adopted to calculate the population density. The length of the route segment along the region of Goldfield was estimated to be about 1.34 km (0.84 miles). Next, the block associated with this segment was identified and the total population of the block assumed to live within 0.5 mile of the segment. Consequently, this segment was defined as a separate link and its population density was estimated by dividing the block population by the buffer area along the length, i.e., 1.34 km, of the segment. This resulted in the link being categorized as a suburban link.

Once the links were defined, a default buffer distance of 800 meters along the highway route was created as a coverage in the GIS environment (see Figure 4). The population density within this buffered region is the required input to RADTRAN. The buffered coverage is then overlaid on the census blocks coverage to obtain the population within this buffered corridor for each link. Then the population density was computed as the ratio of the population to the area within the buffered region for each link or route segment. RADTRAN requires not only the population density, but also aggregated characterization of landuse (either rural, suburban or urban). The population density along each route segment is used to determine the type of landuse for that particular segment. The mean and ranges of population density of RADTRAN default values for different zonal categories are presented in Table 2.

Figure 3. 800m Buffer of Primary Roads In Esmeralda County

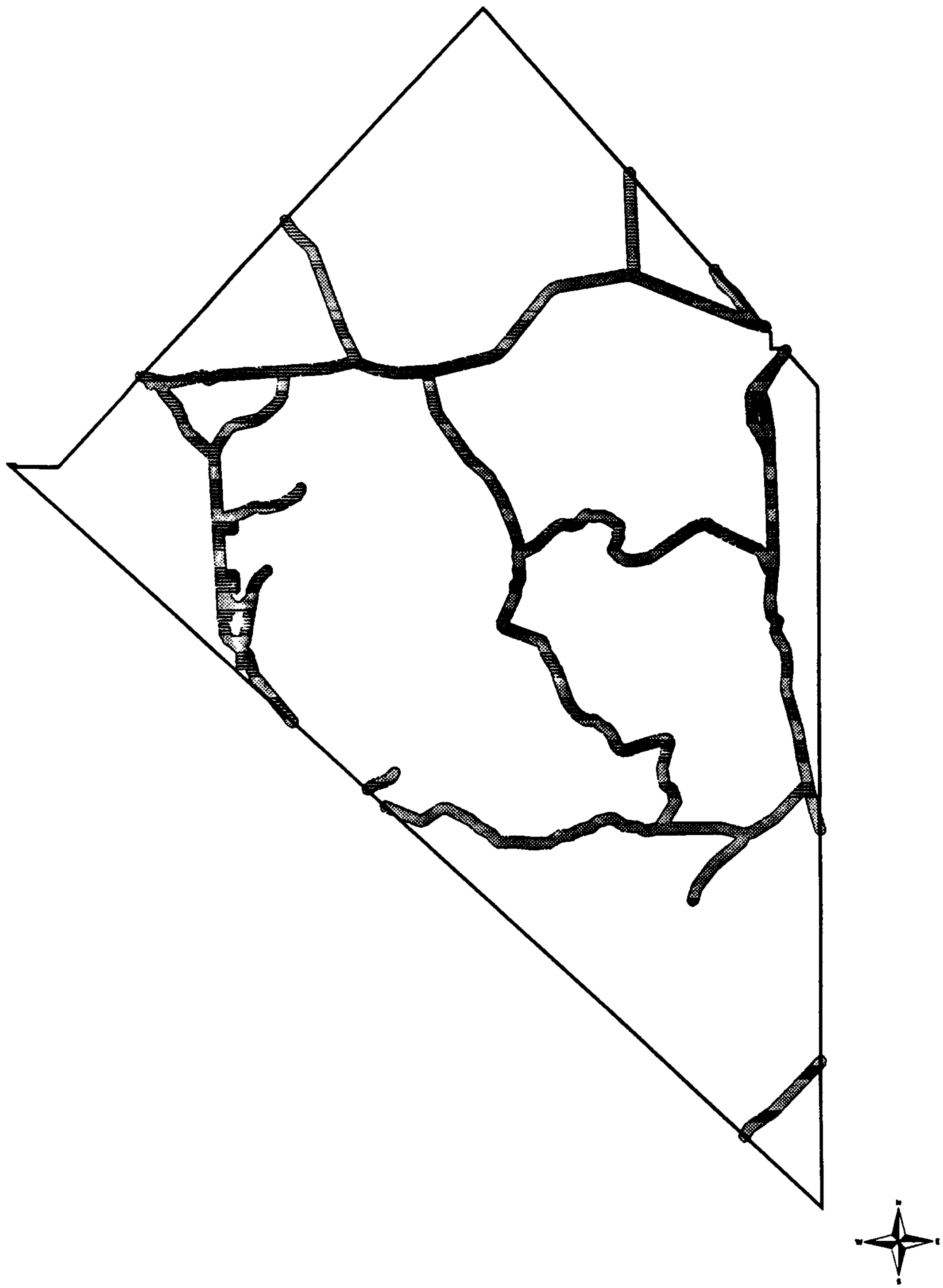


Figure 4. Population Density Within 800m Buffer of Primary Roads

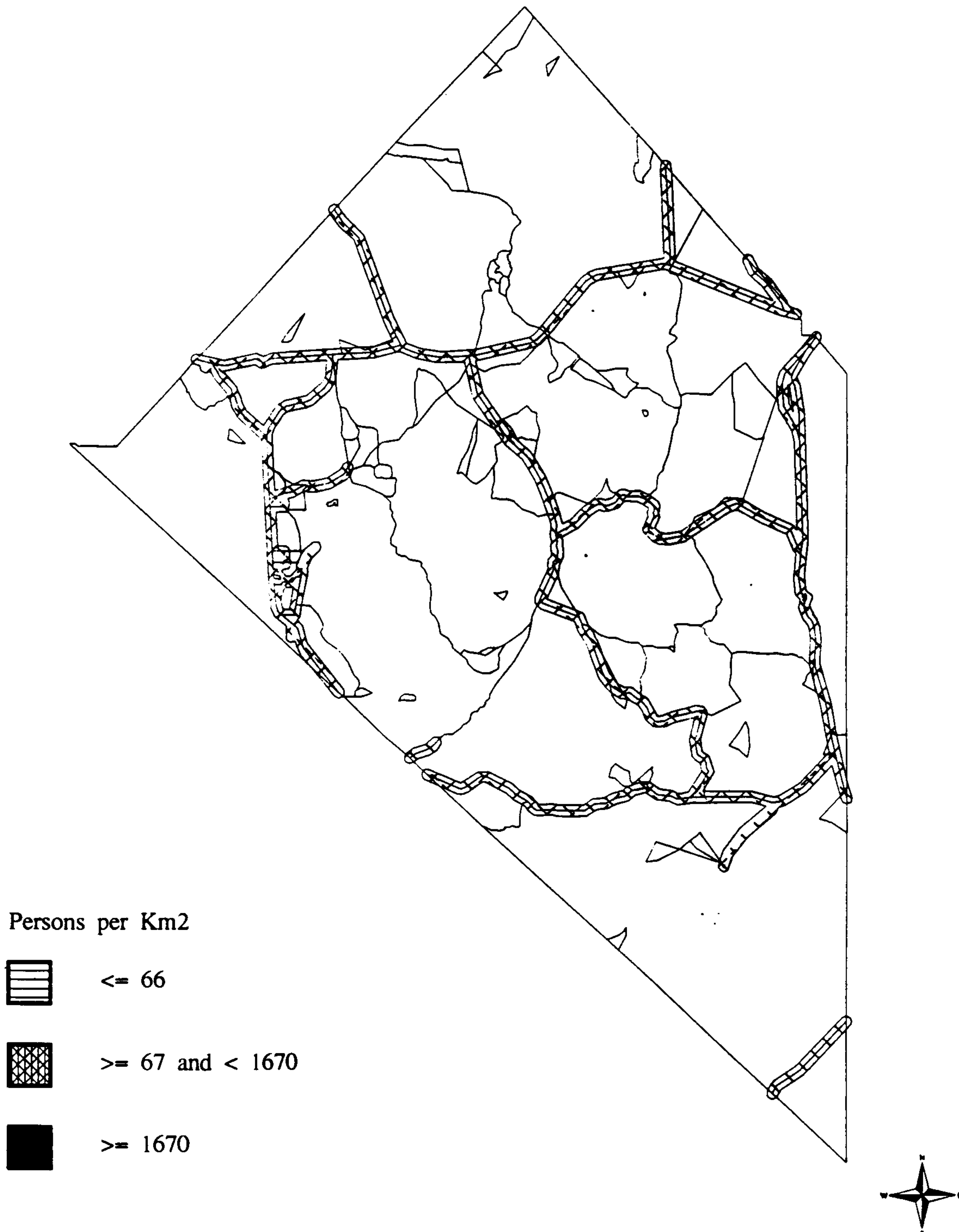


Table 2. Aggregate Data for Population-Density Zones

Zone	Mean Density (persons/km^2)	Range (persons/km^2)
Rural	6	1 to 66
Suburban	719	67 to 1670
Urban	3861	>1670

(Source: Neuhauser and Kanipe, 1992)

Along the buffered route segment, it was observed that the region around Goldfield had a population density which was greater than the remaining portions of the route. This region has a density of approximately 340.043 persons/km^2 compared to the mean density of approximately 3 persons/km^2 for the entire route segment. To highlight the concentration of population within the limits of Goldfield, this region was distinguished as a separate link. The length of this link is 1.34 km. Table 3 shows the links established based on the population density estimates.

Table 3. Link Characteristics Based on Population Density

Link ID	Length (km)	Population Density (persons/km^2)	Zone Type
1	39.21	2.769	Rural
2	1.34	340.043	Suburban
3	29.66	2.769	Rural

Other input variables for each link or route segment such as speed, accident rate, number of vehicle per hour and road type were obtained from historical data and scenarios that reflect local conditions.

3.4 Accident Rates

Historical information on highway operations provide a basis for obtaining safety related data that could be considered in the analysis. Accident rates experienced would be of particular relevance for this purpose, especially those involving trucks. Accident rates are measured in terms of accidents per vehicle kilometer traveled. A mathematical expression to estimate accident rate is as follows:

$$AccRate = \frac{Acc}{(AADT x\ l)\ x\ 365}$$

where:

AccRate = accident rate
Acc = number of accidents per year
AADT = annual average daily traffic
l = length of segment in kilometer

In this study, only the truck accidents were considered. The truck accident and annual average daily traffic (AADT) data for the routes were obtained from Nevada Department of Transportation. The latter is used to estimate vehicle kilometers traveled along a particular segment of the route. In this report, the highway truck accident history data were obtained for a seven year period, 1987 through 1993 from the Safety Engineering Division of the Nevada Department of Transportation (NDOT). Data were aggregated by segments defined to represent homogeneous roadway sections based on operational characteristics. Segment lengths and traffic volumes used for calculating accident rates were obtained from the NDOT Annual Traffic Reports for the various years. Figure 5 shows the historical variation of accident rates by link. The accident rates representing worst and average conditions are shown in Figure 6.

For each of these links the worst and the average accident rates were identified as candidates for use as input data. Table 4 shows links identified on the basis of accident data. These accident rates, especially rural areas, are higher than those used in DOE's 1984 report. Indeed, a DOE report (1990) states that the overall highway accident rates in Nevada have been consistently higher than the national average.

Table 4. Links Based on Accident Rates (Accidents/km)

Link	Segment Length, km	Worst Case Accident per 10 million vkt	Average Case Accident per 10 million vkt
1	6.305	7.05	4.10
2	8.500	7.87	3.99
3	17.035	30.20	1.35
4	5.390	4.97	1.63
5	32.980	4.64	2.28

Figure 5. Esmeralda County Historical Accident Rates by Link (US 95)

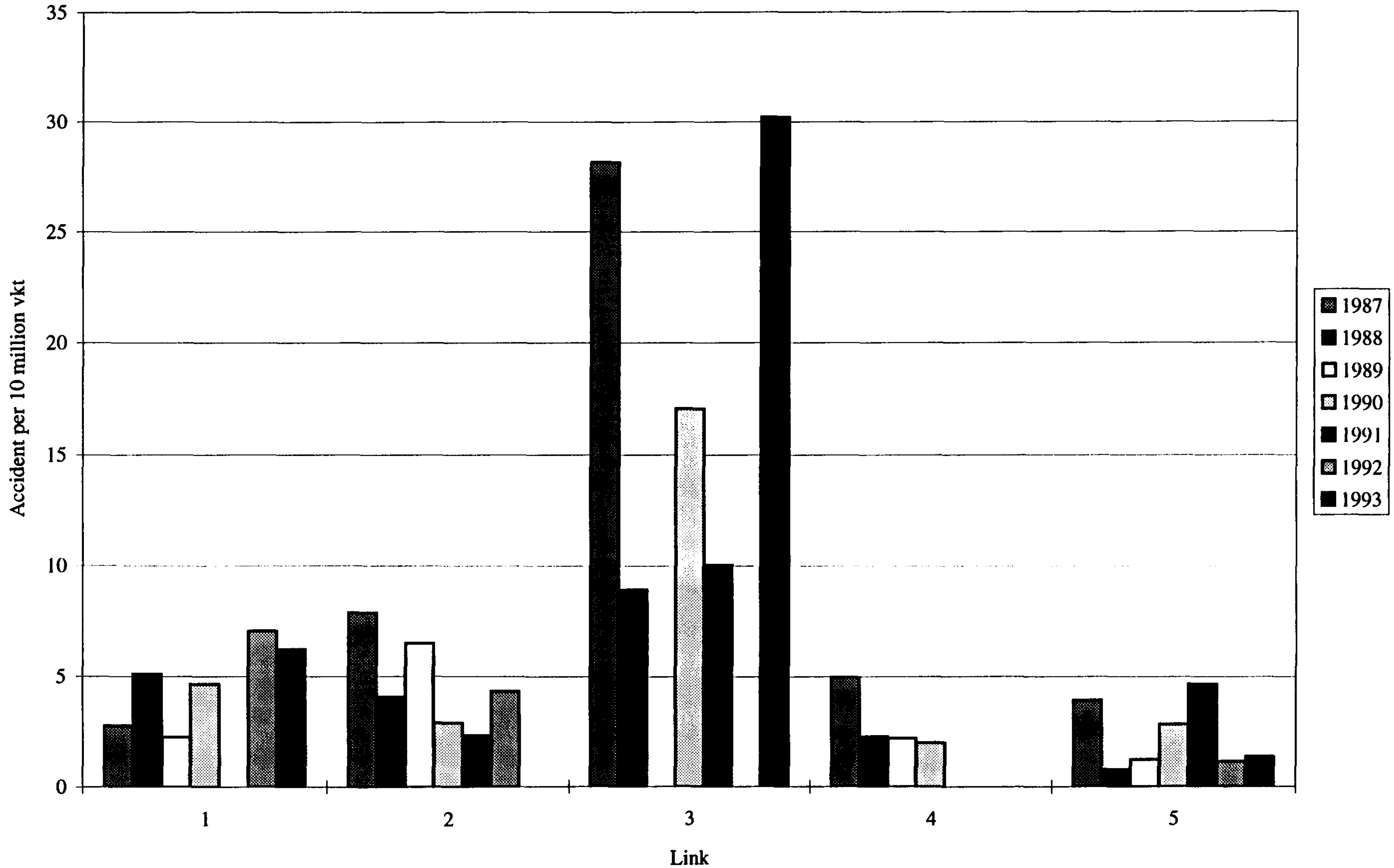
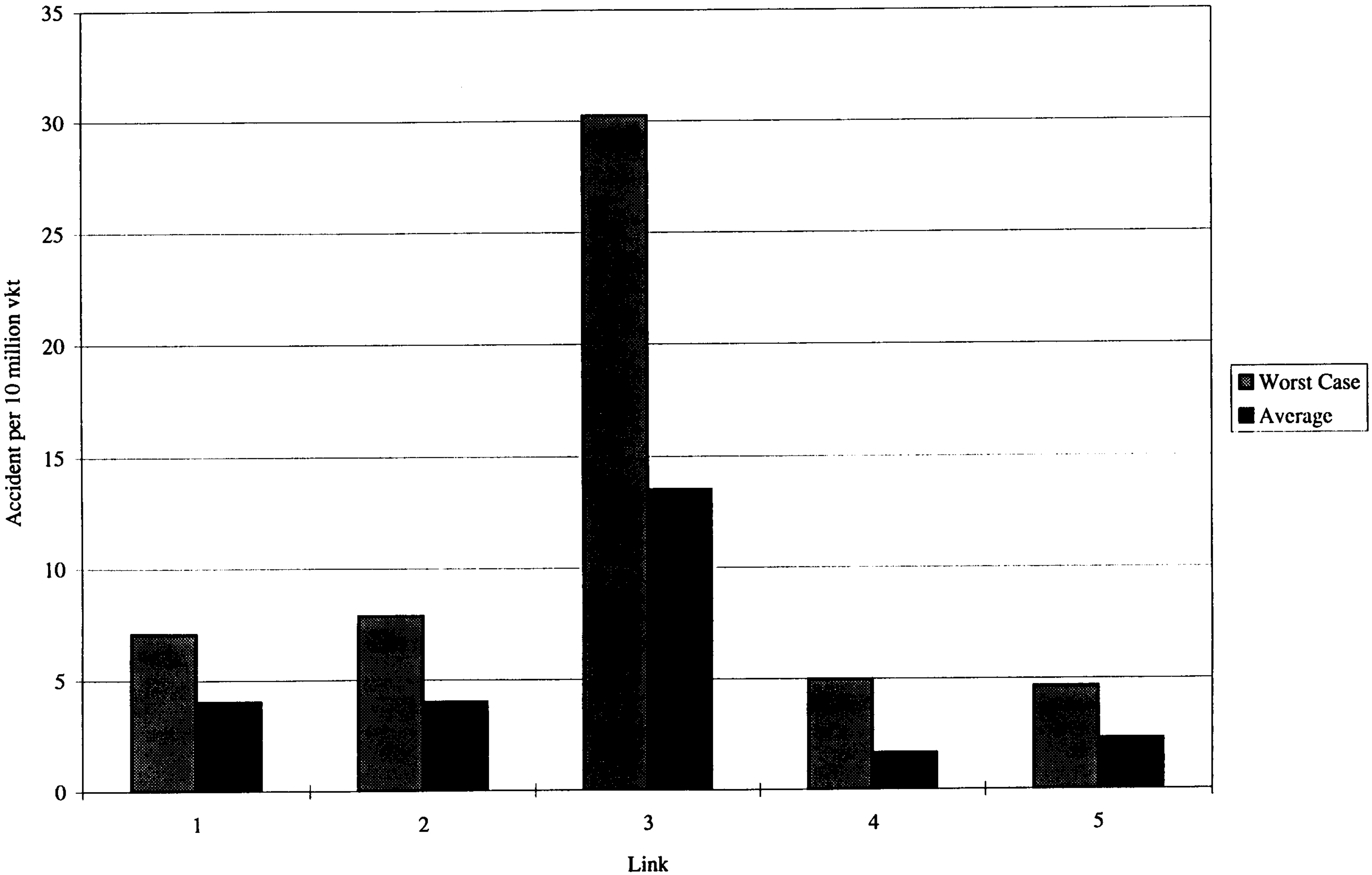


Figure 6. Esmeralda County Accident Rates by Link (US 95)



3.5 Link Definition Based on Population and Accident Rate

In order to establish links that have homogeneous characteristics for "local variables", links are redefined based on population and accident rate information. The three links identified using population as a criterion were combined with the five links defined using accident rates. This combination results in seven links. Each of these seven links has unique characteristics. Figure 7 shows the final links used in risk analysis. The locations of individual link with respect to the route are shown in Figure 8.

3.6 Analytical Scenarios

Based on historical safety data, three safety based scenarios were identified for the RADTRAN risk assessment analysis for Esmeralda County. The first scenario uses the worst highway accident rate within Esmeralda County. The second scenario uses the average highway accident rate for Esmeralda County. The third scenario adopts the rates used by the DOE.

4 INPUT DATA COMPILATION

The input requirements for RADTRAN IV range from transportation system related information to material (cargo or shipment) specific information. The RADTRAN user guide (Neuhauser, 1992) identifies the data requirements. Default data are provided to minimize searching for information. The method followed for this study (Neuhauser, 1992) is briefly outlined below.

4.1 Route Specific Analysis

The Route Specific Analysis option must be used for aggregate data with more than three population-density classes. The LINK option allows independent analysis of up to 40 separate route segments (or data aggregates) in a single computer run. For each link or route segment, the following route related parameters must be quantified: Link-ID, Mode of Shipment (truck, rail, barge, air), Link Distance (km), Speed of Travel (km/hr), Population Density (number of persons per km^2), Number of Vehicles per hour, Accident Rate (accidents/km), Zonal Type (rural, suburban, urban), and Link or Road Type (1 = freeway, 2 = non-freeway, 3 = all other). Each of the above input values have been obtained from different sources, which are listed below:

(a) Link-ID- This is an assigned value based on variations in population density and accident rates along the highway route. Based on the procedure identified in the methodology section, the potential highway route through Esmeralda County has been divided into 7 links. This information is presented in Table 5.

Figure 7. Final Link Definition

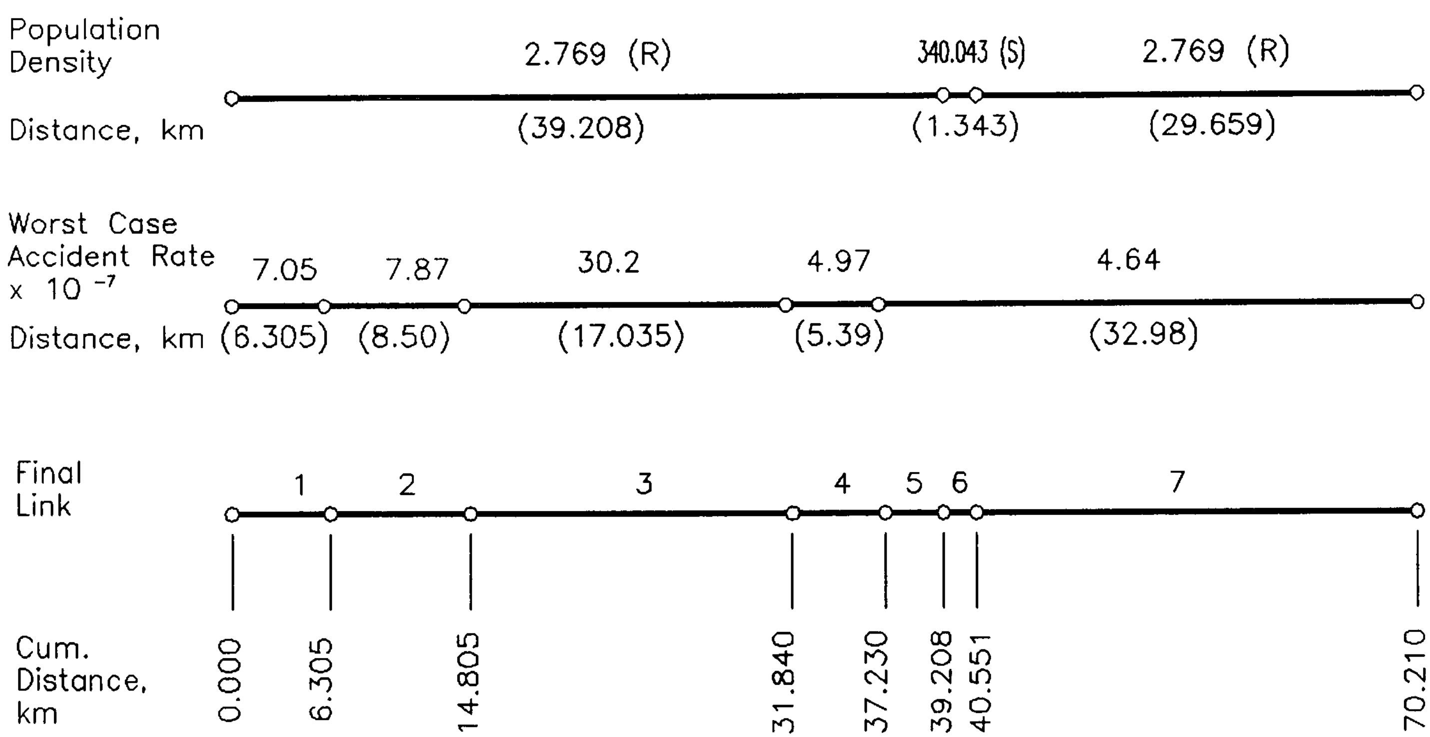


Figure 8. Highway Routes – Link Definition

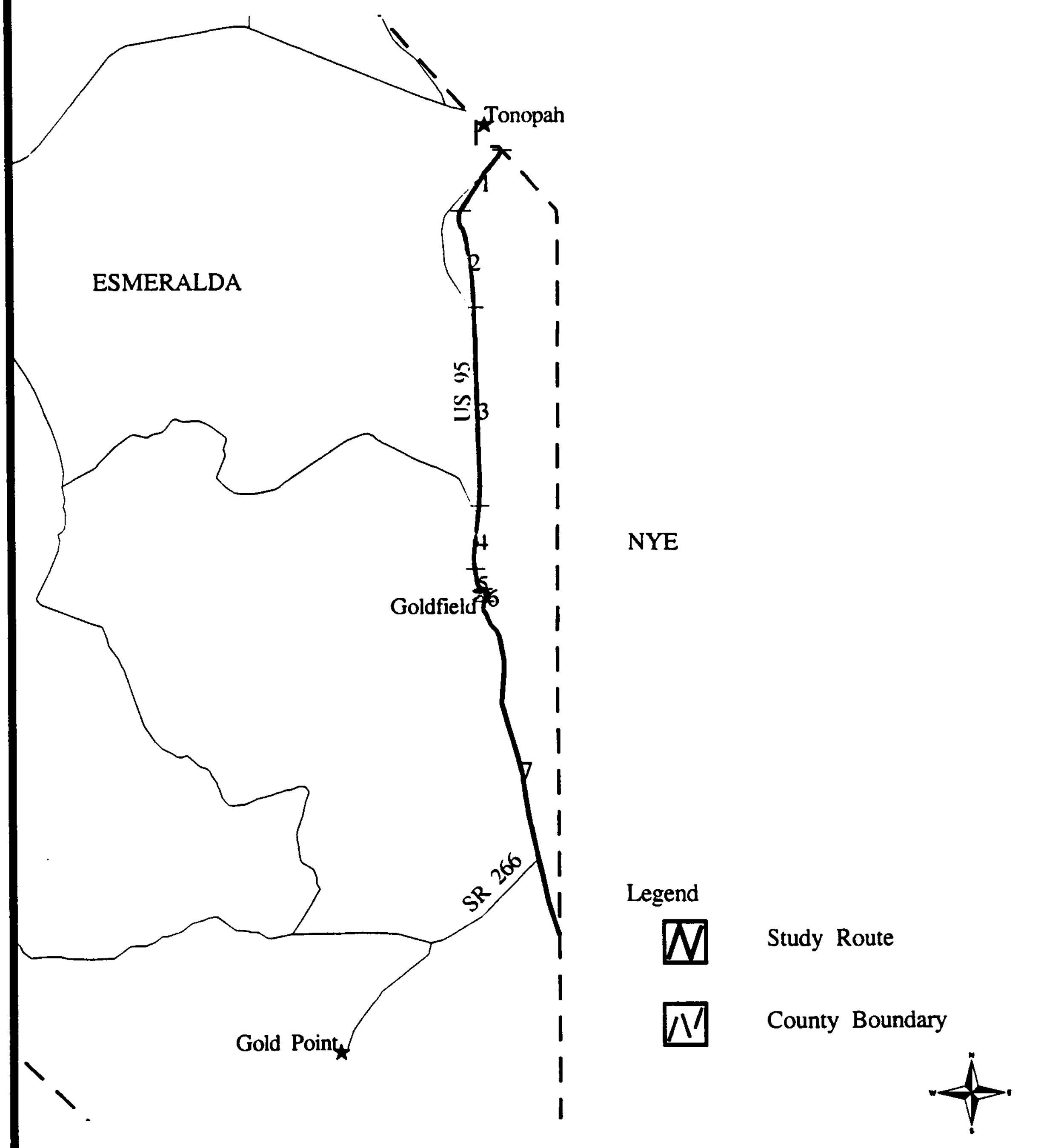


Table 5. Link Data Used as Inputs for RADTRAN Analysis

Link ID	Distance, km	Average speed, km/hr	Population Density, persons/km^2	Traffic Volume, veh/hr	Worst Case Accident per 10 million vkt	Average Case Accident per 10 million vkt	Zone	Road Type
Link 1	6.305	88.50	2.769	321	7.05	4.01	R	2
Link 2	8.500	88.50	2.769	300	7.87	3.99	R	2
Link 3	17.035	88.50	2.769	431	30.2	13.5	R	2
Link 4	5.390	88.50	2.769	368	4.97	1.63	R	2
Link 5	1.978	88.50	2.769	392	4.64	2.28	R	2
Link 6	1.343	40.30	340.043	392	4.64	2.28	S	2
Link 7	29.659	88.50	2.769	392	4.64	2.28	R	2

(b) Mode- The value used to characterize the mode is based on specifications used by RADTRAN. The classification system used for this purpose is summarized in Table 6. As the mode being evaluated is highway, a value of 1 was used as input for the mode variable.

(c) Distance- This is the distance or length of the specified link, in kilometers (km). Links were defined using a GIS-based procedure using variation of population density and transportation characteristics along the route. Therefore, link distance or length were obtained from the same GIS-based procedure. These values are presented in Table 5. The links range in length from 1.343 km (about 0.839 mile) for link 6 to 29.659 km (about 18.537 miles) for link 7.

Table 6. Classification Based on Mode

Mode	Value Assigned
Truck	1
Rail	2
Barge	3
Air	4

(d) Traffic Speed- The speed is classified into three categories based on the aggregate land use (zonal) classification for the region in which the segment lies. These are summarized in Table 7. The zonal classification is based on population densities. The ranges of population densities and the default values used by RADTRAN for each zone were presented in Table 2.

Table 7. RADTRAN's Speed Categories by Zonal Classification

Zone	Speed (Km/hr)
Rural	80.49
Suburban	40.25
Urban	24.16

(e) Population Density- Data pertaining to the population density were obtained using GIS technology using the methodology previously explained. The values used as inputs have been presented in Table 5. Specifically, link 6, which is in the vicinity of Goldfield, has a greater population density than the other links. Thus, it is categorized as a suburban link based on RADTRAN default ranges (see Table 2).

(f) Number of Vehicles per Hour- This input may be obtained from RADTRAN default settings, and is presented in Table 8. In this study, however, the actual design hourly volumes (DHV) along the links were used instead of the default value to reflect the local condition. The DHV is taken as a percentage of the AADT's. For rural areas, DHV ranges from 12 to 18 percent of AADT's with an average of 15 percent, while for urban areas, DHV is taken as 8 to 12 percent of AADT's (AASHTO, 1994). In this study, the upper limits (18 percent for rural, and 12 percent for urban) were used. These percentages were considered to be on the conservative side. In the absence of percentage data for suburban areas, the percentage representing rural areas was used.

Table 8. Number of Vehicles/Hr Based on Zonal Classification

Zone	Vehicles per Hour
Rural	470
Suburban	780
Urban	2800

(g) Accident rates - Accident rates were estimated using the 1987 to 1993 data obtained from the Nevada Department of Transportation. These have been presented in Tables 4 and 5. These (accident rates) are also illustrated in Figures 5 and 6.

(h) Zone - This classification is based on the population density of the link. The ranges of population densities for the three zones have been shown in Table 2. The user should indicate whether each segment is rural, suburban, or urban in character so that the model would in turn select appropriate values for the building-shielding factor and other parameters. Zone designation is performed with the character designation parameter in which the user enters R, S, or U to indicate rural, suburban, or urban, respectively. The population densities for the links range from those corresponding to rural and suburban links (see Tables 2 and 3).

(i) Link Type- Link type is used to identify the roadway type for highway modes only. If the user sets the link type to 1, the segment is modelled as an Interstate Highway (i.e., any limited access, divided highway built to the same engineering standards as Interstate Highways). If the link type is set to 2, then the combination of zone designation and link type determines how the roadway is modeled. If the link type is set to 2 and the zone is designated R or S, then the roadway is modeled as a non-Interstate highway (e.g., a U.S. highway). If the link type is set to 2 and the segment is designated as U in character, then the roadway in that segment is modeled as a city street. For all other modes including rail, the link type is set to 3.

4.2 Unit-Risk Analysis

RADTRAN IV (Neuhauser, 1992) provides the user with three different analytical approaches to model the transportation of radioactive materials. They are the aggregate-data method, the route-specific (LINK) method and the unit-risk-factor method. The need for the use of the unit-risk analysis approach arises due to the fact that DOE (1984) had adopted this approach. The results documented in the report were in terms of unit-risk factors, for each of the three population density zones. Hence, in order to compare the results of the DOE study with those obtained for Esmeralda County, this approach was incorporated in the analysis. Input values used for unit risk analysis are summarized in Tables 9 and 10. For local condition, population densities for rural, suburban, and urban zones were estimated as:

$$PopDen_{zone} = \sum_{i=1}^{n} \frac{(PopDen_{zone\ i} * Link_{zone\ i})}{L_{zone}}$$

where:

$PopDen_{zone}$ = population density of zone (rural, suburban or urban)
$PopDen_{zone\ i}$ = population density of link i in zone
$Link_{zone\ i}$ = length of link i in zone
L_{zone} = cumulative length of links in zone

A similar procedure is used to estimate an average value of DHV for each zone. Accident rates were estimated by averaging the accident rates of all links in each zone.

Table 9. Input Data for Unit Risk Analysis - Population Density and DHV

Zone	Population Density, persons/km^2		Daily Hourly Volume (One-way)	
	Esmeralda County US 95	DOE Default Value	Esmeralda County US 95	DOE Default Value
Rural	2.769	6	382	470
Suburban	340.043	719	392	780
Urban	-	3861	-	2800

Table 10. Input Data for Unit Risk Analysis - Accident Rate

Zone	Accident Rate per vkt		
	Worst Case	Average Case	DOE Default Value
Rural	5.365E-7	2.59E-7	4.00E-8
Suburban	4.640E-7	2.28E-7	8.10E-8
Urban	-	-	4.70E-6

A unit risk analysis was conducted for the highway mode under consideration in Esmeralda County. This provides a basis for comparison of risks between the DOE and the Esmeralda County study. When comparing the average values, the local population densities are about 50 percent lower than the DOE values. The local DHV's are around 20 and 50 percent lower than the DOE values for the rural and suburban segments, respectively. Local accident rates for the rural segments are 7 (average case) and 13 (worst case) times higher than the DOE values. Rural links make up about 98 percent of the total route. For the suburban segments, the accident rates for local conditions are 3 (average case) and 6 (worst case) times higher than the DOE values. These variations are significant in terms of estimating risks.

5 RESULTS AND ANALYSIS

The methodology developed and the specific inputs determined were used to support the analysis. The specific input data were integrated with other default data to create an input data file required by the RADTRAN model. Individual input files were developed to represent each analytical scenario identified. The results of the modelling effort indicate that a strong correlation exists between shipment mode, operating speed and population density and the amount of exposure. As may be expected, variations in accident rates do not significantly affect the results obtained for the Incident-Free Scenario. An analysis of the results obtained from the modelling effort using RADTRAN follows.

5.1 Route Specific Analysis

As previously mentioned, the local data are analyzed using route specific analysis while DOE data are evaluated using unit risk analysis. Total incident-free and population (accident scenario) risks are then compared using those results. Since the unit risk analysis used for DOE data estimates risk only for a unit length of a particular zone, total risk for each zone is estimated by multiplying the length of the total route by the fraction of travel in zone and the unit risk representing the zone. The mathematical expression is as follows:

$$Risk_t = L*[(UR_r*f_r)+(UR_s*f_s)+(UR_u*f_u)]$$

where :

$Risk_t$ = total risk based on unit risk analysis
L = total length of route
UR_r = unit risk, rural
UR_s = unit risk, suburban
UR_u = unit risk, urban
f_r = rural fraction of travel
f_s = suburban fraction of travel
f_u = urban fraction of travel

For the DOE analysis, the fraction of travel is 0.837, 0.152, and 0.011 for the rural, suburban, and rural segments, respectively.

5.1.1 Incident-Free Summary

An examination of the Incident-Free Population Exposure in person-rem for various analytical scenarios helps provide some insight into the sensitivity of potential risk to key assumptions or input variables. The incident-free summary of the output can be broadly divided into two categories, occupational and non-occupational risks. The occupational risks, as the name suggests, comprise the risk to crew and handlers. Whereas the non-occupational one is made up of the remaining risks including, on-link, off-link, storage and stops. Appendix A shows the incident-free importance analysis summary for all links. On examining the output it was found that in all scenarios, the crew receives the highest exposure (around 60 percent) followed by stops(around 30 to 35 percent) as summarized in Table 11. On link and off link population contribute very little to incident-free exposure. Table 12 shows the incident-free risk for highway for all the identified scenarios. These help to compare results of the DOE study with those obtained for Esmeralda County. The risks can be broken down into rural, suburban and urban categories. The results indicate that the incident-free risks for Esmeralda County for rural zone are significantly higher than those for the DOE study but are substantially lower for the suburban zone. For the total risk, local result is around 9 percent lower than the DOE results. This variation is directly related to the fraction of travel, and the DOE urban segment which does not exist in the local condition. The fraction of travel in the rural zone is greater for Esmeralda County at 98 percent compared to the DOE study at 83 percent.

Table 11. Percent Distribution of Incident-Free Exposure - Route Specific Analysis

Population	Local	DOE
Crew	61	60
Stops	35	32
On Link	3.5	2
Off link	<1	<1

Table 12. Incident-Free Population Exposure - Route Specific Analysis

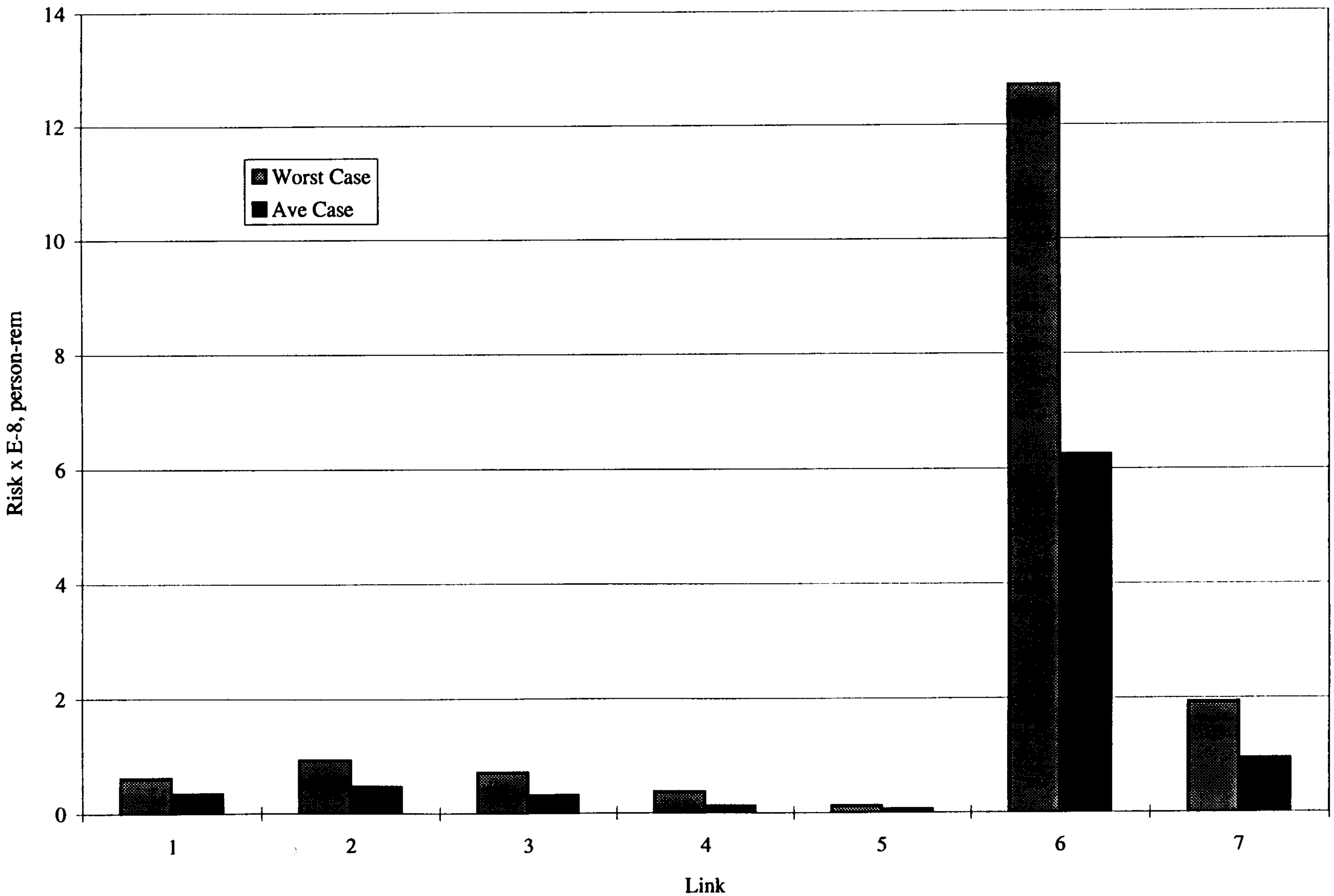
Category	Local Data	DOE Data	Risk Ratio (Local/DOE)
Total	4.53E-3	5.00E-3	0.91
Rural	4.37E-3	3.66E-3	1.19
Suburban	1.63E-4	1.21E-3	0.14
Urban	-	1.35E-4	

5.1.2 Accident Risk Summary

Outputs from RADTRAN include results for a scenario involving an accident. These results are in the form of separate tables of potential risk values for each consequence type broken down by mode, population-density zone or link, and severity category. The user designates the number of accident severity categories based on all possible accident scenarios (different thermal forces and physical forces) and classifies them relative to degree of package damage. The units of the first table are the number of accidents, the second table the number of fatalities, the third table are dollars, and the units of the last table are person-rem. All zero values appearing in any of these tables may indicate that no calculation was performed, because the user is not required to enter data for all calculations (e.g., economic parameters may be omitted). The analysis for this report utilized default values for this scenario.

One advantage of using route specific analysis is that one is able to identify the variation of risk along the entire route, and identify critical links. This is very important in terms of making sound decisions such as link avoidance and/or development of measures to minimize risk. The variation of population risk by link is shown in Figure 9. The most critical link is link 6, which is the suburban segment that lies within the vicinity of Goldfield. The population risks using local data were compared with the results using DOE default values. Route specific analysis is used for local data, while unit risk

Figure 9. Population Risk Distribution by Link - Route Specific Analysis - Accident Scenario



analysis is used for DOE data. The results are summarized in Table 13 and graphically illustrated in Figure 10. Results presented in Figure 10 indicate total accident risk in person-rem for each of the scenarios for the highway mode. For the worst case scenario, the population risks using local data are significantly lower than the risks obtained using DOE data. However, it is critical to note that the component of total risk experienced by the rural segments is much greater for local conditions than those obtained using DOE data. These range from being about 6 times higher in the worst case analysis and about 3 times higher for the average case. For the suburban segment (which represents 1.90 percent of the route), the result using the DOE data is much higher than results obtained using local data for the worst and average cases. Figure 11 shows the variation of population risk ratio (local accident data versus DOE data).

Table 13. Population Risk - Route Specific Analysis - Accident Scenario

Category	Local				DOE		Risk Ratio (Local/DOE)	
	Worst Case		Average Case		Risk, person-rem	%Total	Worst Case	Ave Case
	Risk, person-rem	%Total	Risk, person-rem	%Total				
Total	1.74E-7		8.53E-8		4.22E-6		0.04	0.02
Rural	4.70E-8	27.01	2.28E-8	26.57	7.11E-9	0.02	6.61	3.21
Suburban	1.27E-7	72.99	6.25E-8	73.27	3.74E-6	88.63	0.03	0.02
Urban	-	-	-	-	4.79E-7	11.35	-	-

5.2 Summary of Unit-Risks

As identified in the RADTRAN IV User Guide (Neuhauser and Kanipe, 1992), separate unit-risk factors for each mode and shipment type are calculated for each route subclass with input data that are held constant for all other parameters. The distance travelled and the number of shipments are usually set to unity. In this study, both the distance travelled and the number of shipments were set to unity. The result is a set of unit-risk factors that give risk per unit of travel for each route subclass for (1) incident-free dose to transportation workers (occupational), (2) incident-free dose to the public (nonoccupational), and (3) accident risk. They may be used for direct comparisons of the unit-risks of transport for various shipment types. It is more common, however, to calculate the risk per shipment by multiplying each set of unit-risk factors by the total distance travelled in the appropriate route subclass. These results can, in turn, be multiplied by the expected number of shipments and summed to give total risks. Any

Figure 10. Total Population Risk - Route Specific Analysis - Accident Scenario

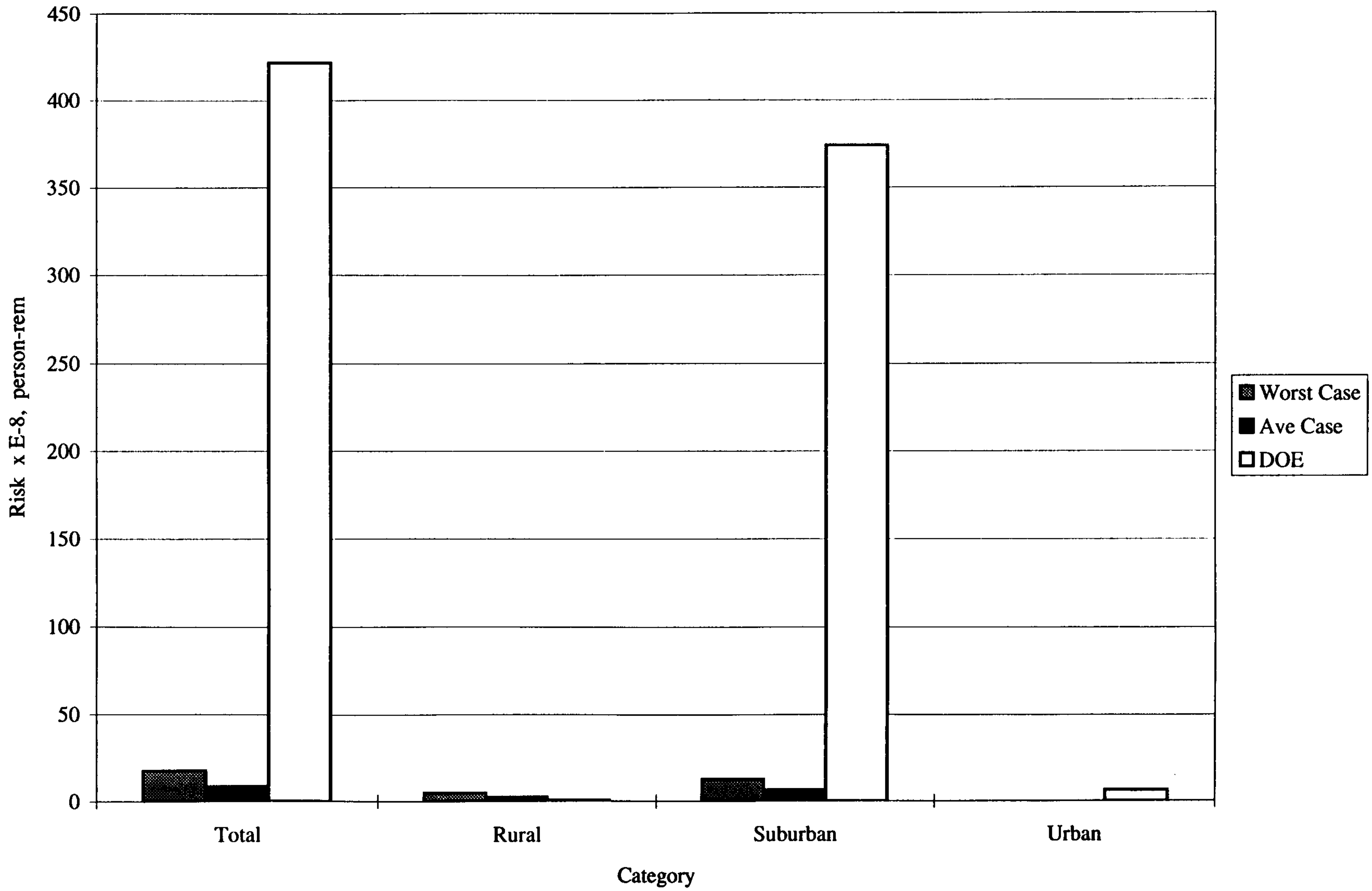
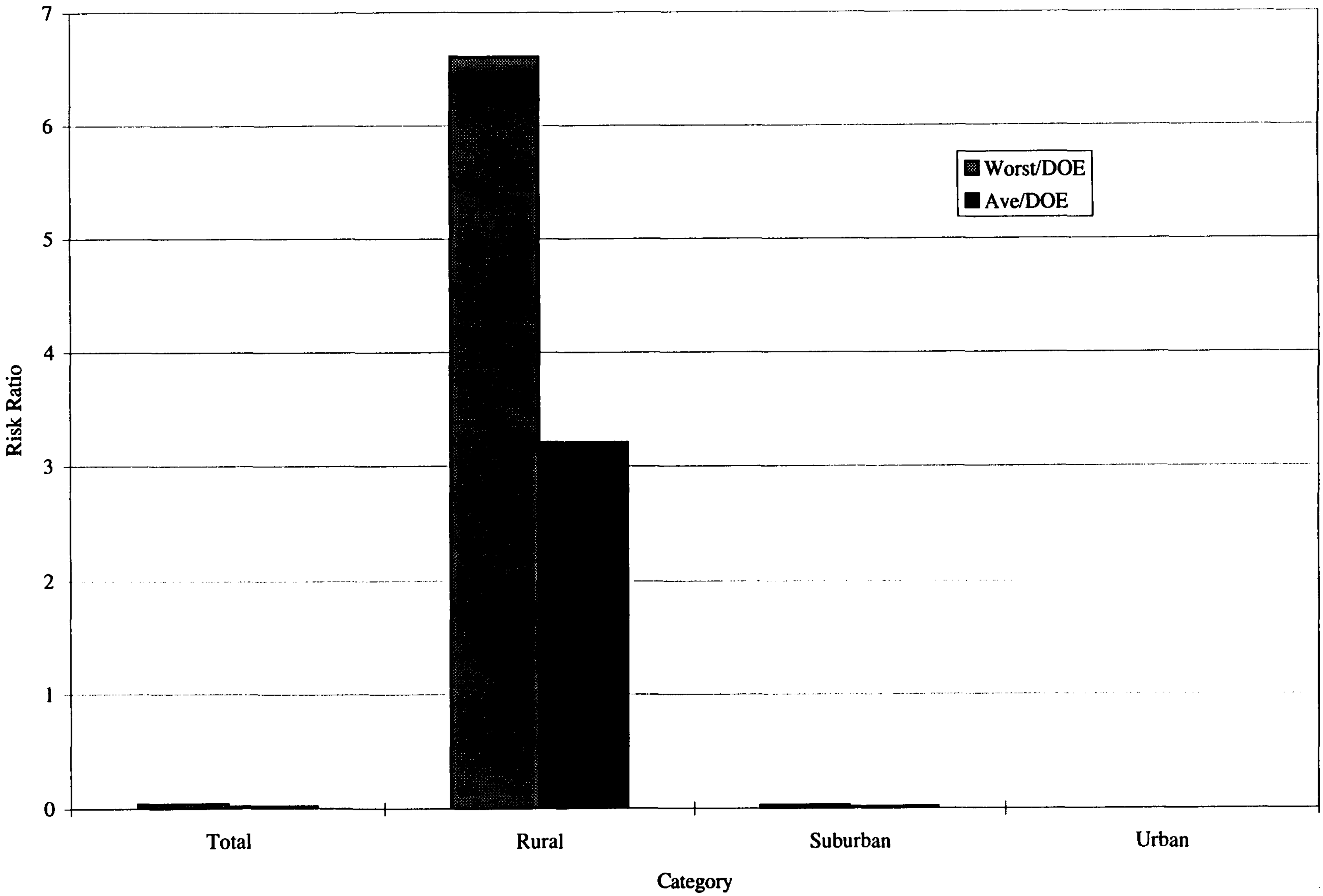


Figure 11. Population Risk Ratio - Route Specific Local vs. Unit Risk DOE



number of such risk factor sets can be generated depending on the subdivision of route characteristics (rural, and suburban) defined by the user. It should be noted that: (1) for unit-distance factors the user must multiply all factors in each set by the number of kilometers of travel in the associated route subclass; (2) the resulting products must be summed to give a total; and (3) neither of these manipulations is performed by RADTRAN IV.

5.2.1 Incident-Free Risk

Results of unit risk analysis using local and DOE data have been compared, It is to be noted that a uniform assumption of zero minimum stop time per trip and a stop time of 0.011 hour per every kilometer of travel is applied for all scenarios. Similar to the results of route specific analysis, the highest exposure is associated to the crew, followed by stops in all scenarios. A summary of incident-free population exposure distribution on rural, suburban, and urban zones is shown in Table 14.

Table 14. Percent Distribution of Incident-Free Exposure - Unit Risk Analysis

Population	Local			DOE		
	Rural	Suburban	Urban	Rural	Suburban	Urban
Crew	61	70		62	76	81
Stops	35	18		36	20	13
On Link	3	9		1.5	2	6
Offlink	<1	3		<1	2	<1

Using local conditions, around 61 percent is to the crew, and 35 percent to stops in the rural segment of the route. In the suburban segment, around 70 percent is attributed to the crew and only 18 percent to the stops. The same trend, although of slightly higher percentage, is observed using DOE data.

The incident-free population exposures are more or less similar for the rural components for all scenarios as shown in Table 15. The column showing local data represent the results for both worst case and average conditions. The rural and suburban incident-free unit risk are almost the same using both local and DOE conditions, as marked by a risk ratio of 1.02 and 1.08. These results indicate that the distribution of risks in the incident-free scenario between the rural, suburban and urban zones is different in Esmeralda County than for the nation as a whole. As can be noted, the difference can be attributed to the urban segment used by DOE. This urban segment does not exist in the local analysis. Considering only the rural and suburban components, the results of analyses using local and DOE data are essentially the same.

To obtain the total incident-free population exposure, the unit risk is multiplied by the length of the segment representing a particular zone. The results are summarized in Table 16. As can be noted, the rural segment contributes 96 percent of the total incident-free population exposure using local data, compared to only 73 percent using DOE data. The suburban segment contributes 4 percent using local data compared to 24 percent using DOE data. In DOE analysis, around 3 percent is to urban segment which is nonexistent in the local condition. Overall, the incident-free risk using DOE analysis is higher than the local condition by about 9 percent. However, the rural segments are exposed to greater risks (about 19 percent) in analyses based on local data when compared to the DOE data based analysis.

Table 15. Incident-Free Population Exposure - Unit Risk Analysis

Category	Local Data	DOE Data	Risk Ratio (Local/DOE)
	Risk, person-rem	Risk, person-rem	
Rural	6.35E-5	6.23E-5	1.02
Suburban	1.22E-4	1.13E-4	1.08
Urban	-	1.75E-4	-

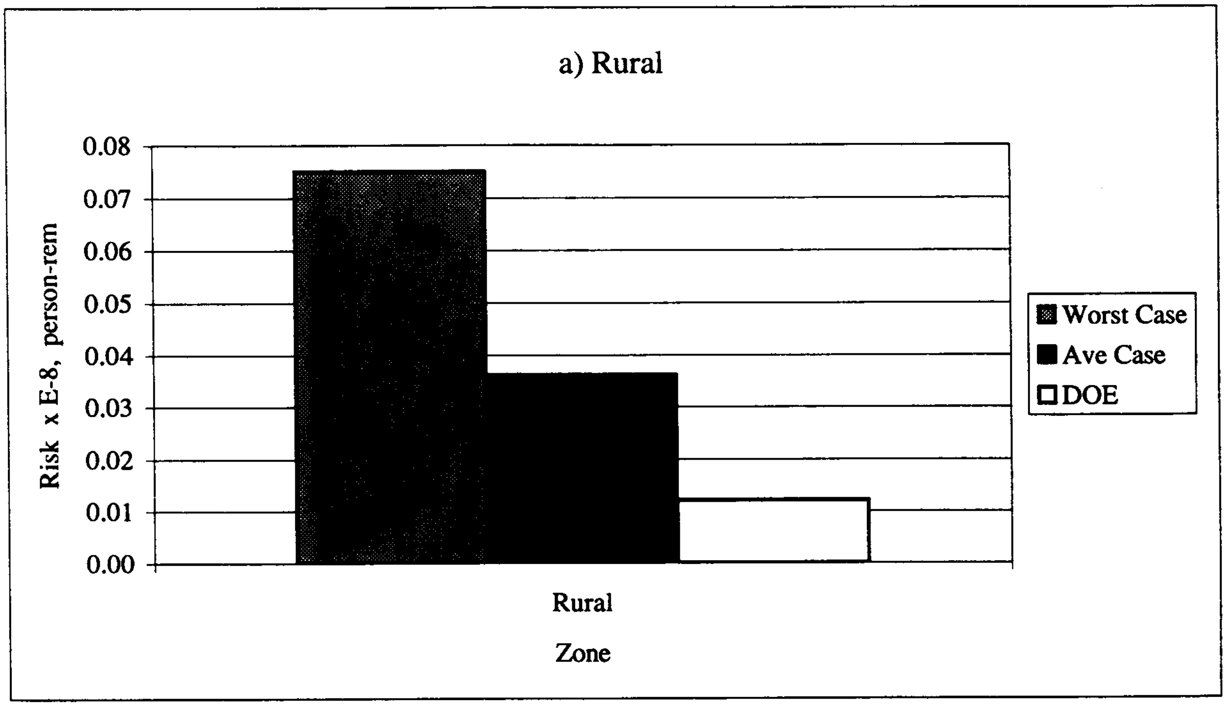
Table 16. Total Incident-Free Population Exposure - Unit Risk Analysis

Category	Local		DOE		Risk Ratio
	Risk, person-rem	%Total	Risk, person-rem	%Total	
Total	4.54E-3		5.00E-3		0.91
Rural	4.37E-3	96.3	3.66E-3	73.2	1.19
Suburban	1.64E-4	3.6	1.21E-3	24.2	0.14
Urban	-	-	1.35E-4	2.7	-

5.2.2 Population Risk

A summary of unit population risk for accident scenario is presented in Table 17, and graphically illustrated in Figure 12. Figure 13 provides a comparison of the results using local and DOE data in terms of risk ratio. For the accident scenario, risks for the rural segments of the route traversing Esmeralda County are significantly greater than

Figure 12. Population Risk - Unit Risk Analysis - Accident Scenario



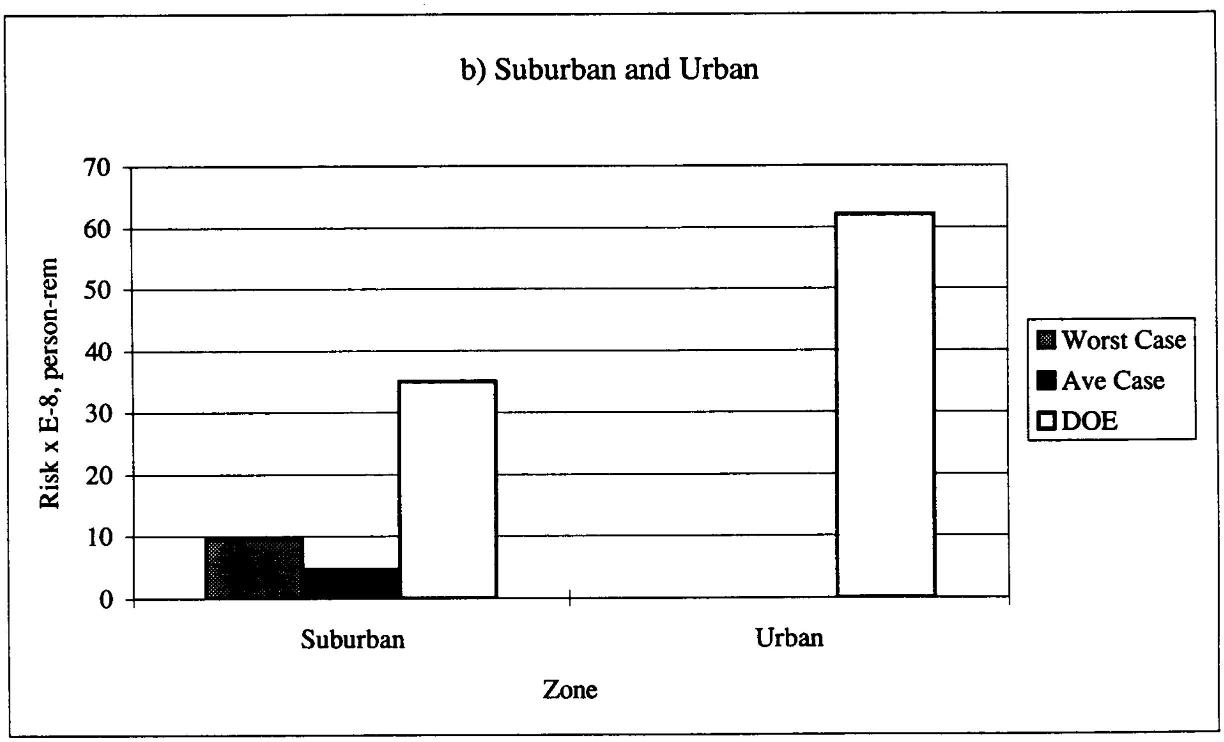
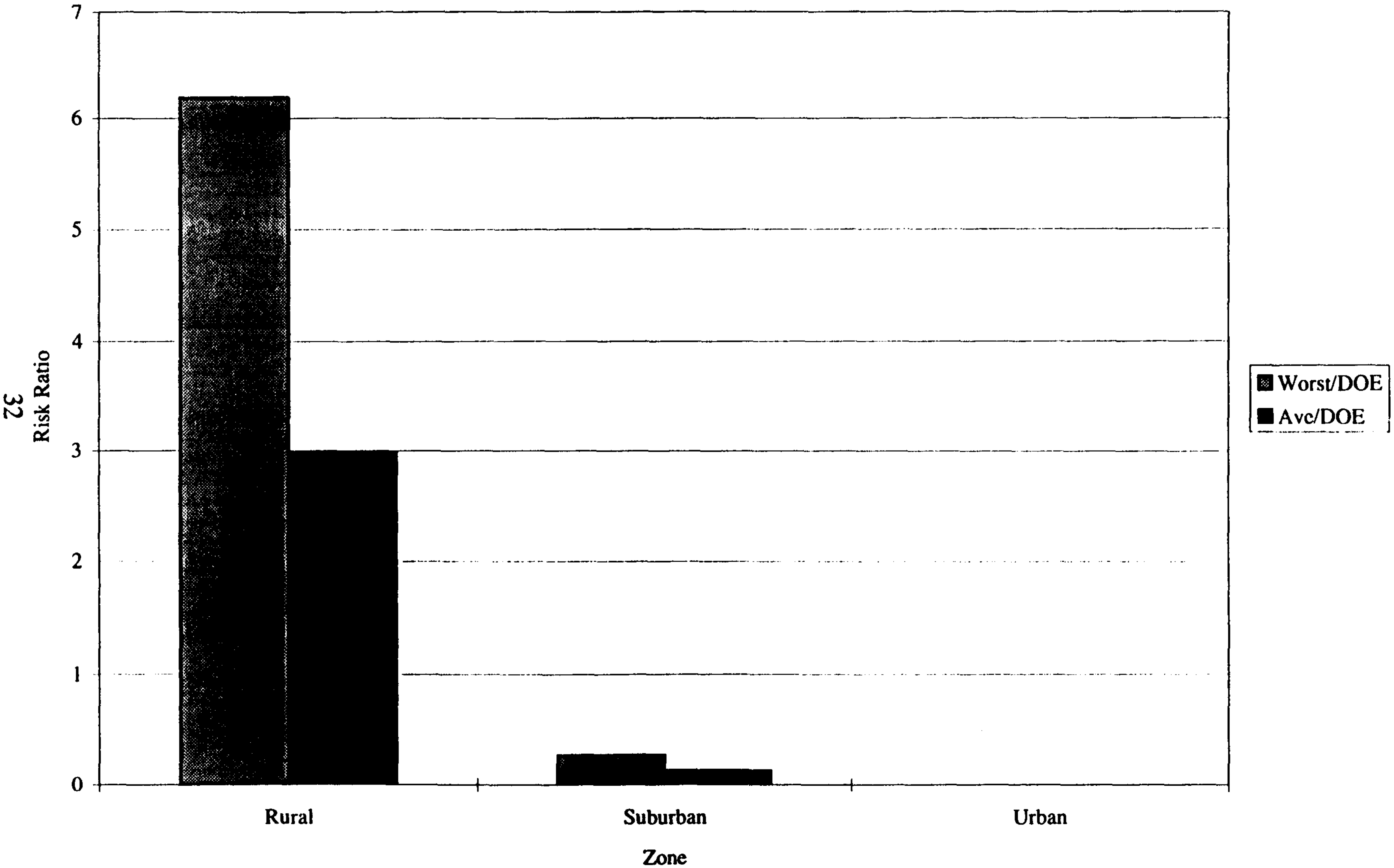


Figure 13. Risk Ratio Based on Unit Risk Analysis - Local vs. DOE



using the DOE data. Rural risk is 6 times greater while suburban risk is 4 times lower when worst case local conditions are compared to the DOE values. For the average condition, local values are 3 times higher in the rural segment and 8 times lower in the suburban segment when compared to the values obtained using DOE data.

Table 17. Unit Population Risk - Accident Scenario

Category	Local Data			Risk Ratio (Local/DOE)	
	Worst Case Risk, person-rem	Average Case Risk, person-rem	DOE Data	Worst Case	Average Case
Rural	7.50E-10	3.62E-10	1.21E-10	6.20	3.00
Suburban	9.49E-8	4.66E-8	3.50E-7	0.27	0.13
Urban	-	-	6.20E-7	-	-

Total population risks are estimated by multiplying the risk on each zone to the total length of the zone. Total population risks are estimated for both local and DOE conditions. A comparison of total risks based on route specific analysis and unit risk analysis is presented in Table 18. When local conditions are evaluated, the total population risks from the unit risk analysis are comparable to the total population risks obtained using route specific analysis. The rural risks are only 8 to 9 percent higher when unit risk analysis is used than when route specific analysis is used. Total risk for the worst case scenario is 3 percent higher using unit risk analysis. When compared with the DOE analysis, the ratio of the total unit risks (local data vs. DOE data) are the same as in Table 13. The rural unit risk, however, is around 7 percent (worst case) and 4 percent (average case) higher than the DOE values. Results representing the suburban segment is similar to that obtained using route specific analysis. Here, it would be appropriate to mention the assumptions regarding the total number of shipments for the rail and highway mode. The number of shipments are 14,600 for highway. The packages per shipment are 1 for highway. These values represent the default values used in the DOE study.

While rural segment risk is higher using local conditions than using DOE data, results representing the suburban segment are much lower. The total risk is lower using local data. The difference between the total risks using the local and DOE data may be attributed to one or a combination of the following reasons: DOE assumes an urban segment which is nonexistent in the local condition; the local population data are 50 percent lower than the DOE data; and local DHV's are 20 to 50 percent lower than the DOE data. These favor the DOE analysis despite the fact that the local accident rates for rural segments are 6 (average case) to 13 (worst case) times higher than the DOE values, and for suburban segments, 3 (average case) to 6 (worst case) times higher than the DOE values.

Table 18. Total Population Risk - Unit Risk Analysis - Accident Scenario

Category	Length, km	Fraction of travel	Worst Case		Average Case		Risk Ratio (Route Specific/ Unit Risk)	
			Route Specific	Unit Risk	Route Specific	Unit Risk	Worst Case	Ave Case
Total	70.21		1.74E-7	1.79E-7	8.53E-8	8.75E-8	0.97	1.00
Rural	68.87	98.09	4.70E-8	5.17E-8	2.28E-8	2.49E-8	0.91	0.92
Suburban	1.34	1.91	1.27E-7	1.27E-7	6.25E-8	6.26E-8	1.00	1.00
Urban	-	-	-	-	-	-	-	-

6 CONCLUSIONS AND RECOMMENDATIONS

The objective of this study was to evaluate the potential risks of transporting radioactive materials by highway through Esmeralda County using RADTRAN IV and to compare the results with those obtained by a similar study that the DOE had conducted in 1984. This report documents the methodology used for this purpose, the data requirements for the modeling process, derivation of data representative of local characteristics, summary of results from the modeling process and critical analysis of the results. A brief summary of the findings of this project is presented in this section followed by some recommendations to further enhance the findings obtained from this study.

ESMERALDA COUNTY CHARACTERISTICS

One of the key characteristics of Esmeralda County pertains to its demographics. The population density distribution in Esmeralda County is different from what the DOE had used. Using local condition, about 98 percent of the links are characterized as rural, and the rest are suburban whereas DOE assumes only around 84 percent as rural and around 16 percent is a combination of suburban and urban links. The population density is generally higher using DOE data than using local data, i.e. 50 percent higher. The local accident rates in the rural segment are 7 (average case) and 13 percent (worst case) times higher than the DOE average value. In the suburban segment, the local accident rates are 3 times (average case) and 6 times (worst case) higher than the DOE average value. The urban segment is nonexistent in the local condition, but exists in the DOE analysis. The local traffic volumes are 20 to 50 percent lower than the DOE values.

RISK ANALYSIS

The risk analysis using RADTRAN suggests that Esmeralda County has potentially lower total risks when compared to the DOE results for the nation as a whole. However, the rural segments in Esmeralda County will be generally subjected to higher proportion of the total risk in Esmeralda County than the nation as a whole. Further, the accident summary output of RADTRAN unit risk analysis shows that the potential risks for the rural segments of the route in Esmeralda County are higher than those found by the DOE. For the suburban segment the potential risks are smaller using the local conditions than the DOE data. Again, there is no urban segment in the local condition. The difference in risk estimates could be attributed to the differences in the values of population densities, accident rates and fractions of rural, suburban and urban zones for the accident scenario. For the incident scenario, the slight variation in the result could be attributed to the traffic volume and the fractions of rural, suburban, and urban zones.

INCIDENT-FREE RISK

For the incident-free risk summary, the crew, stops and persons exposed during stops were observed to be the key contributors to the overall risk under every scenario. More than 60 percent was exposure to the crew, more than 30 percent of the risk was due to exposure during stops. This highlights the importance of stops during the shipment of spent fuel. Thus, the duration and location of stops can play a vital role in developing routing and operating strategies.

POPULATION RISK DURING ACCIDENT SCENARIO

The most significant contributor of risk under the accident scenarios are the accident rates and population densities. These values have a direct impact on the magnitude of risks obtained. The rural and suburban accident rates characteristics of Esmeralda County are higher when compared to the DOE data. But, the population density characteristics are lower when compared to the DOE data. Because of its relatively greater population density, a critical link identified in Esmeralda County is in the vicinity of Goldfield. Once again, in terms of the distribution of risk, the rural segments would be subjected to greater risks in Esmeralda County than the nation as a whole. Any risk management or mitigation strategies should take this into consideration. The DOE analysis does not identify critical segments of the routes. Since the DOE study uses only a single value for each zone, it assumes that the zone has a uniform characteristics which may not necessarily be correct. Each link has a unique characteristic, and therefore, a unique value of estimated risk.

RECOMMENDATIONS FOR FUTURE WORK

The following are recommended for future work:

1) Analysis of temporal distribution of population especially with respect to schools and businesses (hotels/motels, restaurants, and others)

2) Analysis of operational considerations such as time of day shipment, stop location/duration, and others.

3) Evaluation of types and severity of accidents with respect to locations.

4) Use of an improved technique to estimate annual average daily traffic distribution on links.

5) Address cumulative risk issues such as exposure to descendants of people who may have been subjected to "downwind" effects of activities at the Nevada Test Site, and dosage to maximum exposed individual.

REFERENCES

Carr, James, (1992). "Safety of Nevada Railroads: Interim Report", Report No. CIS 92-29, University of Nevada, Reno.

Neuhauser, K. S., and F. L. Kanipe, (1992). "RADTRAN 4: User Guide", SAND-2370, Sandia National Laboratories, Albuquerque, New Mexico. January 1992.

Neuhauser, K. S., J. W. Cashwell, P. C. Reardon and G. W. McNair, (1984). "A Preliminary Cost and Risk Analysis for Transporting Spent Fuel and High-Level Wastes to Candidate Repository Sites", SAND-1795, Sandia National Laboratories, Albuquerque, New Mexico.

Nevada Department of Transportation (NDOT). Planning and Program Development Traffic Section. 1987 to 1993 Annual Traffic Reports.

Nevada Department of Transportation (NDOT). Safety Engineering Division. 1987 to 1993 Annual Traffic Accident Reports.

Resnikoff, Marvin, (1990). "Probabilistic Risk Assessment and Nuclear Waste Transportation: A Case Study of the Use of RADTRAN in the 1986 Environmental Assessment for Yucca Mountain", Radioactive Waste Management Associates, New York, New York.

Sathisan, S.K. and K. Madhavapeddi (1994a). Risk Analysis for Spent Nuclear Fuel Transportation Through Lincoln County. Volume II-A: Highway Shipments. UNLV/TRC/RR-94/12. September 1994.

Sathisan, S.K. Lim, S. and K. Madhavapeddi (1994b). Risk Analysis for Spent Nuclear Fuel Transportation Through Lincoln County. Volume I: Rail Shipments. UNLV/TRC/RR-94/01. September 1994.

Souleyrette, Reginald R., and Kristin Pryor, (1991). "An assessment of RADTRAN Capabilities and Limitations", UNLV/TRC/RR-91/03, Transportation Research Center, University of Nevada, Las Vegas, Nevada.

Souleyrette, Reginald R., and Soon-Tin Lim, (1992). "RADTRAN Analysis for the Canadian Spent Fuel Transportation Scenarios", UNLV/TRC/RR-92/11, Transportation Research Center, University of Nevada, Las Vegas, Nevada.

Souleyrette, Reginald R., Shashi K. Sathisan and Russell diBartolo, (1991). "Yucca Mountain Transportation Routes: Preliminary Characterization and Risk Analysis", UNLV/TRC/RR-91/02, Volumes I, II and III, Transportation Research Center, University of Nevada, Las Vegas, Nevada.

United States. Department of Energy, (1984). "Draft Environmental Assessment: Yucca Mountain Site, Nevada Research and Development Area", DOE/NEVADA-001, Las Vegas, Nevada.

United States. Department of Energy, (1990). "Preliminary Rail Access Study (Yucca Mountain Project)", DOE/YMP-89-16, Yucca Mountain Project Office, Las Vegas, Nevada.

Appendix A

Incident-Free Importance Analysis Summary for All Links

Notes:

1. Incident-free importance analysis summary are the same for worst case and average case conditions.

_ESMERALDA_COUNTY_WORST_CASE_-_ROUTE_SPECIFIC_

INCIDENT-FREE IMPORTANCE ANALYSIS SUMMARY FOR LINK 1
****

INDEX	DESCRIPTION OF PARAMETER	IMPORTANCE
1	DOSE RATE (TRANSPORT INDEX)	3.984E-06
2	NUMBER OF SHIPMENTS	3.984E-06
3	PACKAGES PER SHIPMENT	3.984E-06
4	DISTANCE TRAVELED	3.984E-06
5	K ZERO	3.984E-06
6	FRACTION OF TRAVEL - RURAL	2.563E-06
7	NUMBER OF CREW MEMBERS	2.451E-06
8	STOP TIME	1.422E-06
9	PERSONS EXPOSED WHILE STOPPED	1.422E-06
10	TRAFFIC COUNT - RURAL	1.114E-07
11	NUMBER OF PEOPLE PER VEHICLE	1.114E-07
12	POPULATION DENSITY - RURAL	8.025E-10
13	RURAL SHIELDING FACTOR (RR)	6.729E-10
14	RATIO OF PEDESTRIAN DENSITY (RPD)	1.296E-10
15	HANDLER EXPOSURE DISTANCE	0.000E+00
16	PERSONS EXPOSED PER HANDLING	0.000E+00
17	FRACTION OF TRAVEL - URBAN	0.000E+00
18	NUMBER OF HANDLINGS	0.000E+00
19	EXPOSURE TIME FOR HANDLERS	0.000E+00
20	FRACTION OF TRAVEL ON FREEWAYS	0.000E+00
21	NUMBER OF FLIGHT ATTENDANTS	0.000E+00
22	TRAFFIC COUNT - URBAN	0.000E+00
23	TRAFFIC COUNT - SUBURBAN	0.000E+00
24	FRACTION OF RUSH HOUR TRAVEL	0.000E+00
25	FRACTION OF TRAVEL - SUBURBAN	0.000E+00
26	VELOCITY - URBAN	0.000E+00
27	VELOCITY - SUBURBAN	0.000E+00
28	URBAN SHIELDING FACTOR (RU)	0.000E+00
29	FRACTION OF TRAVEL ON CITY STREETS	0.000E+00
30	POPULATION DENSITY - SUBURBAN	0.000E+00
31	POPULATION DENSITY - URBAN	0.000E+00
32	STORAGE EXPOSURE DISTANCE	0.000E+00
33	NUMBER OF PERSONS EXPOSED DURING STORAGE	0.000E+00
34	SUBURBAN SHIELDING FACTOR (RS)	0.000E+00
35	STORAGE TIME PER SHIPMENT	0.000E+00
36	VELOCITY - RURAL	-2.674E-06
37	EXPOSURE DISTANCE WHILE STOPPED	-2.843E-06
38	DISTANCE FROM SOURCE TO CREW	-4.901E-06

THE IMPORTANCE VALUE ESTIMATES THE PERSON-REM INFLUENCE
OF A ONE PERCENT INCREASE IN THE PARAMETER

_ESMERALDA_COUNTY_WORST_CASE_-_ROUTE_SPECIFIC_

INCIDENT-FREE IMPORTANCE ANALYSIS SUMMARY FOR LINK 2
****

INDEX	DESCRIPTION OF PARAMETER	IMPORTANCE
1	K ZERO	5.357E-06
2	DOSE RATE (TRANSPORT INDEX)	5.357E-06
3	DISTANCE TRAVELED	5.357E-06
4	NUMBER OF SHIPMENTS	5.357E-06
5	PACKAGES PER SHIPMENT	5.357E-06
6	FRACTION OF TRAVEL - RURAL	3.443E-06
7	NUMBER OF CREW MEMBERS	3.301E-06
8	STOP TIME	1.915E-06
9	PERSONS EXPOSED WHILE STOPPED	1.915E-06
10	NUMBER OF PEOPLE PER VEHICLE	1.403E-07
11	TRAFFIC COUNT - RURAL	1.403E-07
12	POPULATION DENSITY - RURAL	1.081E-09
13	RURAL SHIELDING FACTOR (RR)	9.065E-10
14	RATIO OF PEDESTRIAN DENSITY (RPD)	1.745E-10
15	HANDLER EXPOSURE DISTANCE	0.000E+00
16	PERSONS EXPOSED PER HANDLING	0.000E+00
17	FRACTION OF TRAVEL - URBAN	0.000E+00
18	NUMBER OF HANDLINGS	0.000E+00
19	EXPOSURE TIME FOR HANDLERS	0.000E+00
20	FRACTION OF TRAVEL ON FREEWAYS	0.000E+00
21	NUMBER OF FLIGHT ATTENDANTS	0.000E+00
22	TRAFFIC COUNT - URBAN	0.000E+00
23	TRAFFIC COUNT - SUBURBAN	0.000E+00
24	FRACTION OF RUSH HOUR TRAVEL	0.000E+00
25	FRACTION OF TRAVEL - SUBURBAN	0.000E+00
26	VELOCITY - URBAN	0.000E+00
27	VELOCITY - SUBURBAN	0.000E+00
28	URBAN SHIELDING FACTOR (RU)	0.000E+00
29	FRACTION OF TRAVEL ON CITY STREETS	0.000E+00
30	POPULATION DENSITY - SUBURBAN	0.000E+00
31	POPULATION DENSITY - URBAN	0.000E+00
32	STORAGE EXPOSURE DISTANCE	0.000E+00
33	NUMBER OF PERSONS EXPOSED DURING STORAGE	0.000E+00
34	SUBURBAN SHIELDING FACTOR (RS)	0.000E+00
35	STORAGE TIME PER SHIPMENT	0.000E+00
36	VELOCITY - RURAL	-3.583E-06
37	EXPOSURE DISTANCE WHILE STOPPED	-3.830E-06
38	DISTANCE FROM SOURCE TO CREW	-6.602E-06

THE IMPORTANCE VALUE ESTIMATES THE PERSON-REM INFLUENCE
OF A ONE PERCENT INCREASE IN THE PARAMETER

_ESMERALDA_COUNTY_WORST_CASE_-_ROUTE_SPECIFIC_

INCIDENT-FREE IMPORTANCE ANALYSIS SUMMARY FOR LINK 3
****

INDEX	DESCRIPTION OF PARAMETER	IMPORTANCE
1	K ZERO	1.084E-05
2	DOSE RATE (TRANSPORT INDEX)	1.084E-05
3	DISTANCE TRAVELED	1.084E-05
4	NUMBER OF SHIPMENTS	1.084E-05
5	PACKAGES PER SHIPMENT	1.084E-05
6	FRACTION OF TRAVEL - RURAL	7.008E-06
7	NUMBER OF CREW MEMBERS	6.602E-06
8	PERSONS EXPOSED WHILE STOPPED	3.830E-06
9	STOP TIME	3.830E-06
10	NUMBER OF PEOPLE PER VEHICLE	4.030E-07
11	TRAFFIC COUNT - RURAL	4.030E-07
12	POPULATION DENSITY - RURAL	2.162E-09
13	RURAL SHIELDING FACTOR (RR)	1.813E-09
14	RATIO OF PEDESTRIAN DENSITY (RPD)	3.490E-10
15	HANDLER EXPOSURE DISTANCE	0.000E+00
16	PERSONS EXPOSED PER HANDLING	0.000E+00
17	FRACTION OF TRAVEL - URBAN	0.000E+00
18	NUMBER OF HANDLINGS	0.000E+00
19	EXPOSURE TIME FOR HANDLERS	0.000E+00
20	FRACTION OF TRAVEL ON FREEWAYS	0.000E+00
21	NUMBER OF FLIGHT ATTENDANTS	0.000E+00
22	TRAFFIC COUNT - URBAN	0.000E+00
23	TRAFFIC COUNT - SUBURBAN	0.000E+00
24	FRACTION OF RUSH HOUR TRAVEL	0.000E+00
25	FRACTION OF TRAVEL - SUBURBAN	0.000E+00
26	VELOCITY - URBAN	0.000E+00
27	VELOCITY - SUBURBAN	0.000E+00
28	URBAN SHIELDING FACTOR (RU)	0.000E+00
29	FRACTION OF TRAVEL ON CITY STREETS	0.000E+00
30	POPULATION DENSITY - SUBURBAN	0.000E+00
31	POPULATION DENSITY - URBAN	0.000E+00
32	STORAGE EXPOSURE DISTANCE	0.000E+00
33	NUMBER OF PERSONS EXPOSED DURING STORAGE	0.000E+00
34	SUBURBAN SHIELDING FACTOR (RS)	0.000E+00
35	STORAGE TIME PER SHIPMENT	0.000E+00
36	VELOCITY - RURAL	-7.411E-06
37	EXPOSURE DISTANCE WHILE STOPPED	-7.660E-06
38	DISTANCE FROM SOURCE TO CREW	-1.320E-05

THE IMPORTANCE VALUE ESTIMATES THE PERSON-REM INFLUENCE
OF A ONE PERCENT INCREASE IN THE PARAMETER

_ESMERALDA_COUNTY_WORST_CASE_-_ROUTE_SPECIFIC_

INCIDENT-FREE IMPORTANCE ANALYSIS SUMMARY FOR LINK 4
****

INDEX	DESCRIPTION OF PARAMETER	IMPORTANCE
1	DISTANCE TRAVELED	3.417E-06
2	NUMBER OF SHIPMENTS	3.417E-06
3	DOSE RATE (TRANSPORT INDEX)	3.417E-06
4	K ZERO	3.417E-06
5	PACKAGES PER SHIPMENT	3.417E-06
6	FRACTION OF TRAVEL - RURAL	2.203E-06
7	NUMBER OF CREW MEMBERS	2.093E-06
8	PERSONS EXPOSED WHILE STOPPED	1.214E-06
9	STOP TIME	1.214E-06
10	NUMBER OF PEOPLE PER VEHICLE	1.091E-07
11	TRAFFIC COUNT - RURAL	1.091E-07
12	POPULATION DENSITY - RURAL	6.855E-10
13	RURAL SHIELDING FACTOR (RR)	5.748E-10
14	RATIO OF PEDESTRIAN DENSITY (RPD)	1.107E-10
15	HANDLER EXPOSURE DISTANCE	0.000E+00
16	PERSONS EXPOSED PER HANDLING	0.000E+00
17	FRACTION OF TRAVEL - URBAN	0.000E+00
18	NUMBER OF HANDLINGS	0.000E+00
19	EXPOSURE TIME FOR HANDLERS	0.000E+00
20	FRACTION OF TRAVEL ON FREEWAYS	0.000E+00
21	NUMBER OF FLIGHT ATTENDANTS	0.000E+00
22	TRAFFIC COUNT - URBAN	0.000E+00
23	TRAFFIC COUNT - SUBURBAN	0.000E+00
24	FRACTION OF RUSH HOUR TRAVEL	0.000E+00
25	FRACTION OF TRAVEL - SUBURBAN	0.000E+00
26	VELOCITY - URBAN	0.000E+00
27	VELOCITY - SUBURBAN	0.000E+00
28	URBAN SHIELDING FACTOR (RU)	0.000E+00
29	FRACTION OF TRAVEL ON CITY STREETS	0.000E+00
30	POPULATION DENSITY - SUBURBAN	0.000E+00
31	POPULATION DENSITY - URBAN	0.000E+00
32	STORAGE EXPOSURE DISTANCE	0.000E+00
33	NUMBER OF PERSONS EXPOSED DURING STORAGE	0.000E+00
34	SUBURBAN SHIELDING FACTOR (RS)	0.000E+00
35	STORAGE TIME PER SHIPMENT	0.000E+00
36	VELOCITY - RURAL	-2.312E-06
37	EXPOSURE DISTANCE WHILE STOPPED	-2.429E-06
38	DISTANCE FROM SOURCE TO CREW	-4.187E-06

THE IMPORTANCE VALUE ESTIMATES THE PERSON-REM INFLUENCE
OF A ONE PERCENT INCREASE IN THE PARAMETER

_ESMERALDA_COUNTY_WORST_CASE_-_ROUTE_SPECIFIC_

INCIDENT-FREE IMPORTANCE ANALYSIS SUMMARY FOR LINK 5
****

INDEX	DESCRIPTION OF PARAMETER	IMPORTANCE
1	DISTANCE TRAVELED	1.258E-06
2	NUMBER OF SHIPMENTS	1.258E-06
3	PACKAGES PER SHIPMENT	1.258E-06
4	DOSE RATE (TRANSPORT INDEX)	1.258E-06
5	K ZERO	1.258E-06
6	FRACTION OF TRAVEL - RURAL	8.119E-07
7	NUMBER OF CREW MEMBERS	7.690E-07
8	PERSONS EXPOSED WHILE STOPPED	4.461E-07
9	STOP TIME	4.461E-07
10	NUMBER OF PEOPLE PER VEHICLE	4.270E-08
11	TRAFFIC COUNT - RURAL	4.270E-08
12	POPULATION DENSITY - RURAL	2.518E-10
13	RURAL SHIELDING FACTOR (RR)	2.112E-10
14	RATIO OF PEDESTRIAN DENSITY (RPD)	4.065E-11
15	HANDLER EXPOSURE DISTANCE	0.000E+00
16	PERSONS EXPOSED PER HANDLING	0.000E+00
17	FRACTION OF TRAVEL - URBAN	0.000E+00
18	NUMBER OF HANDLINGS	0.000E+00
19	EXPOSURE TIME FOR HANDLERS	0.000E+00
20	FRACTION OF TRAVEL ON FREEWAYS	0.000E+00
21	NUMBER OF FLIGHT ATTENDANTS	0.000E+00
22	TRAFFIC COUNT - URBAN	0.000E+00
23	TRAFFIC COUNT - SUBURBAN	0.000E+00
24	FRACTION OF RUSH HOUR TRAVEL	0.000E+00
25	FRACTION OF TRAVEL - SUBURBAN	0.000E+00
26	VELOCITY - URBAN	0.000E+00
27	VELOCITY - SUBURBAN	0.000E+00
28	URBAN SHIELDING FACTOR (RU)	0.000E+00
29	FRACTION OF TRAVEL ON CITY STREETS	0.000E+00
30	POPULATION DENSITY - SUBURBAN	0.000E+00
31	POPULATION DENSITY - URBAN	0.000E+00
32	STORAGE EXPOSURE DISTANCE	0.000E+00
33	NUMBER OF PERSONS EXPOSED DURING STORAGE	0.000E+00
34	SUBURBAN SHIELDING FACTOR (RS)	0.000E+00
35	STORAGE TIME PER SHIPMENT	0.000E+00
36	VELOCITY - RURAL	-8.546E-07
37	EXPOSURE DISTANCE WHILE STOPPED	-8.921E-07
38	DISTANCE FROM SOURCE TO CREW	-1.538E-06

THE IMPORTANCE VALUE ESTIMATES THE PERSON-REM INFLUENCE OF A ONE PERCENT INCREASE IN THE PARAMETER

_ESMERALDA_COUNTY_WORST_CASE_-_ROUTE_SPECIFIC_

INCIDENT-FREE IMPORTANCE ANALYSIS SUMMARY FOR LINK 6
****

INDEX	DESCRIPTION OF PARAMETER	IMPORTANCE
1	DISTANCE TRAVELED	1.628E-06
2	NUMBER OF SHIPMENTS	1.628E-06
3	PACKAGES PER SHIPMENT	1.628E-06
4	DOSE RATE (TRANSPORT INDEX)	1.628E-06
5	K ZERO	1.628E-06
6	FRACTION OF TRAVEL - SUBURBAN	1.326E-06
7	NUMBER OF CREW MEMBERS	1.143E-06
8	PERSONS EXPOSED WHILE STOPPED	3.019E-07
9	STOP TIME	3.019E-07
10	NUMBER OF PEOPLE PER VEHICLE	1.419E-07
11	TRAFFIC COUNT - SUBURBAN	1.419E-07
12	POPULATION DENSITY - SUBURBAN	4.093E-08
13	SUBURBAN SHIELDING FACTOR (RS)	3.351E-08
14	RATIO OF PEDESTRIAN DENSITY (RPD)	7.416E-09
15	TRAFFIC COUNT - RURAL	0.000E+00
16	EXPOSURE TIME FOR HANDLERS	0.000E+00
17	NUMBER OF HANDLINGS	0.000E+00
18	NUMBER OF FLIGHT ATTENDANTS	0.000E+00
19	PERSONS EXPOSED PER HANDLING	0.000E+00
20	FRACTION OF TRAVEL ON FREEWAYS	0.000E+00
21	FRACTION OF RUSH HOUR TRAVEL	0.000E+00
22	HANDLER EXPOSURE DISTANCE	0.000E+00
23	TRAFFIC COUNT - URBAN	0.000E+00
24	STORAGE EXPOSURE DISTANCE	0.000E+00
25	FRACTION OF TRAVEL ON CITY STREETS	0.000E+00
26	FRACTION OF TRAVEL - URBAN	0.000E+00
27	VELOCITY - RURAL	0.000E+00
28	POPULATION DENSITY - RURAL	0.000E+00
29	FRACTION OF TRAVEL - RURAL	0.000E+00
30	POPULATION DENSITY - URBAN	0.000E+00
31	VELOCITY - URBAN	0.000E+00
32	RURAL SHIELDING FACTOR (RR)	0.000E+00
33	NUMBER OF PERSONS EXPOSED DURING STORAGE	0.000E+00
34	URBAN SHIELDING FACTOR (RU)	0.000E+00
35	STORAGE TIME PER SHIPMENT	0.000E+00
36	EXPOSURE DISTANCE WHILE STOPPED	-6.038E-07
37	VELOCITY - SUBURBAN	-1.468E-06
38	DISTANCE FROM SOURCE TO CREW	-2.286E-06

THE IMPORTANCE VALUE ESTIMATES THE PERSON-REM INFLUENCE OF A ONE PERCENT INCREASE IN THE PARAMETER

_ESMERALDA_COUNTY_WORST_CASE_-_ROUTE_SPECIFIC_

INCIDENT-FREE IMPORTANCE ANALYSIS SUMMARY FOR LINK 7
****

INDEX	DESCRIPTION OF PARAMETER	IMPORTANCE
1	K ZERO	1.887E-05
2	DOSE RATE (TRANSPORT INDEX)	1.887E-05
3	PACKAGES PER SHIPMENT	1.887E-05
4	DISTANCE TRAVELED	1.887E-05
5	NUMBER OF SHIPMENTS	1.887E-05
6	FRACTION OF TRAVEL - RURAL	1.218E-05
7	NUMBER OF CREW MEMBERS	1.153E-05
8	STOP TIME	6.691E-06
9	PERSONS EXPOSED WHILE STOPPED	6.691E-06
10	NUMBER OF PEOPLE PER VEHICLE	6.404E-07
11	TRAFFIC COUNT - RURAL	6.404E-07
12	POPULATION DENSITY - RURAL	3.777E-09
13	RURAL SHIELDING FACTOR (RR)	3.167E-09
14	RATIO OF PEDESTRIAN DENSITY (RPD)	6.098E-10
15	HANDLER EXPOSURE DISTANCE	0.000E+00
16	PERSONS EXPOSED PER HANDLING	0.000E+00
17	FRACTION OF TRAVEL - URBAN	0.000E+00
18	NUMBER OF HANDLINGS	0.000E+00
19	EXPOSURE TIME FOR HANDLERS	0.000E+00
20	FRACTION OF TRAVEL ON FREEWAYS	0.000E+00
21	NUMBER OF FLIGHT ATTENDANTS	0.000E+00
22	TRAFFIC COUNT - URBAN	0.000E+00
23	TRAFFIC COUNT - SUBURBAN	0.000E+00
24	FRACTION OF RUSH HOUR TRAVEL	0.000E+00
25	FRACTION OF TRAVEL - SUBURBAN	0.000E+00
26	VELOCITY - URBAN	0.000E+00
27	VELOCITY - SUBURBAN	0.000E+00
28	URBAN SHIELDING FACTOR (RU)	0.000E+00
29	FRACTION OF TRAVEL ON CITY STREETS	0.000E+00
30	POPULATION DENSITY - SUBURBAN	0.000E+00
31	POPULATION DENSITY - URBAN	0.000E+00
32	STORAGE EXPOSURE DISTANCE	0.000E+00
33	NUMBER OF PERSONS EXPOSED DURING STORAGE	0.000E+00
34	SUBURBAN SHIELDING FACTOR (RS)	0.000E+00
35	STORAGE TIME PER SHIPMENT	0.000E+00
36	VELOCITY - RURAL	-1.282E-05
37	EXPOSURE DISTANCE WHILE STOPPED	-1.338E-05
38	DISTANCE FROM SOURCE TO CREW	-2.307E-05

THE IMPORTANCE VALUE ESTIMATES THE PERSON-REM INFLUENCE
OF A ONE PERCENT INCREASE IN THE PARAMETER