

ATTACHMENT 4-1 TRANSPORTATION EVALUATION

Explanation of RADTRAN Input

The routing code WebTRAGIS (used in this analysis and in most RADTRAN analyses) provides routing data in two different forms: (1) combined rural, combined suburban, and combined urban route segments (links) and population densities for each state transited, and (2) a much more precise output that provides rural, suburban, and urban segments for node-to-node distances, one to about 15 km long. The second method was used in the WCS analysis because it identifies the receptor population much more precisely than the state-to-state routing data. However, this output consists of several hundred links and can have more than a thousand links. The RADTRAN graphical user interface RadCat cannot accommodate more than 60 links in a single analysis, and even if it could, creates an environment in which user input errors are easy to make and difficult to find. RADTRAN itself can accommodate thousands of links, but is equally input error-prone, and the output becomes difficult to read and interpret.

In order to take advantage of the increased precision, the input to RADTRAN for the WCS analyses used a unit risk factor (URF) approach, structured in the same way as the input to NUREG 2125 (NRC, 2014), as follows:

1. A unit risk factor (URF) radiation population dose was calculated by the RADTRAN code. The URF population dose is the dose to a population density of one person per square kilometer (km^2) on a rural, a suburban, and an urban link, each one km. long. This unit population density was also used to calculate doses at representative stops.
2. Population dose is then calculated for each link and each stop using a spreadsheet that allows multiplication of the unit risks by link length and link (or stop) population.

The RADTRAN input and output text files that accompany this explanation are the URF files. The relevant spreadsheets are included in the material sent.

Reference: U.S. Nuclear Regulatory Commission (NRC), "Spent Fuel Transportation Risk Assessment," NUREG-2125, Nuclear Regulatory Commission, Rockville, MD.

Evaluation of Transportation Routes from Shut Down Nuclear Generating Stations

Ruth Weiner

How the transportation routes were evaluated

The purpose of this study was to compare the routes and assess which parameters were most influential. Collective (population) radiation dose to residents along the routes during routine, incident-free transportation provided the means of comparison. Unit doses, doses sustained by a population density of one person per square km, from a vehicle traveling one kilometer per hour, were used to calculate collective doses to residents within a half mile (800 meters) of the route, from a vehicle traveling along the route. Rural, suburban, and urban route segments were analyzed separately and the resulting collective doses were added. Doses were calculated both with and without addition of doses from changes of transportation mode (rail to or from barge, rail to or from heavy haul truck).

The routing code WebTRAGIS, developed by the Oak Ridge National Laboratory (ORNL) was used to analyze the routes. The section of the WebTRAGIS output used in this study was RouteDensityByState, which provides the length and resident population density of each route segment. Unit doses used had been calculated, using the code RADTRAN, version 6.02, for a previous study. Table 1 lists the routing parameters for the present study. Highway routes for San Onofre and Humboldt Bay could not be run in WebTRAGIS; the reason for this could not be determined. Population densities for the appropriate population block (rural, suburban, urban) were used to determine the doses to transfer residents near the mode rather than attempting to estimate the population densities at the mode transfer locations.

Table 1. Parameter Values

Parameter	Parameter value	Units	Comment/Reference
Rural/suburban unit risk	9.11E-08 9.11E-06	Person-rem Person-Sv	Previous WCS study
Urban unit risk	2.05E-09 2.05E-07	Person-rem Person-Sv	Previous WCS study
Rail speed	50	mph	DOE, 2002
Barge speed	8	mph	NRC, 2014
Heavy haul speed	20	mph	DOE, 2002
Rural residential shielding	1	unitless	Weiner, et al., 2014
Suburban residential shielding	0.87	unitless	Weiner, et al., 2014
Urban residential shielding	0.018	unitless	Weiner, et al., 2014
Mode transfer area	2	Km ²	Analyst estimate
Mode transfer time	8	hours	Analyst estimate

Results

Table 2 shows the summarized results.

Table 2. Summarized results

Nuclear Power Plant Origins	Population Dose (Person-rem)			Including Mode Transfer			Including Mode Transfer		
				Population Dose (Person-rem)			Population Dose (Person-Sv)		
	Direct Rail	Rail + Barge	Rail + Heavy Haul	Direct Rail	Rail + Barge	Rail + Heavy Haul	Direct Rail	Rail + Barge	Rail + Heavy Haul
Maine Yankee	5.13E-02	5.13E-02		5.13E-02	5.25E-02		5.13E-04	5.13E-04	
Yankee Rowe			2.26E-02			2.38E-02			2.38E-04
Connecticut Yankee		7.21E-03	2.94E-02		9.07E-03	9.07E-03		9.07E-05	9.07E-05
Humboldt Bay		1.93E-02			1.94E-02			1.94E-04	
Big Rock Point		2.72E-02	2.79E-02		2.87E-02	2.79E-02		2.87E-04	2.79E-04
Rancho Seco	1.80E-02			1.80E-02			1.80E-04		
Trojan	2.79E-02	2.76E-02		2.79E-02	2.77E-02		2.79E-04	2.77E-04	
La Crosse	1.51E-02	2.94E-03		1.51E-02	3.80E-03		1.51E-04	3.80E-05	
Zion	1.55E-02	2.05E-02		1.55E-02	2.27E-02		1.55E-04	2.27E-04	
Crystal River	1.59E-02	1.08E-02		1.59E-02	1.10E-02		1.59E-04	1.10E-04	
Kewaunee		2.50E-02	2.57E-02		3.22E-02	2.76E-02		3.22E-04	2.76E-04
San Onofre	1.07E-02			1.07E-02			1.07E-04		

Collective dose depends of on the size of the exposed population, which in turn depends on the length of the route and the bandwidth. The collective doses in Table 2 are small; the largest calculated collective dose is 0.0513 person-rem, and this dose is spread over approximately 550,000 people and 2200 miles of railroad. All of the collective doses appear to be of the same order of magnitude. Nor does the introduction of a slower vehicle like a barge appear to have a significant impact: Half of the Crystal River dose is from barge travel and half from rail travel, and the total collective dose is similar in magnitude to the others.

This confirms that the most important parameters in estimating risks of routing transportation are the distance traveled and the size of the exposed population, and that all of the collective doses are less than 0.006person-rem (0.00006 person-Sv. The exception is the population dose in urban areas. The urban residential shielding factor, a measure of the gamma energy transmitted to residents, is two orders of magnitude less than the residential shielding to rural residents.

He collective doses that have been calculated are insignificant when compared to background. For example, a rail trip from Maine Yankee to WCS takes six days and results in a dose of 0.0476 person-rem to a population of 110,650; and an average natural background dose of 0.311 rem, the collective background dose is $0.311 \times (6/365) \times 110650 = 471$ person-rem..

Bibliography

USDOE, *Final Environmental Impact Statement for a Geologic Repository Yucca Mountain, for the Disposal of Spent Fuel at Yucca Mountain , Nye County, Nevada*, DOE/EIS-0250F, U.S. Department of Energy, Washington, DC, 2002.

USNRC, *Spent Fuel Transportation Risk Assessment*, NUREG 2125, U. S. Nuclear Regulatory Commission,

Weiner, R.F., Neuhauser, K.S., Heames, T.J., O'Donnell, B.M., Dennis, M.L., *RADTRAN 6 Technical Manual* SAND2013-0780, Sandia National Laboratories, Albuquerque, NM, 2014

Maine Yankee

State	Suburban			Urban		
	Rural PD	Rural Dist.	Rural p	Suburban PD	Suburban P	Urban PD
AR	37.5	204.7	3838.125	953.3	96.22	45863.263
IL	28.2	183.15	2582.415	721.8	44.9	16204.41
IN	46.3	64.76	1499.194	1361.1	87.14	59303.127
MA	51.1	52.47	1340.6085	1298.7	98.75	64123.3125
ME	85.9	27.7	1189.715	973.5	55.93	27223.9275
MO	28.2	76.03	1072.023	774.2	17.92	6936.832
NH	91.4	5.9	269.63	873.1	25.62	11184.411
NY	61.9	210.68	6520.546	1056.2	166.21	87775.501
OH	46.4	139.61	3238.952	1400.2	109.2	76450.92
PA	61.2	18.89	578.034	1760	19.45	17116
TX	34.3	401.83	6891.3845	1192.8	185.53	110650.092
total dist		1385.72			906.87	
km		2230.104447			1459.468594	
population			29020.627		522831.796	
PD (metric)	26.0262492			716.4687179		4286.563065
person-rem			2.64E-03		4.76E-02	1.03E-03

Ranch Seco

State	Rural	Rural Dist.	Rural P	Suburban	Suburban Dist	Suburban P	Urban	Urban Dist	Urban P
AZ	18.6	314.42	2924.106	1046.6	70.53	36908.349	4273.7	5.19	11090.2515
CA	36	407.21	7329.78	1300.5	189.83	123436.9575	5223.9	73.43	191795.4885
NM	7.1	156.66	556.143	917.5	10.86	4982.025	0	0	0
TX	9	207.14	932.13	1058	28.63	15145.27	6508.8	14.08	45821.952
total dist		1085.43			299.85			92.7	
km		1746.83361			482.5627243			149.1865	
population			11742.159			180472.6015			248707.692
PD (metric)	13.4439353			747.9757238			3334.185514		
person-rem			1.07E-03			1.64E-02			5.10E-04

Trojan

State	Rural	Rural Dist.	Rural P	Suburban	Suburban Dist	Suburban P	Urban	Urban Dist	Urban P
AZ	18.6	314.42	2924.106	1046.6	70.53	36908.349	4273.7	5.19	11090.2515
CA	35.6	612.1	10895.38	1245.4	278.52	173434.404	5102.3	94.7	241593.905
NM	7.1	156.66	556.143	917.5	10.86	4982.025	0	0	0
OR	29.9	254.54	3805.373	1044.9	91.89	48007.9305	6650.1	31.22	103808.061
TX	9	207.14	932.13	1058	28.63	15145.27	6508.8	14.08	45821.952
total dist		1544.86			480.43			145.19	
km		2486.215942			773.1786214			233.6611	
population			19113.132			278477.9785			402314.1695
PD (metric)	15.3752791			720.3457798			3443.569881		
person-rem			1.74E-03			2.54E-02			8.25E-04

LaCrosse

State	Rural			Suburban			Urban		
	Rural	Rural Dist.	Rural P	Suburban	Suburban Dist.	Suburban P	Urban	Urban Dist.	Urban P
IA	57.3	14.28	409.122	478.6	5.51	1318.543	0	0	0
IL	24	165.61	1987.32	675.9	27.81	9398.3895	4469.4	1.46	3262.662
KS	23.8	169.24	2013.956	1209.1	52.29	31611.9195	4157.9	6.81	14157.6495
MO	28.1	176.88	2485.164	783.3	18.12	7096.698	8523.2	3.96	16875.936
OK	38.8	168.52	3269.288	1240.4	62.87	38991.974	4791	16.2	38807.1
TX	32.2	305.57	4919.677	1034.1	119.34	61704.747	6083.7	12.96	39422.376
WI	19.2	84.85	814.56	691.2	8.22	2840.832	0	0	0
total dist		985.82			280.43			41.39	
km		1586.526546			451.3092039			66.61088	
population			14675.405			148803.728			112525.7235
PD (metric'	18.5000434			659.4313908			3378.599121		
person-rem			1.34E-03			1.36E-02			2.31E-04
Zion									

State	Rural			Suburban			Urban		
	Rural	Rural Dist.	Rural P	Suburban	Suburban Dist	Suburban P	Urban	Urban Dist	Urban P
IA	45.2	204.71	4626.446	863.8	90.19	38953.061	3794.6	3.33	6318.009
IL	42.4	65.96	1398.352	1498.1	71.02	53197.531	4892.8	28.62	70015.968
KS	28.5	124.58	1775.265	1194.3	30.92	18463.878	3876.6	5.26	10195.458
MO	28.9	108.12	1562.334	1447	20.75	15012.625	8156.5	2.38	9706.235
OK	29.6	187.56	2775.888	1107.5	54.46	30157.225	3532.1	1.87	3302.5135
TX	31.5	314.73	4956.9975	1033.2	131.95	68165.37	5142.5	17.2	44225.5
total dist		690.93			267.34			41.46	
km		1111.946183			430.2428505			66.72353	
population			12138.285			155784.32			99538.1835
PD (metric'	21.8325045			724.1692445			2983.600631		
person-rem			1.11E-03			1.42E-02			2.04E-04

Maine Yankee rail

State	Rural	Rural Dist.	Rural P	Suburban	Suburban	Urban P	Urban	Urban Dist	Urban P
AR	37.5	204.7	3838.125	953.3	96.22	45863.263	5509.4	4.02	11073.894
IL	28.2	183.15	2582.415	721.8	44.9	16204.41	3785.7	0.69	1306.0665
IN	46.3	64.76	1499.194	1361.1	87.14	59303.127	10054.7	10.6	53289.91
MA	51.1	52.47	1340.6085	1298.7	98.75	64123.3125	8695.9	45.63	198396.9585
ME	81.7	22.94	937.099	1045.4	49.47	25857.969	5644.1	7.35	20742.0675
MO	28.2	76.03	1072.023	774.2	17.92	6936.832	0	0	0
NH	91.4	5.9	269.63	873.1	25.62	11184.411	5916.1	3.27	9672.8235
NY	61.9	210.68	6520.546	1056.2	166.21	87775.501	5671.9	22.95	65085.0525
OH	46.4	139.61	3238.952	1400.2	109.2	76450.92	4135.9	20.48	42351.616
PA	61.2	18.89	578.034	1760	19.45	17116	5934.1	5.51	16348.4455
TX	34.3	401.83	6891.3845	1192.8	185.53	110650.092	6694.6	25.77	86259.921
total dist		1380.96			900.41			146.27	
km		2222.444			1449.072			235.3992	
population			28768.011			521465.8375			504526.755
PD (metric)	25.88863			719.7237			4286.563		
person-rem			2.62E-03			4.75E-02			1.03E-03

Trojan from Portland

State	Rural	Rural Dist.	Rural P	Suburban	Suburban	Suburban P	Urban	Urban Dist	Urban P
AZ	18.6	314.42	2924.106	1046.6	70.53	36908.349	4273.7	5.19	11090.2515
CA	35.6	612.1	10895.38	1245.4	278.52	173434.404	5102.3	94.7	241593.905
NM	7.1	156.66	556.143	917.5	10.86	4982.025	0	0	0
OR	28.1	234.88	3300.064	1110.3	79.88	44345.382	6629.5	30.97	102657.8075
TX	9	207.14	932.13	1058	28.63	15145.27	6508.8	14.08	45821.952
total dist		1525.2			468.42			144.94	
km		2454.576			753.8504			233.2588	
population			18607.823			274815.43			401163.916
PD (metric)	15.16174			729.0981			3439.647		
person-rem			1.70E-03			2.50E-02			8.22E-04

LaCrosse from Rock Island

State	Rural	Rural Dist.	Rural P	Suburban	Suburban I	Suburban P	Urban	Urban Dist	Urban P
IA	57.3	14.28	409.122	478.6	5.51	1318.543	0	0	0
IL	23	81.87	941.505	1164.8	24.07	14018.368	3979.7	3.12	6208.332
KS	23.8	169.24	2013.956	1209.1	52.29	31611.9195	4157.9	6.81	14157.6495
MO	28.1	176.88	2485.164	783.3	18.12	7096.698	8523.2	3.96	16875.936
OK	38.8	168.52	3269.288	1240.4	62.87	38991.974	4791	16.2	38807.1
TX	32.2	305.57	4919.677	1034.1	119.34	61704.747	6083.7	12.96	39422.376
total dist		916.36			282.2			43.05	
km		1474.741			454.1577			69.28239	
population			9119.035			21451.8			76049.0175
PD (metric)	12.36696			94.4685			2195.335		
person-rem			8.31E-04			1.95E-03			1.56E-04

Zion from chicago

State	Rural	Rural Dist.		Suburban	Suburban Dist.		Urban	Urban Dist.	
IL	26.2	205.63	2693.753	1268	74.38	47156.92	4836	27.09	65503.62
KS	28.5	124.58	1775.265	1194.3	30.92	18463.878	3876.6	5.26	10195.458
MO	32.4	212.71	3445.902	1313.8	61.8	40596.42	7196.5	15.62	56204.665
OK	29.6	187.56	2775.888	1107.5	54.46	30157.225	3532.1	1.87	3302.5135
TX	31.5	314.73	4956.9975	1033.2	131.95	68165.37	5142.5	17.2	44225.5
			0						
total dist		1045.21			353.51			67.04	
km		1682.106			568.9203			107.8906	
population			15647.8055			204539.813			179431.7565
PD (metric)	18.60502			719.0456			3326.179		
person-rem			1.43E-03			1.86E-02			3.68E-04