

Appendix E –
EDF-3124-0009, *Off-Road Emissions During Construction*

Engineering Design File

Off-Road Emissions During Construction

Portage Project No.: 3124
Project Title: NWMI Environmental Report



TEM-9002
09/29/09
Rev. 0

1. Portage Project No.: 3124 2. Project/Task: NWMI Environmental Report

3. DCN # _____

4. Title: Off-Road Emissions During Construction

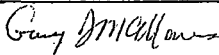


5. NPH PC or SDC: N/A

6. SSC Safety Category: N/A

7 Summary: This EDF documents the assumptions and calculations used to determine the emissions from non-road construction vehicles during the construction phase of the Northwest Medical Isotopes, LLC (NWMI) Radioisotope Production Facility. The emission factors were obtained from the EPA NONROAD model. The results for NO_x, CO, PM-10, PM-2.5, CO₂, and SO_x are presented.

8. Distribution: (Portage, Inc.)

9: Review (R) and Approve (A) Signatures:
(Identify minimum reviews and approvals. Additional reviews/approvals may be added.)

	R/A	Printed Name/ Organization	Signature	Date
Author/Design Agent	A	Gary McManus		1/21/16
Independent Review	R	Dave Thorne		1/21/16
Independent Review	R			
Project Manager	R/A	John Beller		1/21/16

Registered Professional Engineer's Stamp (if required) N/A

Introduction and Purpose

During the construction phase, non-road air emissions would result from the activities of the construction equipment during operation. Off-road vehicle emissions were estimated for diesel-fueled construction equipment used for moving, grading, and compacting earthen materials, using emission factors for off-road construction based on values from the U.S. Environmental Protection Agency (EPA) NONROAD model (EPA, 2008). Model emission factors were based on grams per horsepower hour. These values were combined with the number of pieces of equipment and hours of operation to estimate the total pounds released for each activity.

Assumptions

On-road vehicle emissions were calculated using emission rate in grams(g)/horsepower-hour (hp-hr). Average horsepower ratings for similar types of equipment were found in vendor data and used for the calculation. The number of pieces of equipment used and hours are the same used for the fugitive dust calculations (EDF-3124-0004, *Calculation for Determination of Fugitive Dust During Construction Activities from Construction Equipment*), with the addition of a paver and asphalt roller. Emission factors (EF) are shown in Table 1. The assumed hours of operation for each piece of equipment are provided in Table 2.

Table 1. Emission Factors from NONROAD and AP-42

Equipment	Horsepower	Emission factor (g/hp-hr)					
		NO _x ^a	CO ^a	PM-10 ^a	PM-2.5 ^b	CO ₂ ^c	SO _x ^c
Bulldozer	250	5.58	0.748	0.252	0.189	521	0.931
Compactor	232	5.58	0.748	0.252	0.189	521	0.931
Excavators	145	5.65	0.867	0.280	0.210	521	0.931
Front loaders	100	5.65	0.867	0.280	0.210	521	0.931
Graders	145	5.65	0.867	0.280	0.210	521	0.931
Paver	142	5.65	0.867	0.280	0.210	521	0.931
Asphalt roller	232	5.58	0.748	0.252	0.189	521	0.931

^a Emission factors from EPA Report NR-009d, *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling-Compression-Ignition*, Table D-1, July 2010 (see Attachment 1).

^b Assumes a PM-2.5 to PM-10 ratio of 0.75.

^c From Table 3.3.1 of EPA AP-42, *Compilation of Air Pollutant Emission Factors* (see Attachment 2)

CO = carbon monoxide.
CO₂ = carbon dioxide.
NO_x = nitrogen oxides.

PM-2.5 = particulate matter 2.5 μm or less diameter.
PM-10 = particulate matter 10 μm or less diameter.
SO_x = sulfur dioxide.

Total emissions were calculated using the following equation (EPA Report NR-009d, *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling-Compression-Ignition*):

$$\text{Emissions} = \text{EF} * \text{hp} * \text{hr}$$

where:

EF = emission factor (Table 1)

hp = average rated horse power of type of equipment used (Table 1)

hr = hours of operation (Table 2)

Example calculation:

$$\begin{aligned} \text{Emissions NO}_x &= \text{EF} \times \text{hp} \times \text{hr} \\ &= 5.58 \text{ g/hp-hr} \times 250 \text{ hp} \times 100 \text{ hr} \\ &= 140 \text{ kilograms (kg) (310 pounds [lb])} \end{aligned}$$

The total emission for each type of the equipment in Table 1 was calculated and is shown in Table 2.

Table 2. Off-Road Vehicle Emissions (During 17 Months of Construction)

Equip- ment	Number	Hours	Pollutant(s)											
			NO _x		CO		PM-10		PM-2.5		CO ₂		SO _x	
			(kg)	(lb)	(kg)	(lb)	(kg)	(lb)	(kg)	(lb)	(kg)	(lb)	(kg)	(lb)
Bulldozer	1	100	140	310	19	41	6.3	14	4.7	10	13,000	29,000	23	51
Compactor	1	120	160	340	21	46	7.0	15	5.3	12	15,000	32,000	26	57
Excavators	1	60	49	110	7.5	17	2.4	5.4	1.8	4.0	4,500	10,000	8.1	18
Front loaders	1	120	68	150	10	23	3.4	7.4	2.5	5.6	6,200	14,000	11	25
Graders	1	80	66	150	10	22	3.2	7.2	2.4	5.4	6,000	13,000	11	24
Paver	1	80	64	140	10	22	3.2	7.0	2.4	5.3	5,900	13,000	11	23
Asphalt roller	1	80	100	230	14	31	4.7	10	3.5	7.7	9,700	21,000	17	38
Total			647	1430	91.5	202	30.2	66.0	22.6	50.0	60,300	132,000	107.1	236

CO = carbon monoxide.

CO₂ = carbon dioxide.

NO_x = nitrogen oxides.

PM-2.5 = particulate matter 2.5 µm or less diameter.

PM-10 = particulate matter 10 µm or less diameter.

SO_x = sulfur dioxide.

References

AP-42, *Compilation of Air Pollutant Emission Factors*, Volume I, Chapter 3, "Stationary Internal Combustion Sources," Fifth Edition, U.S. Environmental Protection Agency, Office of Air and Radiation, Washington, D.C., 2000.

EDF-3124-0004, *Calculation for Determination of Fugitive Dust During Construction Activities from Construction Equipment*, Rev. 1, Portage, Inc., Idaho Falls, Idaho, February 3, 2015.

EPA, 2008, "NONROAD Model (nonroad engines, equipment, and vehicles)," U.S. Environmental Protection Agency, <http://www3.epa.gov/otaq/nonrdmdl.htm>, Washington, D.C., 2008.

NR-009d, *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling, Compression-Ignition*, U.S. Environmental Protection Agency, Washington, D.C., July 2010.

Attachment 1

Emission Table D-1 from EPA Report NR-009d (4 pages)

Table D1. Summary of Certification Data for Nonroad Compression Ignition Engines*

>0 to 11 hp									
g/hp-hr	HC	NOx	HC+NOx	CO	PM	HC frac	HC calc	NOx calc	
2000	0.692103	5.170337	5.966223	4.051366	0.452858	0.113196	0.675351	5.290871	
2001	0.828378	5.073763	6.018891	4.174066	0.44201	0.141247	0.850153	5.168738	
average	0.760241	5.12205	5.992557	4.1127	0.4474		0.7628	5.2298	
sample size	HC	NOx	HC+NOx	CO	PM				
2000	4	6	20	20	20				
2001	5	5	19	19	19				
total	9	11	39	39	39				
>11 to 25 hp									
g/hp-hr	HC	NOx	HC+NOx	CO	PM	HC frac	HC calc	NOx calc	
2000	0.489983	3.749647	4.9489	2.207041	0.289982	0.081156	0.401631	4.547269	
2001	0.447831	4.109521	4.80692	2.114884	0.242992	0.09869	0.474395	4.332525	
average	0.468907	3.929584	4.87791	2.1610	0.2665		0.4380	4.4399	
sample size	HC	NOx	HC+NOx	CO	PM				
2000	9	10	40	39	40				
2001	16	16	43	43	43				
total	25	26	83	82	83				
>25 to 50 hp									
g/hp-hr	HC	NOx	HC+NOx	CO	PM	HC frac	HC calc	NOx calc	
1999	0.496458	4.558405	4.983359	1.54213	0.35614	0.047095	0.23469	4.748669	
2000	0.452946	4.893606	5.083919	1.522782	0.331337	0.056039	0.284899	4.79902	
2001	0.472917	4.469647	4.952901	1.532028	0.329222	0.064006	0.317014	4.635887	
average	0.474107	4.640553	5.006726	1.5323	0.3389		0.2789	4.7279	
sample size	HC	NOx	HC+NOx	CO	PM				
1999	11	15	72	72	72				
2000	14	22	95	96	96				
2001	25	35	103	104	104				
total	50	72	270	272	272				

Source: NR-009d, *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling, Compression-Ignition*, U.S. Environmental Protection Agency, Washington, D.C., July 2010.

Table D1. Summary of Certification Data for Nonroad Compression Ignition Engines (cont)*

>50 to 100 hp					
g/hp-hr	HC	NOx	HC+NOx	CO	PM
1998	0.528845	5.682411	4.235576	2.753546	0.472055
1999	0.517642	5.613376	6.569501	2.34687	0.452553
2000	0.46289	5.494892	4.235576	2.047055	0.460428
2001	0.575867	5.604515	5.976957	2.314372	0.506824
average	0.5213	5.5988	5.254402	2.3655	0.4730
sample size	HC	NOx	HC+NOx	CO	PM
1998	18	71	1	21	19
1999	27	91	3	33	31
2000	35	104	1	38	36
2001	40	127	3	47	43
total	120	393	8	139	129
>100 to 175 hp					
g/hp-hr	HC	NOx	HC+NOx	CO	PM
1997	0.297479	5.599201		0.745072	0.281314
1998	0.355336	5.743938		0.961288	0.276378
1999	0.35159	5.749792		0.93731	0.270345
2000	0.33246	5.593736		0.68581	0.282059
2001	0.355107	5.574714		1.003922	0.28934
average	0.3384	5.6523		0.8667	0.2799
sample size	HC	NOx	HC+NOx	CO	PM
1997	29	43	0	29	25
1998	25	52	0	27	24
1999	25	59	0	27	25
2000	27	61	0	29	28
2001	34	69	0	37	36
total	140	284	0	149	138
>175 to 300 hp					
g/hp-hr	HC	NOx	HC+NOx	CO	PM
1996	0.331633	5.667602		0.834876	0.239994
1997	0.307044	5.723983		0.819777	0.24542
1998	0.316321	5.574079		0.722968	0.262486
1999	0.314974	5.549376		0.695869	0.257528
2000	0.26631	5.441729	4.54	0.666725	0.240685
2001	0.314765	5.506545	4.203295	0.744633	0.266622
average	0.3085	5.5772	4.371648	0.7475	0.2521
sample size	HC	NOx	HC+NOx	CO	PM
1996	44	44	0	44	44
1997	43	43	0	43	43
1998	72	72	0	72	72
1999	71	71	0	71	71
2000	64	64	2	64	64
2001	86	86	6	88	88
total	380	380	8	382	382

D3

Source: NR-009d, *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling, Compression-Ignition*, U.S. Environmental Protection Agency, Washington, D.C., July 2010.

Table D1. Summary of Certification Data for Nonroad Compression Ignition Engines
(cont)*

>300 to 600		HC	NOx	HC+NOx	CO	PM
g/hp-hr						
1996	0.260521	6.264393			1.353145	0.195978
1997	0.1553	5.865363			1.431343	0.213156
1998	0.209071	6.126551			1.289223	0.198893
1999	0.201521	6.04976			1.201752	0.192703
2000	0.186024	5.77026	5.24		1.254546	0.203148
average	0.2025	6.0153	5.24		1.3060	0.2008
2001 Tier 2	0.1669	4.3351	4.345348		0.8425	0.1316
sample size	HC	NOx	HC+NOx	CO	PM	
1996	40	40	0	40	40	
1997	35	35	0	35	35	
1998	48	48	0	48	48	
1999	55	55	0	55	55	
2000	51	51	1	51	51	
2001	14	14	35	35	35	
total	243	243	36	264	264	
>600 to 750		HC	NOx	HC+NOx	CO	PM
g/hp-hr						
1996	0.174804	6.063537			1.502117	0.242149
1997	0.135125	5.872338			1.571034	0.236991
1998	0.190719	5.866023			1.277422	0.205116
1999	0.118392	5.723896			1.361031	0.227162
2000	0.126821	5.790567			1.368105	0.225632
2001	0.138065	5.612418	3.975047		0.883305	0.183773
average	0.1473	5.8215	3.975047		1.3272	0.2201
sample size	HC	NOx	HC+NOx	CO	PM	
1996	11	11	0	11	11	
1997	10	10	0	10	10	
1998	12	12	0	12	12	
1999	13	13	0	13	13	
2000	15	15	0	15	15	
2001	16	16	3	17	17	
total	77	77	3	78	78	

Source: NR-009d, *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling, Compression-Ignition*, U.S. Environmental Protection Agency, Washington, D.C., July 2010.

Table D1. Summary of Certification Data for Nonroad Compression Ignition Engines
(cont)*

>750 hp g/hp-hr	HC	NOx	HC+NOx	CO	PM
2000	0.25906	6.252638		0.727419	0.183308
2001	0.313093	6.052394		0.800887	0.203589
average	0.2861	6.1525		0.7642	0.1934
sample size	HC	NOx	HC+NOx	CO	PM
2000	16	16	0	16	16
2001	18	18	0	18	18
total	34	34	0	34	34

* Values in bold are used in NONROAD. All are Tier 1 emission factors, with the exception that both Tier 1 and Tier 2 emission factors are provided for the >300 to 600 hp category.

Source: NR-009d, *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling, Compression-Ignition*, U.S. Environmental Protection Agency, Washington, D.C., July 2010.

Attachment 2

EPA AP-42 Volume 1, Table 3.3.1

Table 3.3-1. EMISSION FACTORS FOR UNCONTROLLED GASOLINE AND DIESEL INDUSTRIAL ENGINES^a

Pollutant	Gasoline Fuel (SCC 2-02-003-01, 2-03-003-01)		Diesel Fuel (SCC 2-02-001-02, 2-03-001-01)		EMISSION FACTOR RATING
	Emission Factor (lb/hp-hr) (power output)	Emission Factor (lb/MMBtu) (fuel input)	Emission Factor (lb/hp-hr) (power output)	Emission Factor (lb/MMBtu) (fuel input)	
NO _x	0.011	1.63	0.031	4.41	D
CO	6.96 E-03 ^d	0.99 ^d	6.68 E-03	0.95	D
SO _x	5.91 E-04	0.084	2.05 E-03	0.29	D
PM-10 ^b	7.21 E-04	0.10	2.20 E-03	0.31	D
CO ₂ ^c	1.08	154	1.15	164	B
Aldehydes	4.85 E-04	0.07	4.63 E-04	0.07	D
TOC					
Exhaust	0.015	2.10	2.47 E-03	0.35	D
Evaporative	6.61 E-04	0.09	0.00	0.00	E
Crankcase	4.85 E-03	0.69	4.41 E-05	0.01	E
Refueling	1.08 E-03	0.15	0.00	0.00	E

^a References 2,5-6,9-14. When necessary, an average brake-specific fuel consumption (BSFC) of 7,000 Btu/hp-hr was used to convert from lb/MMBtu to lb/hp-hr. To convert from lb/hp-hr to kg/kw-hr, multiply by 0.608. To convert from lb/MMBtu to ng/J, multiply by 430. SCC = Source Classification Code. TOC = total organic compounds.

^b PM-10 = particulate matter less than or equal to 10 μm aerodynamic diameter. All particulate is assumed to be ≤ 1 μm in size.

^c Assumes 99% conversion of carbon in fuel to CO₂ with 87 weight % carbon in diesel, 86 weight % carbon in gasoline, average BSFC of 7,000 Btu/hp-hr, diesel heating value of 19,300 Btu/lb, and gasoline heating value of 20,300 Btu/lb.

^d Instead of 0.439 lb/hp-hr (power output) and 62.7 lb/mmBtu (fuel input), the correct emissions factors values are 6.96 E-03 lb/hp-hr (power output) and 0.99 lb/mmBtu (fuel input), respectively. This is an editorial correction. March 24, 2009

Source: AP-42, *Compilation of Air Pollutant Emission Factors*, Volume I, Chapter 3, "Stationary Internal Combustion Sources," Fifth Edition, U.S. Environmental Protection Agency, Office of Air and Radiation, Washington, D.C., 2000.

Attachment 3
Excel Spreadsheet of Calculations

Equipment	hp	NOx ^a	CO ^a	PM10 ^a	PM2.5 ^b	CO2 ^c	SOx ^a
Bulldozer	250	5.58E+00	7.48E-01	2.52E-01	1.89E-01	521	9.31E-01
Compactor	232	5.58E+00	7.48E-01	2.52E-01	1.89E-01	521	9.31E-01
Excavators	145	5.65E+00	8.67E-01	2.80E-01	2.10E-01	521	9.31E-01
Front Loaders	100	5.65E+00	8.67E-01	2.80E-01	2.10E-01	521	9.31E-01
Graders	145	5.65E+00	8.67E-01	2.80E-01	2.10E-01	521	9.31E-01
Paver	142	5.65E+00	8.67E-01	2.80E-01	2.10E-01	521	9.31E-01
Asphalt Roller	232	5.58E+00	7.48E-01	2.52E-01	1.89E-01	521	9.31E-01

a. Emission factors from EPA Report No. NR-009d, July 2010, "Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling-Compression-Ignition" Appendix D Tables
b. Assumes a PM2.5 to PM10 ratio of 0.75
c. From EPA 2000, AP-42, Volume I Table 3.3.1

NR-009d Reference Location
<http://www.epa.gov/otaa/models/nonrdmdl/nonrdmdl2010/420r10018.pdf>

Equipment	Number	Hours	Pollutant(s)											
			NOx		CO		PM10		PM-2.5		CO2		SOx	
			(kg)	(lbs)	(kg)	(lbs)	(kg)	(lbs)	(kg)	(lbs)	(kg)	(lbs)	(kg)	(lbs)
Bulldozer	1	100	139	307	19	41	6	14	5	10	13,025	28,715	23	51
Compactor	1	120	155	342	21	46	7	15	5	12	14,505	31,977	26	57
Excavators	1	60	49	108	8	17	2	5	2	4	4,533	9,993	8	18
Front Loaders	1	120	68	150	10	23	3	7	3	6	6,252	13,783	11	25
Graders	1	80	66	145	10	22	3	7	2	5	6,044	13,324	11	24
Paver	1	80	64	142	10	22	3	7	2	5	5,919	13,048	11	23
Asphalt Roller	1	80	104	228	14	31	5	10	4	8	9,670	21,318	17	38
Total			646	1,422	91	201	30	67	23	50	60,072	132,159	107	236