Calculation Cover Sheet

1. Calculation Title: February 14th, contamination release consequence assessment Rev. 1				2. Page: 1 of 17
3. System: NA	4. AR No.: NA	5. ECO No.: NA	6. Functional Classification: NA	

7. SOURCE OF DATA

1. NARAC plumes
2. Surveys and measurements of samples and locations on and around the WIPP site
3. See reference section
4.
5.

8. SOURCE OF FORMULAS

1.
2.
3.
4.
5.

9. REFERENCES

No.	Drawing No.	Rev. No.	No.	Drawing No.	Rev. No.
1.			6.		
2.			7.		
3.			8.		
4.			9.		
5.			10.		

10. RECORD OF ISSUES

Rev. No.	CE or Author: Date:	Checked By: Date:	CM Approval: Date:
0	Robert Hayes 3/8/14	James Willison 3/8/14	Jennifer Hendrickson 3/8/14
1	Robert Hayes 3/10/14	James Willison 3/10/14	Jennifer Hendrickson 3/10/14
	[redacted]	[redacted]	[redacted]

[redacted] **11. COMMENTS** [redacted]

Additional source term information is expected to be obtained along with higher quality radiochemistry measurements of offsite air samples which may be used to generate another revision of this calculation at a later date.

4. Calculations cont.

Summary

On February 14, 2014, a continuous air monitor (CAM) alarm at the exit of panel 7 in the underground caused the ventilation at the WIPP to shift over to HEPA filtration for its effluent. Subsequent measurements of the effluent (Station B) using representative sampling demonstrated that a release had occurred. Representative sampling of the air entering the HEPA filtration (Station A) confirmed the source term to the HEPA filter banks from the underground effluent air and that the filtration had operated to almost entirely mitigate the environmental release.

Based on modeling using measured effluent activity, onsite dose estimates are less than 10 mrem from inhaled radioactivity. Similarly, offsite dose consequences to nearby dwellings and those accessing public roads are less than 1 mrem with expected doses being closer to 0.1 mrem or less. No worker or public dose limits have been exceeded as of this writing and are not expected at any time in the future based on current measurements and modeling information.

The mine and surface systems are designed to detect radioactive effluent in the mine downstream of the source term prior to releasing to the environment on the surface so that only HEPA filtered air is released. Measurements to date indicate the shift to filtration prevented all regulatory dose limits from being exceeded.

Modeling Assumptions and Measured Parameters

Effluent Activity

Representative air samples were obtained using shrouded probes which permit quality estimations of total released activity. After the CAM alarm in the underground, the ventilation has remained in filtration mode with continual sampling.

The initial measurements of the filter media consist of gross alpha and beta counting with the total initial alpha activity being given in Table 1. The duration for each sample is also presented in Table 1. These source terms are assumed to have been uniformly distributed throughout the time the sample was being taken. The true release rate as a function of time is not known to any greater resolution than that provided in Table 1 and is the best measurement based estimates available on the temporal distribution of activity released. The data in Table 1 does not discount for radon and assumes all measured alpha activity is TRU. Historically, radon will only contribute no more than 10 dpm alpha at Station B, as such the contribution of radon to a source term having 3 orders of magnitude higher levels of activity (see Table 1) and its affect on the NARAC calculation is considered negligible (see Attachment 1). Measured values were in disintegrations per minute (dpm) and converted to Ci for the National Atmospheric Release Advisory Center (NARAC) at Lawrence Livermore National Laboratory using 2.22e12 dpm = 1 Ci.

4. Calculations cont.

Table 1. Source terms used for NARAC models based on gross alpha and beta values measured on a Tennelec counter. A more detailed listing of source terms used for the values reported in Table 1 is provided in Attachment 1 where an asymptotic gross activity level is seen to be in the range of a few 10's of dpm or less.

Date and time	Station B alpha activity (dpm)	Release duration (hrs:min)	Calculated released activity (Ci)
2/14/14 23:14	-	-	-
2/15/14 8:35	2.8E+04	9:21	3.8E-04
2/15/14 14:45	3.6E+04	6:10	4.9E-04
2/15/14 23:05	6.7E+02	8:20	9.1E-06
2/16/14 9:04	3.0E+02	9:59	4.1E-06
2/16/14 17:05	1.4E+02	8:01	1.9E-06
2/17/14 0:30	7.2E+01	7:25	9.7E-07
2/17/14 8:05	4.3E+01	7:35	5.8E-07
2/17/14 16:00	7.8E+01	7:55	1.1E-06

To convert a Station B source term into a release value, the unit conversion of 2.22e12 dpm per Ci is used[1] along with a ratio of the flow rates. The Station B flow rate is 2 cfm and the Station B exhaust is kept around 60e3 cfm. These factors combine to give a total conversion coefficient of 1.4E-8 Ci/dpm as given in Equation 1 for the Curie release from Station B based on an assay of the filter activity in dpm.

$$60 \times 10^3\ cfm/\left(2\ cfm\ \times 2.22 \times 10^{12}\ \frac{dpm}{Ci}\right) = 1.4 \times 10^{-8} \frac{Ci}{dpm} \qquad \text{Eqn. 1}$$

This release profile simply assumes a uniform release rate between each measurement value provided from Station B gross assay results listed in Table 1.

What can be seen from Figure 1 is not only that a variable release rate occurred between 8:35 AM and 2:45 PM with the values steadily decreasing after this and also that the rate seems to become constant under 100 nCi per hour. The rapid decrease appears consistent with an exponential decrease in volume concentration of aerosol concentrations for a ventilated room'. An exponential decrease would appear as a straight line in a semilog plot as shown in Figure 1 after the bulk of the release ended by 2:45 PM on 2/15/14.

[1] A more familiar but equivalent conversion factor is that 2.22 dpm = 1 pCi =1e-12 Ci

4. Calculations cont.

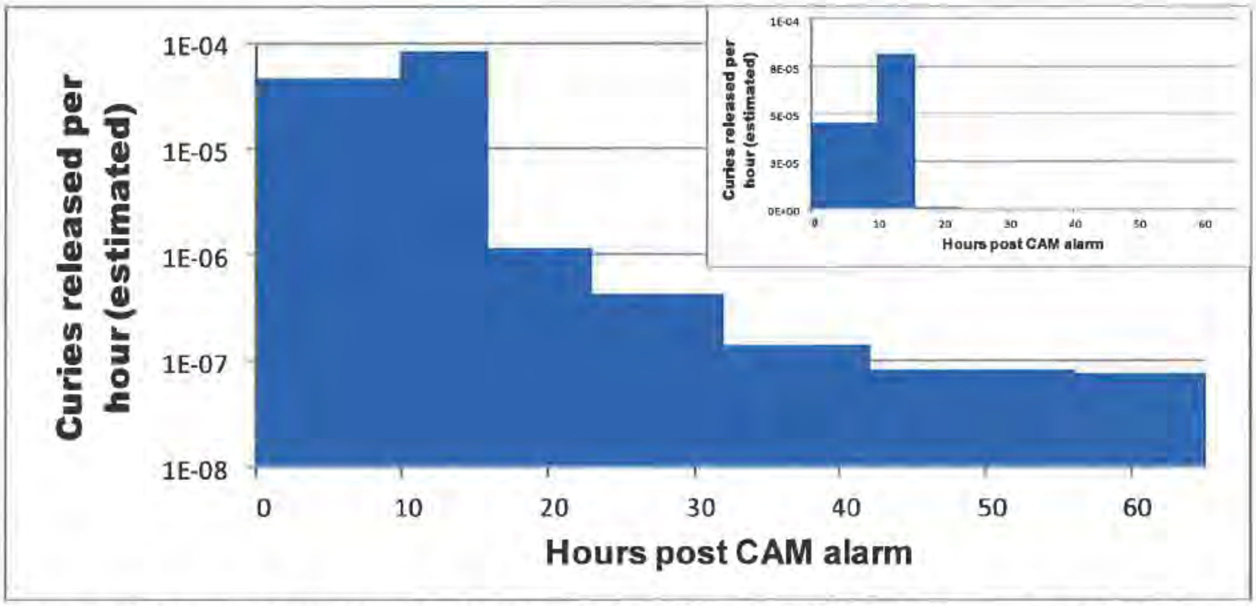


Figure 1. Station B release rates as a function of time after the initial CAM alarm. Note that the axes are presented in a semilog plot so that the vertical axis is not linear but logarithmic. The inset on the upper right is exactly the same plot reproduced on a linear scale for comparison. The linear scale basically shows the first 2 time intervals listed as being the dominant release components of the event.

Meteorological Measurements

The wind direction during the event is shown in Figure 2 as a function of time at heights of 2 meters, 10 meters and 50 meters as measured at the WIPP meteorological station. The wind speed measured during the event is also provided in Figure 3 for the heights of 2 m, 10 m and 50 m.

These measurements (shown in Figures 1 through 3) were all utilized by NARAC staff to generate all of the aerosol dispersion models displayed in this calculation (Figures 4, 5, 7 & 8).

Note that in Figure 2, the apparent discontinuity around 8:15 AM on 2/15/14 in measured wind direction was due to the wind direction changing from 0° to 360°. In polar coordinates this would be a continuous change but in Cartesian coordinates, this looks similar to a step function change.

4. Calculations cont.

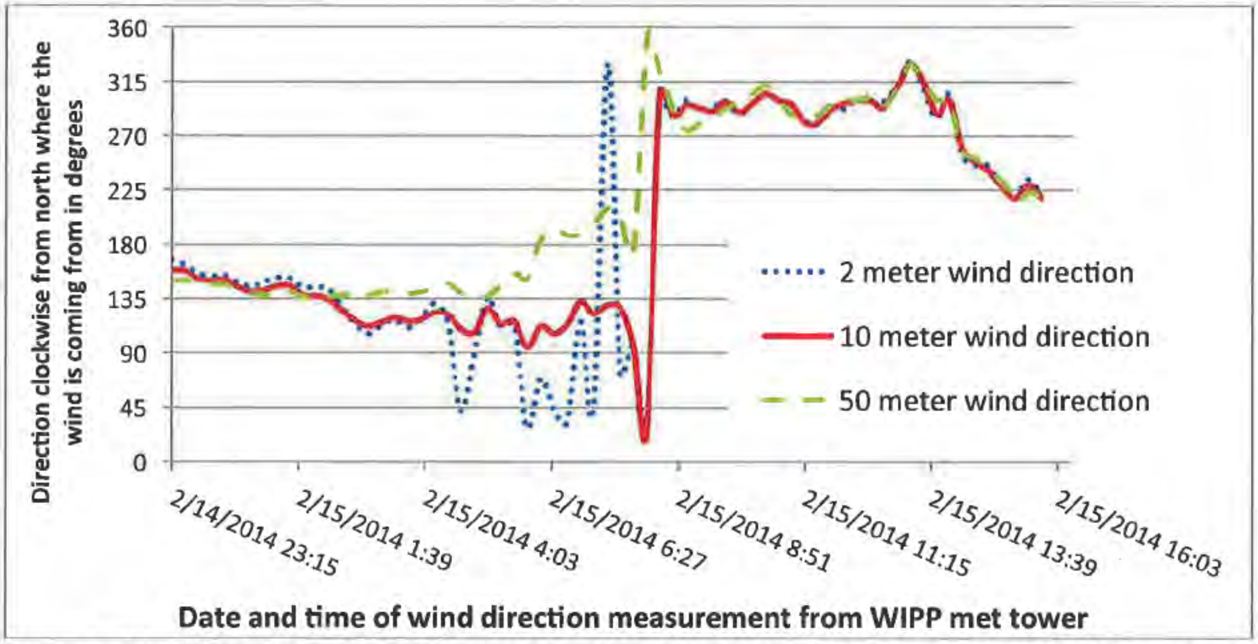


Figure 2. Wind direction at the WIPP site subsequent to the CAM alarm given at heights of 2 m, 10 m and 50 m. The event took place starting on 2/14/14 at 23:14 and continued to 2/15/14 14:45 (refer to Table 1). A large shift in wind direction can be seen to occur around 8:30 AM on 2/15/14.

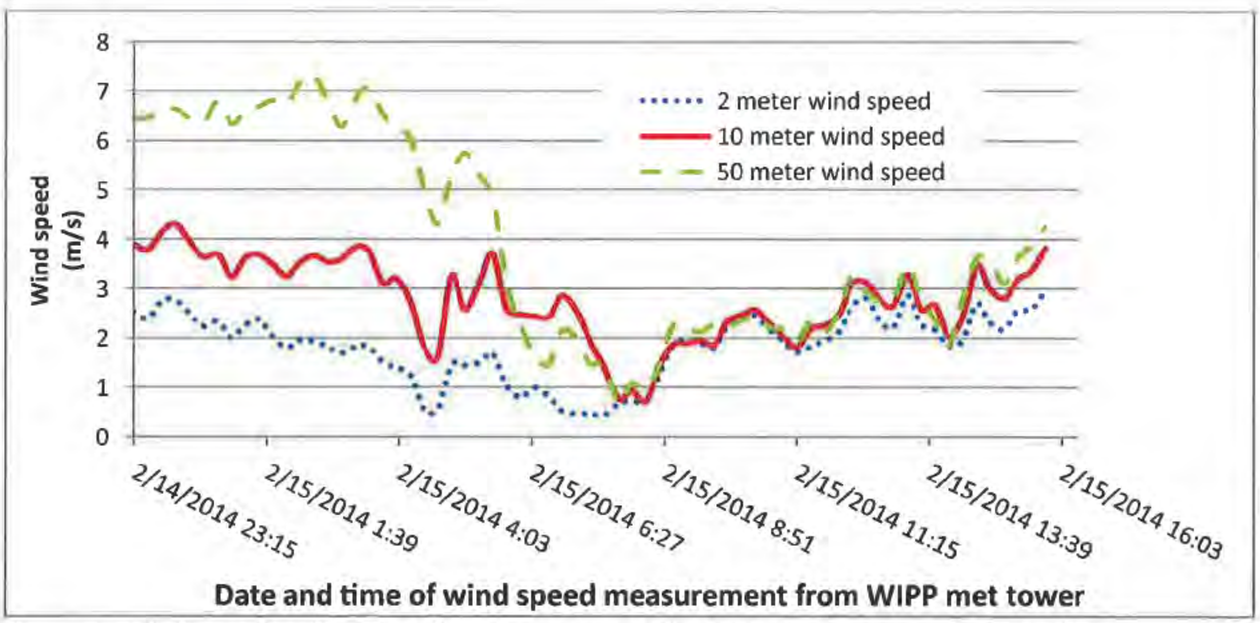


Figure 3. Wind speed at the WIPP site subsequent to the CAM alarm given at heights of 2 m, 10 m and 50 m in units of meters per second. The event took place starting on 2/14/14 at 23:14 and continued to 2/15/14 14:45 (refer to Table 1).

4. Calculations cont.

NARAC Modeling Parameters

An additional parameter utilized in the NARAC models includes assuming all particulates released were in the respirable range of 0.1 to 10 microns. Released particulates were transported using settling rates for particles of that size distribution. Doses calculated using NARAC modeling are in units of rem representing the Total Effective Dose (TED) which includes both internal and external sources of radiation. When utilizing TED, the approach is to recognize that the dose will be spread out over an assumed subsequent 50-year remaining lifetime. With this, all TED doses for long-lived radionuclides if they were to be given on a per-year basis, would be approximately 50 times lower but the total integrated dose is ascribed to the individual on the year of intake, and so is conservative in this sense. The dose conversion factors used are from the International Commission on Radiological Protection publication 60 (ICRP 60[ii]). The models in the TED calculation also conservatively assume 100% Pu239 and only use 15-minute time intervals for the integrated plume model. Using Pu239 for calculation is bounding due to the ICRP 68 values for Am241 resulting in slightly lower TED values.

If the particle size were substantially smaller than the assumed distribution, say in the 0.01 to 0.1 range, then the plate-out and settling rates would be commensurately lower. This would result in greater dilution through longer aeolian transport of the radioactivity lowering dose consequences offsite even further. Alternatively, if the particle size were substantially larger than the respirable range, then plate out and setting would increase, resulting in more radioactivity depositing near the release point and not being transported to large distances. Generally, aerosol deposition for 0.1 to 1 um AMAD particles is in the range of 10% to 90%. If the particle size increases substantially beyond this, the material gets caught and filtered naturally by the bodies extrathoracic airway resulting in clearance outside the lung alveoli with a drastic reduction in dose. Similarly, particles smaller than 0.01 um have much smaller deposition fractions due to simply being breathed back out.

NARAC Plume Models

Using the data from Figures 1 through 3, the plume projection shown in Figure 4 was generated by NARAC staff to represent the best measurement data available for prediction. This plume used the site-specific meteorological conditions shown in Figures 2 through 3 along with mating this to the release profile shown in Figure 1. Based on the current data, this plume displays a current best estimate of the dose consequence from the release which shows the values are very low compared to regulatory limits with the inner contour being 1 mrem and the outer contour bounding the 0.1 mrem extent.

Highlighted by black outline in Figure 4 is the approximate area of the 16 sections derived from the Land Withdrawal Act (LWA) portion allocated for WIPP[iii]. Closer in but still outside of the barbed wire fence area of the property protection area are the Far Field, South and East sampling stations represented by white, orange and black stars respectively. Doses are in Total Effective Dose meaning all sources (external and internal) combined.

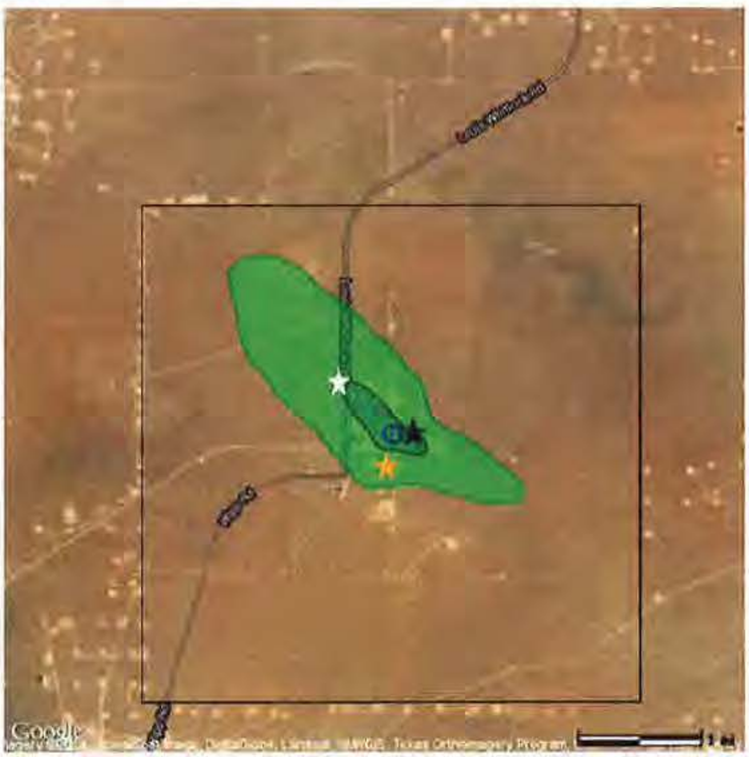
4. Calculations cont.

Figure 4 also shows where Louis Whitlock road is located which is used by local oilfield traffic. The speed limit is posted at 35 mph outside the facility, but it is from 55 to 65 mph outside the 16 sections of the LWA. This is considered to pose the largest dose consequence to a member of the public and will be analyzed in a later section.

Further Distribution Through DOE CBFO

Early Phase TED (0-96 hrs)
(Total Effective Dose Including Plume Passage)

Set 2: TED and Deposition
NARAC Report - Actual Release



Contour Levels			
	Description	**(rem) Extent Area**	**Population**
	Below the EPA Protective Action Guide of 1 rem for sheltering or evacuation. Values are greater than 0.001 rem, but less than 1 rem.	>0.0010 0.9km 0.4km2	0
	Below the EPA Protective Action Guide of 1 rem for sheltering or evacuation. Values are in a range of 0.001-0.0001 rem.	>0.0001 3.0km 5.2km2	0

Note: Areas and counts in the table are cumulative.
Population Source = LandScan USA V1.0.

Effects or contamination from February 15, 2014 15:45 CST to February 19, 2014 15:45 CST
Release Location: 32.372340 N, 103.791610 W
Material: PU-239
Generated On: February 22, 2014 04:59 CST
Model: ADAPT/LODI
Comments:
WIPP calculated release amount from stack monitoring. Release starting at 02/15/2014 06:15:00 UTC for 3 days
WIPP on site meteorological data at 15 min intervals from 02/14/2014 17:00:00 UTC to 02/19/2014 06:45:00 UTC

Map Size: 9.7 km by 9.7 km **Id:** Production.rcE22847.rcC1

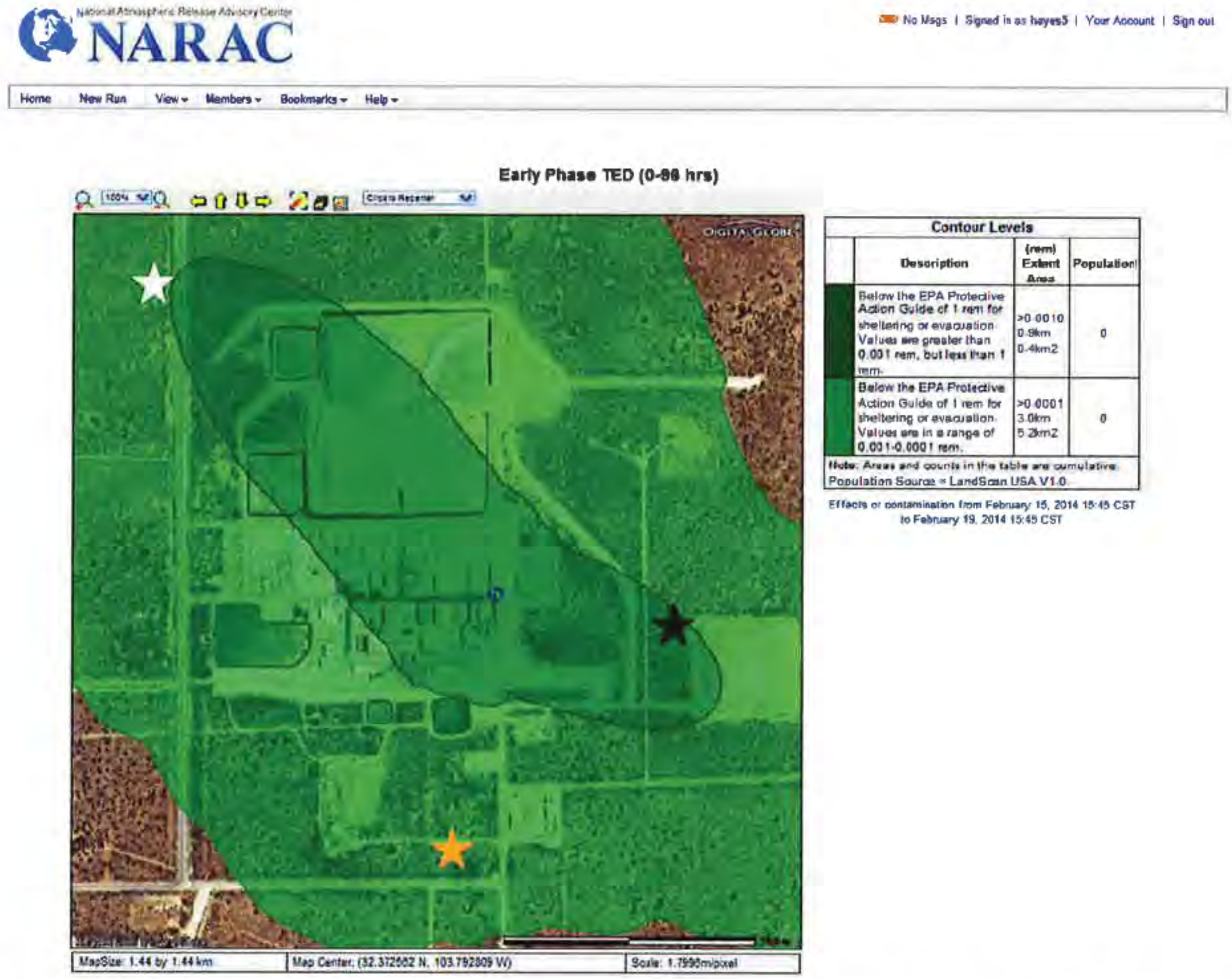
NARAC Operations: (NARAC Staff [redacted]
Requested by: (NIT Ops/ WIPP [redacted]
Approved by: (NARAC Operations; NARAC [redacted]

Further Distribution Through DOE CBFO

Figure 4. Station B estimate for the isodose contours utilizing the input parameters shown in Figures 1 through 3. Local air monitoring stations are labeled with stars such that Far Field Station is labeled with a white star, South Station is labeled with an orange star and East Station is labeled with a black star.

4. Calculations cont.

Figure 5 shows the same plume as Figure 4 at a higher resolution. The specific location of the air samplers relative to the resultant plume can be seen more clearly. The Far Field sample (white star) is outside the 1 mrem contour as is South Station (orange star) but East Station is within the 1 mrem contour boundary.



Back to: Set 2: TED and Deposition

Figure 5. Close up view of Station B estimate for the isodose contours utilizing the input parameters shown in Figures 1 through 3. Far Field Station is labeled with a white star, South Station is labeled with an orange star and East Station is labeled with a black star.

Dosimetry Estimates Using Offsite Air Monitoring Data

Air Concentration Measurements

Radiochemistry results for the Far Field Station show a transuranic (TRU) activity of 52 dpm (with an activity ratio of Am241/Pu239=13). The air sampler was running at 2 cfm, and although it had a total

4. Calculations cont.

volume sampled of 103 ft^3 when removed, it was only sampling for approximately 15 hours after the CAM alarmed in the underground. Using Figure 1, it can be inferred that the majority of the plume was being generated for approximately 15 hrs. Using Figure 2, it can be seen that the wind was only blowing from the ESE (from approximately 135 degrees clockwise from the north) for 8.5 hours toward the Far Field Station.

Using these values, an air concentration can be estimated with Equation 2 which would generate 0.03 Bq/m^3 as the measurement value from the air sample.

$$52\ dpm \times \frac{1\ Bq}{60\ dpm} / \left(2 \frac{ft^3}{min} \times 8.5\ hrs \times \frac{60\ min}{hr} \times \frac{1\ m^3}{35.31\ ft^3}\right) = 0.03 \frac{Bq}{m^3} \qquad \text{Eqn. 2}$$

The analysis of the other air sample measurements has not received the full radiochemistry protocol as of this writing and so activity assay was only by iSolo measurement after a 72-hour decay. The iSolo instrument is an alpha and beta spectrometer which has a solid-state detector shaped similar to a standard smear or air sample which can not only count individual alpha particles which traverse the air gap from the sample to the detector but can measure its energy. By taking a histogram of the alpha energy distribution after the 72-hour decay, those energies which represent TRU activity (measured here from 2.5 up to 6.12 MeV) to include everything from Uranium and Thorium all the way up to Californium and Curium. The iSolo measurement approach was to have a knowledgeable radiological engineer measure the spectra followed by a certified health physicist conducting the spectral analysis concluding with a PhD from the WIPP labs radiochemistry group doing a QA check on the data.

What was found from these measurements was that both East and South Station (black and orange stars) had activity values near 4 dpm each, indicating the release in these directions was less than that in the direction of Far Field which is consistent with the plume modeling.

Consequence and Risk Assessment

There are multiple methods to calculate risks posed by inhalation of radioactive materials. One of these is to utilize the concept of the Annual Limit on Intake (ALI) in order to ascribe dose to an intake value. An ALI is a calculated intake activity which would correspond to a worker receiving their maximum allowable annual radiation dose. In the US, the maximum radiation dose to workers is 5 rem such that if a person were to have an intake of 0.1 ALI, their committed effective dose[2] (CED) would be 0.5 rem. When utilizing the intake pathway of inhalation, the derived air concentration (DAC) is also used where the scaling factor is that being exposed to 2000 DAC for 1 hour will result in 1 ALI of intake or equivalently a CED of 5 rem.

[2] Committed effective dose is the 50-year integrated dose to each organ in a weighted sum using appropriate tissue-weighting factors for the radiation types.

4. Calculations cont.

According to 10 CFR 835 Appendix A, for Pu239 the most conservative value for a single DAC is 0.2 Bq/m^3 (which corresponds to the chemical form of Pu having moderate absorption rates into the bloodstream[3]). This value is based on 1 ALI being a 5 rem CED assuming a 2000 hr exposure, such that 1 DAC will result in 2.5 mrem/hr. Again, Figure 2 shows that the wind was generally only in the direction of the Far Field station for approximately 8.5 hrs giving a time interval for the exposure. From these, a dose estimate of 3 mrem for a person standing next to the air sampler can then also be estimated using Equation 3.

$$3\,mrem \approx\ 0.03\frac{Bq}{m^3} \times \frac{2.5\,mrem/hr}{1\,DAC} \times \frac{1\,DAC}{0.2\frac{Bq}{m^3}} \times 8.5\,hrs \qquad \text{Eqn. 3}$$

This number assumes of course that the person is standing all night next to the air sampler for the duration of the release (the full 8.5 hrs).

Using the same approach for South and East Stations with Equations 2 and 3, this places the worst-case dose estimate around 0.3 mrem at each location as shown in Table 2. According to Figure 5, this is reasonably consistent with the South Station sampler (orange star) which is located between the 0.1 and the 1 mrem contour but shows the East Station location being lower than estimated by the plume model. The plume model in Figure 5 shows East Station being very near the 1 mrem contour line but the sample result is closer to the 0.1 mrem level by measurement. Given the assumptions that are utilized by the plume model (constant release rate over intervals, particulate size distribution etc.), this result is not unexpected.

Table 2. Dose estimates using 8 hour exposure times

	Far Field	South Station	East Station	Southeast Control	Station 4	Station 5	Carlsbad
Radiochemistry (dpm)	52	3.7	4.4	1.3	2.7	4.2	1.6
dose estimate (mrem)	3	0.2	0.3	0.1	0.2	0.3	0.1

It is important to understand the context of plume models and air sample correlation. 10 CFR 835[IV] requires that dose from inhalation be determined using bioassay rather than air monitoring data due to the extremely large variations inherent to these kinds of measurements. Using laboratory conditions, the correlation between a lapel sampler and a general room area fixed air sampler will give a linear correlation but the typical variation between the two is a full order of magnitude[V]. This is partially attributed to the large variation in particle activity[VI] as a fixed specific activity will increase as the cube of the particle radius with different particle sizes. Being able to estimate dose based on air concentration measurements from a plume model is considered to be exceptionally well done if they are within a

[3] This corresponds to 10% at 10 minutes and 90% at 140 days as the range of halftimes for absorption.

4. Calculations cont.

factor of 2 to 5. Plume models within a factor of 10 accuracy are generally considered a reasonable initial value without iteratively perturbing and rerunning the plume models to interpolate measurement results (which has only been done here for the source term and not from separate air sample results).

Figure 6 shows general locations of more distant offsite sample filters including **Station 4 and Station 5**, Southeast Control and Carlsbad samples with red squares. Also shown as an inset in the lower right are the Far Field, South and East sampling stations located just outside the Property Protection area. The resulting iSolo assay and dose estimate consequences from each of these samples is provided in Table 2.

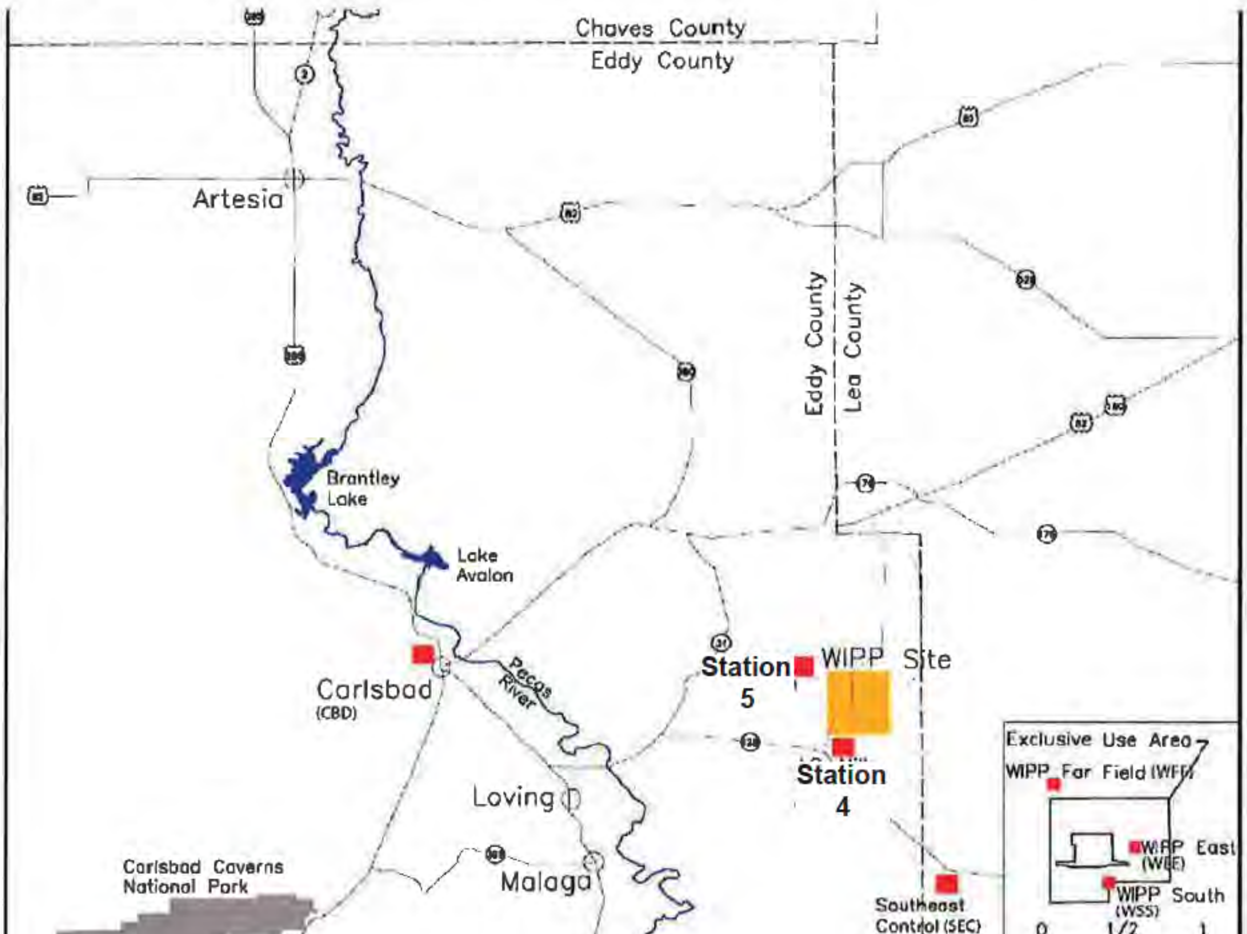


Figure 6. WIPP offsite air sampling locations as marked by red squares. The inset in the lower right shows roughly the same area shown in Figure 2. The upper scale in the lower right corner of the figure is in units of 4 miles. The bottom scale in the lower right is in units of 4 km. This figure was taken from the 2011 ASER (DOE/WIPP-12-3489).

4. Calculations cont.

As seen in Figures 4 and 5, a public road traverses a portion of the predicted plume foot print which effectively serves as the point of nearest public access (near the Far Field station). Assuming a person was in fact driving the speed limit of 35 mph and that the maximum level of the plume extended a full 4 miles along the path (or equivalently that the person stopped and waited at the Far Field station for 7 minutes during the plume passage), then their estimated dose would only be 0.01 mrem. This assumes the release profile is exactly as given in Table 1 and Figure 1 so the release towards Far Field occurred over an 8.5 hr period.

Regulatory Dose Limits

The legal limit for exposure to a standard adult member of the population on the WIPP site is 100 mrem/yr based on 10CFR835. Similarly DOE O 458.1[vii] limits offsite exposures to 25 mrem/yr to children and pregnant women. The most limiting of the regulatory limits would be based on the EPA NESHAPS criteria (40 CFR 61 Subpart H, 61.92) for inhalation[viii], the limit is only 10 mrem/yr in units of effective dose equivalent. Another regulatory limit comes from 40 CFR 191 Subpart A which in units of annual dose equivalent[4] is 25 mrem whole body, and 75 mrem to any critical organ.

Calculations and measurements indicate there are no locations downstream of the HEPA filters which could exceed 100 mrem TED.

Surface Contamination

The estimates of surface contamination coming from Station B are presented in Figures 7 and 8. These values are shown with surface contamination units of dpm/100 cm^2. Radioactive contamination is defined by 10 CFR 835 Appendix D[iv] as being a removable value of greater than 20 dpm/100 cm^2 or a total (fixed plus removable) of greater than 500 dpm/100 cm^2. The values predicted from the plume show contamination levels on site generally greater than 1 dpm/100 cm^2 (but less than 10 dpm/100cm^2) with levels near the property protection area being between 0.1 and 1 dpm/100 cm^2. Currently the entire site has been extensively surveyed for contamination and none found which is consistent with the plume modeling as seen in Figure 7 and displayed in Attachment 2.

[4] Effective dose equivalent is simply the weighted sum of organ dose equivalents using ordained tissue weighting factors for each organ in the sum.

4. Calculations cont.

NARAC

Further Distribution Through DOE CBFO

Deposition in dpm at 96 hrs (Surface Contamination from Deposited Radionuclides)

Set 2: TED and Deposition
NARAC Report - Actual Release

Map Size: 4.8 km by 4.8 km   Id: Production.rcE22847.rcC1

Contour Levels			
	Description	**(dpm/100cm2) Extent Area**	**Population**
	Possibly contaminated area. Use to confirm with monitoring surveys.	>1 0.5km 0.1km2	0
	Possibly contaminated area. Use to confirm with monitoring surveys.	>0.10 2.1km 2.1km2	0

Note: Areas and counts in the table are cumulative.
Population Source = LandScan USA V1.0.

Effects or contamination at February 19, 2014 15:45 CST
Release Location: 32.372340 N, 103.791610 W
Material: PU-239
Generated On: February 22, 2014 04:59 CST
Model: ADAPT/LODI
Comments:
WIPP calculated release amount from stack monitoring. Release starting at 02/15/2014 06:15:00 UTC for 3 days
WIPP on site meteorological data at 15 min intervals from 02/14/2014 17:00:00 UTC to 02/19/2014 06:45:00 UTC

NARAC Operations: { NARAC Staff [redacted]
Requested by: {NIT Ops/ WIPP; DOE [redacted]
Approved by: {NARAC Operations; [redacted]

Further Distribution Through DOE CBFO

Figure 7. Surface contamination estimate assuming modeling distributions given in Figures 1 through 3. The inner contour level is at the 1 dpm/100 cm^2 level of surface activity with the outer contour bounding the 0.1 dpm/100 cm^2 level. The inner contour does not have values greater than 10 dpm / 100 cm^2. Air sampling locations marked as in Figures 4 and 5.

4. Calculations cont.

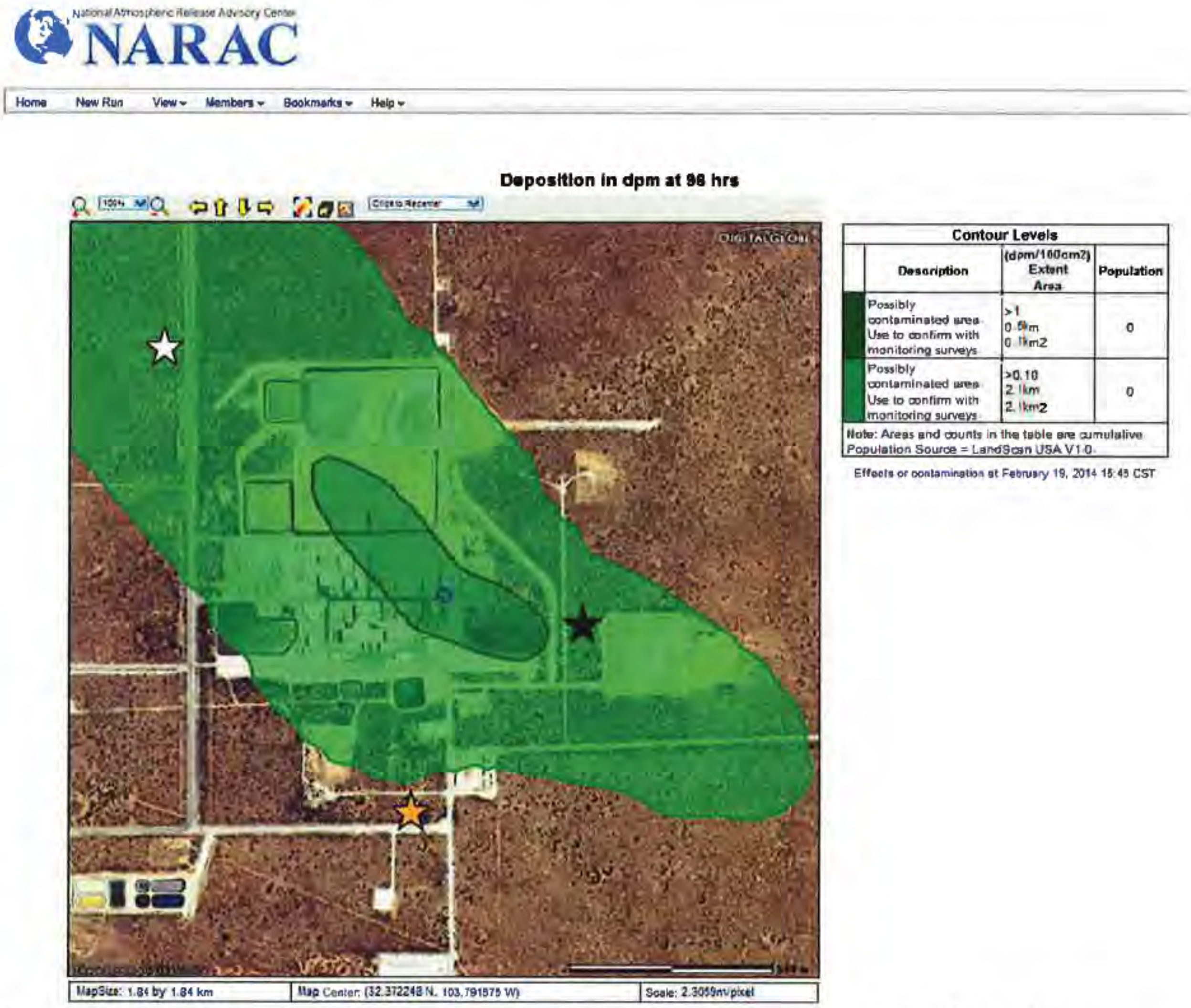


Figure 8. Close up view of predicted contamination levels. The inner contour level is at the 1 dpm/100 cm^2 level of surface activity. The inner contour does not have values greater than 10 dpm / 100 cm^2. Far Field Station is labeled with a white star, South Station is labeled with an orange star and East Station is labeled with a black star.

Plume estimates are consistent with site survey measurements to date which have aggressively searched for contamination both onsite and offsite (offsite measurements were made at the air sampling locations marked by the stars). There was contamination found inside of the Station A building, where the source term air sampling filter to the HEPA banks is located. An air sample assayed by WIPP labs to have 8 million dpm was pulled on 2/15/14. Note that this filter is just the source term to the HEPA banks and Table 1 shows the gross alpha air sample results from radioactivity released through Station B (post-HEPA) as measured at the WIPP using gross alpha-beta counters.

4. Calculations cont.

The formal survey map of onsite measurements ongoing as of this writing and is shown in Appendix 2. Outside of the Station A surveys, no contamination has been found onsite or offsite even though it has been aggressively sought. Fiddler measurements having a detection capability of approximately 1 uCi/m^2 have also been employed also showing no detectable TRU activity. The conversion to more familiar units of dpm/100 cm^2 is given by Equation 4 which shows the detection limits are orders of magnitude above expected contamination levels therefore, not detecting contamination was fully expected.

$$1\frac{dpm}{100\ cm^2} = 1\frac{dpm}{100\ cm^2} \times \frac{1\ Bq}{60\ dpm} \times \frac{uCi}{37{,}000\ Bq} \times \left(\frac{100\ cm}{m}\right)^2 = 4.5 \times 10^{-5}\frac{uCi}{m^2} \qquad \text{Eqn. 4}$$

As this release will increase the TRU activity both on-site and offsite over and above that already occurring due to the ubiquitous anthropogenic background (from historic atmospheric weapons testing resulting in global fallout), a comparison to these levels is of significance. The Centers for Disease Control (CDC, which is a branch of the National Institutes of Health) conducted a study to determine what the cumulative fallout deposition is across the United States resulting from the global fallout term. These values are graphically displayed in Figure 9.

A useful comparison for onsite measurement is that anything under 20 dpm / 100 cm^2 is by definition, not contaminated for surface deposition considerations. This means that projected surface deposition levels of TRU activity offsite are expected to be an order of magnitude lower than contamination levels.

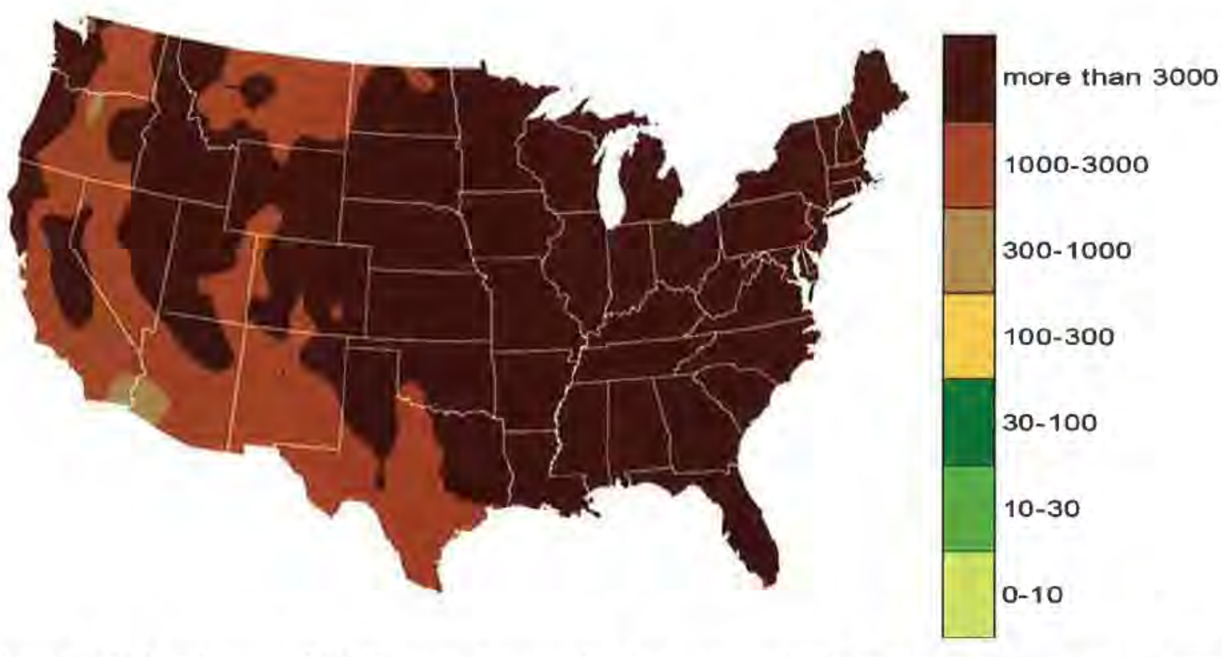


Figure 9. CDC estimates of Cs137 ground deposition from atmospheric nuclear weapons testing. Note that in the region of southeast New Mexico where the WIPP site is located the estimate is in the range of 1000 to 3000 Bq/m^2.

4. Calculations cont.

To date there has been no Cs137 detected in any of the released activity from the Station B stack but the historically ubiquitous anthropogenic Pu deposition can be estimated from Figure 6 using the established WIPP region ratio[ix] of Cs/Pu=30 approximation. In other words, the Cs-137 content present in the WIPP area prior to constructing or operating the WIPP was about 30 times larger than the Pu content. Using the values shown in Figure 9 for Cs, the Pu values would then be 30 times lower in surface deposition from global fallout placing the WIPP area at an estimate of 30 to 100 Bq/m^2. Converting this to more familiar units of dpm/ 100 cm^2 is done in Equation 5 resulting in a historic TRU surface deposition concentration estimate of 42 dpm/100 cm^2 being the initial expected TRU activity prior to WIPP operations.

$$70\,\frac{Bq}{m^2} = 70\,\frac{Bq}{m^2} \times \frac{60\,dpm}{Bq} \times \left(\frac{1\,m}{100\,cm}\right)^2 = 42\,\frac{dpm}{100\,cm^2} \qquad \text{Eqn. 5}$$

With the ubiquitous background being around 40 dpm /100 cm^2 and the deposition projections from the release being substantially lower, it seems reasonable to expect a negligible increase of the offsite background levels for this nuclide nearby the property protection area. Similarly, the estimates onsite for historical levels can be expected to increase by a small but undetectable amount over the background levels based solely on the plume projections as seen in Figure 8.

It is important to note that neither of these levels (onsite or offsite) are detectable and for this reason alone are subsequently consistent will all measurements carried out to date. Later detailed evaluation by radiochemistry of air sample filters from South and East stations may help to further refine how accurate the plume model can be expected to predict the aerosol transport.

It is worth reiterating that a large number of assumptions go into the plume projections and the source term is currently based on measurement from a gross alpha and beta count. The time profile shown in Figure 1 and the projected wind directions shown in Figures 2 through 3 show how largely different the plume distribution is sensitive to the time profile alone. Additional assumptions on particle size could similarly drastically reduce the dose consequences if the particles coming through the HEPA filters such that particles less than 0.001 um aerodynamic median aerosol diameter (AMAD) are effectively transported like a gas through the respiratory tract and are not incorporated through the lung alveoli. In essence, if the HEPA filters only passed aerosol on the order of a nanometer AMAD or less, the dose would drop by as much as a factor of 100[x].

Conclusions

Plume projections and assessed data measured to date are consistent with conservatively estimating offsite doses to be lower than 10 mrem, likely closer to the 1 mrem range with surface contamination levels being below detection limits.

4. Calculations cont.

References

[i] Whicker J, Chpt. 13, Principles of air sampler placement in the workplace, in *Radioactive Air Sampling Methods*. CRC Press, Boca Raton 2011

[ii] ICRP 1991. *1990 Recommendations of the International Commission on Radiological Protection*. ICRP Publication 60. Ann. ICRP 21 (1-3).

[iii] Public Law 102-579 *The Waste Isolation Pilot Plant Land Withdrawal Act* as amended by Public Law 104-201 (H.R. 3230, 104th Congress).

[iv] 10 CFR 835 Occupational Radiation Protection, Department of Energy.

[v] Alvarez JL, Bennet WS, Davidson TL. Design of an airborne plutonium survey program for personnel protection. *HealthPhys.* **66**, 634-642 (1994).

[vi] Munyon WJ, Lee MB. Summary of stationary and personal air sampling measurements made during a plutonium glovebox decommissioning project. *Health Phys.* **82**, 244-253 (2002)

[vii] DOE Order 458.1 Radiation Protection of the Public and the Environment. Department of Energy, 2/11/2011

[viii] 40 CFR 61 Subpart H. National Emission Standards for Emissions of Radionulcides other than Radon from Department of Energy Facilities.

[ix] WIPP TBD 2012-01 Using Isotopic Ratios for Discrimination of Environmental Anthropogenic Radioactivity.

[x] Potter AC, Chpt. 10, Internal dosimetry of inhaled radioactive aerosols, in *Radioactive Air Sampling Methods*. CRC Press, Boca Raton 2011

Attachment 1 – Station B GAB count results

Station B (B-1-3) Downstream of the HEPA filters

Date	Time Installed	Time Removed	Filter ID	Inst Model	Count Time	Alpha (dpm)	Beta (dpm)	First Count	Alpha (dpm)	Beta (dpm)	Re-count	72 Hour Re-count	Alpha (dpm)	Beta (dpm)	Location
2/14/14	2/14/14 0754	2/15/14 0835	B130214 14	Tennelec XLB	10 Mins	28205	5877	021514 /0850							WIPP Labs
2/15/14	2/15/14 0835	2/15/14 1445	B130215 14	Tennelec XLB	10 Mins	36194	7340								SRS Labs
2/15/14	2/15/14 1445	2/15/14 2305	B130215 141445	Tennelec XLB	10 Mins	671	142	021714 /1056							WIPP Labs
2/15/14	2/15/14 2305	2/16/14 0904	B130215 142305	Tennelec XLB	10 Mins	300	152	021614 /0932	253 245 240	63 59 49	021614/1127 021614/1250 021614/1741				WIPP Labs
2/16/14	2/16/14 0904	2/16/14 1705	B130216 140904	Tennelec XLB	10 Mins	144	67	021614 /1755							WIPP Labs
2/16/14	2/16/14 1705	2/17/2014 0030	B130216 141705	Tennelec XLB	10 Mins	72	54	021714 /0046	62	18	021714/1203				WIPP Labs
2/17/14	2/17/14 0030	2/17/14 0805	B130216 140030	Tennelec XLB	10 Mins	43	26	021714 /0930	30 32	23 16	021714/0955 021714/1400				WIPP Labs
2/17/14	2/17/14 0805	2/17/14 1600	B130217 140805	Tennelec XLB	10 Mins	78	35	021714 /1650	58 24	20 13	021714/1958 021814/1823				WIPP Labs
2/17/14	2/17/14 1600	2/18/14 0030	B130217 141600	Tennelec XLB	10 Mins	65	55	021814 /0051	45 36	18 12	021814/0423 021814/0751				WIPP Labs
2/18/14	2/18/14 0030	2/18/14 0901	B130218 140030	Tennelec XLB	10 Mins	42	61	021814 /0928	23	12	021814/1202				WIPP Labs
2/18/14	2/18/14 0901	2/18/14 1655	B130218 140901	Tennelec XLB	10 Mins	41	29	021814 /1754	28	7	021914/0315				WIPP Labs
2/18/14	2/18/14 1655	2/19/14 0105	B130218 141655	Tennelec XLB	10 Mins	42	36	021914 /0144	20	7	021914/0547				WIPP Labs

Attachment 1 – Station B GAB count results

Date	Time Installed	Time Removed	Filter ID	Inst Model	Count Time	Alpha (dpm)	Beta (dpm)	First Count	Alpha (dpm)	Beta (dpm)	Re-count	72 Hour Re-count	Alpha (dpm)	Beta (dpm)	Location
2/19/14	2/19/14 0105	2/19/14 0900	B130219 140105	Tennelec XLB	10 Mins	33	44	021914 /0952	20	15	021914/1222	030614/ 1730	11	4	On-Site
2/19/14	2/19/14 0900	2/19/14 1627	B130219 140900	Tennelec XLB	10 Mins	36	34	021914 /1708	25	10	021914/2036	030614/ 1730	23	3	On-Site
2/19/14	2/19/14 1627	2/20/14 0035	B130219 141627	Tennelec XLB	10 Mins	45	46	022014 /0107	25	9	022014/0359	030614/ 1730	17	0.9	On-Site
2/20/14	2/20/14 0035	2/20/14 0852	B130220 140035	Tennelec XLB	10 Mins	52	21	022014 /1035	38	14	022014/1226	030614/ 1730	42	8	On-Site
2/20/14	2/20/14 0852	2/20/14 1654	B130220 140852	Tennelec XLB	10 Mins	98	22	022014 /1838	101	23	022014/2211	030614/ 1730	95	17	On-Site
2/20/14	2/20/14 1654	2/21/14 0038	B130220 141654	Tennelec XLB	10 Mins	40	19	022114 /0204	33	11	022114/0521	030614/ 1730	34	9	On-Site
2/21/14	2/21/14 0038	2/21/14 0820	B130221 140038	Tennelec XLB	10 Mins	30	6	022114 /1027	27	12	022114/1532	030614/ 1757	25	5	On-Site
2/21/14	2/21/14 0820	2/21/14 1600	B130221 140820	Tennelec XLB	10 Mins	37	15	022114 /1654	41	12	022114/2028	030614/ 1730	33	5	On-Site
2/21/14	2/21/14 1600	2/22/14 0019	B130221 141600	Tennelec XLB	10 Mins	50	28	022214 /0125	42	14	022214/0358	030614/ 1730	37	12	On-Site
2/22/14	2/22/14 0019	2/22/14 0810	B130222 140019	Tennelec XLB	10 Mins	30	22	022214 /0946	19	12	022214/1151	030614/ 1730	13	3	On-Site
2/22/14	2/22/14 0810	2/22/14 1615	B130222 140810	Tennelec XLB	10 Mins	28	17	022214 /1713	22	10	022214/2004	030614/ 1730	15	2	On-Site
2/22/14	2/22/14 1615	2/22/14 2356	B130222 141615	Tennelec XLB	10 Mins	32	33	022314 /0047	22	9	022314/0404	030614/ 1757	11	3	On-Site
2/22/14	2/22/14 2356	2/23/14 0810	B130222 142356	Tennelec XLB	10 Mins	21	29	022314 /0938	19	17	022314/1227	030614/ 1811	9	3	On-Site

Attachment 1 – Station B GAB count results

Date	Time Installed	Time Removed	Filter ID	Inst Model	Count Time	Alpha (dpm)	Beta (dpm)	First Count	Alpha (dpm)	Beta (dpm)	Re-count	72 Hour Re-count	Alpha (dpm)	Beta (dpm)	Location
2/23/14	2/23/14 0810	2/23/14 1605	B130223 140810	Tennelec XLB	10 Mins	7	22	022314 /1642	17	7	022314/2010	030614/ 1757	14	2	On-Site
2/23/14	2/23/14 1605	2/24/14 0015	B130223 141605	Tennelec XLB	10 Mins	40	54	022414 /0054	19	13	022414/0401	030614/ 1811	12	4	On-Site
2/24/14	2/24/14 0015	2/24/14 0846	B130224 140015	Tennelec XLB	10 Mins	14	19	022414 /1136	14	14	022414/1540	030614/ 1811	9	2	On-Site
2/24/14	2/24/14 0846	2/24/14 1635	B130224 140846	Tennelec XLB	10 Mins	22	28	022414 /1733	8	8	022414/2031	030614/ 1811	6	3	On-Site
2/24/14	2/24/14 1635	2/25/14 0016	B130224 141635	Tennelec XLB	10 Mins	45	72	022514 /0029	8	12	022514/0404	030614/ 1811	6	3	On-Site
2/25/14	2/25/14 0016	2/25/14 0902	B130225 140016	Tennelec XLB	10 Mins	41	53	022514 / 1012	14	21	022514/1403	030614/ 1840	9	2	On-Site
2/25/14	2/25/14 0902	2/25/14 1652	B130225 140902	Tennelec XLB	10 Mins	39	59	022514 / 1742	12	7	022514/ 2000	030614/ 1840	5	1	On-Site
2/25/14	2/25/14 1652	2/26/14 0010	B130225 141652	Tennelec XLB	10 Mins	27	41	022614 / 0101	12	10	022614/ 0450	030614/ 1840	7	4	On-Site
2/26/14	2/26/14 0010	2/26/14 0921	B130226 140010	Tennelec XLB	10 Mins	26	21	022614 / 1051	23	16	022614/ 1423	030614/ 1905	19	2	On-Site
2/26/14	2/26/14 0921	2/26/2014 1616	B130226 140921	Tennelec XLB	10 Mins	22	25	022614 / 1727				030614/ 1905	6	1	On-Site
2/26/14	2/26/14 1616	2/27/14 0030	B130226 141616	Tennelec XLB	10 Mins	33	59	022714 / 0129	11	14	022714/0408	030614/ 1825	4	2	On-Site
2/27/14	2/27/14 0030	2/27/14 0806	B130227 140030	Tennelec XLB	10 Mins	22	37	022714 / 0929	7	22	022714/1153	030614/ 1825	1	0.2	On-Site
2/27/14	2/27/14 0806	2/28/1400 12	B130227 140806	Tennelec XLB	10 Mins	27	41	022814 / 0046	16	10	022814/0401	030614/ 1825	9	0.9	On-Site

Attachment 1 – Station B GAB count results

Date	Time Installed	Time Removed	Filter ID	Inst Model	Count Time	Alpha (dpm)	Beta (dpm)	First Count	Alpha (dpm)	Beta (dpm)	Re-count	72 Hour Re-count	Alpha (dpm)	Beta (dpm)	Location
2/28/14	02/28/14 0012	2/28/14 0927	B130228 140012	Tennelec XLB	10 Mins	14	20	022814 / 1024	8	5	022814/1408	030614/ 1825	4	0	On-Site
2/28/14	2/28/14 0927	2/28/14 1705	B130228 140927	Tennelec XLB	10 Mins	6	7	022814 / 1825	5	3	022814/1919	030614/ 1825	5	0.2	On-Site
3/1/14	2/28/14 1705	3/1/14 0144	B130228 141705	Tennelec XLB	10 Mins	16	28	030114 / 0235	6	5	030114 / 0528	030614/ 1825	3	0	On-Site
3/1/14	3/1/14 0144	3/1/14 0915	B130301 140144	Tennelec XLB	10 Mins	21	35	030114 / 0957	6	8	030114/1257	030614/ 1825	2	0	On-Site
3/1/14	3/1/14 0915	3/1/14 1620	B130301 140915	Tennelec XLB	10 Mins	10	10	030114 / 0535	4	1	030114/ 0910	030614/ 1825	4	0.4	On-Site
3/1/14	3/1/14 1620	3/2/14 0045	B130301 141620	Tennelec XLB	10 Mins	17	16	030214 /0108	9	5	030214/ 0512	030614/ 1825	10	9	On-Site
3/2/14	3/2/14 0045	3/2/14 0850	B130302 140045	Tennelec XLB	10 Mins	51	81	030214 / 0925	19	20	030214/ 1156				On-Site
3/2/14	3/2/14 0850	3/2/14 1630	B130302 140850	Tennelec XLB	10 Mins	51	37	030214 / 1723	34	18	030214/ 2122				On-Site
3/2/14	3/2/14 1630	3/3/14 0106	B130302 141630	Tennelec XLB	10 Mins	17	28	030314 / 0152	7	13	030314/ 0559				On-Site
3/3/14	3/3/14 0106	3/3/14 0820	B130303 140106	Tennelec XLB	10 Mins	26	39	030314 / 0855	9	14	030314/ 1217				On-Site
3/3/14	3/3/14 0820	3/3/14 1620	B130303 140820	Tennelec XLB	10 Mins	19	48	030314 / 1812	2	6	030314/ 1812				On-Site
3/3/14	3/3/14 1620	3/4/14 0114	B130303 141620	Tennelec XLB	10 Mins	22	33	030414 / 0208	5	8	030414/ 0543				On-Site
3/4/14	3/4/14 0114	3/4/14 0815	B130304 140114	Tennelec XLB	10 Mins	31	49	030414 / 0846	8	11	030414/ 1130				On-Site

Attachment 1 – Station B GAB count results

Date	Time Installed	Time Removed	Filter ID	Inst Model	Count Time	Alpha (dpm)	Beta (dpm)	First Count	Alpha (dpm)	Beta (dpm)	Re-count	72 Hour Re-count	Alpha (dpm)	Beta (dpm)	Location
3/4/14	3/4/14 0815	3/4/14 1610	B130304 140815	Tennelec XLB	10 Mins	18	26	030414 / 1639	4	4	030414/ 1957				On-Site
3/4/14	3/4/14 1610	3/5/14 0005	B130304 141610	Tennelec XLB	10 Mins	21	34	030514 / 0051	5	5	030514/ 0351				On-Site
3/5/14	3/5/14 0005	3/5/14 0810	B130305 140005	Tennelec XLB	10 Mins	26	36	030514 / 0920	7	14	030514/ 1206				On-Site
3/5/14	3/5/14 0810	3/5/14 1608	B130305 140810	Tennelec XLB	10 Mins	86	49	030514 / 1649	6	8	030514/ 2007				On-Site
3/5/14	3/5/14 1608	3/6/14 0015	B130305 141608	Tennelec XLB	10 Mins	16	29	030614 / 0109	7	9	030614/ 0403				On-Site
3/6/14	3/6/14 0015	3/6/14 0835	B130306 140015	Tennelec XLB	10 Mins	22	45	030614 / 0902	8	8	030614/ 1240				On-Site
3/6/14	3/6/14 0835	3/6/14 1620	B130306 140835	Tennelec XLB	10 Mins	18	27	030614 / 1725	1	4	030614/ 2348				On-Site
3/6/14	3/6/14 1620	3/7/14 0001	B130306 141620	Tennelec XLB	10 Mins	18	35	030714 / 0039							On-Site

Attachment 2 – Site survey map