Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy (DOE) Office of Environmental Management (EM).

Disclaimer:

This work was prepared under an agreement with and funded by the U.S. Government. Neither the U. S. Government or its employees, nor any of its contractors, subcontractors or their employees, makes any express or implied:

1) warranty or assumes any legal liability for the accuracy, completeness, or for the use or results of such use of any information, product, or process disclosed; or
2) representation that such use or results of such use would not infringe privately owned rights; or
3) endorsement or recommendation of any specifically identified commercial product, process, or service.

Any views and opinions of authors expressed in this work do not necessarily state or reflect those of the United States Government, or its contractors, or subcontractors.

Mercury Dispersion Modeling and Purge Ventilation Stack Height Determination for Tank 37H

Arelis M. Rivera-Giboyeaux

July 2019
SRNL-STI-2019-00402, Rev.0

DISCLAIMER

Printed in the United States of America

Prepared for
U.S. Department of Energy

Keywords: *Mercury Emissions; H Tank Farm; Tank 37;*

Retention: *Permanent*

Mercury Dispersion Modeling and Purge Ventilation Stack Height Determination for Tank 37H

A. M. Rivera-Giboyeaux

July 2019

Prepared for the U.S. Department of Energy under contract number DE-AC09-08SR22470.

Savannah River National Laboratory™

OPERATED BY SAVANNAH RIVER NUCLEAR SOLUTIONS

REVIEWS AND APPROVALS

AUTHOR:

A.M. Rivera-Giboyeaux, Atmospheric Technologies Group Date

TECHNICAL REVIEW:

S.W. Weinbeck, Atmospheric Technologies Group Date

APPROVAL:

C.H. Hunter, Manager, Atmospheric Technologies Group Date

P. Carroll, H Tank Farm Systems Engineer Date

J. Stuberfield, H Tank Farm System Engineering Manager Date

EXECUTIVE SUMMARY

The Savannah River National Laboratory (SRNL) Atmospheric Technologies Group performed atmospheric dispersion modeling and analysis of mercury emissions from the H-Tank Farm - Tank 37 ventilation system exhaust to evaluate whether the Short-Term Exposure Limit (STEL) for mercury is exceeded during salt dissolution activities. This analysis was also used to establish a minimum stack height at which ambient mercury concentration would not exceed this regulatory limit. The American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) was used as the dispersion modeling tool for this analysis. Results indicate that the default 10-foot stack results in ground level concentrations that significantly exceed the standards for the mercury discharge scenarios evaluated. A 35-foot stack was necessary to raise the exhaust plume centerline from Tank 37H to a height that prevents mercury exposure problems for the three discharge concentrations modeled.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
AMS	American Meteorological Society
AERMOD	American Meteorological Society/Environmental Protection Agency Regulatory Model
AERMET	AERMOD Meteorological Preprocessor
AERSURFACE	AERMOD Surface Characteristics Preprocessor
ASL	Above Sea Level
AGL	Above Ground Level
ATG	Atmospheric Technologies Group
BPIP-Prime	Building Profile Input Program- Prime Algorithm
EPA	Environmental Protection Agency
DSA	Documented Safety Analysis
LIDAR	Light Detection and Ranging
NAD27	North American Datum 1927
NLCD92	National Land Cover Database 1992
NWS	National Weather Service
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
STEL	Short Term Exposure Limit
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
cfm	Cubic feet per minute

1.0 Introduction

The Atmospheric Technologies Group (ATG) was asked to evaluate the exposure of workers to mercury concentrations resulting from the H-Area Tank Farm Tank 37 purge exhaust systems emissions and ensure ambient air concentrations are within the Industrial Hygiene program requirements (Ref. 1). The American Conference of Governmental Industrial Hygienists (ACGIH) short term exposure limit (STEL) for dimethyl mercury in the workplace is 0.030 mg/m^3 (30 µg/m^3) (Ref. 1). The STEL for dimethyl mercury is used to assess short term exposure because a STEL for elemental mercury has not been reported by the ACGIH. Mercury concentrations were predicted for ground-level breathing height receptors on and around Tank 37H.

To predict the mercury concentrations for Tank 37H, observed weather data for Savannah River Site (SRS) was taken from a five-year (2007-2011) quality assured record of hourly meteorological conditions and used to calculate the amount of atmospheric dispersion for 1-hour time periods. Hourly-averaged modeled concentrations were adjusted to represent 15-minute values for comparison to the 15-minute STEL using the following equation (Ref. 2):

$$\boldsymbol{C_{15min} = C_{60min}\left(\frac{60}{15}\right)^{0.2} = 1.3\ C_{60min}} \tag{1}$$

By multiplying the hourly concentrations by a factor of 1.3, the concentration is representative of concentrations sampled on a 15-minute time averaged period. Comparisons of the calculated concentrations can be made to the standards and estimates of worker exposure and potential mitigation methods can easily be developed.

2.0 Methodology

Modeling was conducted with the Environmental Protection Agency's (EPA) AMS/EPA Regulatory Model (AERMOD) dispersion model, which is recommended by the EPA for regulatory air quality analyses (Ref. 3). The model incorporates boundary layer scaling parameters to allow for vertical variability in wind, turbulence, and temperature, and to accommodate dispersion through the boundary layer in both stable and convective atmospheric situations (Refs. 4 and 5). Information on ATG's software quality assurance plan for AERMOD can be found in C-SQP-G-00076 (Ref. 6). For this regulatory modeling, AERMOD was executed in default (regulatory) mode. AERMOD is routinely used for tank and multiple stack emissions, and has physics included to model building wake effects.

Meteorological data files used as input to AERMOD were prepared using EPA's AERMOD Meteorological preprocessor (AERMET, Ref. 7), which incorporates the National Weather Service's (NWS) hourly observations from Bush Field in Augusta, GA, twice-daily upper air soundings from the NWS Atlanta, GA radiosonde station and, quality assured 15-minute values of wind and temperature at four levels (4, 18, 36 and 61 meters Above Ground Level) of the SRS Central Climatology tower located near N-area.

For onsite data, values were extracted from the meteorological database and written to a text file only if there were no associated quality flags. When the data did not meet quality control criteria, a missing value code was assigned consistent with AERMET requirements. Quality assurance procedures for SRS meteorological data are described in Reference 8. For details on the processing of the most recent five-year quality assured dataset (2007-2011) see References 9 and 10.

Values used by AERMET for roughness length, Bowen ratio and albedo were determined from EPA's AERSURFACE algorithm. Input to the algorithm consisted of a (United States Geological Survey) USGS National Land Cover Data image for 1992 (NLCD92). This image was analyzed for the area around the Central Climatology tower. Monthly values of the three surface parameters were generated and imported into AERMET.

Building information was included in AERMOD to account for downwash and re-circulation effects from nearby buildings. This data was processed using the EPA utility Building Profile Input Program (BPIP-Prime) to determine how these obstacles affect airflow patterns and the transport of effluent discharge. Of particular concern is the downwash of the plume over areas where workers will spend most of their time during operations. Small, ill-defined appurtenances in the vicinity of Tank 37H were not modeled for atmospheric downwash, therefore adding a level of conservatism (these features add additional turbulence for dispersion which can lower atmospheric concentrations). The larger buildings and covered platforms need to be retained for AERMOD to enhance the vertical mixing of the plume centerline down to the receptor heights, increasing the near surface ground concentrations. For this evaluation, 5 structures of various sizes and heights located on the tank area as well as the 3H Evaporator building were included on the domain as described in Reference 1. Tank 37H itself was given a height of 0.3 meters (m) with a base height of 98 m Above Sea Level (ASL). BPIP-Prime was run for every change in stack height to determine the impact of the downwash from each building wake on the stack effluent.

Terrain elevation was determined from SRS high resolution Light Detection and Ranging (LIDAR) dataset for SRS (Refs. 11 and 12). Tank 37H is located on what is known as the West Hill which has been graded to be approximately 98 m ASL (Fig. 2-1). The area surrounding the hill has been graded to be 87 m ASL. The terrain features surrounding Tank 37H were modeled by creating a terraced building to model the impact of the West Hill on plume dispersion (Ref. 13) and placing a series of receptors with different base heights according to the different terrain heights ASL (Figure 2-2, Ref. 14).

The modeling domain is defined by a receptor grid of approximately 13, 488 receptors covering the entire H-tank farm area. Receptor grid spacing of 6 m was used to identify any potential excessive concentrations that may occur near the ground level breathing zones. The flagpole height for ground level receptors is nominally 1.83 m (6 ft, Ref. 1), and is added to all receptor heights to represent the breathing zone of a tall worker standing at ground level. The coordinate system used for this domain was a custom UTM grid, using the NAD27 datum.

The operating characteristics of the stack and source term are defined by the following parameters, also listed in Reference 1. Three discharge concentrations were evaluated: 10 mg/m^3, 25 mg/m^3, 50 mg/m^3 with a flow rate of 233 cfm. The lower bound of the stack discharge temperature range (65°C) was used for conservatism. The inside diameter of the stack is 6 inches (in.) and the current stack height is 10 ft (Ref. 1). For this evaluation the stack height was adjusted, as necessary, to various heights to determine the minimum height at which the estimated mercury concentrations around the stack both at ground level are within Industrial Hygiene program requirements.

In order to have the correct units for input to AERMOD, the given concentration of mercury in the stack discharge was converted to a mass release rate by using the discharge flow rate given Reference 1:

Case 1:

$$\frac{50\text{mg}}{\text{m}^3} \times \frac{1\text{g}}{1000\text{mg}} \times \left(\frac{1\text{m}}{3.28\text{ft}}\right)^3 \times \frac{233\text{ft}^3}{\text{min}} \times \frac{1\text{ min}}{60\text{ sec}} = 0.0055\text{ g/s}$$

Case 2:

$$\frac{25\text{mg}}{\text{m}^3} \times \frac{1\text{g}}{1000\text{mg}} \times \left(\frac{1\text{m}}{3.28\text{ft}}\right)^3 \times \frac{233\text{ft}^3}{\text{min}} \times \frac{1\text{ min}}{60\text{ sec}} = 0.0028\text{ g/s}$$

Case 3:

$$\frac{10\text{mg}}{\text{m}^3} \times \frac{1\text{g}}{1000\text{mg}} \times \left(\frac{1\text{m}}{3.28\text{ft}}\right)^3 \times \frac{233\text{ft}^3}{\text{min}} \times \frac{1\text{ min}}{60\text{ sec}} = 0.0011\text{ g/s}$$

Once mercury concentration values were calculated by the model for each receptor on the grid, values were transformed to express results as percent of corresponding standard for figures included in this report. This was done by multiplying each value by a scaling factor of 4.3 for the 15-minute, period. This scaling factor was obtained using the following calculation:

$$\%\text{ of STEL} = \frac{1.3}{30\ \mu g/m^3} \times 100 = 4.3$$

where the value 1.3 in the first equation is incorporated from Eq. 1 to obtain values representative of a 15-minute period.

Figure 2-1. Aerial photo of West Hill at the H-Tank farm with LIDAR elevations (green contours) around Tank 37H (Ref. 12)

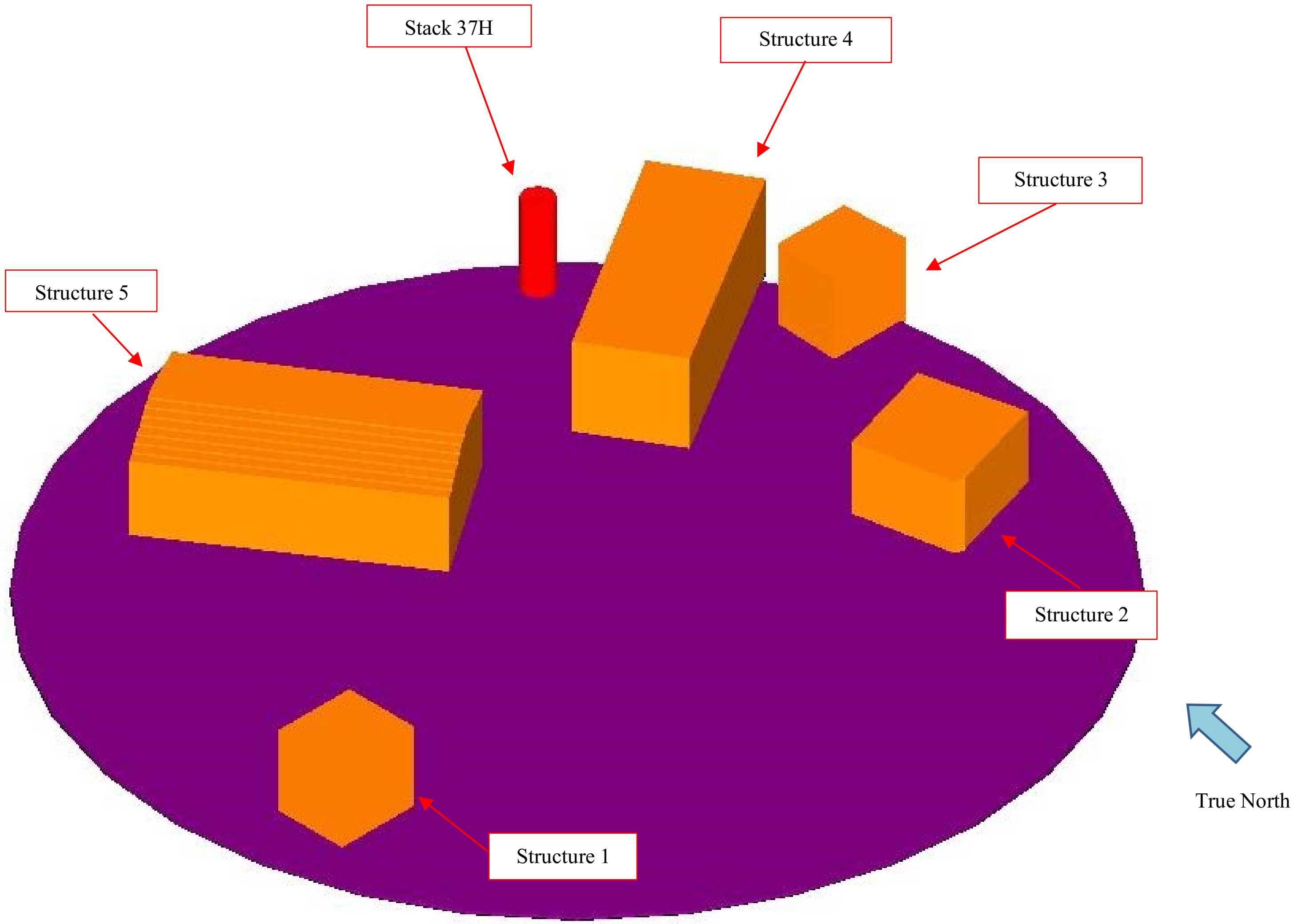

Figure 2-2. Three-dimensional view of Tank 37H for a 10-foot stack. The tanks are represented by purple circles, buildings and enclosed platforms in orange, and the 10-ft stack is in red. Blue arrow shows the direction of the true north.

3.0 Results and Discussion

Modeling was conducted based on the release characteristics previously summarized to assess compliance with the STEL for dimethyl mercury (0.030 mg/m^3 or 30 µg/m^3), which as identified previously is used as a surrogate for elemental mercury. AERMOD provides output of a 1-hour time weighted average which was adjusted to a 15-minute averaging period using the multiplier from Equation 1. The stack discharge concentrations modeled were 10 mg/m^3, 25 mg/m^3, and 50 mg/m^3 (Ref. 1). The stack height was initially set to 10 ft, which is the current height of the stack, and increased by 5 ft increments until the concentration at all receptor locations was below the standard value.

Table 3-1 summarizes the maximum mercury concentration predicted by the model over the entire domain for each modeled stack height and flow rate. A graphical depiction of model results can be found on Figures 3-1 to 3-6 showing the location of receptors exceeding concentration standards. Values at each receptor are expressed as a percent of the standard and only the values over 100% of the standard are depicted in each figure, i.e. values that exceed the standard.

For a 10-ft stack, and a 10 mg/m^3 release concentration, the STEL is not exceeded at the ground level receptors modeled. However the STEL is significantly exceeded for both the 25 mg/m^3 and 50 mg/m^3 cases (Table 3-1). Ground level receptors exhibit concentration values exceeding the STEL over the northwestern and western side of the hill as well as an area located southeast of the stack (Figure 3-1). The highest concentration values are observed at the slope of the hill closest to Tank 37H (northwest side). A similar pattern is observed for the 50 mg/m^3 release concentration with a 10 ft stack, for which a significant area of ground level receptors northwest and southeast of the stack exceed the STEL (Figure 3-2).

Maximum mercury concentration values generally decreased with each incremental increase in stack height though the shape of the area of exceedances remained similar. Beyond the 25-ft height, ground level concentrations remain below STEL for the 25 mg/m^3 release concentration (Table 3-1). However, to reach ground level concentrations below STEL for a release concentration of 50 mg/m^3, the stack needed to be elevated to 35-ft. Hence, a stack height of 35 ft ensures that the STEL is not exceeded for all three discharge concentration cases modeled.

Table 3-1. Maximum estimated ambient concentrations (µg/m^3) associated to Tank 37H emissions for ground-level receptors.

Tank Discharge Concentration	Tank 37H Stack Height					
	10-ft	*15-ft*	*20-ft*	*25-ft*	*30-ft*	*35-ft*
10 mg/m^3	25.8	N/A	N/A	N/A	N/A	N/A
25 mg/m^3	**65.8**	**49.1**	**48.6**	28.7	N/A	N/A
50 mg/m^3	**129.2**	**96.3**	**95.4**	**56.4**	**47.3**	29.2

Values in red exceed exposure limits (0.030 mg/m^3 or 30 µg/m^3 for 15-min STEL)

4.0 Conclusions

The focus of this report was to assess the worst-case 15-min average mercury concentrations at ground level breathing zones on and around Tank 37H for the current stack height of 10 ft. Emissions from this height were found to result in significant exceedances of the STEL during salt dissolution activities. Areas with the higher estimated concentrations were observed on the northwestern side of west hill, although some high concentrations can also be observed southeast of the tank.

Results show that the minimum stack height to ensure concentrations below STEL for all discharge scenarios evaluated is 35 ft. A stack of 30 ft would be sufficient to provide concentrations below the limit value for discharge concentrations of 10 and 25 mg/m^3 but not sufficient when the discharge concentration is 50 mg/m^3.

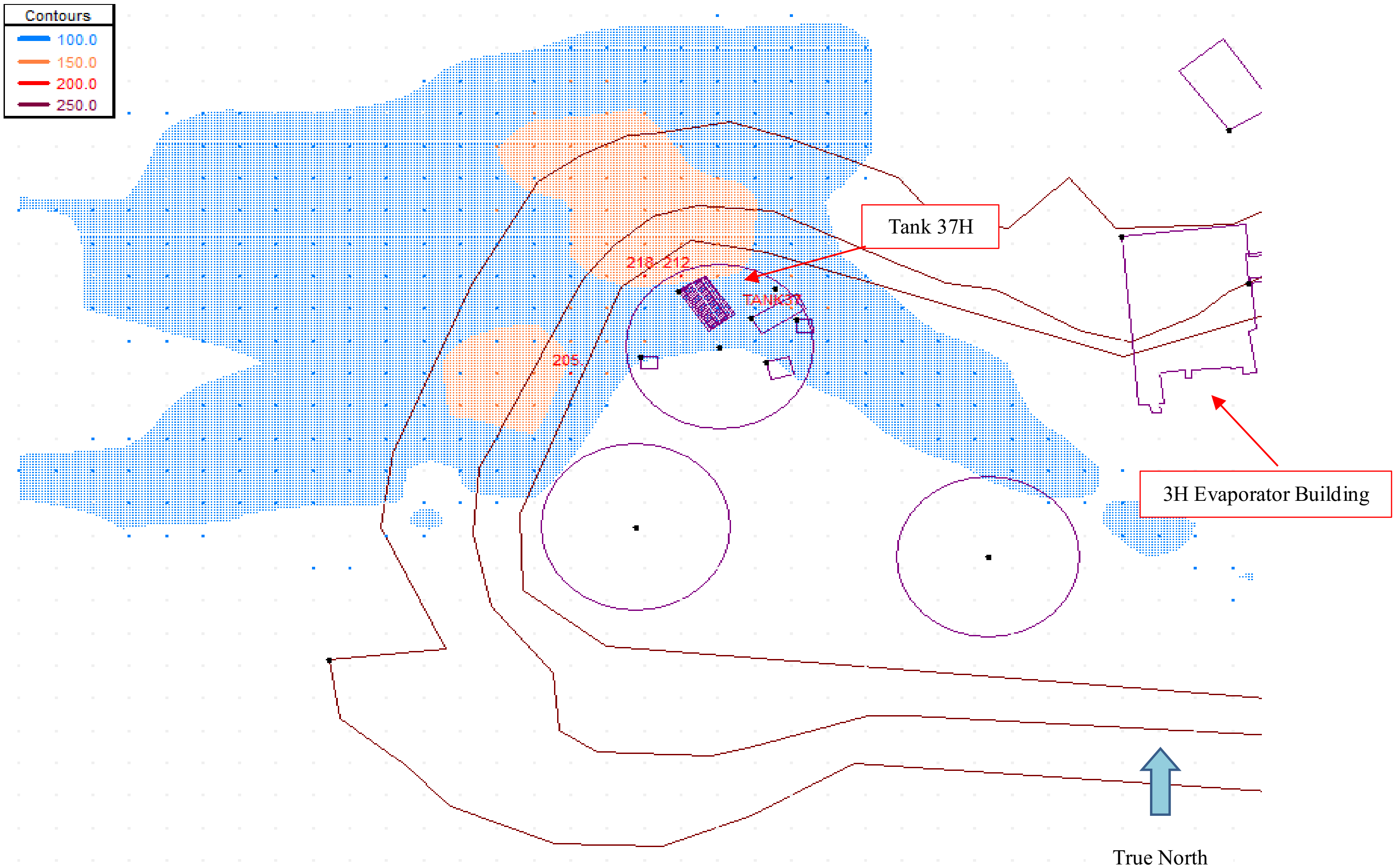

Figure 3-1. STEL Exceedances for Tank 37H with a 10-foot stack and a 25 mg/m^3 discharge. Exceedances for the ground-level breathing zones expressed as a percentage of the STEL standard (30 µg/m^3). Filled contours display areas with concentration values above 100% of standard while numeric values display concentrations above 200% of standard. Terrain, buildings and tanks are shown in brown and purple, respectively.

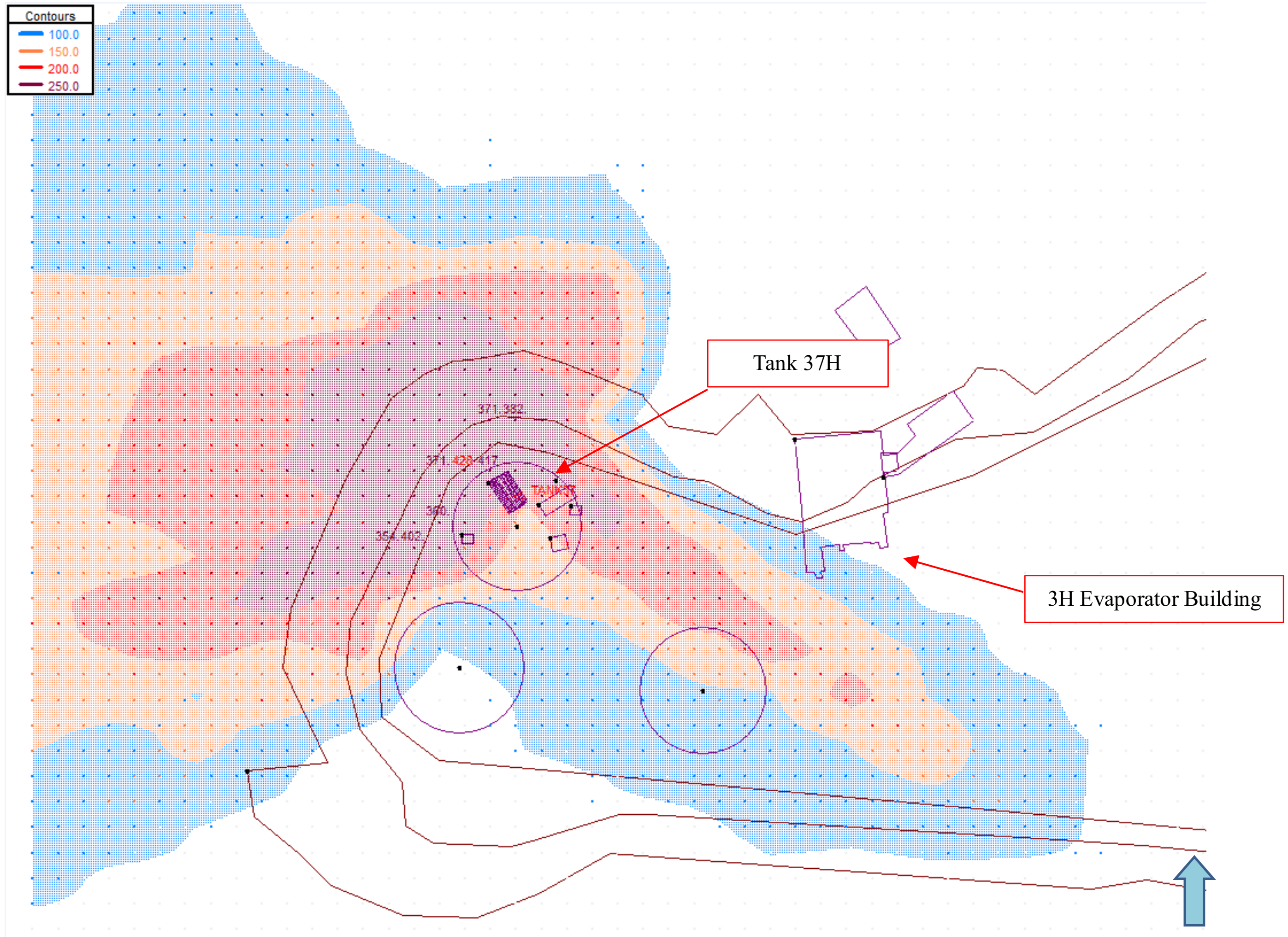

Figure 3-2. STEL Exceedances for Tank 37H with a 10-foot stack and 50 mg/m³ discharge. Exceedances for the ground-level breathing zones expressed as a percentage of the STEL standard (30 µg/m³). Filled contours display areas with values above 100% of the standard. Numeric values display areas with concentration values above 300% of standard. Terrain, buildings and tanks are shown in brown and purple, respectively.

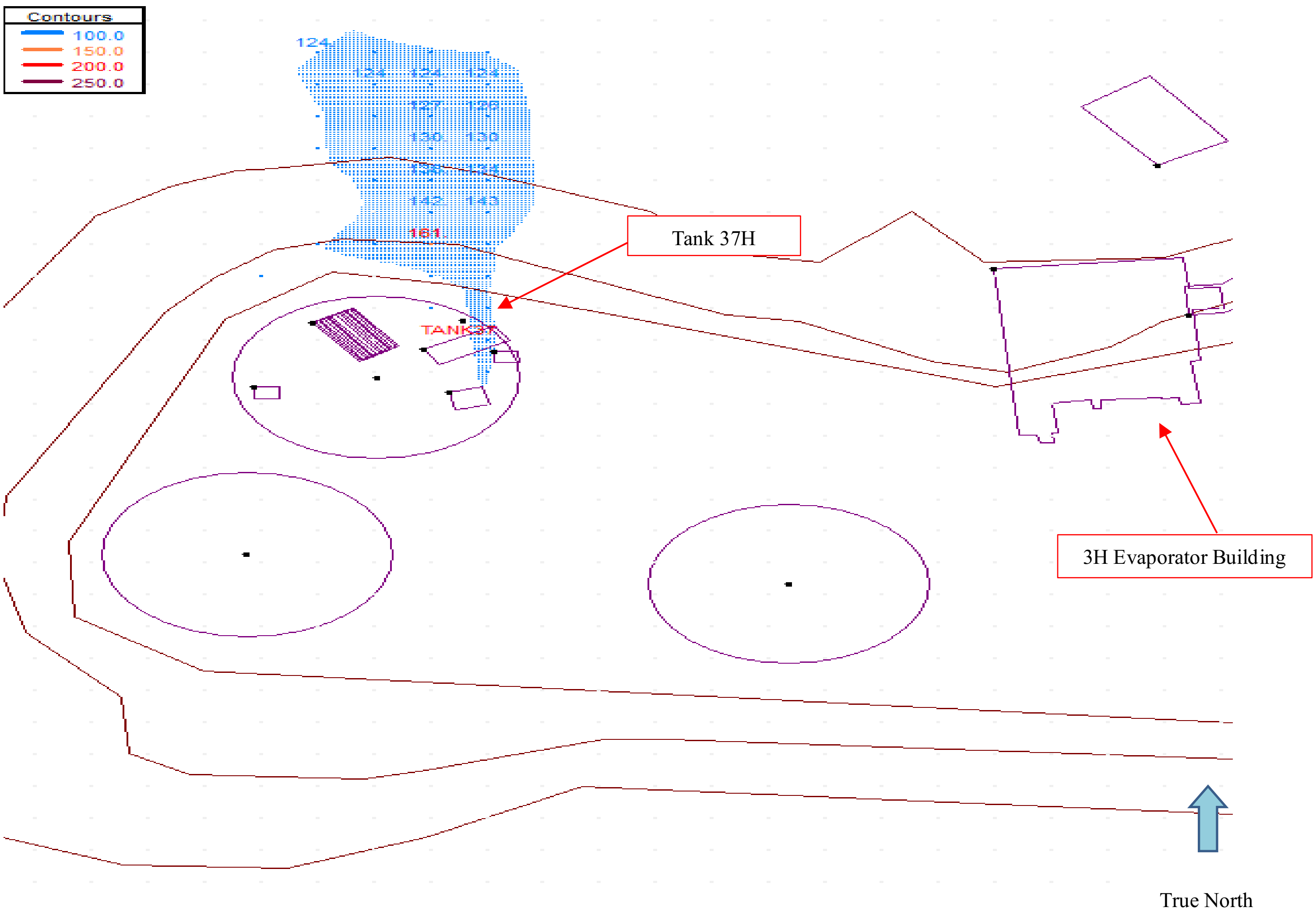

Figure 3-3. STEL Exceedances for Tank 37H with a 20-foot stack and a 25 mg/m^3 discharge. Exceedances for the ground-level breathing zones expressed as a percentage of the STEL standard (30 µg/m^3). Filled contours display areas with values above 100% of the standard. Numeric values display areas with concentration values above 120% of the standard. Terrain, buildings and tanks are shown in brown and purple, respectively.

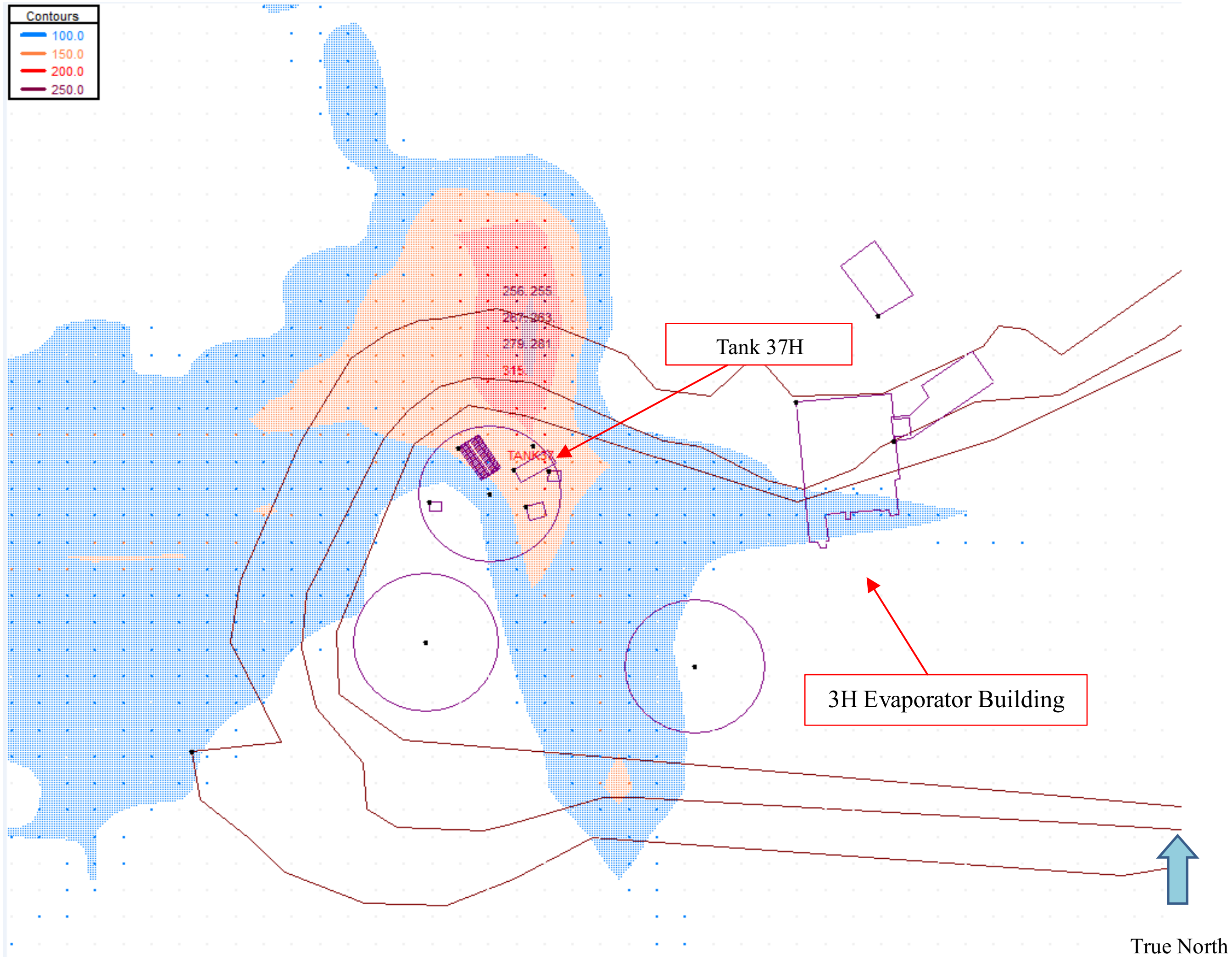

Figure 3-4. STEL Exceedances for Tank 37H with a 20-foot stack and 50 mg/m³ discharge. Exceedances for the ground-level breathing zones expressed as a percentage of the STEL standard (30 μg/m³). Filled contours display areas with values above 100% of the standard. Numeric values display areas with concentration above 250% of standard. Terrain, buildings and tanks are shown in brown and purple, respectively.

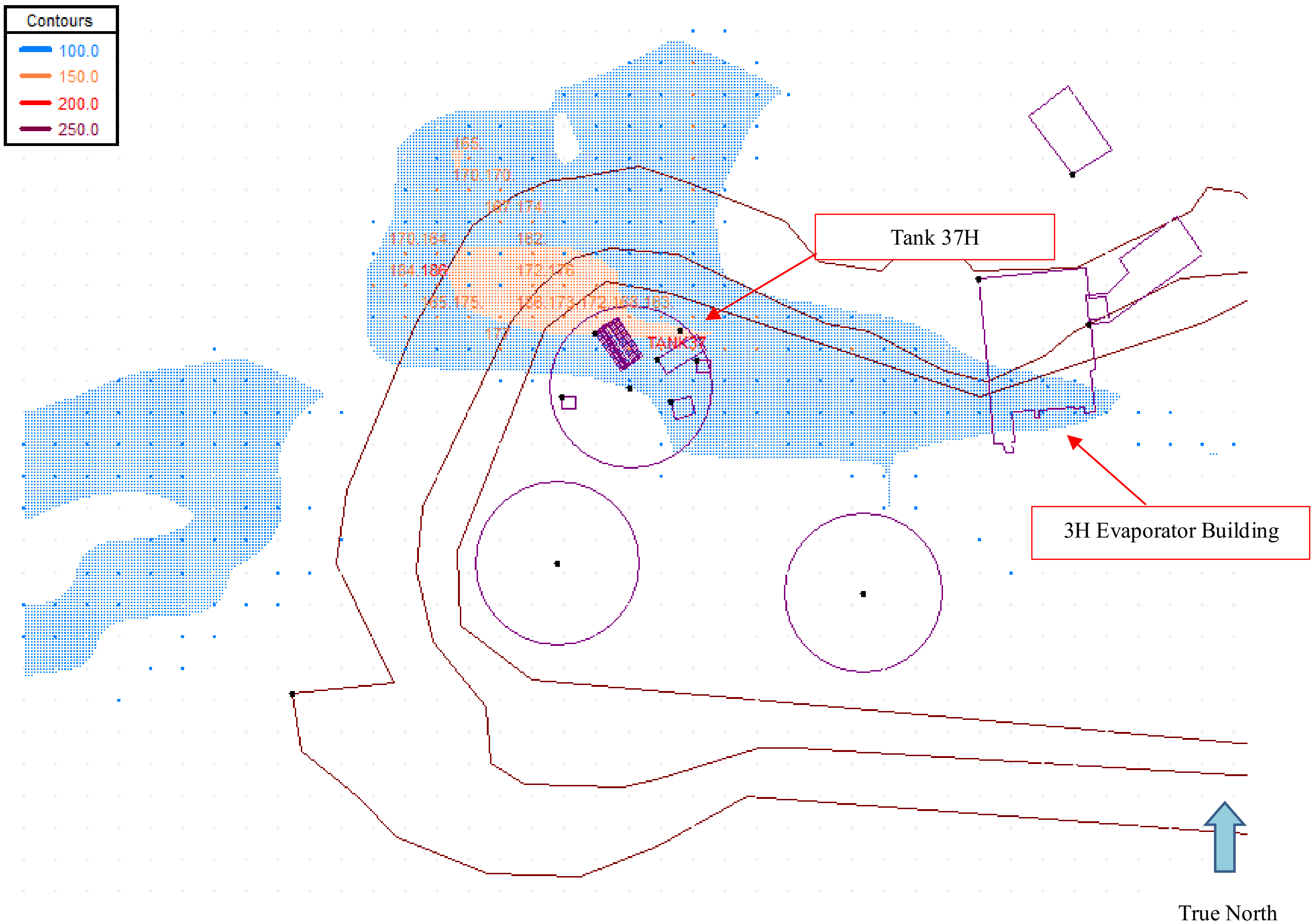

Figure 3-5. STEL Exceedances for Tank 37H with a 25-foot stack and 50 mg/m^3 discharge. Exceedances for the ground-level breathing zones expressed as a percentage of the STEL standard (30 μg/m^3). Filled contours display areas with concentration values above 100% of standard. Numeric values display areas with concentrations above 170% of standard. Terrain, buildings and tanks are shown in brown and purple, respectively.

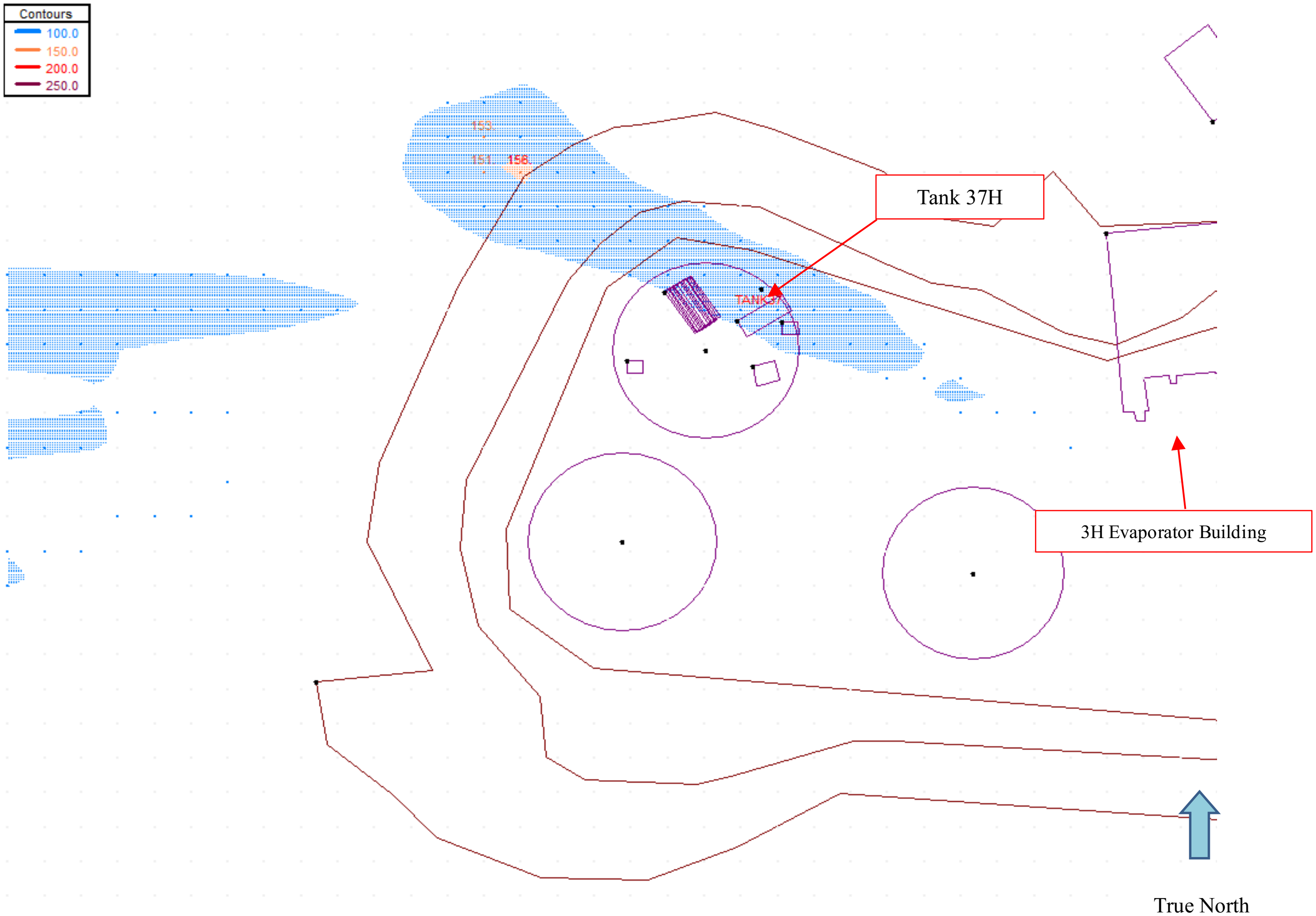

Figure 3-6. STEL Exceedances for Tank 37H with a 30-foot stack and 50 mg/m^3 discharge. Exceedances for the ground-level breathing zones expressed as a percentage of the STEL standard (30 µg/m^3). Filled contours display areas with values above 100% of the standard. Numeric values display areas with concentration above 150% of standard. Terrain, buildings and tanks are shown in brown and purple, respectively.

5.0 References

1. Carroll, P. Mercury Dispersion Modeling and Purge Ventilation Stack Height Determination for Tank 37H, M-TTR-H-00115, Rev. 0.

2. Hanna, S.R., G.A. Briggs and R.P. Hosker, 1982: Handbook on Atmospheric Diffusion. DOE/TIC-11223, Department of Energy, 102 pp.

3. U.S. Environmental Protection Agency, Guideline on Air Quality Models, 40 Code of Federal Regulations, Part 51, Appendix W.

4. U. S. Environmental Protection Agency, AERMOD: Description of Model Formulation, EPA-454/R-03-004 (2004).

5. U. S. Environmental Protection Agency, User's Guide for the AMS/EPA Regulatory Model – AERMOD and Addendum, EPA-454/B-03-001 (2004).

6. Savannah River Nuclear Solutions, Software Quality Assurance Plan for the AMS/EPA Regulatory Model (AERMOD) Software Package, C-SQP-G-00076 (Rev. 1) (2017).

7. U. S. Environmental Protection Agency, User's Guide for the AERMOD Meteorological Preprocessor (AERMET) and Addendum, EPA-454/B03-002 (2004).

8. Westinghouse Savannah River Company, Quality Assurance of Meteorological Data, Procedure Manual 15.3, Meteorological Monitoring Procedures, NTSP T-113 (2015).

9. Viner, B.J. Summary of Data Processing for the 2007-2011 SRS Meteorological Database, SRNL-STI-2013-00268, Savannah River National Laboratory (2013).

10. Scott, K.E. AERMET Meteorological Files, 2007-2011, SRNL-L2200-2013-00045, Savannah River National Laboratory (2013).

11. McGaughtey, R, J., and S.E. Reutebuch, 2009: Savannah River Site 2009 LIDAR Project, FY09 Final Report., United States Department of Agriculture, Forest Service, 11pp.

12. SRS Explorer, http://egis4.srs.gov/srsexplorer/?app=srsroute, accessed on July 9, 2019.

13. Weinbeck, S.W., ETP Mercury Dispersion Modeling Study, SRNL-STI-2017-00669, Rev. 0.

14. Weinbeck, S.W., Mercury Dispersion Modeling and Purge Ventilation Stack Height Determination for Transfer Facility HPP-7, SRNL-STI-2017-00745, Rev. 0.

Distribution:

C. H. Hunter	773-A
E. Poole	241-120H, 1
P. Carroll	241-119H, 8
J. Stubberfield	241-156H, 5
G. Kessinger	773-A, A-211