ECF-HANFORD-19-0132
Revision 0

Hydraulic Gradient and Average Linear Groundwater Velocity Calculation - Quarter 3 Calendar Year 2019

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract 89303320DEM000030

CPCCo
Central Plateau
Cleanup Company

P.O. Box 1600
Richland, Washington 99352

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APPROVED
By Janis Aardal at 1:45 pm, Feb 16, 2021

Release Approval　　　　Date

ENVIRONMENTAL CALCULATION COVER PAGE

SECTION 1 - Completed by the Responsible Manager

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Qualifications Summary

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ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

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SECTION 2 - Completed by Preparer

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SECTION 4 - Document Review and Approval

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ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

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SECTION 5 - Applicable if Calculation is a Risk Assessment or Uses an Environmental Model

Prior to Initiating Modeling:

Required training for modelers completed:
Integration Lead:

Print First and Last Name	*Signature*	*Date*

Safety Software Approved:
Integration Lead:

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Risk/Modeling Integration Manager:

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From: Toomas Parratt
Sent: Thursday, November 05, 2020 11:12 AM
To: Kinsley Binard
Subject: ECF-HANFORD-19-0132

The subject ECF, Titled "Hydraulic Gradient and Average Linear Groundwater Velocity Calculations – Quarter 3 Calendar Year 2019" and dated 11/5/2020, was reviewed and updated. I approve it for publication as of today, November 5, 2020.

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The subject ECF, Titled "Hydraulic Gradient and Average Linear Groundwater Velocity Calculations – Quarter 3 Calendar Year 2019" and dated 11/5/2020, was reviewed and updated. I approve it for publication as of today, November 5, 2020.

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Contents

Figures

Tables

Terms

ASCII	American Standard Code for Information Interchange
AWLN	automated water-level network
CY	calendar year
DWMU	dangerous waste management unit
ECF	environmental calculation file
HISI	Hanford Information Systems Inventory
IDF	Integrated Disposal Facility
MEUK	multi-event universal kriging
LERF	Liquid Effluent Retention Facility
LLBG	low-level burial grounds
RCRA	*Resource Conservation and Recovery Act of 1976*
TRIM	Tikhonov Regularized Inverse Method
WMA	Waste Management Area

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1 Purpose

This environmental calculation file (ECF) describes quarterly hydraulic gradient and average linear velocity calculations at Hanford Site *Resource Conservation and Recovery Act of 1976* (RCRA) facilities located in the 200 East and West Areas. Gradient and average linear velocity calculations for the July through September 2019 quarter were made for the dangerous waste management units (DWMUs)[1, 2,3] listed as follows and depicted in Figures 1-1 and 1-2:

The 200 East Area Facilities (Figure 1-1):

- 216-A-29 Ditch
- 216-A-36B Crib
- 216-A-37-1 Crib
- 216-B-3 Pond
- 216-B-63 Trench
- Integrated Disposal Facility (IDF)
- Liquid Effluent Retention Facility (LERF)
- Low-Level Burial Grounds (LLBG) Waste Management Area (WMA)-1
- LLBG WMA-2
- WMA A-AX
- WMA B-BX-BY
- WMA C

The 200 West Area Facilities (Figure 1-2):

- LLBG Trenches 31 and 34
- LLBG WMA-3
- LLBG WMA-4
- WMA T
- WMA TX-TY
- WMA U
- WMA S-SX
- 216-S-10 Pond and Ditch

This ECF provides the conceptual basis for the hydraulic gradient and velocity calculations performed, details the specific methods and codes used to undertake the calculations, and presents results of calculations based on the average quarterly water-level map for each facility.

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[1] The Single-Shell Tank System unit group includes WMA A-AX, WMA B-BX-BY, WMA C, WMA S-SX, WMA T, WMA TX-TY, and WMA U.

[2] Under interim status, the LLBG unit group includes LLBG WMA-1, LLBG WMA-2, LLBG WMA-3, and LLBG WMA-4. At each WMA, there are specific locations where dangerous waste was disposed after the effective date of RCRA regulation. Where possible, the groundwater evaluation includes the entire WMA; however, in cases where pump and treat remedial action operations affect flow conditions, the specific locations of the dangerous waste within the WMA are the focus of groundwater evaluation.

[3] Under final status, LLBG Trenches 31 and 34 (located within LLBG WMA-3) will become a separate DWMU; therefore, it is included as a distinct 200 West Area facility for evaluation.

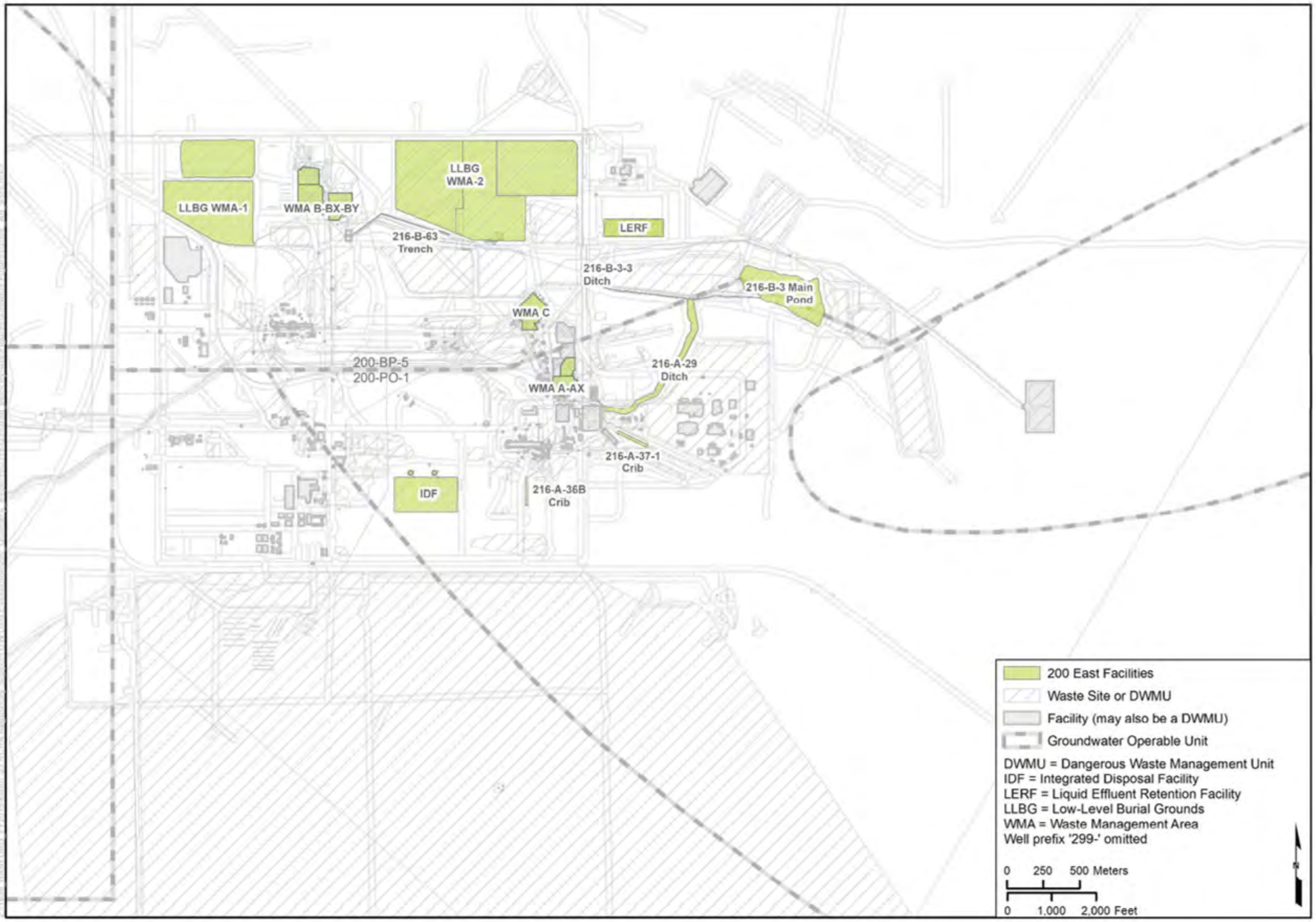

Figure 1-1. 200 East Area DWMUs Evaluated in this ECF

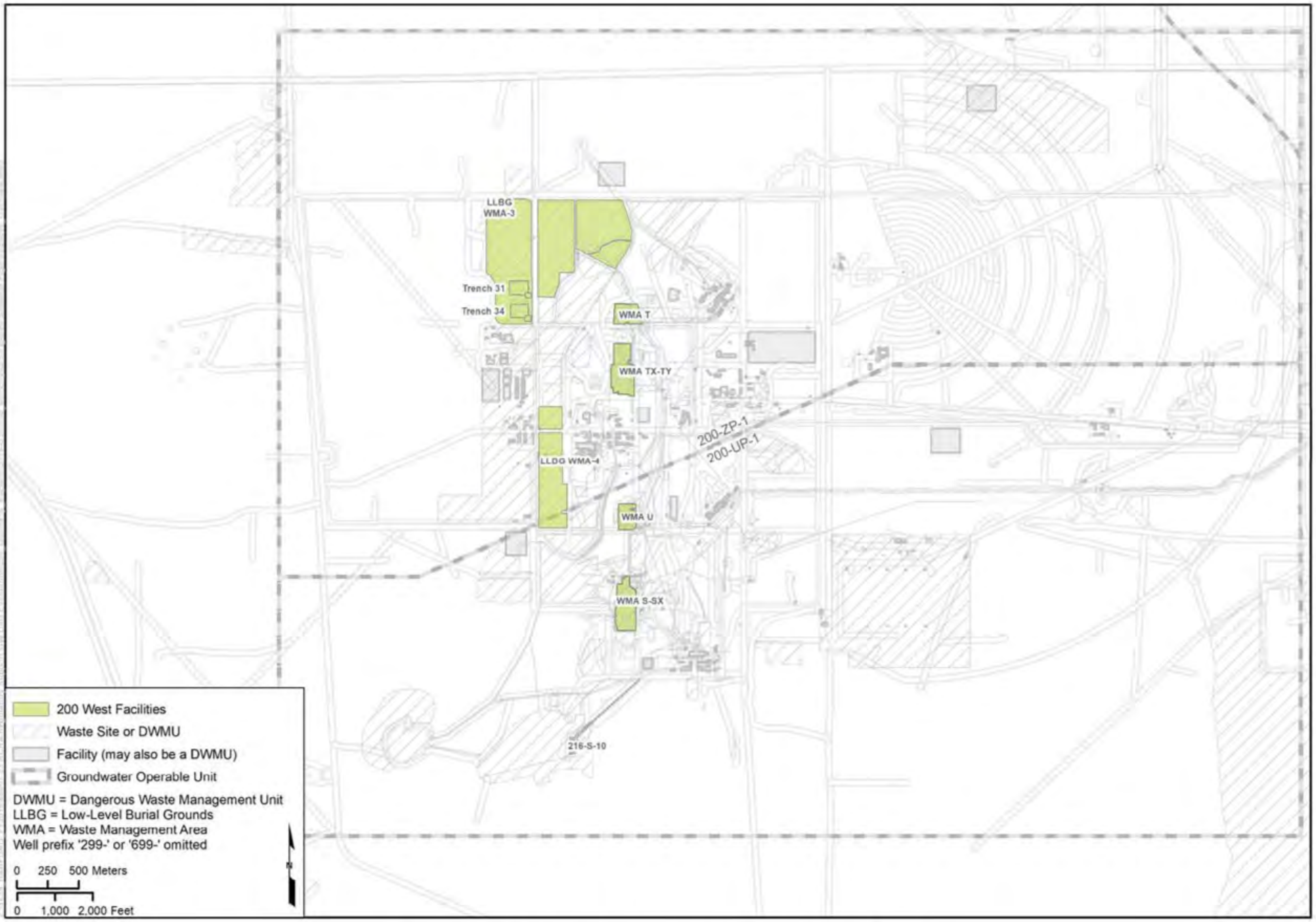

Figure 1-2. 200 West Area DWMUs Evaluated in this ECF

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2 Background

To meet the objectives of this ECF for the 200 Area, groundwater elevation maps were obtained for the 200 East and West Areas using two different methods. For the 200 East Area, a regularized inverse interpolation technique that is referred to as the Tikhonov Regularized Inverse Method (TRIM) (Tikhonov and Arsenin, 1977, *Solutions of Ill-Posed Problems*) is used as described in ECF-200E-19-0081, *Groundwater Elevation Mapping for 200 East Area – Quarter 1 Calendar Year 2019*. For the 200 West Area, groundwater elevations were interpolated using multi-event universal kriging (MEUK), as described in ECF-200W-19-0082, *Groundwater Elevation Mapping for 200 West Area – Quarter 1 Calendar Year 2019*. Both the TRIM and MEUK were used to obtain piecewise, continuous grids of groundwater elevations. The resulting groundwater elevation grids comport well with subject matter expert knowledge of the system and other independent sources of information, and consequently are suitable for tracking particles to evaluate the likely paths of groundwater. Particle tracking also facilitates the evaluation of: (1) hydraulic gradients by integrating the calculated movement of particles between two points along a pathline over a specified time interval and, (2) average linear velocities by adding the principal velocity components of the particle.

For the purposes of this ECF, the magnitude and directions of gradients along with the average linear velocities specific to each facility within the 200 Areas were calculated and are presented herein.

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3 Calculation Methods

This chapter describes the calculation methods used to support this ECF.

3.1 Data Used

The hydraulic gradient and average linear velocity calculations rely on water-level maps developed using groundwater-level measurements from the 200 Areas.

In the 200 East Area, depth-to-water measurements are mainly obtained from the wells of the low-gradient network, supplemented with data from other wells when necessary.

For the 200 West Area, the groundwater elevations are obtained from wells that are part of the water-level measurement and groundwater sampling networks. For wells in the automated water-level network (AWLN), monthly averages of AWLN data are used if no representative manual measurements are available.

The average quarterly values of the groundwater elevations in the 200 Areas were then calculated from the mentioned monitoring well measurements over July through September 2019 in ECF-200E-19-0130, *Groundwater Elevation Mapping for 200 East Area – Quarter 3 Calendar Year 2019* and ECF-200W-19-0131, *Groundwater Elevation Mapping for 200 West Area – Quarter 3 Calendar Year 2019*.

3.2 Generation of General Groundwater Flow Directions Using Particle Tracking

After the grid of groundwater elevations for the third quarter of calendar year (CY) 2019 were generated for the 200 Areas, they were used as the basis for particle tracking within a localized region of each facility. Particle tracking was performed using mod-PATH3DU (Muffels et al., 2018, *User's Guide for mod-PATH3DU, A Groundwater Path and Travel-Time Simulator*).

Ten particles were released from evenly spaced locations along a line upgradient of each facility and tracked considering only advective transport. The resulting particle pathlines allow for: (1) visualization of the general groundwater flow directions in the local region of each facility and, (2) the calculation of gradients and average linear velocities based on those general flow directions.

3.3 Calculation of Average Linear Velocity

The Darcy flux, q, across a unit cross section of porous media is given as follows:

$$q = -Ki \qquad \textbf{Eq. (1)}$$

where, K is the hydraulic conductivity of the aquifer cross-section and i is the hydraulic gradient.

Darcy flux at any point is then divided by the effective aquifer porosity, η, to yield the average linear velocity, ALV as follows:

$$ALV = \frac{q}{\eta} \qquad \textbf{Eq. (2)}$$

Mod-PATH3DU internally computes the average linear velocity components (i.e., in x- and y-directions) at each tracked point using Darcy's Law. Gridded surfaces of aquifer hydraulic conductivities and effective porosities were provided as inputs to mod-PATH3DU. The output was then used to compute the resultant average linear velocity along the calculated pathlines for each facility.

3.4 Calculation of Facility-Wide Gradients

Gradients specific to each facility were back-calculated from the calculated average linear velocities and aquifer properties using Darcy's Law. Substituting Equation 1 into Equation 2 and rearranging for the hydraulic gradient, i, yields the following:

$$i = ALV\left(-\frac{\eta}{K}\right) \qquad \textbf{Eq. (3)}$$

The magnitude of the gradient, i, may then be taken as the absolute value of Equation 3.

The azimuth of the gradient is calculated as the horizontal angle in degrees between north and a vector represented by two pathline points, in a clockwise direction.

4 Assumptions and Inputs

This chapter outlines the assumptions and inputs that underlie the calculations presented in this ECF.

4.1 Assumptions

Calculation of hydraulic gradients and average linear velocities were based on particle pathlines generated using mod-PATH3DU which in turn rely on outputs (i.e., grids of groundwater elevations) computed using TRIM (for the 200 East Area) or MEUK (for the 200 West Area). As a result, the assumptions and limitations that underlie the generation of those maps and associated particle pathlines are implicit in any subsequent calculations of gradients and average linear velocities.

Particle tracking that considers advection as the sole transport mechanism relies on the following:

- The assumptions in the underlying tracking scheme
- The interpolation method it employs
- Limitations in the groundwater flow model, including discretization and boundary effects

The average linear velocity components are evaluated using Darcy's Law in mod-PATH3DU and, as such, corresponding assumptions of steady-state, laminar flow of incompressible fluid at constant temperature also apply.

4.2 Input Data

This section summarizes the general input requirements for the calculations described in this ECF.

4.2.1 Water-Level Maps

Groundwater elevation contour maps, generated from compiled automated and manual elevation measurements, used in this calculation are described below.

4.2.1.1 200 East Area

The average quarterly water-level map computed using the TRIM (ECF-200E-19-0130) is used as the basis for gradient and average linear velocity calculations in the 200 East Area (Figure 4-1). The water-level map also illustrates calibration weights and calibration residuals for monitoring wells included in the calibration process.

4.2.1.2 200 West Area

The average quarterly water-level map computed using MEUK (ECF-200W-19-0131) is used as the basis for gradient and average linear velocity calculations in the 200 West Area (Figure 4-2). The water-level map also illustrates the extraction/injection and monitoring wells used in the kriging dataset.

4.2.2 Migration Parameters for Particle Tracking

The hydraulic conductivity and effective porosity values were defined specific to each hydrostratigraphic unit in CP-47631, *Model Package Report: Central Plateau Groundwater Model, Version 8.4.5* or RPP-CALC-61032, *Vadose Zone and Saturated Zone Flow and Transport Calculations for the Integrated Disposal Facility Performance Assessment*. The values for the hydrostratigraphic units underlying the average linear velocity calculation domains are listed in Table 4-1.

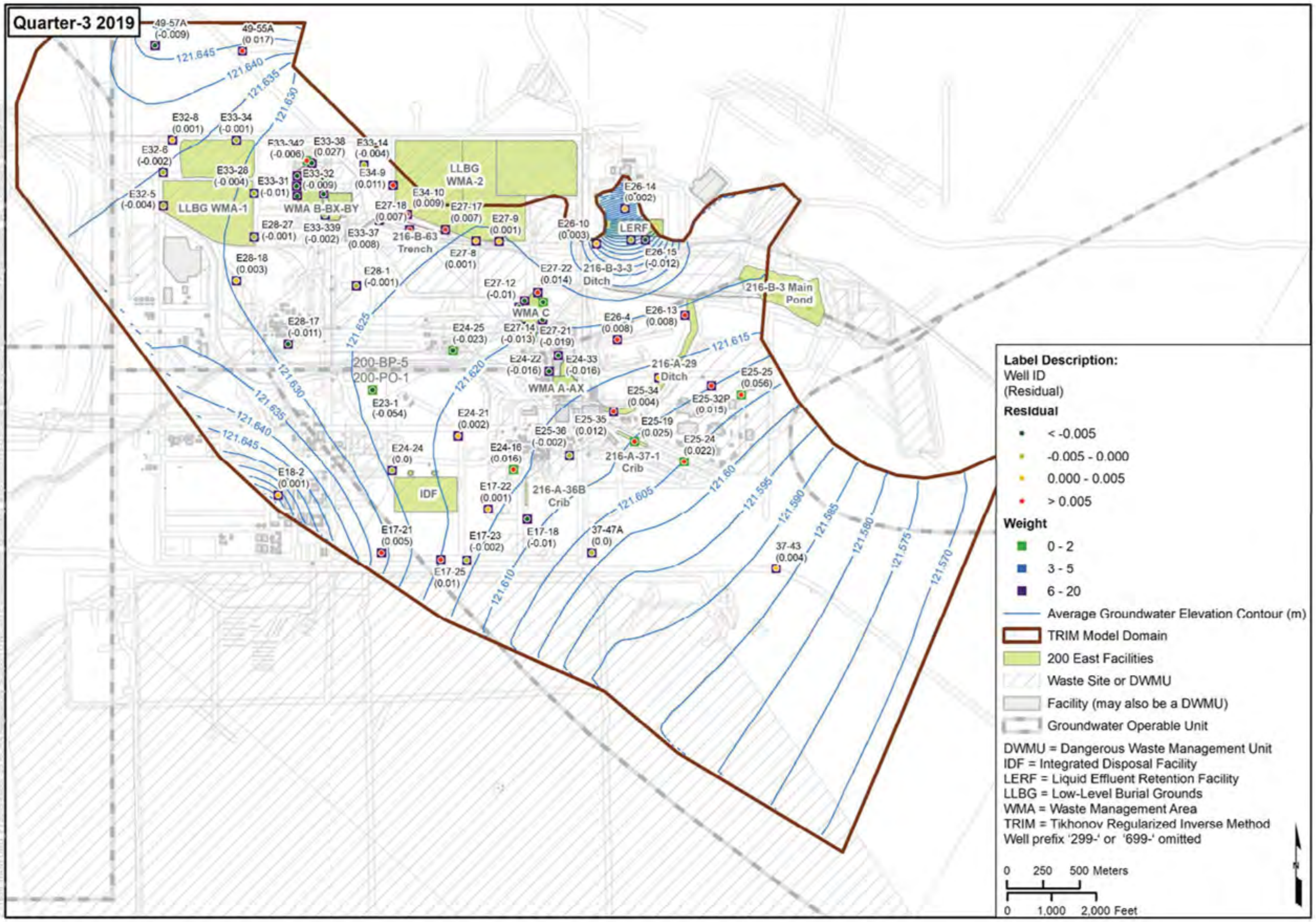

Figure 4-1. 200 East Area Mapped Groundwater Elevations: Third Quarter 2019

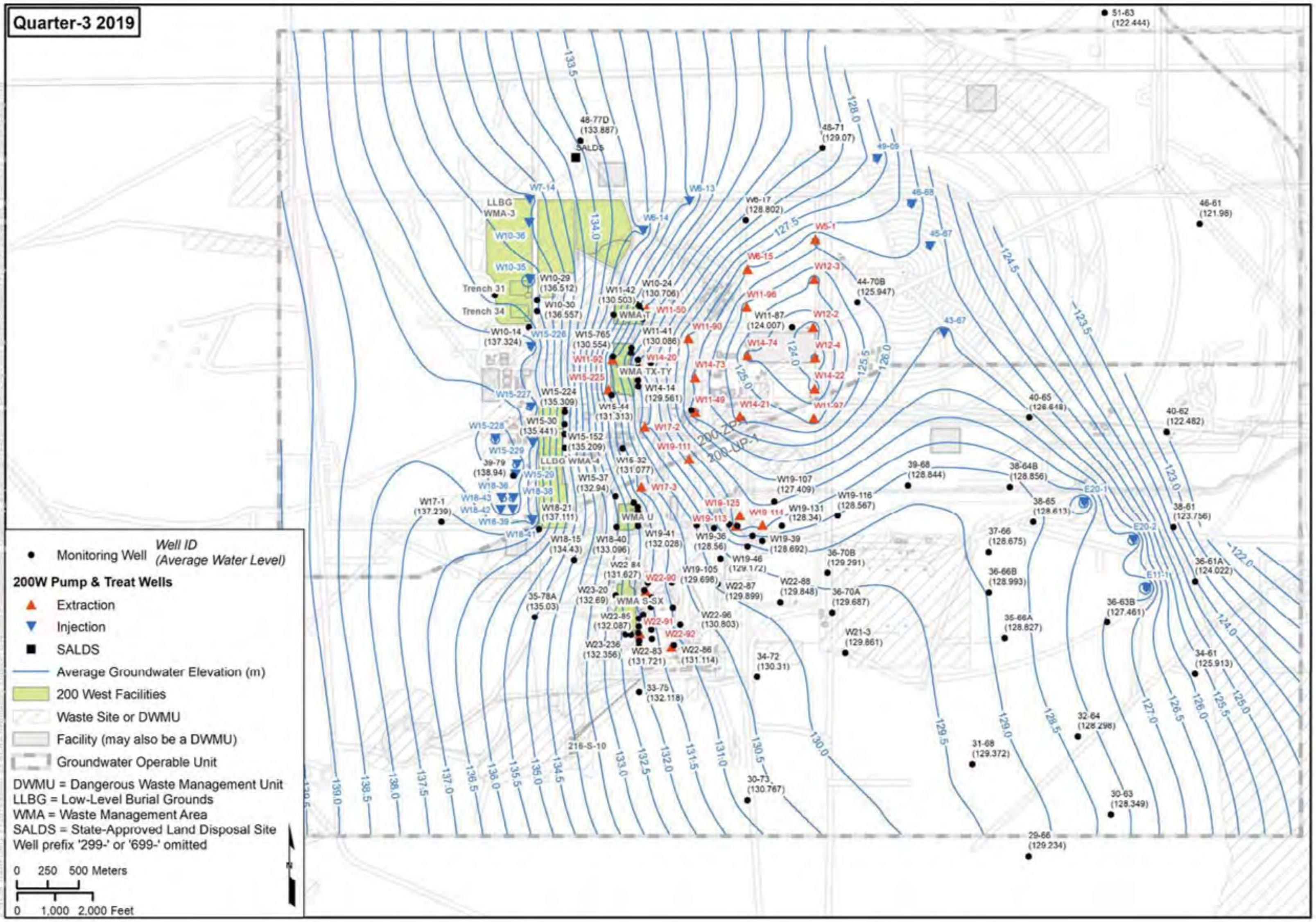

Figure 4-2. 200 West Area Mapped Groundwater Elevations: Third Quarter 2019

Table 4-1. Aquifer Transport Parameter Values

Property		Value	Comments
Hydraulic conductivity	Hanford formation	17,000 m/d (55,800 ft/d)	From RPP-CALC-61032
	CCU gravel	18,200 m/d (59,700 ft/d)	From RPP-CALC-61032h
	Rwie	5 m/d (16 ft/d)	From RPP-CALC-61032
Effective/mobile porosity	Hanford formation	0.25	CP-47631
	Rwie	0.15	CP-47631

References: CP-47631, *Model Package Report: Central Plateau Groundwater Model Version 8.4.5*.

RPP-CALC-61032, *Vadose Zone and Saturated Zone Flow and Transport Calculations for the Integrated Disposal Facility Performance Assessment*.

CCU = Cold Creek unit

Rwie = Ringold Formation member of Wooded Island – unit E

4.2.3 Particle Release Locations

Ten particle release locations were placed at evenly spaced intervals along straight lines immediately upgradient of each facility with some exceptions discussed in the following sections. Six release locations were used for IDF. The lines were oriented such that the resulting pathlines provide uniform coverage of the respective facilities. This was possible for all 200 East Areas except LLBG WMA-2, LERF, and the 216-B-3 Pond. Portions of those 200 East Area facilities fall outside the TRIM model domain, so coverage was limited to the extent within the domain. Full coverage was possible for all 200 West Area facilities except LLBG WMA-3 and Trenches 31 and 34. Due to the locations and operations of injection wells in the vicinity of LLBG WMA-3 and Trenches 31 and 34, the curvature in the flow field upgradient of these facilities would cause particles to travel parallel to the facility if released from upgradient locations. Therefore, particle release locations were placed upgradient of the Green Islands and in the sumps within LLBG WMA-3 and Trenches 31 and 34, respectively, in order to obtain pathlines projecting downgradient over areas of concern.

Figures 4-3 and 4-4 show the particle release locations for the 200 East and 200 West Area facilities, respectively.

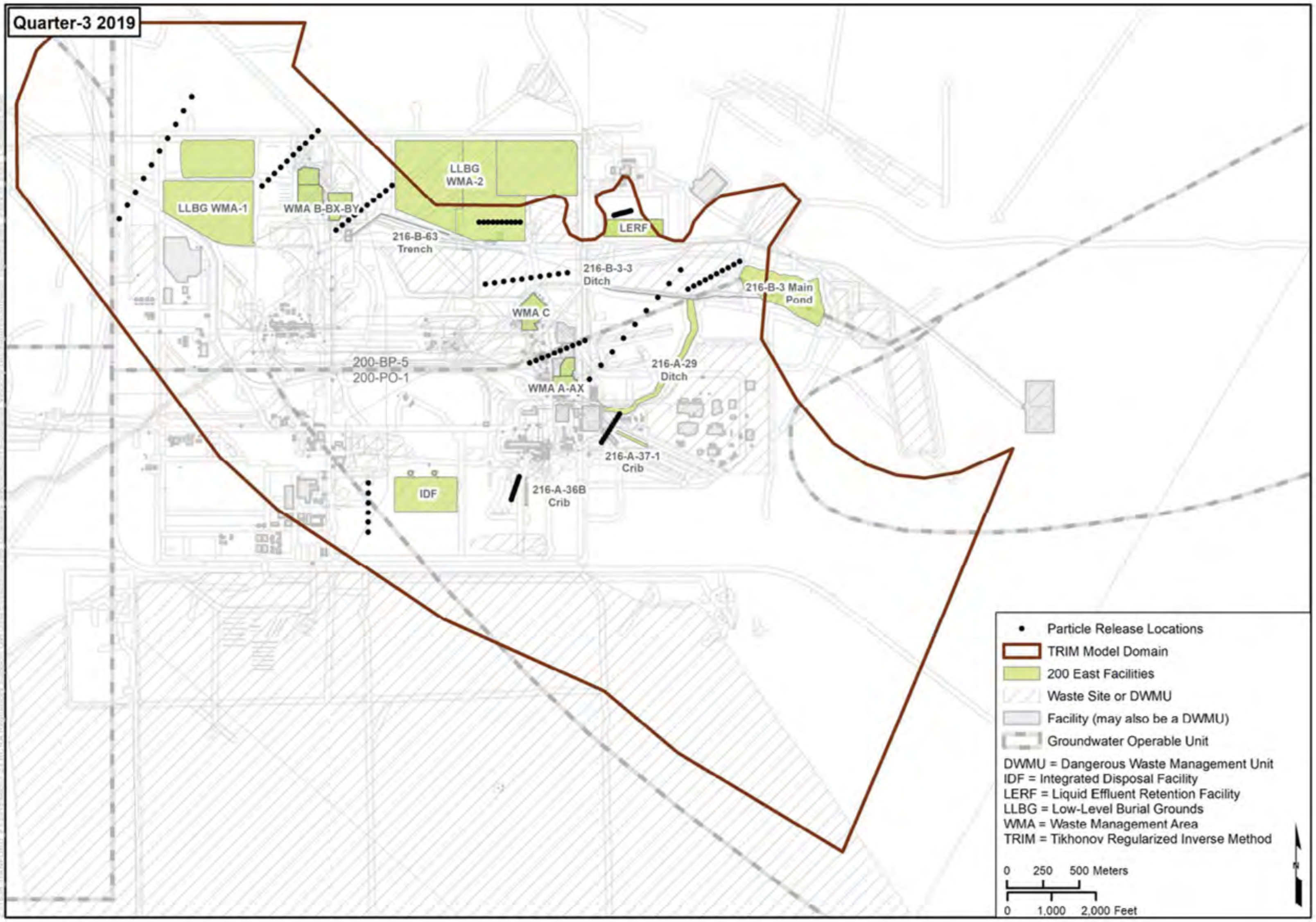

Figure 4-3. Release Locations at 200 East Area Facilities

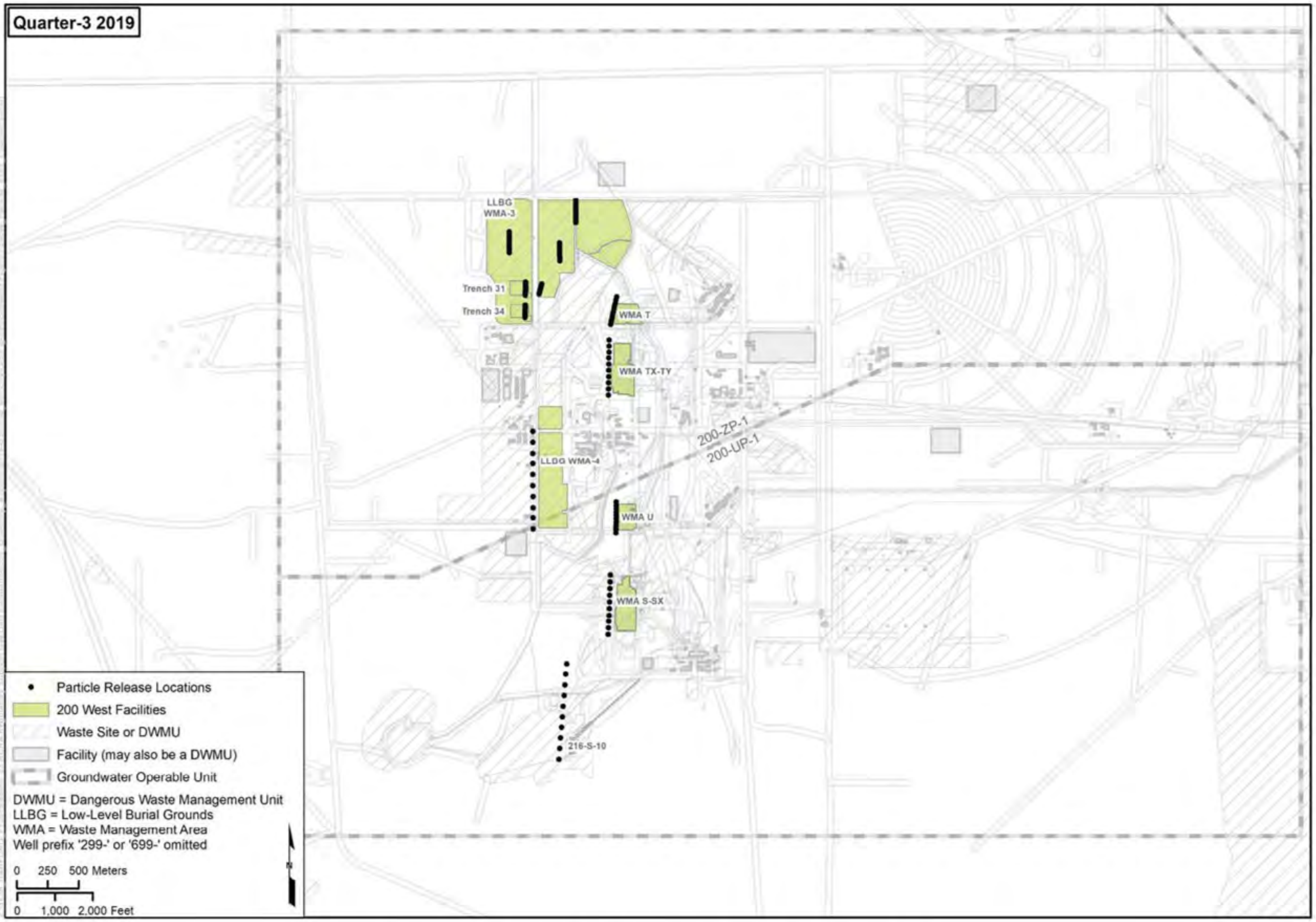

Figure 4-4. Release Locations at 200 West Area Facilities

5 Software Applications

The software used to create the water-table elevation maps used as the basis for the calculations performed herein are described in ECF-200E-19-0130 and ECF-200W-19-0131. Only support software was used to perform the post-processing calculations detailed in this ECF.

The following software programs are classified as support software:

- Groundwater Vistas™: Rumbaugh and Rumbaugh, 2017, *Groundwater Vistas Version 7*. Provided graphical tools used for model quality assurance and model input/output review (Rumbaugh and Rumbaugh, 2017, *Groundwater Vistas Version 7*).
- ArcGIS®: Visualization and post-processing tool for assessing simulated plume distributions, identifying extraction/injection well coordinates, and mapping auxiliary data (Mitchell, 1999, *The ESRI Guide to GIS Analysis, Volume 1: Geographic Patterns & Relationships*).
- Mod-PATH3DU: Particle-tracking code for calculating the three-dimensional flow pathlines and travel times of solute particles.
- writep3doutput: Post-processing program to convert mod-PATH3DU binary output files to commonly used file types (i.e., American Standard Code for Information Interchange [ASCII] text files, dBase database file tables, and Environmental Systems Research Institute shapefiles).
- Python™: Python is a general-purpose, object-oriented programming language. A Python script was used to: (1) calculate gradients and average linear velocities from the water-level mapping and particle-tracking results and , (2) generate facility-specific histogram plots. The script was executed from the command-line using the ArcGIS Python distribution (Python Version 2.7.16, distributed with ArcGIS 10.7 [32 bit]). The following Python packages are utilized within the script:
  - NumPy (Version 1.9.3)
  - Pandas (Version 0.18.1)
  - Matplotlib (Version 1.5.2)

™ Groundwater Vistas is a trademark of Environmental Simulations, Inc., Reinholds, Pennsylvania.
® ArcGIS is a registered trademark of the Environmental Systems Research Institute, Inc., Redlands, California.
™ Python is a registered trademark of Python Software Foundation, Beaverton, Oregon 97008, (www.python.org).

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6 Calculations

This chapter describes the calculations performed to examine all 200 Area facilities. The following steps were taken to develop the necessary input files, perform the calculations, and post-process the outputs to produce the results presented in this ECF.

6.1 Generation of General Groundwater Flow Directions Using Particle Tracking

Particle tracking was performed using mod-PATH3DU.

The grids of groundwater elevations generated for the third quarter of CY 2019 using TRIM and MEUK were used as the basis for particle tracking. Gradients and average linear velocities specific to each facility were then calculated from the tracked particle pathlines representing the general groundwater flow directions within a localized region of the facility.

The calculated groundwater elevations generated throughout the domain were first imported into the Groundwater Vistas Graphical User Interface software and then exported as a regular grid using the Surfer grid format to serve as an input file for mod-PATH3DU. Two ASCII text files each representing grids of hydraulic conductivities and mobile porosities as presented in Table 4-1 were also prepared to serve as the per-cell property input files for mod-PATH3DU.

Particle tracking calculations were carried out for each facility using the following steps:

1. Particle release locations were set up in ArcMap®and then exported as a point ArcGIS shapefile to serve as the particle release location input file for mod-PATH3DU. The particle release locations for each facility in the 200 East and 200 West Areas are shown in Figures 4-1 and 4-2, respectively.
2. The primary mod-PATH3DU input file was generated with the following:
   a. A maximum tracking time that allowed the majority of the particles released to migrate beyond the locations of the facility's boundary during the calculations. Thus, the tracking time varied for each facility, resulting in a different amount of data points.
   b. Particles were tracked via advective transport only.
3. Mod-PATH3DU was executed to make the particle-tracking calculations and produce a binary pathline output file containing the pathlines for each tracked particle. Mod-PATH3DU calculates the advective velocity at any point along the pathline using the hydraulic gradient at that point and the provided cell porosity and hydraulic conductivity.
4. A post-processing program (writep3doutput.exe) was executed to convert the mod-PATH3DU binary pathline output file into an ASCII text file format, which lists particle coordinate locations, travel time, and the advective velocities in the x- and y-directions.

The post-processed mod-PATH3DU output files were then used for visualizing the particle pathlines and calculating the facility-specific average linear velocities and gradients.

6.2 Calculation of Average Linear Velocity

Mod-PATH3DU calculates the advective velocity at any point along the pathline using the gridded water-level surface, cell porosity, and hydraulic conductivity provided as inputs.

® ArcMap is a registered trademark of the Environmental Systems Research, Inc., Redlands, California.

For each facility, a binary pathline output file was produced by mod-PATH3DU containing the pathlines for each tracked particle. The output files were converted into an ASCII text file format as detailed in Section 6.1. The text file lists the advective velocities in the x- and y-directions at each point along the pathline.

The x- and y- components of the advective velocity vector for each tracked point were then added to yield the resultant average linear velocity vector, ALV, as follows:

$$ALV = \sqrt{{v_x}^2 + {v_y}^2} \quad \textbf{Eq. 4}$$

where, v_x and v_y are the advective velocities in the x- and y-directions respectively.

6.3 Calculation of Facility-Wide Gradients

For each facility, a binary pathline output file was produced by mod-PATH3DU containing the pathlines for each tracked particle. The binary pathline output file was converted into an ASCII text file format as detailed in Section 6.1.

Gradient magnitudes and azimuths for each pathline segment were then calculated using (1), the calculated average linear velocities and (2), the gridded surfaces of aquifer hydraulic conductivities and effective porosities as described in Table 4.1.

7 Results

This chapter presents outputs from the previously described calculations. The results presented include the following:

- Summary tables and corresponding plots of calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities for the 200 East and 200 West Area facilities
- Maps of particle pathlines that were calculated using the quarterly mapped groundwater elevations throughout the 200 East and 200 West Areas, respectively, illustrating general groundwater flow directions in the vicinity of each facility
- Histogram plots of gradient magnitudes, gradient azimuths, and average linear velocities calculated from the particle pathlines for each facility

7.1 200 East Area

Summary statistics pertaining to the calculated hydraulic gradients and average linear velocities at the 200 East Area facilities for the third quarter of 2019 are presented in Table 7-1. Figures 7-1 through 7-3 illustrate the same data graphically. The results for each 200 East Area facility are presented in the facility-specific sections below.

Table 7-1. Calculated Hydraulic Gradients and Average Linear Velocities at the 200 East Facilities for the Third Quarter of 2019

Site	Gradient Magnitude [-]				Gradient Azimuth (Degrees from North)				Average Linear Velocity (m/d)			
	Min	Max	Avg	Median	Min	Max	Avg	Median	Min	Max	Avg	Median
216-A-29 Ditch	9.02E-06	5.36E-05	1.51E-05	1.35E-05	122	173	155	156	0.66	3.65	1.09	0.98
216-A-36B Crib	8.75E-06	1.74E-05	1.49E-05	1.52E-05	106	136	130	131	2.92E-04	5.80E-04	4.96E-04	5.06E-04
216-A-37-1 Crib	9.46E-06	1.63E-05	1.23E-05	1.21E-05	122	149	133	133	0.66	1.12	0.88	0.88
216-B-3 Main Pond	5.84E-06	2.36E-05	1.32E-05	1.30E-05	137	176	161	161	0.43	1.72	0.96	0.95
216-B-63 Trench	1.31E-06	4.08E-06	1.85E-06	1.63E-06	120	149	135	135	0.10	0.28	0.13	0.12
IDF	1.81E-06	3.87E-05	1.15E-05	8.43E-06	54	144	90	91	2.59E-04	2.63	0.65	0.51
LERF	7.72E-05	3.84E-04	2.17E-04	2.01E-04	148	204	171	169	2.57E-03	1.28E-02	7.22E-03	6.68E-03
LLBG WMA-1	1.15E-06	2.40E-05	7.96E-06	6.72E-06	89	159	127	129	0.08	1.75	0.56	0.47
LLBG WMA-2	1.42E-06	4.08E-06	2.48E-06	2.48E-06	170	246	204	201	0.10	0.28	0.17	0.17
WMA A-AX	8.25E-06	1.55E-05	9.78E-06	9.39E-06	140	166	152	151	0.58	1.13	0.70	0.68
WMA B-BX-BY	9.60E-07	9.35E-06	2.04E-06	1.73E-06	109	158	144	145	0.07	0.68	0.15	0.13
WMA C	6.11E-06	2.42E-05	1.10E-05	1.04E-05	157	226	181	176	0.42	1.65	0.75	0.71

IDF = Integrated Disposal Facility

LERF = Liquid Effluent Retention Facility

LLBG = Low-Level Burial Grounds

WMA = Waste Management Area

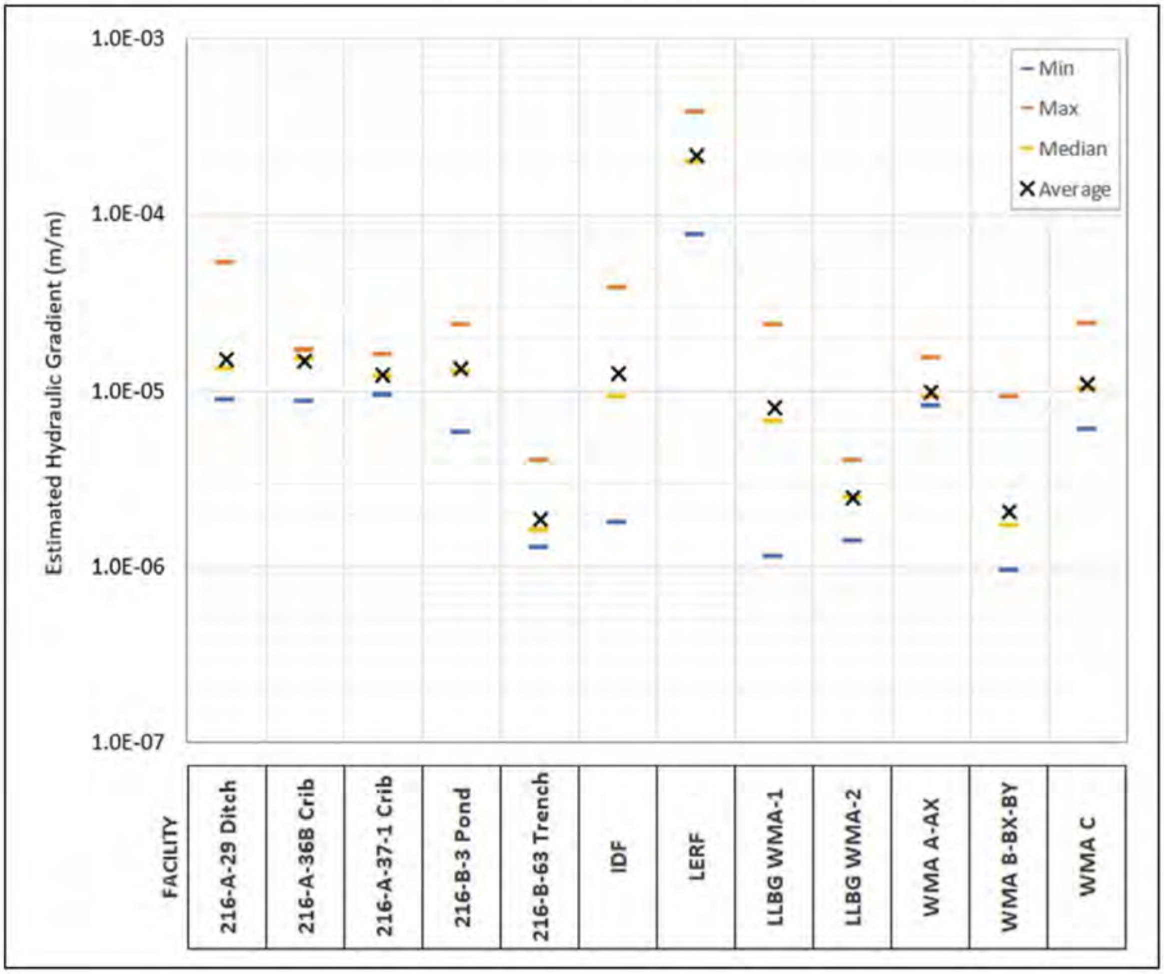

Figure 7-1. Calculated Hydraulic Gradient Magnitudes at the 200 East Area Facilities for the Third Quarter of 2019

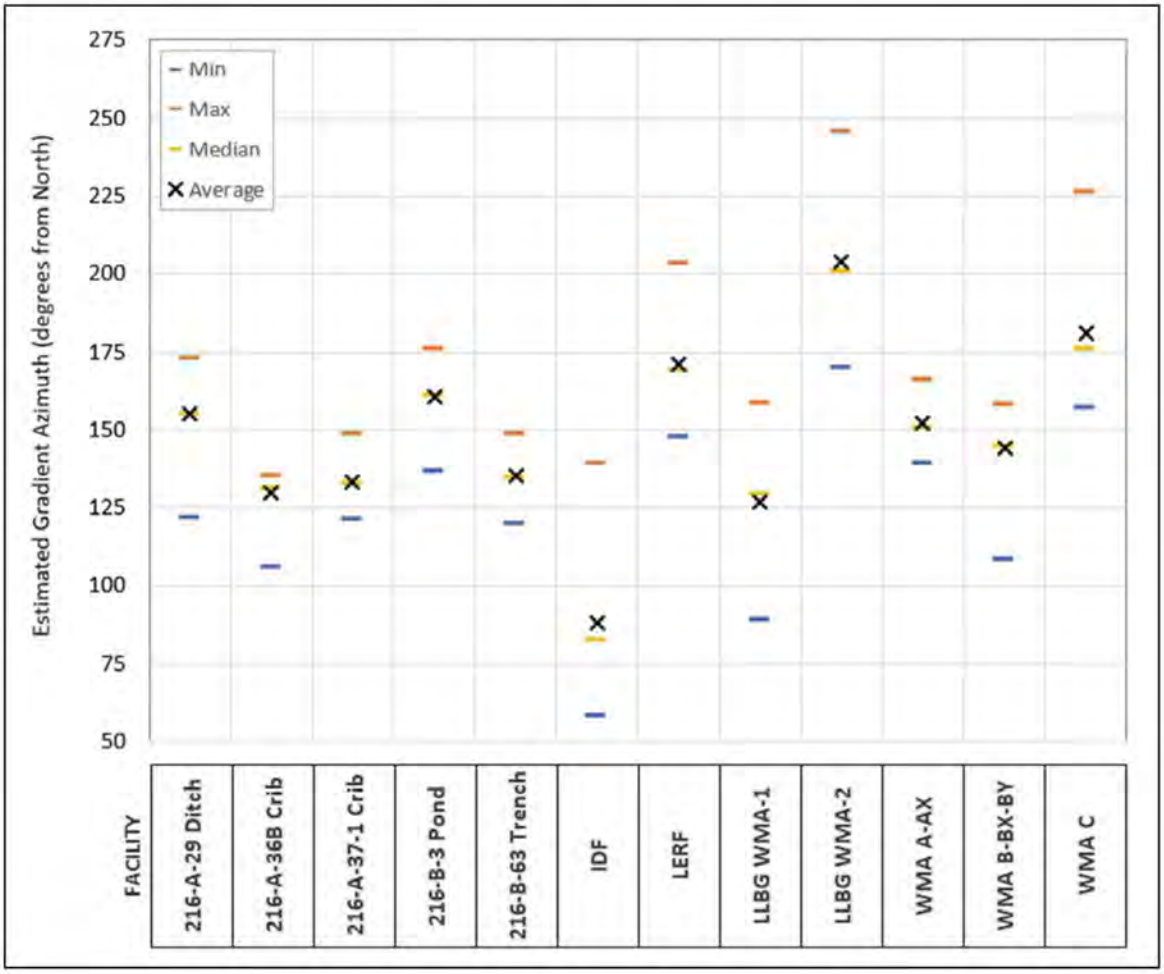

Figure 7-2. Calculated Hydraulic Gradient Azimuths at the 200 East Area Facilities for the Third Quarter of 2019

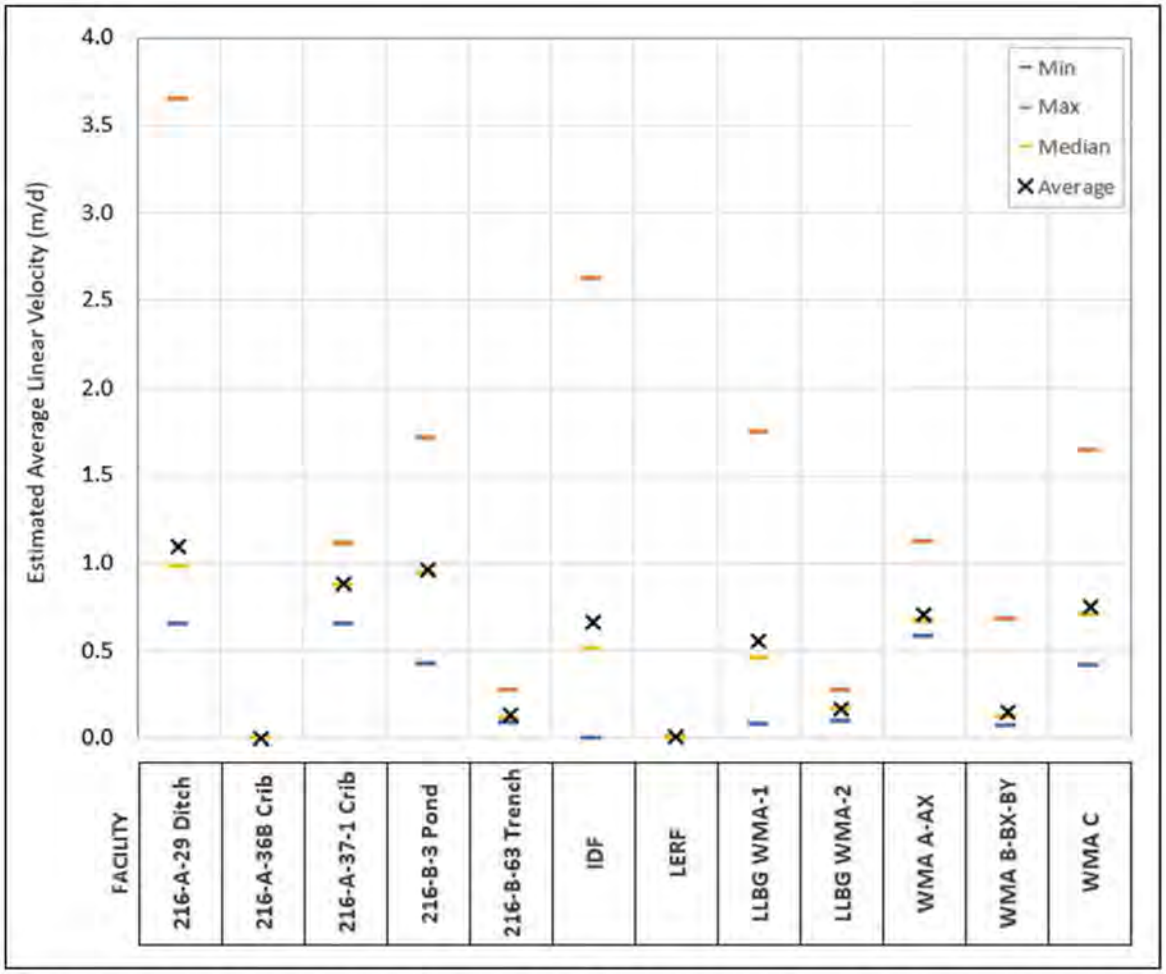

Figure 7-3. Calculated Average Linear Velocities at the 200 East Area Facilities for the Third Quarter of 2019

7.1.1 216-A-29 Ditch

Figure 7-4 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at the 216-A-29 Ditch. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the 216-A-29 Ditch are presented in Figures 7-5 through 7-7.

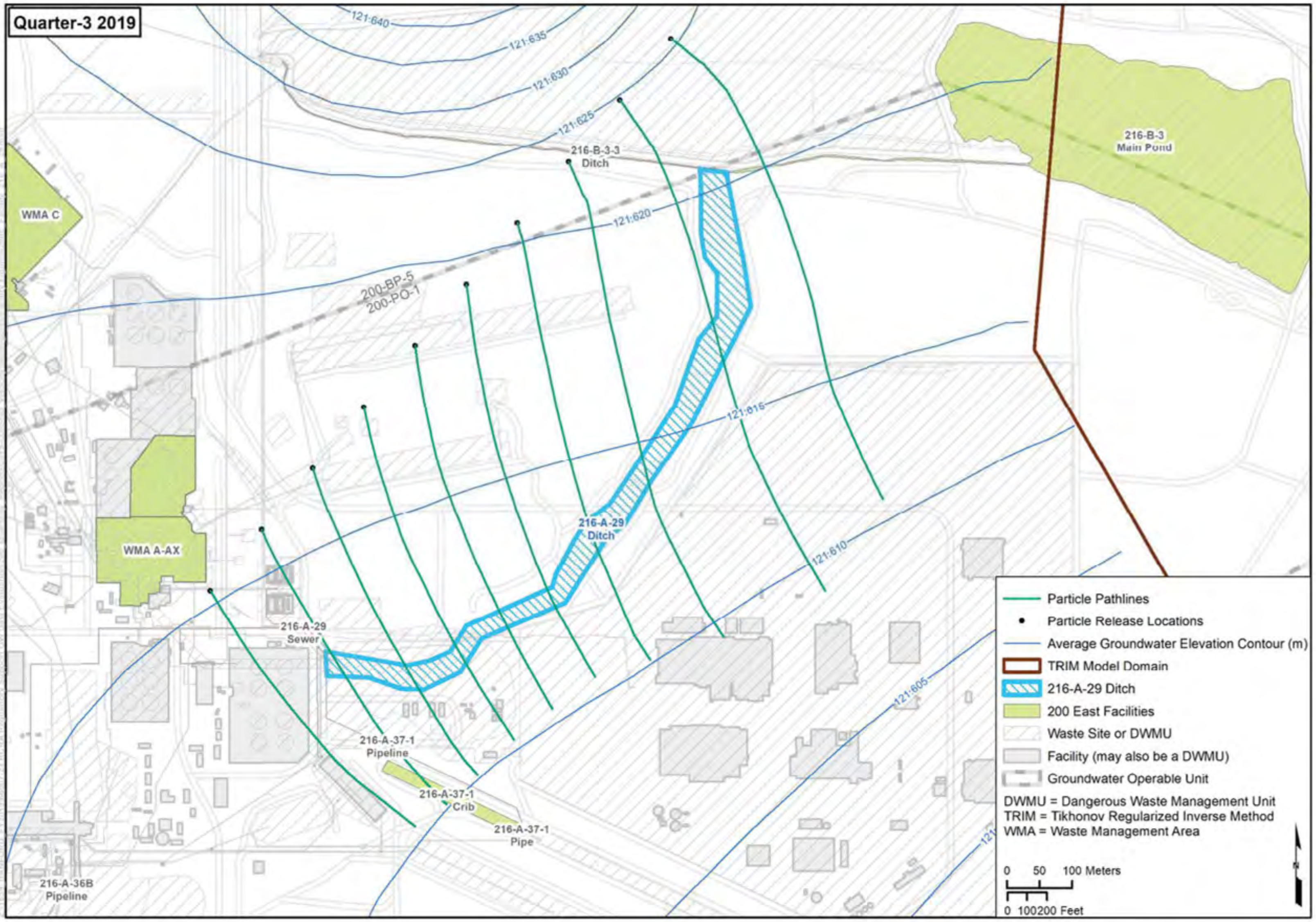

Figure 7-4. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the 216-A-29 Ditch for the Third Quarter of 2019

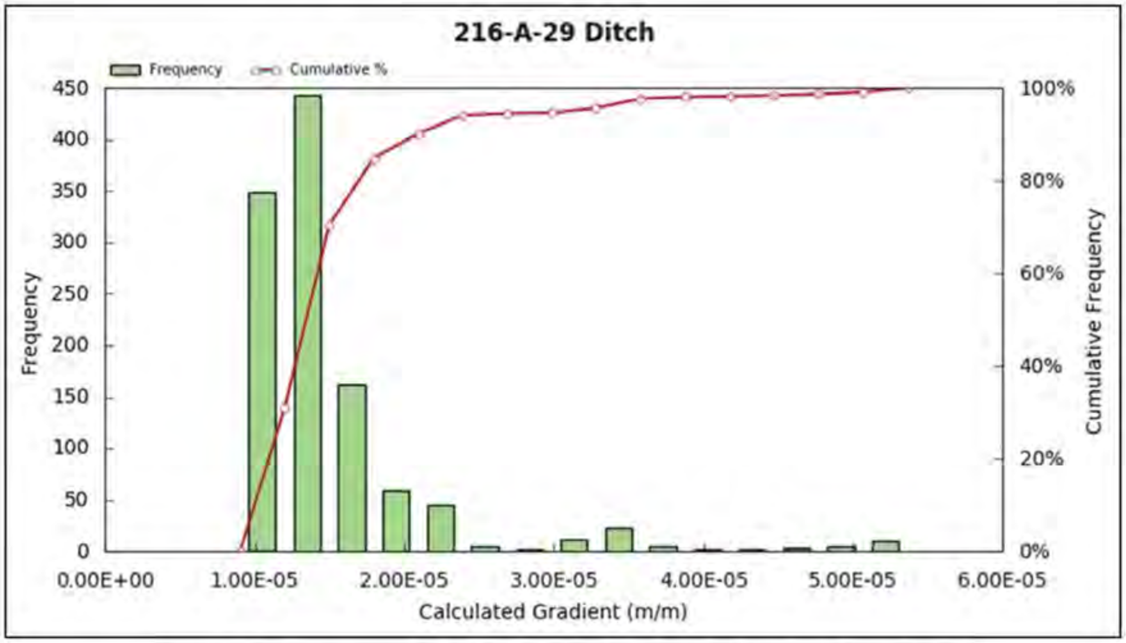

Figure 7-5. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the 216-A-29 Ditch for the Third Quarter of 2019

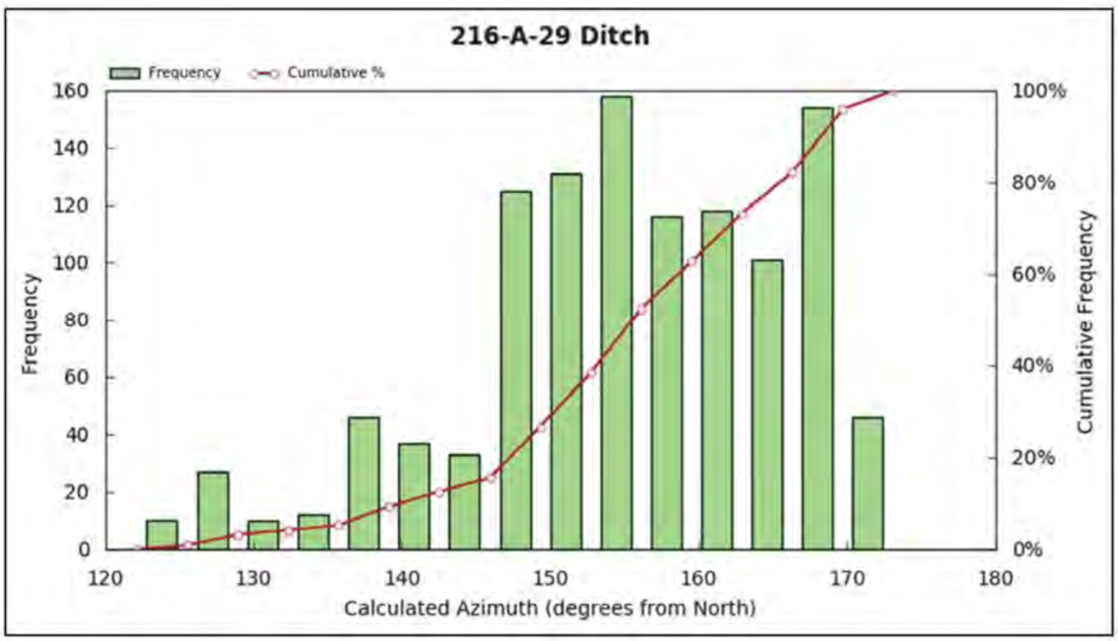

Figure 7-6. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the 216-A-29 Ditch for the Third Quarter of 2019

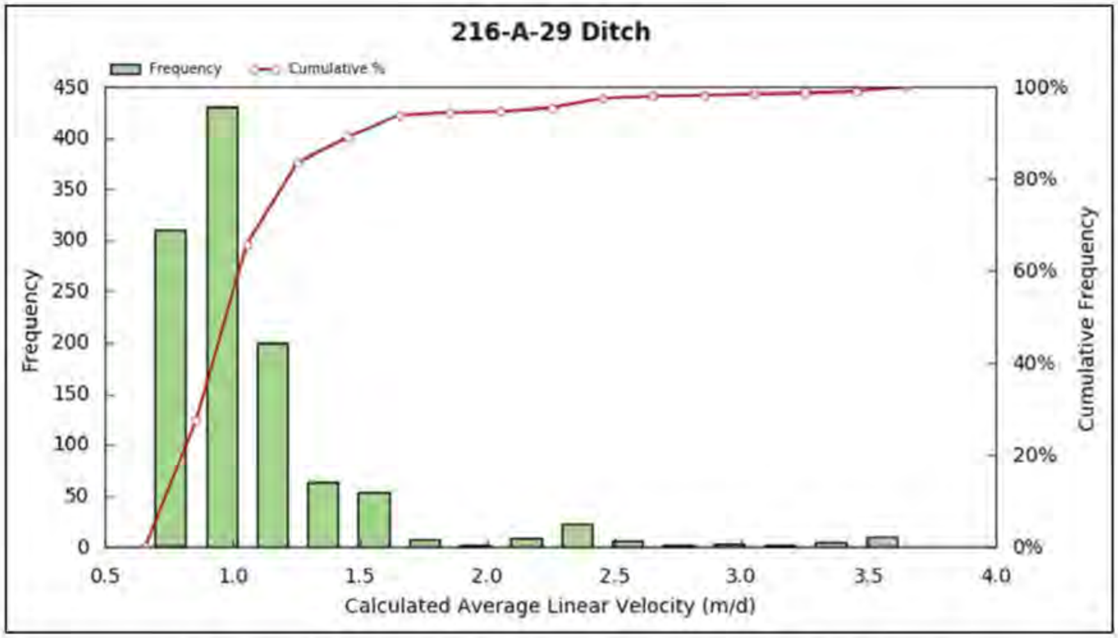

Figure 7-7. Histogram Plot of Calculated Average Linear Velocities at the 216-A-29 Ditch for the Third Quarter of 2019

7.1.2 216-A-36B Crib

Figure 7-8 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at the 216-A-36B Crib. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the 216-A-36B Crib are presented in Figures 7-9 through 7-11.

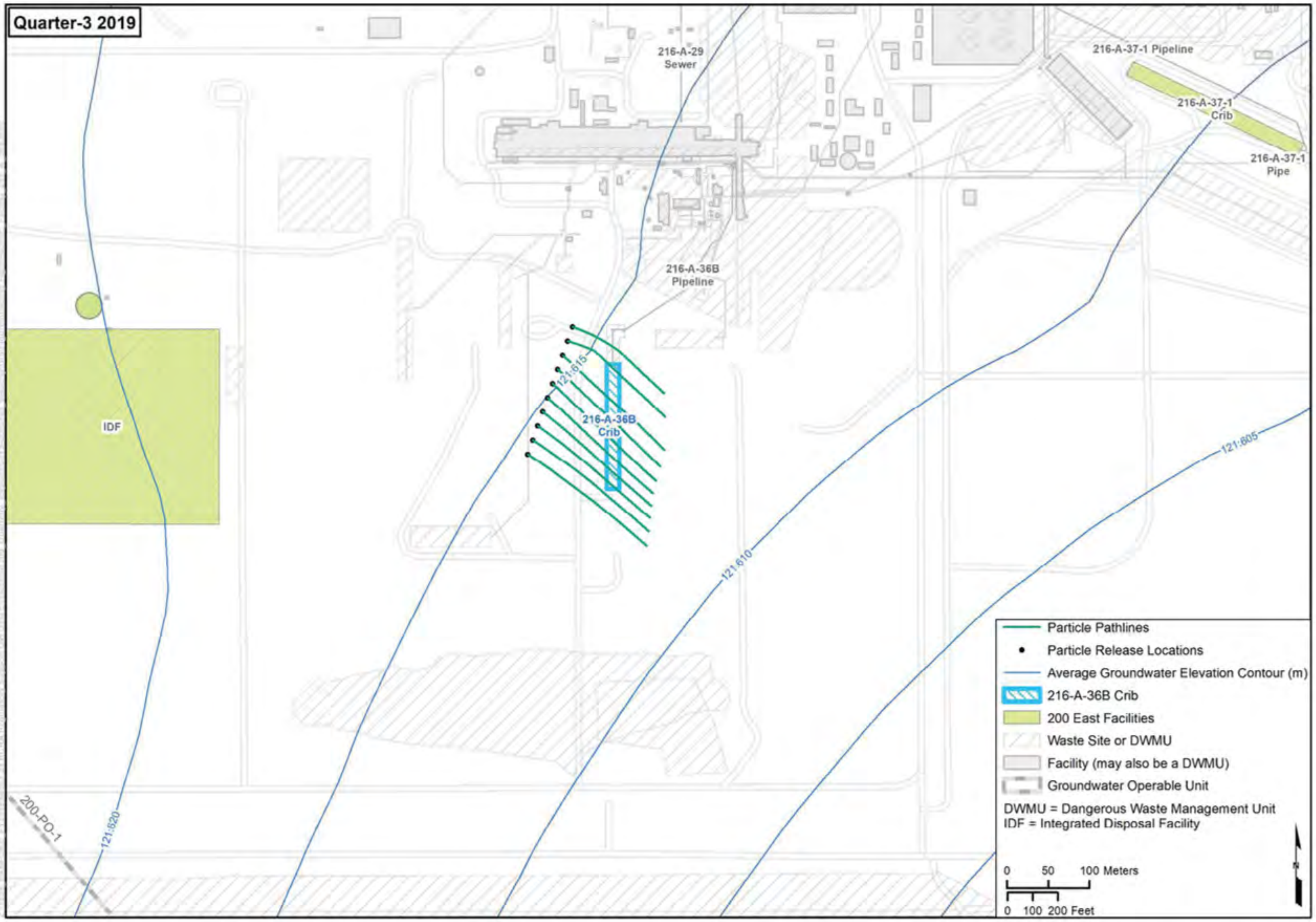

Figure 7-8. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the 216-A-36B Crib for the Third Quarter of 2019

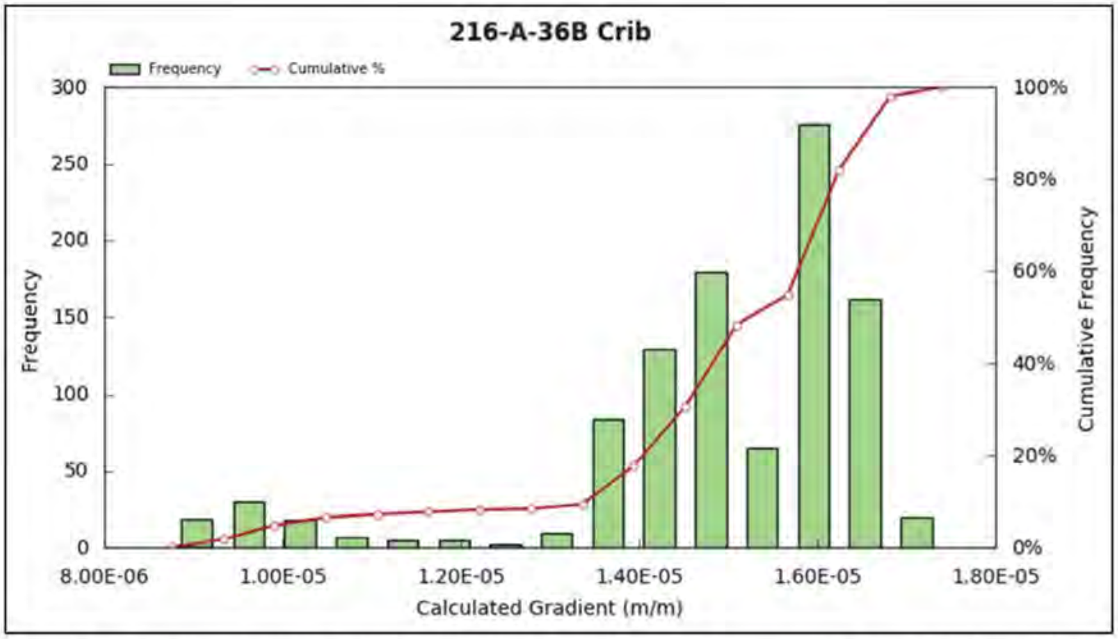

Figure 7-9. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the 216-A-36B Crib for the Third Quarter of 2019

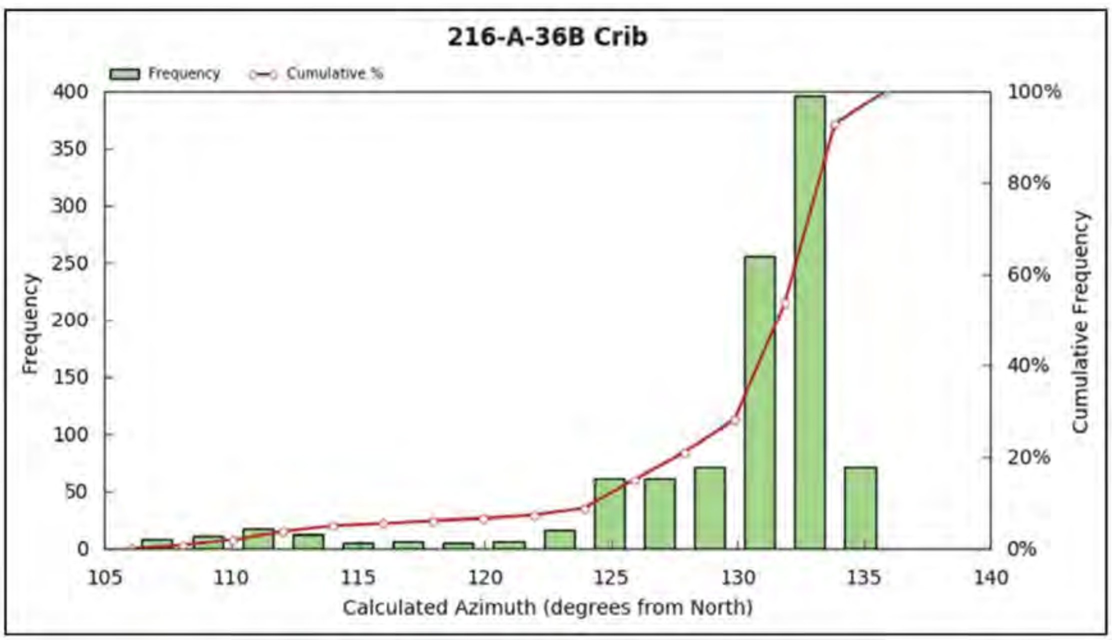

Figure 7-10. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the 216-A-36B Crib for the Third Quarter of 2019

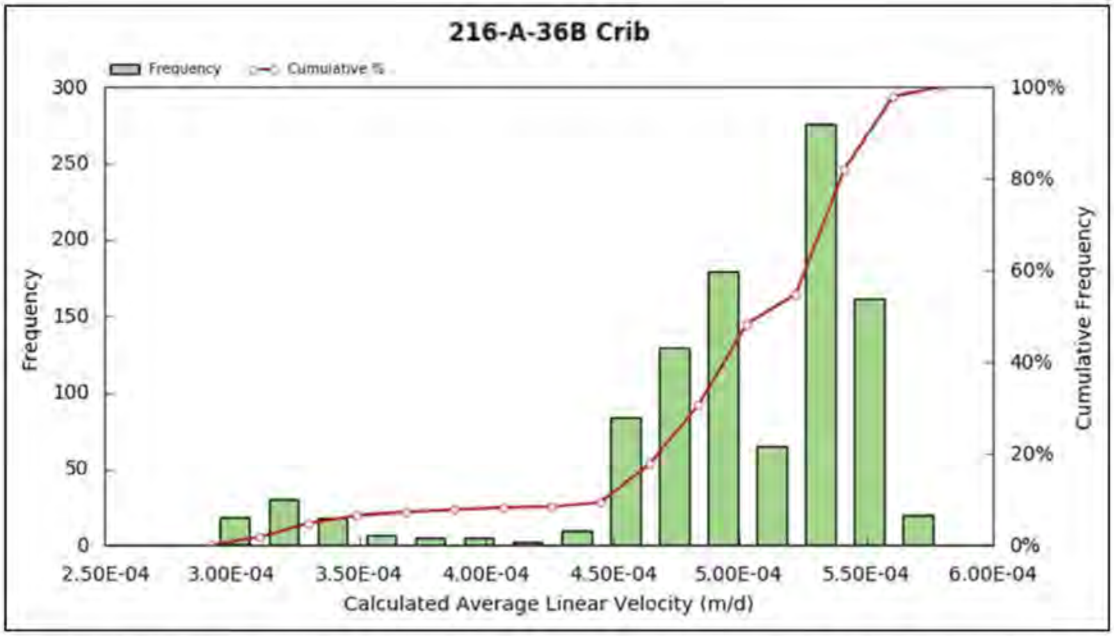

Figure 7-11. Histogram Plot of Calculated Average Linear Velocities at the 216-A-36B Crib for the Third Quarter of 2019

7.1.3 216-A-37-1 Crib

Figure 7-12 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at the 216-A-37-1 Crib. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the 216-A-37-1 Crib are presented in Figures 7-13 through 7-15.

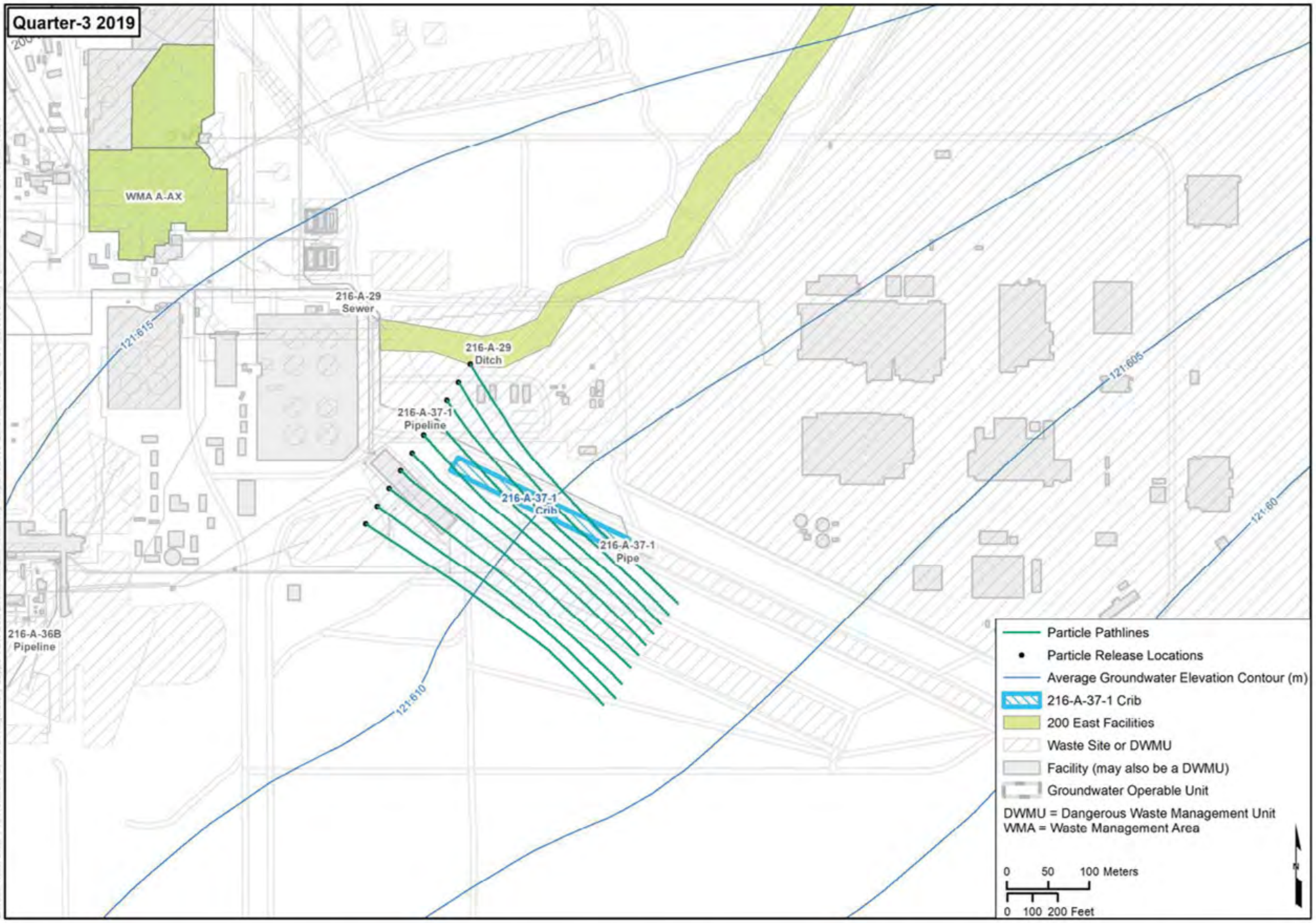

Figure 7-12. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the 216-A-37-1 Crib for the Third Quarter of 2019

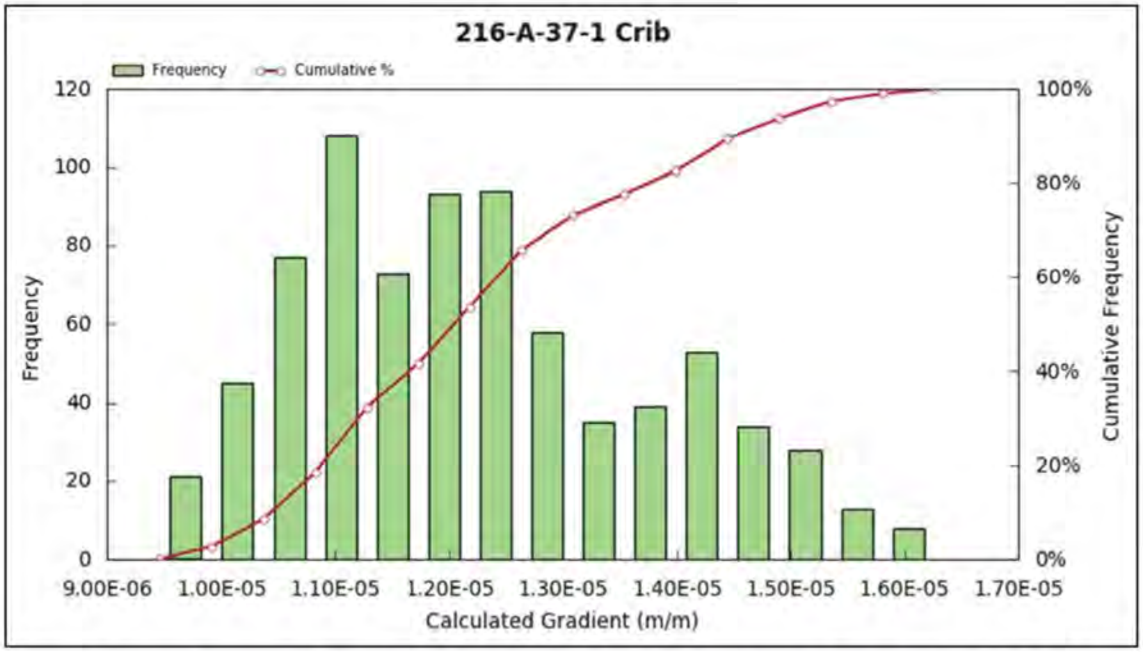

Figure 7-13. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the 216-A-37-1 Crib for the Third Quarter of 2019

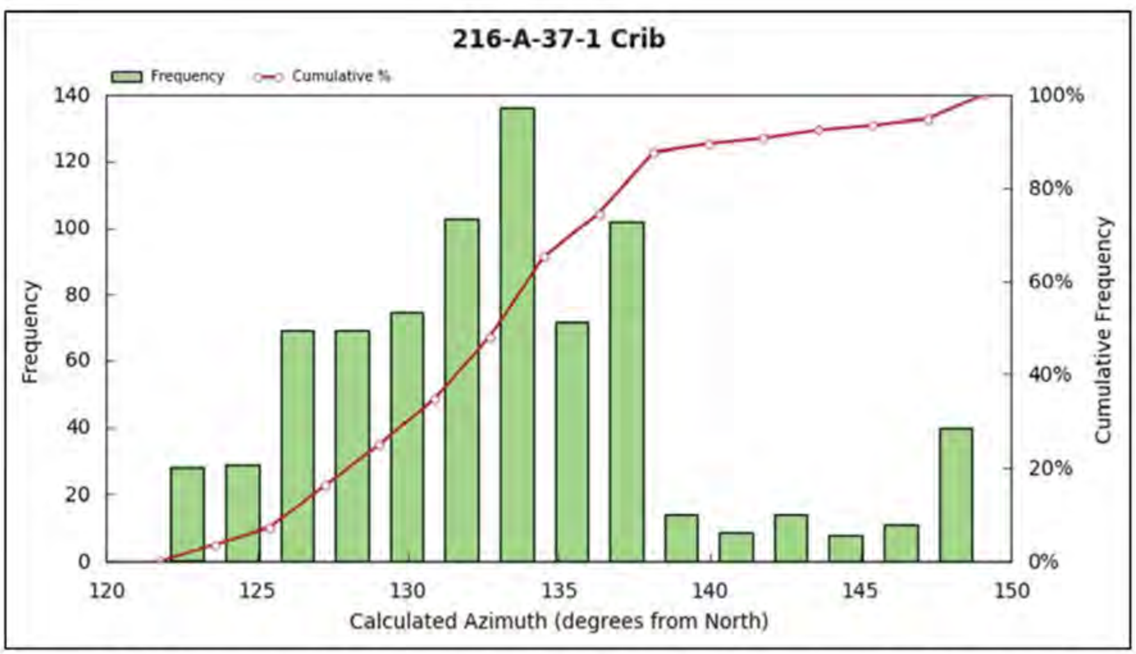

Figure 7-14. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the 216-A-37-1 Crib for the Third Quarter of 2019

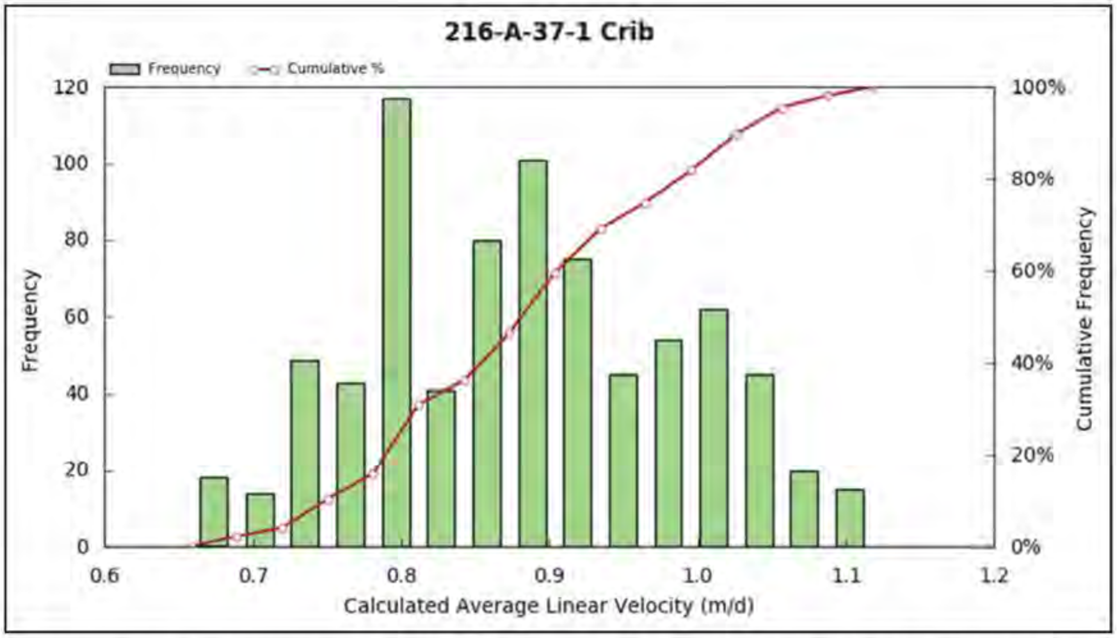

Figure 7-15. Histogram Plot of Calculated Average Linear Velocities at the 216-A-37-1 Crib for the Third Quarter of 2019

7.1.4 216-B-3 Pond

Figure 7-16 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at the 216-B-3 Pond. The extents of the TRIM model domain precluded the placement of particle release locations upgradient of the entire facility. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the 216-B-3 Pond are presented in Figures 7-17 through 7-19.

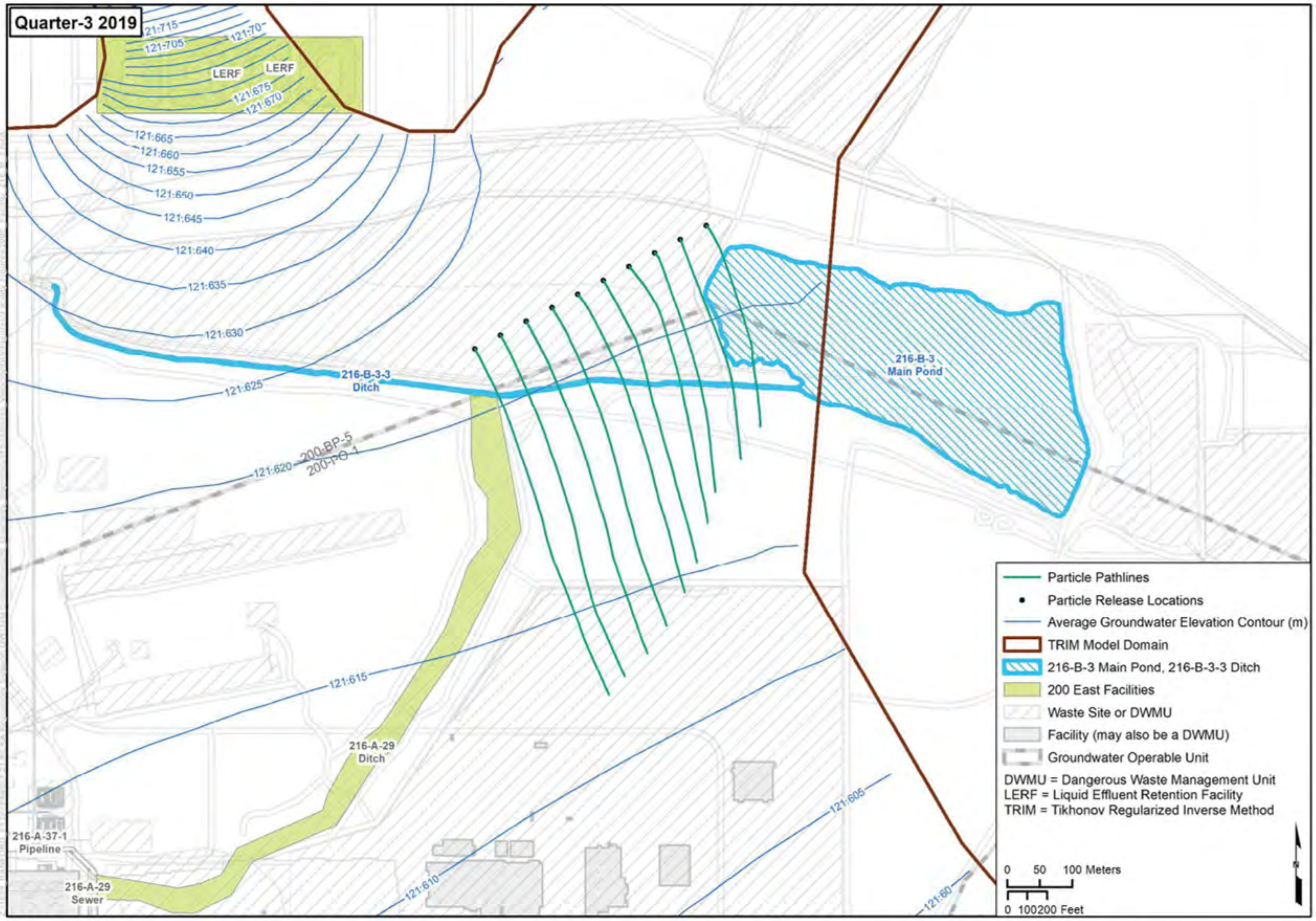

Figure 7-16. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the 216-B-3 Pond for the Third Quarter of 2019

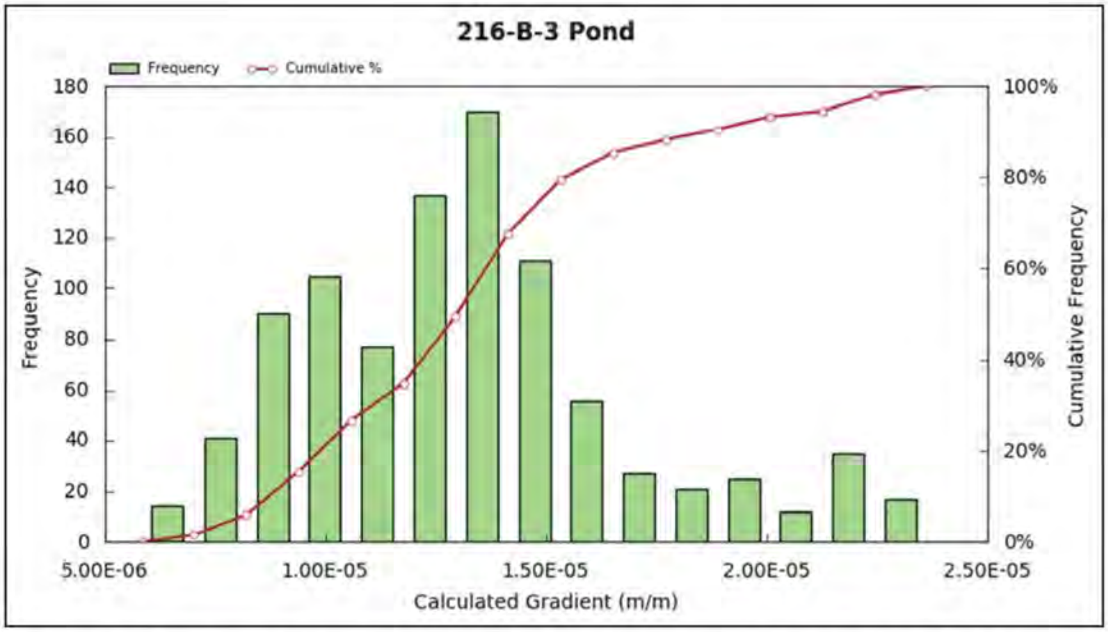

Figure 7-17. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the 216-B-3 Pond for the Third Quarter of 2019

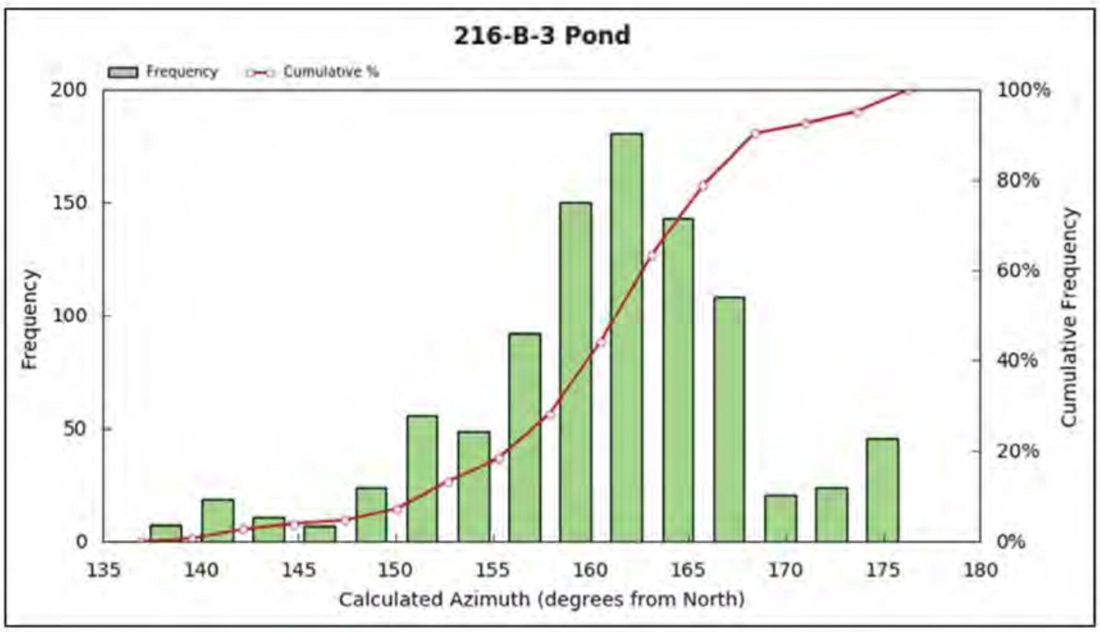

Figure 7-18. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the 216-B-3 Pond for the Third Quarter of 2019

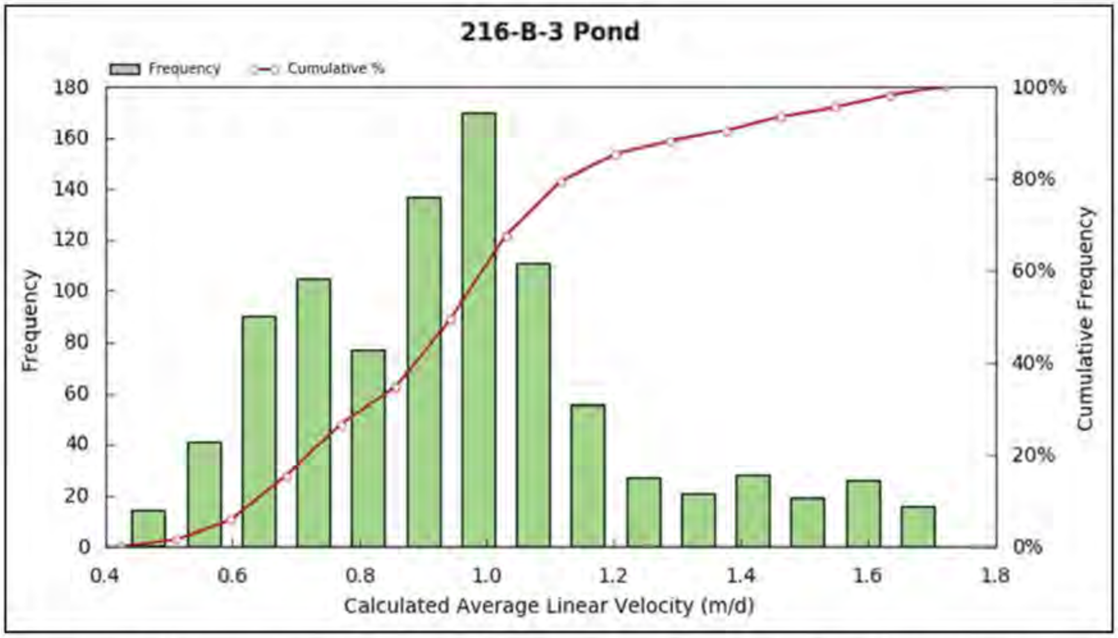

Figure 7-19. Histogram Plot of Calculated Average Linear Velocities at the 216-B-3 Pond for the Third Quarter of 2019

7.1.5 216-B-63 Trench

Figure 7-20 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at the 216-B-63 Trench. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the 216-B-63 Trench are presented in Figures 7-21 through 7-23.

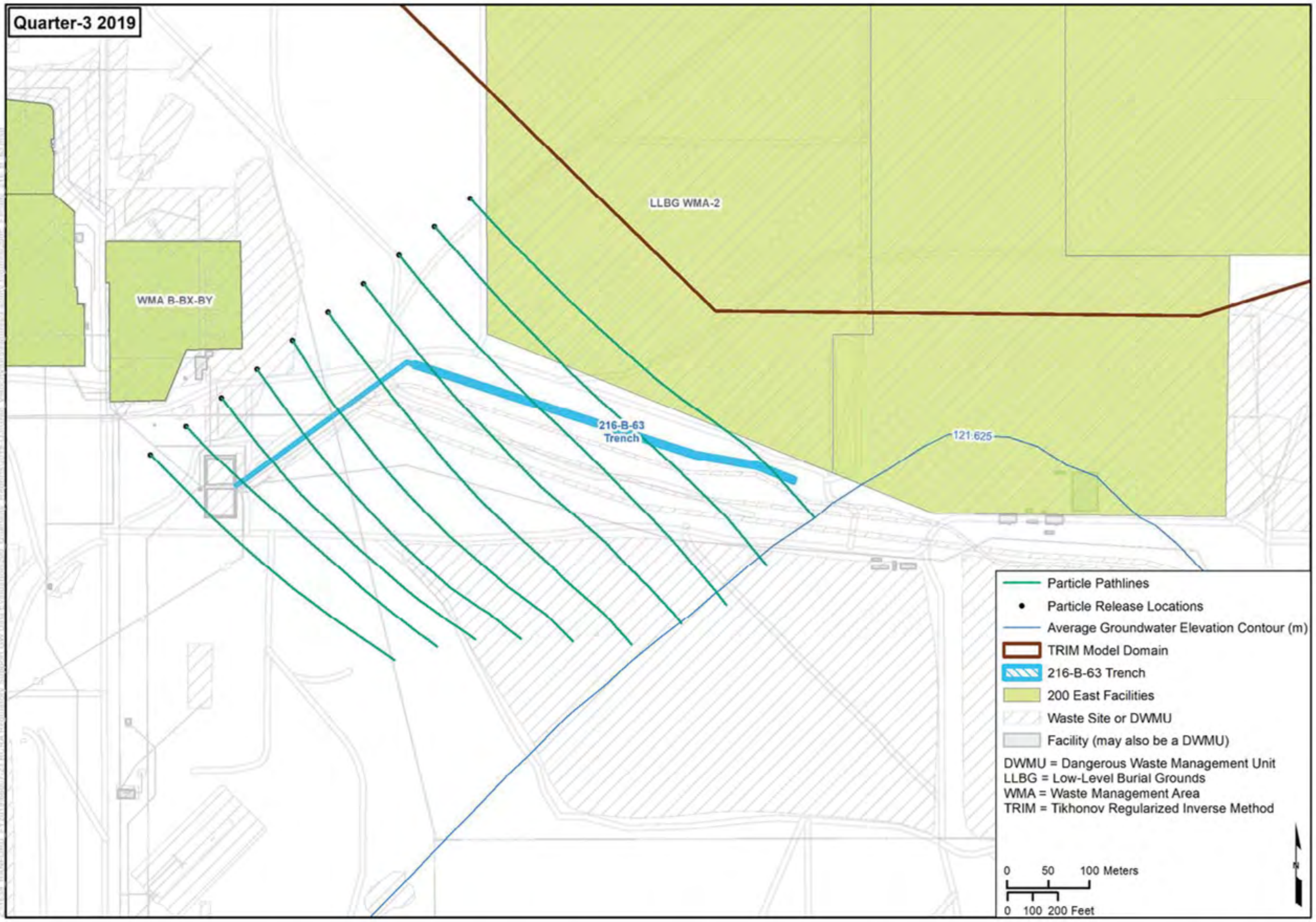

Figure 7-20. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the 216-B-63 Trench for the Third Quarter of 2019

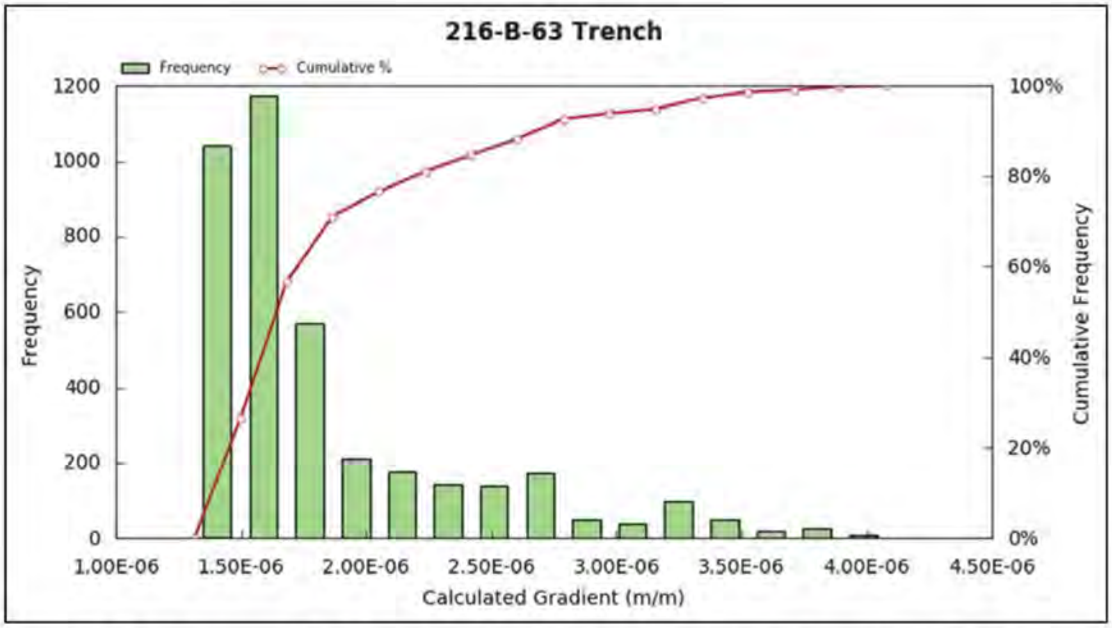

Figure 7-21. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the 216-B-63 Trench for the Third Quarter of 2019

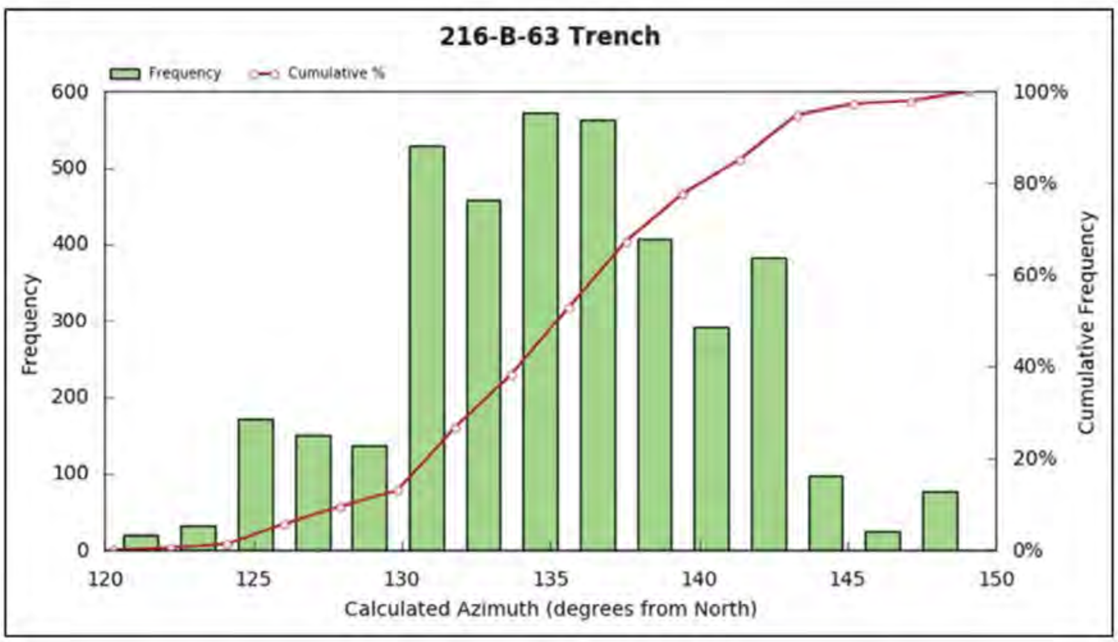

Figure 7-22. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the 216-B-63 Trench for the Third Quarter of 2019

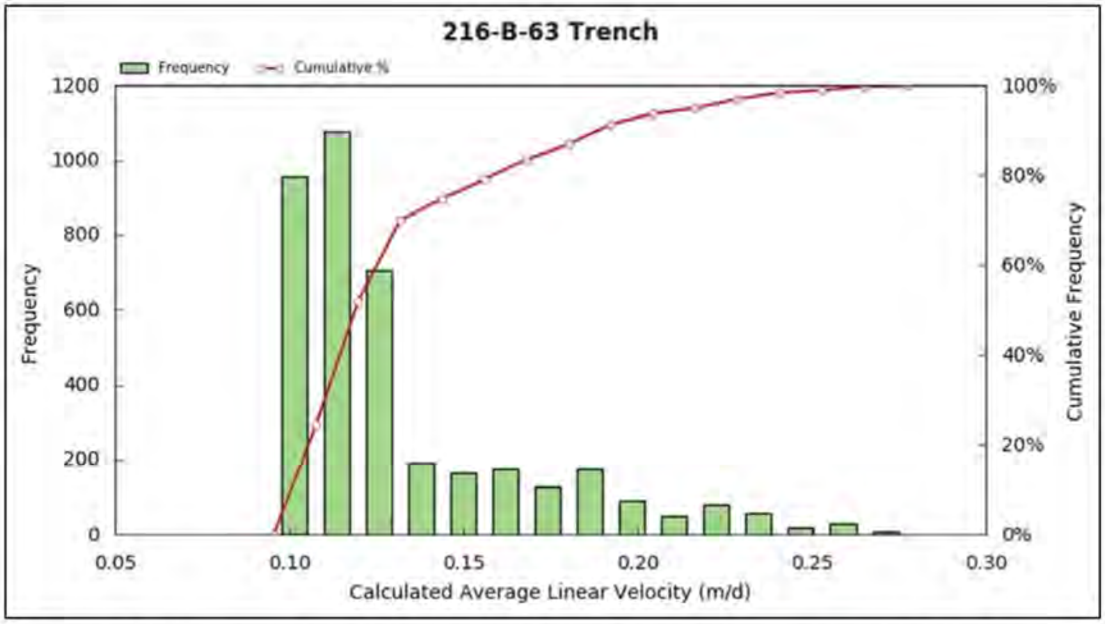

Figure 7-23. Histogram Plot of Calculated Average Linear Velocities at the 216-B-63 Trench for the Third Quarter of 2019

7.1.6 Integrated Disposal Facility

Figure 7-24 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at IDF. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at IDF are presented in Figures 7-25 through 7-27.

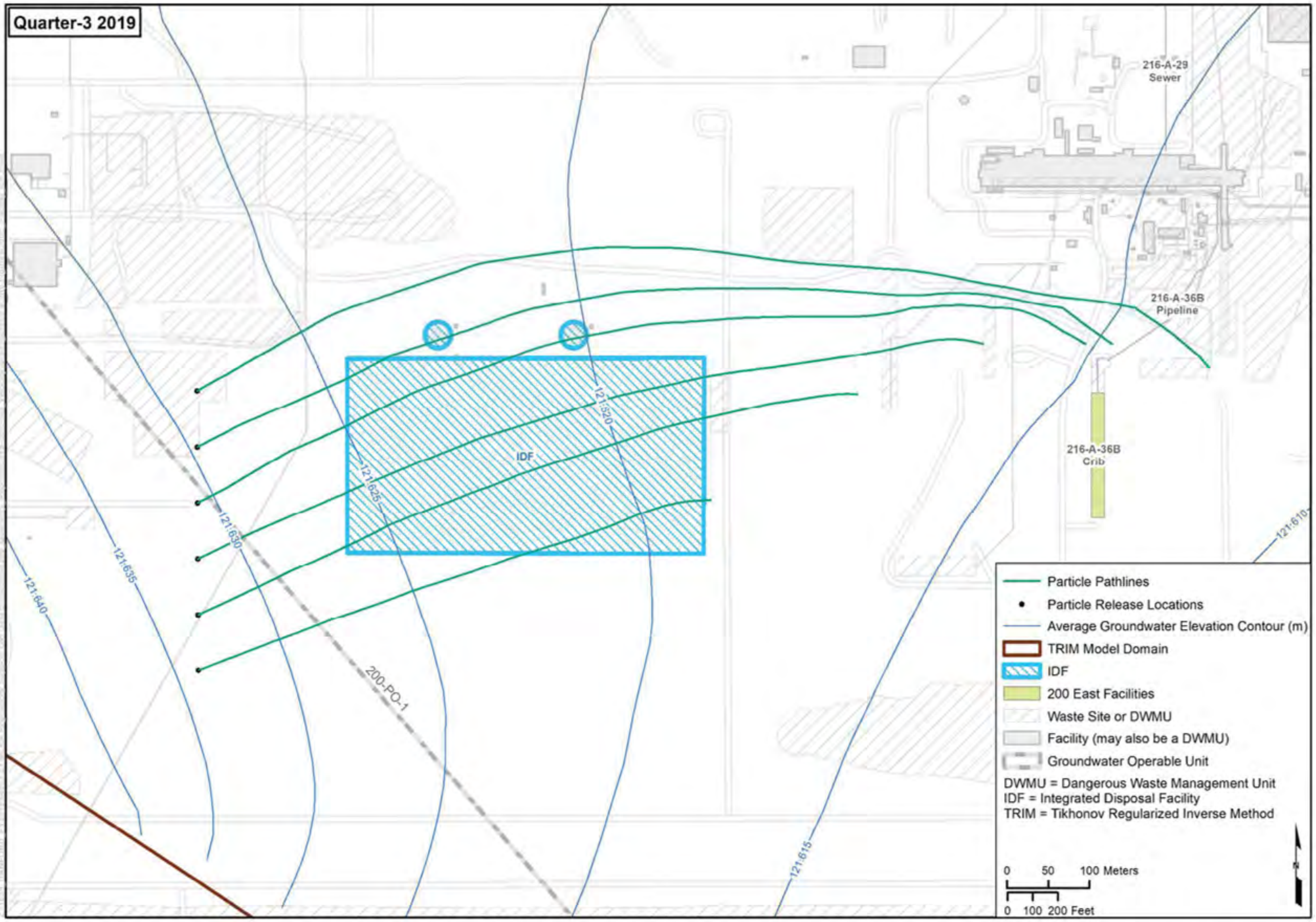

Figure 7-24. Calculated Particle Pathlines Representing General Groundwater Flow Directions at IDF for the Third Quarter of 2019

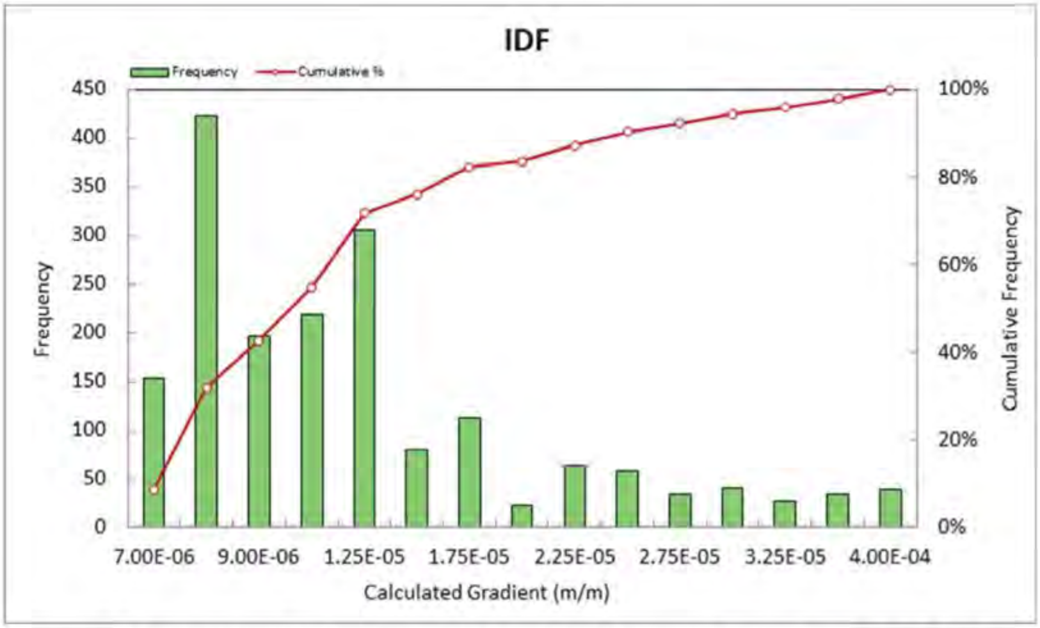

Figure 7-25. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at IDF for the Third Quarter of 2019

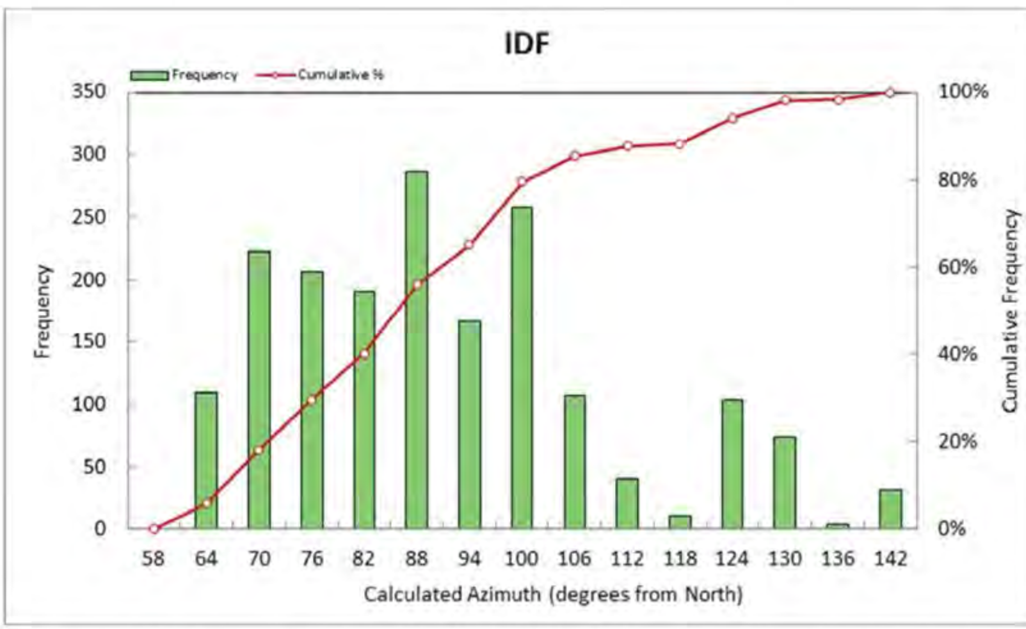

Figure 7-26. Histogram Plot of Calculated Hydraulic Gradient Azimuths at IDF for the Third Quarter of 2019

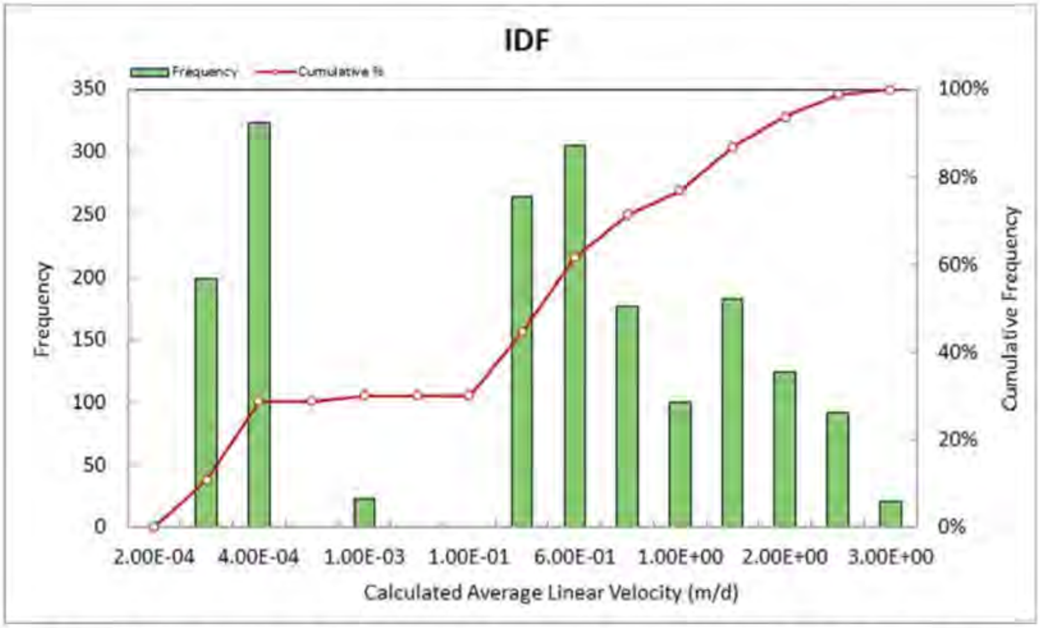

Figure 7-27. Histogram Plot of Calculated Average Linear Velocities at IDF for the Third Quarter of 2019

7.1.7 Liquid Effluent Retention Facility

Figure 7-28 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at LERF. The extents of the TRIM model domain precluded the placement of particle release locations upgradient of the entire facility. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at LERF are presented in Figures 7-29 through 7-31. A portion of LERF is believed to be located in an area of low conductivity sediments overlying the basalt and underlying the Hanford formation. Because of this, the hydraulic properties of the Ringold Formation member of Wooded Island — unit E were considered more appropriate to use for calculations of the average linear velocity than those of the Hanford formation.

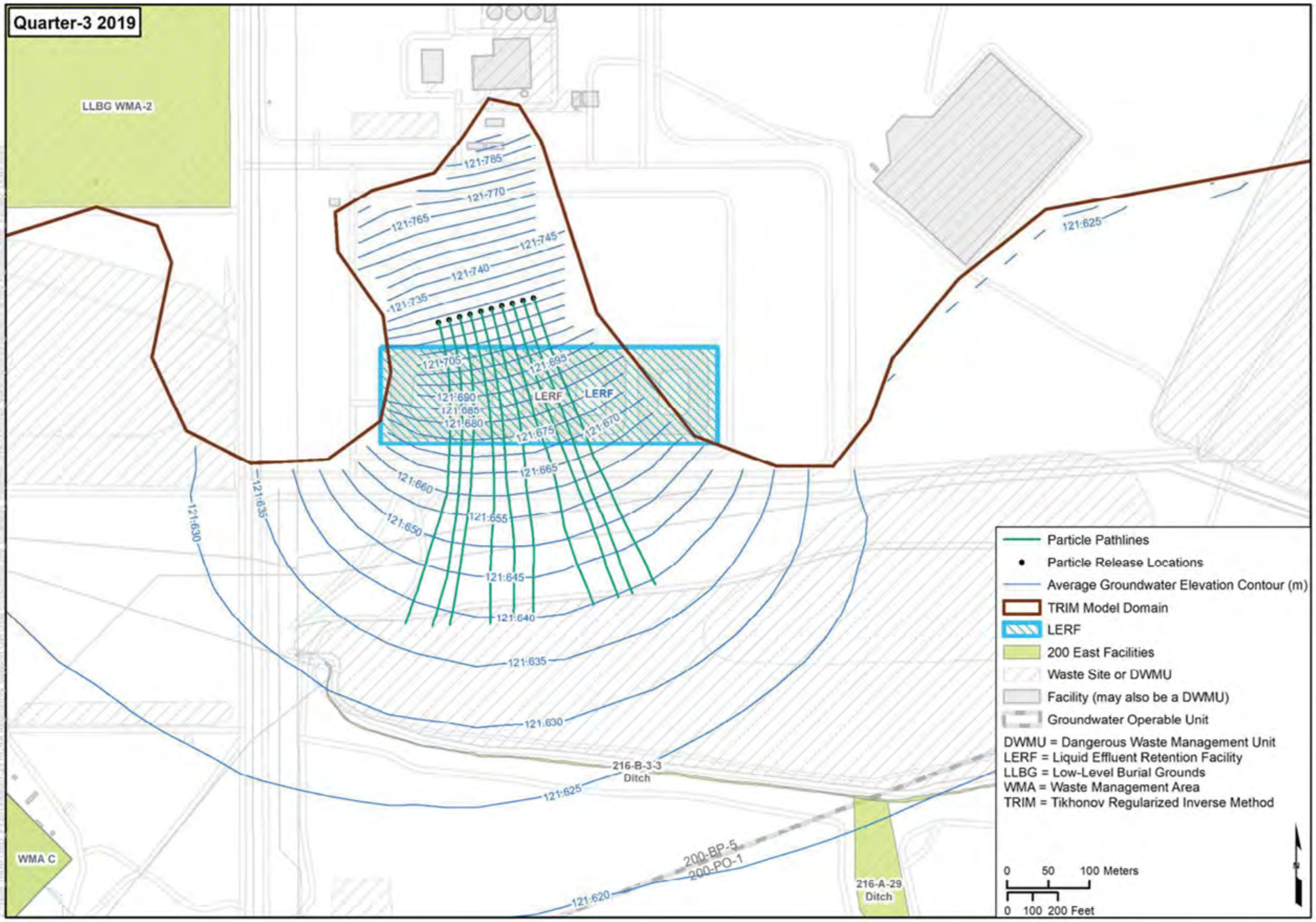

Figure 7-28. Calculated Particle Pathlines Representing General Groundwater Flow Directions at LERF for the Third Quarter of 2019

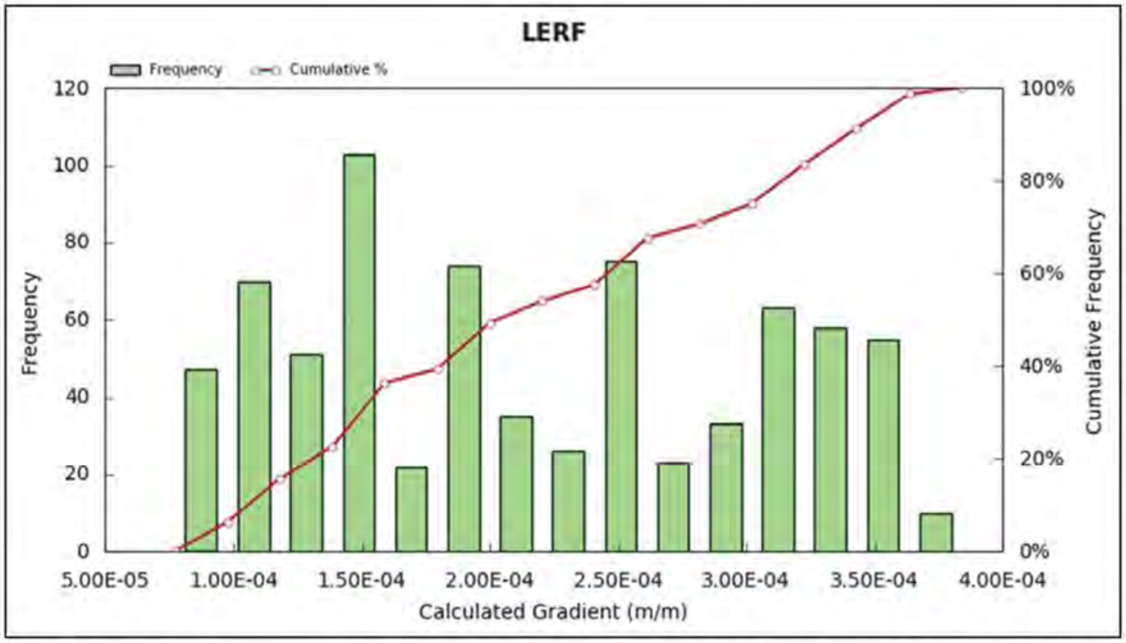

Figure 7-29. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at LERF for the Third Quarter of 2019

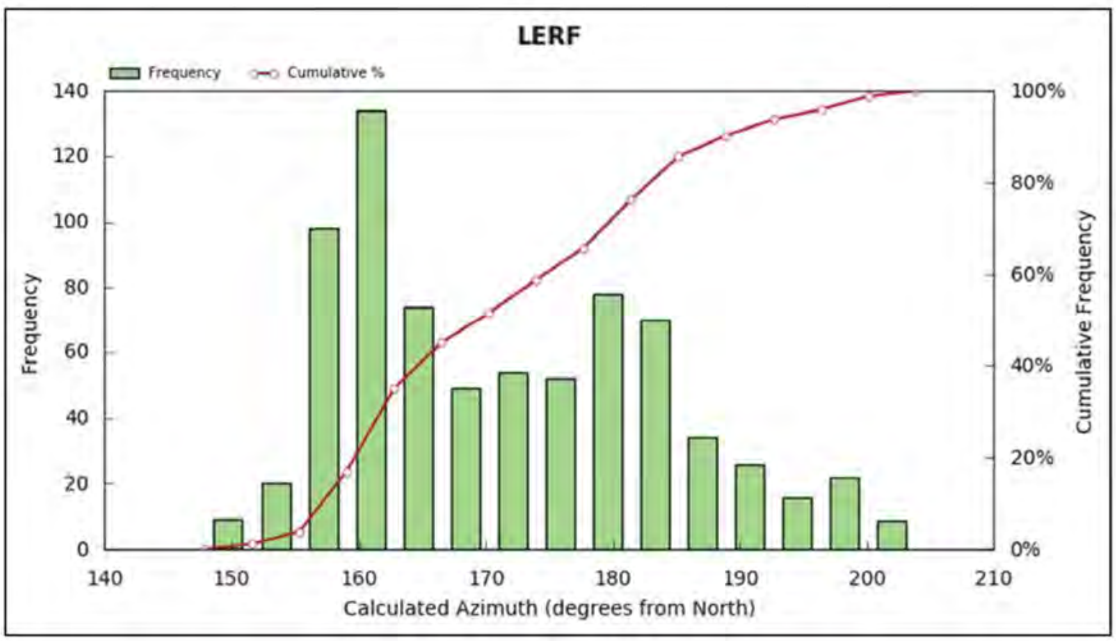

Figure 7-30. Histogram Plot of Calculated Hydraulic Gradient Azimuths at LERF for the Third Quarter of 2019

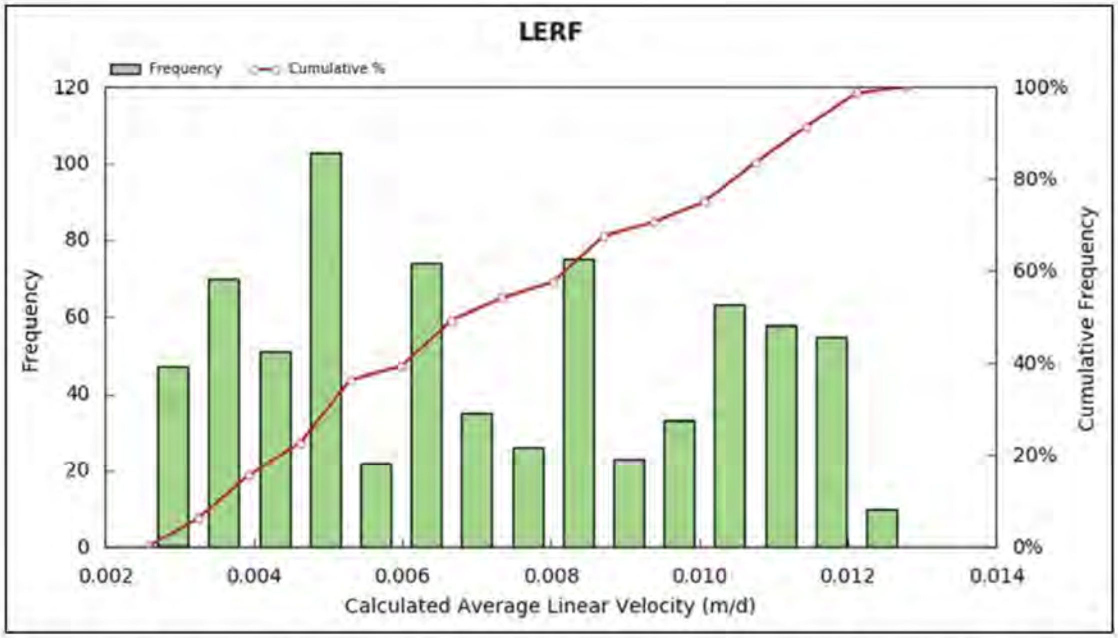

Figure 7-31. Histogram Plot of Calculated Average Linear Velocities at LERF for the Third Quarter of 2019

7.1.8 Low-Level Burial Grounds Waste Management Area-1

Figure 7-32 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at LLBG WMA-1. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at LLBG WMA-1 are presented in Figure 7-33 through 7-35.

Figure 7-32. Calculated Particle Pathlines Representing General Groundwater Flow Directions at LLBG WMA-1 for the Third Quarter of 2019

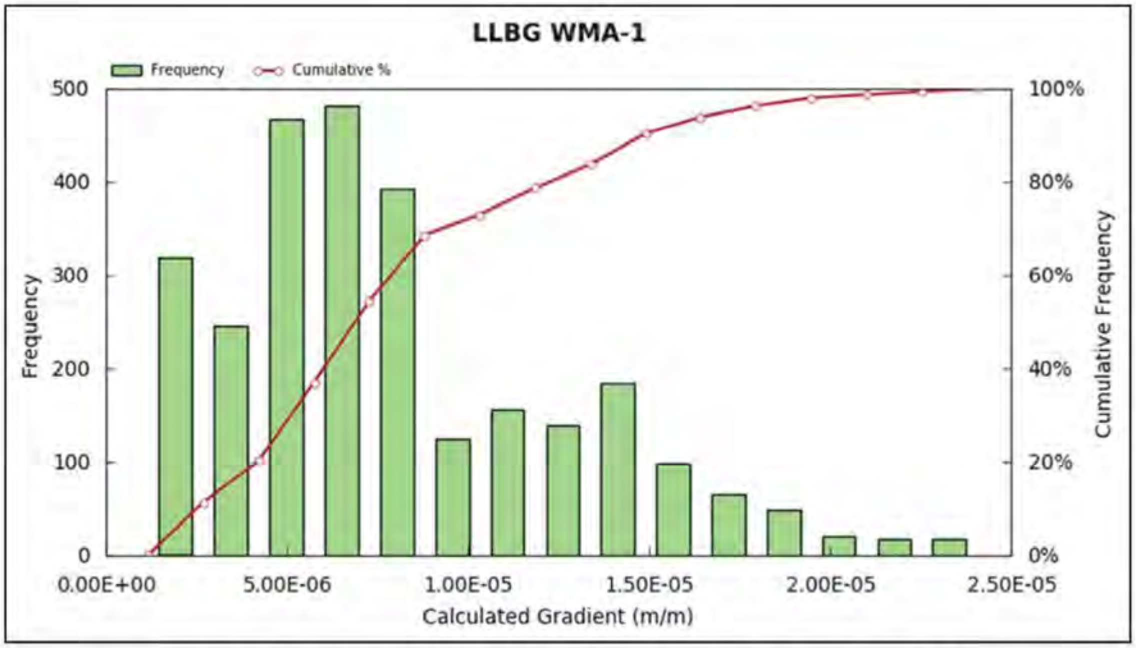

Figure 7-33. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at LLBG WMA-1 for the Third Quarter of 2019

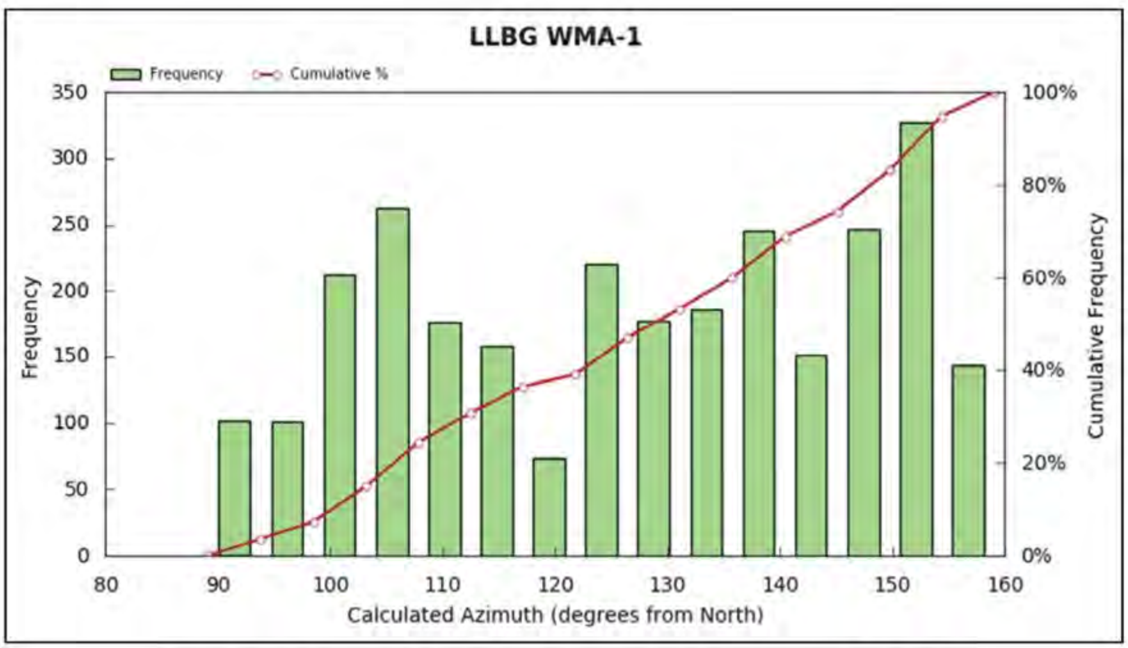

Figure 7-34. Histogram Plot of Calculated Hydraulic Gradient Azimuths at LLBG WMA-1 for the Third Quarter of 2019

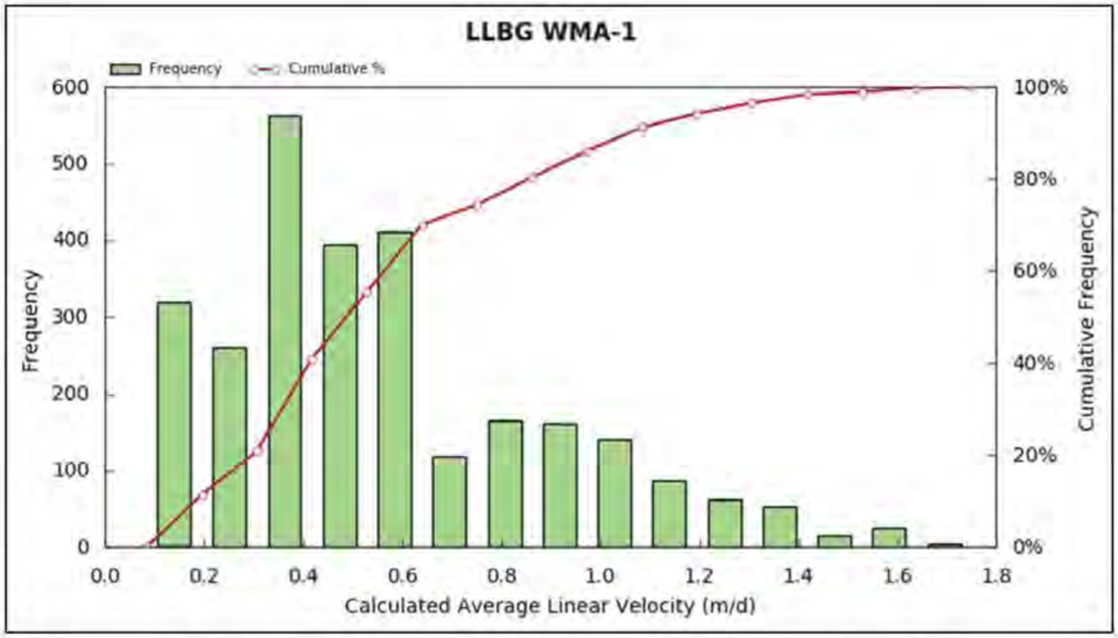

Figure 7-35. Histogram Plot of Calculated Average Linear Velocities at LLBG WMA-1 for the Third Quarter of 2019

7.1.9 Low-Level Burial Grounds Waste Management Area-2

Figure 7-36 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at LLBG WMA-2. The particles were placed to cover Trench 94 (within LLBG WMA-2) to the extent possible, but the extents of the TRIM model domain precluded the placement of particle release locations upgradient of the entire facility. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at LLBG WMA-2 are presented in Figures 7-37 through 7-39.

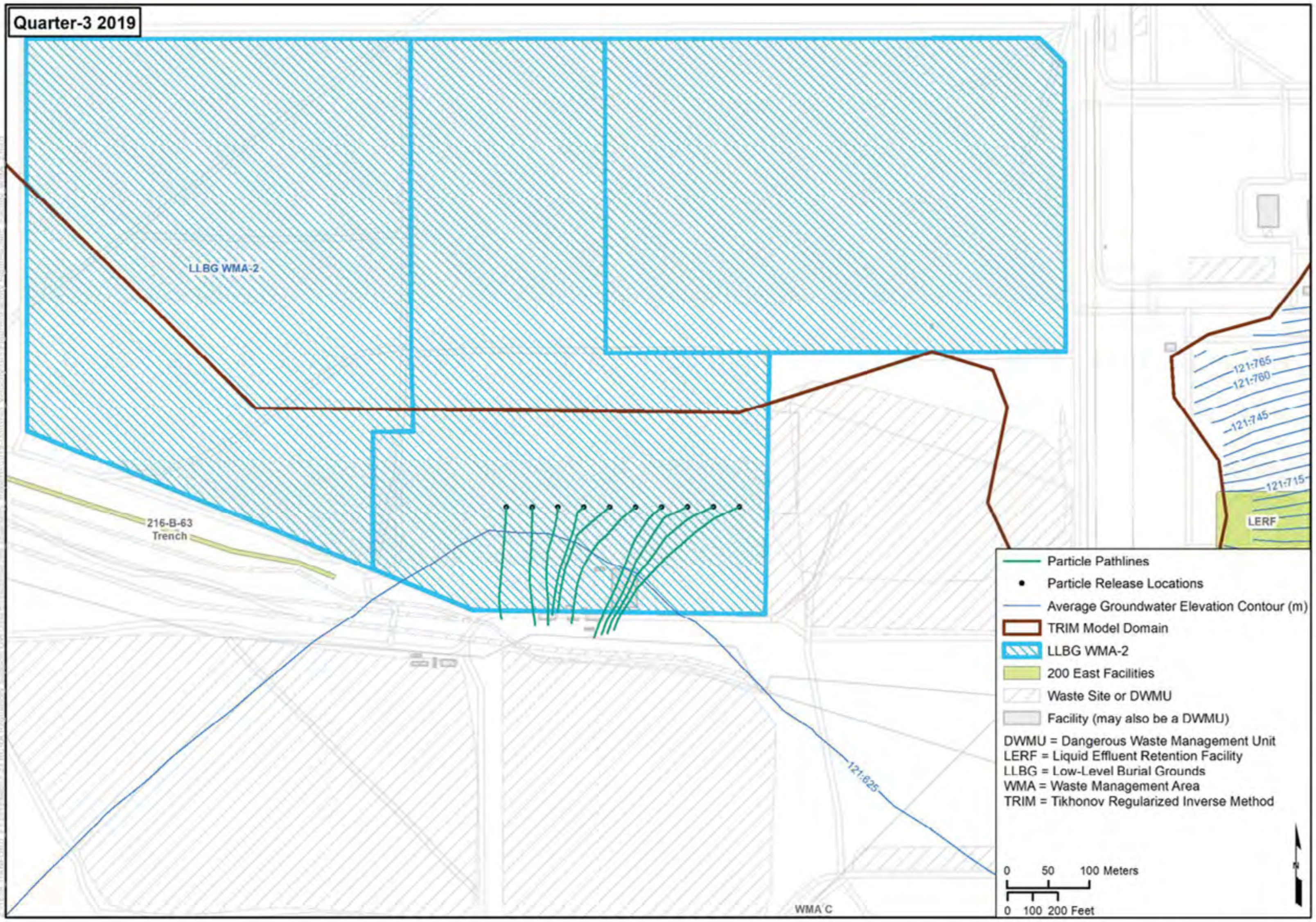

Figure 7-36. Calculated Particle Pathlines Representing General Groundwater Flow Directions at LLBG WMA-2 for the Third Quarter of 2019

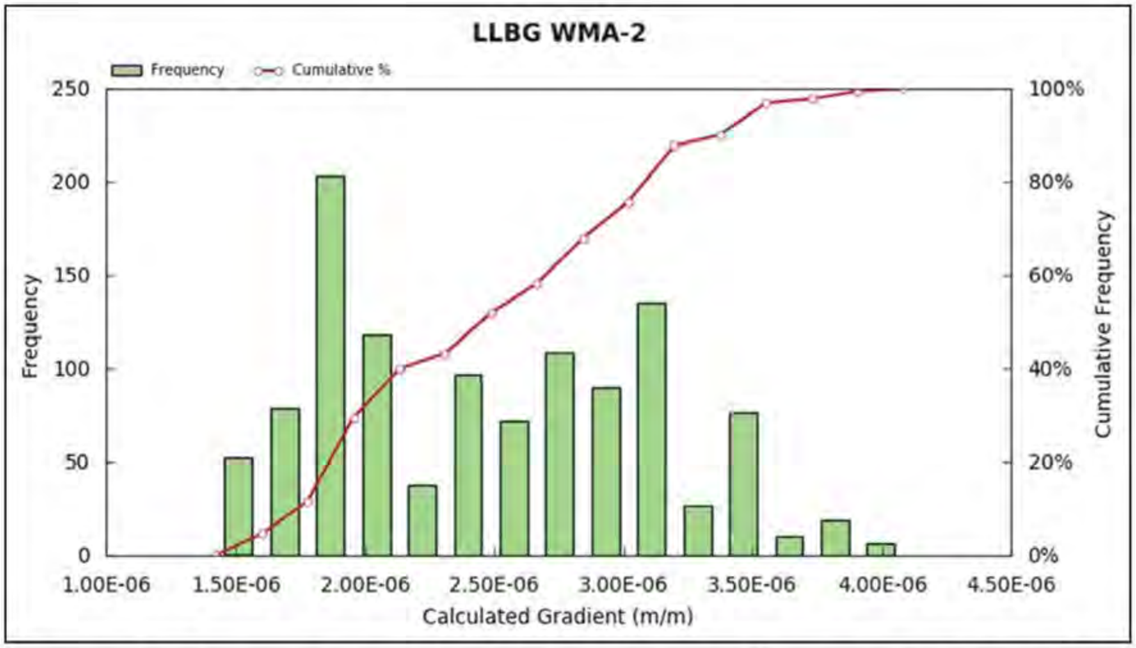

Figure 7-37. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at LLBG WMA-2 for the Third Quarter of 2019

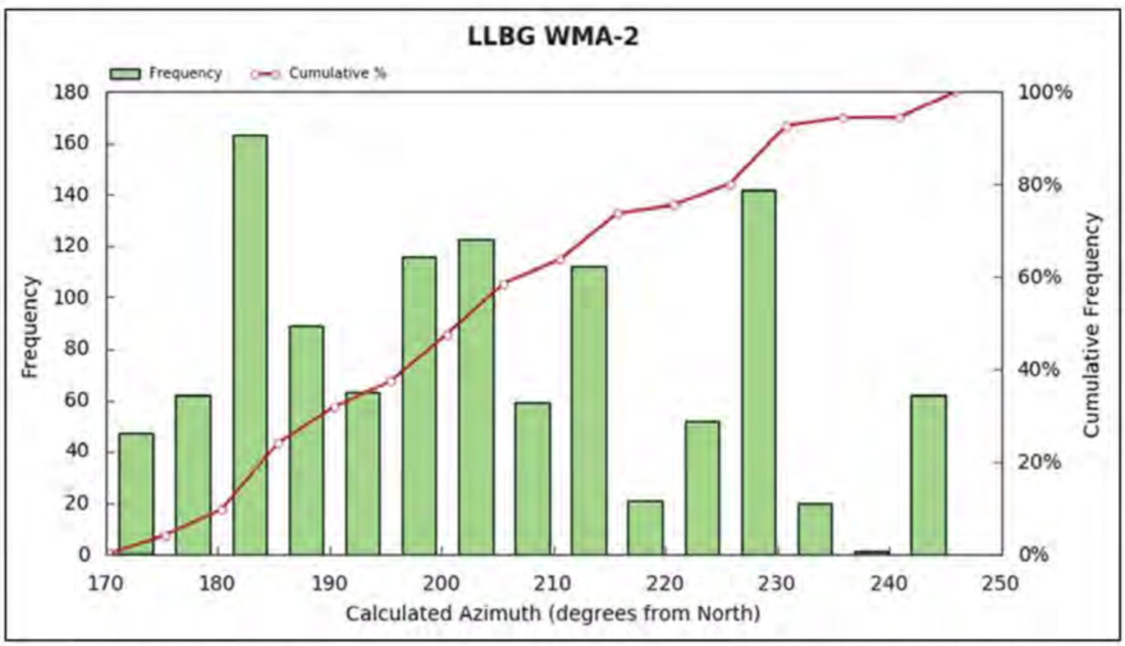

Figure 7-38. Histogram Plot of Calculated Hydraulic Gradient Azimuths at LLBG WMA-2 for the Third Quarter of 2019

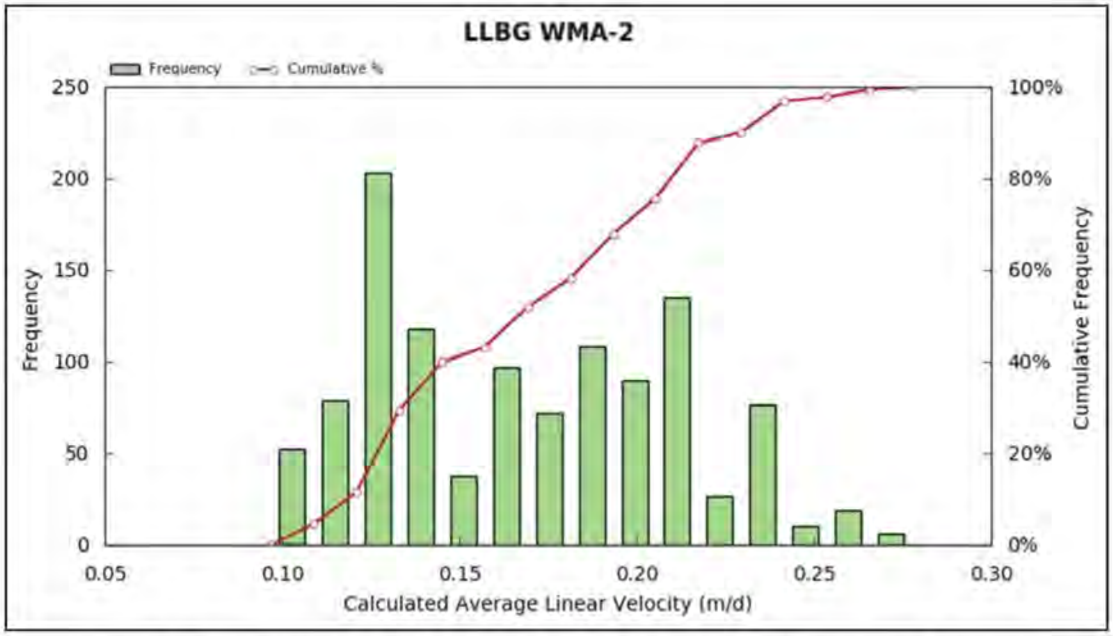

Figure 7-39. Histogram Plot of Calculated Average Linear Velocities at LLBG WMA-2 for the Third Quarter of 2019

7.1.10 Waste Management Area A-AX

Figure 7-40 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at WMA A-AX. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at WMA A-AX are presented in Figures 7-41 through 7-43.

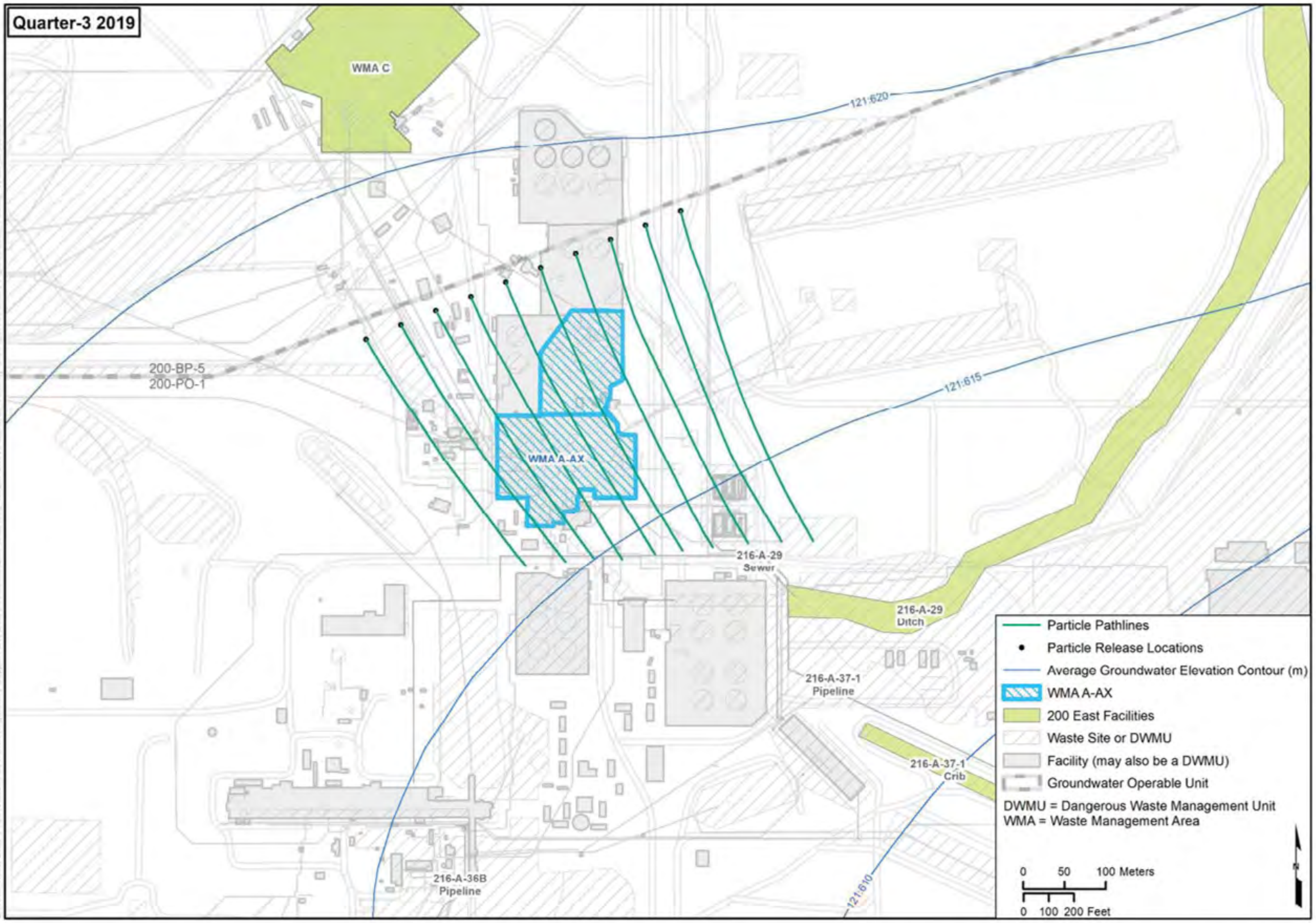

Figure 7-40. Calculated Particle Pathlines Representing General Groundwater Flow Directions at WMA A-AX for the Third Quarter of 2019

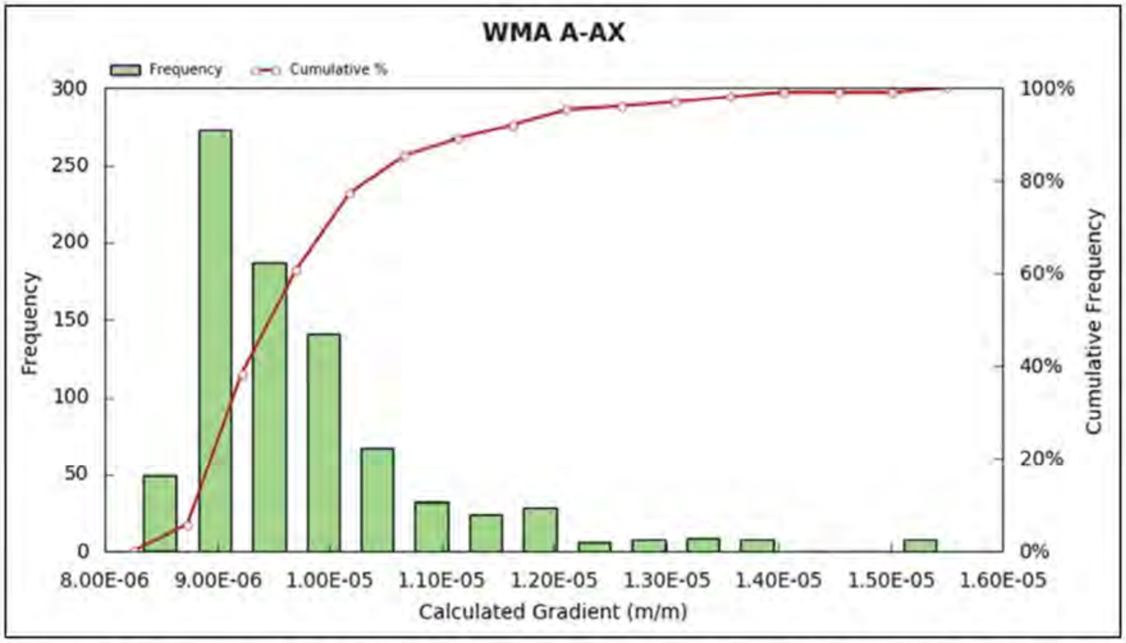

Figure 7-41. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at WMA A-AX for the Third Quarter of 2019

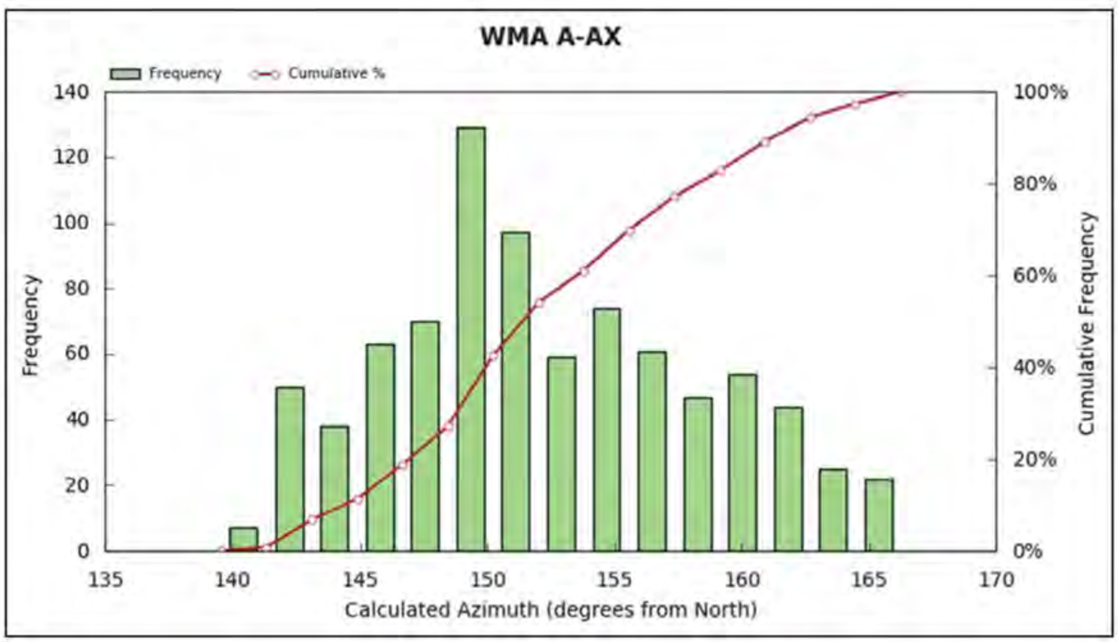

Figure 7-42. Histogram Plot of Calculated Hydraulic Gradient Azimuths at WMA A-AX for the Third Quarter of 2019

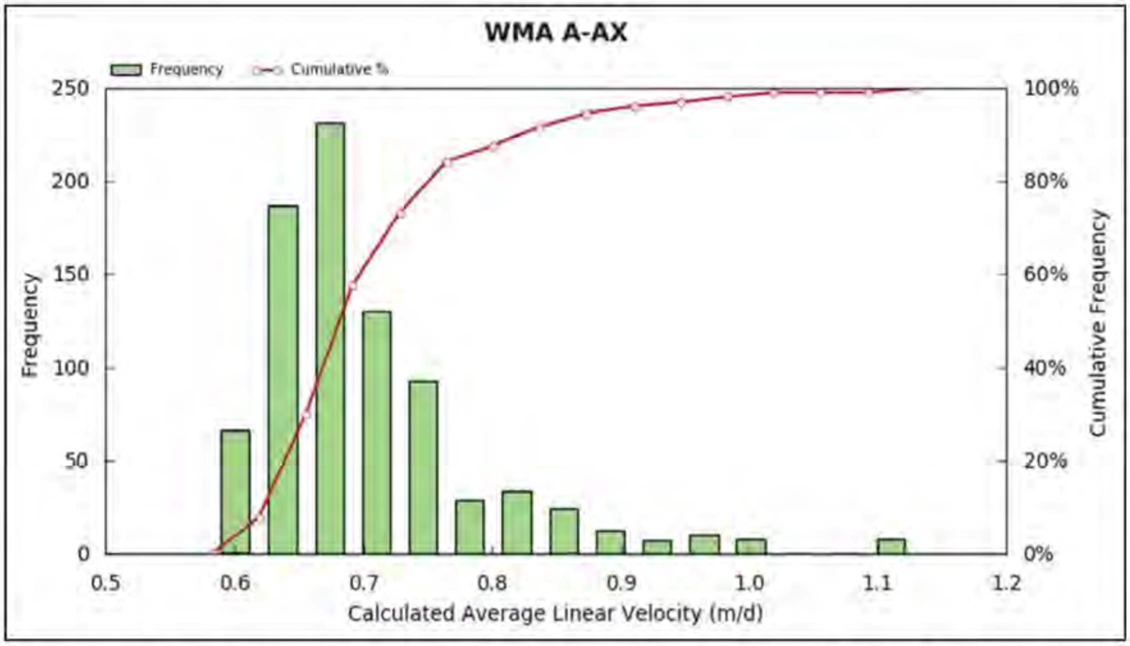

Figure 7-43. Histogram Plot of Calculated Average Linear Velocities at WMA A-AX for the Third Quarter of 2019

7.1.11 Waste Management Area B-BX-BY

Figure 7-44 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at WMA B-BX-BY. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at WMA B-BX-BY are presented in Figures 7-45 through 7-47.

Figure 7-44. Calculated Particle Pathlines Representing General Groundwater Flow Directions at WMA B-BX-BY for the Third Quarter of 2019

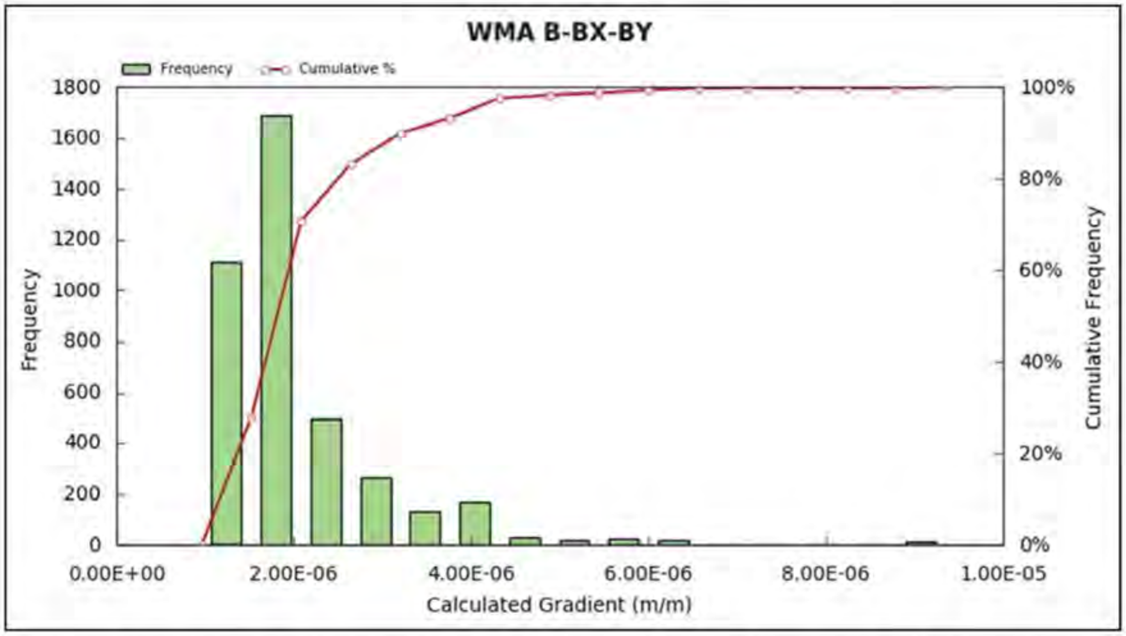

Figure 7-45. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at WMA B-BX-BY for the Third Quarter of 2019

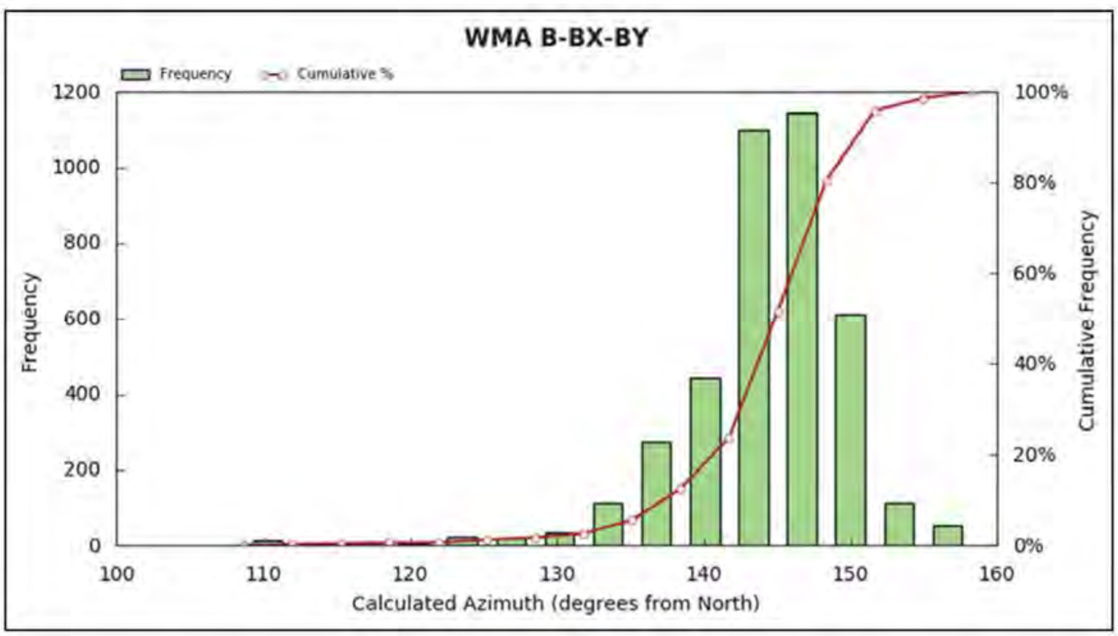

Figure 7-46. Histogram Plot of Calculated Hydraulic Gradient Azimuths at WMA B-BX-BY for the Third Quarter of 2019

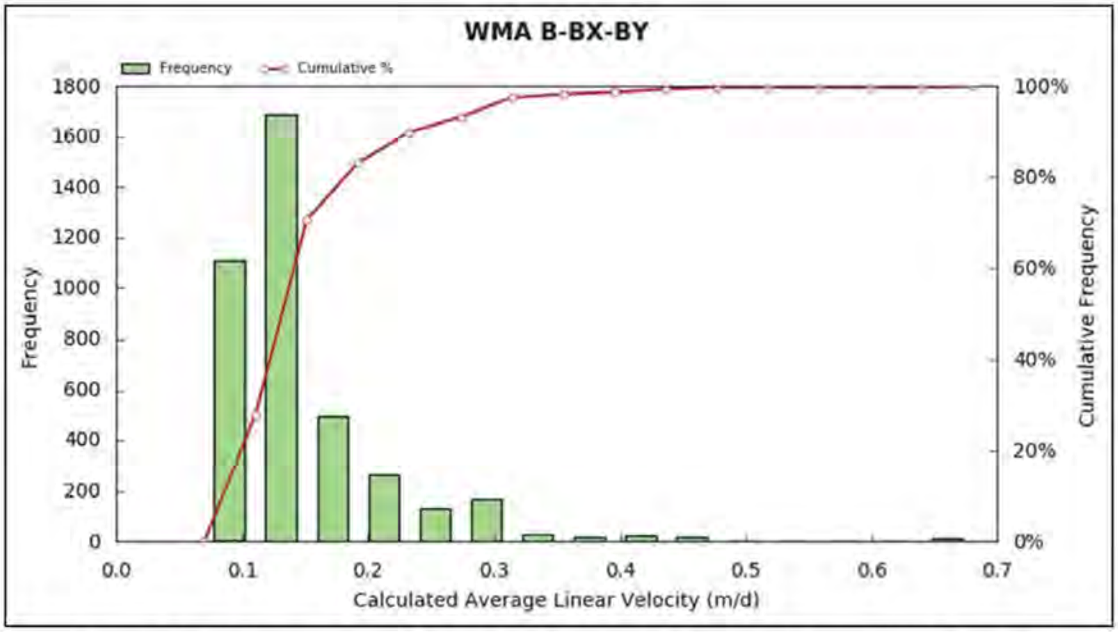

Figure 7-47. Histogram Plot of Calculated Average Linear Velocities at WMA B-BX-BY for the Third Quarter of 2019

7.1.12 Waste Management Area C

Figure 7-48 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at WMA C. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at WMA C are presented in Figures 7-49 through 7-51.

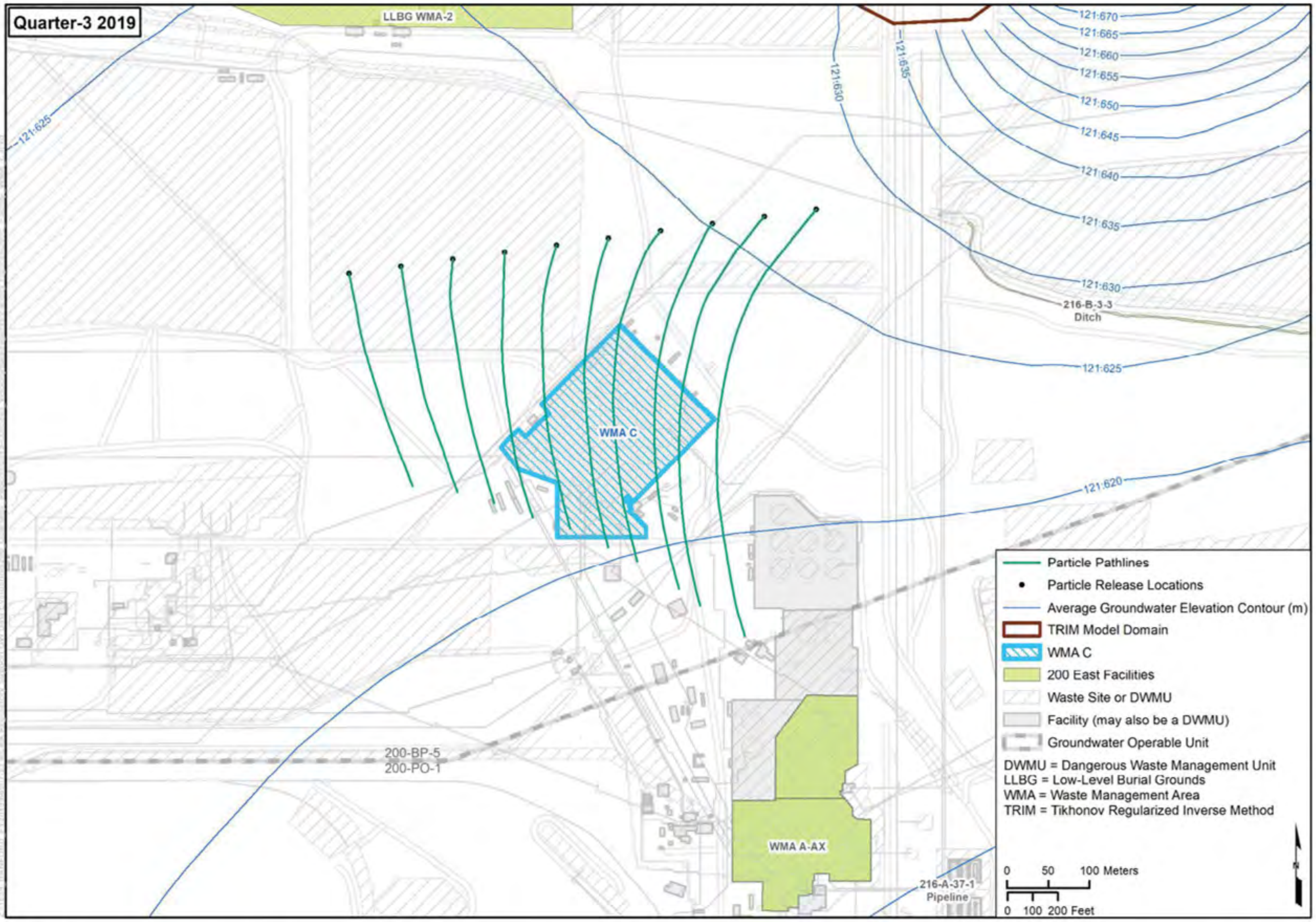

Figure 7-48. Calculated Particle Pathlines Representing General Groundwater Flow Directions at WMA C for the Third Quarter of 2019

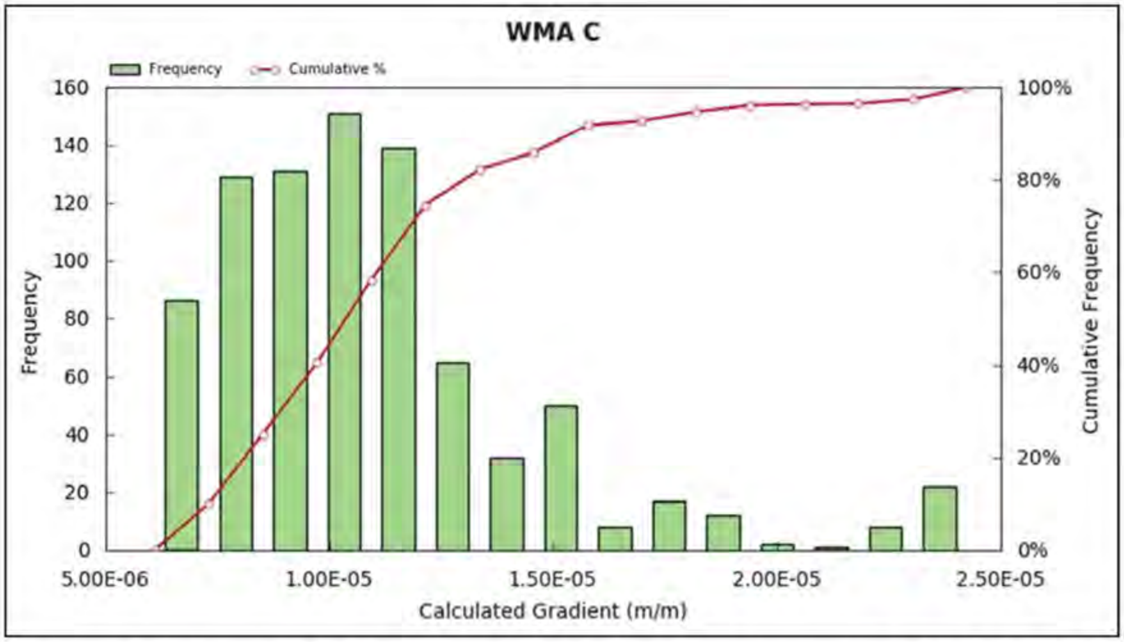

Figure 7-49. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at WMA C for the Third Quarter of 2019

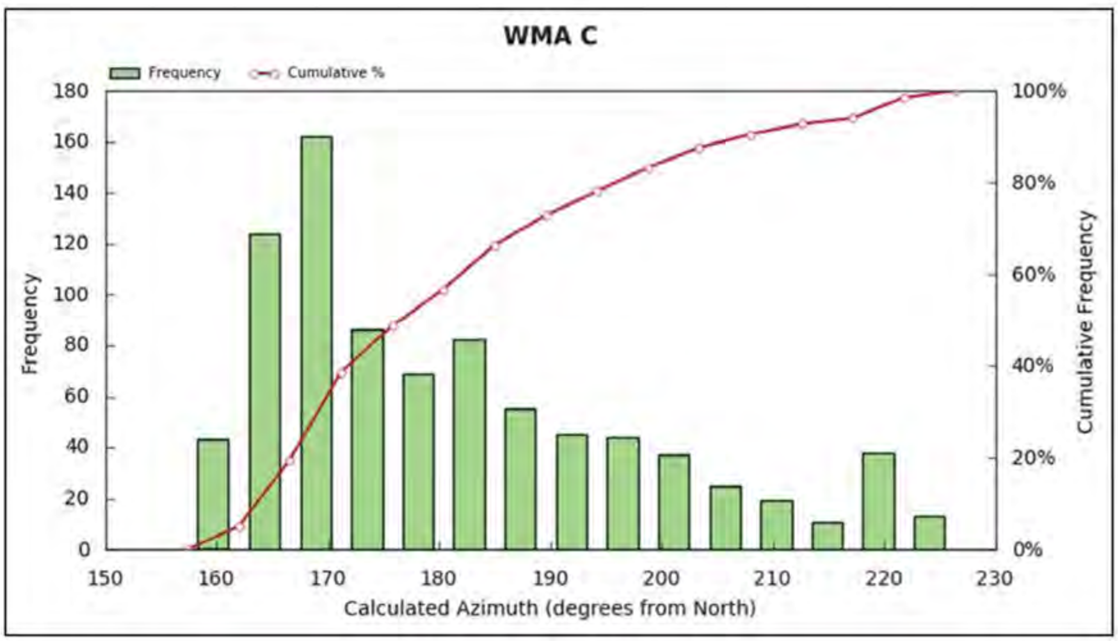

Figure 7-50. Histogram Plot of Calculated Hydraulic Gradient Azimuths at WMA C for the Third Quarter of 2019

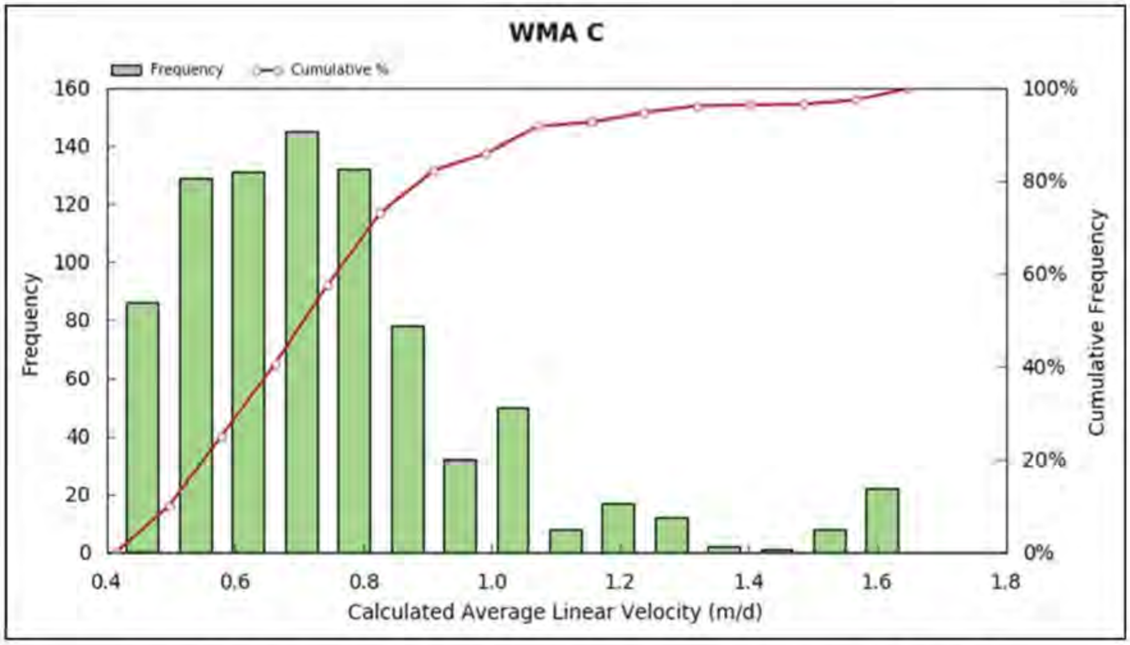

Figure 7-51. Histogram Plot of Calculated Average Linear Velocities at WMA C for the Third Quarter of 2019

7.2 200 West Area

Summary statistics pertaining to the calculated hydraulic gradients and average linear velocities at the 200 West Area facilities for the third quarter of 2019 are presented in Table 7-2. Figures 7-52 through 7-54 illustrate the same data graphically. The results for each 200 West Area facility are presented in the facility-specific sections below.

Table 7-2. Calculated Hydraulic Gradients and Average Linear Velocities at the 200 West Area Facilities for the Third Quarter of 2019

Site	Gradient Magnitude [-]				Gradient Azimuth (Degrees from North)				Average Linear Velocity (m/d)			
	Min	Max	Average	Median	Min	Max	Avg	Median	Min	Max	Average	Median
216-S-10	2.02E-03	3.54E-03	2.91E-03	2.97E-03	59	93	77	77	0.07	0.12	0.10	0.10
Trenches 31 and 34	3.93E-04	5.15E-03	3.18E-03	3.53E-03	36	289	112	96	0.01	0.17	0.11	0.12
WMA-3	1.43E-03	7.49E-03	3.73E-03	3.77E-03	37	124	83	83	0.05	0.25	0.12	0.13
WMA-4	5.95E-03	1.48E-02	8.32E-03	8.24E-03	29	174	92	89	0.20	0.49	0.28	0.27
WMA S-SX	3.34E-03	6.02E-03	4.35E-03	4.29E-03	66	134	93	94	0.11	0.20	0.14	0.14
WMA T	5.67E-03	1.11E-02	8.94E-03	9.32E-03	95	123	111	113	0.19	0.37	0.30	0.31
WMA TX-TY	5.79E-03	1.64E-02	9.31E-03	9.14E-03	41	181	97	94	0.19	0.55	0.31	0.30
WMA U	5.01E-03	1.11E-02	6.39E-03	6.15E-03	38	97	81	85	0.17	0.37	0.21	0.21

WMA = Waste Management Area

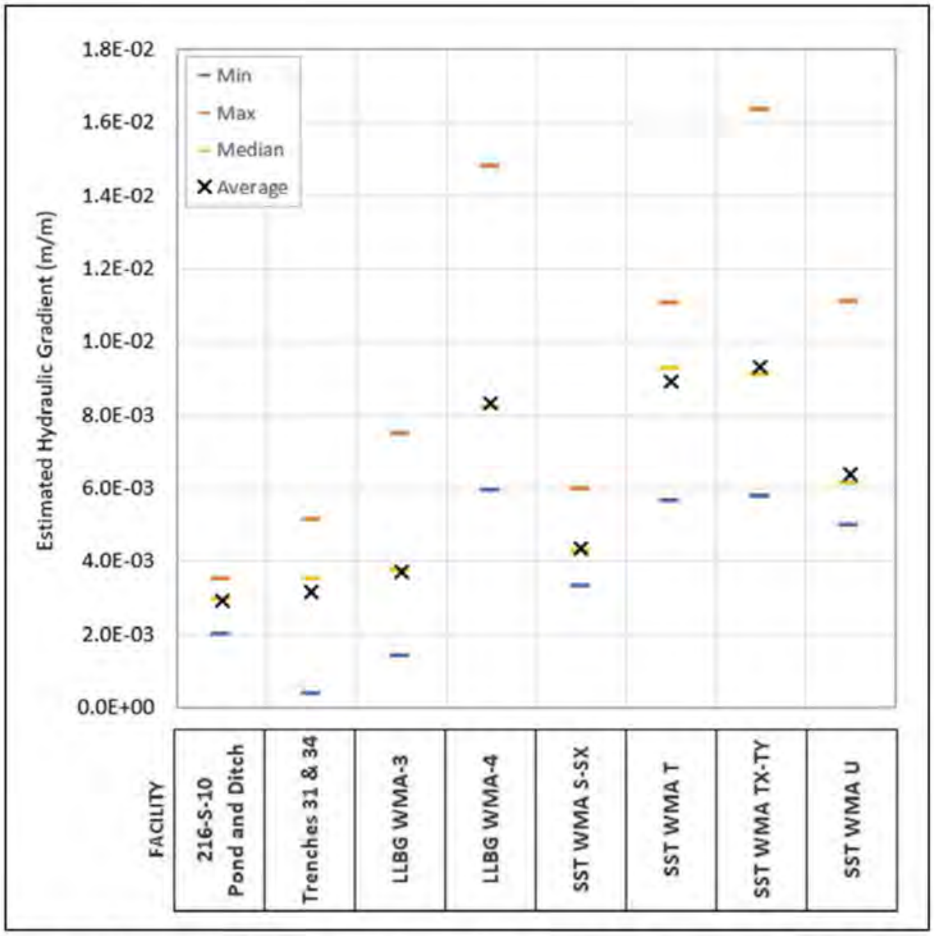

Figure 7-52. Calculated Hydraulic Gradient Magnitudes at the 200 West Area Facilities

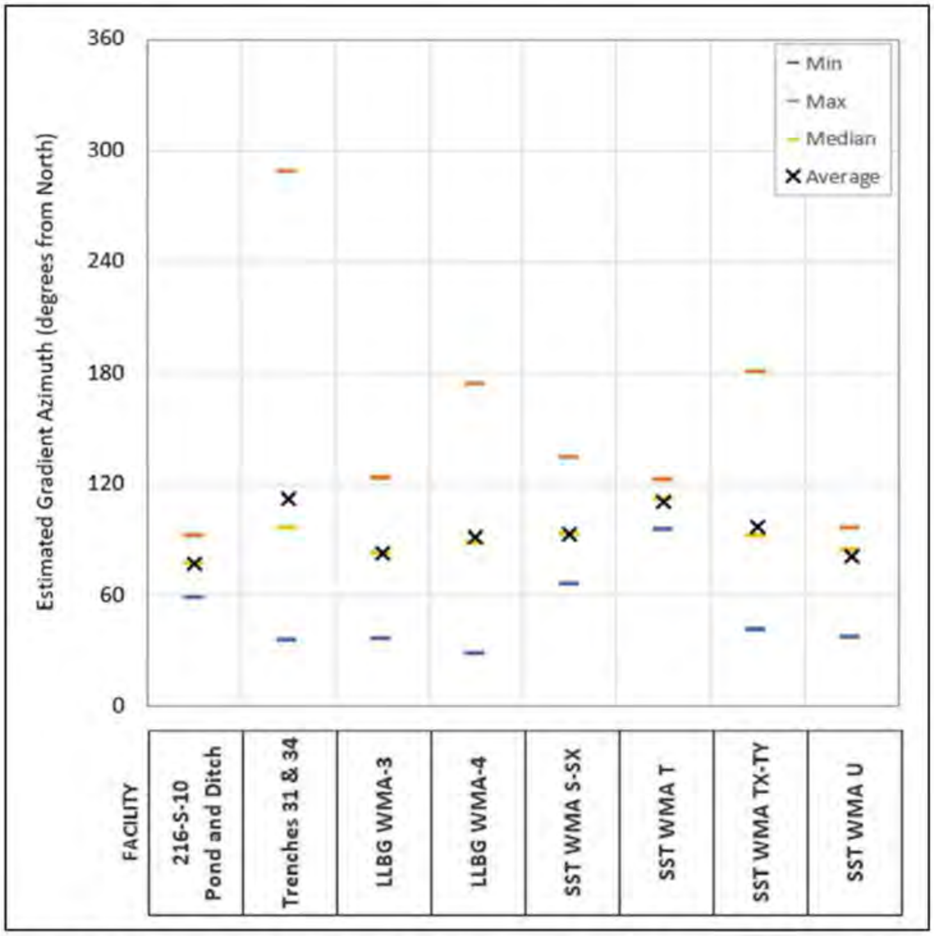

Figure 7-53. Calculated Hydraulic Gradient Azimuths at the 200 West Area Facilities

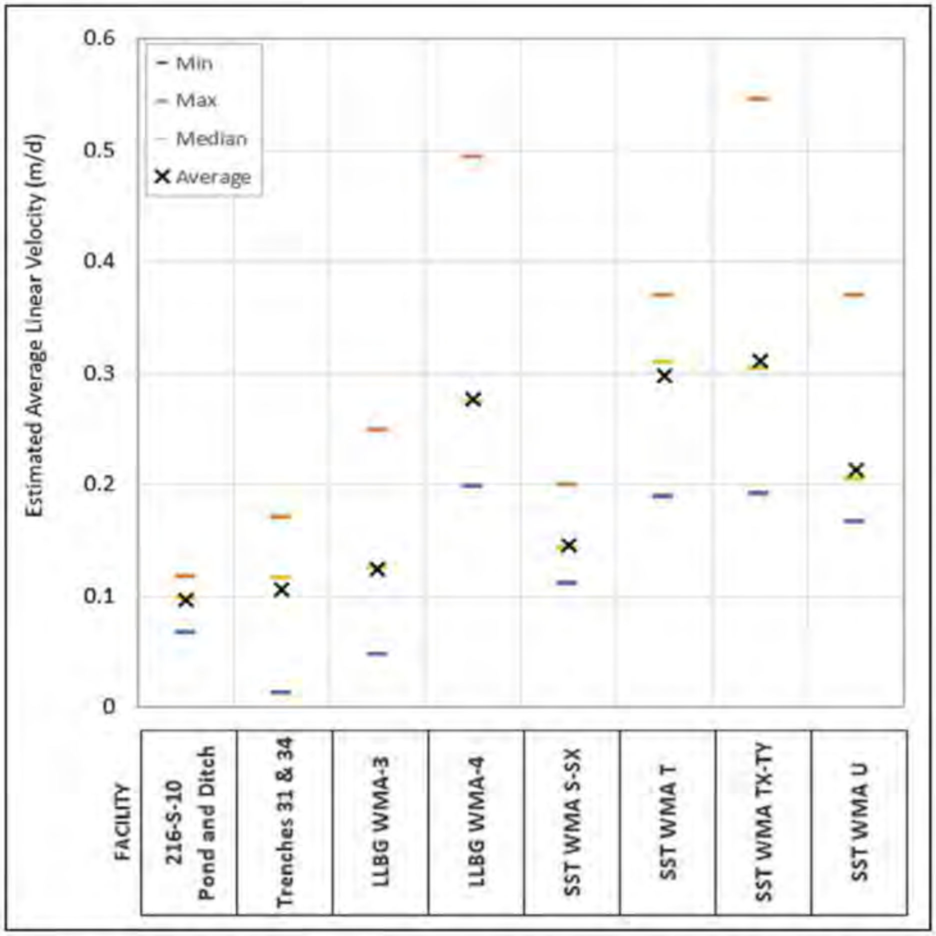

Figure 7-54. Calculated Average Linear Velocities at the 200 West Area Facilities

7.2.1 216-S-10 Pond and Ditch

Figure 7-55 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at the 216-S-10 Pond and Ditch. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the 216-S-10 Pond and Ditch are presented in Figures 7-56 through 7-58.

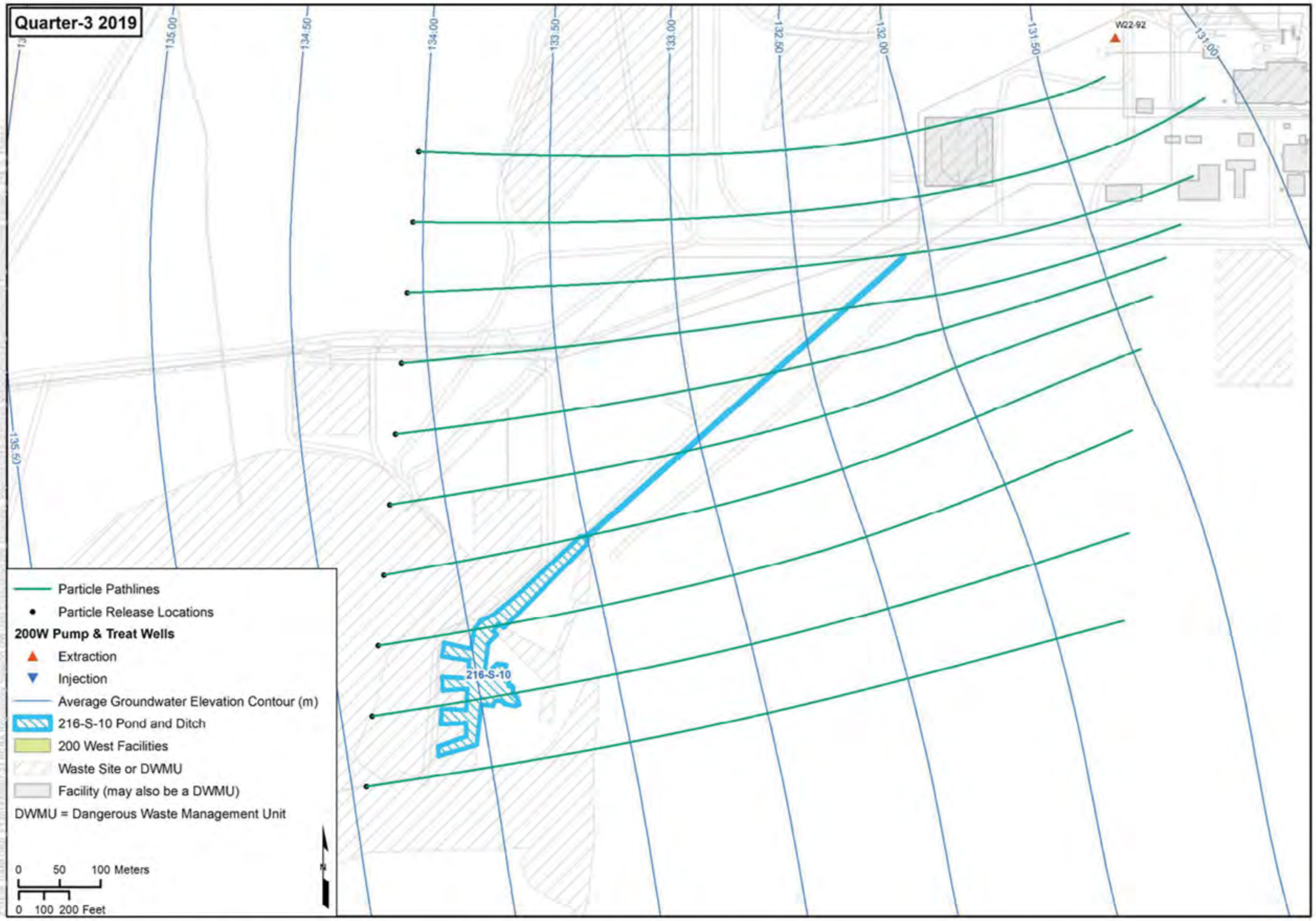

Figure 7-55. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the 216-S-10 Pond and Ditch for the Third Quarter of 2019

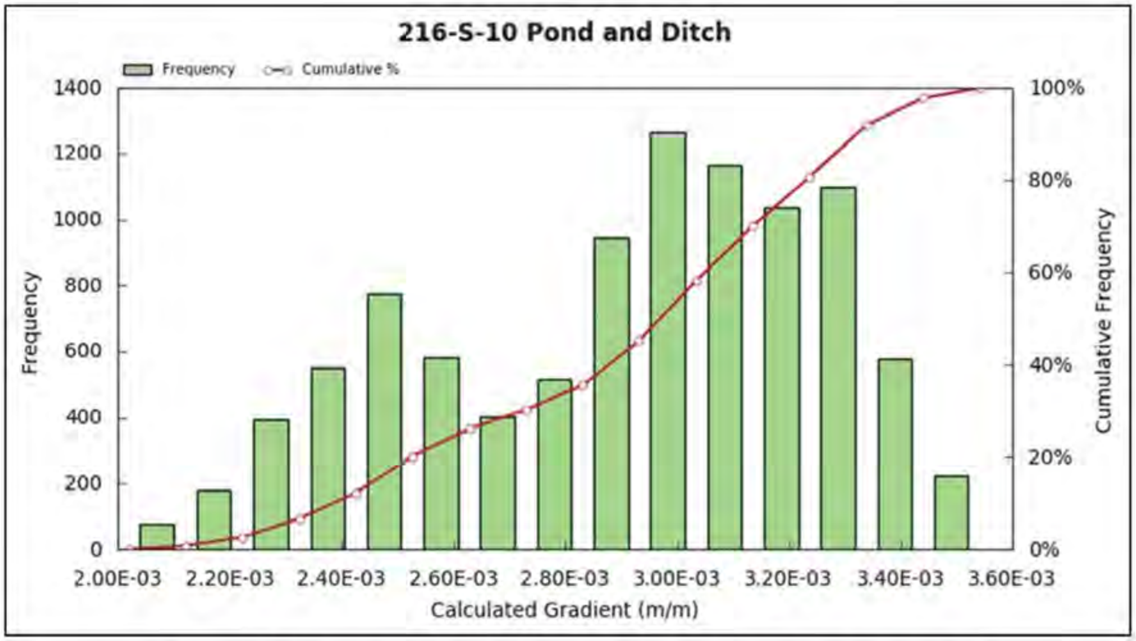

Figure 7-56. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the 216-S-10 Pond and Ditch for the Third Quarter of 2019

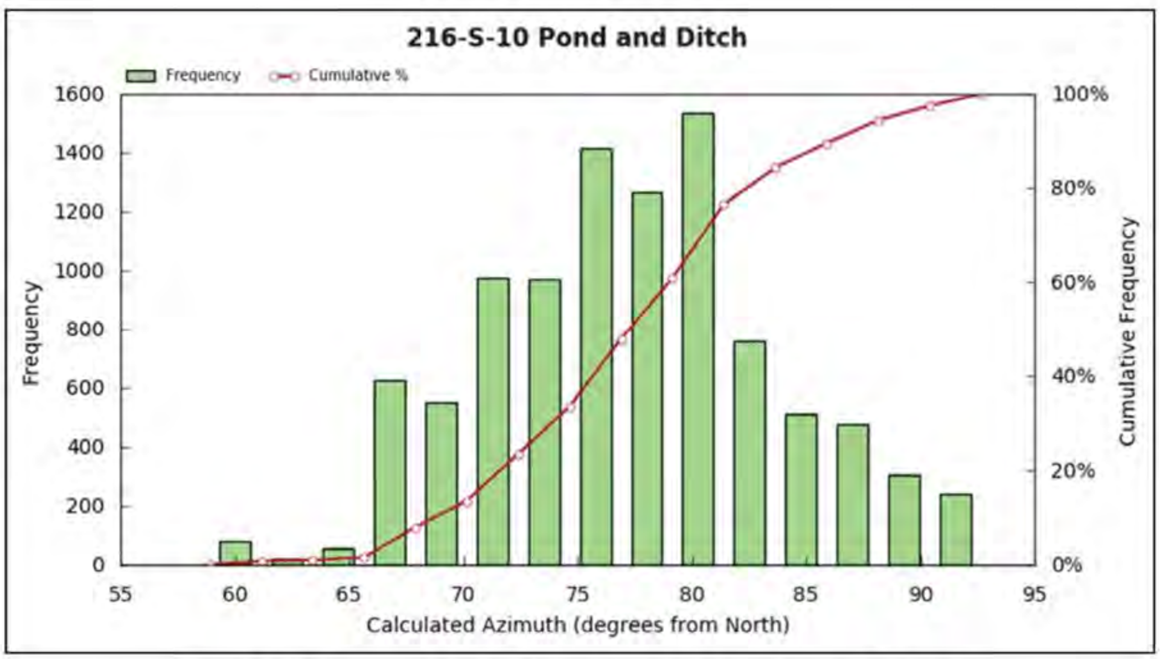

Figure 7-57. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the 216-S-10 Pond and Ditch for the Third Quarter of 2019

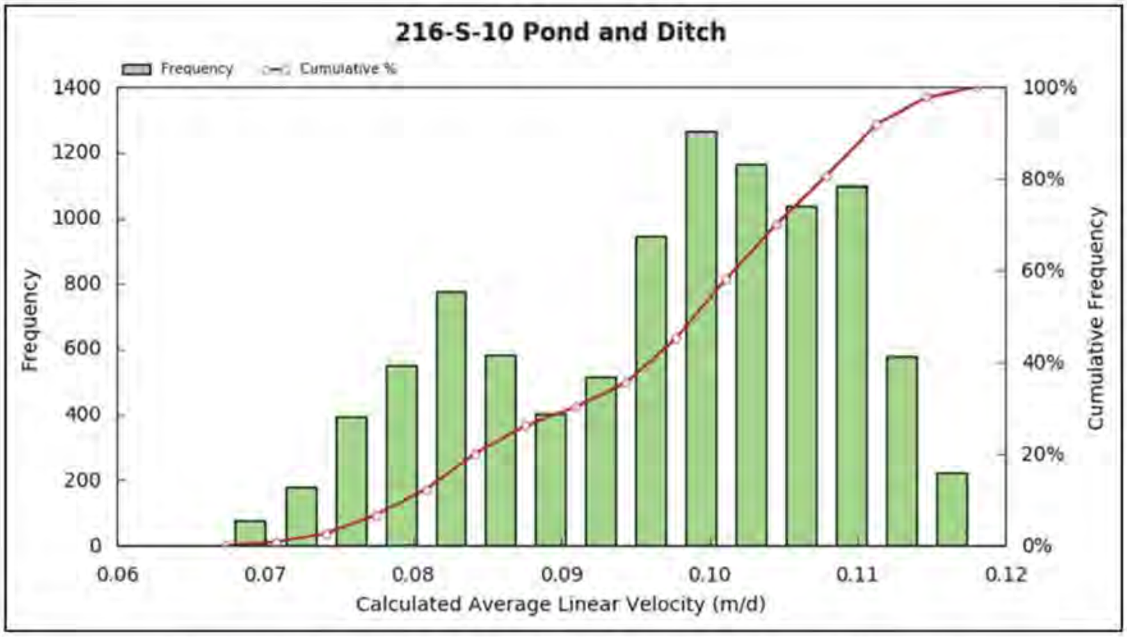

Figure 7-58. Histogram Plot of Calculated Average Linear Velocities at the 216-S-10 Pond and Ditch for the Third Quarter of 2019

7.2.2 Low-Level Burial Grounds Trenches 31 and 34

Figure 7-59 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at LLBG Trenches 31 and 34. Particle release locations were placed inside the trenches so that the resulting pathlines project downgradient. Placing particle release locations upgradient of the entire facility would not allow the resulting pathlines to traverse the facility due to the curvature in the adjacent flow field induced by treated groundwater injection operations. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at LLBG Trenches 31 and 34 are presented in Figures 7-60 through 7-62.

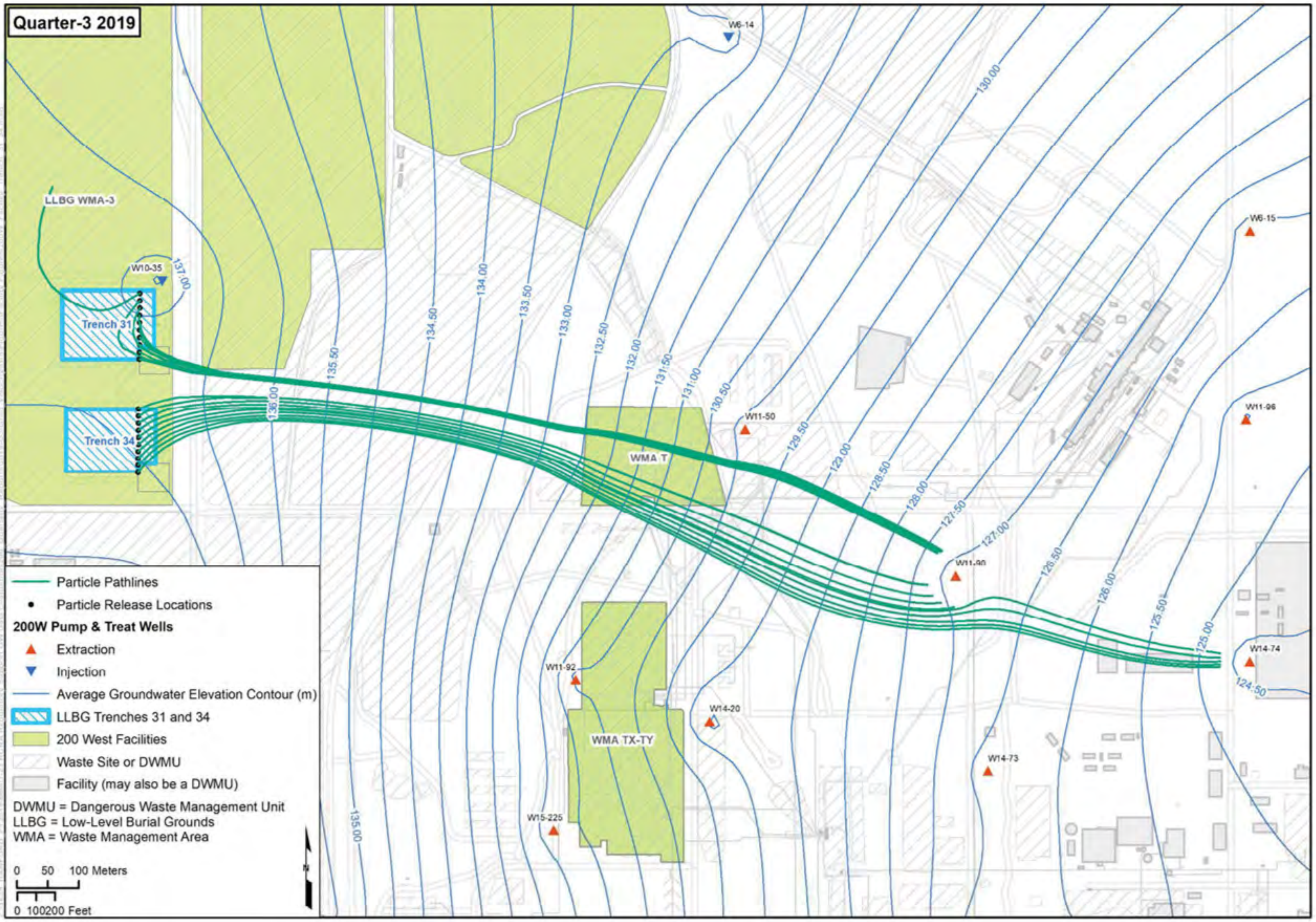

Figure 7-59. Calculated Particle Pathlines Representing General Groundwater Flow Directions at LLBG Trenches 31 and 34 for the Third Quarter of 2019

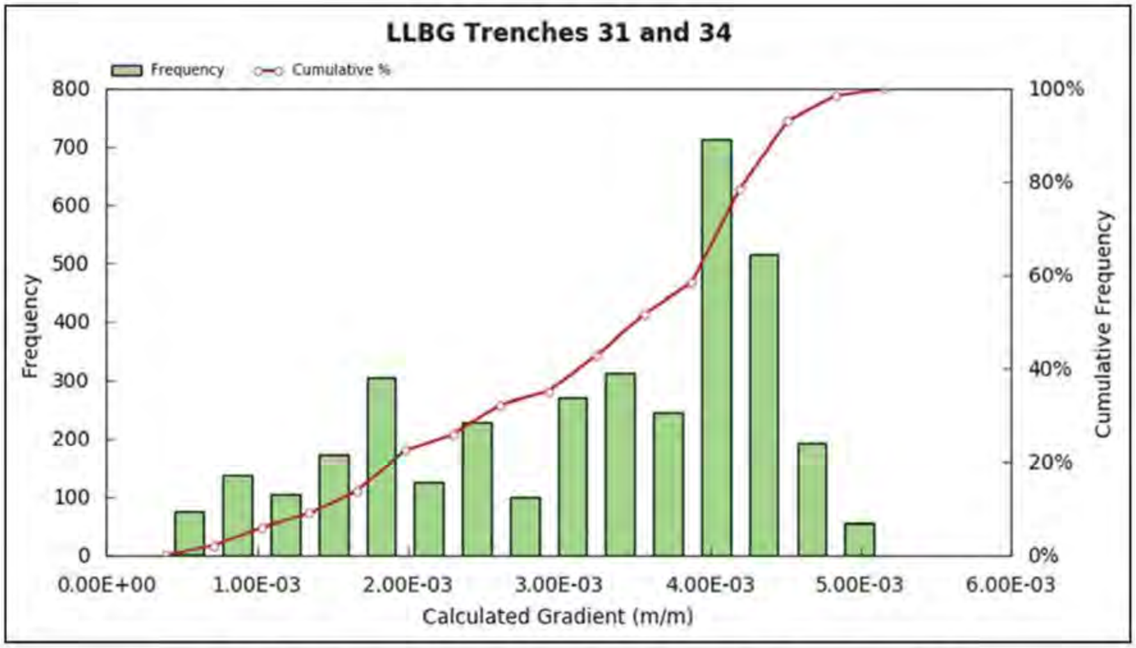

Figure 7-60. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at LLBG Trenches 31 and 34 for the Third Quarter of 2019

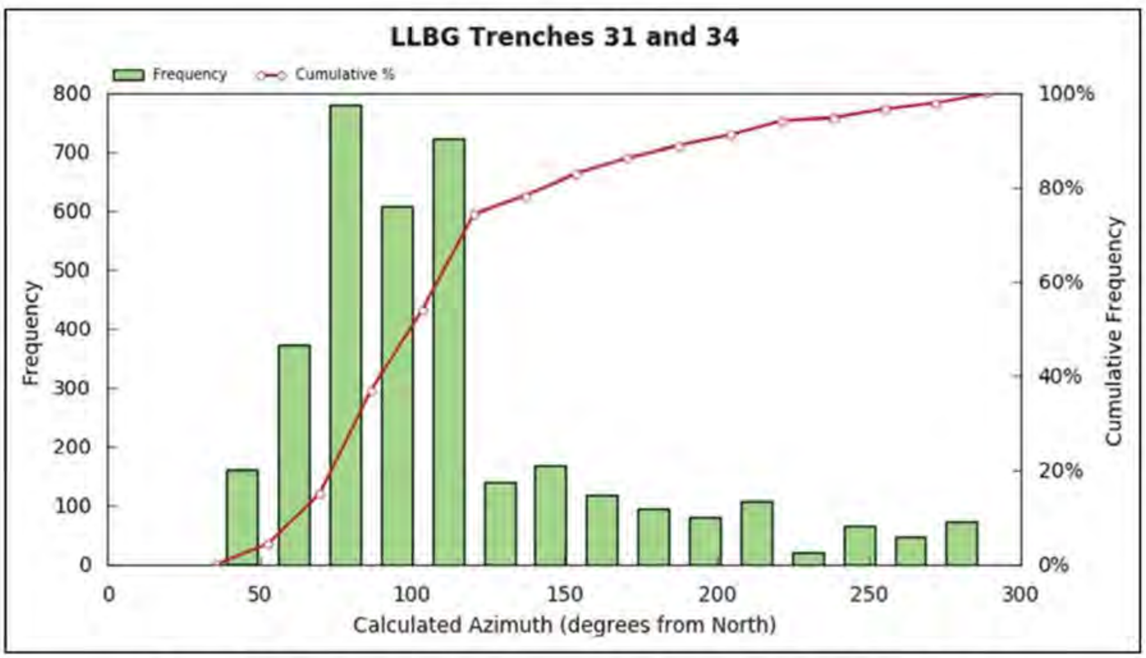

Figure 7-61. Histogram Plot of Calculated Hydraulic Gradient Azimuths at LLBG Trenches 31 and 34 for the Third Quarter of 2019

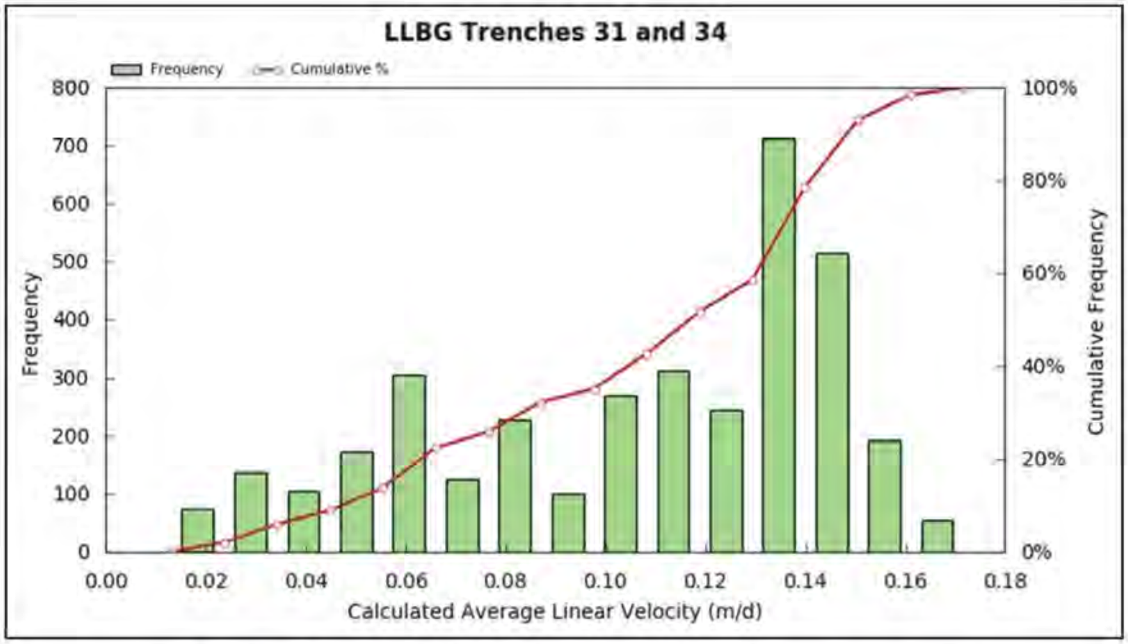

Figure 7-62. Histogram Plot of Calculated Average Linear Velocities at LLBG Trenches 31 and 34 for the Third Quarter of 2019

7.2.3 Low-Level Burial Grounds Waste Management Area-3

Figure 7-63 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at LLBG WMA-3. Particle release locations were placed upgradient of the green islands within WMA-3 in order to obtain pathlines projecting downgradient. Placing particle release locations upgradient of the entire facility would not allow the resulting pathlines to traverse the facility due to the curvature in the adjacent flow field induced by treated groundwater injection operations. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the LLBG WMA-3 are presented in Figures 7-64 through 7-66.

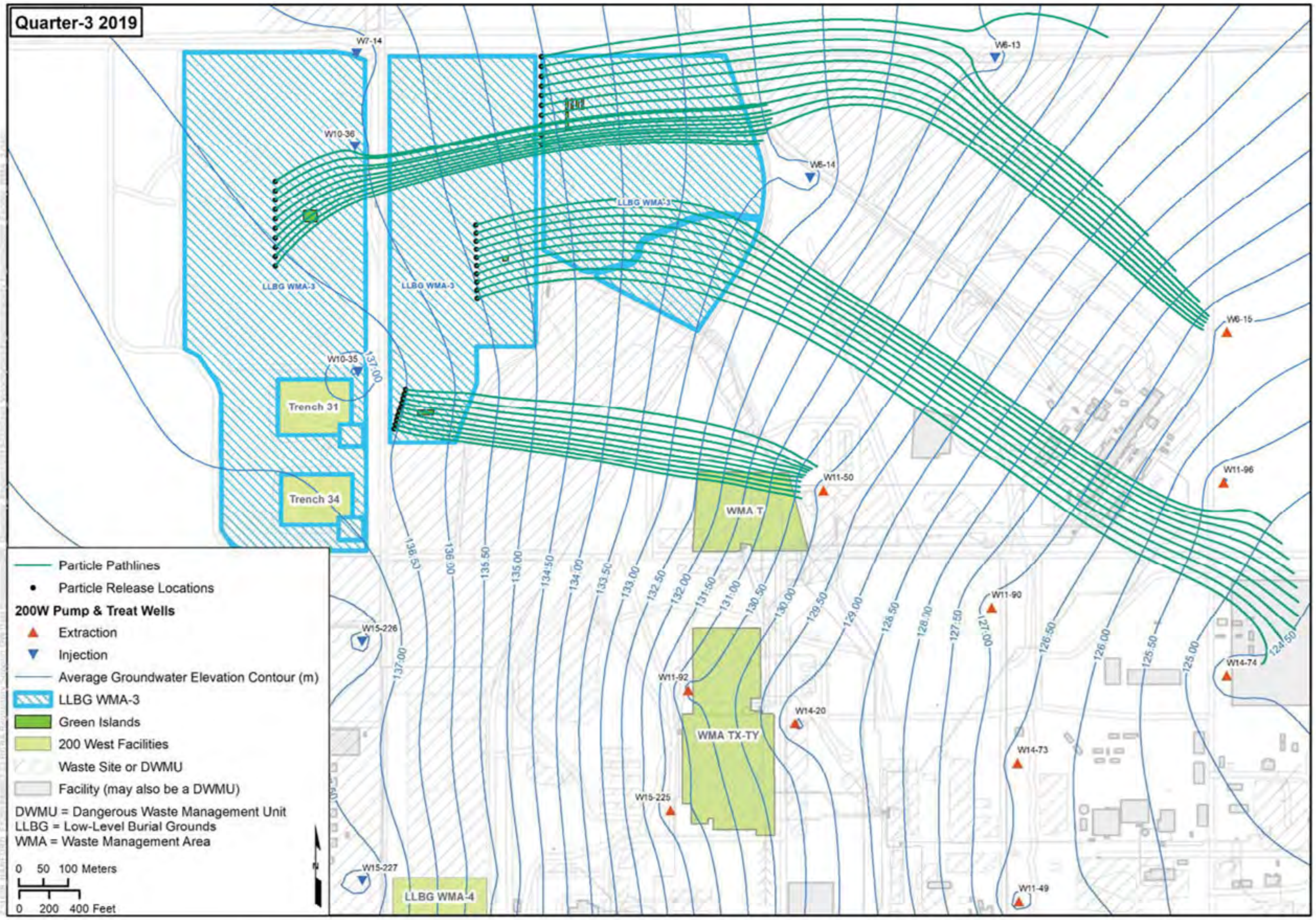

Figure 7-63. Calculated Particle Pathlines Representing General Groundwater Flow Directions at LLBG WMA-3 for the Third Quarter of 2019

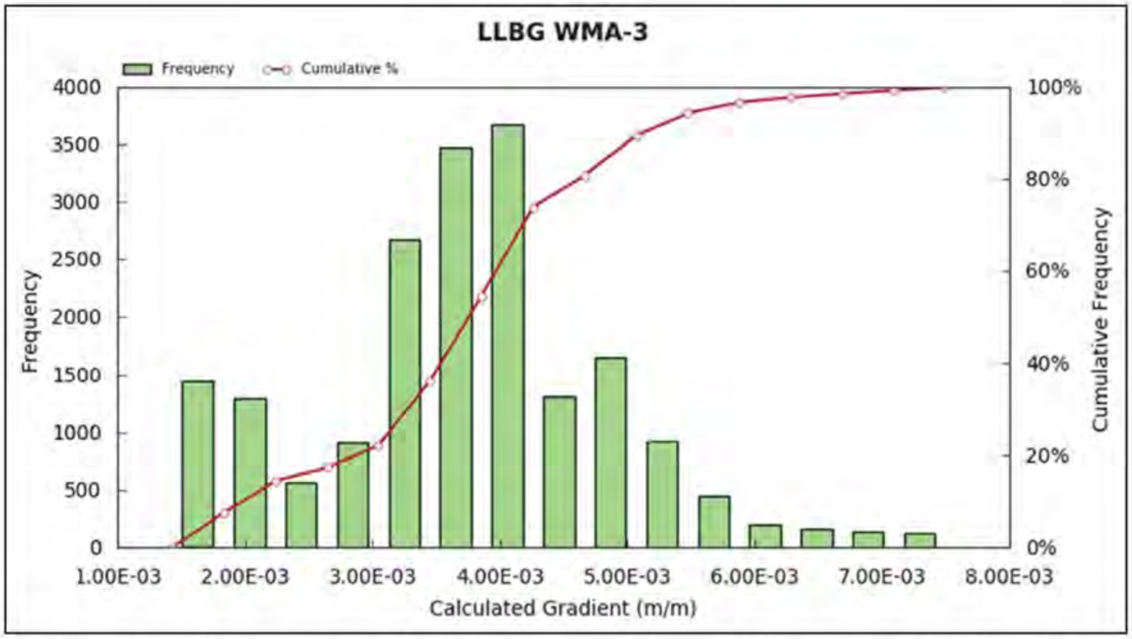

Figure 7-64. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at LLBG WMA-3 for the Third Quarter of 2019

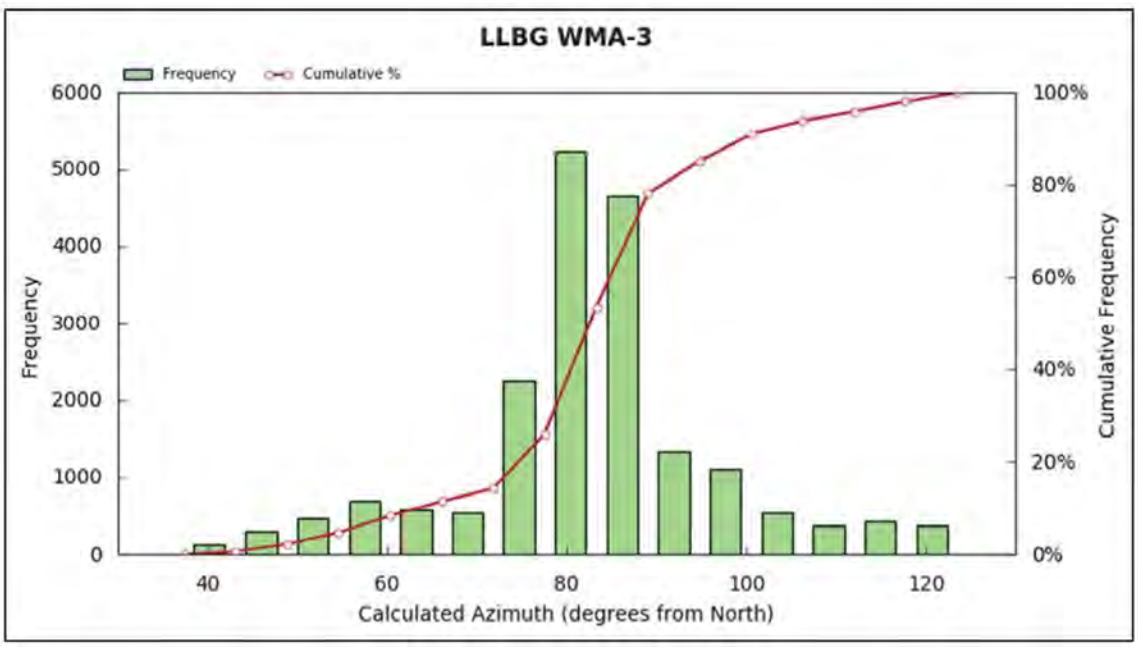

Figure 7-65. Histogram Plot of Calculated Hydraulic Gradient Azimuths at LLBG WMA-3 for the Third Quarter of 2019

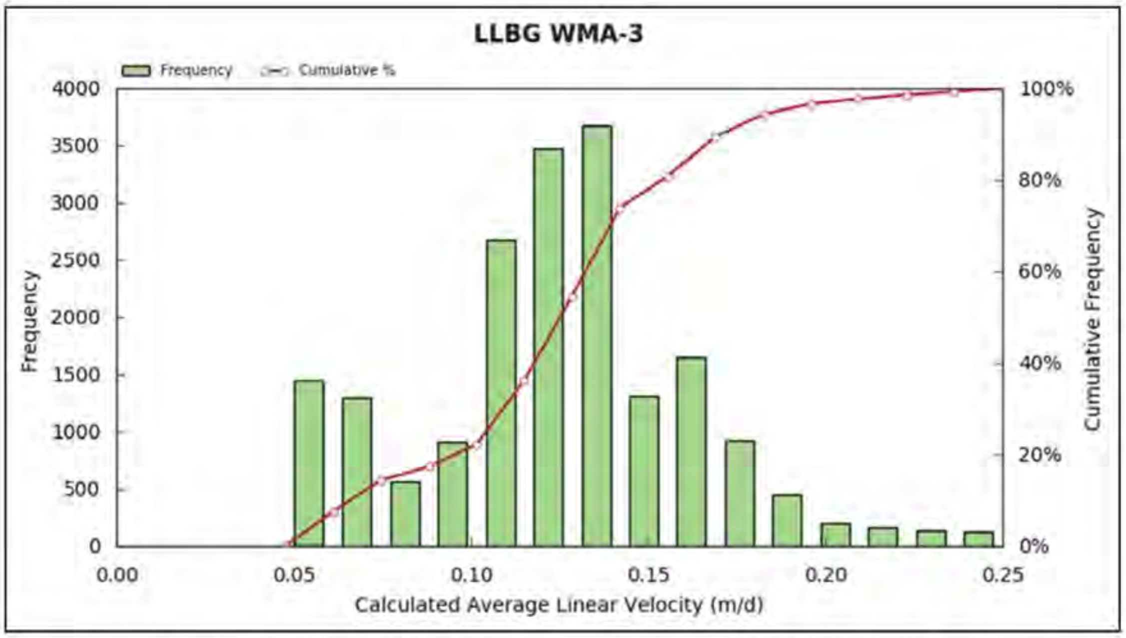

Figure 7-66. Histogram Plot of Calculated Average Linear Velocities at LLBG WMA-3 for the Third Quarter of 2019

7.2.4 Low-Level Burial Grounds Waste Management Area-4

Figure 7-67 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at LLBG WMA-4. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at LLBG WMA-4 are presented in Figures 7-68 through 7-70.

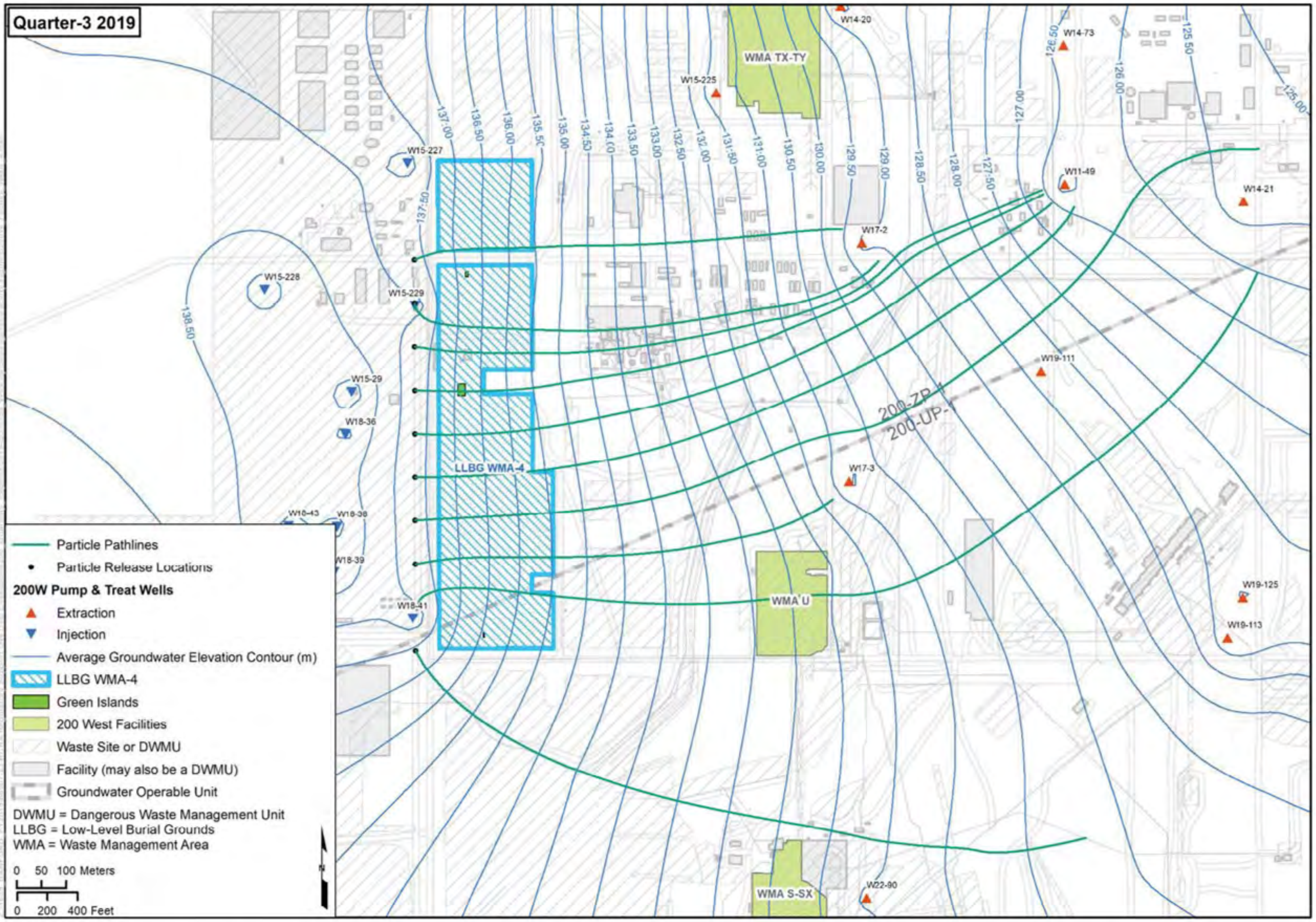

Figure 7-67. Calculated Particle Pathlines Representing General Groundwater Flow Directions at LLBG WMA-4 for the Third Quarter of 2019

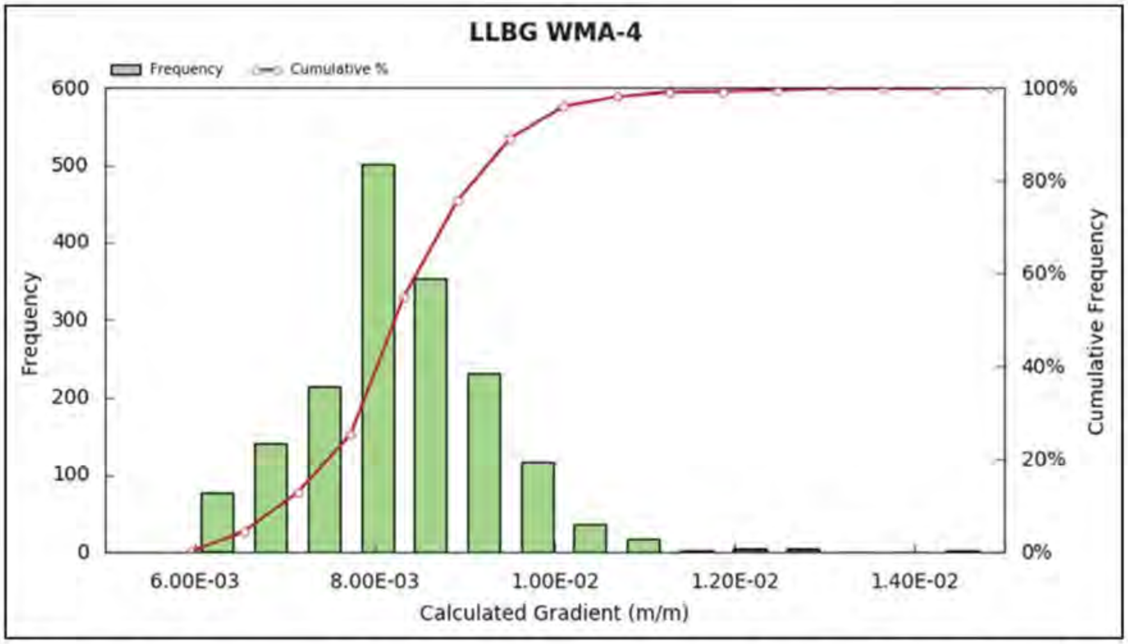

Figure 7-68. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at LLBG WMA-4 for the Third Quarter of 2019

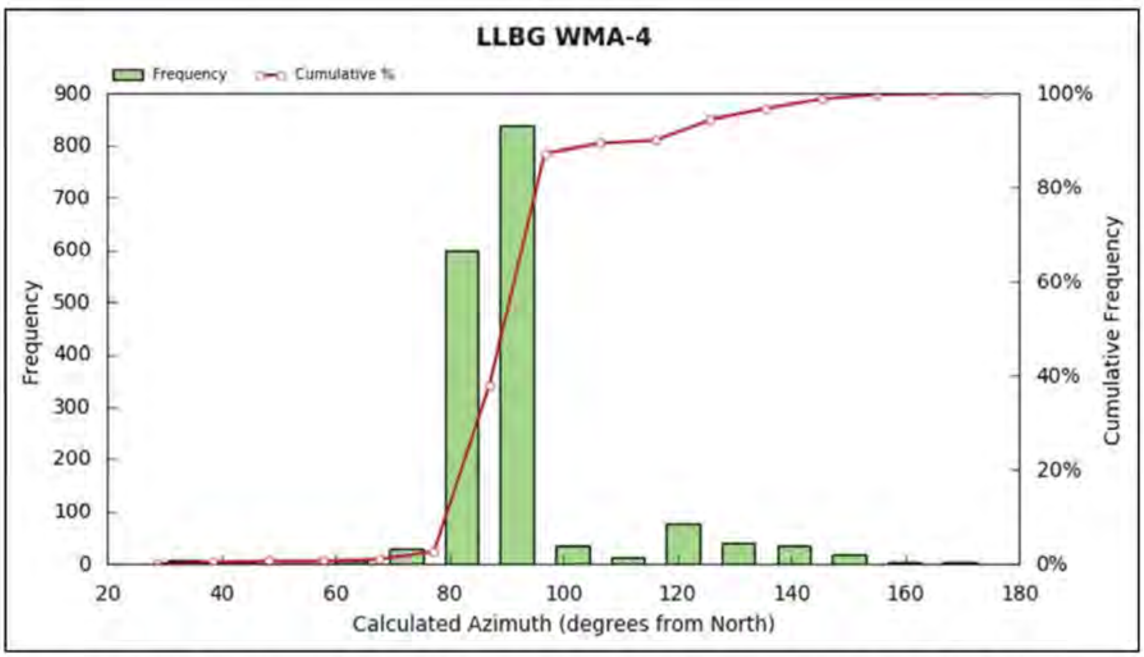

Figure 7-69. Histogram Plot of Calculated Hydraulic Gradient Azimuths at LLBG WMA-4 for the Third Quarter of 2019

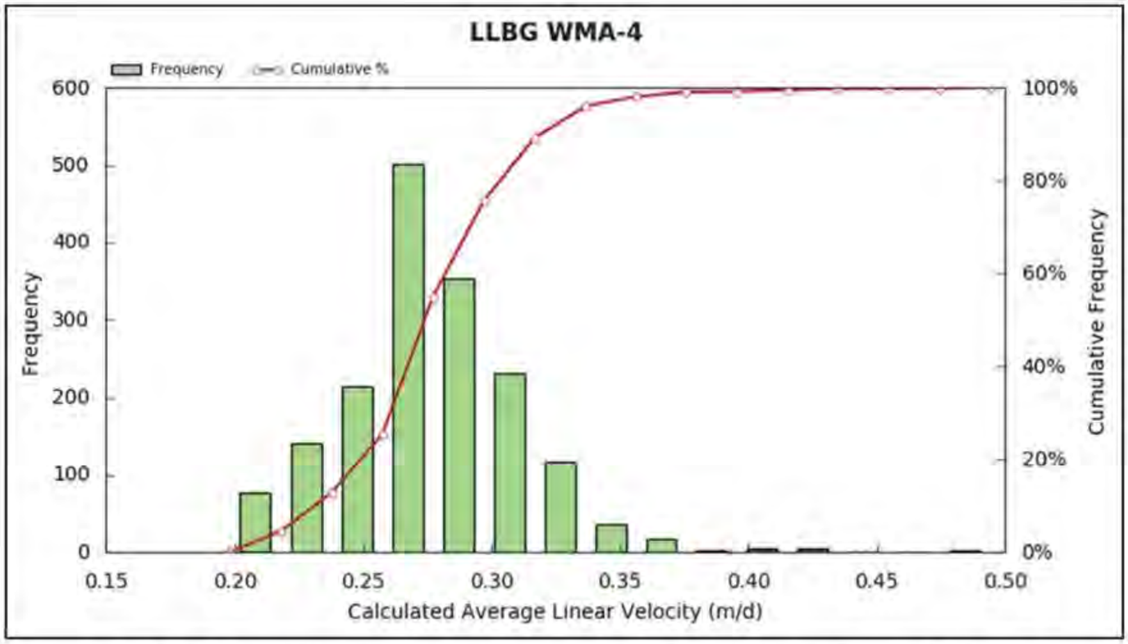

Figure 7-70. Histogram Plot of Calculated Average Linear Velocities at LLBG WMA-4 for the Third Quarter of 2019

7.2.5 Waste Management Area S-SX

Figure 7-71 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at WMA S-SX. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the WMA S-SX are presented in Figures 7-72 through 7-74.

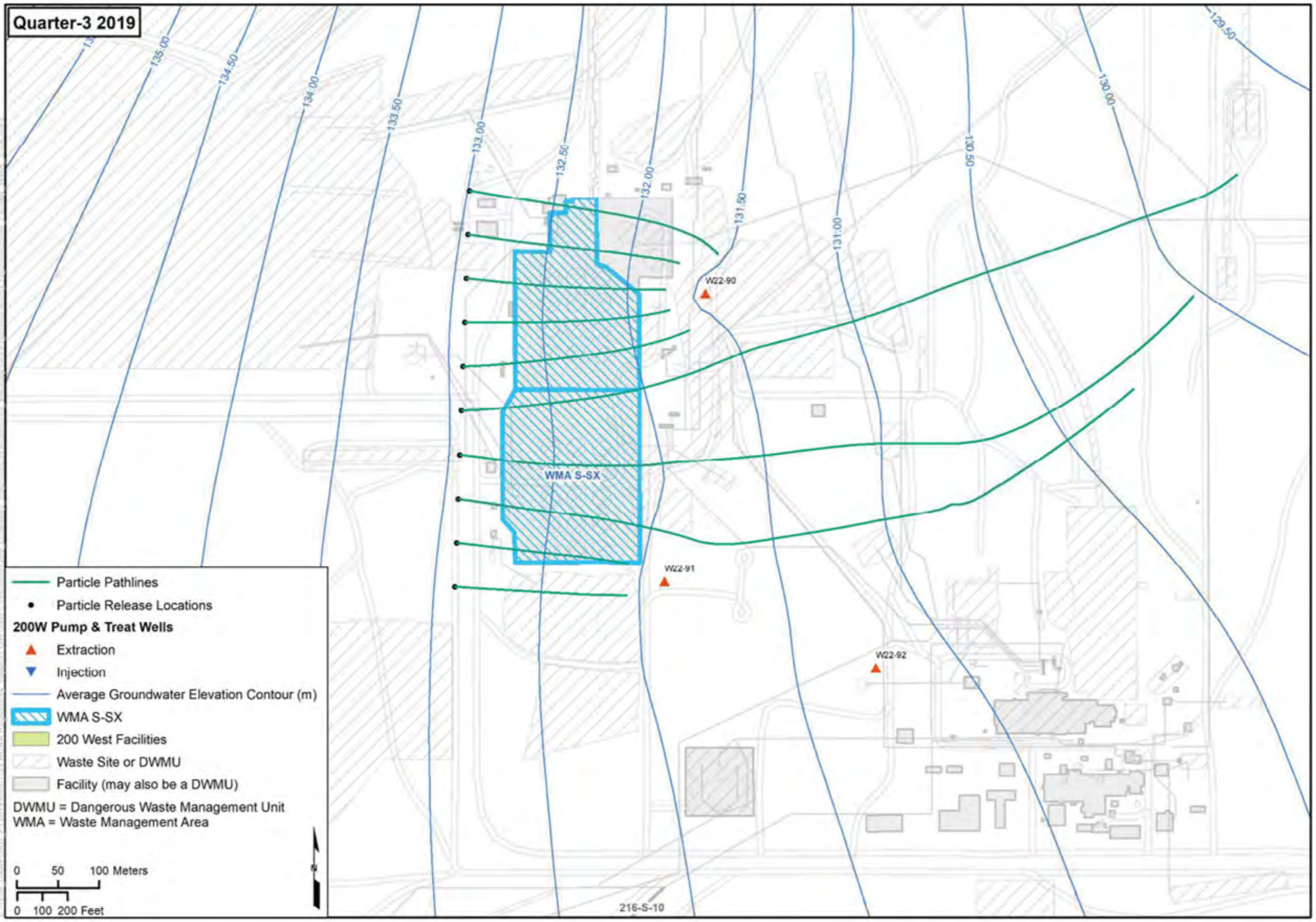

Figure 7-71. Calculated Particle Pathlines Representing General Groundwater Flow Directions at WMA S-SX for the Third Quarter of 2019

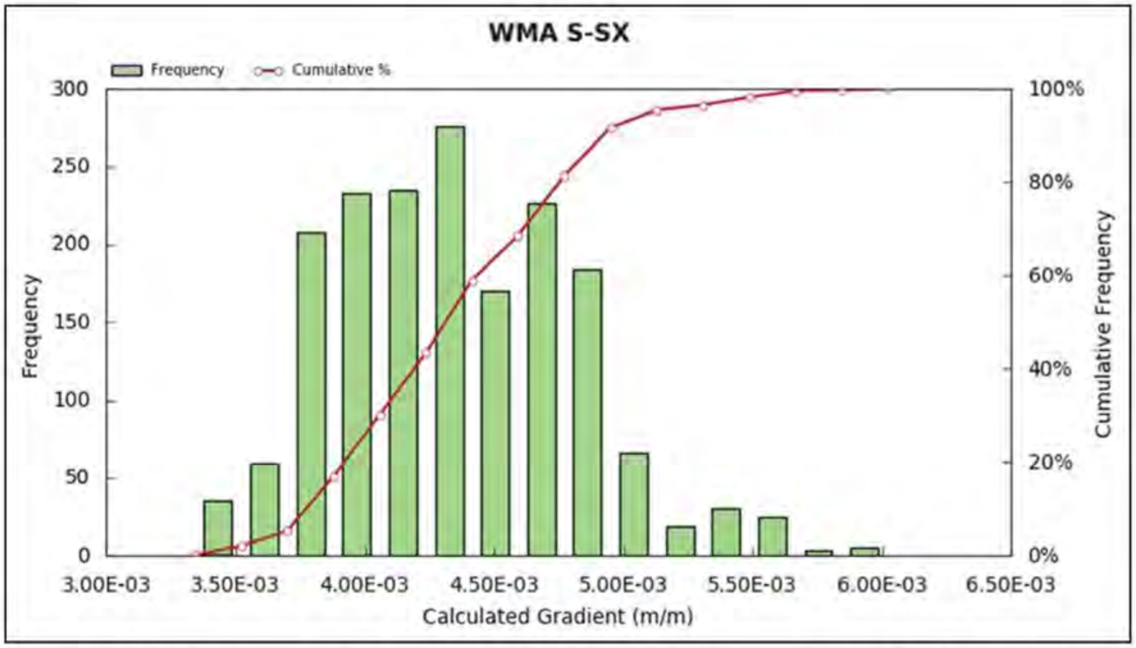

Figure 7-72. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at WMA S-SX for the Third Quarter of 2019

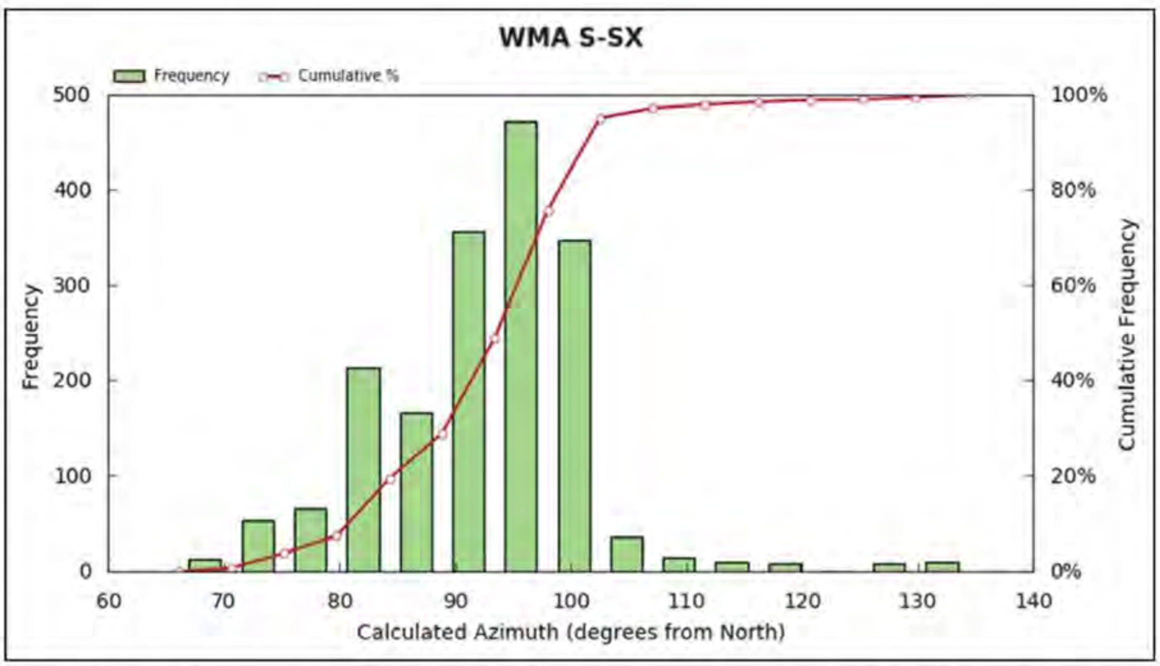

Figure 7-73. Histogram Plot of Calculated Hydraulic Gradient Azimuths at WMA S-SX for the Third Quarter of 2019

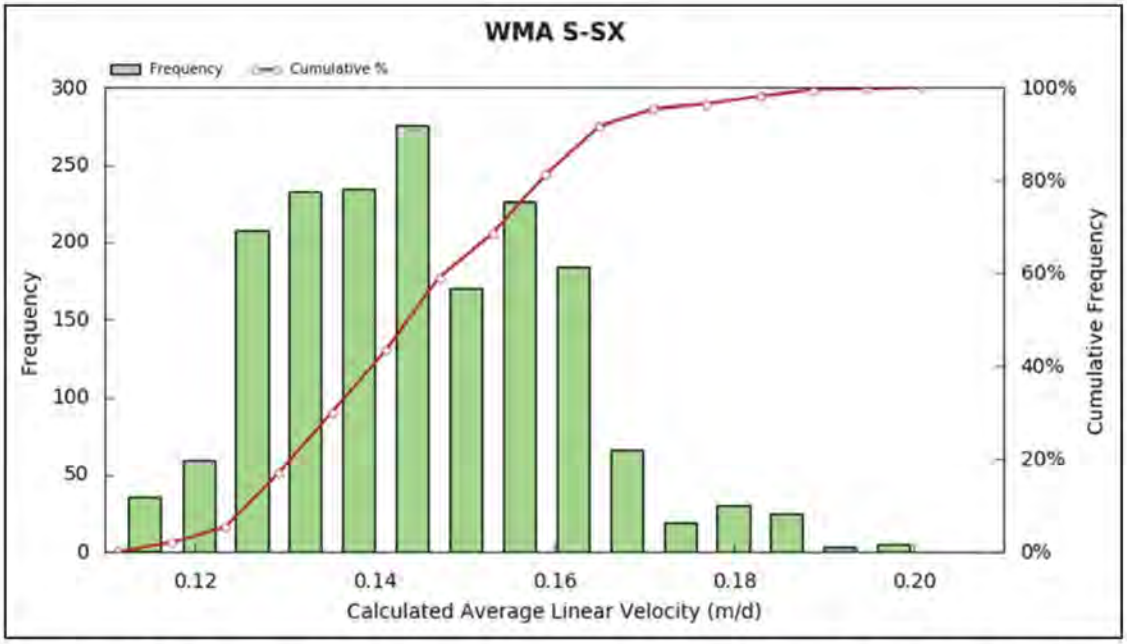

Figure 7-74. Histogram Plot of Calculated Average Linear Velocities at WMA S-SX for the Third Quarter of 2019

7.2.6 Waste Management Area T

Figure 7-75 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at WMA T. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at WMA T are presented in Figures 7-76 through 7-78.

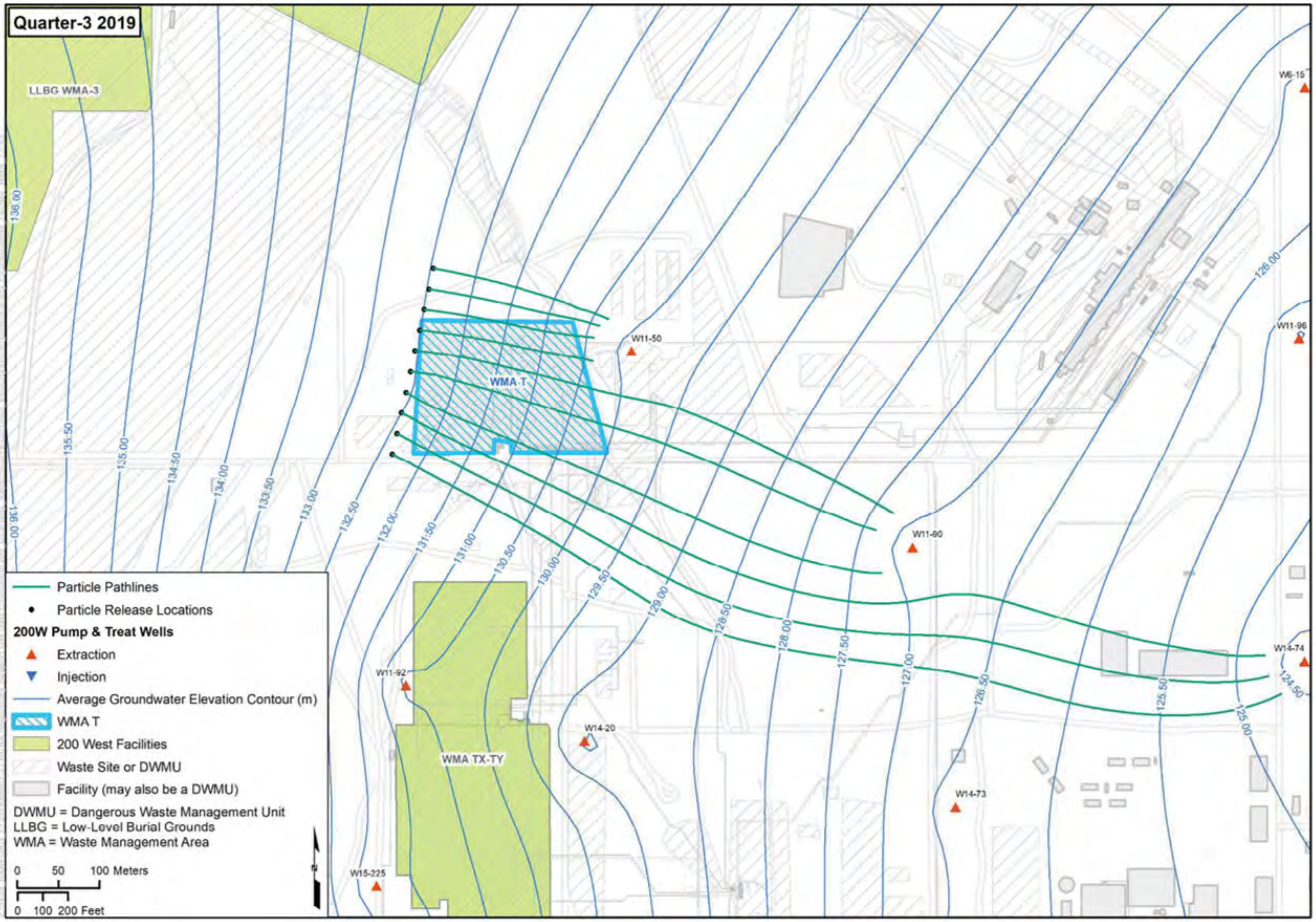

Figure 7-75. Calculated Particle Pathlines Representing General Groundwater Flow Directions at WMA T for the Third Quarter of 2019

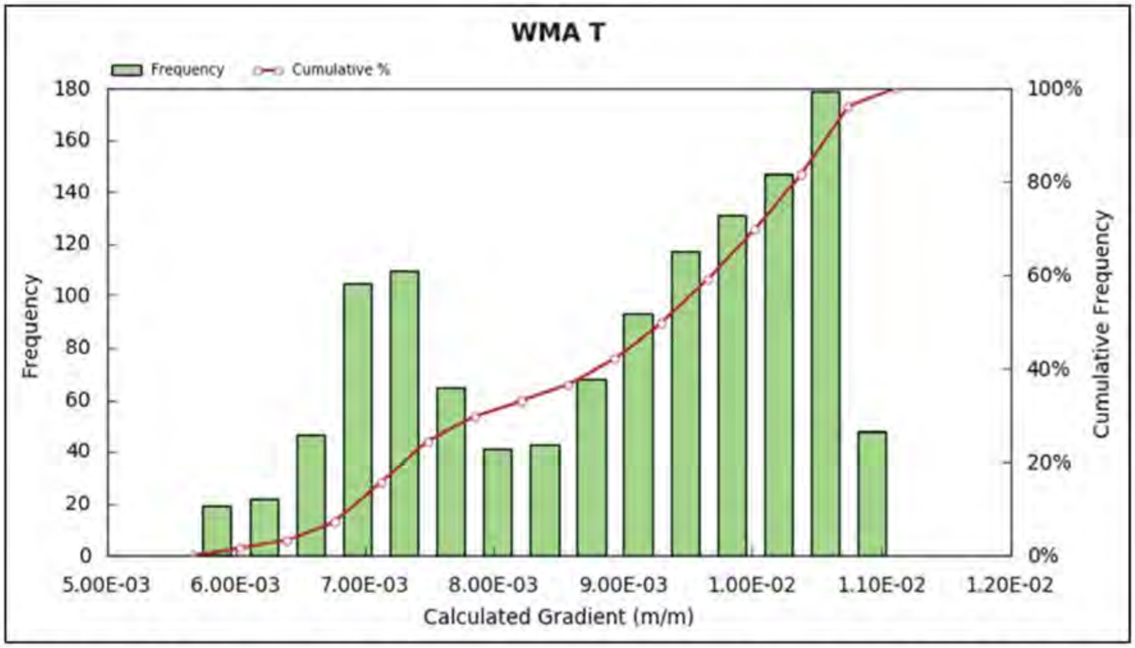

Figure 7-76. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at WMA T for the Third Quarter of 2019

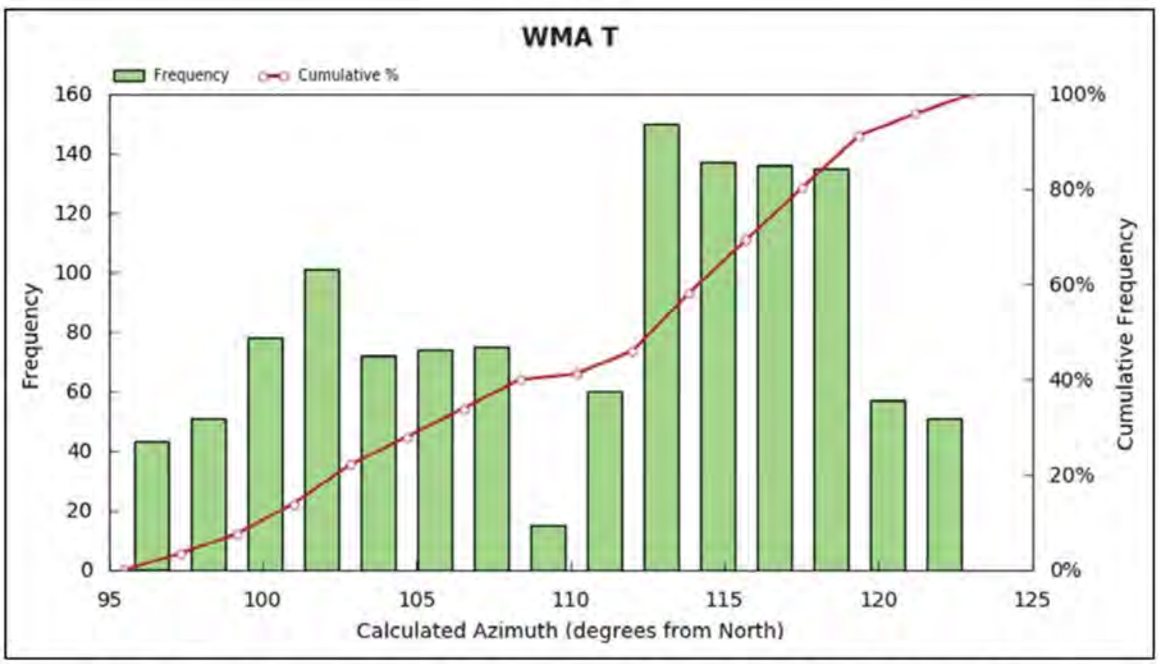

Figure 7-77. Histogram Plot of Calculated Hydraulic Gradient Azimuths at WMA T for the Third Quarter of 2019

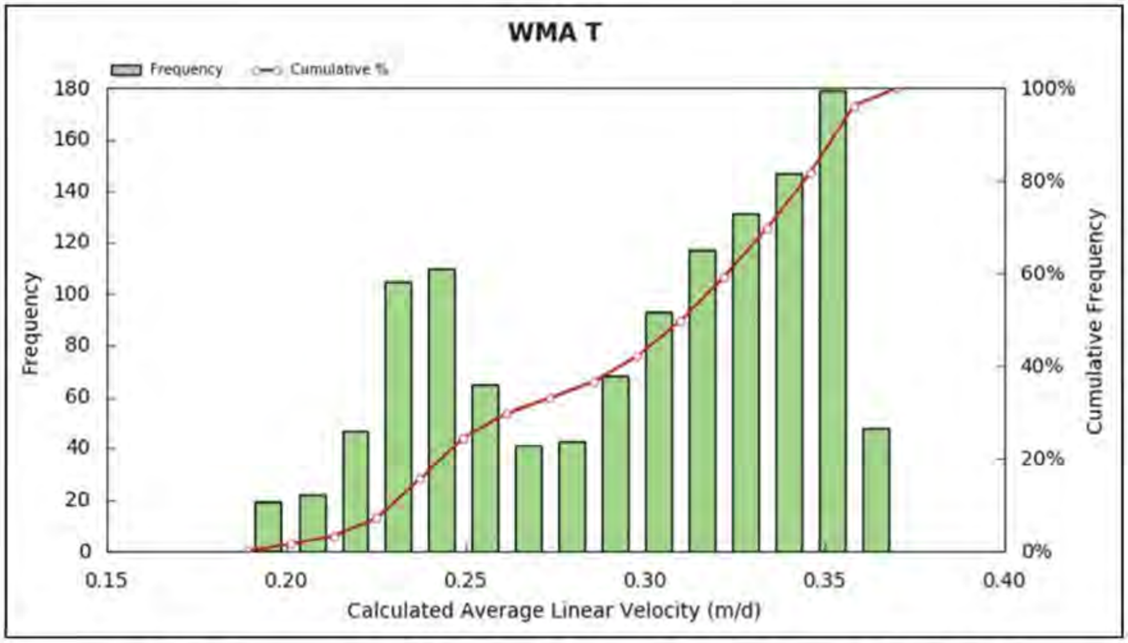

Figure 7-78. Histogram Plot of Calculated Average Linear Velocities at WMA T for the Third Quarter of 2019

7.2.7 Waste Management Area TX-TY

Figure 7-79 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at WMA TX-TY. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at WMA TX-TY are presented in Figures 7-80 through 7-82.

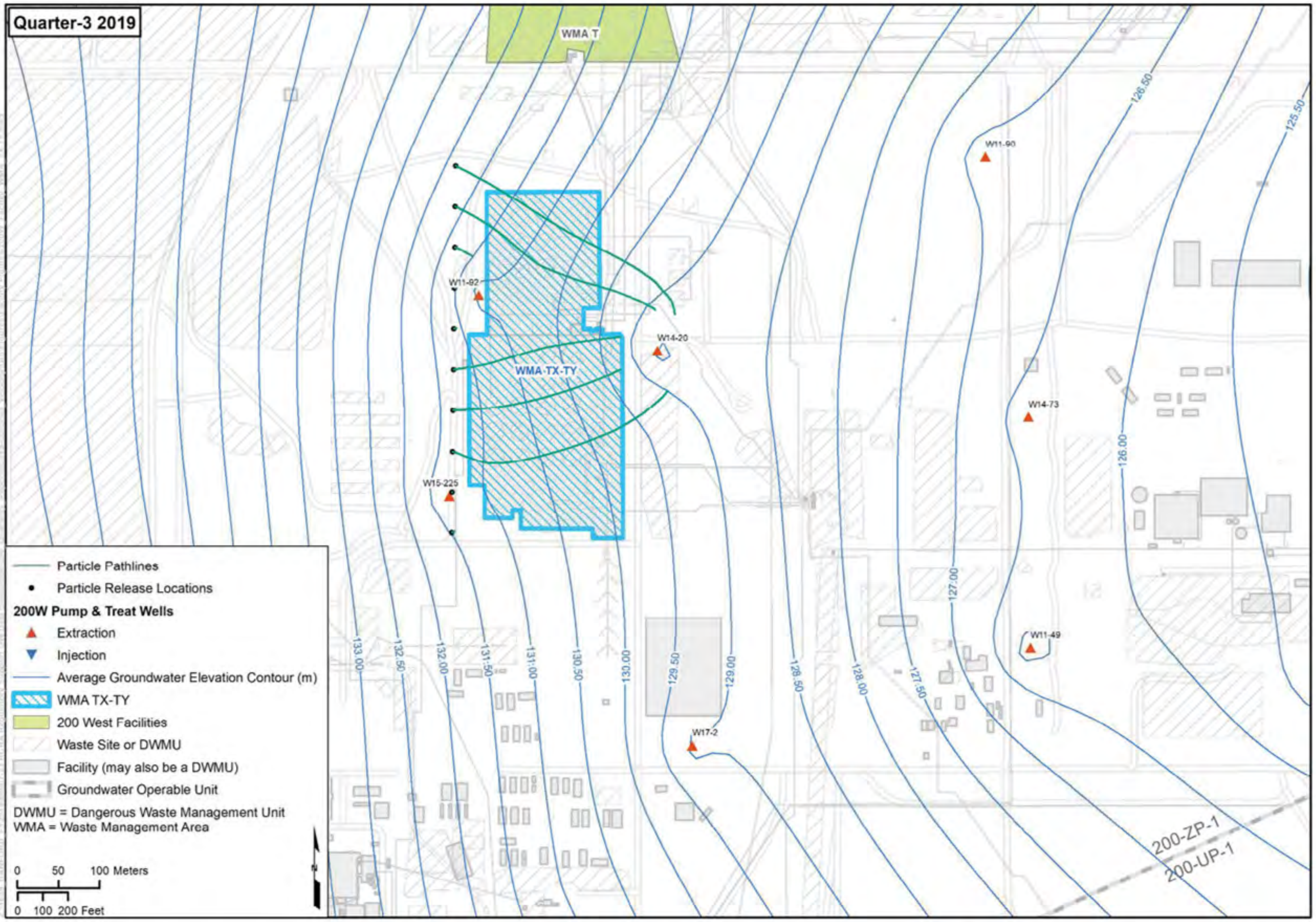

Figure 7-79. Calculated Particle Pathlines Representing General Groundwater Flow Directions at WMA TX-TY for the Third Quarter of 2019

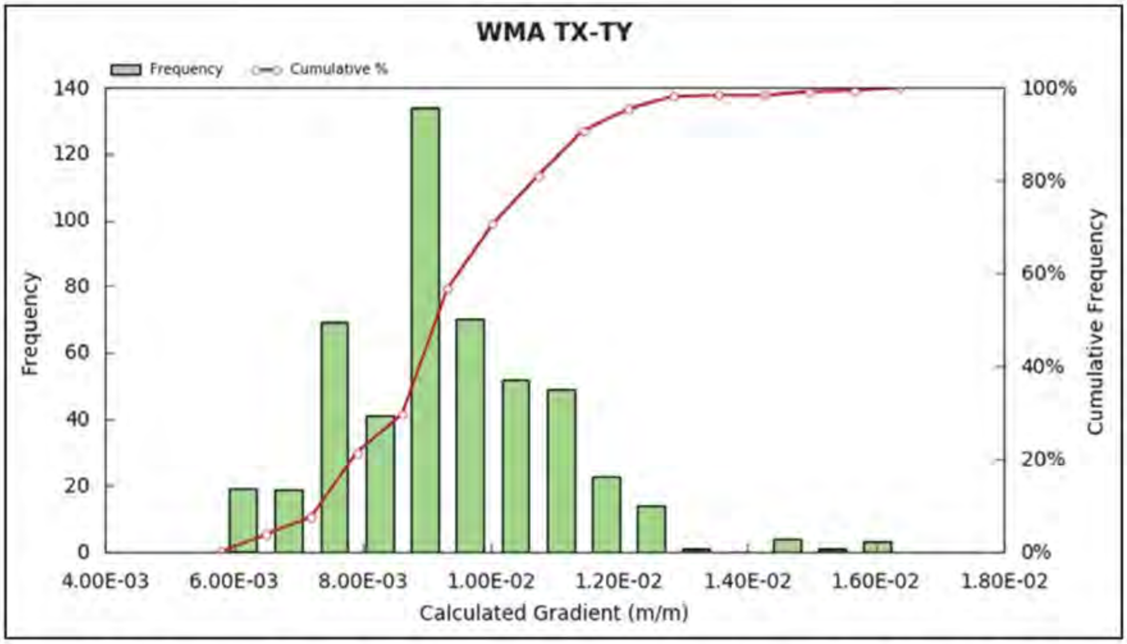

Figure 7-80. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at WMA TX-TY for the Third Quarter of 2019

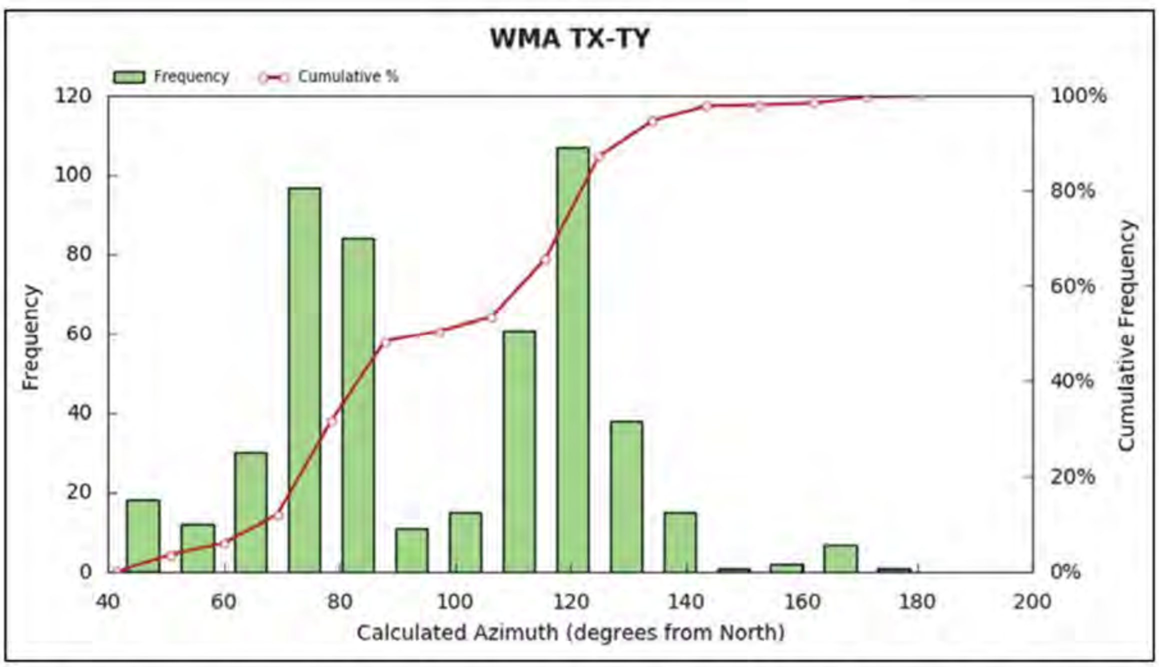

Figure 7-81. Histogram Plot of Calculated Hydraulic Gradient Azimuths at WMA TX-TY for the Third Quarter of 2019

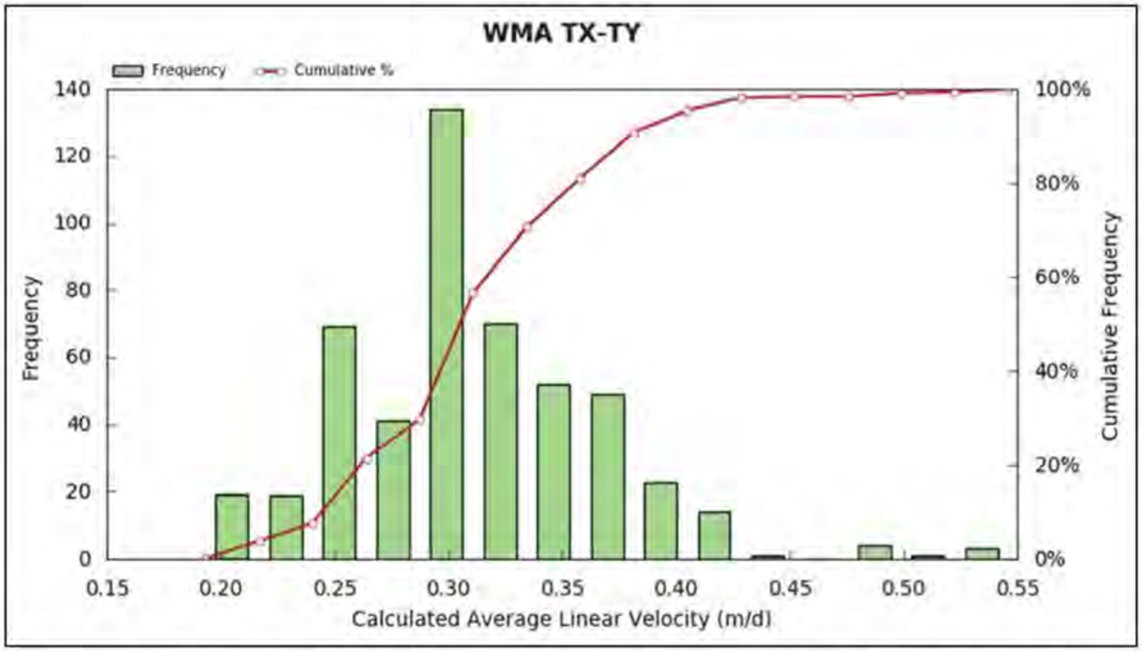

Figure 7-82. Histogram Plot of Calculated Average Linear Velocities at WMA TX-TY for the Third Quarter of 2019

7.2.8 Waste Management Area U

Figure 7-83 shows the calculated particle pathlines representing the general groundwater flow direction for the third quarter of 2019 at WMA U. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at WMA U are presented in Figures 7-84 through 7-86.

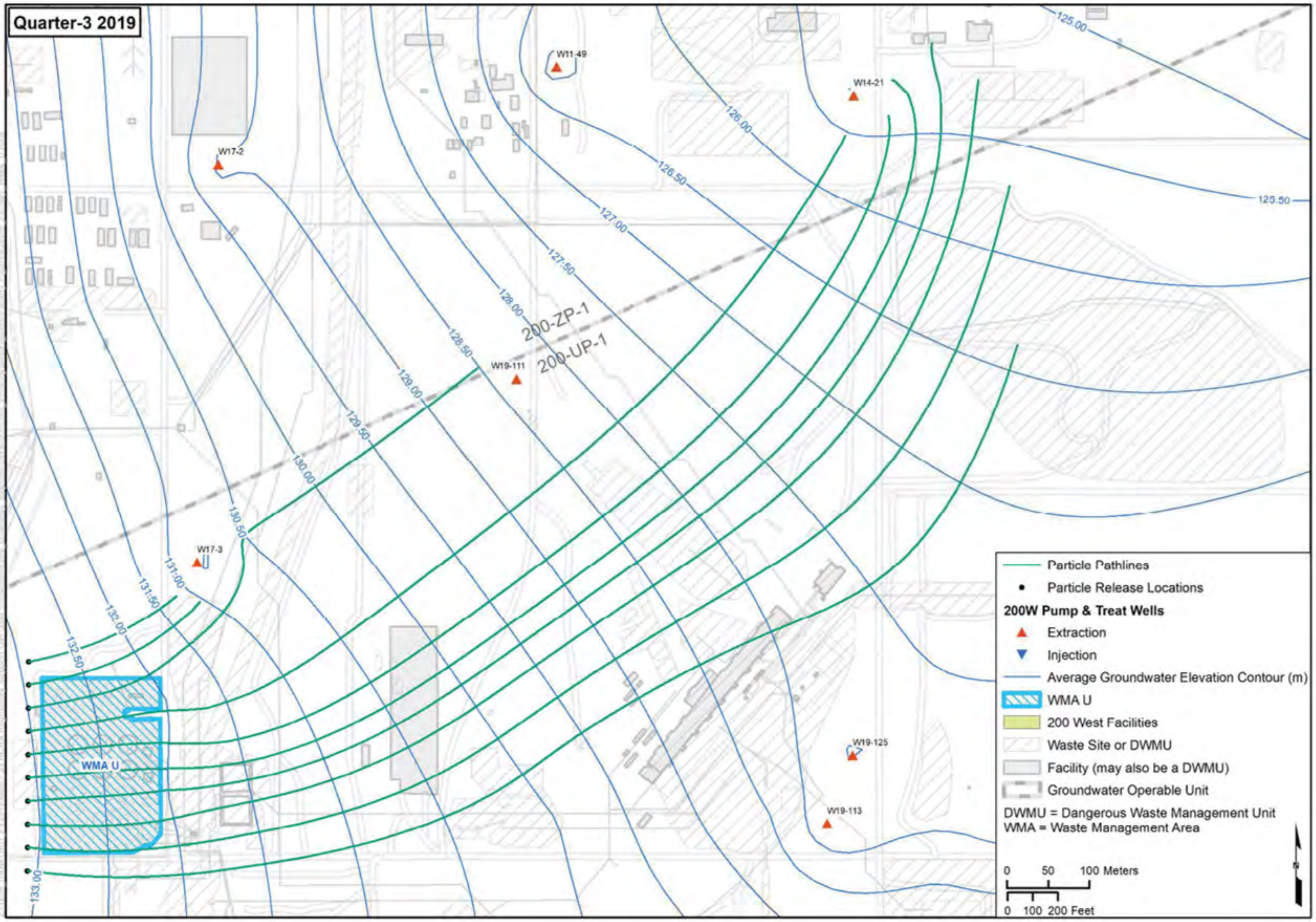

Figure 7-83. Calculated Particle Pathlines Representing General Groundwater Flow Directions at WMA U for the Third Quarter of 2019

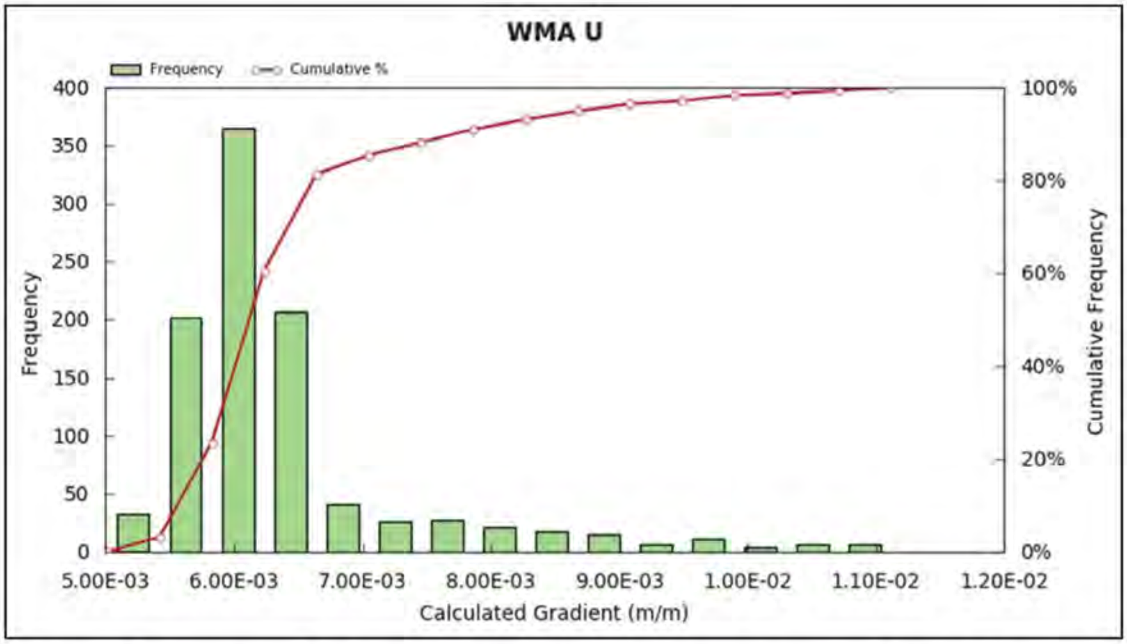

Figure 7-84. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at WMA U for the Third Quarter of 2019

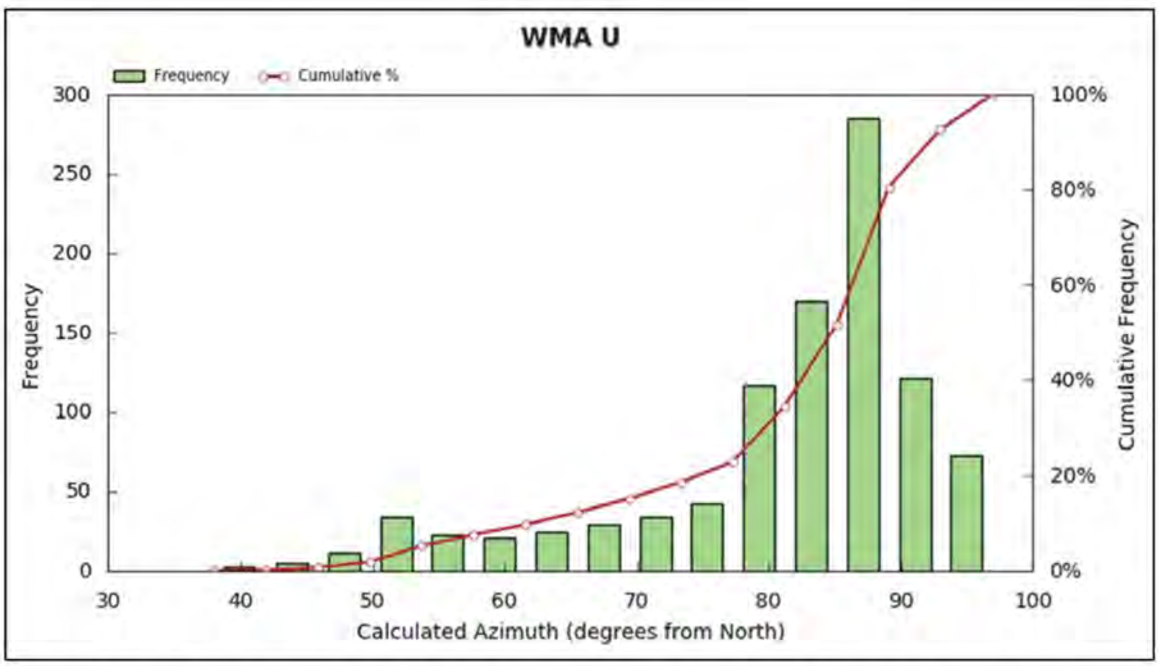

Figure 7-85. Histogram Plot of Calculated Hydraulic Gradient Azimuths at WMA U for the Third Quarter of 2019

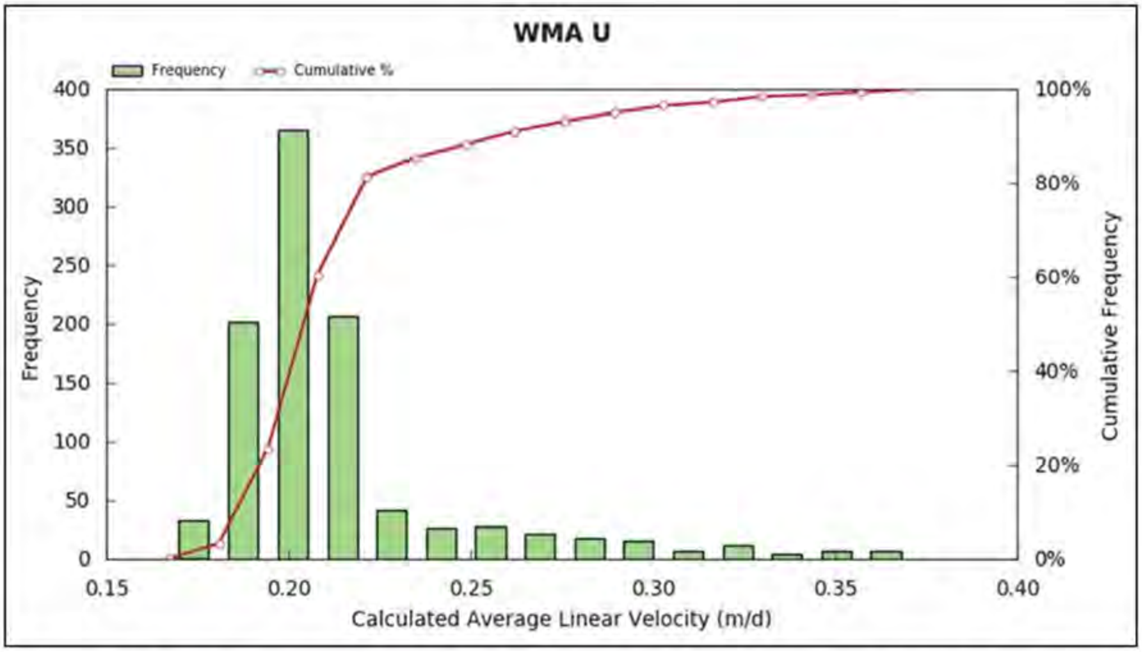

Figure 7-86. Histogram Plot of Calculated Average Linear Velocities at WMA U for the Third Quarter of 2019

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