CP-64995
Revision 0

Model Package Report: Geoframework Model of the Hanford Site 100 Area

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

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

CP-64995
Revision 0

Model Package Report: Geoframework Model of the Hanford Site 100 Area

Document Type: RPT

S. Springer
CH2M HILL Plateau Remediation Company

Date Published
August 2020

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

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company
P.O. Box 1600
Richland, Washington 99352

APPROVED
By Julia Raymer at 8:36 am, Sep 08, 2020

Release Approval Date

Approved for Public Release;
Further Dissemination Unlimited

TRADEMARK DISCLAIMER

Reference herein to any specific commercial product, process, or service by tradename, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

This report has been reproduced from the best available copy.

Printed in the United States of America

CH2M HILL Plateau Remediation Company

ENVIRONMENTAL MODEL PACKAGE REPORT COVER PAGE

SECTION 1 - Completed by Responsible Manager

Project:
Remedial Decision Support

Date:
08/05/2020

Environmental Model Name and Version:
100 Area Geoframework Version 6.0

RELEASE/ISSUE

DATE: Sep 08, 2020 HANFORD RELEASE

SECTION 2 - Completed by Preparer

Document No.: CP-64995

Revision No.: 0

Revision History

Revision No.	Description	Date	Affected Pages
0	Initial issue		All

SECTION 3 - Completed by Responsible Manager

Document Control	Yes	No
1. Is document intended to be controlled within the Document Management Control System (DMCS)?	☒	☐
2. Does document contain scientific and technical information intended for public use?	☒	☐
3. Does document contain controlled-use information?	☐	☒

SECTION 4 - Training and Software Installation Approval *(Completed Prior to Model Implementation)*

Modeler-Required Training Completed:

Training Coordinator:

Print First and Last Name	Position	Signature	Date
William Nichols	Modeling Team Leader	Per Electronic Approval (attached)	

Implementation Software Installation and Checkout Certified:

Modeling Integration Lead:

Print First and Last Name	Position	Signature	Date
William Nichols	Modeling Team Leader	Per Electronic Approval (attached)	

SECTION 5 - Document Review & Approval

Model Developer:

Print First and Last Name	Position	Signature	Date
Sarah Springer	Senior Geologist	SARAH SPRINGER (Affiliate)	Digitally signed by SARAH SPRINGER (Affiliate) Date: 2020.09.03 10:51:59 -07'00'

Model Checker:

Print First and Last Name	Position	Signature	Date
Clark Griffith	Hydrogeologist	Per Electronic Approval (attached)	

Model Senior Reviewer:

Print First and Last Name	Position	Signature	Date
Terry Tolan	Senior Hydrogeologist	Per Electronic Approval (attached)	

A-6007-637 (REV 0)

Springer, Sarah D

From: PRC SharePoint <no-reply@sharepointonline.com>
Sent: Monday, August 10, 2020 8:53 AM
To: Springer, Sarah D
Cc: Springer, Sarah D
Subject: Electronic Approval has completed for document: CP-64995-R0_combined.

Electronic Approval has completed for document: CP-64995-R0_combined.

Please include this email as the Electronic Approval page.

Electronic Approval for document: CP-64995-R0_combined has successfully COMPLETED.

Electronic Approval started by Springer, Sarah D on 8/7/2020 11:12 AM
Comment: Good Afternoon,
I am requesting your electronic approval of the 100-Area Geoframework Model Package Report. Your approval will be integrated into the MPR cover page and Administrative Document Processing and Approval sheet. I appreciate your review, thank you.
Sarah Springer

Approved by Nichols, William E on 8/10/2020 6:31 AM
Comment:

Approved by Aly, Alaa H on 8/10/2020 8:53 AM
Comment:

Springer, Sarah D

From: Clark Griffith <cgriffith@intera.com>
Sent: Monday, August 10, 2020 2:06 PM
To: Springer, Sarah D; Terry Tolan
Subject: RE: Electronic Approval has completed for document: CP-64995-R0_combined.

Approved.

Clark Griffith, PG | INTERA Inc. | 512.425.2091

From: Springer, Sarah D <sarah_d_springer@rl.gov>
Sent: Monday, August 10, 2020 11:30 AM
To: Clark Griffith <cgriffith@intera.com>; Terry Tolan <TTolan@intera.com>
Subject: FW: Electronic Approval has completed for document: CP-64995-R0_combined.

From: PRC SharePoint <no-reply@sharepointonline.com>
Sent: Monday, August 10, 2020 8:53 AM
To: Springer, Sarah D <sarah_d_springer@rl.gov>
Cc: Springer, Sarah D <sarah_d_springer@rl.gov>
Subject: Electronic Approval has completed for document: CP-64995-R0_combined.

Electronic Approval has completed for document: CP-64995-R0_combined.

Please include this email as the Electronic Approval page.

Electronic Approval for document: CP-64995-R0_combined has successfully COMPLETED.

Electronic Approval started by Springer, Sarah D on 8/7/2020 11:12 AM
Comment: Good Afternoon,
I am requesting your electronic approval of the 100-Area Geoframework Model Package Report. Your approval will be integrated into the MPR cover page and Administrative Document Processing and Approval sheet. I appreciate your review, thank you.
Sarah Springer

Approved by Nichols, William E on 8/10/2020 6:31 AM
Comment:

Approved by Aly, Alaa H on 8/10/2020 8:53 AM
Comment:

Springer, Sarah D

From: Terry Tolan <TTolan@intera.com>
Sent: Monday, August 10, 2020 9:34 AM
To: Springer, Sarah D
Subject: RE: Electronic Approval has completed for document: CP-64995-R0_combined.

Approved

Terry Tolan, RG, LHG, LEG
Senior Hydrogeologist
INTERA
GEOSCIENCE & ENGINEERING SOLUTIONS
3240 Richardson Road, Suite 2
Richland, Washington 99354
Office: (509) 946-9898 ext. 1226
Mobile: (509) 378-9215

From: Springer, Sarah D <sarah_d_springer@rl.gov>
Sent: Monday, August 10, 2020 9:30 AM
To: Clark Griffith <cgriffith@intera.com>; Terry Tolan <TTolan@intera.com>
Subject: FW: Electronic Approval has completed for document: CP-64995-R0_combined.

From: PRC SharePoint <no-reply@sharepointonline.com>
Sent: Monday, August 10, 2020 8:53 AM
To: Springer, Sarah D <sarah_d_springer@rl.gov>
Cc: Springer, Sarah D <sarah_d_springer@rl.gov>
Subject: Electronic Approval has completed for document: CP-64995-R0_combined.

Electronic Approval has completed for document: CP-64995-R0_combined.

Please include this email as the Electronic Approval page.

Electronic Approval for document: CP-64995-R0_combined has successfully COMPLETED.

Electronic Approval started by Springer, Sarah D on 8/7/2020 11:12 AM
Comment: Good Afternoon,
I am requesting your electronic approval of the 100-Area Geoframework Model Package Report. Your approval will be integrated into the MPR cover page and Administrative Document Processing and Approval sheet. I appreciate your review, thank you.
Sarah Springer

Approved by Nichols, William E on 8/10/2020 6:31 AM
Comment:

Approved by Aly, Alaa H on 8/10/2020 8:53 AM
Comment:

Model Package Report

Geoframework Model
of the Hanford Site 100 Area

Version 6

May 2020

Prepared for:

Remedial Decision Support

Prepared by:

Sarah Springer (CH2M HILL Plateau Remediation Company)
Sarah Wigginton (Intera Incorporated)

This page intentionally left blank.

Executive Summary

The purpose of the 100 Area Geoframework Model (GFM) is to provide a reasonable, consistent, and defensible three dimensional representation of the hydrostratigraphic units below the River Corridor at the Hanford Site to support contaminant fate and transport models. The GFM is a three dimensional representation of the subsurface geologic structure. From this, three dimensional geologic model-exported results, in the form of points or surfaces, are used as inputs to populate and assemble the various numerical model architectures. The objective of this report is to define the process used to produce a hydrostratigraphic model for the hydrostratigraphic units beneath the Hanford Site 100 Area. The GFM may support several other CH2M HILL Plateau Remediation Company project needs and objectives, including providing geologic information to support remedial investigations and actions and as a tool to present River Corridor geology and contaminant extents. The GFM was constructed based on information through 2019 available in the Integrated Data Management System, Hanford Environmental Information System, and the Hanford Site geologic contacts (GeoContacts) datasets. Revisions to the 100 Area GFM may occur to incorporate new data and information. Each version will be maintained in configuration control using date stamps for identifying supporting databases, figures, and interpretations. Supporting data include the final three dimensional geoframework surfaces, two dimensional structure and isopach maps, and all the geologic contact inputs and interpreted geologic log data. These final products provide a supporting set of geologic information that together allow the creation of the GFM. This information is managed, updated, and maintained via CH2M HILL Plateau Remediation Company under the Environmental Model Management Archive.

This page intentionally left blank.

Contents

1 Purpose 1

1.1 Modeling Need 1

1.2 Background 1

1.3 Document Organization 5

2 Geoframework Model Objectives 6

3 Geoframework Model Technical Approach 6

3.1 Features, Events, and Processes 7

3.2 Defining the Stratigraphy and Interpreting the 100 Area Hydrostratigraphic Units 7

3.2.1 Interpreting Hydrostratigraphic Unit Contacts 8

3.3 Model Validation 11

3.3.1 Data Acquisition 11

3.3.2 Goodness of Fit 11

4 Model Implementation 13

4.1 Software 13

4.1.1 Kingdom Documentation 13

4.1.2 ArcMap Documentation 14

4.2 Model Inputs and Boundaries 14

4.2.1 100 Area GFM Domain 14

4.2.2 Topography and Bathymetry 16

4.2.3 Top of the Columbia River Basalt Group Surface 16

4.2.4 Borehole Data 17

4.2.5 Other Boundaries 18

4.2.6 Control Data 18

4.3 Kingdom Workflow and Model Methodology 22

4.3.1 Creating a Geoframework Model in Kingdom 22

5 Model Results and Uncertainty Analysis 29

5.1 Sensitivity Analysis 29

5.2 Uncertainty Analysis 29

5.3 Results 30

5.3.1 Geology Overview 30

5.3.2 Changes to the 100 Area GFM from Revision 5 to Version 6 32

5.3.3 Difference Maps 32

6 Model Limitations 36

7 Model Configuration Management 36

8 Data Needs 37

9 Model Recommendations 37

10 References 37

Appendices

Appendix A New Boreholes Added to Version 6 of the 100 Area Geoframework Model ..... A-i

Appendix B Boreholes Removed from Version 6 of the 100 Area Geoframework Model ..... B-i

Appendix C 100 Area Geoframework Model (Version 6) Top of Hydrostratigraphic Unit Structure and Isopach Maps ..... C-i

Appendix D Verification and Checking of the Grids in Version 6 of the 100 Area Geoframework Model ..... D-i

Appendix E Software Installation and Checkout Form for Kingdom-Geology ..... E-i

Appendix F Environmental Modeling Data Transmittal Cover Page for EMDT-GR-0039, *Geologic Contacts for the 100-Area Geoframework Model* ..... F-i

Figures

Figure 1. 100 Area Model Domain 2

Figure 2. Annotated Interpreted Borehole Logs for 199-K-230 9

Figure 3. Integrated Borehole Views for Boreholes 199-K-185, 199-K230, and 199-K-190 10

Figure 4. Grids for Each HSU Displayed Behind the Interpreted Stratigraphic Contacts 12

Figure 5. 100 Area GFM Boundary (Version 6) 15

Figure 6. Three Dimensional View of the 100 Area GFM (Version 6) Showing the Model Extent and Borehole Locations (in black) 17

Figure 7. 100 Area GFM (Version 6) Boundary and the RUM Surface Boundary Superimposed 19

Figure 8. Project Option Specifics in Kingdom 23

Figure 9. Project Coordinate System Options 23

Figure 10. Import Grid Dialogue Window in Kingdom 25

Figure 11. Kingdom's Dynamic Depth Conversion and Map Update Module for the 100 Area GFM 26

Figure 12. (A) Math on Two Maps Calculator to Create Final Surfaces (B) GFM Surfaces in Cross Section Before Running the CMAX Function (C) GFM surfaces in Cross Section After Running the CMAX Function 28

Figure 13. Cross Section from North to South Across the 100 Area GFM (Version 6) 31

Figure 14. Cross Section from North-West to South-East Across the 100 Area GFM (Version 6) 31

Figure 15. Map Showing Elevation Differences Between the Revision 5 Hanford HSU Surface and Version 6 Hf HSU Surface 33

Figure 16. Map Showing Elevation Differences Between the Revision 5 Rwie HSU Surface and Version 6 Rwie HSU Surface....34
Figure 17. Map Showing Elevation Differences Between the Revision 5 RUM HSU Surface and Version 6 RUM HSU Surface....35

Tables

Table 1. New Boreholes Added to the 100 Area GFM.... 3
Table 2. Control Points and Polyline Sets Added to the 100 Area GFM (Version 6)....20
Table 3. 100 Area GFM (Version 6) Layers....27

This page intentionally left blank.

Terms

CHPRC	CH2M HILL Plateau Remediation Company
ECF	environmental calculation file
EMDT	Environmental Data Modeling Transmittal
GFM	geoframework model
HEIS	Hanford Environmental Information System
Hf	Hanford formation
HSU	hydrostratigraphic unit
IDMS	Information Data Management System
LiDAR	Light Detection and Ranging
MPR	model package report
OU	operable unit
RUM	Ringold Formation Upper Mud Unit
Rwie	Ringold Formation member of Wooded Island — unit E

This page intentionally left blank.

1 Purpose

This model package report (MPR) provides background and details for the process used in constructing a three dimensional geoframework model (GFM) of the River Corridor (100 Area) at the Hanford Site. IHS Kingdom Geology Suite 2016® software (hereinafter referred to as Kingdom) is a geological interpretation software package that uses geologic data to provide a spatial representation of the subsurface (GFM). GFMs can be used during many stages of project development requiring hydrogeologic evaluations to enhance and improve site characterization, conceptual model development, inputs to other modeling efforts, remedial process evaluations, and remedial action decisions.

The objective of the 100 Area GFM is to provide an accurate representation of the subsurface hydrogeologic environment beneath contaminated waste disposal facilities to support other modeling needs (i.e., contaminant fate and transport), to make informed remedial action decisions, and as an educational tool for presenting complex hydrogeologic concepts and associations to the public.

1.1 Modeling Need

The 100 Area GFM model is considered a regional scale GFM model and provides geologic detail appropriate for the scale of this model. Refined GFMs consisting of smaller extents are often required for supporting project-specific work scope in more localized areas typically defined by the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* operable unit (OU) boundaries. To meet the specific needs of scientists and project managers, we have created smaller GFM domains ("sub models") with greater spatial detail and higher resolution in select areas of interest within the larger 100 Area GFM boundary. To maintain GFM consistency and transparency, the smaller-area GFMs are created by making a copy of the larger regional scale 100 Area GFM in the same workspace and changing/trimming the model extents to define a smaller area domain. Spatial detail and resolution are increased during this process. Currently smaller, project-specific GFMs are available for the 100-K, 100-N, and 100-D/H Areas. For user access purposes, the smaller domain GFMs are maintained with the larger GFMs used to create them but are not necessarily up-to-date with this current 100 Area GFM (Version 6).

1.2 Background

The 100 Area GFM domain encompasses the areas of the Hanford Site north of Gable Mountain and Gable Butte up to the far side of the Columbia River (Figure 1). The region along the shoreline of the Columbia River is known as the River Corridor, where former operations included nine nuclear reactors in the 100-BC, 100-K, 100-N, 100-D, 100-H, and 100-F Areas. During reactor operation, large volumes of effluent were discharged in the 100 Area, transporting contamination into the aquifer, creating large groundwater mounds, and modifying groundwater flow (DOE/RL-2018-66, *Hanford Site Groundwater Monitoring Report for 2018*). Six groundwater OUs are associated with the River Corridor in the 100-Area (Figure 1). The 100 Area GFM includes the six of the seven River Corridor Groundwater OUs, and the regions inland from the River Corridor that are part of the 200-BP-5 and 200-PO-1 Groundwater OUs. The River Corridor OUs are in various points in the *Comprehensive Environmental Response, Compensation, And Liability Act of 1980* cleanup process. Fate and transport modeling of the aquifer system is necessary to support remedial investigations, remedy design, or to evaluate existing remedies. GFMs are the foundation that fate and transport models are built.

® IHS Kingdom Geology Suite 2016 is a registered trademark of IHS Markit, London, United Kingdom.

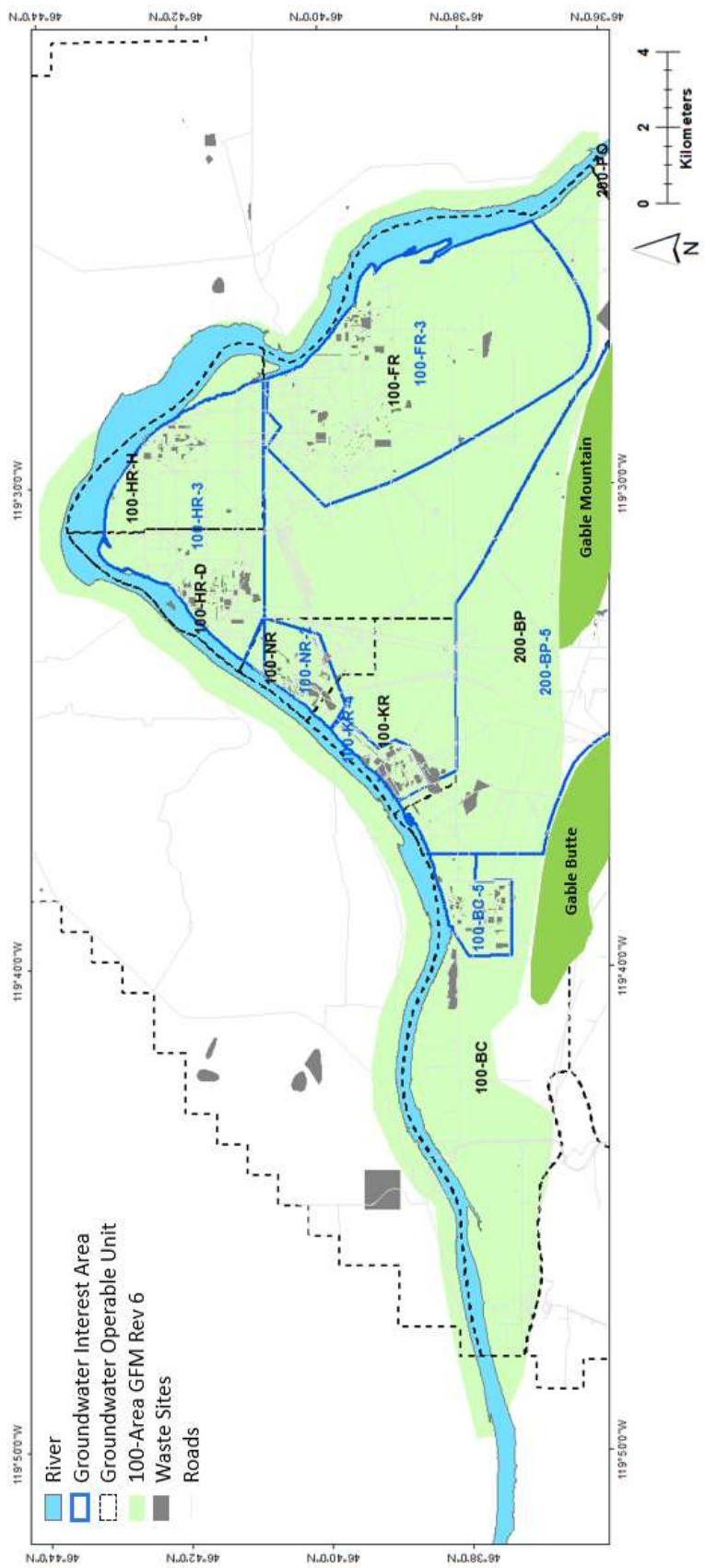


Figure 1. 100 Area Model Domain

The 100 Area GFM was first built in 2013 and documented by ECF-HANFORD-13-0020, *Process for Constructing a Three-Dimensional Geological Framework Model of the Hanford Site 100 Area*. The 100 Area GFM is updated periodically as new boreholes are drilled, providing new lithological data, or when interpretations of existing data are revised. There are five revisions of the 100 Area GFM that are documented with Environmental Calculation Files (ECFs). While previous revisions of the 100 Area GFM have been documented with ECFs, CH2M HILL Plateau Remediation Company (CHPRC) has determined the GFMs are more appropriately documented with MPRs. Thus, this is Version 6 of the 100 Area GFM and Revision 0 of the MPR.

This MPR provides the 2020 updated model results which used the Environmental Data Modeling Transmittal (EMDT-GR-0039, *Geologic Contacts for the 100-Area Geoframework Mode*), hereinafter referred to as the EMDT (Appendix F). This dataset includes the addition of 50 new boreholes to the model (Table 1) and refinements to the stratigraphic unit surfaces based on conceptual model interpretations and expert judgement. The software package used to create the GFM has also been updated; previous versions of the 100 Area GFM were built in Leapfrog Geo® while the most recent update is built in Kingdom. This version of the 100 Area GFM includes new surfaces for topography, the Hanford formation (Hf), the Ringold Formation member of Wooded Island — unit E (Rwie), the Ringold Formation upper mud (RUM), and the top of the Columbia River Basalt Group.

Table 1. New Boreholes Added to the 100 Area GFM

Well Name	X-Coord*	Y-Coord*	Elevation (m)	TD (m)
199-H1-12	576597.90	153898.80	126.90	26.7
199-H1-47	577185.49	153309.63	124.51	13.8
199-H1-48	577185.11	153237.89	125.31	15.4
199-H1-49	577249.67	153144.38	128.63	36.7
199-H1-50	576878.89	153481.09	125.38	34.0
199-H3-12	577842.32	152838.62	130.88	38.3
199-H3-13	577950.58	152815.48	128.63	34.7
199-H3-21	578127.91	152630.66	126.62	18.1
199-H3-22	577897.07	152847.99	128.88	39.6
199-H3-28	577655.35	152822.58	129.18	36.6
199-H3-29	577921.46	152884.22	128.23	70.0
199-H3-30	578100.23	152712.09	127.10	35.1
199-H3-32	577709.81	153063.50	128.11	28.7
199-H7-1	575643.15	153389.04	127.86	33.9
199-K-227	569538.69	146851.61	143.19	53.1
199-K-228	569393.12	896/5	143.35	51.0
199-K-229	568867.99	146311.08	145.66	58.3

® Leapfrog Geo is a registered trademark of ARANZ, Christchurch, New Zealand.

Well Name	X-Coord*	Y-Coord*	Elevation (m)	TD (m)
199-K-230	568738.15	146759.31	135.69	44.2
199-K-231	569511.98	146643.38	146.66	54.2
199-K-232	569245.51	147313.89	127.08	34.4
199-K-234	569005.78	146874.03	136.81	42.6
199-K-235	568829.62	146115.87	148.00	38.1
199-K-236	568856.97	146074.39	147.95	38.3
199-K-238	569322.00	146974.00	141.10	51.4
199-K-239	569039.00	146693.00	142.50	48.9
199-K-240	569382.00	146378.00	150.40	57.5
699-59-44	576617.20	141539.00	230.55	70.0
699-59-4B	576435.00	141542.00	236.10	20.0
699-59-44C	576556.70	141542.00	232.26	20.0
699-60-27	581838.35	141878.48	124.80	46.4
699-60-53F	573795.60	141868.90	250.24	88.4
699-60-59	572038.10	141854.50	155.18	475.7
699-61-53	573714.10	141978.10	233.11	117.3
699-61-55A	573009.20	141983.70	141.12	75.9
699-61-57	572608.20	142435.10	135.33	179.5
699-62-53	573646.20	142518.90	133.93	139.0
699-68-29	581102.94	144382.90	120.60	11.5
699-70-29	581195.52	144752.85	121.90	14.9
699-71-30B	580710.85	145242.64	122.90	15.7
699-71-30C	580709.69	145238.78	122.90	13.2
699-73-30	580687.11	145873.73	121.40	12.3
699-84-34B	579586.40	149244.00	120.00	1022.6
699-84-62A	570882.10	149090.10	138.02	299.0
699-95-45C	576257.19	152576.18	128.11	53.3
699-63-92	561559.74	142637.44	151.84	56.7
699-63-95	560914.64	142650.82	148.33	215.5
699-65-95	560815.43	143192.93	137.91	32.3
699-66-91	562174.81	143476.80	142.62	57.9

Well Name	X-Coord*	Y-Coord*	Elevation (m)	TD (m)
699-61-62	570914.86	141921.66	151.76	57.3
699-61-66	569787.59	142007.96	159.68	68.6

References: NAD83, *North American Datum of 1983*.

NAVD88, *North American Vertical Datum of 1988*.

*Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m); vertical datum is NAVD 1988.

TD = total depth

1.3 Document Organization

This document contains descriptions of the background and details for the process used in constructing a three dimensional GFM of the 100 Area at the Hanford Site.

This MPR is organized into the following sections that describe the steps implemented to construct the 100 Area GFM:

- The overall purpose, need, background, and objectives of the 100 Area GFM are summarized in Sections 1 and 2.
- Section 3 describes the GFM technical approach, beginning with the regional stratigraphy used for the 100 Area GFM domain and the process for interpreting and correlating the borehole data to define the hydrostratigraphic units (HSUs). This section also summarizes the use of Kingdom geologic interpretation software to select the geologic contacts (GeoContacts) data and develop the two dimensional structure maps of the modeled surfaces. Section 3 also includes discussions of data acquisition and how the models were validated.
- Section 4 discusses model implementation, expanding on the workflows, and modeling methodologies used for the Kingdom software.
- Section 5 discusses model uncertainty and compares the Version 6 GFM to the previous GFM revision.
- Section 6 discusses limitations of the 100 Area GFM.
- Section 7 provides the details for model configuration management.
- Sections 8 and 9 contain data needs and future model recommendations.

Supporting information used to construct the 100 Area GFM is contained in the appendices and defined external links. This MPR includes the following six appendices:

- Appendix A contains the new boreholes added to this revision of the 100 Area GFM.
- Appendix B has the table of boreholes removed from this revision of the 100 Area GFM.
- Appendix C contains revised structure-contour and isopach maps for the stratigraphic units for this revision of the 100 Area GFM.

- Appendix D contains verification and checking of the grids in the 100 Area GFM.
- Appendix E contains the Software Installation and Checkout Form for Kingdom.

Model grids and supporting input data are available upon request to the preparer of this MPR or to the CHPRC Risk and Modeling Integration manager.

2 Geoframework Model Objectives

The objective of this GFM development effort is to provide an accurate regional representation of the current understanding of the subsurface geologic environment within the 100 Area in support of sitewide modeling needs. The aim is to capture and track large changes in hydrostratigraphic facies, which can form the foundation for groundwater models. The model is constructed based on the most up-to-date (through fiscal year 2019) and defensible three dimensional interpretations of the Hanford Site's extensive geologic database. Hanford Site geologic data and information is currently archived and accessible internally via CHPRC-managed Integrated Data Management System (IDMS), Hanford Environmental Information System (HEIS), and the Hanford Site GeoContacts datasets.

Overall, the objective of this report is to describe the process used to update the geologic conceptual model for the HSUs beneath the Hanford Site 100 Area. This work is a continuation and update of previous geologic interpretational work completed by past authors as follows:

- WHC-SD-EN-TI-133, *Geology of the 100-B/C Area, Hanford Site, South-Central Washington*
- WHC-SD-EN-TI-155, *Geology of the 100-K Area, Hanford Site, South-Central Washington*
- WHC-SD-EN-TI-221, *Geology of 100-FR-3 Operable Unit Hanford Site South-Central Washington*
- BHI-00184, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington*
- DOE/RL-2008-42, *Hydrogeological Summary Report for 600 Area Between 100-D and 100-H for the 100-HR-3 Groundwater Operable Unit*
- ECF-HANFORD-13-0020
- ECF-100NPL-11-0070, *100 Area Stratigraphic Database Development*
- ECF-HANFORD-13-0029, *Development of the Hanford South Geologic Framework Model, Hanford Site, Washington*
- CP-60925, *Model Package Report: Central Plateau Vadose Zone Geoframework Version 1.0*

3 Geoframework Model Technical Approach

The HSUs defined in the 100 Area GFM are based on the assumption that they are laterally continuous between defining boreholes. The HSU's outer boundaries are defined by borehole control and geologic structural and depositional features, based on existing and previous geologic reports, studies, and other historical interpretational documents. The layered geoframework includes both porous units and less porous, or relatively lower permeability units (i.e., silt and clay dominant zones), that can be defensibly and consistently correlated in the 100 Area.

The facies-based interpretation method generally employed in this GFM is in alignment with a recent U.S. Environmental Protection Agency Groundwater Issue publication (EPA/600/R-17/293, *Best*

Practices for Environmental Site Management: A Practical Guide for Applying Environmental Sequence Stratigraphy to Improve Conceptual Site Models). EPA/600/R-17/293 endorses the idea of using borehole data, knowledge of depositional trends, and the application of environmental sequence stratigraphy to identify and map stratigraphic units to develop geologically defensible conceptual site models. The process sketched out in EPA/600/R-17/293 is similar to the process used to develop the 100 Area GFM.

The methodology followed for the 100 Area GFM is also described in CP-60925 for creating a GFM in Kingdom. The 100 Area model contains surfaces that that are generated from the hydrostratigraphic contacts in boreholes, referred to as Formation Tops in Kingdom terminology. This approach starts by using the existing sitewide published interpretations of major hydrostratigraphic contacts along with interpreting additional contacts where none were previously recorded (EMDT). The best-estimate Formation Tops are uploaded to Kingdom and are used as the input for a mathematical interpolation algorithm to create three dimensional grids. These grids can be altered using polygons and control points to more accurately represent the subsurface geology.

3.1 Features, Events, and Processes

The 100 Area GFM is a static, current representation of the subsurface geologic structure, and therefore, for the modeling workflow remains fixed and unchanged until it is revised in the future. There are no features, events, or processes included in this model construction. However, features and events such as historical geologic depositional environments and related structures were used to inform development of the 100 Area GFM interpretation (Section 3.2).

3.2 Defining the Stratigraphy and Interpreting the 100 Area Hydrostratigraphic Units

The 100 Area GFM is divided into three HSUs. These three HSUs are broadly distinct lithofacies packaged together based on the current understanding of the depositional environments in the Hanford Site. The HSUs are as follows:

- Hf
- Rwie
- RUM

Each of these HSUs is heterogeneous in lithology, but those heterogeneities are not generally mappable at the scale of the 100 Area GFM given the lack of sufficient subsurface data points across the GFM.

The Hf contains both lacustrine (lake) and fluvial (stream/river) depositional environments across the Hanford Site. Ringold sedimentary units present in the 100 Areas were largely deposited in a fluvial setting by the ancestral Columbia River (BHI-00184, DOE/RL-2008-42, WHC-SD-EN-TI-011, *Geology of the Northern Part of the Hanford Site: An Outline of Data Sources and the Geologic Setting of the 100 Areas).* Hf units present beneath the 100 Areas are often characterized by their lateral discontinuity in large part due to post-Ringold periods of uplift and repeated erosion, especially during the Pleistocene cataclysmic flood events. In the 100 Areas, post-Ringold uplift and erosion has removed most of the Taylor Flat and Savage Island Members lacustrine deposits (deposits exposed in the White Bluffs). Ringold coarser-grained sediments, like the gravel-dominated Rwie, represent Columbia River main channel depositional environments. Ringold finer-grained sediments, like the RUM, represent preserved overbank depositional environments of the ancestral Columbia River. A much more detailed discussion of the Ringold facies depositional environments and history can be found in Lindsey and Gaylord, *Lithofacies and Sedimentology of the Miocene-Pliocene Ringold Formation, Hanford Site, South-Central Washington.*

The Hf is an accumulation of Pleistocene-age flood deposits in the Pasco Basin, which forms a nearly continuous deposit across the entire Hanford Site. Alternating periods of erosion and deposition from cataclysmic floods left behind lenses of sand and silt surrounded by sand and gravel. The fine-grained sediment are generally sound near the edges of the basin. In the 100 Areas, the Hanford Site is a thick deposit of mainly unconsolidated sediments, which are gravel and sand dominated (WHC-SD-EN-TI-011). For the purposes of the 100 Area GFM, which is focused on the saturated zone and supports Hanford Site groundwater modeling, the Hanford HSU, which is largely a vadose zone unit, is undifferentiated.

3.2.1 Interpreting Hydrostratigraphic Unit Contacts

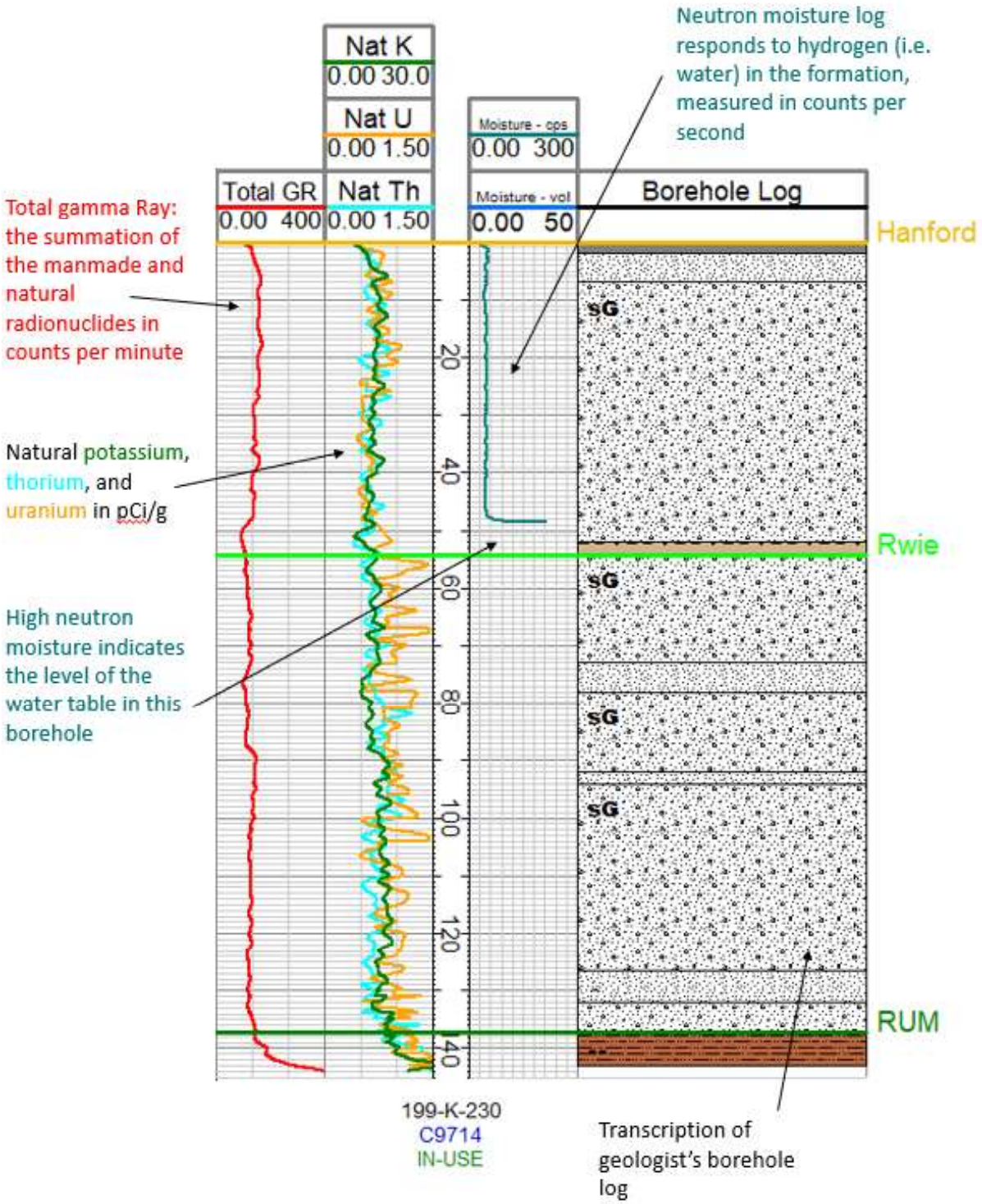
When a borehole is drilled on the Hanford Site, information about the subsurface lithologies encountered become available through observation of drill cuttings returned to the surface during drilling. These observations are recorded in either a driller's log or borehole log with some amount of textural description. A good quality borehole log will describe the sediment classification in the context of sand/gravel/mud ratios, mineralogic composition, color, grain-size variation, degree of cementation, reaction to hydrochloric acid, and other sedimentary features that may aid in HSU interpretation and identification.

In addition, it is standard procedure to conduct downhole geophysical logging surveys of new boreholes. The most common of the geophysical logs performed at the Hanford Site are spectral gamma ray logs, which can differentiate natural radionuclide spectra from manmade signatures. The dominant natural gamma emitters present in sediments are potassium, thorium and uranium. The amounts of those constituents detected in the logs can be good lithology indicators. For example, clay minerals often have more potassium and thorium than siliciclastic sands. Therefore, high spectral gamma peaks often indicate an increase in clay minerals. Carbonate minerals tend to have higher concentrations of natural uranium and lower concentrations in potassium. This is a helpful signature for interpreting the presence of caliche paleosol horizons.

The combination of the borehole log observations with the geophysical logs, in addition to an understanding of regional geologic conceptual models and depositional environments, form the foundation for making HSU contact top interpretations in individual boreholes. A discussion of preferred geologic conceptual models can be found in CP-60925, PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200 East Area and Vicinity, Hanford Site, Washington*, and PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*.

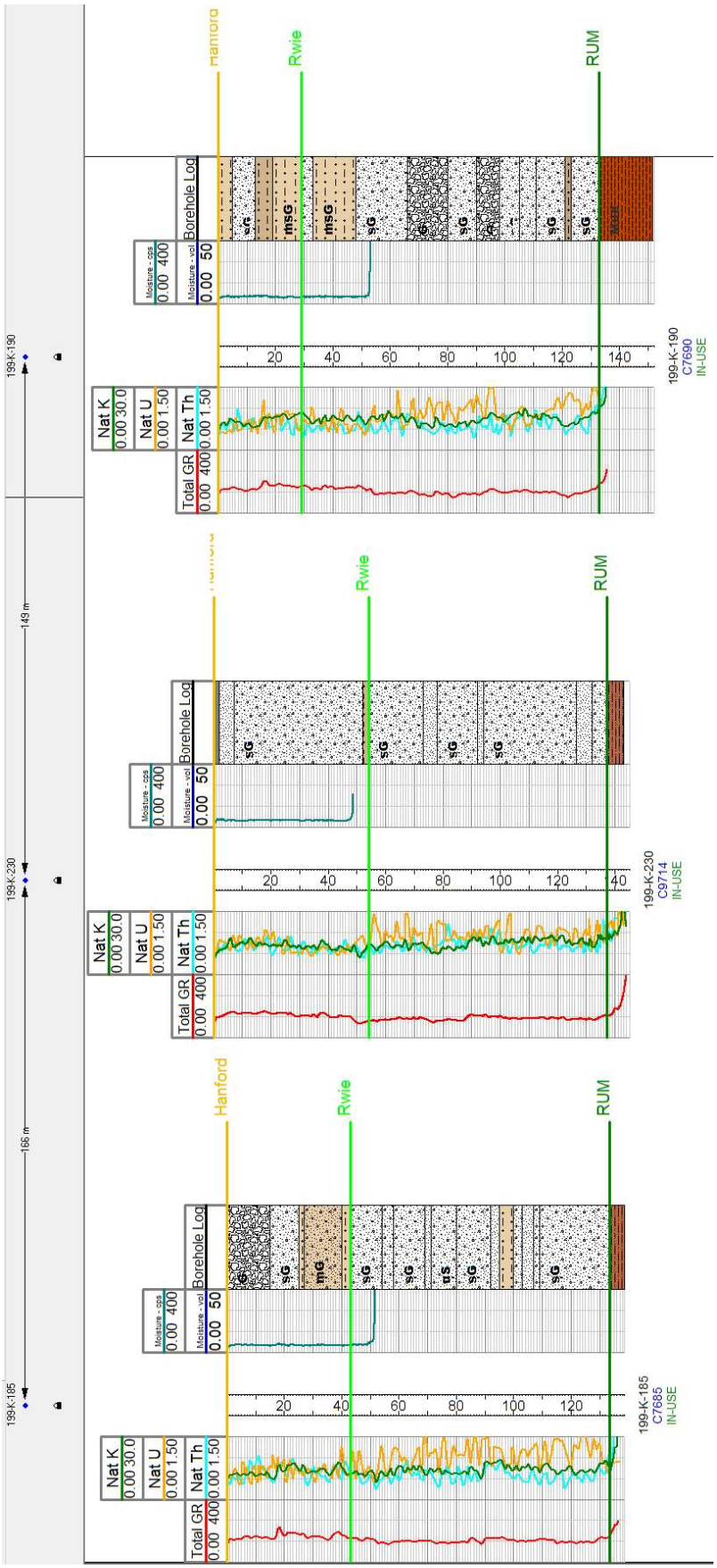
After a borehole is drilled, the data are first collected and integrated in a single view (Figure 2). In some parts of the borehole, the HSU contacts can be identified based on characteristics of the combined data. For example, in borehole 199-K-230 (Figure 2) at 41.75 m (137 ft) below ground surface, there is an abrupt increase in total gamma ray and in the spectral gamma curves. This indicates an increase in naturally occurring radiation from clay minerals, which commonly indicates the presence of a "mud" or clay sediment layer. The increase in gamma radiation also corresponds with a change in the borehole log from sandy gravel to mud as noted by the well site geologist. This change in lithology indicates the contact with a different HSU, the RUM.

Once the scan of the integrated borehole logs is complete, the interpreter may have a set of preliminary HSU contact tops for that borehole. But it is important to evaluate the preliminary HSU borehole picks in the context of the HSU picks in the immediately surrounding boreholes used in the GFM (Figure 3).



Note: HSU tops are noted by horizonal lines (yellow, light green, and dark green). Vertical depth scale is measured in feet below ground surface.

Figure 2. Annotated Interpreted Borehole Logs for 199-K-230



Note: Vertical depth scale is measured in feet below ground surface along the borehole. Horizontal distances between boreholes are not to scale.

Figure 3. Integrated Borehole Views for Boreholes 199-K-185, 199-K230, and 199-K-190

HSU tops are interpreted through correlation to nearby boreholes in order to maintain geologic trends and follow the conceptual model. Interpretations in nearby boreholes are not prescriptive, however. The active Miocene to Pleistocene complex depositional and tectonic setting at the Hanford Site resulted in numerous erosive events that remove some or all of older HSUs in one locality and preserved them at other localities. However, we can use these older nearby boreholes as a guide to our interpretation. All these elements (e.g., borehole logs, geophysical logs, and context of the surrounding boreholes) combine to guide the interpretation of HSU contacts in the new borehole, resulting in a set of HSU contact depths that originally formed, and continue over time to modify, the larger GFM (Figure 4).

3.3 Model Validation

The model validation section describes data acquisition for the 100 Area GFM and how the goodness of fit was evaluated. The 100 Area GFM is constructed from data contained in the stratigraphic database and IDMS. The goodness of fit was determined through construction of "difference maps" and miss-tie analysis found in Appendix D.

3.3.1 Data Acquisition

The GFM is constructed based on consistent interpretations of the Hanford Site's extensive stratigraphic database (as archived in GeoContacts_100-Area_2020_04_16.xlsx). An EMDT contains an explanation of the stratigraphic database, including data description, data intended use, data sources, impact of use/nonuse of data, prior use of data, data acquisition methods, and the assumptions and limitation of data use. The EMDT also includes the list of new boreholes added to the stratigraphic database, the list of existing boreholes removed from the GFM, and a catalogue of changes made to stratigraphic unit top-surface depth/elevation picks for Version 6 of the 100 Area GFM.

The IDMS houses the borehole data such as location, elevation, and drilled depth, as well as the associated geologic datasets like borehole/driller's logs and geophysical logs. The 100 Area GeoContacts datasets (the latest iteration of which is captured in the EMDT) provides interpreted lithologic unit contacts based on the borehole data from IDMS. These data and interpretations are combined with Kingdom interpolation functions to generate the GFM. Supporting data are also imported and uploaded to the GFM to provide improved spatial representation and orientation for the end user. This includes, for example, Light Detection and Ranging (LiDAR)-based ground surface layers, river bathymetry, and facility location information. In addition, user-specified layers can be imported to support multiple projects (i.e., water-table surfaces, contaminant plume interpretations, etc).

3.3.2 Goodness of Fit

There are several ways that errors may be introduced in a constructed HSU surface. One such potential source of error is the method of interpolation of the HSU surface and how tightly it honors the original data. Kingdom uses an interpolation method called "Flex Gridding" to generate surfaces (Section 5.2). We conducted a miss-tie analysis to evaluate potential sources of error between the original HSU top picks and HSU resulting grids. The evaluation was performed by (1) importing the Kingdom grids into ArcGIS®, (2) extracting the elevation of the grids at each borehole in the model, and (3) comparing the extracted elevation of the grid to the HSU top picks from boreholes. This workflow allowed us to calculate a regression line for the grids to evaluate their goodness of fit and to examine the cause of any errors. See Appendix D for the complete verification and checking of the 100 Area GFM.

® ArcGIS is a trademark of the Environmental Systems Research Institute (ESRI), Redlands, California.

Note: Vertical depth scale is in feet below ground surface. Horizontal distances between boreholes are not to scale.

Figure 4. Grids for Each HSU Displayed Behind the Interpreted Stratigraphic Contacts

The second process for model validation was creating "difference maps" between the Version 6 GFM grids and the Revision 5 100 Area GFM. The difference maps were created by (1) exporting XYZ points for each grid from Kingdom, (2) importing them to ArcGIS and creating a raster for each point set, and (3) subtracting the Revision 5 grid from the Version 6 grid for each HSU. This process results in a map which shows the difference between the old and new grids (in feet). The difference maps allow an evaluation of any large changes in the updated grids to assure they can be correlated to changes in input data or attributed to the Kingdom interpolation algorithm. The difference maps and accompanying analysis are in Section 5.3.

4 Model Implementation

This section introduces the modeling software and its qualifications for use in building the 100 Area GFM. It also details the implementation of the software to assemble and interpret the data into two dimensional and three dimensional geologic interpretations of the HSUs.

4.1 Software

Kingdom is software designed for geologic interpretation of spatial and well data, including well logs. It was selected for use because of the ability to quickly and accurately link geophysical borehole log and geologic log data together to create visual displays for subsurface geologic interpretation and correlation. Kingdom also allows well-to-well cross-sectional correlations and structure map generation, which greatly improves consistency and continuity in the geologic unit interpretations.

Software used for this calculation is applicable in accordance with PRC-PRO-IRM-309, *Controlled Software Management.* The following software was used to perform the calculations and was approved and compliant with PRC-PRO-IRM-309. This software is managed under the following documents consistent with the procedure:

4.1.1 Kingdom Documentation

The following approved software was used to perform this calculation:

- Software title: IHS Kingdom Geology Suite 2016
- Software version: 2016.1
- Hanford Information Systems Inventory identification number: 3899 (Safety Software S3, graded to Level C)
- Workstation type and property number (from which software is run): Hanford Local Area Network computer property number WF37416

This approved software is managed under the following software quality assurance documents:

- CHPRC-02937, *Kingdom-Geology Software Management Plan*
- CHPRC-02938, *Kingdom-Geology Software Test Plan*

4.1.1.1 Software Installation and Checkout

A copy of the Software Installation and Checkout Form for Kingdom is provided in Appendix E.

4.1.1.2 Statement of Valid Software Application

Kingdom software identified was used consistent with intended use for CHPRC as identified in CHPRC-02937. This software was used within the limitations defined in CHPRC-02937 for CHPRC applications.

4.1.2 ArcMap Documentation

ArcMap® was used for grid math and interpolations using the spatial analyst tool and three dimensional analyst tools.

- Software title: ArcMap
- Software version: Version 10.2
- Hanford Information Systems Inventory identification number: unregistered
- Workstation type and property number (from which software is run): INTERA Laptop (non-Hanford Local Area Network), tag number 00785

4.1.2.1 Statement of Valid Software Application

Utility software was used for limited purposes to support the use of Kingdom and this use was consistent with the purposes of these commercial, off-the-shelf software packages.

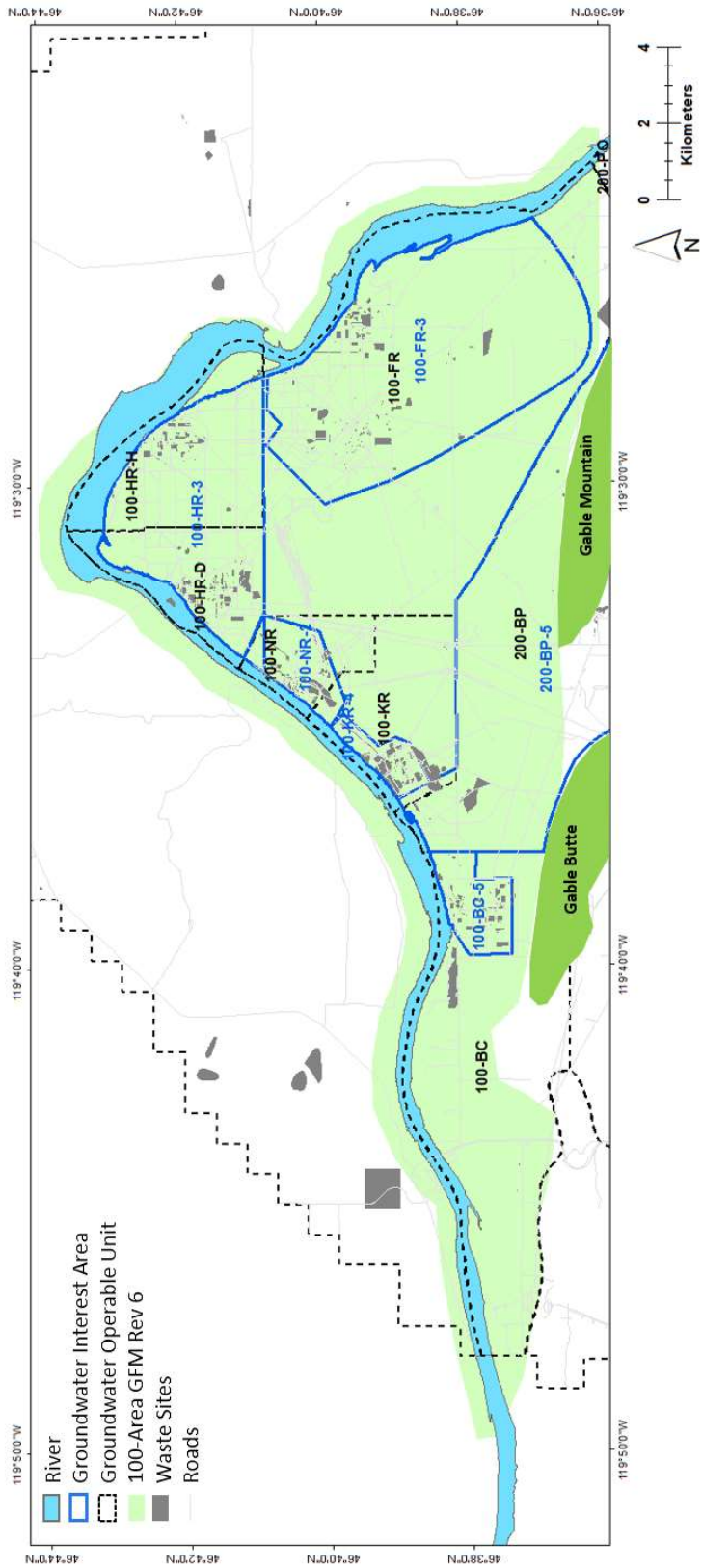
4.2 Model Inputs and Boundaries

Five datasets are used in the construction of the 100 Area GFM model: LiDAR for the topography and bathymetry for the bottom of the Columbia River, borehole data for formation top contact information, control points and polylines, and a top of basalt surface. The data are discussed in detail in the following sections.

4.2.1 100 Area GFM Domain

The 100 Area GFM (Version 6) domain encompasses the areas of the Hanford Site north of Gable Mountain and Gable Butte up to the far side of the Columbia River (Figure 5). There is a small amount of spatial overlap with the Hanford South GFM (ECF-HANFORD-13-0029), any inconsistencies between the two GFMs will be resolved in the newest version of the Hanford Site South GFMs.

® ArcMap is a registered trademark of Environmental Systems Research Institute (ESRI), Redlands, California.



Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure 5. 100 Area GFM Boundary (Version 6)

4.2.2 Topography and Bathymetry

The first step in creating a model is to define the topography, which represents the ground surface or top of the model and all data associated with it. The topography used in Version 6 of the model is a combination of land surface topography, Aero-Metric LiDAR, *RCCC-Hanford Battelle/PNNL/DOE, Digital Orthophotography & LiDAR Surveys Photogrammetric Report*, and the Columbia River bathymetry from PNNL-19878, *Development of a High-Resolution Bathymetry Dataset for the Columbia River through the Hanford Reach*. This surface was created using a continuous (grid) interpolated from 0.5 m resolution LiDAR for land surface, integrated with continuous (grid) 0.2 m bathymetry data to represent the bottom surface of the Columbia River. XYZ points were extracted at a 10 m resolution from both maps in ArcGIS using the "Extract Multi Values to Points" tool. Both grids were imported into Kingdom at a 10 m resolution using those XYZ points and reinterpolated using the Kingdom Flex Gridding algorithm. These two grids (i.e., topography and bathymetry) were combined to create one continuous surface using the "or" function in the Math on Two Maps tool in Kingdom. Where both the topographic map and the bathymetric map existed, the "or" function kept the bathymetric data. The topographic map was retained in all other areas.

4.2.3 Top of the Columbia River Basalt Group Surface

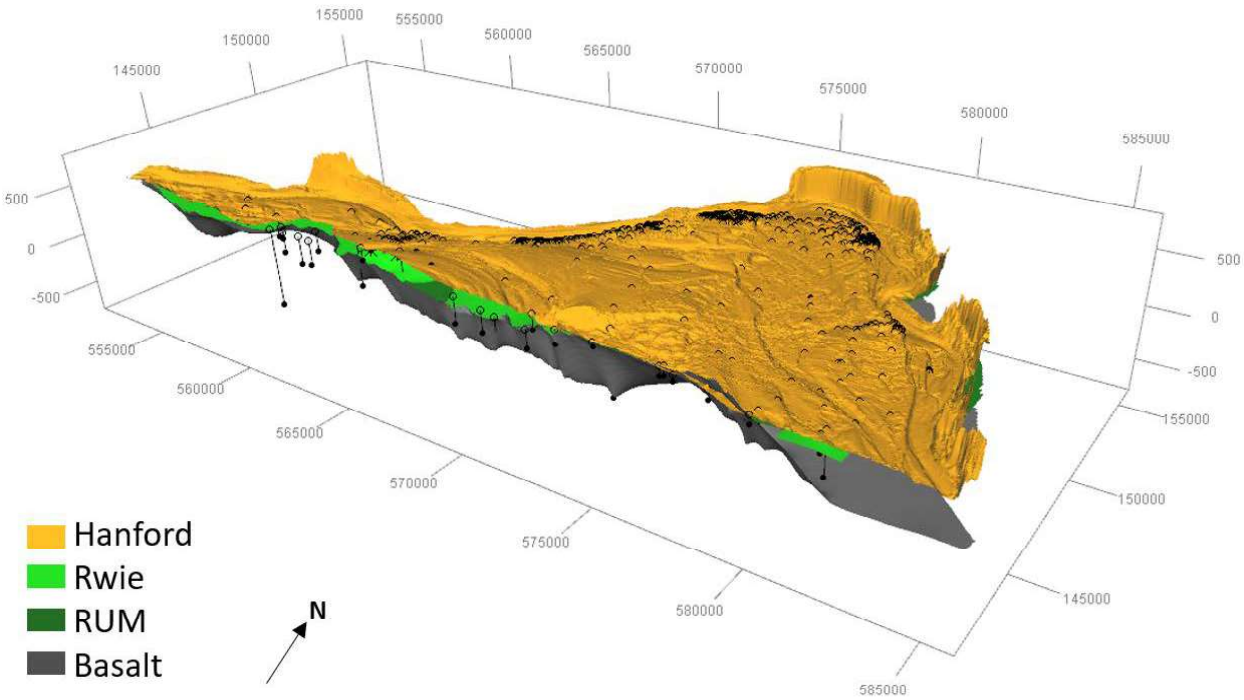
This model assumes that movement of groundwater (confined and unconfined) and related contamination sourced at the Hanford Site is constrained to the sedimentary layers (suprabasalt sediments) above the Columbia River basalt. Therefore, the base of the 100 Area GFM is the top of the basalt.

The top of basalt surface was originally interpolated into a 10 m grid from contours based on published interpretations of the top of basalt surface (i.e., PNNL-14753, *Groundwater Data Package for Hanford Assessments*) using the contours spatial analysis function in ArcMap. Further refinements were made to the top of basalt surface using the Topo-to-Raster function in ArcMap, which can use point data, contour data, boundary data, and drain enforcement to create a hydrologically correct surface with or without sinks or drains. Additionally, a newly revised top of basalt surface that combines the older surface with a new basalt surface data interpretation near Gable Gap and corrects the basalt surface near the southern boundary of the 100 Area model domain has been used in this calculation (ECF-HANFORD-16-0128, *Development of Contiguous Top of Basalt Surface for Use in Development of Site Geoframeworks*). The update to the basalt surface in this GFM Version 6 incorporates the top of basalt surface picks from boreholes in the 100 Area. The updated basalt surface from ECF-HANFORD-16-0128 is integrated with the stratigraphic contacts borehole and interpreted seismic data along a two dimensional seismic line that traverses Gable Gap to the 100-F Area (B040899, 1979, Seismic Velocity Survey, Rockwell Hanford Operations ESG, DC 2, 3, 4, 6 and 7, Benton County, Washington; B067305, 1979, *Final Report on a Seismic Reflection Survey Conducted in Benton and Grant Counties, Washington, FY-79 Program, Pasco Basin, Hanford Site;* andB067306, 1980, *Final Report on a Seismic Reflection Survey Conducted in Benton County, Washington, FY-80 Program, Pasco Basin, Hanford Site*). Due to the widespread extent of the RUM throughout the 100 Area, and the top of RUM being considered the base of the unconfined aquifer in the 100 Area, there are very few boreholes drilled deep enough to reach the top of basalt (23 used in the Version 6 GFM). There is only one well in the interior of the 100 Area GFM that reaches the top of basalt. The well lies along the Basalt Waste Isolation Project seismic line and was used to convert the seismic two-way travel time to depth. The rest of the wells that reach the top of basalt surface are all along the margins of the 100 Area GFM: in the operational areas like 100 N or along the flanks of Gable Mountain and Gable Butte. Therefore, the top of basalt surface away from those limited data control points is based largely on interpolation of this data.

4.2.4 Borehole Data

The next step in the modeling workflow is to construct the spatial representation of the HSU surfaces that can be constrained within the model boundaries (Figure 6). Information for defining the top of each HSU surface is maintained in IDMS and accessible through the Environmental Dashboard Application, and the Hanford Site geological contacts databases. Kingdom requires two types of borehole datasets: best-estimate depth to HSU contacts (in feet below ground surface) and location data, including ground surface elevations (at the time of drilling in feet above mean sea level). The location data for the boreholes is imported into Kingdom as a tab delimited file. The coordinate systems in which the location data are reported are the Washington State Coordinate System (NAD_1983_StatePlane_Washington_South_FIPS_4602 m, horizontally) (NAD83, *North American Datum of 1983*) and NAVD88, *North American Vertical Datum of 1988*, vertically. The process for selecting boreholes, defining HSU contact elevations from borehole logs, and quality assurance for HSU borehole contacts is described in detail in ECF-100NPL-11-0070.

The 100 Area model domain incorporates three HSUs that are based on area-specific geologic interpretations and publications: the Hf (undifferentiated), Rwie, and the RUM. The GeoContacts database contains records of geologic contacts identified by several geologists. As a result, the GeoContacts database contains multiple entries for boreholes with updated interpretations to geologic tops over time (EMDT). Only the most recent borehole lithology interpretation is used from the database into the import file (filtered by the most recent author of the interpretation). Additionally, geologic contact tops in boreholes (which were listed as not penetrated, not deep enough, or not enough data to make an interpretation) are omitted from the lithology file.



Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure 6. Three Dimensional View of the 100 Area GFM (Version 6) Showing the Model Extent and Borehole Locations (in black)

4.2.5 Other Boundaries

Borehole data indicates that the RUM pinches out before the southeastern edge of the GFM. However, without a polygon to define its extent, Kingdom's gridding algorithm interpolates the RUM surface all the way to the southeastern corner of the 100 Area GFM. As a result, an additional polygon is used to define the boundary of the RUM surface within the greater 100 Area GFM extent (Figure 7).

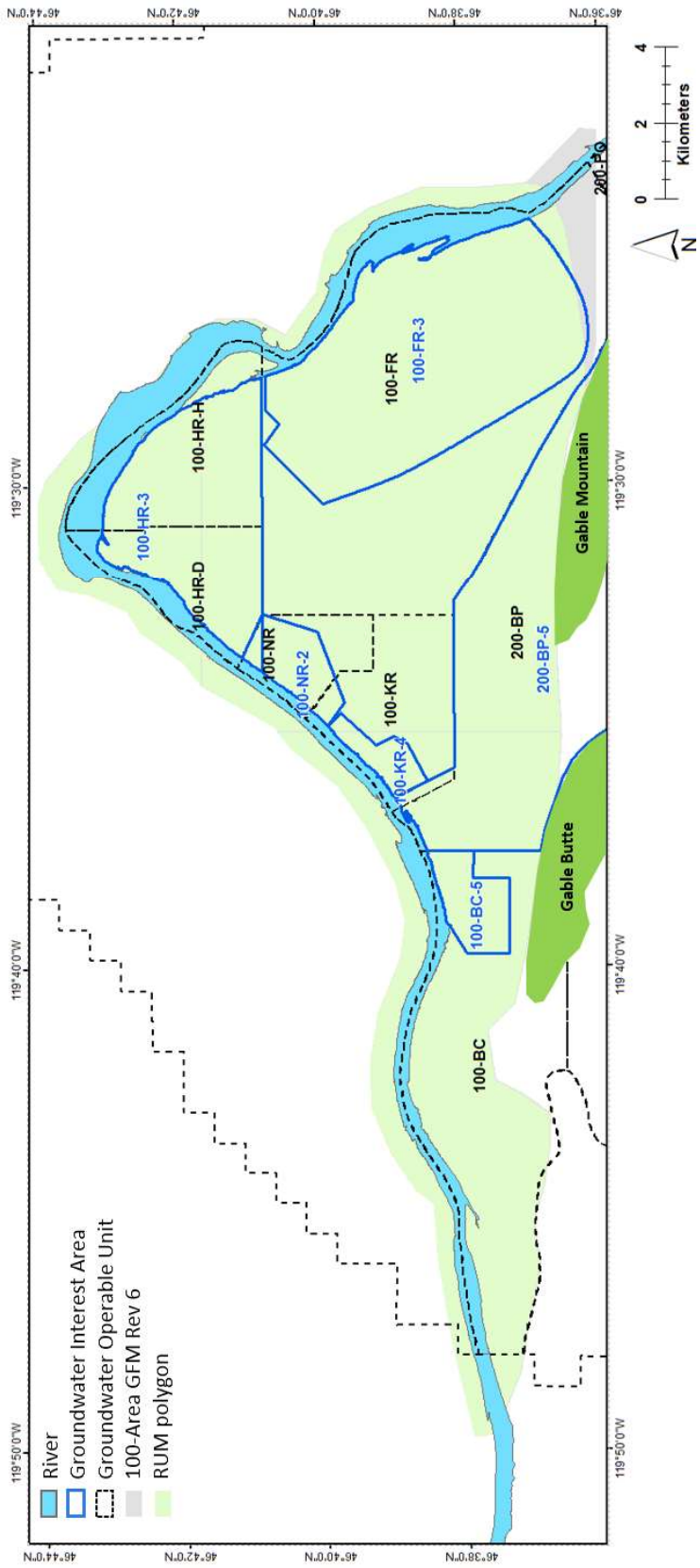
4.2.6 Control Data

This GFM is also shaped using control points and lines. Control data are XYZ coordinates for given model HSU contacts; they are used to guide the trend of the HSU contact surfaces to reflect the conceptual knowledge of the geologists. Control data may be used to define erosional features which are present but would not be properly shaped using the Kingdom interpolation of borehole HSU contacts. Table 2 has a list of all the sets of control data and the surfaces to which the data apply. Table 2 has a list of the purposes of each set of control data. Control borehole data are slightly different than control points and lines. They are included with the borehole data and serve as artificial boreholes with artificial HSU contacts.

Model surfaces in the 100 Area GFM are refined by adding control points to HSU surfaces. Control points in the 100 Area GFM are used in a variety of ways to either assist Kingdom in a grid interaction issue or, more seldom, to reinforce a specific geologic feature of the grid in question. Control points can be inserted in three dimensional space in Kingdom, but it is more common to use them along cross sections removing incorrect grid interactions, smoothing abrupt elevation changes, reinforcing various geologic processes between boreholes, and assisting grid pinchouts. The control point data includes x-coordinate, y-coordinate, and an elevation of the HSU it represents (i.e., Hf, Rwie, RUM, and top of basalt). The logic for placement of control points is based on an underlying understanding of the GFM, which is developed by professionally trained and experienced geologists, and is necessary in areas where the interpolated surface deviates from information that is not represented by borehole HSU contacts (e.g., geologic truncations, faults, etc.). It also may be useful in areas where borehole data are sparse but well defined structural patterns or trends are known or assumed (i.e., the 100-F Area RUM surface trend). Control points may change as new boreholes are drilled or new borehole interpretations become available. The tables containing the control points that are associated with each scene or revision are also uploaded and archived concurrently with each GFM release. Control data used in this version of the 100 Area GFM are listed in Table 2.

The northern boundary of the 100-Area model requires the addition of control points to constrain the RUM. In the absence of well data for the RUM adjacent to either side of the Columbia River, control points were added to extrapolate the surface and maintain the surface trend. The available information from outcrop and well data suggests the Ringold formation remains relatively flat adjacent to the Columbia River, north of HR-3 (BHI-00184). Cross sections from N-S show units of the Ringold formation remaining flat or dipping gently to the south (BHI-00184). However, these control points are highly uncertain and opportunities to collect data about the elevation of the RUM in the HR-3 horn area should be encouraged.

In addition to using control points, specific boreholes and/or borehole geologic intervals were removed from the interpolation use in the GFM. Boreholes and intervals were removed in areas of the 100 Area GFM where questionable HSU contact depths, anomalous highs, and anomalous lows (i.e., gaps, holes) could not be resolved by control points or polylines. These removed borehole data points are listed in the EMDT.



Notes: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m). Both boundaries are the same except for the south-east corner of the model.

Figure 7. 100 Area GFM (Version 6) Boundary and the RUM Surface Boundary Superimposed

Table 2. Control Points and Polyline Sets Added to the 100 Area GFM (Version 6)

Control Point/Polyline	Y-Coord* (m)	X-Coord* (m)	Z-Coord* (ft)	HSU	Purpose
Rwie contacts polylines	146910.42	575981.70	323.73	Rwie	Control the extent of the Rwie in the central portion of the model; prevents over extrapolation
RUM contacts 3 polylines	144301.98	580232.70	374.92	RUM	Control the extent of the Rwie in the central portion of the model; prevents over extrapolation
RUM contacts polylines	153732.27	576813.30	373.79	RUM	Control the extent of the Rwie in the central portion of the model; prevents over extrapolation
RUM 100F contours	144478.00	577301.05	396.98	RUM	Define a known structural trend not adequately represented by borehole data
control_1	154147.41	573314.41	368.14	RUM	Controls the HSUs on the far side of the river, prevents over extrapolation
control_10	154782.37	578207.05	368.41	RUM	Controls the HSUs on the far side of the river; prevents over extrapolation
control_11	154534.81	578624.82	368.60	RUM	Controls the HSUs on the far side of the river; prevents over extrapolation
control_12	154247.52	579021.67	365.75	RUM	Controls the HSUs on the far side of the river; prevents over extrapolation
control_13	153651.13	579341.84	364.11	RUM	Controls the HSUs on the far side of the river; prevents over extrapolation
control_2	154399.19	573763.89	364.21	RUM	Controls the HSUs on the far side of the river; prevents over extrapolation
control_3	155457.96	573764.23	351.18	RUM	Controls the HSUs on the far side of the river; prevents over extrapolation
control_4	155751.98	574318.77	347.83	RUM	Controls the HSUs on the far side of the river; prevents over extrapolation
control_5	155729.93	575156.39	347.64	RUM	Controls the HSUs on the far side of the river; prevents over extrapolation

Control Point/Polyline	Y-Coord*(m)	X-Coord*(m)	Z-Coord*(ft)	HSU	Purpose
control_6	155688.26	575685.45	357.41	RUM	Controls the HSUs on the far side of the river; prevents over extrapolation
control_7	155586.31	576352.00	364.21	RUM	Controls the HSUs on the far side of the river; prevents over extrapolation
control_8	155286.58	576940.29	370.60	RUM	Controls the HSUs on the far side of the river; prevents over extrapolation
control_9	155044.79	577647.78	370.73	RUM	Controls the HSUs on the far side of the river; prevents over extrapolation
RieBC_ctrl 1	145211.48	562126.20	295.34	Rwie	Terminates the edge of the Rwie in the 100-BC Area
RieBC_ctrl 2	144938.51	562378.17	295.41	Rwie	Terminates the edge of the Rwie in the 100-BC Area
RieBC_ctrl 3	144670.80	562740.37	295.34	Rwie	Terminates the edge of the Rwie in the 100-BC Area
RieBC_ctrl 4	144308.59	563013.34	295.28	Rwie	Terminates the edge of the Rwie in the 100-BC Area
RieBC_ctrl 5	144035.63	563470.03	295.18	Rwie	Terminates the edge of the Rwie in the 100-BC Area
RieBC_ctrl 6	143647.17	564204.94	295.14	Rwie	Terminates the edge of the Rwie in the 100-BC Area
RieBC_ctrl 7	143458.20	565412.28	295.41	Rwie	Terminates the edge of the Rwie in the 100-BC Area
RieBC_ctrl 8	143458.20	566661.63	295.14	Rwie	Terminates the edge of the Rwie in the 100-BC Area
RieBC_ctrl 9	143699.67	567412.28	295.18	Rwie	Terminates the edge of the Rwie in the 100-BC Area

Reference: NAD83, *North American Datum of 1983*.

Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

*XYZ coordinates for polylines and contours only show one point within the group.

HSU = hydrostratigraphic unit

RUM = Ringold Formation Upper Mud Unit

Rwie = Ringold Formation member of Wooded Island — unit E

4.3 Kingdom Workflow and Model Methodology

The basic methodology for development and construction of the 100 Area GFM in Kingdom is as follows:

1. Define the model boundaries and gather the site specific descriptions, information, and geologic data for constructing the HSUs of the model. This includes gathering the surface that serves as the top of the model (LiDAR and Columbia River bathymetry).
2. Identify the HSU tops in boreholes, if present, within the domain by integrating geologic and geophysical datasets, and correlating unit tops from borehole to borehole. In Kingdom terminology, these are referred to as Formation Tops.
3. Import the borehole location data and historic stratigraphic contact interpretations.
4. Create the elevation grids of the HSUs within the model. Apply additional control points as necessary to constrain known subsurface geologic features (e.g., pinchouts, faults, erosional truncations, etc.) within the model domain.

Figure 7 depicts the 100 Area GFM areal extent. The Columbia River forms the northern, eastern, and western boundary, and the Gable Mountain and Gable Butte structural lineament forms the southern boundary. Columbia River Basalt Group subcrops and aboveground basalt exposures are assumed to be impermeable boundaries and form the basement rock underlying the entire Hanford Site. There are areas of the Hanford Site Central Plateau where porous basalt is part of the unconfined aquifer, but those areas are localized and the vertical extent of the porous basalt aquifer is poorly defined. Due to the regional scale of the 100 Area GFM, the top surface of the basalt forms the basal layer of this GFM.

4.3.1 Creating a Geoframework Model in Kingdom

The 100 Area GFM (Version 6) described in this document should lead to a virtually identical model to what has already been produced. The first four steps explain how to build an entirely new project in Kingdom. The rest of the steps describe how this GFM model was constructed.

The instructions for creating a GFM model in Kingdom use the Kingdom program terminology. For instance, Kingdom uses the term “well” as a catchall term for all holes drilled in the ground and Formation Tops for any depth discrete HSU contact interpretation at a borehole location. The rest of this MPR, aside from Section 3.4, uses the appropriate descriptive terminology as necessary.

The 100 Area GFM can be constructed from the following steps:

1. Open Kingdom software and create a new project.
   a. Check with the Kingdom administrator to get license and SQL Server® access. If creating a new project, log into SQL with an administrator account. Licensing and data structures will change when new versions of Kingdom are implemented.
   b. Choose an author name.
2. Assign the appropriate project options when prompted. Surface units should be in meters and depth units are in feet (Figure 8).

® SQL Server is a registered trademark of the Microsoft Corporation in the United States and other countries.

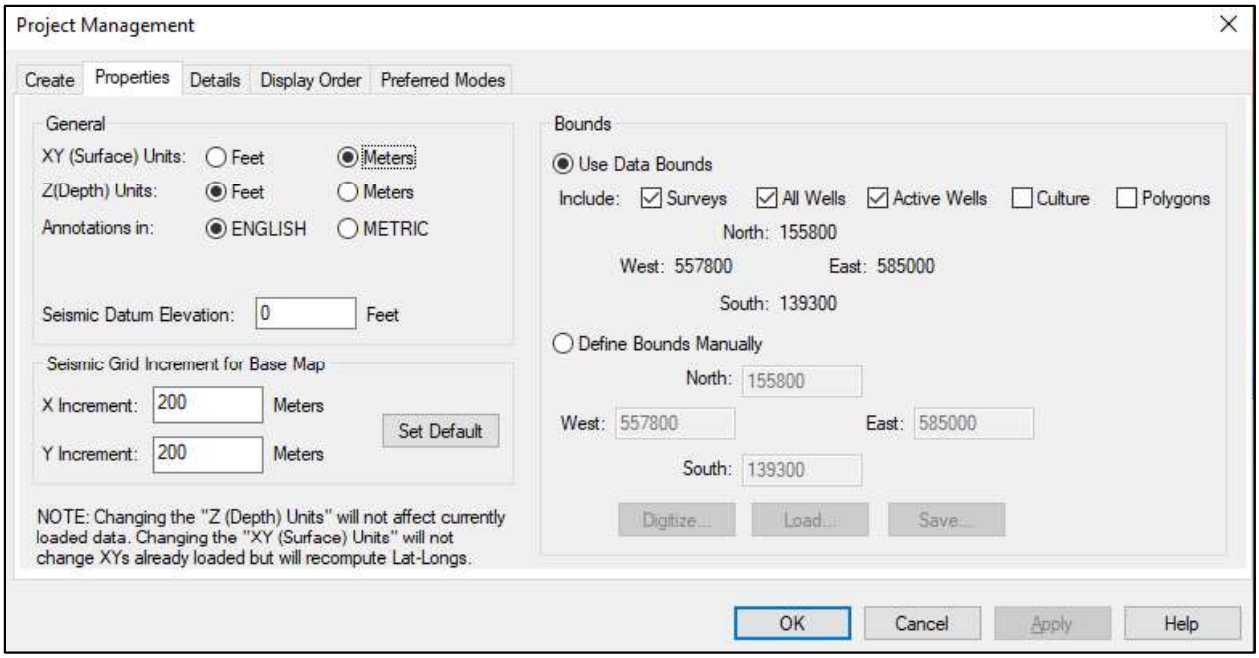
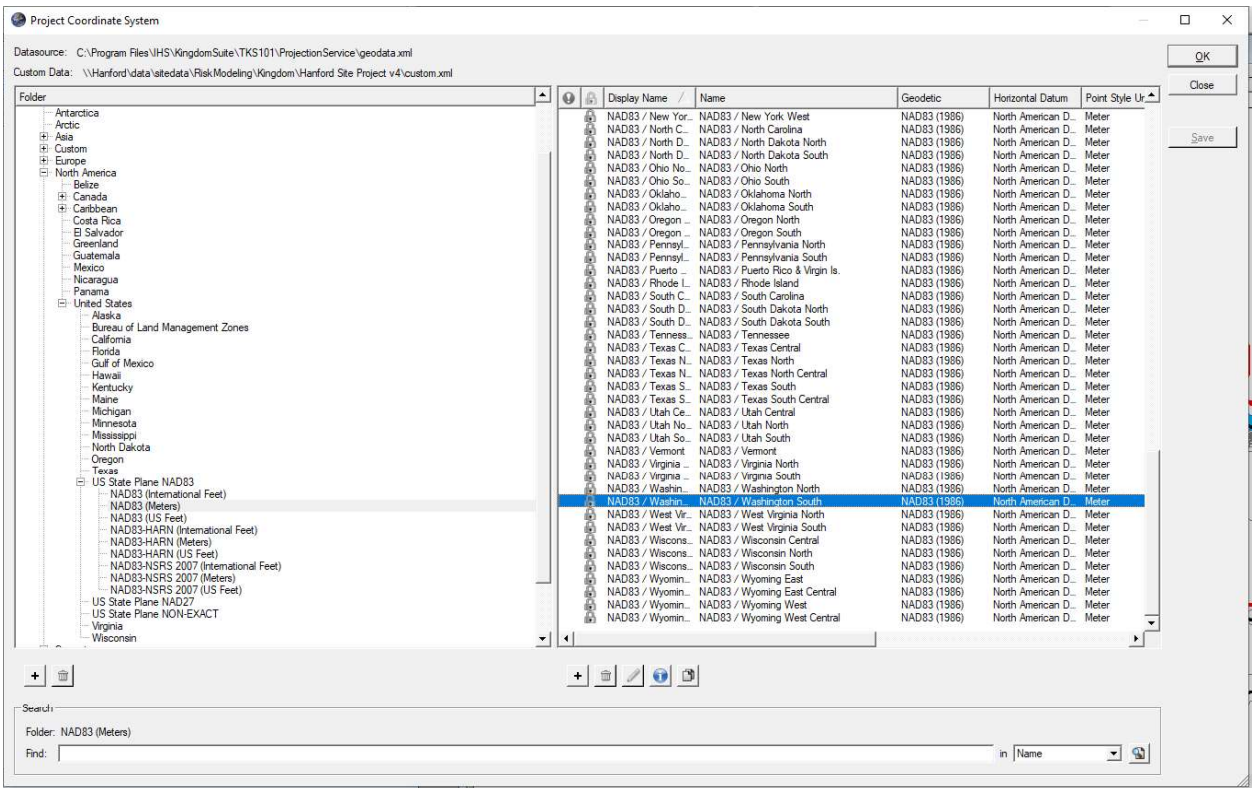


Figure 8. Project Option Specifics in Kingdom

3. Select project coordinate system, U.S State Plane NAD83 in meters (Figure 9).



Note: The modeling extent was defined by the polygon "100Area-GFM."

Figure 9. Project Coordinate System Options

4. Import coordinates for the 100 Area boreholes used in this model.

   a. In Kingdom, select "Wells" from the project tree, right click and select "Import," and then select "File Import." In the Well Import window, select "Wells" and "OK." Browse to the appropriate file if batch loading wells from a data file. Be sure to select "Other Files" in the dropdown in the lower right corner of the window to be able to see your data file. Toggle "UWI as it exists in import data (UWI in import data will not be altered)" and then click "Next."

   b. Assign the appropriate categories to each column. Hanford ID is called "UWI" in Kingdom, and all well data is indexed to UWI. Northing is the y-coordinate, and Easting is the x-coordinate. Elevation should be in feet and elevation reference is ground surface; total depth should be in feet. Click "Next."

   c. A prompt window will open to Specify Units for Input Data. Remember that the convention we selected for the Hanford Site project is for X-Y surface data to be meters and depth to be U.S. feet. Click "OK."

   d. Another opportunity to define the coordinate system of the imported data will come up. Choose the same project coordinate system as above.

   e. The "Available Wells for Import" screen will come up. Toggle the "Add: Create new wells only" and click "Next." The program should then generate the import report. Scroll through the report to verify that everything looks correct.

5. Import Formation Top data for the 679 boreholes used in this model. The process for selecting these HSU tops is described in Section 3.2; it is not generally a prescriptive process. Selecting the Formation (HSU) Tops is largely interpretive and relies on the experience and knowledge of the interpreter. In this part of the process, we are referencing the formation (HSU) tops listed in the EMDT.

   a. Select "Formation Tops" from the project tree, right click, and select "Import." Browse to the appropriate file and select "Next." The easiest file format for Kingdom to read is tab separated. The file should contain the well identifier, top depth in feet, lithology name, and author (if different than the importer).

   b. The File Format Selection window will open. The easiest way to import Formation Tops into a Kingdom project is when the Formation Tops are in columnar order. Therefore, Formation Tops files exported for this GFM will be in columnar order. Toggle that selection and click "Next." Toggle "UWI as it exists in import data (UWI in import data will not be altered)" and then select "Next."

   c. Assign the column categories appropriately (remember to make the Lines to Skip field at the top of the window say "1" to avoid importing the column headers as data). The columns should be UWI, Depth, Formation Top Name, and Author Name. Click "Next."

   d. The "Available Wells for Import" window will open; make sure all are selected and click "Next." If any of the well names are grayed out, some troubleshooting may be necessary.

   e. The Data Import Options window will open; be sure it says the selected data are Formation Tops and import options is "Add and Update Data." Click "Next."

   f. In the Author Assignment window, be sure to assign the appropriate author (your own author name or 100 Area GFM [Version 6]). Click "Next."

g. The Select Depth/Time Type window will open. The Depth Type selected from the dropdown menu should be MD. Click "Next." In the Selection Summary window, click "Next" again.

h. The Import Report is generated. Check that all Formation tops were imported without error and click "Finish."

6. Import structural grid data. The topography/bathymetry and top of basalt surfaces were created separately following the process outlined in Sections 3.1.1 and 3.1.2. They will be used in the model build as input grids rather than reinterpolated through the dynamic map update process.

   a. In the Kingdom project tree, right click on "Grids" and select "Import." A navigation window will appear. Browse to the correct folder and select the grid.

   b. The Import Grid window will appear (Figure 10). The program should read in the x/y min/max and grid increment from the file. It should only be necessary to assign the Author, New Grid Name, and Data Type, and toggle the appropriate depth value.

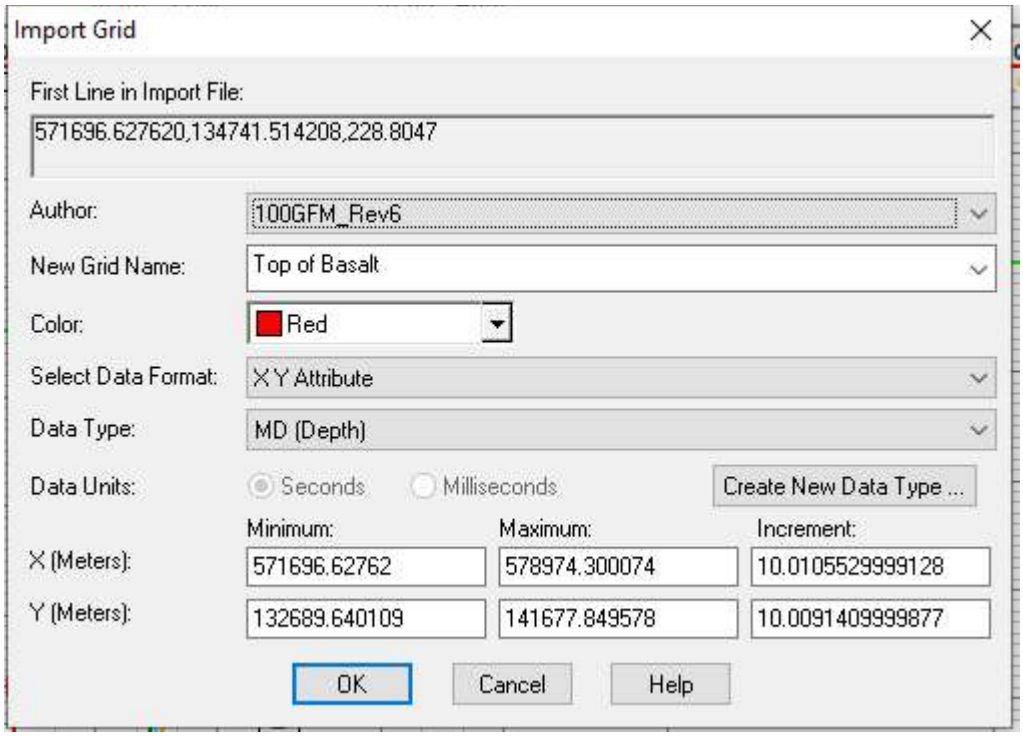


Figure 10. Import Grid Dialogue Window in Kingdom

   c. Importing the grid file in this way leaves the depth type undefined, so it is necessary to go in and define the depth to "Subsea." Right click on the grid name in the project tree and select "Properties." Under depth type, select "Subsea" from the dropdown menu, and click "OK."

   d. Repeat these steps for the other HSUs and the top of the Columbia River Basalt Group.

7. Import relevant control point data.

   a. In the project tree, right click on "Control Point Sets" and navigate to "Import."

b. Browse to the appropriate folder and select the set of control points you are importing (Note: The default file format is control point set or *.cpt. The control point files are stored as text files so they can be used in other platforms. Select the "All Files" is the format option.)

c. Assign the columns appropriately. Each control point should have an x, y, and z point. The confidence and attribute values are optional. Click "OK."

d. Select "Subsea" as the depth type, and assign a name and color to the set. Click "OK."

e. Repeat for all the control point sets associated with the 100 Area GFM (Version 6).

8. Create the GFM using the Dynamic Map Update Module in Kingdom. This is a module originally developed by Kingdom to create velocity models by converting seismic data from two-way travel time to depth. This module can also be employed to develop basic GFM by using conformity rules, onlap, polygon, and extent options to manage various grids into a complete framework. In addition, it allows the combination of using existing HSU surfaces (e.g., the top of basalt grids from Hanford Site South GFM [Revision 5]) and building new grids in a geologically correct manner from formation tops and control points.

9. Under the Grids dropdown in the top menu bar, select "Dynamic Depth Conversion and Map Update" (Figure 11).

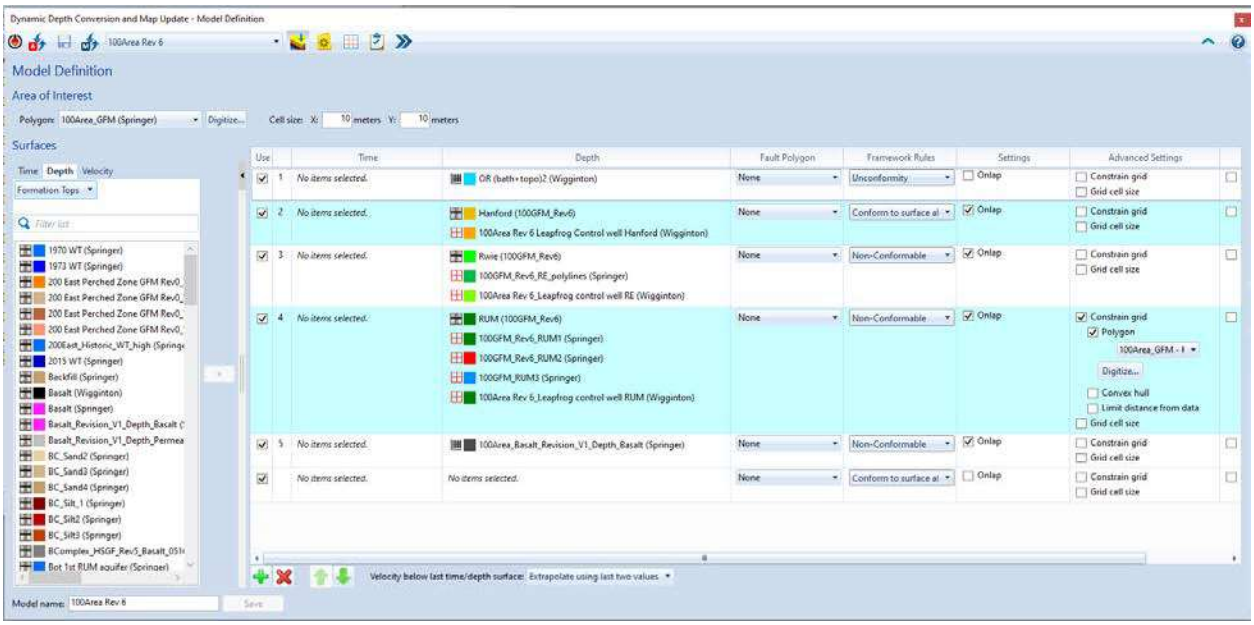


Figure 11. Kingdom's Dynamic Depth Conversion and Map Update Module for the 100 Area GFM

a. Name the model in the lower left field for model name and save. The grids you create in this module will be saved with that model name as the prefix.

b. Select an area of interest polygon.

c. The cell size employed for the 100 Area grids is 10 m by 10 m; enter those values in the fields at the top of the window.

d. To add surfaces to the GFM, select the Depth tab under "Surfaces." Then select "Grids" from the dropdown menu. If using an existing grid such as the HSGFM grids, be sure to highlight the appropriate author under "Author Management" in the main menu. Input data will put the author name in parentheses. Highlight a layer in the main window, then click the appropriate grid to add the layer to the list.

e. Once the grids have been added, change the option under the dropdown from "Grid" to "Formation Top." Select the appropriate Formation Tops (HSUs) and move them into the correct layers using the same method as the grids. Table 3 has HSU stratigraphic order.

Table 3. 100 Area GFM (Version 6) Layers

Layer	Input Depth Data (Author)	Fault Polygon	Framework Rules	Onlap	Constraints
1	OR (bath + topo) (Wigginton)	None	Unconformity	No	None
2	Hf (Wigginton)	None	Conformable	Yes	None
3	Rwie (Wigginton)	None	Nonconformable	Yes	None
4	RUM (Wigginton)	None	Nonconformable	Yes	Constraint polygon (Figure 7)
5	100Area Basalt Revision V1 Depth Basalt (Springer)	None	Nonnonformable	No	None

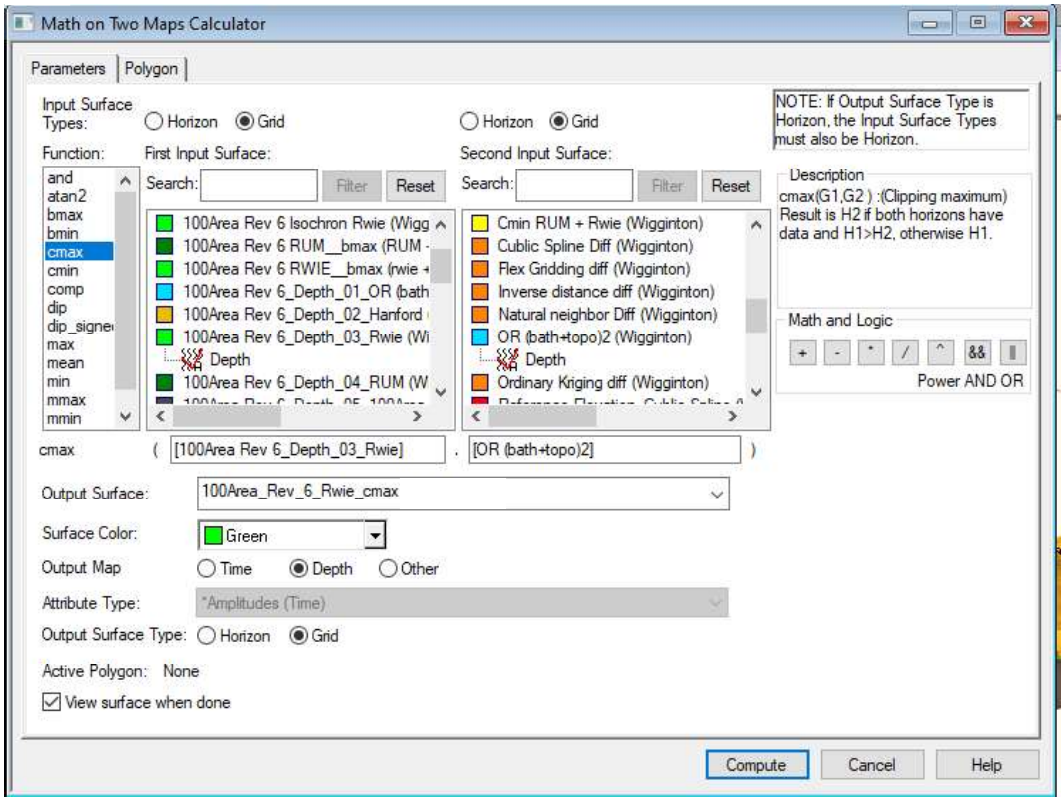
Hf = Hanford formation
RUM = Ringold Formation Upper Mud Unit
Rwie = Ringold Formation member of Wooded Island — unit E

f. Once the Formation Tops and grids have been added, select "Control Points" from the dropdown menu under "Depth" and add where appropriate. Then adjust all additional parameters of "Formation Rules," "Onlap," and the advanced settings containing the polygon rules.

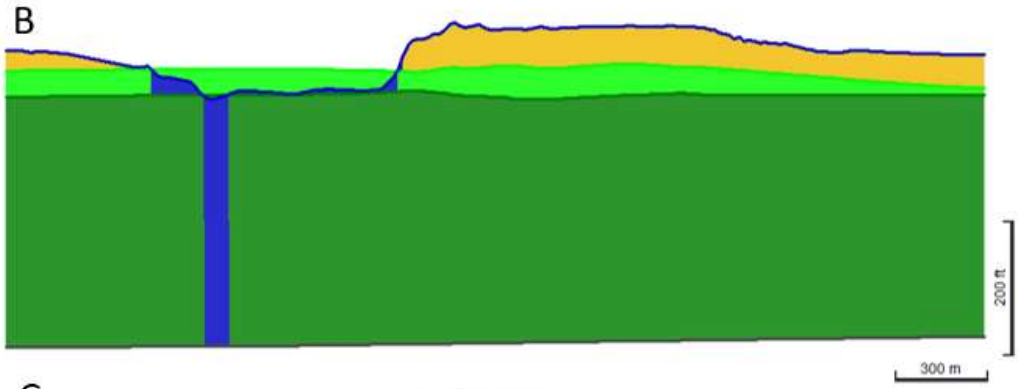
g. Once the parameters are set up, run the model by selecting the "Update" button in the upper left. A dialogue window will open showing the operations occurring and listing any warnings or errors. The result should be a set of five surfaces and isochore grids that can be interrogated in the main map module (i.e., Topography, Hf, Rwie, RUM, and the Columbia River Basalt Group).

10. Use the Math on Two Maps toolbox (Tools > Calculators > Math on Two Maps) to ensure that no grid has a greater elevation than the topographic/bathymetric surface. Use the "cmax" function on each grid, and place the grid in the H1 spot and the topographic surface in the H2 spot (Figure 12A). Complete this calculation for the Hf, Rwie, and RUM surfaces. The resulting grids will assume the elevation of topography/bathymetry where H1>H2 (Figure 12B and 12C) (e.g., in the riverbed).

A



B



C

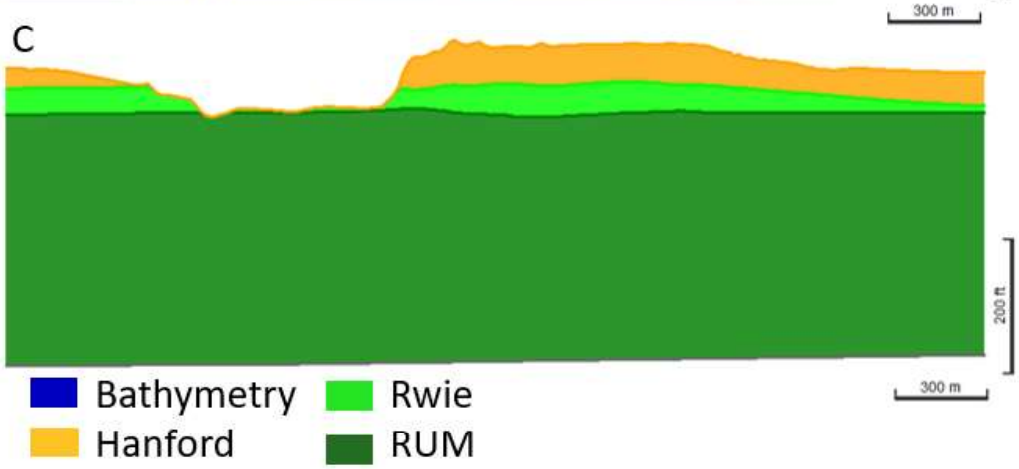


Figure 12. (A) Math on Two Maps Calculator to Create Final Surfaces (B) GFM Surfaces in Cross Section Before Running the CMAX Function (C) GFM surfaces in Cross Section After Running the CMAX Function

5 Model Results and Uncertainty Analysis

This is a static, deterministic GFM that represents the geologic architecture within the subsurface of the 100 Area domain. No sensitivity analysis were performed on this model. Uncertainties are discussed in the following sections.

5.1 Sensitivity Analysis

No sensitivity analyses were performed.

5.2 Uncertainty Analysis

The representation of the HSU surface is affected by the following uncertainties:

- Uncertainties in interpreting HSU contacts
- Errors in reported depth measurements
- Method used to define control points may add bias and is subjective
- Representativeness of individual HSU surface data points with respect to the region surrounding the data point
- Biases and variability introduced by the interpolating algorithm
- Limited deep geologic data

Developing HSU surface configurations from a limited spatial dataset also leads to uncertainty in the shape (geometry) of that surface away from areas of dense borehole control. The issue is how far a HSU data point can be extrapolated away from the borehole or GFM cell containing the borehole?

The 100 Area GFM uses the Flex Gridding algorithm in Kingdom. The algorithm is recommended for a range of dataset densities (e.g., spare, dense, or combination) and aims to honor known data points while reducing curvature of the interpolated surface. The Flex Gridding algorithm prioritizes fitting the interpolated surfaces through the XYZ input data whenever possible. When this direct fit is not possible, the interpolated surface will pass close to the input data points based on mathematical criteria selected by the user.

The following are three options for mathematical criteria that dictate the position of grid nodes in between known data points:

- The minimum tensions method: Uses a function called the LaPlacian operator. The interpolated surface is pinned to each data point, and the remaining grid nodes between the data points are distributed so overall tension is minimized and the known data points are connected by the smallest possible area.
- The minimum curvature method: Uses a solution for the grid nodes called the biharmonic operator. This function produces an interpolated surface that is as smooth as possible between known data points. The last option is to use a combination of the biharmonic operator and the LaPlacian operator and assign a weighted blend of each function.
- A combination of the two methods. Because the minimum tension operator emphasizes the importance of local control point values and the minimum curvature operator emphasizes smoothness, a blend of the two algorithms is also available. The Flex Gridding algorithm is applied with an iterative approach. The algorithm calculates minimum curvature and minimum tension at each grid

node comparing the results to a small subset of local control points. The functions are applied to small grids from the dataset and run iteratively until convergence occurs. Both minimum curvature and minimum tension function were set to 0.5 for the 100 Area GFM. These moderate settings resulted in smooth surfaces without overwriting the naturally undulating geomorphology.

One of the reasons for using HSU control points was to reduce the influence of this modeling limitation. Since HSU control points allow the imposition of the subjective bias by the geologist into the interpolation, the HSU control point placement and the interpretation of their influence are subjective. The control points are mainly used to apply professional judgment where insufficient data exist to fully describe site conditions. The net effect of HSU control points is to maintain consistency with published or interpreted geologic results.

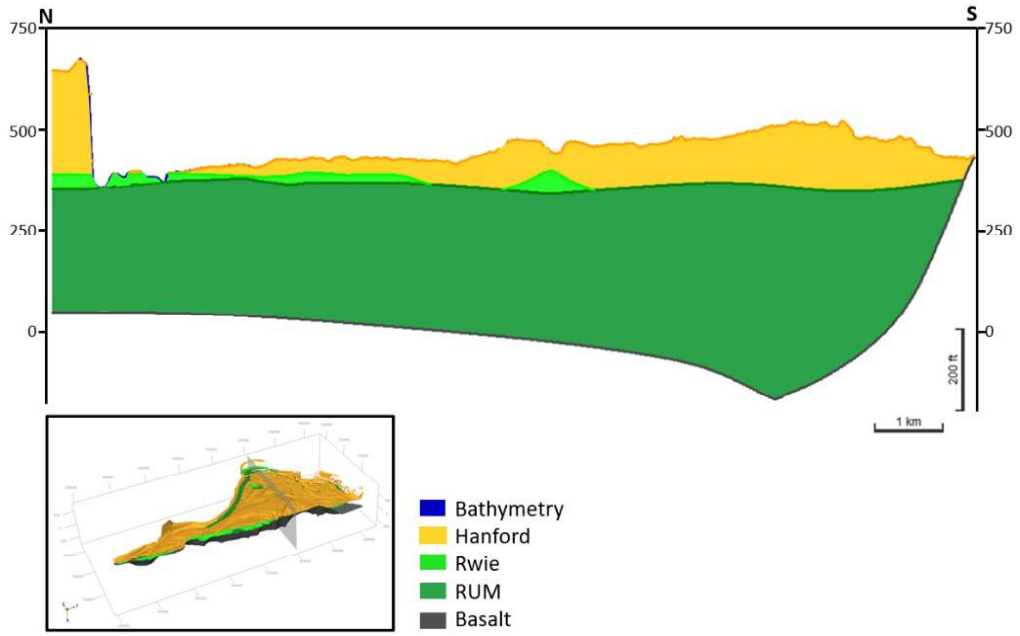
The uncertainties listed above provide a listing of some common uncertainties encountered during any geologic investigation and GFM development. These uncertainties are minimized, where possible, through accurate collection and recording of the raw data that are used to interpret the results by using consistent interpretation techniques, maintenance/archival of the related databases, and hydrogeologic publications that provide the basis for the interpretations.

5.3 Results

The following sections describe the three dimensional surfaces generated in Kingdom for the Hf, Rwie, and RUM HSUs in the 100 Area at the Hanford Site. Results discuss overall site geology and the differences between surfaces created in Revision 5 and Version 6 of the 100 Area GFM.

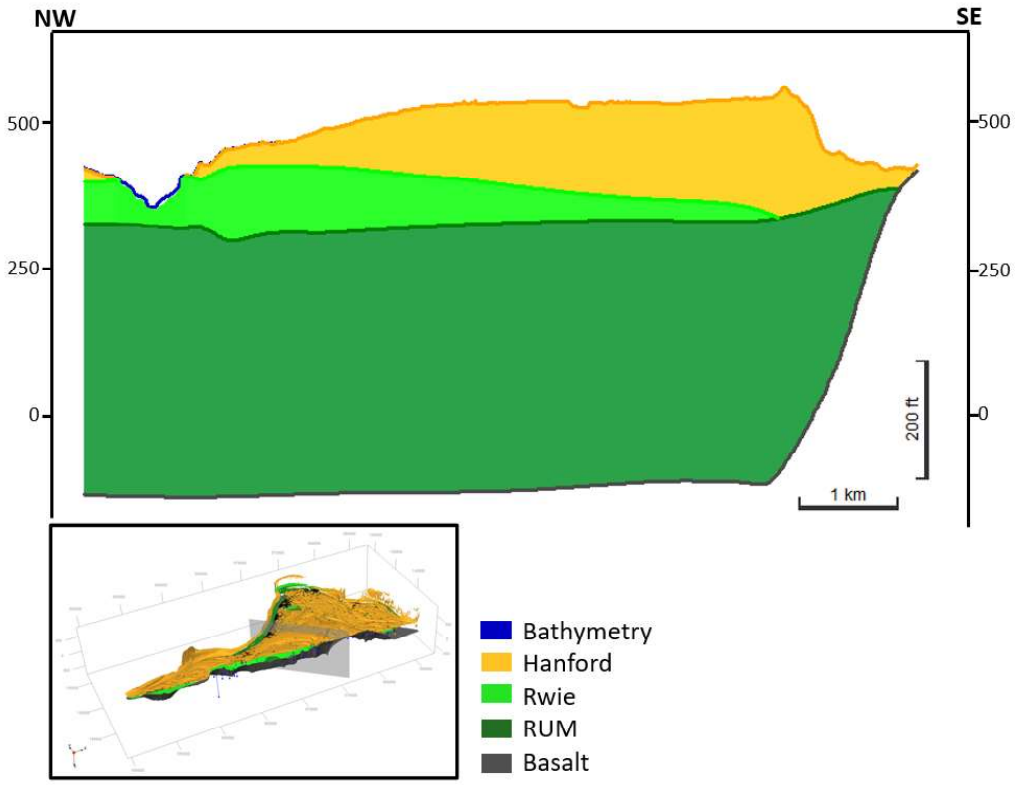
5.3.1 Geology Overview

The top of basalt surface, which defines the basalt boundary of the 100 Area GFM model, is deepest in the eastern/central portion of the GFM (near the 100-K Area) and outcrops to the south on the flanks of Gable Mountain and Gable Butte. The synclinal low in the top of basalt surface is filled in by a thick section of undifferentiated RUM (Figure 13). In this GFM, the RUM is not subdivided into stratigraphic subunits because of the sparsity of deep borehole data. Additionally, the RUM is accepted to be the base of the unconfined aquifer in most of the 100 Area due to this HSU's generally much lower porosity and permeability. The RUM is thickest in the central portion of the 100 Area GFM and thins toward the GFM domain's edges, pinching out before it reaches the southeastern corner of the GFM. The coarser conglomerate of the Rwie is significantly thinner than the RUM and is predominantly found in the western half of the 100 Area GFM. The Rwie is thickest in the eastern/central portion of the 100 Area GFM and thins toward both the north and west (Figure 13). The Rwie is erosionally truncated by thick Hanford Site HSU deposits on the east-side of the 100 Area GFM. The Hf HSU is present across the entire 100 Area GFM domain. The Hf HSU is thickest in the southeastern portion of the 100 Area GFM and thins toward the River Corridor (Figure 13 and Figure 14). Appendix C has structure maps and isopach maps of the 100 Area GFM HSUs.



Note: Vertical scale is elevation in feet.

Figure 13. Cross Section from North to South Across the 100 Area GFM (Version 6)



Note: Vertical scale is elevation in feet.

Figure 14. Cross Section from North-West to South-East Across the 100 Area GFM (Version 6)

5.3.2 Changes to the 100 Area GFM from Revision 5 to Version 6

Changes from Revision 5 to Version 6 of the 100 Area GFM include updates and revisions to borehole data, the addition of newly drilled boreholes, and a change from Leapfrog Geo to Kingdom to build the 100 Area GFM. The EMDT details the updates and revisions to borehole data, the addition of new boreholes, updates to borehole depths, updates to HSU top contact picks, and the removal of borehole data (EMDT). Thirty-three new boreholes were drilled within the 100 Area on the Hanford Site since Revision 5 and have been incorporated into this update of the 100 Area GFM (Appendix A). Two hundred and sixty eight boreholes were removed from this update of the 100 Area GFM because a nearby borehole exists with higher HSU data quality, regions with exceptionally high borehole density (e.g., the 100-N region) were reduced ("thinned") to improve the modeled HSU surfaces, or the borehole did not contain enough lithologic information to reliable pick HSU tops (Appendix B).

Changes were also made to the number of HSUs defined within the 100 Area GFM. The "reworked RUM" HSU was removed from Version 6 of the 100 Area GFM. The regional flow model based on Revision 5 of the 100 Area GFM found little to no improvement in calibration due to the inclusion of the reworked RUM HSU. Therefore, it was decided to reincorporate the reworked RUM back into the other HSUs. In the majority of boreholes where the reworked RUM HSU was interpreted to be present, the description of this HSU's sediments more closely resembled the RUM HSU properties rather than the Rwie or Hanford Site HSUs. Therefore, there were numerous changes to the top of the RUM HSU to accommodate this interpretational framework change. The boreholes where these changes were made are listed in the EMDT.

The grids for Version 6 of the 100 Area GFM were built in Kingdom instead of Leapfrog Geo. Kingdom's interpolation algorithms improved the adherence to HSU tops and control points reducing the errors in the grids (Appendix D). Kingdom's more robust gridding algorithms also provided faster processing speeds. The faster processing speeds allow for increased resolution from 20 m to 10 m across the entire 100 Area GFM.

5.3.3 Difference Maps

Changes to the 100 Area GFM inputs and the software used to create the grids resulted in several notable changes from the Revision 5 HSU surfaces to Version 6 HSU surfaces. Figure 15, Figure 16, and Figure 17 display the differences between Revision 5 and Version 6 HSU surfaces.

Most changes between the Revision 5 and Version 6 Hf grids are due to changes in the gridding algorithm between Leapfrog and Kingdom. The differences are mostly minor (increases or decreases less than 3 m). One notable difference in the Hf structure map is in the south-west portion (Figure 15). This change from 3 to 10 m is created by the addition of control points to the model. Other substantial changes can be seen along the River Corridor due to the inclusion of detailed bathymetry into the topographic surface. The footprint of the Hf surface is also smaller after altering the southern boundary of the model.

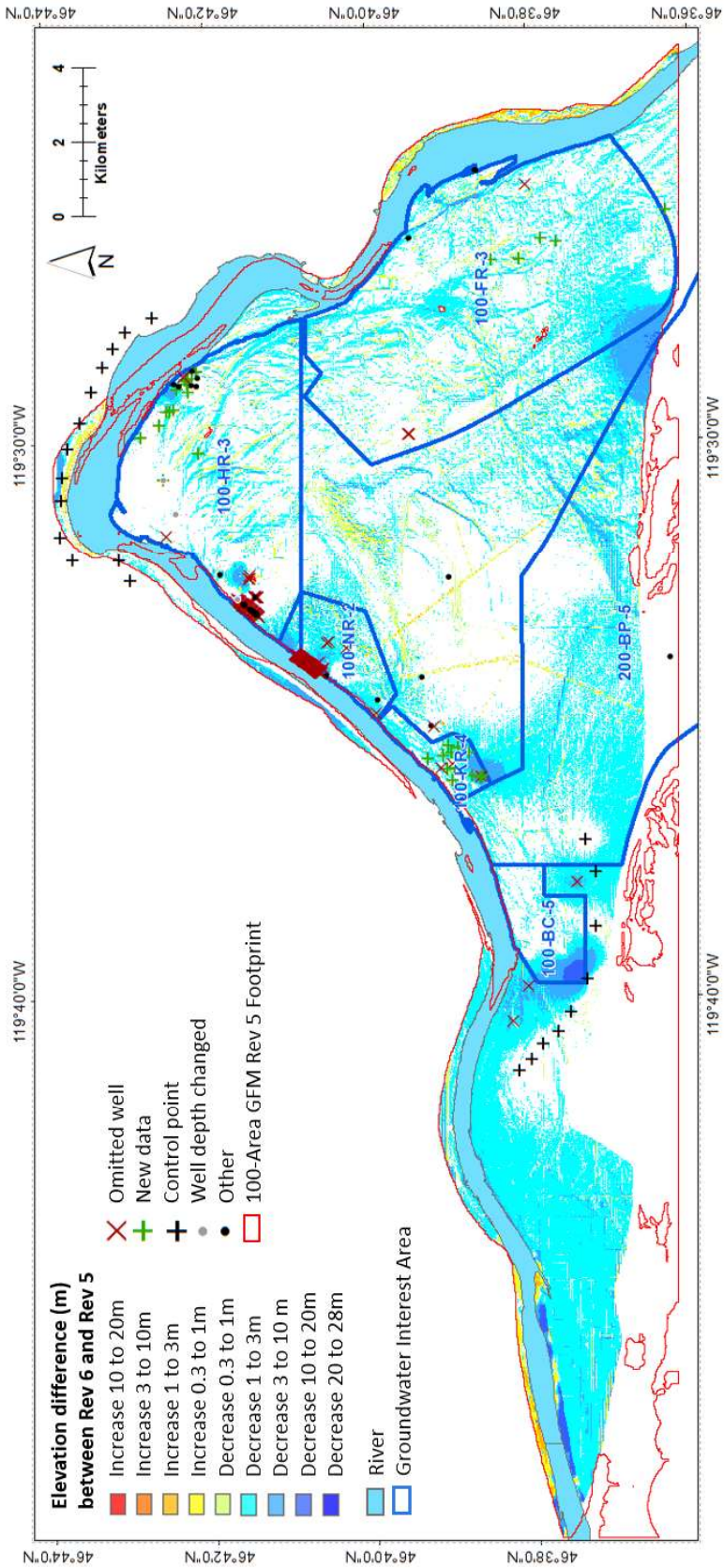


Figure 15. Map Showing Elevation Differences Between the Revision 5 Hanford HSU Surface and Version 6 Hf HSU Surface

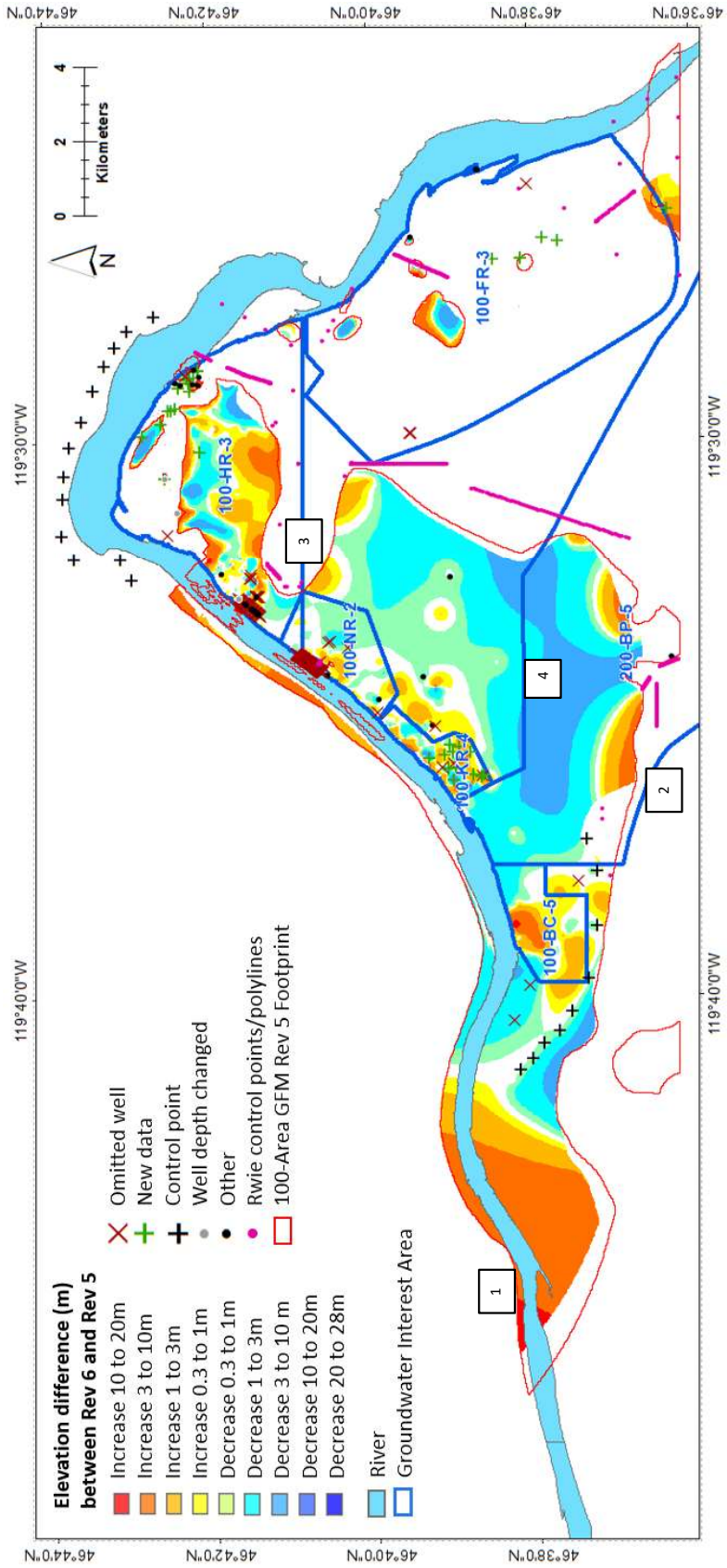


Figure 16. Map Showing Elevation Differences Between the Revision 5 Rwie HSU Surface and Version 6 Rwie HSU Surface

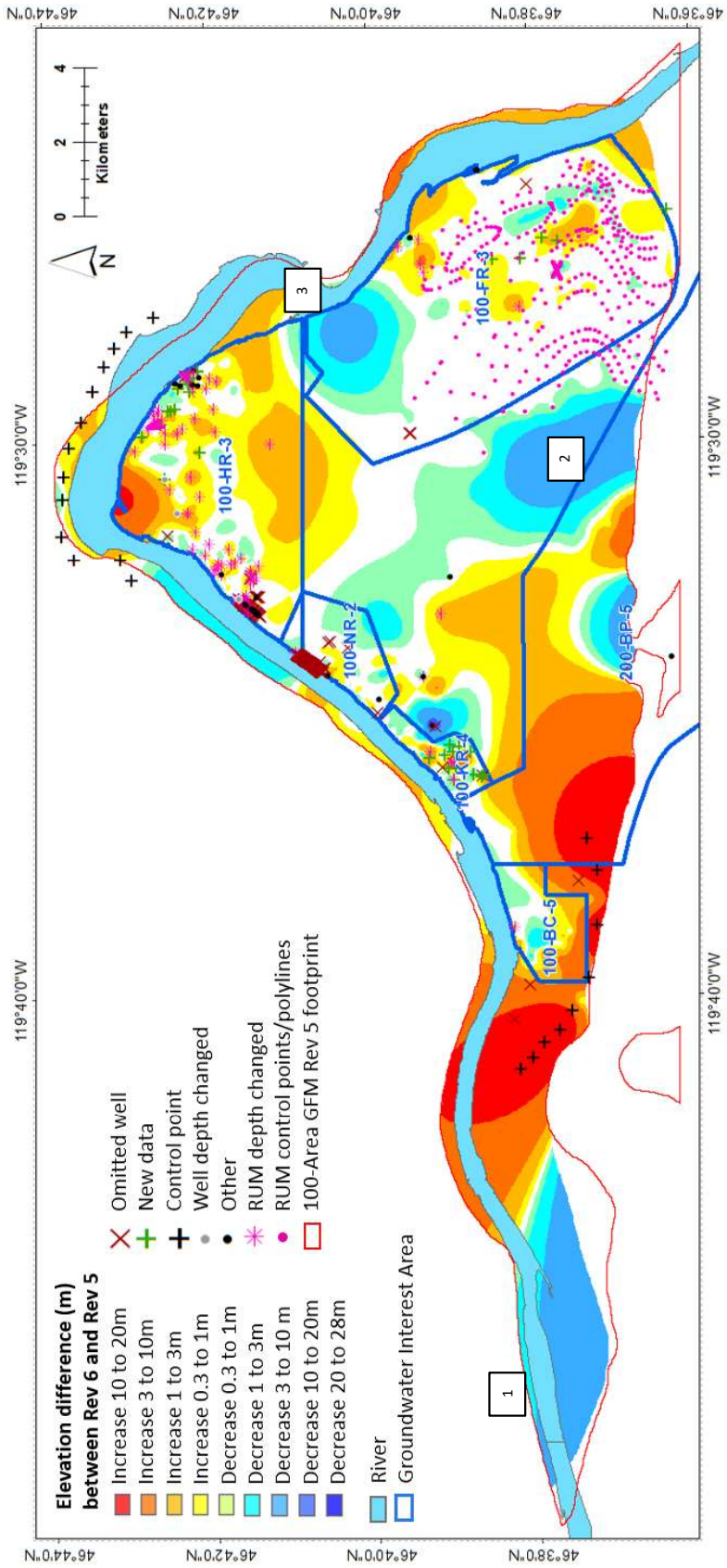


Figure 17. Map Showing Elevation Differences Between the Revision 5 RUM HSU Surface and Version 6 RUM HSU Surface

The Rwie HSU surface shows several notable changes between Revision 5 and Version 6. Many of these differences are attributed to the addition of control points and polylines, addition of new boreholes, and removal of extraneous boreholes (see EMDT and Appendices A and B). The edges of the Rwie HSU grid show an elevation increase in a few locations; this is due in part to the changes in elevation in the RUM HSU surface below and how the Rwie HSU and RUM HSU surfaces interact in the 100 Area GFM (Figure 16). An onlap relationship between the Rwie and the RUM HSUs means that increases in the RUM HSU surface elevation impact the Rwie HSU grid, especially near the 100 Area GFM domain edges (numbers 1, 2, and 3 on Figure 16). Away from control points or borehole data, the differences between Leapfrog and Kingdom interpolation functions is apparent. In the absence of data both interpretations are valid, but the Kingdom interpretation favors a thinner Rwie HSU in between borehole data points in the grid interior (number 4 on Figure 16). The resulting grid satisfactorily reflects the depositional environment and channelized nature of the gravel-dominated Rwie HSU.

Differences between Revision 5 and Version 6 of the RUM HSU surface are due to the addition of control points, addition of new boreholes, removal of boreholes, and changes made to the RUM HSU contact depth due to the removal of the reworked RUM HSU (see EMDT and Appendices A and B). Away from control point or borehole data, the difference between the Leapfrog and Kingdom interpolation functions is apparent again. The Kingdom flex gridding interpolation uses trends between datapoints; this interpolation of the RUM HSU surface has resulted in a decrease in RUM HSU surface elevation in regions with low borehole density (numbers 1, 2, and 3 on Figure 17).

6 Model Limitations

GFMs are typically most limited by the quality and distribution of input data which delineated geologic contacts. This includes borehole data (geophysical logs and driller/borehole logs) and seismic reflection data. The distribution and density of boreholes has a large impact of gridding of the HSU surfaces – sparse borehole data introduces errors to the regions away from well control. There is also a limited amount of seismic reflection profiles on the Hanford Site which is primarily used to determine the elevation of the basalt surface. Limited seismic reflection data leaves room for significant errors in the basalt surface.

Models in Kingdom are also limited in terms of solid model hydraulic property mapping and export options. Kingdom does not create solid models which include hydraulic properties. This means the grids created in Kingdom must be used as the starting point for building solid models in other fate and transport modeling software. Additionally, the 2016 and 2019 versions of Kingdom limits users to exporting surfaces in XYZ points. This means that when the XYZ points from the GFM are imported into other software packages, the surfaces are reinterpolated. The reinterpolation can introduce additional errors to subsequent models.

7 Model Configuration Management

The three dimensional geologic surfaces created in Kingdom that form the 100 Area GFM are exported as XYZ point data in either feet or meters. The grids are output as *.dat files. The complete set of surfaces will be archived and maintained in the Environmental Model Management Archive. In order to assure reproducibility, the Formation Tops from the 100 Area GFM will be added to the GeoContacts dataset and eventually imported into the HEIS GEO, the database slated to replace the Hanford GeoContacts dataset. Control points and model polygons are stored as XYZ points. All information supporting the completion of the surfaces are maintained in the Environmental Model Management Archive (contact the Risk and Modeling manager).

Model updates occur periodically as enough new well data have been collected to appreciably change the modeled HSUs. If a new well is drilled in an area of high well density and the subsurface interpretation comports with the existing GFM, a regional GFM update is not necessary. If several new wells are drilled in areas of sparse well control and the results differ from the interpreted subsurface conditions, a GFM update may be necessary. The determination that an update or new version of the GFM is required will be undertaken by the Remedial Decision support lead or the Risk and Modeling management.

8 Data Needs

The largest areas of uncertainty for the 100 Area GFM are in the central portions of the model and in the depth below the top of the RUM. Drilling wells in these areas would be beneficial to the 100 Area GFM. Similarly, there are a few wells that have been drilled past the top of the RUM, so there is not enough information to map HSUs between the top of the RUM and the Columbia River Basalt Group. The exception being in the HR-3 OU where wells have been drilled near the H Reactor and across the Horn (the northern-most portion of the site where the Columbia River turns from northern to southern flow) to characterize the intra-RUM water-bearing units. A site-specific GFM is currently being developed to map the intra-RUM units in the 100-HR-3 OU, but there are not enough data points to expand that mapping south of the 100-HR-3 OU.

The best data to collect to inform a regional GFM are borehole and geophysical logs from wells being drilled. There is not a strict need for more advanced analyses, although grain-size distribution data are a nice complement to borehole logs. Seismic data collected in the 100 Areas would help to reduce the uncertainty in the top of the Columbia River Basalt Group bedrock surface. However, because the base of the unconfined aquifer (and even the intra-RUM semiconfined units) is a mud unit, reducing the uncertainty in the top of the Columbia River Basalt Group is not critical to the understanding of the 100 Area hydrogeology.

9 Model Recommendations

Additional refinements to the 100 Area GFM will be included in future updates to the model. Recommendations for future revisions include the following:

- Increase vertical resolution of HSUs
- Refine interpretations with increasing well density over time
- Evaluate a facies-based interpretation that would capture lateral and vertical lithology changes within HSUs that may impact fate and transport

All the recommendations for future revisions of the 100 Area GFM will improve the accuracy of the representation of subsurface geology. This will improve resolution for subsequent flow and transport models which support site remediation.

10 References

Aero-Metric LiDAR, 2008, *RCCC-Hanford Battelle/PNNL/DOE, Digital Orthophotography & LiDAR Surveys Photogrammetric Report*, prepared by Aero-Metric, Inc., Seattle, Washington.

BHI-00184, 1995, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington,* Rev. 0, Bechtel Hanford, Inc., Richland, Washington. Available at: https://pdw.hanford.gov/document/0083482H.

B040899, 1979, *Seismic Velocity Survey, Rockwell Hanford Operations ESG, DC 2, 3, 4, 6, and 7, Benton County, Washington*, Birdwell Division of Seismograph Service Corporation for Rockwell Hanford Operations, Richland, Washington.

B067305, 1979, *Final Report on Seismic Reflection Survey Conducted in Benton and Grant Counties, Washington, FY-79 Program, Pasco Basin, Hanford Site, Basalt Waste Isolation Program*, Seismograph Services Corporation for Rockwell Hanford Operations, Richland, Washington.

B067306, 1980, *Final Report on Seismic Reflection Survey Conducted in Benton County, Washington, FY-80 Program, Pasco Basin, Hanford Site, Basalt Waste Isolation Program*, Seismograph Services Corporation for Rockwell Hanford Operations, Richland, Washington,

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 USC 9601, et seq., Pub. L. 107-377, December 31, 2002. Available at: https://www.csu.edu/cerc/researchreports/documents/CERCLASummary1980.pdf.

CHPRC-02937, 2019, *Kingdom-Geology Software Management Plan,* Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

CHPRC-02938, 2019, *Kingdom-Geology Software Test Plan*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

CP-60925, 2018, *Model Package Report: Central Plateau Vadose Zone Geoframework Version 1.0,* CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/0065500H.

DOE/RL-2008-42, 2009, *Hydrogeological Summary Report for 600 Area Between 100-D and 100-H for the 100-HR-3 Groundwater Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/0911161139.

DOE/RL-2018-66, 2019, *Hanford Site Groundwater Monitoring Report for 2018*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-03138.

ECF-100NPL-11-0070, 2017, *100 Area Stratigraphic Database Development*, Rev. 4, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/0067948H.

ECF-HANFORD-13-0020, 2017, *Process for Constructing a Three Dimensional Geological Framework Model of the Hanford Site 100 Area*, Rev. 5, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/064944H.

ECF-HANFORD-13-0029, 2017, *Development of the Hanford South Geologic Framework Model, Hanford Site, Washington,* Rev. 3, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/0072750H.

ECF-HANFORD-16-0128, 2017, *Development of Contiguous Top of Basalt Surface for Use in Development of Site Geoframeworks*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/0072755H.

EMDT-GR-0039, 2020, *Geologic Contacts for the 100-Area Geoframework Model*, Rev. 1, CH2M Hill Plateau Remediation Company, Richland Washington.

EPA/600/R-17/293, 2017, *Best Practices for Environmental Site Management: A Practical Guide for Applying Environmental Sequence Stratigraphy to Improve Conceptual Site Models,* U.S. Environmental Protection Agency, Washington, D.C. Available at: https://pdw.hanford.gov/document/0072755H.

Lindsey, K.A., and Gaylord, D.R., 1990*, Lithofacies and Sedimentology of the Miocene-Pliocene Ringold Formation, Hanford Site, South-Central Washington*, Northwest Science, 64(3), 165-180. Available at: https://research.libraries.wsu.edu/xmlui/bitstream/handle/2376/1664/v64%20p165%20Lindsey%20and%20Gaylord.PDF?sequence=1.

NAD83, 1991, *North American Datum of 1983*, as revised, National Geodetic Survey, Federal Geodetic Control Committee, Silver Spring, Maryland. Available at: https://www.ngs.noaa.gov/datums/horizontal/north-american-datum-1983.shtml.

NAVD88, 1988, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Spring, Maryland. Available at: https://www.ngs.noaa.gov/datums/vertical/north-american-vertical-datum-1988.shtml.

PNNL-12261, 2009, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200 East Area and Vicinity, Hanford Site, Washington*, Pacific Northwest National Laboratory, Richland, Washington. Available at: https://pdw.hanford.gov/document/0906180659.

PNNL-13858, 2002, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*, Pacific Northwest National Laboratory, Richland, Washington. Available at https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-13858.pdf.

PNNL-14753, 2006, *Groundwater Data Package for Hanford Assessments*. Rev. 1, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14753Rev1.pdf.

PNNL-19878, 2010, *Development of a High-Resolution Bathymetry Dataset for the Columbia River through the Hanford Reach*, Pacific Northwest National Laboratory. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19878.pdf.

PRC-PRO-IRM-309, 2017, *Controlled Software Management*, Rev. 6 Chg. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

WHC-SD-EN-TI-011, 1992, *Geology of the Northern Part of the Hanford Site: An Outline of Data Sources and the Geology Setting of the 100 Areas*, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-TI-133, 1993, *Geology of the 100-B/C Area, Hanford Site, South-Central Washington*, Rev. 0-A, Westinghouse Hanford Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/D196134620. https://pdw.hanford.gov/document/D196131231.

WHC-SD-EN-TI-155, 1993, *Geology of the 100-K Area*, *Hanford Site, South-Central Washington*, Rev. 0, Westinghouse Hanford Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/D196129512.

WHC-SD-EN-TI-221, 1994, *Geology of 100-FR-3 Operable Unit Hanford Site South-Central Washington*, Rev. 0, Westinghouse Hanford Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/D196098540.

Appendix A

New Boreholes Added to Version 6 of the 100 Area Geoframework Model

This page intentionally left blank.

Contents

A1 Introduction.....A-1

A1.1 Digital and Composite Logs for Newly Drilled Boreholes Since Revision 5.....A-3

A2 References.....A-37

Figures

Figure A-1. Borehole 199-H1-12.....A-4
Figure A-2. Borehole 199-H1-47.....A-5
Figure A-3. Borehole 199-H1-48.....A-6
Figure A-4. Borehole 199-H1-49.....A-7
Figure A-5. Borehole 199-H1-50.....A-8
Figure A-6. Borehole 199-H3-12.....A-9
Figure A-7. Borehole 199-H3-13.....A-10
Figure A-8. Borehole 199-H3-21.....A-11
Figure A-9. Borehole 199-H3-22.....A-12
Figure A-10. Borehole 199-H3-28.....A-13
Figure A-11. Borehole 199-H3-29.....A-14
Figure A-12. Borehole 199-H3-30.....A-15
Figure A-13. Borehole 199-H3-32.....A-16
Figure A-14. Borehole 199-H7-1 .....A-17
Figure A-15. Borehole 199-K-227.....A-18
Figure A-16. Borehole 199-K-228.....A-19
Figure A-17. Borehole 199-K-229.....A-20
Figure A-18. Borehole 199-K-230.....A-21
Figure A-19. Borehole 199-K-231.....A-22
Figure A-20. Borehole 199-K-232.....A-23
Figure A-21. Borehole 199-K-234.....A-24
Figure A-22. Borehole 199-K-235.....A-25
Figure A-23. Borehole 199-K-236.....A-26
Figure A-24. Borehole 199-K-238.....A-27
Figure A-25. Borehole 199-K-239.....A-28
Figure A-26. Borehole 199-K-240.....A-29
Figure A-27. Borehole 699-60-27 .....A-30
Figure A-28. Borehole 699-68-29 .....A-31
Figure A-29. Borehole 699-70-29 .....A-32
Figure A-30. Borehole 699-71-30B.....A-33

Figure A-31. Borehole 699-71-30C A-34
Figure A-32. Borehole 699-73-30 ..... A-35
Figure A-33. Borehole 699-95-45C A-36

Table

Table A-1. New Boreholes Added to the 100 Area GFM A-1

A1 Introduction

Version 6 of the 100 Area Geoframework Model includes a number of new boreholes (Table A-1). These boreholes are either newly drilled since Revision 5 or where existing boreholes data were used in defining the top of basalt surface. Details are archived in change logs GeoContacts_100-Area_2020-04-16.xlsx. A complete listing of boreholes that carried over from Version 5 of the 100 Area Geoframework Model (ECF-HANFORD-13-0020, *Process for Constructing a Three-Dimensional Geological Framework Model of the Hanford Site's 100 Area*) can be found in EMDT-GR-0039, *Geologic Contacts for the 100-Area Geoframework Model*.

Table A-1. New Boreholes Added to the 100 Area GFM

Borehole Name	X-Coord*	Y-Coord*	Elevation (m)	TD (m)
199-H1-12	576597.9	153898.8	126.9	26.7
199-H1-47	577185.5	153309.6	124.5	13.8
199-H1-48	577185.1	153237.9	125.3	15.4
199-H1-49	577249.7	153144.4	128.6	36.7
199-H1-50	576878.9	153481.1	125.4	34.0
199-H3-12	577842.3	152838.6	130.9	38.3
199-H3-13	577950.6	152815.5	128.6	34.7
199-H3-21	578127.9	152630.7	126.6	18.1
199-H3-22	577897.1	152848.0	128.9	39.6
199-H3-28	577655.4	152822.6	129.2	36.6
199-H3-29	577921.5	152884.2	128.2	70.0
199-H3-30	578100.2	152712.1	127.1	35.1
199-H3-32	577709.8	153063.5	128.1	28.7
199-H7-1	575643.2	153389.0	127.9	33.9
199-K-227	569538.7	146851.6	143.2	53.1
199-K-228	569393.1	146775.6	143.4	51.0
199-K-229	568868.0	146311.1	145.7	58.3
199-K-230	568738.2	146759.3	135.7	44.2
199-K-231	569512.0	146643.4	146.7	54.2
199-K-232	569245.5	147313.9	127.1	34.4
199-K-234	569005.8	146874.0	136.8	42.6
199-K-235	568829.6	146115.9	148.0	38.1
199-K-236	568857.0	146074.4	148.0	38.3
199-K-238	569322.0	146974.0	141.1	51.4

Table A-1. New Boreholes Added to the 100 Area GFM

Borehole Name	X-Coord*	Y-Coord*	Elevation (m)	TD (m)
199-K-239	569039.0	146693.0	142.5	48.9
199-K-240	569382.0	146378.0	150.4	57.5
699-59-44	576617.2	141539.0	230.6	70.0
699-59-4B	576435.0	141542.0	236.1	20.0
699-59-44C	576556.7	141542.0	232.3	20.0
699-60-27	581838.4	141878.5	124.8	46.4
699-60-53F	573795.6	141868.9	250.2	88.4
699-60-59	572038.1	141854.5	155.2	475.7
699-61-53	573714.1	141978.1	233.1	117.3
699-61-55A	573009.2	141983.7	141.1	75.9
699-61-57	572608.2	142435.1	135.3	179.5
699-62-53	573646.2	142518.9	133.9	139.0
699-68-29	581102.9	144382.9	120.6	11.5
699-70-29	581195.5	144752.9	121.9	14.9
699-71-30B	580710.9	145242.6	122.9	15.7
699-71-30C	580709.7	145238.8	122.9	13.2
699-73-30	580687.1	145873.7	121.4	12.3
699-84-34B	579586.4	149244.0	120.0	1022.6
699-84-62A	570882.1	149090.1	138.0	299.0
699-95-45C	576257.2	152576.2	128.1	53.3
699-63-92	561559.7	142637.4	151.8	56.7
699-63-95	560914.6	142650.8	148.3	215.5
699-65-95	560815.4	143192.9	137.9	32.3
699-66-91	562174.8	143476.8	142.6	57.9
699-61-62	570914.9	141921.7	151.8	57.3
699-61-66	569787.6	142008.0	159.7	68.6

References: NAD83, *North American Datum of 1983.*

NAVD88, *North American Vertical Datum of 1988*.

*Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m); vertical datum is NAVD 1988.

TD = total depth

A1.1 Digital and Composite Logs for Newly Drilled Boreholes Since Revision 5

These logs (Figures A-1 through A-33) for the newly added boreholes represent the profiles that are digitally available to date; it is not a complete list. There are some boreholes (older boreholes) that are currently only stored as paper copies or Adobe® Acrobat® PDFs which have not yet been digitized and tabulated for Hanford Environmental Information System Geophysical Logs; this is an ongoing process.

® Adobe and Acrobat are trademarks for Adobe Systems Inc., San Jose, California.

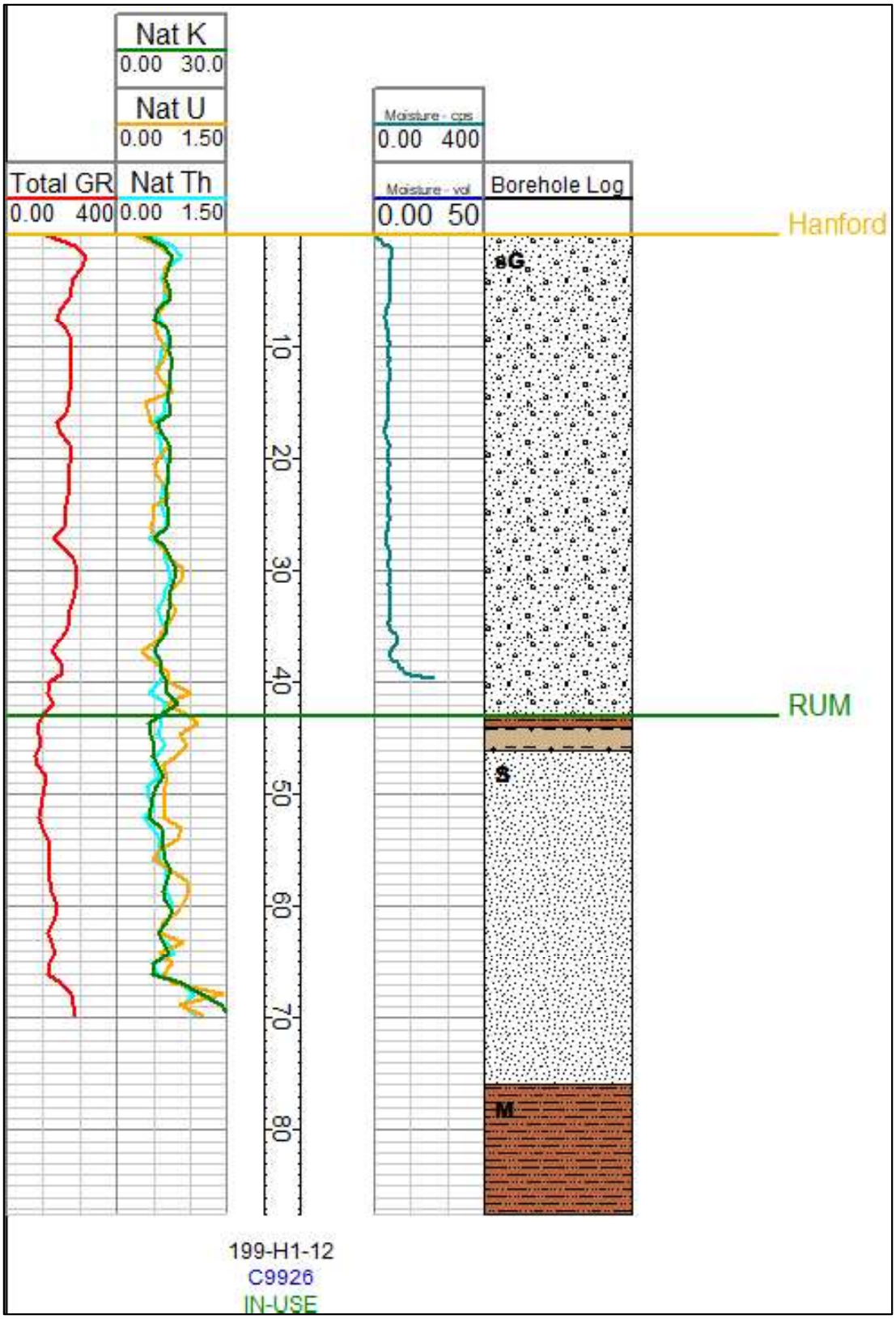


Figure A-1. Borehole 199-H1-12

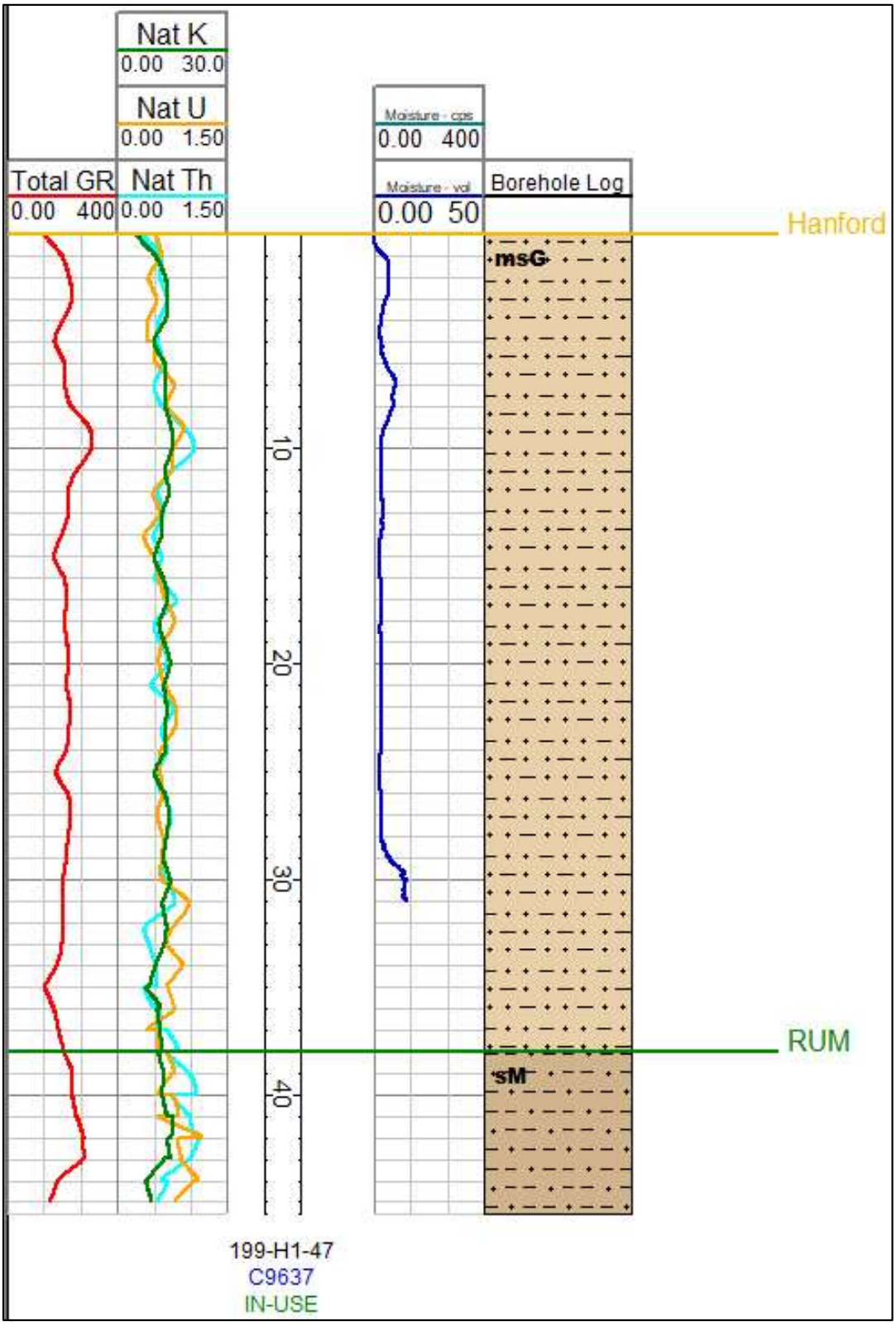


Figure A-2. Borehole 199-H1-47

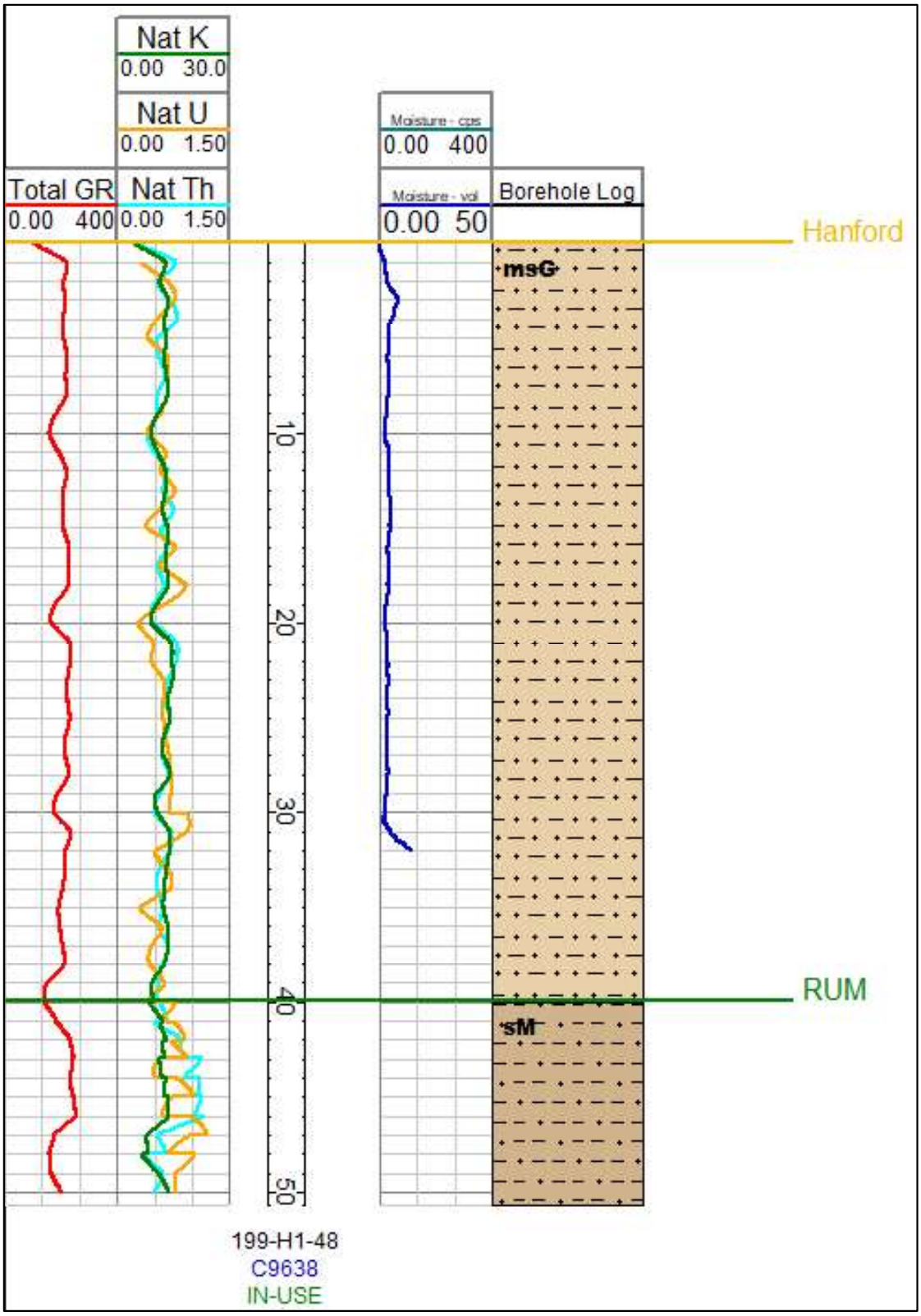


Figure A-3. Borehole 199-H1-48

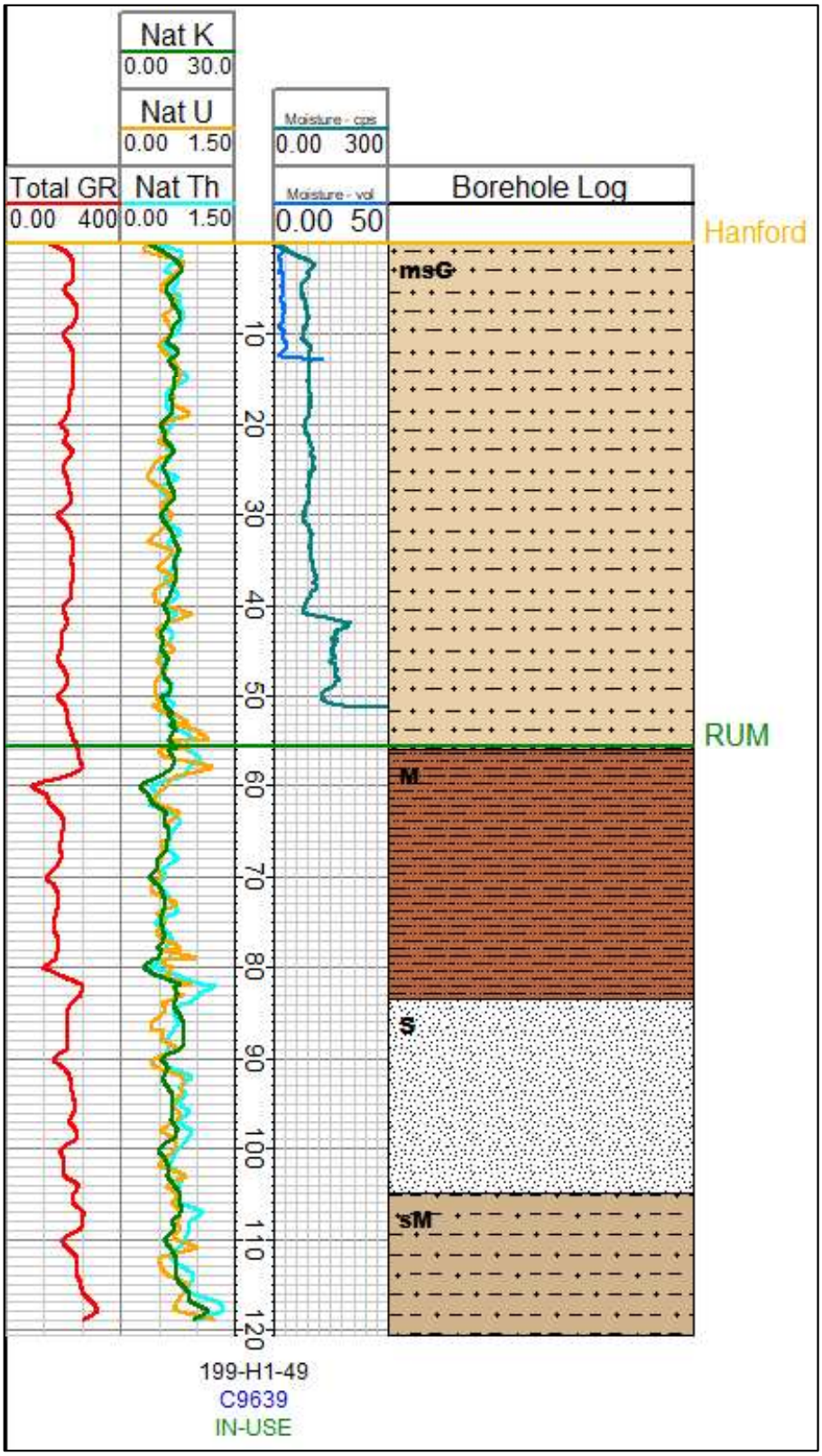


Figure A-4. Borehole 199-H1-49

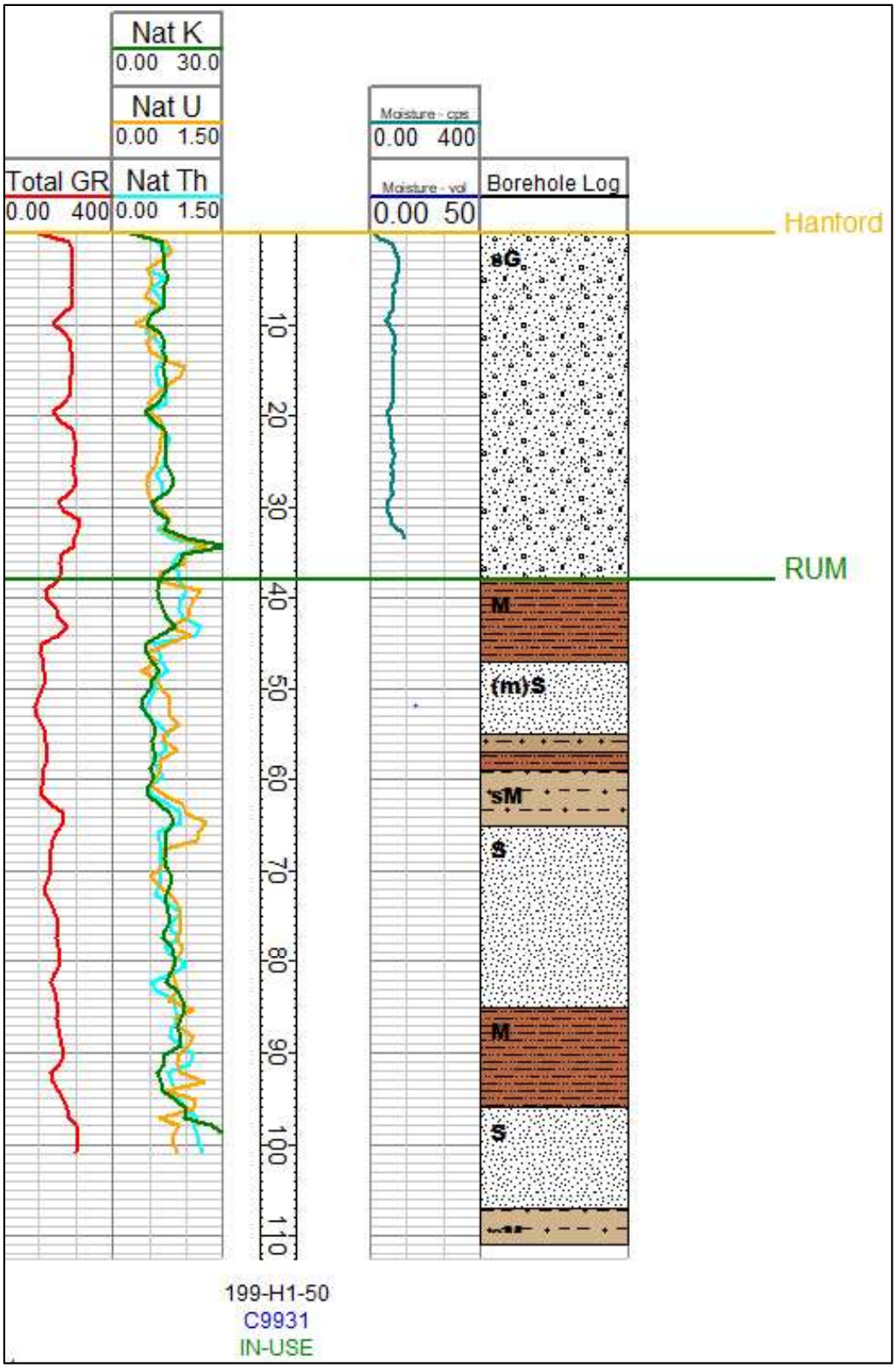


Figure A-5. Borehole 199-H1-50

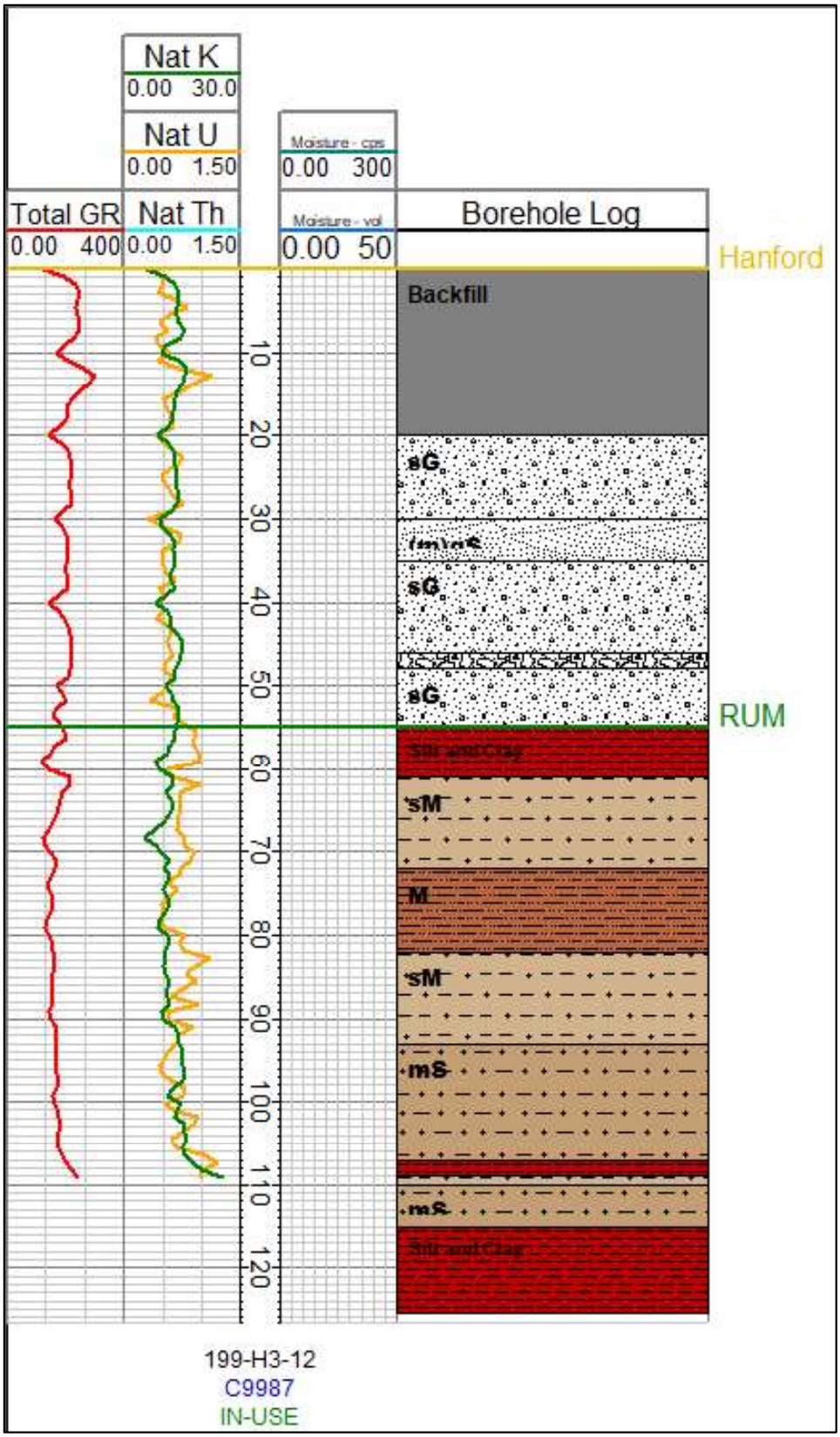


Figure A-6. Borehole 199-H3-12

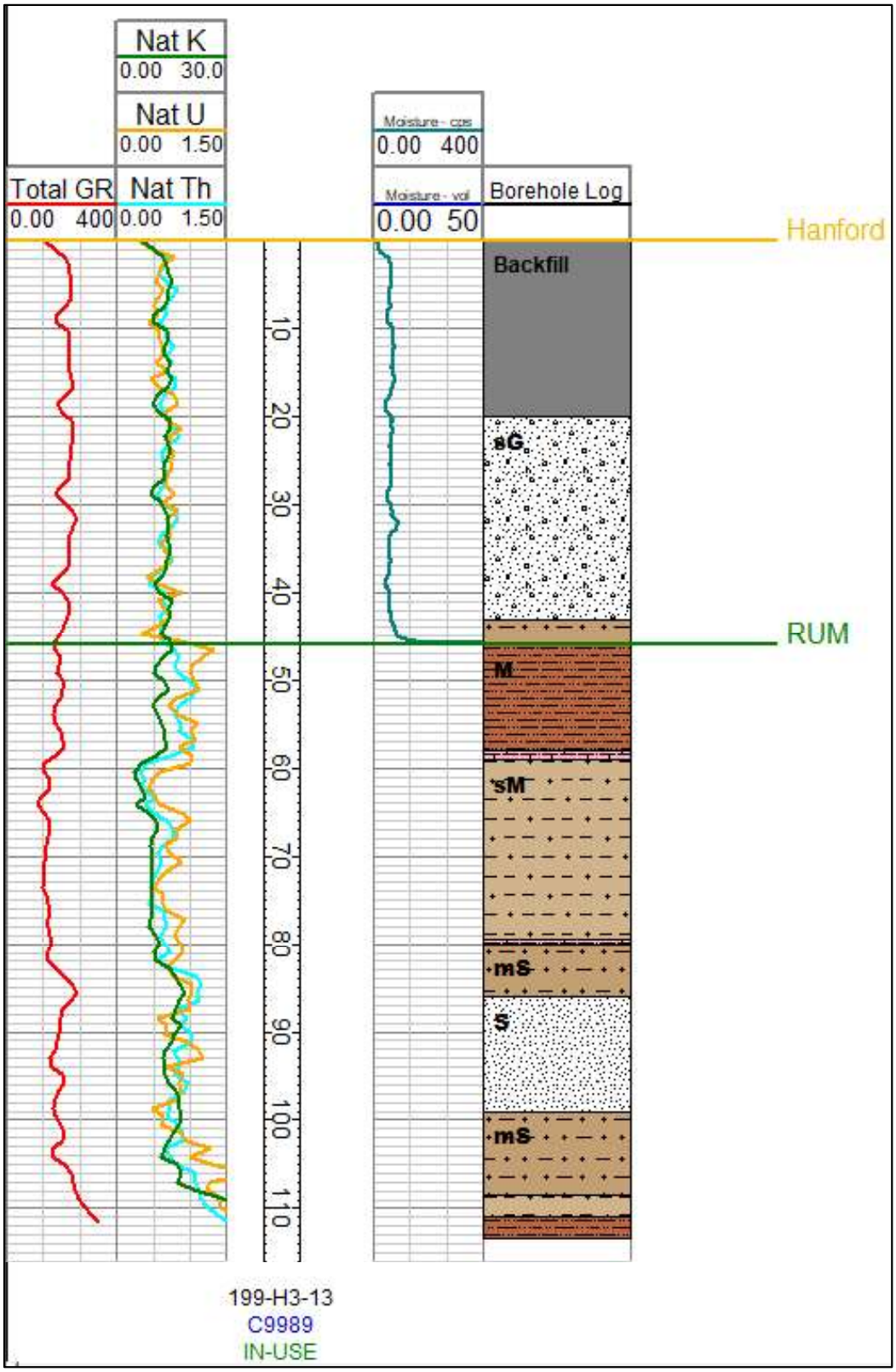


Figure A-7. Borehole 199-H3-13

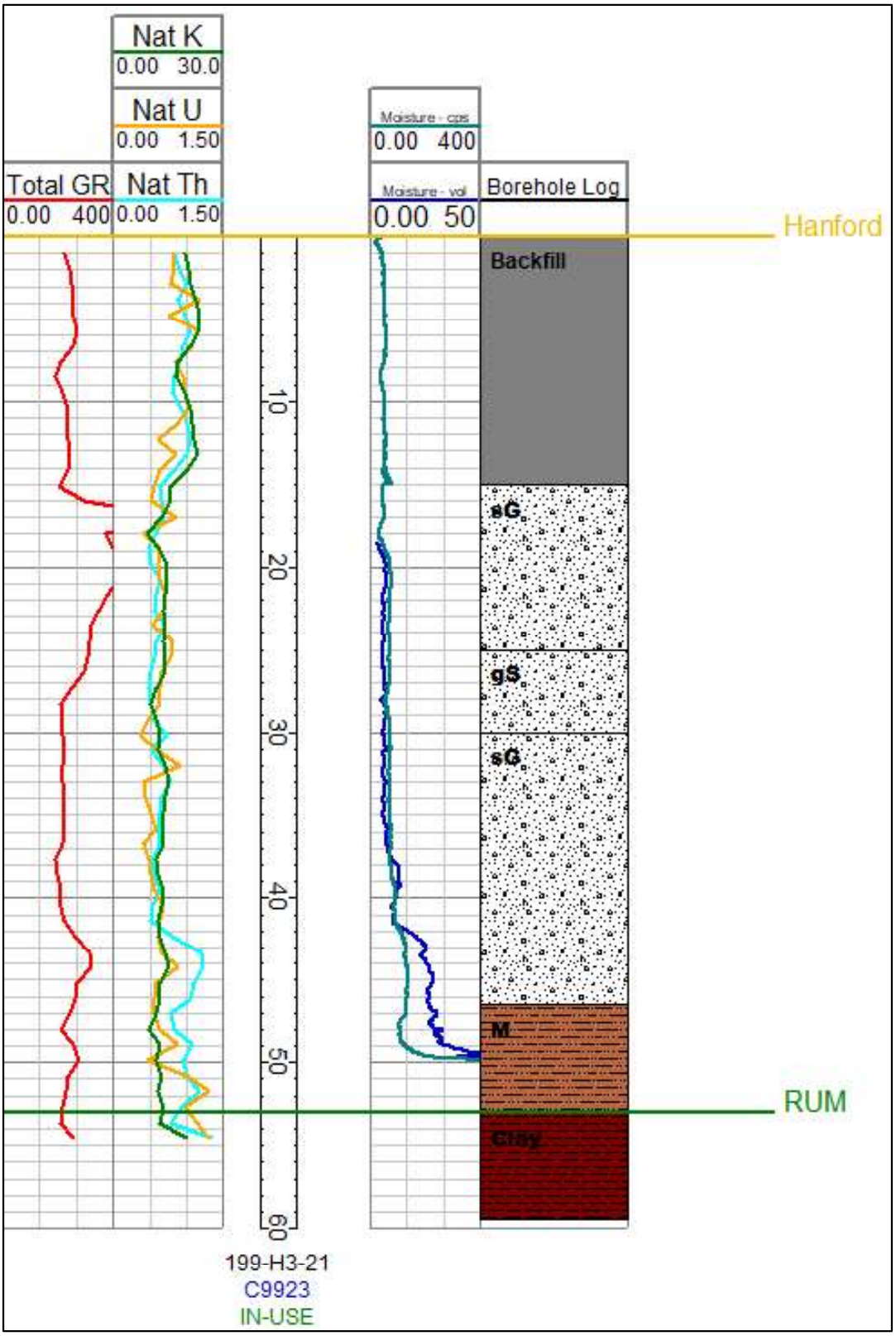


Figure A-8. Borehole 199-H3-21

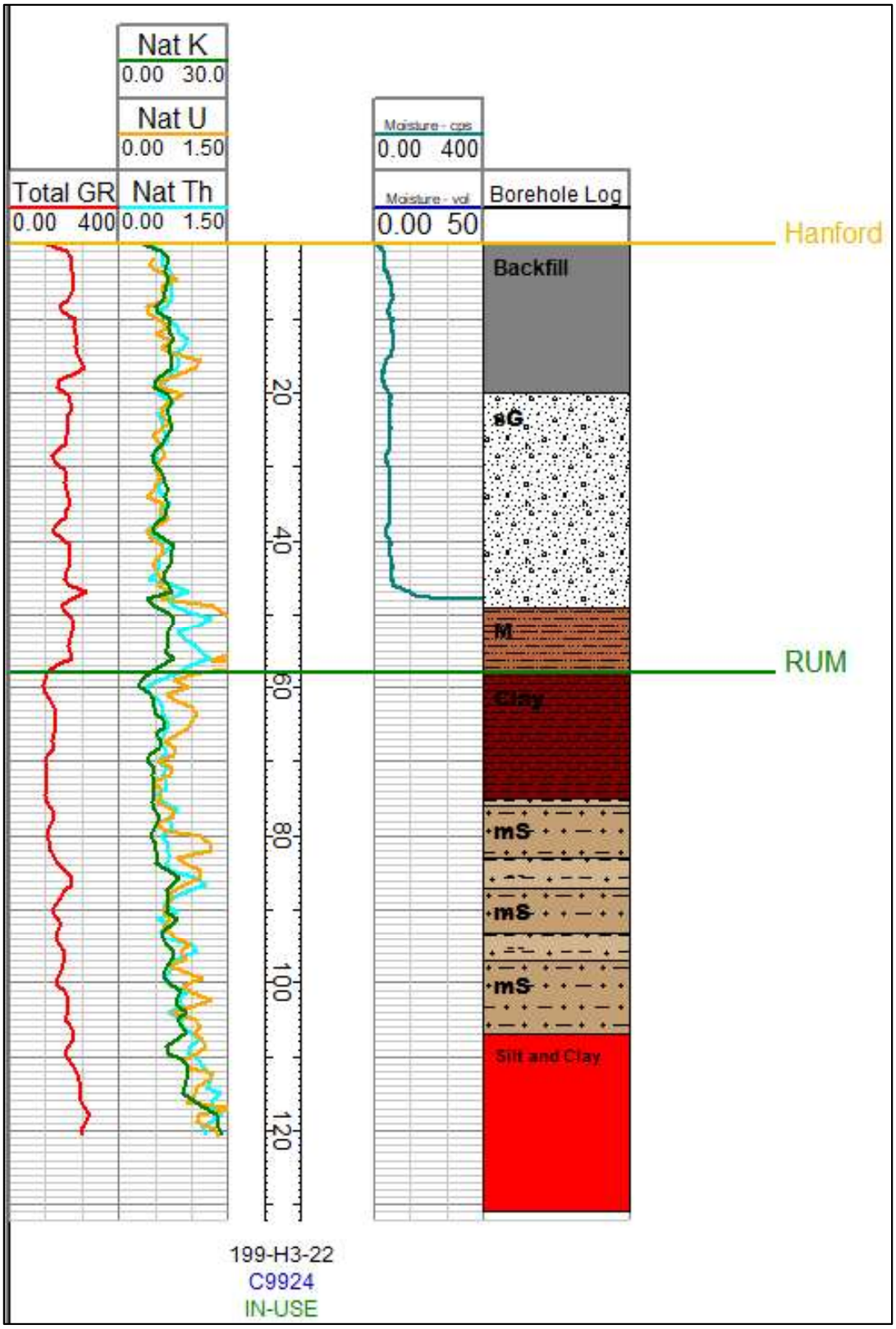


Figure A-9. Borehole 199-H3-22

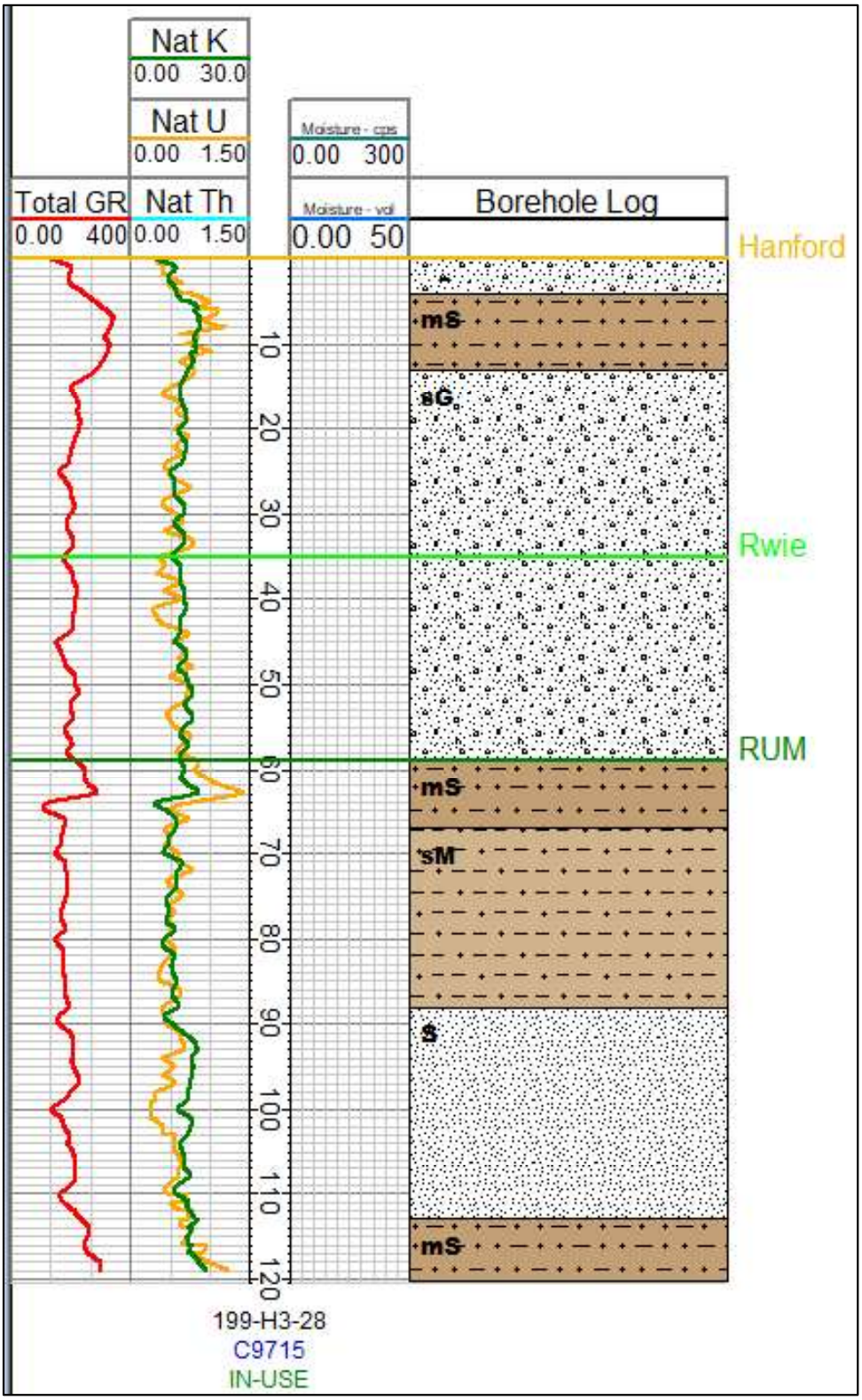


Figure A-10. Borehole 199-H3-28

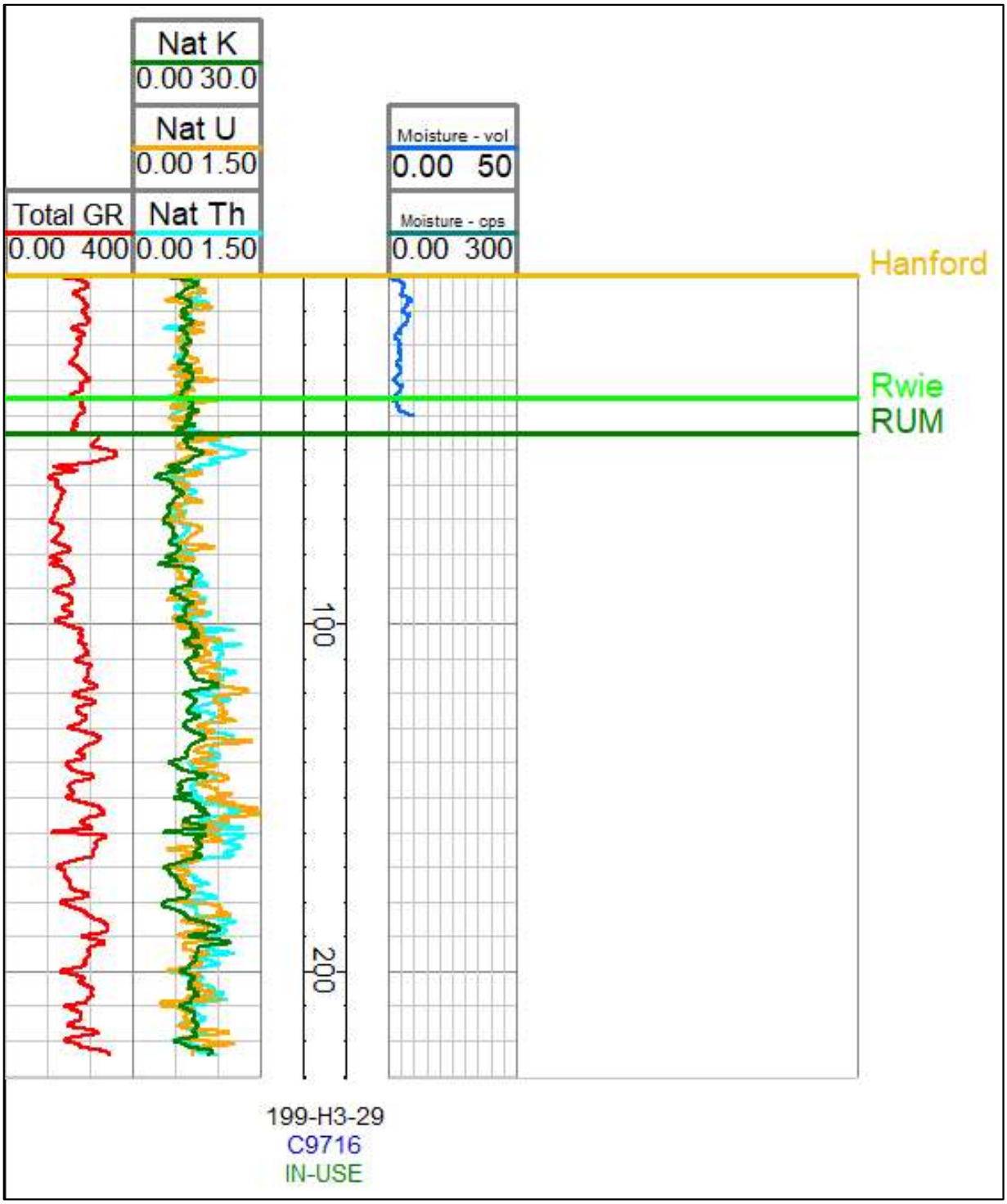


Figure A-11. Borehole 199-H3-29

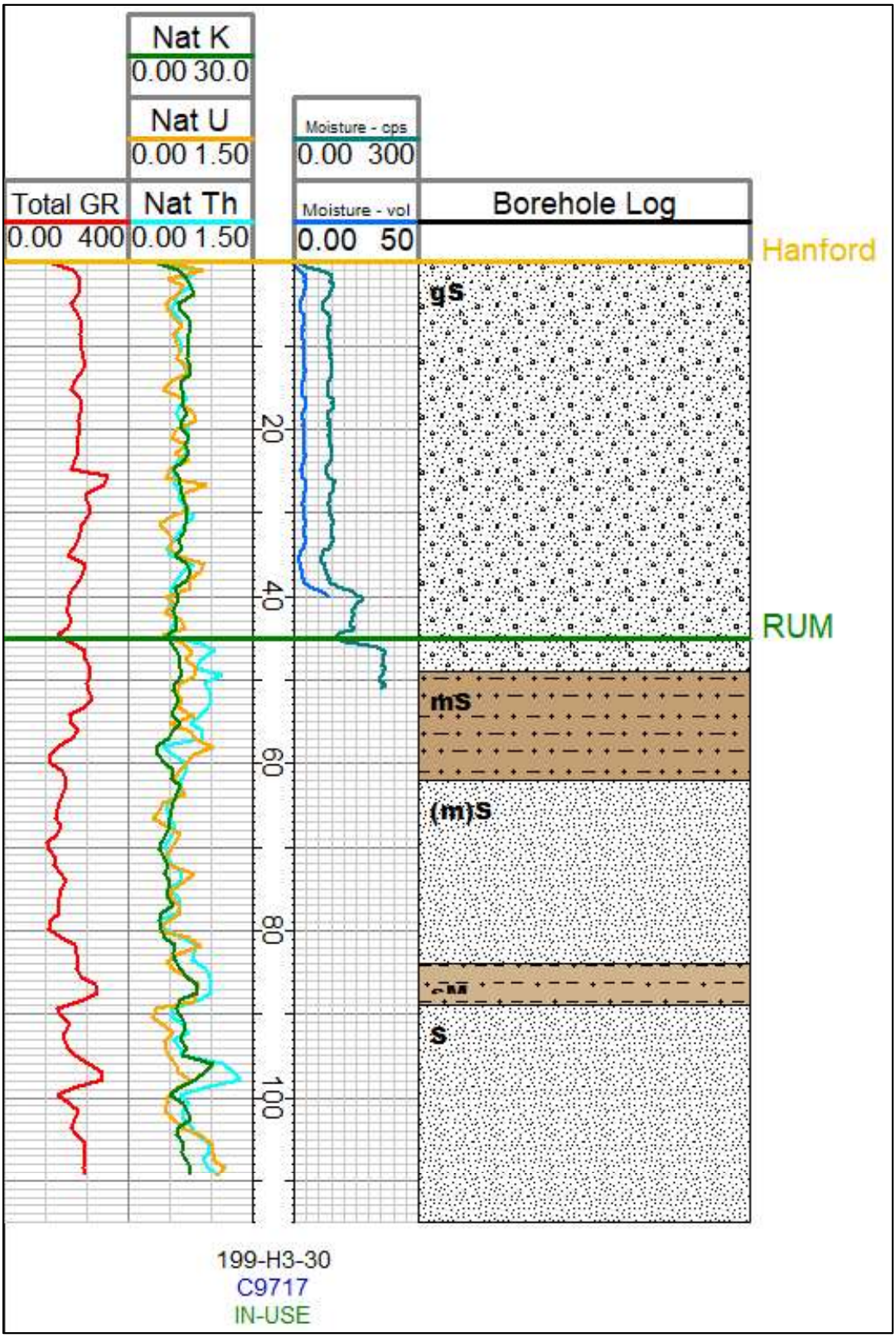


Figure A-12. Borehole 199-H3-30

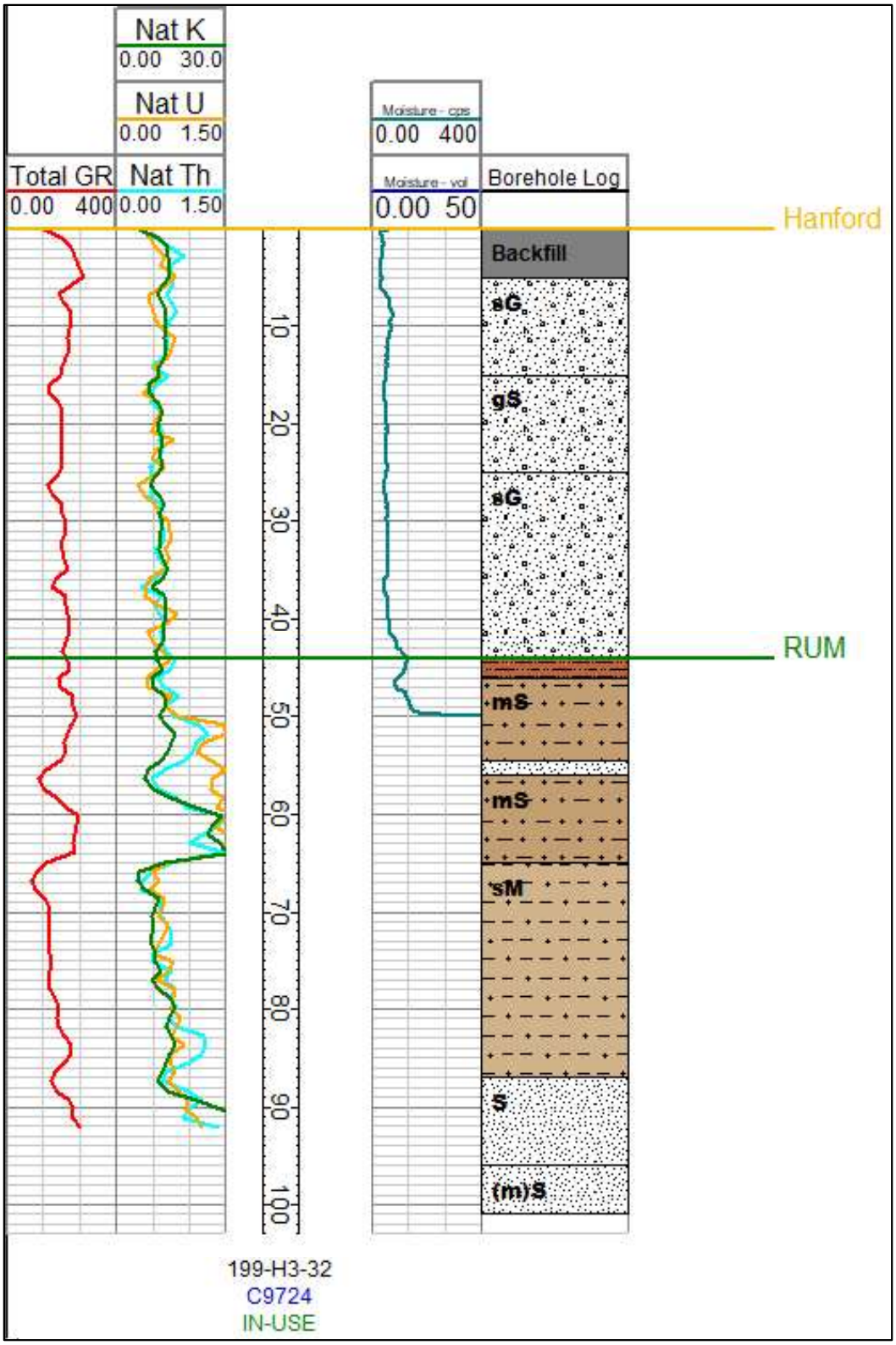


Figure A-13. Borehole 199-H3-32

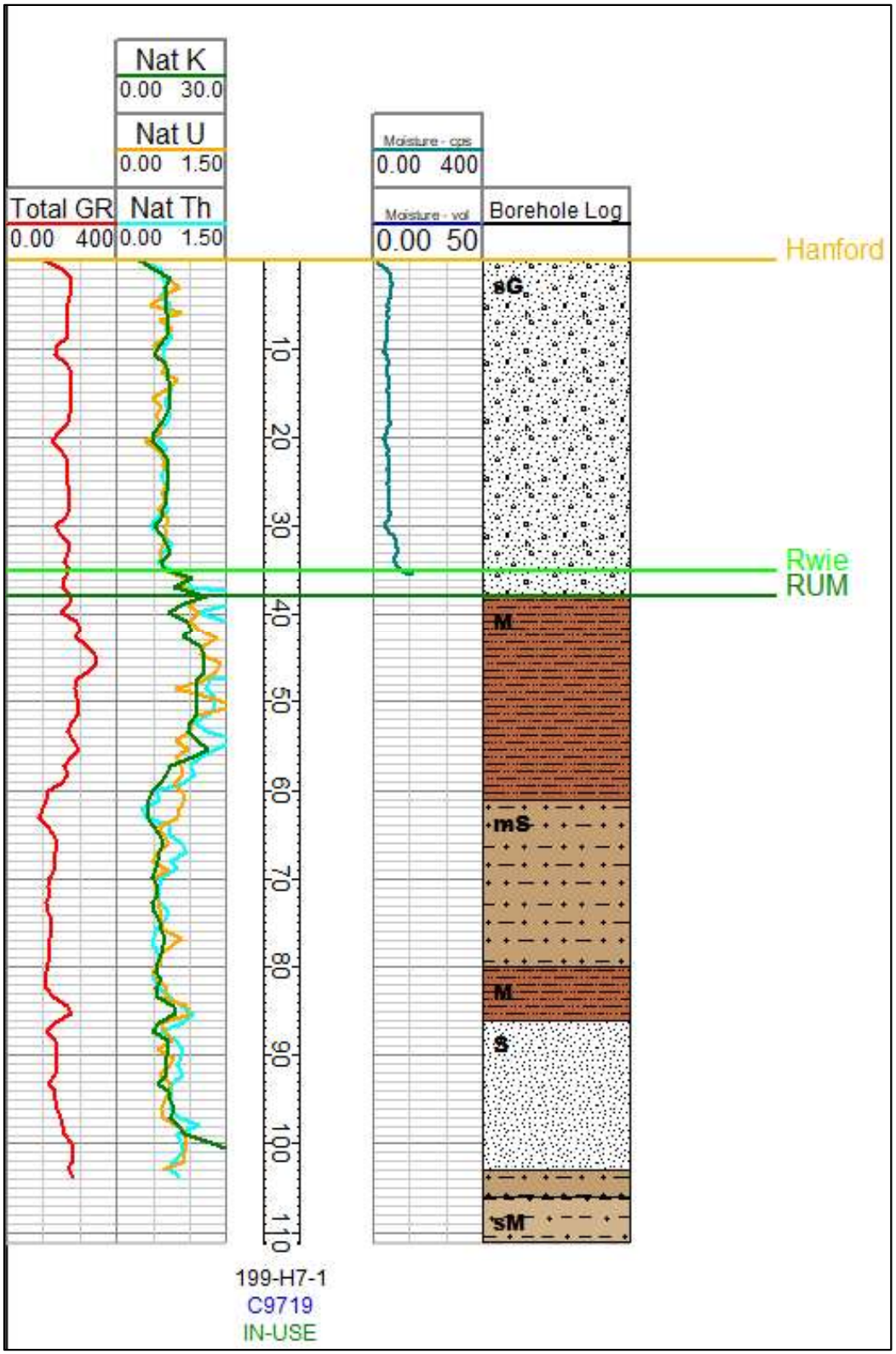


Figure A-14. Borehole 199-H7-1

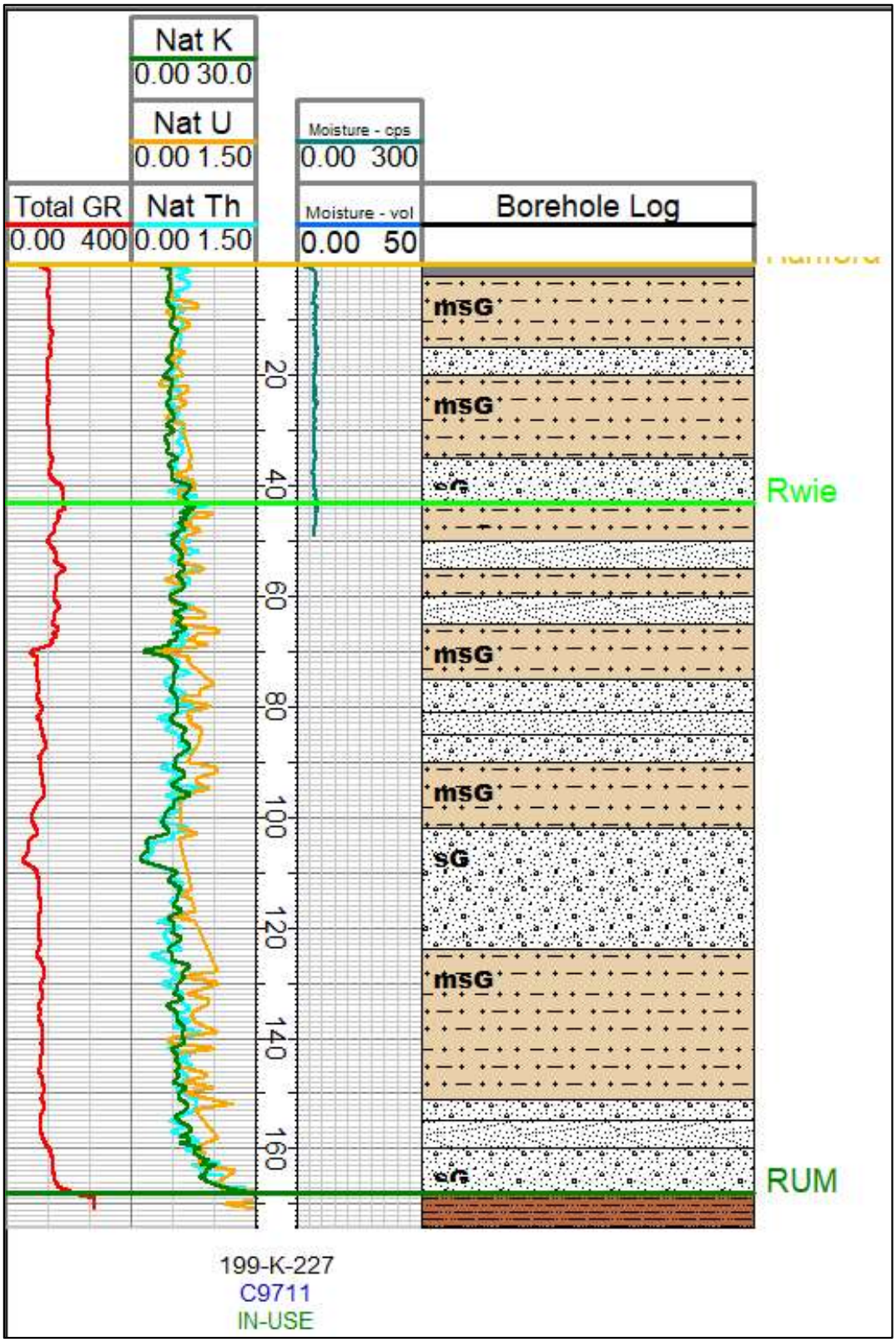


Figure A-15. Borehole 199-K-227

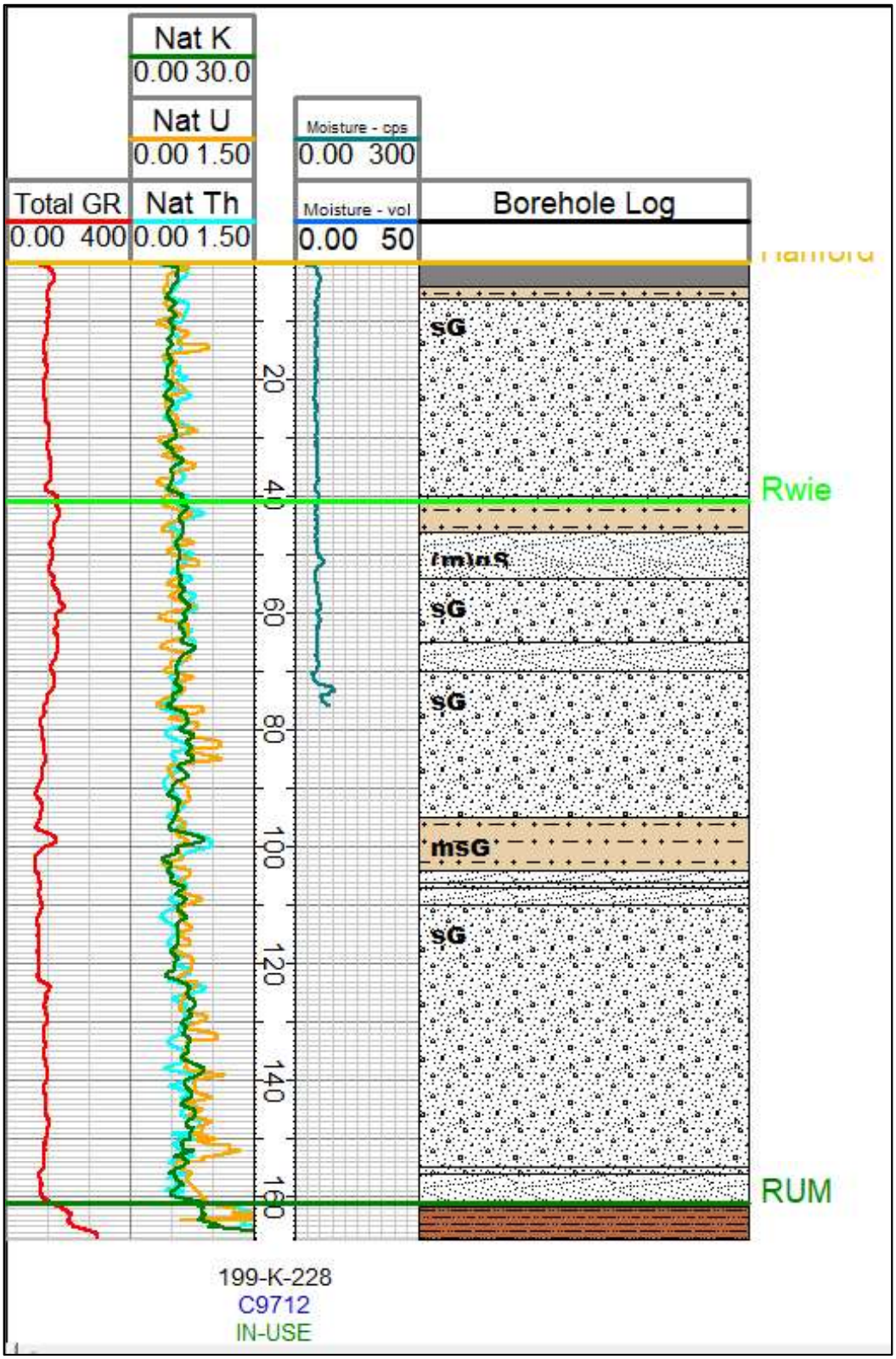


Figure A-16. Borehole 199-K-228

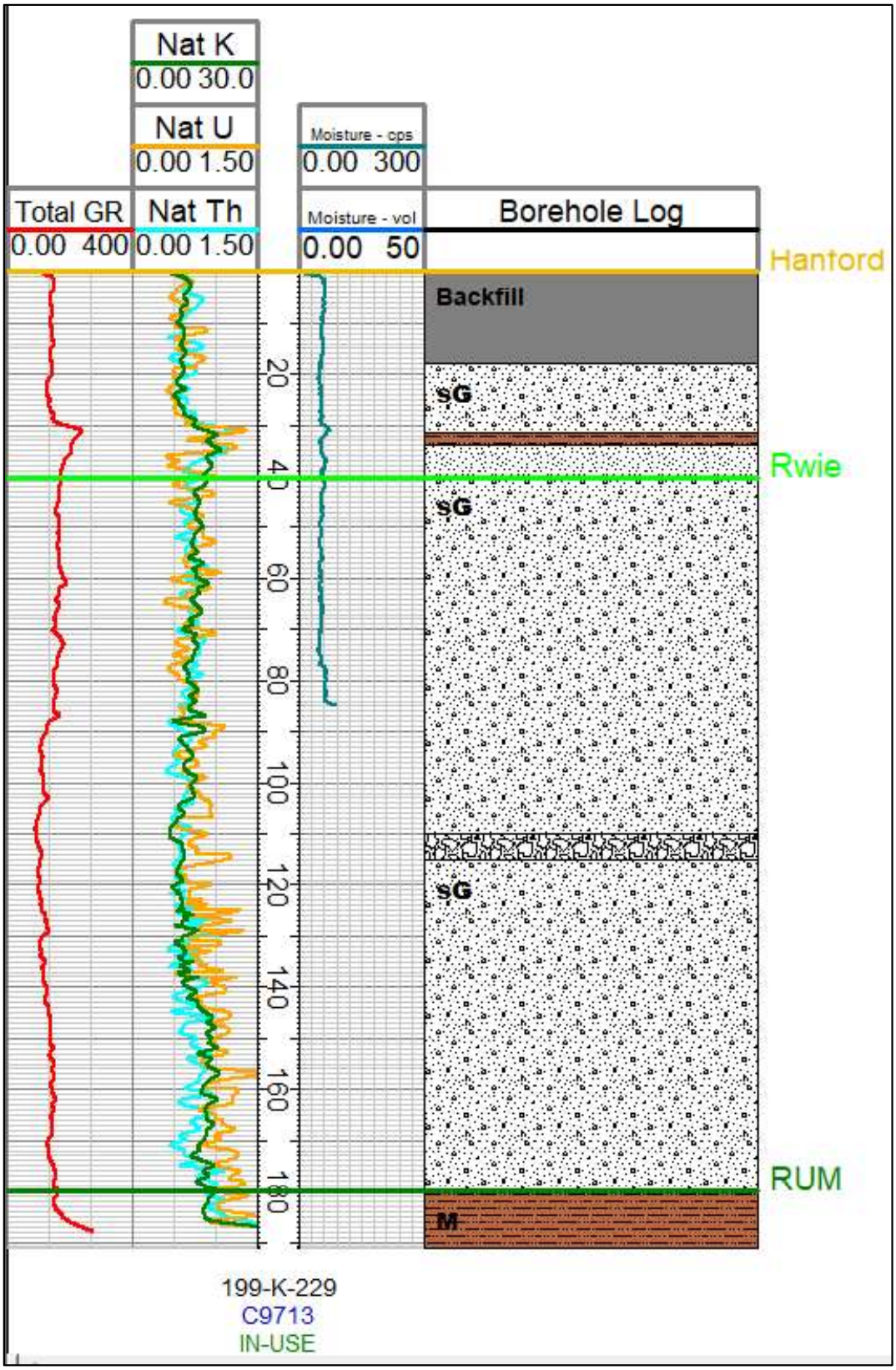


Figure A-17. Borehole 199-K-229

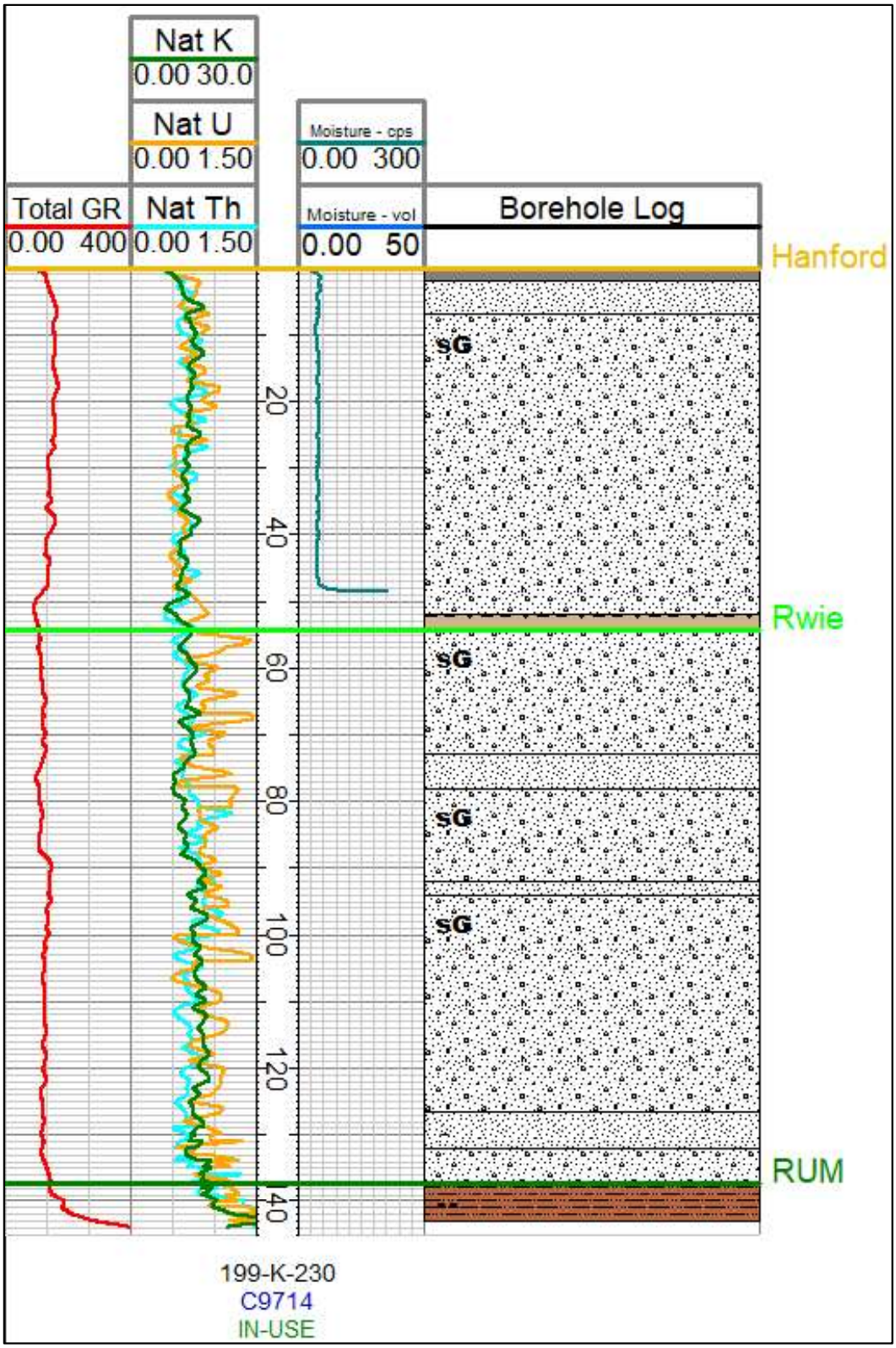


Figure A-18. Borehole 199-K-230

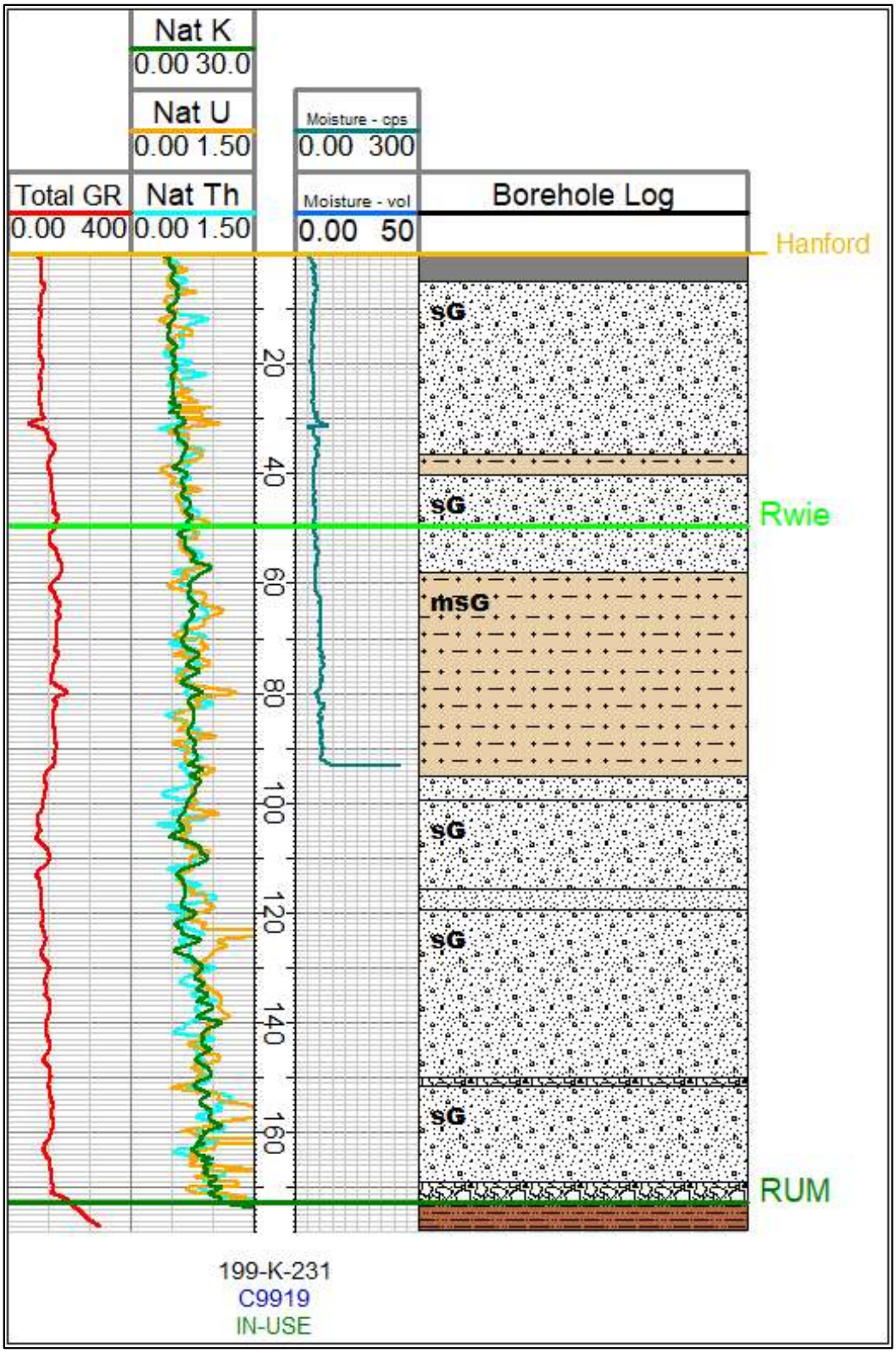


Figure A-19. Borehole 199-K-231

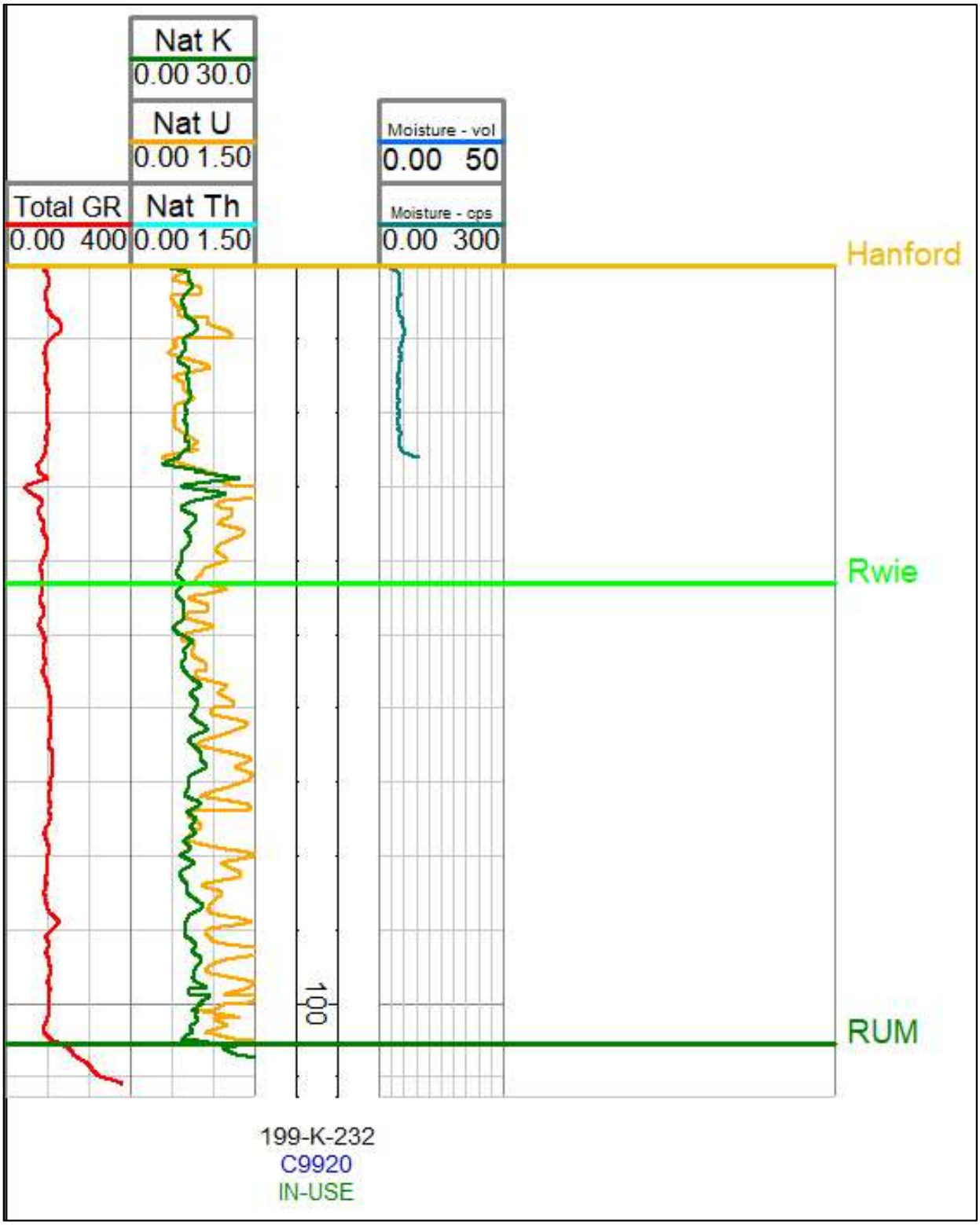


Figure A-20. Borehole 199-K-232

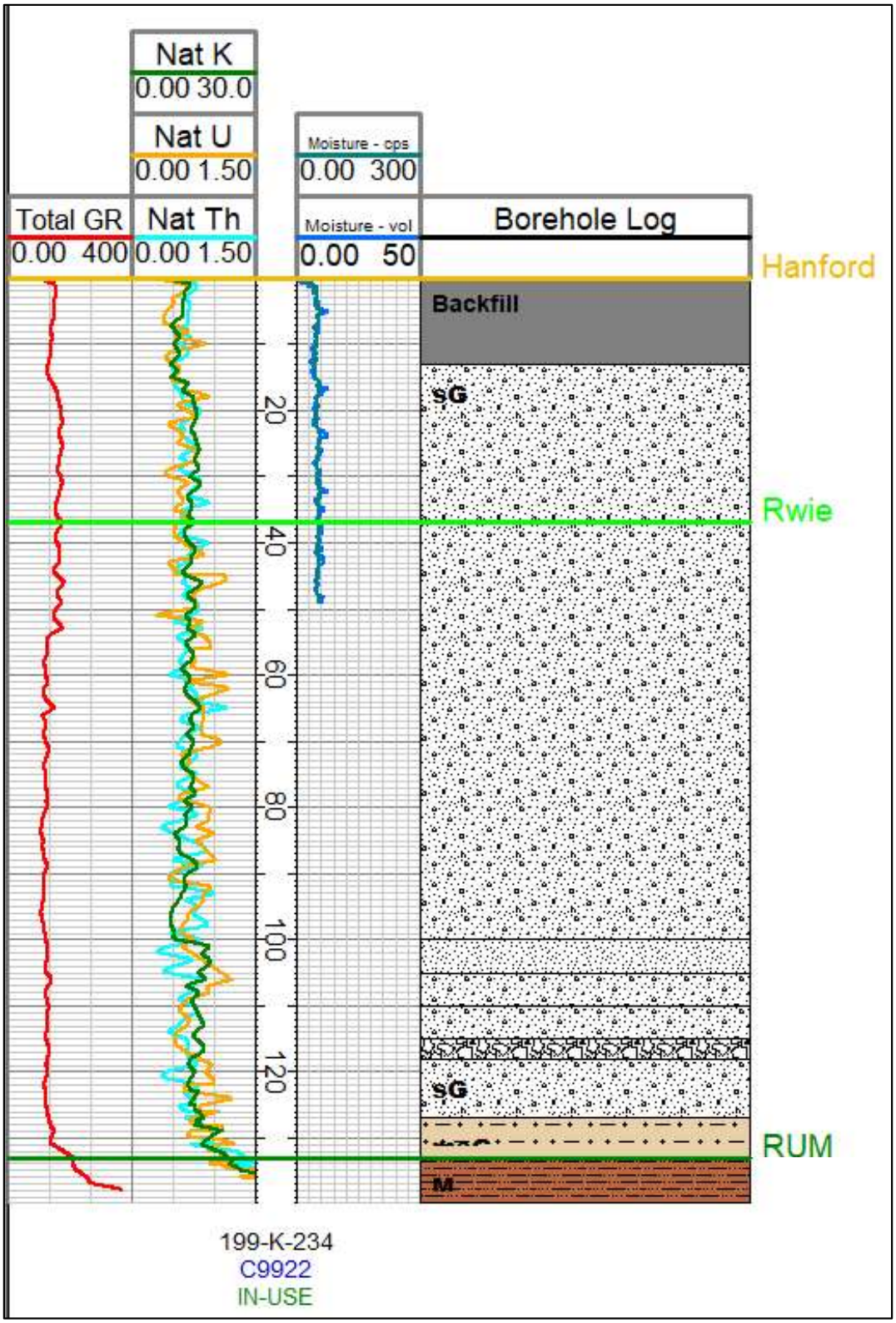


Figure A-21. Borehole 199-K-234

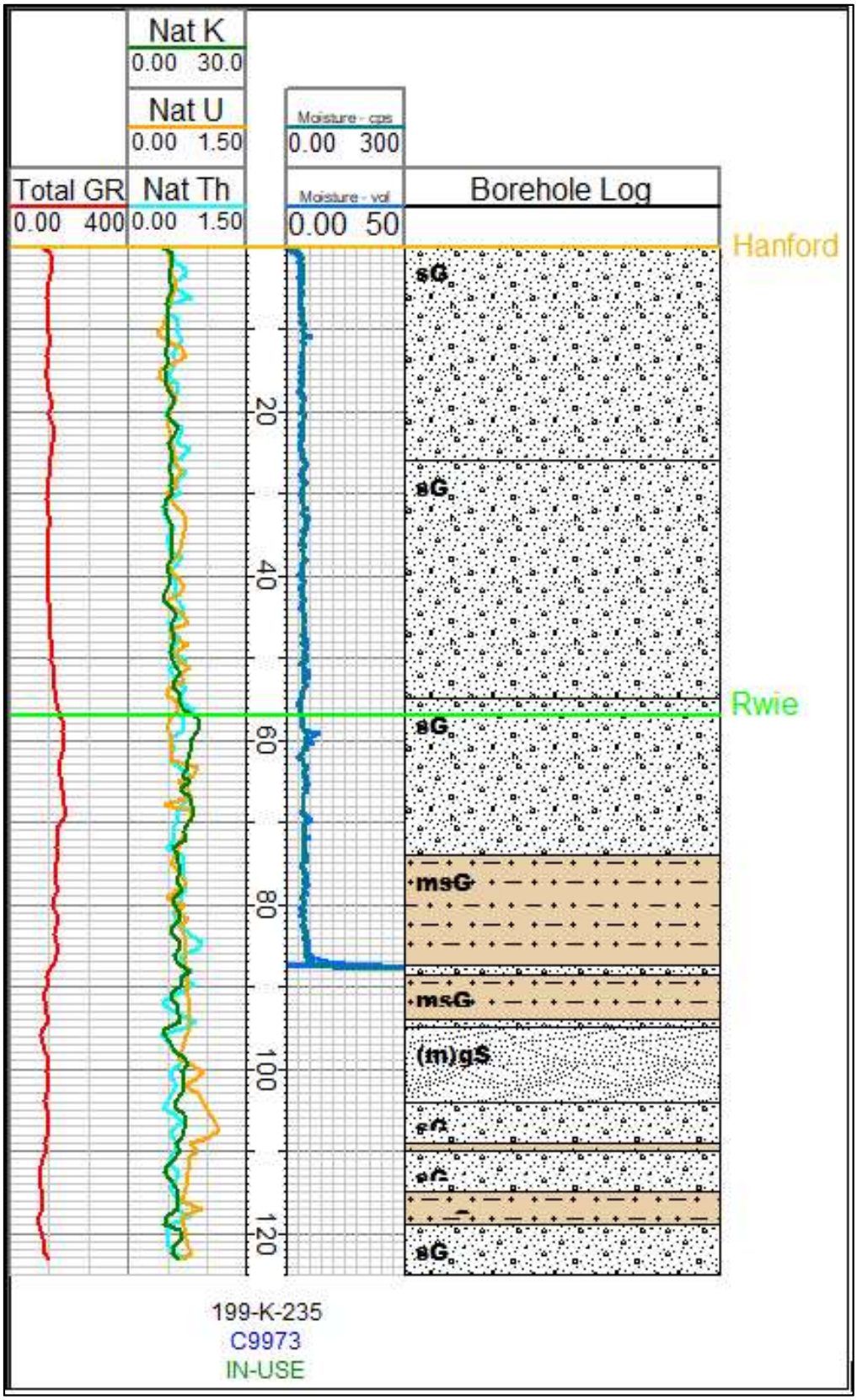


Figure A-22. Borehole 199-K-235

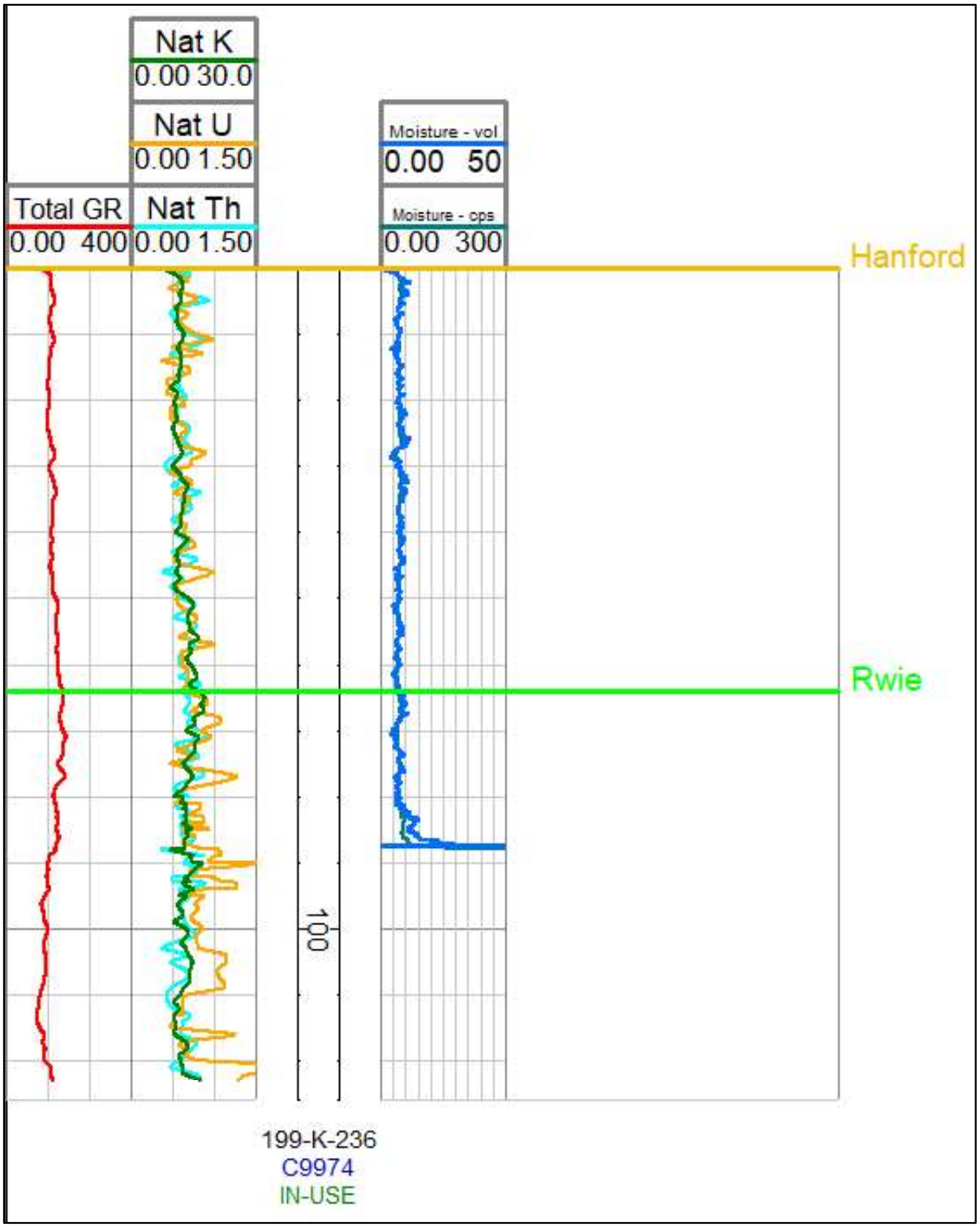


Figure A-23. Borehole 199-K-236

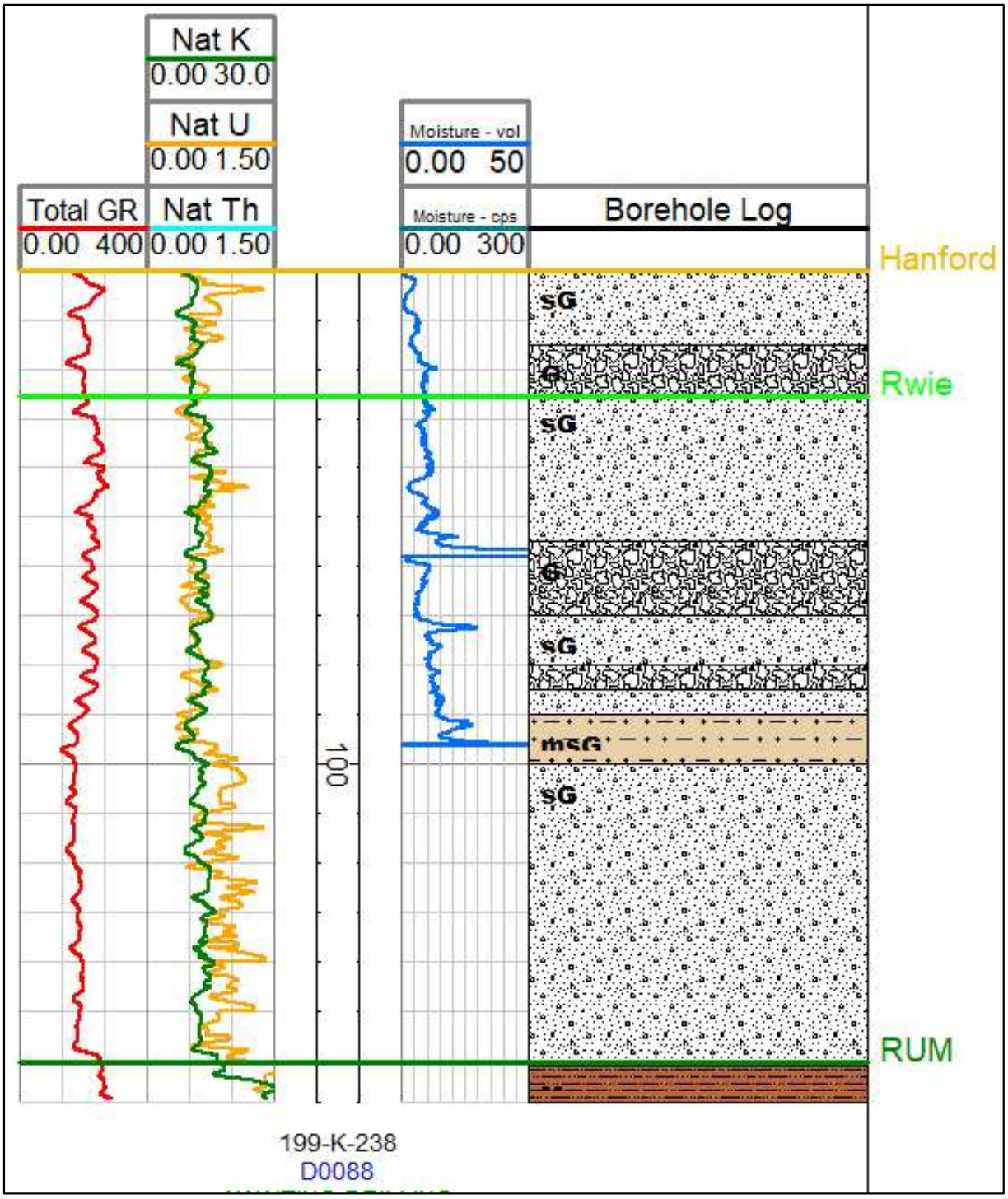


Figure A-24. Borehole 199-K-238

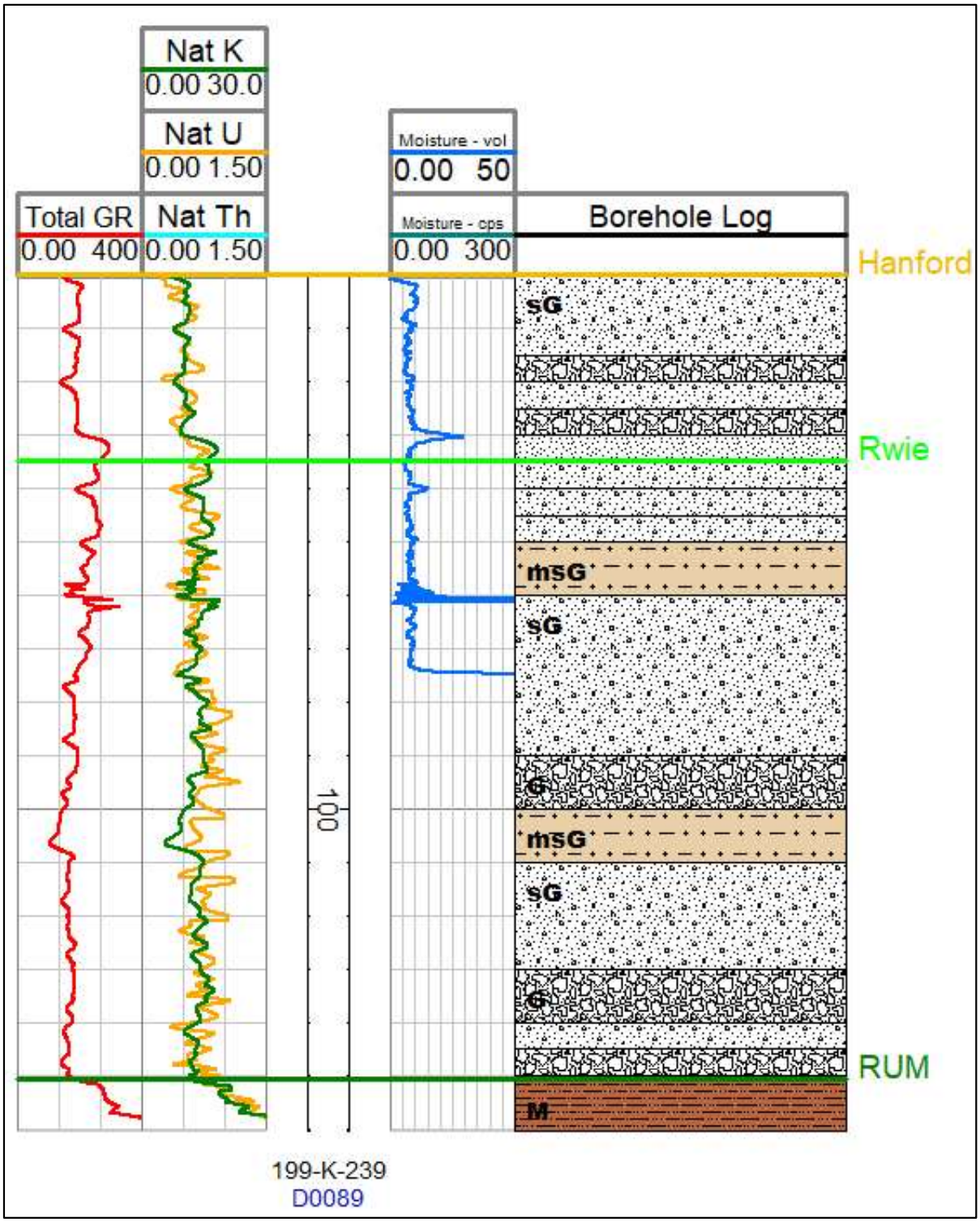


Figure A-25. Borehole 199-K-239

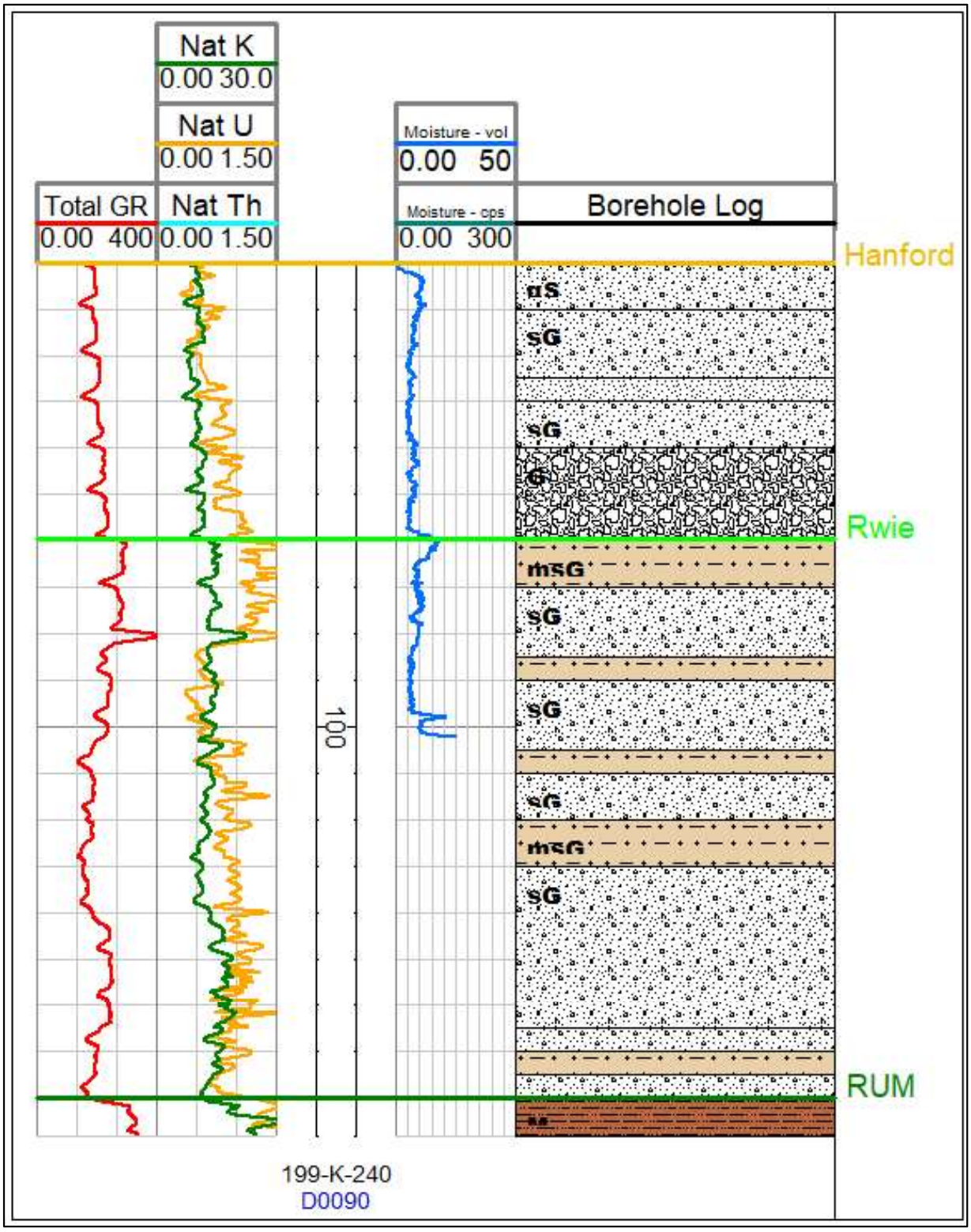


Figure A-26. Borehole 199-K-240

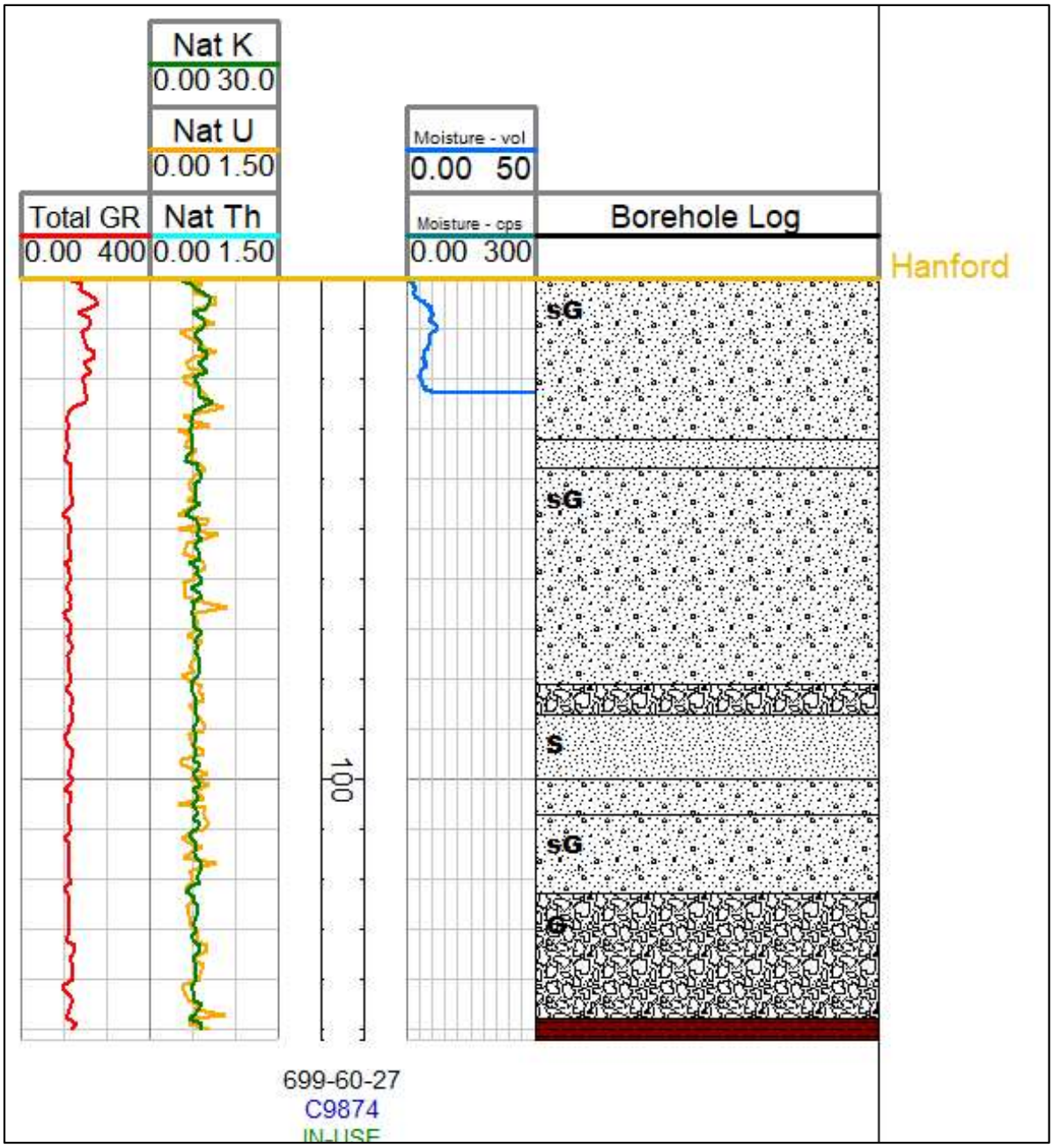


Figure A-27. Borehole 699-60-27

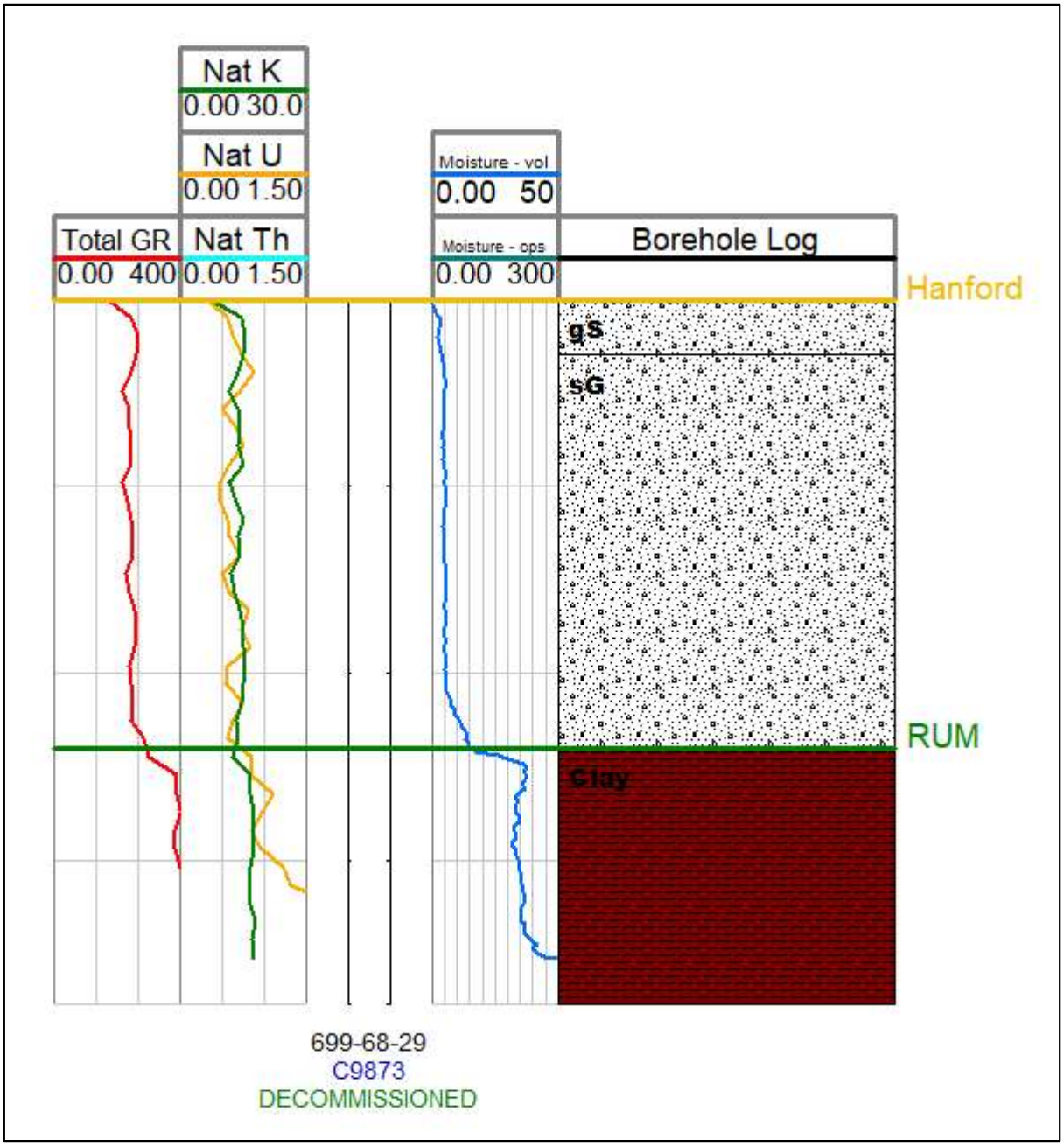


Figure A-28. Borehole 699-68-29

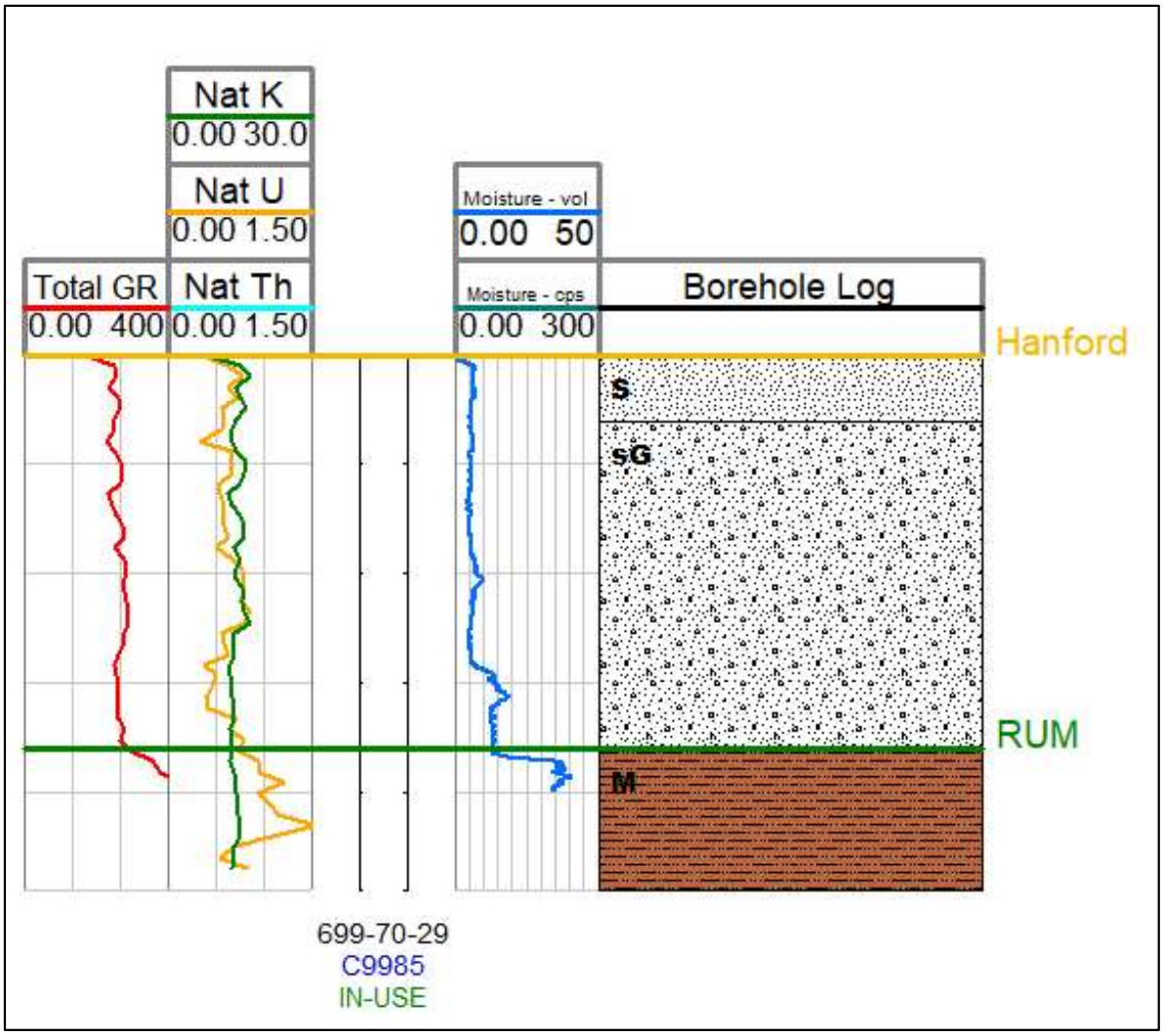


Figure A-29. Borehole 699-70-29

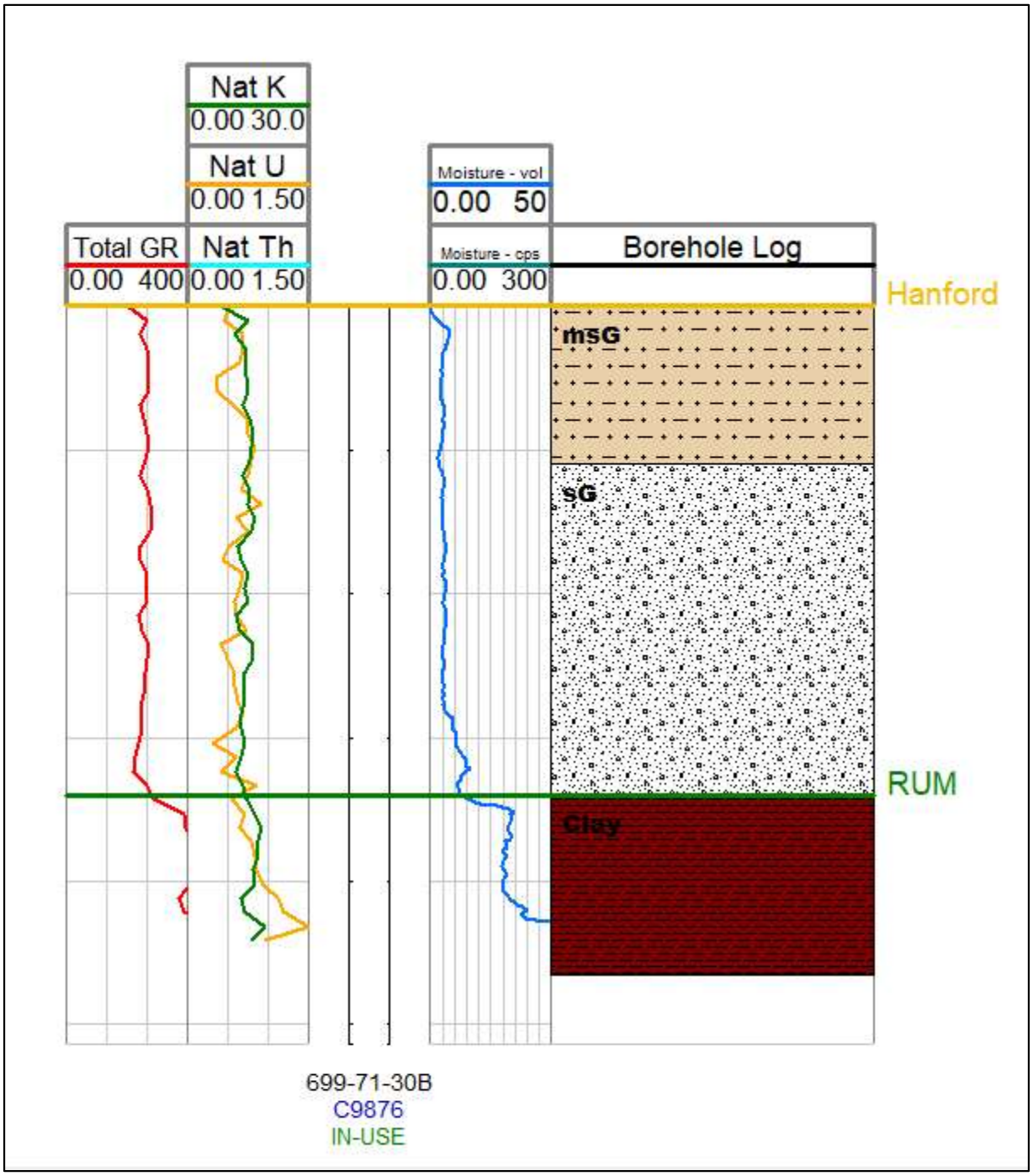


Figure A-30. Borehole 699-71-30B

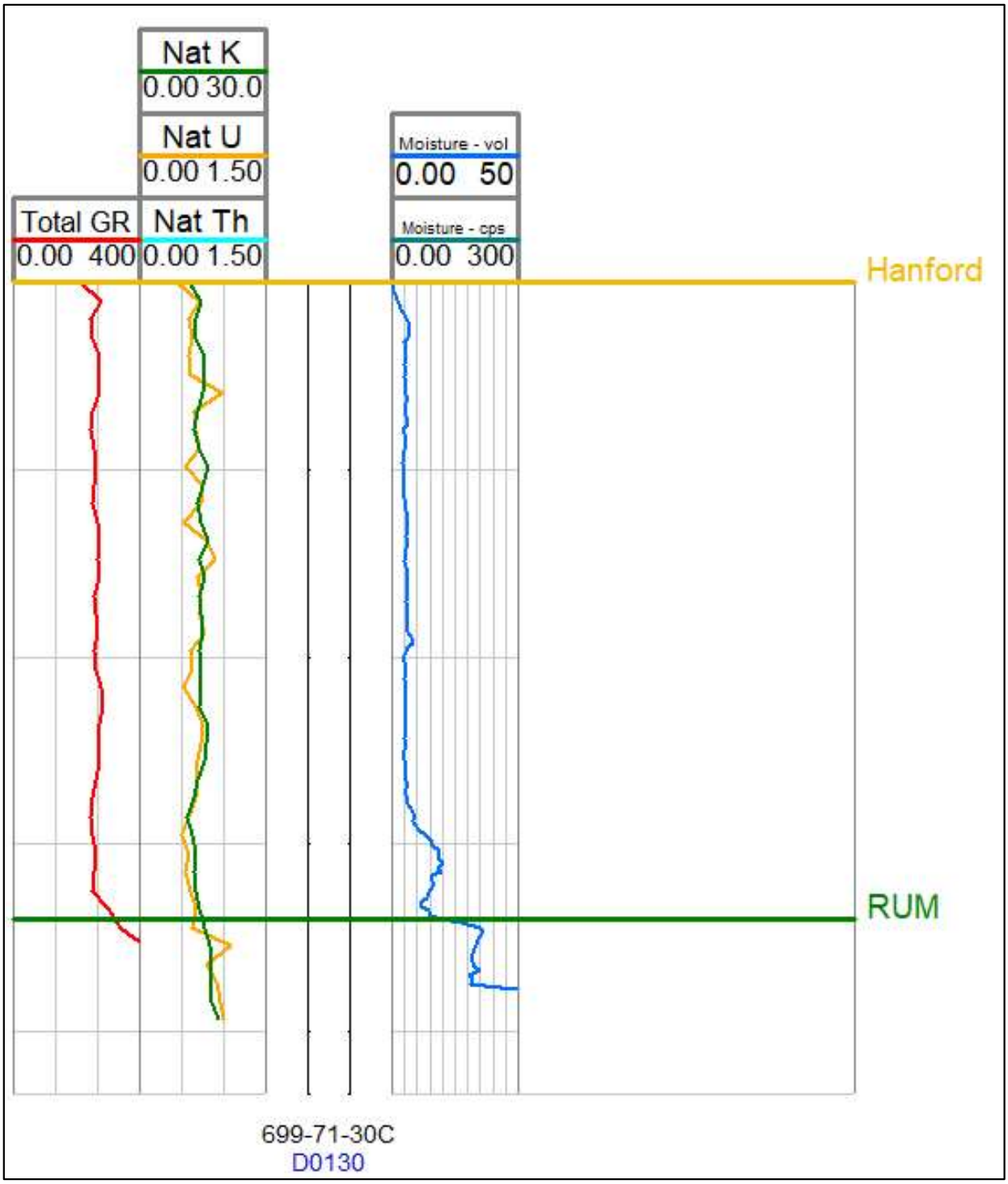


Figure A-31. Borehole 699-71-30C

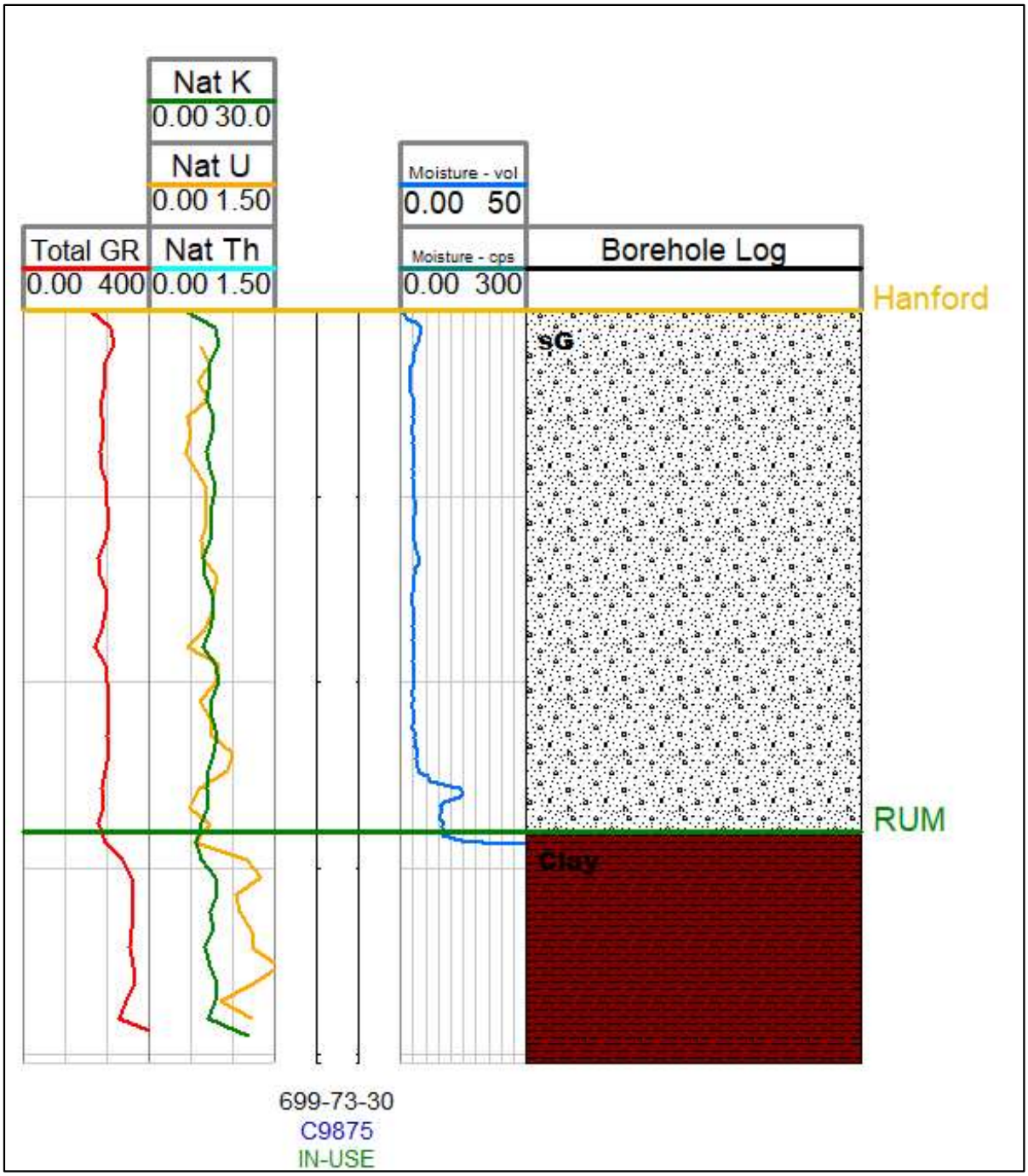


Figure A-32. Borehole 699-73-30

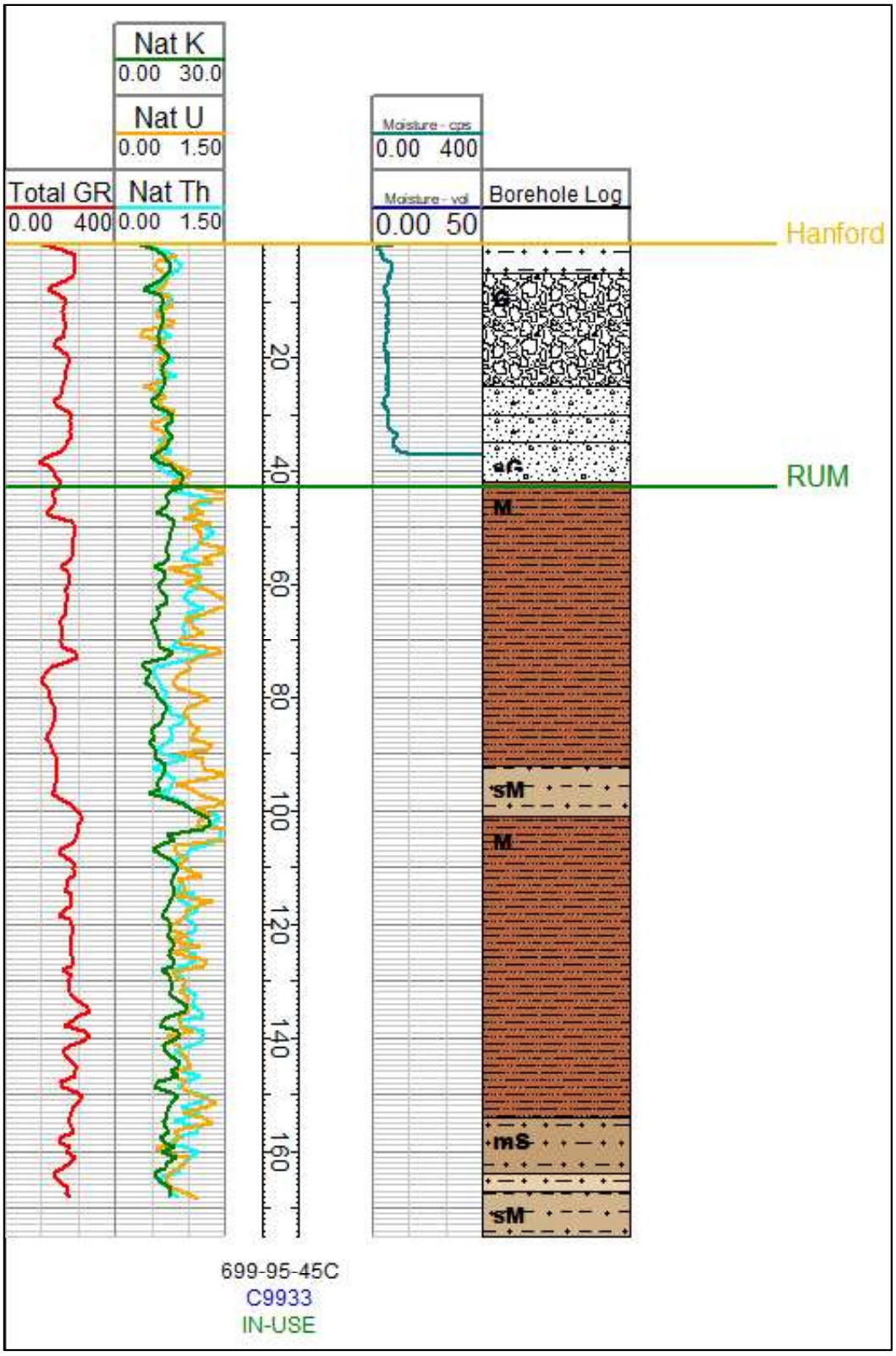


Figure A-33. Borehole 699-95-45C

A2 References

ECF-HANFORD-13-0020, 2017, *Process for Constructing a Three-Dimensional Geological Framework Model of the Hanford Site's 100 Area*, Rev. 5., CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/064944H.

EMDT-GR-0039, 2020, *Geologic Contacts for the 100-Area Geoframework Model*, Rev. 1, CH2M Hill Plateau Remediation Company, Richland Washington.

This page intentionally left blank.

Appendix B

Boreholes Removed from Version 6 of the 100 Area Geoframework Model

This page intentionally left blank.

Contents

B1 Introduction..... B-1

B2 Reference..... B-28

Table

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)..... B-1

This page intentionally left blank.

B1 Introduction

This appendix (Table B-1) provides a listing of boreholes that were not included in the 100 Area Geoframework Model (Version 6) due to uncertainty in the borehole data or because the density of the borehole locations is greater than the model grid, which can cause interpolation errors and unnecessary computational loads. EMDT-GR-0039, *Geologic Contacts for the 100-Area Geoframework Model*, has more details.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-D4-82	151183.90	572470.30	143.23	35.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-80	151202.60	572496.90	143.43	34.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-79	151214.00	572498.20	143.63	35.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-76	151234.20	572526.10	142.97	34.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-77	151231.00	572513.30	142.93	30.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-73	151262.70	572542.20	143.15	34.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-74	151249.80	572539.80	142.90	34.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-71	151278.50	572556.30	143.12	34.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-D4-19	151282.00	572559.30	143.12	33.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-70	151282.70	572568.80	143.13	33.8	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-67	151312.80	572581.90	143.28	33.8	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-68	151299.80	572581.30	143.07	34.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-64	151333.90	572606.90	143.32	33.8	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-65	151329.70	572594.80	143.32	34.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-61	151363.70	572620.70	143.10	31.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-62	151351.10	572619.50	143.19	33.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-58	151385.40	572644.80	143.34	32.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-59	151380.80	572633.30	143.22	31.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-D4-54	151419.70	572662.40	143.17	30.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-55	151414.60	572659.00	143.19	30.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-56	151402.30	572657.70	143.10	29.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-1	151558.90	572752.80	143.25	32.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-2	151544.00	572768.40	143.75	30.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-3	151546.10	572766.10	143.67	31.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-10	151540.40	572750.20	143.44	29.8	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-11	151554.10	572768.90	143.38	29.6	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-12	151562.10	572771.60	143.50	30.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-13	151424.50	572665.90	142.94	30.8	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-D4-14	151641.60	572839.80	143.47	31.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-24	151471.40	572699.90	143.20	30.8	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-26	151488.90	572712.30	143.46	32.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-28	151506.10	572725.10	143.52	31.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-29	151510.70	572736.90	143.81	31.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-31	151528.00	572749.50	143.88	29.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-32	151573.70	572790.90	143.68	30.8	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-33	151585.90	572792.60	143.71	31.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-35	151602.30	572806.30	143.52	31.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-40	151622.60	572832.30	143.57	30.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-D4-42	151642.40	572847.10	143.51	32.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-44	151665.60	572856.10	143.34	31.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-45	151671.80	572868.00	143.28	32.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-47	151690.10	572880.50	143.16	31.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-51	151441.40	572686.60	143.15	30.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-53	151424.60	572674.10	143.14	29.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-5	151556.50	572740.50	143.31	30.8	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-7	151551.30	572760.90	143.36	29.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D3-3	151187.00	572482.50	143.20	34.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-H4-12A	152912.70	578009.20	126.47	14.6	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-H4-12B	152918.50	578004.40	126.46	15.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-234	149883.10	571286.72	123.21	5.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-233	149879.08	571282.66	123.12	8.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-232	149875.71	571279.71	123.07	5.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-231	149871.81	571276.71	123.09	8.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-230	149868.47	571274.06	123.17	4.8	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-229	149864.74	571271.28	123.21	8.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-228	149861.28	571268.42	123.23	4.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-227	149857.51	571265.41	123.31	8.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-226	149853.86	571262.40	123.35	4.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-N-225	149850.47	571259.52	123.40	8.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-224	149846.41	571256.67	123.26	5.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-223	149843.04	571254.31	123.17	8.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-222	149838.48	571251.35	123.13	5.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-221	149835.26	571249.33	123.30	8.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-220	149831.50	571246.49	123.23	8.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-219	149827.76	571243.95	123.25	8.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-218	149824.30	571241.44	123.16	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-217	149820.18	571238.81	123.14	8.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-216	149816.81	571235.59	123.23	5.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-N-215	149813.53	571232.72	123.25	8.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-214	149810.00	571229.81	123.32	4.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-213	149806.30	571226.78	123.40	8.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-212	149802.66	571224.12	123.44	4.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-211	149799.02	571221.25	123.47	8.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-210	149795.42	571218.71	123.46	5.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-209	149791.71	571216.09	123.44	8.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-208	149787.70	571213.76	123.42	4.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-207	149783.59	571211.60	123.37	8.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-206	149779.37	571209.39	123.38	5.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-N-205	149775.60	571207.17	123.44	8.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-204	149771.42	571205.06	123.49	4.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-203	149767.48	571203.02	123.50	8.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-202	149763.38	571200.86	123.51	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-201	149759.46	571198.46	123.48	8.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-200	149755.44	571196.16	123.44	5.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
699-80-43Q	147745.00	576703.20	126.41	70.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
699-80-43R	147760.30	576702.50	126.46	42.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
699-80-43S	147774.70	576701.90	125.28	15.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
699-98-51	153302.70	574339.30	120.40	9.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-D4-88	151553.20	572758.70	143.40	29.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-89	151547.10	572759.60	143.53	29.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-9	151543.30	572758.20	143.60	29.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-90	151616.10	572823.20	143.45	30.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-91	151621.10	572817.70	143.45	30.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-92	151486.30	572714.10	143.52	32.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-93	151491.20	572710.40	143.33	32.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D4-94	151496.10	572712.90	143.33	31.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D5-107	151283.10	572932.40	144.09	31.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D5-108	151222.90	572923.30	144.38	32.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-D5-109	151285.60	572917.40	144.02	31.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D5-110	151277.60	572931.60	144.12	31.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D5-111	151281.50	572943.20	144.11	31.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D5-112	151289.90	572929.10	143.99	28.6	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D5-114	151223.80	572918.00	144.36	31.8	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D5-116	151222.40	572926.90	144.42	31.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D5-117	151225.40	572922.90	144.39	27.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D5-118	151224.50	572921.00	144.37	31.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D5-121	151399.30	573430.20	143.77	34.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-D5-158	151411.50	573358.50	121.02	10.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-D5-99	151402.00	573349.60	143.99	35.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-238	149961.94	571356.49	122.12	8.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-239	149965.75	571359.23	122.17	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-240	149969.69	571361.72	122.22	8.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-241	149973.32	571364.35	122.25	5.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-242	149976.80	571366.89	122.24	4.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-243	149979.88	571369.96	122.28	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-244	149982.83	571373.09	122.28	8.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-245	149986.82	571376.20	122.27	5.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-246	149990.56	571378.88	122.28	8.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-N-247	149994.14	571381.44	122.26	5.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-248	149997.93	571383.91	122.22	8.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-249	150001.56	571386.39	122.17	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-250	150005.61	571388.88	122.14	8.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-251	150009.72	571391.89	122.11	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-252	150013.22	571394.10	122.08	8.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-253	150016.73	571396.29	122.03	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-254	150020.79	571398.85	121.93	8.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-255	150024.75	571401.31	121.90	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-256	150028.61	571403.79	121.84	8.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-N-257	150032.20	571406.10	121.82	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-258	150036.13	571408.97	121.78	8.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-259	150039.97	571411.10	121.82	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-260	150043.62	571413.69	121.82	8.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-261	150047.74	571416.00	121.86	5.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-262	150051.20	571418.51	121.88	8.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-263	150055.46	571421.17	121.88	5.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-264	150058.79	571423.59	121.86	8.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-265	150063.07	571426.10	121.87	5.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-266	150067.07	571428.76	121.87	8.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-N-267	150070.66	571430.86	121.86	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-268	150074.61	571433.49	121.87	8.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-269	150078.94	571436.02	121.84	5.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-270	150082.34	571438.52	121.81	8.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-271	150085.60	571440.22	121.85	5.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-272	150088.52	571441.87	121.90	8.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-273	150093.65	571444.62	121.93	5.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-274	150098.38	571446.84	121.94	7.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-275	150102.90	571448.69	121.95	5.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-276	150106.59	571450.74	121.93	8.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-N-277	150110.78	571452.44	121.83	5.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-278	150114.44	571454.09	121.76	8.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-279	150118.57	571455.71	121.73	5.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-280	150122.77	571457.93	121.69	8.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-281	150127.35	571459.57	121.66	5.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-282	150131.39	571461.92	121.67	8.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-283	150135.71	571463.50	121.62	5.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-284	150139.88	571465.56	121.61	7.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-285	150144.43	571467.37	121.65	5.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-286	150148.69	571468.84	121.68	8.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-N-287	150152.30	571471.23	121.65	5.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-288	150155.50	571474.00	121.67	8.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-289	150158.86	571477.45	121.74	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-290	150161.93	571480.72	121.79	8.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-291	150164.36	571484.24	121.77	5.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-292	150167.75	571488.12	121.81	8.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-293	150170.59	571491.86	121.80	5.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-294	150173.69	571495.07	121.86	8.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-295	150176.51	571498.31	121.92	5.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-296	150179.51	571501.58	121.93	8.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-N-297	150182.74	571504.78	121.95	5.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-298	150186.18	571508.01	121.97	8.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-299	150189.41	571510.99	121.97	5.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-300	150192.87	571513.92	121.96	8.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-301	150196.62	571516.95	121.98	5.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-302	150199.90	571520.09	121.99	8.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-303	150203.35	571523.14	122.00	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-304	150206.87	571525.91	121.98	8.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-305	150210.59	571528.71	121.99	5.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-306	150214.05	571531.65	121.95	8.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-N-307	150217.50	571534.33	121.95	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-308	150221.22	571537.23	121.97	8.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-309	150224.73	571540.07	122.00	5.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-310	150228.42	571542.79	121.99	8.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-311	150232.11	571545.55	121.94	5.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-312	150235.72	571548.23	121.89	8.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-313	150239.58	571550.79	121.85	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-314	150243.43	571553.28	121.87	8.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-315	150247.53	571555.86	121.89	5.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-316	150251.37	571558.24	121.91	8.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-N-317	150254.88	571560.87	121.87	5.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-318	150258.74	571563.67	121.88	8.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-319	150262.58	571565.85	121.88	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-320	150266.48	571568.10	121.88	8.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-321	150270.14	571570.40	121.91	5.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-322	150274.27	571572.74	121.91	8.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-323	150278.17	571575.33	122.02	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-324	150282.50	571577.87	122.08	8.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-325	150286.26	571580.17	122.07	5.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-326	150290.34	571582.32	122.09	8.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-N-327	150294.19	571584.19	122.09	5.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-328	150298.36	571586.19	122.10	7.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-329	150302.33	571588.52	122.12	5.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-330	150306.15	571590.64	122.09	7.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-331	150310.12	571593.06	122.09	5.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-332	150314.30	571595.38	122.14	8.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-333	150318.21	571597.44	122.16	5.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-334	150322.03	571600.32	122.15	8.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-335	150325.46	571602.71	122.13	5.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-336	150329.36	571605.78	122.14	8.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-N-337	150333.10	571608.87	122.13	5.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-338	150336.26	571611.93	122.10	8.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-339	150339.64	571615.10	122.10	5.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-340	150342.67	571618.11	122.08	7.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-341	150346.38	571621.34	122.15	5.2	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-342	150349.47	571623.93	122.20	8.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-343	150353.33	571627.19	122.25	5.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-344	150356.82	571629.88	122.27	8.4	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-345	150360.44	571632.62	122.21	5.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-235	149950.76	571348.34	121.94	4.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-N-236	149954.54	571351.12	121.97	8.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-184	149817.80	571430.70	140.53	32.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-181	149954.80	571352.30	121.95	5.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-176	149953.30	571349.20	121.96	5.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-177	149952.40	571350.40	121.91	5.6	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-178	149957.60	571348.70	122.07	5.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-179	149956.70	571349.80	122.03	6.1	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-174	149955.30	571346.80	122.07	6.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-170	149714.80	571288.50	140.79	25.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-167	149698.30	571296.80	140.70	25.3	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-N-160	149938.00	571333.40	122.08	7.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-161	149932.40	571326.50	122.13	7.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-162	149926.60	571319.70	122.24	7.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-163	149919.70	571313.30	122.22	7.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-142	149916.20	571310.20	122.20	7.8	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-143	149923.00	571316.50	122.26	7.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-144	149929.30	571322.80	122.25	7.8	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-145	149935.10	571329.90	122.08	7.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-136	149940.70	571337.20	122.06	7.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-N-137	149946.30	571344.40	122.00	7.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-K-112A	148503.40	570278.60	126.49	16.5	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-K-205	146090.90	568845.70	148.03	56.7	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-K-221	146753.90	569129.40	137.67	31.9	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
199-K-32A	147006.70	569024.20	135.47	21.0	Borehole omitted from the 100 Area GFM because this borehole had another borehole within 20 m (65.6 ft) with similar or better data.
699-67-77	143896.60	566423.40	149.74	Unknown	No lithology information for borehole; omitted from the borehole list.
699-71-85	145012.90	564039.80	127.26	Unknown	No lithology information for borehole; omitted from the borehole list.
699-72-88	145359.90	563247.30	132.37	16.3	No lithology information for borehole; omitted from the borehole list.
699-71-24	145087.00	582415.00	122.00	17.9	Omitted from GFM; meeting on November 6, 2019 (requested by Sarah Springer).
199-N-237	149958.59	571353.97	122.07	5.1	Borehole omitted from 100 Area GFM; meeting on November 18, 2019 (requested by Sarah Springer).
199-K-122A	147172.90	569975.10	142.43	30.8	Borehole omitted from model– borehole log data was too ambiguous to make confident top picks and nearby boreholes contain sufficient data to constrain the horizon interpolation.
699-84-59	149179.80	571758.00	140.61	305.1	Borehole omitted from model– borehole log data was too ambiguous to make confident top picks and nearby boreholes contain

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
					sufficient data to constrain the horizon interpolation.
199-N-109A	149630.60	571898.20	137.29	19.7	Borehole omitted from GFM. Borehole data too ambiguous to make a pick for RUM and Rwie surface.
199-N-188	149581.50	571906.90	139.31	27.4	Borehole Omitted from GFM. Borehole data too ambiguous to make a pick for RUM and Rwie surface.
199-N-346	149780.23	571203.32	123.61	8.2	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier.
199-N-348	149845.23	571248.28	123.19	8.1	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier.
199-N-349	149866.13	571267.16	123.17	8.1	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier.
199-N-164	149913.10	571307.10	122.18	7.7	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier.
199-N-8P	149924.20	571326.90	124.46	30.5	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier.
199-N-94A	150154.20	571466.10	121.60	18.9	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier.
199-N-95A	149970.00	571360.00	121.61	14.9	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier.
199-N-368	149948.28	571344.44	122.07	8.0	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier.

Table B-1. Boreholes Not Included in the 100 Area GFM (Version 6)

Borehole Name	Northing (m)	Easting (m)	Surface Elevation (m)	Drill Depth (m)	Explanation for Data Removal
199-N-351	149987.11	571373.17	122.30	8.2	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier.
199-N-352	150009.03	571388.72	122.18	8.2	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier.
199-N-354	150055.09	571418.57	121.93	8.2	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier.
199-N-355	150077.00	571431.65	121.96	8.1	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier.
199-N-360	150186.94	571504.04	122.09	8.1	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier
199-N-93A	150260.00	571560.00	120.79	13.1	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier.
199-N-364	150273.49	571569.71	121.91	7.9	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier.
199-N-366	150317.84	571594.87	122.17	7.8	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier.
199-N-367	150340.41	571611.38	122.21	8.3	Borehole omitted from 100 Area GFM to reduce borehole density and resulting surface rugosity near the apatite barrier.

GFM = Geoframework Model
RUM = Ringold Formation upper mud
RWIE = Ringold Formation member of Wooded Island — unit E

B2 Reference

EMDT-GR-0039, 2020, *Geologic Contacts for the 100-Area Geoframework Model*, Rev. 1, CH2M Hill Plateau Remediation Company, Richland Washington.

This page intentionally left blank.

Appendix C

100 Area Geoframework Model (Version 6)
Top of Hydrostratigraphic Unit Structure and Isopach Maps

This page intentionally left blank.

Contents

C1 Introduction **C-1**

C2 Reference **C-39**

Figures

Figure C-1. 100 Area GFM (Version 6) Top of the Hf HSU Structure Map C-3

Figure C-2. 100 Area GFM (Version 6) Isopach Map of the Hf HSU (in feet) C-4

Figure C-3. 100 Area GFM (Version 6) Top of the Rwie HSU Structure Map C-5

Figure C-4. 100 Area GFM (Version 6) Isopach Map of the Rwie HSU (in feet) C-6

Figure C-5. 100 Area GFM (Version 6) Top of the RUM HSU Structure Map C-7

Figure C-6. 100 Area GFM (Version 6) Isopach Map of the RUM HSU (in feet) C-8

Figure C-7. 100 Area GFM (Version 6) Top of the Hf HSU Structure Map in the 100-BC Groundwater Interest Area C-9

Figure C-8. 100 Area GFM (Version 6) Isopach Map of the Hf HSU (in feet) in the 100-BC Groundwater Interest Area C-10

Figure C-9. 100 Area GFM (Version 6) Top of the Rwie HSU Structure Map in the 100-BC Groundwater Interest Area C-11

Figure C-10. 100 Area GFM (Version 6) Isopach Map of the Rwie HSU (in feet) in the 100-BC Groundwater Interest Area C-12

Figure C-11. 100 Area GFM (Version 6) Top of the RUM HSU Structure Map in the 100-BC Groundwater Interest Area C-13

Figure C-12. 100 Area GFM (Version 6) Isopach Map of the RUM HSU (in feet) in the 100-BC Groundwater Interest Area C-14

Figure C-13. 100 Area GFM (Version 6) Top of the Hf HSU Structure Map in the 100-KR and 100-NR Groundwater Interest Area C-15

Figure C-14. 100 Area GFM (Version 6) Isopach Map of the Hf HSU (in feet) in the 100-KR and 100-NR Groundwater Interest Area C-16

Figure C-15. 100 Area GFM (Version 6) Top of the Rwie HSU Structure Map in the 100-KR and 100-NR Groundwater Interest Area C-17

Figure C-16. 100 Area GFM (Version 6) Isopach Map of the Rwie HSU (in feet) in the 100-KR and 100-NR Groundwater C-18

Figure C-17. 100 Area GFM (Version 6) Top of the RUM HSU Structure Map in the 100-KR and 100-NR Groundwater Interest Area C-19

Figure C-18. 100 Area GFM (Version 6) Isopach Map of the RUM HSU (in feet) in the 100-KR and 100-NR Groundwater Interest Area C-20

Figure C-19. 100 Area GFM (Version 6) Top of the Hf HSU Structure Map in the 100-D and 100-H Groundwater Interest Area C-21

Figure C-20. 100 Area GFM (Version 6) Isopach Map of the Hf HSU (in feet) in the 100-D and 100-H Groundwater Interest Area C-22

Figure C-21. 100 Area GFM (Version 6) Top of the Rwie HSU Structure Map in the 100-D and 100-H Groundwater Interest Area C-23
Figure C-22. 100 Area GFM (Version 6) Isopach Map of the Rwie HSU (in feet) in the 100-D and 100-H Groundwater Interest Area C-24
Figure C-23. 100 Area GFM (Version 6) Top of the RUM HSU Structure Map in the 100-D and 100-H Groundwater Interest Area C-25
Figure C-24. 100 Area GFM (Version 6) Isopach Map of the RUM HSU (in feet) in the 100-D and 100-H Groundwater Interest Area C-26
Figure C-25. 100 Area GFM (Version 6) Top of the Hf HSU Structure Map in the 100-F Groundwater Interest Area C-27
Figure C-26. 100 Area GFM (Version 6) Isopach Map of the Hf HSU (in feet) in the 100-F Groundwater Interest Area C-28
Figure C-27. 100 Area GFM (Version 6) Top of the Rwie HSU Structure Map in the 100-F Groundwater Interest Area C-29
Figure C-28. 100 Area GFM (Version 6) Isopach Map of the Rwie HSU (in feet) in the 100-F Groundwater Interest Area C-30
Figure C-29. 100 Area GFM (Version 6) Top of the RUM HSU Structure Map in the 100-F Groundwater Interest Area C-31
Figure C-30. 100 Area GFM (Version 6) Isopach Map of the RUM HSU (in feet) in the 100-F Groundwater Interest Area C-32
Figure C-31. 100 Area GFM (Version 6) Top of the Hf HSU Structure Map in the 200-BP Groundwater Interest Area C-33
Figure C-32. 100 Area GFM (Version 6) Isopach Map of the Hf HSU (in feet) in the 200-BP Groundwater Interest Area C-34
Figure C-33. 100 Area GFM (Version 6) Top of the Rwie HSU Structure Map in the 200-BP Groundwater Interest Area C-35
Figure C-34. 100 Area GFM (Version 6) Isopach Map of the Rwie HSU (in feet) in the 200-BP Groundwater Interest Area C-36
Figure C-35. 100 Area GFM (Version 6) Top of the RUM HSU Structure Map in the 200-BP Groundwater C-37
Figure C-36. 100 Area GFM (Version 6) Isopach Map of the RUM HSU (in feet) in the 200-BP Groundwater Interest Area C-38

Terms

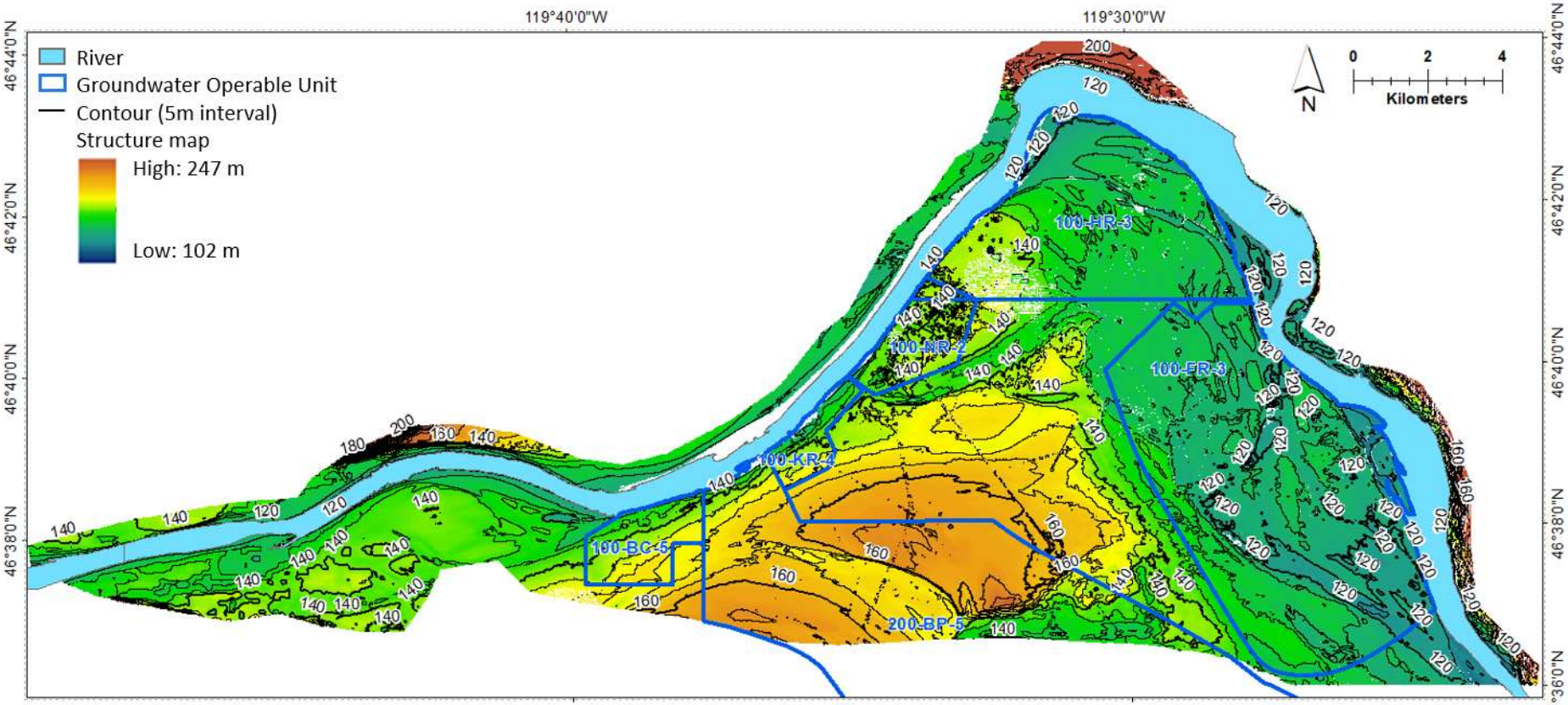
GFM	Geologic Framework Model
HSU	hydrostratigraphic unit
OU	operable unit
RUM	Ringold Formation Upper Mud Unit (undifferentiated)
Rwie	Ringold Formation member of Wooded Island — unit E

This page intentionally left blank.

C1 Introduction

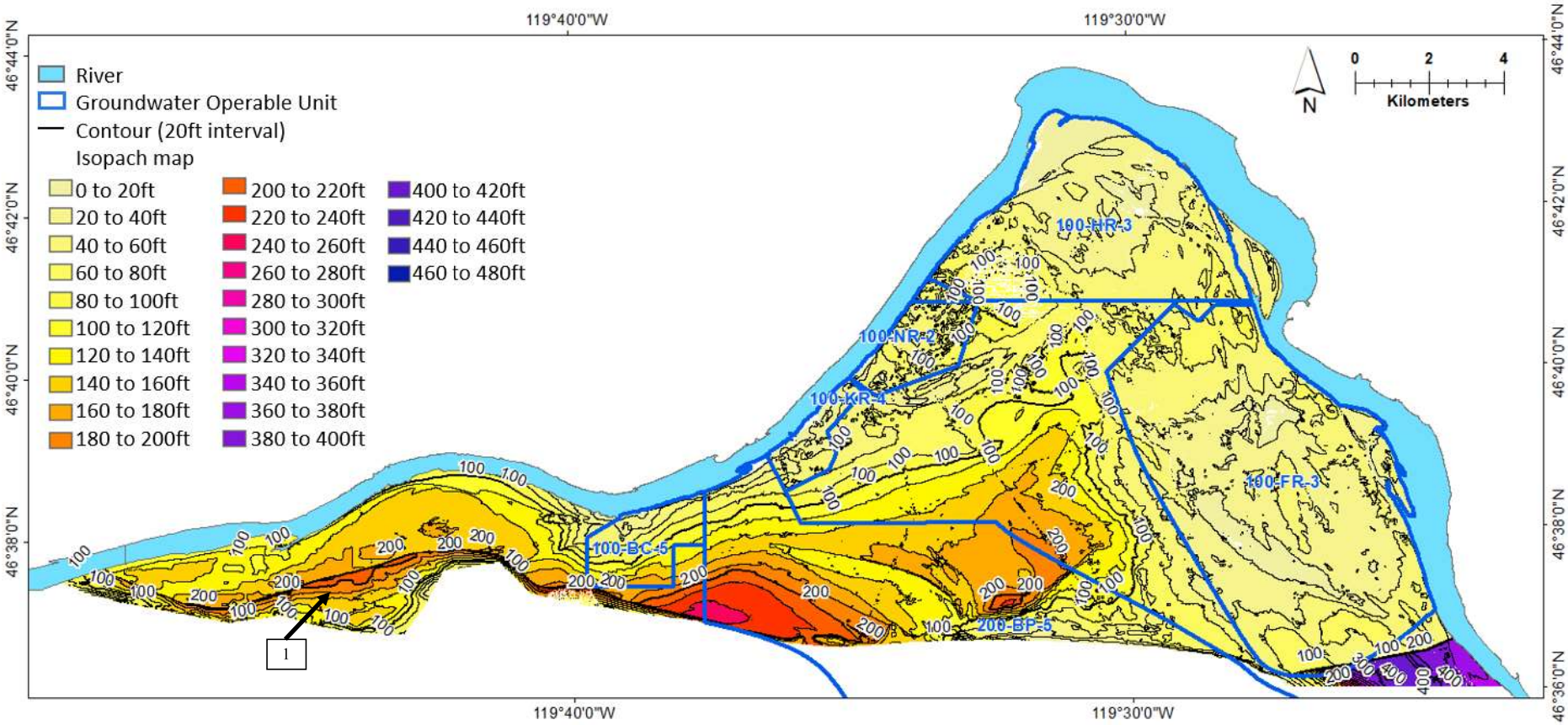
The 100 Area Geoframework Model (Version 6) is divided into three hydrostratigraphic units: the Hanford formation (Hf), the Ringold Formation ember of Wooded Island — unit E (Rwie), and the Ringold Formation upper mud (RUM). This appendix contains revised structure-contour and isopach maps for the Hf, Rwie, and RUM (Figures C-1 through C-36).

This page intentionally left blank.



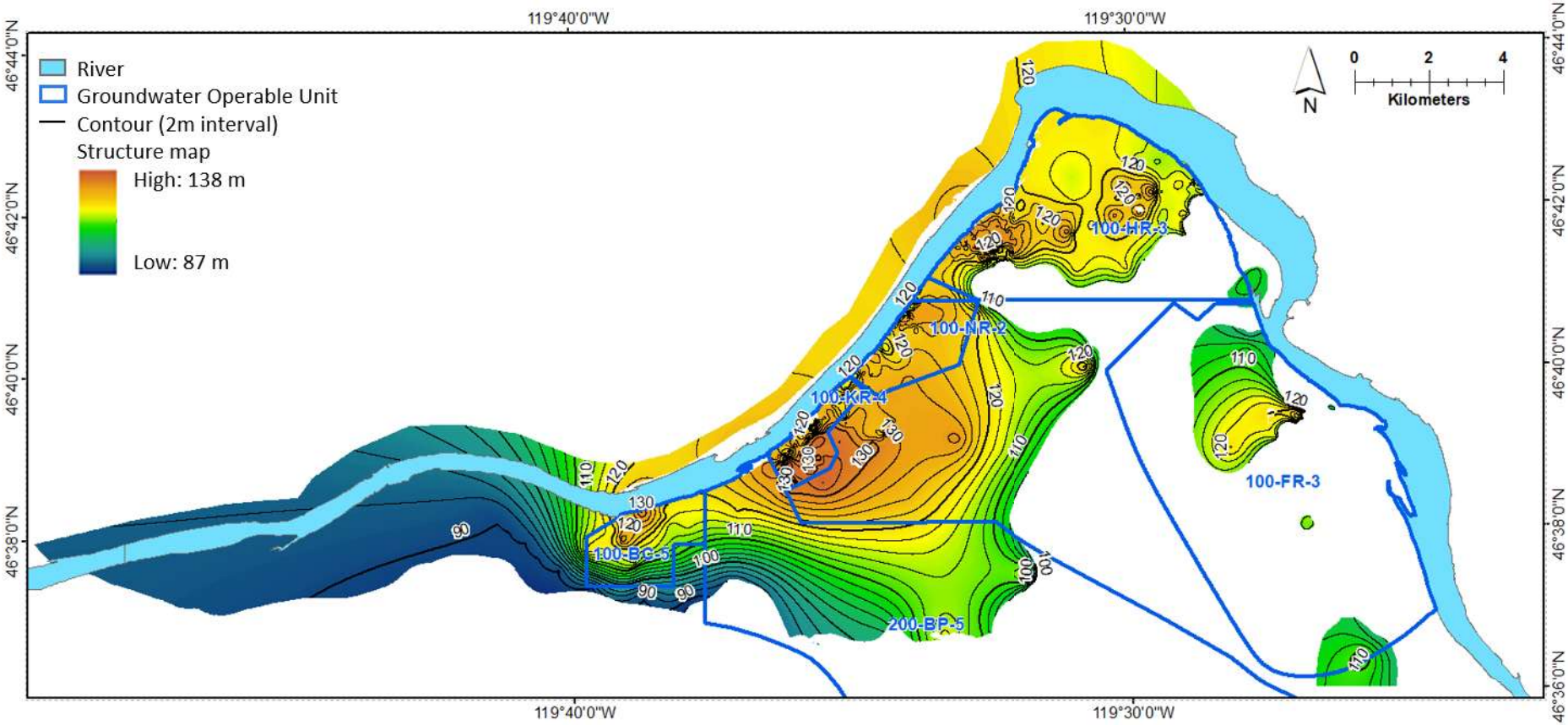
Notes: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m). The structural top of the Hf HSU is equivalent to the ground surface (topography) across most of the model.

Figure C-1. 100 Area GFM (Version 6) Top of the Hf HSU Structure Map



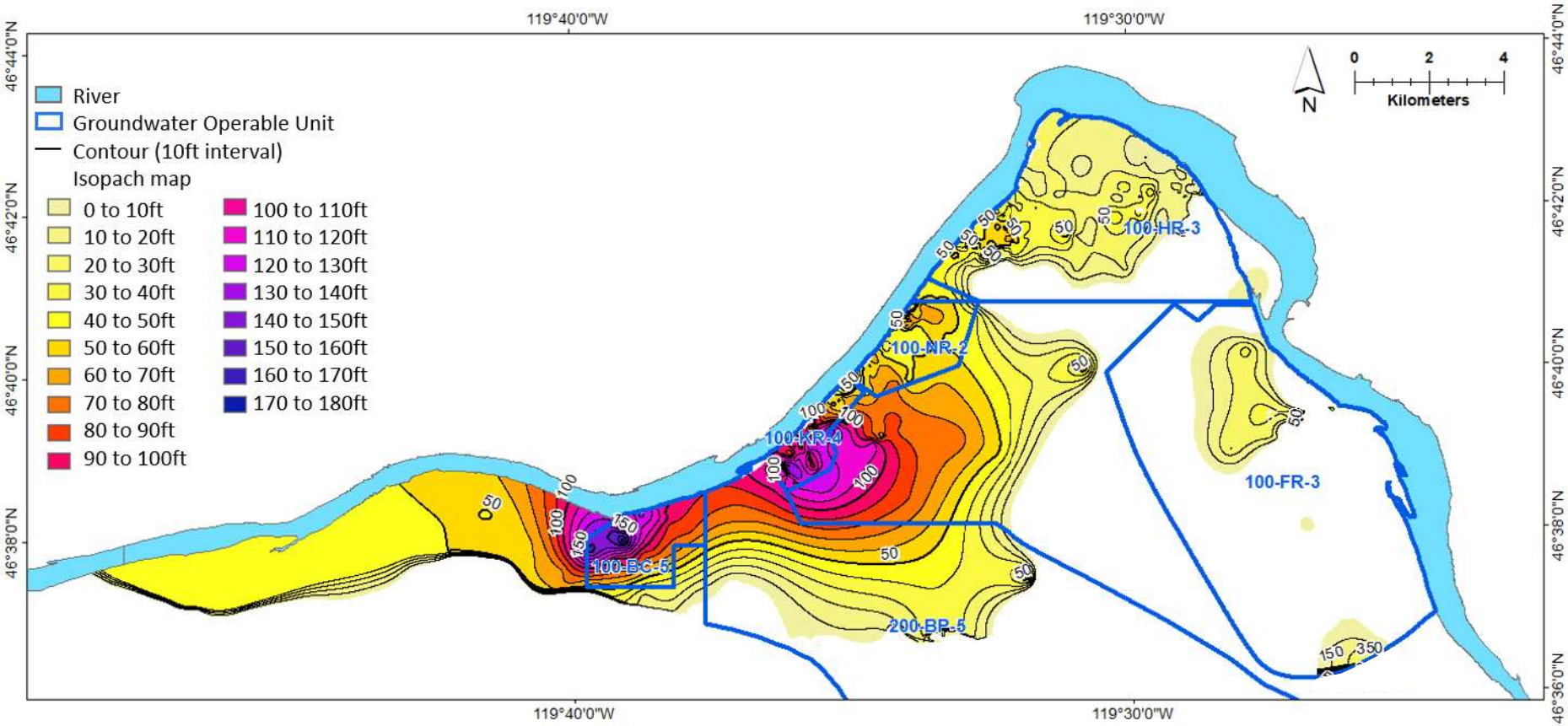
Notes: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m). The abrupt increase in thickness of the Hf HSU in the south-east of the model domain reflects the Hanford HSU directly overlaying basalt where the RUM HSU ends in the 100 Area GFM. Similarly, the abrupt edge seen in the south-west portion of the model denotes the termination of the RUM surface (1 on the figure).

Figure C-2. 100 Area GFM (Version 6) Isopach Map of the Hf HSU (in feet)



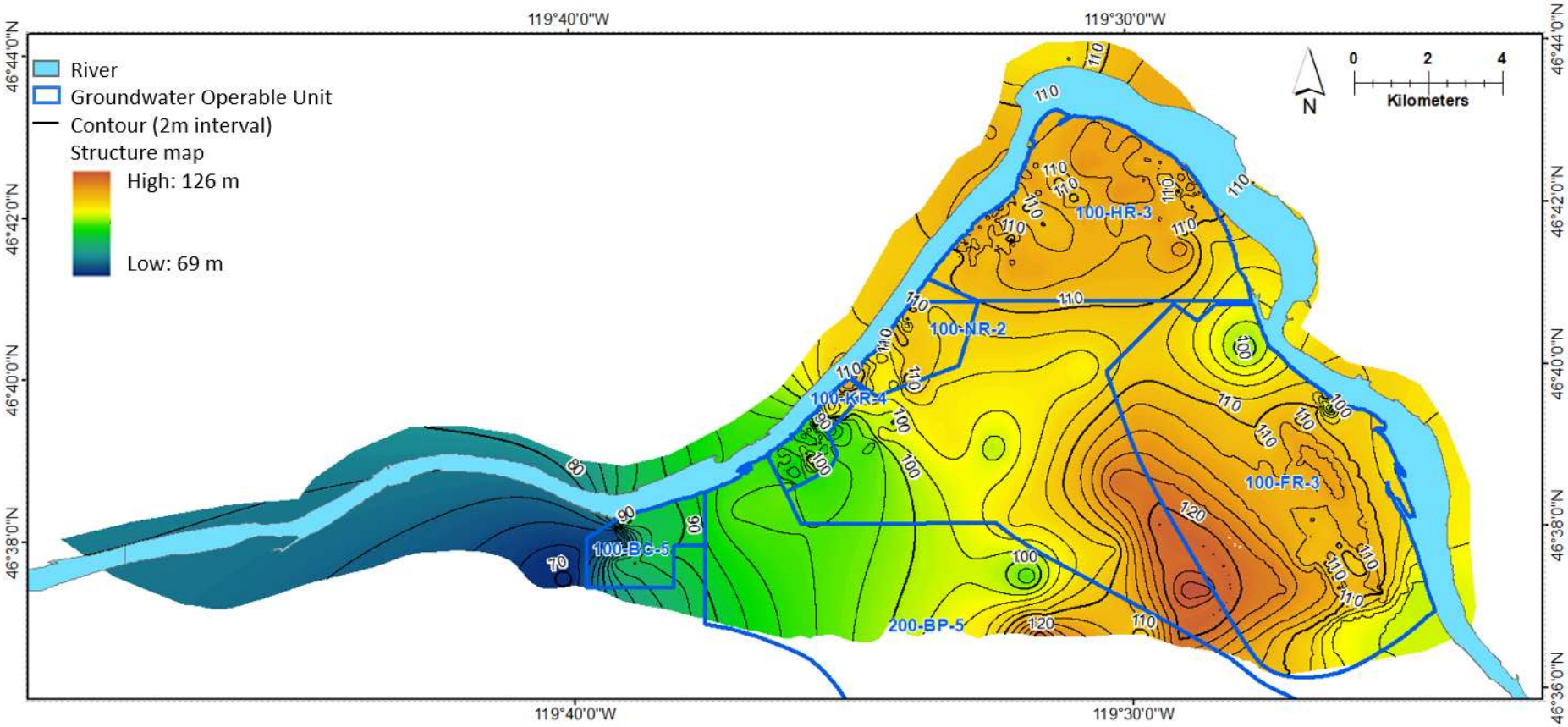
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-3. 100 Area GFM (Version 6) Top of the Rwie HSU Structure Map



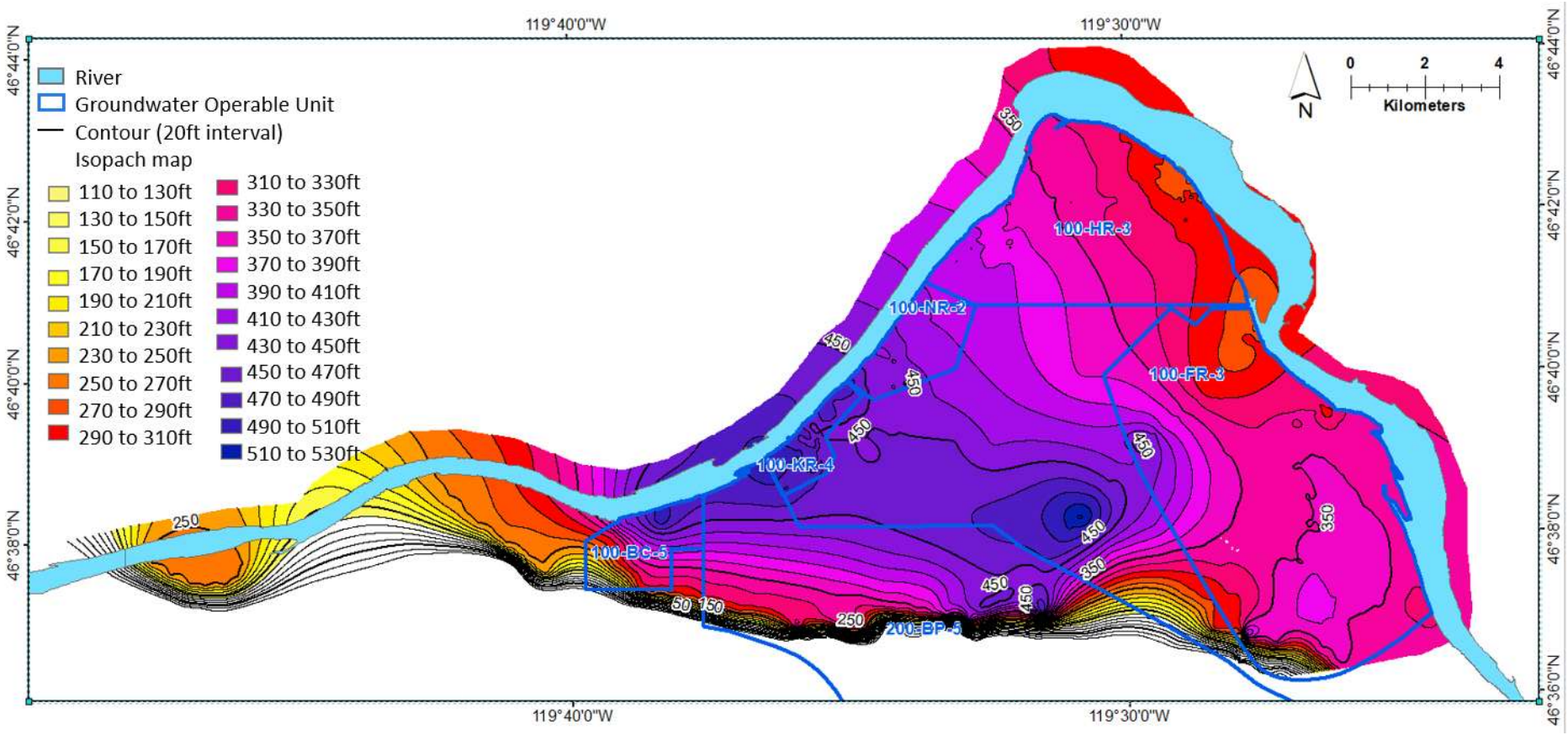
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-4. 100 Area GFM (Version 6) Isopach Map of the Rwie HSU (in feet)



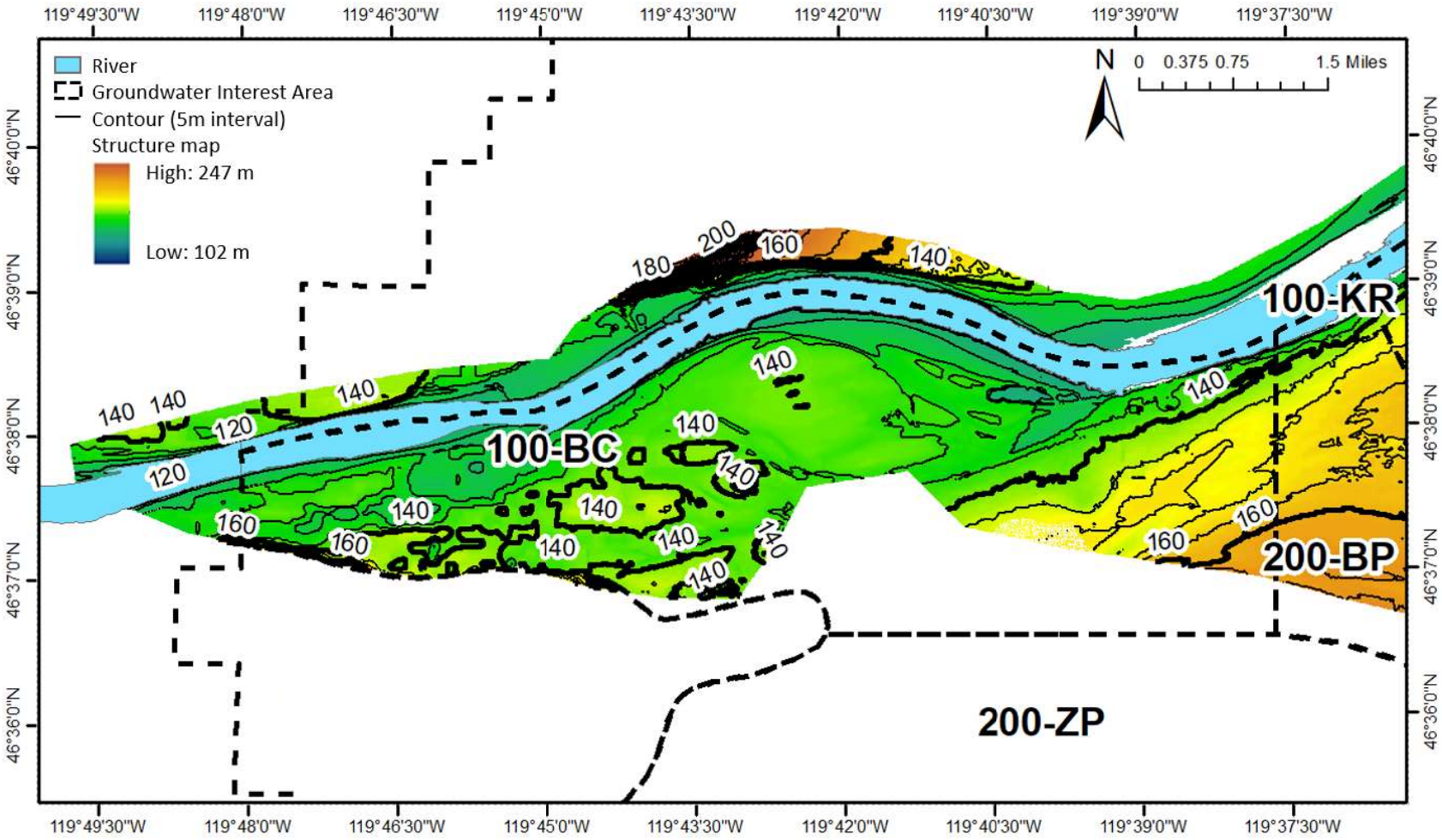
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-5. 100 Area GFM (Version 6) Top of the RUM HSU Structure Map



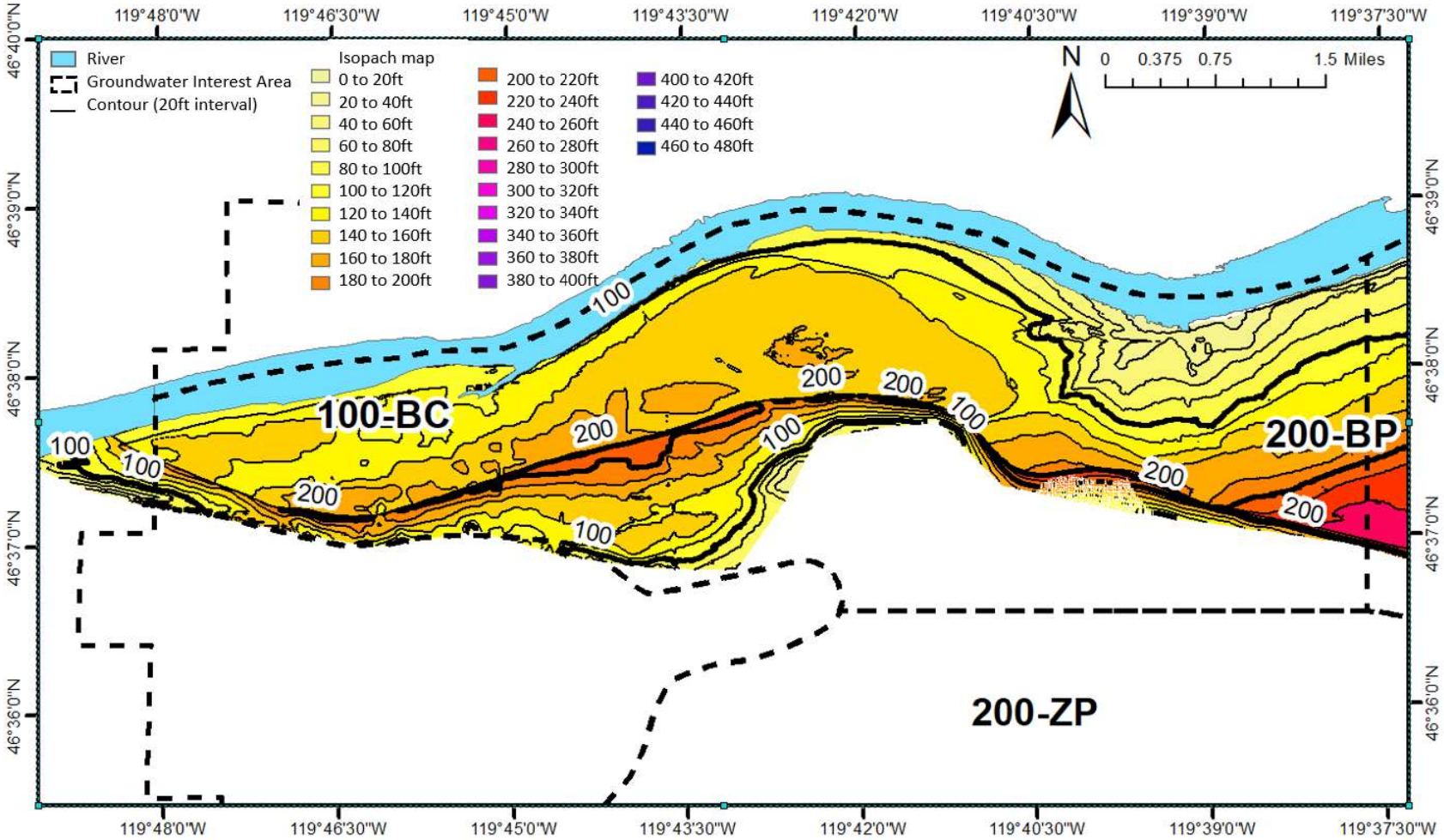
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-6. 100 Area GFM (Version 6) Isopach Map of the RUM HSU (in feet)



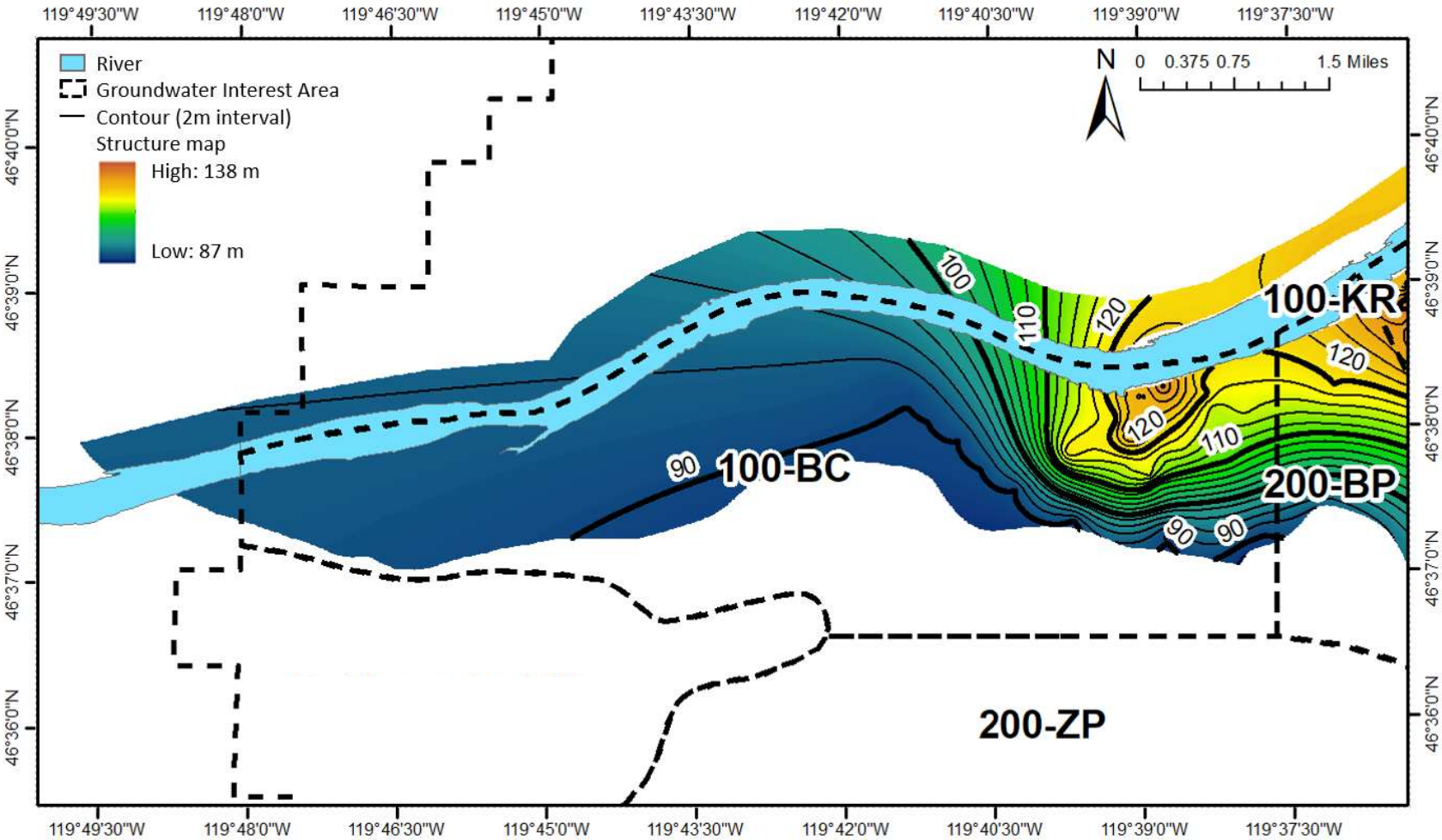
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-7. 100 Area GFM (Version 6) Top of the Hf HSU Structure Map in the 100-BC Groundwater Interest Area



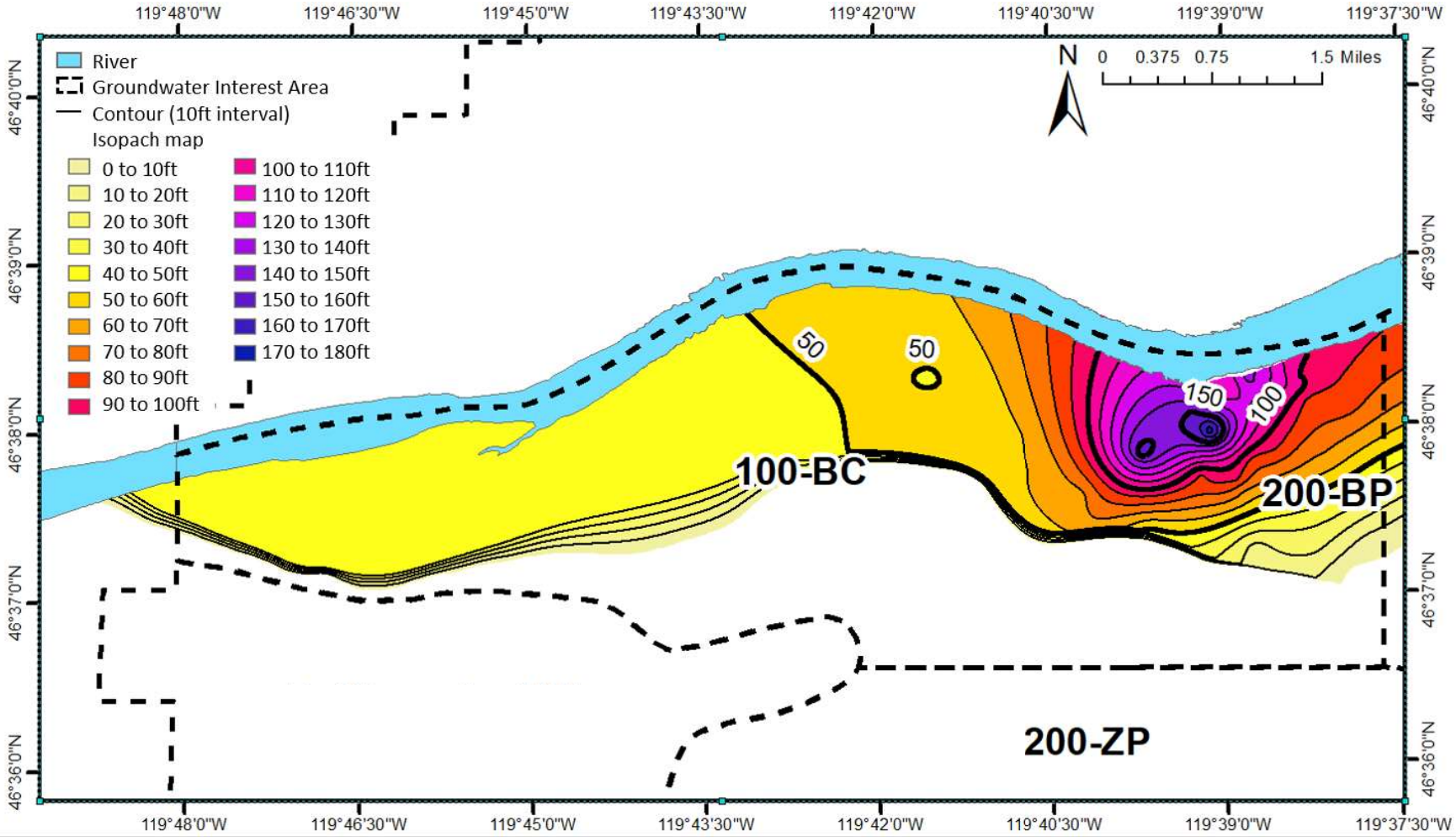
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-8. 100 Area GFM (Version 6) Isopach Map of the Hf HSU (in feet) in the 100-BC Groundwater Interest Area



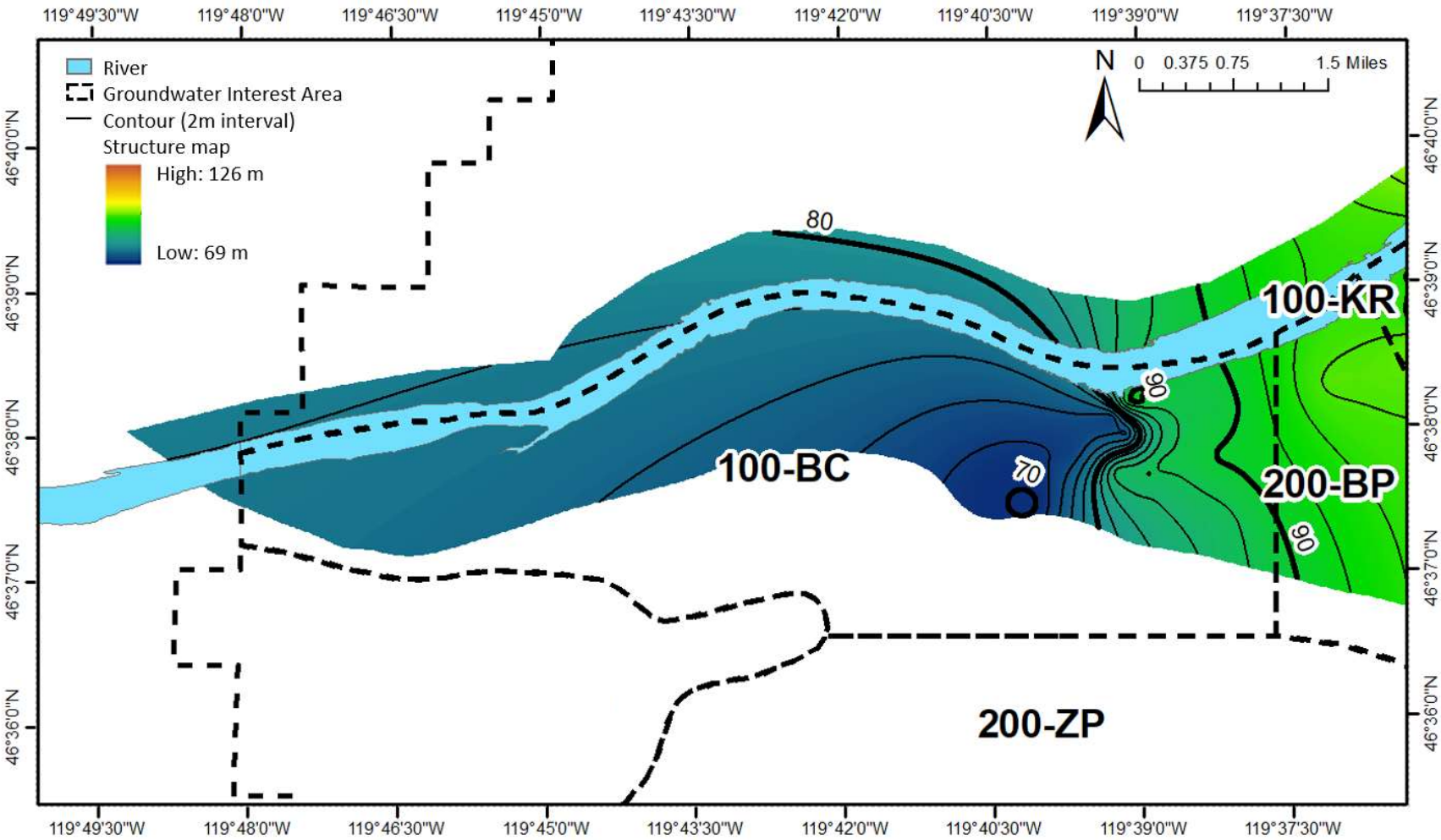
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-9. 100 Area GFM (Version 6) Top of the Rwie HSU Structure Map in the 100-BC Groundwater Interest Area



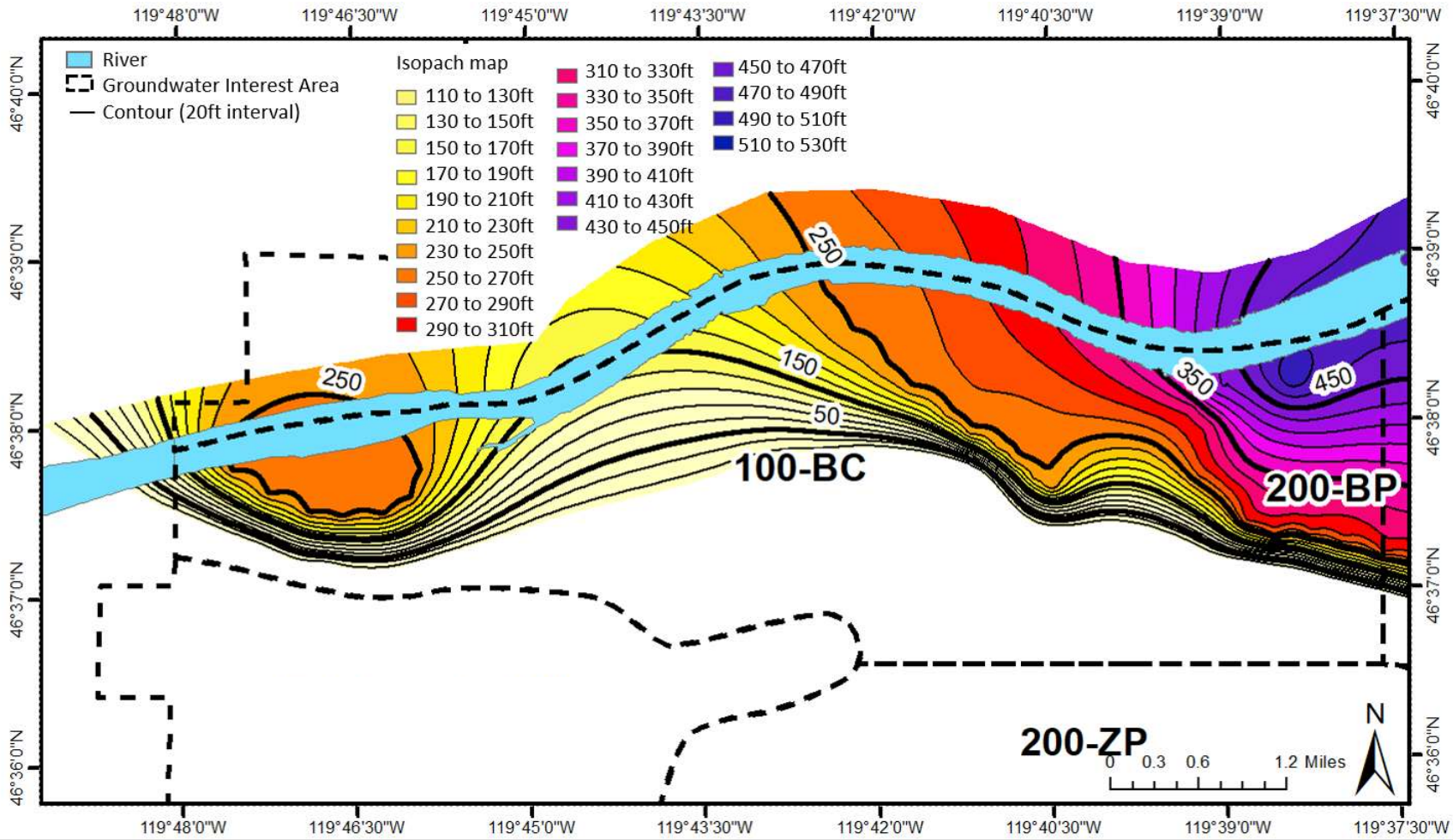
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-10. 100 Area GFM (Version 6) Isopach Map of the Rwie HSU (in feet) in the 100-BC Groundwater Interest Area



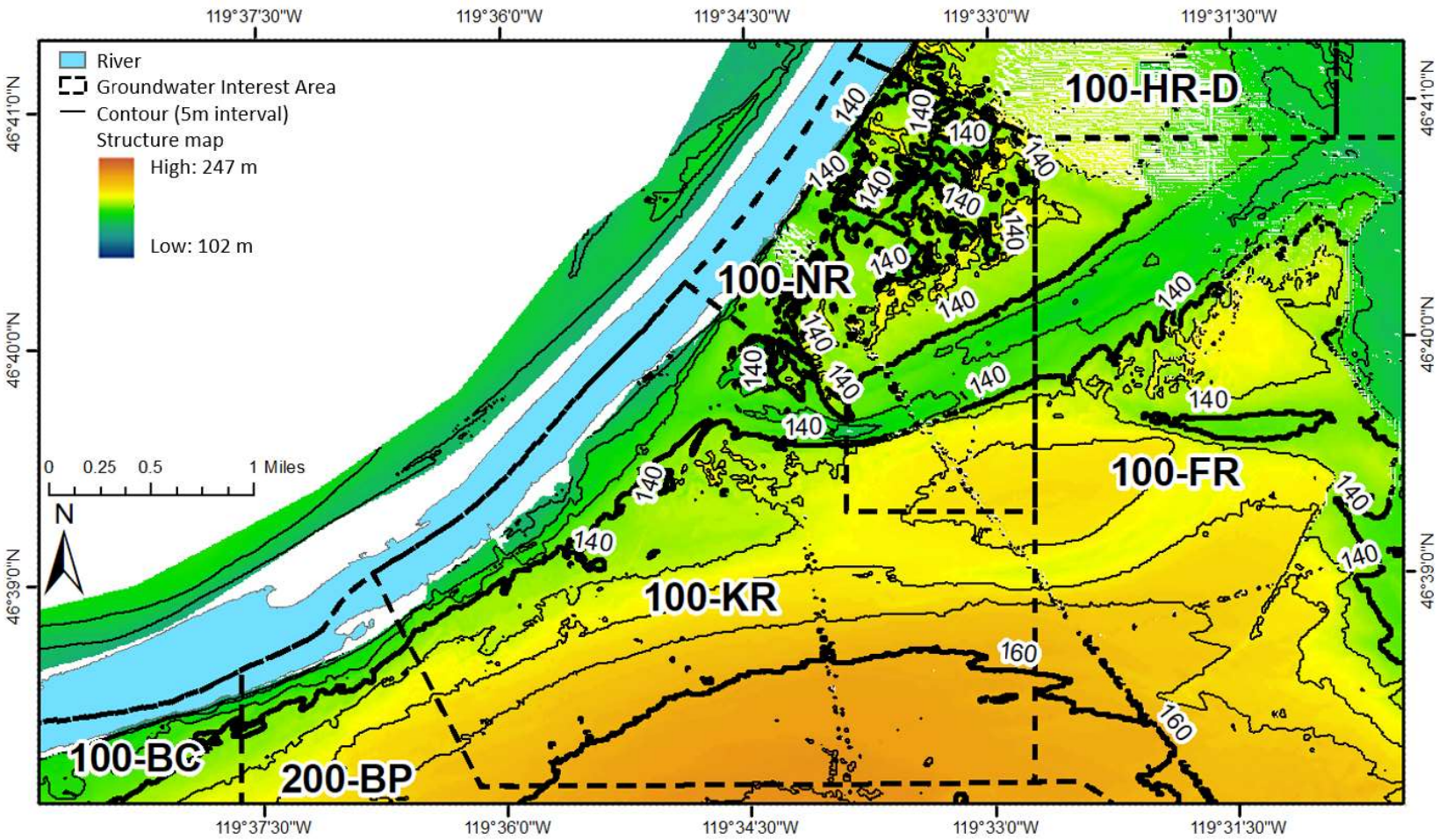
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-11. 100 Area GFM (Version 6) Top of the RUM HSU Structure Map in the 100-BC Groundwater Interest Area



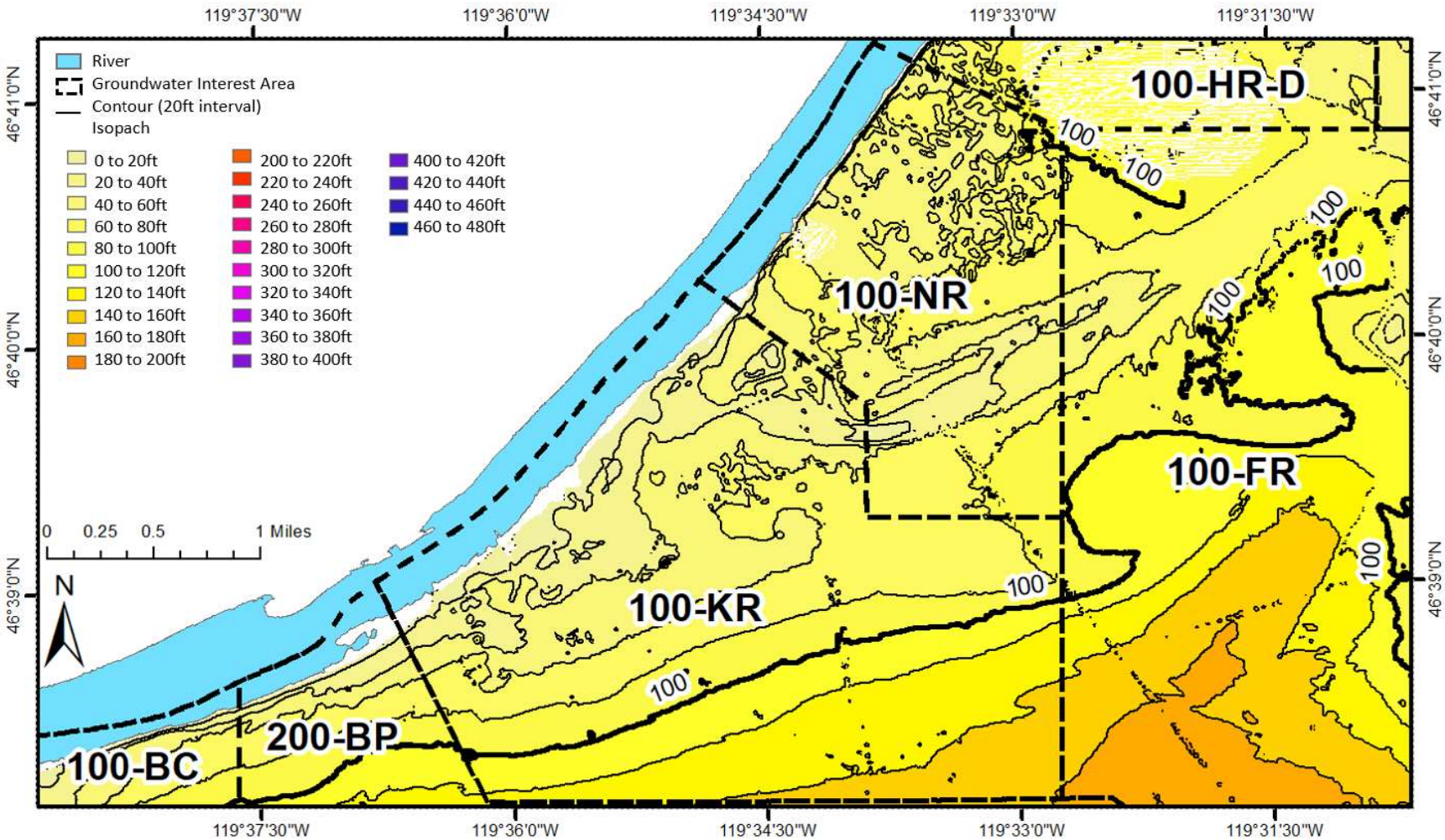
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-12. 100 Area GFM (Version 6) Isopach Map of the RUM HSU (in feet) in the 100-BC Groundwater Interest Area



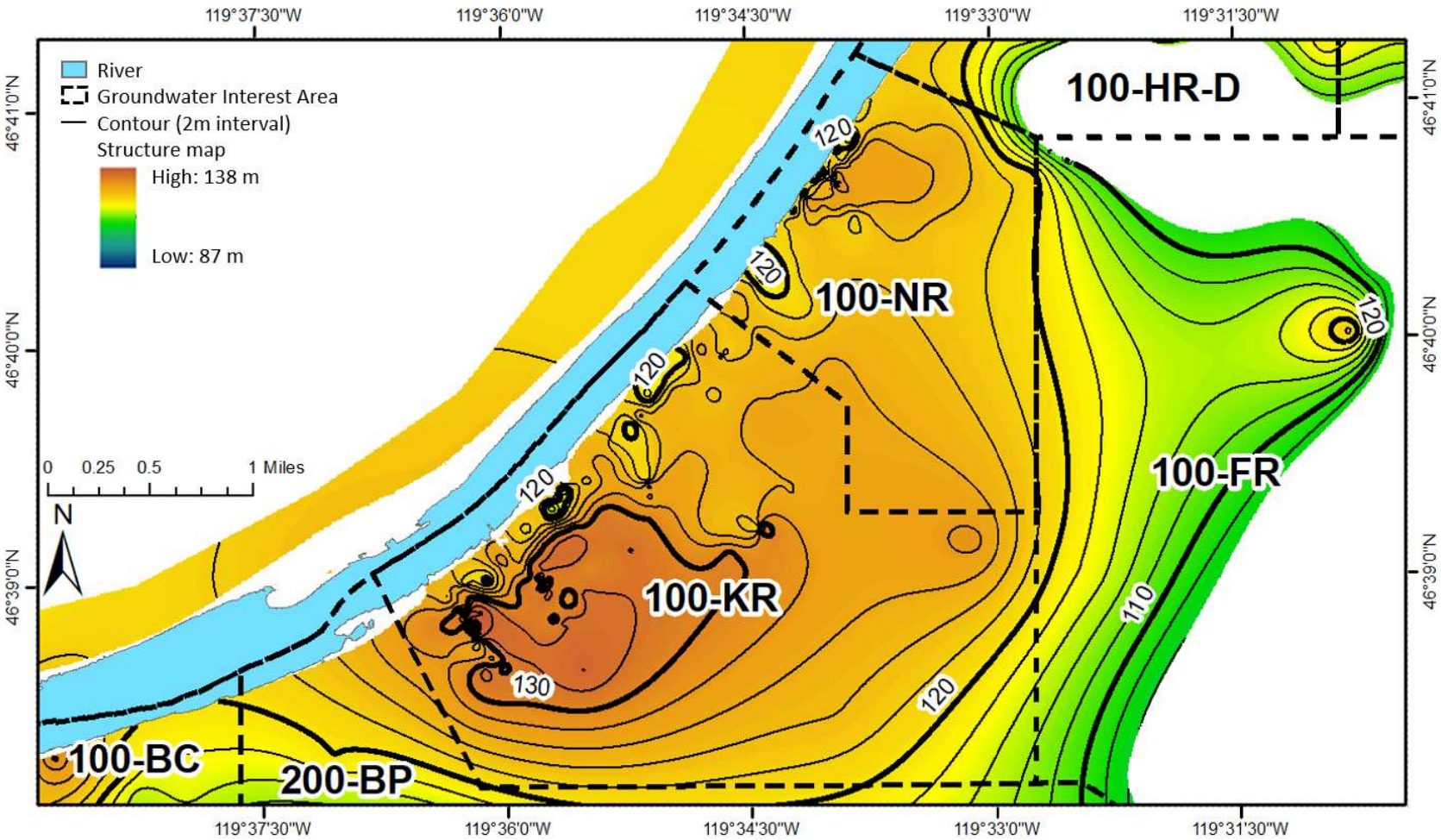
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-13. 100 Area GFM (Version 6) Top of the Hf HSU Structure Map in the 100-KR and 100-NR Groundwater Interest Area



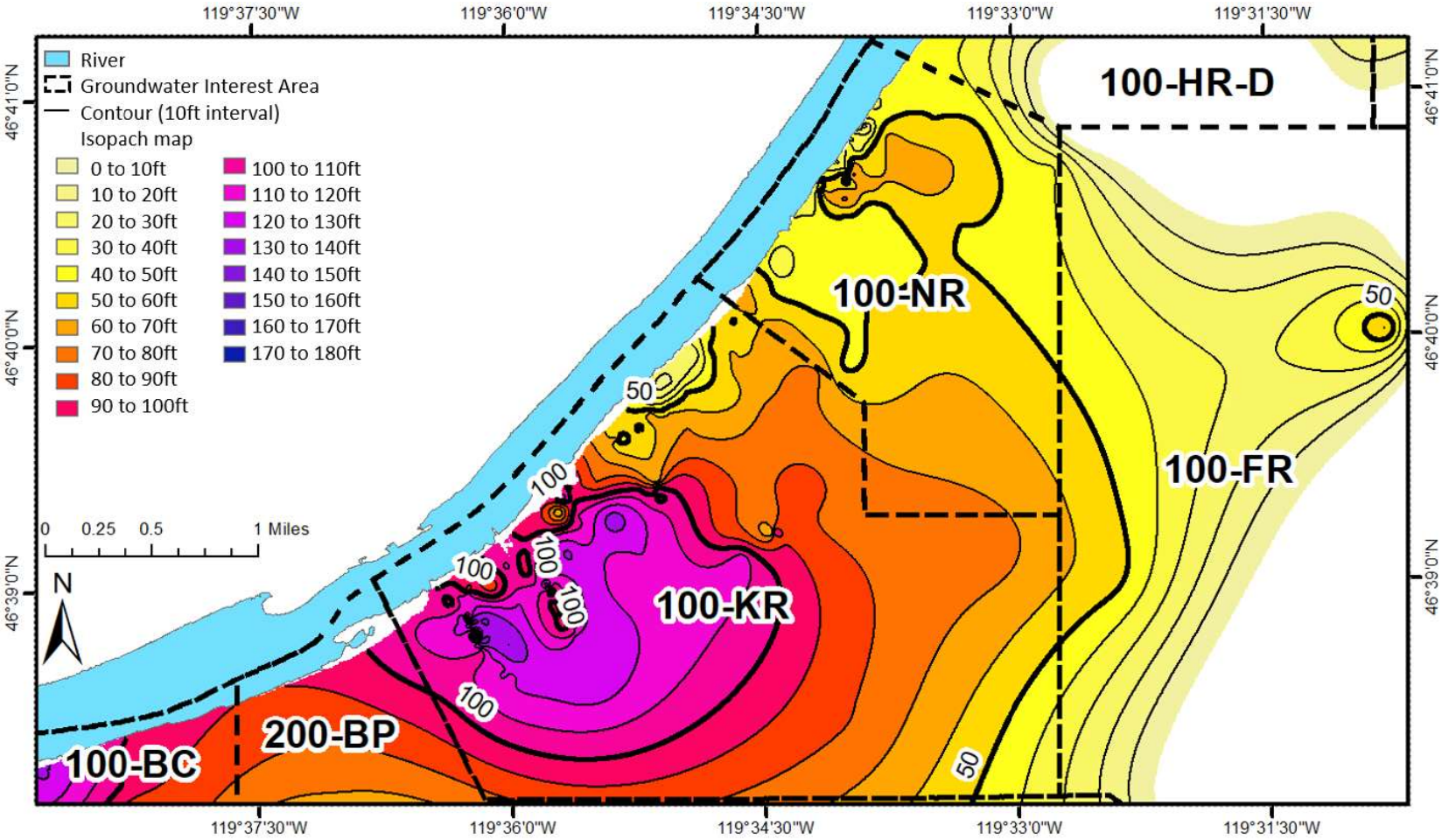
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-14. 100 Area GFM (Version 6) Isopach Map of the Hf HSU (in feet) in the 100-KR and 100-NR Groundwater Interest Area



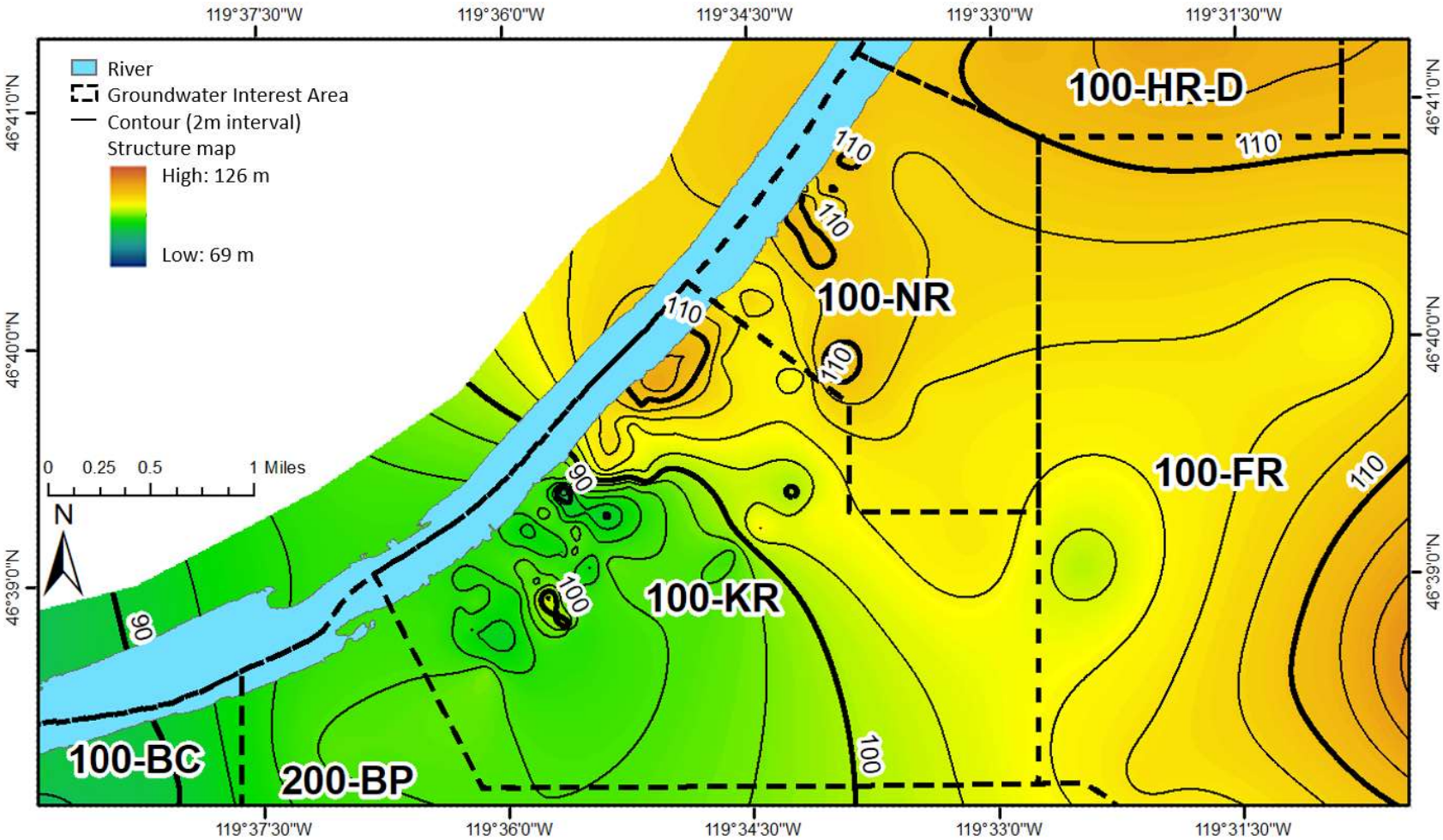
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-15. 100 Area GFM (Version 6) Top of the Rwie HSU Structure Map in the 100-KR and 100-NR Groundwater Interest Area



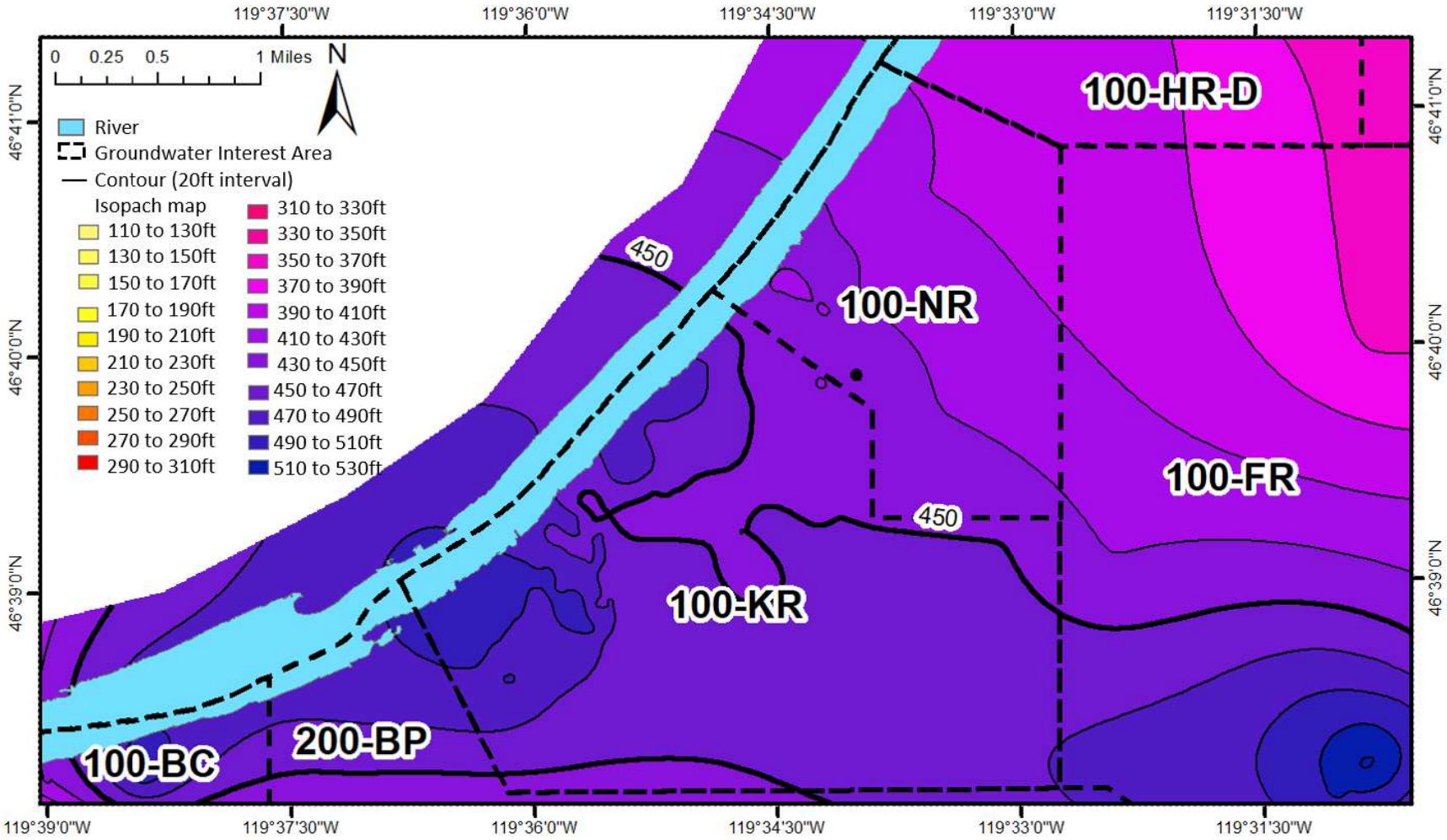
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-16. 100 Area GFM (Version 6) Isopach Map of the Rwie HSU (in feet) in the 100-KR and 100-NR Groundwater



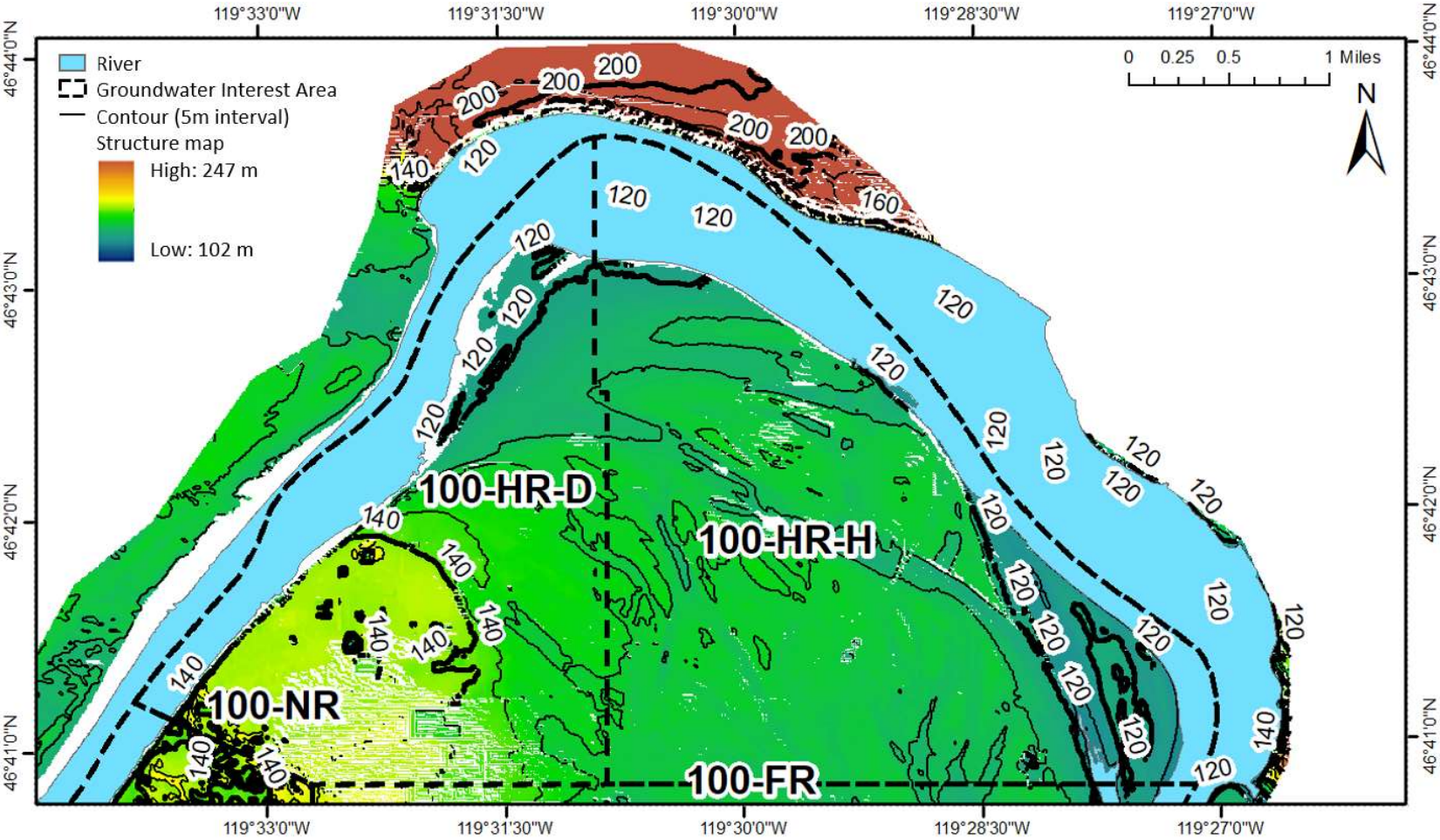
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-17. 100 Area GFM (Version 6) Top of the RUM HSU Structure Map in the 100-KR and 100-NR Groundwater Interest Area



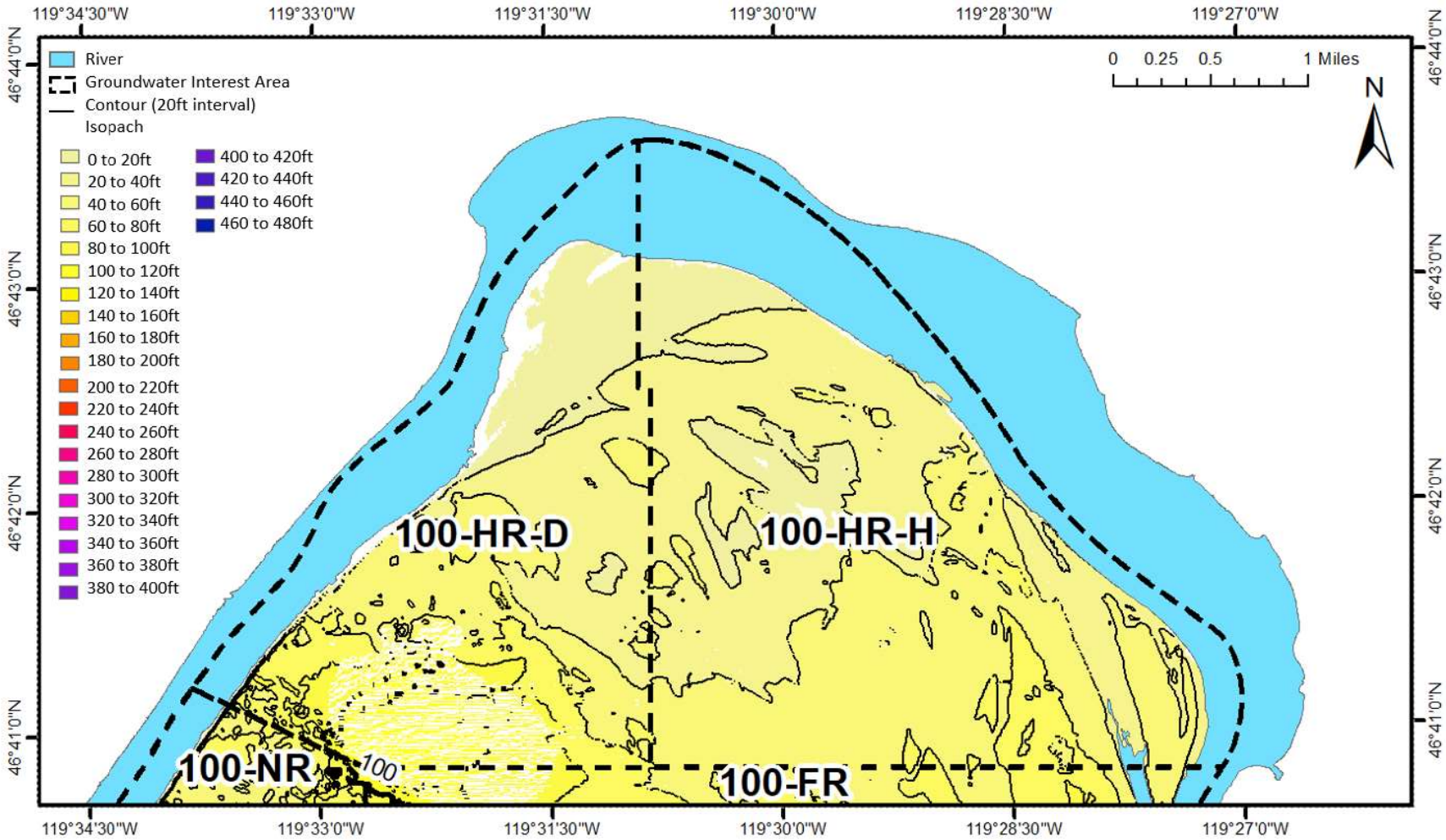
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-18. 100 Area GFM (Version 6) Isopach Map of the RUM HSU (in feet) in the 100-KR and 100-NR Groundwater Interest Area



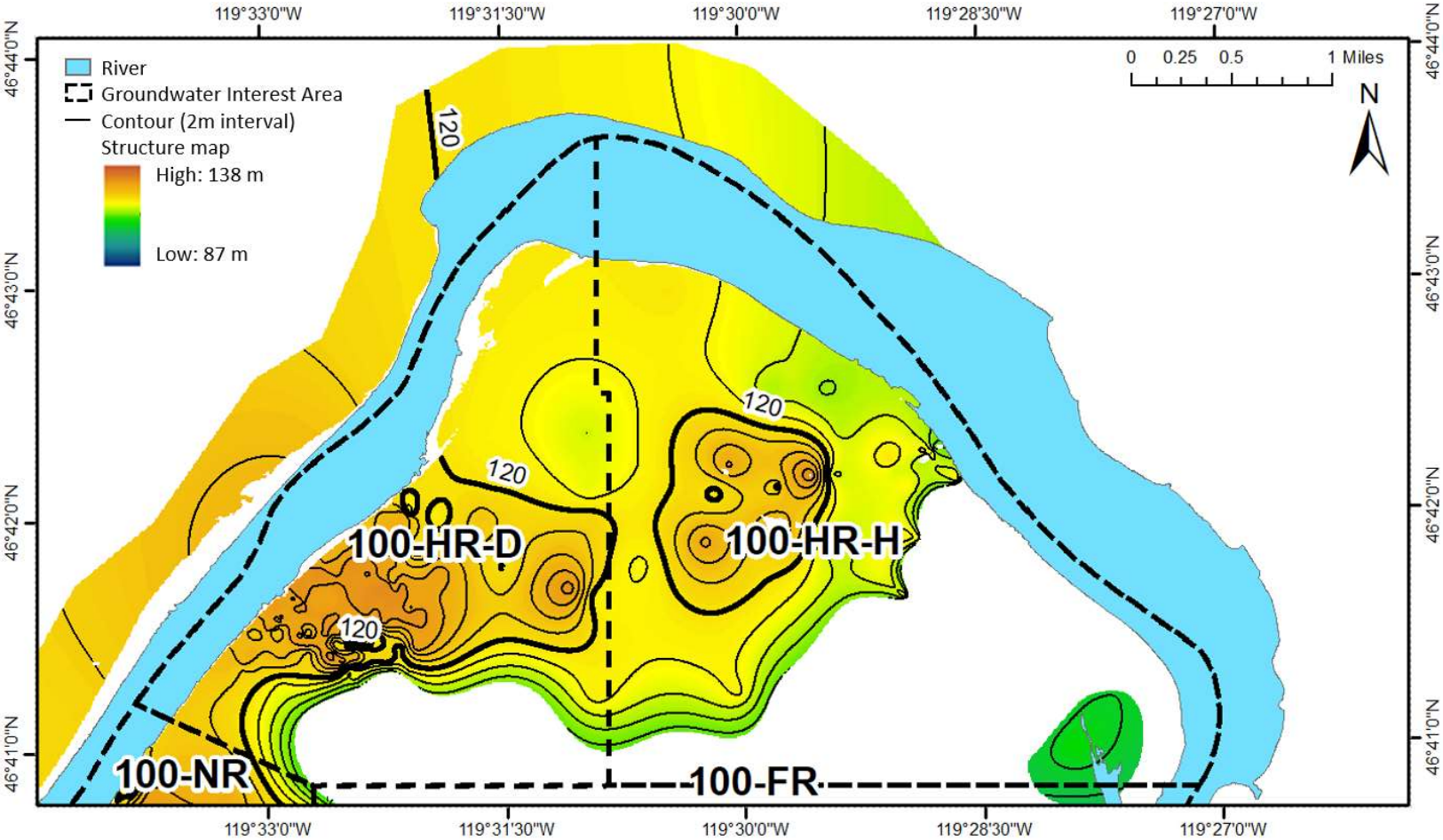
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-19. 100 Area GFM (Version 6) Top of the Hf HSU Structure Map in the 100-D and 100-H Groundwater Interest Area



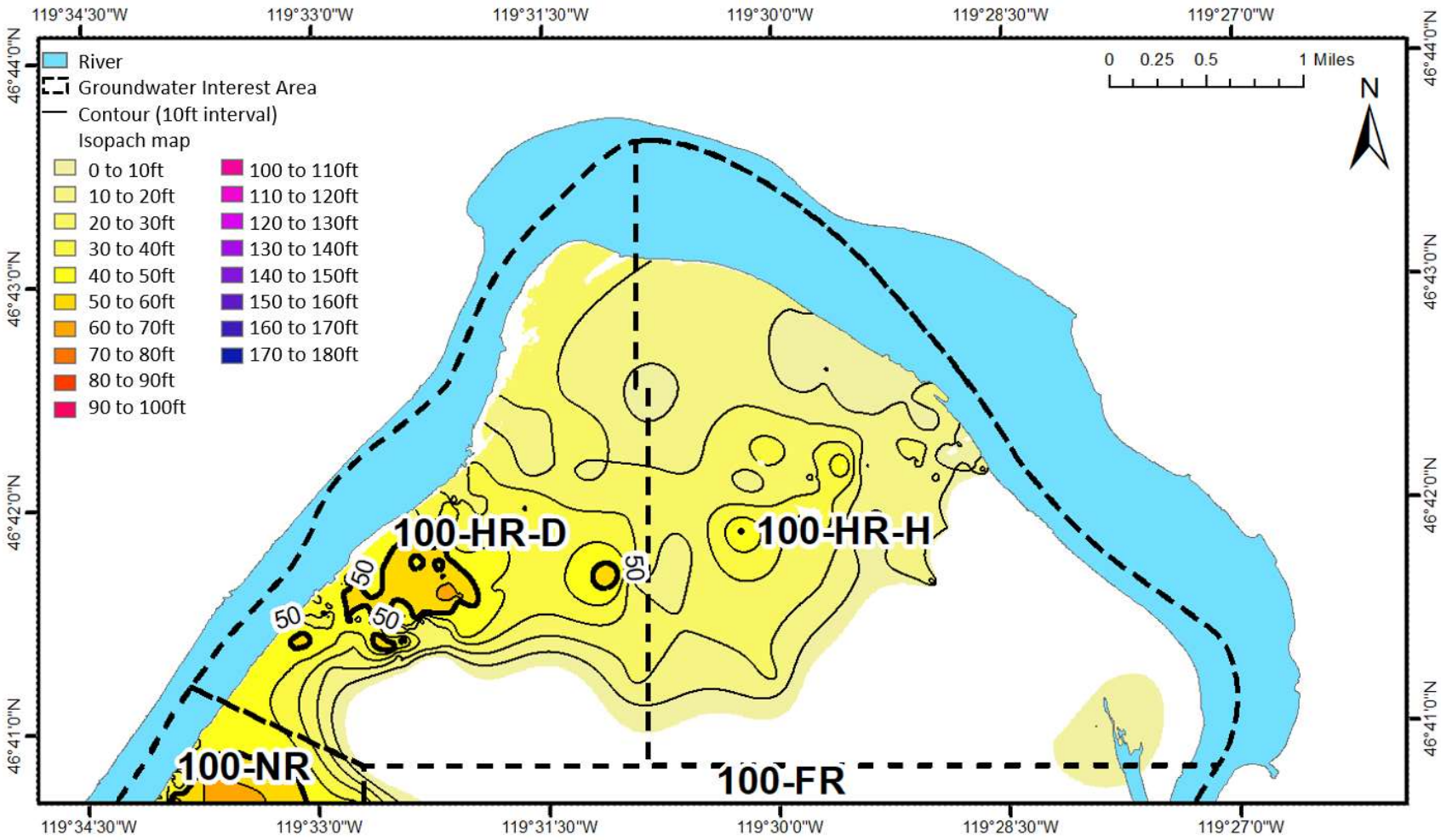
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-20. 100 Area GFM (Version 6) Isopach Map of the Hf HSU (in feet) in the 100-D and 100-H Groundwater Interest Area



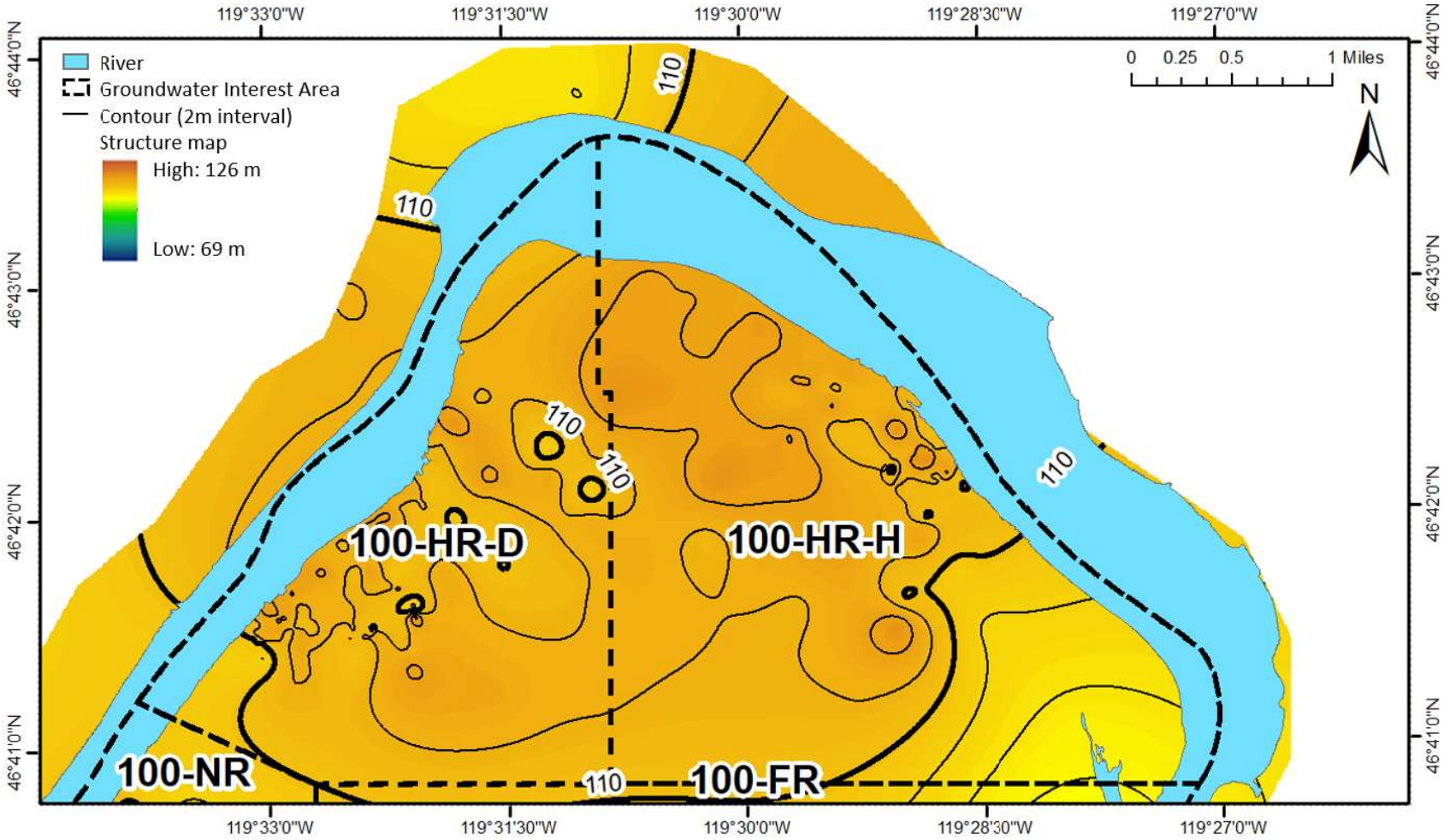
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-21. 100 Area GFM (Version 6) Top of the Rwie HSU Structure Map in the 100-D and 100-H Groundwater Interest Area



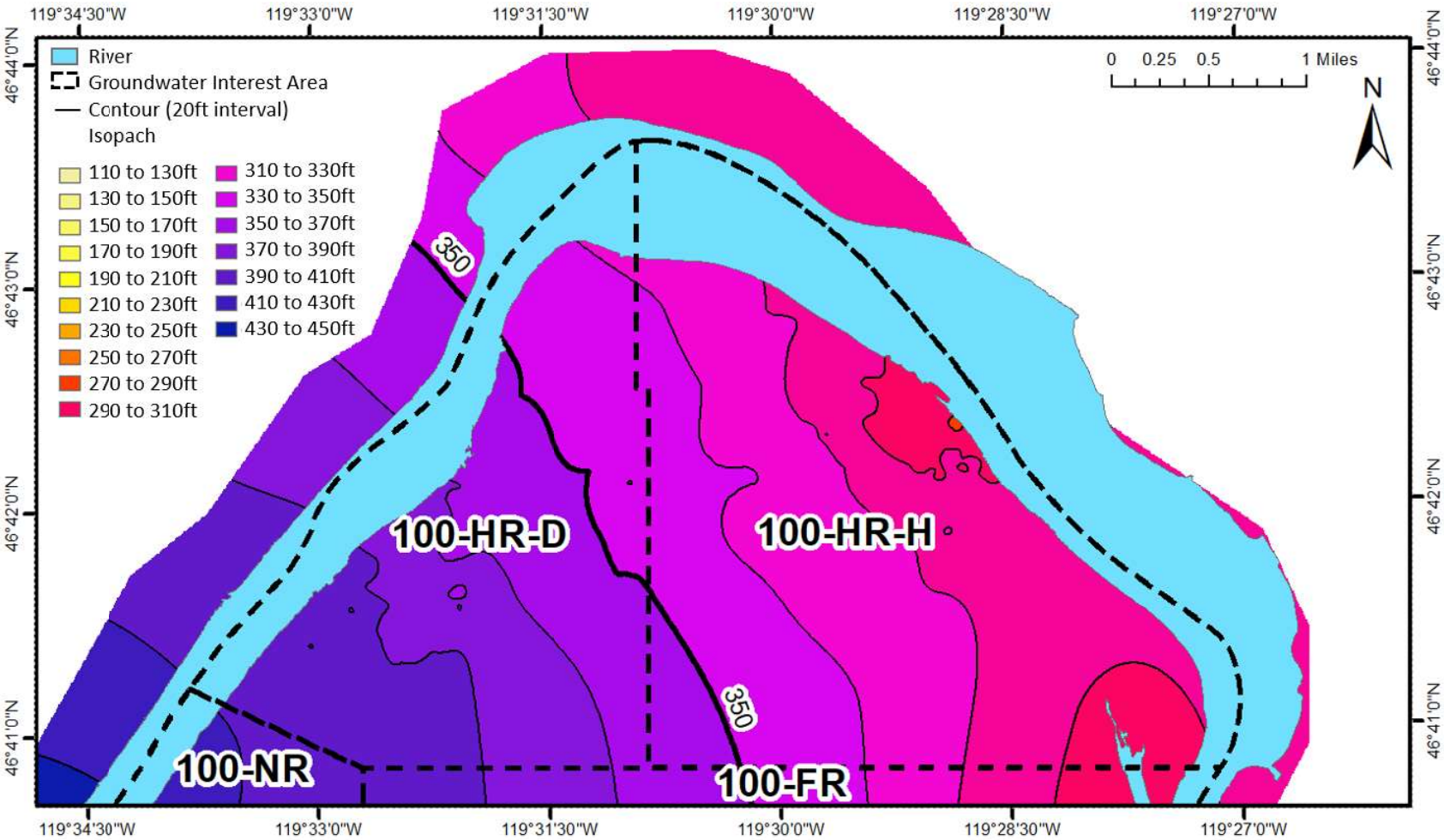
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-22. 100 Area GFM (Version 6) Isopach Map of the Rwie HSU (in feet) in the 100-D and 100-H Groundwater Interest Area



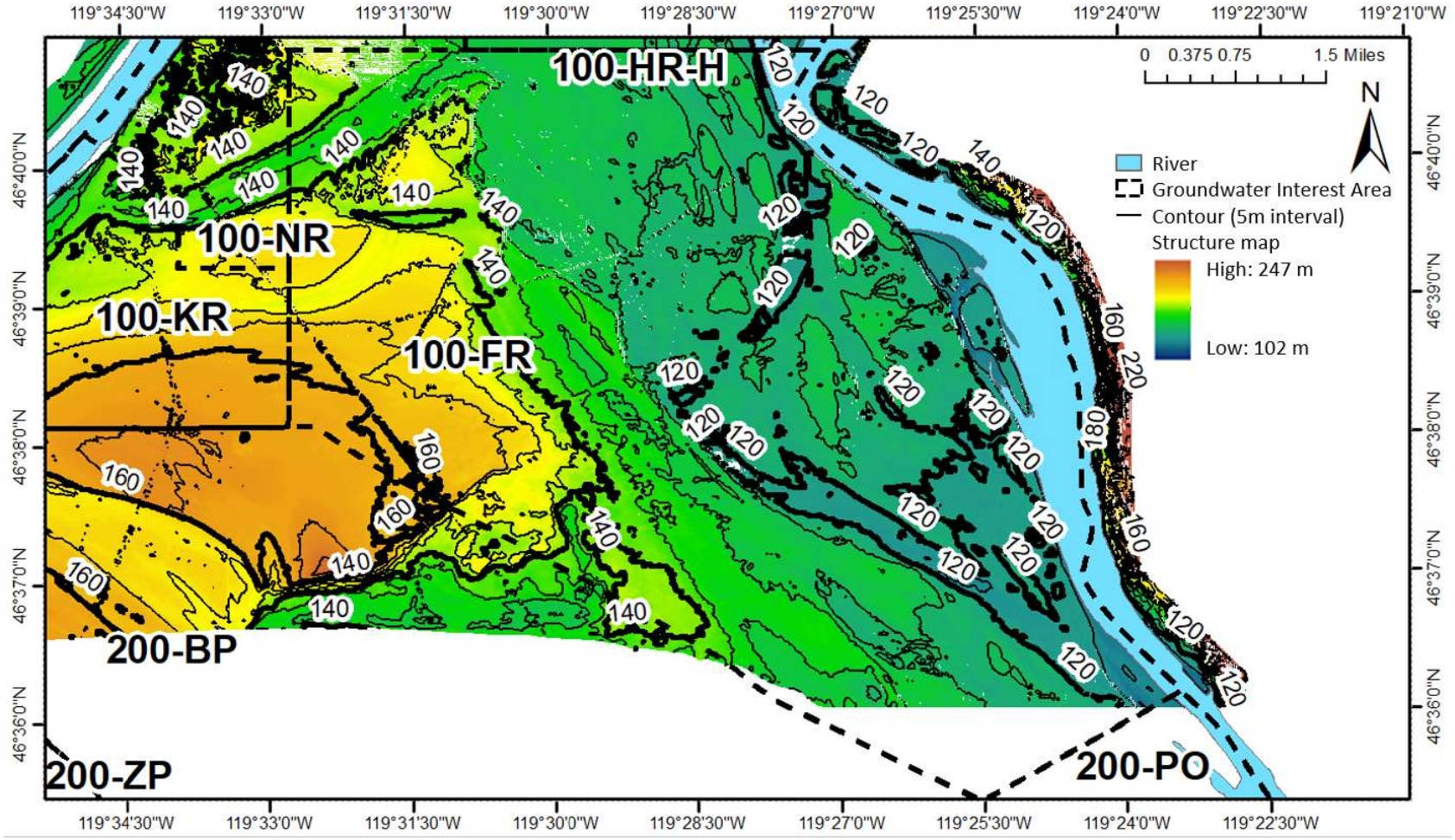
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-23. 100 Area GFM (Version 6) Top of the RUM HSU Structure Map in the 100-D and 100-H Groundwater Interest Area



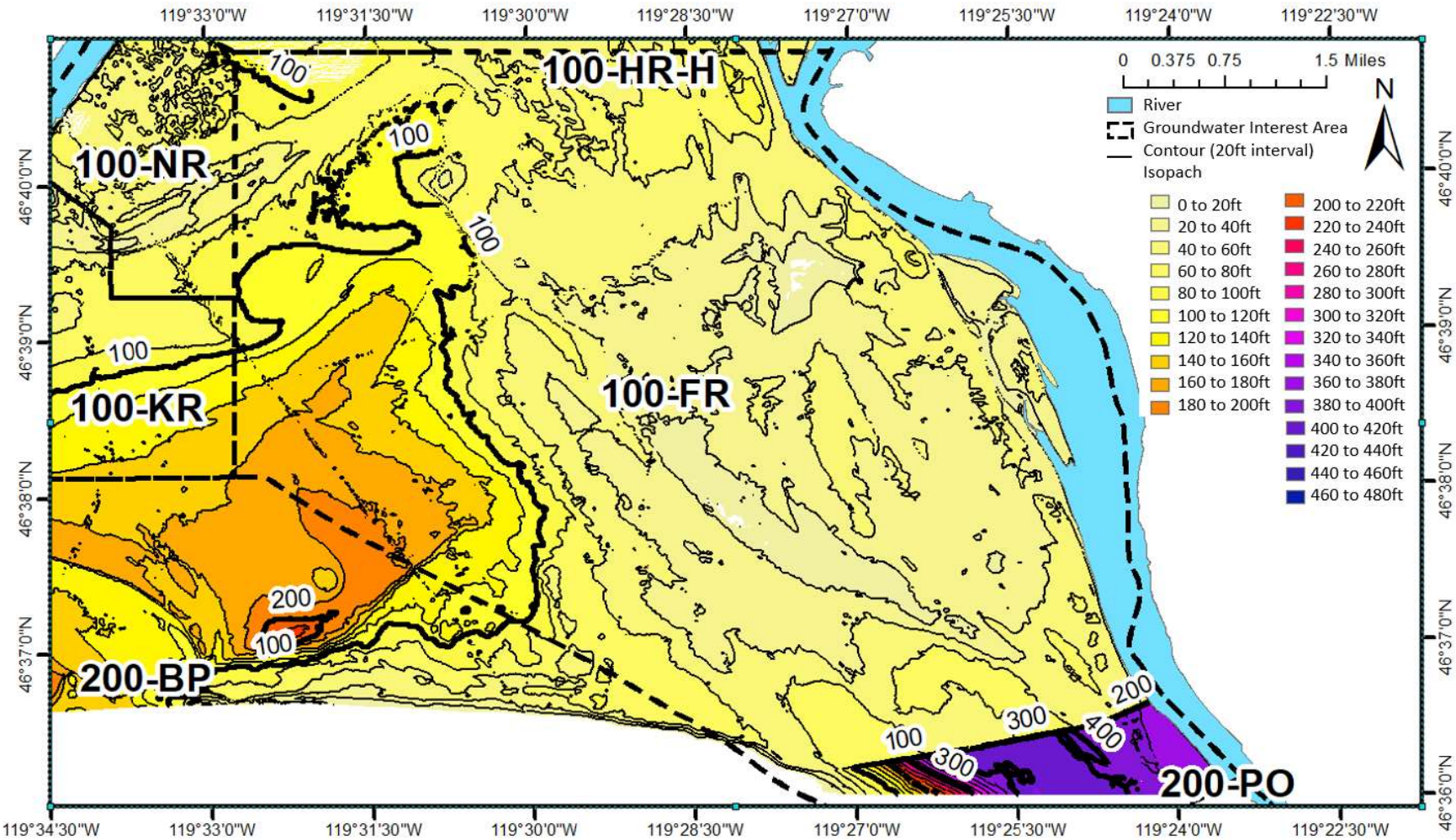
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-24. 100 Area GFM (Version 6) Isopach Map of the RUM HSU (in feet) in the 100-D and 100-H Groundwater Interest Area



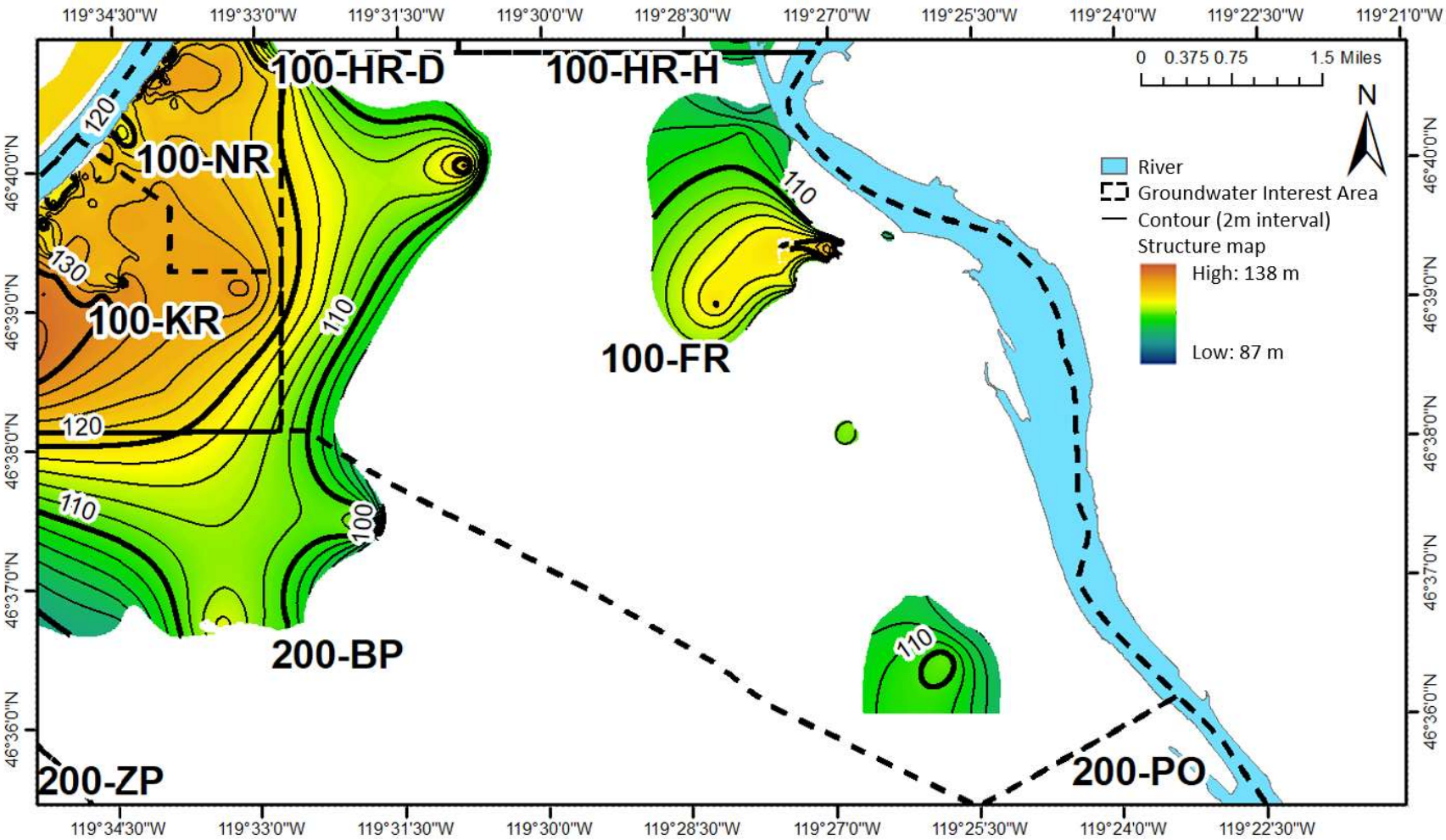
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-25. 100 Area GFM (Version 6) Top of the Hf HSU Structure Map in the 100-F Groundwater Interest Area



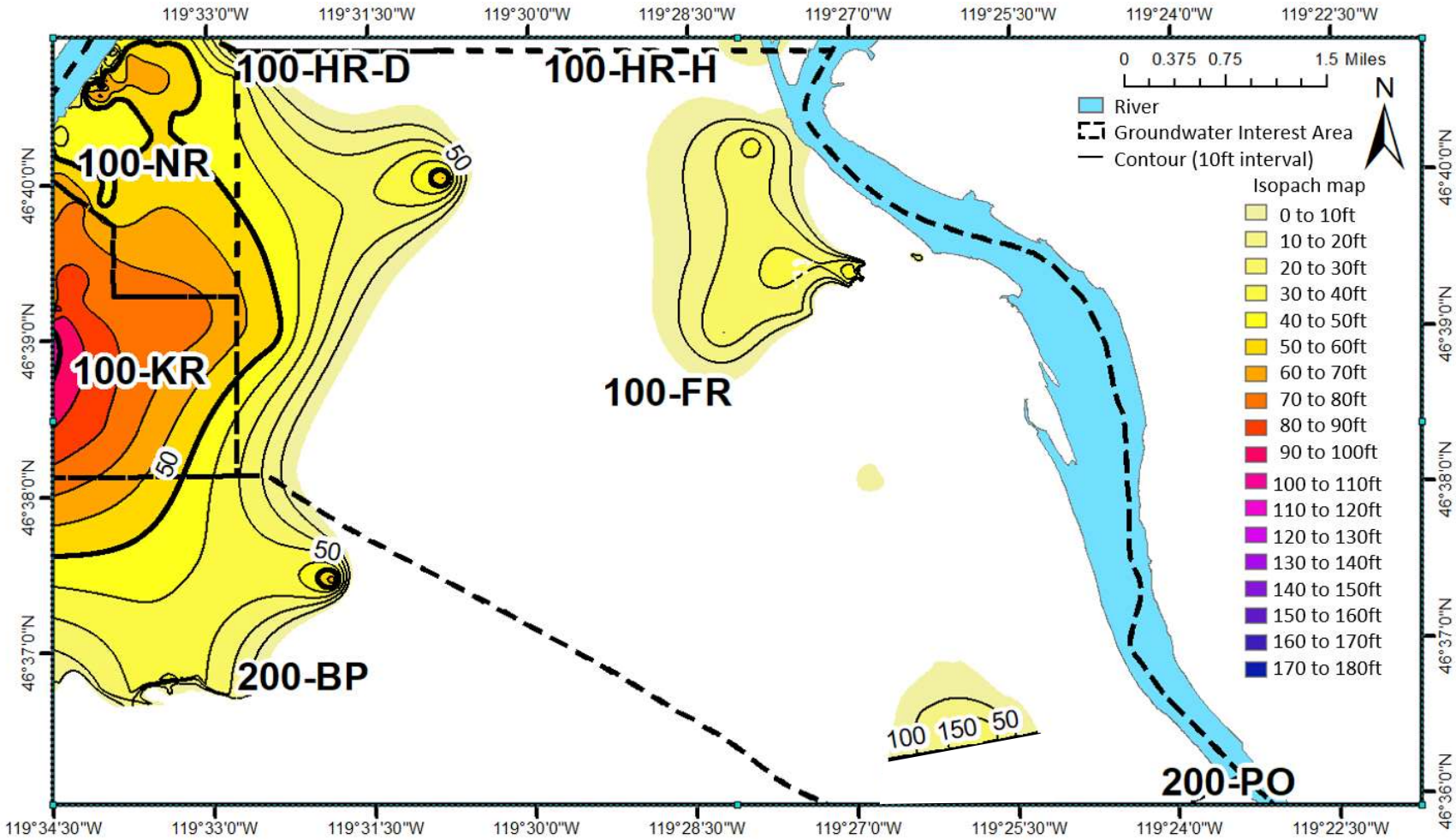
Notes: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m). The thick region in the southeast corner of the model reflects Hf directly overlaying basalt where the RUM surfaces ends in the model.

Figure C-26. 100 Area GFM (Version 6) Isopach Map of the Hf HSU (in feet) in the 100-F Groundwater Interest Area



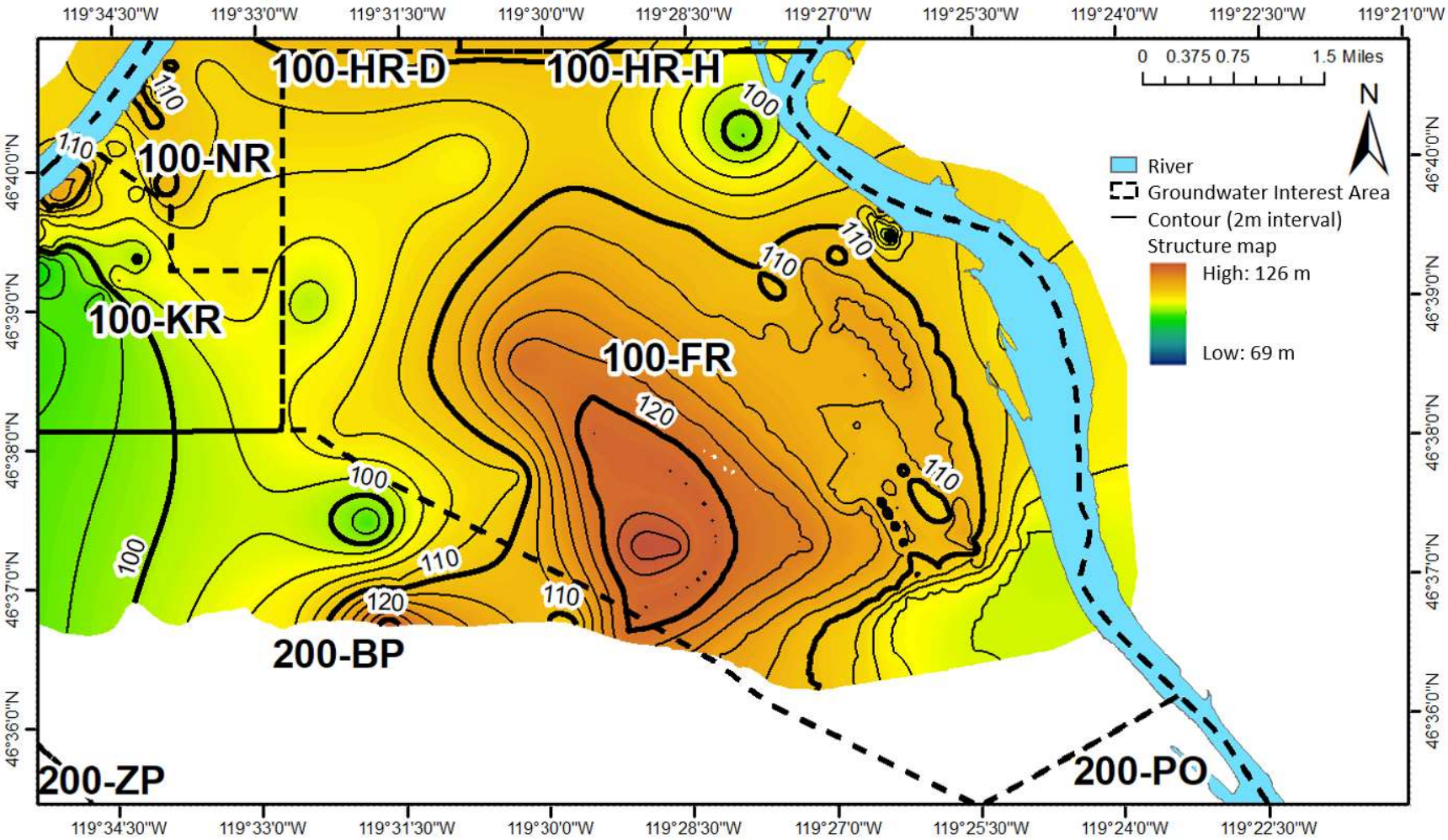
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-27. 100 Area GFM (Version 6) Top of the Rwie HSU Structure Map in the 100-F Groundwater Interest Area



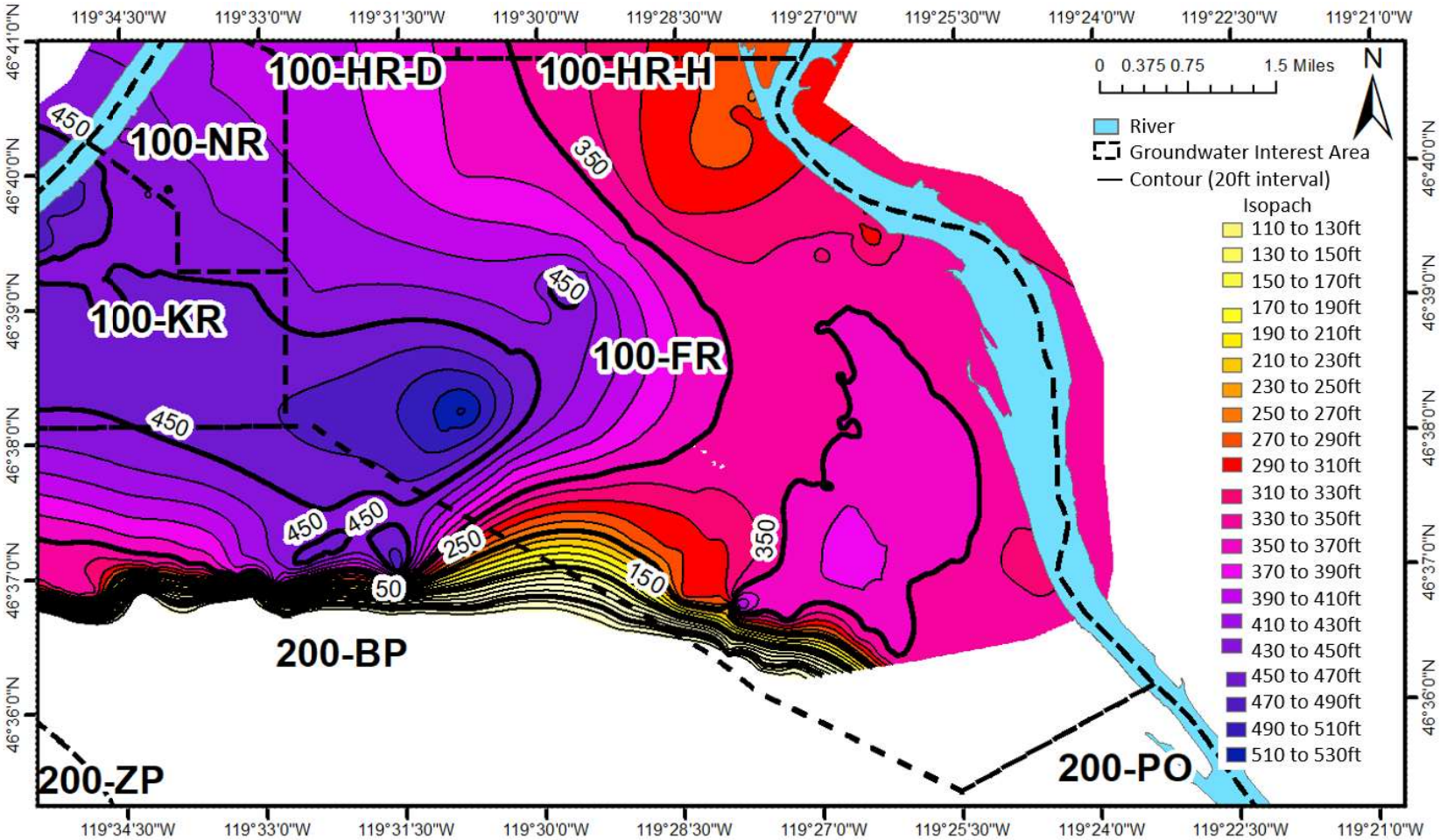
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-28. 100 Area GFM (Version 6) Isopach Map of the Rwie HSU (in feet) in the 100-F Groundwater Interest Area



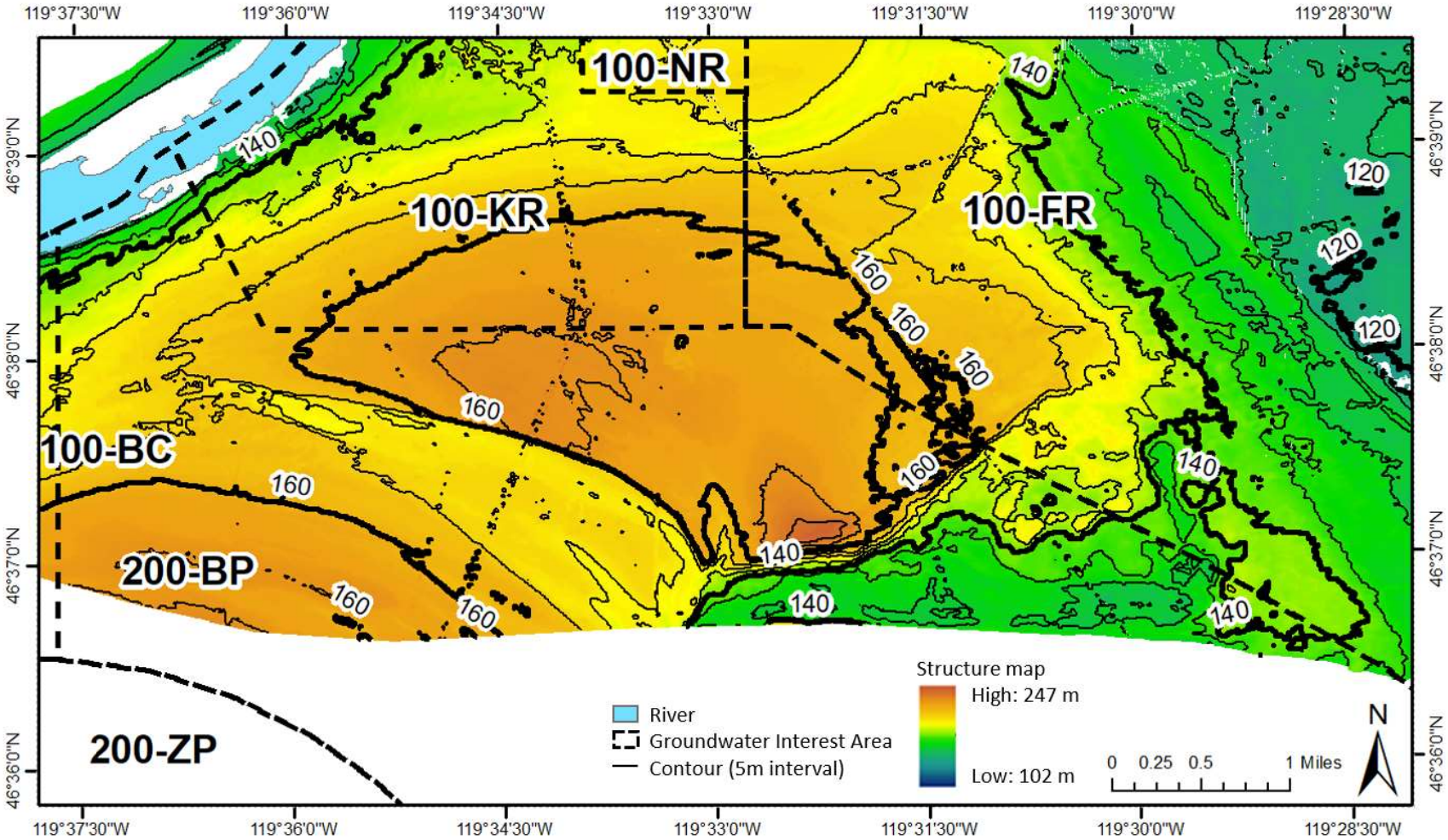
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-29. 100 Area GFM (Version 6) Top of the RUM HSU Structure Map in the 100-F Groundwater Interest Area



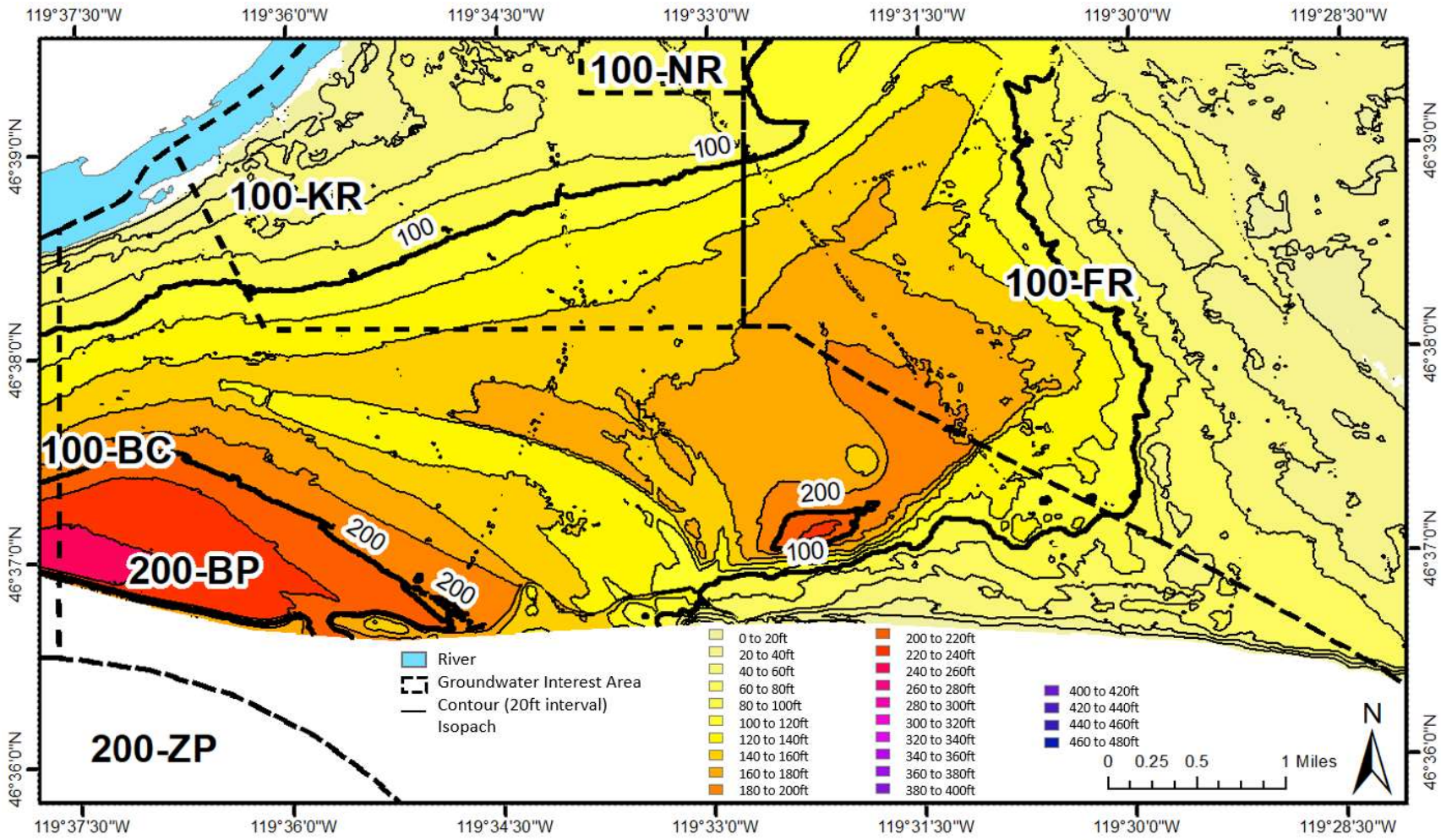
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-30. 100 Area GFM (Version 6) Isopach Map of the RUM HSU (in feet) in the 100-F Groundwater Interest Area



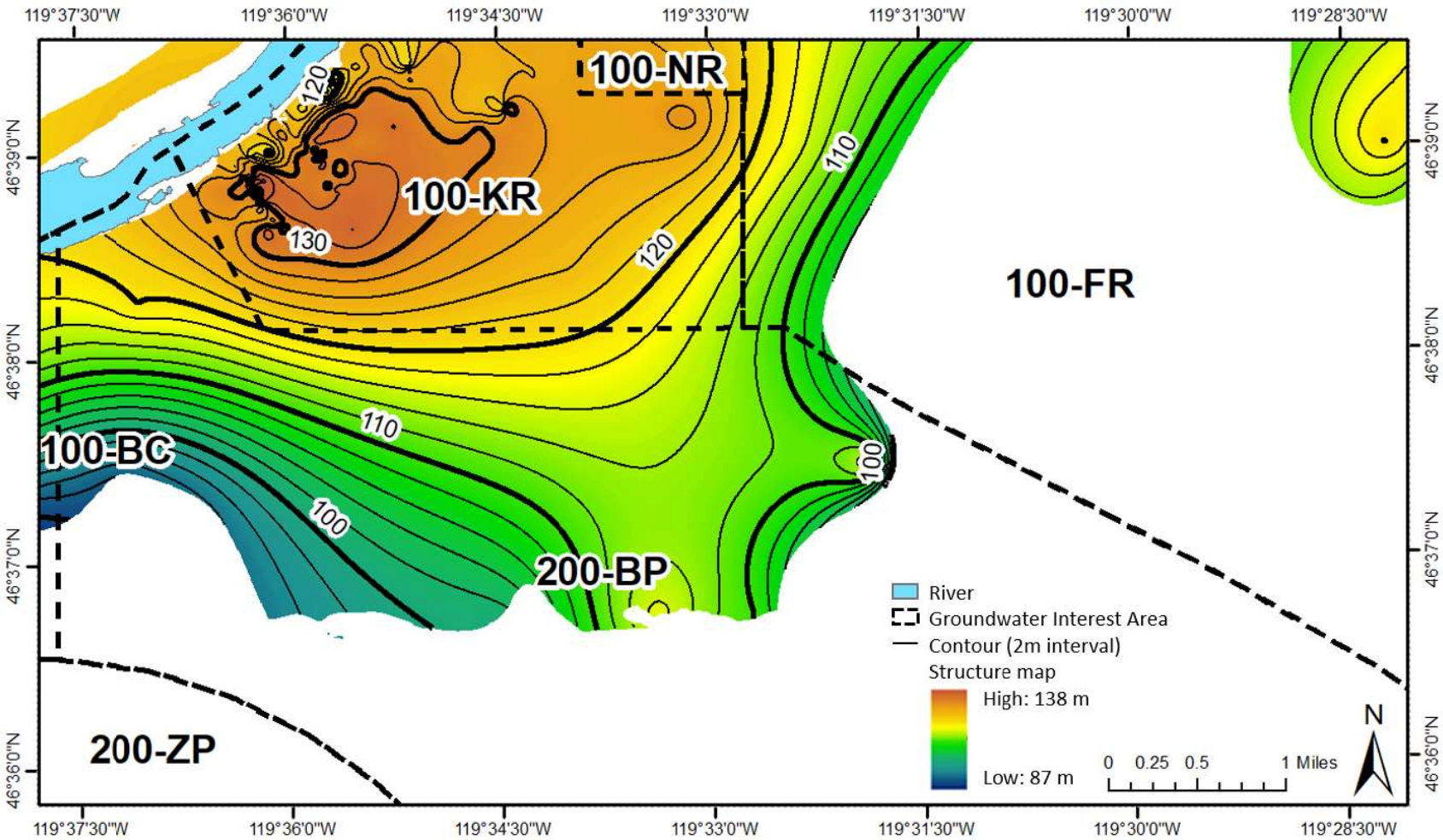
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-31. 100 Area GFM (Version 6) Top of the Hf HSU Structure Map in the 200-BP Groundwater Interest Area



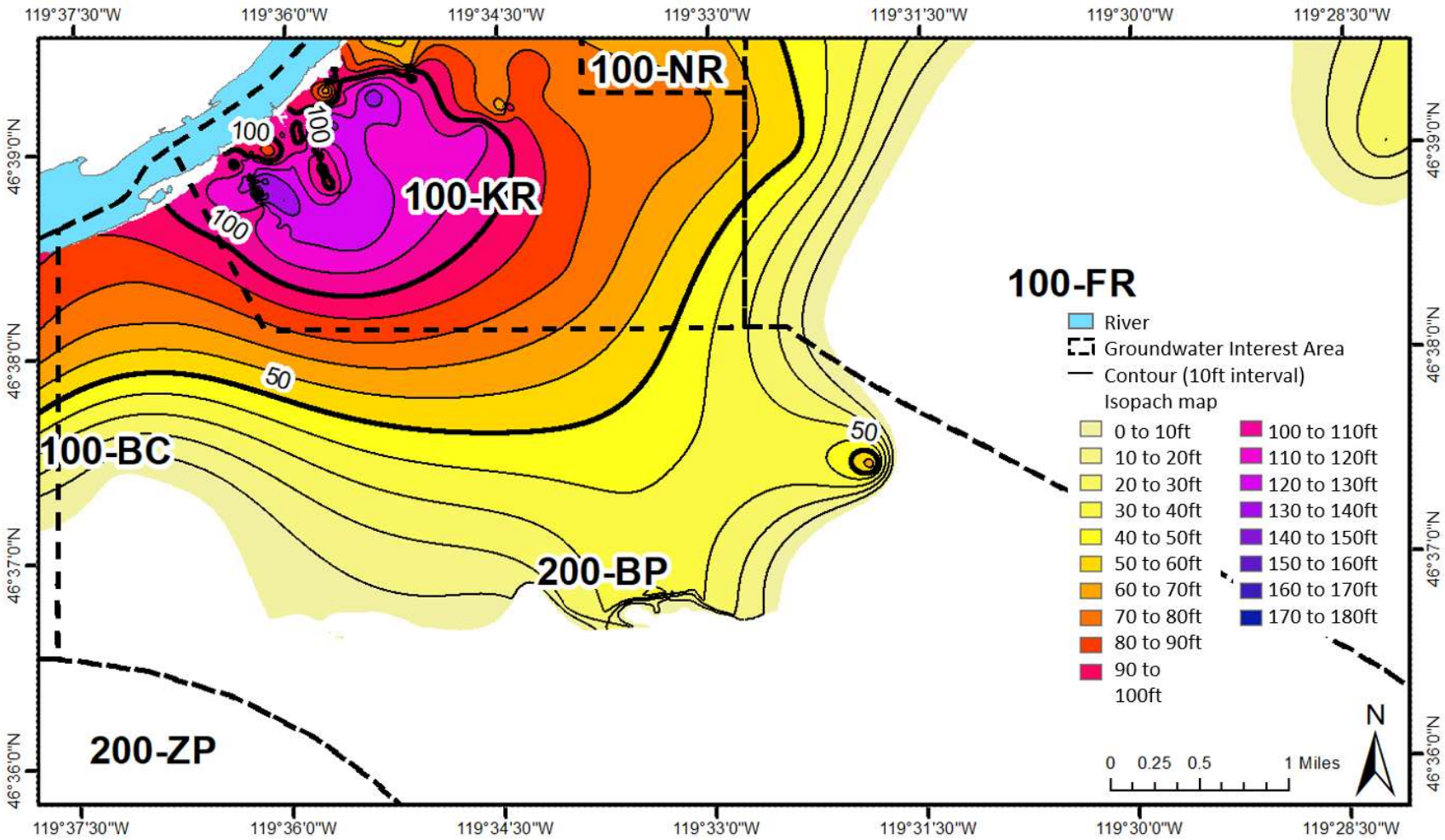
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-32. 100 Area GFM (Version 6) Isopach Map of the Hf HSU (in feet) in the 200-BP Groundwater Interest Area



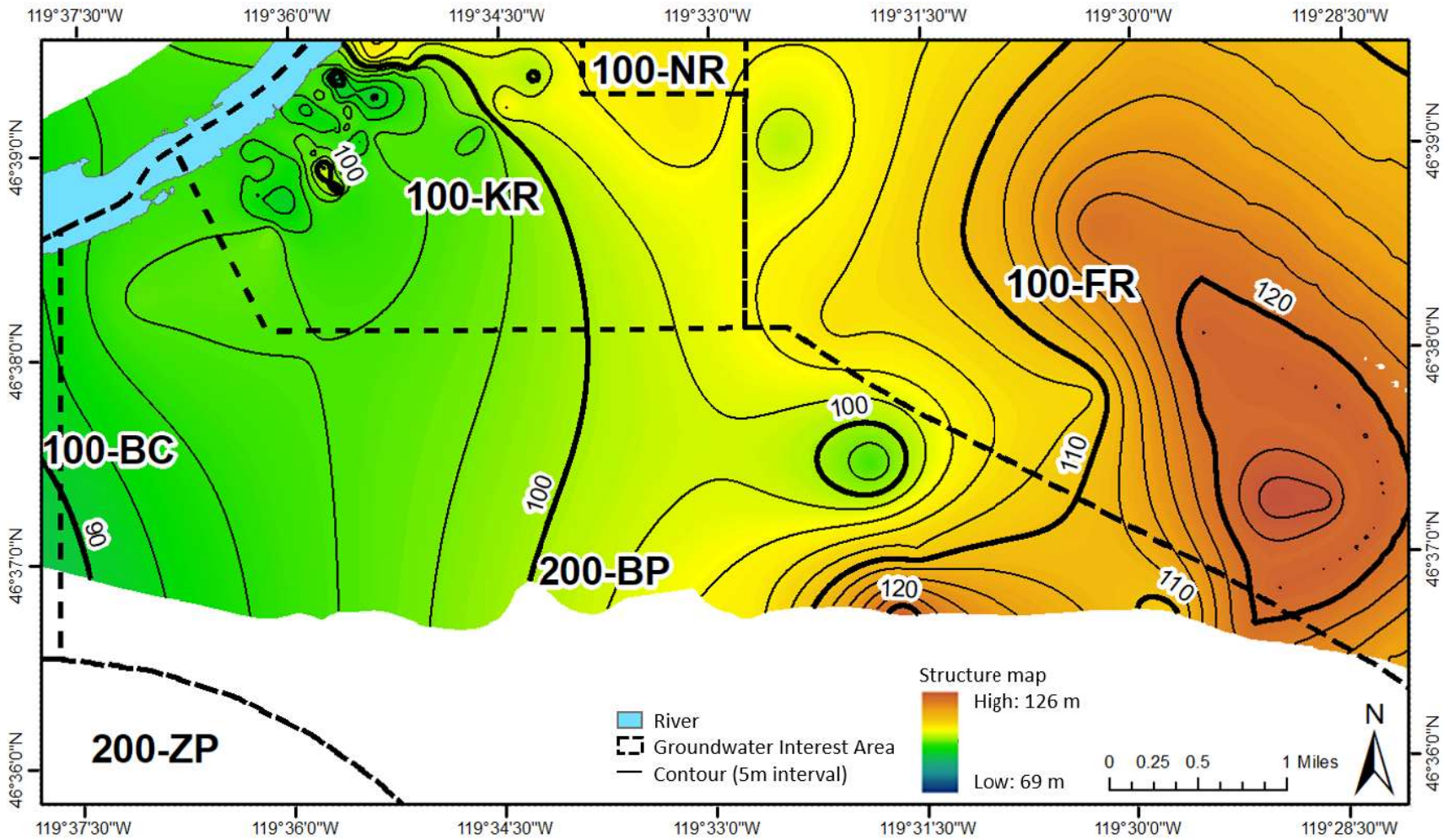
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-33. 100 Area GFM (Version 6) Top of the Rwie HSU Structure Map in the 200-BP Groundwater Interest Area



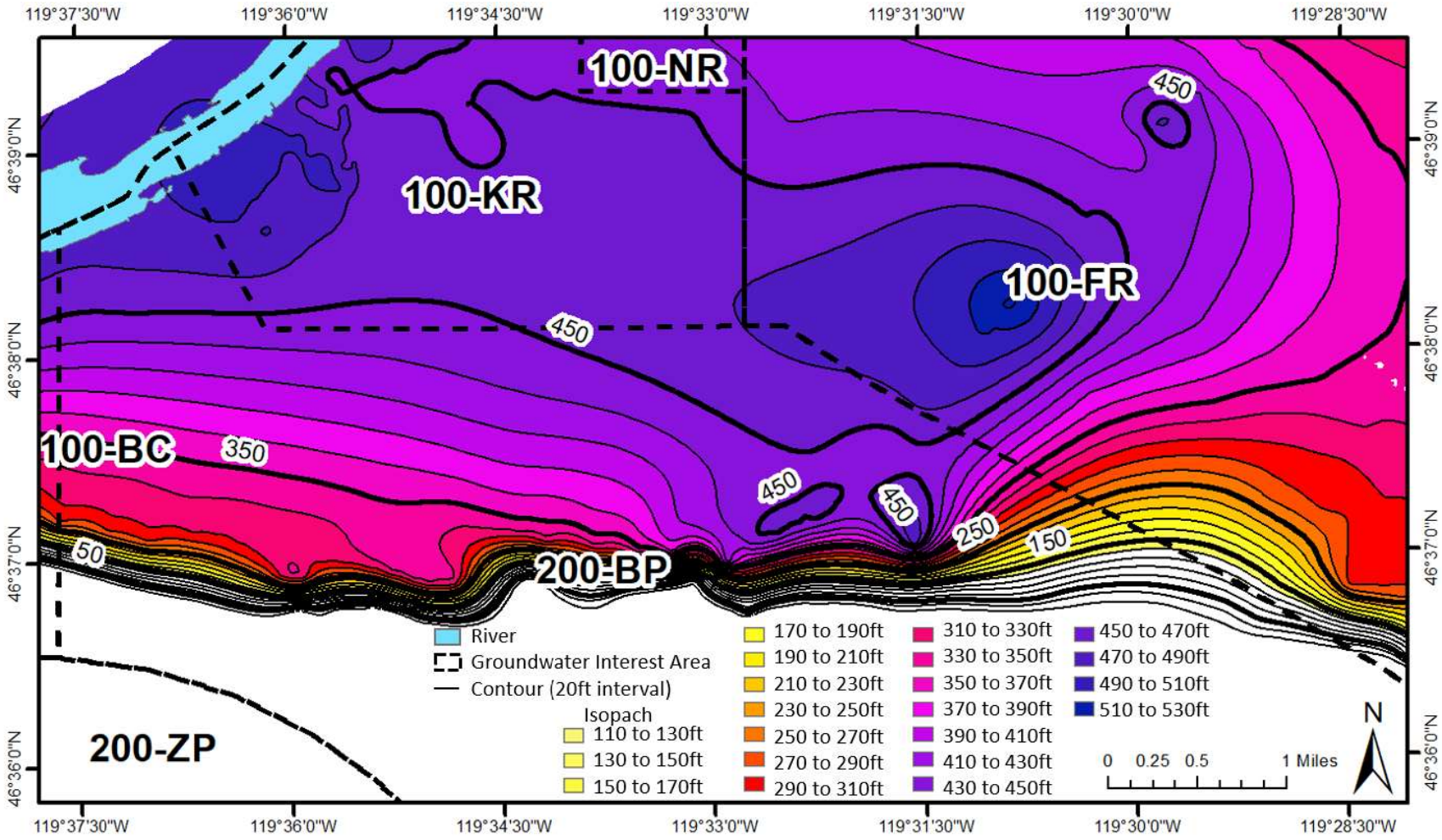
Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-34. 100 Area GFM (Version 6) Isopach Map of the Rwie HSU (in feet) in the 200-BP Groundwater Interest Area



Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-35. 100 Area GFM (Version 6) Top of the RUM HSU Structure Map in the 200-BP Groundwater



Note: Horizontal coordinate system NAD_1983_StatePlane_Washington_South_FIPS_4602 (m).

Figure C-36. 100 Area GFM (Version 6) Isopach Map of the RUM HSU (in feet) in the 200-BP Groundwater Interest Area

C2 Reference

NAD83, 1991, *North American Datum of 1983*, as revised, National Geodetic Survey, Federal Geodetic Control Committee, Silver Spring, Maryland. Available at: https://www.ngs.noaa.gov/datums/horizontal/north-american-datum-1983.shtml.

This page intentionally left blank.

Appendix D

Verification and Checking of the Grids in Version 6 of the 100 Area Geoframework Model

This page intentionally left blank.

Contents

D1 Introduction.....D-1

D2 Top of the Hanford Formation Hydrostratigraphic Unit Grid.....D-2

D3 Top of the Ringold Formation Member of Wooded Island — unit E Hydrostratigraphic Unit Grid.....D-3

D4 Top of the Ringold Formation Upper Mud Unit Hydrostratigraphic Unit Grid.....D-5

Figures

Figure D-1. Kingdom GFM Grid Elevations for the Hf HSU Versus Hf HSU Elevations from Wells in the GeoContacts Database.....D-2

Figure D-2. Kingdom GFM Grid Elevations for the Rwie Versus Rwie HSU Top Elevations From Wells in the GeoContacts Database.....D-4

Figure D-3. Kingdom GFM Grid Elevations for the RUM HSU Versus RUM HSU Top Elevations from Wells in the GeoContacts Database.....D-5

Tables

Table D-1. Wells with Errors > 3 m Between the Hf HSU Top Elevation and the Kingdom Hf HSU Grid Elevation at the Same Well Locations.....D-2

Table D-2. Wells with Errors > 3 m Between the Rwie HSU on Top Elevation and the Kingdom Rwie HSU Grid Elevation.....D-4

Table D-3. Wells with Errors > 3 m Between the RUM HSU Top Elevation and the Kingdom Grid Elevation.....D-5

This page intentionally left blank.

Terms

GFM	geoframework model
Hf	Hanford formation
HSU	hydrostratigraphic unit
RUM	Ringold Formation Upper Mud Unit
Rwie	Ringold Formation member of Wooded Island — unit E

This page intentionally left blank.

D1 Introduction

There are several ways that errors may be introduced in a constructed hydrostratigraphic unit (HSU) surface. One such potential source of error is the method of interpolation of the HSU surface and how tightly it honors the original data. IHS Kingdom Geology Suite 2016® (hereinafter called Kingdom) uses an interpolation method called "Flex Gridding" to generate surfaces. The purpose in this appendix is to evaluate potential sources of error between the original HSU top picks and the resulting grids.

This evaluation was performed in two steps: first by using ArcGIS Pro® to compare two sets of data consisting of the individual borehole locations and the Kingdom grid data output as XYZ point files. A separate file is exported from Kingdom for each grid containing an easting, northing, and elevation point in meters for each grid node. Using ArcGIS, a raster of each grid was built using the Kingdom grid nodes using the "Natural Neighbor" tool, followed by using the "Extract Multi Values to Points" tool to extract an elevation data point from the raster at the intersection between the borehole location and the respective raster grid. To perform this analysis, ArcGIS interpolates the extracted grid nodes from Kingdom when building the raster. This introduces its own interpolation errors, including not honoring the interior curvatures of the Kingdom polygons but is necessary as it allows a reasonable check of the borehole data.

The second stage of the verification involves a simple check using a spreadsheet to compare the value of the extracted elevation point for a given grid at a borehole location against the actual HSU top-pick elevation at that same borehole. Detailed steps of the comparison, results, and linear regression analysis are in the following sections.

Overall, the HSU top elevations and the grid intercepts are a close match with R^2 values of $R^2 = 0.99$ (Hanford formation [Hf], Ringold Formation Upper Mud Unit [RUM]), and $R^2 = 0.97$ (Ringold Formation member of Wooded Island — unit E [Rwie]). The boreholes not appearing on the regression line were checked in both ArcGIS and Kingdom to determine the error. Each figure highlights these outlying wells and provides an explanation.

Grid and HSU top-pick errors found during the regression analysis appear to fall into the following four categories:

1. ArcGIS reinterpolation errors
2. Issues on grid edges between ArcGIS and Kingdom
3. Rapidly changing elevations in grid interiors
4. Legitimate spots where the grid in Kingdom is not honoring the HSU top

The first three of these four error types are useful to note for performing this analysis on a future grid as noted inefficiencies. The final error, where this analysis is spotting legitimate errors in Kingdom between the grid and the HSU top-pick, is the most useful.

® IHS Kingdom Geology Suite 2016 is a registered trademark of IHS Markit, London, United Kingdom.
® ArcGIS Pro is a registered trademark of Environmental Systems Research Institute (ESRI), Redlands, California.

D2 Top of the Hanford Formation Hydrostratigraphic Unit Grid

The Hf HSU elevation comparison (Figure D-1) shows a close match in a linear regression, $R^2 = 0.99$. Forty-three wells for this grid are off by 1 to 3 m (3.2 to 9.8 ft). Highlighted wells show differences between the GFM grid and the HSU tops between 3 to 6 m (3.2 to 9.8 ft) (Table D-1). Most of these large errors can be attributed to changing topography through time; a number of excavations around the Hanford Site have created pits and trenches which render the original elevation of the ground surface inaccurate (true for wells in the 100-D Area). Several smaller errors are attributed to ArcGIS reinterpolation errors and issues on grid edges between ArcGIS and Kingdom. There are a few wells where the grids in Kingdom do not match the HSU tops in the wells. These mismatches occur in regions of exceptionally high well density with rapidly changing elevations in grid interiors (e.g., the 100-K Area and 100-N Area). The mismatches can also be attributed to the wells being right near the edges of the 100 Area GFM (near the river at the apatite barrier).

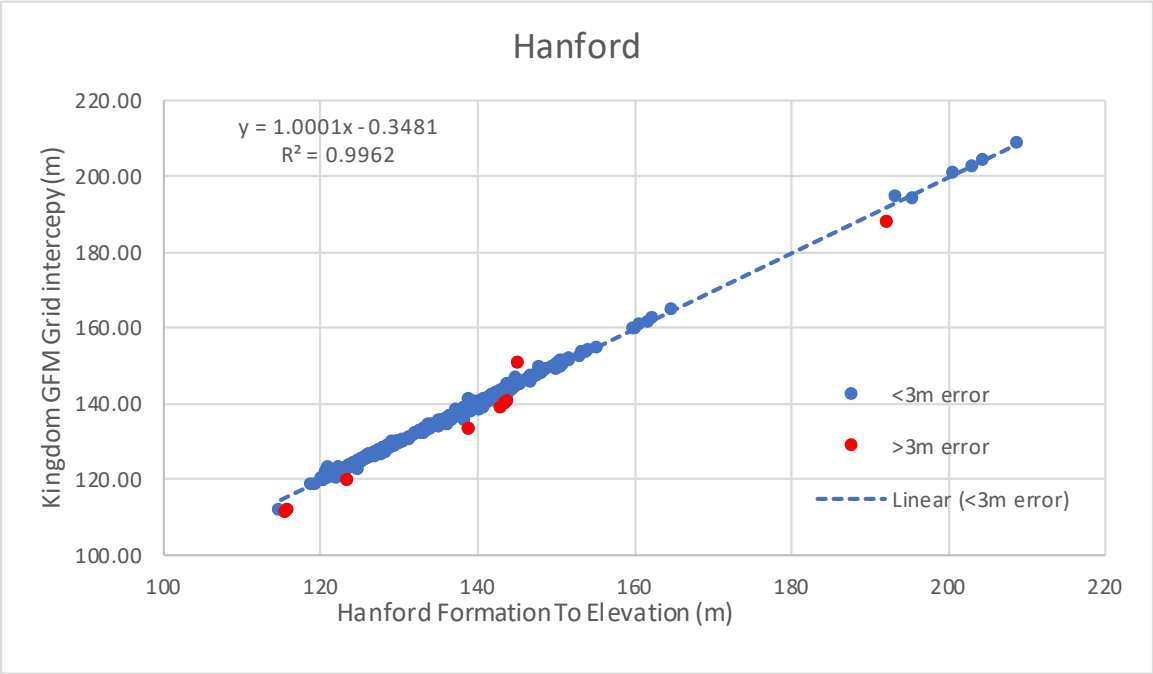


Figure D-1. Kingdom GFM Grid Elevations for the Hf HSU Versus Hf HSU Elevations from Wells in the GeoContacts Database

Table D-1. Wells with Errors > 3 m Between the Hf HSU Top Elevation and the Kingdom Hf HSU Grid Elevation at the Same Well Locations

Well Name	Z (m)	Grid Elevation (m)	Error ABS (m)	Explanation
199-N-372	139.074	133.13	5.95	High well density, near the edge of model.
199-K-220	145.357	150.89	5.54	High well density, matches in Kingdom®.
199-K-227	143.191	138.99	4.20	High well density.

Table D-1. Wells with Errors > 3 m Between the Hf HSU Top Elevation and the Kingdom Hf HSU Grid Elevation at the Same Well Locations

Well Name	Z (m)	Grid Elevation (m)	Error ABS (m)	Explanation
699-75-23B	115.978	111.82	4.16	Wells appears to be drilled in the river; surface elevation likely to fluctuate.
699-75-23A	115.695	111.58	4.11	Wells appears to be drilled in the river; surface elevation likely to fluctuate.
control_3	192.24	188.18	4.06	At the edge of the model near the cliffs.
199-N-346	123.613	119.65	3.97	High well density; near the edge of model.
199-D5-144	143.77	139.93	3.84	Well sits in the middle of a pit (likely dug after the well was drilled).
199-D5-120	143.663	140.11	3.55	Well sits in the middle of a pit (likely dug after the well was drilled).
199-D5-102	143.808	140.52	3.29	Well sits in the middle of a pit (likely dug after the well was drilled).

® IHS Kingdom Geology Suite 2016 is a registered trademark of IHS Markit, London, United Kingdom.

ABS = absolute value

D3 Top of the Ringold Formation Member of Wooded Island — unit E Hydrostratigraphic Unit Grid

The Rwie HSU elevation comparison (Figure D-2) shows a linear regression of $R^2 = 0.97$. Fifty-five wells for this grid are off by 1 to 3 m (3.2 to 9.8 ft). These moderate errors are mostly in regions with exceptionally high well density (e.g., the 100-K area, 100-N Area, 100-H Area, or 100-D Area). Twelve wells show an error between 3 and 7 m (9.8 and 22.9 ft) between the elevation of the HSU top in the well and the elevation of the interpolated grid in Kingdom (Table D-2). As with the Hf HSU, many of these errors are introduced by reinterpolating the surface in ArcGIS (Table D-2). The remaining errors are caused by rapidly changing elevations in grid interiors with high well density.

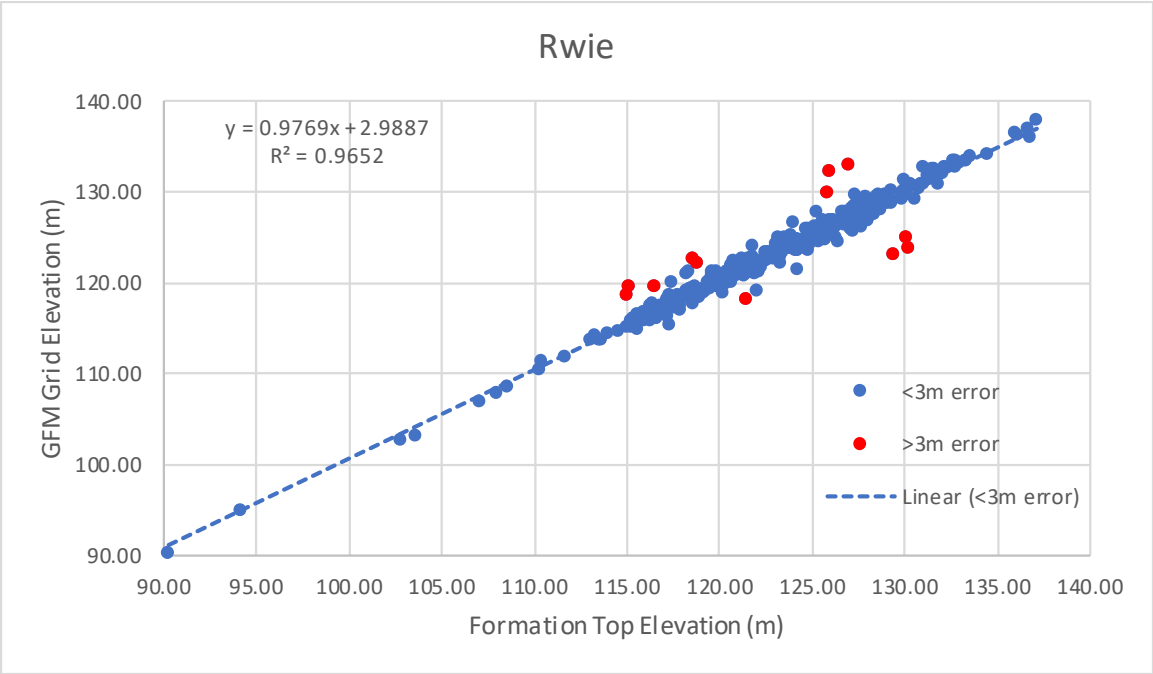


Figure D-2. Kingdom GFM Grid Elevations for the Rwie Versus Rwie HSU Top Elevations From Wells in the GeoContacts Database

Table D-2. Wells with Errors > 3 m Between the Rwie HSU on Top Elevation and the Kingdom Rwie HSU Grid Elevation

Well Name	Formation Top Elevation (m)	Grid elevation (m)	Error ABS (m)	Explanation
199-K-186	125.94	132.29	6.35	High well density
199-K-168	129.49	123.14	6.35	High well density
699-78-62	130.20	123.86	6.34	ArcGIS Pro® interpolation, matches in Kingdom®
199-K-220	127.07	132.82	5.75	High well density
199-N-188	130.17	124.91	5.26	High well density
199-D8-54A	115.12	119.54	4.43	High well density
199-K-225	125.91	129.94	4.03	High well density
199-N-93A	118.65	122.51	3.85	High well density, near edge of the river
199-N-185	115.06	118.65	3.59	High well density, near edge of the river
199-D5-152	118.90	122.21	3.31	ArcGIS interpolation, matches in Kingdom
199-N-346	121.48	118.17	3.31	High well density, near edge of the river
199-H1-21	116.51	119.52	3.02	ArcGIS interpolation, matches in Kingdom

® IHS Kingdom Geology Suite 2016 is a registered trademark of IHS Markit, London, United Kingdom.

® ArcGIS Pro is a registered trademark of Environmental Systems Research Institute (ESRI), Redlands, California.

ABS = absolute value

D4 Top of the Ringold Formation Upper Mud Unit Hydrostratigraphic Unit Grid

The RUM HSU elevation comparison (Figure D-3) shows a close match in a linear regression, $R^2 = 0.99$. There are only five wells with notable outliers between 3 and 7 m (9.8 and 22.9 ft) difference between the well HSU top and the grid for the RUM HSU surface. These mismatches are the result of ArcGIS interpolation and processing errors. The RUM HSU surface in Kingdom matches the elevation of each of the HSU tops in Table D-3; the mismatches only appear after reinterpolating the grid in ArcGIS.

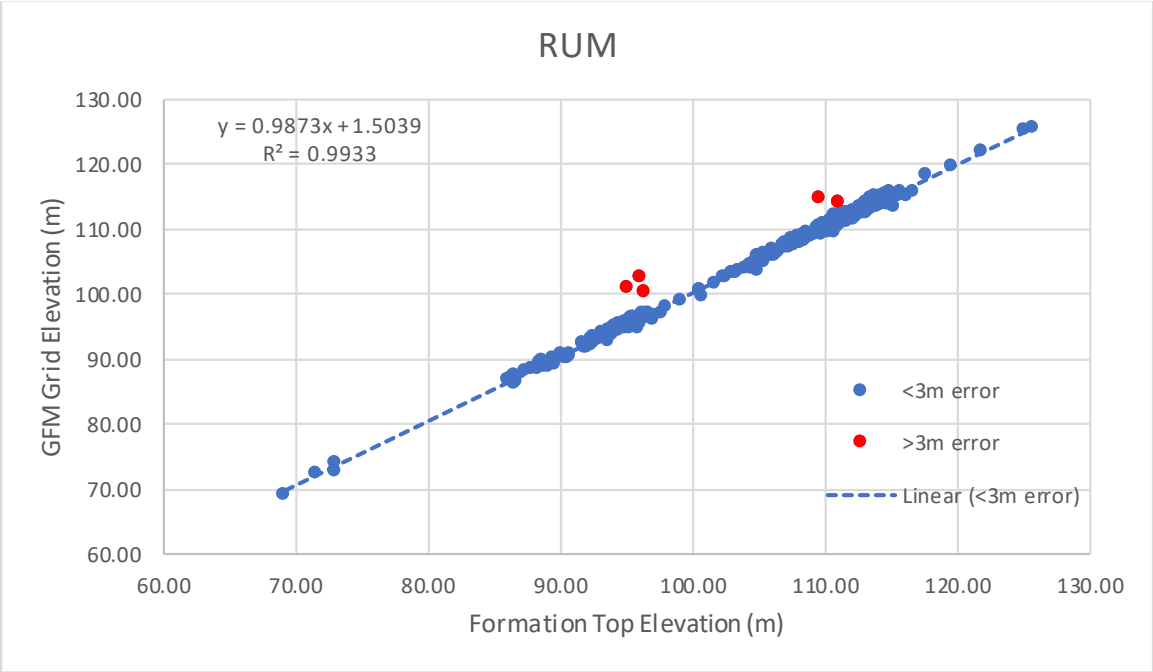


Figure D-3. Kingdom GFM Grid Elevations for the RUM HSU Versus RUM HSU Top Elevations from Wells in the GeoContacts Database

Table D-3. Wells with Errors > 3 m Between the RUM HSU Top Elevation and the Kingdom Grid Elevation

Well Name	Formation Top Elevation (m)	Grid elevation (m)	Error ABS (m)	Explanation
199-K-186	96.07	102.44	6.37	ArcGIS® interpolation; matches in Kingdom®.
199-K-220	95.16	100.80	5.64	ArcGIS interpolation; matches in Kingdom.
199-H1-20	109.53	114.66	5.13	ArcGIS interpolation; matches in Kingdom.
199-K-225	96.34	100.21	3.87	ArcGIS interpolation; matches in Kingdom.
199-H1-21	111.02	114.03	3.01	ArcGIS interpolation; matches in Kingdom.

® IHS Kingdom Geology Suite 2016 is a registered trademark of IHS Markit, London, United Kingdom.

® ArcGIS Pro is a registered trademark of Environmental Systems Research Institute (ESRI), Redlands, California.

ABS = absolute value

This page intentionally left blank.

Appendix E

Software Installation and Checkout Form for Kingdom-Geology

This page intentionally left blank.

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:

Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:

Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: Kingdom Geology Software Version No.: 2016.1

EXECUTABLE INFORMATION:

2. Executable Name (include path):

   C:\Program Files\IHS\KingdomSuite\TKS101\Kingdom.exe

3. Executable Size (bytes): 822 KB

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

   Vendor supplied

5. Operating System (include version number):

   Windows (Vendor supplied)

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

   WF37417

7. Operating System (include version number):

   Windows 10

8. Open Problem Report? (●) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

   U:\Kingdom\Kingdom Evaluation\Quality Assurance\SICO 2016

10. Procedure(s):

    per CHPRC-02938 Rev 0, Kingdom-Geology Software Test Plan

11. Libraries:

    N/A

12. Input Files:

    per CHPRC-02938 Rev 0, Kingdom-Geology Software Test Plan

13. Output Files:

    per CHPRC-02938 Rev 0, Kingdom-Geology Software Test Plan

14. Test Cases:

    ITC-1

15. Test Case Results:

    Pass

16. Test Performed By: Sarah Wigginton

17. Test Results: (●) Satisfactory, Accepted for Use ( ) Unsatisfactory

18. Disposition (Include HISI update):

    Accepted; installation added to Hanford authorized user list.-WEN

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: Kingdom Geology Software Version No.: 2016.1

Prepared By: WILLIAM NICHOLS (Affiliate) Digitally signed by WILLIAM NICHOLS (Affiliate) Date: 2020.05.05 09:32:08 -07'00'

19.	Software Owner (Signature)	WE Nichols Print	Date

20. Test Personnel:

Sign	SS Wigginton Print	04/29/2020 Date
Sign	Print	Date
Sign	Print	Date

Approved By:

21.	Software SME (Signature)	N/R per SMP Print	Date

Appendix F

Environmental Modeling Data Transmittal Cover Page for EMDT-GR-0039, *Geologic Contacts for the 100-Area Geoframework Model*

This page intentionally left blank.

ENVIRONMENTAL MODELING DATA TRANSMITTAL COVER PAGE

No.: EMDT -GR-0039 **Revision No:** 1

(Request EMDT number for Modeling Team Leader)

Title: Geologic Contacts for the 100-Area Geoframework Model **Date:** 06/03/2020

1. Data Description

Provide the description of data set or data type.

The Microsoft Excel workbook contains lithology and coordinate data within the 100-Area. Three sheets are provided: "Geologic Contact Estimations" (GCE), "Change Log" and "Omitted wells". The "Geologic Contact Estimations" sheet contains the following information: Well Name, Well ID, Northing (m), Easting (m), Surface Elevation (m), Elevation Control Reference, Drill Depth (ft), Drill Depth (m), Final Drill Depth (w/de minimis = 0.1) (m), Elevation bottom (m), Depth to RE (ft), Depth to RE (m), Hf/RE Elevation (m), Depth to Reworked Ringold E (ft), Ringold E Depth Data Author, Depth to RUM (ft), Depth to RUM (m), RUM Elevation (m), Depth to Reworked RUM (ft), RUM Depth Data Author, Depth to Basalt (ft), Depth to Basalt (m), and additional comments. RE is equivalent to Rwie HSU. Hf is equivalent to Hanford HSU. The "Change Log" sheet contains a running log detailing the changes made to the "Geologic Contact Estimations" sheet as pertaining to the addition or removal of wells, modification of picks, and other similar modifications. The "Omitted Wells" sheet catalogues the wells which are to be removed from the collar files for input to the 100-area geoframework model (GFM) in Kingdom (see section 10 for more explanation).

2. Data Intended Use

Identify the data's intended use. Describe the rationale for its selection and how the data will be incorporated into a model, report, or database. Include discussion of the extent to which the data demonstrates the properties of interest.

The intended use of this information is to import the information contained in the "GCE" sheet into the GFM. The rationale for including this information is to provide geologic interpretations of the elevations/contacts of the stratigraphic units modeled in the 3D model that constitutes the GFM. The columns for "depth to <insert stratigraphic unit name here>" provide the needed numerical information to building a 3D solid model.

3. Data Sources

List databases, documents, etc. - provide sufficient detail to enable data to be located by independent reviewer.

The information contained in this spreadsheet is a composite of many sources including data package reports, geologist interpretations of borehole logs, well construction summaries, etc. The exhaustive listing of these sources is included in the "GCE" sheet under columns with the word "Author" in the header row.

4. Impact of Use or Nonuse of Data

Describe the importance of the data to the model, report, and/or conclusions which they support. Identify the value added and discuss the impacts of not using the data.

This data directly impacts the 3D solid model mentioned, comprised of the 100-Area GFM and any other site-specific GFMs. Fate and transport models depending on the geologic interpretations of the 100-Area will also be affected, which in turn inform cleanup decisions on the 100-area. Implementation of this data will reduce the uncertainty of the regional geologic interpretation in the 100-Area, and by extension reduce the uncertainties associated with the GFMs and the fate and transport models. Not using the information contained herein will pose no change to the current level of uncertainty inherent in the existing 3D solids model and its derivative works.

5. Prior Use

Identify the data's prior uses. Describe whether the data have been used in similar applications by the scientific or regulatory community. Include the associated verification processes and prior reviews and review results.

ENVIRONMENTAL MODELING DATA TRANSMITTAL COVER PAGE (Continued)

No.: EMDT -GR-0039 **Revision No:** 1

(Request EMDT number for Modeling Team Leader)

Title: Geologic Contacts for the 100-Area Geoframework Model **Date:** 06/03/2020

5. Prior Use

The prior use of this dataset is detailed in ECF HANFORD-13-0020 Rev. 5. The workbook contained in this EMDT however, is a recently updated copy of that used in ECF HANFORD-13-0020 Rev. 5. and should only be compared on the merit of its prior use. The verification procedure in place for this data is a review process by professional geologists familiar with the Hanford Area (especially the 100-area in this case) who ensure that geologic interpretations recorded in this spreadsheet are scientifically accurate. These reviews include analysis of borehole logs and contextual/qualitative analyses in context of neighboring wells and formation properties.

6. Data Acquisition Method(s)

Describe the data acquisition method and associated QA/QC, considering the following:

a. *Qualifications of personnel or organizations generating the data;*
b. *Technical adequacy of equipment and procedures used;*
c. *Environmental and programmatic conditions if germane to the data quality;*
d. *The extent to which acquisition processes reflect modeling requirements;*
e. *The quality and reliability of the measurement control program;*
f. *The degree to which independent audits of the process were conducted;*
g. *Extent and reliability of the associated documentation.*

This data is prepared by a professionally licensed geologist with checks preformed by others to ascertain that the information contained therein is accurate to the best of the team's collective ability. Data available for this compilation of lithology definitions come from myriad of sources pertinent to Hanford geologic work including borings, well construction logs, geologic interpretation by professional geologists, and other similar sources. The data is adequate for the purposes intended and the relevant extent/spatial applicability pertains to the 100-Area.

For databases, identify query language used to obtain data from database (SQL, etc.), briefly describe the query description and attach copy.

Not Applicable

7. Corroborating Data

Identify and discuss any corroborating datasets. Provide any documentation that confirms the corroborating data substantiate existing parameter values, distributions, or data quality.

Not Applicable

8. Data Quality Considerations

Discuss data quality considerations not identified in other sections. Include discussion of data quality indicators (i.e., accuracy, precision, representativeness, completeness, and comparability).

Not Applicable

9. Assumptions and Limitations on Data Use

Document known uncertainties, assumptions, constraints or limits on data.

The assumption accompanying this dataset is that this information is appropriate for generating a regional model encapsulating the 100-Area in its entirety. Outside of this application, professional judgment should be exercised.

ENVIRONMENTAL MODELING DATA TRANSMITTAL COVER PAGE (Continued)

No.: EMDT -GR-0039 | Revision No: 1

(Request EMDT number for Modeling Team Leader)

Title: Geologic Contacts for the 100-Area Geoframework Model | Date: 06/03/2020

DATA CONFIGURATION ITEM SUBMITTAL:

Data Provider Submittal:

Position: Hydrogeologist

Sarah Wigginton	Sarah Wigginton	06/03/2020
Print First and Last Name	*Signature*	*Date*

DATA CONFIGURATION ITEM REVIEW AND VERIFICATION:

10. Verification Process

Describe steps taken to verify that these data are appropriate for intended use, noting any limitations.

ENVIRONMENTAL MODELING DATA TRANSMITTAL COVER PAGE (Continued)

No.: EMDT -GR-0039 **Revision No:** 1

(Request EMDT number for Modeling Team Leader)

Title: Geologic Contacts for the 100-Area Geoframework Model **Date:** 06/03/2020

DATA CONFIGURATION ITEM REVIEW AND VERIFICATION:

10. Verification Process

Data verification for the "GCE" included checking the following: 1) well data in the spreadsheet is formatted properly for import into Kingdom (i.e. values are formatted as "general" or "numbers", not as "text"), 2) well data matches the HEIS/EDA databases, 3) excel equations used to calculate conversions and round values are applied correctly and consistently, 4) lithologic picks for the RE, RUM, and Basalt do not result in zero thicknesses or negative thicknesses.

• Changes to the updated version of the "GCE" have been documented in detail in the "Change Log" sheet of the GeoContacts spreadsheet. The "Change Log" includes the well name, a description of the change that was made to the well data, the date the change was made, and the author responsible for making the change.

• Types of changes made to the updated GeoContacts spreadsheet for Rev. 6 of the 100-Area GFM include the following:

• The addition of new wells to the dataset (detailed in MPR)

• Corrections were made to the XY coordinates or surface elevations for wells if they did not match XY coordinates and surface elevation found in the HEIS/EDA databases (Appendix A).

• The addition of a new column (Final Drill Depth (w/de minimis = 0.1)) which adds a buffer of 0.1 m to the TD of the wells when lithologic units are encountered at TD. This buffer avoids present lithologic units from being assigned a thickness of zero in the model (Appendix A).

• The correction of the depths for the tops of RE and RUM which resulted in negative thicknesses. This error occurred when RE or RUM top picks was deeper than the well TD. Either the TD of the well or the lithologic unit top pick was corrected based on a review of original borehole logs (Appendix A)

• Corrections were applied to a handful of excel equations which resulted in rounding or conversion errors (for feet to meter conversion) (Appendix A).

• Any lithologic unit pick which previously contained "X" has been interpreted as Not Present and was changed to "NP" in the "GCE". Units categorized as NP in the "GCE" were omitted from the lith files for input into Kingdom (Appendix A).

• The removal of wells from the data set. Wells were omitted because 1) a nearby well exists with higher data quality or 2) the well did not contain tops for lithologic units. Wells to be omitted from the GFM are not deleted from the dataset, but are added to the "Omitted Wells" sheet so they can be removed from the model input files (Appendix B).

It's important to note that when making changes to interpretations in the "GCE" sheet all original lithology top interpretations have been preserved with their original author, and new interpretations have been included as additional rows attributed to their new author. This methodology results in multiple entries for wells which have updated interpretations to RE or RUM top picks. When corrections were made to any other column (e.g. drill depths, XYZ coordinates, or any formatting changes) no new entry for the well was created.

o In cases were wells contain multiple entries in the "GCE" the most recent interpretation by Sarah Springer was selected for input when creating the well files for Rev. 6 of the 100-Area GFM in Kingdom.

11. Summary of Data Review

ENVIRONMENTAL MODELING DATA TRANSMITTAL COVER PAGE (Continued)

No.: EMDT -GR-0039 | Revision No: 1

(Request EMDT number for Modeling Team Leader)

Title: Geologic Contacts for the 100-Area Geoframework Model | Date: 06/03/2020

11. Summary of Data Review

The review shall ensure that the report meets the listed criteria. Consideration includes ensuring that the data collection method employed was appropriate for the type of data being considered an confidence in the data acquisition and subsequent processing methodology is warranted.

Is documentation technically adequate, complete, and correct?	☐ Yes	☐ No
Are uncertainties and limitations on appropriate use of data discussed?	☐ Yes	☐ No
Are the assumptions, constraints, bounds, or limits on the data identified?	☐ Yes	☐ No

APPROVAL OF DATA CONFIGURATION ITEM:

Data Reviewer Approval:

Position: Senior Geologist

Sarah Springer		06/03/2020
Print First and Last Name	*Signature*	*Date*

This page intentionally left blank.