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Revision 1

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Automated Water Level Network Functional Requirements

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

ch2m SM

P.O. Box 1600
Richland, Washington 99352

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APPROVED
By Janis Aardal at 2:32 pm, Sep 12, 2017

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Terms

AWLN	automated water-level network
COC	contaminant of concern
CY	calendar year
DTW	depth to water
EOL	end-of-line
HLAN	Hanford Local Area Network
ID	identification
MAD	median absolute deviation
MOL	middle-of-the-line
MP	measuring point
NAVD88	*North American Vertical Datum of 1988*
OU	operable unit
P&T	pump and treat
PLC	programmable logic controller
QA	quality assurance
QC	quality control
RF	radio frequency
RP	reference point
RUM	Ringold upper mud (unit)
S&GRP	Soil and Groundwater Remediation Project
SAP	sampling and analysis plan
TOC	top of casing
UHF	ultra-high frequency
VSWR	Voltage Standing Wave Ratio
VHF	very high frequency

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1 Introduction

Alternative configurations and functional requirements for installing, operating, and maintaining the automated water-level network (AWLN) were previously developed for the 100-HR-3 and 100-KR-4 Groundwater Operable Units (OUs) at the Hanford Site, as presented in SGW-53543, *Automated Water Level Network Functional Requirements Document,* Rev. 0 (the initial issuance of this document). Revised configurations for these OUs and proposed configurations for the 100-BC-5, 100-NR-2, 100-FR-3, and 300-FF-5 OUs are presented in this update.

The AWLN is the combination of equipment, hardware and software for the measurement, collection, transmittal, storage, and management of water-level data in the groundwater underlying the Hanford Site. Water-level data are measured by submersible pressure transducers installed in a network of monitoring stations (i.e., monitoring and/or extraction/injection wells) located across the River Corridor and Central Plateau. The data are then directly transmitted to a base station via telemetry or can be manually downloaded to portable computers. An automated process has been developed for compiling and managing the data, and quality assurance (QA) and quality control (QC) processes are in place to ensure that qualified data sets are provided.

This document presents the initial AWLN configuration for each OU, illustrating the operating status for each monitoring location as of September 30, 2015. The initial AWLN configurations include wells screened in the upper part of the unconfined aquifer near the water table, wells screened in the deeper part of the unconfined aquifer, and wells completed in the Ringold Formation upper mud (RUM) unit. Alternative AWLN configurations are proposed for each OU, focusing on wells screened in the upper part of the unconfined aquifer near the water table, and defined as (1) critical; (2) near-optimal; and (3) optimal, depending on the purpose and extent of the proposed monitoring network. The components of the AWLN and their functional requirements are also presented. The proposed configurations were developed to support recently updated or scheduled revisions to the sampling and analysis plans (SAPs) in each OU:

- **100-HR-3:** DOE/RL-2013-30, *Sampling and Analysis Plan for the 100-HR-3 Groundwater Operable Unit*
- **100-KR-4:** DOE/RL-2013-29, *Sampling and Analysis Plan for the 100-KR-4 Groundwater Operable Unit*
- **100-NR-2:** DOE/RL-2001-27, *Remedial Design/Remedial Action Work Plan for the 100-NR-2 Operable Unit*
- **100-BC-5:** DOE/RL-2003-38, *100-BC-5 Operable Unit Sampling and Analysis Plan*
- **300-FF-5:** DOE/RL-2014-42, *300-FF-5 Operable Unit Remedy Implementation Sampling and Analysis Plan*
- **100-FR-3:** DOE/RL-2014-44-ADD2, *Remedial Design Report/Remedial Action Work Plan Addendum for the 100-F/IU Groundwater*

Monitoring presented in these SAPs is designed to collect data to evaluate groundwater flow patterns and contaminant plume migration, and to assess system performance in those OUs where an active remediation system is in place. Proposed AWLN configurations are presented to support the SAP objectives using the following analyses:

- Water-level mapping
- Calculation of two-point gradients to compare water levels inland against river-stage elevation and determine the potential for contaminant discharges to the river
- Calculation of three-point gradients to determine the magnitude and direction of groundwater flow velocities
- Capture zone estimates in the OUs with a pump and treat (P&T) system in place
- Evaluation of vertical gradients in the aquifer and horizontal gradients in the lower part of the aquifer and/or RUM

The AWLN should be modified to support these analyses. Proposed modifications to the initial AWLN and descriptions of the technical and operational characteristics of its components are presented in the following chapters.

2 Facility Requirements

The AWLN in the River Corridor OUs includes monitoring wells equipped with data loggers to collect continuous water-level data. Other parameters such as temperature and conductance may also be recorded from data loggers if needed to support water quality evaluation, and battery voltage is recorded to monitor system performance. The AWLN was not actively maintained during 2012 and 2013; as a result, only a few wells were reporting data continuously during early 2014. A large number of wells were reporting data only intermittently during 2014, and several monitoring locations were not reporting during the same period. Data provided from the reporting monitoring wells were not always usable, with periods characterized by suspect measurements.

Since mid-2014, as part of an ongoing and continuous effort to improve monitoring coverage and efficiency, CH2M HILL Plateau Remediation Company has upgraded and restored the AWLN, including repairing, maintaining, and installing new stations to support ongoing P&T operations and to restore AWLN functionality along the River Corridor.

Additional modifications to AWLN operations and well network configurations are proposed in this update to ensure uninterrupted operation of the monitoring well network. Three levels of modifications are proposed for wells screened in the upper part of the unconfined aquifer:

- **Critical (minimal) configuration:** Proposes the minimum number of monitoring stations to provide water-level data absolutely necessary to calculate inverse gradients from the Columbia River, although not sufficient for hydraulic capture analyses in the OUs where extraction and injection wells are operating as part of a P&T system. For all other OUs where a P&T remedy is not currently implemented, gradient calculations provide the basis for evaluating flow patterns and the associated contaminant of concern (COC) migration patterns and potential discharge to the Columbia River. Monitoring wells located closest to the shoreline are selected for this purpose.

- **Near-optimal configuration:** Proposes the number and location of monitoring stations that will provide sufficient data to calculate gradients and to delineate capture zones in most areas within the OUs where a P&T system is implemented. Additional monitoring wells are selected from the existing well network so hydraulic capture is evaluated within an extended area encompassing the OU and extending beyond its boundaries. The selection of monitoring locations is based on the available monitoring wells and the mapped footprint of the COC plumes so hydraulic capture is evaluated on the basis of plume extents. Hydraulic capture will not be delineated with confidence in areas where monitoring wells are sparse. Similarly, for the remaining OUs where a P&T remedy is not in place, this configuration provides sufficient water-level data required to map the water table in the aquifer and to evaluate flow patterns within an area encompassing or extending beyond the delineated contamination zone.

- **Optimal configuration:** Proposes the number and location of monitoring stations that will provide sufficient data to calculate gradients and to delineate capture zones in all areas within the OUs where a P&T system is in place. The optimal configuration includes monitoring stations to (1) expand the monitoring network along the shoreline, and (2) provide sufficient coverage for improved confidence in the delineation of hydraulic capture. Monitoring stations along the shoreline will provide better definition of the calculated inverse gradients along the river protection zone and will also provide information that can be used to analyze river/aquifer interaction. For the OUs without a P&T remedy in place, the optimal configuration provides sufficient data to calculate hydraulic gradients and evaluate flow patterns and associated COC plume migration patterns across the entire OU and within an area encompassing or extending beyond the footprint of all COC plumes. Additional monitoring

wells located inland of the plume boundaries will provide necessary control points to calculate hydraulic gradients and water-level mapping.

Some configurations propose uninterrupted functionality of the river gage for calculating inverse gradients. Where river gages are/will not be installed (and given the strong linear correlation between river stages at the Priests Rapids Dam and 100-K, 100-N, 100-D, and 100-H Areas), river-stage elevations are calculated using the methodology presented in ECF-Hanford-13-0028, *Columbia River Stage Correlation for the Hanford Area*. In the absence of river gages, miniature aquifer tube transducer systems could be used instead. However, potential locations for miniature aquifer tube transducers were not evaluated in the proposed alternative AWLN configurations and, therefore, are not presented in this document.

Table 2-1 summarizes the list of the initial AWLN configurations in each OU for shallow monitoring wells; the number of wells required under each proposed configuration for each OU; and the deep/RUM wells. Proposed AWLN configurations are discussed in detail for each OU in the following subsections. The AWLN requirements and configuration for the 200-ZP-1 OU are discussed in DOE/RL-2009-115, *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action*, and are not included in this discussion.

Table 2-1. Number of Monitoring Wells and AWLN Configurations in the River Corridor

OU	Initial[a]	Deep/RUM	Critical	Near-Optimal	Optimal
100-BC-5	13	5	19	21	24
100-KR-4	38	2	15	36	39
100-NR-2	15	1	13	25	29
100-HR-3	53	5	35	73	77
100-FR-3	0	0	12	19	25
300-FF-5[b]	0	0	11	0	0

a. Installed as of September 30, 2015.

b. Maintained and operated by Pacific Northwest National Laboratory.

OU = operable unit

RUM = Ringold upper mud (unit)

2.1 100-BC-5 Operable Unit

Figure 2-1 shows the initial AWLN configuration in the 100-BC-5 OU based on the existing monitoring locations as of September 30, 2015. There was a total of 13 monitoring wells: 8 shallow wells and 5 deep/RUM wells.

In addition to determining horizontal gradients in the upper part of the unconfined aquifer, the need exists to determine vertical gradients and horizontal gradients in the lower part of the aquifer. Therefore, several shallow/deep well pairs are included in the AWLN for the 100-BC-5 OU. Similar pairs are also identified in the other OUs.

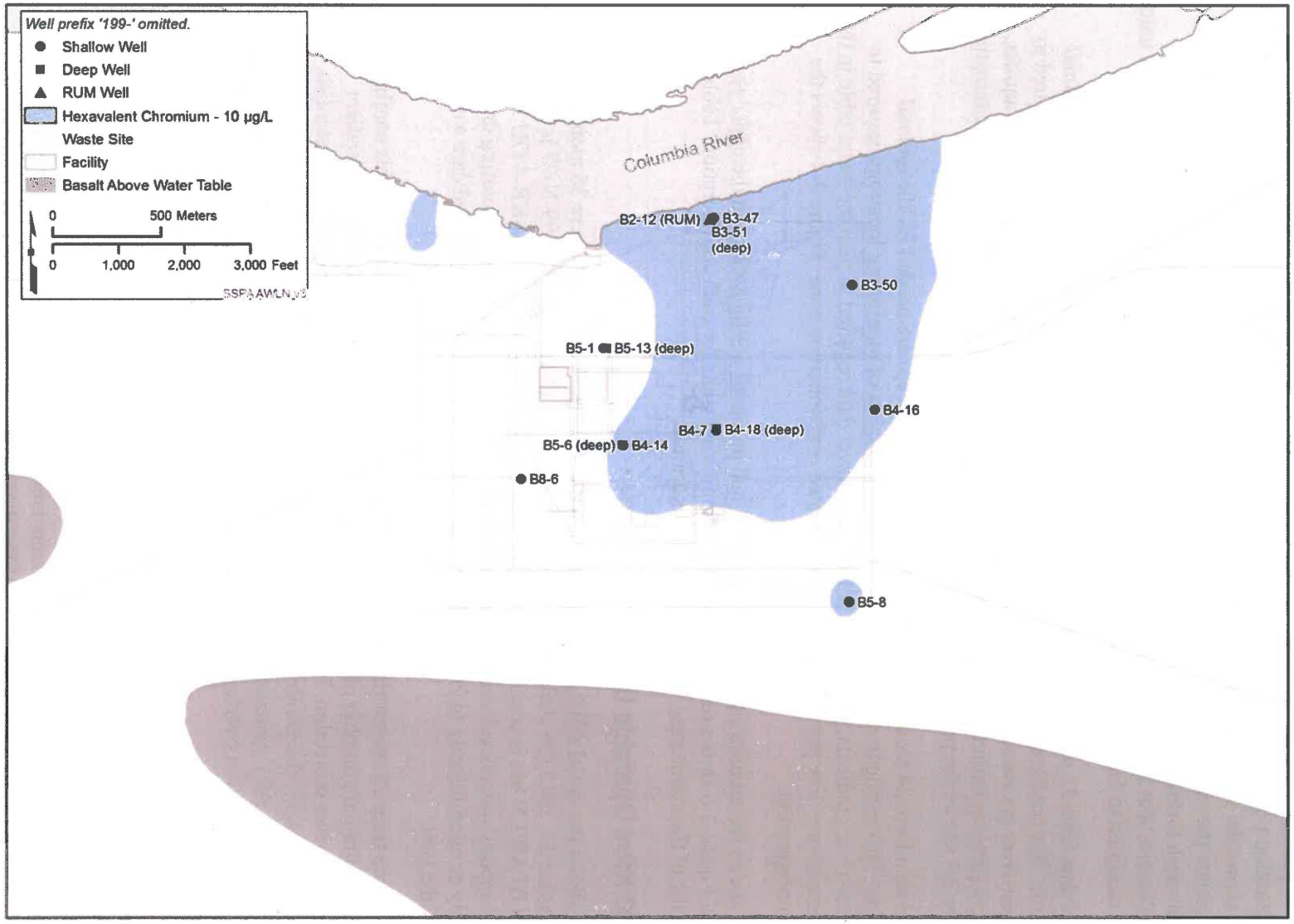

Figure 2-1. Initial AWLN Configuration for the 100-BC-5 OU

Water-level data from 19 monitoring wells (15 shallow and 4 deep) are needed for the *critical* configuration. This configuration represents the minimum number of monitoring locations required to evaluate flow patterns near the shoreline. In some areas, near-river gradients may be difficult to establish. This configuration represents the minimum network required to map water levels in the aquifer. Figure 2-2 shows the proposed configuration overlaying the calendar year (CY) 2014 low-river-stage chromium plume presented in DOE/RL-2015-07, *Hanford Site Groundwater Monitoring for 2014*. A triangular mesh formed by connecting monitoring locations indicates one instance of the set of triangular elements that can be used for calculating hydraulic gradients. This triangular mesh is not unique and can be modified to facilitate gradient calculations within a particular area.

Water-level data from 21 monitoring wells (17 shallow and 4 deep) are needed for the *near-optimal* configuration. This configuration represents a reasonable amount of monitoring locations required to establish near-river gradients, provide water-level data required to map the water table in the aquifer, and evaluate flow patterns within an area encompassing or extending beyond the delineated contamination zone. Figure 2-3 shows the proposed configuration.

Water-level data from 24 monitoring wells (20 shallow and 4 deep) are needed for the *optimal* configuration. This configuration represents the optimal number of monitoring locations required to establish near-river gradients, provide sufficient water-level data required to map the water table in the aquifer, and evaluate flow patterns across the delineated contamination zone. Figure 2-4 shows the proposed configuration.

Figure 2-5 shows the monitoring wells for the initial and proposed configurations in the upper part of the aquifer, and Figure 2-6 shows the deep and RUM monitoring wells for each configuration. Table 2-2 provides a list of the monitoring wells for each configuration.

2.2 100-KR-4 Operable Unit

Figure 2-7 shows the initial AWLN configuration in the 100-KR-4 OU. There were 38 monitoring wells as of September 30, 2015 (36 shallow and 2 deep/RUM wells). (Note that well 199-N-77 is part of the 100-NR-2 OU AWLN but is considered, in this document, also as part of the 100-KR-4 OU AWLN because it supports water-level evaluations for this OU.) The AWLN wells were reporting data either continuously or intermittently in 2014 to 2015, although in several cases the reported data were not usable for parts of the year.

Water-level data from 15 monitoring wells are needed for the *critical* configuration. This configuration represents the minimum number of monitoring locations required to demonstrate downgradient containment and river protection. In some areas, near-river gradients may be difficult to establish. This configuration represents the minimum network required to map water levels in the aquifer and delineate capture zones for the P&T systems; however, capture may be uncertain in some areas. Figure 2-8 shows the proposed configuration overlaying the CY 2014 low-river-stage chromium plume presented in DOE/RL-2015-07.

Water-level data from 34 monitoring wells are needed for the *near-optimal* configuration. This constitutes the network necessary to demonstrate downgradient containment and river protection, as well as to establish near-river gradients in most areas. The network will also provide water-level data required to map the water table in the aquifer and delineate the capture zone of the P&T systems. Mapped water levels and capture zones may be uncertain in some areas because of limited availability of monitoring locations. Figure 2-9 shows the proposed configuration.

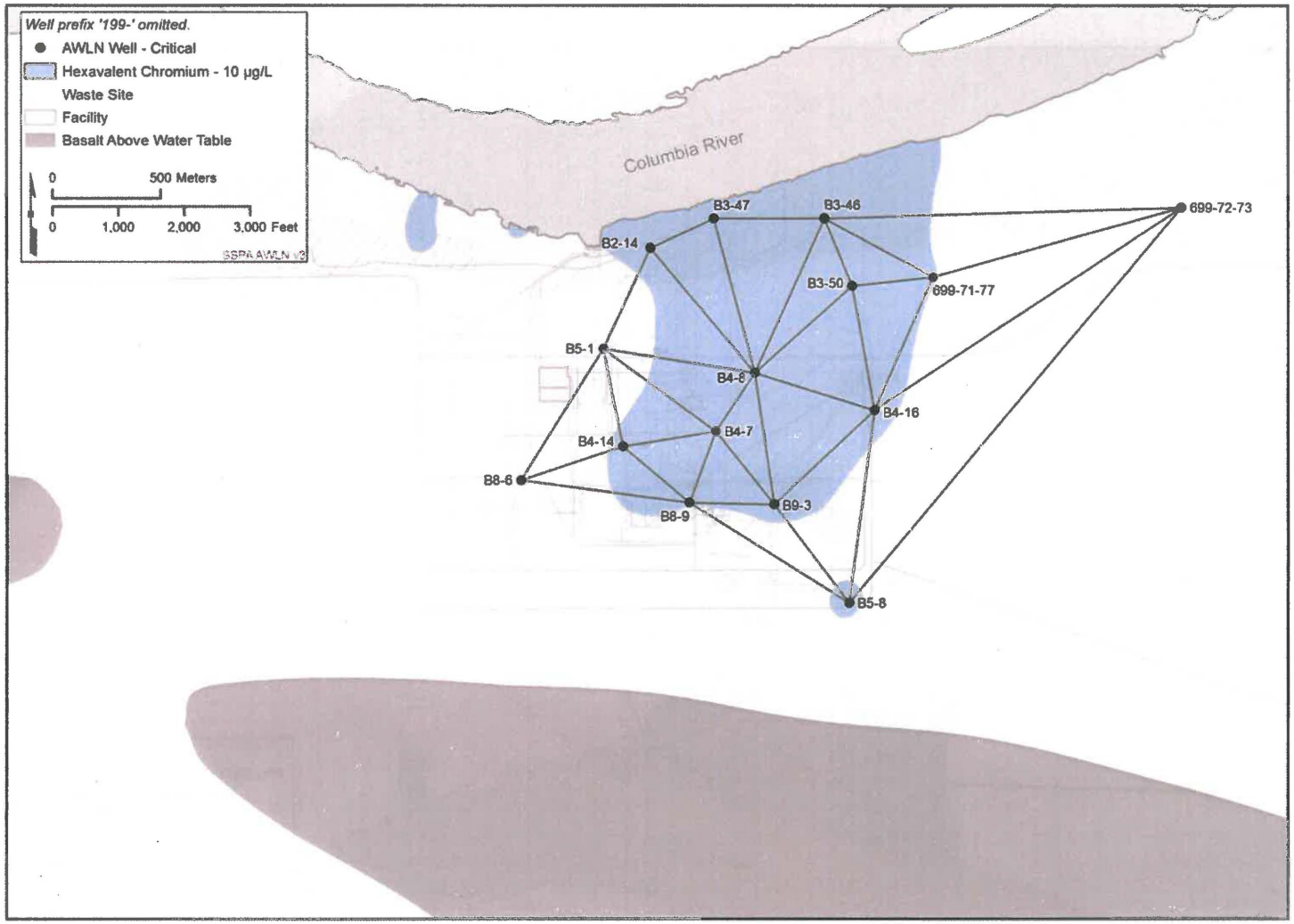

Figure 2-2. Critical AWLN Configuration for the 100-BC-5 OU

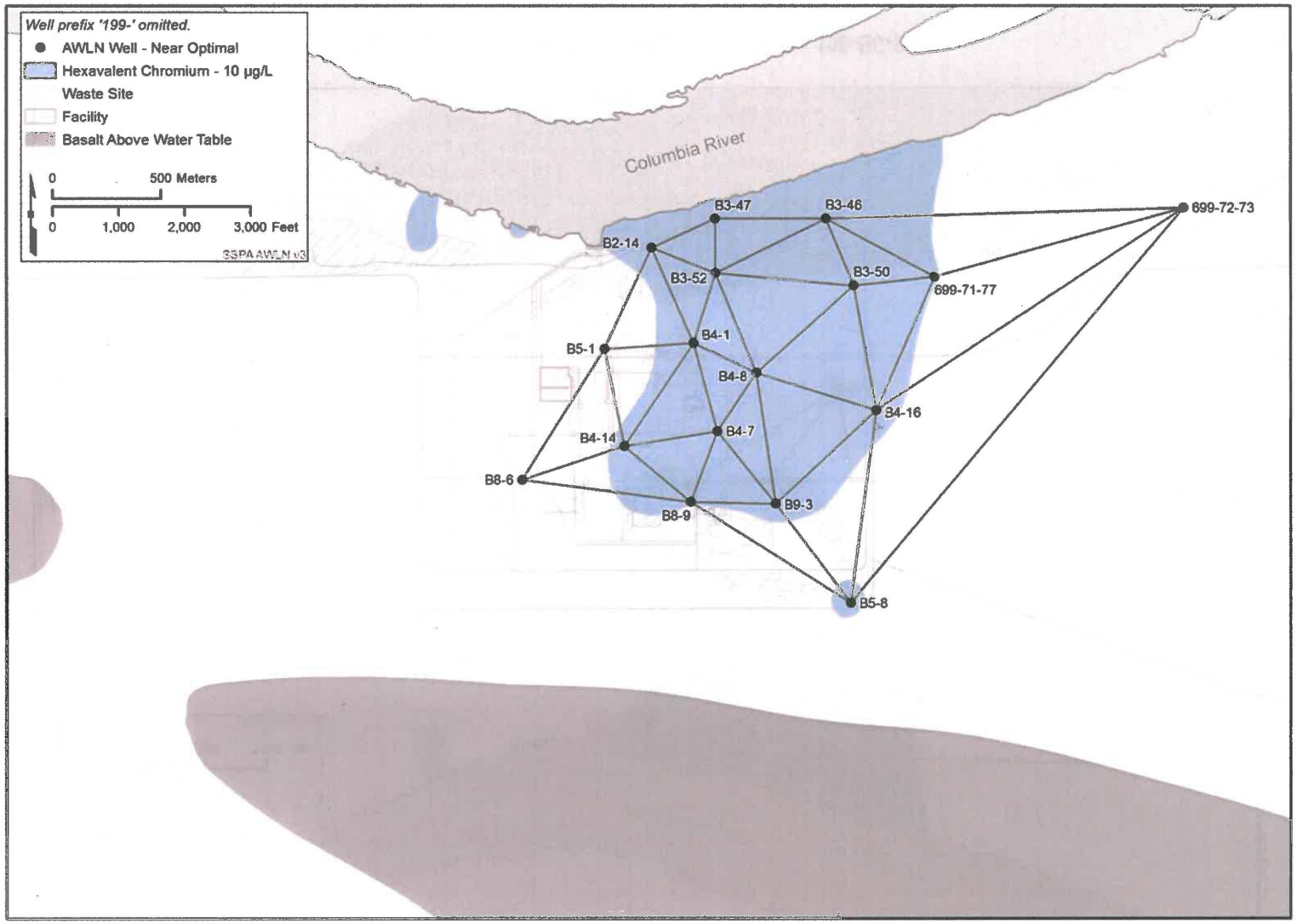

Figure 2-3. Near-Optimal AWLN Configuration for the 100-BC-5 OU

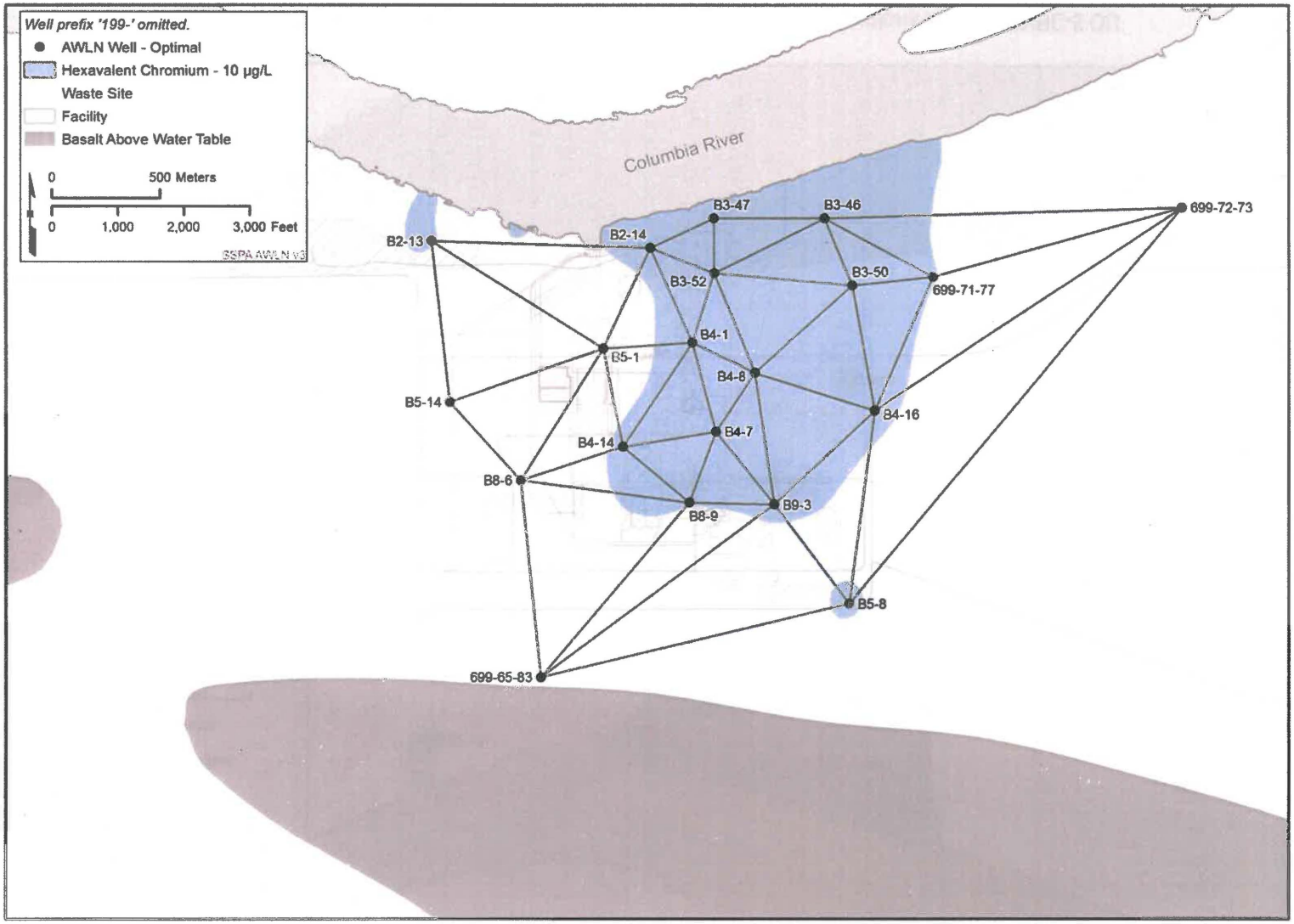

Figure 2-4. Optimal AWLN Configuration for the 100-BC-5 OU

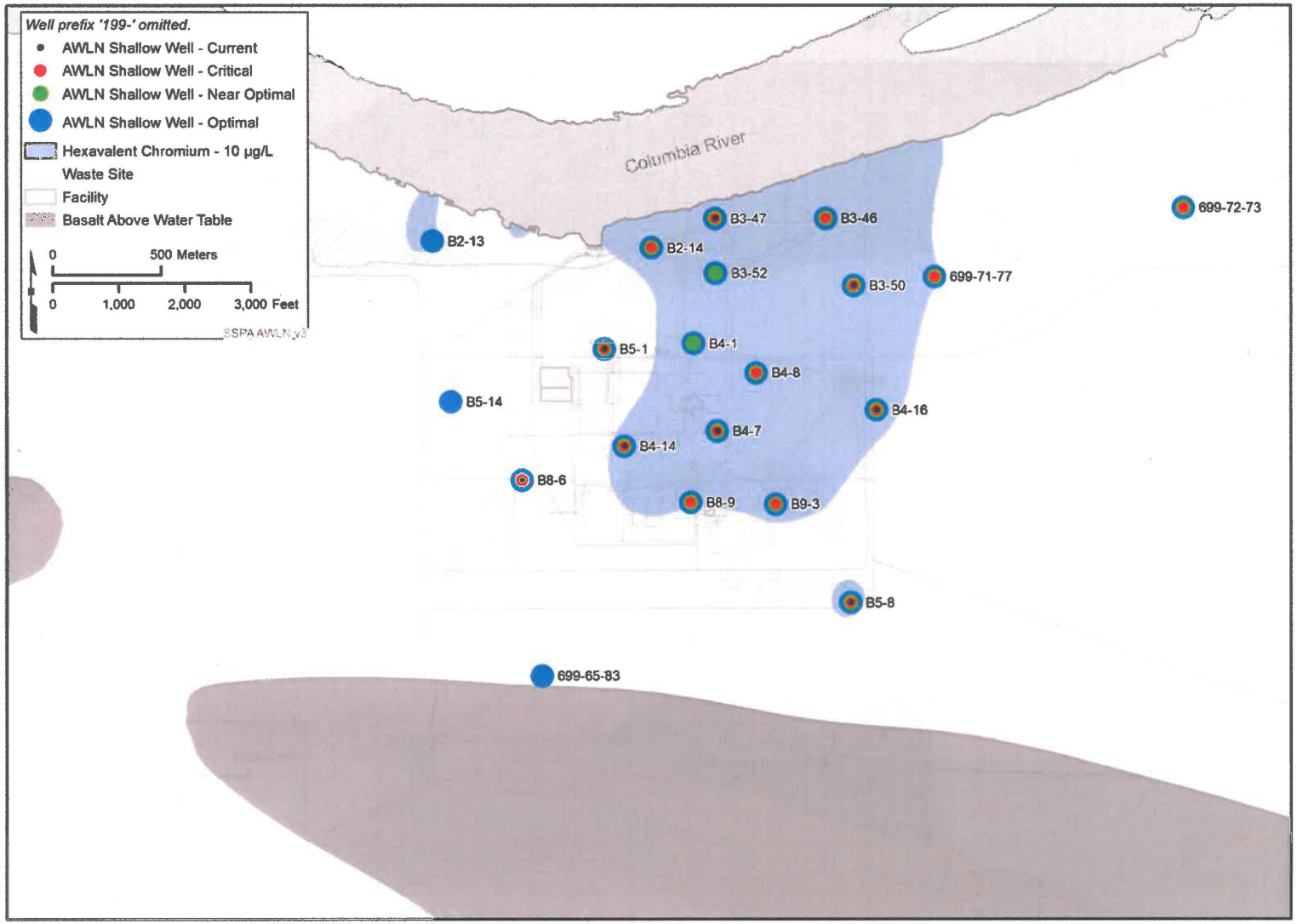

Figure 2-5. Shallow AWLN Wells for the Initial and Proposed Configurations for the 100-BC-5 OU

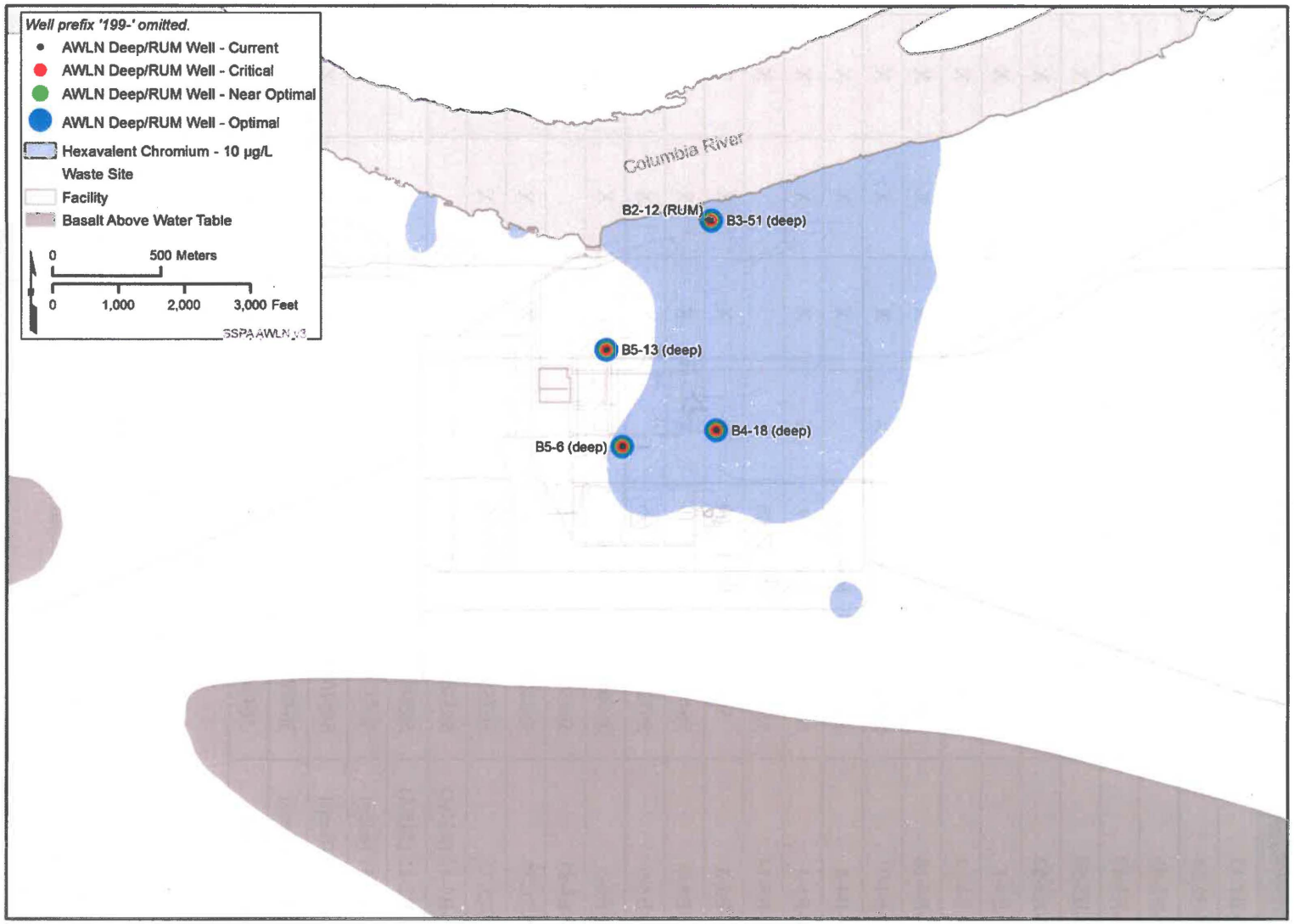

Figure 2-6. Deep and RUM AWLN Wells for the Initial and Proposed Configurations for the 100-BC-5 OU

Table 2-2. List of Monitoring Wells and AWLN Configurations for the 100-BC-5 OU

Well Name[a]	Easting	Northing	Initial[b]	Critical	Near-Optimal	Optimal
199-B2-13	564086.52	145264.56				X
199-B2-14	565095.99	145232.26		X	X	X
199-B3-46	565899.57	145369.04		X	X	X
199-B3-47	565388.66	145368.95	X	X	X	X
199-B3-50	566028.9	145058.21	X	X	X	X
199-B3-52	565391	145115.03			X	X
199-B4-1	565289.81	144791.53			X	X
199-B4-14	564969.25	144313.98	X	X	X	X
199-B4-16	566132.01	144479.91	X	X	X	X
199-B4-7	565398.86	144382.85	X	X	X	X
199-B4-8	565578.45	144653.79		X	X	X
199-B5-1	564878.15	144764.9	X	X	X	X
199-B5-14	564170.23	144520.06				X
199-B5-8	566014	143587.69	X	X	X	X
199-B8-6	564498.83	144157.79	X	X	X	X
199-B8-9	565276.43	144054.45		X	X	X
199-B9-3	565667.36	144046.72		X	X	X
699-65-83	564590.47	143249.09				X
699-71-77	566401.95	145098.61		X	X	X
699-72-73	567551.54	145418.78		X	X	X
199-B2-12 (RUM)	565368.44	145363.68	X			
199-B2-15 (RUM)	565092.32	145230.48				
199-B3-51 (deep)	565379.25	145362.36	X	X	X	X
199-B4-18 (deep)	565401.02	144392.22	X	X	X	X
199-B5-13 (deep)	564893.41	144764.86	X	X	X	X
199-B5-6 (deep)	564967.7	144316.44	X	X	X	X
		Total (shallow)	**8**	**15**	**17**	**20**
		Total (deep/RUM)	**5**	**4**	**4**	**4**
		Total	**13**	**19**	**21**	**24**

a. Wells are screened in the upper part of the unconfined aquifer, except where noted: RUM = screened in Ringold upper mud unit; deep = screened in lower part of unconfined aquifer.

b. Installed as of September 30, 2015.

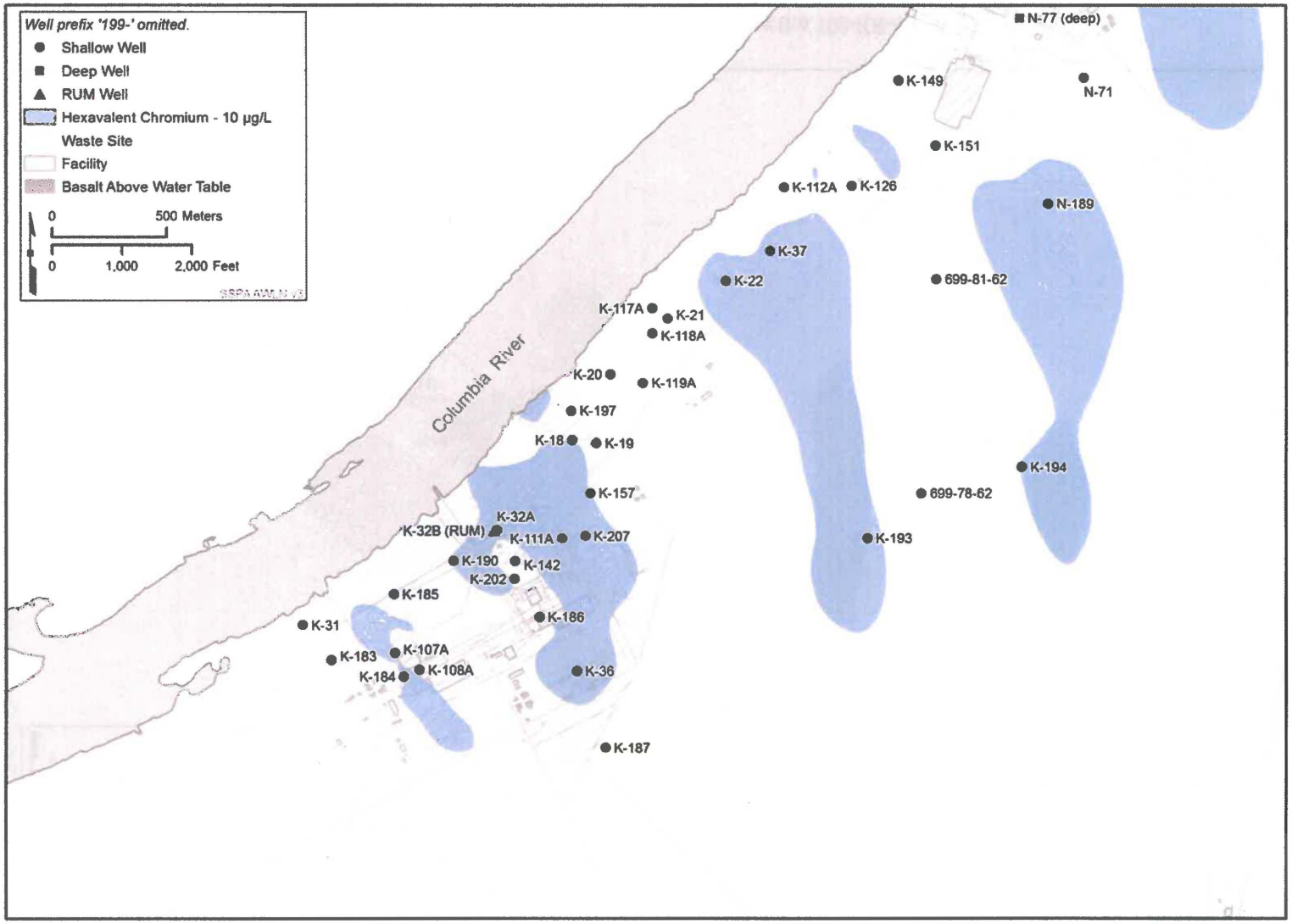

Figure 2-7. Initial AWLN Configuration for the 100-KR-4 OU

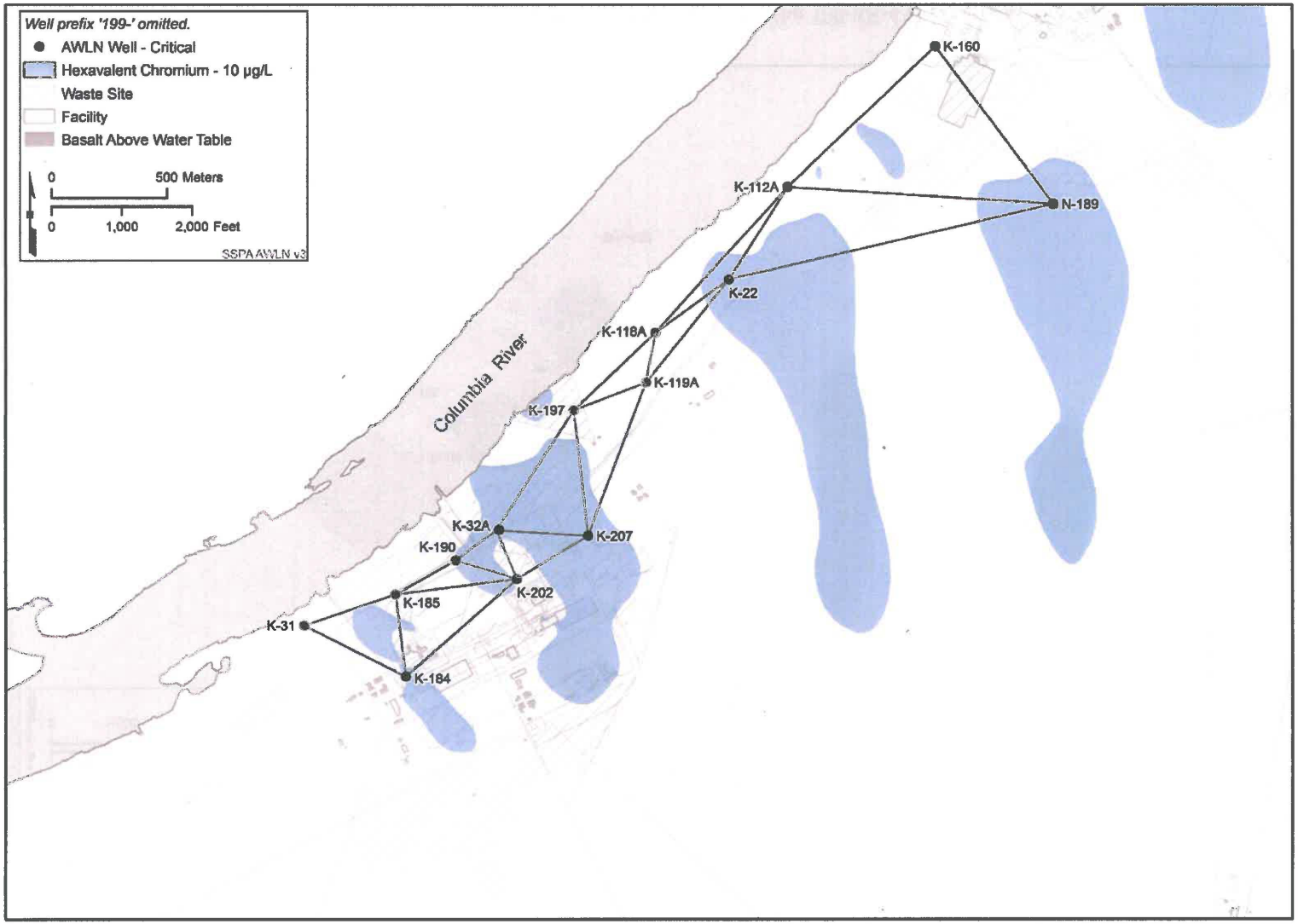

Figure 2-8. Critical AWLN Configuration for the 100-KR-4 OU

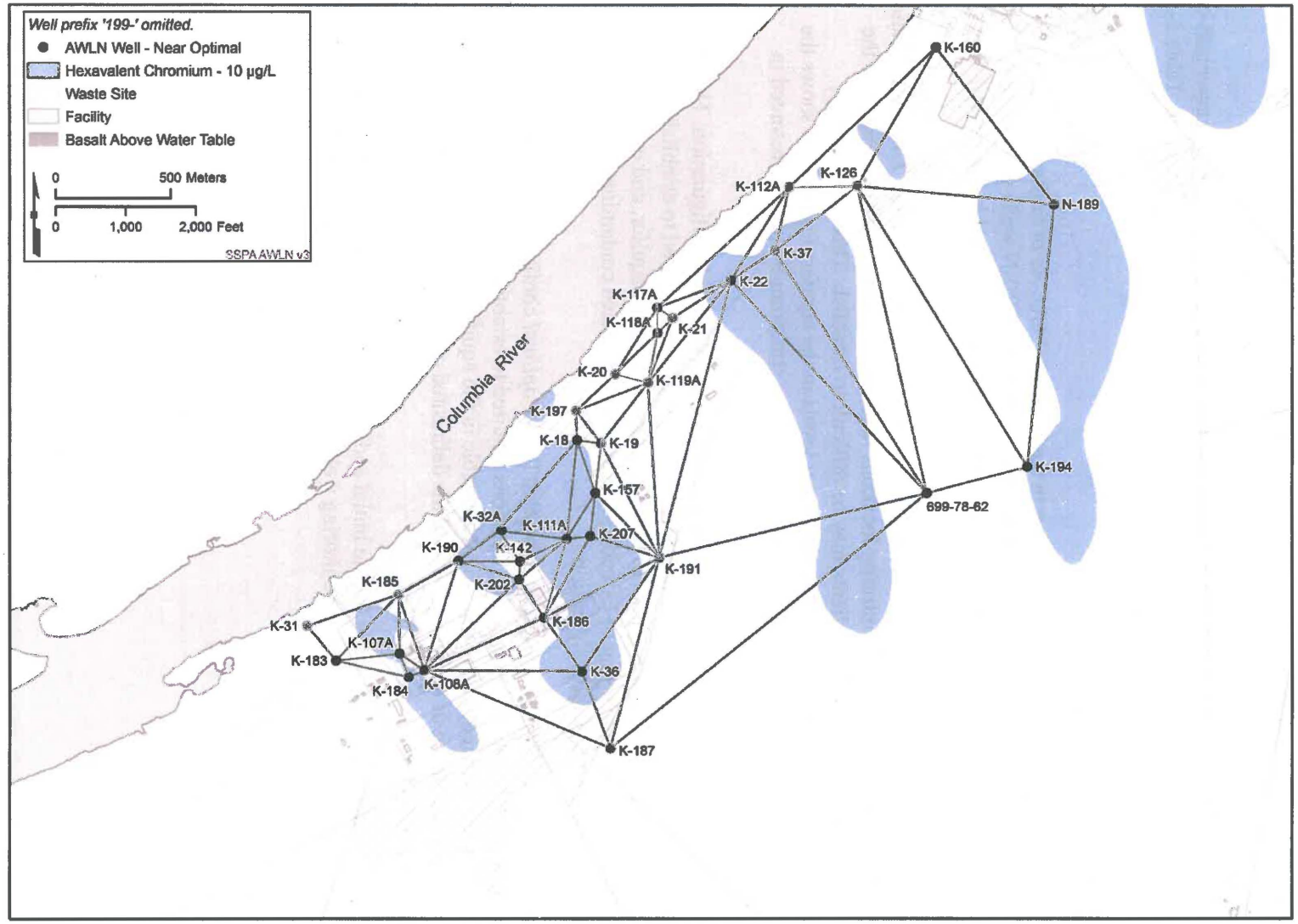

Figure 2-9. Near-Optimal AWLN Configuration for the 100-KR-4 OU

Water-level data from 38 monitoring wells are needed for the *optimal* configuration. This configuration constitutes the network necessary to demonstrate downgradient containment and river protection, as well as to establish near-river gradients in all areas. The network will also provide water-level data required to map the water table in the aquifer and delineate the capture zone of the P&T systems. Figure 2-10 show the proposed configuration.

Figure 2-11 shows the monitoring wells for the initial and proposed configurations in the upper part of the aquifer, and Figure 2-12 shows the deep and RUM monitoring wells for each configuration. Table 2-3 lists the monitoring wells for each configuration.

2.3 100-NR-2 Operable Unit

Figure 2-13 shows the initial AWLN configuration in the 100-NR-2 OU. As of September 30, 2015, there were 15 monitoring wells (14 shallow wells and one deep well). The AWLN wells were reporting data during 2014 and 2015; however, in several cases the reported data were not usable for parts of or even the entire year.

Water-level data from 13 monitoring wells are needed for the *critical* configuration. This configuration represents the minimum number of monitoring locations required to evaluate flow patterns near the shoreline. In some areas, near-river gradients may be difficult to establish. This configuration represents the minimum network required to map water levels in the aquifer. Figure 2-14 shows the proposed configuration overlaying the CY 2014 low river-stage strontium-90 plume presented in DOE/RL-2015-07.

Water-level data from 25 monitoring wells are needed for the *near-optimal* configuration. This configuration represents a reasonable amount of monitoring locations required to establish near-river gradients, provide water-level data required to map the water table in the aquifer, and evaluate flow patterns within an area encompassing or extending beyond the delineated contamination zone. Figure 2-15 shows the proposed configuration.

Water-level data from 29 monitoring wells are needed for the *optimal* configuration. This configuration represents the optimal number of monitoring locations required to establish near-river gradients, provide sufficient water-level data required to map the water table in the aquifer, and evaluate flow patterns within an area encompassing or extending beyond the delineated contamination zone. Figure 2-16 shows the proposed configuration.

Figure 2-17 shows the monitoring wells for the initial and proposed configurations in the upper part of the aquifer, and Figure 2-18 shows the deep monitoring wells for each configuration. Table 2-4 lists the monitoring wells for each configuration.

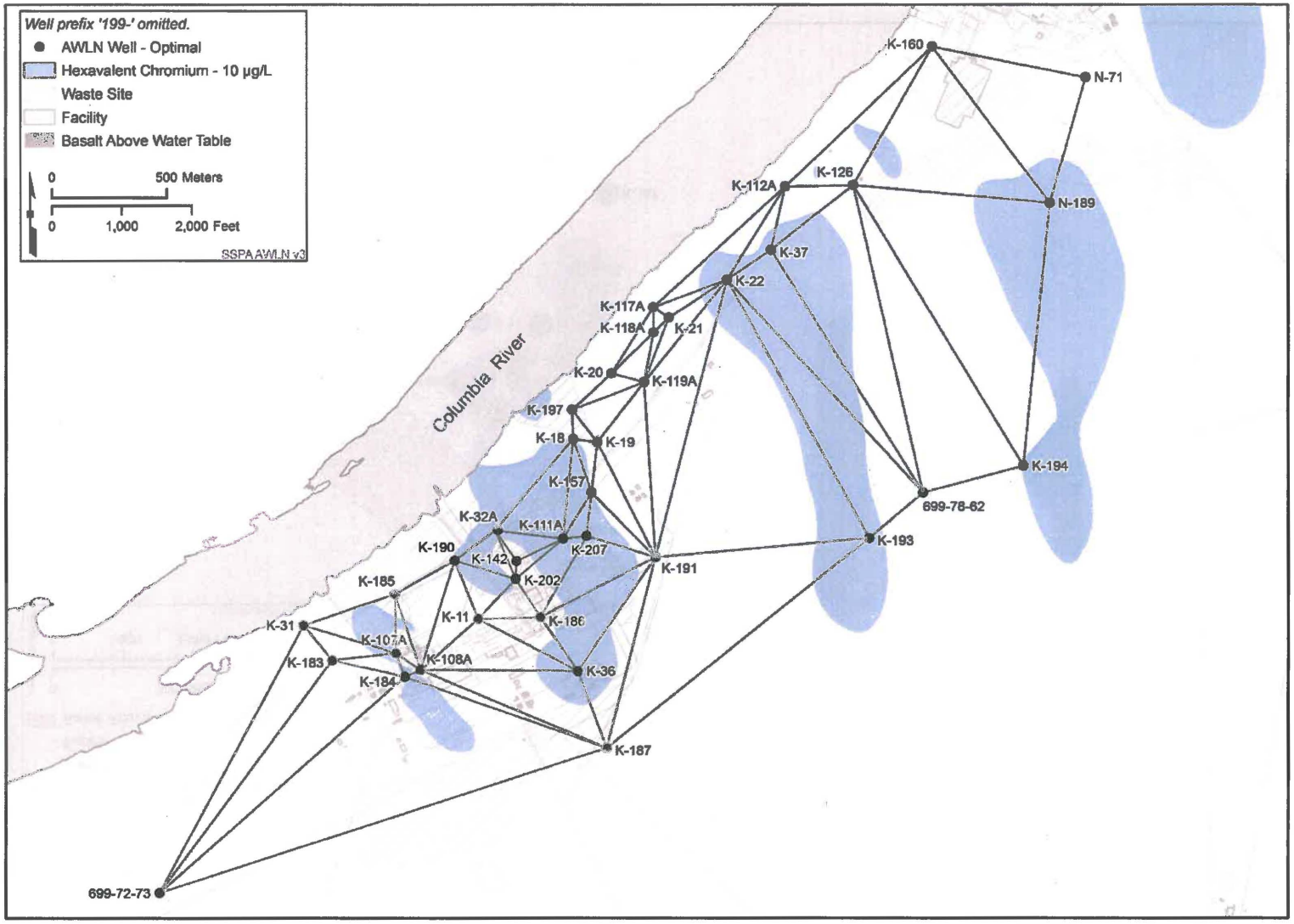

Figure 2-10. Optimal AWLN Configuration for the 100-KR-4 OU

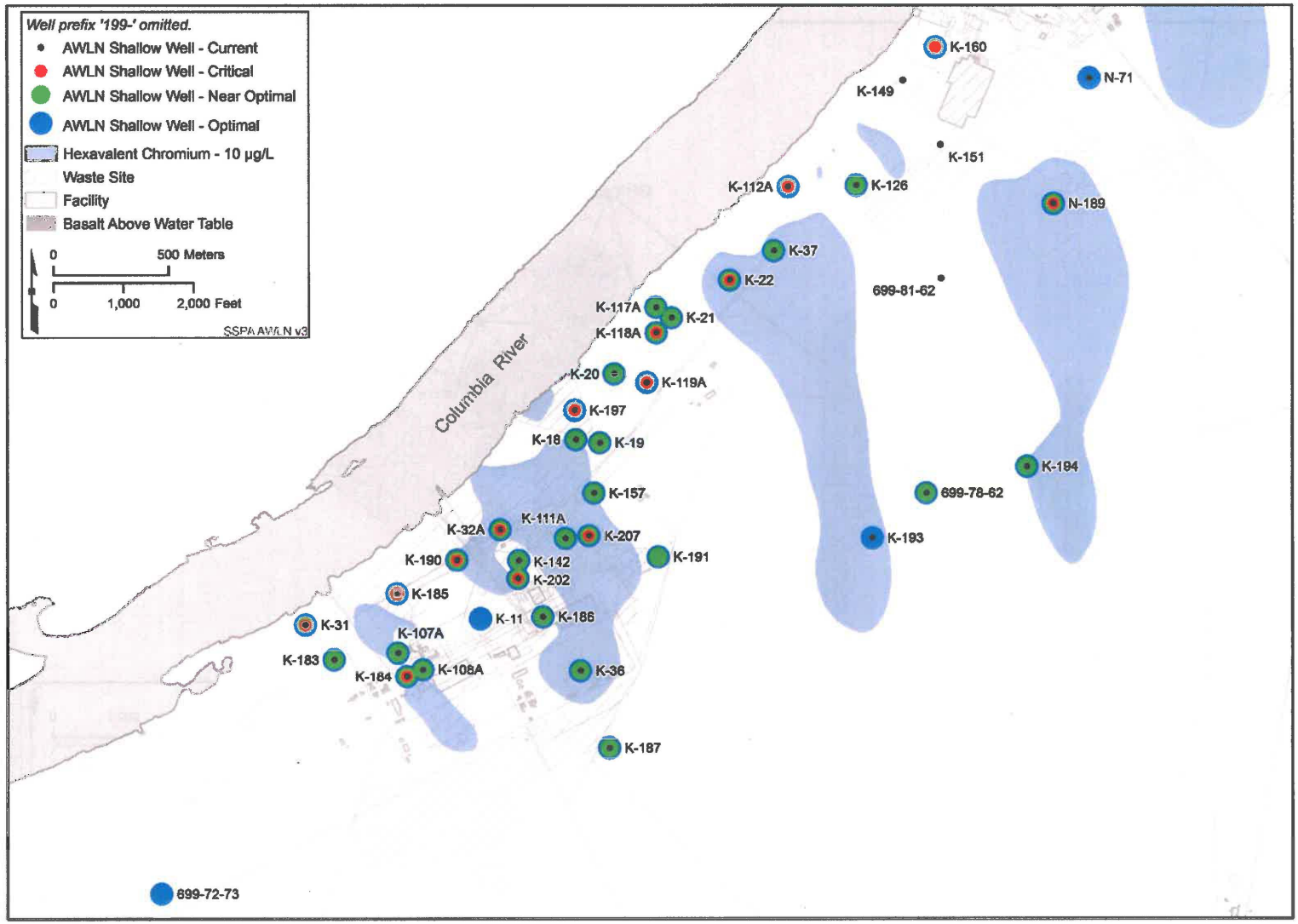

Figure 2-11. Shallow AWLN Wells for the Initial and Proposed Configurations for the 100-KR-4 OU

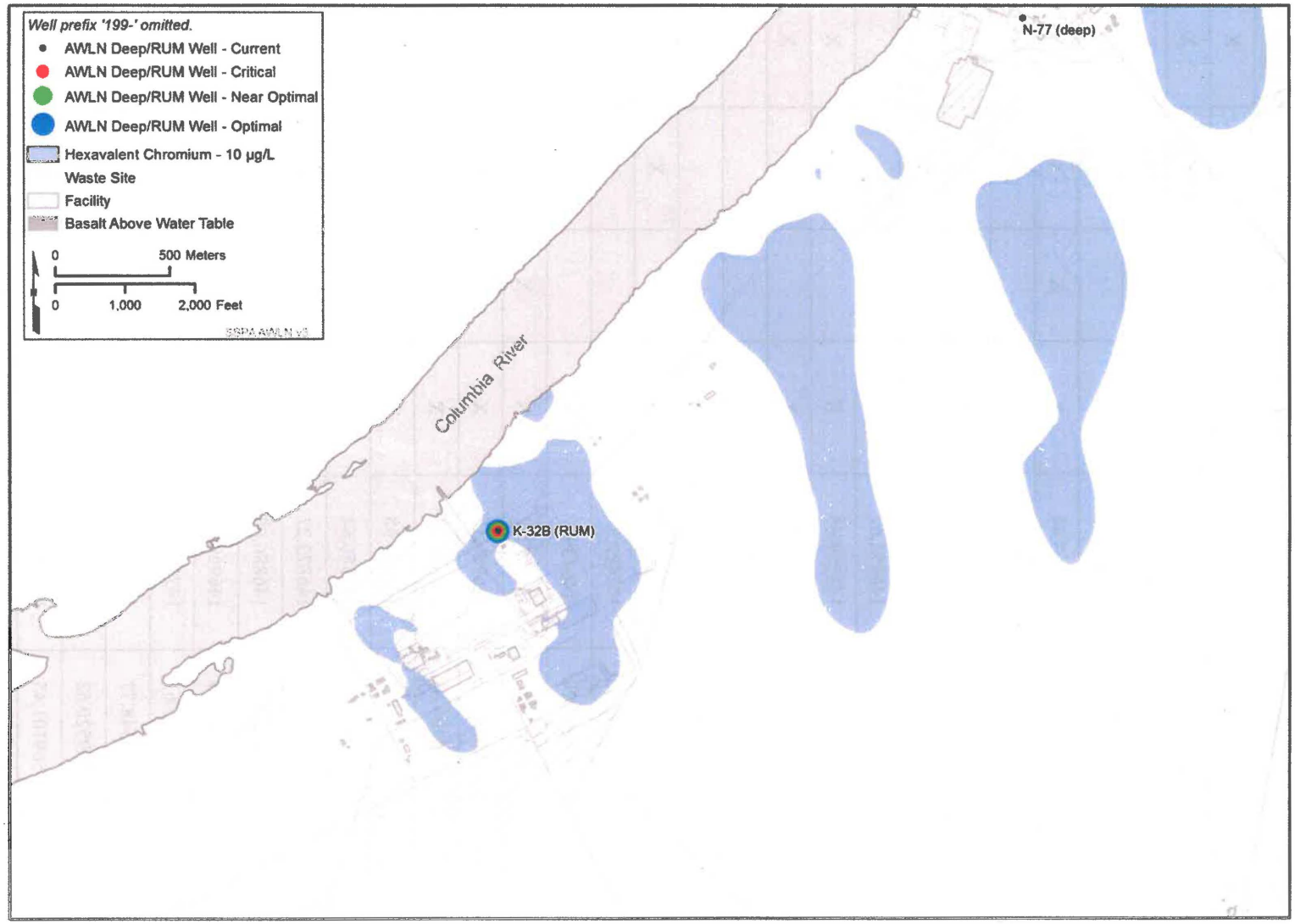

Figure 2-12. Deep and RUM AWLN Wells for the Initial and Proposed Configurations for the 100-KR-4 OU

Table 2-3. List of Monitoring Wells and AWLN Configurations for the 100-KR-4 OU

Well Name[a]	Easting	Northing	Initial[b]	Critical	Near-Optimal	Optimal
199-K-107A	568579.94	146468.81	X		X	X
199-K-108A	568687.2	146396.14	X		X	X
199-K-11	568938	146617.76				X
199-K-111A	569308.17	146968.88	X		X	X
199-K-112A	570278.6	148503.44	X	X	X	X
199-K-117A	569702.56	147976.98	X		X	X
199-K-118A	569703.06	147865.9	X	X	X	X
199-K-119A	569661.8	147649.69	X	X	X	X
199-K-124A[c]	569867.94	146991.67				
199-K-126	570574.73	148509.65	X		X	X
199-K-142	569104.26	146870.94	X		X	X
199-K-149	570778.25	148970.74	X			
199-K-151	570941.32	148686.44	X			
199-K-157	569432.18	147167.94	X		X	X
199-K-18	569353.69	147400.81	X		X	X
199-K-183	568302.28	146439.7	X		X	X
199-K-184	568618.68	146366.32	X	X	X	X
199-K-185	568574.92	146726.17	X	X	X	X
199-K-186	569209.65	146625.36	X		X	X
199-K-187	569499	146054.68	X		X	X
199-K-19	569458.52	147386.64	X		X	X
199-K-190	568835.28	146873.27	X	X	X	X
199-K-191	569711.2	146886.65			X	X
199-K-193	570641.99	146969.58	X			X
199-K-194	571315.65	147281.98	X		X	X
199-K-197	569348.77	147528.77	X	X	X	X
199-K-20	569520.52	147687.24	X		X	X
199-K-202	569101.45	146792.64	X	X	X	X
199-K-207	569409.92	146979.85	X	X	X	X
199-K-21	569769.9	147932.06	X		X	X

Table 2-3. List of Monitoring Wells and AWLN Configurations for the 100-KR-4 OU

Well Name[a]	Easting	Northing	Initial[b]	Critical	Near-Optimal	Optimal
199-K-22	570023.7	148097.38	X	X	X	X
199-K-31	568177.56	146591.11	X	X	X	X
199-K-32A	569024.15	147006.68	X	X	X	X
199-K-36	569373.61	146390.47	X		X	X
199-K-37	570216.2	148226.54	X		X	X
199-N-189	571431.65	148430.52	X	x	X	X
199-N-71	571588.82	148982.17	X			X
699-72-73	567551.54	145418.78				X
699-78-62	570877.3	147166.22	X		X	X
699-81-62[d]	570943.03	148103.09	X			
199-K-160	570919.58	149116.02		X	X	X
199-K-32B (RUM)	569012.4	147004.81	X	X	X	X
199-N-77 (seep)	571309.79	149243.05	X			
		Total (shallow)	**36**	**14**	**33**	**37**
		Total (seep/RUM)	**2**	**1**	**1**	**1**
		Total	**38**	**15**	**34**	**38**

a. Wells are screened in the upper part of the unconfined aquifer, except where noted: RUM = screened in Ringold upper mud unit; deep = screened in lower part of unconfined aquifer.

b. Installed as of September 30, 2015.

c. Well 199-K-124A was initially identified for AWLN inclusion; however, the well was later converted to for injection well service.

d. An examination of the construction of well 699-81-62 indicates that the observed head measurement is not representative of the shallow unconfined aquifer. The AWLN station at this well will be relocated to another selected location.

AWLN = automated water-level network

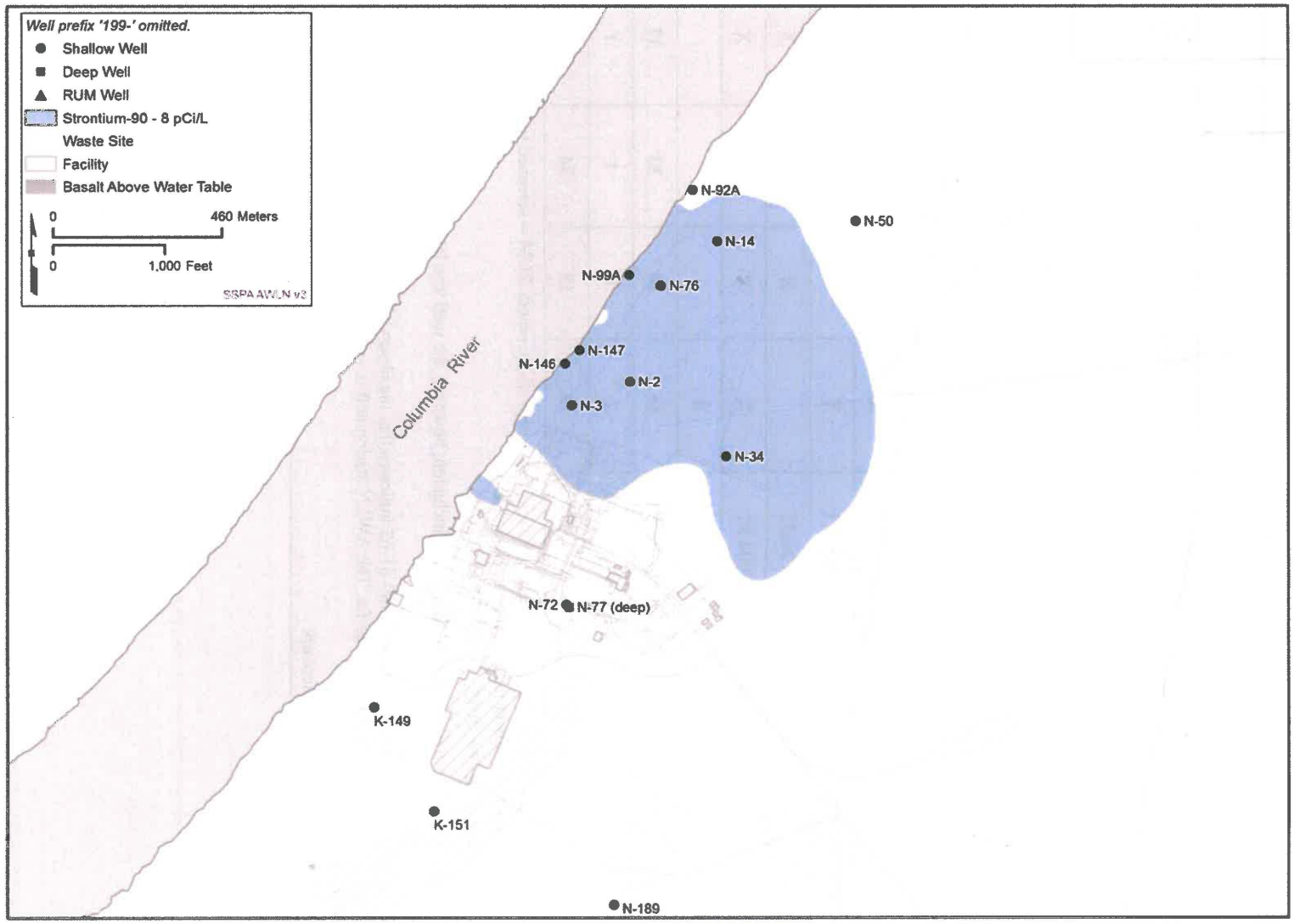

Figure 2-13. Initial AWLN Configuration for the 100-NR-2 OU

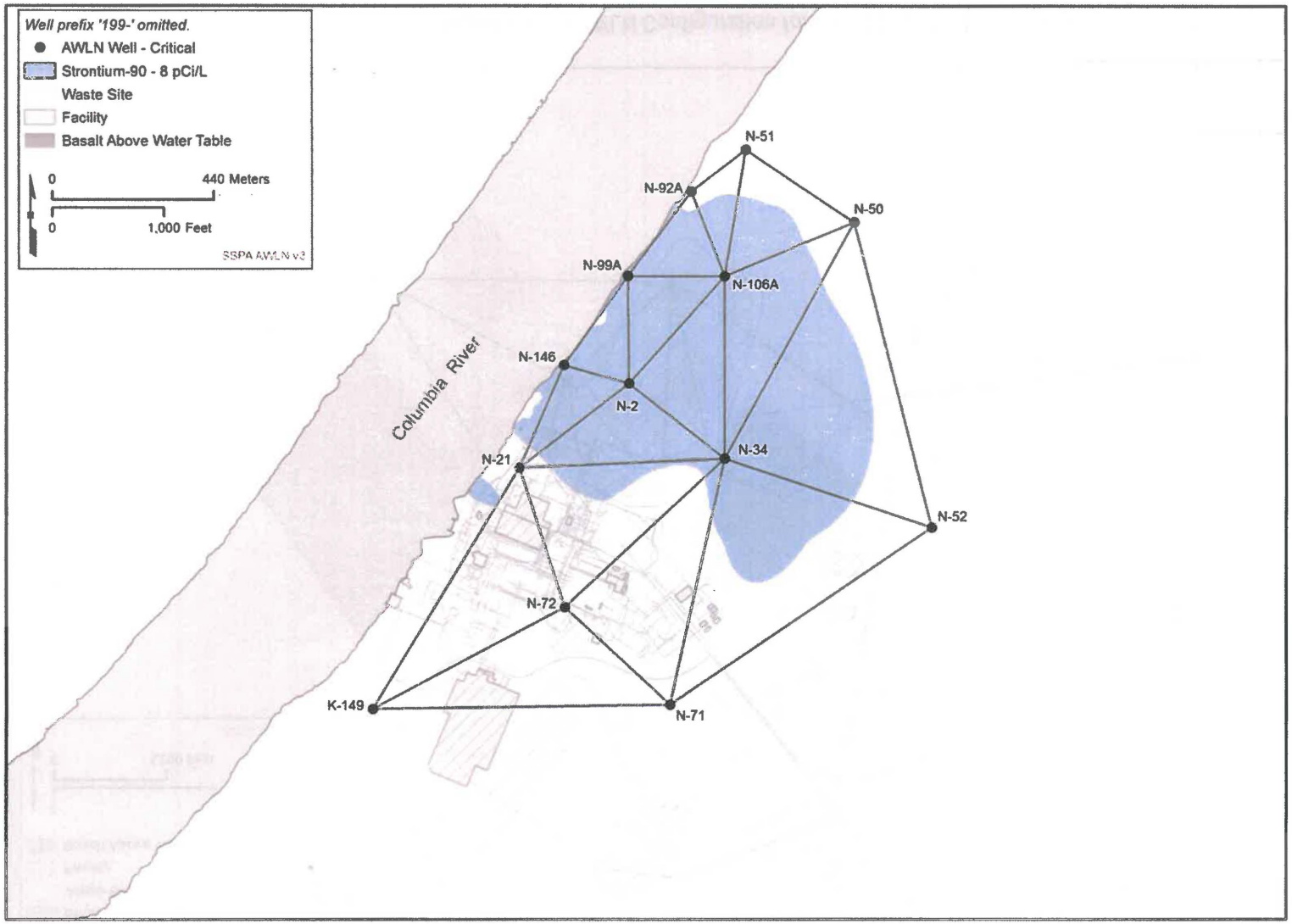

Figure 2-14. Critical AWLN Configuration for the 100-NR-2 OU

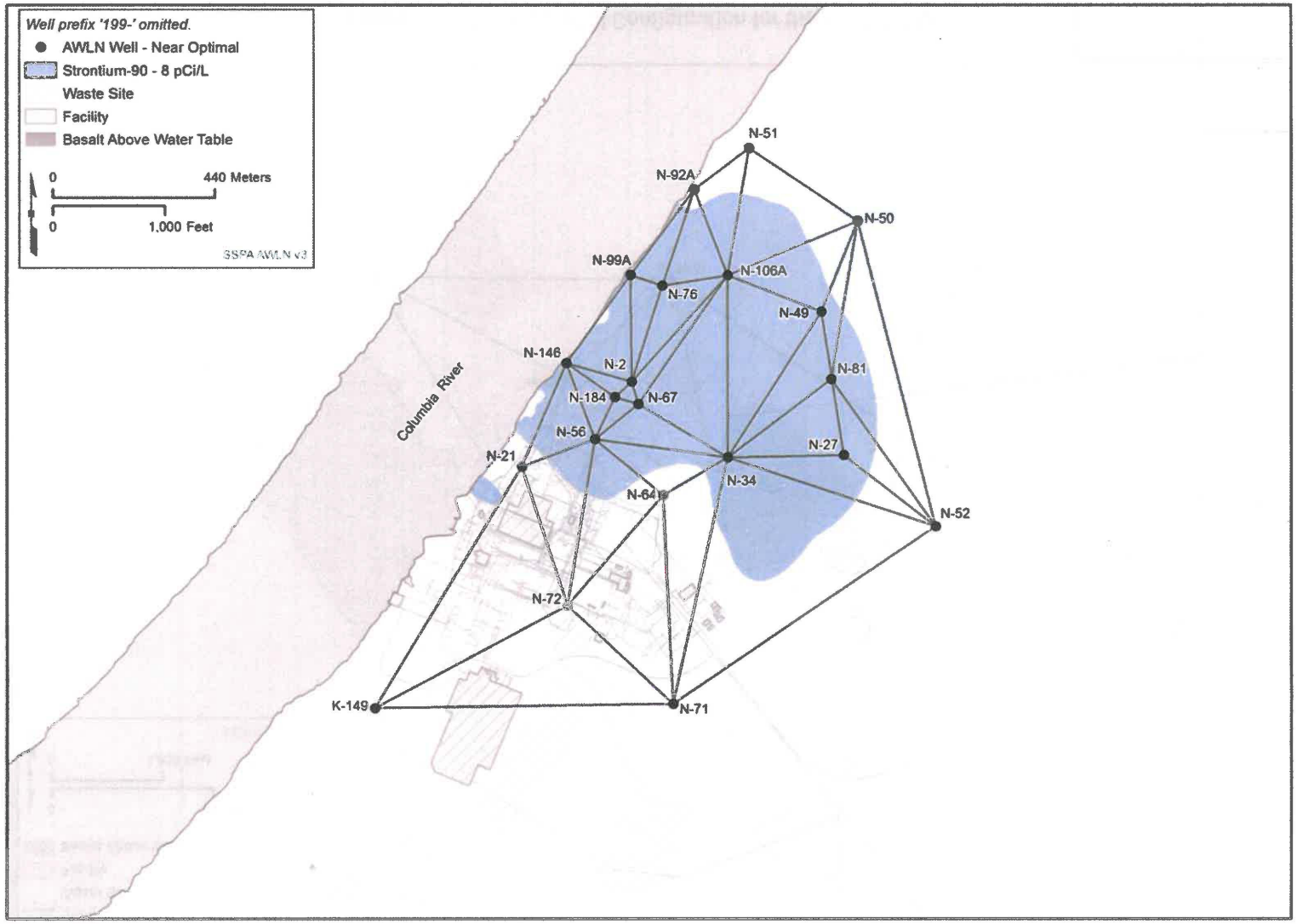

Figure 2-15. Near-Optimal AWLN Configuration for the 100-NR-2 OU

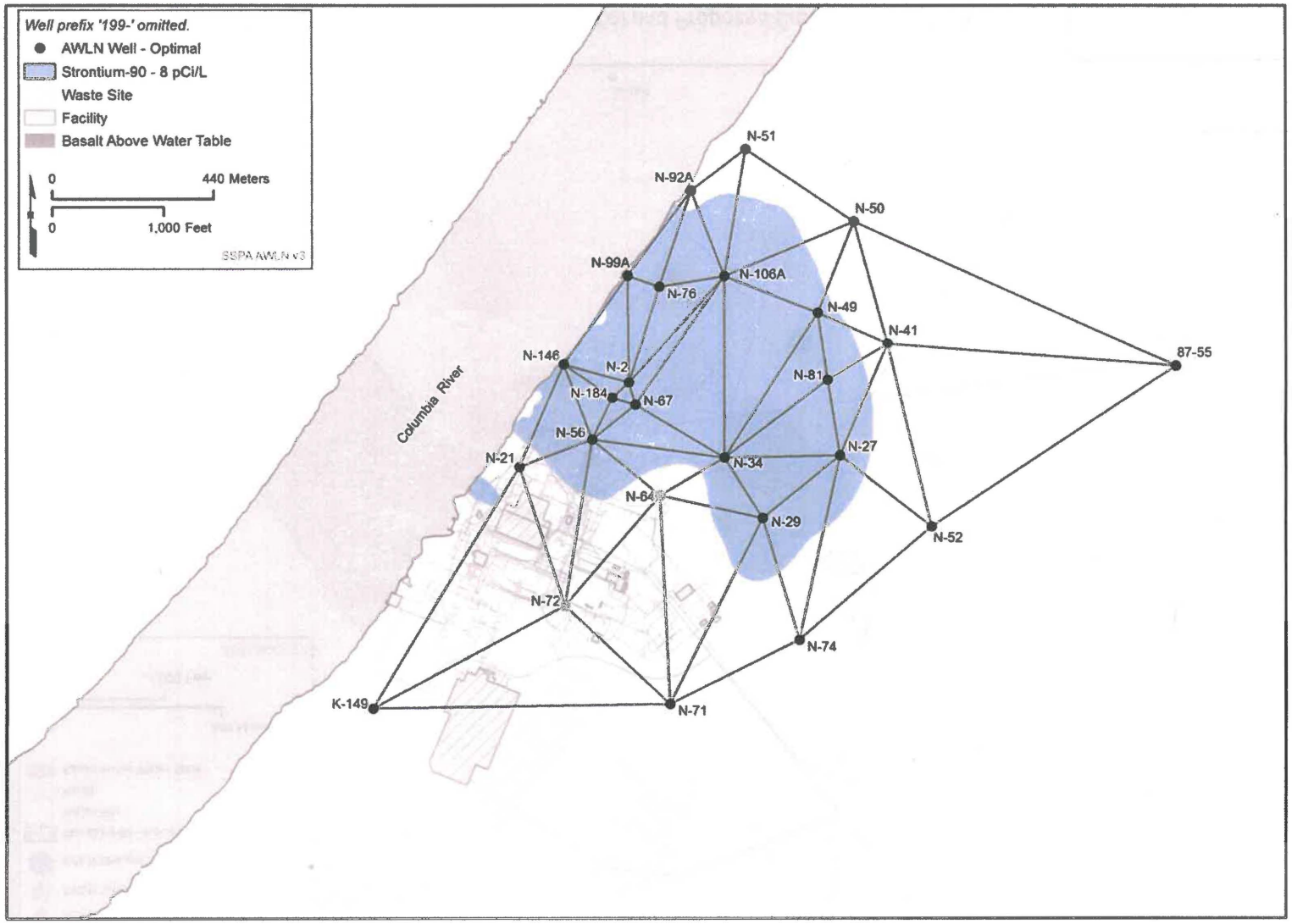

Figure 2-16. Optimal AWLN Configuration for the 100-NR-2 OU

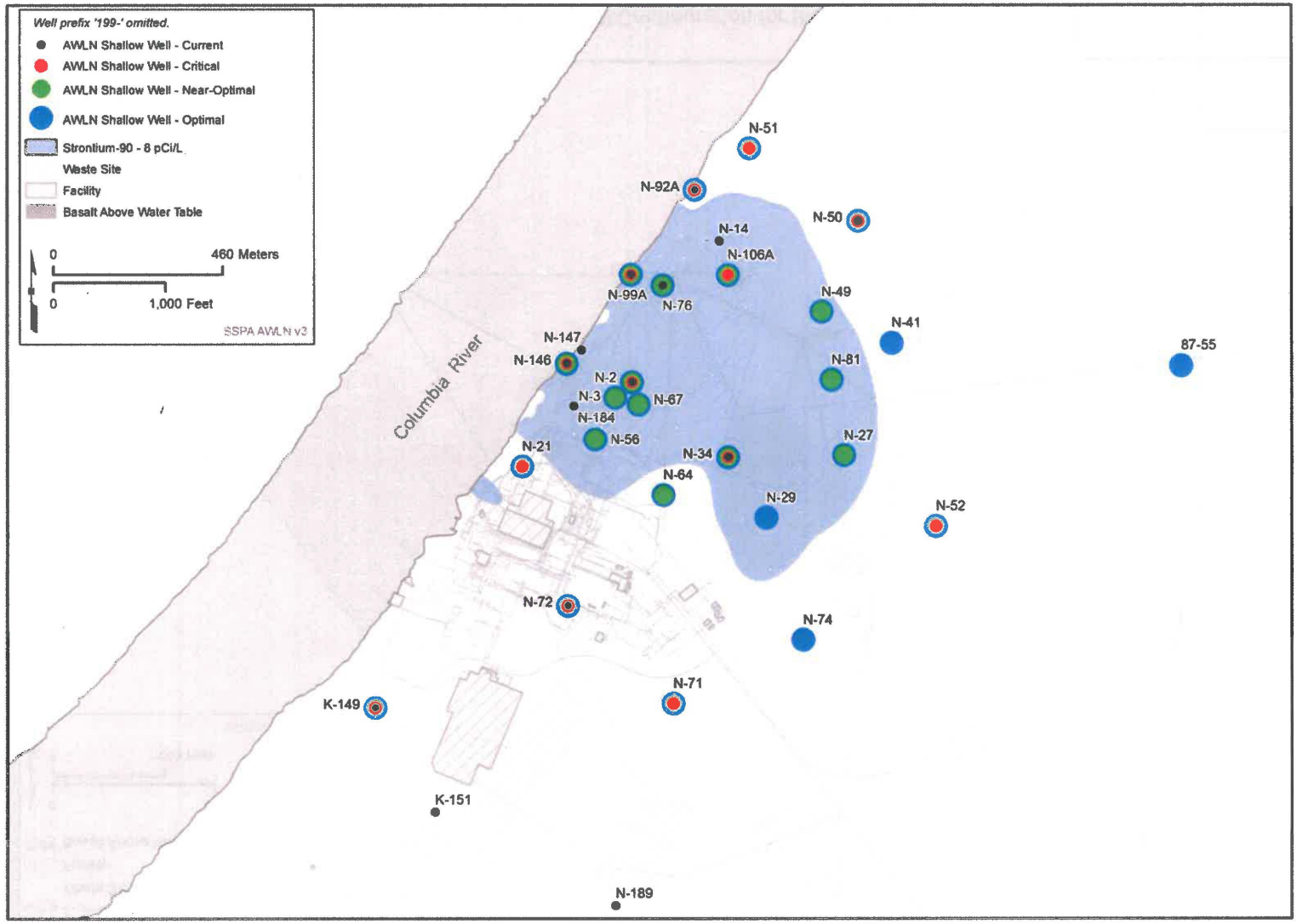

Figure 2-17. Shallow AWLN Wells for the Initial and Proposed Configurations for the 100-NR-2 OU

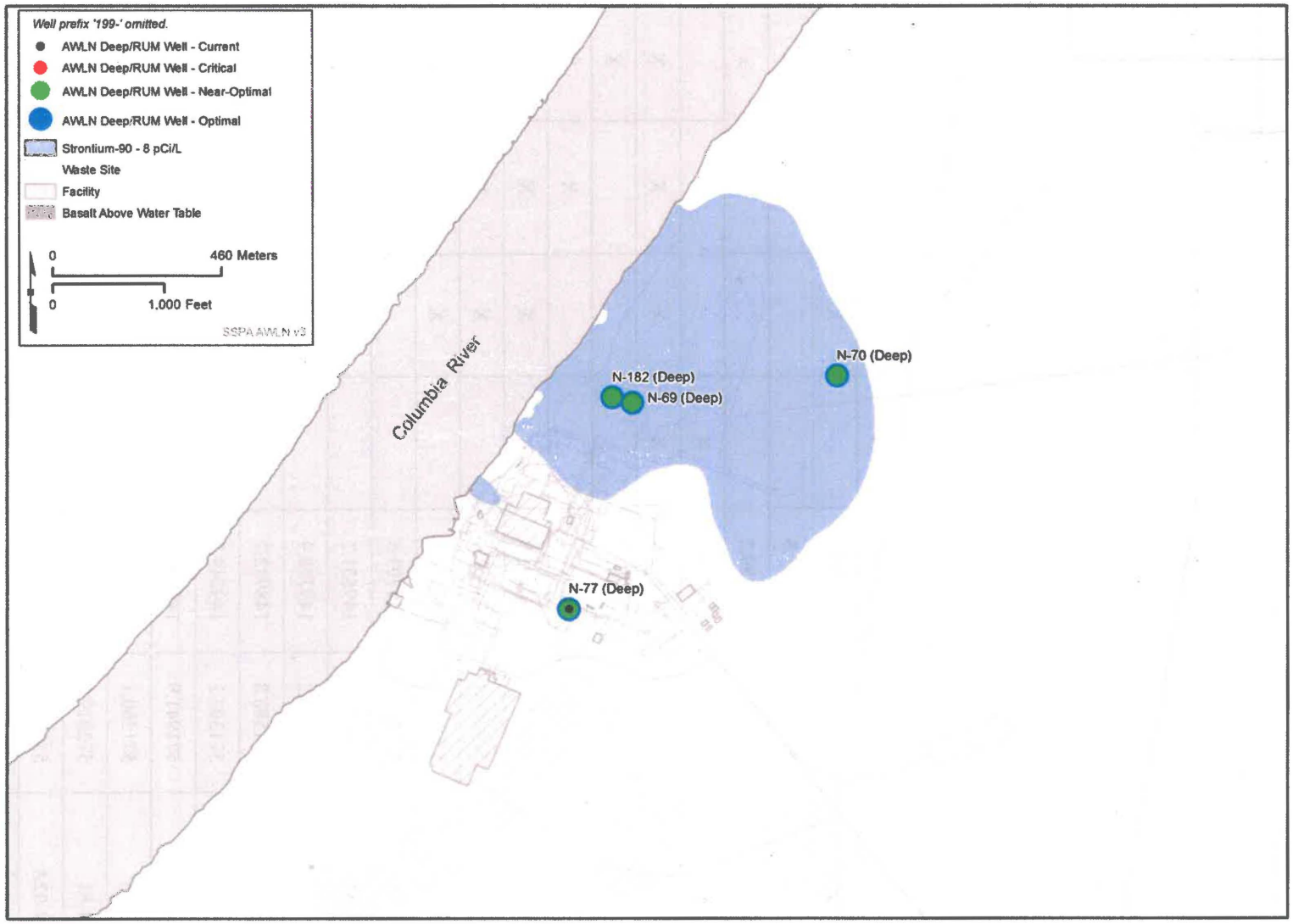

Figure 2-18. Deep AWLN Wells for the Initial and Proposed Configurations for the 100-NR-2 OU

Table 2-4. List of Monitoring Wells and AWLN Configurations for the 100-NR-2 OU

Well Name[a]	Easting	Northing	Initial[b]	Critical	Near-Optimal	Optimal
199-K-149	570778.3	148970.7	X	X	X	X
199-K-151	570941.3	148686.4	X			
199-N-106A	571737.6	150150.9		X	X	X
199-N-14	571713.1	150243.4	X			
199-N-146	571298.8	149909.7	X	X	X	X
199-N-147	571338.3	149946.5	X			
199-N-184	571430.7	149817.8			X	X
199-N-189	571431.7	148430.5	X			
199-N-2	571476.2	149859.4	X	X	X	X
199-N-21	571177.8	149629.4		X	X	X
199-N-27	572052.6	149659.8			X	X
199-N-29	571841.4	149489.2				x
199-N-3	571317.4	149794.6	X			
199-N-34	571737.4	149653.9	X	X	X	X
199-N-41	572182.2	149965.3				X
199-N-49	571991.7	150050.3			X	X
199-N-50	572090.9	150298.8	X	X	X	X
199-N-51	571796.1	150497		X	X	X
199-N-52	572302.9	149466.2		X	X	X
199-N-56	571375.9	149703.5			X	X
199-N-64	571561.4	149551.2			X	X
199-N-67	571494.2	149798.9			X	X
199-N-71	571588.8	148982.2		X	X	X
199-N-72	571302.2	149249.7	X	X	X	X
199-N-74	571941.9	149156.1				X
199-N-76	571560.1	150122.1	X		X	X
199-N-81	572019.2	149866.1			X	X
199-N-92A	571647.4	150383.5	X	X	X	X
199-N-99A	571473.7	150151.4	X	X	X	X
699-87-55	572969.8	149904				X

Table 2-4. List of Monitoring Wells and AWLN Configurations for the 100-NR-2 OU

Well Name[a]	Easting	Northing	Initial[b]	Critical	Near-Optimal	Optimal
199-N-182 (deep)	571428.7	149819.9			X	X
199-N-69 (deep)	571483.89	149804.8			X	X
199-N-70 (deep)	572042	149878			X	X
199-N-77 (deep)	571309.8	149243.1	X		X	X
		Total (shallow)	**14**	**13**	**21**	**25**
		Total (deep/RUM)	**1**	**0**	**4**	**4**
		Total	**15**	**13**	**25**	**29**

a. Wells are screened in the upper part of the unconfined aquifer, except where noted: RUM = screened in Ringold upper mud unit; deep = screened in lower part of unconfined aquifer.

b. Installed as of September 30, 2015.

2.4 100-HR-3 Operable Unit

Figure 2-19 shows the initial AWLN configuration. As of September 30, 2015, there were 58 monitoring wells (53 shallow wells and 5 RUM wells). The AWLN wells have been reporting data either continuously or intermittently in 2014 and 2015, although in several cases the reported data were not usable for parts of or even the entire year.

Water-level data from 35 monitoring wells are needed for the *critical* configuration. This configuration represents the minimum number of monitoring locations required to demonstrate downgradient containment and river protection. In some areas, near-river gradients may be difficult to establish. This configuration represents the minimum network required to map water levels in the aquifer and delineate capture zones for the P&T systems; however, capture may be uncertain in some areas. Figure 2-20 shows the proposed configuration overlaying the CY 2014 low river-stage chromium plume presented in DOE/RL-2015-07.

Water-level data from 73 monitoring wells are needed for the *near-optimal* configuration. This constitutes the network necessary to demonstrate downgradient containment and river protection, as well as to establish near-river gradients in most areas. The network will also provide water-level data required to map the water table in the aquifer and delineate the capture zone of the P&T systems. Mapped water levels and capture zones may be uncertain in some areas because of limited availability of monitoring locations. Figure 2-21 shows the proposed configuration.

Water-level data from 77 monitoring wells are needed for the *optimal* configuration. This configuration constitutes the network necessary to demonstrate downgradient containment and river protection, as well as to establish near-river gradients in all areas. The network will also provide water-level data required to map the water table in the aquifer and delineate the capture zone of the P&T systems. Figure 2-22 shows the proposed configuration.

Figure 2-23 shows the monitoring wells for the initial and proposed configurations in the upper part of the aquifer, and Figure 2-24 shows the RUM wells for each configuration. Table 2-5 lists the monitoring wells for each configuration.

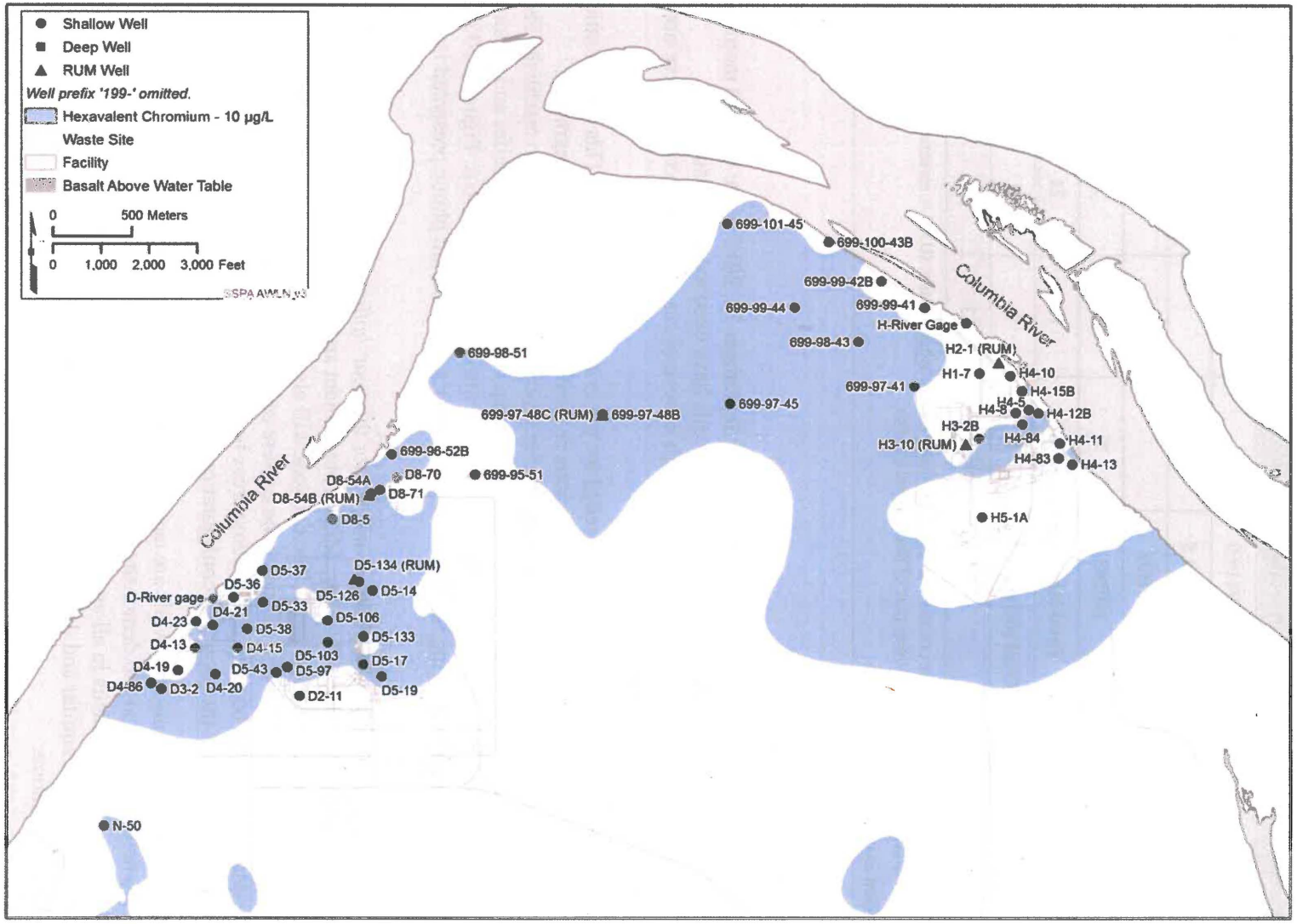

Figure 2-19. Initial AWLN Configuration for the 100-HR-3 OU

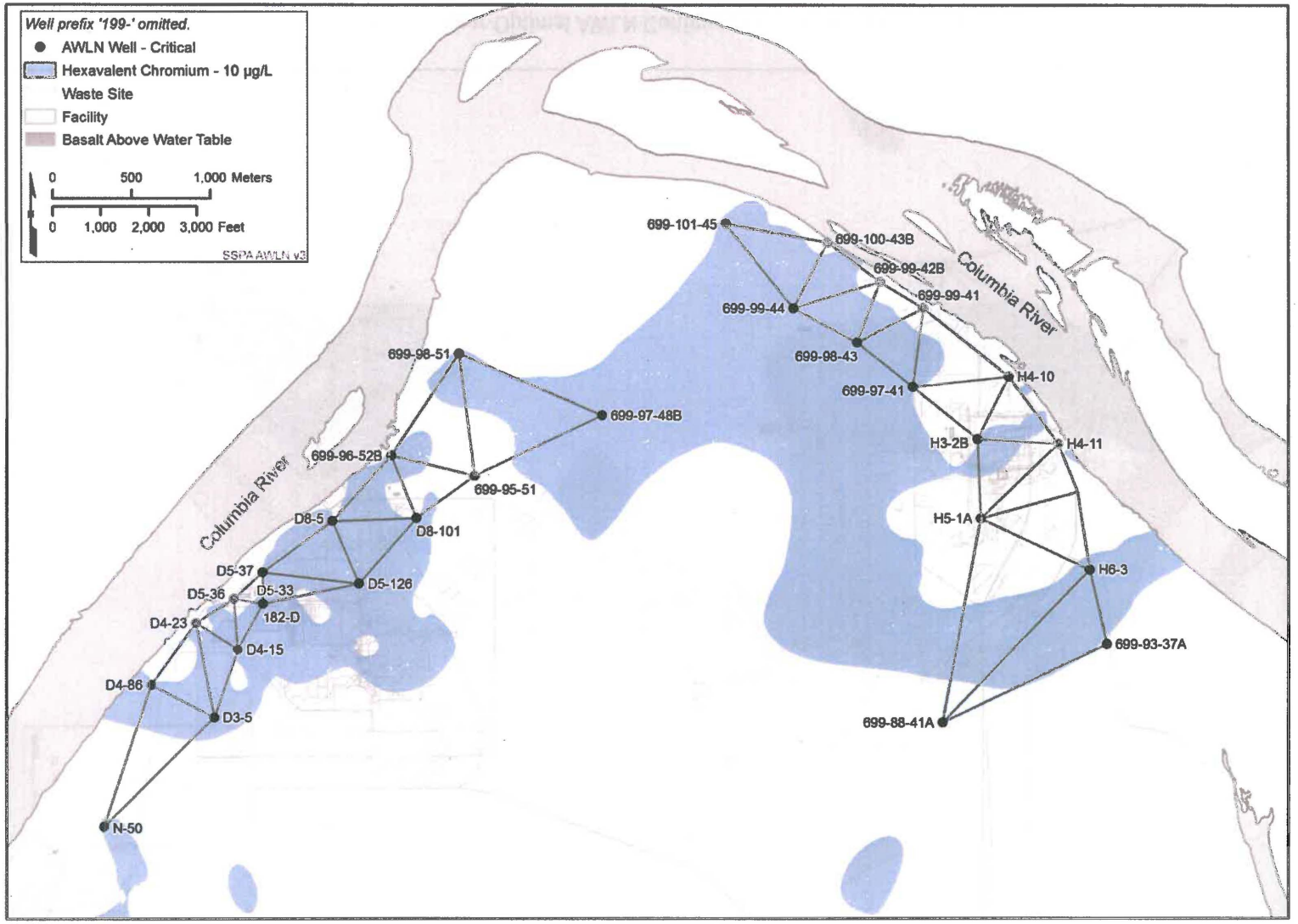

Figure 2-20. Critical AWLN Configuration for the 100-HR-3 OU

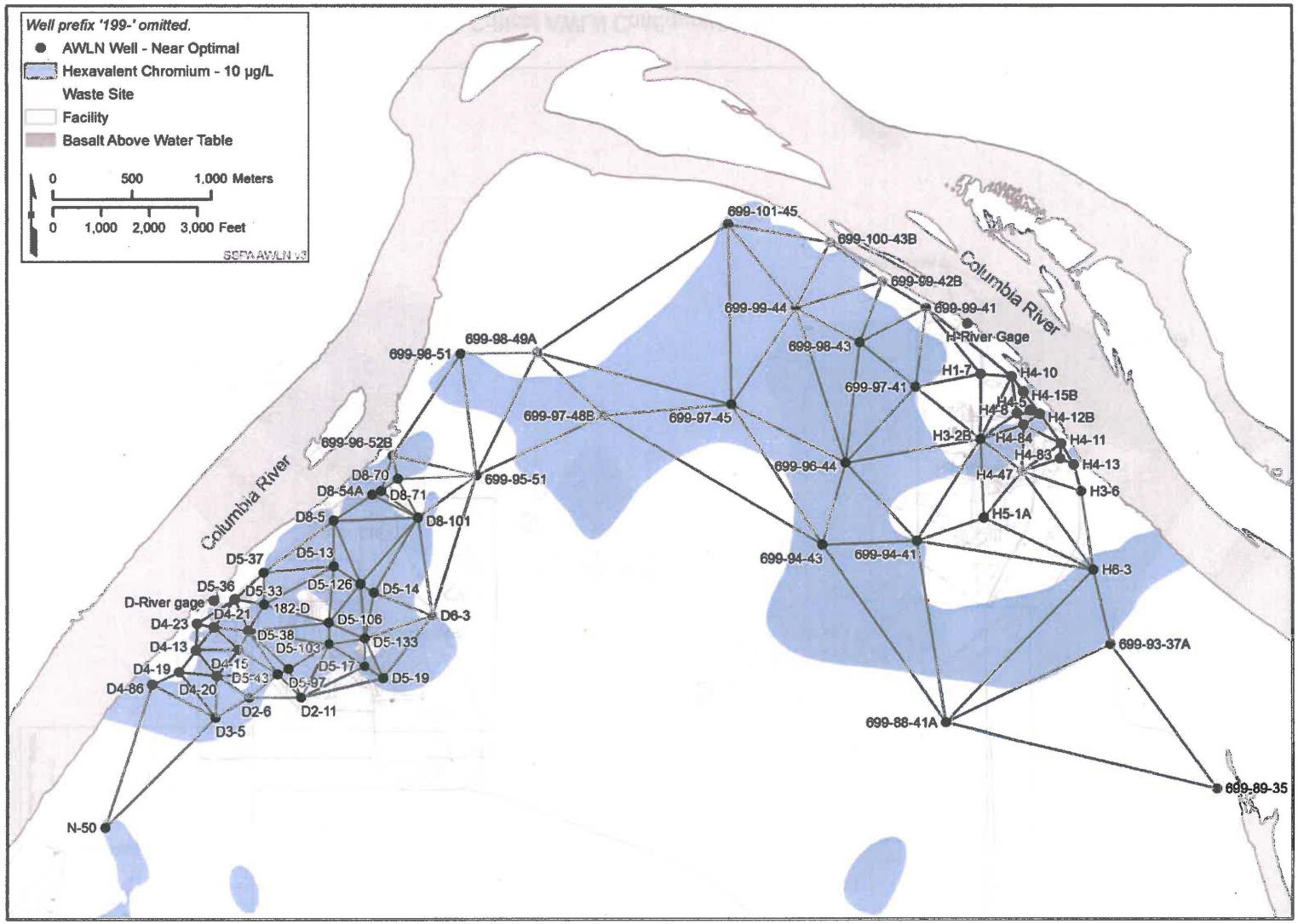

Figure 2-21. Near-Optimal AWLN Configuration for the 100-HR-3 OU

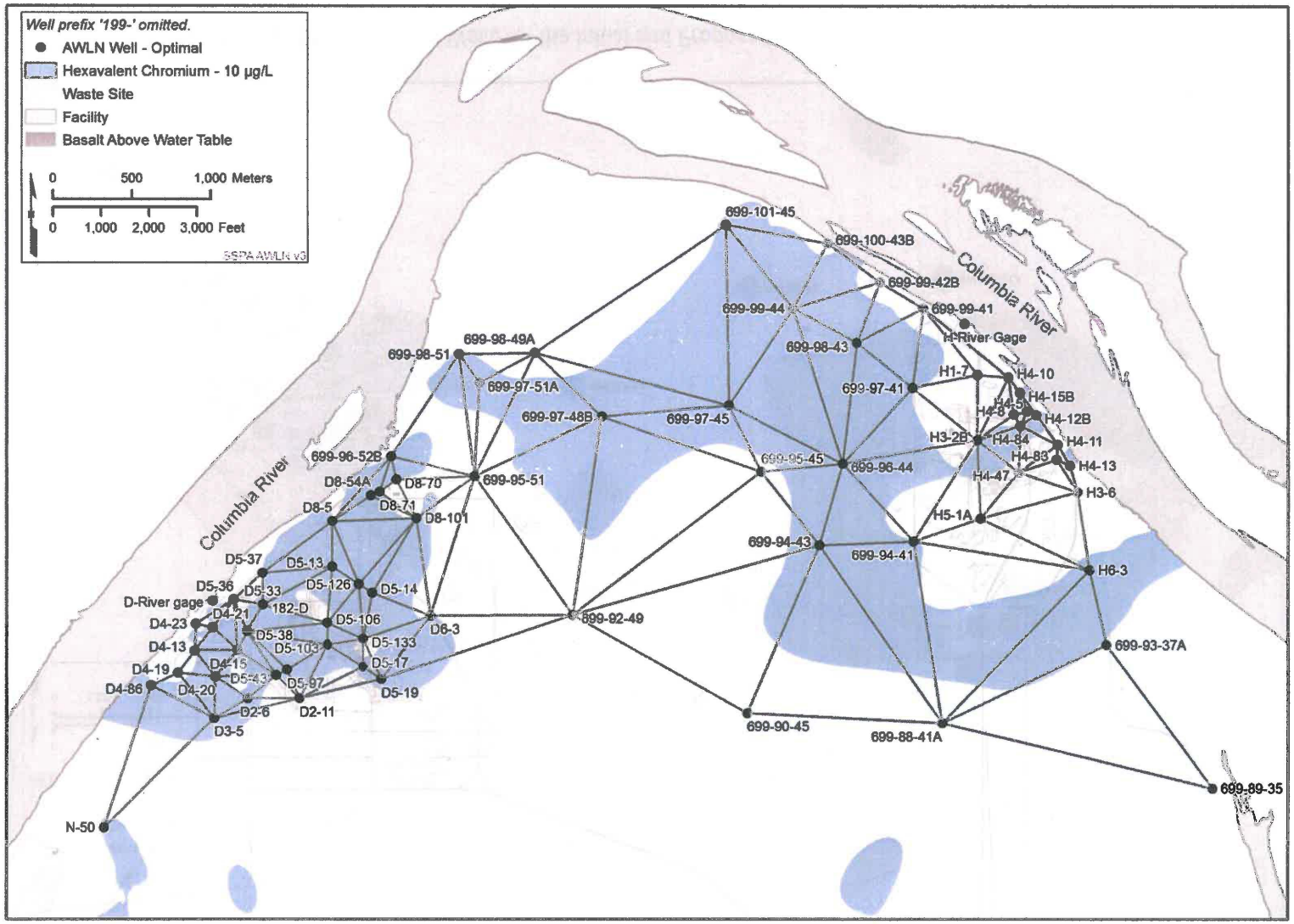

Figure 2-22. Optimal AWLN Configuration for the 100-HR-3 OU

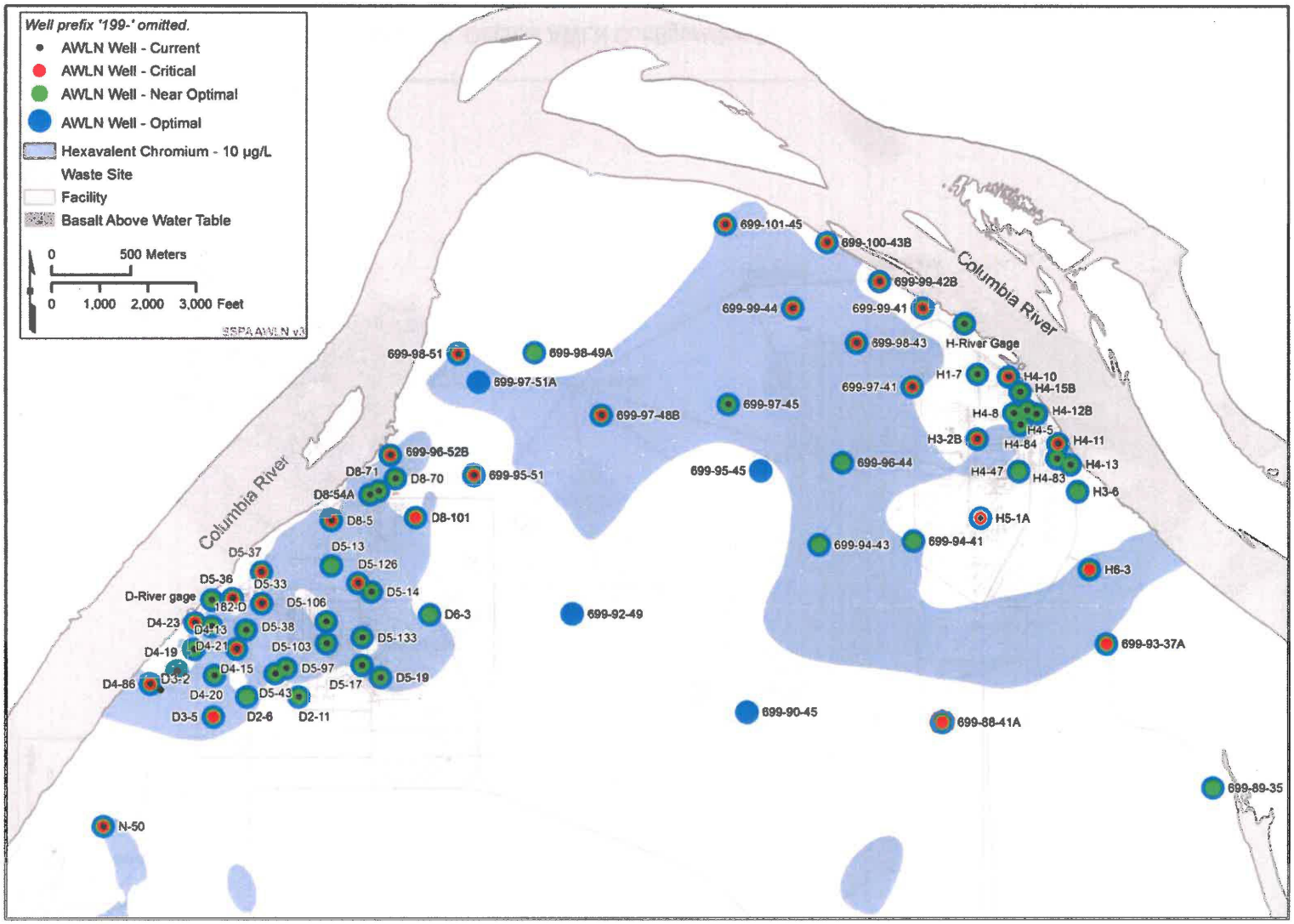

Figure 2-23. Shallow AWLN Wells for the Initial and Proposed Configurations for the 100-HR-3 OU

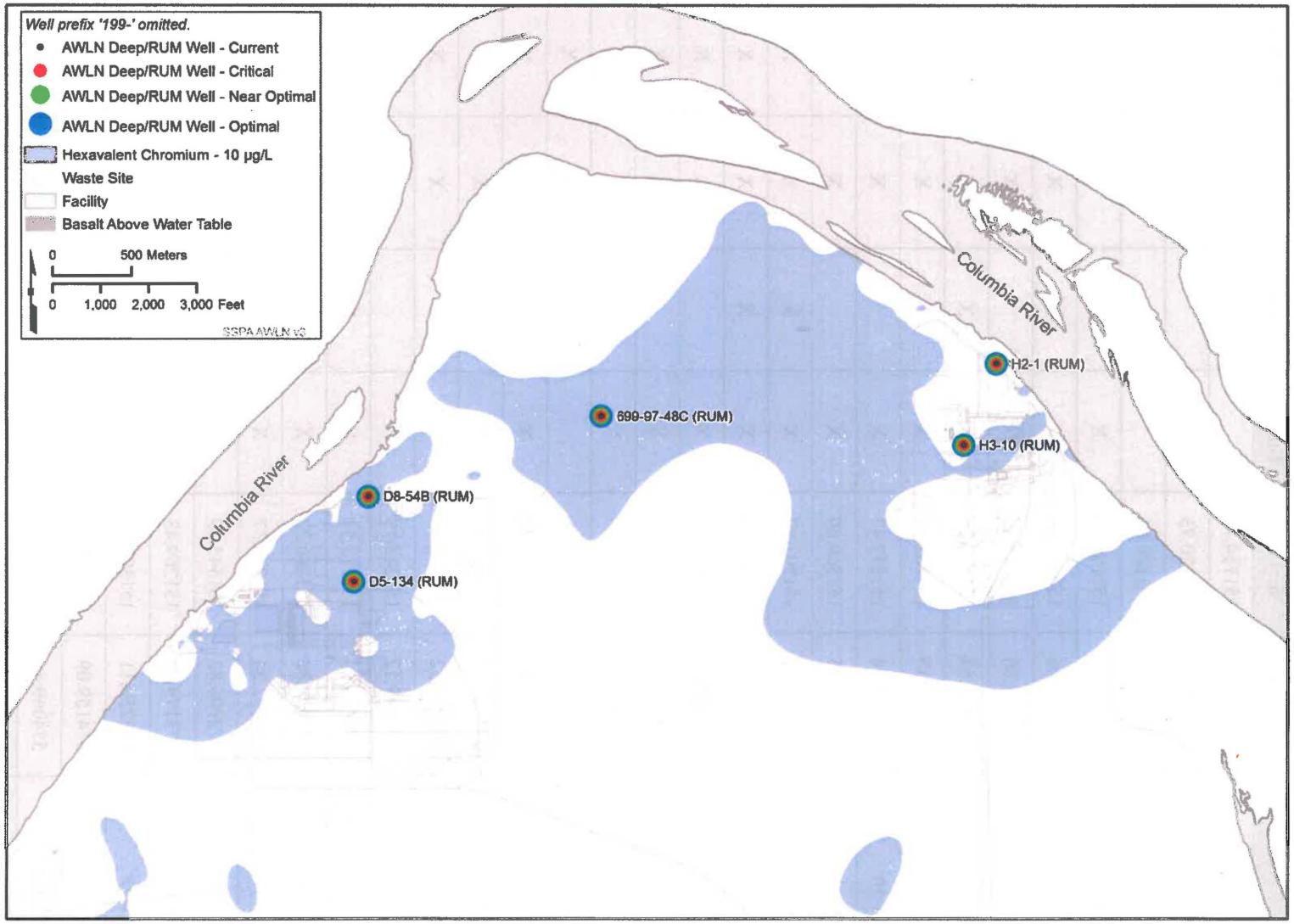

Figure 2-24. RUM AWLN Wells for the Initial and Proposed Configurations for the 100-HR-3 OU

Table 2-5. List of Monitoring Wells and AWLN Configurations for the 100-HR-3 OU

Well Name[a]	Easting	Northing	Initial[b]	Critical	Near-Optimal	Optimal
182-D	573095.10	151714.70		X	X	X
199-D2-11	573328.16	151120.73	X		X	X
199-D2-6	573000.21	151119.86			X	X
199-D3-2	572453.96	151165.65	X			
199-D3-5	572787.66	150994.54		X	X	X
199-D4-13	572665.86	151424.47	X		X	X
199-D4-15	572936.64	151424.86	X	X	X	X
199-D4-19	572559.35	151282.04	X		X	X
199-D4-20	572794.04	151257.47	X		X	X
199-D4-21	572778.85	151569.80	X		X	X
199-D4-23	572672.46	151592.87	X	X	X	X
199-D4-86	572389.06	151202.14	X	X	X	X
199-D5-103	573505.87	151460.87	X		X	X
199-D5-106	573503.74	151597.97	X		X	X
199-D5-126	573705.71	151843.28	X	X	X	X
199-D5-13	573535.53	151955.18			X	X
199-D5-133	573731.55	151497.37	X		X	X
199-D5-14	573789.63	151787.99	X		X	X
199-D5-17	573730.52	151322.83	X		X	X
199-D5-19	573849.12	151243.19	X		X	X
199-D5-33	573095.03	151714.54	X	X	X	X
199-D5-36	572909.82	151746.32	X	X	X	X
199-D5-37	573092.24	151916.37	X	X	X	X
199-D5-38	572996.82	151545.59	X		X	X
199-D5-43	573179.98	151269.43	X		X	X
199-D5-97	573250.11	151302.47	X		X	X
199-D6-3	574159.09	151643.85			X	X
199-D8-101	574069.46	152262.43		X	X	X
199-D8-5	573537.15	152243.50	X	X	X	X
199-D8-54A	573781.17	152408.03	X		X	X

Table 2-5. List of Monitoring Wells and AWLN Configurations for the 100-HR-3 OU

Well Name[a]	Easting	Northing	Initial[b]	Critical	Near-Optimal	Optimal
199-D8-70	573942.10	152508.74	X		X	X
199-D8-71	573837.10	152429.39	X		X	X
199-H1-7	577629.60	153172.10	X		X	X
199-H3-2B	577628.27	152757.16	X	X	X	X
199-H3-6	578266.47	152425.33			X	X
199-H4-10	577827.21	153155.81	X	X	X	X
199-H4-11	578141.91	152728.43	X	X	X	X
199-H4-12B	578004.39	152918.47	X		X	X
199-H4-13	578219.30	152595.27	X		X	X
199-H4-15B	577899.60	153059.55	X		X	X
199-H4-47	577891.18	152553.30			X	X
199-H4-5	577944.94	152939.78	X		X	X
199-H4-8	577860.69	152921.70	X		X	X
199-H4-83	578135.04	152634.01	X		X	X
199-H4-84	577902.58	152848.73	X		X	X
199-H5-1A	577650.08	152257.72	X	X	X	X
199-H6-3	578340.40	151929.35		X	X	X
199-N-50	572090.90	150298.79	X	X	X	X
699-100-43B	576675.90	154008.65	X	X	X	X
699-101-45	576032.40	154124.17	X	X	X	X
699-88-41A	577407.59	150959.08		X	X	X
699-89-35	579121.74	150543.51			X	X
699-90-45	576169.25	151024.53				X
699-92-49	575063.14	151647.47				X
699-93-37A	578448.99	151455.33		X	X	X
699-94-41	577223.05	152111.68			X	X
699-94-43	576625.60	152087.90			X	X
699-95-45	576257.00	152556.28				X
699-95-51	574439.50	152528.59	X	X	X	X
699-96-44	576773.10	152608.21			X	X

Table 2-5. List of Monitoring Wells and AWLN Configurations for the 100-HR-3 OU

Well Name[a]	Easting	Northing	Initial[b]	Critical	Near-Optimal	Optimal
699-96-52B	573910.16	152656.22	X	X	X	X
699-97-41	577217.50	153090.38	X	X	X	X
699-97-45	576051.70	152978.95	X		X	X
699-97-48B	575247.59	152909.76	X	X	X	X
699-97-51A	574468.12	153122.09				X
699-98-43	576863.24	153371.37	X	X	X	X
699-98-49A	574823.37	153310.15			X	X
699-98-51	574339.32	153302.71	X	X	X	X
699-99-41	577283.99	153590.74	X	X	X	X
699-99-42B	577010.23	153761.02	X	X	X	X
699-99-44	576458.77	153592.40	X	X	X	X
D-River gage	572778.40	151738.40	X		X	X
H-River gage	577547.50	153493.00	X		X	X
199-D5-134 (RUM)	573675.32	151862.46	X	X	X	X
199-D8-54B (RUM)	573768.24	152398.65	X	X	X	X
199-H2-1 (RUM)	577752.31	153239.89	X	X	X	X
199-H3-10 (RUM)	577545.14	152723.52	X	X	X	X
699-97-48C (RUM)	575245.39	152909.66	X	X	X	X
		Total (shallow)	**53**	**30**	**68**	**72**
		Total (deep/RUM)	**5**	**5**	**5**	**5**
		Total	**58**	**35**	**73**	**77**

a. Wells are screened in the upper part of the unconfined aquifer, except where noted: RUM = screened in Ringold upper mud unit; deep = screened in lower part of unconfined aquifer.

b. Installed as of September 30, 2015.

2.5 100-FR-3 Operable Unit

No wells are depicted in Figure 2-25 as part of the 100-FR-3 OU AWLN. Only two monitoring wells were available and reporting data until March 24, 2014; however, these wells are scheduled to be reactivated in FY 2016.

Water-level data from 12 monitoring wells are needed for the *critical* configuration. This configuration represents the minimum number of monitoring locations required to evaluate flow patterns near the shoreline. In some areas, near-river gradients may be difficult to establish. This configuration represents the minimum network required to map water levels in the aquifer. Figure 2-26 shows the proposed configuration overlaying the CY 2014 nitrate plume presented in DOE/RL-2015-07.

Water-level data from 19 monitoring wells are needed for the *near-optimal* configuration. This configuration represents a reasonable amount of monitoring locations required to establish near-river gradients, provide water-level data required to map the water table in the aquifer, and evaluate flow patterns within an area encompassing or extending beyond the delineated contamination zone. Figure 2-27 shows the proposed configuration.

Water-level data from 25 monitoring wells are needed for the *optimal* configuration. This configuration represents the optimal number of monitoring locations required to establish near-river gradients, provide sufficient water-level data required to map the water table in the aquifer, and evaluate flow patterns within an area encompassing or extending beyond the delineated contamination zone. Figure 2-28 shows the proposed configuration, and Figure 2-29 shows the monitoring wells for the initial and proposed configurations. Table 2-6 lists the monitoring wells for each configuration.

2.6 300-FF-5 Operable Unit

The AWLN for the 300-FF-5 OU is designed and maintained by Pacific Northwest National Laboratory. The proposed SAP for this OU defines 11 monitoring locations within the 300 Area Industrial Complex that provide the basis for evaluating groundwater flow and COC migration patterns within that area. Table 2-7 lists the monitoring wells for the proposed configuration. Figure 2-30 shows the proposed configuration overlaying the CY 2014 low river-stage uranium plume presented in DOE/RL-2015-07.

As indicated in the DOE/RL-2014-42, water-level data from 11 monitoring wells are needed for the *critical* configuration. Each monitoring station will consist of a pressure transducer connected to a data collection telemetry unit. The AWLN will be used to collect data at multiple locations hourly to establish migration pathways and changes in the migration pathways. The AWLN data obtained simultaneously from wells that form triangles will be used to calculate hydraulic gradients (Figure 2-30). AWLN data will also be used to evaluate water-level changes in response to river-stage fluctuations. The AWLN stations will be maintained by Pacific Northwest National Laboratory for the first 5 years of monitoring and will then be re-evaluated. Manually collected water-level data will be used to verify the automated data (e.g., to evaluate drift).

An automated river gauge will collect river-level, specific conductance, and temperature data at the same times and frequency at the remainder of the AWLN.

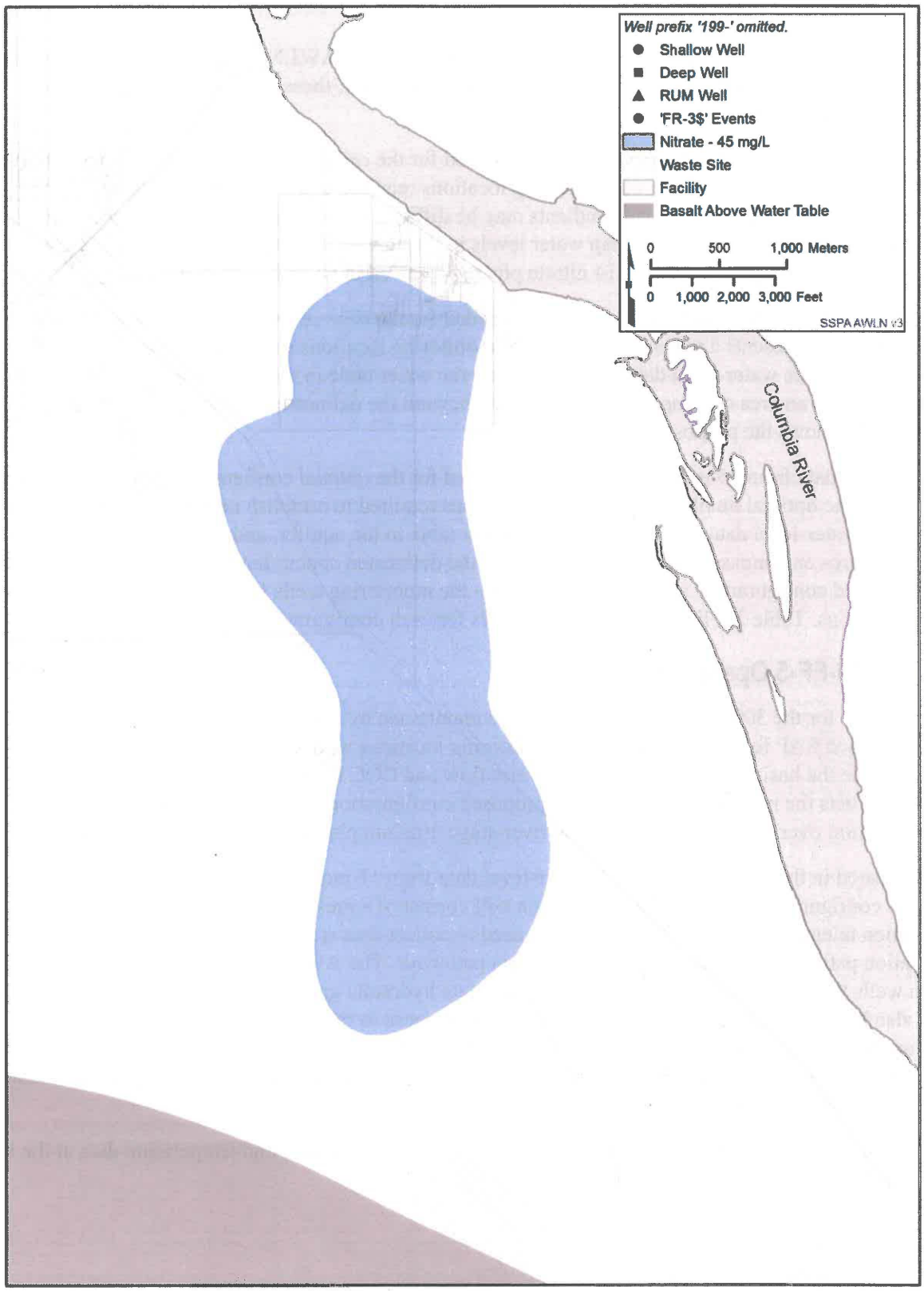

Figure 2-25. Initial AWLN Configuration for the 100-FR-3 OU

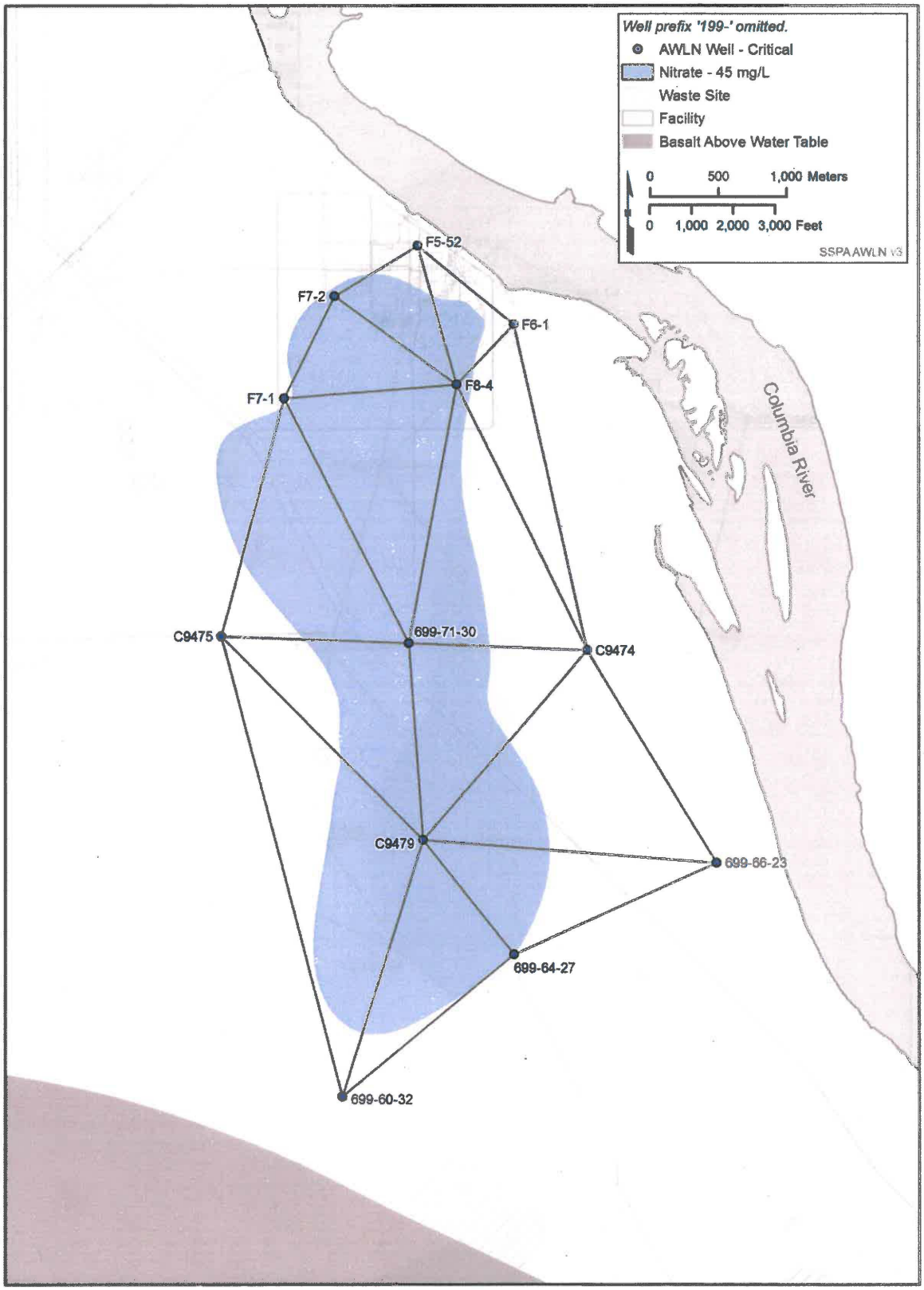

Figure 2-26. Critical AWLN Configuration for the 100-FR-3 OU

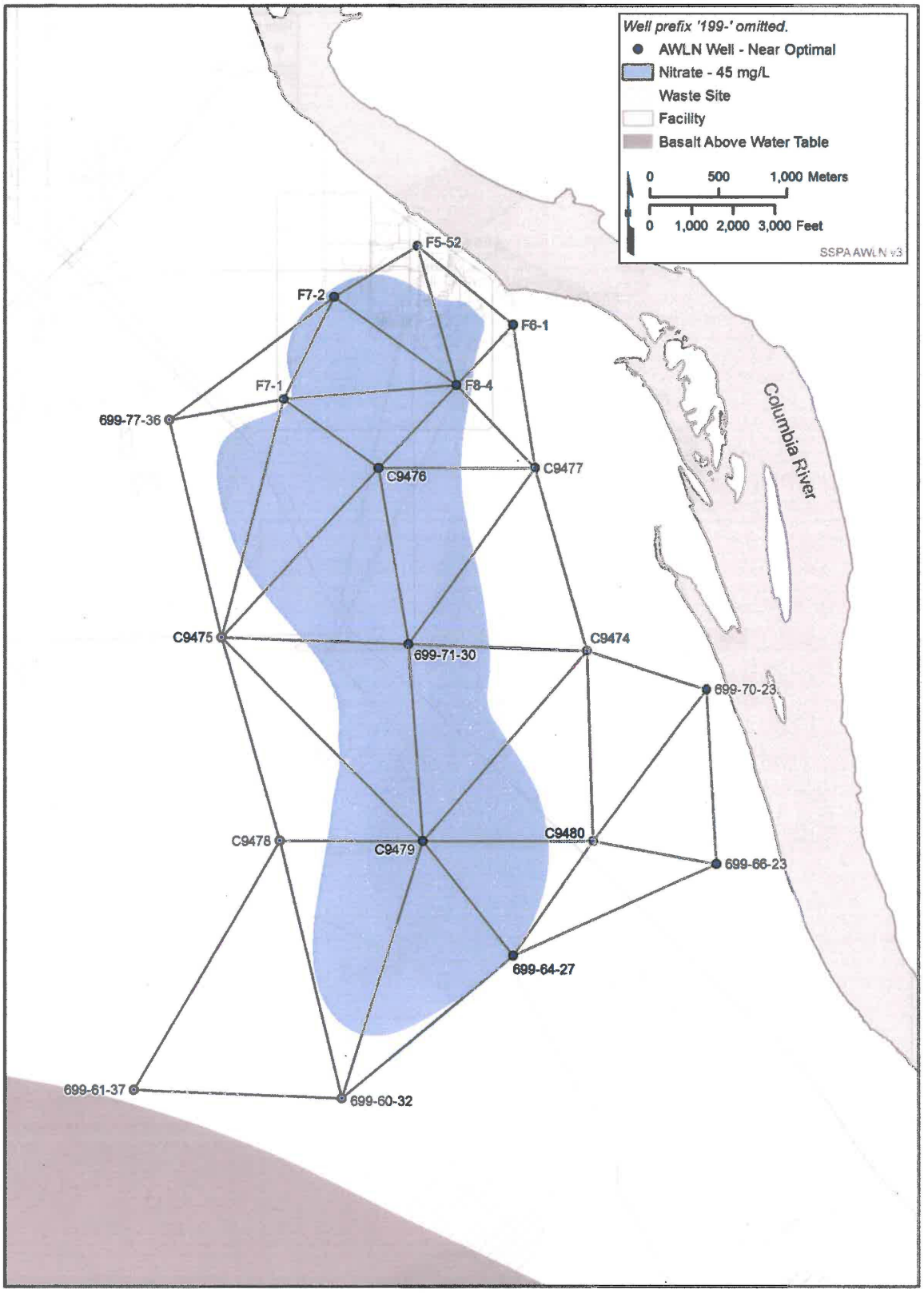

Figure 2-27. Near-Optimal AWLN Configuration for the 100-FR-3 OU

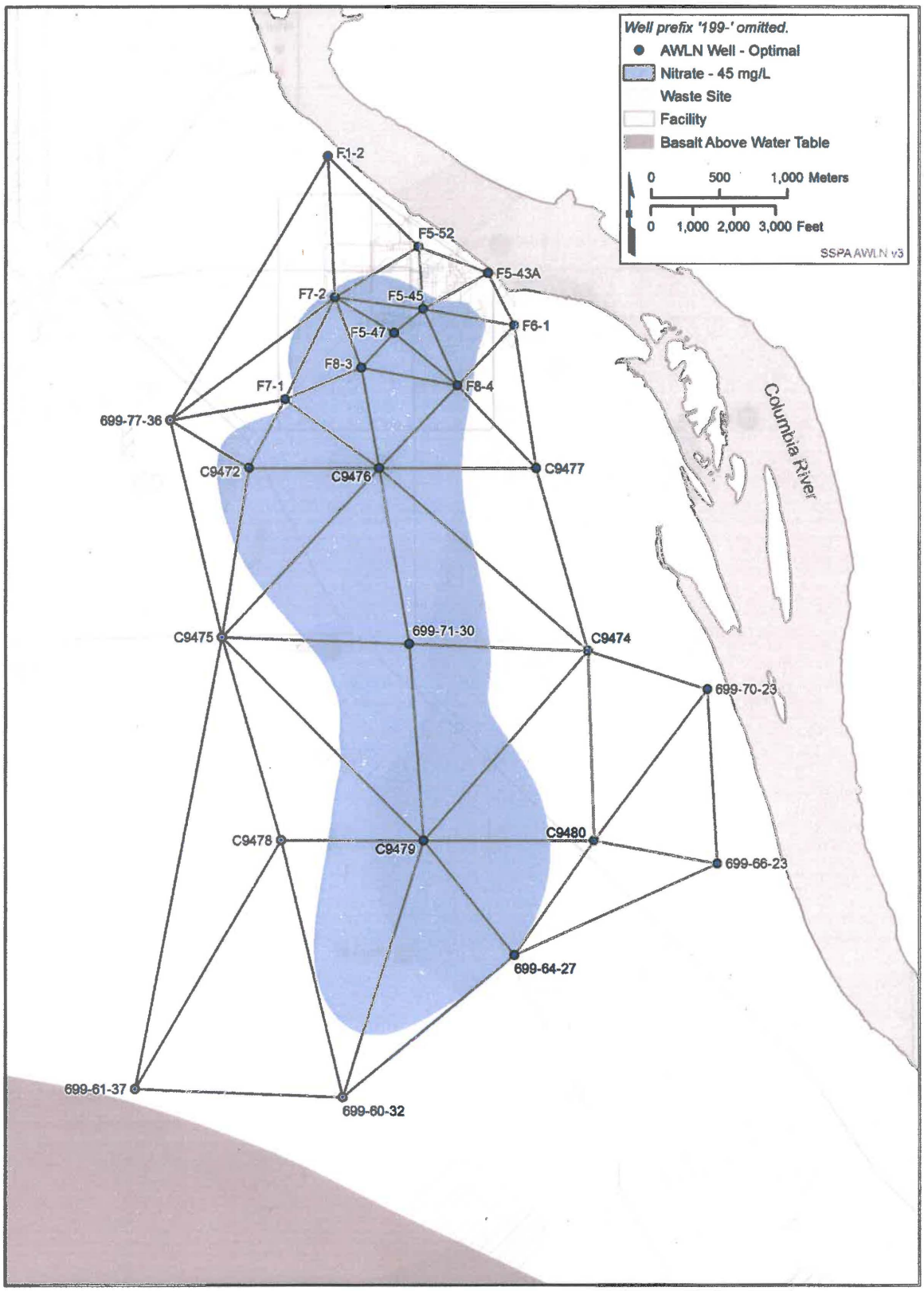

Figure 2-28. Optimal AWLN Configuration for the 100-FR-3 OU

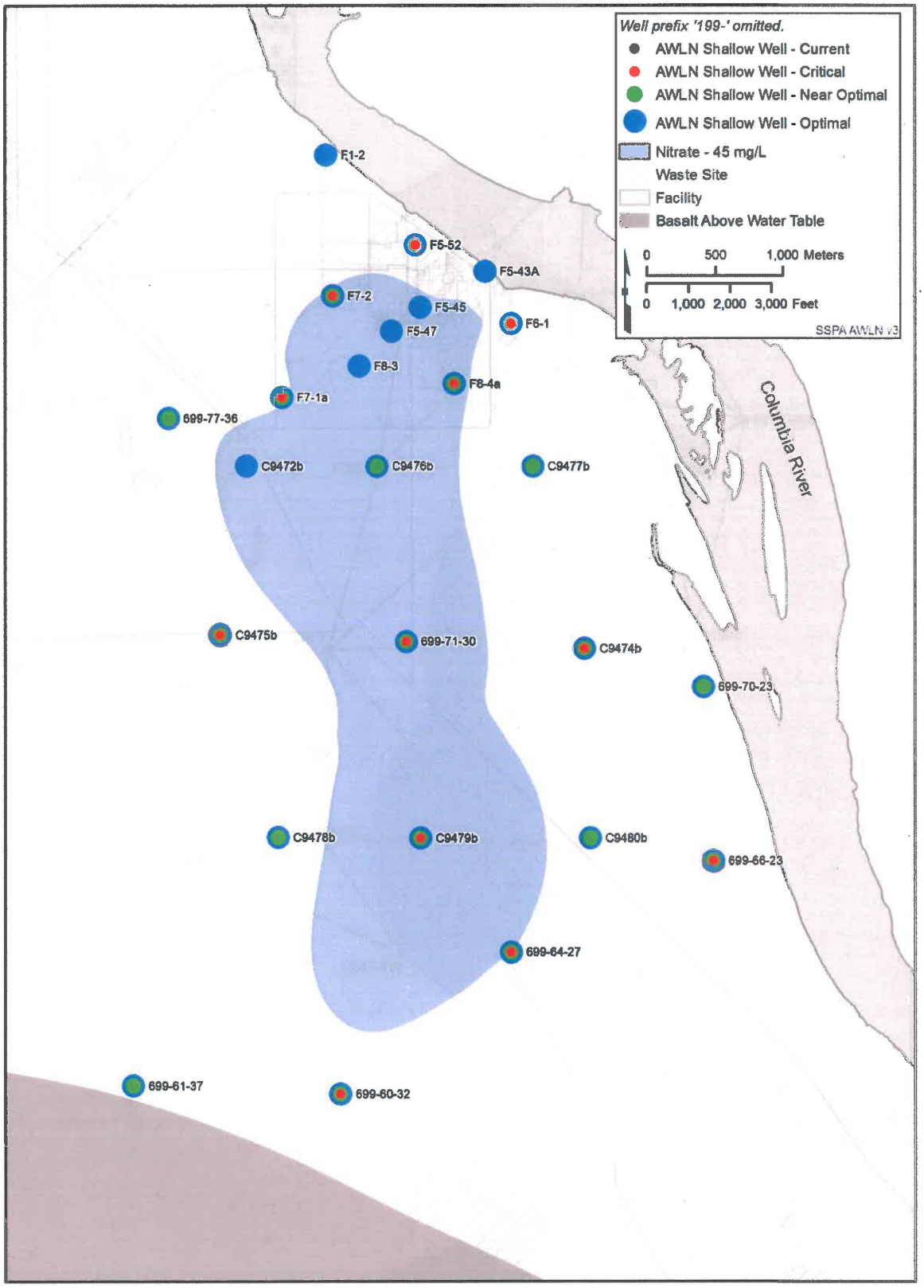

Figure 2-29. AWLN Wells for the Initial and Proposed Configurations for the 100-FR-3 OU

Table 2-6. List of Monitoring Wells and AWLN Configurations for the 100-FR-3 OU

Well Name	Easting	Northing	Initial[b]	Critical	Near-Optimal	Optimal
199-F1-2	580011.04	148805.3				X
199-F5-43A	581183.87	147948.07				X
199-F5-45	580706.88	147683.92				X
199-F5-47	580495.51	147508.45				X
199-F5-52	580672.81	148143.82		X	X	X
199-F6-1	581375.87	147564.51		X	X	X
199-F7-1a	579687.17	147022.43		X	X	X
199-F7-2	580060.04	147770.4		X	X	X
199-F8-3	580253.99	147253.37				X
199-F8-4a	580958.51	147123.53		X	X	X
699-60-32	580115.08	141901.98		X	X	X
699-61-37	578587.19	141964.33			X	X
699-64-27	581375.46	142946.08		X	X	X
699-66-23	582864.76	143617.19		X	X	X
699-70-23	582790.89	144895.82			X	X
699-71-30	580603.35	145226.91		X	X	X
699-77-36	578847.21	146868.94			X	X
C9472[a]	579424.8	146518.7				X
C9474[a]	581917.5	145173.9		X	X	X
C9475[a]	579229.9	145276.1		X	X	X
C9476[a]	580385.7	146516.3			X	X
C9477[a]	581538.1	146514.8			X	X
C9478[a]	579657.2	143788.4			X	X
C9479[a]	580708.9	143784.5		X	X	X
C9480[a]	581960.7	143783.7			X	X
		Total	**0**	**12**	**19**	**25**

a. Proposed for drilling during fiscal year 2016 (DOE/RL-2014-44-ADD2, *Remedial Design Report/Remedial Action Work Plan Addendum for the 100-F/IU Groundwater*).

b. Installed as of September 30, 2015.

Table 2-7. List of Monitoring Wells and AWLN Configurations for the 300-FF-5 OU

Well Name*	Easting	Northing
399-1-10A	594346.50	116734.00
399-1-15	593988.30	116964.20
399-1-16A	594318.10	116414.20
399-1-32	594137.50	116432.40
399-3-18	594464.70	116020.00
399-3-19	594071.90	116030.20
399-4-7	594603.20	115492.60
399-6-1	593527.20	115807.10
399-8-1	593632.20	116332.00
399-8-5A	593384.20	116565.50
699-S27-E14	594114.10	115212.70

* Maintained and operated by Pacific Northwest National Laboratory.

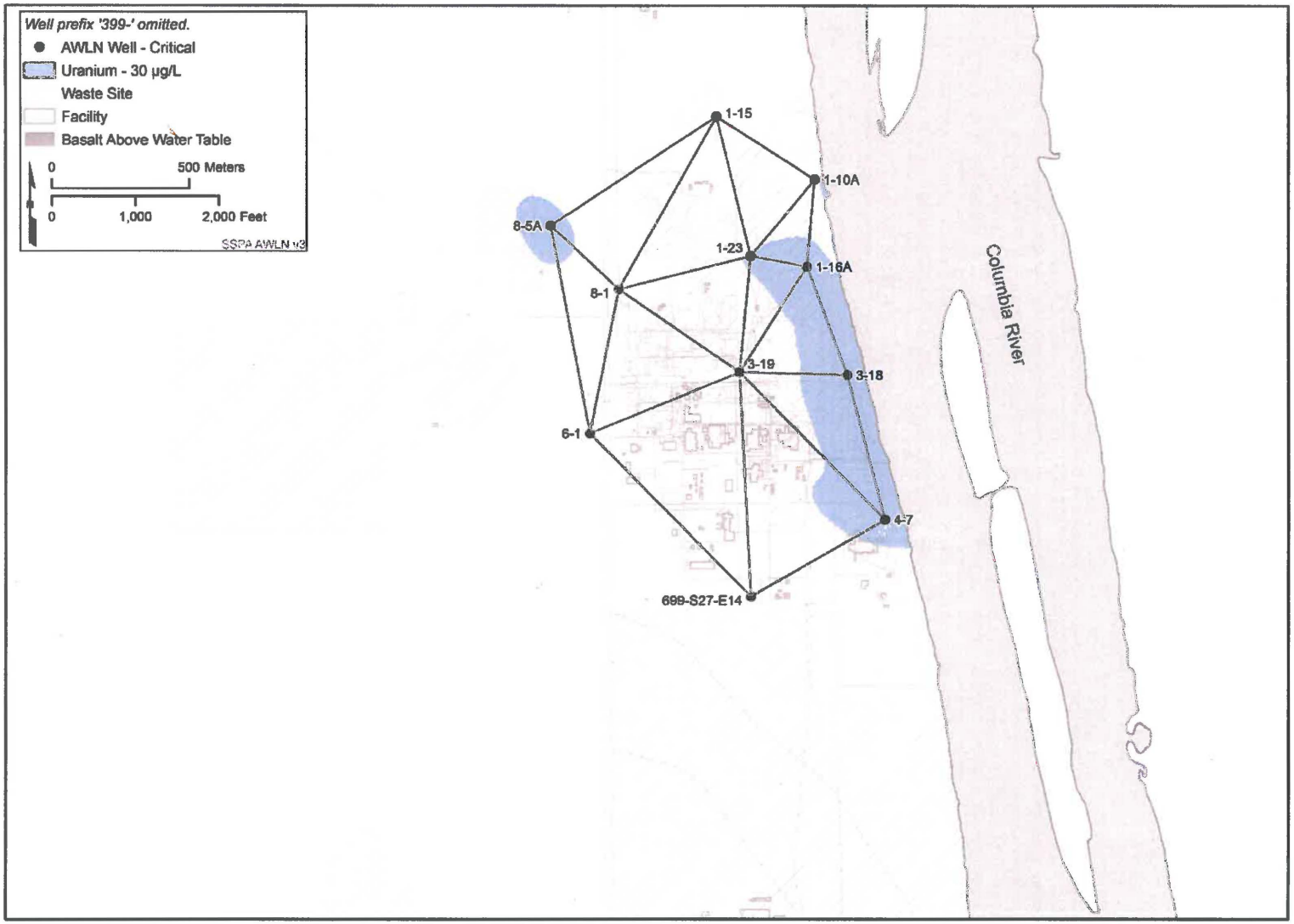

Figure 2-30. Critical AWLN Configuration for the 300-FF-5 OU

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3 Operating Requirements

The automation of water-level monitoring has several advantages compared to manual measurements, namely the ability to take simultaneous measurements across a large area at regular intervals. The stations that make up the AWLN typically record head pressure readings (in the form of mV readings or feet of water) once every hour, 24 hours per day, 7 days per week, and 365 days per year. The cost and manpower required to obtain the equivalent data manually would be cost prohibitive for any project.

The operation of the AWLN consists of the following major components:

- **Field measurements:** Automated hardware and manual field trips to measure desired data at remote stations.
- **Telemetry network:** A system that allows for remote data transmittal and retrieval.
- **Data collection and management:** Software systems for collecting, storing, and retrieving data at the base station.
- **Data processing:** Conversion of raw data to useful data, data processing, storage, and QA/QC.

Figure 3-1 illustrates the operation of the AWLN. The data collection process begins at the remote field stations. The field measurement instrumentation measures the desired data and transmits it to the base station via the telemetry network. The base station is equipped with required hardware and software to retrieve the data. The data are then sent to a data collection and management system.

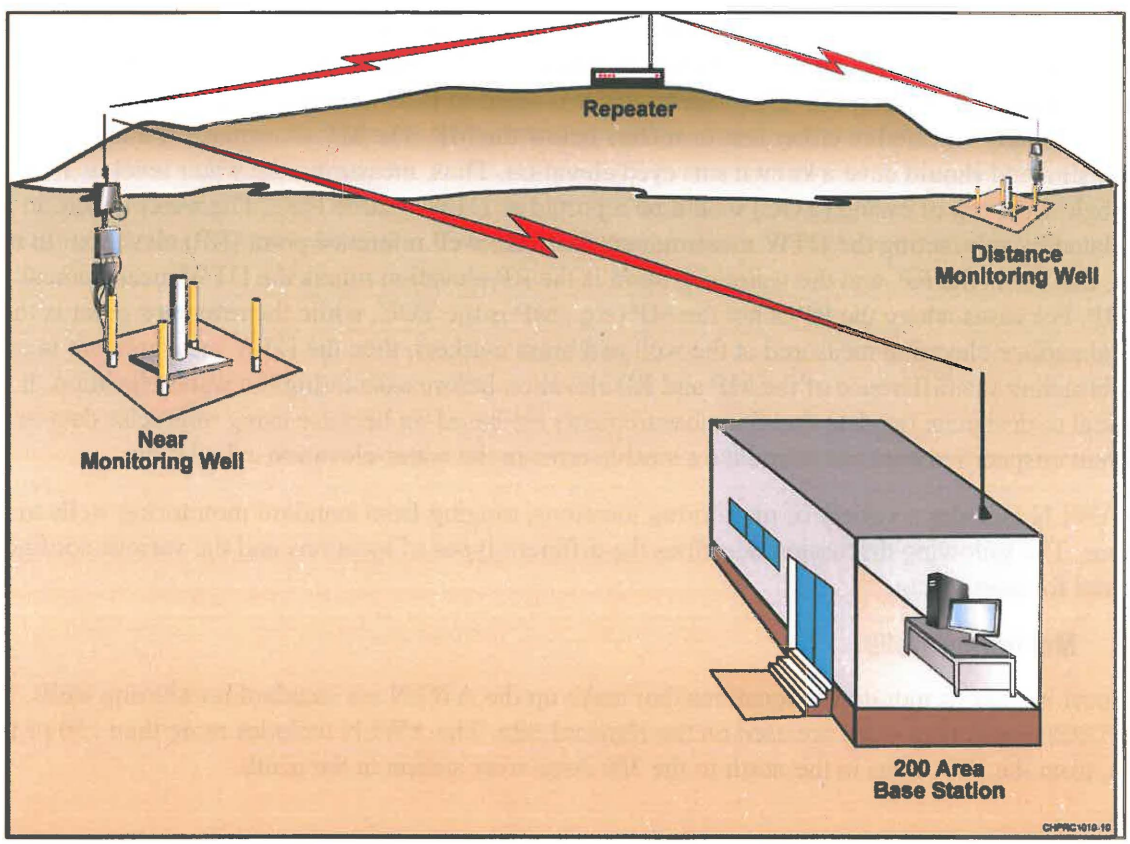

Figure 3-1. AWLN Configuration and Operation

3.1 Field Measurements

The first item determined when setting up a remote data collection station is the desired type of data to be collected. The AWLN mainly collects water-level data but can also collect other parameters, such as temperature and conductivity. The type of data desired determines the instrumentation needed, which in turn dictates the other equipment needs for the station.

After the target data and probe/sensor configuration has been selected, a compatible data collection device is selected. Commonly referred to as a data logger, this collection device is the central element of the remote station. The data logger collects the data produced by the sensors/probes and often also provides the excitation voltage and programming used by the transducers or probes to measure the target parameter.

Water-level data are measured using a submersible electronic pressure transducer that measures the pressure head exerted by the column of water above the transducer (either in mV or in feet of water, depending on the transducer). An important consideration when choosing the correct type submersible pressure transducer is the potential range of water-level change in the candidate well. Pressure transducers come in a variety of ranges, indicated by its maximum psi rating. The transducers used in the AWLN typically range from 2.5 to 14 psi. A column of water exerts 1 psi for every 2.3067 ft of water. Thus, a 2.5 psi transducer can handle up to 5.77 ft of head before being over its range and losing accuracy. Therefore, a well that has large fluctuations (i.e., near-river wells) many require a 14 psi transducer compared to a well that typically has little water-level fluctuation (i.e., an inland well in a flat-gradient location). Section 4.1.3 provides detailed discussion on the various types of transducers used in the AWLN.

A manual "tag" of a water level in a well is the starting point for all water-elevation data. The standard method for taking the water level in a well is by measuring the depth to the top of the water surface from a known measuring point (MP). This measurement is referred to as the well's depth-to-water (DTW), which is usually reported in either feet or meters below the MP. The MP is normally the top of the outer well casing and should have a known surveyed elevation. Thus, measuring the water level in a well as 20 ft below the top of casing (TOC) would be reported as DTW = 20 ft TOC. The water elevation is calculated by subtracting the DTW measurement from the well reference point (RP) elevation. In most cases, the MP is the RP, and the water elevation is the RP elevation minus the DTW measurement from the MP. For cases where the RP is not the MP (e.g., MP is the TOC, while the reference point is the ground surface elevation measured at the well pad brass marker), then the DTW measurement is corrected by subtracting the difference of the MP and RP elevation before calculating the water elevation. It is essential to designate the data that the measurements are based on because using imprecise data or using different unspecified data can introduce a sizable error in the water-elevation calculation.

The AWLN includes a variety of monitoring locations, ranging from standard monitoring wells to river stations. The following discussion describes the different types of locations and the various configurations required for monitoring.

3.1.1 Monitoring Wells

The most numerous monitoring locations that make up the AWLN are standard monitoring wells. More than 5,000 monitoring wells are used on the Hanford Site. The AWLN includes more than 150 of these wells, from the 100 Areas in the north to the 300 Area river station in the south.

3.1.2 River Stations

The AWLN river stations are in several different configurations and are dependent on the structures available at each location. The configuration styles and locations of the river stations currently part of the AWLN are as follows:

- **Building/roof configuration:** The station at the 100-D Area is mounted on the roof of the 181D river pump house. The transducer is installed inside a stilling pipe from the building roof.
- **Outfall structure or slope configuration:** The stations at the 100-F (formerly) and 100-H Areas are installed at locations that do not have a nearby building to mount the stations. Instead, a concrete outfall structure was used at the 100-F Area (which has since been removed) and the uniform slope of the shoreline is used at the 100-H Area.

3.2 Telemetry Network

Retrieving data from remote sites can be difficult, depending on the station's location. The AWLN collects data from field stations across the site through radiofrequency (RF) telemetry, although onsite manual downloading via laptop can be performed if necessary. Data loggers can be accessed remotely by RF telemetry, which requires no physical connection from the base station computer to the data logger. The RF telemetry link reduces the number of visits to a remote site for data collection. The RF telemetry systems are designed for complete remote control of field stations via a base station computer.
The telemetry system is controlled using computer software that assists with the programming, data collection, and retrieval and storage of the data collected over the entire network. The AWLN telemetry system uses Campbell Scientific Inc.® LoggerNet software to collect the data from the data loggers, transmit data logger programs, and perform real-time monitoring from individual data loggers.
The AWLN RF telemetry network is limited by the physical limitations of ultra-high-frequency (UHF) radio communication, which includes the following:

- The distance between radio stations cannot be greater than 40.2 km (25 mi).
- The stations cannot have major obstacles between them; therefore, the stations must be within line-of-sight of each other.

Radiotelemetry is the process of transferring information (data) in the form of radiowaves. The data are transferred on a carrier wave, which normally has a sinusoidal form. Therefore, the carrier wave can be described entirely by the frequency, amplitude, and phase with respect to a reference. The commonly used term for radiotelemetry, RF, refers to radiofrequency, which in actuality is the frequency of the carrier wave. Radiowaves can be divided into three categories: (1) ground waves, (2) direct waves, and (3) sky waves. All AWLN communication is performed via direct waves. Direct waves travel line-of-sight at a maximum distance of approximately 40.2 km (25 mi). Energy is lost from radiowaves as they travel away from the transmitting antenna. One reason for this is the loss due to dispersion of energy over a larger area, similar to water waves reducing in size (energy) as they get farther from the source. This is also due to energy that is absorbed by the earth over the distance of travel. Eddy currents cut down signal power, and intervening terrain and buildings can prevent a signal from being strongly received.
The higher the frequency, the stronger the radiation field; however, at higher frequencies, more energy is absorbed by the ground surface. The very high frequencies (VHFs) and UHFs can travel only a short distance between radio stations. The direct wave (when there are no obstacles between stations) will transmit further than any indirect waves that have been transmitted through or reflected from obstacles.

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The AWLN primary carrier frequency is 411.0125 MHz (UHF), with a legacy frequency of 419.099625 MHz (UHF).

The carrier wave can be thought of as the "vehicle" that carries the data from one radio to the next. The data is carried as an electrical signal that rides like a package in a vehicle (the carrier wave) from the sending station to the base station. The process of placing the data, as a signal, on the carrier wave is called modulation. The signal is also in the form of a wave, but usually the signal has a much lower frequency. The carrier with the modulating signal is called the modulated carrier and can be visualized as a vehicle with a package inside. The signal wave is not used as a carrier wave because radio transmission must be of a high frequency to keep radio components small, antennas small, filtering efficient, and to isolate the radiowaves from common low-frequency, man-made noise. The main forms of modulation are amplitude, frequency, and pulse modulation. Frequency modulation is used by the AWLN. Each station is given a unique address so the base station can differentiate the data packages from each station.

3.3 Data Collection and Management

The key to communicating with the field stations is the Campbell Scientific Inc.'s software LoggerNet 4.0 (or the most recent version). Additional information on the software is provided in the LoggerNet user's manual.[1]

LoggerNet is designed to use a unique communication path for each data logger field site. A typical RF communication path starts with the base station computer, which is connected to an RF base station (typically through the computer's serial port), and then through the RF base station to each field station's radio and modem before connecting to the field station data logger. Each station is part of the network map that is set up in the LoggerNet software. Each field station is assigned a unique RF address that allows LoggerNet to differentiate the incoming signals and place each station's data in its own file.

If remote automated data collection is not possible, the data can be collected by visiting the station in the field, where the data can be transferred from the data logger to a laptop computer. Data files are then sent to the system administrator for review and processing.

3.4 Data Processing

The raw data collected by the AWLN stations depend on the type of measurement probe used (e.g., data from a pressure transducer can be in either mV or in feet of water). The data are relative to the individual transducer placement and well. To be useful for hydraulic analysis, the raw values must be converted to elevation with common data. Over the last several years, newer transducers called smart probes have replaced the differential mV reading transducers and require less processing to determine the final water elevation measure. However, even the newer transducers require some processing.

Pressure transducers measure the column head pressure of the water above the transducer in the well. These measurements in older transducers are recorded in mV, and in the newer CS450 or CS451 models are recorded in feet of water. The head measurements are relative and are particular to the individual well in which the transducer is installed. To convert the measurement to an elevation measurement to be used for a variety of purposes, a point of reference must be established; the transducer data then records the change in the water level from that point. Therefore, elevation calculations based on transducer data must start with a referenced point in time. This reference point in time is the combination of a DTW

[1] The user's manual for LoggerNet software is available in PDF format on the Campbell Scientific, Inc. website at www.campbellsci.com.

measurement (measured with an e-tape) and the corresponding transducer measurement. The calculation is performed using Equation 3-1:

$$Elev.Well = RP - DTW_{ref} + (XD - XD_{ref}) \times SF \qquad \textbf{(Equation 3-1)}$$

where:

RP	=	elevation of the surveyed reference point
DTW_{ref}	=	depth-to-water from the measurement point (adjusted for any difference from the surveyed reference point) at the reference time
XD	=	current transducer measurement
XD_{ref}	=	transducer reading at the reference time
SF	=	scale factor for the subject transducer (for CS450 or CS451 transducers, this is simply 1, as the mV reading is converted to feet of water internally)

The DTW is typically recorded in feet and the scale factor converts the transducer mV reading into feet of water. The measurements, as they are typically taken for the AWLN, are calculated using Equation 3-2:

$$Elev.Well = RP - (DTW_{ref} \times 0.3048) + ((XD - XD_{ref}) \times SF) \times 0.3048 \qquad \textbf{(Equation 3-2)}$$

where 0.3048 is conversion factor from feet to meters.

Figure 3-2 illustrates the typical setup of a transducer and the parameters used in calculating the water elevation in a well. In this case, the MP is equal to the surveyed RP. AWLN water elevation data are calculated and reported in meters using the survey data for the individual well's MP, which is based on *North American Vertical Datum of 1988* (NAVD88).

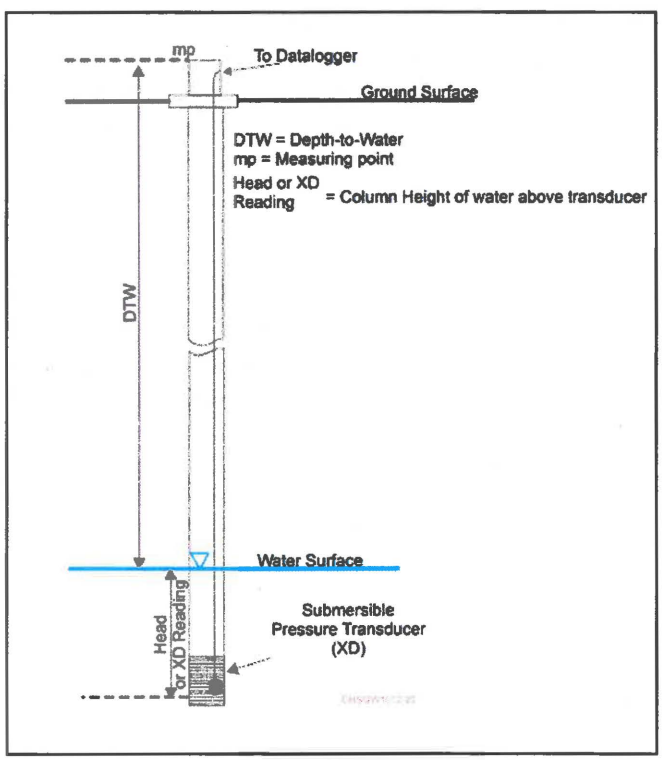

Figure 3-2. Typical Transducer Setup

Equation 3-3 shows an example of the calculation of a water elevation measurement from raw data using actual readings obtained from well 199-D5-36:

$$MP = 143.855;\ DTW_{ref} = 85.65;\ XD_{ref} = 7.2762;\ SF = 0.9998 \qquad \textbf{(Equation 3-3)}$$

Time Stamp	XD
6/16/2010 0:00	8.5054
6/16/2010 1:00	8.5186
6/16/2010 2:00	8.5165
6/16/2010 3:00	8.5267

$$Elev.Well = MP - (DTW_{ref} \times 0.3048) + ((XD - XD_{ref}) \times SF) \times 0.3048$$

$$Elev.Well = 143.855 - (85.65 \times 0.3048) + ((8.5054 - 7.2762) \times 0.9998) \times 0.3048$$

$$Elev.Well = 143.855 - (26.106) + ((1.2292) \times 0.9998) \times 0.3048$$

$$Elev.Well = 143.855 - (26.106) + (0.3745)$$

$$Elev.Well = 118.124$$

The data collected at the AWLN field stations depends on the data needs for that station. Most stations typically collect water-level data from one to three wells. The format of the raw data is determined by the station's data logger. Older data loggers (e.g., CR10, CR510, and CR10X) are array-based data loggers and collect data based on a set array of parameters. In the data logger program, each parameter (or set of parameters) is assigned an array identification (ID) number, and each line of data is given the array ID number that corresponds to that set of parameters. A station's battery voltage is read once every 12 hours (i.e., noon and midnight), which allows remote checking of the battery state. A station battery is considered to be normal when the battery reading taken at the noon reading is >12 volts (while the solar panel is charging) and the battery does not significantly drop in voltage (<11 volt reading) at the midnight reading. A significant drop in voltage is an indicator that the station's battery has lost the capacity to hold a charge and the battery should be replaced. If the station's battery voltage drops below 9 volts, the station data logger will not function.

Newer data loggers use a table format in collecting data. In this format, the data are collected in tables that are defined in the programming. The battery check data is collected in a separate table in an individual file (or, more recently, added as an additional column in the hourly data file). In the most recent table format, the Julian day and clock time is replaced by a time stamp in the format of "YYYY-MM-DD hh:mm:ss." There is no array ID, and a record number is inserted between the time stamp and first parameter reading.

Depending on the type of transducer, a scale factor may need to be applied to the raw measurement to convert head readings from mV to feet of water. Some transducers (smart probes) perform the calculation internally and report the measurements in feet of water.

4 Design Requirements

For optimal operation, all AWLN components need to work seamlessly. This chapter describes various AWLN design requirements, including a detailed discussion of the equipment and controls.

4.1 Equipment and Controls

The AWLN consists of several different types of stations: (1) field stations, also referred to as monitoring stations, which cover the component of field measurements; (2) repeater stations, which are dedicated stations that rely on the radio signals between the base station and the targeted field station covering the component of the telemetry network; and (3) the central base station, which is connected to the central computer operating the LoggerNet software and collects the data from the individual field stations and facilitates data collection and management.

4.1.1 Field Stations

A field station is the central point of data collection and communication for the AWLN. Each station comprises the following equipment:

- **Weather box:** A white, weather-tight enclosure that protects the data collection and telemetry equipment. The AWLN uses the Campbell Scientific, Inc. ENC-12/14 weatherproof enclosure.
- **Data logger:** The central data collection unit that also executes the program operating the station's probe(s). The data logger also interfaces with the telemetry equipment.
- **Transducers and sensors:** Provides pressure and temperature measurements. The transducer/sensor is installed in the well at a fixed depth below the water.
- **Telemetry equipment (radio, modem, and antenna):** The typical radio for the AWLN is a UHF transceiver tuned to one of the two network operating frequencies. The modem for each station is compatible with the station radio and connects the radio to the data logger. An antenna is mounted on the top of the station mast with cable connecting inside the weather box to the radio. The AWLN antennas are tuned to the UHF range of the station.
- **Power supply:** Can be a combination of an external and internal battery, with a regulator or an internal battery and regulator. The external battery is typically an automotive-style battery in a container that is separate from the weather box. The internal battery (typically a small motorcycle-type) is located in the weather box and is typically part of the power supply component that contains the regulator.
- **Solar panel:** Typically connected to the station mast and is wired to the regulator inside the weather box. The solar panel charges the station battery to allow for long-term, uninterrupted operation.

4.1.2 Data Loggers

The AWLN has been used for more than 20 years (since startup in May 1991), and data logger technology has vastly changed over time. The older models of each type of equipment are being phased out and will ultimately be replaced with updated equipment.

The original AWLN data loggers, the CR10, had much less storage capacity then the later generations and also had volatile memory. The more current standard data loggers, the CR800 series, have 4 MB of memory that is nonvolatile. The data loggers currently used in the AWLN are listed below:

- **CR10:** The earliest data logger used by the AWLN, this data logger has volatile memory and is being phased out.
- **CR10X:** This is the nonvolatile replacement of the CR10. This model is no longer manufactured by Campbell Scientific, Inc., and the more current model has been upgraded to a Pak-bus operating system.
- **CR510:** This is a nonvolatile model that is smaller and used for stations that only require one six-wire transducer (Figure 4-1).
- **CR1000:** This is the Pak-bus/table format model that is the current replacement for model CR10X.
- **CR800 series:** This is the Pak-bus/table format model that is the current replacement for model CR510. It is smaller and typically has less storage than the CR1000.

The original data loggers used by the AWLN were Campbell Scientific, Inc., model CR10, which collected data in onboard volatile memory in an array format. Each data type was recorded under an array ID number, which was followed by a Julian day time/date stamp and then the recorded data readings. The next generation of data loggers, CR10X and CR510, were also array-format data loggers but had onboard, nonvolatile flash memory. Later versions of the CR10X and CR510 were loaded with a tabular data operating system.

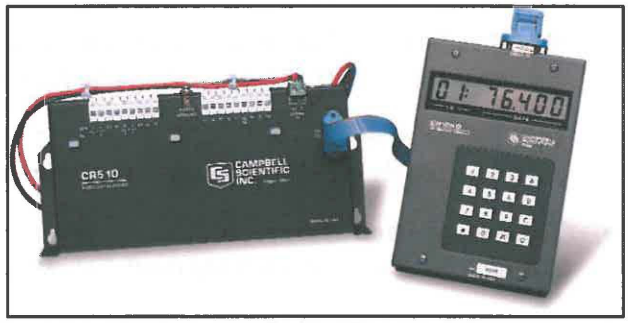

Figure 4-1. Data Logger Model CR510 Using an Array Format

The latest generation data loggers, the CR800 series and CR1000 (Figure 4-2), have been manufactured with greater memory capacity, work with a tabular data collection format and CRBasic programming language, and are enabled with Campbell Scientific Inc.'s proprietary CRBasic communication protocol. A summary of features of the various data loggers is provided in Table 4-1.

Figure 4-2. Data Logger Models CR800 and CR1000 Using CRBasic Format

Table 4-1. Summary of Features of Various Data Loggers

	CR10	CR21	CR10X	CR23	CR510	CR800	CR850	CR1000
Format	Array	Array	A/T	A/T	A/T	Table	Table	Table
Memory	Volatile	Volatile	Non-volatile	Non-volatile	Non-volatile	Non-volatile	Non-volatile	Non-volatile
Capacity	560 kB	560 kB	1 MB	1 MB	1 MB	4 MB	4 MB	4 MB
Inputs	12 Analog	7 Analog	12 Analog	24 Analog	4 Analog	6 Analog	6 Analog	16 Analog
Programming	EdLog	EdLog	EdLog	EdLog	EdLog	CRBasic	CRBasic	CRBasic
Operating System	—	—	—	—	—	PakBus	PakBus	PakBus

4.1.3 Transducers and Sensors

The AWLN currently uses two different types of transducers, both of which are vented through the signal cable to compensate for barometric pressure.

Figure 4-3. Druck PDCR Series Transducer

Druck PDCR-series transducers include models 940/950 and 1830-8388, which use differential voltage readings (in mV) to measure the pressure against the sensor diaphragm and measure the head pressure. These transducers (Figure 4-3) have pressure ranges of 1, 2.5, 5, 10, and 30 psi, with an excitation range of 0 to 2,500 mV.

The CS450 or CS451 transducers, referred to as "smart probes," consist of a piezoresistive sensor and a temperature sensor housed in a 316 L stainless-steel case. The CS451 model transducer (Figure 4-4) replaces the CS450 model, which is no longer available. The CS451 is designed to provide a reliable, accurate pressure/level measurement that is fully temperature-compensated. The transducer reverts to a low-power sleep state between measurements. A series of measurements are performed to determine a temperature and pressure value. This measurement cycle takes <1.5 seconds. The transducer can also be configured to output pressure only in <1 second. The measurement cycle is activated by using the SDI-12 or RS-232 terminal commands.
The default output units of the measurements are psig and degrees Celsius but can be changed by the field station data logger's programming.

Figure 4-4. CS451 Transducer

4.1.4 Telemetry Equipment

The AWLN is a telemetry-based system that uses UHF transceivers (Figure 4-5) to communicate with a central base station and computer. Each field station is equipped with a radio and modem that are connected to both the data logger and an external antenna. This setup allows the base station to "call" the field station and request data, and the field station then transmits the requested data to the base station to be uploaded to the SQL database. The AWLN telemetry communication operates on two different frequencies: 419.99 MHz and 411.0125.

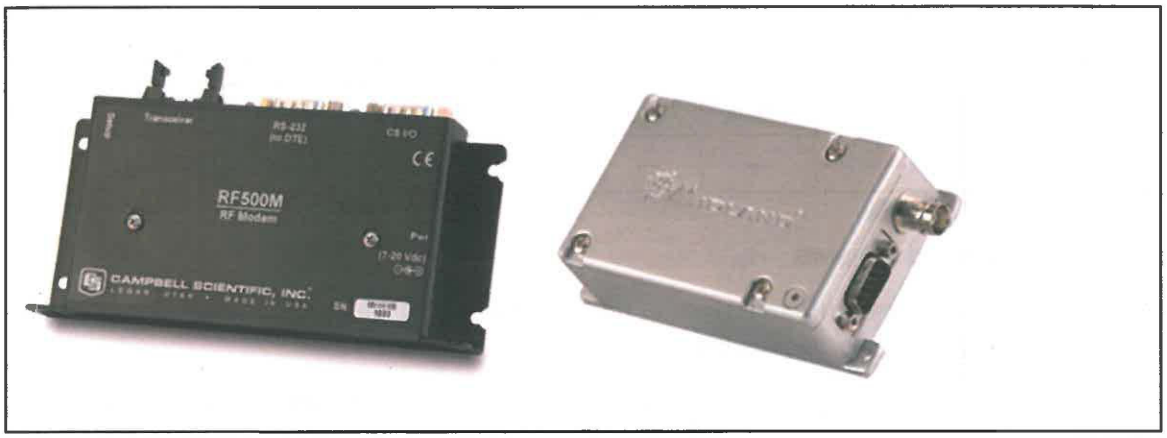

Figure 4-5. Transceivers

The purpose of a transceiver (radio) is to both transmit and receive modulated carrier waves. The radio is similar to a station entry way or a garage door from which the vehicle (carrier wave) carrying a package or letter (data or command information) enters or exits the station. The main component in the transmitter is the oscillator, and the frequency of oscillation is provided electronically (or in the case of older radios, by a crystal). The electronics (or crystal) oscillates at a desired frequency, which is specific for the carrier frequency. The oscillator converts direct-current power to an alternating-current signal. This signal is then amplified, modulated with the signal, and transmitted through the antenna. The receiver consists of an amplifier, frequency converter to slow the signal, a limiter to provide constant amplitude but the same frequency, and a discriminator or demodulator. The radio has a known impedance, or resistance. Maximum power is transferred if the impedance of the radio matches the impedance of the antenna and cable (the impedance is generally 50 ohms). Mismatching of impedance will cause less transmitting power and will result in a higher voltage standing wave ratio (VSWR). When the transmission cable and antenna do not match the impedance of the output circuit of the radio, all of the energy fed down the cable will not flow into the antenna. A percentage of the energy will be reflected back forming standing waves on the cable. The ratio of voltage across the line at the high voltage points to that at the low voltage points is known as the VSWR. When the VSWR is ≥3.0:1, the percentage of errors per data value is >50%. The VSWR should be maintained <1.5:1 for error-free radiotelemetry.

The RF modem is the main communication control device in a radiotelemetry network. The RF modem enables a central base site to communicate with up to 254 different RF stations. The RF modem is a microprocessor-controlled device that codes all transmissions for a specific communication path. Each has a hardware ID switch to identify different stations. The purpose of the RF modem is to control operation of the radio and protect data integrity. The RF modem controls the communication sequences, sets data to be transferred into data blocks, creates signatures of data blocks, modulates the radio carrier wave, and stores information on communication quality. The user at the computer is responsible for naming the desired communication path with a setup string. This setup string contains any repeater or

middle-of-the-line (MOL) modem IDs and the destination or end-of-line (EOL) modems ID in sequence. After sending this information to the RF system, all of the RF modems in the specified link (similar to a vehicle travel path or road) will set themselves in the proper mode. The RF modem has different modes to distinguish responsibilities at various localities within a link. Establishing an RF link consists of setting all RF modems in the proper mode and receiving a verification block from the EOL modem (destination). The modem is similar to a gate keeper and package/letter checker. The RF modem does not let packages or letters intended for other stations to enter its station, but it also assists vehicles that are bound for other stations that are not directly accessible to get to their destination (EOL).

4.1.5 Power Supply

Each AWLN field station is self-contained and self-powered with a combination of battery, regulator, and solar panel to provide the 12-volt power supply that the station requires. The following are elements of the power supply system for a typical field station:

- **Solar panel:** Either 10 or 20 watts, with some of the 20-watt panels being self-regulating.
- **Internal power supply and regulator:** Usually a PS-100 with and internal motorcycle-style, 12-volt battery included.

  Beginning in 2015, a relay switch and program modification have been added to turn the radio and modem off and conserve power during darkness, then turning power back on during daylight hours. The systems collect data during this period but do not transmit to the base station.
- **External battery:** Usually in the form of an automotive-style, 12-volt battery contained in a separate battery box and connected to the data logger by a power cable. An example of a power supply system is shown in Figure 4-6.

Figure 4-6. Power Supply Systems

4.1.6 Manual Measurement

The device used to measure a DTW on the Hanford Site is known as an electronic sounder measuring tape, or e-tape (also referred to as a water-level meter). The standard e-tape used on the AWLN is an RST Model WL2030 e-tape (Figure 4-7). This device consists of a nonstretch, flat, metal tape, permanently marked in 1/100 ft or 1 mm graduations, and wound on a reel. The tape has two conductor cables on either side of the tape that serve to both lower the probe and connect the probe to the output circuit board in the reel. An insulating gap in the probe serves as a switch, closing upon contact with the water. The closed circuit creates a signal that is amplified and fed to the reel's light/buzzer, thereby signaling contact with the water both audibly and visually. Since the water acts as the electrolyte, a sensitivity adjustment is provided to compensate for the varying conductivity of the water in the well measured. E-tape comes in a variety of materials, graduations, and lengths. It should be noted that the water being measured must contain sufficient dissolved ions in order to complete the electrical circuit in the end of the probe, thus indicating water contact. E-tape will not operate in deionized water or any nonconductive liquid.

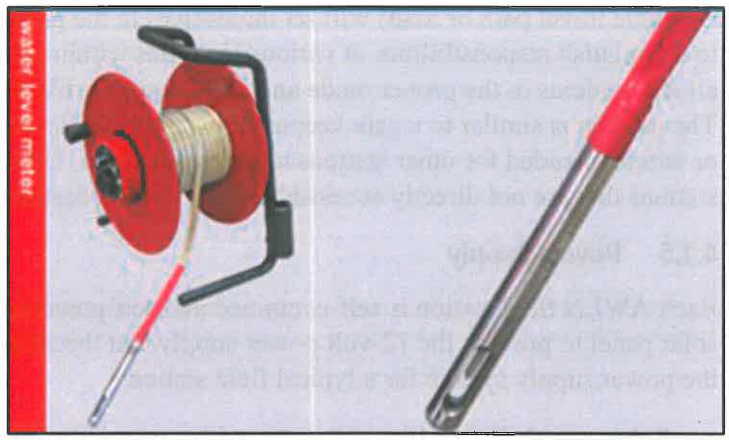

Figure 4-7. E-Tape

4.1.7 Unique Configurations

Unlike well locations, transducers at river stations do not hang from an outer casing. Most river stations use a stilling pipe that is installed from a structure that allows a straight drop into the river. The MP is typically a surveyed point on the structure at which an accurate DTW can be made and is hydraulically connected to the point that the transducer is measuring. An exception to this is the river station at the 100-H Area (Figure 4-8), where the stilling pipe is inserted at a known angle and the reference DTW is multiplied by the sine of the angle the pipe makes between the river and the MP. In this case, the water elevation equation is modified as follows (Equation 4-1):

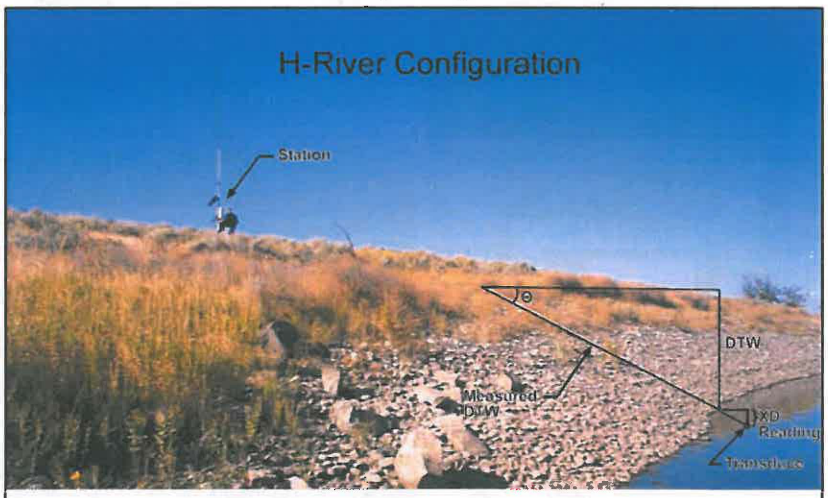

Figure 4-8. 100-H Stilling Pipe Configuration

$$Elev.Well = MP - ((DTW_{ref}) \times Sin\Theta) \times 0.3048) + ((XD - XD_{ref}) \times SF) \times 0.3048 \qquad \textbf{(Equation 4-1)}$$

where Sin Θ is the sine of the angle of the stilling pipe.

4.1.8 Repeater Stations

The purpose of a repeater station is to relay information between two communicating stations separated by a long distance or by an obstacle that impedes direct line-of-sight communication (e.g., a tall ridge or mountain). A dedicated repeater is not always required in an RF telemetry network, as field stations can also be used in the role of a repeater.

A dedicated repeater station requires the following equipment:

- UHF transceiver radio
- RF modem with radio and data logger cables
- Power supply and solar panel
- Antenna and RG8 cable (to connect to the radio)

4.1.9 Base Station

The base station is the central collection point for all field stations in a telemetry network. The base station is connected to a computer running software that allows it to communicate with the field stations. Data are retrieved, field stations are remotely programmed, and systems can be analyzed from the base station. A base station requires the following equipment:

- Radio
- RF base station
- Computer with LoggerNet software
- Antenna with cable
- Power supply with alternating-current converter

One feature of LoggerNet software is automated data collection. LoggerNet can be setup to call each station based on time. The AWLN is setup for a weekly automated download. Each station is mapped, and a scheduled collection time is set. The collection interval, primary retry interval, number of primary retries, and secondary retry interval are set in the LoggerNet setup configuration. Figure 4-9 shows a screen capture of the LoggerNet setup screen showing the hardware tab.

Because of the nature of RF communications, calls for data are not always successful. Therefore, the automated setup for data collection has a built-in mechanism to ensure that each station has multiple opportunities to download data. LoggerNet has a primary retry interval setting, which is the time between calls when the first call attempt failed. The "number of primary retries" option is how many times the software will continue to call when the call fails.

The time between each call is the primary retry interval. After the number of primary retries is used up, LoggerNet will go into the secondary retry interval (if this option is enabled). The secondary retry interval will continue until the call is successful or the schedule is turned off. The secondary retry interval is usually set to a longer period (e.g., hours rather than minutes). Figure 4-10 is an example of the schedule tab for station 179, which monitors the river at the 100-D Area. In this example, the first call will be initiated at 4:15 a.m. (base time) every 7 days (collection interval). If unsuccessful on the initial try, LoggerNet will try every 2 minutes (primary retry interval) for three tries (number of primary retries). If the three primary retries are also unsuccessful, LoggerNet will attempt retries every 2 hours (secondary retry interval) until the station has successfully downloaded the data, or the schedule is altered or turned off.

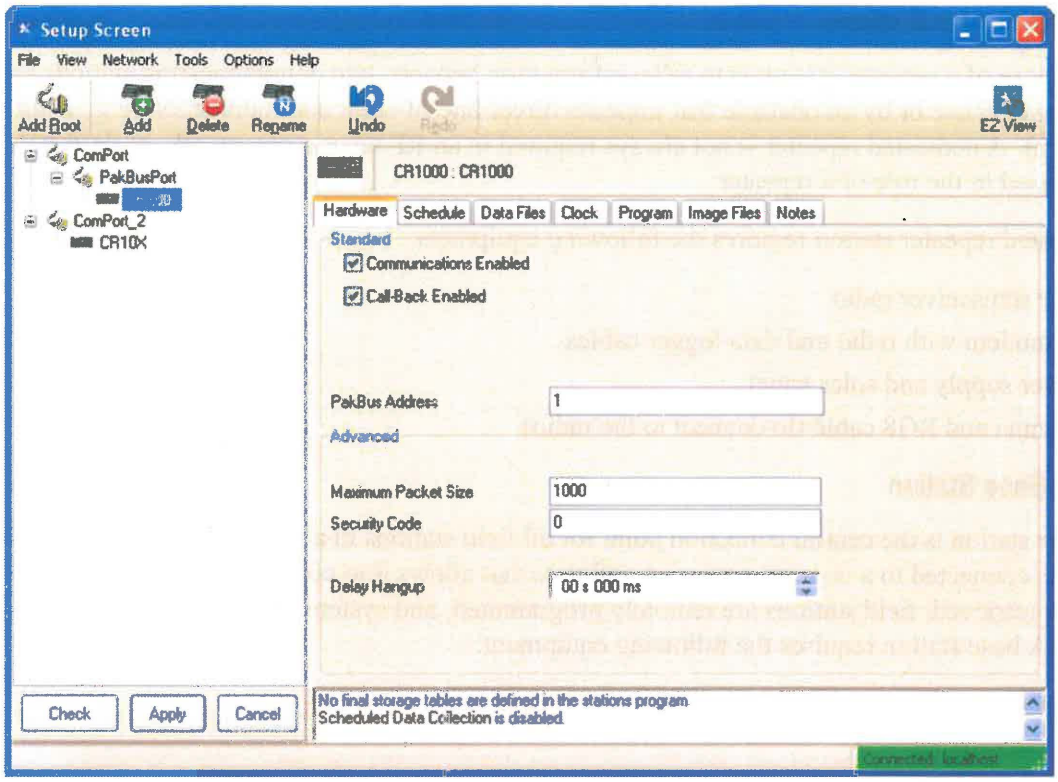

Figure 4-9. LoggerNet Setup Screen – Hardware Tab

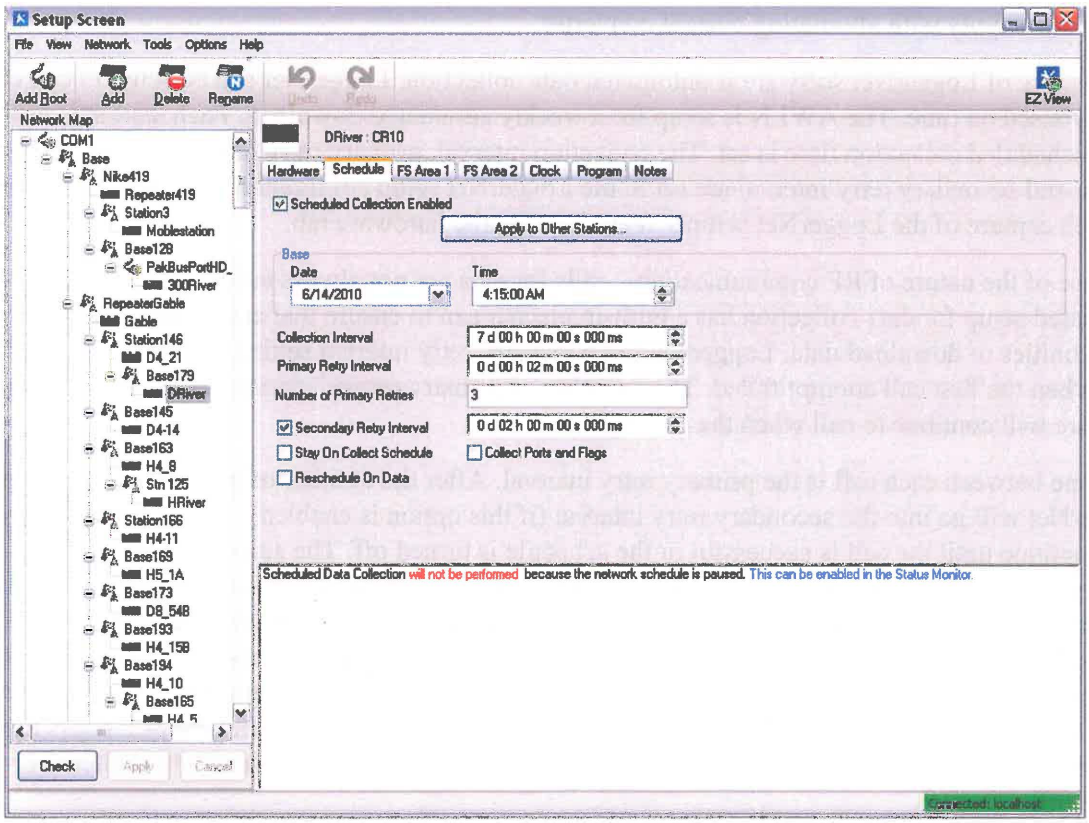

Figure 4-10. LoggerNet Setup Screen – Schedule Tab

The network downloading status can be monitored using LoggerNet's status monitoring screen. Figure 4-11 shows an annotated screen capture of an actual download session. This example shows the December 13, 2010, download from the D-River (station 179). The far-left column shows the communication path, which starts from the base computer's COM1 port, goes through the base station, then through the repeater at Gable Mountain and station 146 at well D4-21, and then ending at D-River station 179. The far left of the left-hand column shows the communication status, which is normal. The next column to the right shows that station 179 is online, which means it is actively communicating. The two far-right columns show the values to be collected and the values collected for this session. In this case, 10 data values out of 10 were collected; thus, the session was successful.

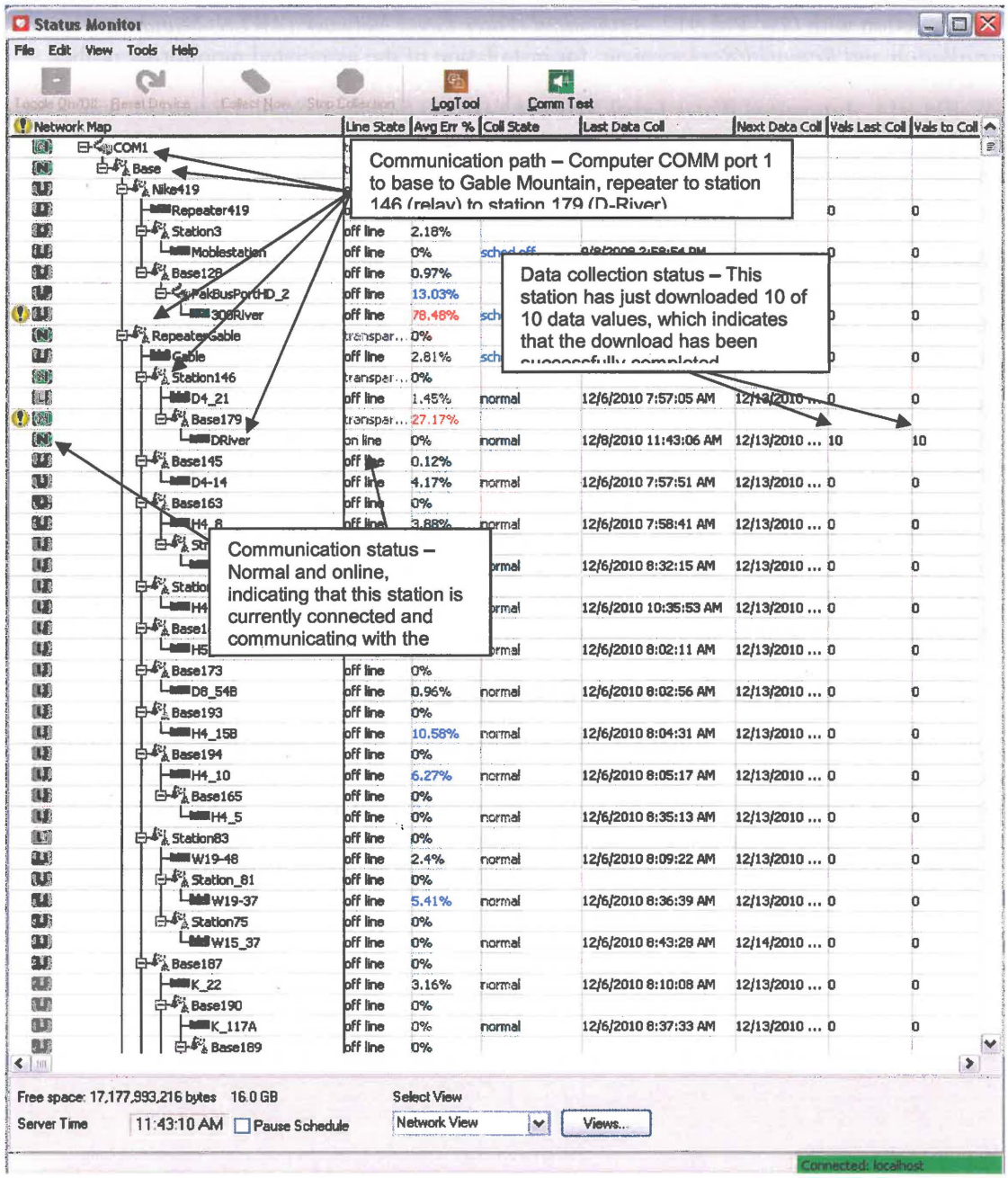

Figure 4-11. Status Monitoring Screen

4.2 Maintenance Provisions

General station installation, maintenance, upgrades, removal, and replacement are performed under specific maintenance procedures applicable to the AWLN, as described below:

- GW-PM-852, *Calibration of Submersible Pressure Transducers (mVolt and SDI-12)*, which covers the acceptance testing of submersible current-loop pressure transducers used to support the Soil and Groundwater Remediation Project (S&GRP) operations.
- GW-PM-910, *Automated Water Level Network (AWLN) Standard Station Installation*, which covers the installation of an AWLN monitoring station to support S&GRP operations. This procedure is used in conjunction with GW-PM-912, *Automated Water Level Network (AWLN) Standard Transducer Installation and Removal/Replacement*, for installation of the associated monitoring probes.
- GW-PM-911, *Automated Water Level Network (AWLN) Standard Station Removal*, which covers the removal of an AWLN monitoring station used, used in conjunction with procedure GW-PM-912, *Automated Water Level Network (AWLN) Standard Transducer Installation and Removal/Replacement*, for the removal of the associated monitoring probes.
- GW-PM-912, *Automated Water Level Network (AWLN) Standard Transducer Installation and Removal/Replacement*, which covers the installation of a pressure transducer into an AWLN well and connection to a monitoring station. This procedure also includes the reinstallation/replacement of a transducer.
- GW-PM-913, *Automated Water Level Network (AWLN) Field Station Troubleshooting and Equipment Upgrades*, which covers a series of tasks, including invasive station troubleshooting, component changeouts, and upgrades to station telemetry equipment to support the AWLN. This procedure covers work performed by S&GRP Hanford Atomic Metal Trades Counsel instrument technicians to maintain the AWLN in proper working order. Common station components included in this procedure are weather enclosures, data loggers, RF transceivers and modems, power supplies, antenna, mast or mounting poles, solar panels, and associated cables. The installation and removal of entire AWLN field stations and transducers is covered by the procedures identified above.

4.3 Spare Capacity and/or Future Expansion Needs

The monitoring network should provide a sufficient amount of data to perform system performance evaluations in accordance with the remedial design/remedial action work plan developed to implement the interim action Records of Decision for the River Corridor groundwater OUs. To support performance evaluations, components of the AWLN cannot be inactive for more than 3 weeks at a time under any configuration, which would impact the ability to perform monthly groundwater-level interpretations.

5 Interrelationships with Other Systems

The AWLN data is used in conjunction with well pumping data from P&T systems to augment water-level mapping. The AWLN data are accessible to Hanford Local Area Network (HLAN) users through the Virtual Library web application. This chapter describes the interrelationships of these systems

5.1 Interrelationship with Pump-and-Treat Well Pumping Data

Water-level data collected by the AWLN is used in conjunction with water-level data measured in the pumping wells. The water-level data from the pumping wells will be used to augment water-level mapping and determining the specific capacity of pumping wells.

Data from each P&T programmable logic controller (PLC) is downloaded into separate Microsoft® Excel files (i.e., one file each for the KW, KR4, KX, DX, and HX P&T systems). On a monthly basis, data containing the following information are downloaded from P&T PLC data storage to summary Microsoft Excel files:

- Daily total volumes of water extracted from the aquifer for each P&T extraction well
  - Recorded volumes are totalizer volumes, so actual daily volume is the difference in the totalized volume and the totalized volume from the previous day.
- Daily total volumes of water injected to the aquifer for each P&T injection well
  - Recorded volumes are totalizer volumes, so actual daily volume is the difference in the totalized volume and the totalized volume from the previous day.
- Daily water-level measurements as recorded from level transducers in each P&T extraction and injection well
  - Extraction well water levels are recorded in feet of water in the well above the transducer.
  - Injection well water levels are recorded as negative value in feet below the well concrete pad surface.

Calculation of the water elevation in the P&T extraction and injection wells is dependent on knowledge of the actual depth of the level transducer placed in the well referenced to ground surface. The transducer depths programmed into the P&T PLC are provided by engineering drawings. Actual field logs of well maintenance activities indicate different depth settings for some of the wells. In these instances, the water elevations are calculated as follows:

- For extraction wells, the water elevation is calculated using Equation 5-1:

$$\textit{(Ground surface elevation)} - \textit{(corrected transducer depth)} + \textit{(measured water level)} \qquad \textbf{(Equation 5-1)}$$

- For injection wells, the water elevation is calculated using Equation 5-2:

$$\textit{(Ground surface elevation)} + \textit{(measured water elevation)} - \textit{(corrected transducer depth)} + \textit{(programmed transducer depth)} \qquad \textbf{(Equation 5-2)}$$

® Microsoft and Excel are registered trademarks of Microsoft Corporation in the United States and/or other countries.

Table 5-1 identifies the initial data set used for the PLC-programmed transducer depth (obtained from engineering drawings) and the corrected transducer depths based on well maintenance logs and ground surface elevation. The data set is periodically updated to reflect changes in the transducer depth settings based on well realignments and maintenance activities.

Table 5-1. Transducer Depth for P&T Wells

P&T System	Well ID	Extraction/ Injection	Programmed Transducer Depth (ft)	Corrected Transducer Depth (ft)	Ground Surface Elevation (ft)
KW	199-K-132	Extraction	73	72.43	445.9324
KW	199-K-138	Extraction	80.5	79.8	440.24488
KW	199-K-139	Extraction	96	94.85	468.40696
KW	199-K-140	Extraction	95	94.15	467.59024
KW	199-K-168	Extraction	154	150.9	467.70832
KW	199-K-166	Extraction	163	160.62	474.09776
KW	199-K-165	Extraction	162	159.6	477.10552
KW	199-K-137	Extraction	94	90.9	470.35856
KW	199-K-158	Injection	100	97.62	477.24656
KW	199-K-174	Injection	118	115.59	486.05008
KW	199-K-175	Injection	134	131.46	500.11144
KR4	199-K-162	Extraction	122	118.6	411.3776
KR4	199-K-116A	Extraction	83	78.95	426.20976
KR4	199-K-145	Extraction	112	107.7	411.66624
KR4	199-K-127	Extraction	92	90.1	433.5176
KR4	199-K-120A	Extraction	91	89.1	413.96552
KR4	199-K-144	Extraction	88	83.42	414.592
KR4	199-K-113A	Extraction	35	33	413.07336
KR4	199-K-115A	Extraction	48	43	415.17256
KR4	199-K-129	Extraction	42	41.4	415.22176
KR4	199-K-114A	Extraction	34.5	30.4	412.38456
KR4	199-K-121A	Injection	80	79	466.24872
KR4	199-K-122A	Injection	80	79.03	467.17368
KR4	199-K-123A	Injection	80	79	468.51848
KR4	199-K-179	Injection	80	77	457.53704
KR4	199-K-128	Injection	80	79	471.008
KX	199-K-178	Extraction	89	86.6	445.00088
KX	199-K-171	Extraction	89	137	473.04816
KX	199-K-141	Extraction	99	94.3	464.35616
KX	199-K-154	Extraction	93	88.42	450.00944
KX	199-K-163	Extraction	97.8	93.6	452.4596
KX	199-K-153	Extraction	74	86.7	450.70808

Table 5-1. Transducer Depth for P&T Wells

P&T System	Well ID	Extraction/ Injection	Programmed Transducer Depth (ft)	Corrected Transducer Depth (ft)	Ground Surface Elevation (ft)
KX	199-K-161	Extraction	42	37.5	414.86096
KX	199-K-147	Extraction	73	69	443.01648
KX	199-K-130	Extraction	70	68	438.39168
KX	199-K-148	Extraction	94	88.57	453.0172
KX	199-K-131	Extraction	76	76	440.87464
KX	199-K-152	Extraction	109	108.05	460.00688
KX	199-K-146	Extraction	47	42.95	421.21432
KX	199-K-159	Injection	80	77.75	455.7396
KX	199-K-160	Injection	80	77.53	456.65472
KX	199-K-169	Injection	80	77.5	465.31064
KX	199-K-143	Injection	80	77.5	445.24032
KX	199-K-156	Injection	80	77.6	460.7744
KX	199-K-170	Injection	80	77.5	465.86496
KX	199-K-164	Injection	80	77.5	461.30904
KX	199-K-180	Injection	90	90	479.71968
KX	199-K-172	Injection	80	77.55	473.16296
DX	199-D4-38	Extraction	92	89.59	468.40368
DX	199-D4-39	Extraction	90.25	87.7	469.65664
DX	199-D4-83	Extraction	93	90.3	468.67264
DX	199-D4-84	Extraction	98.75	96.49	471.09
DX	199-D4-85	Extraction	104.2	104.2	470.05024
DX	199-D4-95	Extraction	108	105.49	470.25688
DX	199-D4-96	Extraction	99	96.5	472.98912
DX	199-D4-97	Extraction	102	99.5	471.8936
DX	199-D4-98	Extraction	99	96.5	469.38112
DX	199-D4-99	Extraction	105	102.5	469.696
DX	199-D4-101	Extraction	102.65	100.4	471.0244
DX	199-D5-101	Extraction	104	101.5	471.746
DX	199-D5-127	Extraction	101.63	98.1	471.7624
DX	199-D5-104	Extraction	105	88	472.47744
DX	199-D8-69	Extraction	58.11	53.65	428.1384
DX	199-D8-90	Extraction	48	45.6	413.14224
DX	199-D8-91	Extraction	26	33.55	405.85736
DX	199-D8-97	Extraction	76.4	74.17	461.99128
DX	199-D8-95	Extraction	89.16	89.16	465.1204
DX	199-D5-130	Extraction	83.59	91.1	467.08512

Table 5-1. Transducer Depth for P&T Wells

P&T System	Well ID	Extraction/ Injection	Programmed Transducer Depth (ft)	Corrected Transducer Depth (ft)	Ground Surface Elevation (ft)
DX	199-D7-3	Extraction	72.76	79.16	444.05952
DX	199-D5-131	Extraction	91.79	102.25	471.50656
DX	199-D8-98	Extraction	78.76	79.86	452.73184
DX	199-D8-96	Extraction	86.21	87.1	460.76784
DX	199-D7-6	Extraction	36.2	33.9	410.04592
DX	199-H1-5	Extraction	39	36.7	406.69704
DX	199-H4-82	Extraction	49.7	47.2	425.09456
DX	199-H4-81	Extraction	35.5	33.2	409.29808
DX	199-H4-80	Extraction	54.22	60.9	424.24504
DX	199-D8-6	Extraction	101.7	100.65	476.96448
DX	199-D5-20	Extraction	90.02	89.4	468.93504
DX	199-D5-32	Extraction	97.15	101.05	469.48608
DX	199-D5-39	Extraction	96.7	95.5	472.24456
DX	199-D5-92	Extraction	91.6	89.03	467.318
DX	199-D8-88	Extraction	94.6	91.12	462.7916
DX	199-D8-73	Extraction	87.2	83.4	465.08104
DX	199-D8-89	Extraction	75	75	452.94504
DX	199-D5-44	Injection	101.3	98.79	467.91824
DX	199-D5-42	Injection	104.5	103	471.82472
DX	199-D5-129	Injection	100.65	98.3	470.14864
DX	199-D5-128	Injection	94.09	91.57	469.52872
DX	199-D8-55	Injection	79	76.16	444.77784
DX	199-D2-12	Injection	27	24.07	395.47288
DX	199-D2-10	Injection	30	27.1	394.57416
DX	199-D8-94	Injection	29	26.1	394.54464
DX	199-D8-93	Injection	13	10.5	394.91856
DX	199-D7-5	Injection	56.68	54.43	431.074
DX	199-D6-2	Injection	72.76	70.41	438.61472
DX	199-D7-4	Injection	67.18	64.88	438.71968
DX	199-D8-99	Injection	76.04	73.04	447.86432
DX	199-D6-1	Injection	95.07	92.77	473.0416
HX	199-H1-45	Extraction	50.91	48.6	419.4956
HX	199-H4-15A	Extraction	38.76	37.4	408.79056
HX	199-H4-69	Extraction	52.93	50.6	424.3828
HX	199-H4-70	Extraction	52.15	49.7	425.10112
HX	199-H4-75	Extraction	46.57	42.1	421.61776

Table 5-1. Transducer Depth for P&T Wells

P&T System	Well ID	Extraction/ Injection	Programmed Transducer Depth (ft)	Corrected Transducer Depth (ft)	Ground Surface Elevation (ft)
HX	199-H4-4	Extraction	40.58	37.35	416.12104
HX	199-H4-63	Extraction	52.93	51.8	418.51488
HX	199-H4-64	Extraction	37.68	33.25	410.94792
HX	199-H3-2C	Extraction	106.23	103.8	419.91136
HX	199-H4-12C	Extraction	78	76.8	414.40128
HX	199-H1-34	Extraction	34.97	32.66	411.17424
HX	199-H1-35	Extraction	37.97	35.86	411.87288
HX	199-H1-36	Extraction	35.48	33.20	411.49568
HX	199-H1-37	Extraction	37.91	35.53	413.43416
HX	199-H1-38	Extraction	38.85	36.44	414.0672
HX	199-H1-39	Extraction	35.32	32.98	411.85976
HX	199-H1-40	Extraction	36.37	34.12	413.11928
HX	199-H1-42	Extraction	35.48	33.16	408.74704
HX	199-H1-43	Extraction	39.57	37.21	411.14144
HX	199-H1-3	Extraction	39.08	36.53	421.68336
HX	199-H1-2	Extraction	42.81	38.53	420.25984
HX	199-H1-1	Extraction	29.95	25.62	405.14232
HX	199-H4-76	Extraction	43.89	41.56	425.2684
HX	199-H1-4	Extraction	38.68	35.73	419.44968
HX	199-H4-77	Extraction	40.16	35.97	419.49232
HX	199-H1-6	Extraction	33.75	31.40	411.4268
HX	199-H1-25	Extraction	28.47	24.48	403.29568
HX	199-H1-27	Extraction	31.35	28.89	405.2932
HX	199-H1-32	Extraction	40.4	38.00	418.05896
HX	199-H1-33	Extraction	35.6	33.89	413.56536
HX	199-H3-4	Extraction	40.45	39.75	414.79208
HX	199-H6-2	Injection	49.81	49.8	423.19544
HX	199-H4-73	Injection	63.27	63.27	424.14336
HX	199-H4-72	Injection	55	55	421.12248
HX	199-H4-71	Injection	60.07	60.07	425.69152
HX	199-H4-18	Injection	50	50	423.45128
HX	199-H3-27	Injection	55.79	55.79	421.00768
HX	199-H3-26	Injection	49.98	49.98	417.55384
HX	199-H3-25	Injection	53.7	53.7	419.15448
HX	199-H4-74	Injection	38	38	411.1644
HX	199-H4-78	Injection	58	58	424.90104

Table 5-1. Transducer Depth for P&T Wells

P&T System	Well ID	Extraction/ Injection	Programmed Transducer Depth (ft)	Corrected Transducer Depth (ft)	Ground Surface Elevation (ft)
HX	199-H4-79	Injection	59.08	59.08	430.67056
HX	199-H1-21	Injection	32.11	32.11	398.13624
HX	199-H1-20	Injection	31.44	31.44	397.25392
HX	199-H4-17	Injection	45	45	420.96416
HX	199-H4-14	Injection	50	50	421.85328

ID = identification
P&T = pump and treat

5.2 Interrelationship with the Virtual Library

The Virtual Library is a web application from which HLAN users can access various data used in environmental studies. The Virtual Library is organized into modules for the various available data sets. The data include environmental sample data and manual water-level measurements (in the EM module), automated water-level network data (in the AWLN module), effluent volume and discharge data (in the EVSDS module), soil particle-size distribution data (in the ROCSAN module), and soil coefficient data (in the K_d module). The EM module data are obtained from the Hanford Environmental Information System database and are updated nightly. AWLN data are stored on the Virtual Library server and are managed using the AWLN administrative module. This module differs from most other modules in the Virtual Library in that it is not designed to be a data presentation module. Instead, it is designed to allow the owners of the AWLN data to collect, edit, and maintain their data sets. This module will be used by the data owners to process the raw electronic data readings from the AWLN into a form readily understandable for the Hanford Site. The module will also be used by the AWLN owners to monitor the condition of the network itself (e.g., reporting issues such as battery life of the individual data collection sites).

The AWLN user interface module, also referred to as the AWLN data viewer, allows data users to access the data in several ways. This module allows for viewing the data from all AWLN wells in both a tabular and graphic format and for exporting data in a spreadsheet format.

The AWLN administrative module interface allows the AWLN lead to view the AWLN data in the same ways as the user interface but also provides access to the raw data and processing functions of the SQL server database.

After the weekly data download, the raw data files are uploaded to a SQL server database that is accessed through a module in the HLAN Virtual Library.

6 Environmental Considerations During Project Execution

Cultural resource reviews following the guidelines of the DOE/RL-98-10, *Hanford Cultural and Historic Resources Management Plan*, will be conducted as necessary when installing AWLN components at new locations within culturally sensitive areas.

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7 Quality Assurance Provisions

Data collected from the AWLN should be compiled, reviewed, and validated to detect, adjust, and eliminate erroneous measurements. Manual water-level measurements and AWLN measurements are compiled and reviewed for potential outliers. Review for potential outliers is essential to identify erroneous data entries or data requiring further investigation and/or correction. Section 7.1 provides a brief description of the outlier tests implemented as part of the monthly reporting process.

Data corrections based on field checks and data validation should be performed to ensure that appropriate water-level values from transducer data are used to measure remedy performance. Section 7.2 provides examples of data corrections.

7.1 Data Review and Validation

Water-level measurements are reviewed to identify any potential outliers. The process is somewhat subjective, and the purpose is to quickly and consistently identify measurements that are possibly problematic and require further investigation. These outliers, which may or may not be erroneous values, may arise due to a variety of reasons, such as (1) perturbations to the hydraulic system, (2) malfunctioning devices, (3) measurement reference point errors; and (4) measurement or data entry errors. Tests performed for outliers in the MGROI automated script (programmed in *R*) are briefly described in the following subsections. The outlier tests are followed by a comprehensive data quality evaluation where each data point is ranked based on the outcome of the individual outlier tests. Flags are assigned to the data points to reflect the relevant level of confidence for the particular measurement.

7.1.1 Well Geometry Test

The well geometry outlier test compares reported water levels (both transducer and manual measurements) to the well geometry: elevation of the top of the well casing, elevation of the bottom of the well screen, and elevation of the bottom of the well bore. The validity of this test relies on the quality of the well geometry data available in the database. Water-level measurements that are below the bottom of the screen, below the elevation of the total depth of the well bore, or above the elevation of the top of the casing are flagged (flag TESTGEO: FAIL). Water-level data that fail any of the well geometry tests are flagged as a FAIL. The failed data are removed from the water-level data set because they are considered erroneous values and to prevent impacting the remaining outlier tests that are based on statistical analysis of the data.

7.1.2 Rolling Median Test

The rolling median outlier test compares individual measurements with the median measurement over a period of approximately 2 days. This test is only applied to the more regular time-series data of the AWLN data (manual measurements are not applicable). The median water level is calculated along a moving window (2 days), and the water levels within that window are compared to the median of the moving window. For each well, if the difference between the transducer measurement and the rolling median at a given measurement time is >50 times the average difference between the transducer measurement and the rolling median, the value is flagged as a potential outlier (flag OUTROLL: FAIL). This threshold is based on long-term data observation and is considered a functional rather than absolute threshold. The threshold is subject to change if more or less restrictive definitions of outliers are deemed necessary.

7.1.3 Central Tendency Test

The central tendency test is conducted for transducer and manual water-level data. This test compares individual measurements to the median value and the median absolute deviation (MAD) of the data set for the past 3 years, as shown in Equation 7-1:

$$MAD = median_i\,(X_i - median_j\,(X_j)) \qquad \textbf{(Equation 7-1)}$$

where:

$median_j$ = median of data set j

X_i = value of interest

$median_i$ = median of the absolute difference between the value and the median

If the measurement (1) is 5 m above or below the median value, or (2) is >15 absolute deviations, from the median value, then the measurement is flagged as a potential outlier (flag OUTSDM: FAIL). These thresholds for both the comparison to the median and the MADs are based on long-term data observation and are considered functional rather than absolute thresholds. The thresholds are subject to change if more or less restrictive definitions of outliers are deemed necessary.

Table 7-1 shows the user defined values used for determining outliers, which can be adjusted as desired.

Table 7-1. User-Defined Values to Determine Water-Level Outliers

Description	Value
Number of years of data to use	5 years
Central Tendency Test	
Maximum difference from the median value	5 m
Maximum number of MADs from the median value	10
Rolling Median Test	
Time window for rolling median	2 days
Number of values used in the rolling median window	49
Automated versus Manual Measurement Test	
Time window for AWLN and manual measurement data	3 days
Maximum allowable difference between AWLN and manual measurements	0.1 m

AWLN = automated water-level network
MAD = median absolute deviation

7.1.4 Manual Comparison Outlier Test

The manual comparison outlier test compares transducer data and manual measurements. The comparison is made for transducer data that are collected within 3 days of a manual measurement. Data are flagged as potential outliers if the difference between the transducer and closest manual measurement is >0.1 m (flag OUTCOMP: FAIL). This threshold is based on long-term data observation and is considered a functional rather than absolute threshold. The threshold is subject to change if more or less restrictive definitions of outliers are deemed necessary.

7.1.5 Hydrographs

Time-series plots incorporating the results from the data quality evaluation were constructed for all wells with transducer data. Each measurement type (transducer or manual) is represented by a different point shape, and each data quality flag is represented by a distinct color. Data with a flag of "NONE" are also included in the time-series plots and are highlighted in red. Summary statistics for each monitoring location and well geometry data (when available) are included with the time series plots. The river stage is determined based on a convolution methodology the relates the U.S. Geological Survey-reported stage at station 12472800 (a location upstream from the Hanford Site and below Priest Rapids Dam) and river stage measurements for the Columbia River at the 100-K, 100-N, 100-D, 100-H, and the 300 Areas. ECF-Hanford-13-0028 provides further discussion of the methodology.

7.1.6 Comprehensive Data Quality Evaluation

Data quality evaluations were conducted based on the results from all outlier tests. For each data entry, flags for each test are compiled, and the data point is assigned a final flag to reflect the level of confidence on this measurement, as determined by the outlier tests. The final flag for each data point is determined based on the number of PASS/FAIL/NO_COMP flags. Tables 7-2 and 7-3 summarize the rules of the data quality evaluation scheme for transducer and manual measurements, respectively.

Table 7-2. Data Quality Evaluation Scheme for Transducer Data

TESTGEO	OUTROLL	OUTSDM	OUTCOMP	Flag
FAIL	No evaluation			NONE
PASS	PASS	PASS	PASS	ABSOLUTE
PASS	PASS	PASS	NO_COMP	HIGH
PASS	PASS	FAIL	PASS	HIGH
PASS	FAIL	FAIL	PASS	MEDIUM
PASS	PASS	FAIL	NO_COMP	MEDIUM
PASS	FAIL	PASS	PASS	MEDIUM
PASS	FAIL	PASS	NO_COMP	LOW
PASS	FAIL	FAIL	NO_COMP	LOW
PASS	PASS	PASS	FAIL	LOW
PASS	PASS	FAIL	FAIL	MINIMAL
PASS	FAIL	FAIL/PASS	FAIL	NONE

Table 7-3. Data Quality Evaluation Scheme for Manual Data

TESTGEO	OUTSDM	Flag
FAIL	—	NONE
PASS	PASS	ABSOLUTE
PASS	FAIL	MEDIUM

7.2 Data Corrections

Objective data evaluation procedures use of a formal set of rules rather than subjective judgment to detect, adjust, and eliminate erroneous measurements during an evaluation. For the AWLN, this is accomplished using field checks and data validation.

The hydrograph shown in Figure 7-1 presents an example of water elevation data from well 199-D5-36 for CY 2004. The blue line represents the hourly transducer readings, and the red diamonds are manual field checks. In this example, the field check data line up with the transducer data to provide a high level of confidence that the transducer was operating properly and was accurately measuring water-level response in this well.

The field checks serve two very important functions: (1) as the original reference points to convert the raw readings into elevation data, and (2) as a QC check. For long-term monitoring, two different problems can occur with the transducer that must be monitored using the field check data. The first problem that could result is a correctable shift in the transducer due to some event that has physically moved the transducer. The second problem that could result is referred to as transducer drift. In some cases, the drift can be compensated and corrected but, in most cases, it cannot be corrected to provide sufficient confidence in the resulting data. Transducer drift is the result of either hard water deposits building up or the beginning of transducer failure. Transducer failure can be due to moisture in the vent tube or some type of electrical failure.

Figure 7-2 shows an example of an event on September 20, between 11:00 a.m. and 12:00 p.m., that shifted the transducer data downward, as demonstrated by the later field check data (shown by red diamonds). Figure 7-3 shows the results of using the field check data from October and applying them to the raw data from 12:00 p.m. on September 20 and forward. The water elevation data now aligns with the field check data and restores confidence in the transducer data accuracy. In cases of transducer drift, the water elevation data would continue to drift from the field check points with increasing error. Techniques are available to determine the linear slope of the error and correct for the drift, but this is only applicable to cases where the drift has uniform error.

Data QA checks should be performed every time manual water-level measurements are collected to ensure that appropriate water-level values from transducer data are used to measure remedy performance. Manual water-level measurements of the AWLN wells should be obtained when samples are collected at the well (or at least semiannually) to support P&T system performance assessments that will not be hampered by the use of provisional data.

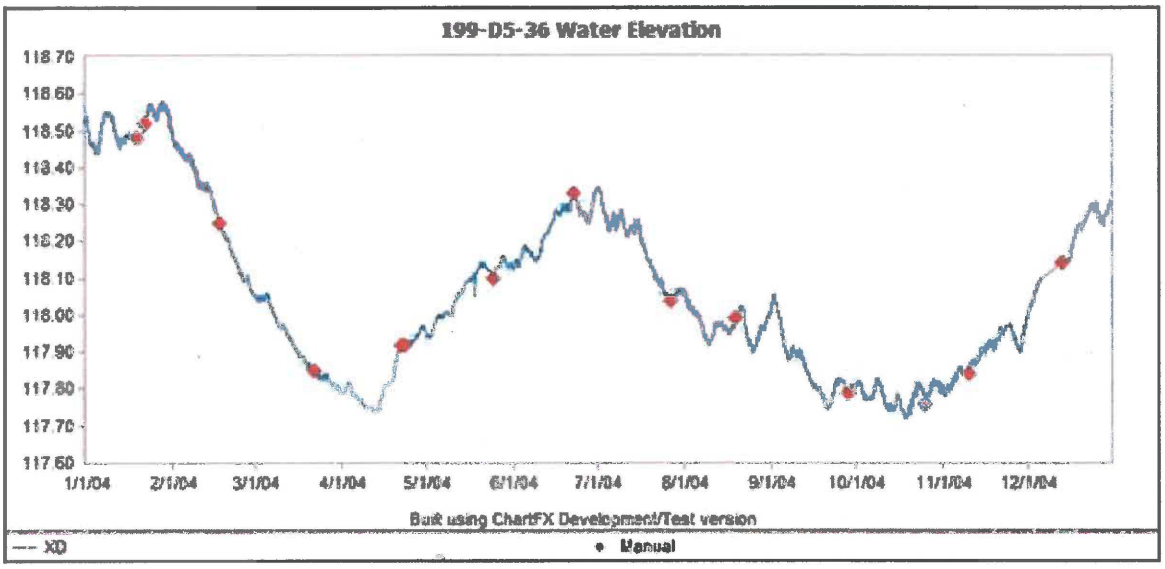

Figure 7-1. Data Corrections and Limitations

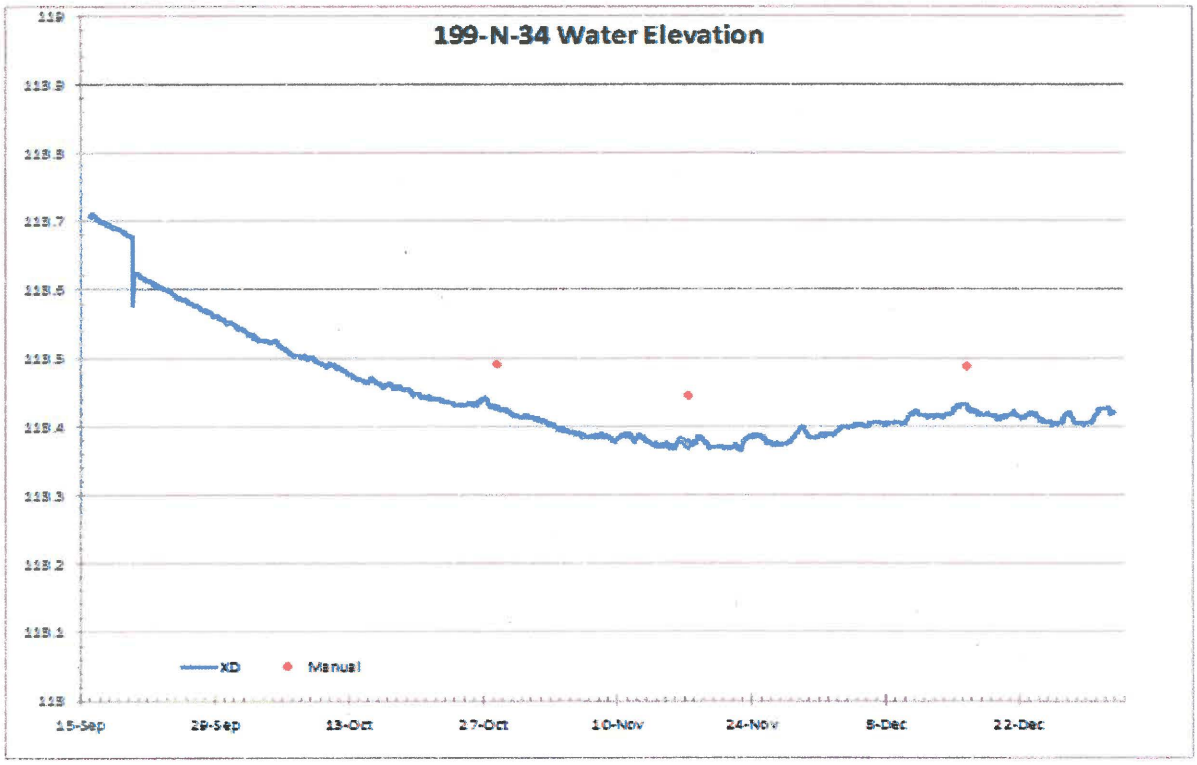

Figure 7-2. Example of Transducer Shift

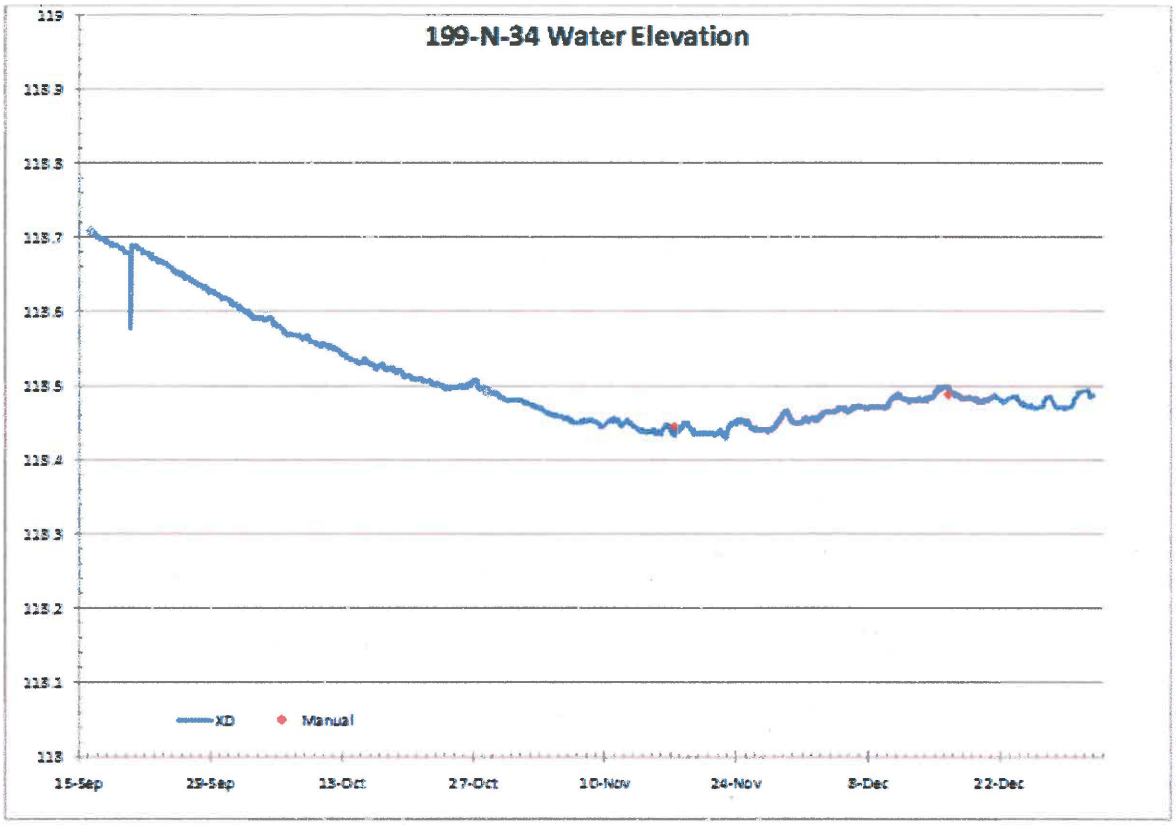

Figure 7-3. Example of Corrected Transducer Shift

8 Communication Requirements

The field instruments measuring water-level data and the base station must have faultless communication to meet the objectives for the AWLN. A lapse in communication can be a result of several scenarios including, but not limited to, (1) transducer failure, in which case the transducer must be replaced; (2) communication failure, which could be a result of the failure of some of the instruments such as the radio, modem, transceiver, or power supply; and (3) well decommissioning.

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