2.3 WATER

This section describes the physical, chemical, biological, and hydrological characteristics of surface water and groundwater in the vicinity of the Clinch River Nuclear (CRN) Site that may affect water supply or that may be reasonably assumed to be affected by the construction and operation of two or more small modular reactors (SMRs). The following lists the Section 2.3 subsections, with descriptions:

- Subsection 2.3.1 provides a detailed description of the surface water bodies and groundwater aquifers that can affect the CRN Site water supply and effluent disposal or may be affected by construction or operation of the SMRs.
- Subsection 2.3.2 describes surface water and groundwater uses in the vicinity of the facility that can affect or be affected by the construction and operation of two or more SMRs.
- Subsection 2.3.3 provides detailed water quality information regarding the surface water and groundwater in the vicinity of the CRN Site.

2.3.1 Hydrology

This subsection presents descriptions of the surface water and groundwater resources that could be affected by the construction and operation of two or more SMRs. The physical and hydrologic water resource characteristics of the site and region are summarized below.

2.3.1.1 Surface Water

The CRN Site is located on a peninsula created by a bend in the Clinch River arm of Watts Bar Reservoir (Figure 2.3.1-1). The CRN Site is located between approximately Clinch River Mile (CRM) 14.5 and approximately CRM 19.0 and is approximately 10.7 miles (mi) southwest of the City of Oak Ridge, Tennessee. Within the CRN Site, the proposed surface water intake is located at CRM 17.9, and the proposed discharge is located at approximately CRM 15. 5. The Barge/Traffic Area is located between CRN 14.0 and CRN 14.5.

The location of the CRN Site and Barge/Traffic Area with respect to major surface water features is shown in Figure 2.3.1-1. The upstream boundary of the CRN Site is located approximately 4.1 mi downstream of Melton Hill Dam, which is located at CRM 23.1. The CRN Site is located approximately 8.2 mi east of the confluence of the Tennessee and Clinch Rivers, with the downstream boundary of the site about 14.5 mi upstream of the confluence. The confluence of the two rivers is located at CRM 0 on the Clinch River, and at Tennessee River Mile (TRM) 567.8 on the Tennessee River (Reference 2.3.1-1). Further downstream on Watts Bar Reservoir, Watts Bar Dam is located at TRM 529.9 or 52.4 mi downstream of the CRN Site (Reference 2.3.1-2). Regulated releases of surface water to Watts Bar Reservoir are made not only from Melton Hill Dam but also Fort Loudoun Dam located at TRM 602.3, and Tellico Dam located near TRM 601.1.

As shown on Figure 2.3.1-1, a number of creeks located in the vicinity of the CRN Site discharge into the reservoir (Figure 2.3.1-1). Upstream of the CRN Site, between Melton Hill Dam at CRM 23.1 and the intake at CRM 17.9, three streams enter the reservoir. These include: Whiteoak Creek, entering the reservoir from the north at CRM 21.0; Raccoon Creek, entering the reservoir from the north at CRM 19.5; and Paw Paw Creek, entering the reservoir from the south at CRM 19.3. Within the reach of the CRN Site, four streams enter the reservoir. These include: Caney Creek, entering the reservoir from the south at CRM 17.0; Poplar Springs Creek, entering the reservoir from the south at CRM 16.2; Bear Creek, entering Poplar Creek and subsequently entering the reservoir at CRM 12, and Grassy Creek entering the reservoir from the north at CRM 14.5. One other prominent tributary, the Emory River, enters the reservoir between the CRN Site and the Tennessee River. The Emory River enters the reservoir from the north, at CRM 4.5 (Reference 2.3.1-3).

2.3.1.1.1 Hydrologic Setting

2.3.1.1.1.1 Tennessee River Watershed

The headwaters of the Tennessee River watershed originate in the mountains of western Virginia and North Carolina, eastern Tennessee, and northern Georgia. The Tennessee River is formed by the confluence of the Holston and the French Broad Rivers near Knoxville, Tennessee. The river flows to the southwest and receives water from three principal tributaries: Little Tennessee, Clinch, and Hiwassee Rivers. As the Tennessee River flows south, west, and then north, two other major tributaries, the Elk and Duck rivers, contribute to the flow that eventually joins the Ohio River at Paducah, Kentucky. (Reference 2.3.1-4)

The Tennessee River and its tributaries have a drainage area of approximately 41,910 square (sq) mi and pass through 125 counties that cover much of Tennessee and parts of Alabama, Kentucky, Georgia, Mississippi, North Carolina, and Virginia (Reference 2.3.1-5). The drainage area from the point of headwater origination to Chattanooga, Tennessee, is approximately 21,400 sq mi; west of Chattanooga to the Ohio River, the drainage area is approximately 19,500 sq mi (Reference 2.3.1-4).

The Tennessee River watershed is subdivided by the U.S. Geological Survey (USGS) into 32 hydrologic units, each identified by a hydrologic unit code (HUC). The USGS divides the Tennessee River Basin into two subbasins: the Upper Tennessee River Basin and the Lower Tennessee River Basin. The boundary between these subbasins is TRM 465 on the mainstem of the Tennessee River at Chattanooga, Tennessee. (Reference 2.3.1-5)

The CRN Site is located in the Upper Tennessee River Basin. The Upper Tennessee River Basin contains some of the most rugged terrain in the eastern United States, including the Great Smoky Mountains range. The Upper Tennessee River Basin encompasses approximately 21,400 sq mi and includes the entire drainage area of the Tennessee River and its tributaries upstream from the USGS gaging station in Chattanooga, Tennessee. It also includes parts of four states: Tennessee, 11,500 sq mi; North Carolina, 5480 sq mi; Virginia, 3130 sq mi; and

Georgia, 1280 sq mi. Parts of three physiographic provinces (Cumberland Plateau, Valley and Ridge, and Blue Ridge) compose the Upper Tennessee River Basin. Elevations range from 621 feet (ft) above mean sea level (msl) at Chattanooga to 6684 ft msl at Mount Mitchell, which is located just northeast of Asheville, North Carolina, and is the highest point in the eastern United States. (Reference 2.3.1-6)

2.3.1.1.1.2 Tennessee River Management

The Tennessee River system, managed by the Tennessee Valley Authority (TVA), is a network of dams and reservoirs that generates power, controls flooding, provides recreational opportunities, and boosts the regional and national economies. The Tennessee River system has approximately 11,000 mi of public shoreline, and under Section 26a of the TVA Act, TVA has the authority to regulate land use and development along the shoreline. TVA owns or operates 49 dams and reservoirs in the mainstem Tennessee and Cumberland watersheds, including nine dams on the Tennessee River (Reference 2.3.1-7). The dams and reservoirs are operated year-round by TVA for the purposes of navigation, flood control, power generation, water supply, water quality, and recreation. Operation of the reservoirs is linked to rainfall and runoff patterns in the watershed. (Reference 2.3.1-8)

2.3.1.1.1.3 Clinch River Watershed

The Clinch River originates in Southwest Virginia and flows to the southwest while receiving water from a number of tributaries, including the Powell River, above Norris Dam. The Clinch River is more than 300 mi long, formed by the junction of two forks in southwestern Virginia and flowing generally southwest across eastern Tennessee towards its confluence with the Tennessee River at Kingston, Tennessee. The Clinch River watershed has a drainage area of approximately 4413 sq mi. (Reference 2.3.1-5)

The CRN Site lies within the Lower Clinch River Watershed (USGS HUC 06010207). Surrounding the Lower Clinch River Watershed are the Powell, Holston, Lower French Broad, Tennessee River (Watts Bar Reservoir), and Emory watersheds. The Lower Clinch River Watershed includes portions of eight counties in East Tennessee including Anderson, Campbell, Grainger, Knox, Loudon, Morgan, Roane, and Union. (Reference 2.3.1-9)

2.3.1.1.1.4 Clinch River Management

The CRN Site includes approximately 935 acres (ac) of land on the north side of the Clinch River arm of the Watts Bar Reservoir between approximately CRM 14.5 and CRM 19.0. The upstream boundary of the CRN Site is approximately 4.1 mi downstream of Melton Hill Dam, which is located at CRM 23.1. The portion of the Clinch River below Melton Hill Dam is part of Watts Bar Reservoir, an impoundment created by Watts Bar Dam, located on the Tennessee River at TRM 529.9, approximately 52.35 mi downstream of the CRN Site (Reference 2.3.1-2).

There are four dams upstream of the CRN Site which may affect the hydrology of the site:

- Norris Dam located at CRM 79.8
- Melton Hill Dam located at CRM 23.1
- Whiteoak Dam and Whiteoak Creek Embayment Sediment Control Dam, on Whiteoak Creek located near CRM 21.0 (Reference 2.3.1-3; Reference 2.3.1-10)

Norris Dam is located approximately 60.8 mi upstream from the CRN Site, and forms the Norris Reservoir. Norris Reservoir is the confluence of the Powell and Clinch River basins, and it is one of the largest of TVA's 10 tributary storage reservoirs (Reference 2.3.1-11). The dam was completed in 1936 and is 265 ft high and stretches 1860 ft across the Clinch River. It is a hydroelectric facility with two generating units with a net dependable capacity of 110 megawatts (MWe). With normal rainfall throughout the year, the water level in the reservoir fluctuates approximately 29 ft from summer to winter to provide seasonal flood storage. (Reference 2.3.1-12)

Melton Hill Dam is located on the Clinch River at CRM 23.1, approximately 4.1 river mi upstream of the CRN Site, and forms the Melton Hill Reservoir (Reference 2.3.1-3). The dam was completed in 1963 and is 103 ft high and stretches 1020 ft across the Clinch River. Melton Hill Dam is a hydroelectric facility with two generating units. These two generating units are capable of producing a net dependable capacity of 79 MWe. Melton Hill Reservoir has the only dam in the tributary reservoir system with a navigation lock, which has a 75- by 400-ft chamber and a maximum lift of 60 ft. (Reference 2.3.1-13)

Unlike most of TVA's multipurpose tributary projects, Melton Hill Dam does not provide any significant flood damage reduction benefits, nor does it provide any significant seasonal flow regulation because of the little useful storage volume available. The average weekly discharge from Melton Hill Dam over its lifetime (1962-present) is 4832 cubic ft per second (cfs) with a maximum weekly discharge of 25,455 cfs. Figure 2.3.1-3 shows the expected flow frequency of the weekly average flow from Melton Hill Dam based on 100 years (yr) of reservoir and system simulation conducted for the development of the current reservoir operating policy. The minimum discharge requirement for Melton Hill is 400 cfs average daily flow, but the frequency of this minimum flow continuing for as long as seven days is less than 0.1 percent as shown in Figure 2.3.1-3. (Reference 2.3.1-11)

The two dams on Whiteoak Creek are located near its confluence with the Clinch River arm of the Watts Bar Reservoir, near CRM 21.0. The primary dam is Whiteoak Dam, constructed in 1943 to contain radioactive sediment and minimize the spread of contamination from past activities on what is now the U.S. Department of Energy (DOE) Oak Ridge Reservation (ORR). Whiteoak Dam forms the 25-ac Whiteoak Lake, which has a drainage area of 6.0 sq mi. immediately downstream of the Whiteoak Dam is Whiteoak Creek Embayment, which is separated from the Clinch River arm of the Watts Bar Reservoir by Whiteoak Creek Embayment Sediment Control Dam. The Sediment Control Dam was constructed in 1992 in order to maintain a constant water level and prevent fluctuations in water level in Whiteoak Creek Embayment due to storm flows and TVA power operations. (Reference 2.3.1-14)

Two other dams, neither located on the Clinch River, affect the surface water hydrology of the Watts Bar Reservoir at the CRN Site. These are:

- Watts Bar Dam, located at TRM 529.9 (Reference 2.3.1-2)
- Fort Loudoun Dam located at TRM 602.3.

Watts Bar Dam is located on the Tennessee River at TRM 529.9, approximately 52.35 river mi downstream of the CRN Site (Reference 2.3.1-2). Construction on the Watts Bar Dam began 1939 and was completed in 1942. Watts Bar Dam is 112 ft high and stretches 2960 ft across the Tennessee River. All outflows from Watts Bar Reservoir are controlled by releases at Watts Bar Dam. Watts Bar Dam has one lock that is 60 ft by 360 ft and lifts and lowers barges as high as 70 ft from the Watts Bar Reservoir to the Chickamauga Reservoir. The net dependable capacity at Watts Bar Dam is 182 MWe. In addition to forming the navigable reservoir on the Tennessee River, the Watts Bar Dam also creates a slack-water channel for navigation more than 20 mi up the Clinch River to the Melton Hill Dam, and 12 mi up the Emory River. (Reference 2.3.1-7)

Regulated releases of surface water enter Watts Bar Reservoir not only by releases from Melton Hill Dam but also from Fort Loudoun Dam, located on the Tennessee River at TRM 602.3. Construction on Fort Loudoun Dam began in 1940 and was completed in 1943. Fort Loudoun Dam is 122 ft high and stretches 4190 ft across the Tennessee River. The Fort Loudoun lock is 60 ft by 360 ft, and raises and lowers river craft approximately 70 ft between the Fort Loudoun Reservoir and the Watts Bar Reservoir. The net dependable capacity of Fort Loudoun’s four units is 162 MWe. Fort Loudoun Reservoir is connected by a short canal to Tellico Reservoir on the nearby Little Tennessee River. Water is diverted through the canal to Fort Loudoun for power production. The canal also offers commercial barges access to Tellico Reservoir without the need for a lock. (Reference 2.3.1-15)

Just downstream of Fort Loudoun Dam, at approximately TRM 601.1, Tellico Dam also can provide regulated releases to Watts Bar Reservoir from the Little Tennessee River. However, Tellico Dam contains only a spillway (i.e., no hydro capabilities), which is operated very rarely, only in extreme flood events.

2.3.1.1.1.5 Local Site Drainage

The CRN Site covers approximately 935 ac and is bounded to the west, south, and east by the Clinch River arm of Watts Bar Reservoir and to the north by the DOE ORR. As stated in Subsection 2.2.1.1 and shown in Figure 2.2-1, a series of roughly parallel ridges of gradually lower elevations stretches from the Chestnut Ridge, near the CRN Site entrance and in the Grassy Creek Habitat Protection Area (HPA), to approximately the center of the peninsula.

In addition to the Clinch River arm of the Watts Bar Reservoir, TVA identified four perennial streams and one intermittent stream on the CRN Site, and one perennial stream and three intermittent streams in the Barge/Traffic Area[1]. Hydrologic flow within all of these streams is affected by precipitation and stormwater runoff. In addition, hydrologic flow within the Clinch River arm of the Watts Bar Reservoir (stream S02) and a tributary to the reservoir (stream S04) are affected by water levels within the reservoir. Hydrologic flow within streams S01, S06, and S08 is also affected by discharge from springs. (Reference 2.3.1-16) Descriptions of these streams are included in Subsection 2.4.2.1.3 and Table 2.4.2-5, and their locations are shown in Figure 2.4.1-2.

TVA also identified 19 ephemeral streams/wet-weather conveyances (WWCs) on the CRN Site, and 15 WWCs at the Barge/Traffic Area (Reference 2.3.1-16). WWCs are natural or constructed drainages that have flow conditions only in direct response to precipitation and stormwater runoff (Reference 2.3.1-17). Descriptions of these WWCs are included in Subsection 2.4.2.1.3 and Table 2.4.2-5, and their locations are shown in Figure 2.4.1-2.

Six man-made ponds were identified on the CRN Site, and two ponds were identified in the Barge/Traffic Area. The ponds on the CRN Site were constructed as part of a stormwater management system, and their hydrology is caused by precipitation and stormwater runoff. (Reference 2.3.1-16) Descriptions of these ponds are included in Subsection 2.4.2.1.3 and Table 2.4.2-5, and their locations are shown in Figure 2.4.1-2.

2.3.1.1.1.6 Local Wetland Areas

TVA identified and delineated 12 wetlands on the CRN Site. Each wetland is described in Subsection 2.4.1.2 and shown on Figure 2.4.1-2. Hydrologic flow within each of these wetlands is affected by precipitation and stormwater runoff. In addition, hydrologic flow within wetlands W003, W005, W007, W008, and W011 is influenced by water levels within the Clinch River arm of the Watts Bar Reservoir. Hydrologic flow within four wetlands (W005, W008, W009, and W010) is also affected by groundwater discharge. (Reference 2.3.1-18) TVA also identified and delineated five wetlands at the Barge/Traffic Area. Hydrologic flow within these wetlands is also affected by precipitation and stormwater runoff. In addition, hydrologic flow within one of these wetlands (W017) is influenced by water levels within the Clinch River arm of the Watts Bar Reservoir (Reference 2.3.1-19).

2.3.1.1.2 Reservoir Characteristics

Three separate reservoirs can potentially affect, or be affected, by SMR operations. The impoundments are:

- Melton Hill Reservoir
- Watts Bar Reservoir

[1] Surveys were conducted on the portions of the Barge/Traffic Area (101-ac.) with the highest potential for disturbance that had not been previously surveyed.

- Fort Loudoun Reservoir

Melton Hill Dam, located on the Clinch River 4.1 mi upstream of the CRN Site, impounds Melton Hill Reservoir and releases water into the Clinch River arm of the Watts Bar Reservoir. The Clinch River arm of the Watts Bar Reservoir is the source and receiving water body for CR SMR plant operations. Fort Loudoun Dam, on the mainstem of the Tennessee River, releases water from Fort Loudon Reservoir into Watts Bar Reservoir. Therefore, operation of the Fort Loudoun Dam can affect water levels and other characteristics of the Watts Bar Reservoir.

2.3.1.1.2.1 Reservoir Description

Under flood conditions, TVA's water management objective for Melton Hill, Watts Bar and Fort Loudon Reservoirs and most other dams within the system is to operate the reservoir system to minimize flood damage by timing turbine discharges, gate openings, and spillway discharges as required.

Melton Hill Reservoir is on the Clinch River, extends almost 57 mi upstream from Melton Hill Dam to Norris Dam, and drains approximately 628 sq mi. Figure 2.3.1-1 illustrates the location of Melton Hill Dam and Melton Reservoir relative to the CRN Site. The reservoir provides nearly 193 mi of shoreline and 5470 ac of water surface for recreation. (Reference 2.3.1-13) It is a run-of-river reservoir, meaning water is passed through the reservoir without being stored long-term and allows barge traffic up to Clinton, Tennessee. Melton Hill Reservoir is a multipurpose reservoir providing for navigation, hydroelectric power production, water supply, water quality, and recreation. The average residence time for water in the reservoir is approximately 11 days (Reference 2.3.1-8). Actual elevations of the reservoir immediately upstream of the dam are measured continuously. The elevation range of normal operation fluctuates between 793 and 795 ft msl (Reference 2.3.1-13).

Watts Bar Dam forms the Watts Bar Reservoir. Watts Bar Reservoir is located on the Tennessee River and extends approximately 72.4 mi upstream from Watts Bar Dam to Fort Loudoun Dam (Reference 2.3.1-2). The reservoir drains approximately 17,310 sq mi and has 722 mi of shoreline and over 39,090 ac of water surface. The reservoir has a flood-storage capacity of 379,000 ac-ft. (Reference 2.3.1-7) The average residence time for water in the reservoir is approximately 17 days (Reference 2.3.1-8).

Discharging from Melton Hill Dam, the Clinch River forms only a small portion of the Watts Bar Reservoir. The Tennessee River below Fort Loudoun Dam comprises the main body of the reservoir. The water elevation in Watts Bar Reservoir is controlled by releases from Watts Bar Dam. The water elevation in Watts Bar Reservoir is generally maintained between 735 ft msl and 741 ft msl. (Reference 2.3.1-11)

The CRN Site Probable Maximum Flood (PMF) elevation is 799.9 ft National Geodetic Vertical Datum of 1929 (NGVD29). The combined effect maximum flood level is 806.0 ft NGVD29.

Fort Loudoun Reservoir is the uppermost in the chain of nine TVA reservoirs that form a continuous navigable channel on the Tennessee River. The average residence time for water in the reservoir is approximately 10 days (Reference 2.3.1-8). The reservoir has 379 mi of shoreline and 14,600 ac of water surface. It has a flood storage capacity of 111,000 ac-ft. To maintain the water depth required for navigation, Fort Loudoun Reservoir is kept at a minimum winter elevation of 807 ft. The typical summer operating elevation is between 812 and 813 ft. (Reference 2.3.1-15)

River flow direction at the CRN Site can be upstream, downstream, or quiescent, depending on the modes of operation of Melton Hill Dam, Watts Bar Dam, and Fort Loudoun Dam. Flow reversal may occur from an abrupt shutdown of Melton Hill and Watts Bar Dams and by releasing water from Fort Loudoun Dam. (Reference 2.3.1-11)

2.3.1.1.2.2 Reservoir Operating Rules

TVA adopted its current reservoir operating policy in 2004 based upon the comprehensive Reservoir Operations Study (ROS), which was conducted in cooperation with the U.S. Army Corps of Engineers (USACE) and the U.S. Fish and Wildlife Service (USFWS) as well as representatives of other agencies and members of the public. Two of the features of the operating policy pertinent to this discussion are that it was designed to meet the future off-stream water needs in the Tennessee Valley as well as maintain minimum stream flow at critical locations in the Valley. (Reference 2.3.1-11)

The operating policy requires TVA to store water in tributary reservoirs during the spring when there is relatively high surface water flow into the reservoir system for release during the summer when there is relatively little surface water flow into the system. An important requirement of the operating policy is to meet minimum flow targets. Each of the 10 major tributary projects has such a target. There are also system minimum flow targets on main-stem projects. Chickamauga and Kentucky are projects with key system minimum flow targets. (Reference 2.3.1-11)

The individual tributary project minimum releases provide for instream flow uses such as aquatic habitat in the tailwaters below the projects. These project minimum flows plus additional flow from local tributaries and Chickamauga or Kentucky Dams comprise the system minimum flow. When the surface water flow from local tributaries is too low to meet the governing system minimum flow target, the tributary project releases are increased until the governing system minimum flow target is reached. (Reference 2.3.1-11)

Because rainfall varies across the watershed from year to year, there are some years when reservoirs on one tributary river have relatively less water in them than reservoirs on another tributary river. The operating policy requires TVA to balance the drawdown from all the tributary projects, which slows the drawdown on reservoirs at relatively low levels and increases the drawdown on reservoirs at relatively high levels. (Reference 2.3.1-11)

TVA uses Operating Guides for each reservoir to determine the timing and volume of releases from the dams. The Operating Guides are based on decades of operating experience, and are developed to provide seasonal variation in water levels to accommodate flood waters. The Operating Guides provide a daily target for the water elevation in each reservoir. The operating guide for the Headwater Elevation (HWEL) at Watts Bar Dam is shown in Figure 2.3.1-4. In the winter, TVA targets a pool elevation at Watts Bar Dam between approximately 735 ft and 737 ft msl. Between late March and mid-May, the reservoir is filled to the summer operating range, targeting a pool elevation between approximately 740 ft and 741 ft msl. Between late October and early December the pool is returned to the winter operating range.

2.3.1.1.2.3 Intake and Discharge Description

As shown in Figure 2.3.1-1, water for the plant cooling system is withdrawn from the Clinch River arm of the Watts Bar Reservoir by an intake structure located near CRM 17.9. Heated water from the plant is returned to the reservoir by a discharge structure located at about CRM 15.5.

2.3.1.1.2.4 Flow

To evaluate the hydrothermal impact of the proposed SMRs on Watts Bar Reservoir, TVA conducted a Hydrothermal Task Force study which evaluated the historical data regarding water flow in the reservoir. The following subsection is adapted from the Hydrothermal Task Force Report, and describes the flow information relevant to the analysis of hydrothermal impacts.

The release from Melton Hill Dam is the main source of water for the Clinch River arm of the Watts Bar Reservoir at the CRN Site. The current operating policy of the TVA river system, implemented in 2004, is defined by the TVA Reservoir Operations Study, or ROS (Reference 2.3.1-8). Historical river data used in the hydrothermal analyses was limited to ROS years, beginning in 2004. This is because the operating policy of the TVA river system for the period of operation of the SMRs is expected to be the same as the current ROS operating policy. Under the ROS operating policy, the daily average releases from Melton Hill Dam for 2004 through 2013 are shown in Figure 2.3.1-5. For this period, the overall average release, and consequently the expected approximate average river flow past the CRN Site, is approximately 4670 cfs. The maximum Melton Hill Dam daily average release observed for this period is approximately 21,700 cfs. The minimum single-day average release may be 0 cfs.

The ROS guideline for the minimum daily average release from Melton Hill Dam is 400 cfs. Shown in Figure 2.3.1-6 is the percentile for the Melton Hill Dam daily average release shown in Figure 2.3.1-5. Approximately 60 percent of the time, the scheduled daily average release for Melton Hill Dam is less than the overall average flow (i.e., less than 4670 cfs). The minimum daily average release of 0 cfs cited above occurred on Monday, December 22, 2008, the day of the coal ash spill in the Emory River at the Kingston Fossil Plant, located approximately 14 mi downstream of the CRN Site. Since the Kingston ash spill, TVA has maintained the 400 cfs minimum daily average release for Melton Hill Dam.

The powerhouse at Melton Hill Dam contains two hydro generating units. The operation of the hydro units can provide a minimum release of between approximately 4000 cfs and 5000 cfs (one unit at minimum load) and a maximum release of between approximately 21,000 cfs and 23,000 cfs (two units at maximum load). On an hourly basis, Melton Hill Dam releases usually are scheduled in keeping with TVA's desire to provide low cost power. In this context, and due to the high flexibility and low fuel cost for hydropower, the Melton Hill Dam daily allotment of water is usually dispatched during those hours when the price for power is at or near the daily peak. In this manner, little or no releases are made during other hours of the day. This scheduling pattern is known as hydro peaking. Figure 2.3.1-7 shows the percentile for Melton Hill Dam hourly releases for the period 2004 through 2013 (i.e., since implementation of the current TVA reservoir operating policy). Approximately 50 percent of the time there are no hourly releases from Melton Hill Dam (i.e., flow of 0 cfs). When the daily allotment of water from Melton Hill Dam is very low (e.g., when dry conditions dictate a daily average flow approaching the ROS minimum of 400 cfs) the daily allotment can be provided by only one hour of hydro operation per day. If this type of operation is provided in the first hour of one day and the last hour of the following day, there can be up to 46 continuous hours of no releases from Melton Hill Dam. Although this is possible when following the current operating policy, such usually does not occur in practice. Figure 2.3.1-8 shows the average annual frequency of no release events from Melton Hill Dam for the period 2004 through 2013. On the average, the number of no release events per year is approximately 425. The average duration of these events is approximately 11.25 hours (hr). On the average, the number of no release events lasting more than 24 hr is only approximately 9 per yr. Events with no Melton Hill Dam releases for periods in excess of 36 hr are extremely rare, on the average less than one event per year.

2.3.1.1.2.5 Regional Surface Water Evaporation

Mean monthly, seasonal, and annual pan evaporation for the Tennessee River Basin was evaluated using the National Oceanic and Atmospheric Administration *Mean Monthly, Seasonal and Annual Pan Evaporation for the United States* technical report. Table 2.3.1-1 lists average pan evaporation based on estimates of monthly evaporation derived from hydrometeorological measurements, using a form of the Penman equation described by Kohler, et. al. in 1955.

Using data from Table 2.3.1-1, average annual evaporation in Tennessee is 52.01 inches (in.), and average annual evaporation for the Knoxville station near the CRN Site is 50.61 in.

2.3.1.1.2.6 Water Surface Elevation and Current Patterns

The water surface elevation (WSEL) for the section of the Clinch River arm of the Watts Bar Reservoir adjacent to the CRN Site, in general, follows the pool elevation at Watts Bar Dam. The current pattern in the river is usually in the downstream direction. Figure 2.3.1-9 shows the daily average WSEL measured at the CRN Site (at CRM 16.1) and the daily average HWEL measured at the Watts Bar Hydro plant. The data are for 2013. The daily average WSEL at CRM 16.1 varies between 736 and 744.5 ft above mean sea level, a range of approximately 8.5 ft. The WSEL follows the general trend of daily average HWEL at Watts Bar Dam. However, differences occur between the WSEL at the CRN Site and WSEL at Watts Bar Dam due to hydraulic conditions between the site and Watts Bar Dam. At the CRN Site, the surface water flow from Melton Hill Dam provides the greatest influence on local variations in WSEL. During periods when the daily average release from Melton Hill Dam was in excess of approximately 5000 cfs (e.g., late January and early February 2013), it was not uncommon for the WSEL at the CRN Site to rise 1.0 ft or more above the HWEL at Watts Bar Dam. This dynamic also occurs at smaller time scales. For example, on an hourly basis, peaking operations at Melton Hill Dam can cause the WSEL at the CRN Site to rise above the HWEL at Watts Bar Dam. Sloshing of the reservoir from peaking operations at the Watts Bar, Melton Hill, and Fort Loudoun hydro plants also can cause the opposite to occur, with the WSEL at the CRN Site falling below the HWEL at Watts Bar Dam. During these events, the current pattern in the Clinch River arm of the Watts Bar Reservoir is reversed, with flow moving upstream rather than downstream.

Figure 2.3.1-10 shows the maximum, minimum, and average values of the daily midnight HWEL at Watts Bar Dam for the period of record from 2004 through 2013 (the years encompassing the current ROS operating policy). Large rainfall/runoff (flood) events caused the HWEL at Watts Bar Dam to spike above the target operating ranges. Such events are apparent in Figure 2.3.1-10.

2.3.1.1.2.7 Temperature and Water Velocity Measurements

For the ROS operating period including 2004 and 2008 through 2013, Figure 2.3.1-11 shows an estimate of the hourly water temperature in the tailwater below Melton Hill Dam. The data is a composite of information from several locations. These include: (1) monitors on the taildeck at Melton Hill Dam, (2) monitors for the generator cooling water inside the dam, (3) a monitor in the tailrace about 0.5 miles downstream of the dam (CRM 22.6), and (4) a monitor in the river about 19.2 mi downstream (CRM 3.9). Composite data are used because no single monitor provides valid data throughout the entire period of record. For years 2005, 2006, and 2007, equipment outages with the Melton Hill Dam taildeck monitors resulted in no usable data for those years. Composite data from the other locations are used primarily for 2004 and the first part of 2008. Almost all of the data after May 2008 are from the monitor in the tailrace about 0.5 mi downstream of the Melton Hill Dam.

In general, the water temperature for the portion of the Clinch River arm of the Watts Bar Reservoir immediately below Melton Hill Dam depends not only on meteorology, but also on the manner of operation of TVA facilities located upstream. Norris Dam, located at CRM 79.8, provides significant storage of cold water from winter and spring rainfall/runoff. Therefore, the manner of operation of Norris throughout the summer impacts the arrival of cold water at Melton Hill Dam. The Bull Run Fossil Plant, located at CRM 47.0, adds heat to Melton Hill Reservoir, thereby contributing to temperature stratification behind Melton Hill Dam. With this, scheduling of the number, magnitude, and duration of operation of the two hydro units at Melton Hill Dam affects the character of the withdrawal zone for the hydro intakes, and consequently the temperature of the water released downstream. All of these factors are represented in the variability exhibited by the data in Figure 2.3.1-11. Because the basic operating policy of ROS is expected to continue in the future, the data in Figure 2.3.1-11 are considered adequate for estimating the potential range in release water temperature from Melton Hill Dam. The record encompassing 2004 and 2008 through 2013 includes a year of extreme drought (2008), a year of extreme rainfall (2013), a year of extreme summer heating (2010), and a year of extreme winter cooling (2011).

Figure 2.3.1-12 shows the daily maximum, minimum, and average values of the hourly temperature data presented in Figure 2.3.1-11. The data suggest hourly release temperatures from Melton Hill Dam range between approximately 39 degrees Fahrenheit (°F) in the winter and 75°F in the summer. The minimum reading occurred in 2010 and the maximum reading occurred in 2012. The proposed discharge structure for the CRN Site is located approximately 7.65 mi downstream of Melton Hill Dam. Depending on meteorology, the surface water in this reach may be cooled or warmed before it arrives at the SMR discharge. To examine the potential magnitude of this cooling and warming, 2013 data were examined for hourly water temperature measurements collected from the Melton Hill Dam tailrace monitor at CRM 22.6 and a temporary monitor installed at CRM 16.1. The percentile for the change in water temperature between the upstream (CRM 22.6) and downstream (CRM 16.1) monitor locations is shown in Figure 2.3.1-13. As shown, the change in hourly temperature generally varied between about -1°F to +3°F. As a result, for examining thermal impacts on the Clinch River arm of the Watts Bar Reservoir, the ambient temperature of the surface water was assumed to range between a minimum of 38°F (winter) and maximum of 78°F (summer).

In 2013, the temperature profile of the reservoir was also measured at CRM 13.0, 16.1, and 19.0, in order to evaluate the thermal regime and the presence of thermal stratification in the reach of the reservoir near the CRN Site. CRM 16.1 is near the proposed discharge location, and CRM 19.0 is approximately 1 mi upstream of the proposed intake location. Data were collected on a 15-minute basis. The profile at CRM 13.0 included measurements at depths of 3 ft, 10 ft, 20 ft, and at a bottom anchor. The measurements at CRM 16.1 were made at depths of 5, 10, and 15 ft. The measurements at CRM 19.0 were made at 3, 10, and 15 ft. At CRM 13.0, the water temperature differences between the 3 ft sensor and the bottom were generally on the order of 2-4°F during the summer months and typically less than a degree during the winter months. The largest temperature gradient at all three locations occurred within the surface layer of the river. At the two upstream locations, the gradient between the surficial and deeper depths was even smaller than at CRM 13.0. The temperature difference at CRM 13.0 from the 10-ft depth to the bottom was minimal, typically on the order of 0.1 to 0.3°F. The temperature gradient in summer often had a typical diurnal pattern, with a temperature peak occurring in the afternoon due to surficial warming during the hottest time of the day. This daily temperature gradient was then either flushed out by daily dam releases, or its heat dissipated with nighttime atmospheric cooling.

2.3.1.1.2.8 Bathymetry

In support of the hydrologic evaluation of the CRN Site, TVA performed hydrographic surveys of the Watts Bar Reservoir from CRM 13 to CRM 21. The surveys were performed in June 2013, using an automated sounding system operating at 200 khz. The survey consisted of 762 transects across the reservoir, and an additional 96 transects across the Emory River arm of the Watts Bar Reservoir.

A prominent feature of the bathymetry of the reservoir near the CRN Site is the presence of a submerged island near CRM 15.9. The bathymetry at this location is shown in Figure 2.3.1-14. The conceptual plot plan for the CR SMR Project originally planned for the discharge to be located at CRM 15.9, directly adjacent to this feature. Based on TVA's hydrothermal modeling for the SMR discharge, TVA noted that the presence of this feature would encumber the mixing of the thermal effluent, resulting in a thermal plume hugging the shoreline. As a result, TVA modified the discharge location to approximately CRM 15.5, which is downstream of the island and in a location where the bathymetry would not interfere with mixing.

2.3.1.1.2.9 Erosion and Sediment Transport

There are currently no site-specific data available on erosion and sediment transport in the vicinity of the CRN Site as evaluations rely on specific characteristics of the final plant design. This information is to be developed as the facility design is completed, and is evaluated as part of the combined license application.

2.3.1.2 Groundwater

Regional and local groundwater resources that could be affected by the construction and operation of the CRN Site are described in this subsection. Note that all references to elevation given in this subsection are to North American Vertical Datum of 1988 (NAVD 88) unless otherwise specified.

2.3.1.2.1 Description and Onsite Use

This subsection describes the regional and local groundwater resources that could be affected by the construction and operation of the CRN Site.

The hydrogeologic conceptual model presented in this subsection was developed from multiple conceptual hydrogeologic models that vary in scale and hydrostratigraphic framework. Considerations of the scale and framework were not mutually exclusive, but were intertwined during a series of steps designed to develop a tenable site hydrogeologic conceptual model. Five steps were involved in the development of the scale-dependent conceptual models, and include:

1. A regional "desktop" study based on published state, Federal (including TVA and DOE ORR studies) and other sources.

2. A review of documentation to address the previously proposed, demonstration Clinch River Breeder Reactor Project (CRBRP) to be constructed at the site, including site-specific studies performed for the purpose of the CRBRP (Reference 2.3.1-20).
3. Review of preliminary SMR plant layout, plot plans and excavation plans for the CRN Site.
4. A site-specific geotechnical, geologic, and hydrogeologic field study conducted for the proposed CRN Site (Reference 2.3.1-21).
5. An evaluation of site-specific data in conjunction with regional and local information.

The first step of site model conceptualization involved formulating an understanding of the hydrogeologic conditions near the CRN Site including the ORR and surrounding areas. Regional geologic and hydrogeologic information available from the USGS, Tennessee Department of Environment and Conservation (TDEC), DOE, TVA, and other sources were reviewed to identify the hydrogeologic framework of the area. The second step involved a review of documentation addressing local hydrogeologic conditions such as that available from the DOE and the subsurface studies performed in support of CRBRP previously proposed at the CRN Site. The third step was a review of the preliminary CR SMR plant layout, plot plans and excavation plans developed for the conceptual placement of the SMRs that could be constructed at the CRN Site.

During the fourth step, a site-specific subsurface investigation (SI) was implemented at the proposed CRN Site. The hydrogeologic aspects of the SI were based on the preliminary conceptual model (developed as described above) and were modified when appropriate during the field program (as field data were collected and evaluated), as the understanding of site-specific conditions for SMR construction evolved.

The fifth step involved analysis of the SI field data with the regional and local information. From this effort, site-specific data were integrated with existing CRN Site information and local and regional information to formulate the conceptual site model described in the following sections. The conceptual model was then evaluated to determine potential changes to the hydrogeologic system as the result of constructing and operating the SMR units.

2.3.1.2.1.1 Physiography and Geomorphology

The CRN Site is located in Roane County, Tennessee, within the City of Oak Ridge (Figure 2.3.1-15). The CRN Site is approximately 10.7 mi southwest of the center of the City of Oak Ridge, with the site and the city center separated by the ORR. The City of Kingston is approximately 7.2 mi west of the CRN Site. The closest major metropolitan center is Knoxville, approximately 25.2 mi to the east-northeast of the CRN Site.

The site is located on a peninsula formed by a meander of the Clinch River arm of the Watts Bar Reservoir between approximately river miles 14.5 and 19. Headwaters of the Clinch River are in Tazewell County, Virginia. From its headwater, the Clinch River flows approximately 350 mi in a southwesterly direction to its confluence with the Tennessee River near Kingston, Tennessee, approximately 6 mi west of the CRN Site. The Clinch River basin is in an area of comparatively narrow parallel ridges and somewhat broader intervening valleys oriented in a northeast-southwest direction. The northwestern boundary of the basin is formed by the Cumberland Mountains, which range up to 4200 ft in elevation; the southeastern boundary follows Clinch Mountain and Black Oak Ridge with elevations ranging up to 4700 ft. (Reference 2.3.1-20)

Water levels in the Clinch River arm of the Watts Bar Reservoir, which surrounds the CRN Site to the east, south, and west, are regulated by TVA. The water elevation in Watts Bar Reservoir is generally maintained between 735 ft msl and 741 ft msl (Reference 2.3.1-11). Plant grade is at an elevation of approximately 821 ft NAVD 88; placing the SMRs about 80 ft above the water level of the river.

The CRN Site is located in eastern Tennessee near the western boundary of the Valley and Ridge Physiographic Province. The Valley and Ridge Physiographic Province is characterized by folded and faulted sedimentary geologic units of Paleozoic age, which produces a series of valleys and ridges. This province extends south through Georgia and Alabama and north to Pennsylvania and New Jersey (Reference 2.3.1-22).

In eastern Tennessee, the processes of folding, faulting, and erosion have resulted in a series of northeast trending ridges and valleys. Compressive forces from the southeast have caused these rocks to yield, first by folding and subsequently by repeated breaking along a series of thrust faults (Reference 2.3.1-22). This successive faulting has resulted in several outcropping units in the area that occur in parallel belts aligned roughly with the topography. The folding/faulting process has produced a repeated sequence of outcropping units. Major units present in the area include, from youngest to oldest, the Chickamauga Group, the Knox Group, the Conasauga Group, and the Rome Formation. All are composed primarily of Ordovician and Cambrian carbonate rocks. The dip of these formations is to the southeast in nearby Melton Valley in ORR (east of the CRN Site). Rock units generally strike between 50 and 60 degrees northeast, while dips vary with proximity to faults (Reference 2.3.1-23). Dips in Melton Valley are more gentle (10 to 20 degrees) away from the fault and steeper close to faults (45 to 90 degrees) (Reference 2.3.1-23). The extent of the Appalachian Ridge and Valley Region in eastern Tennessee is shown in Figure 2.3.1-16.

The topography of the site has been altered by anthropogenic changes. In 1972, the site was selected for permitting and construction of the CRBRP (Reference 2.3.1-24). Site preparation for the CRBRP began in September 1982. A Limited Work Authorization was granted by the U.S. Nuclear Regulatory Commission (NRC) in May 1983. Excavation for the nuclear island was completed in September 1983. Approximately three million cubic yards of earth and rock were excavated from the site (Reference 2.3.1-24). The Secretary of Energy issued a statement in October 1983 that the department would terminate the project. In November of that year, an agreement was reached by the DOE, TVA, the affected utilities and project stakeholders to begin an orderly termination of the project (Reference 2.3.1-24).

The topography of the site prior to alteration as the result of the CRBRP site preparation is described in the CRBRP Preliminary Safety Analysis Report (PSAR) (Reference 2.3.1-20). A representation of the pre-construction topography and site geology is shown in Figure 2.3.1-17. The site was characterized as a series of parallel ridges separated by long, narrow valleys extending in a northeast-southwest direction. It was reported that there were no perennial streams on the site; however, after a heavy rain, surface water flowed from the ridges into the valleys and subsequently into the river. It was anticipated that construction of the CRBRP would not significantly alter the drainage pattern of the site (Reference 2.3.1-20).

The topography of the approximately 935-ac CRN Site is shown in Figure 2.3.1-18 as a hillshade map based on a recent Light Detection and Ranging (LiDAR) survey of the site area. Areas of disturbance as the result of CRBRP site preparation and excavation can be seen by the flattened hillshade areas in Figure 2.3.1-19. The ground surface elevation varies from approximately 740 ft at the Clinch River arm of the Watts Bar Reservoir to over 1100 ft along Chestnut Ridge at the northwestern site boundary. At the CRN Site Powerblock Area (Figure 2.3.1-18), the ground surface elevation is approximately 800 ft with the exception of the CRBRP partially backfilled excavation area.

A more detailed discussion of the regional and local surface water features and geologic descriptions are presented in Subsection 2.3.1.1 and Section 2.6., respectively.

2.3.1.2.1.2 Regional Hydrogeology and Groundwater Aquifers

As previously stated, the Valley and Ridge Physiographic Province is characterized by a sequence of folded and faulted, northeast-trending Paleozoic sedimentary rocks that form a series of alternating valleys and ridges. The Valley and Ridge Province in the eastern part of Tennessee is underlain by rocks that are primarily Cambrian and Ordovician in age. Minor Silurian, Devonian, and Mississippian rocks also are present in the province. In general, soluble carbonate rocks and easily eroded shale underlie the valleys in the province, and more erosion-resistant siltstone, sandstone, and some cherty dolomite underlie ridges (Reference 2.3.1-22).

The arrangement of the northeast-trending valleys and ridges and the broad expanse of the Cambrian and the Ordovician rocks are the result of a combination of folding, thrust faulting, and erosion. Compressive forces from the southeast have caused these rocks to yield, first by folding and subsequently by repeatedly breaking along a series of thrust faults (Reference 2.3.1-22). The result of this faulting is that geologic formations can be repeated several times across the faults. In eastern Tennessee, the thrust faults are closely spaced and are more responsible than the folds for the present distribution of the rocks. Following the folding and thrusting, erosion produced the sequence of ridges and valleys on the present land surface.

The principal aquifers in the Valley and Ridge Province consist of carbonate rocks that are Cambrian, Ordovician, and Mississippian in age as shown in Figure 2.3.1-20. These aquifers are typically present in valleys and rarely present on broad, dissected ridges; and underlie more than half of the Valley and Ridge Province in Tennessee. Most of the carbonate-rock aquifers are directly connected to sources of recharge, such as rivers or lakes, and solution activity has enlarged the original openings in the carbonate rocks. Other types of rocks in the province can yield large quantities of water to wells where they are fractured or contain solution openings or are directly hydraulically connected to sources of recharge (Reference 2.3.1-22).

Groundwater in aquifers primarily is stored in and moves through fractures, bedding planes, and solution openings in the rocks. These types of openings are secondary features that developed after the rocks were deposited and lithified. Little primary porosity and permeability remain in these rocks after the process of lithification. Some groundwater moves through primary pore spaces between the particles that constitute the alluvium along streams and the residuum of weathered material that overlies most of the rocks in the area (Reference 2.3.1-22).

In the carbonate rocks, the fractures and bedding planes have been enlarged by dissolution of part of the rocks. Slightly acidic water, especially that circulating in the upper 200 to 300 ft of the zone of saturation, dissolves some of the calcite and dolomite that compose the principal aquifers. Most of this dissolution takes place along fractures and bedding planes where the largest volumes of acidic groundwater flow (Reference 2.3.1-22).

Groundwater movement in the Valley and Ridge Province in eastern Tennessee is localized, in part, by the repeating lithology created by thrust faulting and, in part, by streams. Major streams are parallel to the northeast-trending valleys and ridges, and tributary streams are perpendicular to the valleys and ridges. Older rocks (primarily the Conasauga Group and the Rome Formation) have been displaced upward over the top of younger rocks (the Chickamauga and the Knox Groups) along thrust fault planes, forming a repeating sequence of permeable and less permeable hydrogeologic units. The repeating sequence, coupled with the stream network, divides the area into a series of adjacent, isolated, shallow groundwater flow systems. Within these local flow systems, most of the groundwater movement takes place within 300 ft of land surface. In recharge areas, most of the groundwater flows across the strike of the rocks. The water moves from the ridges where the water levels are high toward lower water levels adjacent to major streams that flow parallel to the long axes of the valleys as shown on Figure 2.3.1-21. Most of the groundwater is discharged directly to local springs or streams, but some of it moves along the strike of the rocks, following highly permeable fractures, bedding planes, and solution zones to finally discharge at more distant springs or streams. Although fracture zones locally are present in the clastic rocks, the highly permeable zones, which are primarily present in the carbonate rocks, act as collectors and conduits for the water (Reference 2.3.1-22).

The most important aquifers in the Valley and Ridge Province in eastern Tennessee are the carbonate rocks underlying the majority of the province. The Knox Group is the most important aquifer in eastern Tennessee. Of particular interest, near the CRN Site, are the Chickamauga Group and the Knox Group (Reference 2.3.1-20). Most of the carbonate-rock aquifers are directly connected to surface water such as rivers and lakes. Other types of rocks can yield large quantities of water to wells where they are fractured, contain solution openings, or are hydraulically connected to a source of recharge (Reference 2.3.1-22).

Secondary porosity features, in the form of bedding planes, fractures, and solution openings, comprise the primary flow pathways in the Valley and Ridge Province, as most rocks in the province have low primary porosity. Regolith layers are composed of clayey soils and saprolite. Typical conceptual cross sections in the province consist of a storm-flow zone near the surface, a less permeable vadose zone, and a groundwater zone consisting of fractured bedrock with fracture density decreasing with depth (Reference 2.3.1-25). Groundwater flow is generally from recharge areas at high elevation (ridges) to local streams and rivers at lower elevations. The repeating geological sequences described above along with the regional stream network can create a series of adjacent, isolated, shallow groundwater flow systems (Reference 2.3.1-22).

Long-term average annual precipitation is approximately 50 in. in the vicinity of the CRN Site, with an estimated long-term average runoff of 25 to 30 in. (Reference 2.3.1-22). Most of the precipitation that percolates downward becomes groundwater recharge to the shallow aquifers; a small portion enters the deep aquifer. Mixing at depth in carbonate formations have also been studied (Reference 2.3.1-26).

Well yields in the Valley and Ridge Province vary from 1 to 2500 gallons per minute (gpm) (Reference 2.3.1-22). The largest yields are from wells completed in Ordovician and Cambrian carbonate rocks (e.g., the Knox Group). Wells completed in the middle and lower parts of the Chickamauga Group, the Knox Group, and the upper part of the Conasauga Group have reported yields around 500 gpm in some locations. The median yield of wells completed in the principal aquifers range from about 11 to 350 gpm (Reference 2.3.1-22).

Spring discharges also vary greatly across the Valley and Ridge Province, ranging from about 1 to 5000 gpm, with median discharges from the principal aquifers varying from 20 to 175 gpm (Reference 2.3.1-22). The largest spring discharges issue from limestone formations of the Chickamauga Group; springs from the Knox Group have reported discharges as high as 4000 gpm (Reference 2.3.1-22). Spring discharges can be highly dependent on rainfall with some springs discharging as much as 10 times more water during high precipitation events as compared to periods of little rainfall (Reference 2.3.1-22). Wet-weather perched water tables and intermittent springs have been noted to occur (Reference 2.3.1-25).

Groundwater on the ORR, which is adjacent to the CRN Site, occurs in the unsaturated zone as transient, shallow subsurface storm flow as well as within the deeper saturated zone (Reference 2.3.1-27). An unsaturated zone of variable thickness separates the stormflow zone and water table. Adjacent to surface water features or in valley floors, the water table is found at shallow depths where the stormflow and unsaturated zones are undistinguishable. Along the ridge tops or near high topographic areas, the unsaturated zone is thick, and the water table often lies at considerable depths (approximately 50 to more than 150 ft).

Recharge of the groundwater system is reported to be strongly seasonal at the ORR. The amount of water that recharges the groundwater zone is highly variable depending on the shallow soil characteristics, permeability and degree of regolith fracturing beneath the soil, and the presence of dolines and man-made paved or covered areas. Higher recharge is expected in areas of karst hydrogeology such as the Knox aquifer. In the ORR aquitards, groundwater is transmitted through fractures (Reference 2.3.1-27).

The chemical quality of water in the freshwater parts of the Valley and Ridge aquifers is similar for shallow wells and springs. The water is hard, a calcium-magnesium-bicarbonate type, and typically has a dissolved-solids concentration of 170 parts per million (ppm) or less. The ranges of concentrations are thought to be indicators of the depth and rate at which groundwater flows through the carbonate-rock aquifers. In general, the smaller values for a constituent represent water that is moving rapidly along shallow, short flow paths from recharge areas to points of discharge. This water has been in the aquifers for a short time and has accordingly dissolved only small quantities of aquifer material. Conversely, the larger values represent water that is moving more slowly along deep, long flow paths. Such water has been in contact with aquifer minerals for a longer time and thus has had greater opportunity to dissolve the minerals. Also, water that moves into deeper parts of the aquifers can mix with saltwater (brine) that might be present at depth (Reference 2.3.1-22).

The chemical characteristics of the groundwater in the ORR aquitards range from a mixed-cation-bicarbonate water type at shallow depths to a sodium-bicarbonate water type at deeper depths, to sodium-calcium-chloride water type as evidenced from very deep wells. These chloride-rich waters appear to be a zone of dilution on top of deeper saline sodium-calcium-chloride brines, similar to those encountered within the Conasauga Group at depths greater than 1000 ft in Melton Valley (Reference 2.3.1-26). The Knox aquifer is characterized by a calcium-magnesium-bicarbonate water type.

The hydrogeologic conditions at the CRN Site are similar to those observed at the ORR with the exception of land disturbance areas resulting from earlier site work performed for the CRBRP where excavations and fill material are present.

2.3.1.2.1.3 Local Hydrogeology

Description of the local hydrogeology is based on information from the adjacent ORR. The hydrogeology of the ORR is defined by two broad hydrogeologic groups: the Knox aquifer consisting of the Knox Group and the Maynardville Limestone and the ORR aquitards, which include the Chickamauga Group, Conasauga Group, and the Rome Formation (Reference 2.3.1-28). In the vertical dimension, the Knox aquifer and the ORR aquitards are subdivided into:

- The stormflow zone, which is a thin region at the surface where transient, precipitation generated flow accounts for 90 percent or more of the water moving through the subsurface.
- The vadose zone is the unsaturated zone above the water table, which varies in thickness from nearly non-existent along stream channels to greater than 100 ft beneath ridges underlain by the Knox aquifer.

- The groundwater zone, which is continuously saturated and is the region where most of the remaining 10 percent of subsurface flow occurs. This zone is typically encountered near the top of bedrock.
- The aquiclude is a zone within the bedrock, within which water movement, if it occurs, probably is on the scale of thousands of years or more.

2.3.1.2.1.3.1 *Chickamauga Group*

The Middle to Upper Ordovician age Chickamauga Group consists of limestone, shale, and siltstone. In eastern Tennessee it is subdivided into upper, middle, and lower parts. The upper part of the Chickamauga consists of 700 to 1000 ft of limestone and shale. The middle and lower parts, together range in thickness from about 2000 to 6000 ft, consisting of limestones, shales, and siltstone (Reference 2.3.1-20). However, due to thrust faulting, the entire Chickamauga Group sequence is frequently not present (Figure 2.3.1-20) The lower and middle parts of the Chickamauga Group are generally considered to be better aquifers than the upper part (Reference 2.3.1-20). Figure 2.3.1-22 presents the subdivisions of the Chickamauga Group based on the stratigraphy of Bethel Valley in the ORR (Reference 2.3.1-29). The unit designations developed by Stockdale were used during the CRBRP investigation (Reference 2.3.1-30). The formation names shown on the figure are the names used in this investigation.

Groundwater in the Chickamauga Group is largely restricted to fractures which have been enlarged by solutioning. The fracturing of the formation by folding has resulted in a system of cavities which are more or less interconnected. The quality of water in the Chickamauga Group is varied and is influenced by local topography, local land-use patterns, depth below ground surface at which the formation is encountered, and small scale geologic considerations (Reference 2.3.1-20). Many springs occur at the shale-limestone contacts and where solution-widened joints or fractures extend to ground surface in topographic lows. In the lower and middle parts of the Chickamauga limestones, small springs are common, and several can yield more than 450 gpm. Wells in these rocks usually have low yields when located on hills or other topographic highs and have larger yields when located near permanent streams. In the upper part of the Chickamauga limestones, some springs can yield more than 100 gpm (Reference 2.3.1-20).

2.3.1.2.1.3.2 *Knox Group*

The Upper Cambrian to Lower Ordovician age Knox Group is the most important aquifer in eastern Tennessee. The Knox Group consists of 2000 to 3000 ft thickness of dolomites, limestones, and sandstones. The Knox Group in eastern Tennessee is subdivided into five formations:

- Mascot Dolomite
- Kingsport Formation
- Longview Dolomite

- Chepultepec Dolomite
- Copper Ridge Dolomite (Reference 2.3.1-29)

The occurrence of water is controlled by the extent of solution enlargement of fractures (that are the result of ancient folding and faulting). Numerous springs are found in these rocks and the water is generally of good quality. The yield of water to wells ranges from small to large. Generally the largest fractures and thus greatest well yields are found in the first few hundred ft of formation depth (Reference 2.3.1-20).

2.3.1.2.1.3.3 *Conasauga Group*

The Middle to Upper Cambrian age Conasauga Group shows lithofacies changes along north-south trending belts from clastics in the west to carbonates in the east. The site area falls within the central area of the group, which exhibits an interfingering of clastic and carbonate deposits. Six formations can be identified within the group:

- Maynardville Limestone
- Nolichucky Shale
- Dismal Gap formation (formerly Maryville Limestone)
- Rogersville Shale
- Friendship formation (formerly Rutledge Limestone)
- Pumpkin Valley Shale

The Conasauga Group has an average thickness of approximately 1800 ft in Melton and Bear Creek Valleys. The Maynardville Limestone is associated with the overlying Knox Group and functions as a single hydrologic unit known as the Knox aquifer. The remainder of the group is considered to be an aquitard (Reference 2.3.1-29).

2.3.1.2.1.3.4 *Rome Formation*

The Early Cambrian age Rome Formation is the oldest bedrock unit exposed in the site area. The Rome Formation consists of mixed siliciclastic and carbonate rocks. The lithologies represented in the formation include sandstone, siltstone, and shale with dolomite and dolomitic sandstone intervals. Studies have suggested that the true stratigraphic thickness of this formation is between 300 and 400 ft. This formation is considered to be an aquitard (Reference 2.3.1-29).

2.3.1.2.1.3.5 *Unconsolidated Deposits*

The unconsolidated deposits in the CRN Site area typically consist of four types: residuum, colluvium, alluvium, and anthropogenic materials.

Residuum

The residuum is composed of the remains of bedrock weathering. In the site area bedrock weathers to a clayey residual soil, which locally contains chert gravel. During the CRBRP investigation, the thickness of the residuum was found to vary from 1 to 78 ft, depending on the type of underlying bedrock (Reference 2.3.1-20).

Colluvium

Colluvium is an unconsolidated deposit sometimes found at the toe of a slope, and it represents material that has been moved by gravity. Colluvial deposits are generally identified by a lack of residual rock structure (bedding or joints) with disoriented rock fragments. This material tends to have more rock fragments than either residuum or alluvium. Colluvial deposits may be reworked by surface water action resulting in a hybrid colluvium-alluvium mixture (Reference 2.3.1-29).

Alluvium

The alluvium includes deposits by the Clinch River and smaller tributary streams. During the CRBRP investigation, alluvial terrace deposits were identified on the site. These deposits consisted of silty clay with thin layers of rounded quartz, chert, and quartzite gravel. Additionally a sand and clay alluvial layer was found to occur in the Clinch River floodplain, with a thickness of approximately 32 ft (Reference 2.3.1-20).

Anthropogenic Materials

Anthropogenic materials are primarily associated with artificial backfill. These materials include overburden and shot-rock (i.e., rock that has been excavated by blasting). Materials were excavated during site preparation for the CRBRP. These materials were moved and placed to facilitate laydown and parking area construction and to implement the site redress plan, when the project was canceled (Reference 2.3.1-24).

2.3.1.2.1.3.6 *Summary of Local Hydrogeology*

Figure 2.3.1-23 shows the vertical relationship of the bedrock subdivisions for the Knox aquifer and the ORR aquitards. The figure indicates that fracture frequency decreases and the concentrations of sodium and chloride increase in the groundwater with increasing depth.

Numerous groundwater investigations have been performed at the ORR providing hydrogeologic property data for the bedrock units. Testing has included slug tests, packer tests, aquifer pumping tests, and tracer tests (Appendix 2.3-A). Figure 2.3.1-24 summarizes the hydraulic conductivity test results (box and whisker plot and hydraulic conductivity versus depth) by geologic formation and by depth below ground surface. The hydraulic conductivity by depth graph suggests that at approximately 100 ft below ground surface (bgs), hydraulic conductivities decrease with depth, although this trend is less obvious in the Knox aquifer, since both fracturing and solutioning are active in this unit. Figure 2.3.1-25 summarizes the results of selected aquifer pumping tests performed on the ORR (presented in Appendix 2.3-A). The statistics presented on the figure indicate a geometric mean transmissivity of 32.5 feet squared per day (ft^2/d) and a storage coefficient of 5.9 x 10^{-4} ft^2/d for the Conasauga Group tests.

Additional hydrogeologic parameters for the stormflow and groundwater zones on the ORR are summarized on Table 2.3.1-2. The information presented in Table 2.3.1-2 suggests the transmissivity values for the ORR aquitards are approximately one order of magnitude less than those of the Knox aquifer.

2.3.1.2.1.4 Site Specific Hydrogeology

Site specific hydrogeology has been investigated during the CRBRP licensing effort and preparation for the early site permit application.

2.3.1.2.1.4.1 *CRBRP Investigation*

As part of the licensing activities for the CRBRP, the site was investigated by drilling 129 borings, installing 37 observation wells, installing 11 piezometers, and performing 117 bedrock packer permeability tests in boreholes. The investigation also included collection of groundwater level data and performing a survey of local groundwater users (Reference 2.3.1-20). Abandoned wells from the CRBRP were identified on site. The identified CRBRP wells will be evaluated for closure in accordance with applicable TVA and TDEC requirements.

The CRBRP SI identified four bedrock joint set orientations at the site:

- N52°E 37°SE
- N52°E 58°NW
- N25°W 80°SW
- N65°W 75°NE (Reference 2.3.1-20)

The predominant joint set is oriented N52°E 37°SE, which corresponds with the bedding plane partings in bedrock. The N52°E 58°NW joint set has a joint spacing of between one and six ft (Reference 2.3.1-20).

The results of the CRBRP packer hydraulic conductivity tests are shown on Figure 2.3.1-26 (and presented in Appendix 2.3-B), includes summary plots (box and whisker and hydraulic conductivity vs. depth) of the packer test results. The results can be classified in three groups: the Chickamauga long interval tests (test section length 40 ft and greater), the Chickamauga discrete interval tests (test section length less than 40 ft), and the Knox Group tests. The CRBRP packer-test-derived hydraulic conductivity results are similar to hydraulic conductivity test results from the ORR. Both sets of results indicate a decreasing trend in hydraulic conductivity at depths greater than approximately 100 ft bgs.

Water level measurements on the site indicated fluctuation in water levels as much as 20 ft. Maximum water levels were observed in January and February and minimum water levels were observed in October and November. Movement of groundwater is described as generally from topographically high areas to topographic lows; however, this pattern is modulated by the extent of weathering in the bedrock. Ultimately, the Clinch River acts as a sink for site groundwater flow. The investigation concluded that major ridges on the site may be regarded as approximate locations of groundwater divides (Reference 2.3.1-20).

2.3.1.2.1.4.2 *CRN Site Investigation*

The CRN Site field investigation included drilling 82 borings, installing 3 test pits, installing 44 wells, and performing in-situ/ex-situ tests on soil, rock, and groundwater. Groundwater characterization activities included monitoring groundwater levels and performing packer tests in boreholes, slug tests in monitoring wells, an aquifer pumping test, and groundwater geochemical sampling. Groundwater level monitoring is discussed in Subsections 2.3.1.2.2.2 and 2.3.1.2.2.3, aquifer properties are discussed in Subsection 2.3.1.2.2.4, and geochemical results are discussed in Subsection 2.3.3.2.

The locations of observation wells installed during this investigation are shown on Figure 2.3.1-18 and well installation details are provided on Table 2.3.1-3. The figure and table include permanent observation wells (OW prefix) and supplemental wells (PT-OW and PT-PW prefixes) installed for the aquifer pumping test. Well suffixes of “U,” “L,” and “D” were assigned to wells to designate the upper, lower, and deeper monitoring zones respectively. The screened depth intervals for the site observation wells for the upper monitoring zone range from 15 to 105 ft bgs, the lower monitoring zone range from 89 to 178 ft bgs, and the deeper monitoring zone range from 176 to 297 ft bgs.

A three-well cluster was installed east of the OW-101 well cluster, at boring location MP-422 (OW-422 U, L and D). During well completion, groundwater contamination was observed in OW-422L, and TVA notified TDEC and provided it with results of well sampling. The contamination was determined to be non-radiological petroleum products. Due to the contamination in OW-422L, this well cluster (OW-422 U, L and D) was not developed; however, it remains in place, locked and under TVA control. TVA has no plans to perform any additional work in the location, and TDEC will make a determination regarding the disposition of the well. Because the wells were not developed and monitoring of water levels in these wells was not performed, the OW-422 well series is not included in the discussion of site observation wells. Well clusters OW-428 and OW-429 (installed north and south of the OW-422 cluster) were installed to provide replacement geological/groundwater data.

Additional as-built information for the site wells is presented in the “Data Report for Geotechnical Exploration and Testing” (Reference 2.3.1-21). All permanent observation wells at the CRN Site were sampled after well development and no evidence of petroleum products was observed in the wells. The contamination seems to be restricted to the immediate well OW-422 area since no evidence of petroleum products were observed before and after the 72-hr pumping test conducted near the OW-423 U, L, and D well cluster (up dip of OW-422L). The hydrogeology of the CRN Site is expected to be similar to the hydrogeology of the ORR as a result of the site's physical proximity and similarity in geology. The primary differences are in the storm-flow and vadose zones at the CRN Site. The extensive excavation and reworking of unconsolidated and weathered bedrock materials associated with the CRBRP site preparation has either significantly modified or obliterated these zones at the CRN Site.

2.3.1.2.1.5 Groundwater Sources and Sinks

This subsection describes the regional, local, and site-specific discharge and recharge areas, mechanisms, and characteristics of the different aquifer units.

2.3.1.2.1.5.1 *Groundwater Discharge*

Natural discharge of the Valley and Ridge Province aquifers is primarily through streams, rivers, springs and evapotranspiration. In the site area, the Clinch River acts as a sink to which all groundwater at the site migrates (Reference 2.3.1-20).

Studies performed by the DOE for the Melton Valley offsite monitoring system, which is located approximately two miles east of the CRN Site, investigated the groundwater flow relationship with the Clinch River (Reference 2.3.1-31). Figure 2.3.1-27 presents a section through the river showing the head distribution. This head distribution suggests discharge to the Clinch River from the surrounding groundwater system.

2.3.1.2.1.5.2 *Groundwater Recharge*

Groundwater recharge is derived primarily from precipitation. Although periodic recharge from the Clinch River during high stages of the river may also be occurring, this is not considered to represent a significant part of the recharge to the aquifer. Recharge is most effective in those areas where the overburden soils are thin and permeable. Recharge may also occur through sinkholes that penetrate relatively thick and impervious formations (Reference 2.3.1-20).

2.3.1.2.2 Groundwater Sources

This subsection contains information pertaining to sole-source aquifers, groundwater flow directions and hydraulic gradients, seasonal and long-term variations of groundwater levels, hydraulic conductivity and effective porosity of the geologic formations. This information has been organized into five subcategories: (1) identification of sole source aquifers, (2) groundwater flow directions, (3) temporal groundwater trends, (4) aquifer properties, and (5) hydrogeochemical characteristics.

2.3.1.2.2.1 Sole Source Aquifers

A sole-source aquifer is defined as the sole or principal source of drinking water that supplies 50 percent or more of drinking water for an area, with no reasonable available alternative sources should the aquifer becomes contaminated. Figure 2.3.1-28 shows the location of sole-source aquifers in U.S. Environmental Protection Agency (EPA) Region 4, which encompasses Tennessee. Because surface water is abundant in the area, the EPA's Sole Source Aquifer Program has not identified any sole source aquifers in Tennessee as shown in Figure 2.3.1-28 (Reference 2.3.1-32). The identified sole-source aquifers in EPA Region 4 are beyond the boundaries of the local and regional hydrogeologic systems associated with the CRN Site. Therefore, the CRN Site will not impact any identified sole-source aquifer.

2.3.1.2.2.2 Temporal Groundwater Trends

The USGS maintains a network of observation wells in Tennessee to monitor trends in water levels. The closest permanent observation well is approximately 48 mi southeast of the CRN Site as shown on Figure 2.3.1-29 (Reference 2.3.1-33). This observation well is screened in the Great Smoky Group aquifer and is approximately 220 ft deep. The well indicates typical annual fluctuations of between 1 and 3 ft. The USGS also presents data from a manual water level measurement well located approximately 0.5 mi east of the CRN Site as shown on Figure 2.3.1-30 (Reference 2.3.1-34). This well is screened in the Valley and Ridge aquifer and is approximately 610 ft deep. The period of record is only approximately 3 months; however the hydrograph shows an approximate 5 ft range of water levels fluctuations. Neither of these USGS wells monitor the hydrogeologic units relevant to the site.

During the CRBRP investigation, periodic water level measurements were made in the site observation wells and piezometers. Examination of these measurements suggests an annual fluctuation of 10 to 25 ft with maximum water levels occurring in January and February and minimum water levels occurring in October and November (Reference 2.3.1-20).

The CRN Site hydrogeologic characterization program consisted of two years of groundwater level measurements in site observation wells. This included periodic manual measurements in all wells (except the OW-422 well cluster), beginning September 23, 2013, and continuous measurements from a recording pressure transducer in the following wells, beginning on November 23 and 24, 2013:

- OW-101
- OW-202
- OW-409
- OW-417
- OW-423

Figure 2.3.1.-31 presents hydrographs for the site well clusters, along with Clinch River (Watts Bar Reservoir) stage and site precipitation data for comparison. Water level responses from wells OW-101D, OW-409U, OW-416U/L, OW-420L, and OW-421D show correspondence to the Watts Bar Reservoir stage with periodic deviations that appear to be associated with

precipitation events. All of the site wells show a response to precipitation events, with OW-417L and OW-421U showing the most subdued response to precipitation. The location of well clusters OW-417 and OW-421 in proximity to the Clinch River may explain the subdued responses in these wells.

Observation wells OW-202L, OW-421L, OW-421D, OW-428U, OW-428L, and OW-428D show water level artifacts from well installation, development, and water sampling; these wells are excluded for the purpose of characterizing the range of fluctuation. The range of water level elevation fluctuations in the site observation wells was from approximately 1ft (OW-421U) to 25 ft (OW-409U). These fluctuations appear to be associated with precipitation events. The large magnitude of fluctuation at OW-409U may be further indication that this well is located in a recharge area.

2.3.1.2.2.3 Groundwater Flow Directions

Groundwater flow directions in the ORR are generally characterized as from the ridge tops to drainages within the adjacent valley or as a subdued replica of topography. Figure 2.3.1-32 presents conceptual block flow diagrams for Bethel Valley, which has similar geology as the CRN Site (Reference 2.3.1-35). The figure indicates localized influences such as springs, discontinuity orientations (fractures and bedding planes), man-made features (pipelines, tank farms, and building basements), and solution features have an impact on flow directions.

Groundwater flow directions were evaluated during the CRBRP PSAR by preparing two groundwater contour maps, one for December 24, 1973 and one for January 2, 1974 (Reference 2.3.1-20). Both maps indicate a general flow direction toward the southeast or southwest in the area of the proposed nuclear island. An average hydraulic gradient of approximately 0.007 feet per foot (ft/ft) is reported for the two maps (Reference 2.3.1-20). It should be noted that these maps were prepared using water level measurements from observation wells with long screened intervals and thus the equipotentials represent a vertically averaged head.

The CRN Site investigation included synoptic measurements of groundwater levels in the site observation wells. These measurements were used to prepare maximum potentiometric surface maps for the site. The maximum potentiometric surface maps used the maximum groundwater level elevation at each well cluster. Figures 2.3.1-33 through 2.3.1-42 present the potentiometric surface maps. The maps indicate a southwest to southeast flow direction in the area of the proposed CRN Site Powerblock Area. Hydraulic gradients were measured along selected flow lines on each figure. Table 2.4.12-8 in the Site Safety Analysis Report (SSAR) presents the horizontal hydraulic gradients for the ten potentiometric surface maps. The horizontal hydraulic gradients range from 0.03 to 0.12 ft/ft. Horizontal gradients were also evaluated using just the upper site observation wells for the eight quarters (December 2013, March 2014, May 2014, August 2014, November 2014, February 2015, May 2015, and August 2015), resulting in horizontal gradients ranging from 0.05 to 0.17 ft/ft. For comparison the average hydraulic gradient between the maximum water level at OW-101U and OW-202U and the Clinch River arm of the Watts Bar Reservoir is 0.05 ft/ft. This is derived based on a shortest distance of 1400 ft from the power block area to the edge of the Clinch River arm of the Watts Bar Reservoir; lowest stage of the reservoir at 735 ft NAVD88 (during the monitoring period); and the maximum water levels at OW-101U and OW-202U of 798.99 and 800.30 ft NAVD88. Due to the complexity of the subsurface hydrogeologic conditions at the CRN Site, the maximum potentiometric groundwater elevation at each well cluster is used, representing a single hydrogeological unit. Given that the “U,” “L,” and “D” wells generally screened within different hydrogeologic units, the “maximum potentiometric surface” maps do not represent a true potentiometric surface. These maps can, however, be considered bounding in terms of depicting the maximum groundwater elevations at the site.

Vertical hydraulic gradients were determined at each well cluster to evaluate the potential for vertical movement in the subsurface. The average vertical hydraulic gradients range from -0.69 to 1.03 ft/ft (Appendix 2.3-C). A negative vertical hydraulic gradient indicates an upward flow potential and a positive one indicates a downward flow potential. The upward flow potential would suggest groundwater discharge and the downward flow potential would suggest groundwater recharge. A majority of the wells with upward flow potential are located on the western and eastern sides of the site suggesting discharge towards incised site drainage features or to the Clinch River. The exception to this is well cluster OW-409U/L, which is located near the center of the site. This cluster may be indicating groundwater discharge to the adjacent CRBRP excavation. The cluster with the highest downward flow potential is OW-429U/L, suggesting a recharge area. Figure 2.3.1-43 represents the spatial variation of equipotential in the vertical plane in a cross-section along the strike of the bedding plane based on June 13, 2014 observations. Groundwater discharges from the higher equipotential area (at OW-202) to the Clinch River arm of the Watts Bar Reservoir, with OW-202 at the center of the CRS peninsula as a likely location of the groundwater divide.

2.3.1.2.2.4 Aquifer Properties

Aquifer properties at the CRN Site were determined by in-situ testing and from laboratory testing of rock core and soil samples collected during the investigation. The following sections present the results of this testing.

2.3.1.2.2.4.1 *Hydrogeological Parameters*

The primary hydrogeological properties of interest at the site are the hydraulic conductivity and effective porosity of the bedrock. Hydraulic conductivity was evaluated qualitatively through fracture frequency analysis and quantitatively through in-situ testing. The in-situ tests performed were borehole packer tests, well slug tests, and an aquifer pumping test. Effective porosity is based on a series of studies performed on the ORR.

Fracture Frequency Analysis

Fracture frequency analysis was performed by plotting the open fractures identified on the acoustic televiewer borehole geophysical logs. Figure 2.3.1-44 presents the resulting frequency distribution histogram. The histogram shows three general areas: 1) from elevation 812 to 712 ft NAVD 88, a pervasively fractured zone; 2) from elevation 712 to 612 ft NAVD 88, a moderately fractured zone; and 3) from 612 to 487 ft NAVD 88, a slightly fractured zone. It should be noted that the upper elevation of the pervasively fractured zone is somewhat biased, since most boreholes were cased into the top of bedrock prior to performing the geophysical surveys, and thus the number of open fractures at the top of rock is not accurately represented and are likely under-reported. Figure 2.3.1-45 presents an example geophysical log demonstrating this bias.

The fracture distribution identified at the CRN Site is consistent with observations at the ORR. In nearby Melton and Bethel Valleys, the transition from fractured to less fractured bedrock occurs at approximately 150 ft bgs (Reference 2.3.1-28). Figure 2.3.1-24, which is a plot of ORR hydraulic conductivity test results, indicates a generalized decrease in hydraulic conductivity at approximately 100 ft bgs.

Borehole Packer Tests

A borehole packer test is a constant head test of an isolated interval in a borehole to determine the hydraulic conductivity. For the CRN Site investigation, a double packer arrangement was used to isolate the test zone. A total of 41 packer tests were performed in 12 open boreholes during the field investigation. Of these tests, 5 exhibited evidence of flow by-passing around the packers and 14 had flow rates less than the quantifiable rate for the test, and thus were not analyzed. Table 2.3.1-5 presents the test results.

The tests were performed and interpreted using USACE method 381-80 (Reference 2.3.1-36). The borehole packer test results were arranged by geologic unit and are presented in a box and whisker plot on Figure 2.3.1-46. Summary statistics for these tests are included on the figure. The results were also compared with the packer tests performed during the CRBRP investigation as shown on Figure 2.3.1-46. In general the two data sets agree; however, the CRBRP Chickamauga long interval and CRBRP Knox tests exhibit an order of magnitude, or more, lower range of values. This may in part be due to the deeper test intervals selected during the CRBRP investigation. The upper range of values is similar for both data sets.

The CRN packer results were plotted versus depth below ground surface as shown on Figure 2.3.1-47. The results show a similar pattern as the CRBRP tests (Figure 2.3.1-26) and the ORR hydraulic conductivity tests (Figure 2.3.1-24). The hydraulic conductivities decrease below 150 ft bgs. This is most probably the result of the decreased frequency of open fractures below this depth.

Well Slug Tests

The slug test method involves creating a sudden water level displacement in the well and observing the water level change as it returns to the pre-test level. Slug tests were performed in selected site observation wells. Observation wells excluded from testing include OW-202U, OW-402U, and OW-429L because of low water levels in the wells and OW-428D because the well was still recovering from development activities. Slug tests used either a solid slug or pneumatic slug to induce the water level change. Two tests were performed in each well, one where the water level was raised in the well and allowed to fall back to the pre-test level (falling head) and one test where the water level in the well was lowered and allowed to rise back to the pre-test level (rising head). A recording pressure transducer was placed in the well to monitor the water level changes. Slug test results were entered into the AQTESOLV (HydroSOLVE 2007) computer program and the Bouwer and Rice method was used for interpretation (Reference 2.3.1-37; Reference 2.3.1-38).

The slug test solution is a porous medium method and is applied to fractured bedrock. Porous medium slug test method results were compared with discrete fracture interval method results (Reference 2.3.1-39). Their comparison found that using porous medium methods, the results were on the same order of magnitude as the results for the discrete fracture interval methods. A porous medium assumption is appropriate in highly fractured materials and where fluid exchange between the fractures and the rock matrix is either very limited or very rapid (Reference 2.3.1-40). The observation wells were located in the most fractured intervals identified in the borehole logs. Information from the ORR on Table 2.3.1-2 indicates that a matrix hydraulic conductivity of 2.8 x 10^{-7} ft/d is representative of the ORR Aquitards, which includes the Chickamauga Group. This matrix hydraulic conductivity suggests that the rock matrix is not contributing significantly to flow. These studies suggest that the use of the porous medium assumption is reasonable for the CRN Site tests.

Table 2.3.1-6 presents the results of the slug test interpretations. Examination of the table indicates that the test results from four wells (OW-202L, OW-401D, OW-415U, and OW-421D) could not be interpreted. Additionally, the results from five wells (OW-409U, OW-415L, OW-421L, OW-423D, and OW-429U) had one test (falling or rising head) that could not be interpreted. For those wells with one test, the average hydraulic conductivity is equivalent to the results of the test (falling or rising head) that could be interpreted.

Figure 2.3.1-48 presents the slug test results graphically. The figure includes a box and whisker plot of hydraulic conductivity by observation well monitoring zone and a scatter plot of hydraulic conductivity versus depth below ground surface. The box and whisker plot indicates that the hydraulic conductivities in the upper and lower zones are similar, while those in the deep zone are lower. The scatter plot of hydraulic conductivity versus depth below ground surface in general shows a pattern of decreasing range in hydraulic conductivity with depth similar to plots in Figure 2.3.1-26 and Figure 2.3.1-47. Figure 2.3.1-49 is a box and whisker plot comparing the slug test results with the CRN Site packer test results for the two major geologic units (Chickamauga Group and Knox Group) present at the site. The figure indicates a similar central tendency in the results of both tests, but the slug tests have a much broader range of values. The breadth of this range may be due to the longer test intervals for the slug tests as compared to the packer test intervals.

Aquifer Pumping Test

An aquifer pumping test was performed at the CRN Site. The aquifer pumping test array consisted of a pumping well (PT-PW) and nine proximal observation wells (PT-OW-U1, PT-OW-L1, PT-OW-U2, PT-OW-L2, PT-OW-U3, PT-OW-L3, OW-423U, OW-423L, and OW-423D) as shown on Figure 2.3.1-18. The installation completion data for these wells are included on Table 2.3.1-3. The pumping well was screened in the Fleanor and Eidson members of the Lincolnshire formation and the Blackford formation. The upper zone observation wells were screened in the Eidson member of the Lincolnshire formation and the lower and deep zone observation wells were screened in the Blackford formation. The aquifer thickness was taken to be 155 ft, which represents the difference between the static water level in the pumping well and the bottom elevation of the primary flow zone. (A review of the geologic log cores did not identify an overlying confining bed; it is presumed that leakage is derived from an underlying confining bed.) A constant rate pumping test was performed in the pumping well for a period of 72 hr with an average pumping rate of 14.5 gpm.

Pumping and observation well responses were reviewed and diagnostic plots of each well were prepared. Based on a review of the observation well water level responses, a portion of the observation wells were discarded from further analysis, because they were outside the radius of influence of the pumping well or they were completed in different hydrogeologic unit. Interpretation of the diagnostic plots for the results that were retained indicated that a leaky aquifer model most accurately represents the observed response. The water level response and pumping rate data were entered into the AQTESOLV (HydroSOLVE 2007) computer program for analysis (Reference 2.3.1-38). The solution method used was that presented in Hantush and Jacob (Reference 2.3.1-41).

Table 2.3.1-7 presents the results of the constant rate pumping test interpretation. Examination of the results suggests the maximum transmissivity and hydraulic conductivity is observed at OW-423L, which is oriented with the N52°E strike of the bedding planes relative to the pumping well. The observation wells (PT-OW-U2 and PT-OW-L2) oriented perpendicular (N38°W) to the strike of the bedding planes show approximately an order of magnitude lower transmissivity and hydraulic conductivity. Comparison of the results of this aquifer pumping test with tests performed on the ORR, as shown on Figure 2.3.1-25, indicates that the transmissivities are within the same range, but the storage coefficient values have a greater range for the CRN Site aquifer pumping test.

Effective Porosity

Table 2.3.1-8 summarizes the results of petrophysical testing of rock samples to determine the effective porosity of rock from the Conasauga and Knox Groups on the ORR. The test methods used include helium, mercury, and immersion-saturation porosimetry. The authors indicate that the immersion-saturation method would produce the results that most accurately approach the true value of effective porosity. The average effective porosity of bedrock determined from these tests is approximately 4 percent.

2.3.1.2.2.4.2 *Geotechnical Parameters*

During the CRN Site investigation, soil and rock samples were collected and tested. Interpretation of the test results has resulted in best estimates of properties of the different materials that are present or may be present in the future at the site. Table 2.3.1-9 summarizes the estimates of parameters important to radionuclide transport.

2.3.1.2.2.4.3 *Summary of Aquifer Properties*

Hydrogeologic testing information for the CRN Site area were obtained from 1) published bedrock aquifer testing from the ORR area; 2) CRBRP investigation packer tests; 3) CRN Site packer tests; 4) CRN Site slug tests: and 5) the CRN Site aquifer pumping test. The Conasauga Group, Knox Group, and the Chickamauga Group are the three major geologic strata in which the hydrogeologic testing were undertaken. Evaluation of these results suggests that hydraulic conductivity, in the bedrock, generally decreases with depth irrespective of the lithology.

Additional petrophysical testing, such as bulk density and porosity testing have been performed at the ORR and at the site. The results of these tests show generally uniform properties in the bedrock units.

2.3.1.2.2.5 Hydrogeochemical Characteristics

Site specific groundwater chemical data was collected from selected CRN onsite observation wells and compared to existing hydrogeochemical data from the surrounding area. Results and evaluation of these data sets are presented in Subsection 2.3.3.2.

2.3.1.2.3 Subsurface Groundwater Pathways

The CRN Site is surrounded on three sides by the Clinch River arm of the Watts Bar Reservoir, which is interpreted to be the discharge area for site groundwater. The most likely pathway for groundwater flow is recharge in the upland areas of the site with discharge to the Clinch River arm of the Watts Bar Reservoir. An alternate groundwater pathway is recharge in the upland areas with seepage to onsite drainages and surface water discharge into the Clinch River arm of the Watts Bar Reservoir. It is very unlikely that there is shallow groundwater flow underneath the Clinch River arm of the Watts Bar Reservoir and exposure to water users on the opposite side of the Reservoir. This conclusion is based on 1) the absence of cavities and contiguous fractures below elevation 720 ft, 2) the head relationships observed at the Melton Valley Exit Pathway monitoring wells (Reference 2.3.1-31), and 3) the observed vertical hydraulic gradients demonstrate that the Clinch River arm of the Watts Bar Reservoir acts as a hydrologic sink. This is further supported by the following observations:

- There is no evidence of contiguous cavities or fractures originating from the power block area and extending below the Clinch River arm of the Watts Bar Reservoir, based on geologic core analysis from subsurface investigations;

- The CRBRP excavation, completed to an elevation of 714 ft NGVD29 and 6 ft below the invert elevation of the Clinch River arm of the Watts Bar Reservoir, showed no evidence of any continuous groundwater flow; this is likely due to an absence of cavities and continuous fractures below elevation 720 ft;

- Only 5 percent of the observed cavities fall below elevation 718.4 ft with the average elevation of observed cavities being 782.6 ft; and

- An analysis of site-specific geologic core analysis, fracture frequency analysis, and groundwater vertical gradient data provides no evidence supporting a pathway for radionuclide transport occurring underneath the Clinch River arm of the Watts Bar Reservoir within the shallow groundwater system.

Advective Transport

Advective transport in groundwater is assumed to occur in an equivalent porous medium. This assumption is based on the findings of the aquifer pumping test and other hydraulic conductivity tests and is restricted to the shallow groundwater system. In the deeper groundwater system, that is not pervasively fractured, discrete fractures control the movement of groundwater. However, as discussed in Subsection 2.3.1.2.1.2 and shown on Figure 2.3.1-23, greater than 90 percent of groundwater flow occurs in the shallow zone.

The porous medium flow is represented by Darcy's law, when written in terms of linear velocity is:

$$v = -K/n_e \times dh/dl$$

Where:

v = linear groundwater velocity [L/T]

K = hydraulic conductivity [L/T]

n_e = effective porosity

dh/dl = hydraulic gradient (change in head over change in length) (Reference 2.3.1-42)

The travel time (T) is determined by dividing the distance to the receptor (D) (Clinch River arm of the Watts Bar Reservoir) by the linear groundwater velocity (v):

$$T = D/v$$

Table 2.3.1-10 presents a summary of these parameters and the linear velocity and travel time determined from these parameters. Using the representative parameter values, a travel time of 359 days is determined (Table 2.3.1-10).

2.3.1.3 References

Reference 2.3.1-1. Tennessee Valley Authority, "Watts Bar Reservoir Land Management Plan, Panel 2 Map," February, 2009.

Reference 2.3.1-2. Tennessee Valley Authority, "Watts Bar Reservoir Land Management Plan, Panel 1 Map," February, 2009.

Reference 2.3.1-3. Tennessee Valley Authority, "Watts Bar Reservoir Land Management Plan, Panel 4 Map," February, 2009.

Reference 2.3.1-4. U. S. Geological Survey, "Estimated Use of Water in the Tennessee River Watershed in 2000 and Projections of Water Use to 2030," WRI 03-4302, 2004.

Reference 2.3.1-5. Tennessee Valley Authority, "Bellefonte Nuclear Plant Units 3 & 4, COL Application, Part 3, Applicant's Environmental Report - Combined License Stage, Revision 1," ML083100297, 2013.

Reference 2.3.1-6. U.S. Geological Survey, Introduction to the Upper Tennessee River Basin, Website: http://pubs.usgs.gov/circ/circ1205/introduction.htm, 2015.

Reference 2.3.1-7. Tennessee Valley Authority, Watts Bar Reservoir Website, Website: http://www.tva.com/sites/wattsbarres.htm, 2015.

Reference 2.3.1-8. Tennessee Valley Authority, "Programmatic Environmental Impact Statement, Reservoir Operations Study," May, 2004.

Reference 2.3.1-9. U.S. Environmental Protection Agency, Watershed Maps, Website: http://water.epa.gov/type/watersheds/., 2015.

Reference 2.3.1-10. U.S. Geological Survey, Bethel Valley Quadrangle Tennessee 7.5-Minute Series, 2013.

Reference 2.3.1-11. Tennessee Valley Authority, "Clinch River Small Modular Reactor Site Regional Surface Water Use Study - Revision 2," April 24, 2015.

Reference 2.3.1-12. Tennessee Valley Authority, Norris Reservoir Website, Website: http://www.tva.gov/sites/norris.htm, 2015.

Reference 2.3.1-13. Tennessee Valley Authority, Melton Hill Reservoir, Website: http://www.tva.gov/sites/meltonhill.htm, 2013.

Reference 2.3.1-14. Department of Energy, Oak Ridge National Laboratory: White Oak Dam and Sediment Control Structure, Website: http://www.oakridge.doe.gov/em/ssab/Minutes/FY2010/Presentations/Kopotic%20SSAB%2011-18-09.pdf, November 18, 2008.

Reference 2.3.1-15. Tennessee Valley Authority, Fort Loudoun Reservoir Website, Website: http://www.tva.com/sites/fortloudoun.htm, 2015.

Reference 2.3.1-16. Howard, Charles S., Henderson, Andrew R., and Phillips, Craig L., "Clinch River Small Modular Reactor and Barge/Traffic Site Evaluation of Aquatic Habitats and Protected Aquatic Animals Technical Report - Revision 5," Tennessee Valley Authority, December 22, 2015.

Reference 2.3.1-17. Tennessee Department of Environment and Conservation, "Guidance for Making Hydrologic Determinations," Division of Water Pollution Control, May, 2011.

Reference 2.3.1-18. Pilarski-Hall, Kim and Lees, Britta P., "Clinch River Small Modular Reactor Site - Wetland Survey Report - Revision 4," November 19, 2015.

Reference 2.3.1-19. Pilarski-Hall, Kim and Kennon, R. A., "Clinch River Small Modular Reactor Site - Supplemental Wetland Survey Report Barge/Traffic Area - Revision 1," Tennessee Valley Authority, June 17, 2015.

Reference 2.3.1-20. Project Management Corporation, "Clinch River Breeder Reactor Project, Preliminary Safety Analysis Report," Volume 2, Amendment 68, May, 1982.

Reference 2.3.1-21. AMEC Environmental and Infrastructure, Inc., "Data Report, Geotechnical Exploration and Testing, Clinch River SMR Project," October 16, 2014.

Reference 2.3.1-22. Lloyd, O. B. and Lyke, W. L., Ground Water Atlas of the United States: Segment 10, Illinois, Indiana, Kentucky, Ohio, Tennessee, USGS Hydrological Atlas 730-K, 1995.

Reference 2.3.1-23. Tucci, P., "Hydrology of Melton Valley at Oak Ridge National Laboratory, Tennessee," U.S. Geological Survey, Water-Resources Investigations Report 92-4131, 1992.

Reference 2.3.1-24. Breeder Reactor Corporation, "Final Report The Clinch River Breeder Reactor Plant Project," January, 1985.

Reference 2.3.1-25. Moore, G. K., "Hydrograph Analysis in a Fractured Rock Terrane Near Oak Ridge, Tennessee," Oak Ridge National Laboratory, Oak Ridge, Tennessee, U.S. Department of Energy, Office of Environmental Restoration and Waste Management, 1991.

Reference 2.3.1-26. Saunders, J. A. and Toran, L. E., "Evidence for Dedolomitization and Mixing in Paleozoic Carbonates Near Oak Ridge, Tennessee, Ground Water 32, No. 2: 207-214, 1994.

Reference 2.3.1-27. Parr, P. D. and Hughes, J. F., "Oak Ridge Reservation Physical Characteristics and Natural Resources," U.S. Department of Energy by Oak Ridge National Laboratory, Managed by UT-Batelle, LLC, Oak Ridge, Tennessee under contract DE-AC05-00OR22725, October, 2006.

Reference 2.3.1-28. Solomon, D. K., Moore, G. K., Toran, L. E., Dreier, R. B., and McMaster, W. M., "A Hydrologic Framework for the Oak Ridge Reservation, Status Report," ORNL/TM-12026, U.S. Department of Energy under Contract number DE-AC05-840R21400 by the Oak Ridge National Laboratory Environmental Services Division, May, 1992.

Reference 2.3.1-29. Hatcher, Jr. R. D., Lemiszki, P. J., Dreier, R. B., Ketelle, R. H., Lee, R. R., Lietzke, D. A., McMaster, W. M., Foreman, J. L., and Lee, S-Y., "Status Report on the Geology of the Oak Ridge Reservation," ORNL/TM-12074, U.S. Department of Energy by Oak Ridge National Laboratory, managed by Martin Marietta Energy Systems, Inc., under contract DE-AC05-84OR21400, October, 1992.

Reference 2.3.1-30. Stockdale, P. B., "Geologic Conditions at the Oak Ridge National Laboratory (X-10) Area Relevant to the Disposal of Radioactive Waste," ORO-58, U.S. Department of Energy, Oak Ridge, Tennessee, 1951.

Reference 2.3.1-31. Bechtel Jacobs Company, LLC, "Melton Valley Exit Pathway and Offsite Groundwater Monitoring Results: July 2010 - March 2011," U.S. Department of Energy Office of Environmental Management under contract DE-AC05-98OR22700, June, 2011.

Reference 2.3.1-32. U.S. Environmental Protection Agency, Sole Source Aquifers in the Southeast, Website: http://www.epa.gov/region4/water/groundwater/%20r4ssa.html, 2014.

Reference 2.3.1-33. U.S. Geological Survey, National Water Information System: Web Interface, Groundwater levels for the Nation: USGS 3539220833345600 SV:E-002, Website: http://nwis.waterdata.usgs.gov/nwis/gwlevels?site_no=353922083345600&agency_cd=USGS&format=gif, 2014.

Reference 2.3.1-34. U.S. Geological Survey, National Water Information System: Web Interface, Groundwater levels for Tennessee: USGS 35332084220301 Ro. M-021, TDEC HD2, Website: http://nwis.waterdata.usgs.gov/tn/nwis/%20gwlevels/?site_no=355332084220301&agency_cd=USGS&amp, 2014.

Reference 2.3.1-35. Science Applications International Corporation, "Engineering Study Report for Groundwater Actions in Bethel Valley, Oak Ridge, Tennessee," DOE/OR/01-2219&D2, U.S. Department of Energy Office of Environmental Management under contact DE-AC05-98OR22700, November, 2005.

Reference 2.3.1-36. U.S. Army Corps of Engineers, "Suggested Method for In Situ Determination of Rock Mass Permeability, Rock Testing Handbook Method 381-80," Geotechnical Library, Rock Mechanics Branch, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, 2016.

Reference 2.3.1-37. Bouwer, H. and Rice, R. C., "A Slug test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells, Water Resources Research Vol. 12, No. 3: 423-428, 1976.

Reference 2.3.1-38. HydroSOLVE, "AQTESOLV for Windows Version 4.5 User's Guide," Reston, VA, 2007.

Reference 2.3.1-39. Shapiro, A. M. and Hsieh, P. A., "How Good Are Estimates of Transmissivity from Slug Tests in Fractured Rock?, Ground Water 36, No. 1: 37-48, 1998.

Reference 2.3.1-40. Butler, Jr. J. J., The Design, Performance, and Analysis of Slug Tests, Lew Publishers, CRC Press, Boca Raton, Florida, 1998.

Reference 2.3.1-41. Hantush, M. S. and Jacob, C. E., "Non-Steady Radial Flow in an Infinite Leaky Aquifer," Transactions, American Geophysical Union 36, No. 1: 95-100, 1955.

Reference 2.3.1-42. Domenico, P. A. and Schwartz, F. W., "Physical and Chemical Hydrogeology," John Wiley & Sons, New York, p. 360, 1990.

Reference 2.3.1-43. National Oceanic and Atmospheric Administration, "Mean Monthly, Seasonal, and Annual Pan Evaporation for the United States," Technical Report NWS 34, December, 1982.

Reference 2.3.1-44. Moore, G. K. and Toran, L. E., "Supplement to a Hydrologic Framework for the Oak Ridge Reservation," ORNL/TM-12191, U.S. Department of Energy, Office of Environmental Sciences Division under contract DE-AC05-85OR21400, November, 1992.

Reference 2.3.1-45. Dorsch, J., Katsube, T. J., Sandford, W. E., Dugan, B. E., and Tourkow, L. M., "Effective Porosity and Pore-Throat Sizes of Conasauga Group Mudrock: Application, Test and Evaluation of Petrophysical Techniques," ORNL/GWPO-021, U.S. Department of Energy under contract DE-AC05-96OR22464, Oak Ridge National Laboratory Environmental Services Division, April, 1996.

Reference 2.3.1-46. Dorsch, J., "Effective Porosity and Density of Carbonate Rocks (Maynardville Limestone and Copper Ridge Dolomite) within Bear Creek Valley on the Oak Ridge Reservation Based on Modern Petrophysical Techniques," ORNL/GWPO-026, U.S. Department of Energy under contract DE-AC05-96OR22464, Oak Ridge National Laboratory Environmental Services Division, February, 1997.

Reference 2.3.1-47. Tennessee Valley Authority, "Preliminary Information on Clinch River Site for LMBFR Demonstration Plant," Atomic Energy Commission, August 23, 1972.

Table 2.3.1-1
Monthly Means of Estimated Pan Evaporation Computed from Meteorological Measurements Using a Form of the Penman Equation[1]

State	Station Name	Station Index No.	Latitude & Longitude	May - Oct	Nov - Apr	Annual	Record Began Mo/Yr	Latest Data Mo/Yr
Tennessee	Bristol WB Airport	1094	36° 28', 82° 23'	30.34	14.36	44.70	Nov-59	Dec-70
	Chattanooga WB Airport	1656	35° 01', 85° 11'	33.99	15.95	49.94	May-61	Oct-79
	Knoxville WB Airport	4950	35° 49', 83° 58'	34.57	16.04	50.61	Dec-41	Dec-79
	Memphis WE Airport	5954	35° 03', 89° 58'	41.97	19.40	61.37	May-66	Oct-79
	Nashville WB Airport	6402	36° 07', 86° 40'	37.34	16.07	53.41	Oct-36	Nov-48
	Average			35.64	16.36	52.01		

1 Evaporation measured in inches.

Source: (Reference 2.3.1-43)

Table 2.3.1-2 (Sheet 1 of 2)
Summary of Hydrogeologic Properties on the ORR

Residuum/Stormflow Zone		
Property	**Conditions**	**Value**
Stormflow Zone Thickness	Grassland	0.2 to 0.4 m
	Forest	0.6 to 2.0 m
Infiltration rate	Grassland	1.1 m/d
	Forest	8.8 m/d
Total Porosity	General	0.4
Specific Yield	General	0.035
Hydraulic Conductivity	General	9.2 m/d
Hydraulic Gradient	General	0.075
Discharge Rate	General	0 to 110 $L/sec \cdot km^2$
Groundwater Zone		
Property	**Knox aquifer**	**ORR aquitards**
Thickness		
Permeable interval	------	1.5 m
Low-permeability interval	------	12 m
Water table fluctuation	5.3 m	1.5 m
Total porosity (matrix)	-------	9.6×10^{-3}
Fracture porosity	-------	5.0×10^{-4}
Specific yield	3.3×10^{-3}	2.3×10^{-3}
Fractures		
Spacing	-------	35 cm
Aperture	0.25 mm	0.12 mm
Unfractured rock matrix hydraulic conductivity	-------	8.7×10^{-8} m/d

Table 2.3.1-2 (Sheet 2 of 2)
Summary of Hydrogeologic Properties on the ORR

Groundwater Zone (continued)		
Property	**Knox aquifer**	**ORR aquitards**
Low-permeability intervals		
Transmissivity	-------	1.1 x 10-3 m^2/d
Hydraulic conductivity	-------	4.0 x 10-4 m/d
Permeable intervals		
Transmissivity	1.0 m^2/d	0.12 m^2/d
Hydraulic conductivity	-------	0.068 m/d
Continuum		
Transmissivity	7.0 m^2/d	0.75 m^2/d
Hydraulic conductivity	-------	0.18 m/d
Hydraulic gradient	0.02	0.05
Average recharge	65 mm	20 mm
Maximum discharge	1030 L/min·km^2	280 L/min·km^2
Average discharge	120 L/min·km^2	38 L/min·km^2

Source: (Reference 2.3.1-44)

Table 2.3.1-3 (Sheet 1 of 6)
Well Construction Summary

Well	Northing (NAD 83)	Easting (NAD 83)	Geologic Unit[1]	Top of Casing Elevation (NAVD 88)	Top of Concrete Elevation (NAVD 88)	Ground Surface Elevation (NAVD 88)	Top of Bentonite Seal	
							Depth below Ground (ft)	Elevation (NAVD 88)
OW-101U	570235.5	2448339.3	Benbolt	803.72	800.73	800.58	15.0	785.6
OW-101L	570262.0	2448370.8	Rockdell	803.48	800.81	800.66	126.6	674.1
OW-101D	570274.9	2448386.4	Rockdell	803.57	800.82	800.65	219.2	581.5
OW-202U	570946.0	2448081.1	Fleanor	815.38	812.11	811.83	4.3	807.5
OW-202L	570934.2	2448064.9	Fleanor	815.05	812.23	811.97	141.1	670.9
OW-202D	570909.7	2448033.7	Eidson	815.00	812.21	812.10	260.0	552.1
OW-401U	571967.9	2447619.9	Newala	820.48	817.55	817.39	5.2	812.2
OW-401L	571973.8	2447628.0	Newala	820.57	817.47	817.22	126.7	690.5
OW-401D	571941.2	2447589.7	Newala	821.28	818.41	818.17	215.6	602.6
OW-409U	570557.1	2448130.3	Rockdell	809.70	807.12	806.91	44.4	762.5
OW-409L	570570.8	2448143.3	Rockdell	809.51	806.82	806.67	82.7	724.0
OW-415U	569590.2	2448180.2	Bowen/Benbolt	787.22	784.41	784.13	19.5	764.6
OW-415L	569564.4	2448148.1	Benbolt	786.75	783.93	783.65	146.9	636.8
OW-416U	569990.0	2447535.9	Rockdell	812.82	809.82	809.54	67.6	741.9
OW-416L	569965.2	2447504.9	Rockdell	812.73	809.72	809.43	98.4	711.0
OW-417U	569927.1	2446646.9	Fleanor	775.03	772.36	772.20	40.4	731.8
OW-417L	569903.0	2446614.6	Fleanor	775.71	772.78	772.65	81.8	690.9
OW-418U	570526.8	2447065.0	Eidson	812.94	810.30	810.01	78.0	732.0
OW-418L	570506.0	2447038.8	Blackford	814.41	811.80	811.44	124.9	686.5
OW-419U	571283.4	2446716.1	Newala	803.13	800.21	799.98	48.8	751.2
OW-419L	571257.7	2446683.4	Newala	802.72	799.89	799.75	90.5	709.3
OW-420U	572009.6	2446886.0	Newala	805.70	803.10	802.85	15.0	787.9
OW-420L	572021.1	2446902.0	Newala	806.15	803.31	803.07	120.0	683.1
OW-421U	570557.7	2446471.7	Blackford	808.27	805.55	805.36	41.2	764.2
OW-421L	570544.2	2446455.6	Blackford/ Newala	807.81	805.05	804.78	92.4	712.4
OW-421D	570520.1	2446424.4	Newala	805.20	802.63	802.49	165.2	637.3
OW-422U	570450.2	2448763.8	Benbolt	804.90	---	802.40	9.7	792.7
OW-422L	570438.1	2448748.1	Benbolt	803.70	---	801.70	147.3	654.4
OW-422D	570444.3	2448756.2	Rockdell	805.40	---	802.10	281.2	520.9
OW-423U	571494.1	2448309.5	Eidson	800.21	797.53	797.41	31.5	765.9
OW-423L	571481.6	2448293.2	Blackford	801.13	798.33	798.02	127.9	670.1
OW-423D	571457.9	2448262.0	Blackford	802.86	800.13	799.89	236.9	563.0

Table 2.3.1-3 (Sheet 2 of 6)
Well Construction Summary

Well	Top of Filter Pack		Well Casing Diameter (inches)	Well Casing Schedule	Well Material	Screen Slot Size (inches)	Top of Screen	
	Depth below Ground (ft)	Elevation (NAVD 88)					Depth below Ground (ft)	Elevation (NAVD 88)
OW-101U	21.4	779.2	2	40	PVC	0.020	26.0	774.6
OW-101L	133.6	667.1	2	80	PVC	0.020	138.0	662.7
OW-101D	225.8	574.9	2	80	PVC	0.020	230.5	570.2
OW-202U	11.1	800.7	2	40	PVC	0.020	15.7	796.1
OW-202L	147.0	665.0	2	80	PVC	0.020	150.5	661.5
OW-202D	273.0	539.1	2	80	PVC	0.020	276.4	535.7
OW-401U	10.5	806.9	2	40	PVC	0.020	15.2	802.2
OW-401L	130.8	686.4	2	80	PVC	0.020	135.2	682.0
OW-401D	221.9	596.3	2	80	PVC	0.020	226.6	591.6
OW-409U	52.4	754.5	2	40	PVC	0.020	54.9	752.0
OW-409L	86.6	720.1	2	40	PVC	0.020	89.1	717.6
OW-415U	24.1	760.0	2	40	PVC	0.020	28.1	756.0
OW-415L	151.9	631.8	2	80	PVC	0.020	154.9	628.8
OW-416U	71.8	737.7	2	40	PVC	0.020	75.4	734.1
OW-416L	107.6	701.8	2	40	PVC	0.020	110.6	698.8
OW-417U	46.7	725.5	2	40	PVC	0.020	50.0	722.2
OW-417L	91.5	681.2	2	40	PVC	0.020	95.0	677.7
OW-418U	90.1	719.9	2	40	PVC	0.020	95.0	715.0
OW-418L	133.6	677.8	2	80	PVC	0.020	136.8	674.6
OW-419U	54.4	745.6	2	40	PVC	0.020	57.2	742.8
OW-419L	101.0	698.8	2	40	PVC	0.020	104.5	695.3
OW-420U	21.2	781.7	2	40	PVC	0.020	26.0	776.9
OW-420L	127.4	675.7	2	40	PVC	0.020	130.9	672.2
OW-421U	51.4	754.0	2	40	PVC	0.020	55.0	750.4
OW-421L	101.0	703.8	2	40	PVC	0.020	104.8	700.0
OW-421D	172.8	629.7	2	80	PVC	0.020	175.7	626.8
OW-422U	17.9	784.5	2	40	PVC	0.020	21.0	781.4
OW-422L	155.2	646.5	2	80	PVC	0.020	158.0	643.7
OW-422D	286.2	515.9	2	80	PVC	0.020	290.0	512.1
OW-423U	39.1	758.3	2	40	PVC	0.020	42.2	755.2
OW-423L	136.6	661.4	2	80	PVC	0.020	139.6	658.4
OW-423D	244.2	555.7	2	80	PVC	0.020	248.1	551.8

Table 2.3.1-3 (Sheet 3 of 6)
Well Construction Summary

Well	Bottom of Screen		Bottom of Well Cap		Bottom of Borehole	
	Depth below Ground (ft)	Elevation (NAVD 88)	Depth below Ground (ft)	Elevation (NAVD 88)	Depth below Ground (ft)	Elevation (NAVD 88)
OW-101U	46.0	754.6	46.5	754.1	50.0	750.6
OW-101L	158.0	642.7	158.5	642.2	161.0	639.7
OW-101D	250.5	550.2	251.0	549.7	261.5	539.2
OW-202U	35.7	776.1	36.2	775.6	39.0	772.8
OW-202L	170.5	641.5	171.0	641.0	173.0	639.0
OW-202D	296.4	515.7	296.9	515.2	303.0	509.1
OW-401U	35.2	782.2	35.7	781.7	37.5	779.9
OW-401L	155.2	662.0	155.7	661.5	159.3	657.9
OW-401D	246.6	571.6	247.1	571.1	251.7	566.5
OW-409U	74.9	732.0	75.4	731.5	78.0	728.9
OW-409L	109.1	697.6	109.6	697.1	112.0	694.7
OW-415U	48.1	736.0	48.6	735.5	51.1	733.0
OW-415L	174.9	608.8	175.4	608.3	177.4	606.3
OW-416U	95.4	714.1	95.9	713.6	97.5	712.0
OW-416L	130.6	678.8	131.1	678.3	133.0	676.4
OW-417U	70.0	702.2	70.5	701.7	73.1	699.1
OW-417L	115.0	657.7	115.5	657.2	118.0	654.7
OW-418U	105.0	705.0	105.5	704.5	108.0	702.0
OW-418L	156.8	654.6	157.3	654.1	160.0	651.4
OW-419U	77.2	722.8	77.7	722.3	79.6	720.4
OW-419L	124.5	675.3	125.0	674.8	126.5	673.3
OW-420U	46.0	756.9	46.5	756.4	48.5	754.4
OW-420L	150.9	652.2	151.4	651.7	152.4	650.7
OW-421U	75.0	730.4	75.5	729.9	78.0	727.4
OW-421L	124.8	680.0	125.3	679.5	128.0	676.8
OW-421D	195.7	606.8	196.2	606.3	198.0	604.5
OW-422U	41.0	761.4	41.5	760.9	44.0	758.4
OW-422L	178.0	623.7	178.5	623.2	181.0	620.7
OW-422D	310.0	492.1	310.5	491.6	313.0	489.1
OW-423U	62.2	735.2	62.7	734.7	65.0	732.4
OW-423L	159.6	638.4	160.1	637.9	163.0	635.0
OW-423D	268.1	531.8	268.6	531.3	273.0	526.9

Table 2.3.1-3 (Sheet 4 of 6)
Well Construction Summary

Well	Northing (NAD 83)	Easting (NAD 83)	Geologic Unit[1]	Top of Casing Elevation (NAVD 88)	Top of Concrete Elevation (NAVD 88)	Ground Surface Elevation (NAVD 88)	Top of Bentonite Seal	
							Depth below Ground (ft)	Elevation (NAVD 88)
OW-428U	570781.4	2448710.6	Rockdell	807.78	804.57	804.33	24.4	779.9
OW-428L	570767.9	2448696.6	Rockdell	807.06	804.18	803.86	100.5	703.4
OW-428D	570741.9	2448666.5	Rockdell	807.03	804.02	803.73	172.2	631.5
OW-429U	569989.1	2448606.2	Bowen/ Benbolt	799.17	796.41	796.21	27.8	768.4
OW-429L	569965.3	2448576.5	Benbolt	799.49	796.52	796.26	136.1	660.2
PT-OW-U1	571512.5	2448235.3	Eidson	801.52	798.71	798.55	19.8	778.8
PT-OW-L1	571493.2	2448235.2	Blackford	803.13	800.09	799.77	129.7	670.1
PT-OW-U2	571489.5	2448182.4	Eidson	805.31	802.60	802.19	32.9	769.3
PT-OW-L2	571478.7	2448192.1	Blackford	804.32	801.22	800.89	124.8	676.1
PT-OW-U3	571418.4	2448310.6	Eidson	801.65	799.31	799.17	24.6	774.6
PT-OW-L3	571420.6	2448290.2	Blackford	803.12	800.41	800.07	127.5	672.6
PT-PW	571432.2	2448229.1	Eidson/ Blackford	804.03	802.41	802.06	29.4	772.7

**Table 2.3.1-3 (Sheet 5 of 6)
Well Construction Summary**

Well	Top of Filter Pack		Well Casing Diameter (inches)	Well Casing Schedule	Well Material	Screen Slot Size (inches)	Top of Screen	
	Depth below Ground (ft)	Elevation (NAVD 88)					Depth below Ground (ft)	Elevation (NAVD 88)
OW-428U	34.4	769.9	2	40	PVC	0.020	40.4	763.9
OW-428L	110.2	693.7	2	40	PVC	0.020	115.2	688.7
OW-428D	185.2	618.5	2	80	PVC	0.020	190.2	613.5
OW-429U	31.8	764.4	2	40	PVC	0.020	36.8	759.4
OW-429L	140.1	656.2	2	80	PVC	0.020	145.1	651.2
PT-OW-U1	36.8	761.8	2	40	PVC	0.020	41.8	756.8
PT-OW-L1	134.9	664.9	2	40	PVC	0.020	139.7	660.1
PT-OW-U2	37.0	765.2	2	40	PVC	0.020	42.0	760.2
PT-OW-L2	135.0	665.9	2	40	PVC	0.020	139.8	661.1
PT-OW-U3	34.1	765.1	2	40	PVC	0.020	42.6	756.6
PT-OW-L3	135.5	664.6	2	40	PVC	0.020	140.5	659.6
PT-PW	34.6	767.5	6	40	PVC	0.020	39.3	762.8

Table 2.3.1-3 (Sheet 6 of 6)
Well Construction Summary

Well	Bottom of Screen		Bottom of Well Cap		Bottom of Borehole	
	Depth below Ground (ft)	Elevation (NAVD 88)	Depth below Ground (ft)	Elevation (NAVD 88)	Depth below Ground (ft)	Elevation (NAVD 88)
OW-428U	60.4	743.9	60.9	743.4	63.0	741.3
OW-428L	135.2	668.7	135.7	668.2	138.0	665.9
OW-428D	210.2	593.5	210.7	593.0	213.0	590.7
OW-429U	56.8	739.4	57.3	738.9	60.0	736.2
OW-429L	165.1	631.2	165.6	630.7	168.0	628.3
PT-OW-U1	61.8	736.8	62.3	736.3	65.0	733.6
PT-OW-L1	159.7	640.1	160.2	639.6	163.0	636.8
PT-OW-U2	62.0	740.2	62.5	739.7	65.0	737.2
PT-OW-L2	159.8	641.1	160.3	640.6	163.0	637.9
PT-OW-U3	62.6	736.6	63.1	736.1	65.0	734.2
PT-OW-L3	160.5	639.6	161.0	639.1	163.0	637.1
PT-PW	169.3	632.8	171.8	630.3	173.0	629.1

[1] Geologic units from Table B.1.2 in the Clinch River Data Report (Reference 2.3.1-21)

Table 2.3.1-4 (Sheet 1 of 5)
Horizontal Hydraulic Gradients

September 24, 2013 Potentiometric Surface Map

Direction	Length (ft)	Elevation at the Well or Contour (upgradient) (ft NAVD 88)	Elevation at the Well or Contour (downgradient) (ft NAVD 88)	Head Difference (ft)	Horizontal Hydraulic Gradient (ft/ft)
Section 1	266	810.0	780.0	30.0	0.11
Section 2	582	810.0	760.0	50.0	0.09
Section 3	162	810.0	798.7	11.3	0.07
Section 4	830	770.0	740.0	30.0	0.04
Section 5	273	790.0	760.0	30.0	0.11
Section 6	700	800.0	750.0	50.0	0.07

Note: Based on Figure 2.3.1-33; Maximum Water Levels in Each Nested Well Cluster

December 20, 2013 Potentiometric Surface Map

Direction	Length (ft)	Elevation at the Well or Contour (upgradient) (ft NAVD 88)	Elevation at the Well or Contour (downgradient) (ft NAVD 88)	Head Difference (ft)	Horizontal Hydraulic Gradient (ft/ft)
Section 1	227	805.0	785.0	20.0	0.09
Section 2	423	795.0	765.0	30.0	0.07
Section 3	332	805.0	795.0	10.0	0.03
Section 4	650	775.0	745.0	30.0	0.05
Section 5	96	775.0	765.0	10.0	0.10
Section 6	351	795.0	765.0	30.0	0.09
Section 7	253	785.0	775.0	10.0	0.04

Note: Based on Figure 2.3.1-34; Maximum Water Levels in Each Nested Well Cluster

Table 2.3.1-4 (Sheet 2 of 5)
Horizontal Hydraulic Gradients

January 13, 2014 Potentiometric Surface Map

Direction	Length (ft)	Elevation at the Well or Contour (upgradient) (ft NAVD 88)	Elevation at the Well or Contour (downgradient) (ft NAVD 88)	Head Difference (ft)	Horizontal Hydraulic Gradient (ft/ft)
Section 1	266	810	790	20	0.08
Section 2	629	800	760	40	0.06
Section 3	389	810	800	10	0.03
Section 4	646	780	750	30	0.05
Section 5	189	790	770	20	0.11
Section 6	398	780	760	20	0.05

Note: Based on Figure 2.3.1-35; Maximum Water Levels in Each Nested Well Cluster

March 16, 2014 Potentiometric Surface Map

Direction	Length (ft)	Elevation at the Well or Contour (upgradient) (ft NAVD 88)	Elevation at the Well or Contour (downgradient) (ft NAVD 88)	Head Difference (ft)	Horizontal Hydraulic Gradient (ft/ft)
Section 1	401	810	780	30	0.07
Section 2	653	810	760	50	0.08
Section 3	339	810	800	10	0.03
Section 4	707	790	750	40	0.06
Section 5	128	780	770	10	0.08
Section 6	686	810	760	50	0.07
Section 7	306	780	770	10	0.03

Note: Based on Figure 2.3.1-36; Maximum Water Levels in Each Nested Well Cluster

Table 2.3.1-4 (Sheet 3 of 5)
Horizontal Hydraulic Gradients

May 15, 2014 Potentiometric Surface Map

Direction	Length (ft)	Elevation at the Well or Contour (upgradient), ft NAVD 88	Elevation at the Well or Contour (downgradient), ft NAVD 88	Head Difference (ft)	Horizontal Hydraulic Gradient (ft/ft)
Section 1	329	810	780	30	0.09
Section 2	564	810	760	50	0.09
Section 3	318	810	800	10	0.03
Section 4	588	780	750	30	0.05
Section 5	85	780	770	10	0.12
Section 6	539	810	760	50	0.09
Section 7	191	780	770	10	0.05

Note: Based on Figure 2.3.1-37; Maximum Water Levels in Each Nested Well Cluster

August 18, 2014 Potentiometric Surface Map

Direction	Length (ft)	Elevation at the Well or Contour (upgradient), ft NAVD 88	Elevation at the Well or Contour (downgradient), ft NAVD 88	Head Difference (ft)	Horizontal Hydraulic Gradient (ft/ft)
Section 1	394	810	780	30	0.08
Section 2	696	810	760	50	0.07
Section 3	356	810	800	10	0.03
Section 4	591	780	750	30	0.05
Section 5	97	780	770	10	0.10
Section 6	948	810	750	60	0.06
Section 7	255	780	770	10	0.04

Note: Based on Figure 2.3.1-38; Maximum Water Levels in Each Nested Well Cluster

Table 2.3.1-4 (Sheet 4 of 5)
Horizontal Hydraulic Gradients

November 4, 2014 Potentiometric Surface Map

Direction	Length (ft)	Elevation at the Well or Contour (upgradient), ft NAVD 88	Elevation at the Well or Contour (downgradient), ft NAVD 88	Head Difference (ft)	Horizontal Hydraulic Gradient (ft/ft)
Section 1	319	810	780	30	0.09
Section 2	736	810	750	60	0.08
Section 3	275	810	800	10	0.04
Section 4	430	780	750	30	0.07
Section 5	120	780	770	10	0.08
Section 6	841	810	750	60	0.07
Section 7	286	780	770	10	0.04

Note: Based on Figure 2.3.1-39; Maximum Water Levels in Each Nested Well Cluster

February 12, 2015 Potentiometric Surface Map

Direction	Length (ft)	Elevation at the Well or Contour (upgradient), ft NAVD 88	Elevation at the Well or Contour (downgradient), ft NAVD 88	Head Difference (ft)	Horizontal Hydraulic Gradient (ft/ft)
Section 1	399	810	780	30	0.08
Section 2	609	810	760	50	0.08
Section 3	335	810	800	10	0.03
Section 4	492	780	750	30	0.06
Section 5	107	780	770	10	0.09
Section 6	609	810	760	50	0.08
Section 7	259	780	770	10	0.04

Note: Based on Figure 2.3.1-40; Maximum Water Levels in Each Nested Well Cluster

Table 2.3.1-4 (Sheet 5 of 5)
Horizontal Hydraulic Gradients

May 19, 2015 Potentiometric Surface Map

Direction	Length (ft)	Elevation at the Well or Contour (upgradient), ft NAVD 88	Elevation at the Well or Contour (downgradient), ft NAVD 88	Head Difference (ft)	Horizontal Hydraulic Gradient (ft/ft)
Section 1	293	810	780	30	0.10
Section 2	693	810	750	60	0.09
Section 3	243	810	800	10	0.04
Section 4	349	780	750	30	0.09
Section 5	208	780	760	20	0.10
Section 6	929	810	750	60	0.06
Section 7	285	780	770	10	0.04

Note: Based on Figure 2.3.1-41; Maximum Water Levels in Each Nested Well Cluster

August 10, 2015 Potentiometric Surface Map

Direction	Length (ft)	Elevation at the Well or Contour (upgradient), ft NAVD 88	Elevation at the Well or Contour (downgradient), ft NAVD 88	Head Difference (ft)	Horizontal Hydraulic Gradient (ft/ft)
Section 1	296	810	780	30	0.10
Section 2	682	810	750	60	0.09
Section 3	230	810	800	10	0.04
Section 4	250	770	750	20	0.08
Section 5	111	780	770	10	0.09
Section 6	520	810	760	50	0.10
Section 7	260	780	770	10	0.04

Note: Based on Figure 2.3.1-42; Maximum Water Levels in Each Nested Well Cluster

Mean Horizontal Hydraulic Gradient = 0.07 ft/ft
Minimum Horizontal Hydraulic Gradient = 0.03 ft/ft
Maximum Horizontal Hydraulic Gradient = 0.12 ft/ft

Table 2.3.1-5 (Sheet 1 of 3)
Borehole Packer Test Results Summary

Boring	Zone	Geologic Unit Formation	Depth (ft below ground)	Estimated Transmissivity (ft^2/day)	Estimated Hydraulic Conductivity (ft/day)	Analysis Notes
MP-101	Z1	Chickamauga Benbolt	27.5 to 35.0	7	0.9	None
MP-101	Z2	Chickamauga Rockdell	145.0 to 152.5	20	3	None
MP-202	Z1	Chickamauga Fleanor member	41.7 to 49.2	Low	Low	Low/negligible flow suggests low hydraulic conductivity.
MP-202	Z2	Chickamauga Fleanor member	153.0 to 160.5	2	0.3	None
MP-202	Z3	Chickamauga Fleanor member	182.0 to 189.5	Low	Low	Low/negligible flow suggests low hydraulic conductivity.
MP-401	Z2	Knox Newala	28.0 to 35.5	Low	Low	Low/negligible flow suggests low hydraulic conductivity.
MP-401	Z3	Knox Newala	77.0 to 84.5	Low	Low	Low/negligible flow suggests low hydraulic conductivity.
MP-401	Z4	Knox Newala	237.0 to 244.5	3	0.4	Test results indicate higher transmissivity value for higher pressures. Possible explanations for the test behavior include fracture dilation or fracture washout.
MP-415	Z1	Chickamauga Bowen	27.5 to 35.0	High	High	High flow rates (exceeding 80 gpm) with pressure increase in the transducer above the test interval. The target test pressure in the interval was not achieved and the test was aborted. The high flow rates suggest high hydraulic conductivity.
MP-415	Z2	Chickamauga Benbolt	162.5 to 170.0	Low	Low	Low/negligible flow suggests low hydraulic conductivity.
MP-415	Z3	Chickamauga Benbolt	252.5 to 260.0	Low	Low	Low/negligible flow suggests low hydraulic conductivity.
MP-416	Z2	Chickamauga Rockdell	89.0 to 96.5	1	0.2	Flow for this test was low, behavior suggests non-linear flow.

Table 2.3.1-5 (Sheet 2 of 3)
Borehole Packer Test Results Summary

Boring	Zone	Geologic Unit Formation	Depth (ft below ground)	Estimated Transmissivity (ft^2/day)	Estimated Hydraulic Conductivity (ft/day)	Analysis Notes
MP-416	Z3	Chickamauga Rockdell	109.0 to 116.5	8	1	None
MP-416	Z4	Chickamauga Rockdell	205.0 to 212.5	Low	Low	Low/negligible flow suggests low hydraulic conductivity.
MP-417	Z1	Chickamauga Fleanor member	61.5 to 69.0	10	2	Some response was observed in the transducers above and below the test interval. Flow did not increase in highly non-linear fashion, suggesting an indirect connection to the borehole outside the test interval.
MP-417	Z2	Chickamauga Fleanor member	84.0 to 91.5	3	0.5	None
MP-417	Z3	Chickamauga Eidson member	210.5 to 218.0	3	0.4	None
MP-418A	Z1	Chickamauga Eidson member	86.0 to 93.5	40	5	None
MP-418A	Z2	Chickamauga Blackford	139.0 to 146.5	1	0.2	None
MP-418A	Z3	Chickamauga Blackford	240.0 to 247.5	0.3	0.04	None
MP-419	Z1	Knox Newala	210.0 to 217.5	1	0.2	None
MP-419	Z2	Knox Newala	135.0 to 142.5	Low	Low	Low/negligible flow suggests low hydraulic conductivity.
MP-419	Z3	Knox Newala	120.0 to 127.5	2	0.3	None
MP-419	Z4	Knox Newala	109.0 to 116.5	Low	Low	Low/negligible flow suggests low hydraulic conductivity.
MP-420	Z2	Knox Newala	79.0 to 86.5	2	0.2	None

Table 2.3.1-5 (Sheet 3 of 3)
Borehole Packer Test Results Summary

Boring	Zone	Geologic Unit Formation	Depth (ft below ground)	Estimated Transmissivity (ft^2/day)	Estimated Hydraulic Conductivity (ft/day)	Analysis Notes
MP-420	Z3	Knox Newala	100.0 to 107.5	10	2	None
MP-420	Z4	Knox Newala	132.5 to 140.0	8	1	None
MP-420	Z5	Knox Newala	166.0 to 173.5	5	0.7	None
MP-420	Z6	Knox Newala	186.0 to 193.5	10	1	None
MP-421	Z1	Chickamauga Blackford	57.0 to 64.5	1	0.2	None
MP-421	Z2	Chickamauga Blackford	99.0 to 106.5	Low	Low	Low/negligible flow suggests low hydraulic conductivity.
MP-421	Z3	Knox Newala	121.0 to 128.5	0.8	0.1	None
MP-421	Z4	Knox Newala	228.0 to 235.5	Low	Low	Low/negligible flow suggests low hydraulic conductivity.
MP-422	Z1	Chickamauga Benbolt	31.5 to 39.0	Low	Low	Low/negligible flow suggests low hydraulic conductivity.
MP-422	Z2	Chickamauga Benbolt	50.0 to 57.5	Low	Low	Low/negligible flow suggests low hydraulic conductivity.
MP-422	Z3	Chickamauga Benbolt	170.0 to 177.5	Low	Low	Low/negligible flow suggests low hydraulic conductivity.
MP-423	Z2	Chickamauga Eidson member	68.5 to 76.0	5	0.7	Much higher flows in later portion of test, which achieved the highest test pressure. There was no response in the transducers above or below the test interval, indicating that there was no hydraulic connection outside the test interval. Possible explanations for the test behavior include fracture dilation or fracture washout.

Notes: Hydraulic conductivity values were computed based on unrounded transmissivity values; both values were then rounded to one significant figure.
Low – qualitative indication of low transmissivity and hydraulic conductivity.
High – qualitative indication of high transmissivity and hydraulic conductivity.

Table 2.3.1-6 (Sheet 1 of 2)
Well Slug Test Results Summary

Well Name	Test Type	Falling Head Hydraulic Conductivity Estimate (ft/day)	Rising Head Hydraulic Conductivity Estimate (ft/day)	Test Average Hydraulic Conductivity (ft/day)	Geologic Unit Formation	Analysis Notes
OW-101D	Pneumatic	0.13	0.063	0.097	Chickamauga Group Rockdell	None
OW-101L	Pneumatic	7.6	7.5	7.6	Chickamauga Group Rockdell	None
OW-101U	Pneumatic	0.049	0.053	0.051	Chickamauga Group Benbolt	None
OW-202D	Solid	0.068	0.024	0.046	Chickamauga Group Eidson Member	None
OW-202L	Solid	--	--	--	Chickamauga Group Fleanor	Both tests discarded – Static water level discrepancy and normalized head never reaches 0.3 to 0.2
OW-401D	Solid	--	--	--	Knox Group Newala	Not analyzed – Head does not change after initiation
OW-401L	Pneumatic	0.059	0.092	0.076	Knox Group Newala	None
OW-401U	Pneumatic	0.089	0.065	0.077	Knox Group Newala	None
OW-409L	Pneumatic	0.069	0.061	0.065	Chickamauga Group Rockdell	None
OW-409U	Solid	--	0.14	0.14	Chickamauga Group Rockdell	Falling head not analyzed – Irregular response
OW-415L	Pneumatic	--	0.29	0.29	Chickamauga Group Benbolt	Falling head discarded – Normalized head never reaches 0.3 to 0.2
OW-415U	Solid	--	--	--	Chickamauga Group Bowen/Benbolt	Not analyzed – Irregular response
OW-416L	Pneumatic	0.61	0.48	0.54	Chickamauga Group Rockdell	None
OW-416U	Pneumatic	1.2	1.1	1.2	Chickamauga Group Rockdell	None
OW-417L	Pneumatic	0.31	0.44	0.38	Chickamauga Group Fleanor Member	None

Table 2.3.1-6 (Sheet 2 of 2)
Well Slug Test Results Summary

Well Name	Test Type	Falling Head Hydraulic Conductivity Estimate (ft/day)	Rising Head Hydraulic Conductivity Estimate (ft/day)	Test Average Hydraulic Conductivity (ft/day)	Geologic Unit Formation	Analysis Notes
OW-417U	Pneumatic	2.2	1.6	1.9	Chickamauga Group Fleanor Member	None
OW-418L	Pneumatic	0.16	0.14	0.15	Chickamauga Group Blackford	None
OW-418U	Pneumatic	0.21	0.21	0.21	Chickamauga Group Eidson Member	None
OW-419L	Pneumatic	2.7	3.6	3.2	Knox Group Newala	None
OW-419U	Pneumatic	11	13	12	Knox Group Newala	None
OW-420L	Solid	0.062	0.048	0.055	Knox Group Newala	None
OW-421D	Solid	--	--	--	Knox Group Newala	Not analyzed – Irregular early-time response
OW-421L	Solid	--	0.00055	0.00055	Knox/Chickamauga Newala/Blackford	Falling head not analyzed – Head does not decrease after initiation
OW-421U	Solid	0.066	0.036	0.051	Chickamauga Group Blackford	None
OW-423D	Pneumatic	0.039	--	0.039	Chickamauga Group Blackford	Rising head discarded – Normalized head never reaches 0.3 to 0.2
OW-423L	Solid	0.10	0.095	0.098	Chickamauga Group Blackford	None
OW-423U	Pneumatic	2.3	0.66	1.5	Chickamauga Group Eidson Member	None
OW-428L	Solid	0.012	0.0022	0.0071	Chickamauga Group Rockdell	None
OW-428U	Solid	0.0016	0.012	0.0068	Chickamauga Group Rockdell	None
OW-429U	Solid	0.0035	--	0.0035	Chickamauga Group Bowen/Benbolt	Rising head discarded – Normalized head never reaches 0.3 to 0.2

Table 2.3.1-7
CRN Constant Rate Aquifer Pumping Test Results

Well Name	Orientation Relative to Pumping Well	Transmissivity Pumping Period T_p (ft^2/d)	Transmissivity Recovery Period T_r (ft^2/d)	Storage Coefficient Pumping Period (dimensionless)	Hydraulic Conductivity $(T_p+T_r)/2/155$ ft (ft/d)
PT-OW-U1	N7°E	10.6	7	5.37×10^{-4}	0.06
PT-OW-L1	N7°E	129.3	128.7	3.10×10^{-3}	0.8
PT-OW-U2	N38°W	28.4	22.2	4.83×10^{-2}	0.2
PT-OW-L2	N38°W	28.1	30.3	2.28×10^{-3}	0.2
PT-OW-L3	S7°E	11.8	8.0	2.73×10^{-4}	0.06
OW-423L[1]	N52°E	410.1	391.1	8.1×10^{-3}	2.6

[1] A storage coefficient of 8.9×10^{-10} was reported for the pumping period of observation well OW-423L and is considered a nonrealistic value; however, for the same well in the recovery period, a value of 8.1×10^{-3} was reported – the recovery period derivative data exhibited less noise.

Table 2.3.1-8 (Sheet 1 of 5)
Rock Effective Porosity Measurements on the Oak Ridge Reservation

Borehole	Group	Unit[1]	Depth (m)	Depth (ft)	Effective Porosity (%)				Grain Density		Bulk Density		Data Source[3]
					Helium	Mercury	Immersion[2]	Other	(g/cm^3)	(pcf)	(g/cm^3)	(pcf)	
Joy-1	Conasauga	Pumpkin Valley Shale	201.2	660	---	---	0.46	---	---	---	---	---	A
Joy-1	Conasauga	Pumpkin Valley Shale	219.2	719	---	---	1.1	---	---	---	---	---	A
Joy-1	Conasauga	Pumpkin Valley Shale	244.2	801	---	---	1.9	---	---	---	---	---	A
05MW013A	Conasauga	Dismal Gap	52.1	171	---	---	---	0.4	---	---	---	---	A
05MW013A	Conasauga	Dismal Gap	52.7	173	---	---	---	0.1	---	---	---	---	A
05MW013A	Conasauga	Dismal Gap	57.9	190	---	---	---	1.1	---	---	---	---	A
05MW013A	Conasauga	Dismal Gap	58.5	192	---	---	---	0.4	---	---	---	---	A
05MW013A	Conasauga	Dismal Gap	65.1	214	---	---	---	0.3	---	---	---	---	A
05MW013A	Conasauga	Dismal Gap	66.1	217	---	---	---	1.5	---	---	---	---	A
05MW013A	Conasauga	Dismal Gap	71.8	236	---	---	---	0.7	---	---	---	---	A
05MW013A	Conasauga	Dismal Gap	73	240	---	---	---	0.1	---	---	---	---	A
05MW013A	Conasauga	Dismal Gap	77	253	---	---	---	2.0	---	---	---	---	A
05MW013A	Conasauga	Dismal Gap	80.2	263	---	---	---	0.8	---	---	---	---	A
05MW013A	Conasauga	Dismal Gap	81.7	268	---	---	---	1.9	---	---	---	---	A
05MW013A	Conasauga	Dismal Gap	83.5	274	---	---	---	2.7	---	---	---	---	A
05MW013A	Conasauga	Dismal Gap	93.9	308	---	---	---	1.5	---	---	---	---	A
05MW013A	Conasauga	Dismal Gap	94.6	310	---	---	---	1.9	---	---	---	---	A
05MW013A	Conasauga	Rogersville Shale	105.8	347	---	---	---	3.4	---	---	---	---	A
05MW013A	Conasauga	Rogersville Shale	107.3	352	---	---	---	1.8	---	---	---	---	A
05MW013A	Conasauga	Rogersville Shale	115.9	380	---	---	---	1.3	---	---	---	---	A
05MW013A	Conasauga	Rogersville Shale	116.3	382	---	---	---	0.9	---	---	---	---	A
05MW013A	Conasauga	Rogersville Shale	122.7	403	---	---	---	1.0	---	---	---	---	A
05MW013A	Conasauga	Rogersville Shale	130.8	429	---	---	---	2.3	---	---	---	---	A
05MW013A	Conasauga	Rogersville Shale	132.6	435	---	---	---	1.3	---	---	---	---	A
05MW013A	Conasauga	Rogersville Shale	135.3	444	---	---	---	1.4	---	---	---	---	A

Table 2.3.1-8 (Sheet 2 of 5)
Rock Effective Porosity Measurements on the Oak Ridge Reservation

Borehole	Group	Unit[1]	Depth (m)	Depth (ft)	Effective Porosity (%)				Grain Density		Bulk Density		Data Source[3]
					Helium	Mercury	Immersion[2]	Other	(g/cm^3)	(pcf)	(g/cm^3)	(pcf)	
05MW013A	Conasauga	Rogersville Shale	138.1	453	---	---	---	2.1	---	---	---	---	A
05MW013A	Conasauga	Rogersville Shale	141.4	464	---	---	---	1.7	---	---	---	---	A
05MW013A	Conasauga	Rogersville Shale	141.7	465	---	---	---	1.6	---	---	---	---	A
05MW013A	Conasauga	Rogersville Shale	147.2	483	---	---	---	0.8	---	---	---	---	A
05MW013A	Conasauga	Rogersville Shale	151.5	497	---	---	---	0.6	---	---	---	---	A
GW-133	Conasauga	Dismal Gap	41.07	135	11.4	3.8	7.67	---	2.73	170	2.64	165	A
GW-133	Conasauga	Dismal Gap	67.18	220	12.7	4.9	11.47	---	2.78	174	2.71	169	A
GW-133	Conasauga	Dismal Gap	80.52	264	10.2	3.1	11.83	---	2.74	171	2.73	170	A
GW-133	Conasauga	Dismal Gap	114.53	376	7.6	3.4	11.51	---	2.74	171	2.70	169	A
GW-133	Conasauga	Rogersville Shale	138.73	455	11.5	3	10.9	---	2.72	170	2.67	167	A
GW-133	Conasauga	Rogersville Shale	163.12	535	12.7	3.5	11.03	---	2.75	172	2.71	169	A
GW-133	Conasauga	Rogersville Shale	165.56	543	19.2	4.4	9.75	---	2.81	175	2.74	171	A
GW-132	Conasauga	Friendship	45.95	151	---	---	9.16	---	---	---	---	---	A
GW-132	Conasauga	Friendship	65.33	214	5.1	2.9	9.39	---	2.73	170	2.72	170	A
GW-132	Conasauga	Pumpkin Valley Shale	90.73	298	9.3	3.8	9.24	---	2.77	173	2.70	169	A
GW-132	Conasauga	Pumpkin Valley Shale	102.97	338	10.7	3.0	10.35	---	2.76	172	2.72	170	A
GW-132	Conasauga	Pumpkin Valley Shale	130.71	429	---	---	11.41	---	---	---	---	---	A
GW-132	Conasauga	Pumpkin Valley Shale	130.76	429	6.3	4.5	9.43	---	2.82	176	2.72	170	A
GW-132	Conasauga	Pumpkin Valley Shale	187.83	616	3.8	3.1	11.44	---	2.78	174	2.77	173	A
GW-134	Conasauga	Nolichucky Shale	44.45	146	9.9	2.7	9.46	---	2.73	170	2.69	168	A
GW-134	Conasauga	Nolichucky Shale	58.27	191	12.2	3.4	11.52	---	2.78	174	2.70	169	A
GW-134	Conasauga	Nolichucky Shale	80.29	263	3.2	3.8	12.04	---	2.79	174	2.71	169	A
GW-134	Conasauga	Nolichucky Shale	99.80	327	2.9	4.3	13.29	---	2.79	174	2.69	168	A
GW-134	Conasauga	Nolichucky Shale	109.53	359	4.9	4.3	15.87	---	2.76	172	2.77	173	A
GW-134	Conasauga	Nolichucky Shale	151.59	497	3.9	4.0	9.16	---	2.79	174	2.70	169	A
GW-134	Conasauga	Nolichucky Shale	158.27	519	4.7	5.1	11.60	---	2.70	169	2.68	167	A

Table 2.3.1-8 (Sheet 3 of 5)
Rock Effective Porosity Measurements on the Oak Ridge Reservation

Borehole	Group	Unit[1]	Depth (m)	Depth (ft)	Effective Porosity (%)				Grain Density		Bulk Density		Data Source[3]
					Helium	Mercury	Immersion[2]	Other	(g/cm^3)	(pcf)	(g/cm^3)	(pcf)	
GW-134	Conasauga	Nolichucky Shale	171.86	564	14.7	4.2	11.95	---	2.79	174	2.67	167	A
GW-134	Conasauga	Nolichucky Shale	181.14	594	4.1	3.7	11.74	---	2.77	173	2.69	168	A
GW-134	Conasauga	Nolichucky Shale	201.19	660	10.4	3.2	10.57	---	2.80	175	2.67	167	A
WOL-1	Conasauga	Nolichucky Shale	12.04	40	---	---	13.00	---	---	---	---	---	A
WOL-1	Conasauga	Nolichucky Shale	26.67	88	4.4	4.2	3.67	---	2.83	177	2.74	171	A
WOL-1	Conasauga	Nolichucky Shale	38.41	126	5.3	4.1	---	---	2.79	174	2.71	169	A
WOL-1	Conasauga	Nolichucky Shale	57.38	188	6.0	5.2	10.81	---	2.82	176	2.72	170	A
WOL-1	Conasauga	Nolichucky Shale	99.90	328	10.9	3.2	11.80	---	2.77	173	2.71	169	A
WOL-1	Conasauga	Dismal Gap	243.84	800	15.4	3.4	7.43	---	2.79	174	2.67	167	A
WOL-1	Conasauga	Friendship	320.09	1050	7.8	3.5	6.84	---	2.79	174	2.74	171	A
WOL-1	Conasauga	Pumpkin Valley Shale	352.60	1157	3.5	3.2	5.35	---	2.79	174	2.76	172	A
0.5MW012A	Conasauga	Dismal Gap	38.34	126	---	---	5.41	---	---	---	---	---	A
0.5MW012A	Conasauga	Dismal Gap	51.44	169	3.9	3.1	12.84	---	2.77	173	2.72	170	A
0.5MW012A	Conasauga	Rogersville Shale	83.10	273	11.8	4.2	4.58	---	2.81	175	2.73	170	A
0.5MW012A	Conasauga	Rogersville Shale	118.10	387	---	---	9.59	---	---	---	---	---	A
0.5MW012A	Conasauga	Rogersville Shale	135.13	443	3.7	4.5	7.97	---	2.78	174	2.70	169	A
0.5MW012A	Conasauga	Friendship	148.10	486	3.6	4.5	6.44	---	2.78	174	2.68	167	A
GW-131	Knox	Copper Ridge Dolomite	127.76	419	0.59	---	1.02	---	2.83	177	2.82	176	B
GW-131	Knox	Copper Ridge Dolomite	134.80	442	0.22	---	0.56	---	2.82	176	2.81	175	B
GW-131	Knox	Copper Ridge Dolomite	136.96	449	1.13	---	1.30	---	2.82	176	2.79	174	B
GW-131	Knox	Copper Ridge Dolomite	148.69	488	2.77	---	1.82	---	2.83	177	2.75	172	B
GW-131	Knox	Copper Ridge Dolomite	149.23	490	1.25	---	1.03	---	2.84	177	2.80	175	B
GW-131	Knox	Copper Ridge Dolomite	151.56	497	2.40	---	2.43	---	2.86	179	2.79	174	B
GW-131	Knox	Copper Ridge Dolomite	154.28	506	2.17	---	3.62	---	2.79	174	2.73	170	B
GW-131	Conasauga	Maynardville Limestone	183.72	603	0.45	---	0.45	---	2.82	176	2.81	175	B

Table 2.3.1-8 (Sheet 4 of 5)
Rock Effective Porosity Measurements on the Oak Ridge Reservation

Borehole	Group	Unit[1]	Depth (m)	Depth (ft)	Effective Porosity (%)				Grain Density		Bulk Density		Data Source[3]
					Helium	Mercury	Immersion[2]	Other	(g/cm^3)	(pcf)	(g/cm^3)	(pcf)	
GW-131	Knox	Copper Ridge Dolomite	159.56	523	1.19	---	2.04	---	2.80	175	2.77	173	B
GW-131	Knox	Copper Ridge Dolomite	175.16	575	1.62	---	1.65	---	2.84	177	2.79	174	B
GW-131	Knox	Copper Ridge Dolomite	179.05	587	0.81	---	0.54	---	2.81	175	2.79	174	B
GW-131	Conasauga	Maynardville Limestone	188.93	620	0.61	---	0.54	---	2.70	169	2.69	168	B
GW-131	Conasauga	Maynardville Limestone	195.45	641	1.12	---	0.88	---	2.78	174	2.75	172	B
GW-131	Conasauga	Maynardville Limestone	205.92	676	1.06	---	0.67	---	2.78	174	2.75	172	B
GW-131	Conasauga	Maynardville Limestone	206.35	677	8.13	---	4.52	---	2.85	178	2.62	164	B
GW-131	Conasauga	Maynardville Limestone	217.02	712	0.37	---	0.24	---	2.71	169	2.70	169	B
GW-131	Conasauga	Maynardville Limestone	231.27	759	0.37	---	0.22	---	2.73	170	2.72	170	B
GW-131	Conasauga	Maynardville Limestone	236.88	777	0.22	---	0.21	---	2.71	169	2.71	169	B
GW-131	Conasauga	Maynardville Limestone	248.26	815	0.22	---	1.45	---	2.72	170	2.72	170	B
GW-131	Conasauga	Maynardville Limestone	258.62	848	0.37	---	0.22	---	2.71	169	2.70	169	B
GW-131	Conasauga	Maynardville Limestone	266.27	874	0.37	---	0.31	---	2.71	169	2.70	169	B
GW-131	Conasauga	Maynardville Limestone	268.28	880	0.45	---	0.31	---	2.76	172	2.75	172	B
GW-131	Conasauga	Maynardville Limestone	290.04	952	0.22	---	0.17	---	2.73	170	2.73	170	B
GW-131	Conasauga	Maynardville Limestone	294.44	966	0.22	---	0.29	---	2.72	170	2.72	170	B
GW-131	Conasauga	Maynardville Limestone	301.60	990	0.30	---	0.30	---	2.72	170	2.72	170	B
GW-131	Conasauga	Maynardville Limestone	311.56	1022	0.52	---	0.62	---	2.72	170	2.71	169	B
GW-131	Conasauga	Maynardville Limestone	326.49	1071	0.22	---	0.44	---	2.71	169	2.70	169	B
GW-131	Conasauga	Maynardville Limestone	333.60	1094	0.22	---	0.51	---	2.71	169	2.71	169	B
GW-135	Knox	Copper Ridge Dolomite	155.85	511	0.21	---	0.34	---	2.84	177	2.83	177	B
GW-135	Knox	Copper Ridge Dolomite	177.78	583	0.48	---	0.81	---	2.83	177	2.81	175	B
GW-135	Knox	Copper Ridge Dolomite	184.53	605	0.55	---	1.72	0.3[4]	2.79	174	2.78	174	B
GW-135	Knox	Copper Ridge Dolomite	186.23	611	1.47	---	2.91	0.5[4]	2.80	175	2.76	172	B
GW-135	Knox	Copper Ridge Dolomite	189.74	623	0.92	---	1.39	---	2.83	177	2.80	175	B
GW-135	Knox	Copper Ridge Dolomite	193.09	633	1.53	---	1.81	1.0[4]	2.82	176	2.78	174	B

Table 2.3.1-8 (Sheet 5 of 5)
Rock Effective Porosity Measurements on the Oak Ridge Reservation

Borehole	Group	Unit[1]	Depth (m)	Depth (ft)	Effective Porosity (%)				Grain Density		Bulk Density		Data Source[3]
					Helium	Mercury	Immersion[2]	Other	(g/cm^3)	(pcf)	(g/cm^3)	(pcf)	
GW-135	Knox	Copper Ridge Dolomite	202.49	664	4.99	---	3.41	1.3[4]	2.87	179	2.72	170	B
GW-135	Conasauga	Maynardville Limestone	212.24	696	0.10	---	0.24	0.3[4]	2.74	171	2.73	170	B
GW-135	Conasauga	Maynardville Limestone	223.11	732	3.34	---	2.18	1.4[4]	2.84	177	2.75	172	B
GW-135	Conasauga	Maynardville Limestone	227.25	746	4.10	---	1.31	2.3[4]	2.84	177	2.72	170	B
GW-135	Conasauga	Maynardville Limestone	234.44	769	1.79	---	1.84	1.7[4]	2.84	177	2.79	174	B
GW-135	Conasauga	Maynardville Limestone	243.46	799	0.10	---	0.14	1.2[4]	2.70	169	2.70	169	B
GW-135	Conasauga	Maynardville Limestone	249.53	819	0.46	---	0.24	0.4[4]	2.76	172	2.75	172	B
GW-135	Conasauga	Maynardville Limestone	255.40	838	0.34	---	0.29	2.3[4]	2.70	169	2.69	168	B
GW-135	Conasauga	Maynardville Limestone	268.91	882	0.28	---	0.26	0.2[4]	2.75	172	2.75	172	B
GW-135	Conasauga	Maynardville Limestone	290.53	953	0.36	---	0.29	0.8[4]	2.75	172	2.74	171	B
GW-135	Conasauga	Maynardville Limestone	306.58	1006	0.24	---	0.26	0.4[4]	2.74	171	2.73	170	B
GW-135	Conasauga	Maynardville Limestone	314.96	1033	0.14	---	0.24	0.3[4]	2.70	169	2.70	169	B
GW-135	Conasauga	Maynardville Limestone	318.01	1043	0.56	---	0.29	0.2[4]	2.74	171	2.72	170	B
GW-135	Conasauga	Maynardville Limestone	324.08	1063	0.17	---	0.60	0.4[4]	2.71	169	2.70	169	B
GW-135	Conasauga	Maynardville Limestone	345.49	1133	0.15	---	0.46	0.2[4]	2.71	169	2.70	169	B
GW-135	Conasauga	Maynardville Limestone	365.02	1198	0.06	---	0.34	0.3[4]	2.73	170	2.73	170	B
Number of tests					83	33	90	46	83	83	83	83	

1 Unit names for Maryville Limestone and Rutledge Limestone changed to current usage of Dismal Gap and Friendship respectively.
2 Some values represent the average of several tests.
3 Data Sources:
A — (Reference 2.3.1-45)
B — (Reference 2.3.1-46)
4 Results from a sample approximately collocated with the other results.

	Effective Porosity (%)				Grain Density		Bulk Density	
	Helium	Mercury	Immersion	Other	(g/cm^3)	(pcf)	(g/cm^3)	(pcf)
Average	3.85	3.79	4.67	1.11	2.77	173	2.73	170
Minimum	0.06	2.7	0.14	0.1	2.70	169	2.62	164
Maximum	19.2	5.2	15.87	3.4	2.87	179	2.83	177

Table 2.3.1-9
Representative Soil and Rock Properties Important to Radionuclide Transport

Group	Unit	Material	Total Unit Weight		Specific Gravity	
			Best Estimate (pcf)	Range (pcf)	Best Estimate	Range
unconsolidated	Existing Fill/Residual Soil	Silt and Clay	120	NA	2.75	NA
	New Granular Backfill[1]	well graded Sand	135	NA	2.70	NA
	Weathered Rock	Limestone/Siltstone	140	NA	NA	NA
Chickamauga	Benbolt formation	Limestone/Siltstone	168	163-170	2.70	2.62-2.72
	Rockdell formation	Limestone	168	160-169	2.69	2.57-2.71
	Fleanor member	Siltstone	168	166-176	2.70	2.67-2.83
	Eidson member	Limestone	168	164-169	2.69	2.64-2.71
	Blackford formation	Limestone/Siltstone	168	164-169	2.68	2.64-2.71
Knox	Newala formation	Dolomite	175	161-177	2.80	2.59-2.84

[1] based on Tennessee Department of Transportation Type A specification

Note:
NA = information not available

Table 2.3.1-10
Groundwater Linear Velocity and Travel Time

Property	Representative Value	Source
Hydraulic Conductivity (ft/d)	2.6	Maximum calculated value as documented in SSAR Table 2.4.12-6 (observation well OW-423L)
Horizontal Hydraulic Gradient (ft/ft)	0.07	Mean value as presented in SSAR Table 2.4.12-8
Effective Porosity (decimal)	0.0467	Mean value determined in SSAR Table 2.4.12-7, using the Immersion test method results which the referenced author identified as the test method that yields results that most accurately approaches the true effective porosity value.
Distance to Receptor (ft)	1400	Shortest distance from edge of power block area to Clinch River arm of the Watts Bar Reservoir (Figure 2.3.1-19)

Calculated Values	
Linear Velocity (ft/d)	3.90
Travel Time (days)	359
Travel Time (years)	0.98

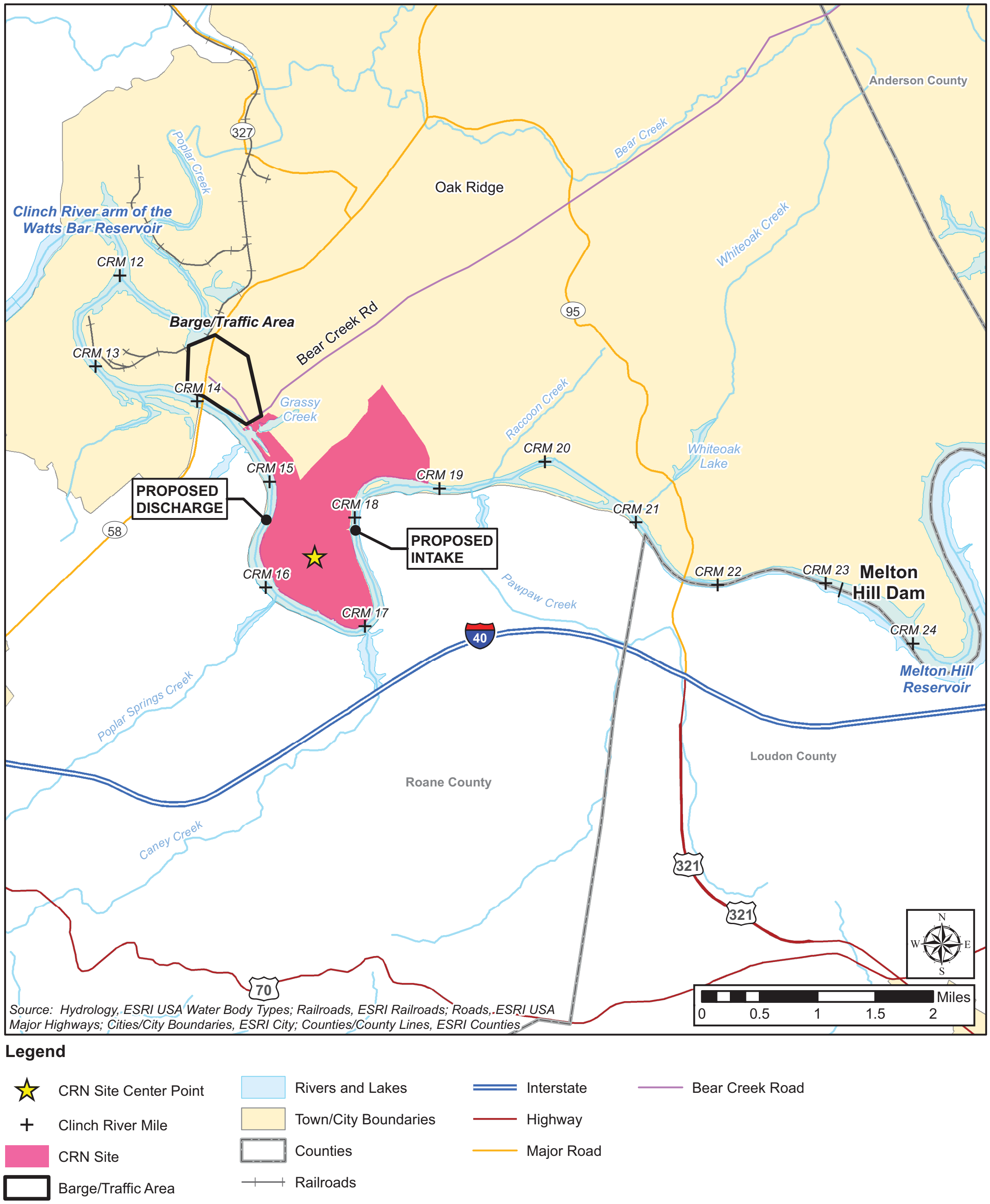


Figure 2.3.1-1. CRN Site Vicinity Water Resources

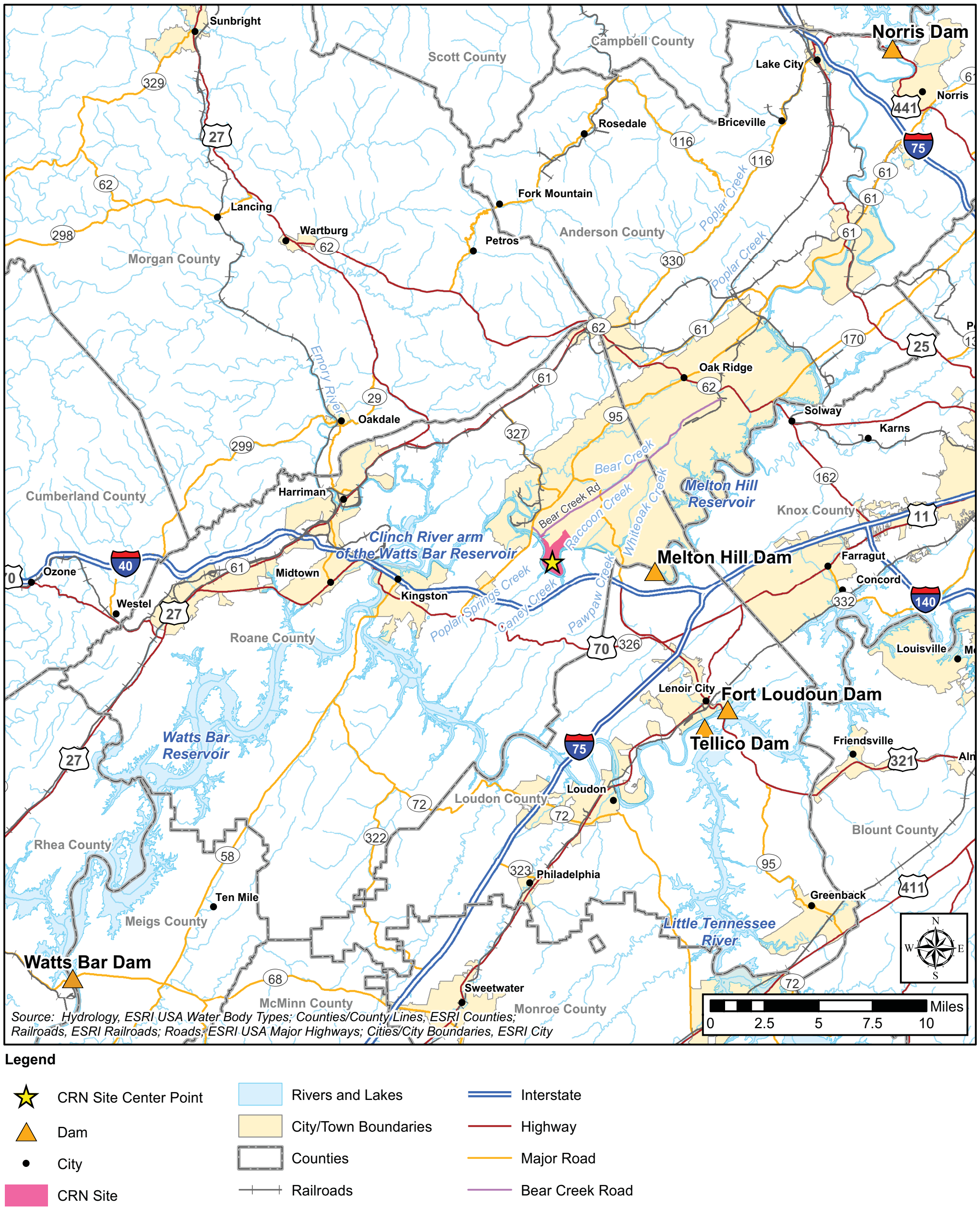


Figure 2.3.1-2. CRN Site Regional Water Resources

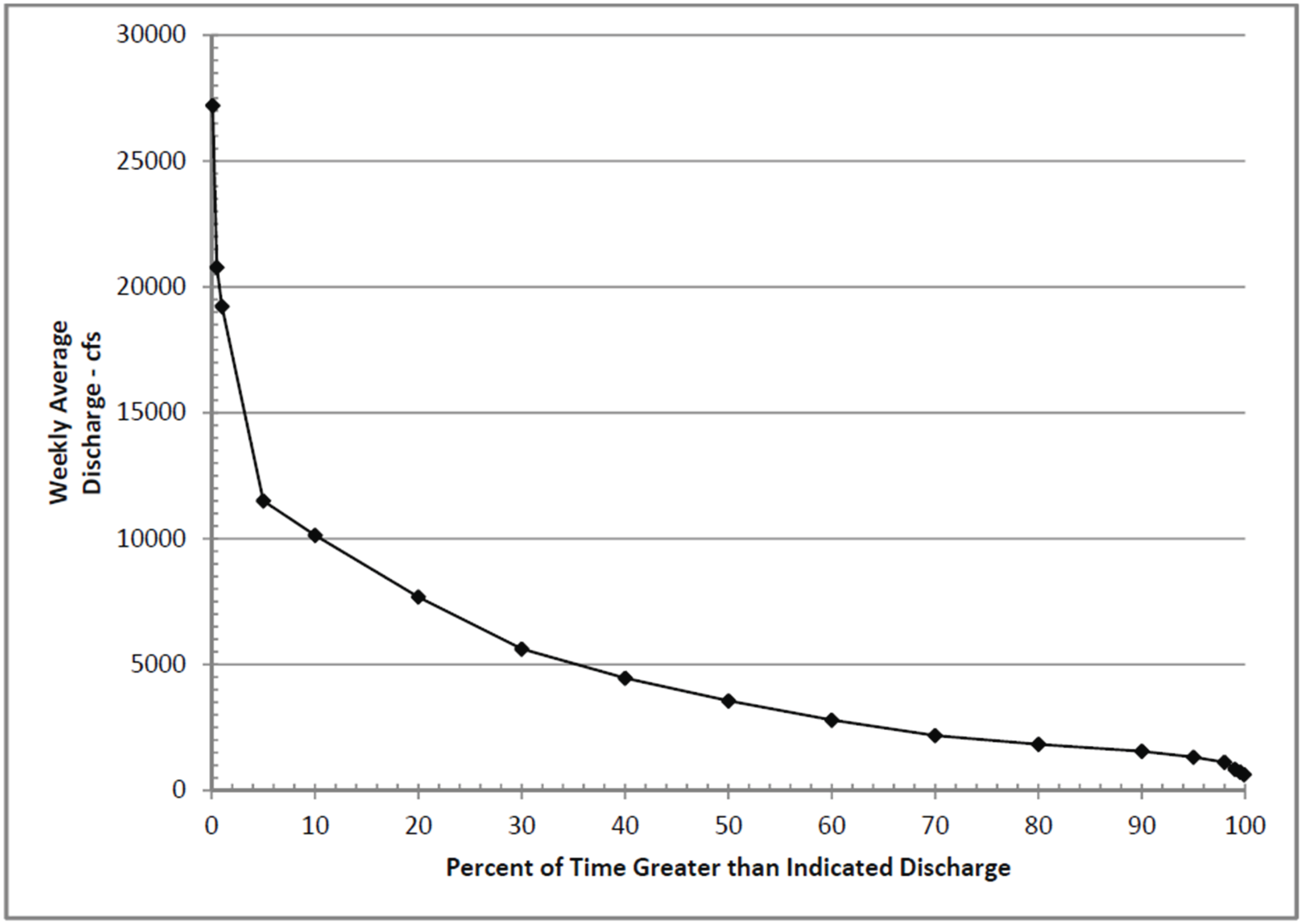


Figure 2.3.1-3. Melton Hill Dam Weekly Discharge Frequency

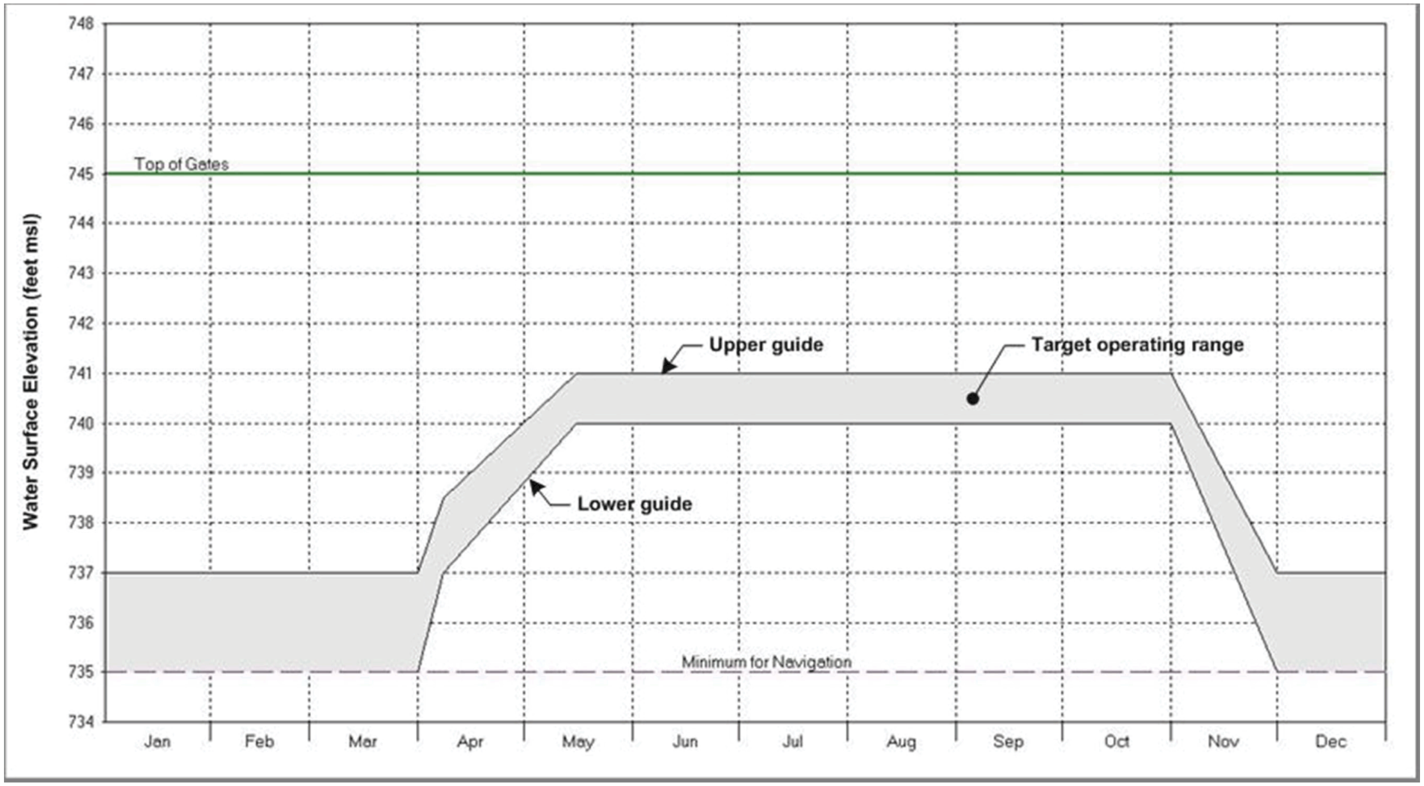


Figure 2.3.1-4. Operating Guide for Headwater Elevation at Watts Bar Dam

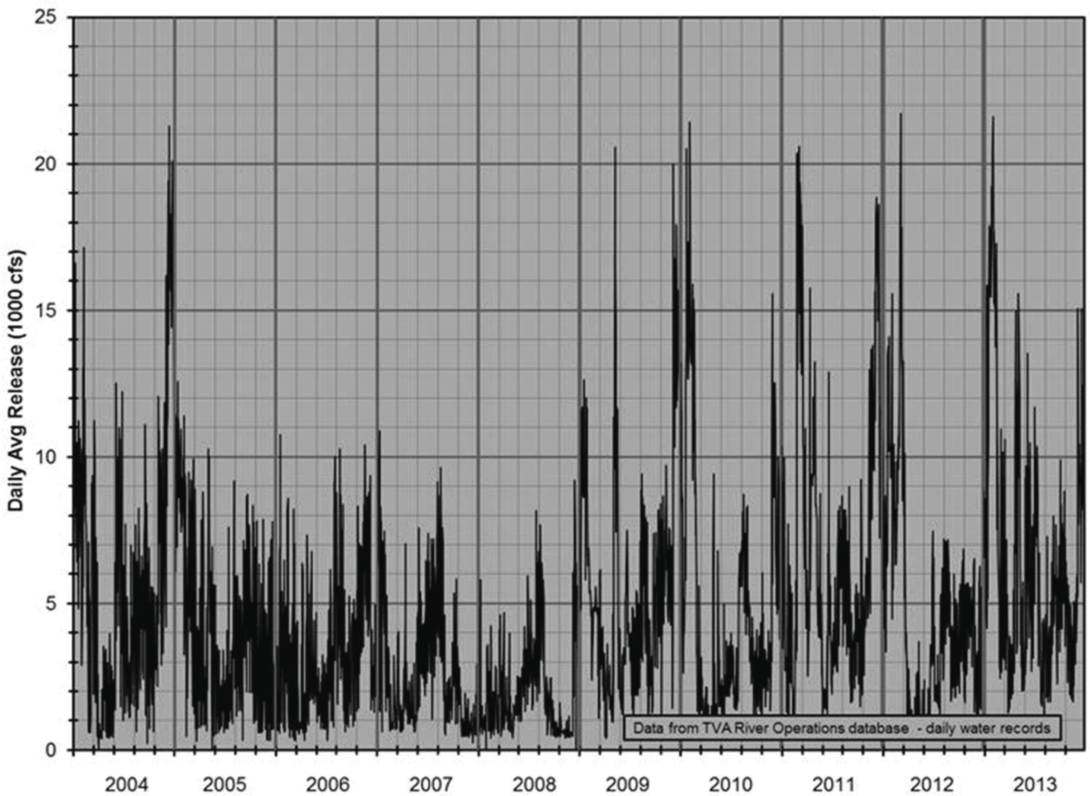


Figure 2.3.1-5. Daily Average Release from Melton Hill Dam

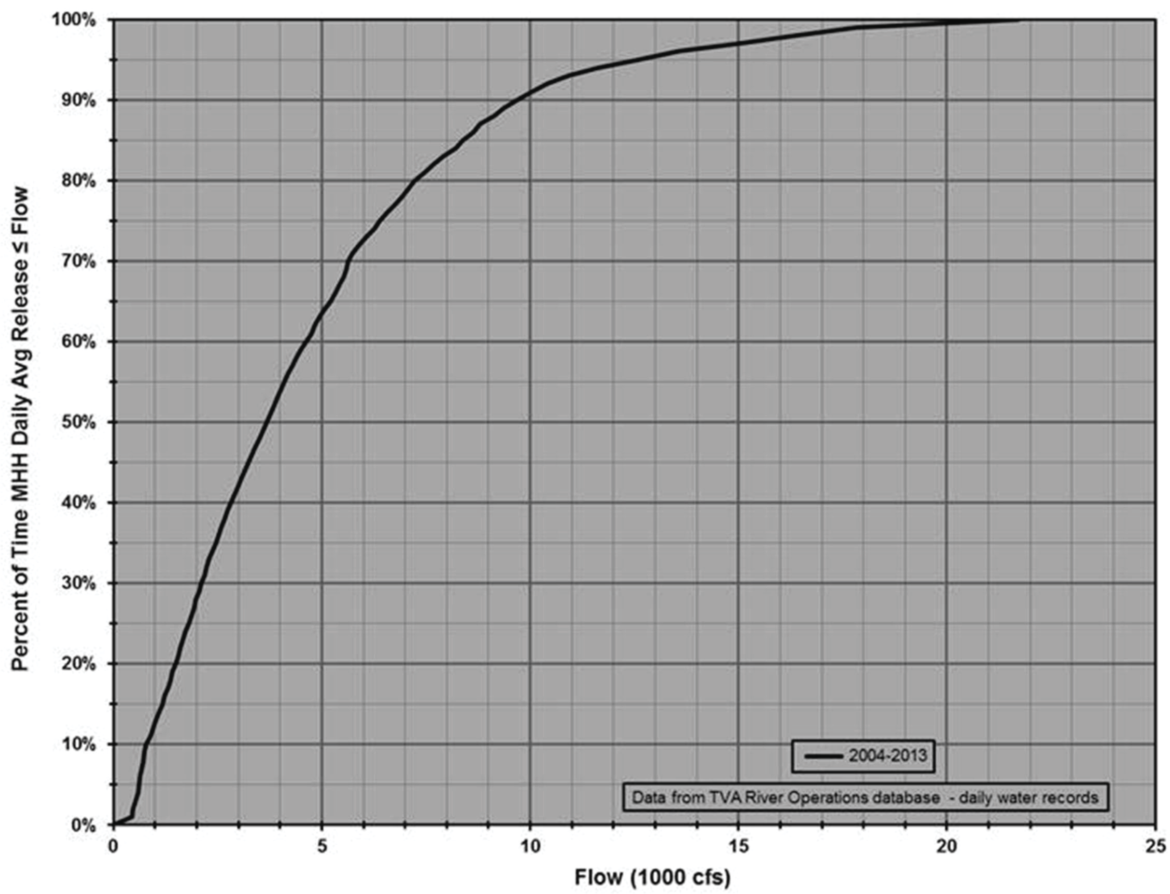


Figure 2.3.1-6. Percentile for Daily Average Release from Melton Hill Dam

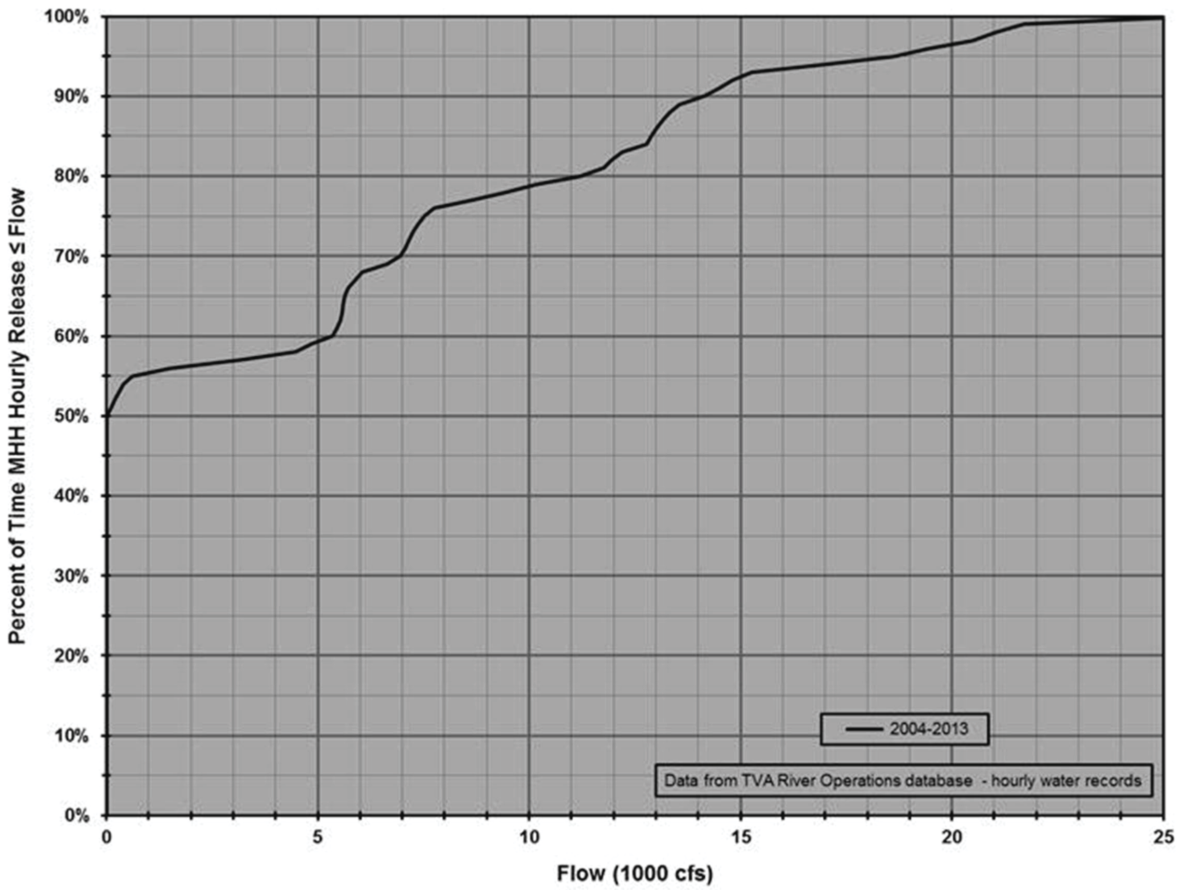


Figure 2.3.1-7. Percentile for Hourly Average Release from Melton Hill Dam

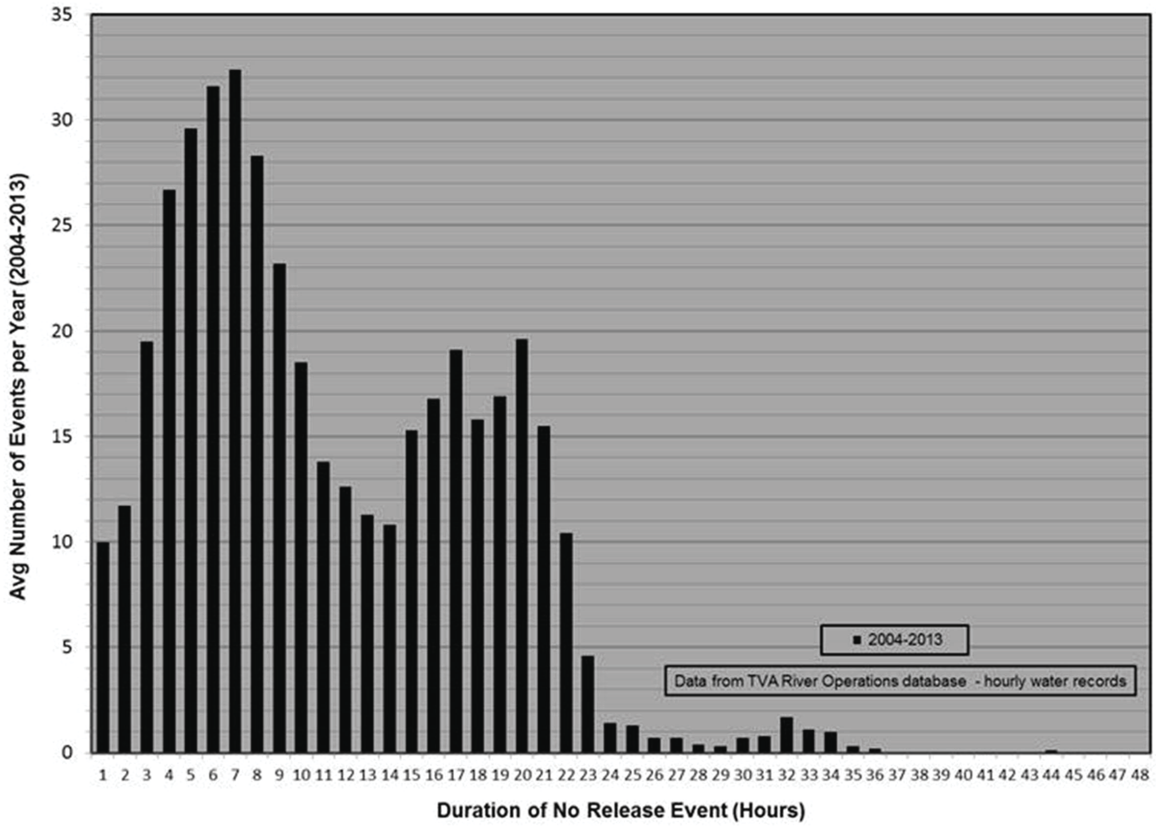


Figure 2.3.1-8. Average Annual Frequency of No Release Events from Melton Hill Dam

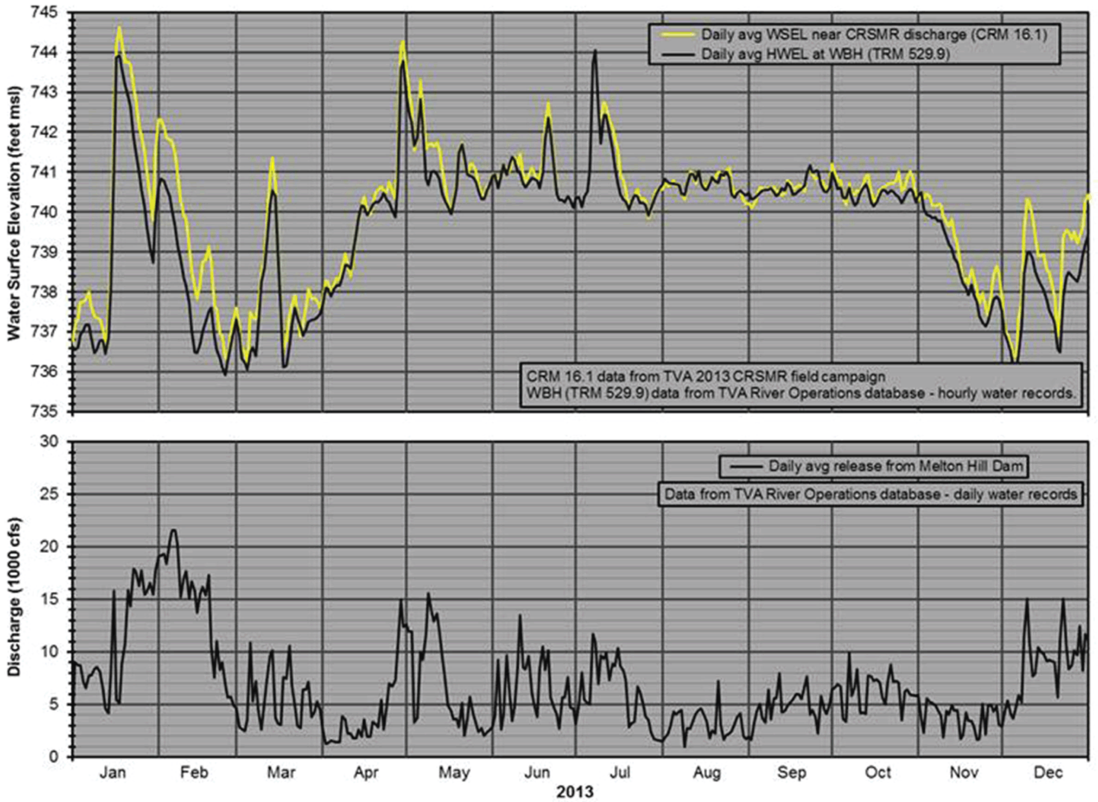


Figure 2.3.1-9. WSEL Measurements at CR SMR and WBH, and Discharge Measurements at Melton Hill Dam

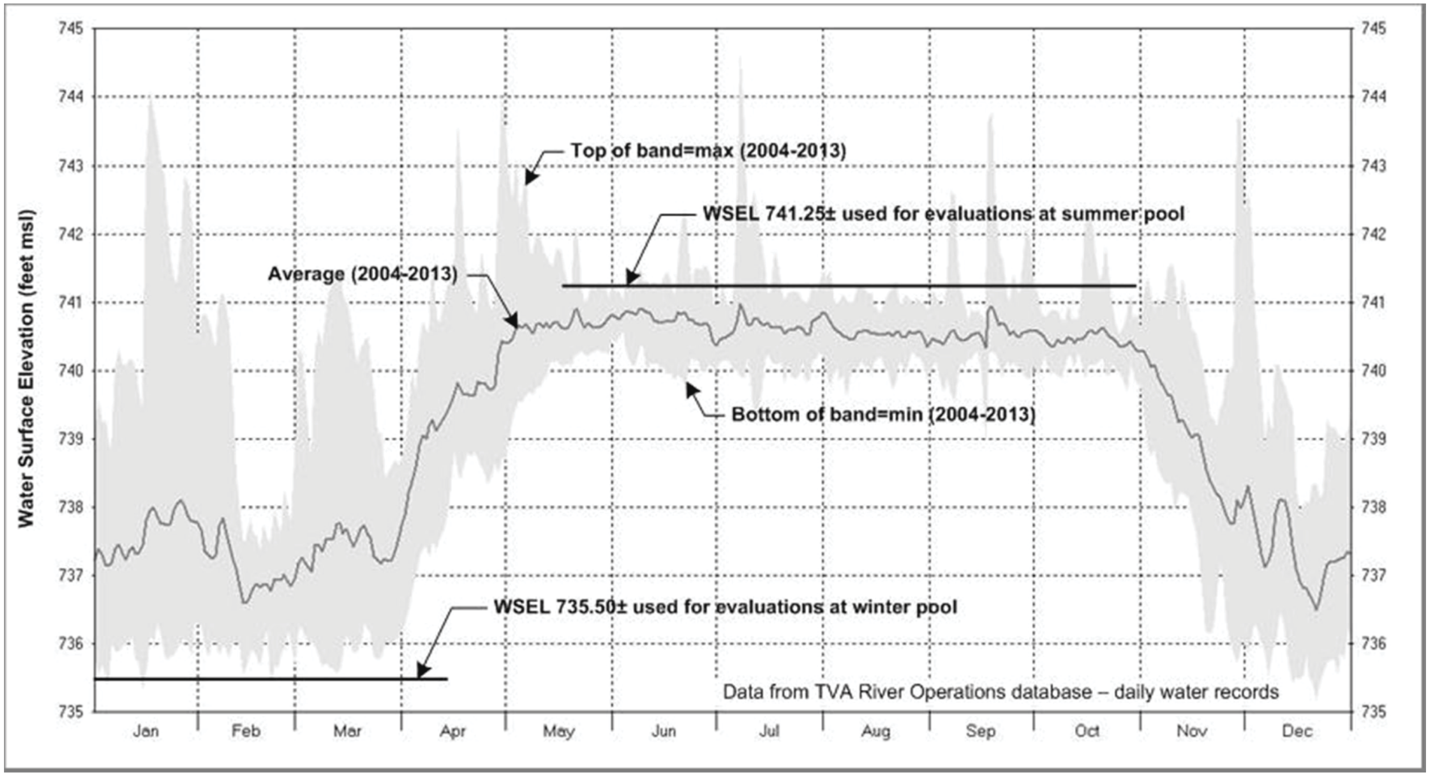


Figure 2.3.1-10. Headwater Elevation at Watts Bar Dam, Showing Max, Min, and Average Values of Daily Midnight Readings, 2004-2013

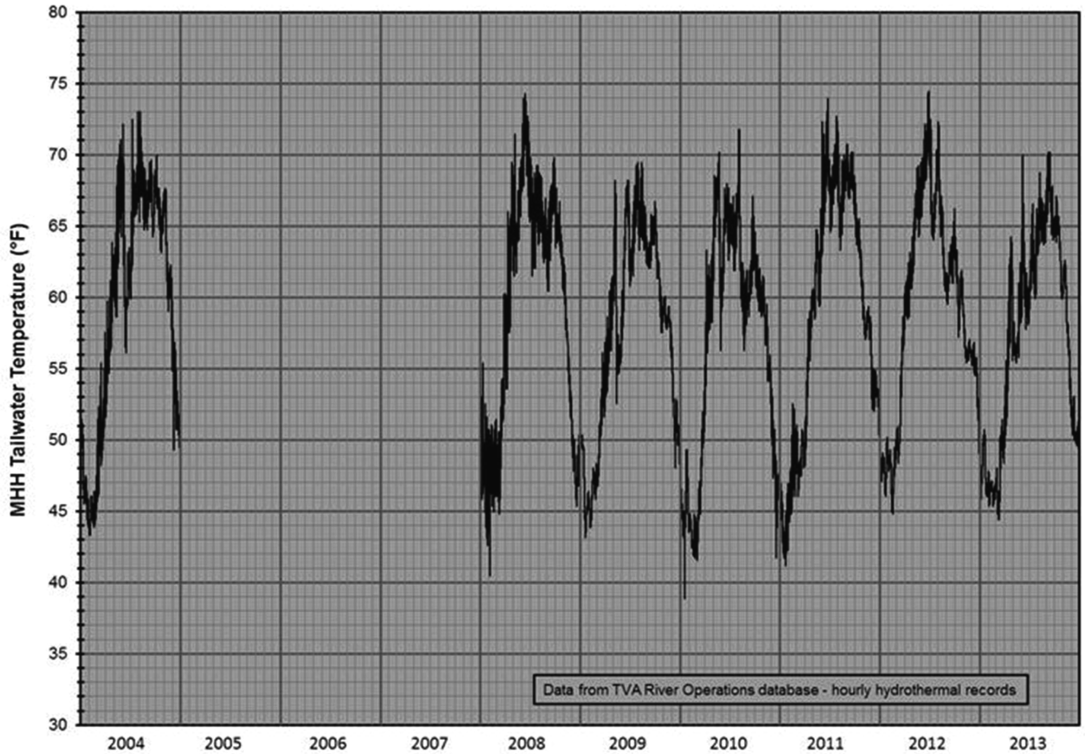


Figure 2.3.1-11. Hourly Water Temperature for Tailwater Below Melton Hill Dam

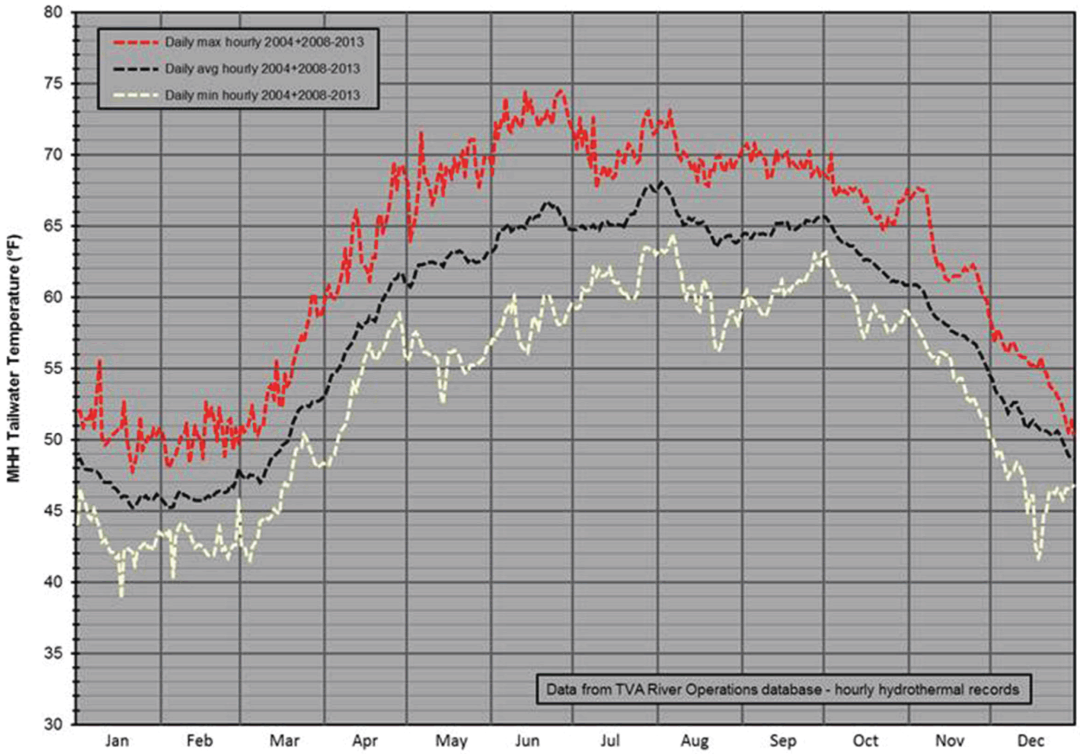


Figure 2.3.1-12. Daily Maximum, Minimum, and Average Hourly Water Temperature for Tailwater Below Melton Hill Dam

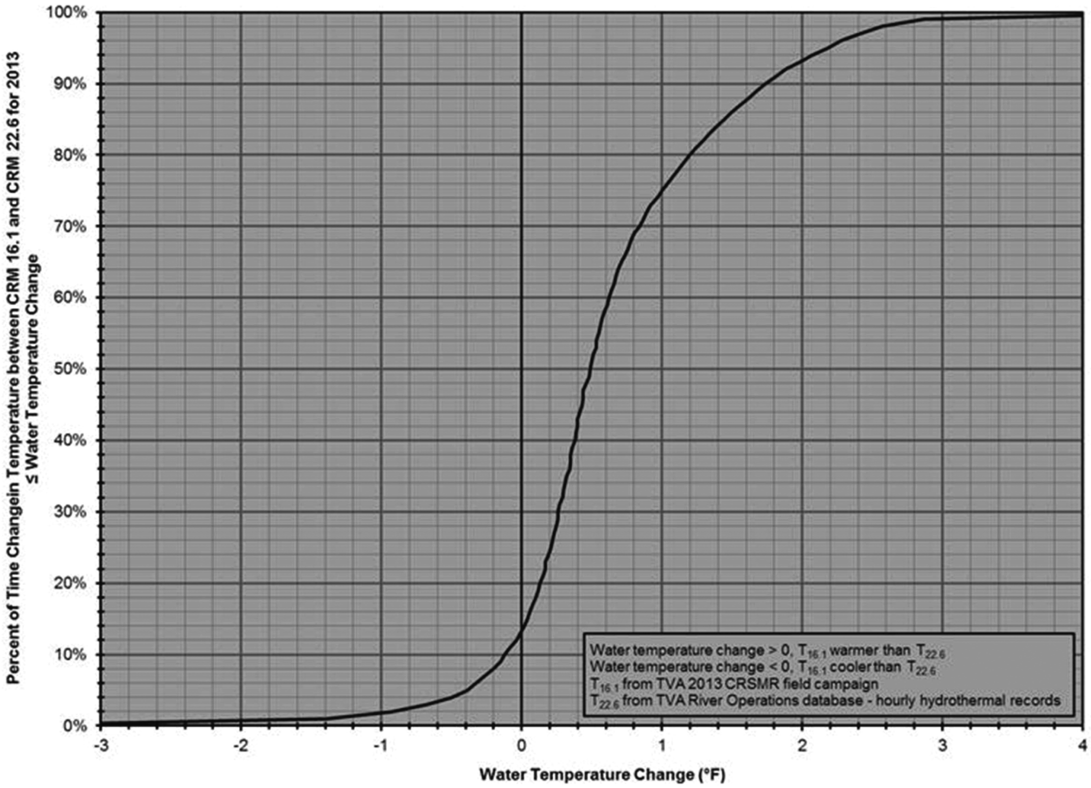


Figure 2.3.1-13. Percentile for Change in Hourly Water Temperature between CRM 16.1 and CRM 22.6/MHH Tailwater

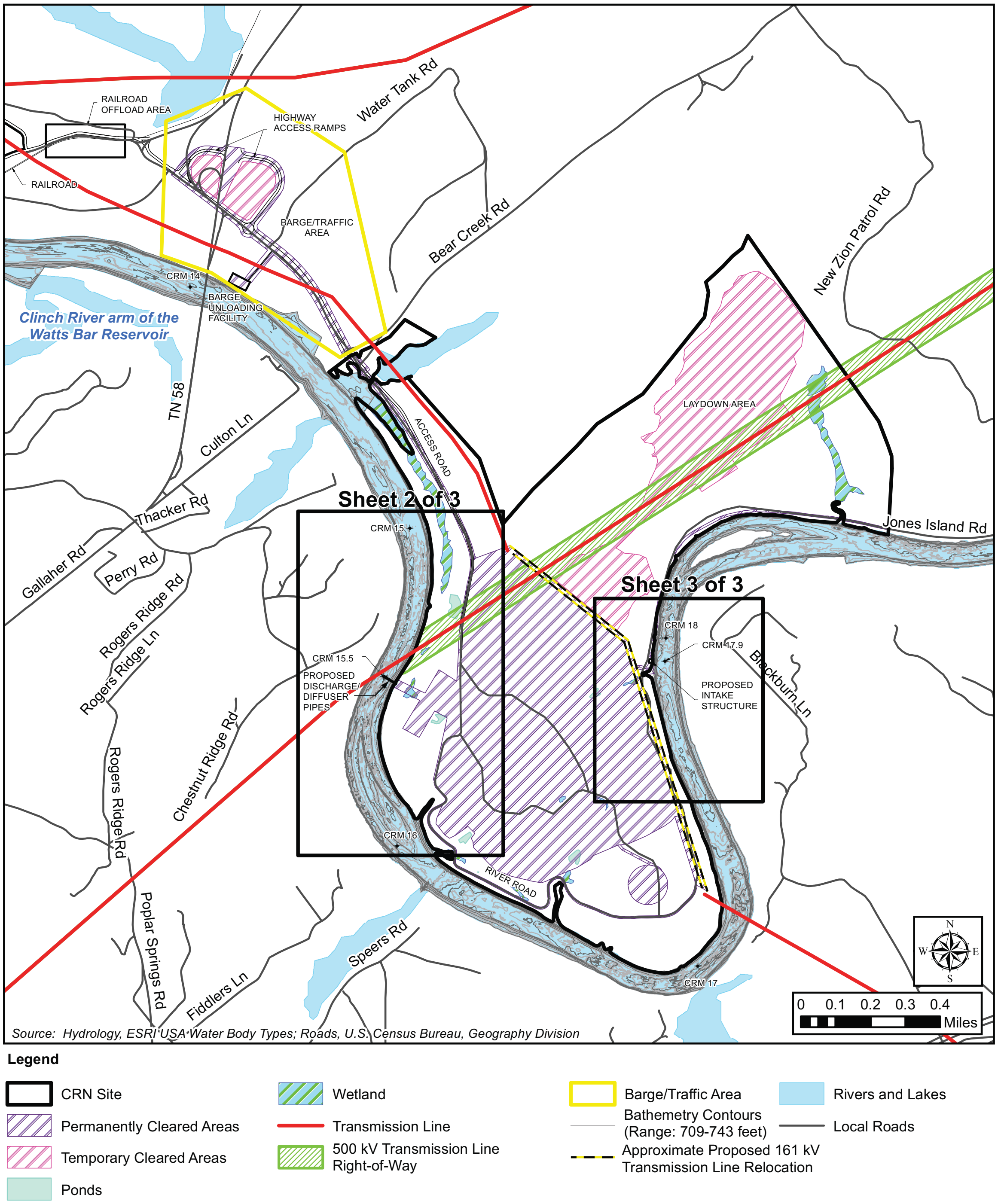


Figure 2.3.1-14. (Sheet 1 of 3) CRN Site Bathemetry

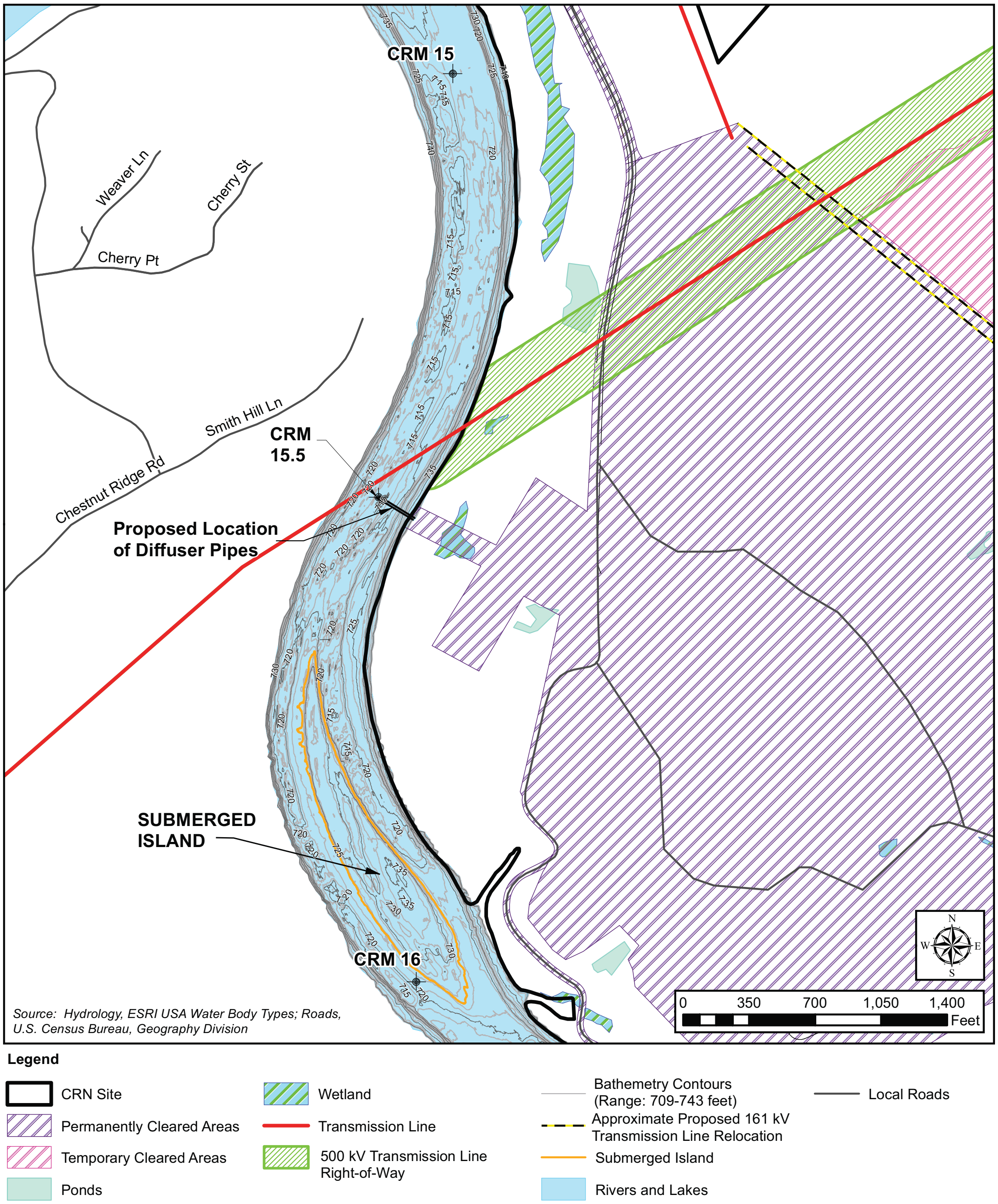


Figure 2.3.1-14. (Sheet 2 of 3) CRN Site Bathemetry

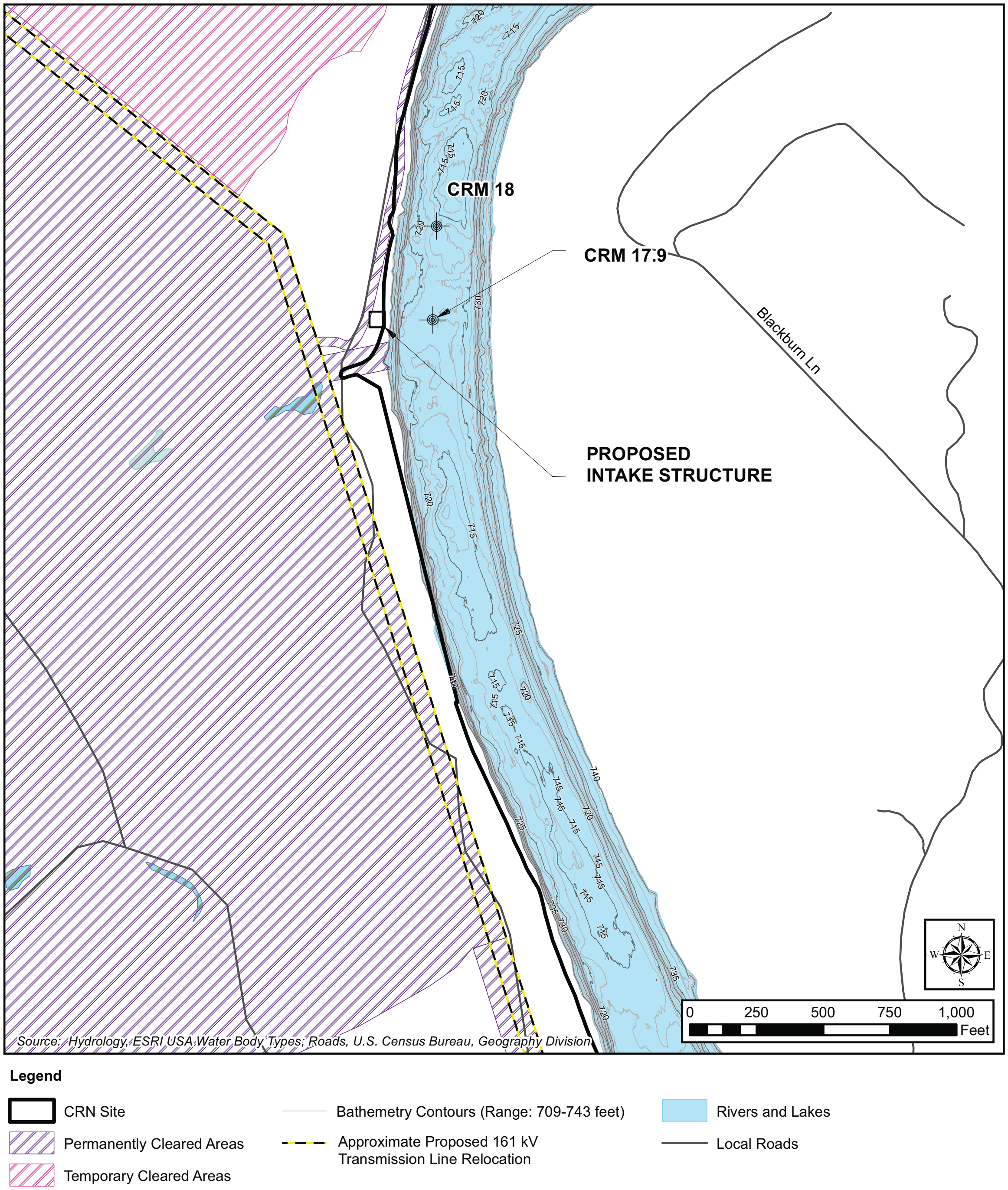


Figure 2.3.1-14. (Sheet 3 of 3) CRN Site Bathemetry

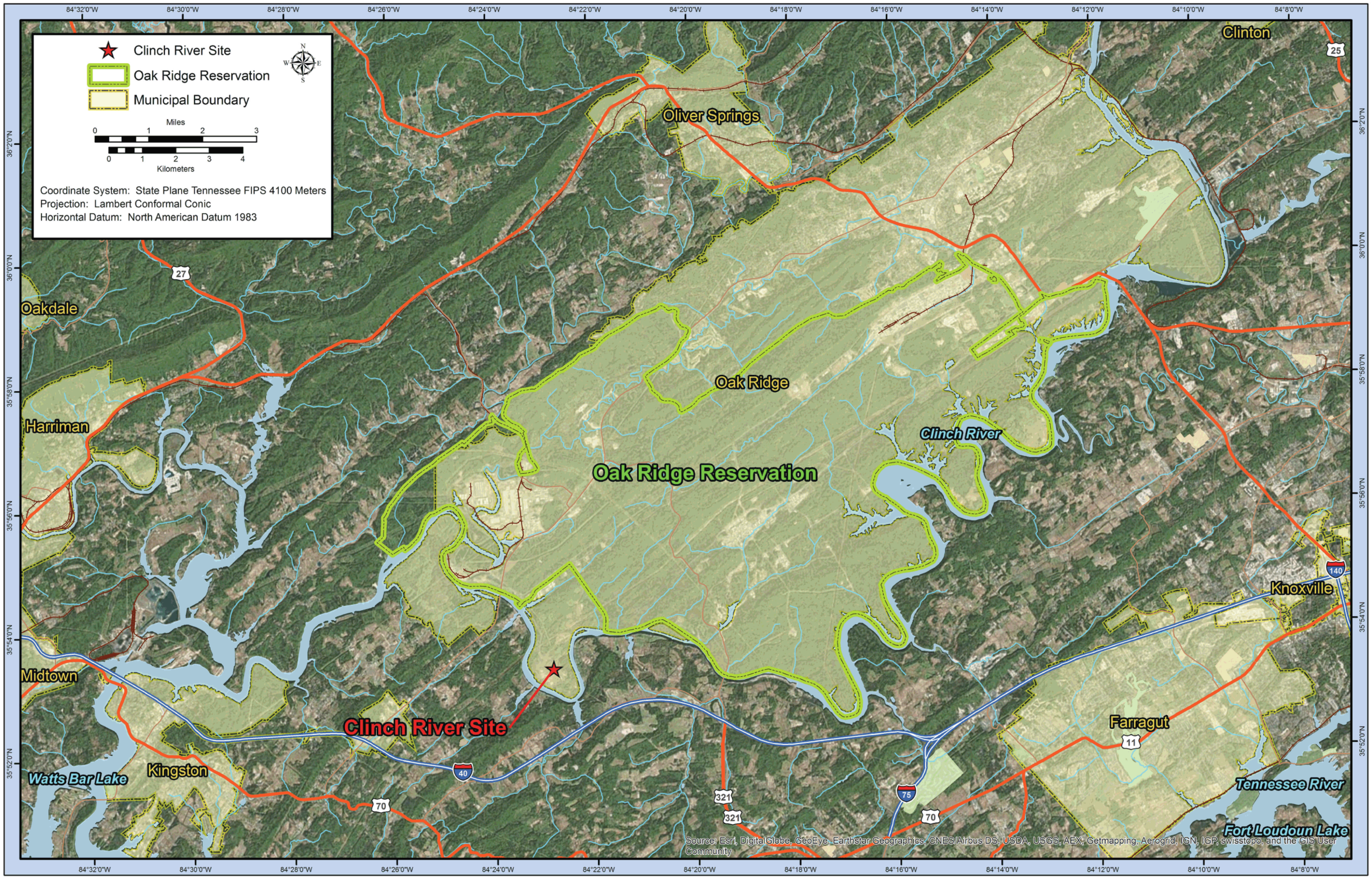


Figure 2.3.1-15. Location Map - ORR and CRN Site

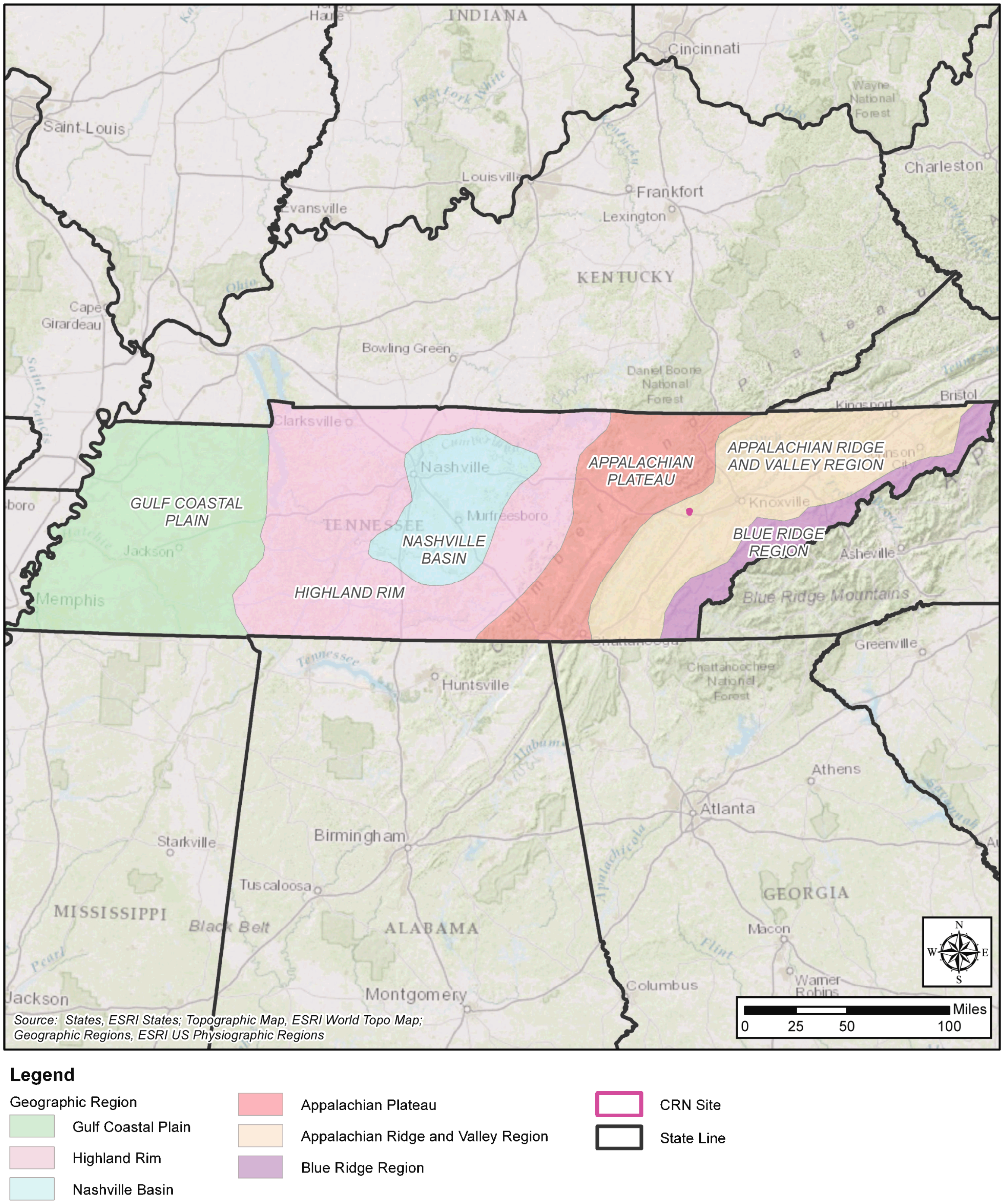
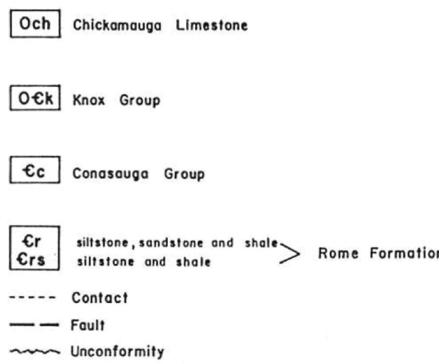


Figure 2.3.1-16. Geographic Regions of Tennessee

Adapted from: (Reference 2.3.1-47)
1 inch = 4000 ft
Contour Interval = 20 ft



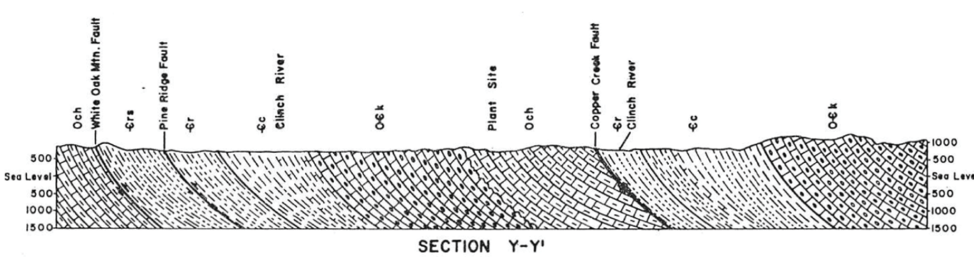


Figure 2.3.1-17. Preconstruction Topographic and Geologic Map and Cross-Section of the CRBRP Project

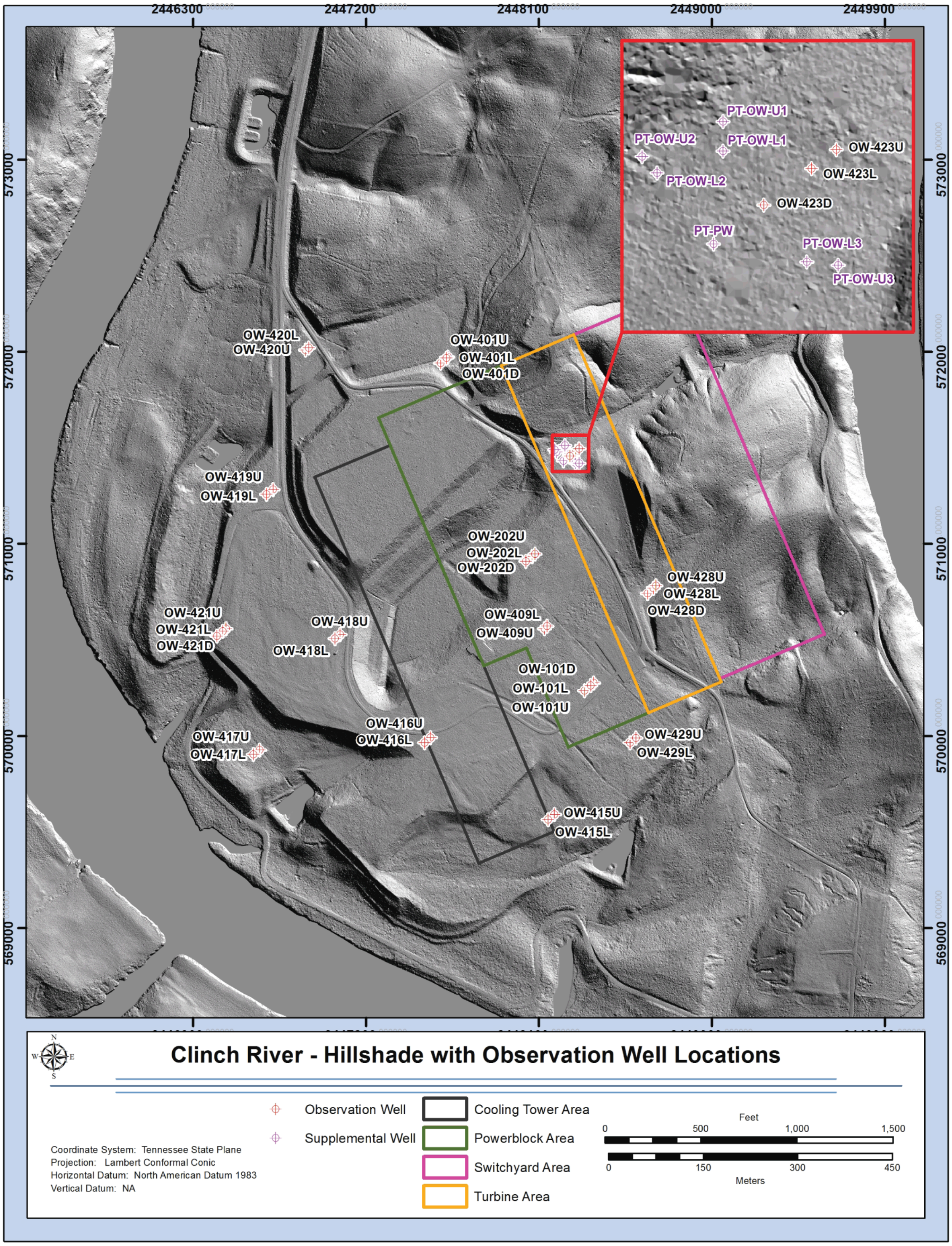


Figure 2.3.1-18. Current Site Topography and Observation Well Locations

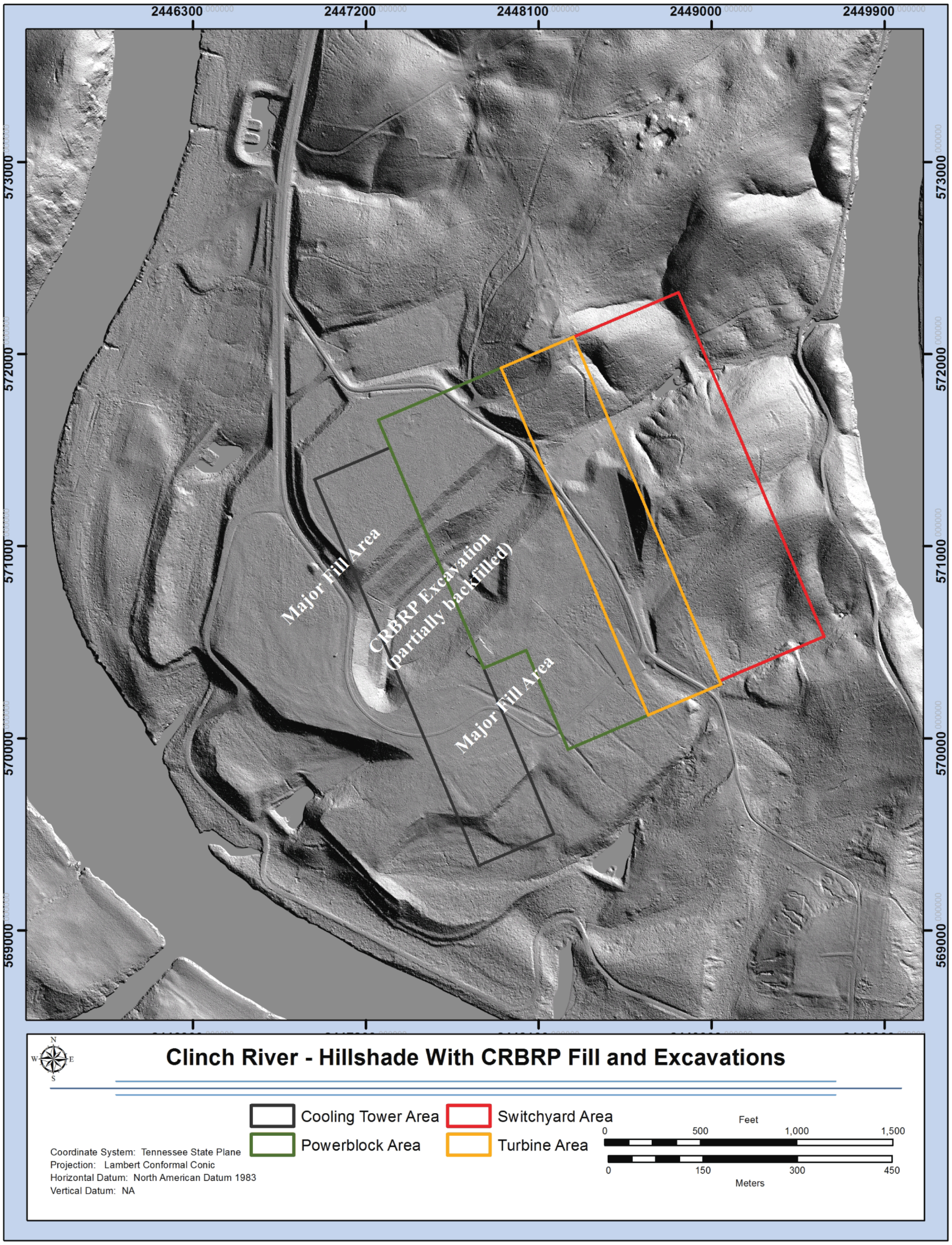
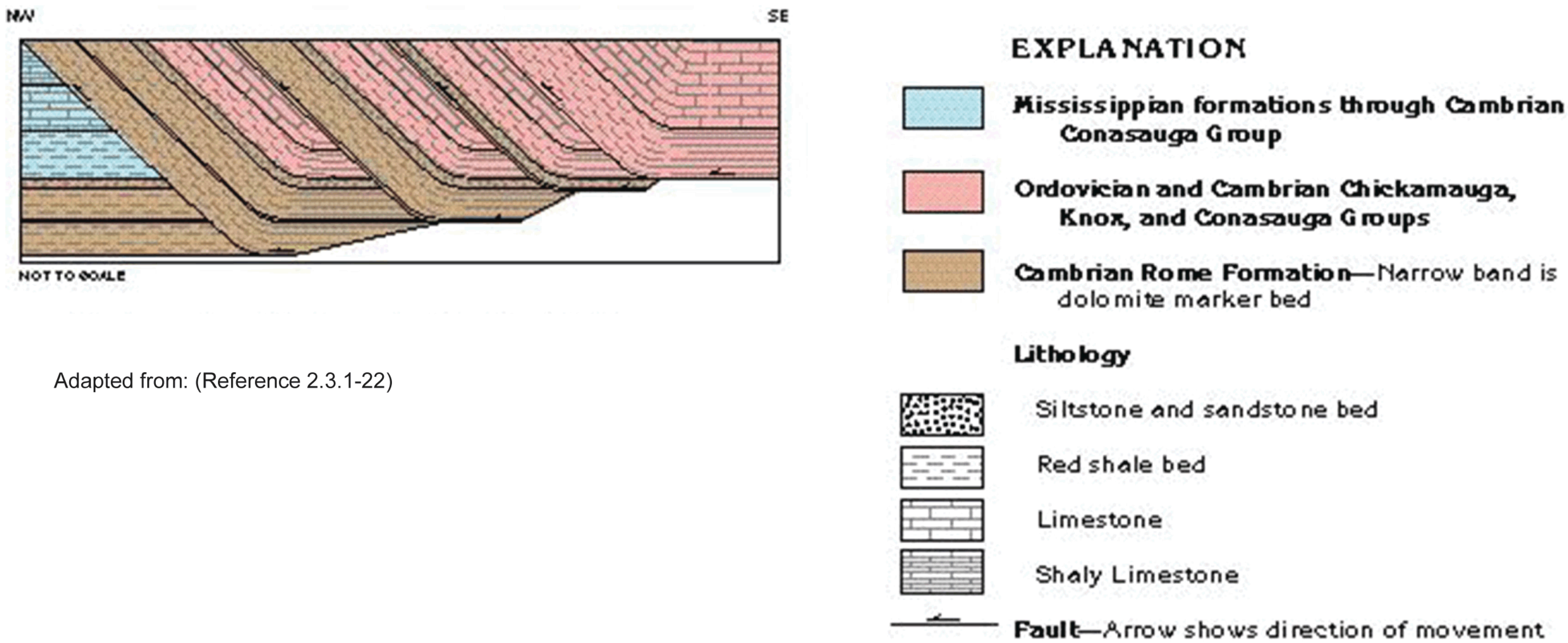
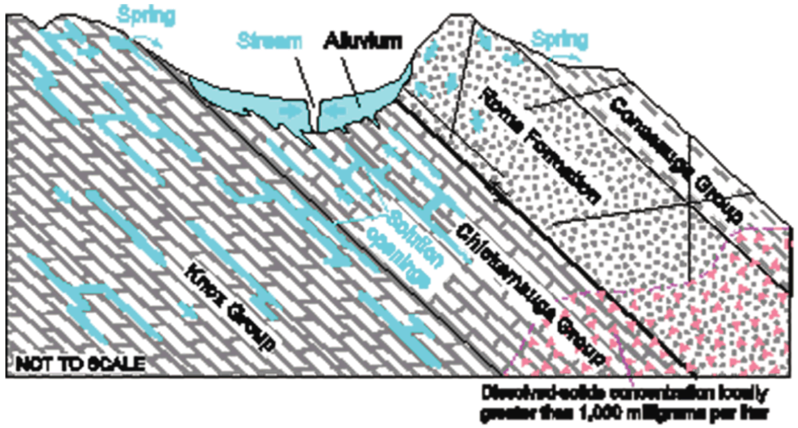


Figure 2.3.1-19. CRBRP Fill and Excavation Areas



Adapted from: (Reference 2.3.1-22)

Figure 2.3.1-20. Cambrian and Ordovician Aquifers



Adapted from: (Reference 2.3.1-22)

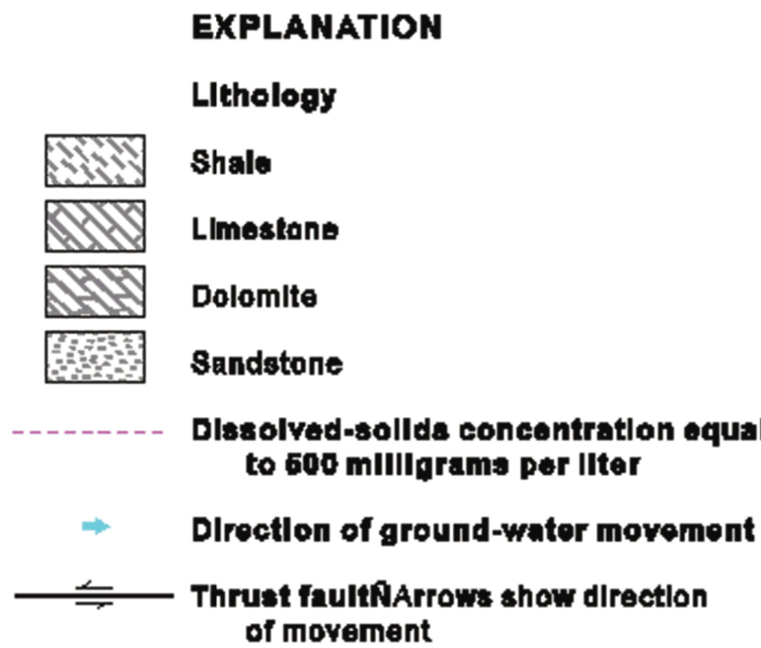
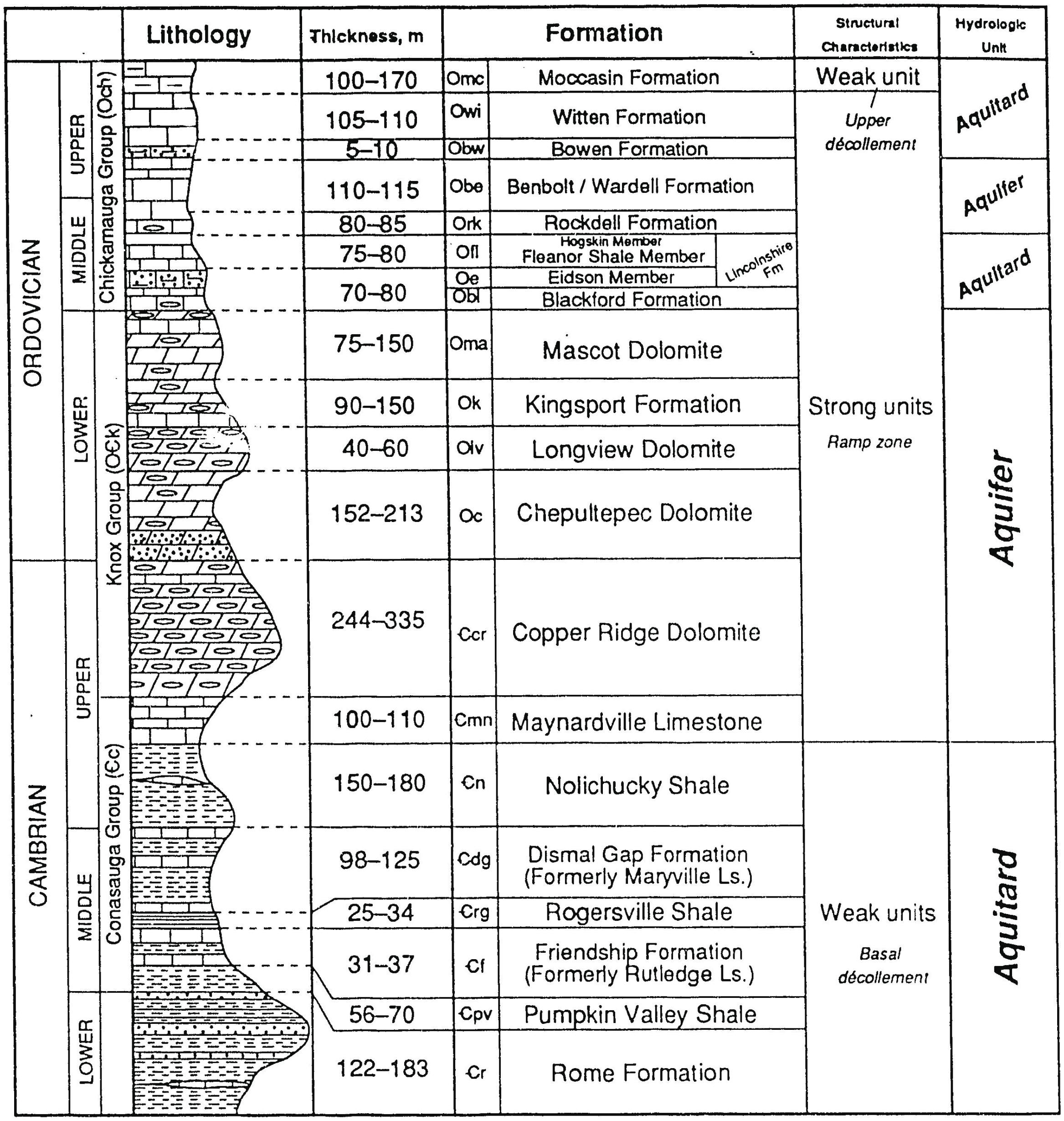
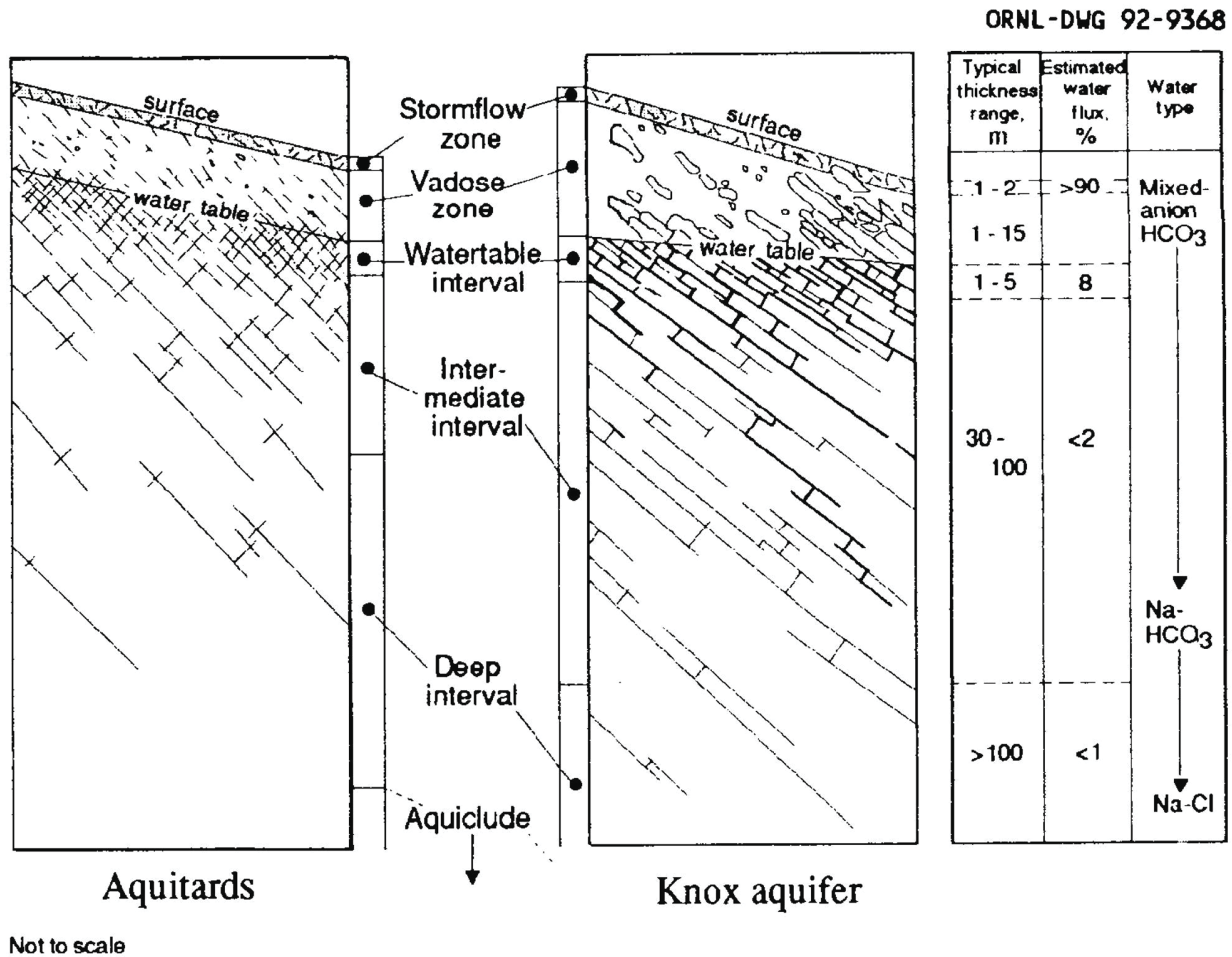


Figure 2.3.1-21. Typical Cross-Section of the East Tennessee Aquifer System



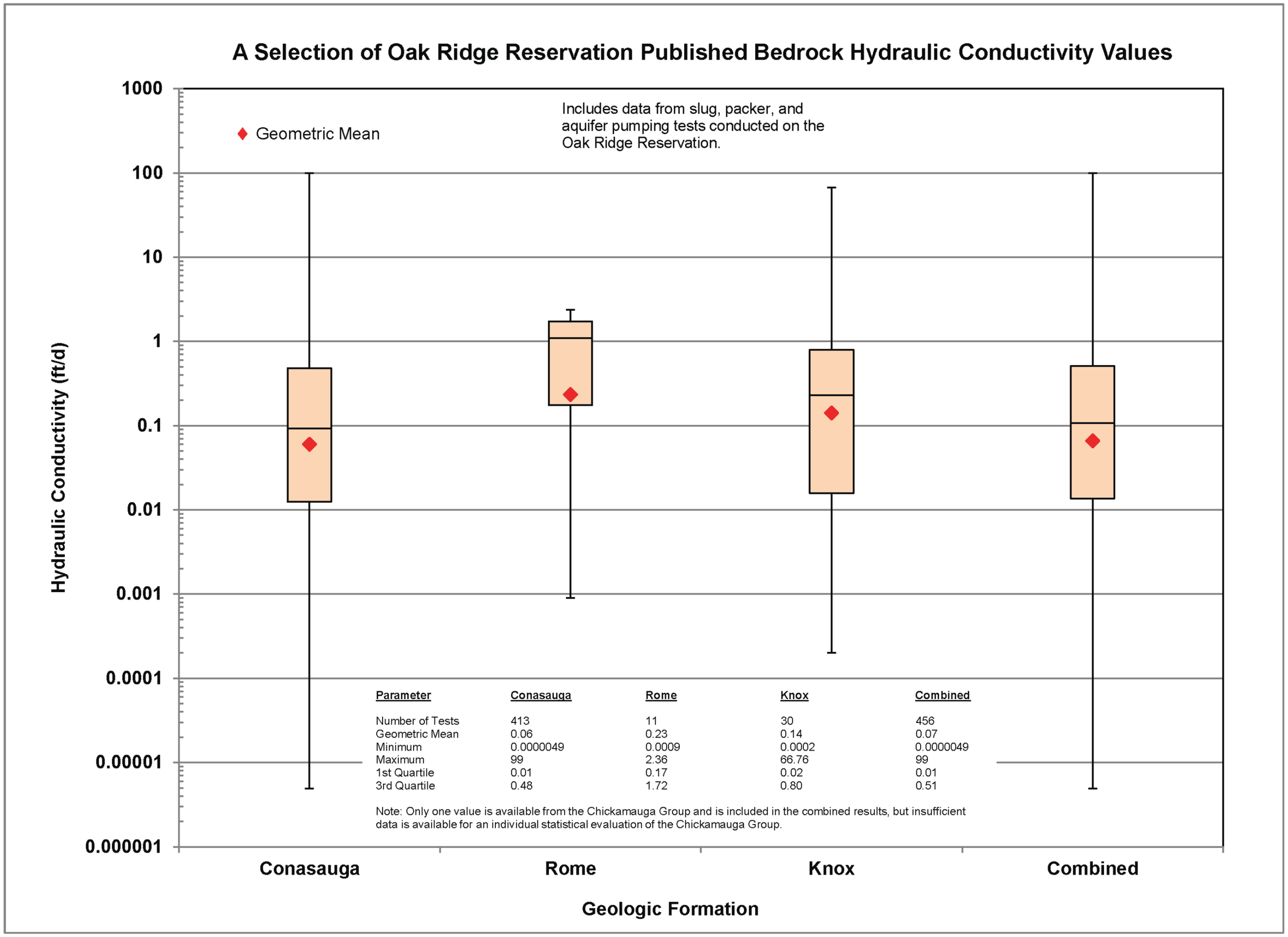
Source: (Reference 2.3.1-29).

Figure 2.3.1-22. Site Area Hydrogeostratigraphy



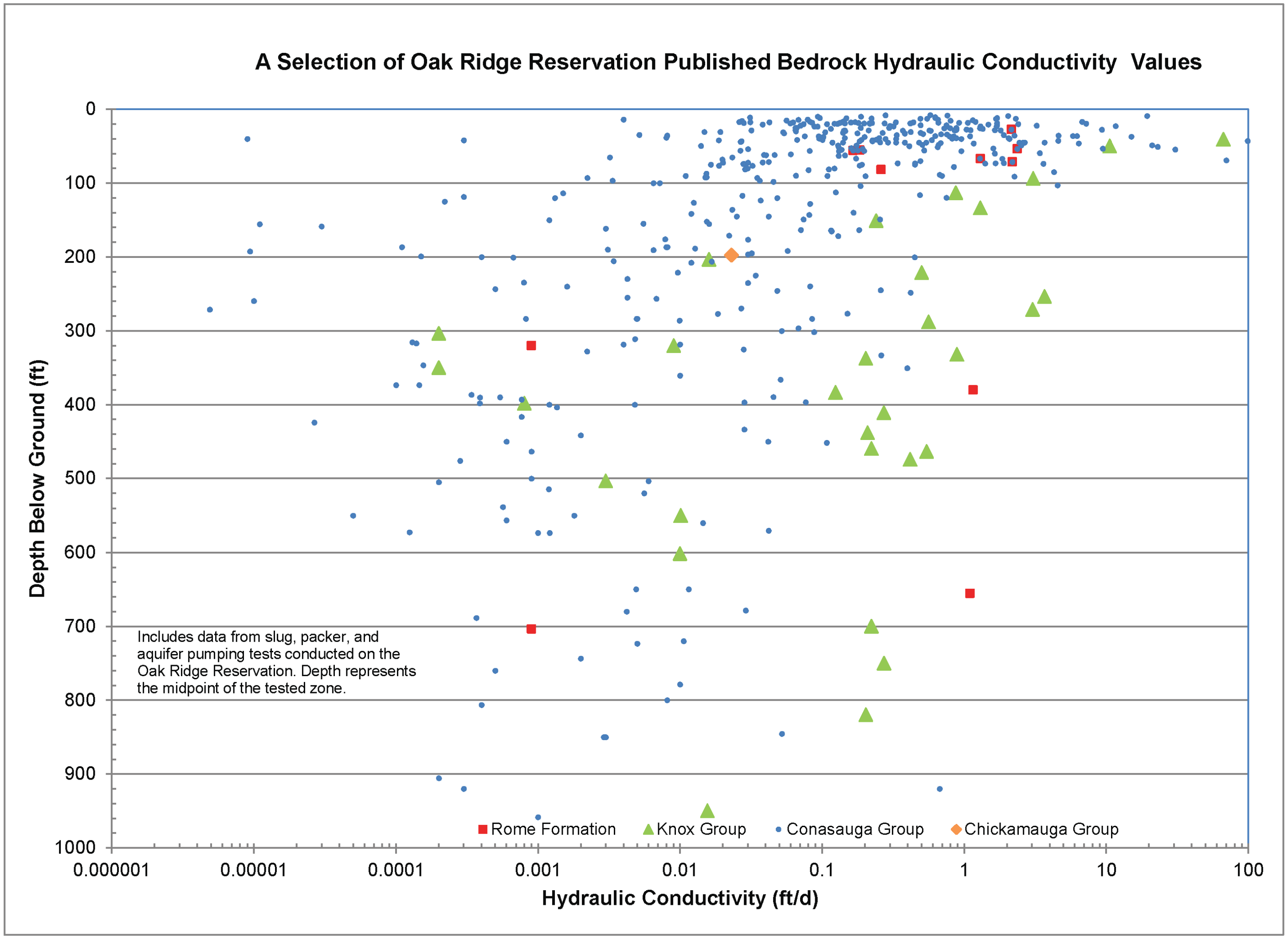
Source: (Reference 2.3.1-28)

Figure 2.3.1-23. ORR Vertical Flow Conceptualization



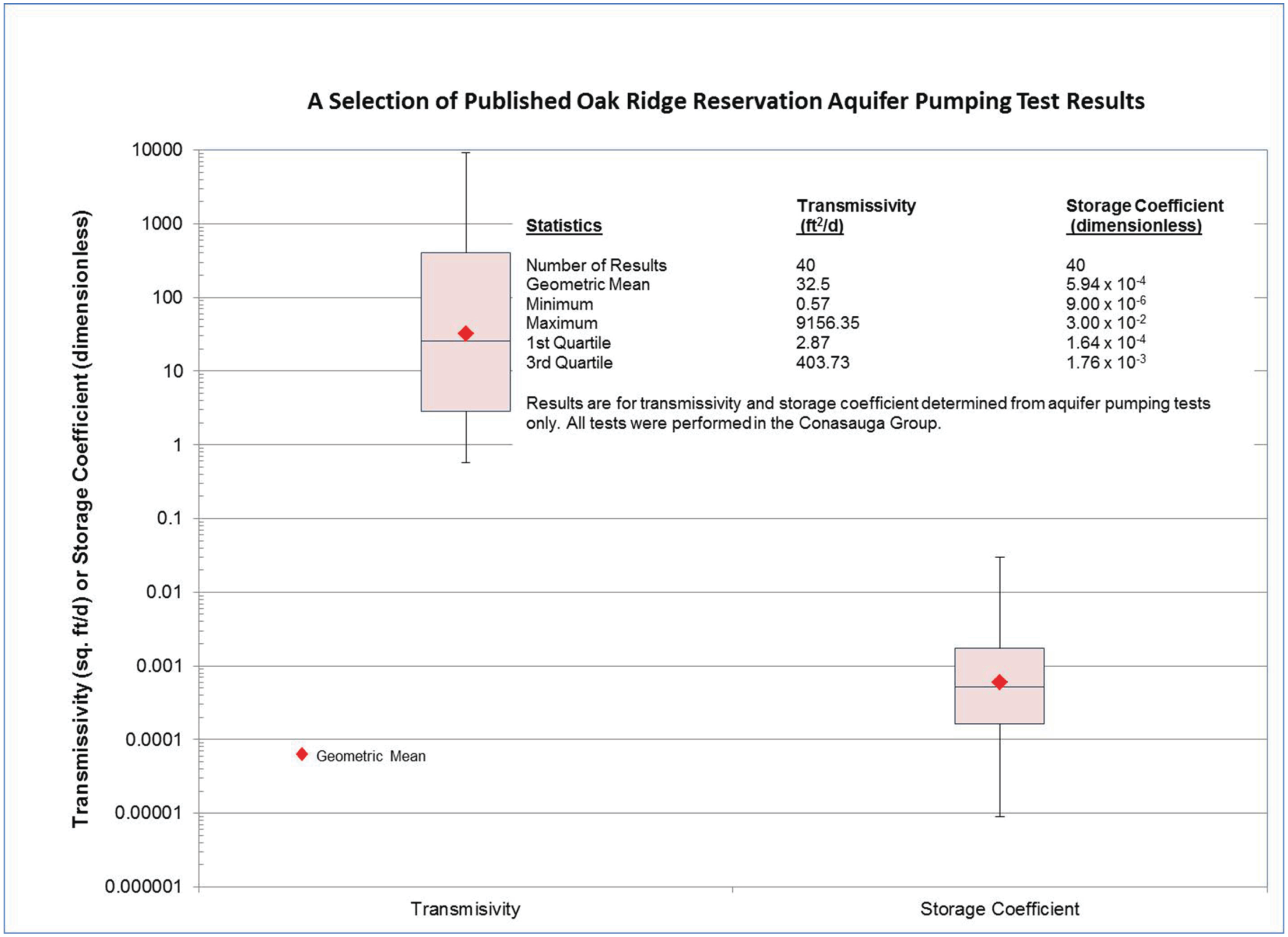
a) Box and whisker plot of hydraulic conductivity tests by geologic formation. Data presented in Appendix 2.3-A

Figure 2.3.1-24. (Sheet 1 of 2) ORR Historic Bedrock Hydraulic Conductivity Test Data



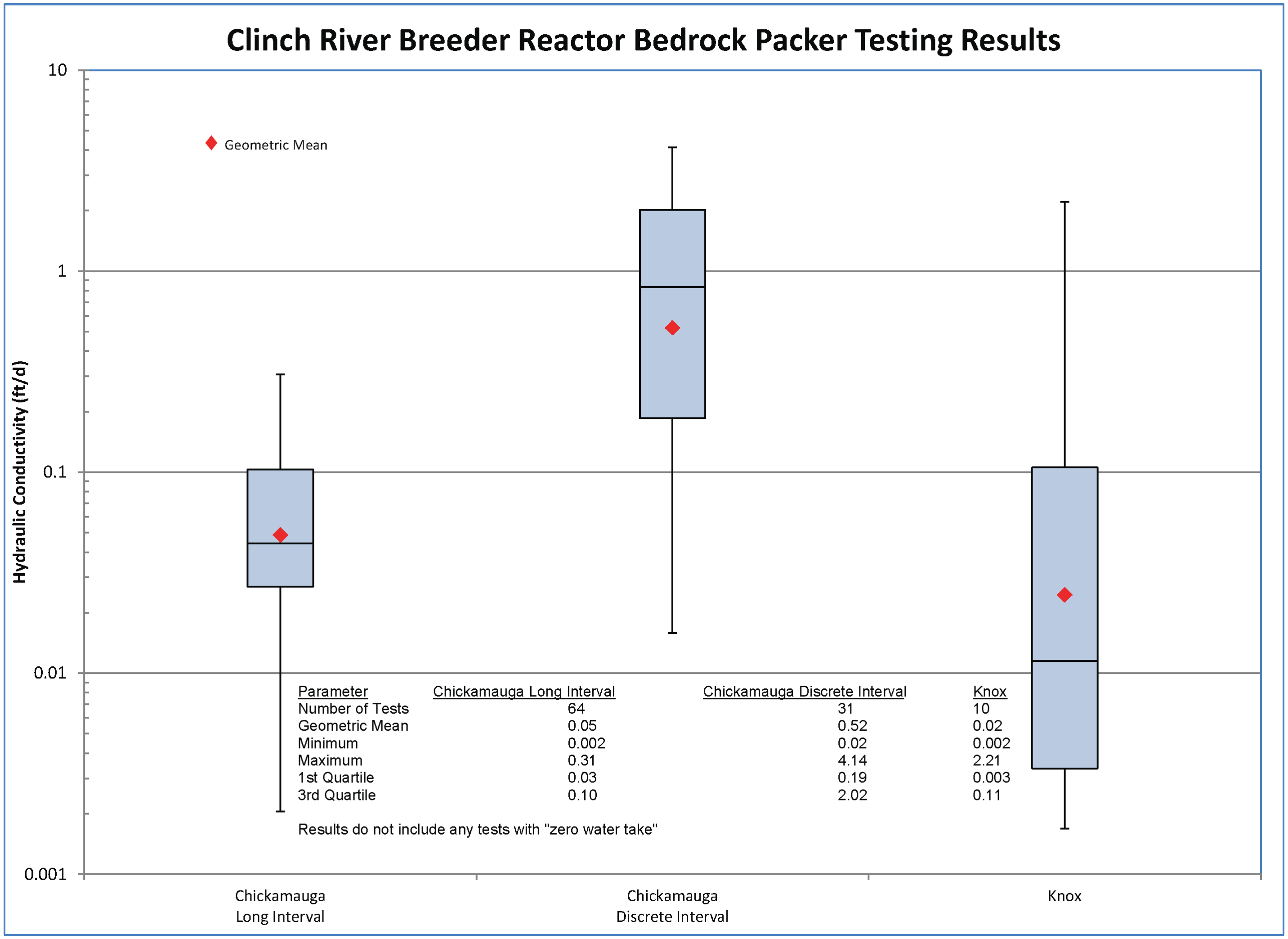
b) Scatter plot of hydraulic conductivity versus depth. Data presented in Appendix 2.3-A

Figure 2.3.1-24. (Sheet 2 of 2) ORR Historic Bedrock Hydraulic Conductivity Test Data



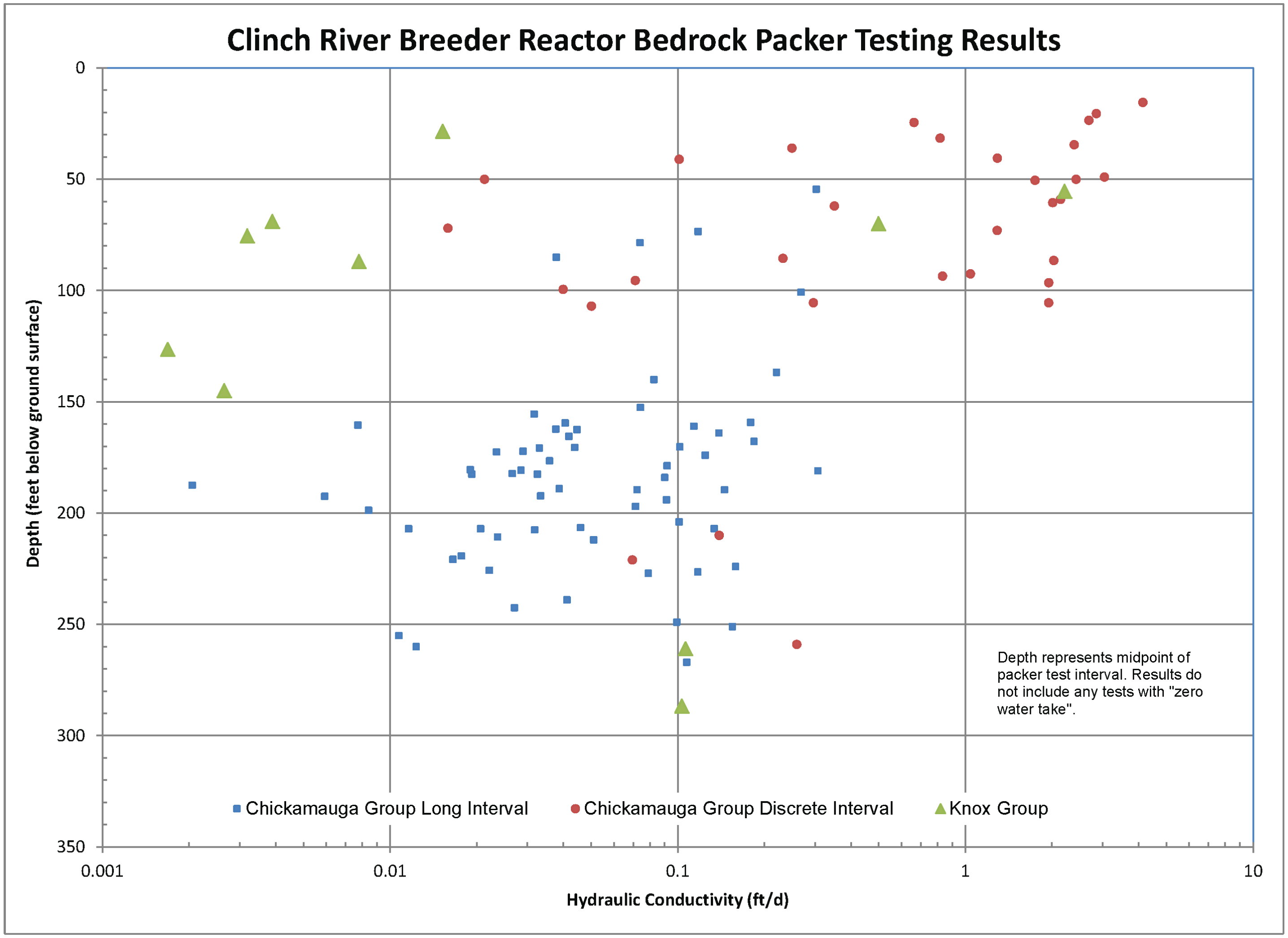
Data presented in Appendix 2.3-A

Figure 2.3.1-25. ORR Aquifer Pumping Test Results



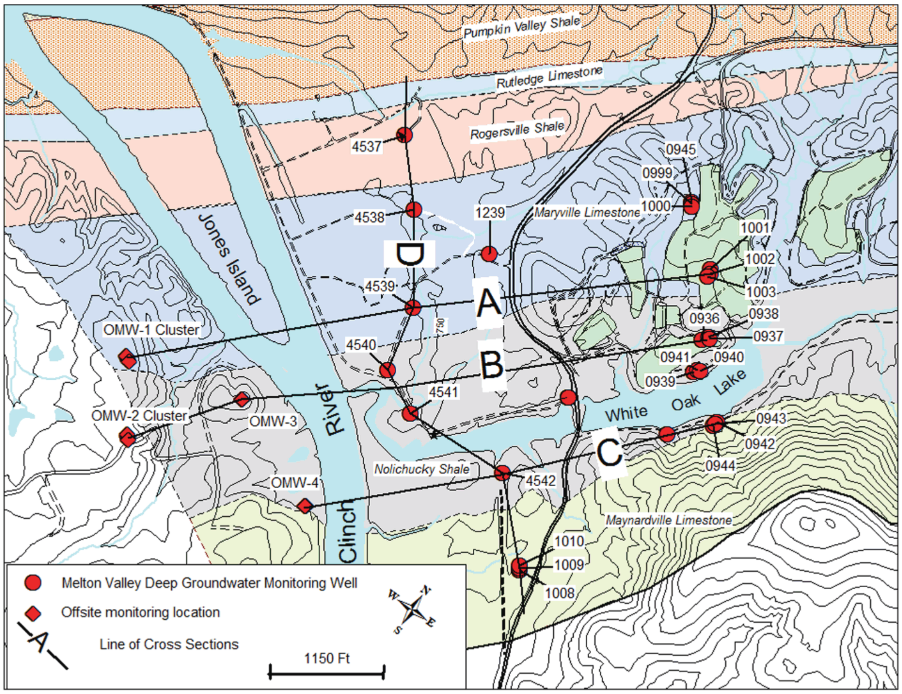
a) Box and whisker plot of CRBRP bedrock packer test results. Data presented in Appendix 2.3-B

Figure 2.3.1-26. (Sheet 1 of 2) CRBRP Bedrock Packer Hydraulic Conductivity Tests

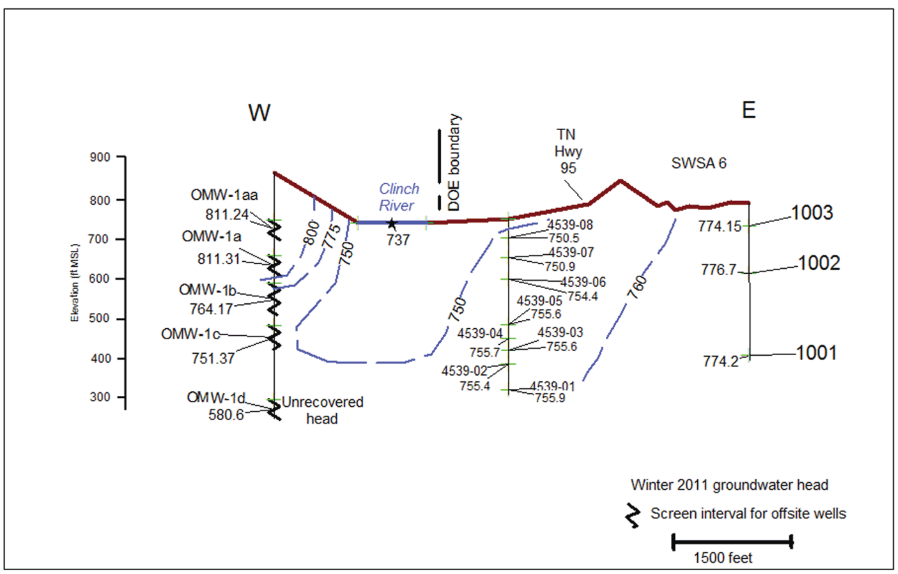


b) Hydraulic conductivity versus depth plot of CRBRP bedrock packer test results. Data presented in Appendix 2.3-B

Figure 2.3.1-26. (Sheet 2 of 2) CRBRP Bedrock Packer Hydraulic Conductivity Tests



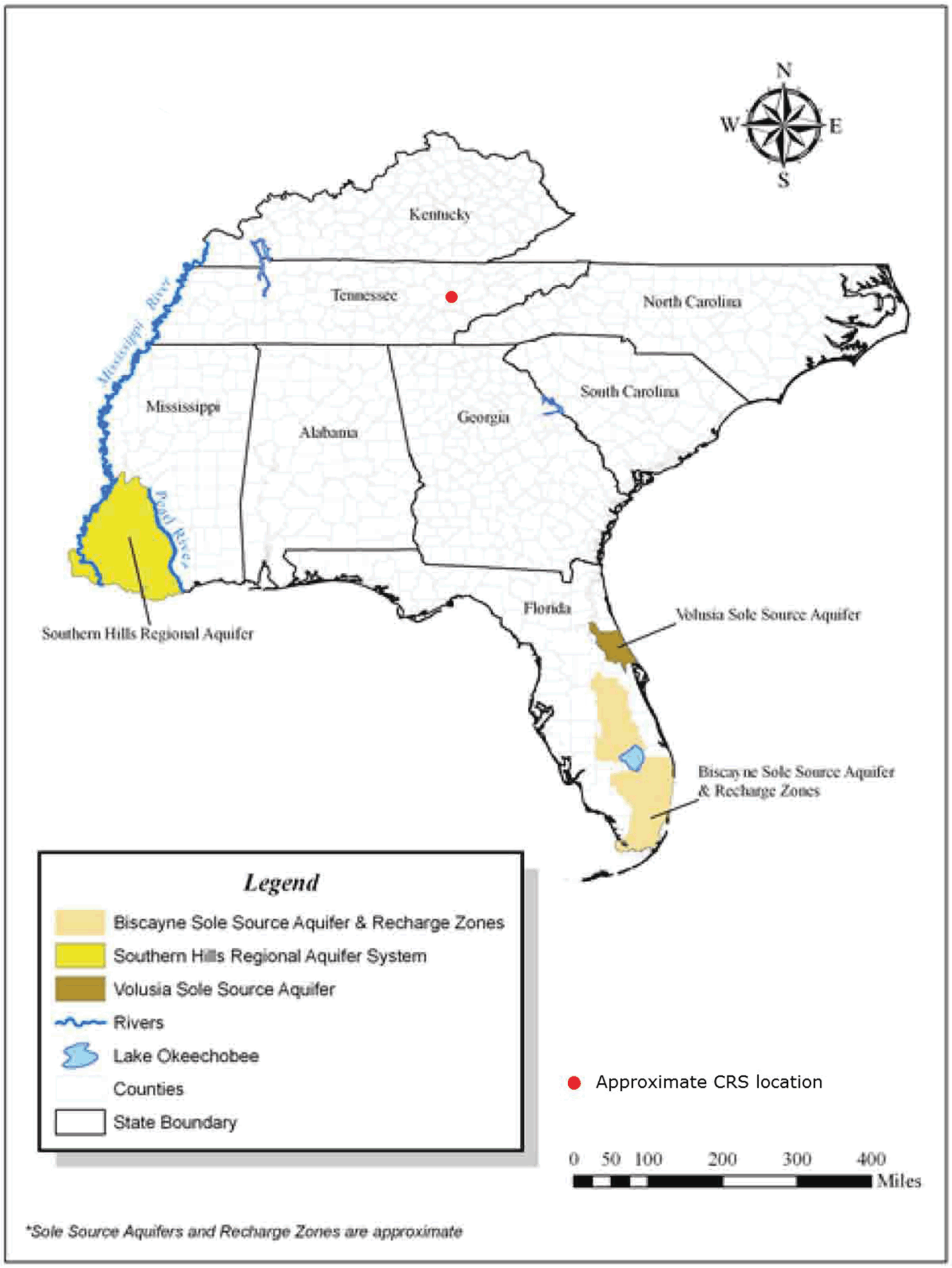
Hydrologic Cross Section Alignments



Hydrologic Cross Section A

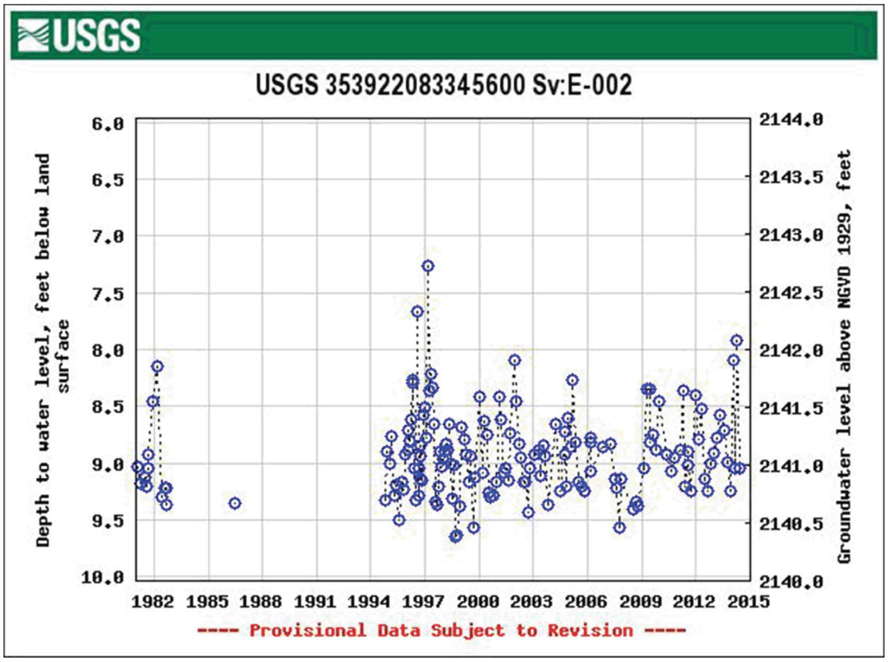
Source: (Reference 2.3.1-31)

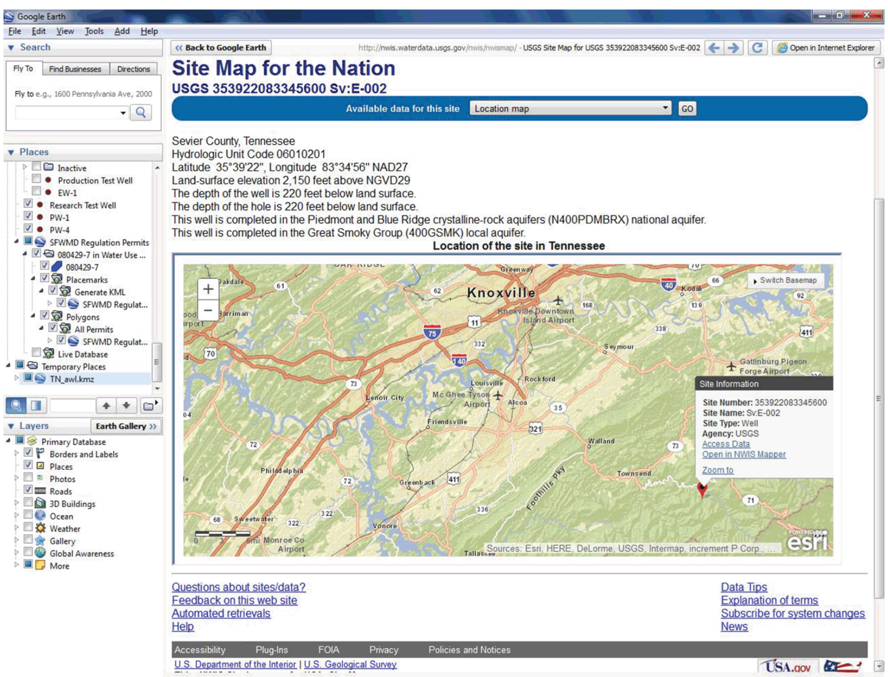
Figure 2.3.1-27. Groundwater Levels Adjacent to the Clinch River



Source: (Reference 2.3.1-32)

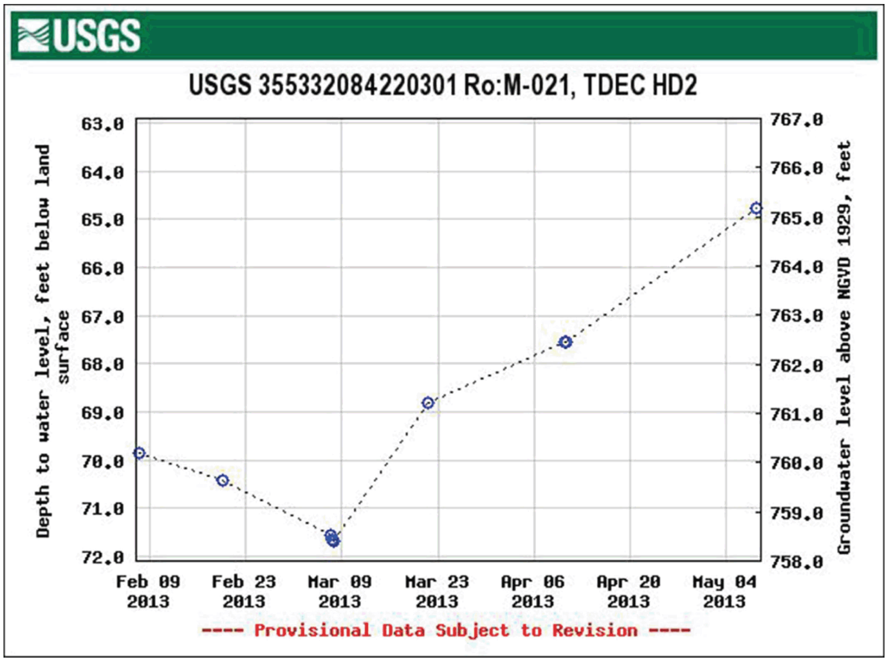
Figure 2.3.1-28. Sole Source Aquifers in EPA Region IV

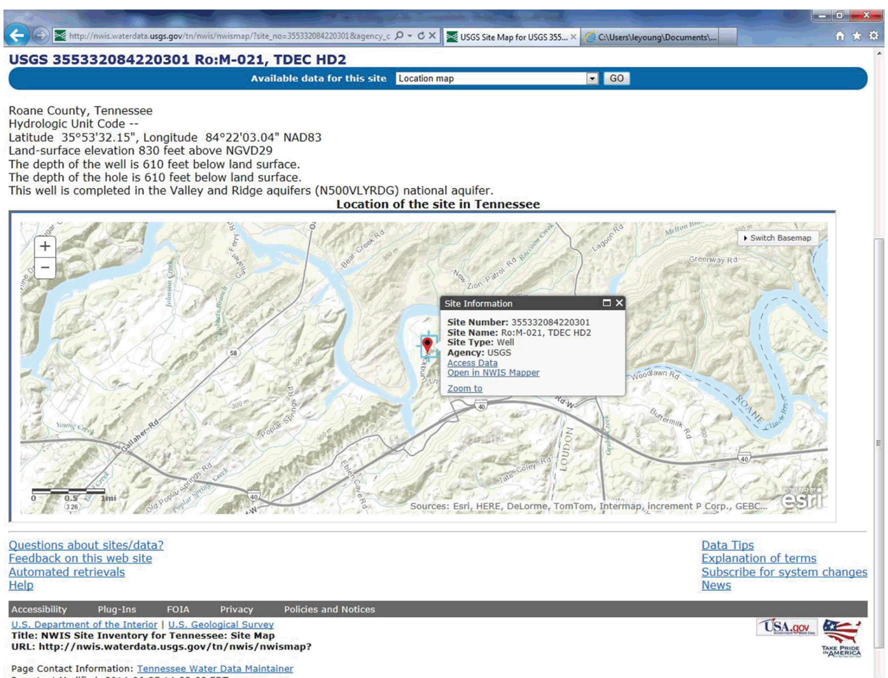




Source: (Reference 2.3.1-23)

Figure 2.3.1-29. U.S. Geological Survey Regional Hydrograph





Source: (Reference 2.3.1-34)

Figure 2.3.1-30. U.S. Geological Survey Hydrograph Near the CRN Site

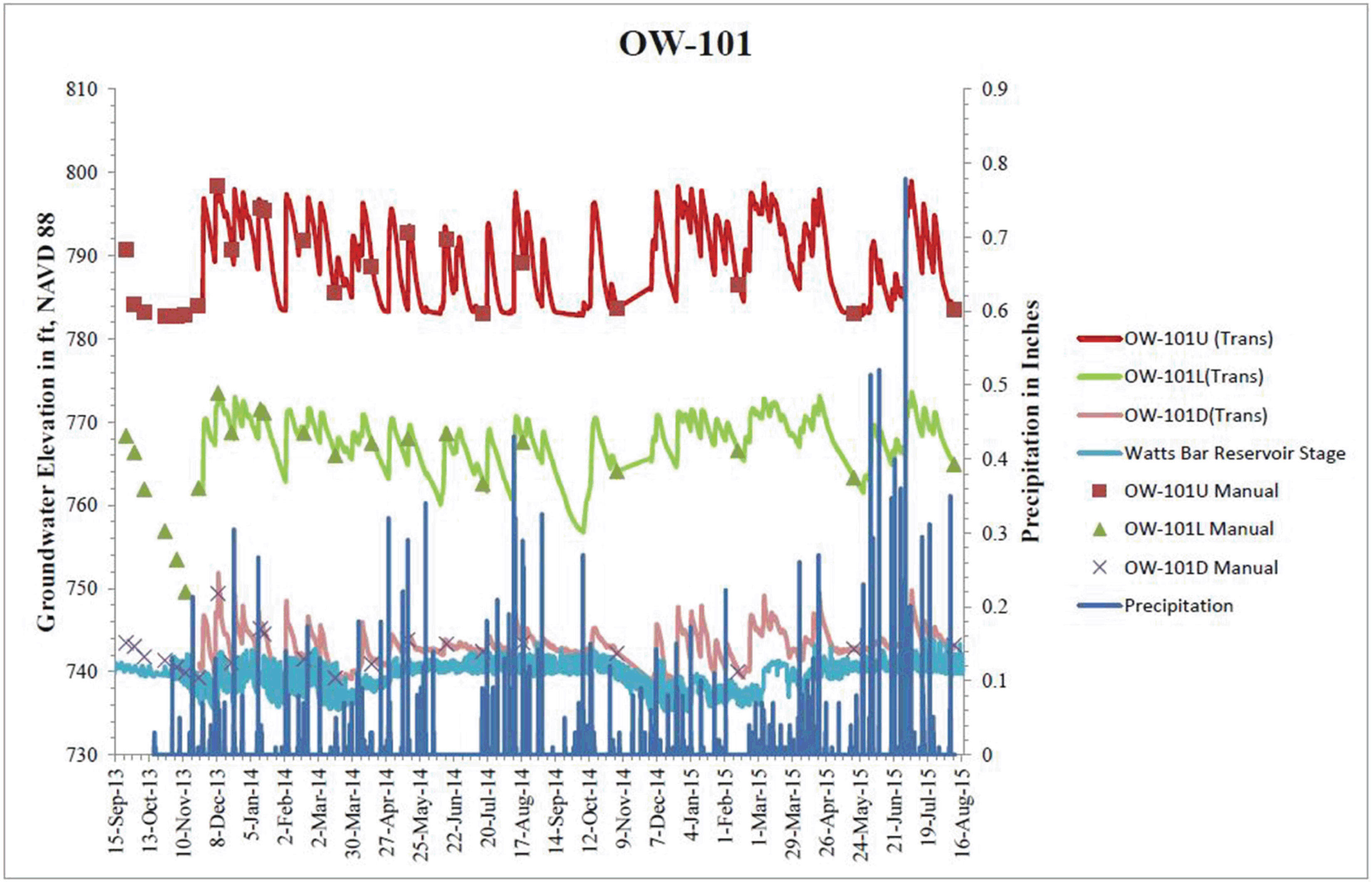


Figure 2.3.1-31. (Sheet 1 of 14) Hydrograph of OW-101 Well Cluster

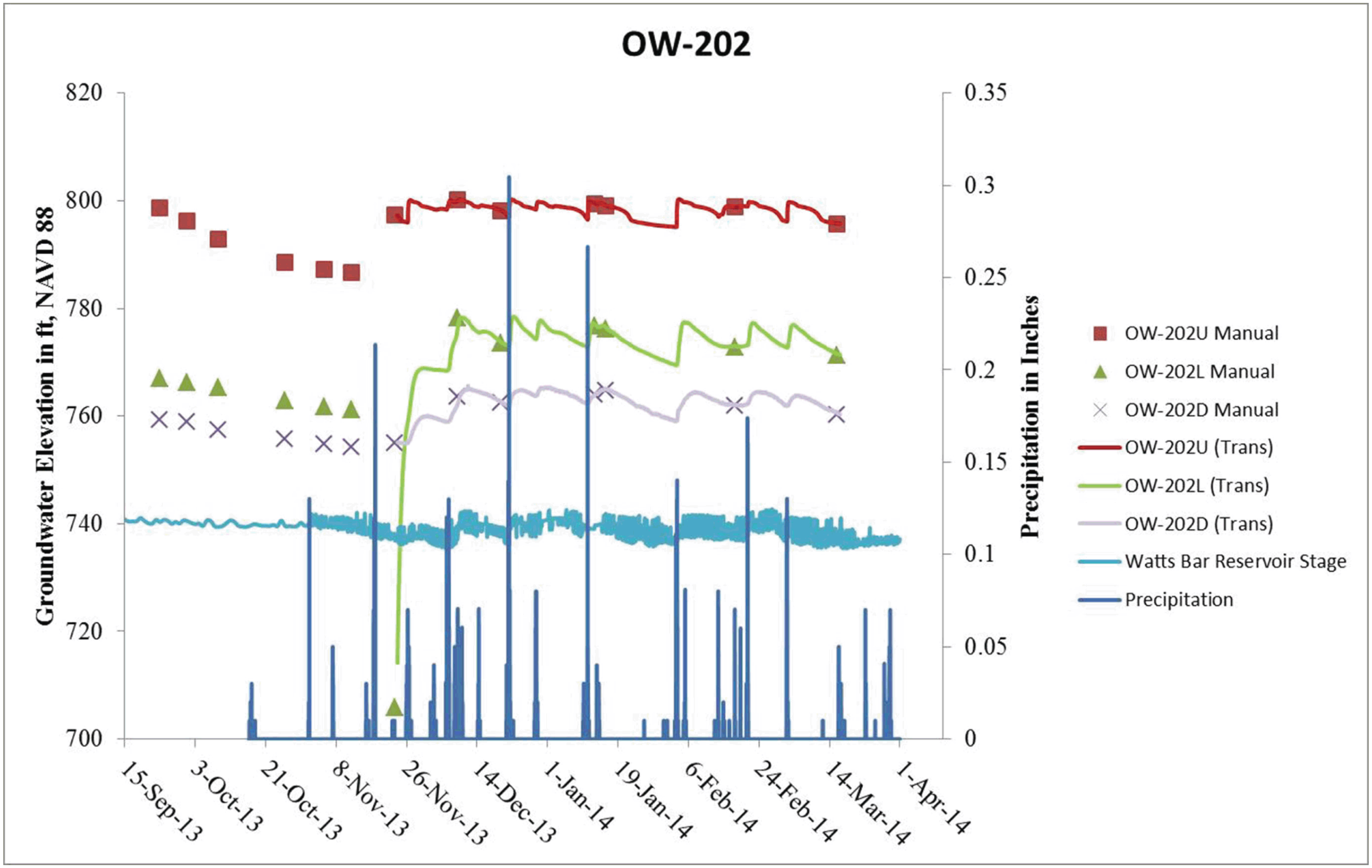


Figure 2.3.1-31. (Sheet 2 of 14) Hydrograph of OW-202 Well Cluster

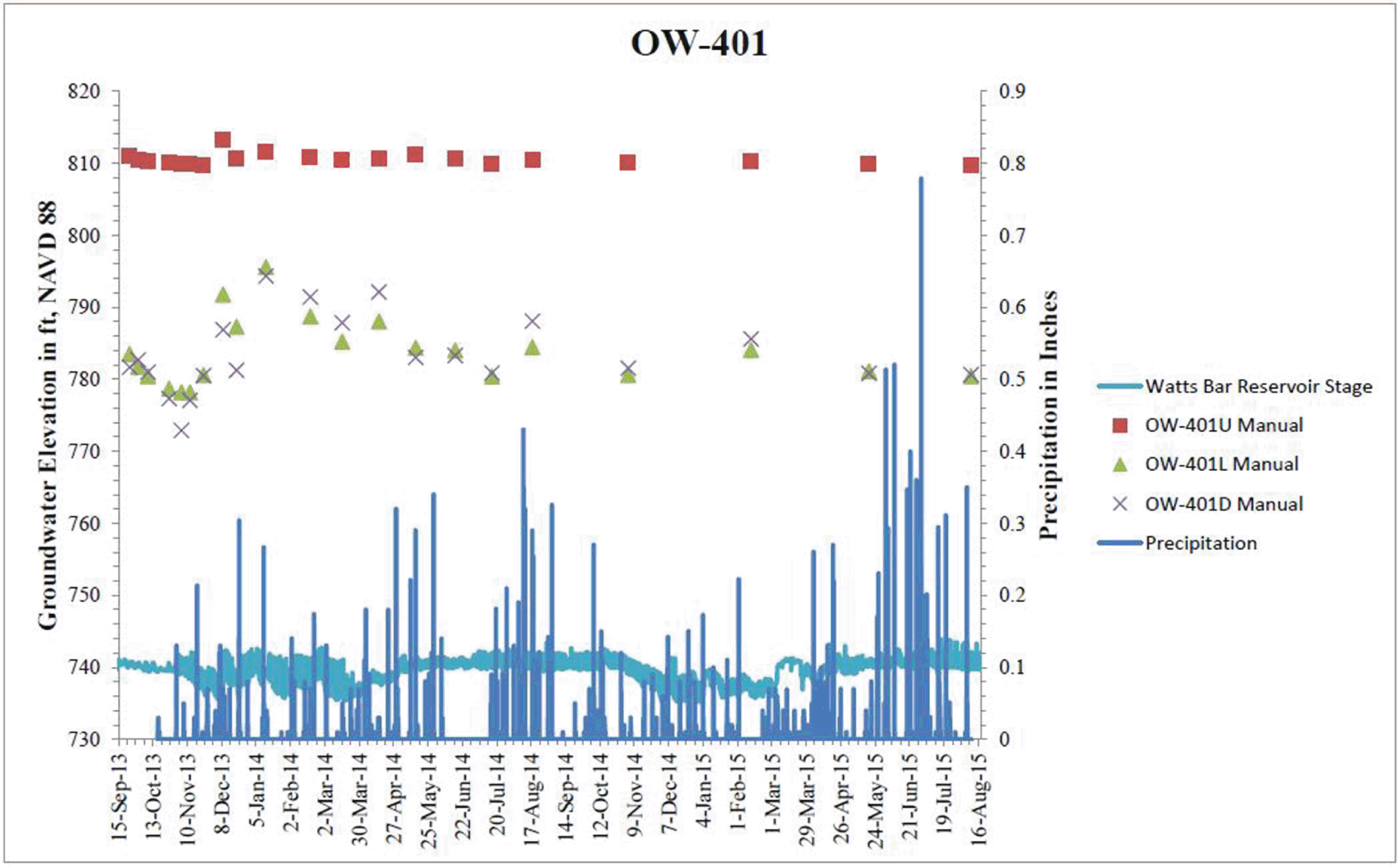


Figure 2.3.1-31. (Sheet 3 of 14) Hydrograph of OW-401 Well Cluster

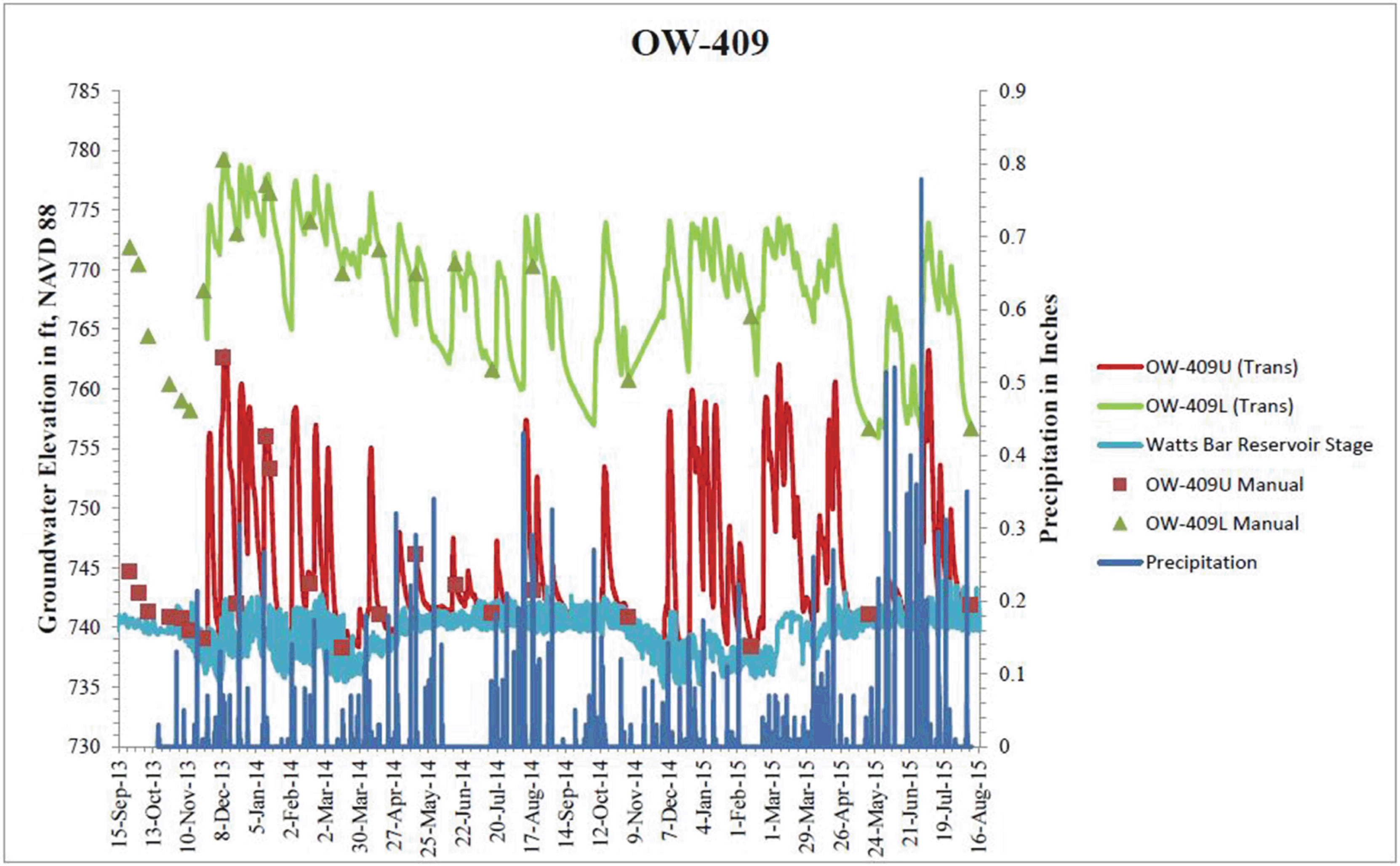


Figure 2.3.1-31. (Sheet 4 of 14) Hydrograph of OW-409 Well Cluster

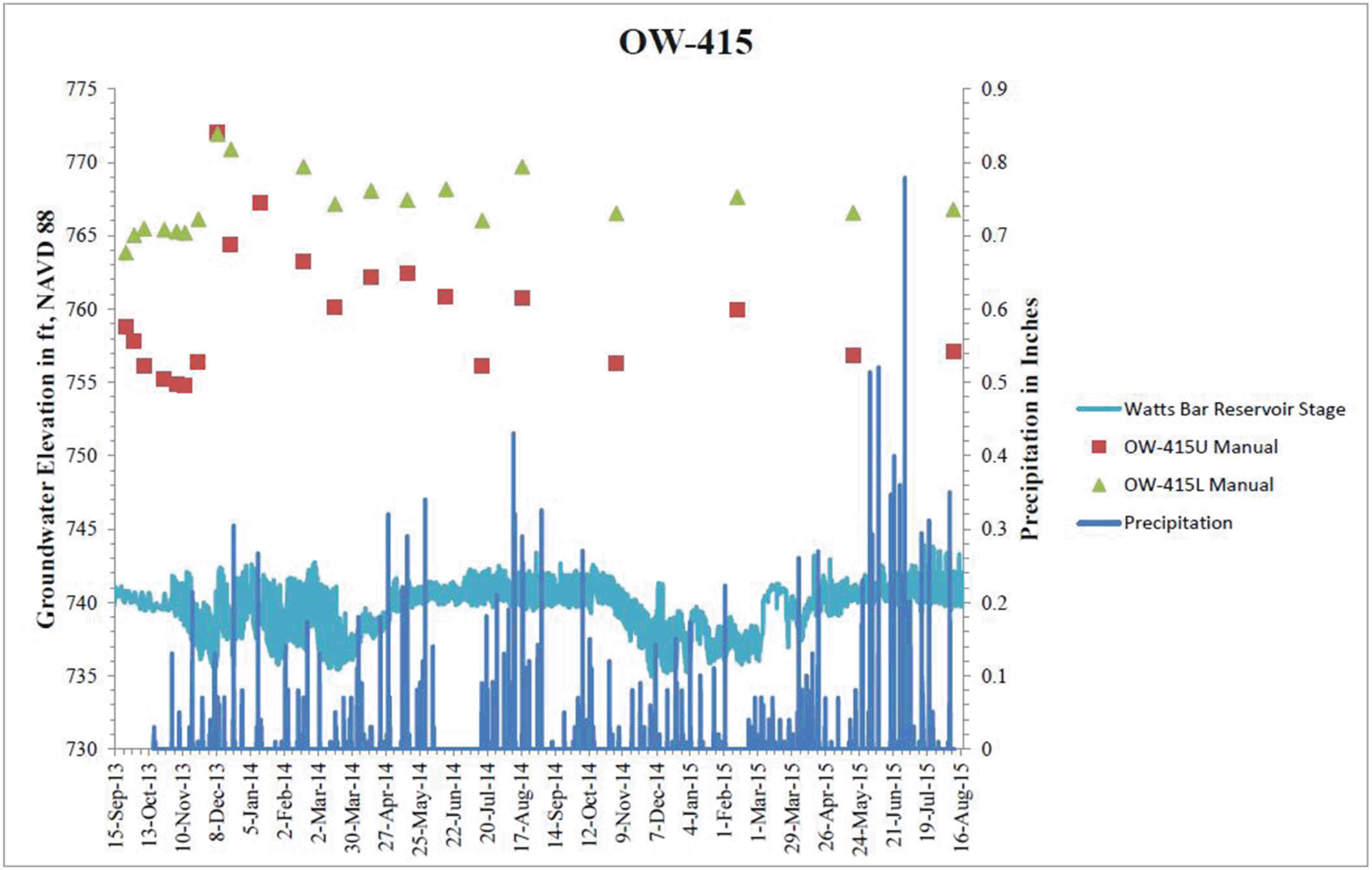


Figure 2.3.1-31. (Sheet 5 of 14) Hydrograph of OW-415 Well Cluster

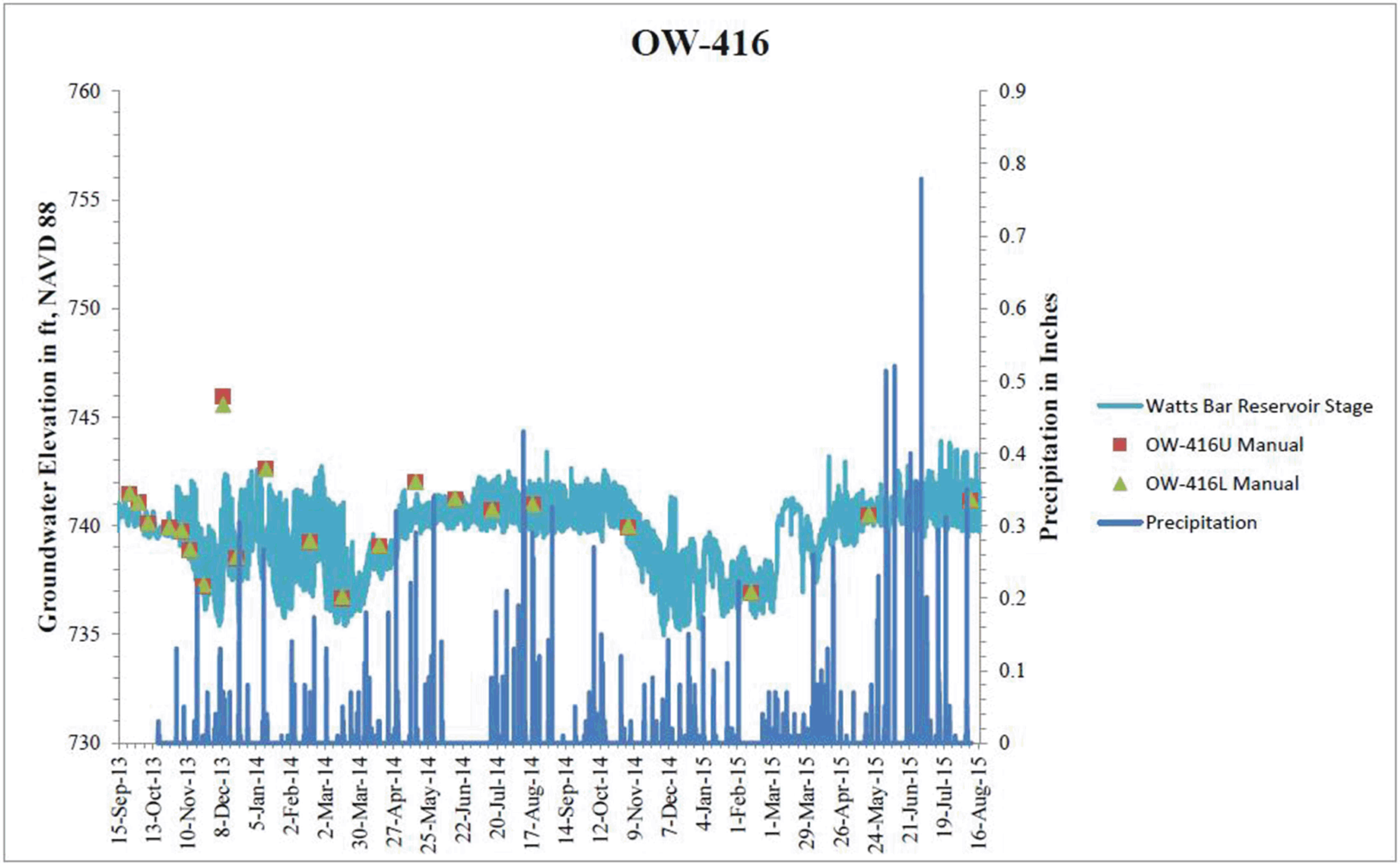


Figure 2.3.1-31. (Sheet 6 of 14) Hydrograph of OW-416 Well Cluster

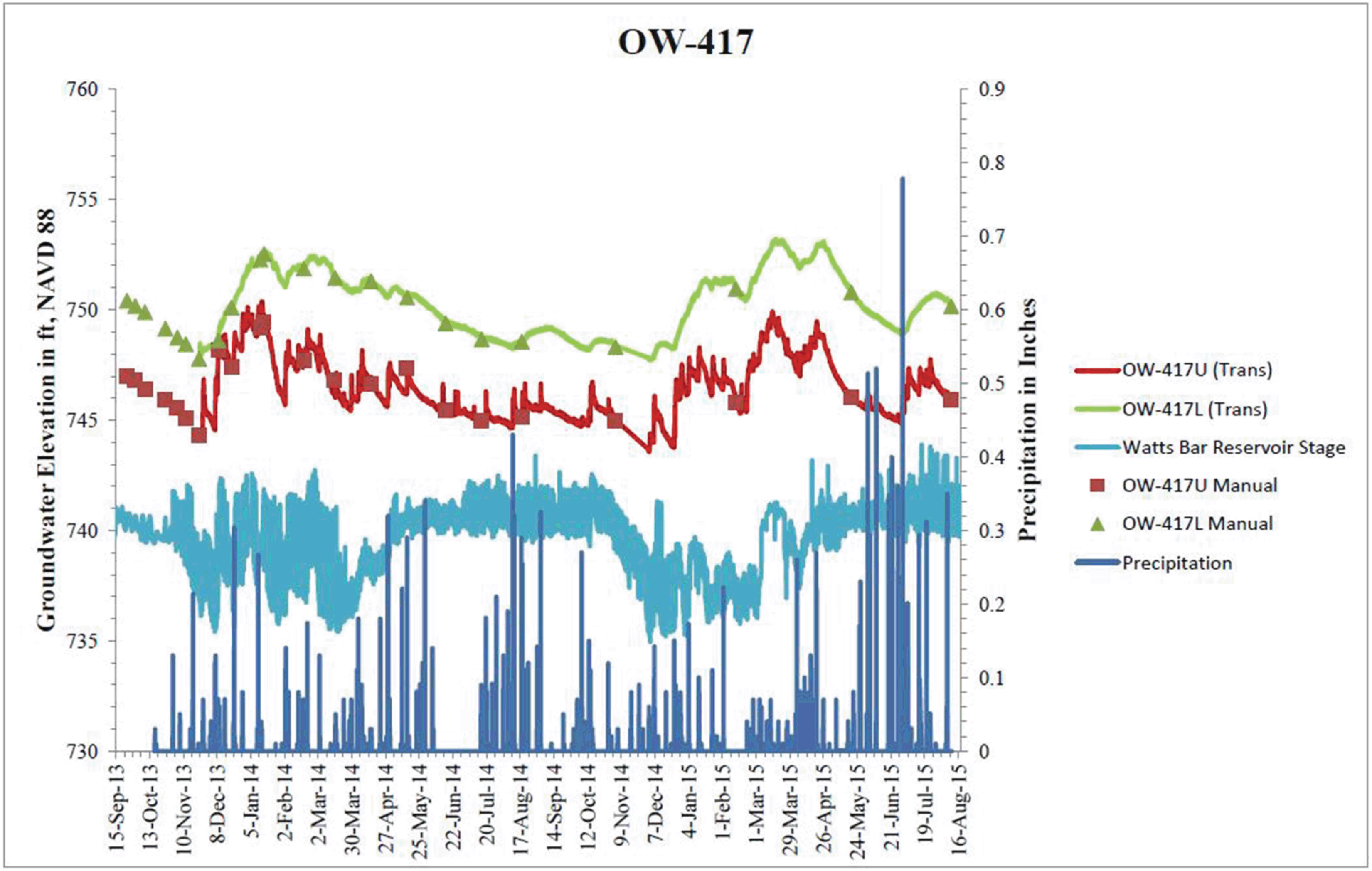


Figure 2.3.1-31. (Sheet 7 of 14) Hydrograph of OW-417 Well Cluster

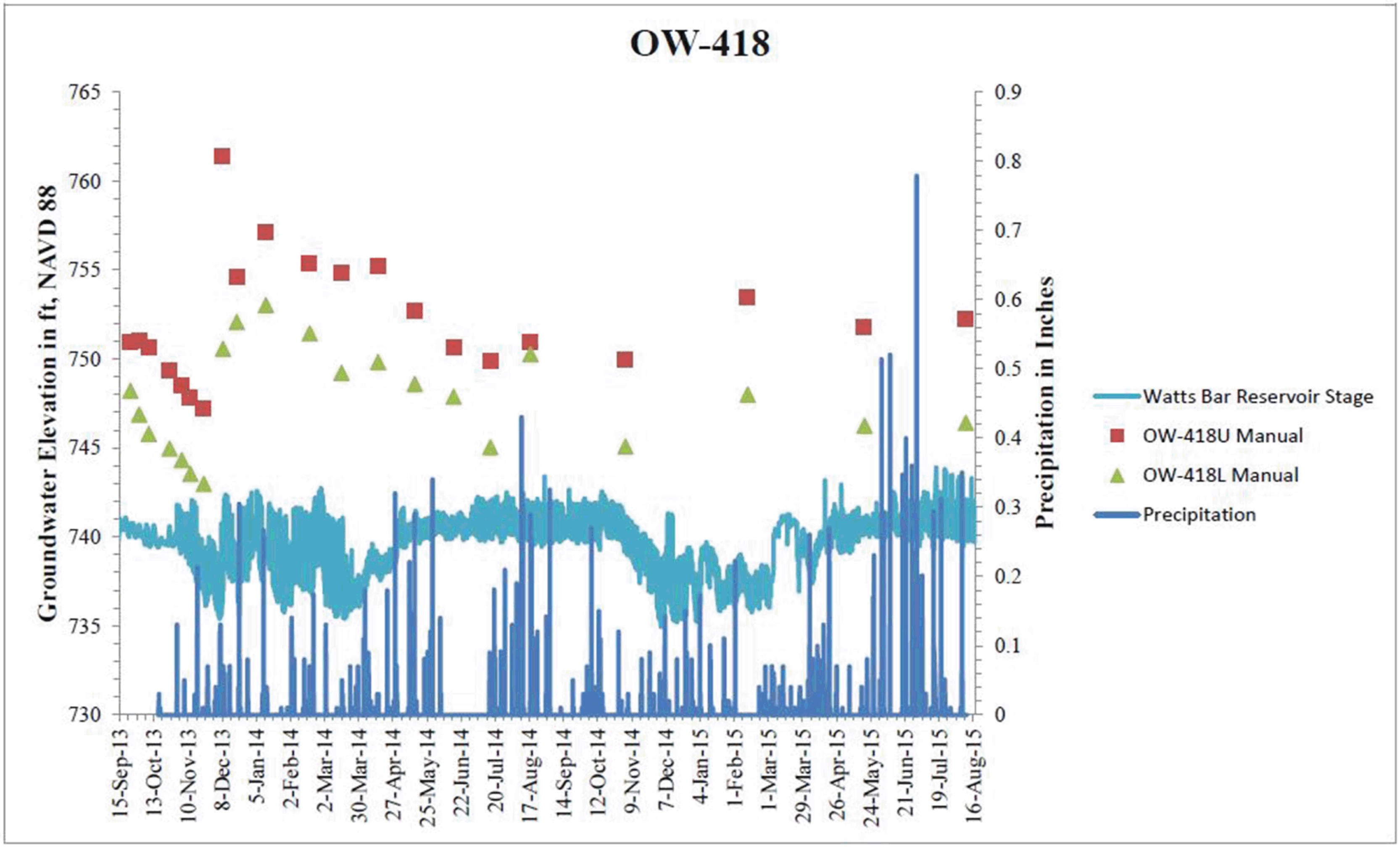


Figure 2.3.1-31. (Sheet 8 of 14) Hydrograph of OW-418 Well Cluster

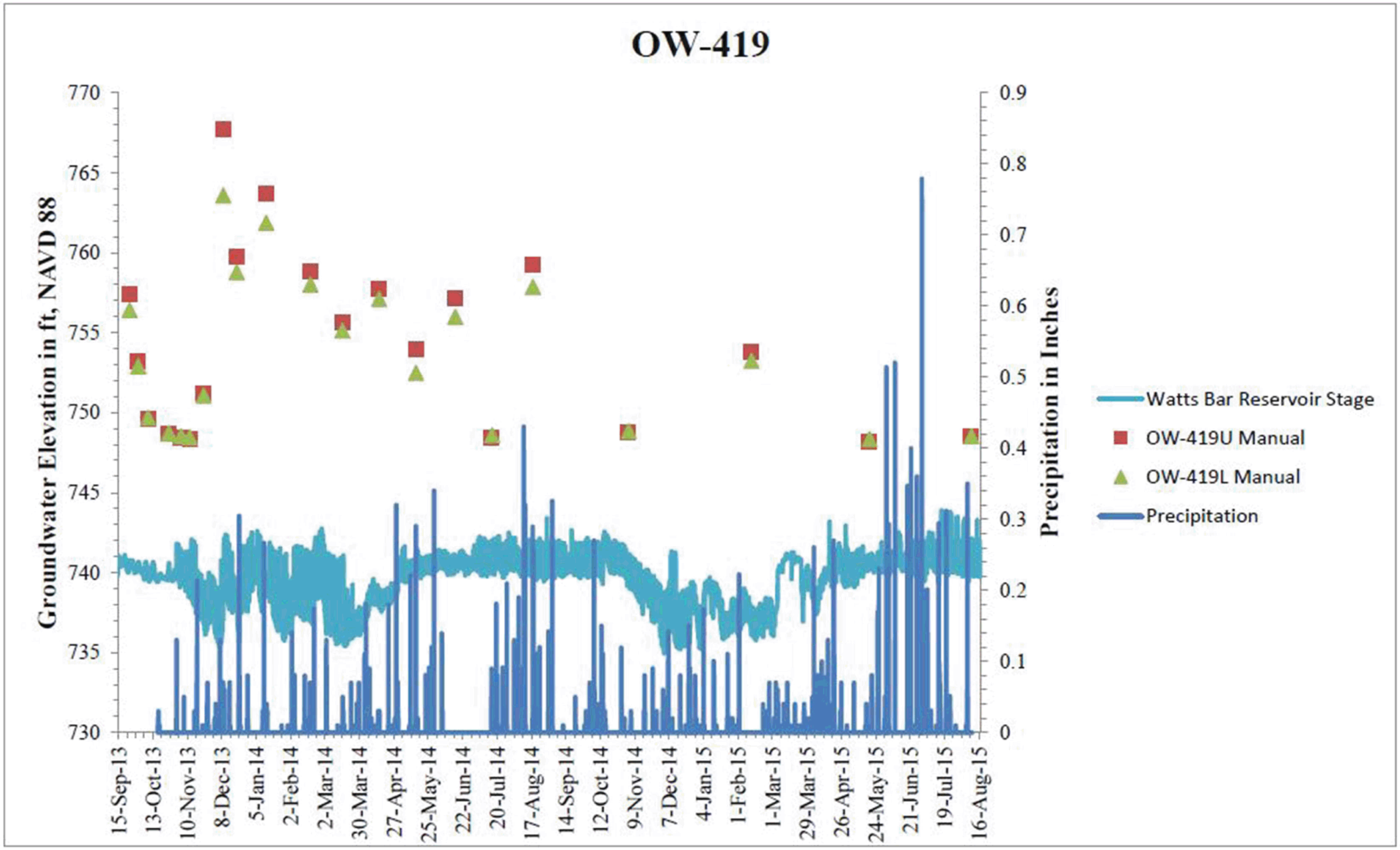


Figure 2.3.1-31. (Sheet 9 of 14) Hydrograph of OW-419 Well Cluster

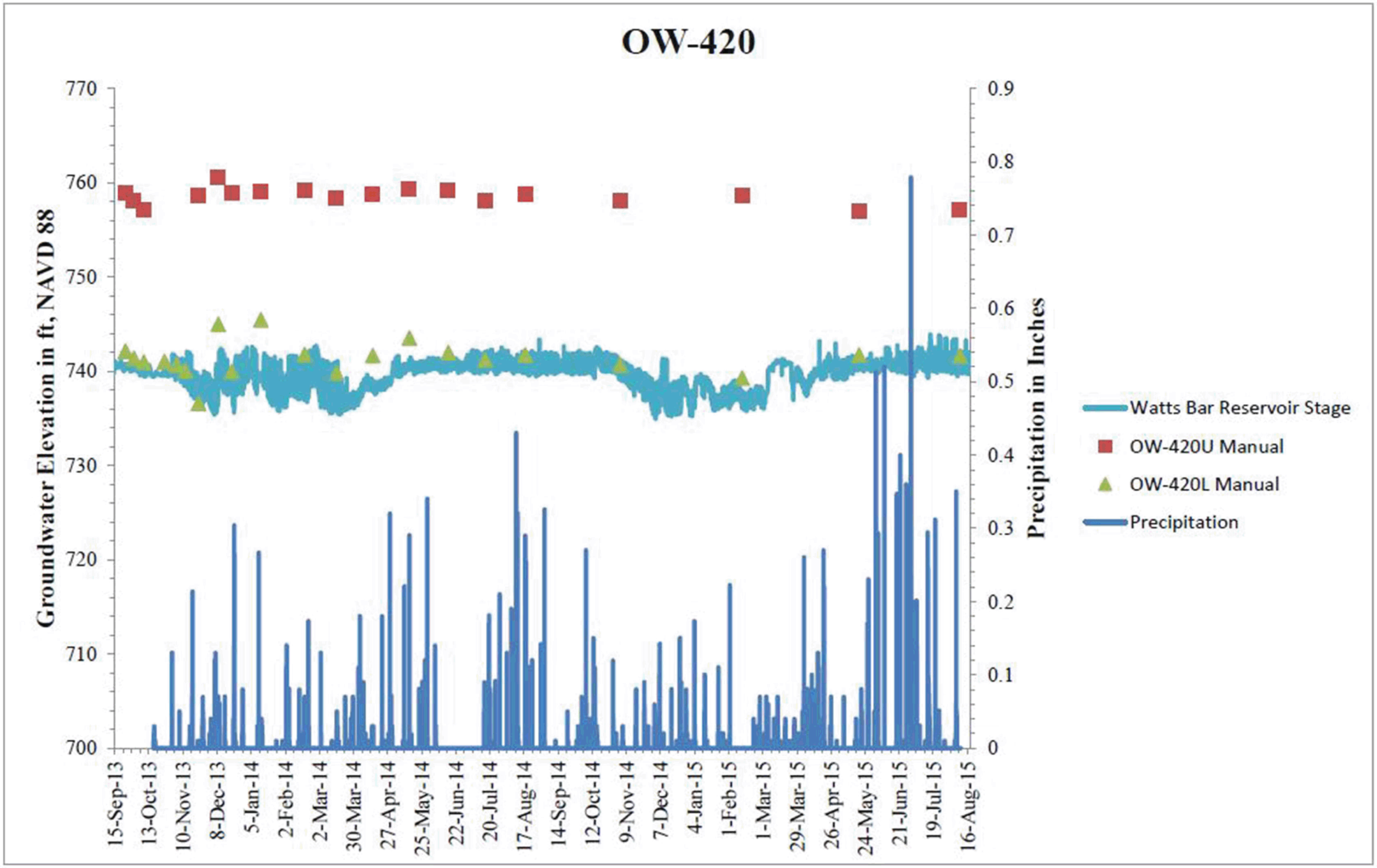


Figure 2.3.1-31. (Sheet 10 of 14) Hydrograph of OW-420 Well Cluster

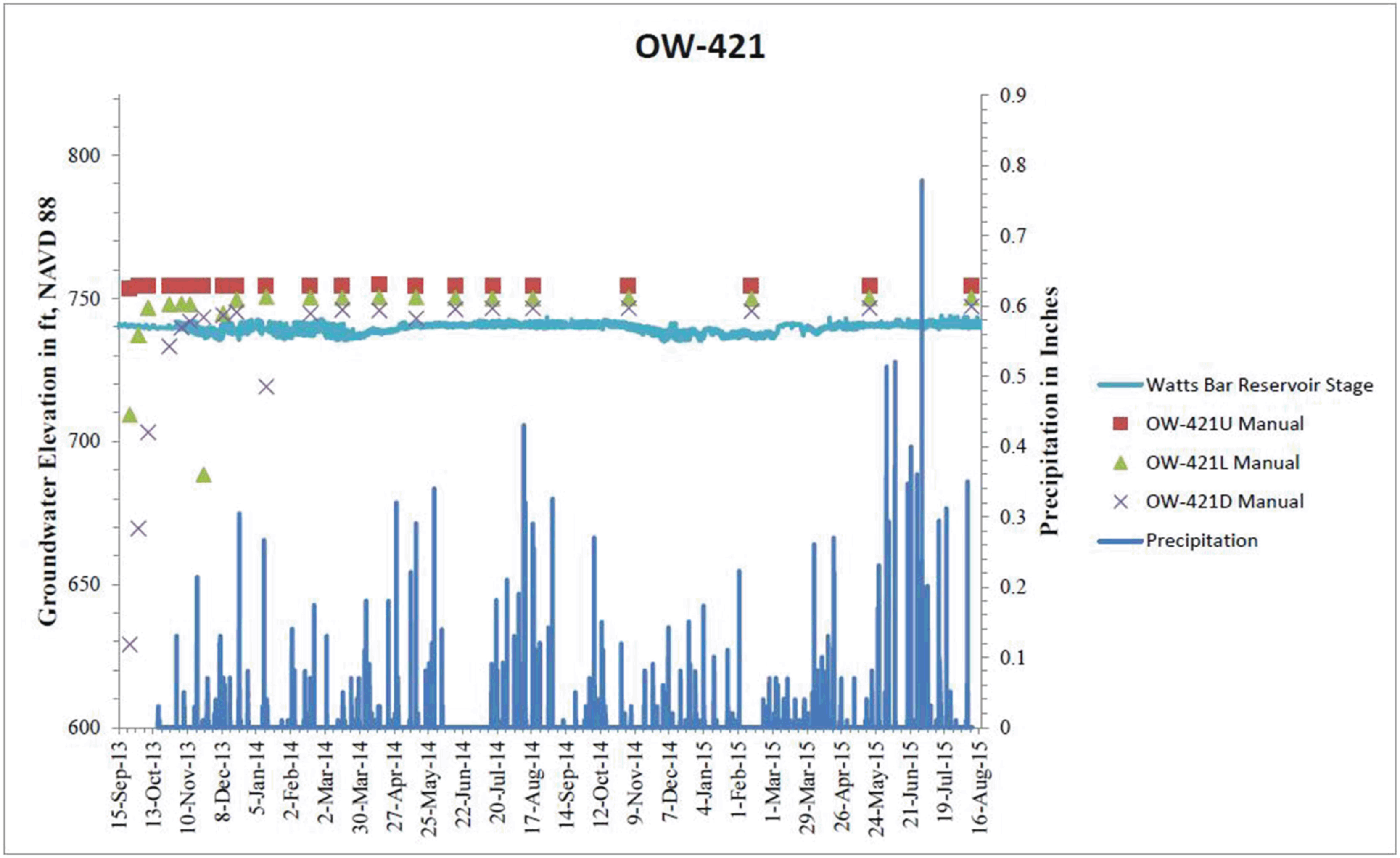


Figure 2.3.1-31. (Sheet 11 of 14) Hydrograph of OW-421 Well Cluster

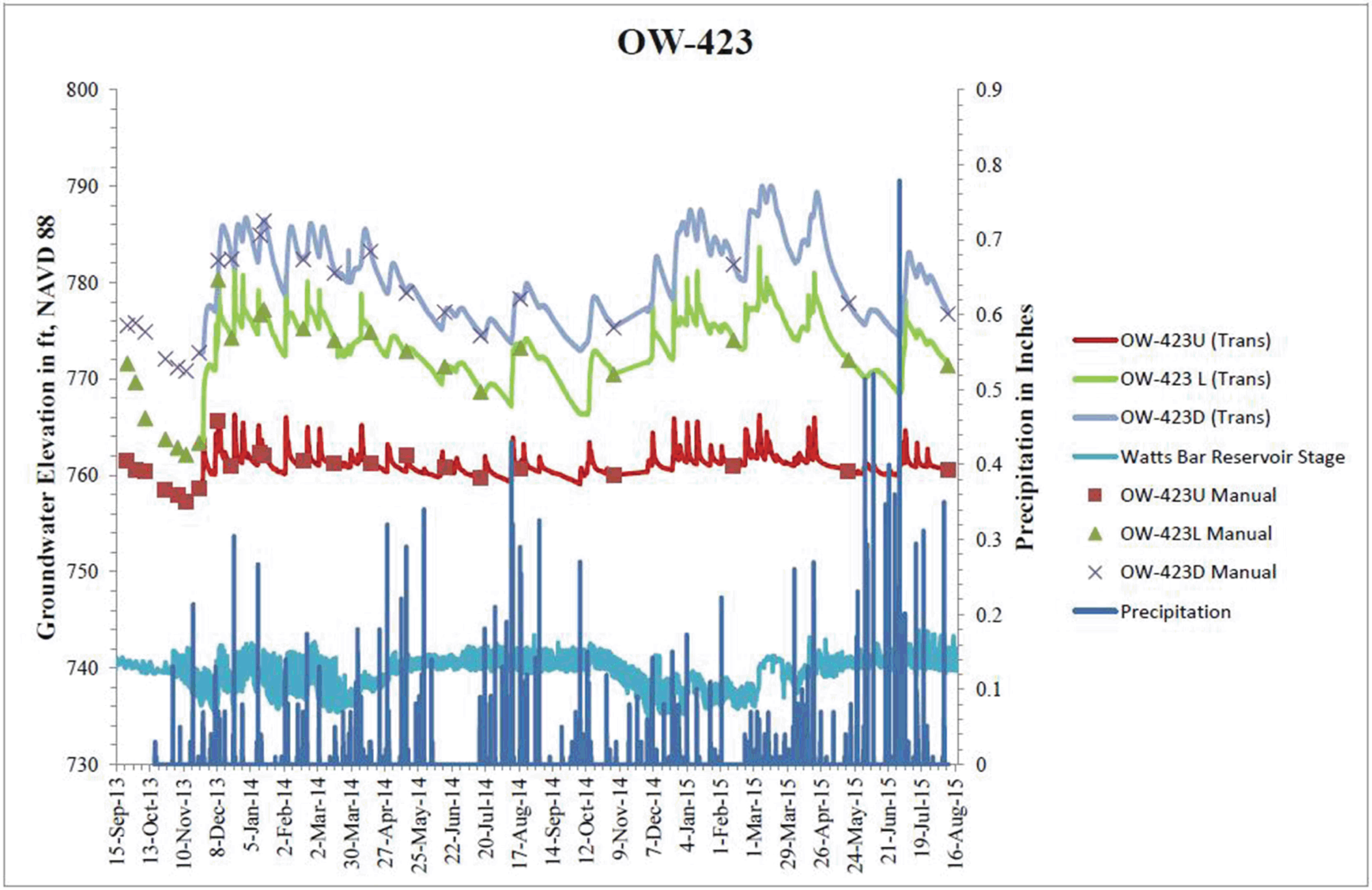


Figure 2.3.1-31. (Sheet 12 of 14) Hydrograph of OW-423 Well Cluster

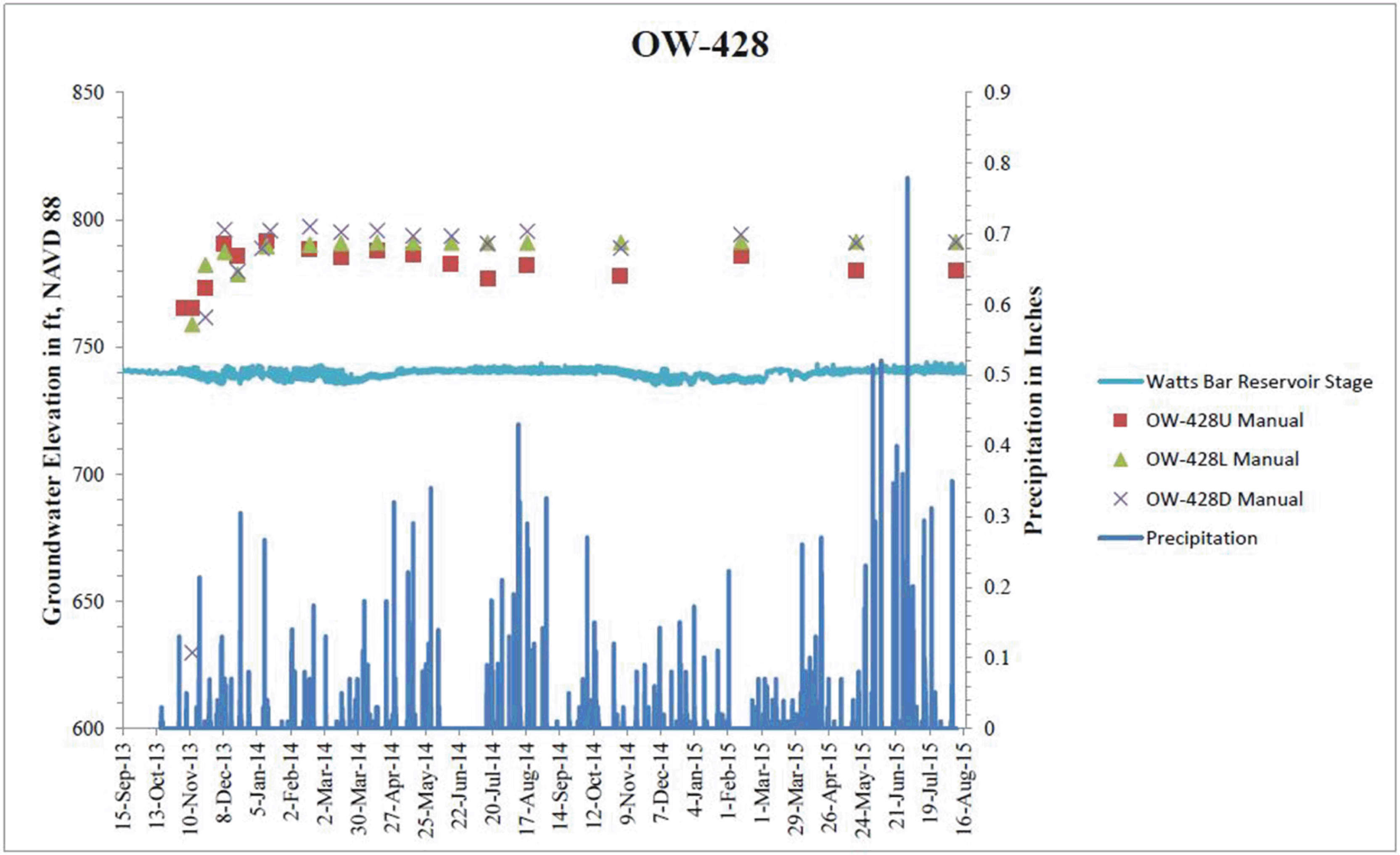


Figure 2.3.1-31. (Sheet 13 of 14) Hydrograph of OW-428 Well Cluster

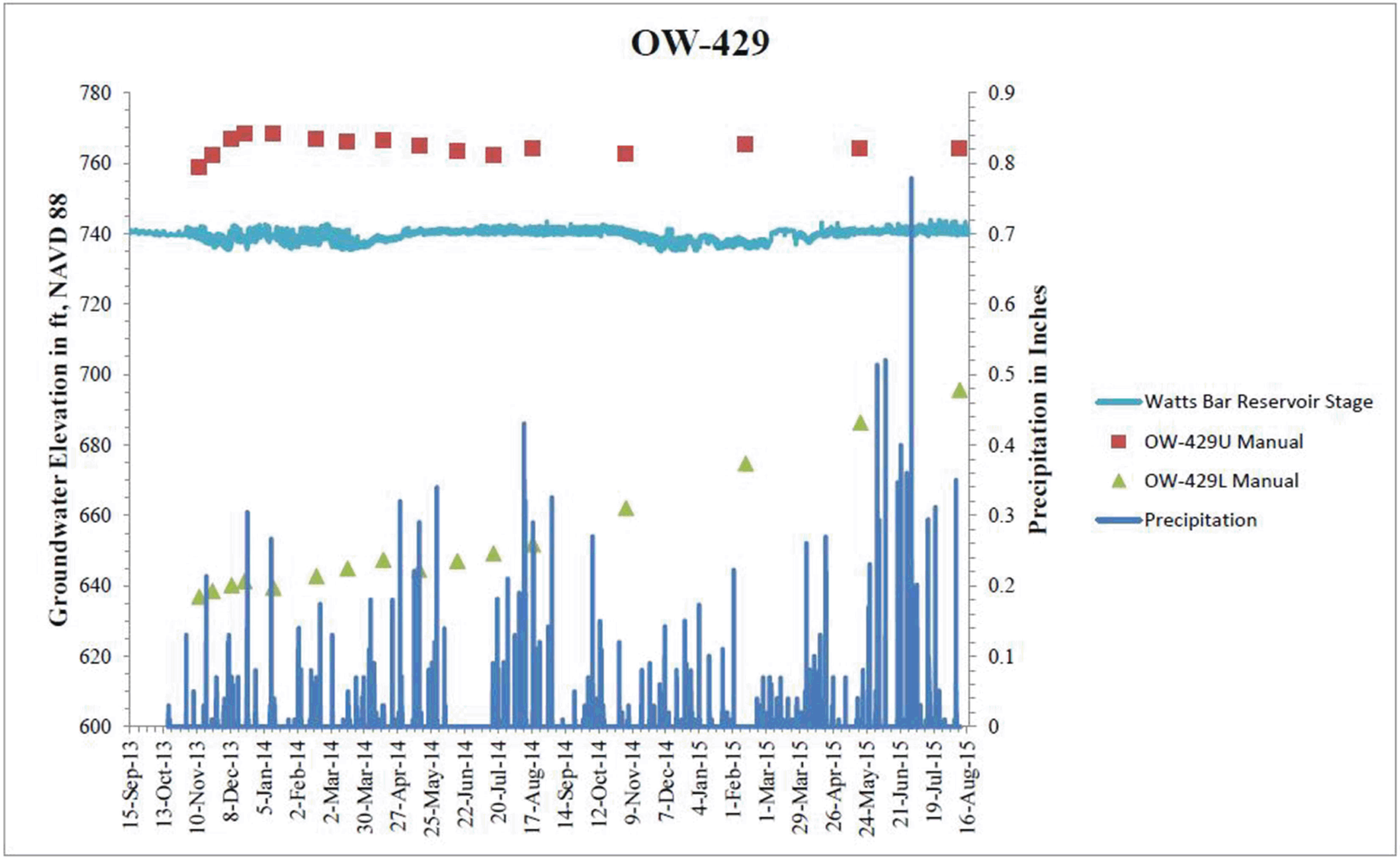
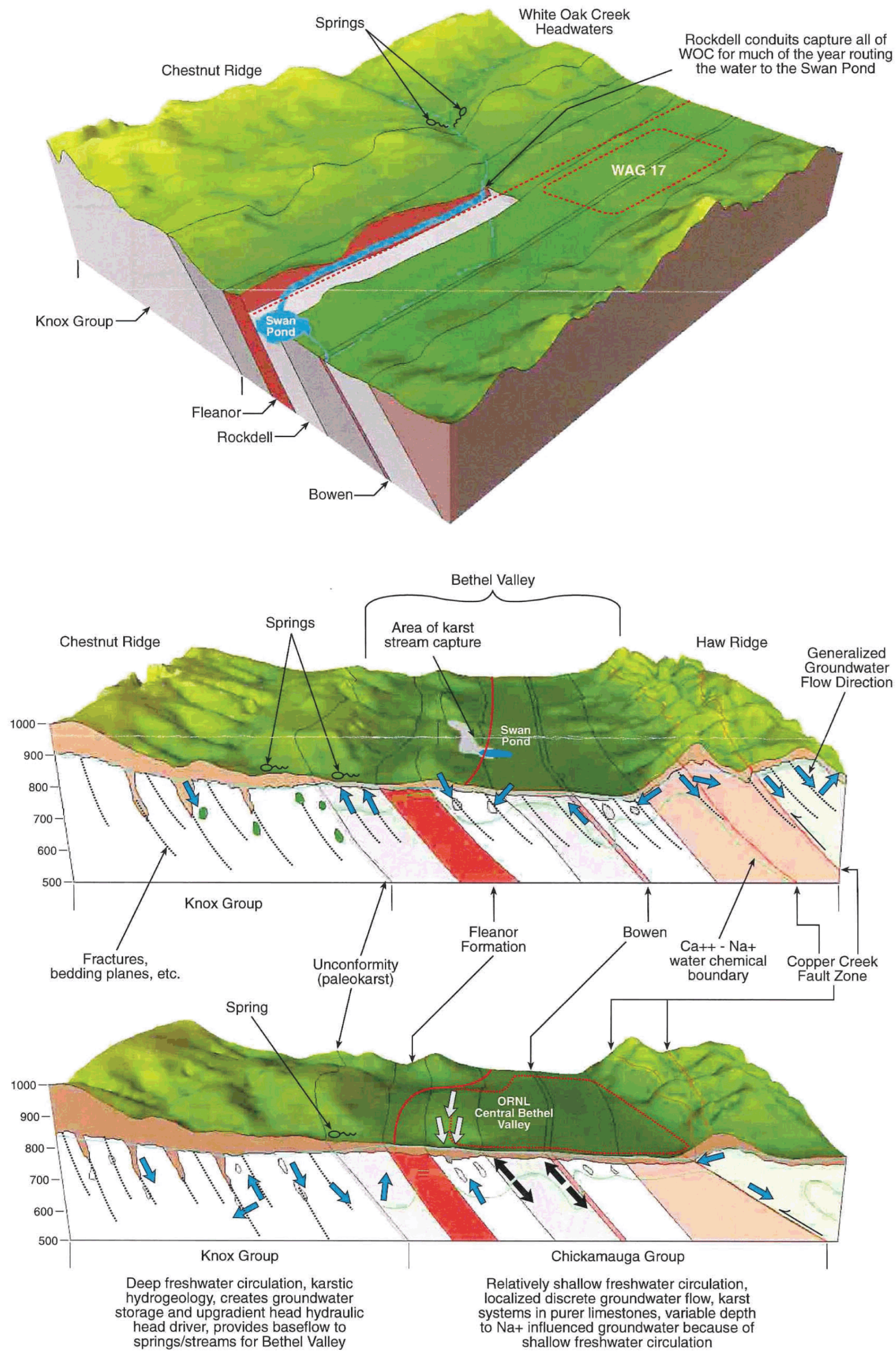


Figure 2.3.1-31. (Sheet 14 of 14) Hydrograph of OW-429 Well Cluster



Source: (Reference 2.3.1-35)

Figure 2.3.1-32. Bethel Valley Flow Conceptualization

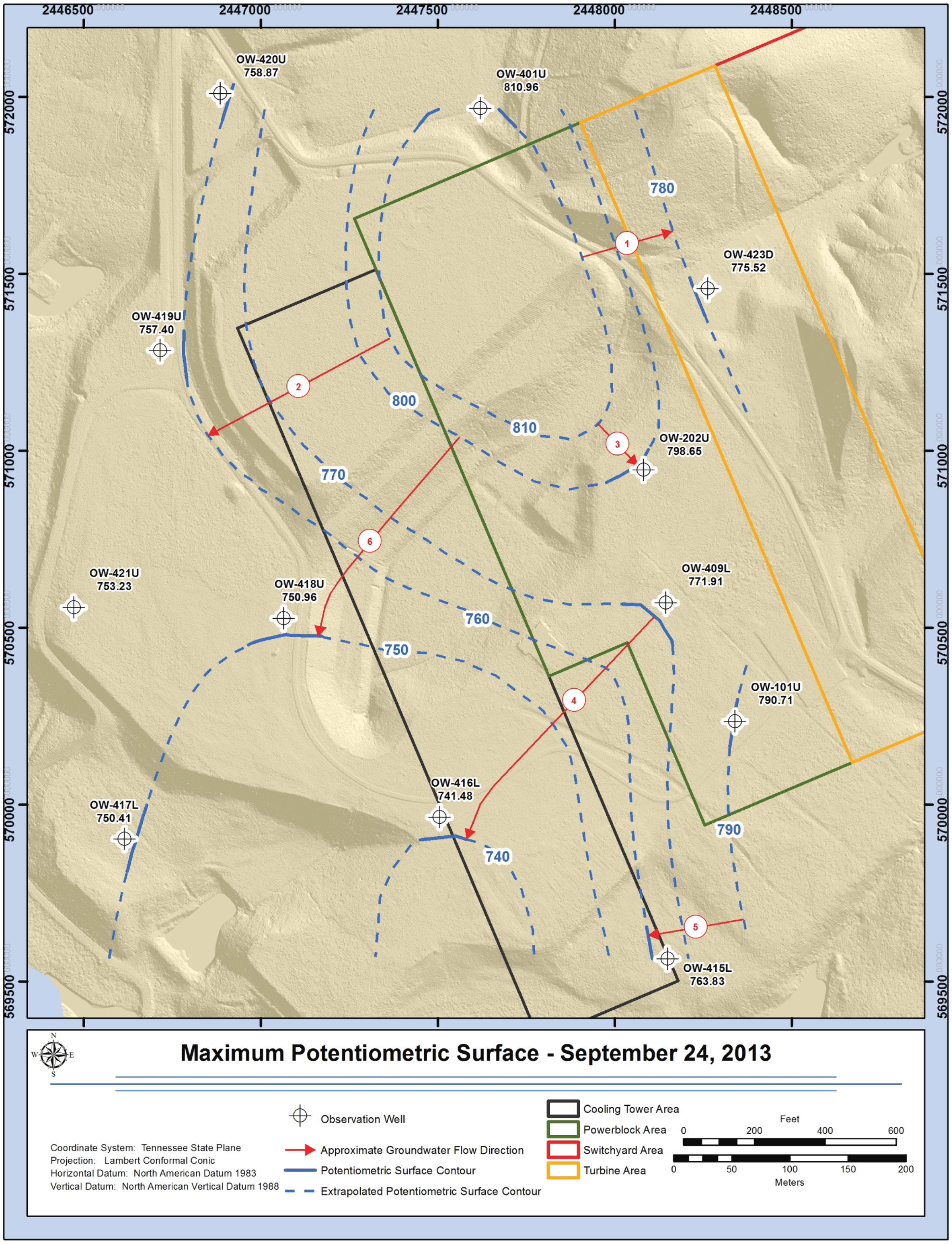


Figure 2.3.1-33. Potentiometric Surface Map for September 24, 2013

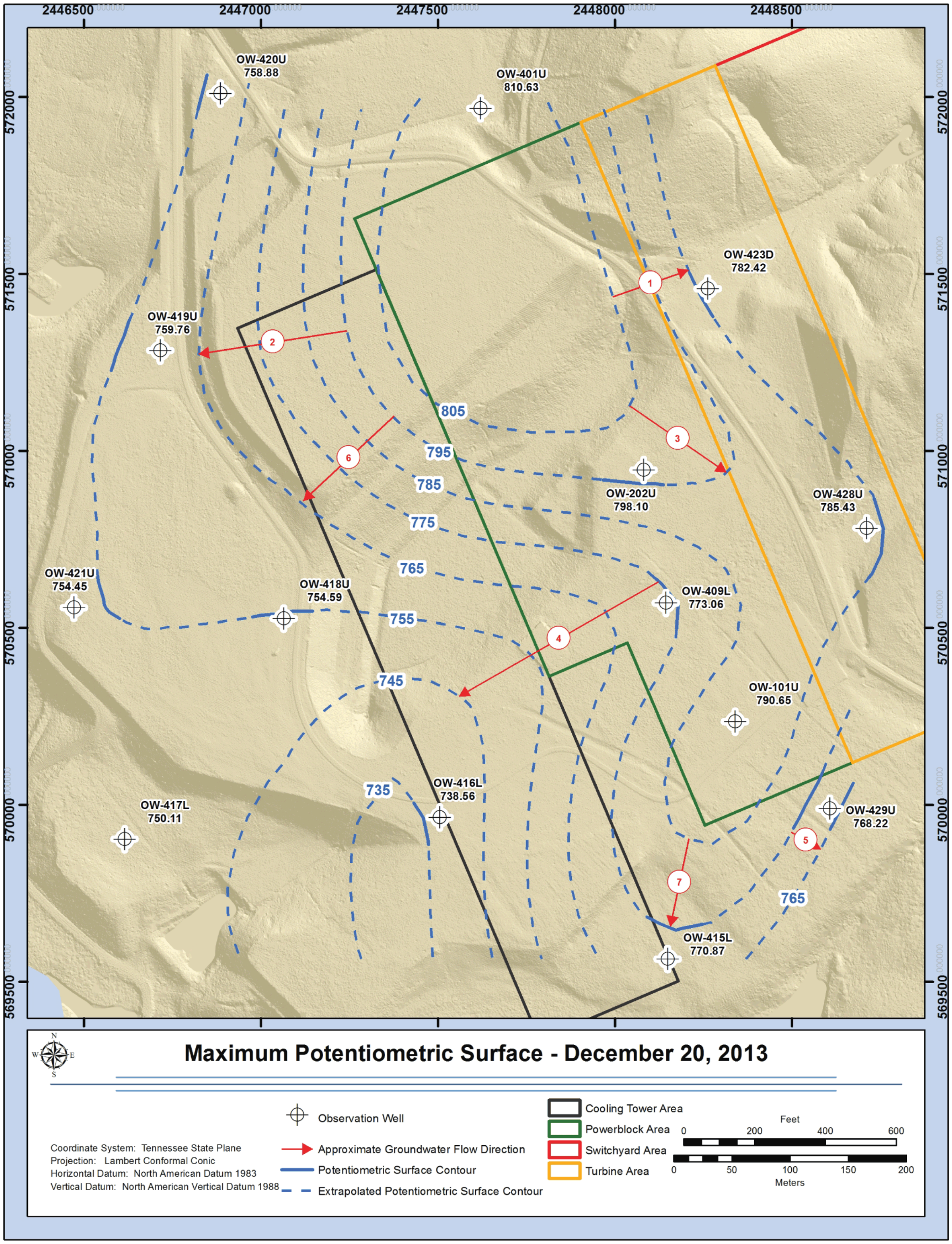


Figure 2.3.1-34. Potentiometric Surface Map for December 20, 2013

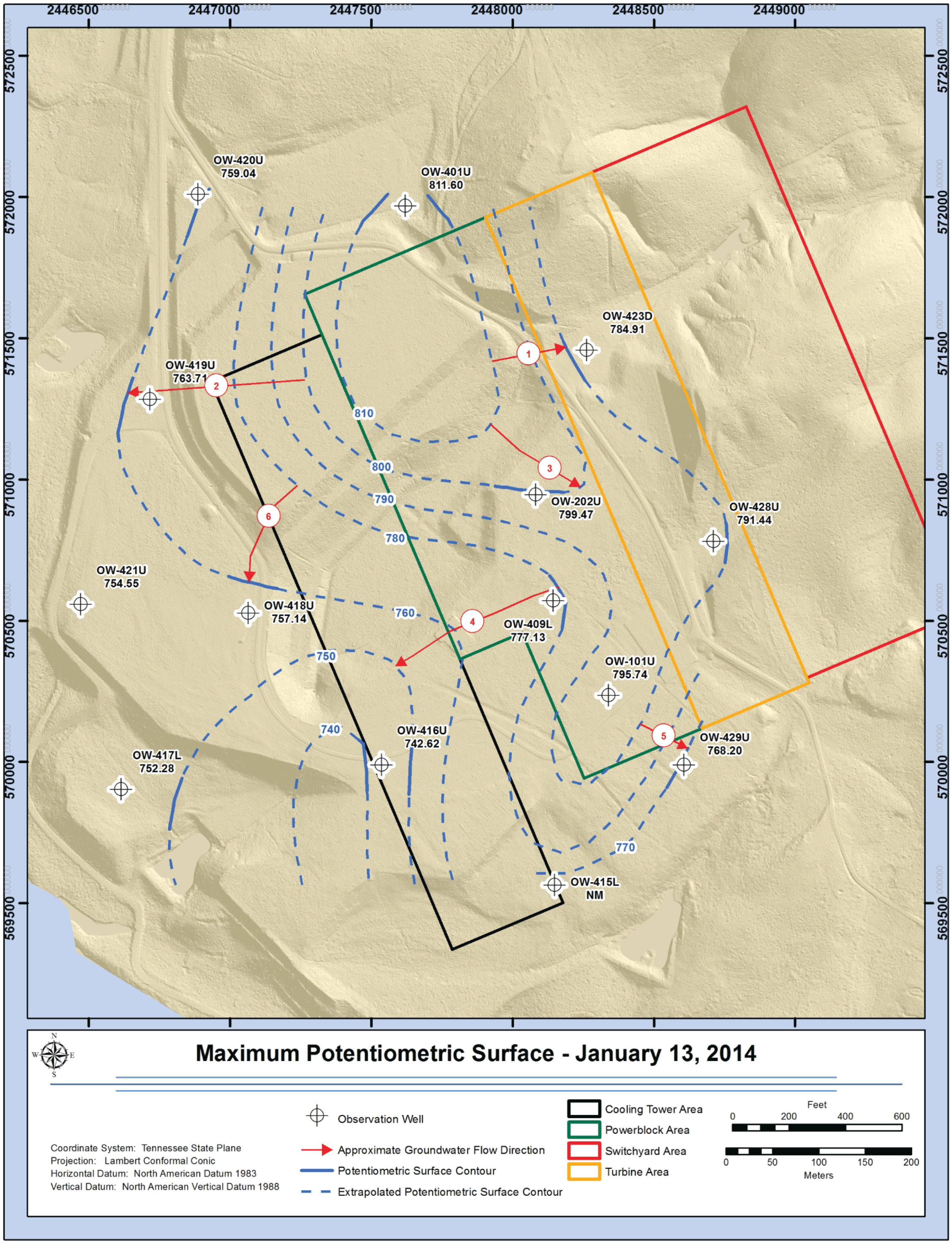


Figure 2.3.1-35. Potentiometric Surface Map for January 13, 2014

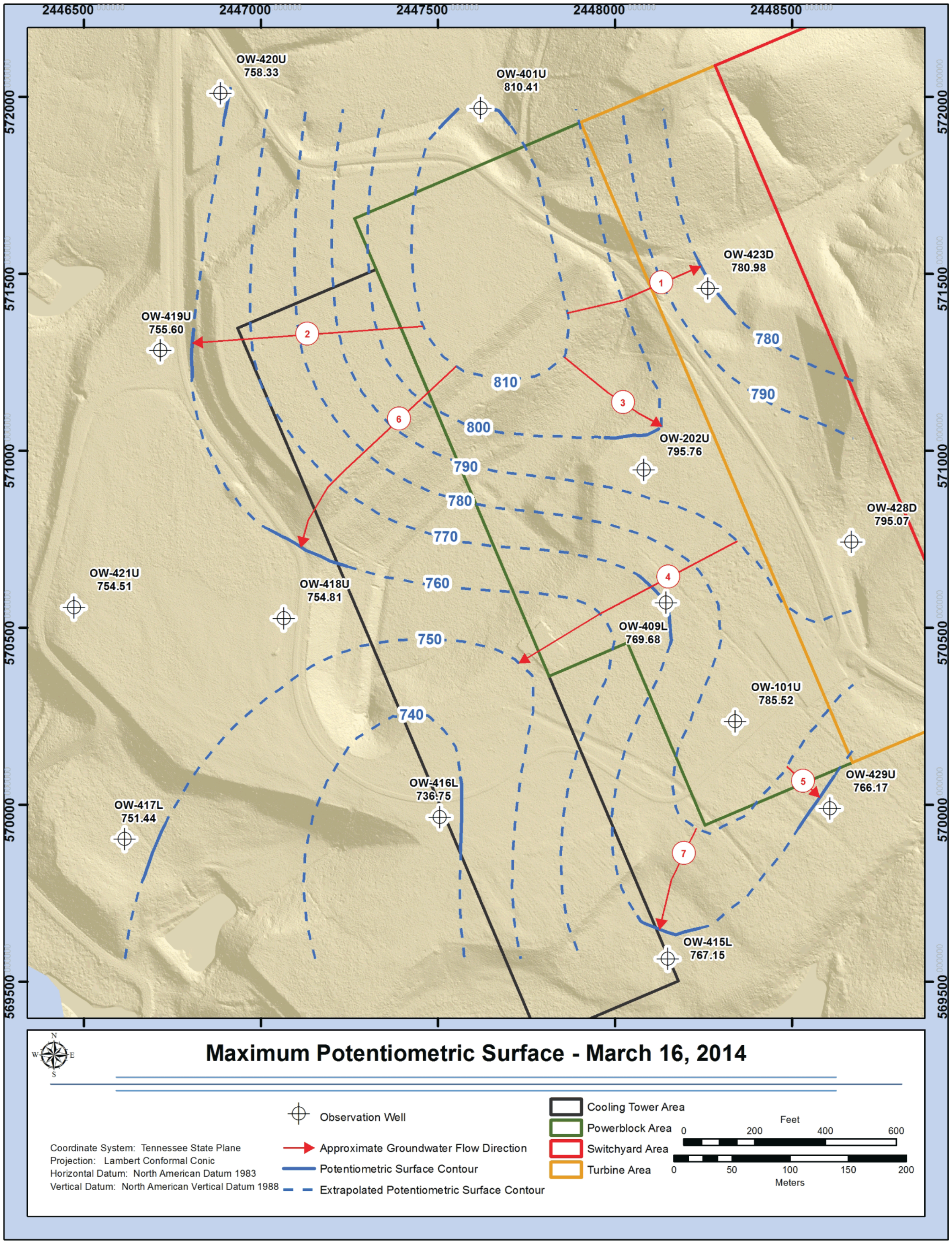


Figure 2.3.1-36. Potentiometric Surface Map for March 16, 2014

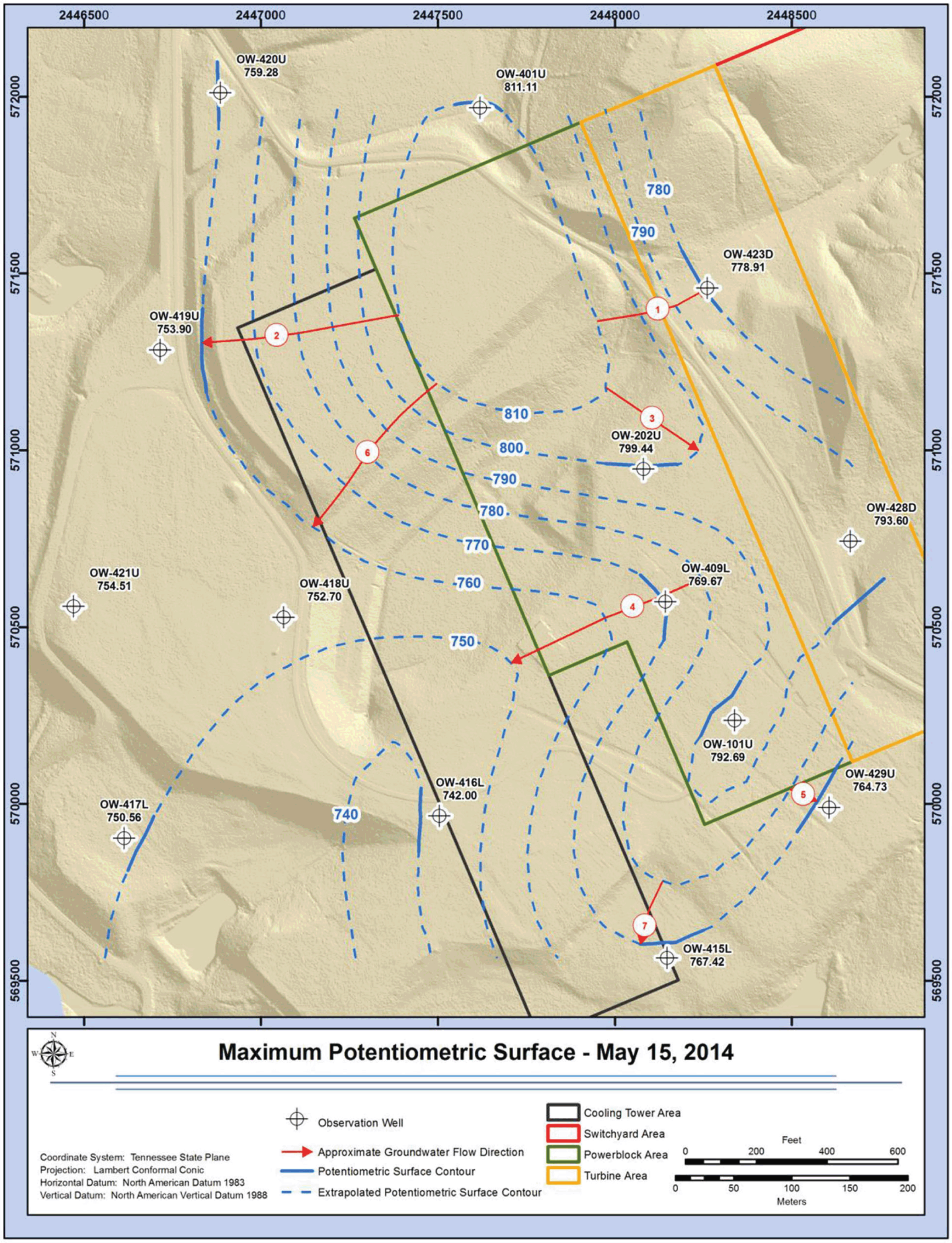


Figure 2.3.1-37. Potentiometric Surface Map for May 15, 2014

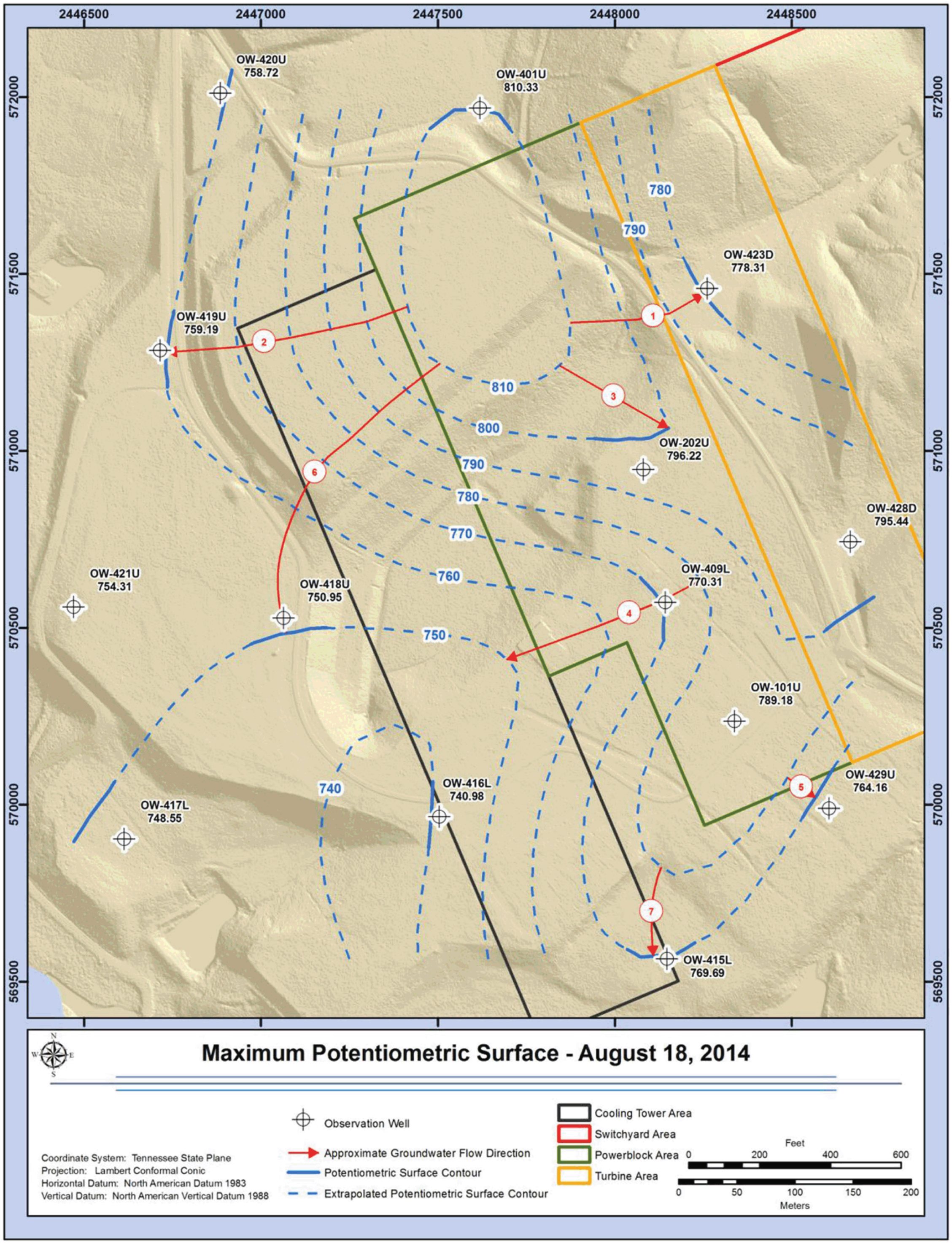


Figure 2.3.1-38. Potentiometric Surface Map for August 18, 2014

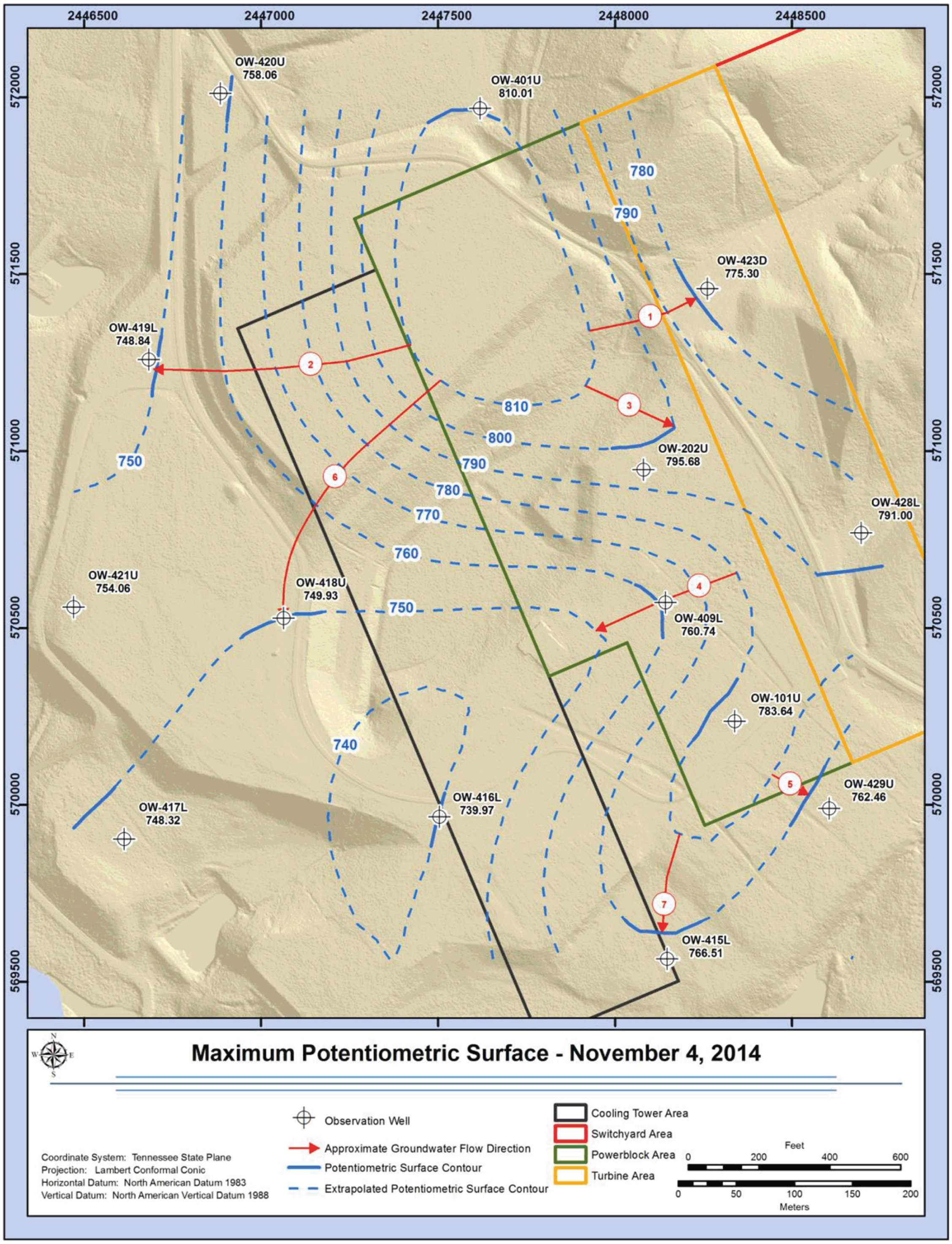


Figure 2.3.1-39. Potentiometric Surface Map for November 4, 2014

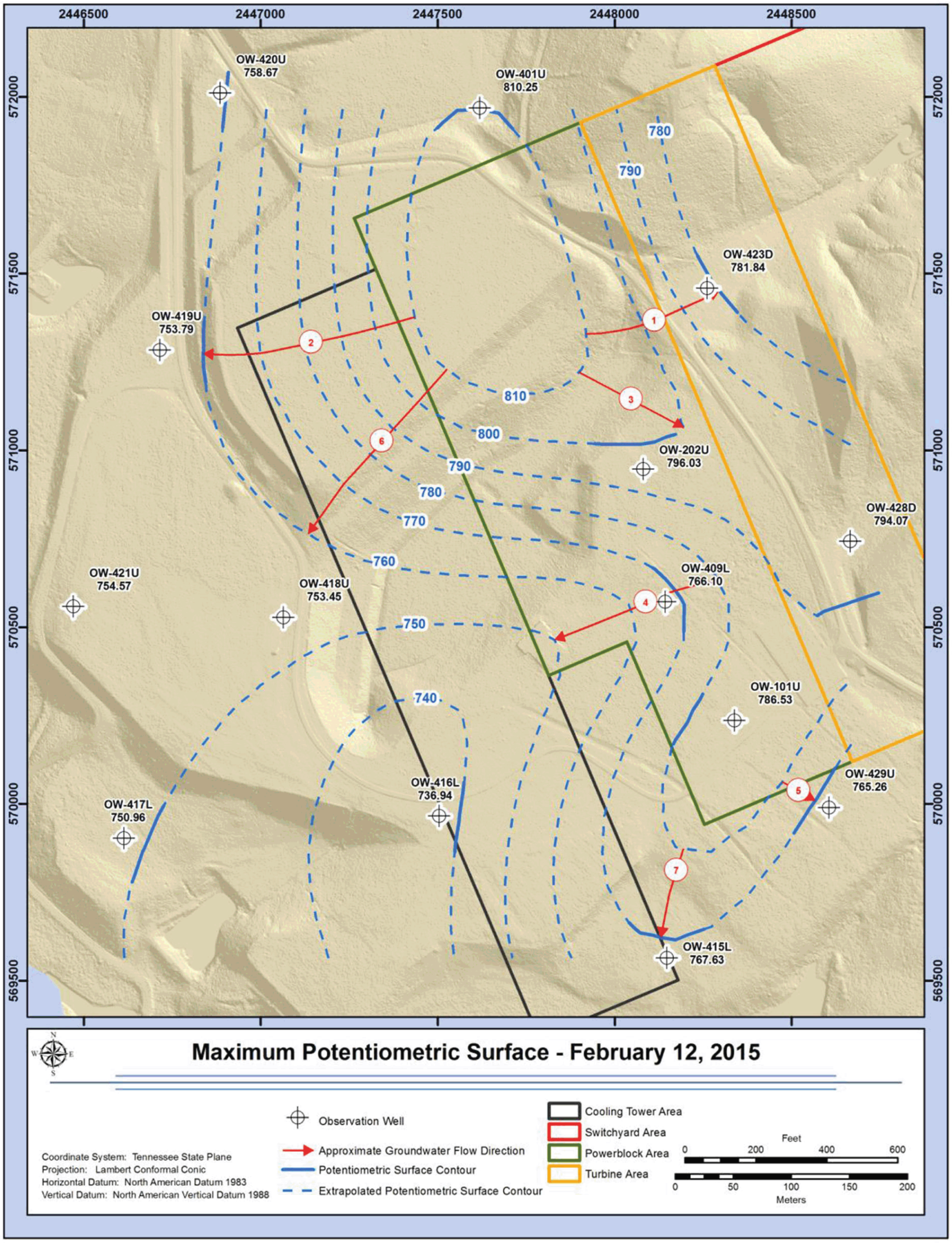


Figure 2.3.1-40. Potentiometric Surface Map for February 12, 2015

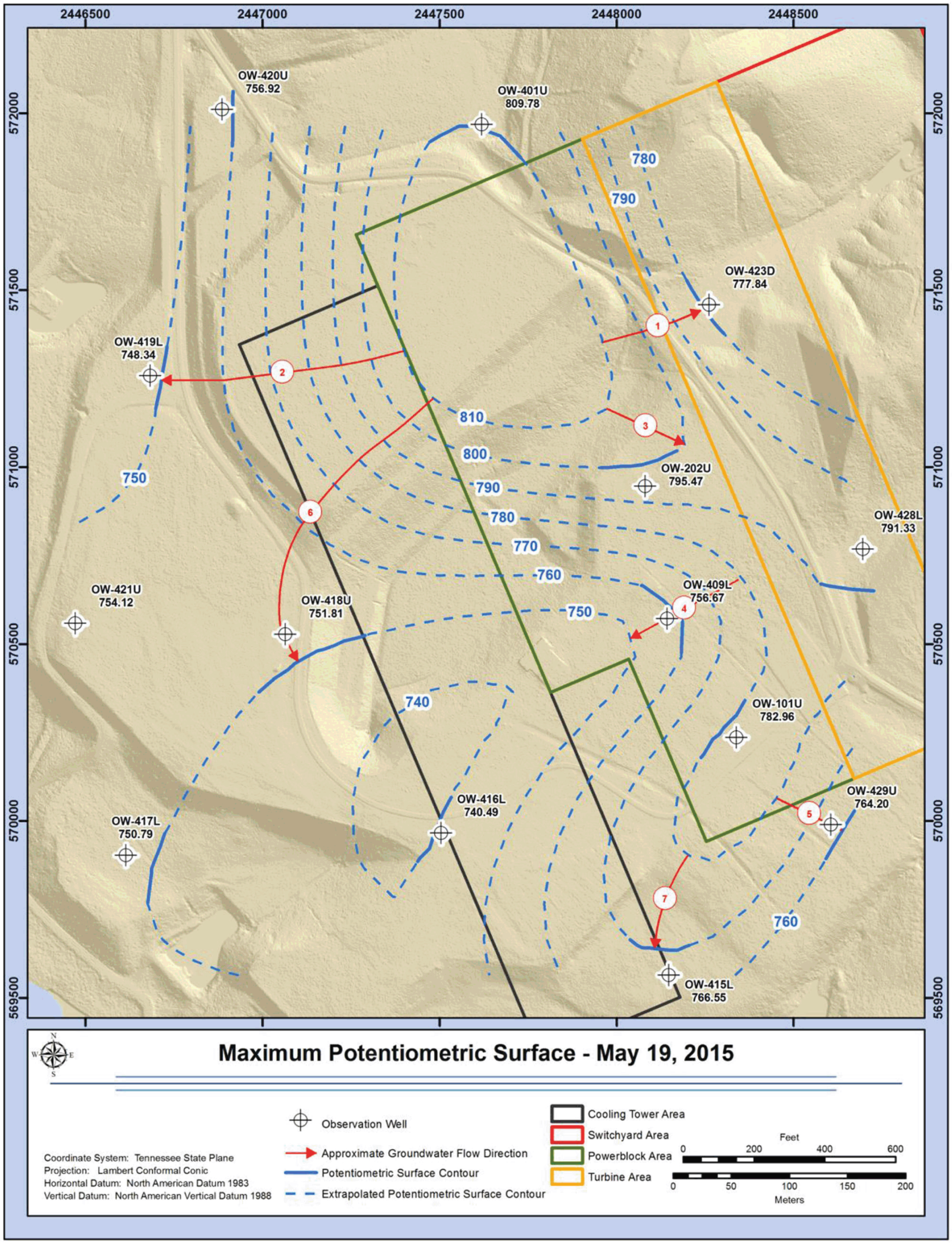


Figure 2.3.1-41. Potentiometric Surface Map for May 19, 2015

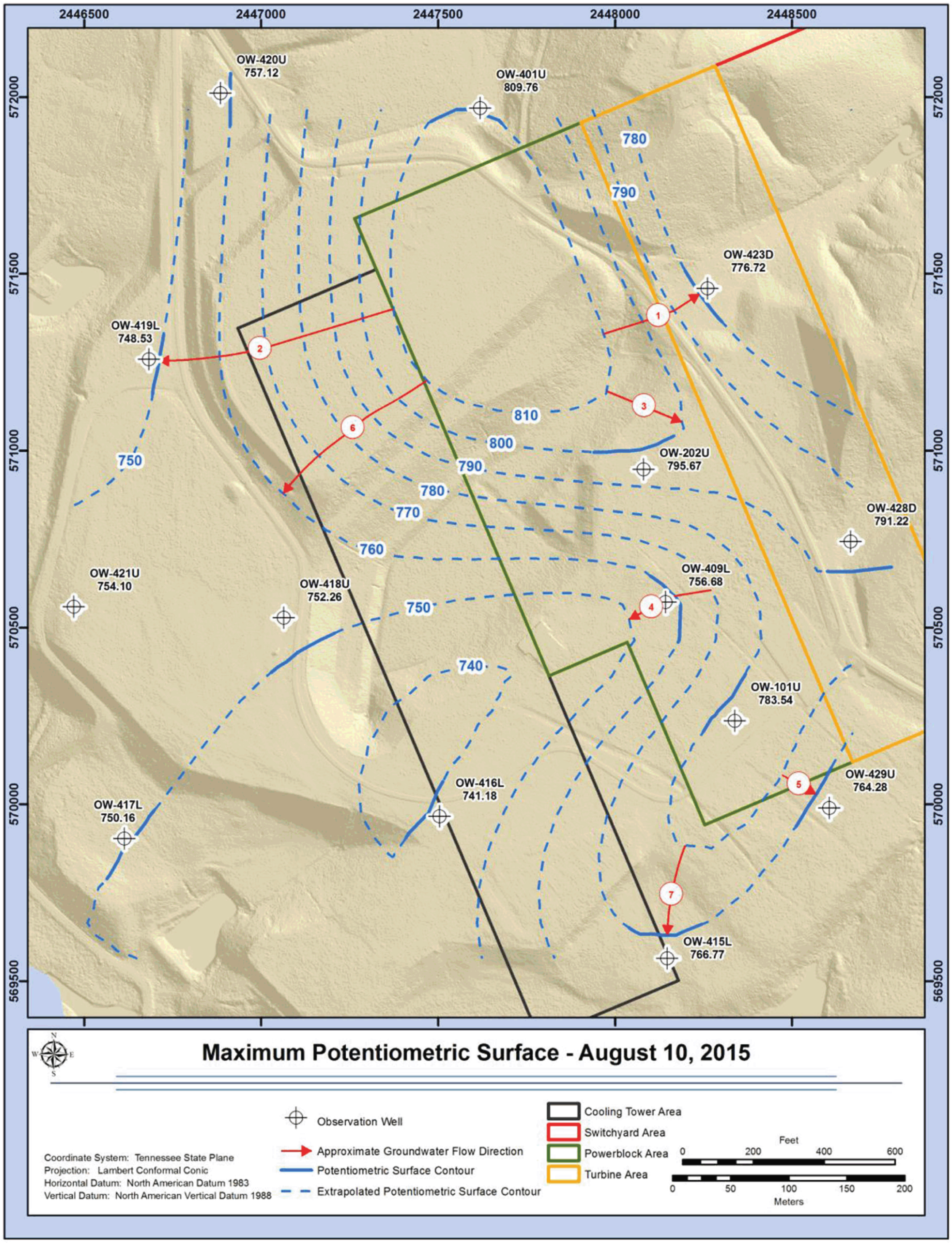


Figure 2.3.1-42. Potentiometric Surface Map for August 10, 2015

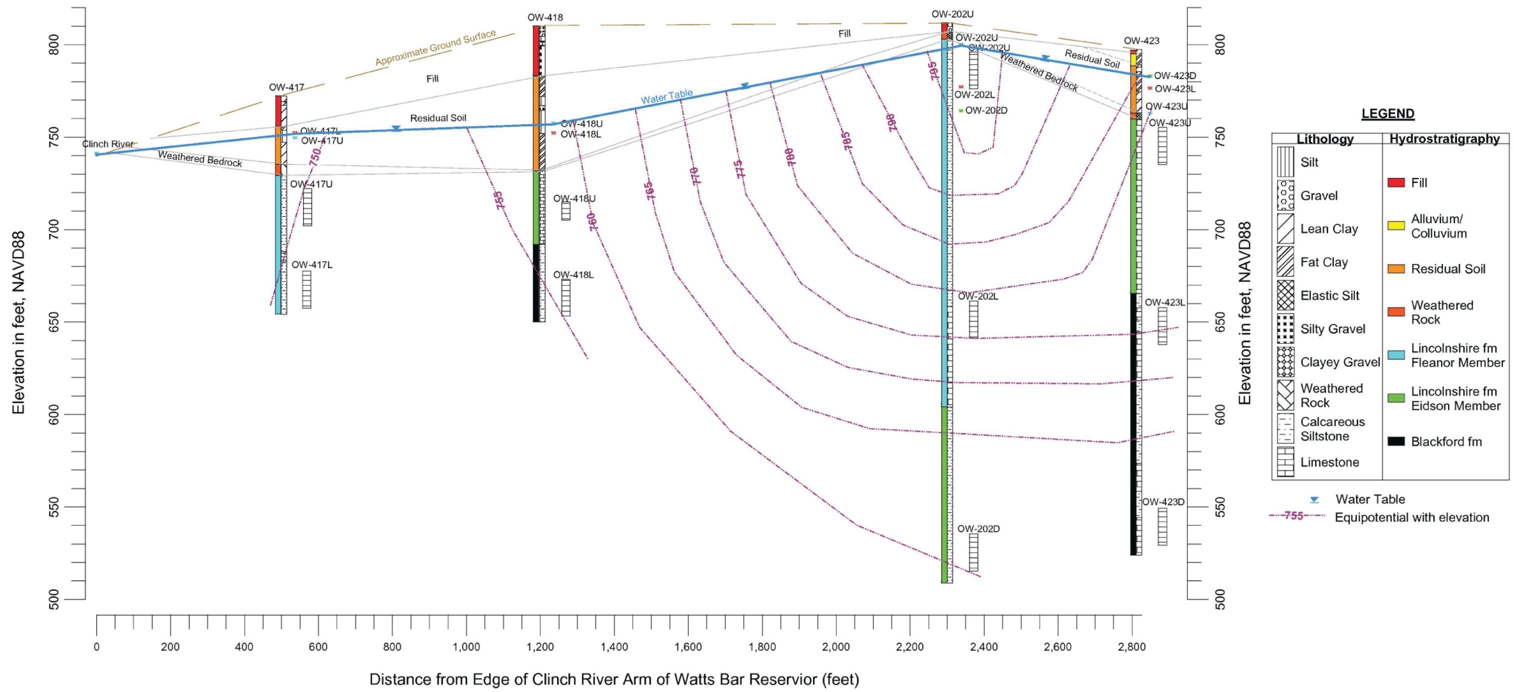


Figure 2.3.1-43. Snapshot in Time Showing Equipotential Lines in the Vertical Plane Along the Strike of the Bedding Plane on June 13, 2014

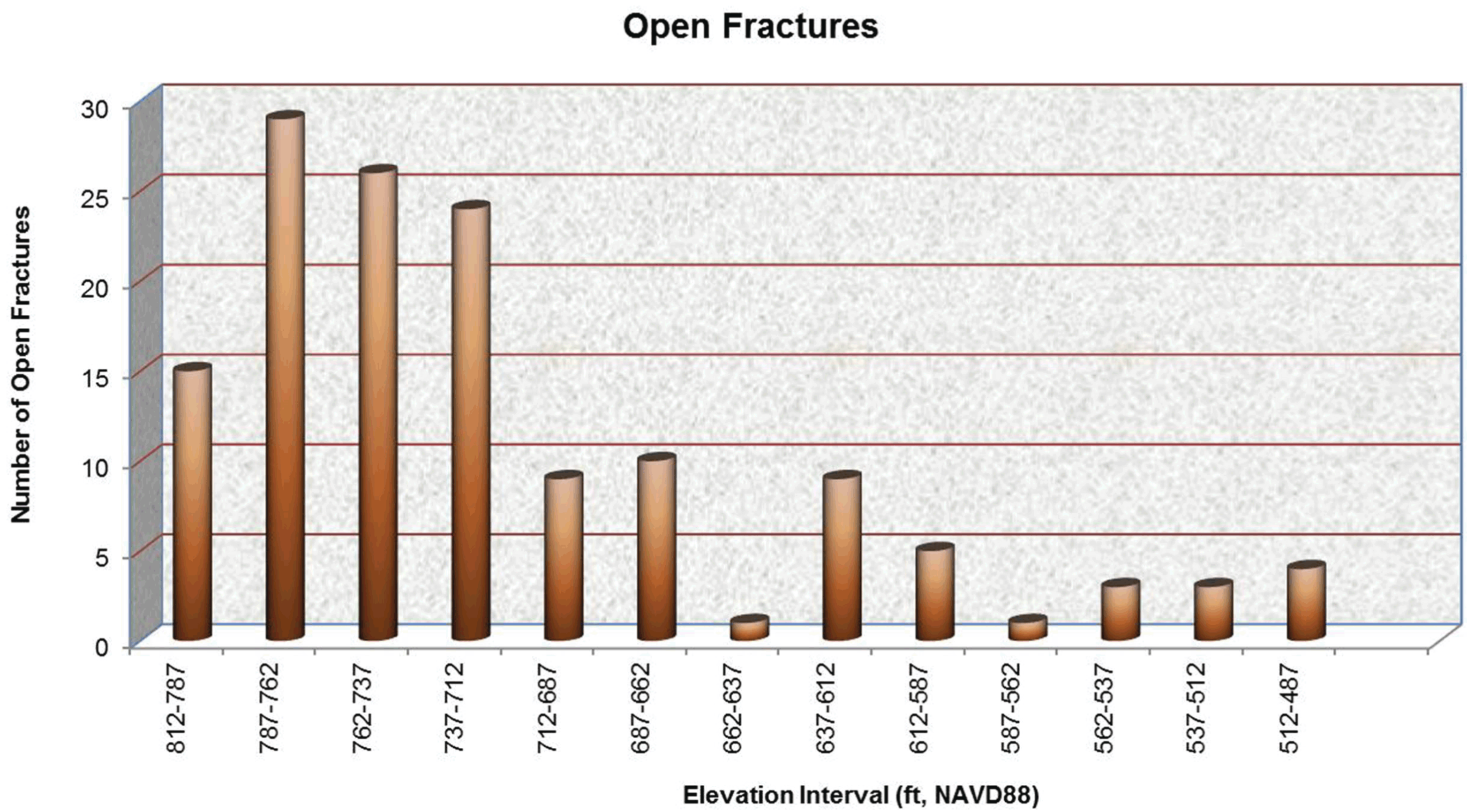
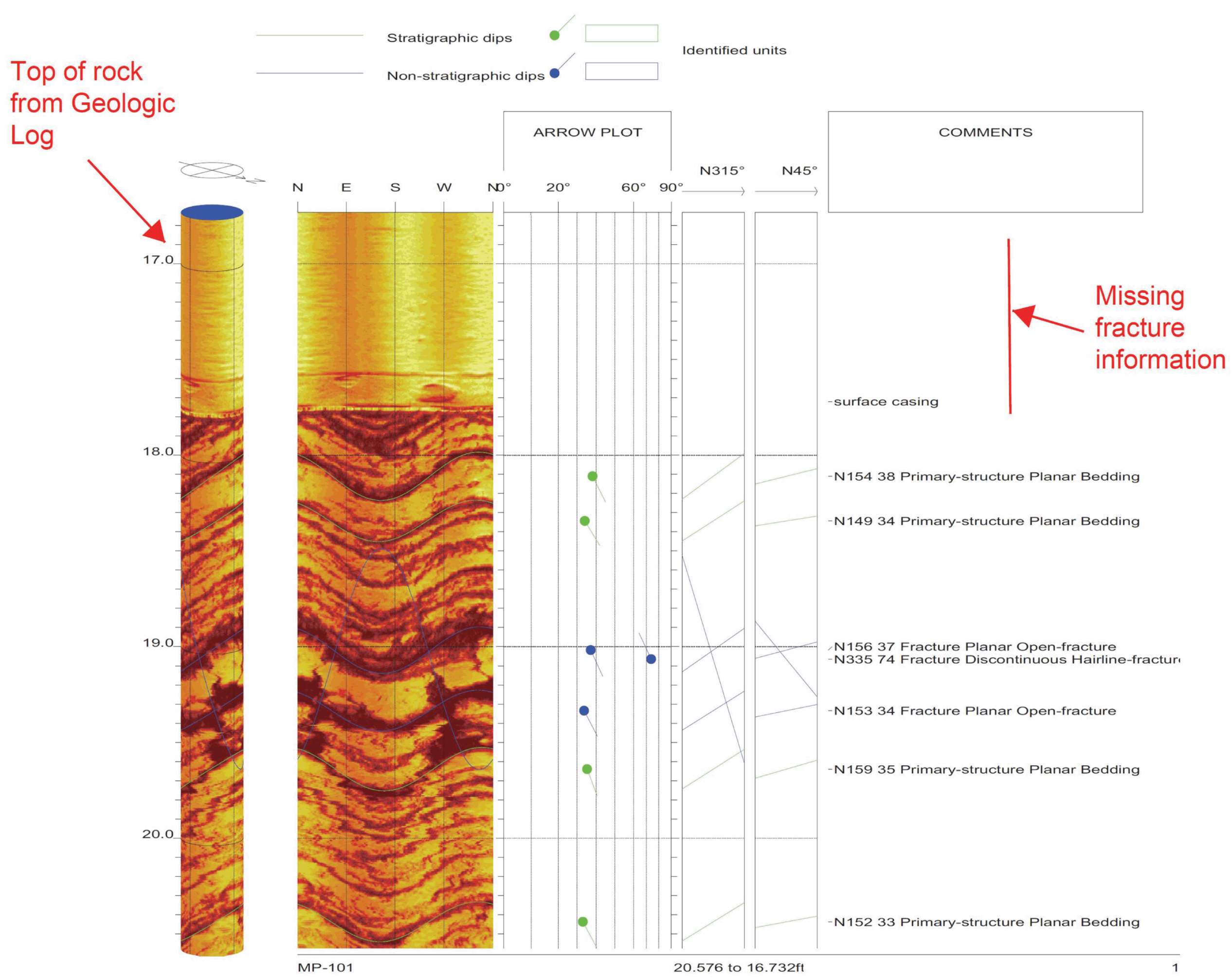
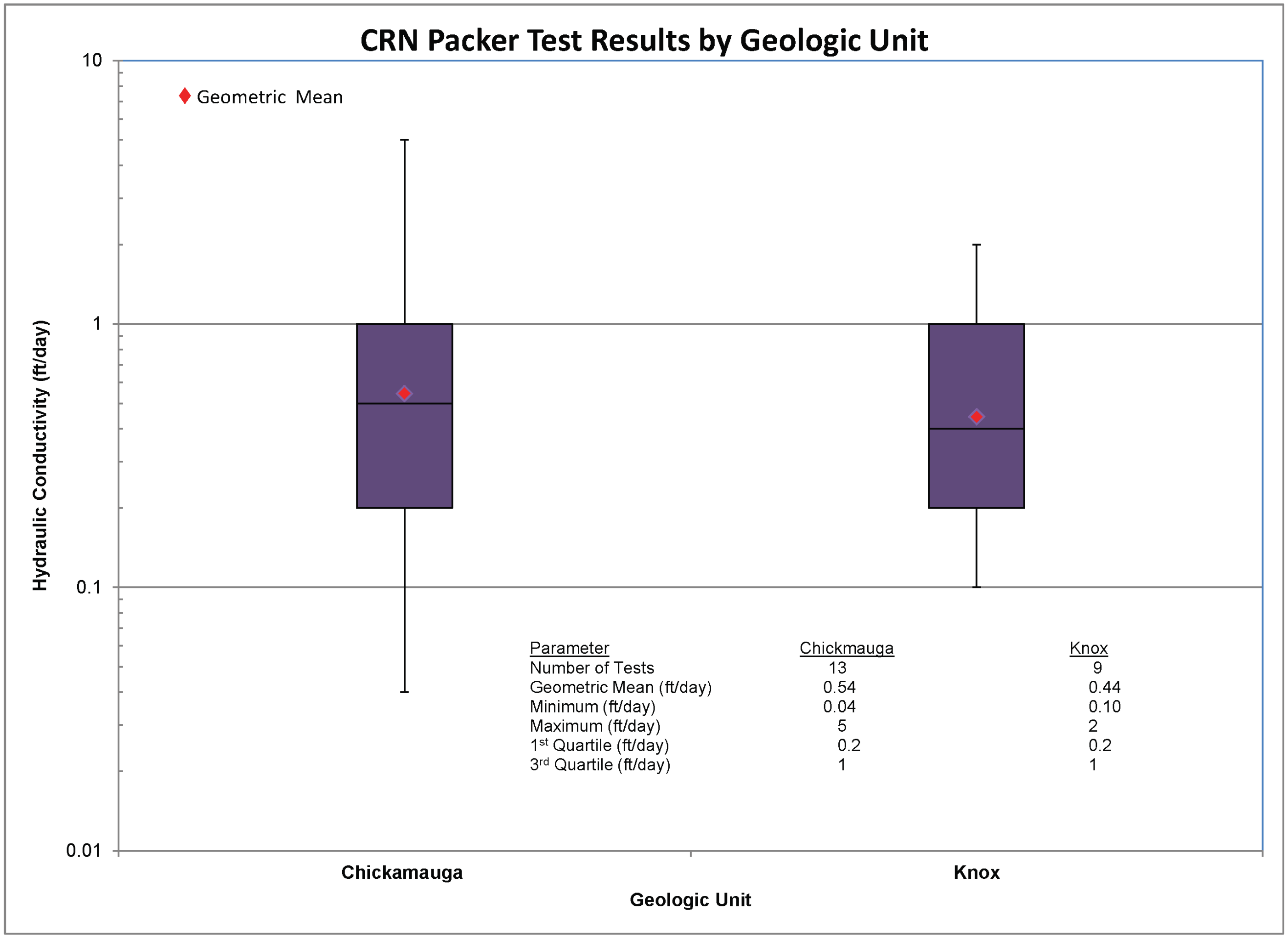


Figure 2.3.1-44. Fracture Frequency Histogram



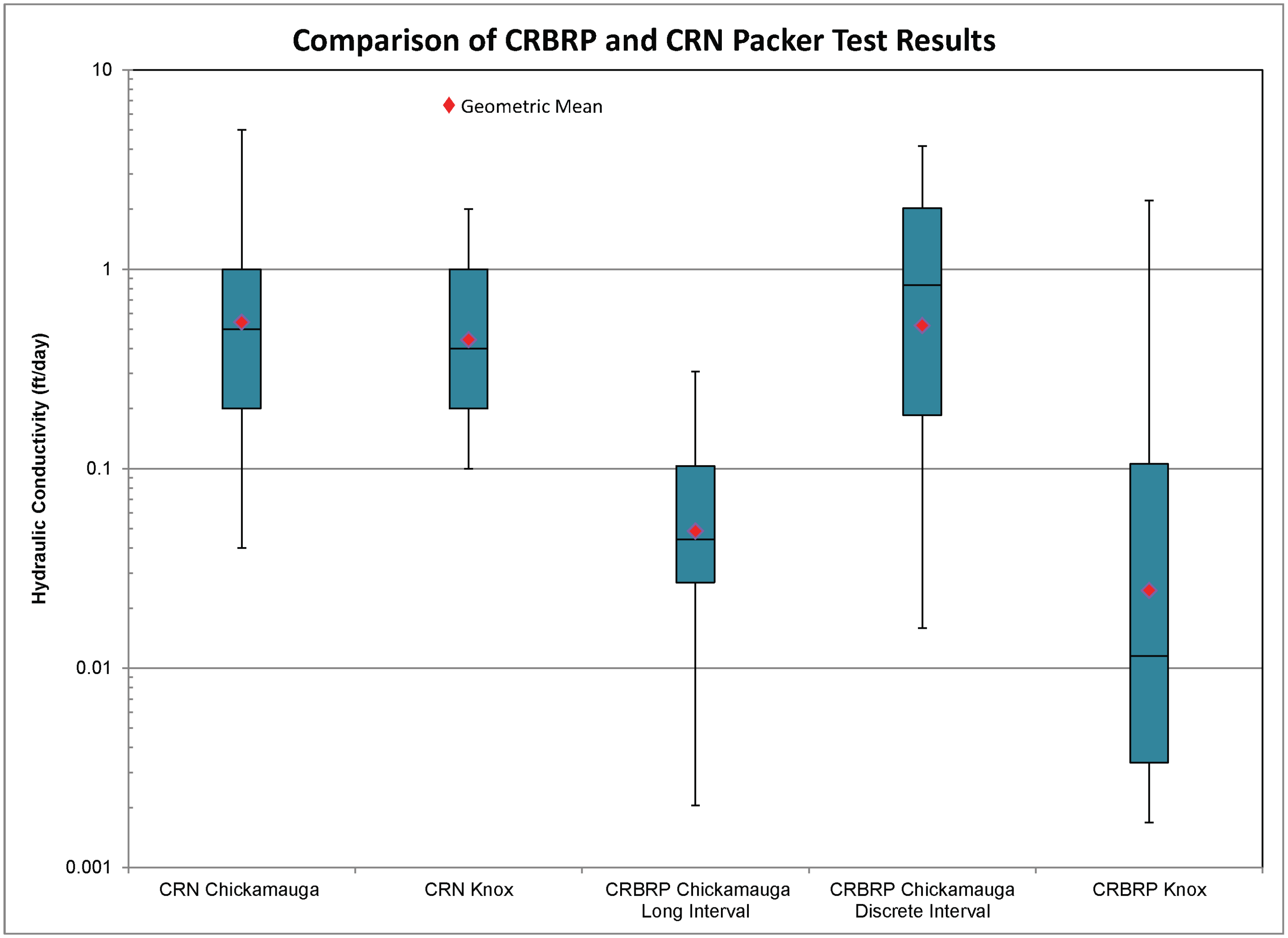
Adapted from: (Reference 2.3.1-21)

Figure 2.3.1-45. Example Acoustic Televiewer Geophysical Log



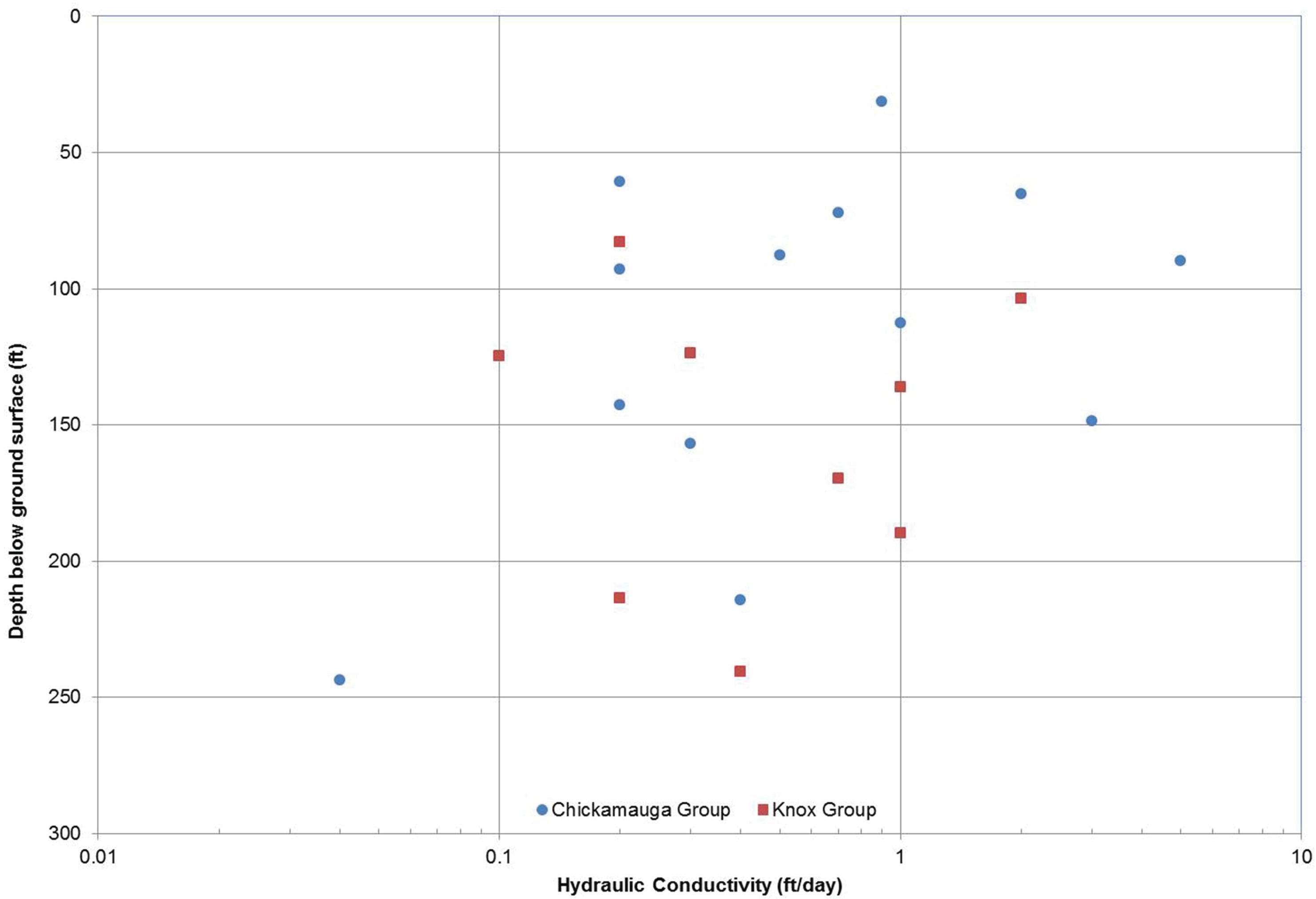
a) Box and whisker plot of CRN packer test results by geologic unit. Data from Table 2.3.1-5 and Appendix 2.3-B

Figure 2.3.1-46. (Sheet 1 of 2) Clinch River Nuclear Borehole Packer Test Results Box and Whisker Plots



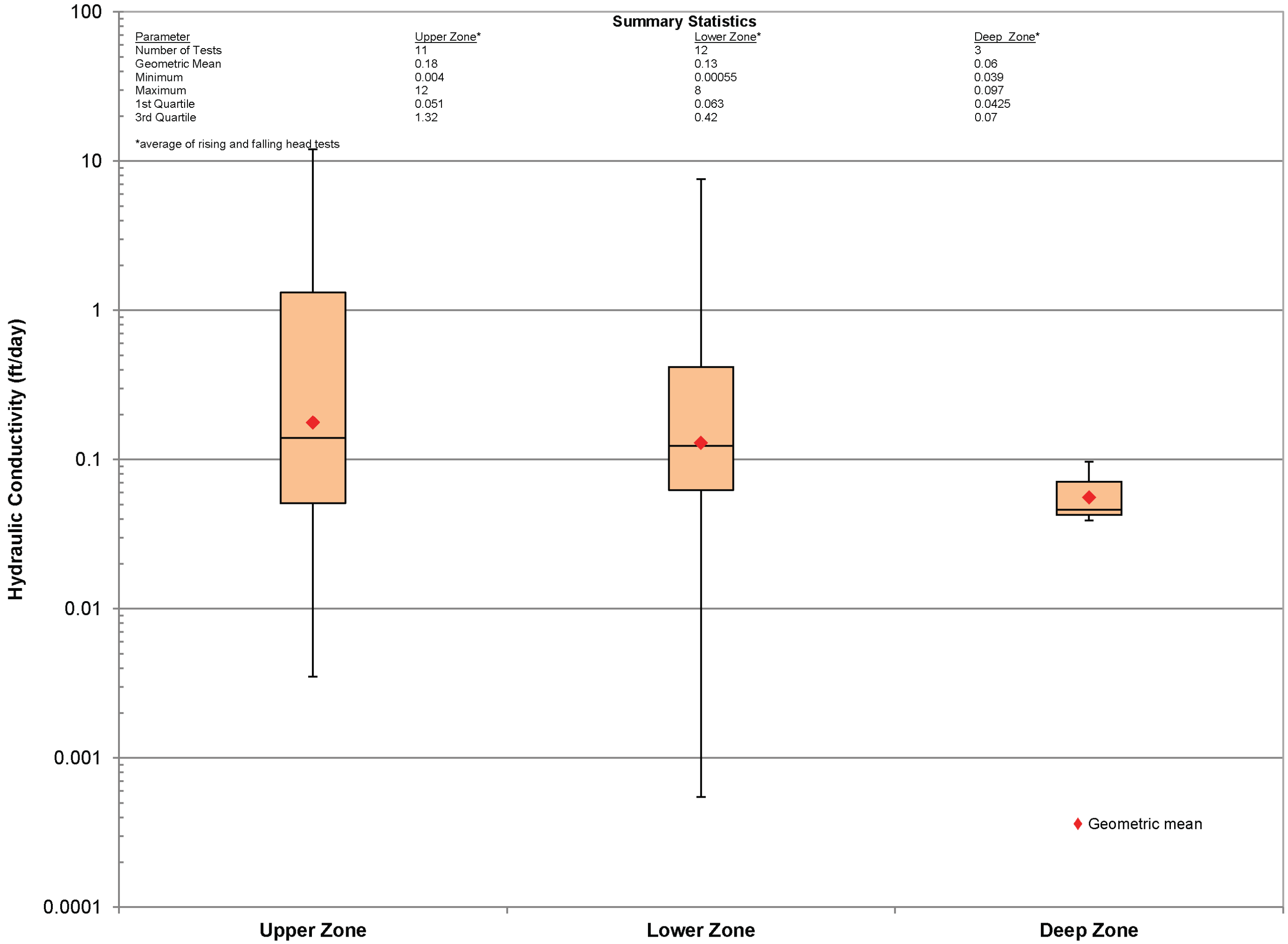
b) Box and whisker plot comparing CRN packer test results with CRBRP packer test results. Data from Table 2.3.1-5 and Appendix 2.3-B

Figure 2.3.1-46. (Sheet 2 of 2) Clinch River Nuclear Borehole Packer Test Results Box and Whisker Plots



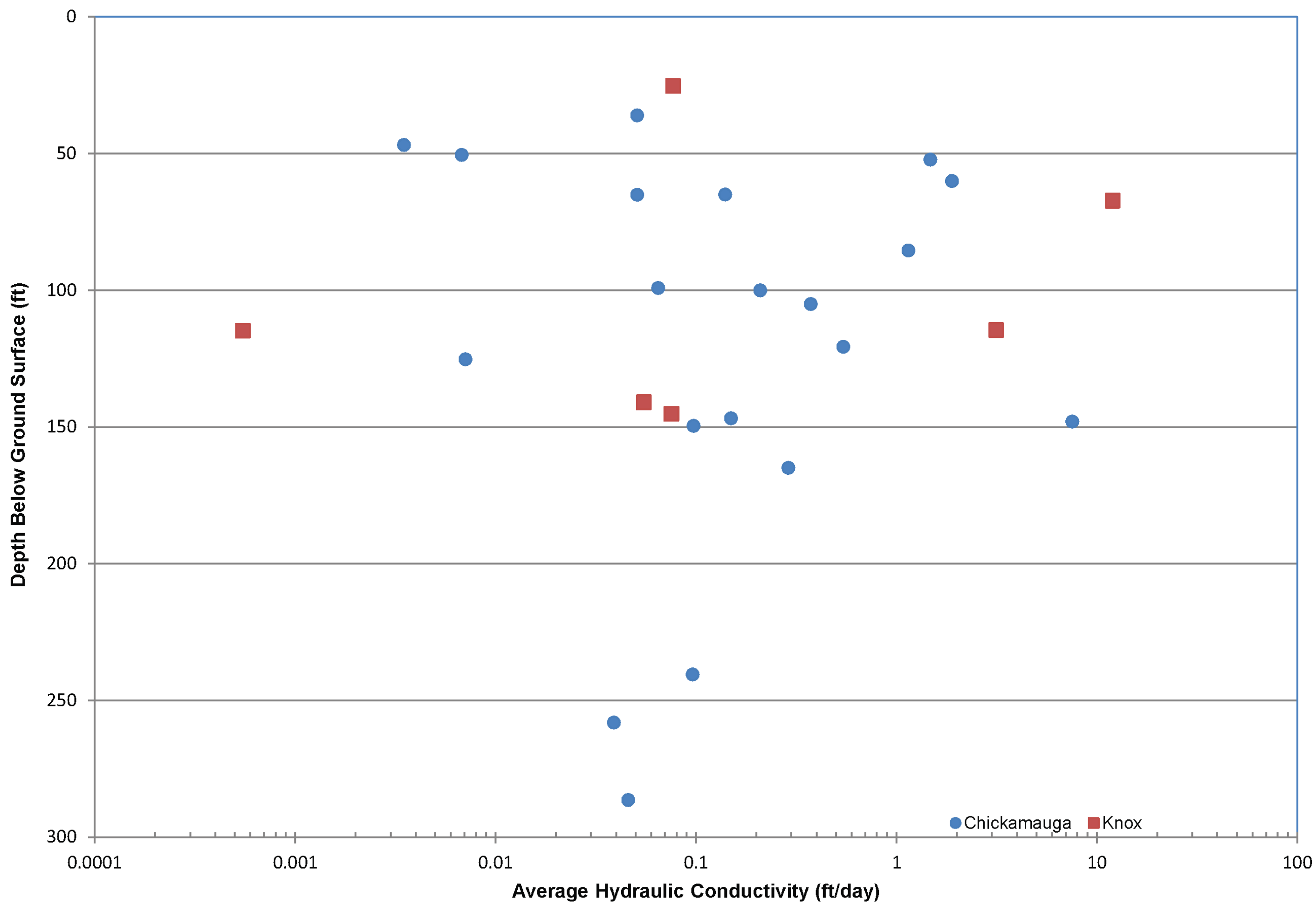
Data from Table 2.3.1-5

Figure 2.3.1-47. Scatter Plot of Clinch River Nuclear Packer Test Hydraulic Conductivity Results with Depth



a) Box and whisker plot of slug test hydraulic conductivity by observation well monitoring zone. Data from Table 2.3.1-6

Figure 2.3.1-48. (Sheet 1 of 2) Slug Test Results for CRN Site



b) Scatter plot of slug test hydraulic conductivity with depth below ground surface. Data from Table 2.3.1-6

Figure 2.3.1-48. (Sheet 2 of 2) Slug Test Results for CRN Site

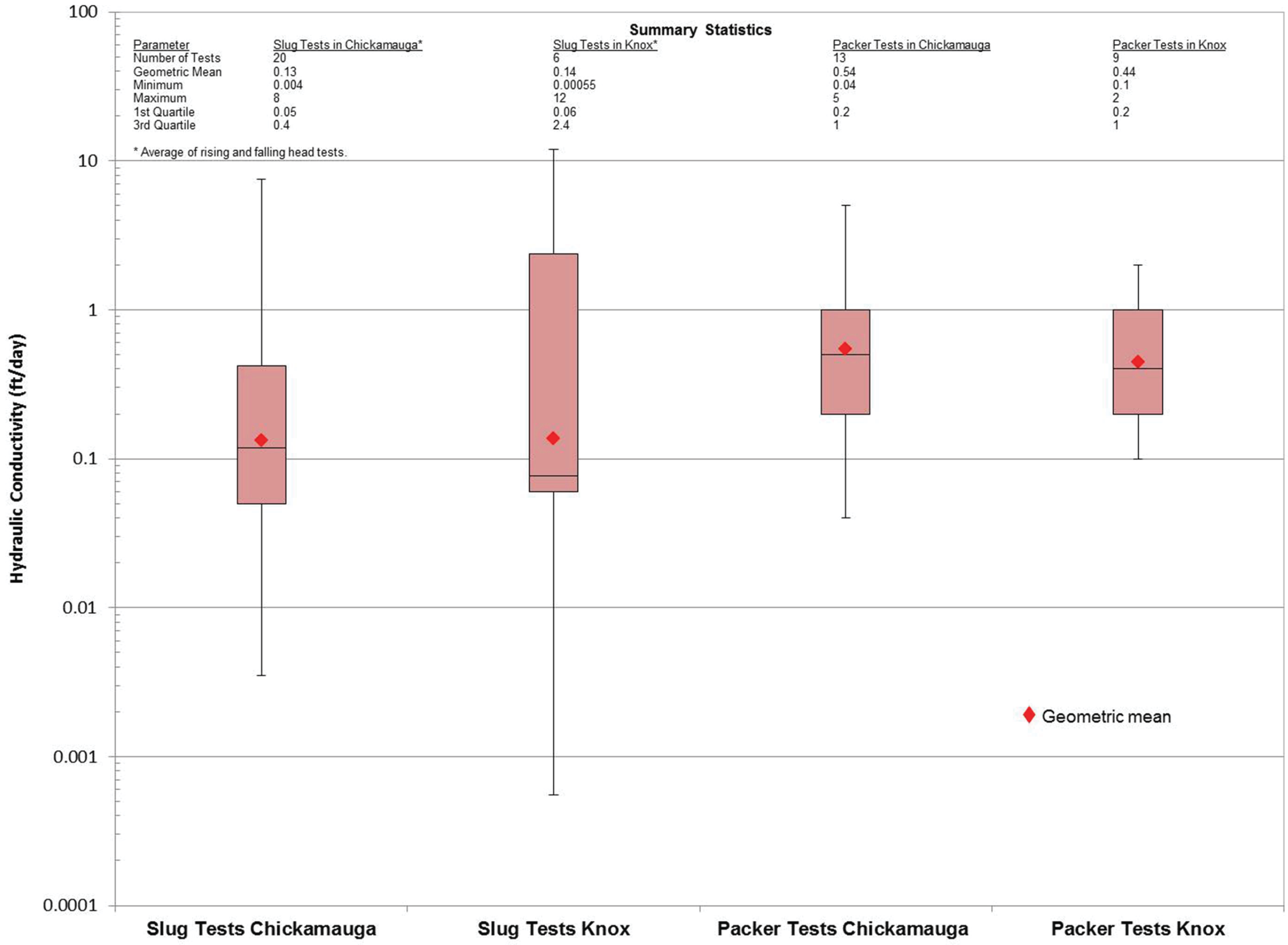


Figure 2.3.1-49. Comparison of Slug and Packer Test Results