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2.4.9 Channel Diversions

This section describes the effects of channel diversions as potential hazards to small modular reactors (SMRs) being considered at the Clinch River Nuclear (CRN) Site. Based on the review of hydrologic, hydraulic, climatic, topographic and geologic evidence and anthropogenic impacts near the CRN Site, as described below, channel diversions are not expected to cause flooding hazards at the site. Additionally, the SMR designs being considered do not require safety-related water supply from the Clinch River arm of the Watts Bar Reservoir. Consequently, the safety of the plant will not be compromised due to a loss of water supply even in the highly unlikely event of a channel diversion near the site.

2.4.9.1 Historical Channel Diversions

The CRN Site is located on a peninsula formed by a meander of the Clinch River arm of the Watts Bar Reservoir between Clinch River Miles (CRM) 14.5 and 19. Topographic maps from the U.S. Geological Survey (USGS) and Tennessee Valley Authority (TVA) are available beginning in 1935 that show the historical river course near the site. As shown in Figures 2.4.9-1, 2.4.9-2, 2.4.9-3 and 2.4.9-4 (for 1935, 1953, 1968 and 2013, respectively) (References 2.4.9-1 through 2.4.9-8), the river course near the site has remained nearly unchanged between 1935 and 2013 with no evidence of river channel diversion.

Although the Clinch River basin experienced multiple flood events in the past, there has been no evidence or report of channel diversion incidences. The five highest flood stages ever recorded at the USGS stream gage (03528000) on the Clinch River above Tazewell, Tennessee (Reference 2.4.9-9), occurred in 1957, 1962, 1963, 1973, and 1977. The gage began operation in 1919 (Reference 2.4.9-10). No record of river course change due to erosion or meander cutoff can be identified in USGS maps nor has been documented in the literature.

Subsection 2.5.3.2.5.2 describes the age and morphology of Clinch River terraces near the site area. Terrace surfaces delineated based on topographic expressions in the Lidar-based digital elevation model (DEM) and field observations during reconnaissance surveys show that Clinch River terraces are extensively preserved within the site area. The terraces record a history of incision of the river likely dating back to the early Pleistocene or into the Tertiary, which is indicative of a broad, stable landscape (see Subsection 2.5.3.2.5.2 for further discussions). The only known absolute age control of Clinch River terrace deposits was obtained from archaeological excavations during the CRN Site investigation. The oldest material dated was obtained from organic materials in the alluvium that underlies the Clinch River floodplain and yielded an age of about 2500 years old. This can be interpreted as indicating that the area where the samples were taken likely would not have been affected by riverbank erosion or meander cutoff over this 2500-year period.

The Virginia Department of Game and Inland Fisheries reported that a segment of the Clinch River was permanently diverted around the town of St. Paul, Virginia to prevent the town from flooding (Reference 2.4.9-11). The diversion was completed in 1982 (Reference 2.4.9-12), where the diversion river channel was blasted out of solid rock (Reference 2.4.9-11). A literature search has not revealed any historical record of any other diversion of the Clinch River due to geologic, seismic, topographic, thermal or anthropogenic causes.

For reservoir and mainstem tailwater (where tailwater of an upstream dam is influenced by the backwater elevation of the downstream dam) shorelines, like the shorelines near the CRN Site, wave actions by boats and winds would be the primary cause of erosion (Reference 2.4.9-13). Other causes of shoreline erosion include flow velocities, river bank slope stability, surface cover and land use change, and onshore construction. The impacts from these types of erosion processes are typically local and can be readily mitigated as necessary. They are therefore not considered a risk to the safety of the plant. Further, TVA implements a Shoreline Management Policy requiring restoration of riparian zones and a permit process for any public construction along the shoreline (Reference 2.4.9-14). Consequently, it is unlikely that river bank erosion could cause a channel diversion affecting the safety of the CRN Site.

2.4.9.2 Regional Topographic Evidence

The topography and geology of the CRN Site area, which is located in the Valley and Ridge Physiographic Province, is characterized by northeast-southwest trending sub-parallel ridges and valleys (Reference 2.4.9-15). The ridges and valleys are formed due to (thrust) faulting and folding of Paleozoic sedimentary strata. The ridges are formed in less soluble and erosion resistant strata, and valleys are developed in more soluble and erodible strata (References 2.4.9-15 and 2.4.9-16). Small streams have developed following the valley lines with nearly perpendicular drainage from the ridges. Major rivers, on the other hand, are incised and believed to be older than the present ridge and valley formation with the region uplifting slowly enough that the rivers were able to maintain their course, cutting through the ridges as they developed (Reference 2.4.9-16). There is no geologic evidence that any of the thrust faults are active or still undergoing movement (see Subsection 2.5.1 for further discussion).

Figure 2.4.9-5 shows the USGS landslide incidence and susceptibility map for the site area. The figure indicates low landslide incidence and moderate susceptibility for the CRN Site. Land use in the Upper Tennessee River basin within the Valley and Ridge Physiographic Province, which also includes the Clinch River basin, is comprised of forest (51 percent), pasture (36 percent), cropland (4 percent), urban (6 percent), water (3 percent), and barren land (less than 1 percent) (Reference 2.4.9-15). The forested areas are located mostly on the steeper ridges, cropland in the valley bottoms and benches, and pastures on the less steep parts of ridges and in the valleys. Based on the low landslide incidence, moderate susceptibility and forested land cover in the steeper slopes near the site, it can be concluded that there is no potential for a large scale landslide in the river banks that could block river flows and flood the CRN Site. However, in the unlikely event that a landslide occurs near the site, the low relief and relatively gentle slope on the banks would allow the river to overflow its banks, thereby preventing complete blockage of the river or a flooding wave from reaching the site.

Based on the discussions above, it is unlikely that a diversion in the Clinch River due to geologic or topographic causes could occur or would affect the safety of the CRN Site. Additionally, the geologic and topographic settings in the region preclude stream diversions from adjacent river basins that could affect the Clinch River and cause a flood hazard to the CRN Site.

2.4.9.3 Ice Causes

As described in Subsection 2.4.7, infrequent ice jam incidences had affected the site region between 1780 and 2014. However, no record of ice jam-induced flooding or damage was reported over this period. Therefore, channel diversions near the site due to ice jams or other ice causes are not expected. In addition, because the site is located in a continental, humid subtropical climate region, permafrost is not a concern.

2.4.9.4 Flooding of Site Due to Channel Diversions

As indicated above, there is no credible evidence that flooding as a result of channel diversion could occur near the CRN Site that would affect the safety of the site.

2.4.9.5 Human-Induced Causes of Channel Diversions

Flows in the Clinch River arm of the Watts Bar Reservoir are regulated by two TVA dams located upstream of the site: Norris Dam and Melton Hill Dam. The construction of Norris Dam in 1936 significantly altered the downstream hydrology of the Clinch River, with reduced annual peak streamflows and daily mean discharges, as shown in Figures 2.4.9-6 and 2.4.9-7 (Reference 2.4.9-17). Melton Hill Reservoir does not provide significant flood protection or seasonal flow regulation as it has very little storage volume. It has a narrow operating range, fluctuating only a maximum of six feet during the course of a year, with a normal daily fluctuation of about two feet. Further details of dams in the Clinch River watershed are provided in Subsection 2.4.1.

Graf (Reference 2.4.9-18) indicates that controlled flows from major dams eliminate large floods downstream, such that many areas of previously active river processes become stabilized. This results in a reduction in sediment transport and other changes to the river planform in specific zones. Graf observed similar changes in the river processes in reaches downstream of the eastern regional dams (Reference 2.4.9-18) including the Clinch River downstream of Norris Dam. This leads to the conclusion that any potential for channel diversions in the Clinch River, if it exists, is further reduced by the presence of the Norris and Melton Hill dams and reservoirs.

High flow velocities due to the failure of upstream dams (Subsection 2.4.4) could potentially induce large erosion (or deposition) of bank and/or bed materials near the site. However, as described in Subsection 2.4.4, the CRN Site will not be affected by flooding in the worst case failure scenario of the two upstream dams. Therefore, erosion/deposition from the dam break flows is not expected to affect the site. Also, failures of other manmade structures on the river, for example, levees, intakes, outfalls and jetties, although they may locally block flows on portions of the river channel cross-section and cause local high flow velocities, are unlikely to cause a diversion of the river near the site.

As described in Subsection 2.4.9.1, other anthropogenic activities including river bank erosion due to waves from boats, surface cover and land use change, and reservoir level fluctuations are unlikely to cause a channel diversion.

Therefore, it can be concluded that operations of dams and reservoirs and other anthropogenic activities on the Clinch River would not cause a migration of the river course or increase the potential for a future channel diversion.

2.4.9.6 Alternative Water Sources

The SMRs being considered for the CRN Site do not rely on the Clinch River arm of the Watts Bar Reservoir for safety-related water use. However, it is the source for the nonsafety-related cooling tower makeup water for the normal heat sink with the water intake located on the river. The nonsafety-related makeup water intake, while unlikely to be affected by channel diversions under normal operation conditions, could be subject to impacts from shoreline erosion. As described previously, the shoreline erosion processes would occur at a localized scale and at a rate that could be mitigated. In the unlikely event that a channel diversion occurs (due to, for example, dam break and slope failure) interrupting the nonsafety-related makeup water supply, the plant can still be safely shutdown. Plant water use is further described in Subsection 2.4.11.

2.4.9.7 Other Site-Related Evaluation Criteria

No other site-related evaluation criteria have been identified as the site will not be affected by channel diversions.

2.4.9.8 Conclusions

A review of hydrologic, hydraulic, climatic, topographic and geologic evidence and anthropogenic impacts on the Clinch River arm of the Watts Bar Reservoir near the CRN Site indicates that channel diversions are not expected in the Clinch River during the operating life of the plant. Moreover, in the unlikely event that channel diversions occur, there will be no safety-related impact at the CRN Site.

2.4.9.9 References

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2.4.9-2. USGS, TVA, “Tennessee, Elverton Quadrangle, 130-NW,” 1935.

2.4.9-3. USGS, TVA, “Bethel Valley Quadrangle, Tennessee, 7.5 Minute Series (Topographic), 130-NE,” 1953.

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2.4.9-7. USGS, The National Map, “U.S. Topo, Bethel Valley Quadrangle, Tennessee, 7.5 Minute Series,” 2013.

2.4.9-8. USGS, The National Map, “U.S. Topo, Elverton Quadrangle, Tennessee, 7.5 Minute Series,” 2013.

2.4.9-9. NOAA, National Weather Service, “Advanced Hydrologic Prediction Service, Clinch River Above Tazewell.” Available at http://water.weather.gov/ahps2/hydrograph.php?wfo=mrx&gage=tazt1&hydro_type=2, accessed May 28, 2014.

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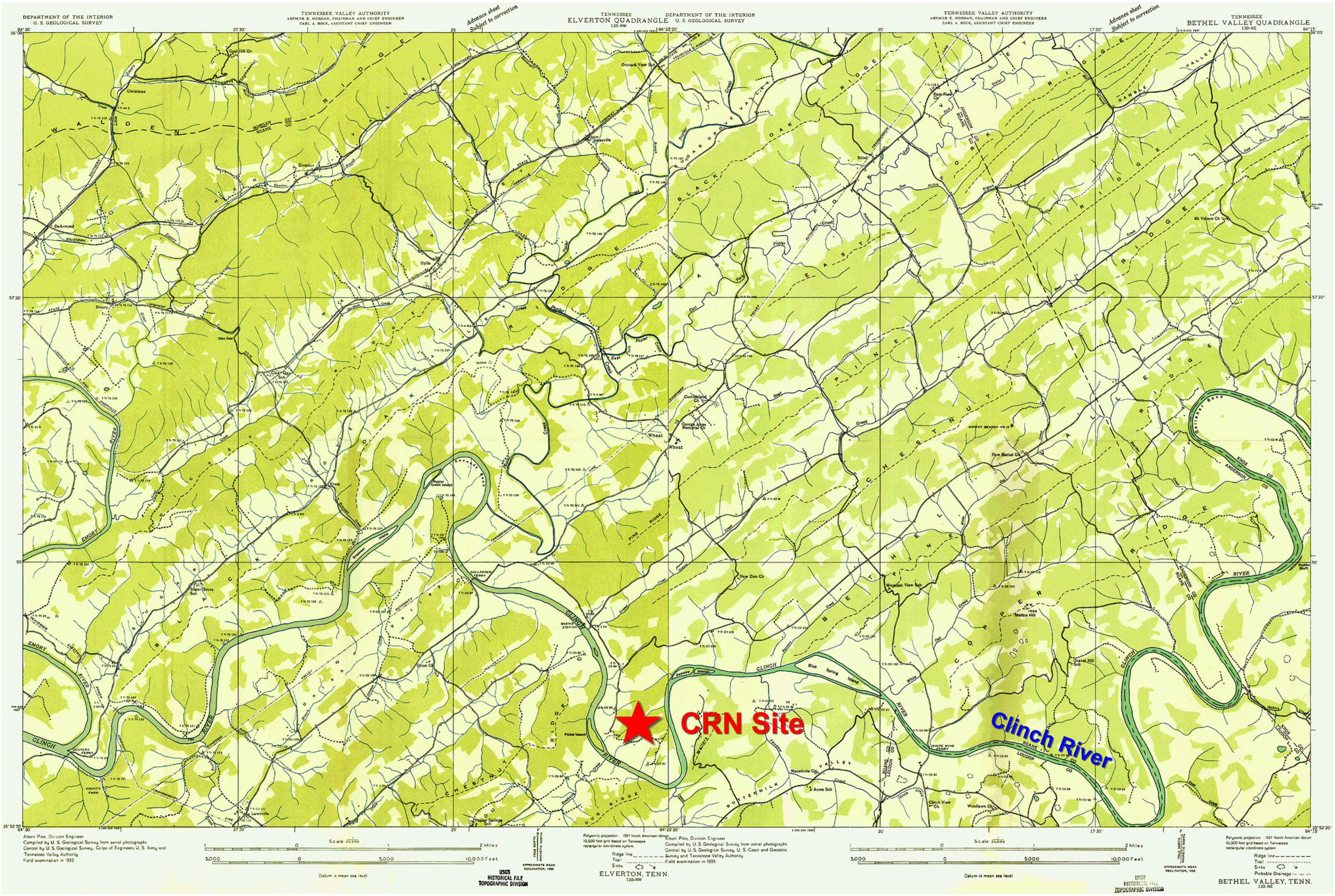
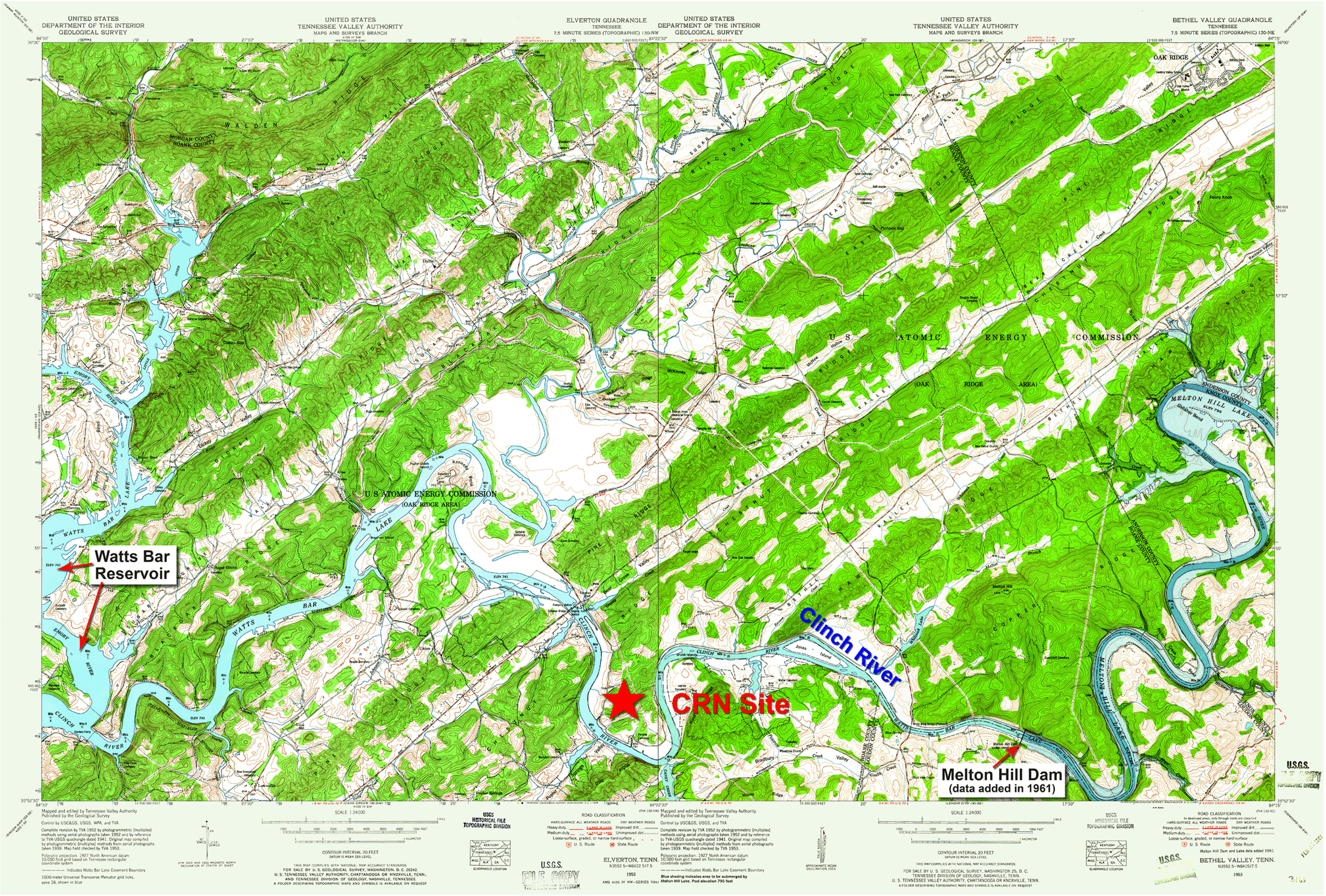
2.4.9-18. Graf, W.L., *Downstream Hydrology and Geomorphic Effects of Large Dams on American Rivers*, Geomorphology, No. 79, pp. 336–360, 2006.

2.4.9-19. USGS, National Atlas, "Map Maker." Available at http://www.nationalatlas.gov/mapmaker/mapmaker/printableMap, accessed May 15, 2014.



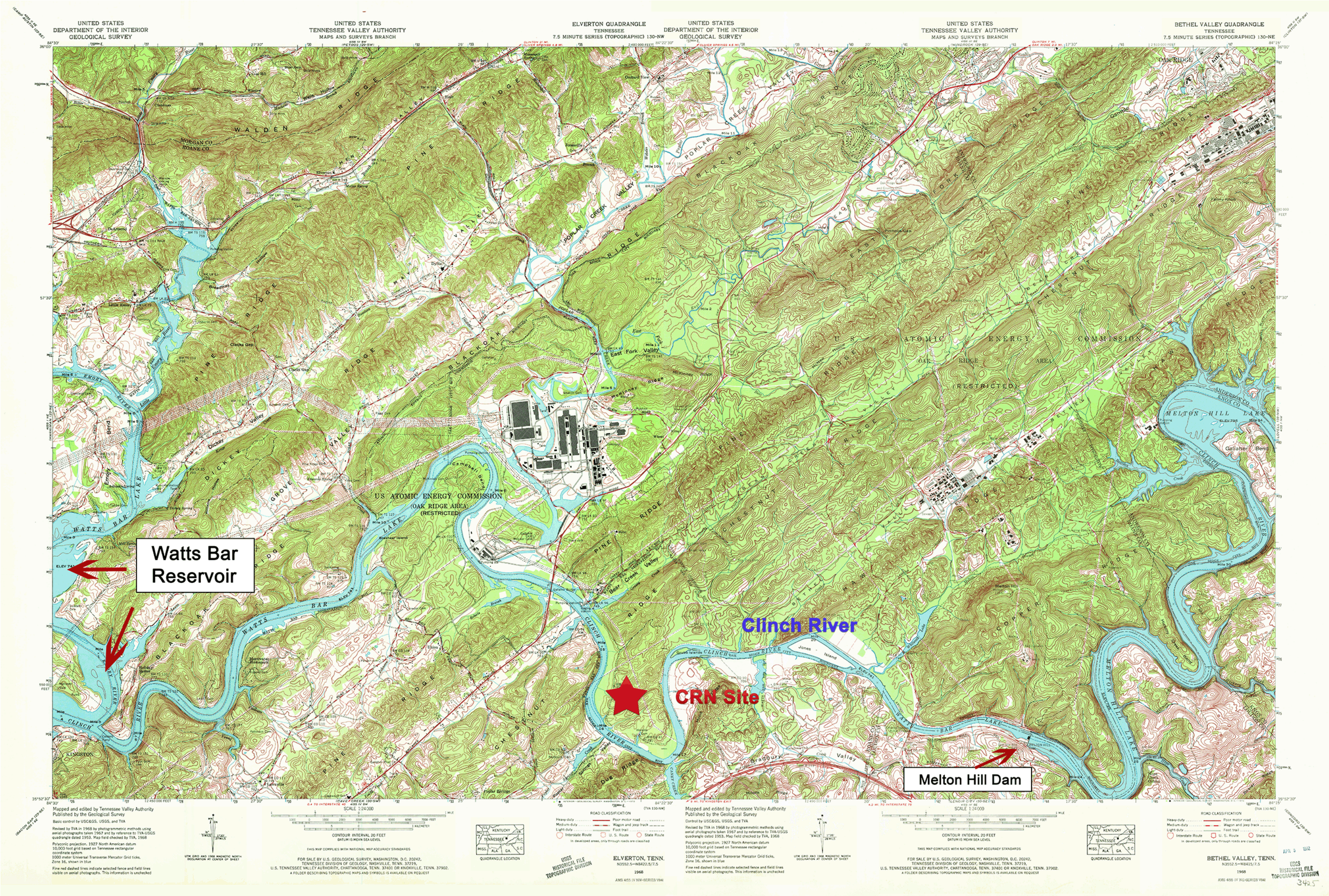
Source: References 2.4.9-1 and 2.4.9-2

Figure 2.4.9-1. The Clinch River Planform Near the Clinch River Nuclear Site, 1935



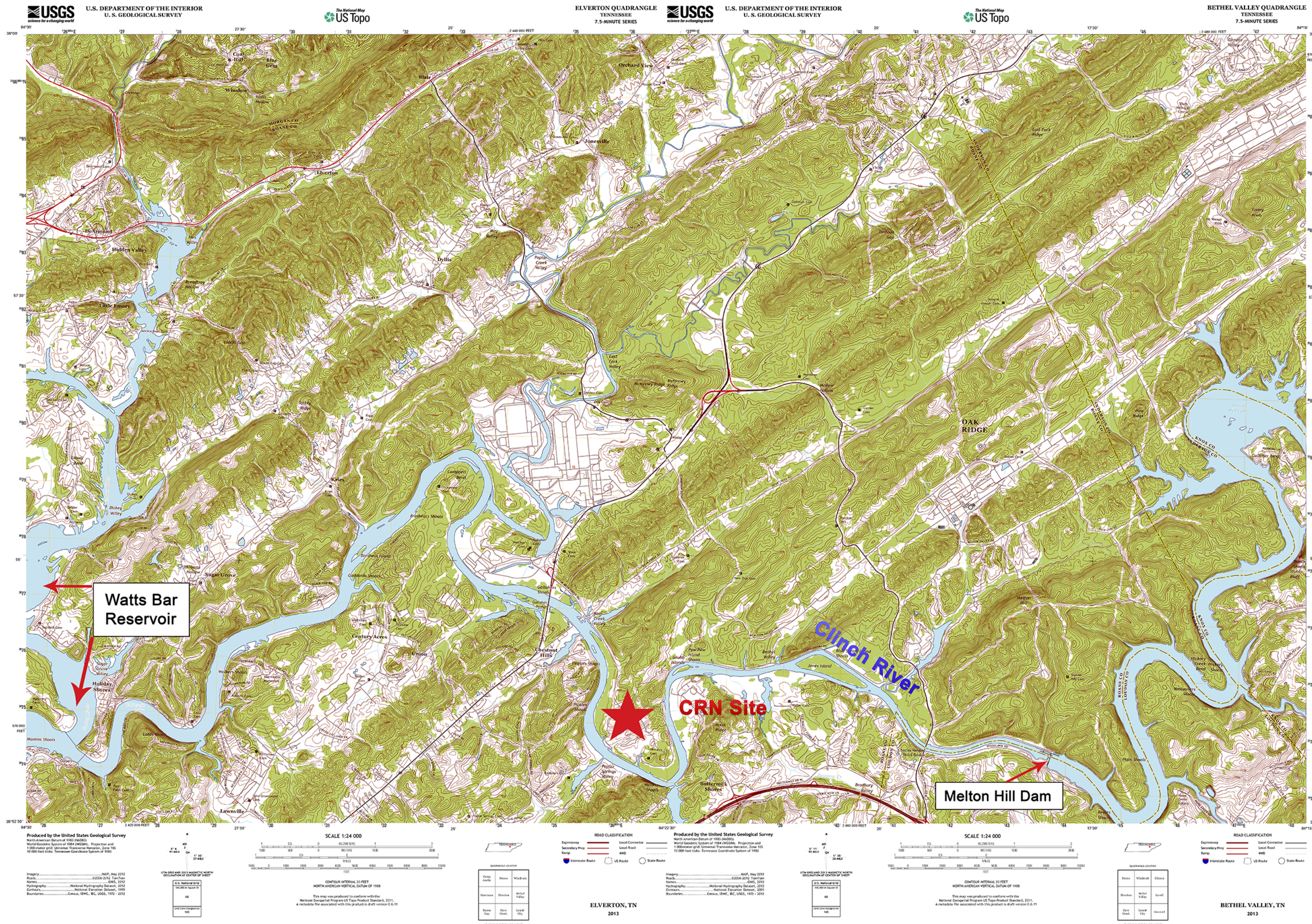
Source: References 2.4.9-3 and 2.4.9-4

Figure 2.4.9-2. The Clinch River Planform Near the Clinch River Nuclear Site, 1953



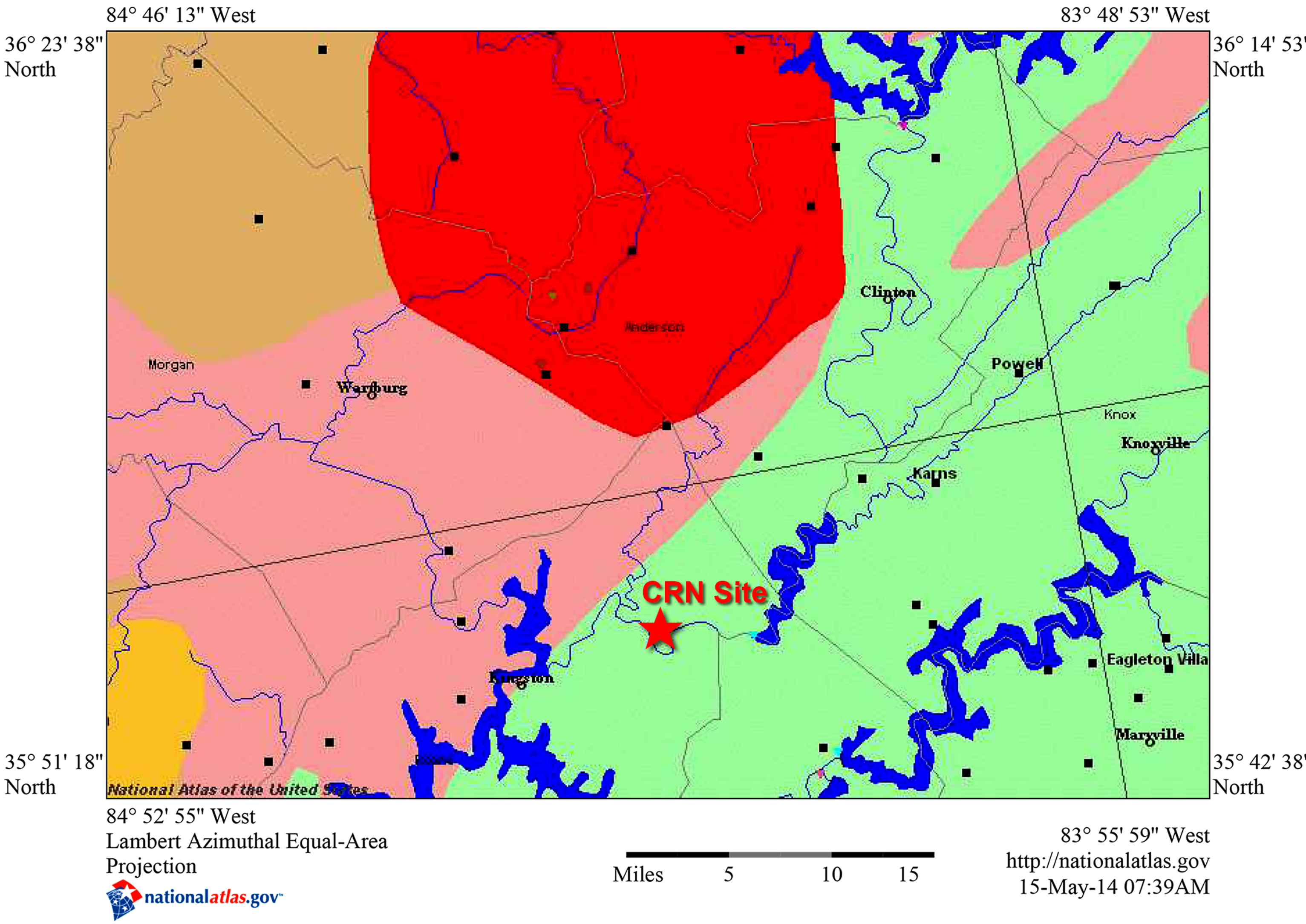
Source: References 2.4.9-5 and 2.4.9-6

Figure 2.4.9-3. The Clinch River Planform Near the Clinch River Nuclear Site, 1968



Source: References 2.4.9-7 and 2.4.9-8

Figure 2.4.9-4. The Clinch River Planform Near the Clinch River Nuclear Site, 2013



Source: Reference 2.4.9-19

Figure 2.4.9-5. (Sheet 1 of 2) Landslide Incidence and Susceptibility Map Near the Clinch River Nuclear Site

Landslide Incidence and Susceptibility
Source: U.S. Geological Survey
Layer partially covered by another layer

Landslide Incidence and Susceptibility

Landslide Incidence
- Low (less than 1.5 % of area involved)
- Moderate (1.5%-15% of area involved)
- High (greater than 15 % of area involved)

Landslide Susceptibility/ Incidence
- Moderate susceptibility/low incidence
- High susceptibility/low incidence
- High susceptibility/moderate incidence

Cities and Towns
Source: U.S. Geological Survey
- State Capitals
- County Seats
- Other Cities

Dams
Source: U.S. Army Corps of Engineers

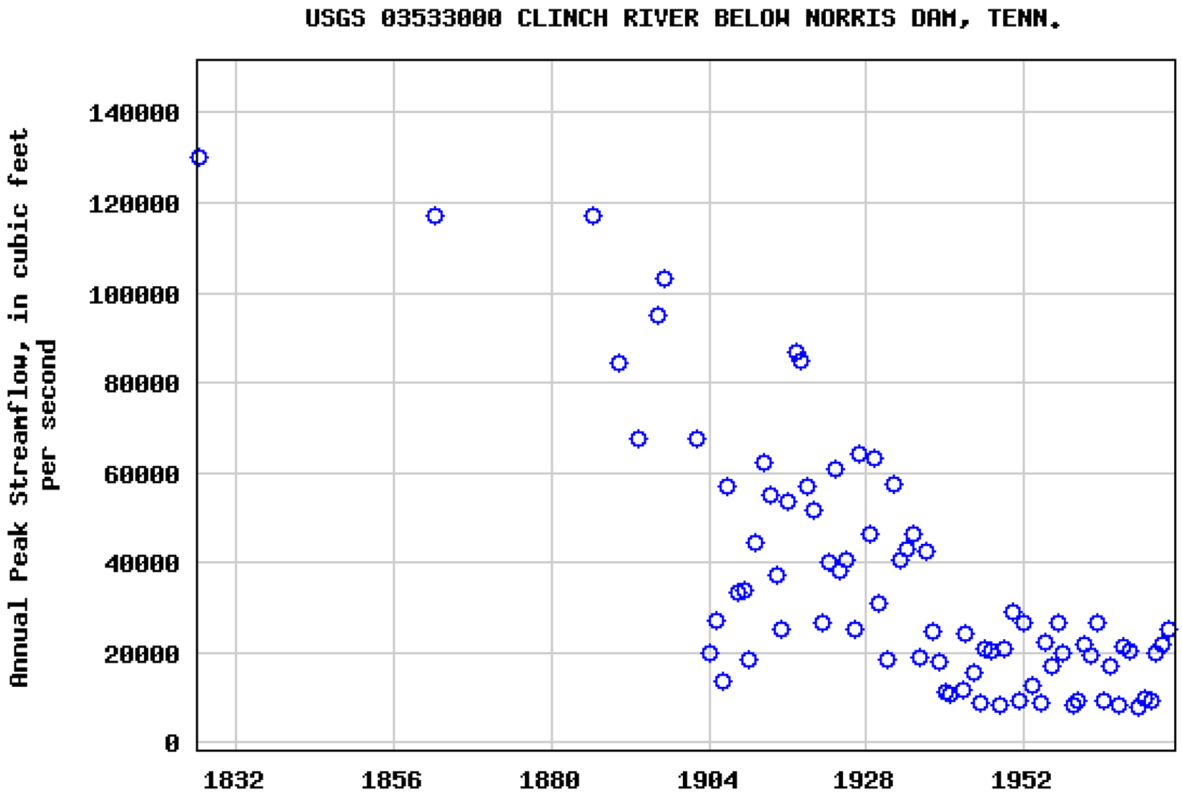
Primary Purpose
- Debris Control
- Fire/Farm Pond
- Fish and Wildlife
- Flood Control
- Hydroelectric
- Irrigation
- Navigation
- Recreation
- Tailings
- Water Supply
- Other

Streams and Waterbodies
Source: U.S. Geological Survey
Layer partially covered by another layer

Streams and Waterbodies
- Aqueduct, Canal, Ditch, Intracoastal Waterway, or Stream
- Bay, Estuary, or Ocean
- Canal, Lake, Reservoir, or Stream
- Dam
- Dry Lake
- Glacier
- Intermittent Lake or Reservoir
- Swamp or Marsh

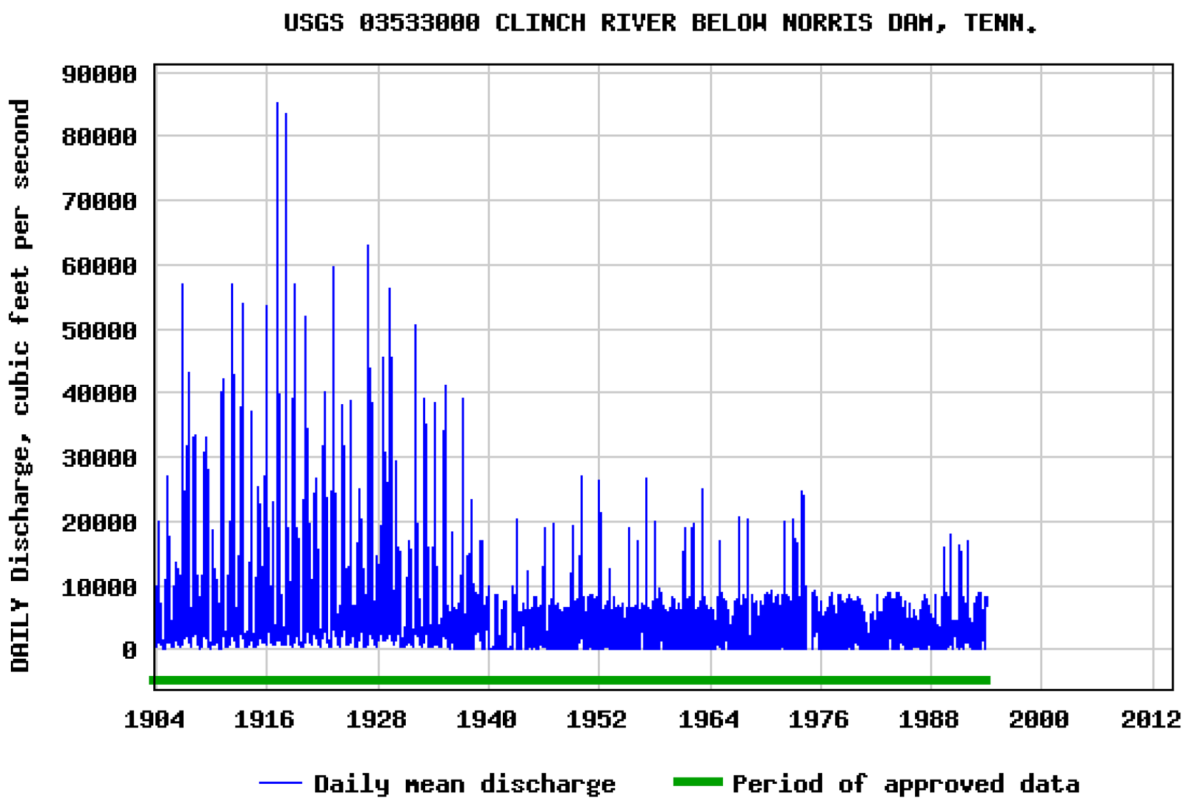
Source: Reference 2.4.9-19

Figure 2.4.9-5. (Sheet 2 of 2) Landslide Incidence and Susceptibility Map Near the Clinch River Nuclear Site



Source: Reference 2.4.9-17

Figure 2.4.9-6. Temporal Variations of Annual Peak Stream Flows in the Clinch River Below Norris Dam, Before and After Dam Construction in 1936



Source: Reference 2.4.9-17

Figure 2.4.9-7. Temporal Variations of Daily Mean Discharge in the Clinch River Below Norris Dam, Before and After Dam Construction in 1936