Hindcasting, forecasting, and controlling erosion at the Western New York Nuclear Service Center

Lee M. Gordon
New York State Energy Research and Development Authority, West Valley, NY 14171
LMG@nyserda.ny.gov

Christopher S. Andrzejewski
New York State Energy Research and Development Authority, West Valley, NY 14171
CSA@nyserda.ny.gov

Paul J. Bembia
New York State Energy Research and Development Authority, West Valley, NY 14171
PJB@nyserda.ny.gov

INTRODUCTION

The Western New York Nuclear Service Center (Center), comprising 3,340 acres approximately 30 miles southeast of Buffalo, New York (Figure 1), is the site of the only commercial nuclear fuel reprocessing facility that has operated in the United States. As a result of reprocessing activities and shallow-land disposal of radioactive waste, significant inventories of long-lived radioactive materials are present at the site. Although significant decontamination and decommissioning of site facilities has occurred over the past two decades and continues today, the state and federal agencies managing the site are evaluating a range of options between in-place closure and removal of the remaining facilities and contamination. In order to evaluate decommissioning options for the site, the agencies are working to better understand how erosion has shaped the site in the past and how it will continue to do so far into the future. Given inherent uncertainties in hindcasting/forecasting of erosion and the dynamic nature of the local upland stream systems, it is appropriate that the current focus of erosion controls be on the near-term (decades) in areas close to critical site facilities.

GLACIAL GEOLOGY

The Center is located almost entirely within the 29 mi^2 watershed of Buttermilk Creek (Figure 1), a tributary to Cattaraugus Creek that empties into Lake Erie approximately 40 miles downstream of the Center. The watershed generally occupies a shale and sandstone valley scoured by glaciation of the area. Repeated glaciations have veneered and filled the valley with tills, lacustrine sediments, morainal deposits and outwash. The till buries the bedrock valley to a depth of up to 500 ft (150 m) along the valley axis. The till is thinner on the hillsides and bedrock is nearly exposed on the hill summits peripheral to the watershed.

THE ONSET OF INCISION

Post-glacial incision of Buttermilk Creek and its tributaries is thought to have begun in the Late Wisconsinan, shortly after the retreat of the Lavery ice, although direct evidence obtained in the vicinity of the Center has been elusive. Lafleur (1979) dated a high stream terrace suggesting incision of Buttermilk Creek was underway by about 11,500 years before present (YBP). Organic material associated with Defiance-Lake Escarpment outwash to the north of the Center suggests final ice retreat in the area occurred no later than 17,700 YBP (Calkin and Miller, 1977; note ^{14}C [radiocarbon] years are corrected to calendar years before present following Fairbanks et al., 2005). Recently, wood fragments found near the surface of the till plateau adjacent to Buttermilk Creek (Figure 2) indicate a meltwater environment may have still been present until about 14,000 - 14, 600 YBP. These particular wood fragments were not found in fluvial deposits; they were located approximately 0.5 - 1.0m below the surface within homogenous clay deposits. The wood fragments were colocated with very thin, horizontal deciduous leaf mats, suggesting deposition in meltwater/backwater. Once the ice retreated, thus opening northern (Buttermilk Creek) drainage, it is unclear what other mechanism could have emplaced these materials in such a manner at this particular location. Given this information, the onset of incision of Buttermilk Creek may have occurred between 14,000 and 15,000 YBP. As ice retreated further out of the Erie and Ontario Basins, the lowering lake levels would have occasioned the final dissection of the regional plateau drainage by the west-flowing Cattaraugus Creek, which serves as the current local baselevel for the Buttermilk system.

DENUDATION RATE(S)

The timing of ice retreat and onset of incision of Buttermilk creek is important to understanding downcutting rates within the system. Buttermilk Creek has eroded approximately 55m (180 ft) near its confluence with Cattaraugus Creek. Previous estimates using Lafleur's (1979) radiocarbon date of a high stream terrace put average downcutting at approximately 4.8 m/1,000 yr. Given the upper bound date described above (~14,500 YBP) yields a slower average rate of 3.7 m/1,000 yr. These limited data, while constraining to some degree the timing of incision onset, provide no information about changes in the incision rate through time, possible variability in incision rate throughout different parts of the watershed, or about the watershed's baselevel history near its confluence with Cattaraugus Creek (Trip Stop 6). While the existing conceptual model for landscape evolution at the site assumes a constant rate of downcutting, Lafleur (1979) notes that incision rates are expected to slow over time, particularly in reaches where the glacial sediment substrate becomes increasingly armored by clast lag buildup. Further, quartz-based optically stimulated luminescence (OSL) data collected at various terrace elevations along Buttermilk Creek suggest the incision of Buttermilk Creek was much more rapid early in its development (as much as 20x as rapid) than occurs today (USDOE, 2010).

A prominent feature of the Buttermilk Creek watershed topography is a hanging abandoned meander on the west side of the valley near the Center, ~ 20m below the till plateau and ~30m above the valley floor (Trip stop 5, Figure 2). The elevation of the meander suggests it represents a point in time when approximately 40% of the total incision observed today had occurred. OSL dated samples from the top of the till plateau and within the abandoned meander date both features to ~17,000 YBP. Recently collected ^{14}C samples date the top of the plateau at ~14,000 YBP and the meander at ~5,200 YBP. While the OSL data implausibly suggest the first 40% of incision occurred instantaneously, the ^{14}C data suggest the first 40% of incision occurred over a 9,000-year timeframe, the remaining 60% of incision having occurred in the last 5,000 years. It is obvious that additional dating studies are needed to better constrain both the onset of incision and changes in the incision rate over time and space. Samples near the watershed outlet could be particularly valuable for understanding baselevel history.

AGGRADING AND DEGRADING STREAM TERRACES

An interesting follow on discussion is the apparent absence of any net incision at locations within the Buttermilk Creek watershed and neighboring Connoisarauley Creek watershed over the past 1,000 to 2,000 years. This conclusion is drawn from age-dating a number of eroding stream terraces at the valley floor. As the channel sweeps laterally within the valley, remnant stream terraces are exposed and eroded. Within these terraces, exposed wood at the present day level of the stream consistently dates to approximately 1,000 to 2,000 YBP (Trip Stop 7, Figures 4 and 5), indicating that while the stream system may have migrated laterally a great deal during that timeframe, it has not appreciably incised (net incision). Moreover, the terraces being eroded at present stream level appear to be of a much larger scale than those being created within the system at present (Figure 6). These eroding terraces appear to be valley-filling aggradational units of sorted fluvial material, suggesting that while these materials were deposited by flowing water (not landslide or mudflow deposits) it was deposited in a fluvial regime not resembling the one we see today.

DISPOSAL AREA IMPLICATIONS

The large tributaries to Buttermilk Creek have dissected and incised the Lavery till plateau and generally occupy steep, deep V-shaped valleys lacking any floodplain. The discussion that follows focuses on the large Buttermilk Creek tributary known as Frank's Creek and its smaller tributary Erdman Brook (Figure 7). The convex longitudinal profile of Frank's Creek/Erdman Brook (Figure 8) is interpreted to mean that the system is inherently unstable and will continue to incise even if the baselevel at the confluence does not change. The instability is evidenced by the continued headward incision and dissection of the landscape, coupled with valley widening. The development and migration of knickpoints appear to drive much of the development of Buttermilk Creek's tributaries. As knickpoints incise the stream, adjacent slopes are over-steepened, and mass wasting in the form of small slides, slumps, and rotational failure serves to widen the valley (Trip Stop 4 to active landslide).

Near the headwaters of many of Buttermilk's tributaries, there is a sharp transition from a deep V-shaped valley to a more broad U-shaped valley, which coincides with a change in the longitudinal profile of the stream to a gentler grade (Figure 8). In Erdman Brook and Frank's creek, this transition has generally mirrored the location of large knickpoints (Trip Stops 2 and 3, Figures 11 and 12). Upstream of the transition/knickpoints, the floodplains occupy a wide, flat valley bottom, and in many cases (typically in wetland areas), a defined stream channel is not evident. While the V-shaped reaches are incised in Lavery till, the upland U-shaped reaches have been filled with 1 m to 3 m of fine-grained sediment in the recent past, evidently by beaver dams (Figures 11 and 12). Beaver dams are common in the area and effectively result in deposition of large amounts of sediment in these upland stream reaches. Beaver dams/ponds also serve as a natural means of erosion protection, providing grade control and energy dissipation. In order to monitor and manage the streams in a stable condition, beavers (and their dams) have been removed from Frank's Creek and Erdman Brook since the development of the Center (1960s). In the absence of beaver dams to hold the deposited sediments in place, knickpoints moving upstream out of the V-shaped reaches have encountered the highly erodible deposits, and over the past ~50 years have incised more than 100 m of both Erdman Brook and Frank's Creek. As these knickpoints have moved closer to the radioactive waste disposal areas, the state and federal agencies managing the site have taken steps to control the erosion.

On both Erdman Brook and Frank's Creek a number of grade-control structures have been installed during 2009-2013. The structures are typically based on a pool-riffle design with incorporated anchored grade control (Trip Stops 2 and 3, Figures 13 and 14). At knickpoint brinkpoints, interlocking subsurface concrete block walls have been installed perpendicular to the stream valley and keyed into the Lavery till that underlies the more erodible surface deposits. These walls extend outward from the center of the valley to the extent of the 100-year floodplain. Immediately downstream of these grade-control walls, the knickpoint scour pools have been reshaped and armored, and designed to outflow into engineered rock riffles. These structures, while relatively new, have functioned as designed with minimal maintenance, and should protect these localized reaches from erosion over the next several decades -- an appropriate nearby and near-term focus for erosion control, absent a better understanding of the system over millennial timeframes.

CONCLUSION

Converging lines of evidence suggest the existing simple conceptual model of Holocene landscape development may not adequately describe the evolution of the Buttermilk valley in a manner that allows for meaningful long-term erosion forecasts. As the state and federal agencies at West Valley continue to safely manage the site and conduct decommissioning activities, we are also focusing effort on developing a better understanding of the history of the Buttermilk Creek basin. This work may eventually lead to the development of longer-term, basin wide erosion forecasts and broader erosion control strategies. In the meantime, the agencies will continue to deploy, monitor, and maintain decade-scale, local controls, which are proving to be effective at mitigating erosion in the tributaries adjacent to critical site facilities

REFERENCES CITED

Calkin, P.E., and K.E. Miller, 1977. Late Quaternary Environment and Man in Western New York. Annals of the New York Academy of Sciences, 288: 297-315

Fairbanks, R.G., R.A. Mortlock, T.C. Chiu, L. Cao, A. Kaplan, T.P. Guilderson, T.W. Fairbanks, A.L. Bloom, P.M. Grootes, and M.J. Nadeau, 2005. Radiocarbon Calibration Curve Spanning 0 to 50,000 Years BP Based on Paired $^{230}Th/^{234}U/^{238}U$ and ^{14}C Dates on Pristine Corals. Quaternary Science Reviews, v. 24, 1781-1796

Lafleur, R.G., 1979. Glacial Geology and Stratigraphy of Western New York Nuclear Service Center and Vicinity, Cattaraugus and Erie Counties, New York. US Geological Survey, Open File Report 79-989.

United States Department of Energy, 2010. Final Environmental Impact Statement For Decommissioning and/or Long-Term Stewardship at the West Valley Demonstration Project and Western New York Nuclear Service Center (DOE/EIS-0226).

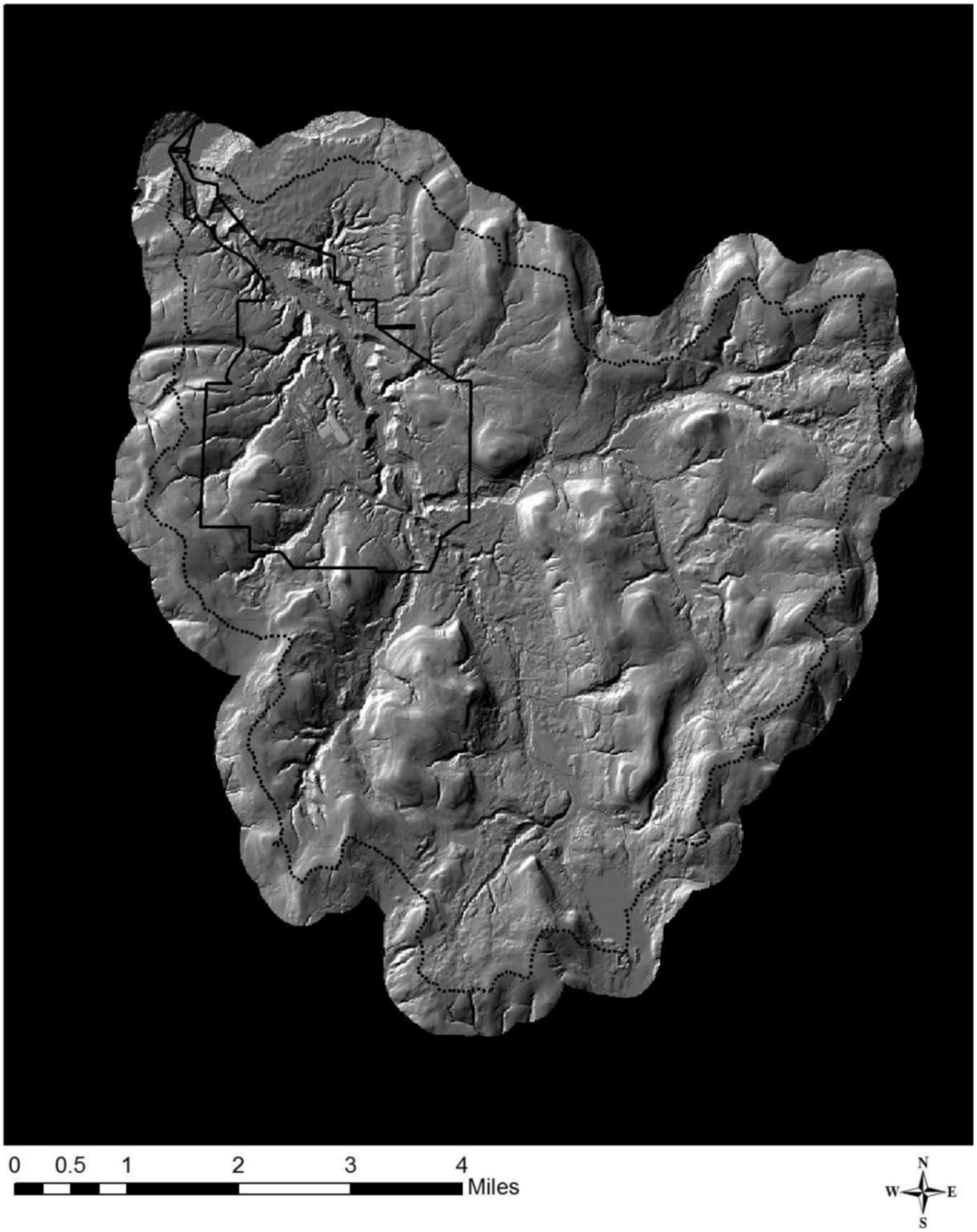

Figure 1: LiDAR-derived hillshade relief of Buttermik Creek watershed (outer dashed line) and Western New York Nuclear Service Center (inner solid line).

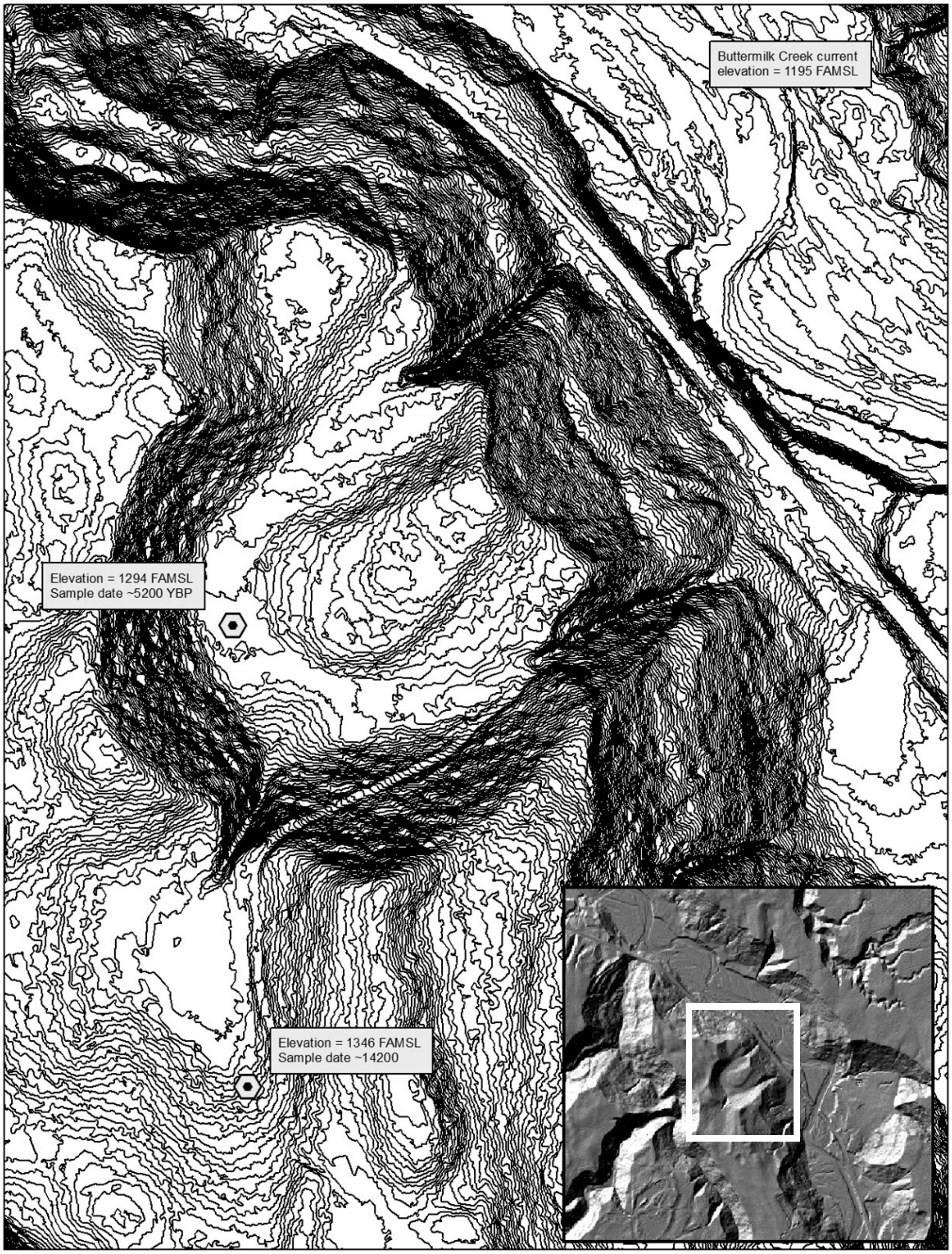

Figure 2 - LiDAR l.Oft contour lines depicting hanging cutoff meander on Buttermilk Creek valley wall. Two dated wood sample locations are identified.

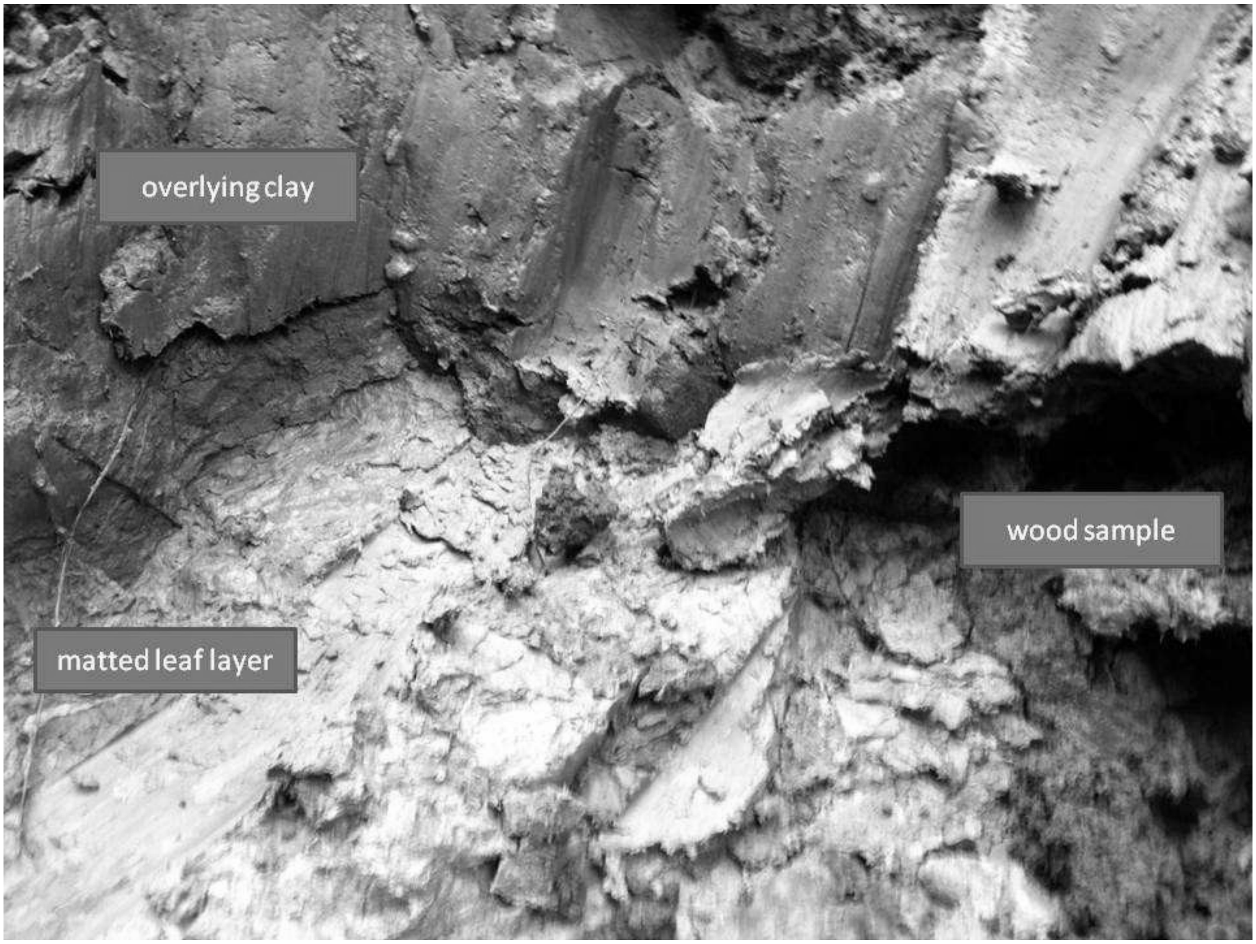

Figure 3 - Wood sample collected near top of till plateau at 0.89m deep (bottom). Samples were found in homogenous clay deposits colocated with mats of deciduous leaves. Three samples date to ~14,200 YBP.

Figure 4 - Large wood sample at base of ~3m terrace at interface between Lavery till and fluvial cobbles. Wood sample dated to ~2,300 YBP. Sample in Connoisarauley Creek, which occupies the next watershed to the west of Buttermilk Creek.

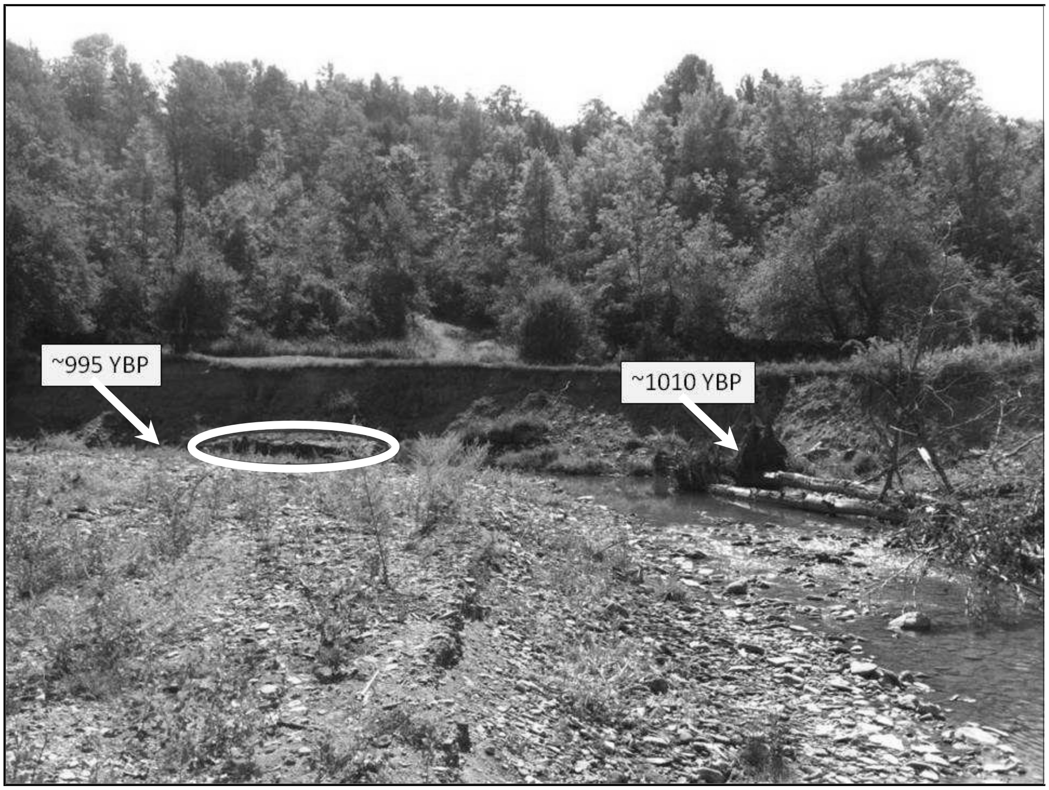

Figure 5 - Eroding terrace in Connoisarauley Creek. Two wood samples from the base of the terrace date to ~995 YBP and ~1010 YBP. A Lavery till outcrop is circled.

Figure 6 - "Valley-filling" fluvial terrace on Buttermilk Creek, a ~4.0m high aggradational feature. Intact lavery till can be found at the base of the terrace. A wood sample excavated at the base of the red pole dates to ~520 YBP.

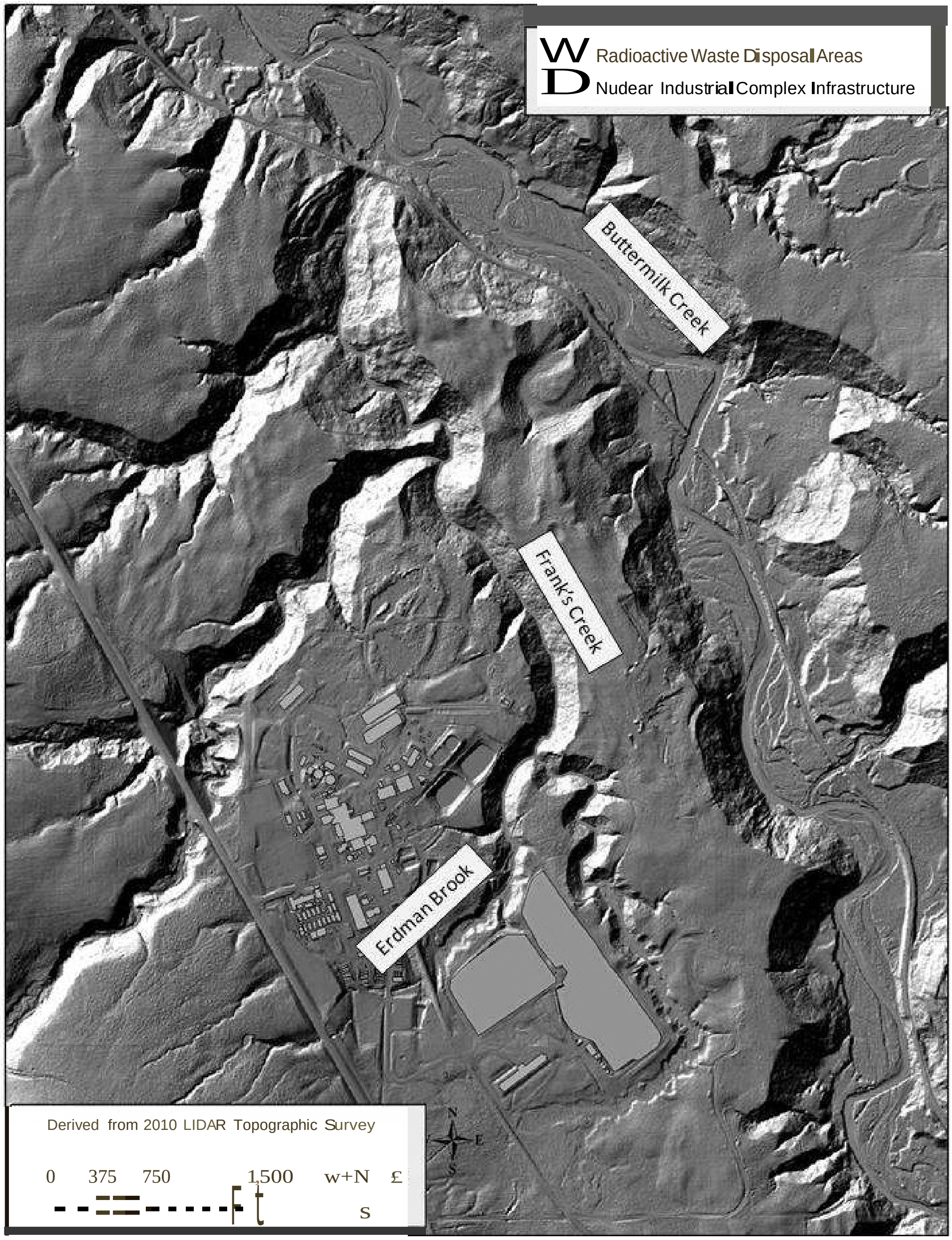

Figure 7 - Hillshade topography highlighting Buttermilk Creek and tributaries Frank's Creek and Erdman Brook and their proximity to the radioactive waste disposal areas and the infrastructure ofthe industrial complex

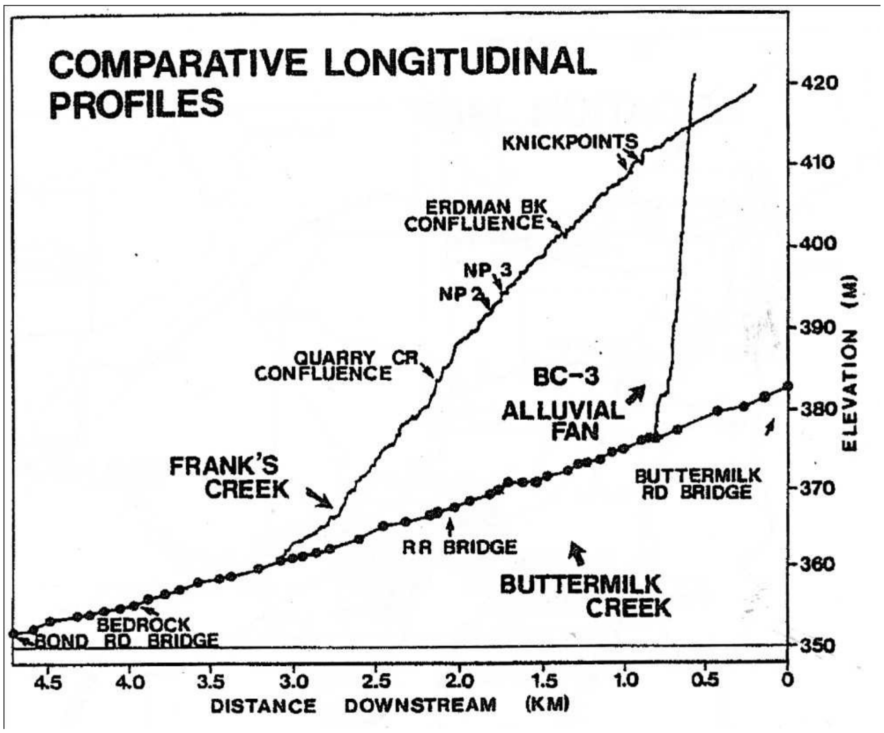

Figure 8 - Longitudinal profiles of Buttermilk Creek, Frank's Creek, and a small valley wall alluvial fan (Boothroyd et al., 1982)

Figure 9 - Active knickpoint on Erdman Brook. Stained gravel layer at waterline marks interface between fine-grained fluvial deposits (above) and Lavery till (below). Exposed branch below waterline dates to ~400 YBP. Total knickpoint height is ~1.5m.

Figure 10 - Active knickpoint on Frank's Creek. Stained gravel layer marks interface between fine-grained fluvial deposits (above) and Lavery till (below). Exposed branch dates to ~180 YBP. Total knickpoint height is ~2.5m.

Figure 11 - Beaver dam constructed on Frank's Creek near the radioactive waste disposal areas.

Figure 12 - Log exposed by migrating knickpoint in Frank's Creek shows evidence of having been felled by beavers. Log had been covered by approximately 2 meters of fine-grained deposits and was resting on intact Lavery till. Log dates to approximately 220 YBP.

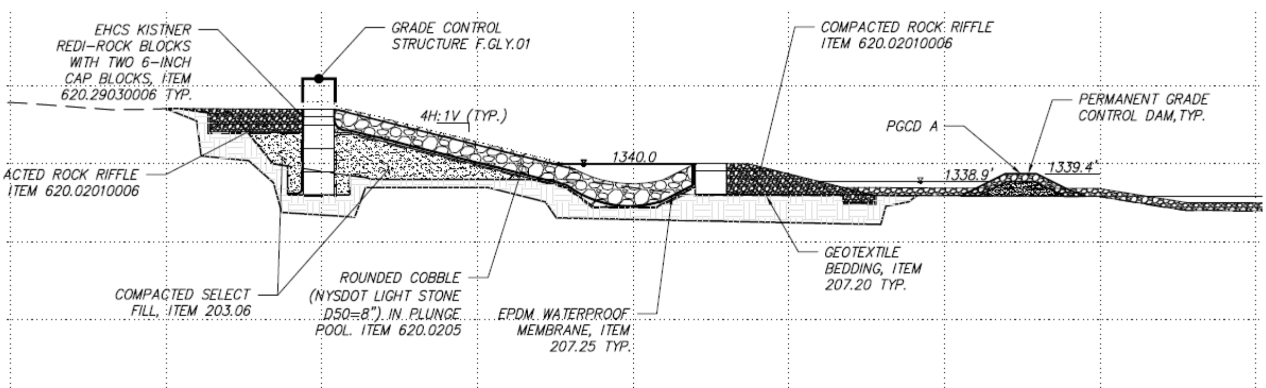

Figure 13 - Typical erosion control structure design with anchored grade control wall and pool-riffle sequence.

Figure 14 - Erosion Control Structures Installed on Erdman Brook. Shown are a series of pools and riffles. Looking downstream.

Trip Stops

Stop #1. The Ashford Office Complex, 9030 Route 219, West Valley, NY (Lat: 42.396014, Long: -78.674458): Trip participants will meet at the office of the New York State Energy Research and Development Authority to sign visitor forms and watch a safety video.

Travel to and enter **West Valley Demonstration Project (WVDP) and Western New York Nuclear Service Center (WNYNSC), 10282 Rock Springs Rd., West Valley, NY 14171** (Lat: 42.448975, Long: -78.657178): **Note: In order to enter the WVDP and WNYNSC, you are required to be escorted at all times by a NYSERDA employee.**

Stop #2. Erdman Brook Erosion Controls: Grade control and armored pool-riffle sequences for mitigating knickpoint erosion. Installed 2009-2012.

Stop #3. Franks Creek Erosion Controls: Grade control and armored pool-riffle sequence for mitigating knickpoint erosion. Installed 2013.

Stop #4. Buttermilk Creek Active Landslide: 180' landslide on west bank of Buttermilk Creek. Last major slide event during flood of August 9, 2009. Exposures of glacial till and lacustrine sediments.

Stop #5. Abandoned Hanging Meander: A 5,000-year old cutoff meander high on the valley wall.

Leave WVDP/WNYNSC.

Stop #6. Scoby Dam, Scoby Hill Rd., Springville, NY (Lat: 42.481144, Long: -78.700192): Visit Cattaraugus Creek near the confluence with Buttermilk Creek for discussion of baselevel control.

Stop #7. Connoisarauley Creek, Connoisarauley Rd. North, West Valley, NY (Lat: 42.448189, Long: - 78.715517) : Visit large stream terraces for discussion of aggradation/degredation over past 1000 years.