Issues the Core Team Needs to Address

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January 15, 2008

These comments provide an outline of four issues that the Core Team needs to address, if they have not already done so, as a prerequisite for any defensible proposal of a preferred alternative for decommissioning of the West Valley Demonstration Project and Western New York Nuclear Service Center. These four issues are not intended to be a comprehensive list of items needed for a defensible proposal of a preferred alternative, but they are crucial points, especially given the West Valley site's well-known sensitivity to water-related impacts such as erosional impacts from geomorphic downcutting, mass wasting, etc.

These four issues, if not already addressed, should have been on the Core Team's "radar screen" from the outset, based on the professional expertise of its members. The issues are not obscure. The West Valley Citizen Task Force has been attempting for several months to bring these issues to the Core Team's attention through a more convenient and interactive process (presentation to the Core Team at one of its meetings) but has not been allowed to do so; hence this written format. My own schedule during the past several months has been too busy to allow me to prepare these written comments until now. I regret the delay but reiterate that these are issues of which the Core Team should already be cognizant based on its members' scientific expertise.

The four issues, discussed below in more detail, are:

1. *Faults and seismic risk do not appear to be sufficiently characterized at the West Valley site to provide a reasonable understanding of long-term slope stability.* The seismic shock of earthquakes is a well-known cause or catalyst for slope failures. Seismically induced slope failures are a particular concern for this site because they greatly accelerate the erosional processes that will eventually undercut, expose, and release low-level, transuranic, Greater-Than-Class-C, and high-level wastes buried at the site. Seismic events can trigger near-instantaneous downslope movement of earthen materials, and the associated backcutting of ravine edges, that would take centuries under more ordinary erosional conditions.

2. *Current proposals to calibrate erosion modeling against the past several millennia of postglacial erosion cannot succeed unless postglacial uplift and the sequence of postglacial base levels are taken into account.* Lake Erie and its drainage basin have undergone very substantial differential uplift (glacial rebound) during the past several millennia, as is well known. The importance of uplift is well known to erosion modelers. The postglacial drainage history of the Cattaraugus Creek watershed has been discussed in the scientific literature and is at least approximately understood, and the associated base-level history of the Buttermilk-Franks tributaries can thus be inferred reasonably well. These complex histories are crucial parts of, and must be incorporated into, any erosion-model calibration. The importance of base level is well known to erosion modelers.

3. *Current proposals to calibrate erosion modeling against the past several millennia of postglacial erosion, and to conduct erosion modeling for several millennia into the future, cannot produce reasonable results unless both paleoclimate and future climate are estimated reasonably accurately.* As is well known, climate has not been uniform over the past several millennia; model calibration needs to reflect what is known. The best available predictions of future climate show a higher frequency of extreme events (including more severe droughts, more severe storms, etc.), as is increasingly evident in present-day weather events. These trends also need to be taken into account in a reasonable manner. The importance of climate is well known to erosion modelers.

4. *Performance assessments for various critical systems at the West Valley site cannot be defensibly based on deterministic risk assessment; they need to be based on probabilistic risk assessment.* Many of the decommissioning decisions for restricted release at the West Valley site require complex chains of logic, involving poorly constrained input parameters, to demonstrate that site integrity can be maintained for millennia in the absence of institutional controls. There is no reasonable way to apply purely deterministic risk assessment to such decisionmaking.

Faults and seismic risk in relation to slope failures

A seismic survey by Bay Geophysical (2001), conducted on behalf of West Valley Nuclear Services Company in response to comments by Vaughan (1996) and others, has identified two deep-seated faults near the West Valley site. These previously unacknowledged faults, termed the "Sardinia feature" and the "Cattaraugus Creek feature," are interpreted as being present in both the Precambrian basement and overlying Paleozoic bedrock. Both "appear to exhibit displacement extending from the Precambrian basement into the middle and potentially the upper Paleozoic section of the stratigraphic section." However, due to the limited scope of the work conducted by Bay Geophysical (2001), many questions remain unanswered about these faults. Neither the strike nor the extent is known for either fault (in other words, there is currently no reliable information on the geographic direction or the geographic extent of either one), so there is currently no way to know whether either fault extends close to, or directly beneath, the West Valley site. Other unanswered questions are whether future seismic activity or "reactivation" may occur on either fault, and, if so, what is the likely relationship between earthquake magnitude and recurrence interval. All of these questions are susceptible to investigation, and reliable answers are needed to understand whether future seismic activity poses a serious risk to site integrity.

The fault known as the "Cattaraugus Creek feature" has been mapped (Bay Geophysical 2001, Fig. 4-1) immediately north of the US 219 bridge over Cattaraugus Creek. Coincidentally or otherwise, this is the same location where severe landsliding, said to be reactivation of an ancient landslide. has recently occurred (Bonfatti 2007). Three faults of small displacement, visible in the gorge of Cattaraugus Creek near this location (Vaughan et al. 1993), may potentially be surface expressions of the "Cattaraugus Creek feature." The mapped location of the fault is roughly 3 miles or 5 km from the West Valley site; however, as noted above, it is not yet known whether the fault extends closer to the site. See Vaughan (2005) for further discussion of possible fault relationships in the vicinity of this fault.

The fault known as the "Sardinia feature" may potentially be the southwestward extension of a known fault, the Attica Splay of the Clarendon-Linden Fault. If so, the potential for reactivation of the "Sardinia feature" would appear to be high, based on the well-known 1929 Attica earthquake and other, smaller-magnitude seismic activity on the Attica Splay. However, the current lack of information on the strike and geographic extent of the "Sardinia feature" does not allow reliable conclusions to be drawn about either its connection with the Attica Splay or its nearest approach to the West Valley site. Its mapped location near Sardinia, NY (Bay Geophysical 2001, Fig. 4-1) is roughly 10 miles or 16 km from the West Valley site; however, if this fault is indeed a southwest continuation of the Attica Splay, its southwestward projection from Sardinia implies an approach much closer than 10 miles to the West Valley site. See Vaughan (2005) for further discussion of possible fault relationships in the vicinity of this fault.

Effects on slope stability are a primary reason why seismic activity needs to be well understood at the West Valley site. The site is highly susceptible to both erosion and slope failures (for example, see DOE and NYSERDA 1996, including Figures 4-13 and L-1; Albanese et al. 1984; Boothroyd et al. 1979; Boothroyd et al. 1982); however, seismically-induced slope failures have not been adequately addressed (see Vaughan 1996) and cannot be reliably addressed without a better understanding of faults, seismicity, and recurrence intervals in the immediate vicinity of the West Valley site.

The connection between slope failures (i.e., landslides of various types) and earthquakes is well-known (Sidle et al. 1985; Keller 1985). The 1964 Alaska earthquake produced slope failures on a massive scale (see photos in Hansen 1971, attached hereto as Appendix C), but smaller seismic events may also cause failures on susceptible slopes. Sidle et al. (1985) note that, "For most landslides that were initiated by earthquakes, the direct physical and mechanical influence of the ground motions appeared sufficient to generate failures on slopes that were in a delicate state of balance." The "delicate state of balance" criterion seems to be met at the West Valley site, given the many slope failures that are presently occurring at the site without additional seismic enhancement (DOE and NYSERDA 1996, including Figures 4-13 and L-1; Albanese et al. 1984; Boothroyd et al. 1979; Boothroyd et al. 1982). The main impact of seismically induced slope failures at the West Valley site under loss-of-institutional-control scenarios would be an intermittent acceleration of the backcutting of ravine edges. Such accelerated backcutting of ravine edges would expose buried wastes more rapidly than under normal erosional conditions.

Slope failures elsewhere in western New York State, including locations close to the West Valley site, may be instructive. See discussion in Vaughan (1994), including information on unstable lacustrine sediments (similar to quick clays) observed north of Springville, NY, by Owens et al. See also Gephart-Ripstein (1990) for a review, based on anecdotal and historical sources, of earthquakes and slope failures in Wyoming County, NY. Some of the earthquakes cited there are apparently not listed in standard modern earthquake catalogs. The slope failures reviewed by Gephart-Ripstein (1990), typically involving 6 to 20 acres, are not explicitly linked to earthquakes yet are of interest because some are located along the Tonawanda Creek valley between Attica and Varysburg, NY. This creek valley, apparently structurally controlled, follows the Attica Splay of the Clarendon-Linden Fault (see Fakundiny et al. 1978; Fakundiny and Pomeroy 2002). Despite the lack of explicit linkage to seismicity, the slope failures may be fault-related if the fault serves as a conduit for fluid flow.

Postglacial uplift and base levels

The Lake Erie drainage basin has experienced a very high rate of differential uplift (glacial rebound) during the postglacial period. As can be seen from Newman et al. (1981), the Great Lakes are within an area that experienced one of the highest uplift rates anywhere in the world during the past several thousand years. Holcombe et al. (2003) provide a more detailed view of the uplift, particularly the differential uplift, for Lake Erie. The net effect, recognized for more than a century (see Tarr 1897), is that the eastern end of Lake Erie has risen tens of meters relative to the western end during the past several thousand years. Holcombe et al. (2003), p. 693 and Fig. 8b, infer a differential uplift of 45 m over a horizontal distance of 100 km during the past 13,400 years. This uplift rate applies to the eastern basin of Lake Erie, which is the portion of the lake into which Cattaraugus Creek drains. Tarr (1897), p. 113, infers a somewhat lower uplift of about 1 foot per mile at the eastern end of the lake. These rates, while they cannot be applied verbatim to the generally parallel and immediately adjacent drainage basin of Cattaraugus Creek, serve as a reminder that the differential rates of uplift for Cattaraugus, Buttermilk, and Franks Creeks are likely to be high and need to be established with reasonable accuracy for any erosion modeling runs conducted for the postglacial period.

Not only the intra-watershed differential uplift but also the regional uplift and associated base levels need to be established for modeling runs. Tucker and Bras (1998), for example, use a parameter *U* to represent the uplift or base lowering rate; this parameter, which they equate with the steady-state erosion rate, is incorporated into key equations of their model.

Even without the added complication of differential uplift, the sequence of postglacial base levels for the drainage areas that we now identify as Cattaraugus, Buttermilk, and Franks Creeks is complex. During and after glacial retreat, drainage along today's west-flowing Cattaraugus Creek was blocked for some period of time. Flow was initially blocked by the ice dam of the glacier face and subsequently by a sequence of rock and/or ice dams that persisted until downcutting of today's Zoar Valley gorge (between Zoar Bridge and Gowanda, NY) was achieved. Impounded water, called "Lake Cattaraugus" for purposes of this discussion, persisted for some period of time and served as the sporadically decreasing base level for the drainage areas that we now identify as Buttermilk and Franks Creeks. This "Lake Cattaraugus" base level fell as new outlet channels for the lake became available, following the sequence described by Fairchild (1932). Briefly, this sequence starts with glacially impounded meltwater in the eastern part of today's Cattaraugus Creek basin; the surface of this initial glacial lake was about 1640' above modern sea level, corresponding to the elevation of the lowest terrain (near Machias, NY) over which water could flow out of the glacial impoundment. As the glacier retreated west and north, the level of "Lake Cattaraugus" fell progressively as the receding ice uncovered lower outlet channels at Ellicottville (1620'), Little Valley (1610'), New Albion (1440'), Persia (1320'), and finally Perrysburg (1300' and lower). However, when the level of "Lake Cattaraugus" dropped to roughly 1200', it was rock-dammed by the "Zoar Valley" bedrock into which the spectacular modern gorge had not yet been cut. Downcutting through the shale bedrock, no doubt aided by existing joints and small splays of Bass Island Trend faulting, was required before Cattaraugus Creek could flow westward through its modern channel. In the interim, "Lake Cattaraugus" remained the base level for the drainage areas that we now identify as Buttermilk and Franks Creeks.

Any landscape evolution modeling of the postglacial period needs to make reasonable assumptions about the duration of each "Lake Cattaraugus" base level *and also needs to make a differential-uplift adjustment or correction to each of the base-level elevations cited above.* Fairchild (1932) assigns the modern elevation above sea level to each of his outlet channels (e.g., 1300' at Persia, NY), but an early post-glacial "Lake Cattaraugus" surface level that matches a modern 1300' elevation at Persia is not likely to match a modern 1300' elevation in the drainage areas that we now identify as Buttermilk and Franks Creeks. Differential uplift requires some amount of correction, including both an initial adjustment and an ongoing, time-varying adjustment. Such adjustments are not necessarily large but may be important for a landscape evolution model whose initial condition "is a nearly flat surface seeded with a small random perturbation in the elevation of each cell" and where the boundary condition "is a single fixed outlet in one corner" whose base level is apparently lowered at a rate U (Tucker and Bras 1998). The "nearly flat surface" assumed as an initial condition is not likely to remain flat and horizontal as differential uplift proceeds. (Phenomena such as stream capture or flow reversal may occur as the surface tilts.) The rate U needs to be tied to both the changing elevation of the "Lake Cattaraugus" outlet and the elevation correction needed to compensate for differential uplift between the lake outlet and model outlet.

Paleoclimate and future climate

The relationship between precipitation and erosion is very non-linear. Much greater erosion occurs when a given amount of rain falls during a short time (e.g., in an intense storm) than when the same amount of rain falls gently over an extended period. Part of the reason is the difference in velocity, and especially the difference in kinetic energy, of the water flowing though stream channels in the two different cases.

Because erosion is so dependent on the rate at which precipitation is delivered, erosion modelers need to 1) model the precipitation-erosion relationship accurately, using appropriate algorithms in their computer code, and 2) use realistic precipitation data, or realistic sequences of assumed precipitation, for modeling runs that simulate either *past* or *future* erosion.

For example, any modeling of past erosion at the West Valley site (e.g., for model calibration purposes) needs to use realistic sequences of assumed precipitation that are based on, and consistent with, available paleoclimate information. Likewise, any modeling of future erosion at the West Valley site needs to use realistic sequences of assumed precipitation that are based on, and consistent with, a good understanding of climate change.

Two potentially useful sources of paleoclimate information, not intended to be exhaustive, are Noren et al. (2002) and Holcombe et al. (2003). Based on sediments deposited in lakes in Vermont and eastern New York, Noren et al. (2002) identified four periods of intense storminess that occurred about 11,900, 9,100, 5,800, and 2,600 years ago. Interspersed between the second and third of these storm periods was the middle Holocene climatic optimum (9,000 to 6,000 years ago), during which "warmer temperatures and greater aridity" characterized the climate of the Lake Erie region, according to Holcombe et al. (2003). Such paleoclimate information provides guidance needed for modeling of past erosion at the West Valley site.

Any modeling also needs to ensure, in accordance with principles of mass balance, that a reasonable sink exists for water discharged from the model outlet. While this is not likely to impose a substantial constraint on modeling, and certainly would not be a constraint under today's drainage conditions where the Atlantic Ocean is the sink for water discharged from Cattaraugus, Buttermilk, and Franks Creeks, modelers should be aware that Holcombe et al. (2003) consider Lake Erie to have been a closed basin during part of the postglacial period. At times when the lake is considered a closed basin, the discharge flow rate of water from the outlet of a landscape evolution model should not be an disproportionate share of the flow that could reasonably be accepted by the closed lake basin.

Future climate inputs to erosion models must reflect the increasing frequency of extreme weather events, especially intense storms, that are a predicted consequence of climate change. Recent intense storms in New York and surrounding areas, regardless of whether they are early signs of this trend, provide perspective when compared to the most severe storm to affect the West Valley site in the past decade. This storm, whose 3.25" overnight rainfall produced noticeable erosion on the West Valley site and washed out part of Schwartz Road near the site, delivered a mere fraction of the rain that recent intense storms have brought to other locations such as Peterborough, Ontario (8" in July 2004), parts of PA-MD-VA (over 12" in June 2006), the Painesville, OH area (10-12" in July 2006), and north-central OH (9" in August 2007). Short-duration storms of this type are not uncommon and are likely to increase as climate change becomes more severe. (Part of the reason is simple: Warmer air can carry more moisture.) Thus, any modeling of future erosion at the West Valley site needs to incorporate these storm trends.

Probabilistic Risk Assessment

Probabilistic risk assessment (PRA), used by various industries and regulators, "allows analysts to quantify risk and identify what could have the most impact on safety." It "systematically looks at how the pieces of a complex system work together to ensure safety." (NRC 2007.) A complex system might consist of a space shuttle, all of whose components must function properly to ensure a productive mission and safe return to Earth, or it might consist of a nuclear waste disposal system, all of whose components must likewise work properly to protect public health and the environment. Members of the Core Team should recognize the applicability of PRA to complex waste disposal proposals (such as in-ground closure of grouted high-level waste tanks at the West Valley site) and should insist that PRA be used in preference to a "seat of the pants" approach.

PRA is a good way to analyze complex results, especially where there is uncertainty in the results and in the values that must be assumed to calculate results. PRA results "do not take the form of a single number. Instead, PRA provides a spectrum of possible outcomes. The frequency with which each of these outcomes is expected is a *distribution* of values." PRA results can often be summarized by a single representative value or *point estimate*, but PRA's main advantage is that it helps decisionmakers understand "how much larger or smaller the actual risks might be." (NRC 2007.)

The Nuclear Regulatory Commission has used PRA for many years for nuclear power plant analyses. According to NRC (2007), "PRA use is expected to continue growing as part of a longstanding NRC policy for increased use in all regulatory matters. This should result in a more predictable and timely regulatory approach throughout the agency." Even though NRC has not yet made an effort to apply PRA to the West Valley site, it should do so. PRA methods are needed at the site regardless of whether NRC sees its role as "regulatory." Other Core Team members need to ensure that PRA methods are adopted at the site *or need to be willing to discuss, in an accessible forum, why they are reluctant to do so.* Complex outcomes such as in-place closure scenarios at the West Valley site are ideal candidates for PRA; they would benefit from its structure and logic.

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