5.16 Shoreline Erosion

5.16.1 Introduction

Erosion caused by TVA system operations occurs in both the reservoirs and the tailwater riverine sections. This section analyzes the impacts of reservoir operation alternatives on erosion in reservoirs and tailwaters, and provides a relative ranking of the impacts of the alternatives.

5.16.2 Impact Assessment Methods

Erosion in reservoirs is primarily influenced by wave energy affecting the shoreline and dislodging soil particles. Wave energy is derived from two sources: wind-generated waves and boat-generated waves. Wind waves are a function of the wind velocity and the fetch, the open distance, across the reservoir along which waves can build energy. Boat-generated waves in TVA reservoirs are due to recreational boat traffic and commercial activities, such as barge traffic. In general, commercial boat traffic is more prominent on TVA mainstem reservoirs than on tributaries.

In reservoirs, the area that is subject to wave action at the highest normal reservoir elevations is of the most interest. This zone is now subject to modification by water, whereas areas down slope have been subject to wave action and exposure to weather for decades. This zone has property than can be affected by erosion, and is of most concern for cultural resources (see Sections 4.18 and 5.18, Cultural Resources). For this analysis, the shoreline erosion zone is defined as the elevations between the June 1 flood guide elevation and 3 feet below the June 1 flood guide.

Wave energy is particularly important in the shoreline erosion zone; boat waves are more frequent due to summer recreational use and there are known critically eroded areas in the shoreline erosion zone (see the description of TVA ALIS data in Section 4.16). Much of the shoreline considered "poor" in the ALIS data set has a vertical or steep bank that is vulnerable to wave action. Relatively gentle slopes distribute wave energy over a large area, while steep banks absorb all of the energy in a small area. If a reservoir is not held at a higher water elevation for as long, these areas do not see as much wave action, and the wave energy is generally distributed over less abrupt slopes. If the reservoir is not filled as full, these areas never see wave action, and the waves generally only affect areas that have already eroded to a flatter slope. Conversely, if the reservoir surface elevation is held in the shoreline erosion zone longer, erosion effects are exacerbated. Shoreline shape (convex vs. concave, and radius of curvature) and the angle of wave action relative to the shoreline can have a large affect on local rates of erosion. Combined with the wind exposure, this factor makes islands and peninsulas more prone to erosion than coves or straight shore lines.

Another form of erosion of concern in reservoirs is mass wasting. Mass wasting is the slumping, sliding, or toppling of sections of bank, caused by structural failure. An example of this is the slumping of cohesive, saturated soils from a steep embankment when water levels are dropped. Mass wasting is usually caused by erosion of the shoreline at the toe of the slope or by undercutting of steep slopes. The resulting slope failure may occur after drawdown, but is not caused by drawdown.

Raindrops that land on exposed, unvegetated soils can initiate the erosion process by dislodging soil particles from the force of raindrop impact on the ground. This process is of concern to the TVA reservoir shorelines in the drawdown zone between maximum pool elevation and winter pool elevation. This drawdown zone has been exposed to raindrop impacts for many decades. It is likely that where there is rocky soil or shallow soil over bedrock, most of these soils have already eroded. Erosion in the drawdown zone may cause minor water quality impacts, but there is generally less concern about this erosion because usable land is not lost by this process. Reservoir storage capacity is not lost because eroded material generally originates within the pool. Unlike the shoreline erosion zone, erosion conditions of the drawdown zone have not been surveyed.

At winter pool elevations, wave energy also affects the shore, which are often unvegetated bare soils. The lowest pool levels can expose the areas around the original stream banks, which are frequently more subject to erosion than thinner, stonier upland soils. On the other hand, boat traffic typically is considerably less in winter than in summer. As with the drawdown zone, the winter pool shoreline conditions have not been surveyed.

Another factor affecting shoreline erosion is potential removal of vegetative cover from the shoreline. As discussed in the SMI EIS, healthy stands of woody and herbaceous vegetation around a riparian zone of a reservoir provide substantial protection of the shoreline from erosion. Development of the shoreline that would modify the shoreline vegetative cover would adversely affect erosion. Modification of shoreline vegetative covers from development was not a major consideration in this analysis for the following reasons. As described in Section 4.16, TVA has permit authority through Section 26a of the TVA Act to require erosion control measures for any shoreline development. In addition, TVA has designated a finite amount of shoreline land that is available for development. Although each of the policy alternatives may slightly modify the anticipated buildout date of the land available for development (see Section 4.15, Land Use), this change is not anticipated to affect the overall erosion conditions of the reservoirs.

Erosion in tributary tailwaters generally takes two forms. Surface erosion is the detachment and transport of surface material by flowing water that affects both the bed and the banks of a stream when they are exposed to flowing water. Mass wasting, as described above, can also occur in tailwaters when shoreline soils are saturated and water levels are dropped, especially where banks are steep.

Because mainstem tailwaters are essentially the upstream end of the next downstream reservoir, erosion in both reservoirs and mainstem tailwaters are influenced more by wave energy, whereas tributary tailwaters are primarily influenced by the forces of flowing water. Therefore, separate analyses were conducted for reservoir and mainstem tailwater shorelines and for tributary tailwater shorelines.

The analysis conducted for this EIS considered the following elements to evaluate potential impacts of reservoir operations policy alternatives. Three primary factors were evaluated:

- Duration of reservoir elevations in the shoreline erosion zone. Longer periods at high pool levels would cause wave energy to exacerbate existing erosion.

- Changes in boat-wave energy from recreational boat activity and commercial barge operations. Longer periods at high pool levels would result in higher recreational boat traffic, which would accelerate the rate of erosion.

- Cumulative shear stress hours over a year. None of the alternatives would increase existing maximum tailwater flows, so peak shear stresses would remain the same. However, some alternatives would change the duration and balance between the annual peak flows and secondary peak flows and could result in higher net cumulative shear stress over the annual cycle, potentially resulting in increased erosion.

Other potential contributing factors that were considered include:

- Erosion of the drawdown zone between maximum pool elevation and winter pool elevation due to raindrop impact forces on bare unvegetated soils and from mass wasting of saturated soils from the drawdown action;

- Erosion of the shorelines at winter pool elevations, which may erode bare unvegetated shorelines;

- Development of the shoreline—removal of vegetation on the shoreline—can accelerate erosion; however, existing TVA policies and land management practices were anticipated to eliminate or render unsubstantial any differences in development-related erosion potential between the policy alternatives; and,

- Changes in reservoir surface area—higher reservoir levels create longer distances for wind energy to build up. None of the policy alternatives were anticipated to modify the surface areas of the reservoirs to the degree that a change in wind fetch would be measurable; therefore, this metric was not considered in the analysis.

Data used to evaluate the potential changes in erosion from the policy alternatives are summarized in the tables below.

Table 5.16-01 provides the percent change in the duration of reservoir pool levels in the shoreline erosion zone compared to the Base Case that is projected for each representative reservoir. The number of days at shoreline erosion zone elevations is an indicator of the relative impacts from wave energy affecting shorelines; higher values show a higher relative risk of increase in shoreline erosion.

Table 5.16-01 Comparison of Duration of Reservoir Surface Elevations in the Shoreline Erosion Zone of Policy Alternatives to Base Case for Representative Reservoirs

	Alternative							
	Reservoir Recreation A	Reservoir Recreation B	Summer Hydropower	Equalized Summer/Winter Flood Risk	Commercial Navigation	Tailwater Recreation	Tailwater Habitat	Preferred
Watauga	66.7%	241.7%	41.7%	166.7%	0.0%	75.0%	141.7%	33.3%
S. Holston	77.8%	111.1%	-22.2%	-22.2%	0.0%	155.6%	111.1%	77.8%
Boone	0.0%	-4.8%	-66.7%	-52.4%	0.0%	-4.8%	0.0%	4.8%
Cherokee	133.3%	200.0%	-16.7%	-100.0%	0.0%	200.0%	233.3%	50.0%
Douglas	27.3%	63.6%	-54.5%	-100.0%	0.0%	63.6%	127.3%	-9.1%
Fontana	71.4%	128.6%	-42.9%	-100.0%	0.0%	128.6%	171.4%	57.1%
Norris	100.0%	144.4%	-22.2%	-100.0%	0.0%	122.2%	166.7%	66.7%
Chatuge	42.9%	64.3%	-14.3%	-100.0%	0.0%	50.0%	114.3%	14.3%
Nottely	100.0%	137.5%	-12.5%	-75.0%	0.0%	100.0%	212.5%	50.0%
Hiwassee	33.3%	77.8%	-55.6%	-100.0%	0.0%	44.4%	122.2%	22.2%
Blue Ridge	53.8%	53.8%	-38.5%	-100.0%	0.0%	53.8%	153.8%	7.7%
Tims Ford	0.0%	15.8%	-57.9%	-100.0%	0.0%	15.8%	0.0%	0.0%
Ft Loudon	3.0%	3.0%	-45.5%	-27.3%	0.0%	3.0%	3.0%	0.0%
Watts Bar	3.0%	3.0%	-45.5%	-9.1%	-6.1%	3.0%	3.0%	0.0%
Chickamauga	7.4%	7.4%	-44.4%	-11.1%	3.7%	7.4%	7.4%	3.7%
Nickajack	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Guntersville	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Wheeler	32.1%	28.6%	-32.1%	-3.6%	3.6%	28.6%	32.1%	10.7%
Wilson	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pickwick	33.3%	29.6%	-29.6%	0.0%	0.0%	29.6%	33.3%	14.8%
Kentucky	22.7%	136.4%	-22.7%	0.0%	136.4%	136.4%	22.7%	-4.5%
Mean tributary	**58.9%**	**102.8%**	**-30.2%**	**-65.2%**	**0.0%**	**83.7%**	**129.5%**	**31.2%**
Mean mainstem	**11.3%**	**23.1%**	**-24.4%**	**-5.7%**	**15.3%**	**23.1%**	**11.3%**	**2.7%**
Mean overall	**38.5%**	**68.7%**	**-27.7%**	**-39.7%**	**6.6%**	**57.7%**	**78.9%**	**19.0%**

The number of cumulative shear stress hours over a median year in tailwaters is an indication of the degree that shear stress forces may dislodge soil particles from streambanks.
Table 5.16-02 compares the cumulative shear stress hours calculated from projected median flows of the policy alternatives to the Base Case. The days exhibiting highest flows are typically in spring, with minimal flows in late spring-early summer, and some high-flow periods in fall, but the alternatives change the relative duration of the spring and fall peak discharges. Because maximum generator discharge capacity does not change, the cumulative shear stress calculated from the projected flow curves did not show substantial variability among the alternatives (many are probably within the uncertainty of the models used), and some decrease the potential for erosion compared to the Base Case.

Table 5.16-02 Change in Cumulative Shear Stress of Policy Alternatives Compared to Base Case for Representative Reservoirs

Reservoir	Alternative							
	Reservoir Recreation A	Reservoir Recreation B	Summer Hydropower	Equalized Summer/Winter Flood Risk	Commercial Navigation	Tailwater Recreation	Tailwater Habitat	Preferred
Tributary Reservoirs								
Chatuge	-0.6%	-3.6%	-2.2%	-3.7%	NC	-2.2%	-4.3%	-2.0%
Cherokee	2.8%	-3.5%	16.5%	-1.4%	NC	-3.4%	-1.2%	-5.8%
Douglas	-0.1%	-2.0%	0.4%	-1.0%	NC	-1.3%	-3.9%	+0.1%
Nottely	2.3%	-2.8%	-0.3%	-5.1%	NC	-0.2%	-1.5%	-3.4%
Mainstem Reservoirs								
Pickwick	+1.0%	+1.4%	-3.5%	+0.2%	-0.4%	+1.4%	+0.6%	-0.4%

Notes:

NC = No change.

Positive entries designate increase in cumulative shear stress (higher erosion) for this alternative compared to the Base Case; negative entries designate a decrease.

As this analysis developed, it became clear that the reservoirs chosen to represent the affected environment in Chapter 4 did not fully represent the changes in operations in the proposed alternatives. Reservoirs were added to the analysis to fully illustrate the range of impacts from the alternatives.

Projected changes in recreational use of the TVA reservoir system are discussed in Section 4.24, Recreation. Table 5.24-01 provides forecasted recreational use numbers in user days over the 35 TVA projects, and Table 5.24-02 provides an overall summery of the forecasts. The recreation analysis did not consider projections for each individual reservoir. The main recreational factor of interest for the erosion analysis is the overall projected changes in recreation use from the Base Case. Also of interest are the projected changes in recreational use below the dams (tailwaters). This information is summarized in Table 5.16-03.

Table 5.16-03 Summary of Change from Base Case in Recreation Use by Policy Alternative (August, September, and October)

	Alternative							
	Reservoir Recreation A	Reservoir Recreation B	Summer Hydropower	Equalized Summer/Winter Flood Risk	Commercial Navigation	Tailwater Recreation	Tailwater Habitat	Preferred
Public access use below dams	No change	Slight increase	Slight decrease	Slight decrease	No change	Slight increase	No change	No change
Overall projected change	Large increase	Large increase	Moderate decrease	Slight increase	Slight decrease	Large increase	Large increase	Moderate increase

5.16.3 Base Case

The Base Case would result in continued erosion of reservoir shorelines and implementation of treatments and BMPs by TVA and others to improve shoreline conditions. Reservoir shorelines would continue to erode at their present rate, or potentially at a slightly accelerated rate due to projected increased recreational use.

As with reservoir shorelines, tributary tailwater streambanks would continue to erode under the Base Case at their present rate or potentially at a slightly accelerated rate due to projected increased recreational use.

5.16.4 Reservoir Recreation Alternative A

Duration of pool levels in the shoreline erosion zone under Reservoir Recreation Alternative A would be substantially longer in most reservoirs compared to the Base Case, thereby increasing the existing rate of erosion. Increased recreational boating would also contribute to erosion of the shoreline. Higher winter levels would decrease exposure of any sediment deposits formed since impoundment and the original stream channel and floodplains. This would reduce erosion in these areas. Overall the effect of Reservoir Recreation Alternative A on reservoir shoreline erosion is projected to be adverse.

Under Reservoir Recreation Alternative A, the higher winter pool increases discharges during the early spring, already the highest-discharge period. This is mitigated during drawdown in fall, when discharges are generally a little lower than Base Case for a longer period than the spring peak. The net effect is that there is likely to be little change in potential for tailwater erosion under this alternative.

5.16.5 Reservoir Recreation Alternative B and Tailwater Recreation Alternative

Reservoir Recreation Alternative B would substantially increase the duration in the shoreline erosion zone in most reservoirs, especially tributary reservoirs. A large increase in boat activity is also projected. Therefore, this alternative has high erosion potential. The Tailwater Recreation Alternative would also increase shoreline erosion zone durations at most reservoirs, but not to the degree of Reservoir Recreation Alternative B in the tributaries. Large increases in boat wave energy are also projected for the Tailwater Recreation Alternative. Higher winter levels would decrease exposure of any sediment deposits formed since impoundment and the original stream channel and floodplains. This would reduce erosion in these areas.

Under Reservoir Recreation Alternative B and the Tailwater Recreation Alternative, there would be longer periods of high flows during the early spring, already the highest-discharge period in the tailwaters of the representative reservoirs. This is mitigated during drawdown in fall, when discharges are generally a little lower than Base Case for a longer period than the spring peak. The net effect is that there is likely to be little change in potential for tailwater erosion under this alternative.

5.16.6 Summer Hydropower Alternative

The Summer Hydropower Alternative would result in shorter periods of wave impact in the shoreline erosion zone than the Base Case and a consequent decrease in existing reservoir shoreline erosion. There would also be a large decrease in erosion from a corresponding decrease in recreational boating. Higher winter levels would decrease exposure of any sediment deposits formed since impoundment and the original stream channel and floodplains. This would reduce erosion in these areas.

Tailwater cumulative shear stress results were highly variable for this alternative. The largest impact for any of the cases calculated occurred for the Cherokee tailwater, where there was a 17 percent increase in cumulative shear stress, suggesting the potential for a slight increase in erosion rates there if this alternative were chosen. Other tailwaters would see increases small enough that they are unlikely to be noticeable.

5.16.7 Equalized Summer/Winter Flood Risk Alternative

The Equalized Summer/Winter Flood Risk Alternative generally would result in substantially shorter durations of high pool elevations than the Base Case except at Watauga. A slight increase in recreational boating activities is projected. The lower duration at shoreline erosion zone elevations and higher winter pool elevations would reduce the area of the exposed drawdown zone to rainfall impacts. Except in Tims Ford, higher winter levels would decrease exposure of the sediment deposits formed since impoundment and the original stream channel and floodplains. This would reduce erosion in these areas; lower winter elevations in Tims Ford would increase erosion in these areas. Overall, this alternative would likely result in less erosion than the Base Case.

Cumulative shear stress analysis indicates that there is likely to be little change in potential for tailwater erosion under this alternative.

5.16.8 Commercial Navigation Alternative

The Commercial Navigation Alternative is the only policy alternative that would result in substantial changes to commercial boat traffic. This alternative, which enhances navigation in the mainstem by deepening the channel, would allow for barges to be loaded more fully. The heavier barges would have a deeper draft, which would send more wave energy to the shorelines. However, fewer trips are projected under this alternative. The reduction in trips would likely offset the increased wave energy from the heavier barges, and no substantial change in erosion from the Base Case would be caused by commercial boat traffic.

Other erosion impacts under the Commercial Navigation Alternative would be similar to those described for the Base Case, particularly for tributary reservoirs, where this alternative makes little or no change in operation. There is only slight change in cumulative sheer stress. The duration at high-pool elevation for each representative reservoir would be similar to the Base Case, and no change in recreational use is projected for the Commercial Navigation Alternative.

5.16.9 Tailwater Habitat Alternative

Summer water levels under the Tailwater Habitat Alternative would be in the shoreline erosion zone for substantially longer durations than under the Base Case, especially on tributary reservoirs, resulting in more erosion. A large increase in recreational boating would result in a corresponding increase in erosion.

Tailwater cumulative sheer stress shows little change.

5.16.10 Preferred Alternative

The Preferred Alternative would increase the duration of pool levels in the shoreline erosion zone in most tributary reservoirs and would increase the erosion in these areas. There would be little change on mainstem reservoirs. Higher winter levels on tributary reservoirs would decrease exposure of any sediment deposits formed since impoundment and the original stream channel and floodplains reducing erosion rates in these areas. The overall result on reservoir shoreline erosion would be slightly adverse.

Changes in potential for tributary tailwater erosion would vary between reservoirs. Because the amount of change is small, the net impact of this alternative would be minimal.

5.16.11 Summary of Impacts

Table 5.16-04 provides a summary of impacts on erosion by policy alternative. The Base Case would result in continued erosion of reservoir and tailwater shorelines, and implementation of treatments and BMPs by TVA and others to improve shoreline conditions. Recreational use of the TVA system is projected to increase under the Base Case; therefore, erosion could accelerate. As described in the table, Reservoir Recreation Alternative A, Reservoir Recreation Alternative B, the Tailwater Recreation Alternative, the Tailwater Habitat Alternative, and the Preferred Alternative are anticipated to increase the rate of erosion compared to the Base Case. The Summer Hydropower Alternative and the Equalized Summer/Winter Flood Risk Alternative are anticipated to decrease the rate of erosion, while the Commercial Navigation Alternative is anticipated to cause similar erosion effects as the Base Case. Based on an analysis of cumulative shear stress in tailwaters, there would not be substantial impacts from any of the alternatives.

Table 5.16-04 Summary of Impacts on Shoreline Erosion by Policy Alternative

Alternative								
Base Case	**Reservoir Recreation A**	**Reservoir Recreation B**	**Summer Hydropower**	**Equalized Summer/ Winter Flood Risk**	**Commercial Navigation**	**Tailwater Recreation**	**Tailwater Habitat**	**Preferred**
Reservoir Effects								
No change – Shoreline erosion would continue at existing rates.	Adverse – Longer reservoir pool durations at summer levels and large increases in recreational boat waves would increase reservoir shoreline erosion.	Adverse – Longer reservoir pool durations at summer levels and large increases in recreational boat waves would result in an increase in existing erosion.	Beneficial – Shorter reservoir pool durations at summer levels and a large decrease in recreational boat waves would decrease existing erosion.	Beneficial, especially on tributary reservoirs – Shorter reservoir pool durations at summer levels and a smaller drawdown zone affected by raindrop impact would result in less reservoir shoreline erosion.	No change – Shoreline erosion would continue at existing rates.	Adverse – Longer reservoir pool durations at summer levels and large increases in recreational boat waves would increase reservoir shoreline erosion.	Substantially adverse – Substantially longer reservoir pool durations at summer levels and large increases in recreational boat waves would result in an increase in existing erosion.	Slightly adverse – Longer reservoir pool duration at summer levels in some reservoirs would result in an increase in erosion on some reservoirs.
Tailwater Effects								
No change – Shoreline erosion would continue at existing rates.	No change – Shoreline erosion would continue at existing rates.	No change – Shoreline erosion would continue at existing rates.	No change – Shoreline erosion would continue at existing rates.	No change – Shoreline erosion would continue at existing rates.	No change – Shoreline erosion would continue at existing rates.	No change – Shoreline erosion would continue at existing rates.	No change – Shoreline erosion would continue at existing rates.	No change – Shoreline erosion would continue at existing rates.