APPENDIX A

YADKIN RIVER SEDIMENTATION MODELING

Several studies have examined the sedimentation processes that have and are occurring in the Yadkin and Yadkin-Pee Dee River Project areas, focusing on the area in the far upstream reaches of High Rock reservoir (SRU, 2006a, 2006b; MBH, 2007; Doyle, 2007). Sections 3.3, *Geology and Soils*, and 3.4, *Water Resources*, present staff's analysis of the results of these studies related to the Projects. In this appendix, we provide the details of the models and the studies themselves.

HEC-6T Modeling to Determine the Thalweg

MBH (2007) performed detailed modeling to determine the elevation of the thalweg[64] between 1928 and 2058 and changes in the cross-sectional area of the Yadkin River channel. MBH used the HEC-6T numerical sedimentation model which is its proprietary version of the Scour and Deposition in Rivers and Reservoirs (HEC-6) computer model developed by the Corps' Hydrologic Engineering Center. Specifically, MBH used the HEC-6T model to calculate future sedimentation conditions and water-surface elevations in the Yadkin River from High Rock dam to a point 31.3 river miles above the dam. The numerical model was assembled using available data gathered from previous investigators and data collection agencies. The model was calibrated using historical information and was then used to predict future changes in river bed elevations using historical runoff records. Sources for input into the model and key assumptions include the following:

- Geometry inputs were developed from existing topography, light detection and ranging,[65] and bathymetric survey data supplied by Alcoa Generating and the city of Salisbury. An existing steady-state HEC-RAS backwater model, developed by the city of Salisbury in 2006, was used to obtain cross-section data for the HEC-6T numerical model. An aerial survey of reservoir topography above elevation 612 feet was completed in 1997.
- Annual hydrographs in the numerical model were developed using data from the USGS gages on the Yadkin and South Yadkin rivers. Computation intervals of one day were assigned in the numerical model to coincide with the mean daily data reported by USGS. A long-term hydrograph between 1928 and 1997 was used to calibrate the numerical model.
- The downstream water-surface elevations at High Rock dam were based on daily measurements provided by Alcoa Generating.
- Field and model data was used to develop sediment inflow to the numerical model. Measured sediment data at the USGS Yadkin River at Yadkin College gage was

---

[64]Thalweg is defined as the line defining the lowest points along the profile of a river bed or valley.

[65]Light detection and ranging (LIDAR) is a remote sensing system used for the collection of topographic data.

used to determine suspended sediment inflow concentrations. Bed-material gradations collected from the Yadkin River were used to calculate bed-material sediment inflow concentrations.

- Historical deposition in High Rock reservoir was estimated by comparing cross sections developed from the 1917 topographic maps and cross sections developed from 1997 surveys. The model was calibrated so that calculated deposition between 1928, (when impoundment began) and 1997 matched measured deposition during the same period. In addition, calculated water-surface elevations in the numerical model were calibrated to historical high-water marks at the water intake pumping station.
- A sensitivity analysis was conducted to determine uncertainty associated with the calculated model results. The sensitivity of the total calculated sediment accumulation in the delta to sediment inflow, sediment transport equation, and variability in channel bottom elevations between High Rock dam and the water intake structure, was evaluated.

The calibrated model was used to run a base test consisting of a long-term historical hydrograph, added to the end of the 1928-1997 hydrograph, with flood peaks inserted after years 2038, 2048, and 2058 and at 5-year increments. This analysis provided predictions of the magnitude and characteristics of sedimentation and flooding over the long-term and in response to flood events.

The calibrated numerical model was used to evaluate Salisbury's initial four scenarios related to sediment and compare channel response and water surface elevations to those calculated for the base test. The first scenario evaluated discontinued sand extraction. Current sand mining continues at the discretion of the private operator and is not part of a maintenance plan. The second scenario evaluated was an increase in the sand extraction rate at the confluence of the South Yadkin River. The third scenario was a sediment trap that included an initial dredging of the river at the confluence of the South Yadkin River and subsequent annual maintenance dredging. The fourth scenario evaluated was a flood relief channel, dredged between the water intake structure and Swearing Creek at RM 7 in the reservoir delta. The fourth scenario also required annual maintenance dredging and probably has substantial impacts on areas within the sediment delta which are now classified as wetlands (see EIS section 3.6, *Terrestrial Resources*, for related discussion). See section 3.3, *Geology and* Soils, for list of the measures related to sediment that were ultimately recommended by the city of Salisbury.

HEC-RAS[66] Modeling To Show Increases in Water Surface Elevations

The city of Salisbury's report "High Rock Dam and High Rock Lake Sedimentation flooding Effects as Estimated Using HEC-RAS Modeling" (SRU, 2006b) shows modeling results using pre-project topography provided by Alcoa Generating to develop a no dam/no sediment baseline condition and a dam/no sediment condition. Cross sections were constructed from pre-project (1918) topographic maps with contour intervals of 10 feet below elevation 600 feet and 5 feet above elevation 600 feet. The riverbed profile below the water levels shown on the topographical maps used a straight line approximation from the bed elevation of 550 feet at High Rock dam to the known bed elevation of 604 feet in 1927 near the pump station. For the river cross-section geometry below the water surface, bank slopes of the channel were approximated as 25 percent of the bank width and a flat bottom at 50 percent of the bank width. The dam/1997 sediment condition was based on cross sections obtained from Alcoa Generating that include sedimentation as it existed in 1997 and a full pool starting water surface elevation of 623.9 feet at High Rock dam. For the dam/no sediment condition, Salisbury used the same cross-sections as 1918 (no dam/no sediment) and a starting water surface elevation of 623.9 feet at the dam. Table A-1 provides the results and shows the modeled increase in water surface elevations based on the construction of the dam and sedimentation in the upper reservoir.

Table A-1. Water surface elevations near the city of Salisbury's water pump station based on the Salisbury 2006 HEC-RAS modeling. (Source: SRU, 2006b)

Flow (cfs) near the Salisbury pump station (RM 19.4)	Water Surface Elevation (USGS)			Increase in Water Surface (feet)	
	No Dam/No Sediment (1918)	Dam/No Sediment (1927)	Dam/With Sediment (1997)	1918 to 1997	1927 to 1997
30,000	622.73	626.64	631.41	8.68	4.77
40,000	625.51	628.16	633.47	7.96	5.31
70,000	631.73	632.64	638.38	6.65	5.74
117,700	638.04	638.33	644.25	6.21	5.92

Note: cfs – cubic feet per second

[66]HEC-RAS is a public domain computer program or river analysis system developed by the Corps' HEC for modeling the hydraulics of water flow through natural rivers and other channels to determine flood plain extent, elevation and other aspects.

The city of Salisbury modeling results shown in table A-1 for the 1997 conditions are very close to the elevations produced by the 2003 FERC hydraulic study for discharges at 40,000 and 70,000 cfs, two flow values that were modeled in both studies.

HEC-6T Modeling to Determine the Thalweg

MBH (2007) used the HEC-6T model to examine the potential effects on flooding attributed to the continuing delta sediment aggradation in the upper reaches of High Rock reservoir (MBH, 2007). Based on the review of the river bed bottom used in the 2006 HEC-RAS analysis, MBH raised the river bottom elevations by about 12 feet near RMs 6 to 15 based on the 1917 topographic maps and plans used for the construction of the US Route 29/70 Bridge near RM 15. The bridge plans indicated a gravel and or bedrock elevation of 602 feet, just slightly below the pre-impoundment river bed elevation of 604 feet about 4 river miles upstream near at the Salisbury pumping station. In sensitivity tests conducted by MBH, the choice of the initial river bed profile was determined to be relatively unimportant compared to the effects of the reservoir.

The HEC-6T model, unlike the HEC-RAS model, also included two surveyed cross-sections on the South Yadkin River within 1 mile of the confluence and 11 cross-sections between RMs 21.3 and 31.3, upstream of confluence. All of the new cross-sections in the HEC-6T model included elevation below the water surface.

Based on the new geometry and sediment accumulation, MBH compared the modeled high water marks at the Salisbury pump station to observed elevations (table A-2). While the modeled elevations vary from the observed flood elevations, we find the correlation reasonable due to the effects of debris, overbank roughness coefficients that vary seasonably, variations in the sediment deposition, and the normal expected variance in hydrologic and hydraulic modeling.

Table A-2. Comparison of recorded flood elevations and modeled flood elevations at the Salisbury pump station. (Source: MBH, 2007)

Date	Flow (cfs)	Recorded peak flood elevation (feet)	Modeled peak flood elevation (feet)	Difference (feet)
6/22/1972	90,693	639.0	639.2	0.2
4/6/1947	44,068	635.6	635.7	0.1
3/15/1975	52,768	637.2	637.0	-0.2
1/27/1978	50,472	635.2	636.8	1.6
9/23/1979	77,125	638.3	639.3	1.0
3/2/1987	77,899	639.5	639.5	0.0
4/26/1987	45,338	636.0	636.1	0.1
1/28/1998	31,906	633.8	634.2	0.4

Date	Flow (cfs)	Recorded peak flood elevation (feet)	Modeled peak flood elevation (feet)	Difference (feet)
3/21/2003	67,926	640.7	639.2	-1.5
9/29/2004	44,284	635.2	636.4	1.2

Note: cfs – cubic feet per second

As a baseline condition, MBH analyzed the deposition of natural sediment deposition on the Yadkin River to determine the effects of the sedimentation that would naturally occur without the backwater caused by High Rock reservoir. This analysis shows that, by natural sedimentation alone (a no-dam scenario) the 10- year, 100-year, and design flood water surface elevations at the Grant Creek wastewater treatment plant and the Salisbury pump station would increase by about 1 to 2 feet between the year 1920 and 2058. However, the background documentation for these baseline conditions of sediment deposition for the 'no-dam' scenario is absent other than the graphs and tables of the results submitted by city of Salisbury. With the dam in place, the modeling results presented in table A-3 show that at the pump station and Grant Creek wastewater treatment plant, the flood elevations have increased by about 9 to 10 feet since the dam was constructed. In the next 40 to 50 years, the same modeling indicates additional increases of about 2 to 3 feet for the 10 year, 100-year, and the design flow stages.

Table A-3. Predicted water surface elevations (feet) 1920 to 2058. (Source: MBH, 2007)

	Water Intake RM 19.4[a]			WWTP RM 16.72		
Year	**Design**	**100 Year**	**10 Year**	**Design**	**100 Year**	**10 Year**
1920	635.5	633.1	630.2	630.1	628.0	625.0
1928	636.2	634.0	631.6	631.6	629.9	627.9
2004	644.5	642.1	639.1	640.1	637.8	634.5
2044	645.7	643.1	640.1	642.0	639.6	636.3
2054	646.5	644.0	640.8	642.9	640.4	637.1
2058	646.3	643.8	640.6	642.8	640.4	637.0
Increase (feet) from 1920 (pre dam)						
1928	0.7	0.9	1.4	1.5	1.9	2.9
2004	9.0	9.0	8.9	10.0	9.8	9.5
2044	10.2	10.0	9.9	11.9	11.6	11.3
2054	11.0	10.9	10.6	12.8	12.4	12.1
2058	10.8	10.7	10.4	12.7	12.4	12.0

	Water Intake RM 19.4[a]			WWTP RM 16.72		
Year	**Design**	**100 Year**	**10 Year**	**Design**	**100 Year**	**10 Year**
Predicted increase as compared to 1928 (immediately after dam construction)						
2004	8.3	8.1	7.5	8.5	7.9	6.6
2044	9.5	9.1	8.5	10.4	9.7	8.4
2054	10.3	10.0	9.2	11.3	10.5	9.2
2058	10.1	9.8	9.0	11.2	10.5	9.1
Predicted increases as compared to 2004						
2044	1.2	1.0	1.0	1.9	1.8	1.8
2054	2.0	1.9	1.7	2.8	2.6	2.6
2058	1.8	1.7	1.5	2.7	2.6	2.5

Notes: Modeling assumed existing conditions of sediment inflow, hydrology, sand extraction and reservoir level operations at High Rock dam would continue.

[a] At RM 19.4 (pump intake) the design discharge is 121,000 cfs, 100-year is 101,000 cfs, and the 10-year is 65,000 cfs.

This page intentionally left blank.