INUNDATION STUDY AND VERIFICATION OF HAZARD CLASSIFICATION

FOR THE

SOUTH RIVER DAM #19

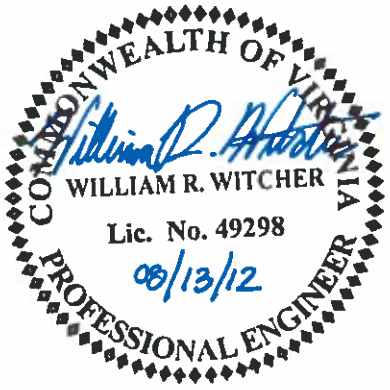
(INVENTORY NO. 01514)

AUGUSTA COUNTY, VIRGINIA

PREPARED FOR

VIRGINIA DEPARTMENT OF CONSERVATION AND RECREATION

RICHMOND, VIRGINIA



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I. EXISTING CONDITIONS AND BACKGROUND INFORMATION

Dam and Outlet Works

South River Dam #19 is an earth embankment dam approximately 800 feet long and 35 feet high. The dam is located on an unnamed tributary of the South River 0.8 miles upstream of the confluence of this tributary with the South River in Augusta County, Virginia. The principal spillway consists of a reinforced concrete riser and a 24" diameter conduit through the dam. A 100-foot wide trapezoidal auxiliary spillway is located on the west abutment of the dam. The auxiliary spillway consists of an excavated, grassed channel which is currently traversed by a local road. Elevations and capacities of the dam and reservoir are given in Table 1 below. This data was obtained from as-built drawings of the dam dated April 1956.

Table 1
South River Dam #19 and Reservoir – Existing Conditions

Location	Elevation	Reservoir Surface Area (acre)	Reservoir Storage (acre-feet)
Primary Spillway (normal pool)	1388	11	29
Emergency Spillway	1406.5	57	466

The primary spillway at South River Dam #19 is a concrete riser/intake structure. A 3.0 ft. square concrete overflow spillway riser controls the normal pool (El. 1388), and an 18" diameter gate valve is located at the bottom of the spillway riser (invert el. 1381.50) that serves to drain the reservoir. A 24" diameter reinforced concrete pipe conveys flow from the riser structure to the downstream channel. For the purpose of analysis, the gate valve located at the bottom of the riser structure has been modeled as closed due to siltation around the valve rendering it inoperable.

Drainage Basin Hydrology

The following section includes the development of rainfall distributions and runoff calculations associated with the South River Dam #19 basin.

Precipitation Data

Rainfall values for the Probable Maximum Precipitation (PMP) were obtained from Hydrometeorological Report Number 51 (HMR51), and were distributed using the NRCS 6-hour distribution. The 6-hour distribution results in the largest peak outflow for the PMP and 0.5 PMP rainfall values. Rainfall values for return period events (i.e., 2 through 500-year storm events) were obtained from NOAA Atlas 14, Volume 2,

Precipitation Frequency for the Ohio River Basin and Surrounding States, and distributed using the NRCS Type II 24-hour distribution. Precipitation data is presented in Table 2.

Table 2
Precipitation Data

Return Event	Rainfall Depth (in)	Rainfall Distribution	Peak Flow (cfs)
PMP 6-hour	28.0	NRCS 6-hour	7,637
PMP 12-hour	28.0	NRCS 12-hour	6,496
PMP 24-hour	28.0	NRCS 24-hour	5,162
0.5 PMP 6-hour	14.0	NRCS 6-hour	3,276
0.5 PMP 12-hour	14.0	NRCS 12-hour	2,923
0.5 PMP 24-hour	14.0	NRCS 24-hour	2,369
100-year 24-hour	7.5	NRCS 24-hour	1,371
50-year 24-hour	6.6	NRCS 24-hour	1,093

Unit Hydrograph and Loss Rate Parameters

The drainage area contributing to South River Dam #19 is approximately 3.0 square miles, and is mostly wooded and agricultural lands with light development. Downstream of the dam, the unnamed tributary has a channel bed slope of approximately 0.01 ft/ft.

The unit hydrographs for the basin were computed using the HEC-HMS hydrologic modeling software with NRCS input parameters. The input parameters include the NRCS Runoff Curve Number (CN) and Lag Time (T_L) for the basin. Lag time is computed as 0.6 x time of concentration, where time of concentration is a summation of overland sheet flow, shallow concentrated flow, channel flow, and kinematic wave flow in the basin. The flow path that results in the longest time is used for the basin time of concentration in the model. Calculations for the CN and T_L are included in Appendix C. A summary of the basin hydrologic parameters are given in Table 3.

Table 3
Waynesboro Nursery Reservoir Basin Hydrologic Parameters

Area (sq. mi.)	CN	T_C (hours)	T_L (hours)
3.0	67	3.96	2.37

Analysis and Results

Hydrologic and hydraulic analyses were performed for the Dam #19 basin using the Army Corps of Engineers' HEC-RAS computer program. The HEC-RAS model consists of input hydrographs developed for the basin using HEC-HMS software, stream/river cross sections, and structure data including all bridges, culverts, and the South River Dam #19. Cross section input was obtained from a field survey conducted by Thompson & Litton in March 2009. Field survey data has been supplemented using Virginia Geographic Information Network (VGIN) topographic mapping where needed. The analysis has been continued downstream to the confluence of the South River with the North River, which is approximately 32.6 miles downstream of Dam #19.

Cross Section data for the portions of the unnamed tributary and the South River modeled in this analysis was obtained from VGIN mapping. In addition to river cross sections, eighteen bridges and the South River Dam #19 are included in the analysis. The bridges modeled are presented in Table 4.

Table 4
Downstream Bridges/Culverts

Crossing	Distance Downstream of Dam (ft)	Estimated Low Point of Road/Bridge Surface
Route 624 Bridge	1,480	1376.0
Norfolk Southern Railroad Bridge	2,570	1380.0
Driveway Culvert	3,670	1363.0
Route 635 Bridge	12,023	1365.4
Route 632 Bridge	25,587	1353.1
Route 664 Bridge	31,342	1342.6
Route 650 Bridge	41,965	1327.0
Interstate 64 Bridges	45,066	1346.6
Lyndhurst Road Bridge	49,173	1320.2
Wayne Avenue Bridge	60,005	1296.3
Main Street Bridge	65,492	1284.9
Broad Street Bridge	65,965	1284.7
Norfolk Southern Railroad Bridge	66,542	1295.9
Second Street Bridge	70,819	1279.0
Hopeman Parkway Bridge	76,179	1271.4
Route 611 Bridge	90,431	1252.0
Private Road Bridge	91,772	1246.4
Route 612 Bridge	115,851	1219.8
Route 778 Bridge	150,411	1151.7
Route 844 Bridge	168,332	1105.7
Route 256 Bridge	172,229	1100.8

Hydrographs developed for the basin were routed through the South River Dam #19 utilizing all obtained data. The results of the model are presented in Table 5.

Table 5
South River Dam #19 – Existing Conditions Hydraulic Model Results

Storm Event	Inflow (cfs)	Outflow (cfs)	Peak Stage	Overtopping Depth (ft)
PMF	7,637	7,381	1413.10	0.00
0.5 PMF	3,276	3,045	1410.45	0.00
100-year	1,371	1,042	1408.29	0.00

II. DAM BREACH ANALYSIS MODELING

Requirements

The *Virginia Impounding Structures Regulations (Dam Safety)* require that a dam breach analysis be performed as part of a dam's recertification process. Four analysis scenarios are included in the requirements:

1. A "sunny day" dam break analysis utilizing the volume retained at the normal or typical water surface elevation of the impounding structure.
2. An analysis utilizing the spillway design flood without a dam failure.
3. A dam break analysis utilizing the spillway design flood with a dam failure.
4. A dam break analysis utilizing the probable maximum flood with a dam failure.

Each of these scenarios have been modeled for the South River Dam #19 with the Army Corps of Engineers' HEC-RAS hydraulic modeling software. The methodology and results of each scenario are discussed below.

1. Sunny Day Dam Break Analysis

A dam break analysis for the South River Dam #19 was performed assuming a "sunny day" failure with the initial reservoir level at the auxiliary spillway elevation. The method of failure modeled for this scenario was piping along the 24" outlet conduit through the dam. Breach parameters used in this analysis were developed using methodology by Froehlich (1995). Breach parameters were as follows:

Breach bottom elevation:	EL 1384
Breach bottom width:	10 ft
Side slopes of breach:	0.5H:1V
Breach development time:	0.5 hr

Results of the analysis are presented in Table 6.

Table 6
Sunny Day Dam Break Analysis Results

River Station	Distance from Dam (ft)	Description	Max. Stage	Max. Depth (ft)	Peak Flow(cfs)
04374	0	South River Dam #19	1405.58	N/A	2,467
02692	1,480	Route 624 Bridge	1381.11	5.1	2,467
01608	2,570	NS Railroad Bridge	1381.10	1.1	2,467
00518	3,670	Driveway Culvert	1364.37	1.4	2,467
178932	12,023	Route 635 Bridge	1362.48	0.0	13,210
165368	25,587	Route 632 Bridge	1354.12	1.0	13,210
159613	31,342	Route 664 Bridge	1345.24	2.6	13,210
148990	41,965	Route 650 Bridge	1329.76	2.8	13,210
145889	45,066	Interstate 64 Bridges	1319.28	0.0	13,210
141782	49,173	Lyndhurst Road Bridge	1317.23	0.0	13,210
130950	60,005	Wayne Avenue Bridge	1293.73	0.0	20,157
125463	65,492	Main Street Bridge	1284.46	0.0	20,857
124990	65,965	Broad Street Bridge	1281.01	0.0	20,857
124413	66,542	NS Railroad Bridge	1279.86	0.0	20,857
120136	70,819	Second Street Bridge	1273.38	0.0	21,057
114776	76,179	Hopeman Parkway Bridge	1261.29	0.0	21,547
100524	90,431	Route 611 Bridge	1254.08	2.1	21,547
99183	91,772	Private Road Bridge	1249.50	3.1	21,547
75104	115,851	Route 612 Bridge	1214.06	0.0	21,547
40544	150,411	Route 778 Bridge	1146.76	0.0	21,547
22623	168,332	Route 844 Bridge	1104.32	0.0	21,547
18726	172,229	Route 256 Bridge	1089.45	0.0	26,742

The results of the analysis indicate that eight roads/railroads would likely be impacted by a sunny day failure breach failure of Dam #19.

2. Probable Maximum Flood (PMF) Dam Breach Analysis

A dam breach analysis for the South River Dam #19 was performed assuming an overtopping breach failure in conjunction with the PMF event. Breach parameters used in this analysis were developed using methodology by Froehlich (1995). Breach parameters were as follows:

Breach bottom elevation:	EL 1384
Breach bottom width:	60 ft
Side slopes of breach:	0.5H:1V
Breach development time:	0.5 hr

Reservoir storage and dam breach modeling were performed using the U.S. Army Corps of Engineers' HEC-RAS computer model. Cross section data was obtained from VGIN mapping and field survey data. The HEC-RAS unsteady flow model was used to model flow in the downstream reach of the unnamed tributary to the South River. Bridges and culverts were incorporated into this model. Results of the analysis are contained in Table 7.

Table 7
PMF Breach Analysis Results

River Station	Distance from Dam (ft)	Description	Max. Stage	Max. Depth (ft)	Peak Outflow(cfs)
04374	0	South River Dam #19	1410.99	N/A	39,642
02692	1,480	Route 624 Bridge	1385.72	9.7	39,642
01608	2,570	NS Railroad Bridge	1385.52	5.5	39,642
00518	3,670	Driveway Culvert	1374.1	11.1	39,642
178932	12,023	Route 635 Bridge	1371.21	5.8	50,385
165368	25,587	Route 632 Bridge	1357.62	4.5	50,385
159613	31,342	Route 664 Bridge	1349.89	7.3	50,385
148990	41,965	Route 650 Bridge	1333.73	6.7	50,385
145889	45,066	Interstate 64 Bridges	1330.45	0.0	50,385
141782	49,173	Lyndhurst Road Bridge	1329.57	9.4	50,385
130950	60,005	Wayne Avenue Bridge	1305.35	9.0	50,385
125463	65,492	Main Street Bridge	1290.07	5.2	50,385
124990	65,965	Broad Street Bridge	1288.56	3.9	50,385
124413	66,542	NS Railroad Bridge	1284.63	0.0	50,385
120136	70,819	Second Street Bridge	1281.91	2.9	50,385
114776	76,179	Hopeman Parkway Bridge	1264.7	0.0	50,385
100524	90,431	Route 611 Bridge	1258.68	6.7	50,385
99183	91,772	Private Road Bridge	1251.84	5.4	50,385
75104	115,851	Route 612 Bridge	1222.37	2.6	50,385
40544	150,411	Route 778 Bridge	1150.51	0.0	50,385
22623	168,332	Route 844 Bridge	1110.36	4.7	50,385
18726	172,229	Route 256 Bridge	1094.85	0.0	50,385

The results of the analysis indicate that sixteen roads/railroads would likely be impacted by an overtopping breach failure of South River Dam #19.

III. INCREMENTAL DAMAGE ANALYSIS & VERIFICATION OF HAZARD CLASSIFICATION

Basis and Regulations

The *Virginia Impounding Structures Regulations (Dam Safety)* allow the spillway design flood requirement for a dam to be reduced when justified by results of an incremental damage analysis (4VAC50-20-52). The incremental damage analysis may be used to determine the limiting flood condition that is less than the minimum requirements of the Hazard Potential Classification for Impounding Structures (4VAC50-20-40). The flood will be based upon a comparison of two flood simulations occurring with the dam in question present: one, a flood that has a size that would cause failure of the dam, but has been modeled without any effects from a dam failure, and two, the same flood, but modeled to include the dam breach discharges based on the most severe hypothetical dam failure that is possible. The spillway capacity and inflow design flood are acceptable where it can be shown that the dam failure flood would cause no expected additional loss of life and would not cause significant incremental flood damages downstream of the dam. Additional potential loss of life, health or property in the downstream reach is expected if the incremental depth of flow between the dam failure and non-failure floods is greater than 2.0 feet. The minimum threshold flood event for incremental damage analysis is based on the Hazard Potential Classification of the dam, and is given in Table 1 of the Impounding Structure Regulations.

Results

An incremental damage analysis has been performed for South River Dam #19 by comparing the results of the spillway design flood event without a dam failure with the results of the spillway design flood event with a dam failure and the effects of the scenarios on the downstream road crossings. Several downstream crossings are classified as primary roadways, which necessitates use of the PMF event as the spillway design flood. The results of the analyses are presented in Table 8, and are discussed on the following page.

Table 8
Impact of Spillway Design Flood (PMF) Failure and Non-Failure Events on Downstream Bridges

Bridge / Culvert	River Station	Minimum Deck/Railing Elev.	SDF Failure WSEL	Overtopping Depth (ft)	SDF Non-Failure WSEL	Overtopping Depth (ft)	Incr. Depth (ft)
Route 624	02692	1376.0	1385.72	9.7	1382.05	6.0	3.7
NS Railroad Bridge	01608	1380.0	1385.52	5.5	1382.01	2.0	3.5
Driveway Culvert	00518	1363.0	1374.1	11.1	1366.66	3.7	7.4
Route 635 Bridge	178932	1365.4	1371.21	5.8	1364.59	0.0	5.8
Route 632 Bridge	165368	1353.1	1357.62	4.5	1354.67	1.6	2.9
Route 664 Bridge	159613	1342.6	1349.89	7.3	1345.84	3.2	4.1
Route 650 Bridge	148990	1327.0	1333.73	6.7	1330.42	3.4	3.3
Interstate 64 Bridges	145889	1346.6	1330.45	0.0	1321.31	0.0	0.0
Lyndhurst Road Bridge	141782	1320.2	1329.57	9.4	1320.02	0.0	9.4
Wayne Avenue Bridge	130950	1296.3	1305.35	9.0	1295.05	0.0	9.0
Main Street Bridge	125463	1284.9	1290.07	5.2	1286.34	0.0	5.2
Broad Street Bridge	124990	1284.7	1288.56	3.9	1282.94	0.0	3.9
NS Railroad Bridge	124413	1295.9	1284.63	0.0	1281.09	0.0	0.0
Second Street Bridge	120136	1279.0	1281.91	2.9	1273.99	0.0	2.9
Hopeman Parkway Bridge	114776	1271.4	1264.7	0.0	1262.44	0.0	0.0
Route 611 Bridge	100524	1252.0	1258.68	6.7	1256.7	4.7	2.0
Private Road Bridge	99183	1246.4	1251.84	5.4	1249.96	3.6	1.9
Route 612 Bridge	75104	1219.8	1222.37	2.6	1215.6	0.0	2.6
Route 778 Bridge	40544	1151.7	1150.51	0.0	1147.46	0.0	0.0
Route 844 Bridge	22623	1105.7	1110.36	4.7	1108.63	2.9	1.7
Route 256 Bridge	18726	1100.8	1094.85	0.0	1090.55	0.0	0.0

Verification of Hazard Classification and Recommendations

The *Virginia Impounding Structures Regulations (Dam Safety)* classify dams according to their hazard potential should a failure occur. It is our understanding that the South River Dam #19 is currently classified as a Significant Hazard structure; however, the Virginia Department of Conservation and Recreation (DCR), Division of Dam Safety and Floodplain Management requires verification of the hazard classification based on a dam breach and inundation analysis as part of their recertification program. A Significant Hazard Potential Dam is defined as an impounding structure whose failure may cause loss of life or appreciable economic damage. "May cause loss of life" means that impacts will occur that could cause a loss of human life, including but not limited to impacts to facilities that are frequently utilized by humans other than residences, businesses, or other occupied structures, or to secondary roadways. Economic damage may occur to, but not be limited to, building(s), industrial or commercial facilities, public utilities, secondary roadways, railroads, personal property, and agricultural interests. "Secondary roadways" include, but are not limited to, secondary highways, low-volume urban streets, service roads, or other low-volume roadways.

Sixteen bridges and culverts are impacted by the Sunny Day and PMF breach failures of the South River Dam #19. Based upon the results of the analyses performed in this study, and the designation of several downstream crossings as a primary roadways, it is the opinion of Thompson & Litton that the South River Dam #19 should be reclassified as a High Hazard Potential impounding structure per Dam Safety regulations. A High Hazard Potential Dam is defined as an impounding structure whose failure would result in probable loss of life and serious economic damage. "Probable loss of life" means that impacts will occur that are likely to cause a loss of human life, including but not limited to impacts to residences, businesses, other occupied structures, or major roadways. Economic damage may occur to, but not be limited to, building(s), industrial or commercial facilities, public utilities, major roadways, railroads, personal property, and agricultural interests. "Major roadways" include, but are not limited to, interstates, primary highways, high-volume urban streets, or other high-volume roadways.

The spillway design flood (SDF) of a High Hazard dam is defined as the Probable Maximum Flood (PMF) event. The structure must perform so as to safely pass this storm event in order to meet Dam Safety regulations. When appropriate, the SDF requirement may be reduced to the 0.5 Probable Maximum Flood event for a High Hazard dam provided that the incremental damage analysis justifies lowering the SDF requirement. Due to the overtopping of several downstream bridges during the PMF and PMF breach scenarios, the results do not justify reducing the spillway design flood of Dam #19 to below the PMF event. However, based on hydraulic analysis in this study, Dam #19 currently passes the PMF event without overtopping. The analysis indicates that the Dam currently meets the hydraulic requirements of current Dam Safety regulations for a High Hazard Potential impounding structure.