# INUNDATION STUDY AND VERIFICATION OF HAZARD CLASSIFICATION

# FOR THE

# SOUTH RIVER DAM #6

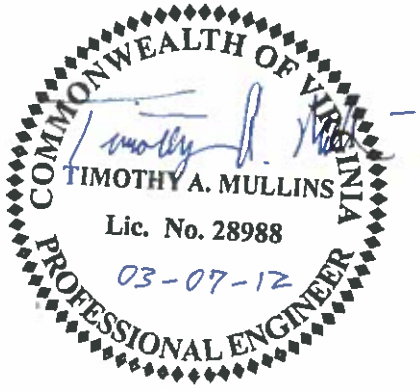
# (INVENTORY NO. 01509)

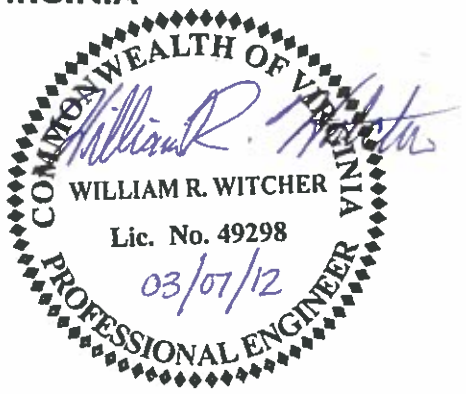
# AUGUSTA COUNTY, VIRGINIA

**PREPARED FOR**

**VIRGINIA DEPARTMENT OF CONSERVATION AND RECREATION**

**RICHMOND, VIRGINIA**



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# 1. EXISTING CONDITIONS AND BACKGROUND INFORMATION

## Dam and Outlet Works

South River Dam #6 is an earth embankment dam approximately 950 feet long and 56 feet high. The dam is located on Deep Pond Run 2.1 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 150-foot wide trapezoidal auxiliary spillway is located on the west abutment of the dam. The auxiliary spillway consists of an excavated, grassed channel which currently serves as a parking lot for the adjacent camp. 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 May 1958.

**Table 1**
**South River Dam #6 and Reservoir – Existing Conditions**

| Location | Elevation | Reservoir Surface Area (acre) | Reservoir Storage (acre-feet) |
|---|---|---|---|
| Primary Spillway (normal pool) | 1601.5 | 12.3 | 30.2 |
| Auxiliary Spillway | ~~1633.0~~ 1635.0 | 49.2 | 1102.0 |

DAM TOP = 1642.0 D 2DW

The primary spillway at South River Dam #6 is a concrete riser/intake structure. A 3.0 ft. square concrete overflow spillway riser controls the normal pool (el. 1601.5), and an 18" diameter gate valve is located at the bottom of the spillway riser (invert el. 1592.5) 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.

## Drainage Basin Hydrology

The following section includes the development of rainfall distributions and runoff calculations associated with the South River Dam #6 basin.

## Precipitation Data

Rainfall values for the Probable Maximum Precipitation (PMP) and One-Half Probable Maximum Precipitation (0.5 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 (50-year and 100-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 24-hour distribution. Precipitation data and corresponding peak flows for the basin are 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 | 15,800 |
| PMP 12-hour | 28.0 | NRCS 12-hour | 13,565 |
| PMP 24-hour | 28.0 | NRCS 24-hour | 10,553 |
| 0.5 PMP 6-hour | 14.0 | NRCS 6-hour | 6,680 |
| 0.5 PMP 12-hour | 14.0 | NRCS 12-hour | 6,034 |
| 0.5 PMP 24-hour | 14.0 | NRCS 24-hour | 4,745 |
| 100-year 24-hour | 8.00 | NRCS 24-hour | 3,776 |
| 50-year 24-hour | 7.00 | NRCS 24-hour | 2,936 |

## Unit Hydrograph and Loss Rate Parameters

The drainage area contributing to South River Dam #6 is approximately 4.1 square miles, and is mostly wooded with light development. Downstream of the dam, Deep Pond Run 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**
**Stoney Creek Reservoir Basin Hydrologic Parameters**

| Area (sq. mi.) | CN | $T_C$ (hours) | $T_L$ (hours) |
|---|---|---|---|
| 4.1 | 63 | 1.66 | 1.00 |

## Analysis and Results

The hydraulic analysis was performed for the Dam #6 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 and the South River Dam #6. 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.

Attempts were made to obtain a copy of the South River digital hydraulic model from FEMA. However, after discussion with Mr. Daniel Hufford with the FEMA Engineering Library, hydraulic backup data for the South River was not located. Cross Section data for the portion of the South River modeled in this analysis was obtained from VGIN mapping, and the model was calibrated to "fit" the South River hydraulic data published in the Augusta County Flood Insurance Study.

In addition to river cross sections, field surveys of three bridges and the South River Dam #6 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 608 Bridge | 2,400 | 1557 |
| Norfolk & Western Railroad Bridge | 10,000 | 1483 |
| Route 658 Bridge | 10,600 | 1477 |

Hydrographs developed for the basin were routed through the South River Dam #6 utilizing all obtained data. The results of the model are presented in Table 5.

**Table 5**
**South River Dam #6 – Existing Conditions Hydraulic Model Results**

| Storm Event | Inflow (cfs) | Outflow (cfs) | Peak Stage | Overtopping Depth (ft) |
|---|---|---|---|---|
| PMF | 15,800 | 15,155 | 1642.18 | 2.0 |
| 0.5 PMF | 6,680 | 6,693 | 1640.4 | 0.2 |
| 100-year | 3,776 | 3,889 | 1638.59 | 0 |
| 50-year | 2,936 | 3,739 | 1638.46 | 0 |

## II. DAM BREAK ANALYSIS MODELING

### Requirements

The *Virginia Impounding Structures Regulations (Dam Safety)* require that a dam break 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, unless the purpose of the dam is for flood control, in which case the analysis utilizes the volume retained at the auxiliary spillway elevation.
2. A dam break analysis utilizing the spillway design flood without a dam failure.
3. An analysis utilizing the spillway design flood without 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 #6 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 #6 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 1593 |
| 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 Breach Analysis Results**

| River Station | Distance from Dam (ft) | Structure | Max. Stage | Max. Depth (ft) | Peak Flow(cfs) |
|---|---|---|---|---|---|
| 10829 | 0 | South River Dam #6 | 1633.0 | N/A | 11,231 |
| 08399 | 2,400 | Route 608 Bridge | 1562.39 | 13.49 | 11,231 |
| 00781 | 10,050 | N&W Railroad Bridge | 1487.62 | 13.72 | 13,104 |
| 00221 | 10,610 | Route 658 Bridge | 1482.47 | 13.47 | 13,104 |

Table 7 shows structures that could be impacted by a sunny day breach failure of South River Dam #6. Structures where the peak water surface elevation was within two feet of the finished floor elevation are shown, along with those where the finished floor elevation is inundated.

**Table 7**
**Potentially Impacted Structures – Sunny Day Breach**

| Structure No. | Distance from Dam (miles) | First Floor Elevation | Peak Stage |
|---|---|---|---|
| 1 | 0.4 | 1565.7 | 1562.4 |
| 2 | 0.5 | 1544.8 | 1550.9 |
| 3 | 0.5 | 1546.0 | 1550.9 |
| 4 | 0.8 | 1532.8 | 1530.8 |
| 5 | 1.2 | 1505.9 | 1508.9 |

The results of the analysis indicate that at least three roads and three structures would likely be impacted by a sunny day breach failure of South River Dam #6. It should be noted that the analysis showed significant attenuation due to backwater from all three bridges modeled downstream of the dam.

## 2. Probable Maximum Flood (PMF) Dam Break Analysis

A dam break analysis for the South River Dam #6 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 1591 |
| Breach bottom width: | 78 ft |
| Side slopes of breach: | 0.5H:1V |
| Breach development time: | 0.5 hr |

Reservoir storage and dam break 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 8.

**Table 8**
**PMF Overtopping Breach Analysis Results**

| River Station | Distance from Dam (ft) | Structure | Max. Stage | Max. Depth (ft) | Peak Flow(cfs) |
|---|---|---|---|---|---|
| 10829 | 0 | South River Dam #6 | 1640.93 | N/A | 32,547 |
| 08399 | 2,400 | Route 608 Bridge | 1565.71 | 16.81 | 32,547 |
| 00781 | 10,050 | N&W Railroad Bridge | 1491.46 | 18.66 | 34,420 |
| 00221 | 10,610 | Route 658 Bridge | 1486.47 | 17.47 | 34,420 |

Table 9 shows structures that could be impacted by an overtopping breach failure of South River Dam #6. Structures where the peak water surface elevation was within two feet of the finished floor elevation are shown, along with those where the finished floor elevation is inundated.

**Table 9**
**Potentially Impacted Structures – PMF Overtopping Breach**

| Structure No. | Distance from Dam (miles) | First Floor Elevation | Peak Stage |
|---|---|---|---|
| 1 | 0.4 | 1565.7 | 1565.6 |
| 2 | 0.5 | 1544.8 | 1554.2 |
| 3 | 0.5 | 1546.0 | 1554.2 |
| 4 | 0.8 | 1532.8 | 1536.6 |
| 5 | 1.2 | 1505.9 | 1513.1 |

The results of the analysis indicate that at least two roads, one railroad and five structures would likely be impacted by an overtopping breach failure of South River Dam #6. It should be noted that the analysis showed significant attenuation due to backwater from all three bridges modeled downstream of the dam. These structures were not designed to retain a significant flood pool. Based on these findings, it is believed that the South River Dam #6 would classify as a High Hazard Dam according to VADCR, Division of Dam Safety and Floodplain management.

## 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 or the product of the average floodplain flow velocity and the incremental depth is greater than 7.0 $ft^2$/second. 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 #6 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 Route 608, Norfolk & Western Railroad, and Route 658 bridges, and on each of the five structures. Route 608 is classified as a primary roadway, while Route 658 is classified as a secondary roadway. The results of the analyses are presented in Tables 10 and 11, and are discussed on the following page.

## Table 10
## 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 | SDF Failure Velocity (fps) | Overtopping Depth (ft) | SDF Non-Failure WSEL | SDF Non-Failure Velocity (fps) | Overtopping Depth (ft) |
|---|---|---|---|---|---|---|---|---|
| Route 608 | DPR 08399 | 1557.0 | 1565.71 | 7.07 | 8.71 | 1563.20 | 5.76 | 6.20 |
| N&W Railroad Bridge | DPR 00781 | 1483.0 | 1491.46 | 7.72 | 8.46 | 1493.90 | 2.95 | 10.90 |
| Route 658 | DPR 00221 | 1477.0 | 1486.47 | 9.11 | 9.47 | 1483.34 | 7.36 | 6.34 |

## Table 11
## Impact of Spillway Design Flood (PMF) Failure and Non-Failure Events on Downstream Structures

| Structure No. | River Station | FFE | SDF Failure WSEL | SDF Failure Velocity (fps) | Overtopping Depth (ft) | SDF Non-Failure WSEL | SDF Non-Failure Velocity (fps) | Overtopping Depth (ft) | Incr. Depth (ft) | Incr. Depth x Velocity |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | DPR 08717 | 1565.7 | 1565.6 | 4.9 | 0.0 | 1563.2 | 3.4 | 0.0 | 0.0 | 0.0 |
| 2 | DPR 08189 | 1544.8 | 1554.2 | 11.2 | 9.4 | 1549.9 | 8.9 | 5.1 | 4.4 | 39.2 |
| 3 | DPR 08189 | 1546.0 | 1554.2 | 11.2 | 8.2 | 1549.9 | 8.9 | 3.9 | 4.3 | 38.3 |
| 4 | DPR 06605 | 1532.8 | 1536.6 | 9.1 | 3.8 | 1534.7 | 8.0 | 1.9 | 1.9 | 15.2 |
| 5 | DPR 04493 | 1505.9 | 1513.1 | 11.2 | 7.2 | 1511.8 | 9.9 | 5.9 | 1.3 | 12.9 |

## 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 #6 is currently classified as a High 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 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.

Four permanent residential/commercial structures and three bridges are impacted by the Sunny Day and PMF (SDF) breach failures of the South River Dam #6. Based upon the results of the analyses performed in this study, and the designation of Route 608 as a primary roadway, it is the opinion of Thompson & Litton that the South River Dam #6 qualifies as a High Hazard Potential impounding structure per Dam Safety regulations.

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. The results of the incremental damage analysis of Dam #6 at the Route 608 bridge show that the incremental depth between the PMF failure and non-failure events is greater than 2.0 feet. The results do not justify reducing the proposed spillway design flood of Dam #6. Dam #6 currently does not pass the PMF event without overtopping. The analysis indicates that the primary and auxiliary spillways together are capable of passing 5,950 cfs before the dam is overtopped, which is equal to 37.7% of the PMF peak flow. Therefore, it is recommended that modifications be performed on the dam in order to bring the dam into compliance with Dam Safety regulations, which require that the dam safely pass the spillway design flood without overtopping.