# Summary of a Safe Yield Analysis for the Rivanna Water and Sewer Authority System
# DEQ Office of Surface and Ground Water Supply Planning
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## Overview

A water supply model was constructed to evaluate previously unexamined combinations of system upgrades in the Rivanna Water and Sewer Authority (RWSA) system. The main objectives were to 1) validate the currently accepted safe yield study (Gannett-Fleming January 2004, July 2004), and the Ragged Mountain full expansion study (Hydrologics, 2010), 2) to employ this new model to evaluate scenarios involving enhancements to the Ragged Mountain Dam and dredging approaches to the South Fork Rivanna reservoir, and 3) to determine if the flow-by rules established in the 2008 VWP permit would be feasible under these alternative scenarios. DEQ's model was run on two scenarios for which results were available for the Gannett-Flemming/Hydrologics model and in both cases the results were very similar or identical (Table 1). DEQ's model indicates that the proposed project alternative of dredging the South Fork Rivanna Reservoir in combination with increasing the height of the Ragged Mountain Reservoir by 13 feet (hereafter referred to as dredging and dam renovation) in the context of the existing instream flow permit conditions in VWP Permit 06-1574 would achieve a safe yield of approximately 16.8 mgd. This yield is less than the projected 2055 demand of 18.7 mgd as presented in the 2006 community water supply plan. Our modeling indicates that the currently permitted Ragged Mountain Reservoir expansion would result in a safe yield of approximately 18.7 mgd under the same permit conditions.

## Modeling Details

### Modeled Permit Conditions

The current permit conditions related to instream flows and conservation measures were predicated on the proposed replacement of the Ragged Mountain Reservoir with a new larger dam with a normal pool elevation of 686.0 feet, an increase in height of 45 ft, and the construction of a pipeline from the South Fork Rivanna Reservoir. Therefore, the evaluation of an alternative set of reservoir resources (dredging of the South Fork Rivanna Reservoir and a 13 ft expansion of Ragged Mountain Reservoir) that was not considered during the development of the current permit special conditions is somewhat problematic. However, an evaluation of alternative reservoir resources in the context of the existing permit conditions can provide an indication of whether or not the desired stream flow and water demands can be met. The scenarios presented in this summary assume that either the historic operating conditions are followed or that special conditions in Part I.F.4. from VWP Permit 06-1574 are implemented. The special conditions are designed for the completed RWSA system and we feel are indicative of the desired long-term instream flow conditions.

**Assumptions**

- The total volume at Ragged Mountain under a 13 foot expansion would be 791.4 MG, with an estimated 85% usable for a final usable volume of 672.7 MG (Tom Frederick, personal communication, October 2009).
- The usable volume of the South Fork Rivanna River under continuous dredging is assumed to be 1,026 million gallons (85% of the total reservoir capacity).
- The usable volume of the South Fork Rivanna Reservoir in 2055 without maintenance dredging is assumed to be 200 million gallons.
- In order to satisfy any additional safe yield based on an increase in storage of the Ragged Mountain dam, it is assumed that the pipeline taking water from the Ragged Mountain supply has sufficient capacity to satisfy 100% of the system demand.
- All scenarios assume that Ragged Mountain Reservoir is full on May 1, 2002. The model simulations concluded that this would in fact be the case, due to natural inflow. However, in the event of different meteorological patterns adequate pumpage would be required to insure that this was the case.
- Ragged Mountain could be refilled from local inflow and pumping from the Mechums River station (when available), at a max refill rate of 4 MGD. However, it was the conclusion of the most recent system safe yield study that this ability did not increase the system capacity during the drought of 2002. This conclusion was verified in this review.
- Beaver Creek Reservoir Demand – Town of Crozet was modeled as having a demand of 1.1 MGD (Gannett-Fleming, July 2004) for the existing safe yield study, and then at 1.5 MGD for the 2055 analysis of Ragged Mountain expansion options.
- Total system demand in 2055 is assumed to be 18.7 MGD (Gannett-Fleming, May 2004)
- During the duplication of the safe yield study by Gannett-Fleming, it was assumed that the withdrawals from Sugar Hollow reservoir went directly into the water supply system. During the simulation of the 13 ft and 45 ft expansion and duplication of the OASIS model, these were modeled as flow augmentation releases via Moormans River, which were subject to a 20% loss due to channel seepage on the way to South Fork Rivanna Reservoir.

**Results**

Scenario 1 in Table 1 evaluates the system safe yield in context of the historic reservoir operating approach and the existing reservoir infrastructure and indicates that the DEQ model generally agrees with the results of the Gannett-Fleming/Hydrologics model. Scenario 4 evaluates the safe yield in context of the existing permit conditions Part I.F.4. along with the dredging and dam renovation alternative. Scenario 4 results in as estimated safe yield of 16.8 mgd. Our modeling indicates that the currently permitted Ragged Mountain Reservoir expansion (45 ft) would result in a safe yield of approximately 18.7 mgd under the same permit conditions (Scenario 5).

**Table 1:** Scenario results. Permitted operating conditions are the flowby conditions in VWP Permit Conditions 06-1574 Part I.F.4. Scenario 5 was run using the estimated volume of the South Fork Reservoir in 2005 without dredging.

| Scenario | Scenario Description | | Ragged Mountain Usable Vol. | Sugar Hollow Usable Vol. | South Fork Usable Vol. | Total System Usable | Safe Yield. Hydrologics/ Gannett-Flem | Safe Yield, DEQ |
|---|---|---|---|---|---|---|---|---|
| | Operating Conditions | Infrastructure | | | | | | |
| 1 | Historic | Existing | 463 MG | 324 MG | 800 MG | 1,587 MG | 12.9* MGD | 13.1* MGD |
| 2 | Permitted | Existing with dredging of SF | 463 MG | 324 MG | 1,026 MG | 1,813 MG | n/s | 15.5 MGD |
| 3 | Historic | Dredging and Dam renovation | 672 MG | 324 MG | 1,026 MG | 2,022 MG | n/s | 15.7 MGD |
| 4 | Permitted | Dredging and Dam Renovation | 672 MG | 324 MG | 1,026 MG | 2,022 MG | n/s | 16.8 MGD |
| 5 | Historic | Permitted 45ft Ragged Mountain Dam (2055) | 1759.5 MG | 324 MG | 200 MG | 2,283.5 MG | 18.7 MGD | 18.7 MGD |

* All simulations are relative to the 2002 drought, since a more comprehensive flow record is available for that period of time. This results in a slightly higher (0.2 MGD) yield in the DEQ model due to differences between the 1930s and 2000s drought period. For the expanded system, the meteorological conditions of the 2002 drought proved more severe than the drought of the 1930s. Also, Crozet demand was run as 1.1 MGD to be consistent with Gannett-Fleming Safe Yield Study, supplement.

**Table 2:** Dry Year Flow Summary: mean flows by month for 2002. Comparing Scenario 4 with Scenario 5.

| Year-Month | South Fork (Scenario 4) | South Fork (Scenario 5) | % Difference | Sugar Hollow (Scenario 4) | Sugar Hollow (Scenario 5) | % Difference |
|---|---|---|---|---|---|---|
| 2002-01 | 19.9 | 17.1 | 16.1% | 1.43 | 1.43 | 0.0% |
| 2002-02 | 13.9 | 12.0 | 15.9% | 1.49 | 1.49 | 0.0% |
| 2002-03 | 67.2 | 62.9 | 6.9% | 6.79 | 6.79 | 0.0% |
| 2002-04 | 86.5 | 82.9 | 4.3% | 8.39 | 8.39 | 0.0% |
| 2002-05 | 42.6 | 40.5 | 5.1% | 3.65 | 3.65 | 0.0% |
| 2002-06 | 5.0 | 5.0 | 0.0% | 0.26 | 0.26 | 0.1% |
| 2002-07 | 2.2 | 2.1 | 0.0% | 0.05 | 0.05 | 2.6% |
| 2002-08 | 2.0 | 2.0 | 0.0% | 0.000 | 0.00 | 0.0% |
| 2002-09 | 2.0 | 2.0 | 0.0% | 0.266* | 0.02 | 996.2% |
| 2002-10 | 5.5 | 5.5 | -0.1% | 0.62 | 0.60 | 3.4% |
| 2002-11 | 110.9 | 148.5 | -25.3% | 9.06 | 10.34 | -12.4% |
| 2002-12 | 193.8 | 190.3 | 1.8% | 11.74 | 12.19 | -3.7% |

* Flow is modeled according to permit special condition F.4.b.ii.b at 10% full.

One interesting outcome of the Rivanna permit is that the flow-bys are generally maintained at a higher level under typical conditions (and on average over the whole period modeled), however, under the most severe drought conditions, two trade-offs occur: 1) the single day and 7 day low flows decrease out of the South Fork reservoir, and 2) the refill time for South Fork reservoir increases. Thus, while the reservoir is allowed to hold back more water during the driest times, it comes at the price of replenishing storage more gradually. This can be seen in Figure 1, where the new flow by becomes less than the historical flow-by in mid-June, and continues to be larger until mid-August,

when the inflow to the reservoir decreases below 1.3 MGD. In mid-October and through November, however, the new flow-by begins to increase relative to the historical voluntary flow-by as system storage begins to rebound (see Table 3).

**Table 3:** Comparison of average daily flow-bys at the South Fork Rivanna River reservoir for each month of the critical period of the 2002 drought.

| Year | Month | Historic Voluntary Flow-by (cfs) | VWP Permit Flow-by (cfs) | Difference (cfs) |
|---|---|---|---|---|
| 2002 | 4 | 12.36 | 30.04 | 17.68 |
| 2002 | 5 | 12.38 | 27.22 | 14.84 |
| 2002 | 6 | 11.18 | 8.87 | -2.31 |
| 2002 | 7 | 6.41 | 2.96 | -3.45 |
| 2002 | 8 | 1.69 | 2.00 | 0.31 |
| 2002 | 9 | 1.59 | 2.02 | 0.44 |
| 2002 | 10 | 9.20 | 7.83 | -1.37 |
| 2002 | 11 | 12.38 | 26.44 | 14.07 |

**Figure 1:** Comparison of historical flow-bys, and flow-bys in South Fork Rivanna reservoir as described in the VWP Permit (45' expansion of Ragged Mountain, 2055 conditions). The difference between the two flow-by regimes results in a decrease in flow-by during the most critical time of approximately 1 MGD, yielding a slightly higher overall safe yield.

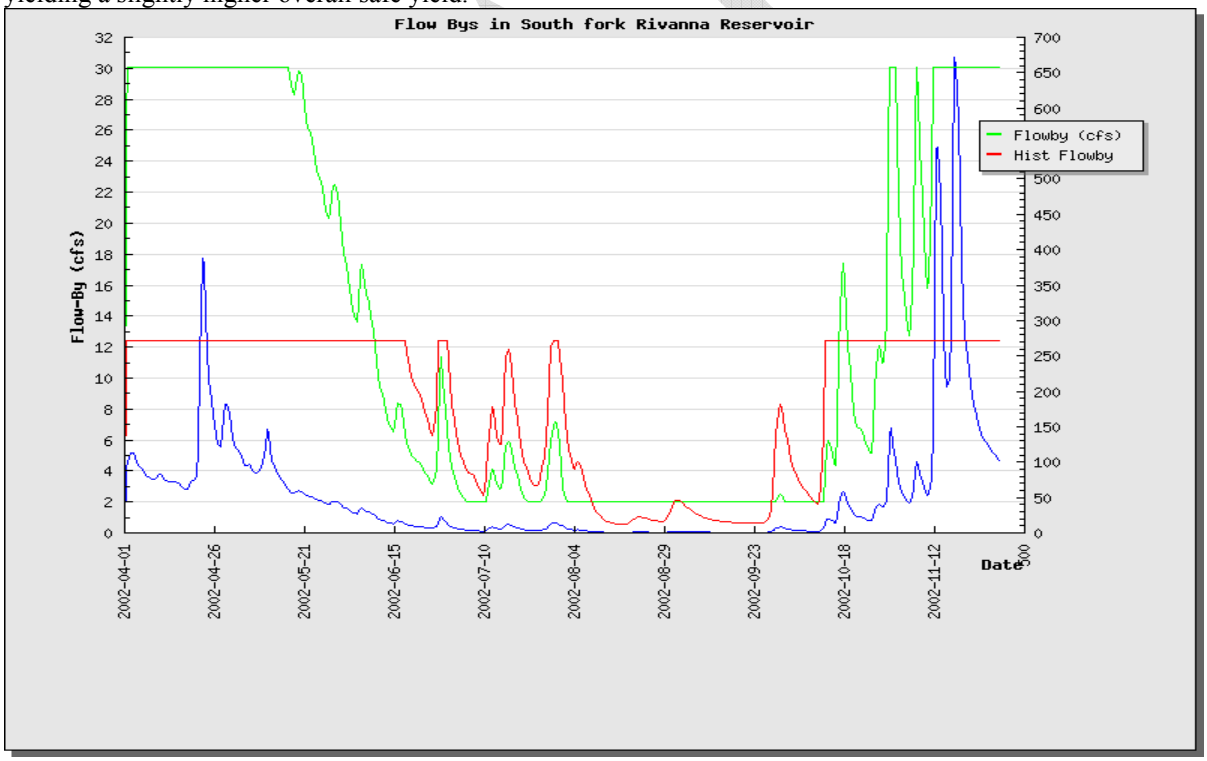
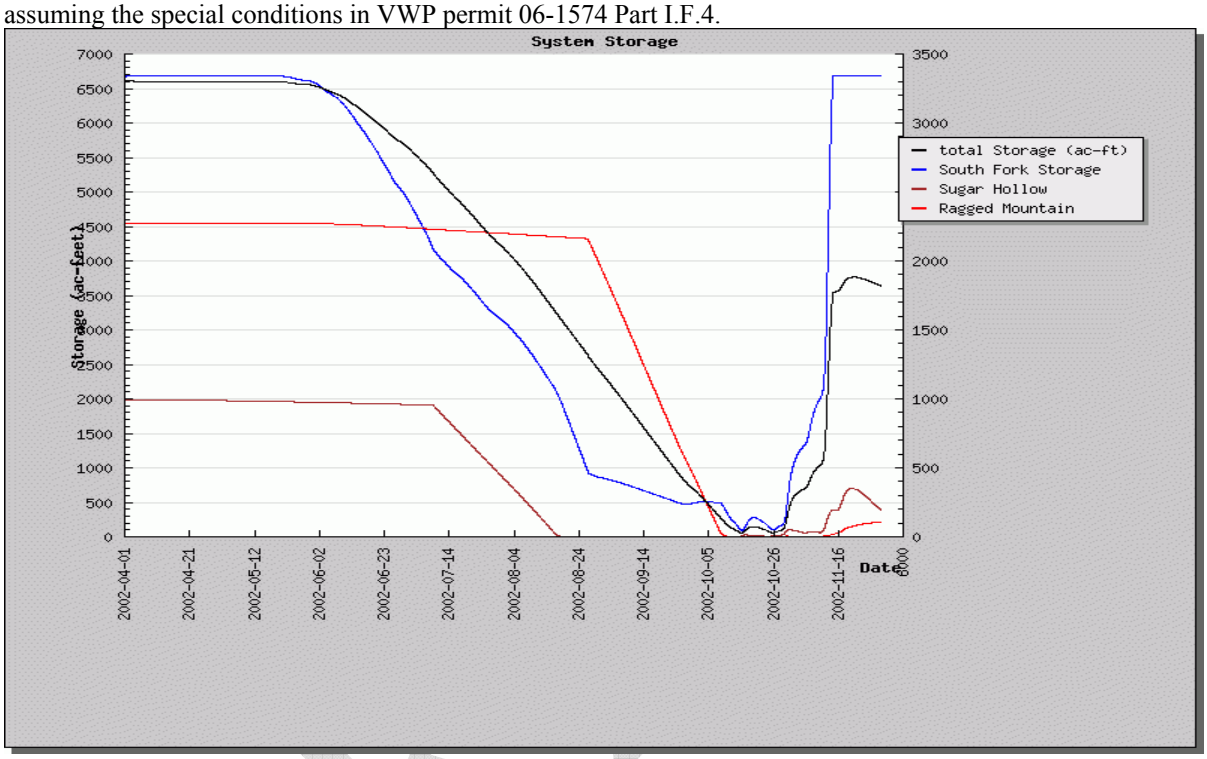


**Figure 2:** Modeled storage in the RWSA system during the drought of 2002. Values for total system storage (in black) are given on the left-hand axis, while individual reservoirs are found on the right-hand axis. All values are from the model run which examined a continuous dredging condition in the South Fork Reservoir (85%), and a 13 foot increase in the spillway height at the Lower Ragged Mountain Dam assuming the special conditions in VWP permit 06-1574 Part I.F.4.



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