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RWSA Safe Yield and Reliability Analysis Update Report

Work Authorization No. 1
Hazen Project No. 31430-000
July 23, 2020



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1. Introduction and Purpose

To keep RWSA's comprehensive water supply and infrastructure planning up-to-date, and in accordance with the Ragged Mountain Dam Agreement (RMDA) dated January 1, 2012 (Appendix A), RWSA contracted Hazen and Sawyer (Hazen) to conduct a water demand forecast and safe yield analysis for the Urban Water System. This report addresses the safe yield analysis. The water demand forecast is covered in a separate report by Hazen.¹

2. Overview

The RMDA states that at least once every ten years after the date of the Agreement, and not later than the year 2020, RWSA shall "update the analysis of safe yield of the Urban Water System following each new bathymetric survey of the South Rivanna Reservoir...using the latest available data on useable storage in the South Rivanna Reservoir, the Ragged Mountain Reservoir, and the Sugar Hollow Reservoir." The method for determining safe yield "shall be as set forth in the regulations of the Virginia Department of Health [VDH]".

Per 12VAC5-590-830 of VDH regulations for surface water sources, the safe yield for a "complex intake", which is applicable to RWSA, is defined as "the minimum withdrawal rate available to withstand the worst drought on record in Virginia since 1930."

Hazen used the RWSA OASIS Hydrologic Model to compute the safe yield for the Urban Water System under a range of infrastructure upgrade and operating scenarios. Developed by HydroLogics (now part of Hazen and Sawyer), the OASIS model has been used extensively by RWSA for analysis on its supply system, including safe yield analysis and drought trigger development².

Figure 2-1 shows a schematic of the Urban Water System that depicts the reservoirs, water production facilities, and raw water diversions between the Urban reservoirs.

¹ RWSA Urban System Water Demand Forecast Report, Hazen and Sawyer, July 14, 2020. Hazen and Sawyer Project No. 31430-000.

² Modeling RWSA's Water Supply Operations with OASIS, June 2018, HydroLogics

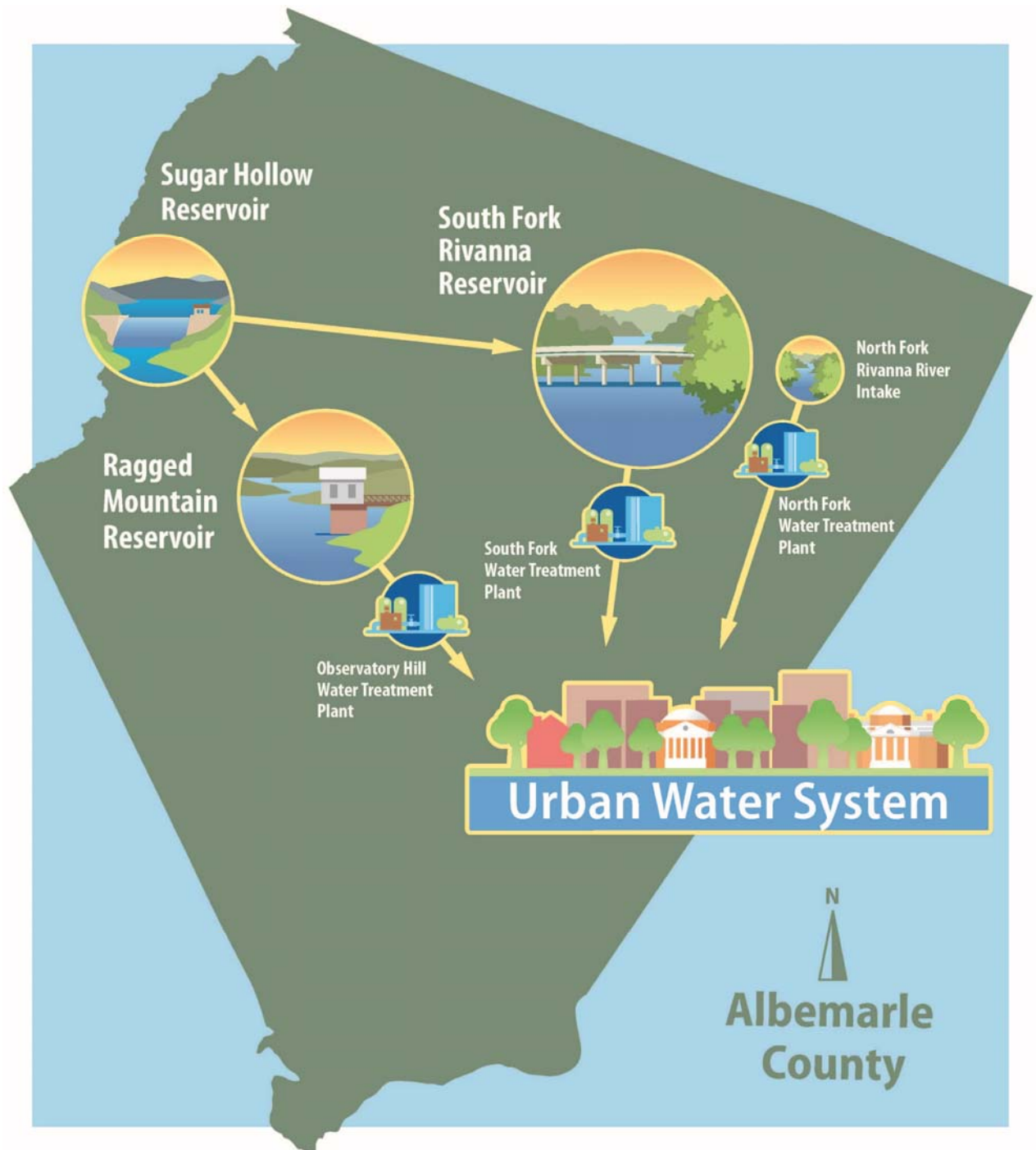


Figure 2-1: RWSA Urban Water System Schematic

The OASIS model is used to simulate the flow of water through the system, with the goal of meeting water supply demands and minimum releases from reservoirs subject to constraints on useable storage and capacities of treatment plants and raw water pipelines.

This report will focus specifically on the safe yield metric. Other measures of reliability – such as the frequency, severity, and duration of drought plan restrictions and drawdown in individual reservoirs – have been explored as part of previous studies and operations exercises.

Hazen evaluated yield under a variety of scenarios related to infrastructure and operations. Yields were categorized as defined below:

1. **“Theoretical” Safe Yield** - This is the best-case scenario in which only the raw water supply sources are limiting. Factors such as treatment capacity and raw water and finished water conveyance capacities are not incorporated into the calculations. This approach is consistent with VDH’s definition for safe yield and is typically how RWSA safe yield for the Urban Water System has been presented in the past. This calculation of yield provided the basis for the capacity upgrades following the 2002 drought and the Department of Environmental Quality (DEQ) Virginia Water Protection (VWP) permit for the Urban Water System.
2. **“Operational” Safe Yield** – This calculation factors in the production constraints at the treatment plants which may limit how much of the raw water supply can be used, along with the drought plan triggers which result in cutbacks to demand. Furthermore, it includes the constraints of conveying water between reservoirs and the treatment plants. For example, the operations in the 2020 model scenario reflect that Ragged Mountain Dam water can only be treated at the Observatory water treatment plant (OWTP), and South Rivanna Reservoir water can only be treated at the South Rivanna WTP. Once the future Ragged Mountain to South Rivanna Raw Water Pipeline is installed, water from either reservoir can be treated at either WTP. This will increase redundancy and resiliency as well as operational safe yield. This category of yield provides a more realistic picture of system reliability since it factors in the limitations of what can be withdrawn from the reservoirs for meeting water supply demands.
3. **“DEQ Regulatory” Yield** – Current DEQ staff guidance to municipalities has included consideration for maintaining a system storage reserve in the worst drought (set equal to 60 days of unrestricted demand). While this is not a current regulation, Hazen has proactively evaluated this condition for the RWSA system as the worst-case scenario.

Hazen worked with RWSA staff to develop a comprehensive matrix of yield model runs for a wide variety of structural and operational scenarios over a 50-year planning horizon. These scenarios included infrastructure upgrades (like the South Rivanna to Ragged Mountain pipeline) and operational assumptions (like factoring in demand reductions as a drought develops). These scenarios in turn were organized into timelines to inform the sequencing of capital investments relative to the projected water demands.

3. Reservoir Bathymetry

Bathymetry is defined as the subaqueous survey of lakes and reservoirs to determine the topography of the lake bottom, total volume and the stage-storage curve (which provides incremental volume calculation). Bathymetric studies of the RWSA reservoirs are completed on a periodic basis with the Urban reservoir surveys no more than once every 10 years. Results from the latest updates by Draper Aden Associates are summarized in Table 3-1. Appendix B provides the surveys in graphical form.

Reservoir	Prior Useable Storage (MG) and Year of Survey	Current Useable Storage (MG) and Year of Survey	Changes (MG)
Ragged Mountain	1,513 (2014)	1,441 (2018)	-72
South Rivanna	883 (2009)	885 (2018)	+2
Sugar Hollow	350 (1995)	339 (2015)	-11
Total	2,746	2,600	

Table 3-1: Urban Reservoir Bathymetry Summary

Safe yield is impacted by South Rivanna Reservoir sedimentation and sedimentation rates. Figure 3-1 shows the impact of sedimentation over time. The usable storage appeared to slightly increase with the last bathymetric survey. It is unknown whether it was due to a storm event, improvements in bathymetric survey techniques, or other factors, but it will continue to be monitored in future surveys. This safe yield work utilized the previous sedimentation rate estimate of 15 MG/year to be conservative.

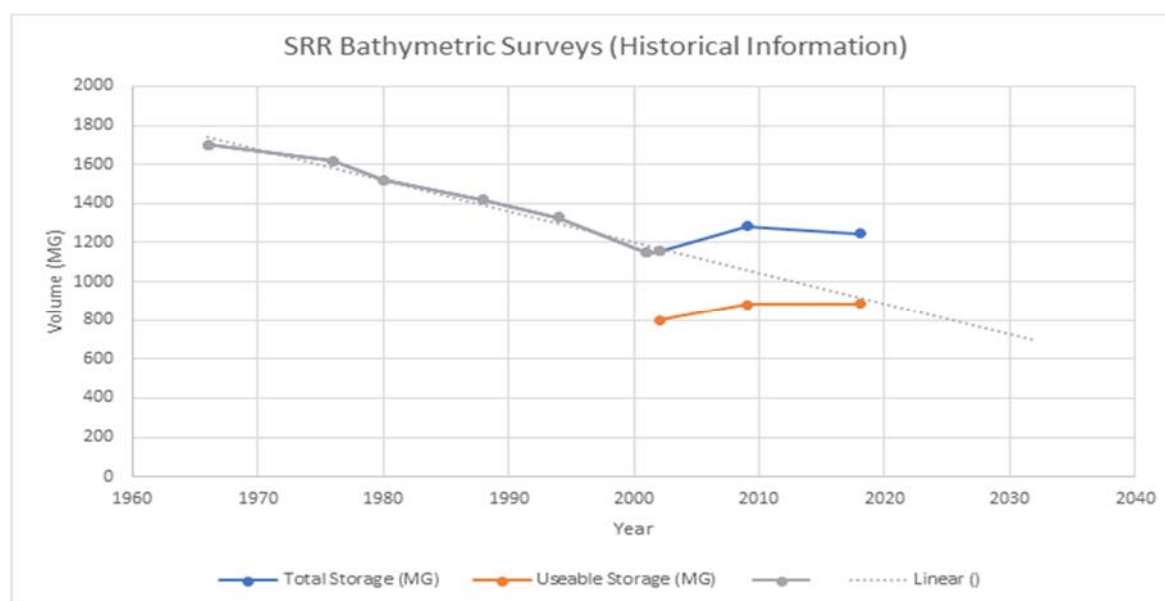


Figure 3-1: Bathymetry for South Rivanna Reservoir

4. Assumptions for Yield Modeling

Key structural improvements considered in the yield analysis included the following:

- (1) Upgrades to the OWTP in 2023, which will raise the OWTP capacity to 10 mgd and no longer require a minimum production level (which helps to preserve Ragged Mountain storage)
- (2) Addition of the South Rivanna to Ragged Mountain (SR-RM) pipeline, which would accelerate refill of Ragged Mountain, allow water to be pumped in both directions between the South Rivanna Reservoir and Ragged Mountain Reservoir (and both the South Rivanna WTP and OWTP), and increase flow in the Moormans River because the Sugar Hollow to Ragged Mountain pipeline would no longer be used
- (3) Raising Ragged Mountain 12 feet to a normal full pool elevation of 683 feet to increase storage capacity (by about 700 MG) and therefore increase yield

The OASIS inflow record starts in the mid-1920s and extends through present, ensuring consideration of the 1930 drought per VDH regulation, as well as the 2001-02 drought. In recent years, HydroLogics staff (now with Hazen and Sawyer) improved the accuracy of the inflows after an extensive verification process using historical operating data and consultation with RWSA staff. Note that model inflows are unregulated, or naturalized -- in which the impacts of historic regulation like reservoir operations on streamflow data are removed-- allowing the user to look at operating the system or meeting demands that may differ from those in the past.

For each OASIS yield run, a set of facilities (infrastructure), demands, and operating rules are simulated over the nearly 100-year unregulated inflow record (as if they were in place for the 100 years), and annual average demand is increased until the simulated system storage (useable storage in Sugar Hollow, South Rivanna, and Ragged Mountain) is fully depleted, or in the case of the DEQ regulatory yield scenario, until the system storage reaches 60 days of supply remaining. The critical drought defining the yield for all scenarios is the 2001-02 drought which produced the lowest inflows on record. This drought lasted approximately 18 months, from the summer of 2001 to the end of 2002. The North Rivanna intake is assumed to withdraw water to help meet system demand (and thus increase yield), with the withdrawal set to a maximum of 2 mgd in the “theoretical” safe yield runs and normal operating limit of 0.5 mgd in the other yield runs. The North Rivanna withdrawal may be limited by available upstream inflow, which does occur in the second year of the 2001-02 drought.

Operating rules include minimum release requirements in accordance with the VWP permit (percent of inflow tied to useable storage, up to a maximum discharge), timing and transfer of water between sources, monthly demand patterns (Appendix C), and in the case of the operational and regulatory yield scenarios, drought plan triggers and associated water use reductions. To take advantage of the useable storage in the reservoirs, Hazen adjusted the operating rules (e.g., shift production from South Rivanna to Observatory WTPs) depending on the assumed storage and production capacities in each of the yield scenarios. Hazen did not adjust the drought plan triggers, which were designed for current conditions but appear to be robust for a wide range of demands. Sedimentation is also factored in for South Rivanna Reservoir, with reductions of 15 MG/year of useable storage. As an example, a simulation of the year 2050 conditions

would result in 300 MG less storage in South Rivanna compared to the year 2030 conditions with the consideration of 20 years of sedimentation.

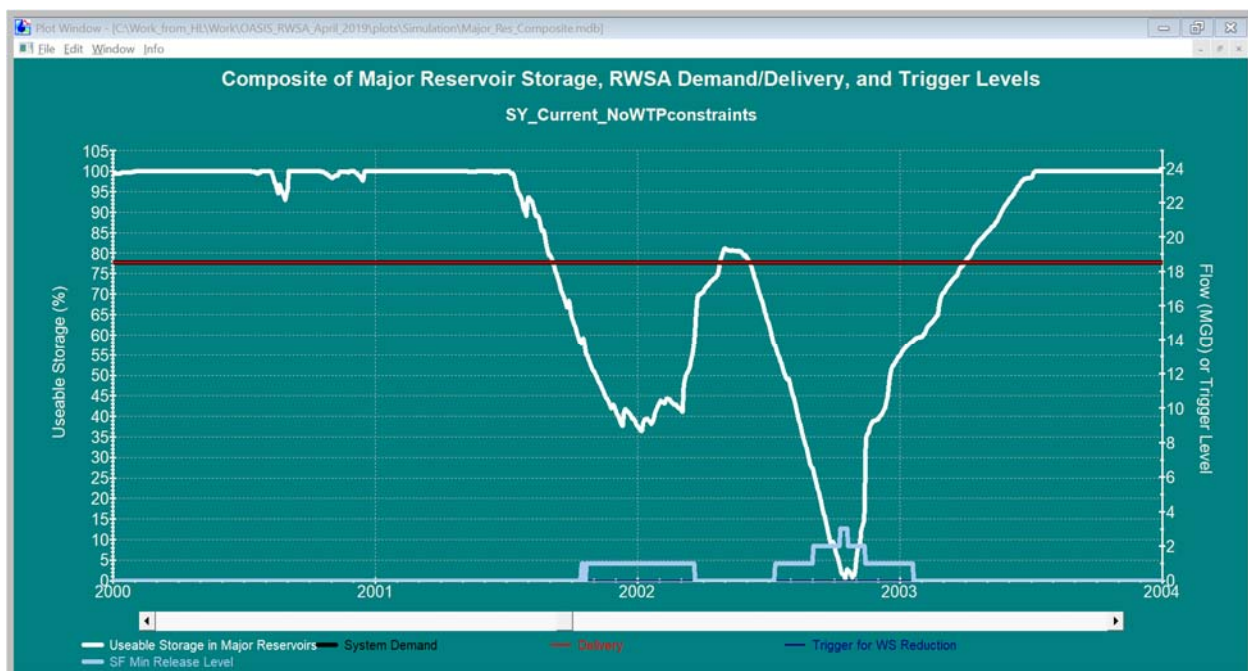
5. Yield Results

1. “Theoretical” Safe Yield

Theoretical safe yield is calculated using the following assumptions. These are consistent with previous calculations of system safe yield.

- No operational constraints for treatment capacity or conveyance at South Rivanna and Ragged Mountain
- No active drought plan
- No monthly demand pattern
- North Rivanna withdrawal up to 2 mgd to help meet system demand

Model run output is shown below in Figure 5-1, with the key variables shown in white (simulated storage, representing the sum of useable storage in Sugar Hollow, South Rivanna, and Ragged Mountain) and red (simulated water supply delivery). Annual average demand that can be met by the system in a repeat of the critical drought (2001-02) without fully depleting storage is 18.6 mgd. This “theoretical” safe yield is based on current (2020) useable system storage summarized in Table 3-1. In future years, safe yield declines due to projected loss in useable storage in South Rivanna associated with sedimentation.



**Figure 5-1: Theoretical Safe Yield Determination for Drought of Record
(Using 2020 Storage Conditions)**

Simulated storage by reservoir for this run is shown in Figure 5-2. In this safe yield run, all storage is exhausted to meet the 18.6 mgd demand. Note that the operating rules are designed to maximize yield. Since South Rivanna Reservoir (labeled South Fork in the plot) with its larger watershed refills quickly, priority is given to meeting water demand from this reservoir first so that raw water is captured for water supply and not spilled unnecessarily downstream. As South Rivanna draws down, water from Ragged Mountain (and supplemented by diversions and releases from Sugar Hollow) will be relied upon to meet relatively more of the demand. No limits on WTP capacity or conveyance exist in the theoretical safe yield run, allowing for flexibility in which supply source to pull from. It should be noted that other considerations, like preferences on minimum reservoir operating levels, are also ignored in order to maximize yield.



**Figure 5-2: Useable Storage by Reservoir from Theoretical Safe Yield Run
(Using 2020 Storage Conditions)**

2. “Operational” Safe Yield

Operational safe yield is calculated using the following assumptions.

- Limits on WTP capacity at the Observatory
 - 2020: 1 mgd minimum, 4.5 mgd maximum
 - 2023: 0 mgd minimum, 10 mgd maximum
- Limits on WTP capacity at South Rivanna
 - 2020: No minimum, 11 mgd maximum

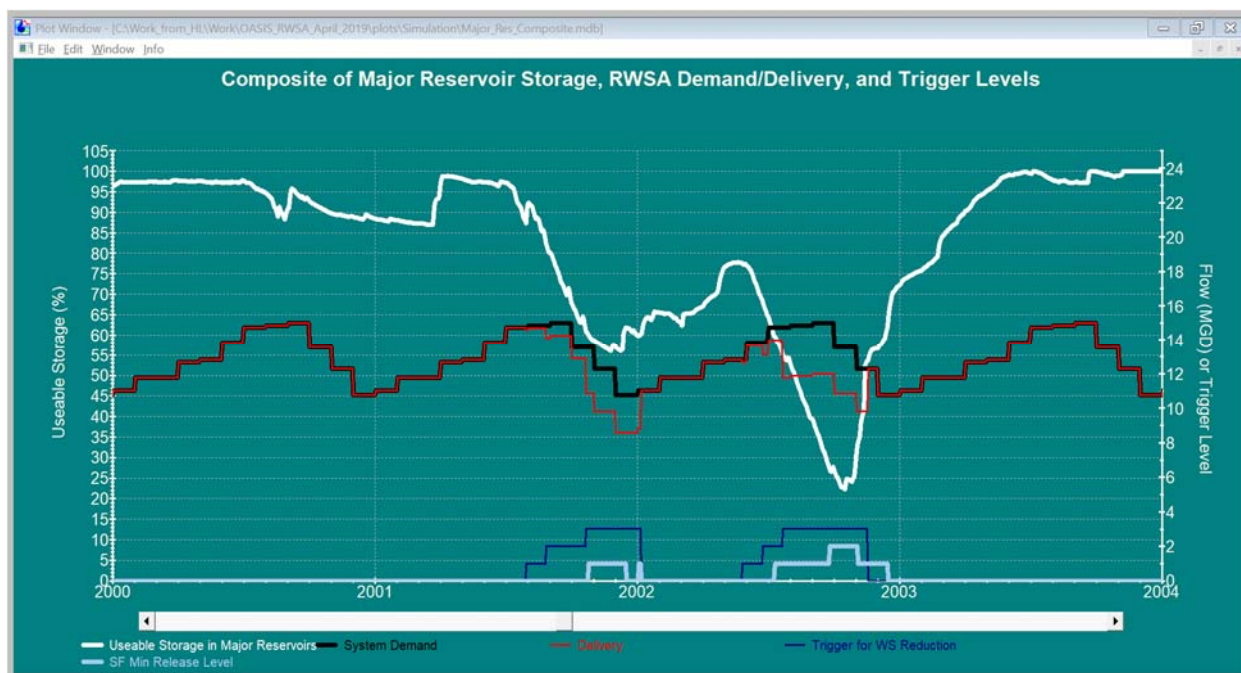
- 2023: No minimum, 12 mgd maximum
- Drought plan is active
- Monthly demand pattern (see Appendix C)
- North Rivanna withdrawal up to 0.5 mgd to help meet system demand

When limitations on treatment capacity (both minimum and maximum production) are introduced, thereby limiting flexibility on raw water withdrawals from the reservoirs, the yield is negatively impacted. Under the assumptions described above, the “operational” safe yield in 2020 (where 2020 useable storage is used) is much lower (12.8 mgd) than the theoretical safe yield (18.6 mgd) because of today’s WTP constraints. The drawdown plots for 2020 are shown below in Figures 5-3 and 5-4.

Figure 5-3 shows system drawdown in the drought of record. Important differences from the theoretical safe yield run are seen. Focusing on the key variables (storage in white and delivery in red), it can be seen that system storage is not exhausted. In fact, over 20% storage remains. The WTP production constraints in this run require that water be withdrawn at all times from the respective sources (South Rivanna WTP from South Rivanna Reservoir, and OWTP from Ragged Mountain Reservoir). If either supply source has emptied, then the system delivery cannot be met in full, which is required in a safe yield run. It should also be noted that the monthly demand pattern and drought plan are incorporated in this run, meaning that delivery will be reduced by the amount of demand reduction (up to three levels) targeted in the drought plan. The impact of the demand reductions is reflected in the difference between the red (nominal demand) and black (delivery) lines in the plot below.

Figure 5-4 shows simulated drawdown for each of the reservoirs during this drought. Because South Rivanna Reservoir has limited storage capacity, the required production from the WTP causes it to draw down quickly. Once the South Rivanna Reservoir has reached bottom, system demand (after accounting for demand restrictions) can no longer be met, explaining why system storage (in the three Urban reservoirs and shown to be over 20% in the previous figure) is not close to being depleted. Sugar Hollow empties early as water is diverted to Ragged Mountain through the connecting Sugar Hollow pipeline in order to replenish storage in Ragged Mountain. Ragged Mountain is drawing down since OWTP is always operating at minimum capacity or higher when supplementing South Rivanna WTP’s capacity.

Note when OWTP capacity in 2023 is increased to 10 mgd, the operational safe yield will increase from 12.8 mgd to 15.1 mgd, mainly because more of the water demand can be met from Ragged Mountain and thus more of the Ragged Mountain storage can be used. System storage is fully depleted under the 2023 condition, so yield is maximized.



**Figure 5-3: Operational Safe Yield Determination for Drought of Record
(Using 2020 Storage Conditions)**



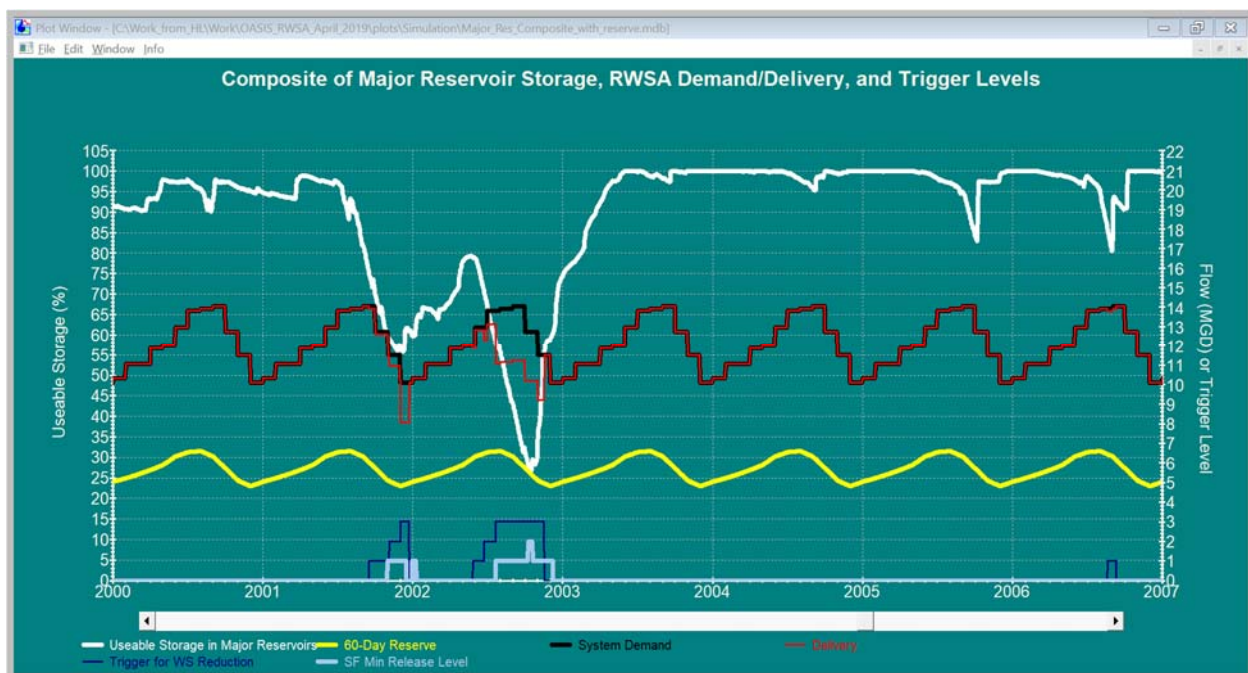
**Figure 5-4: Useable Storage by Reservoir from Operational Safe Yield Run
(Using 2020 Storage Conditions)**

3. “DEQ Regulatory” Safe Yield

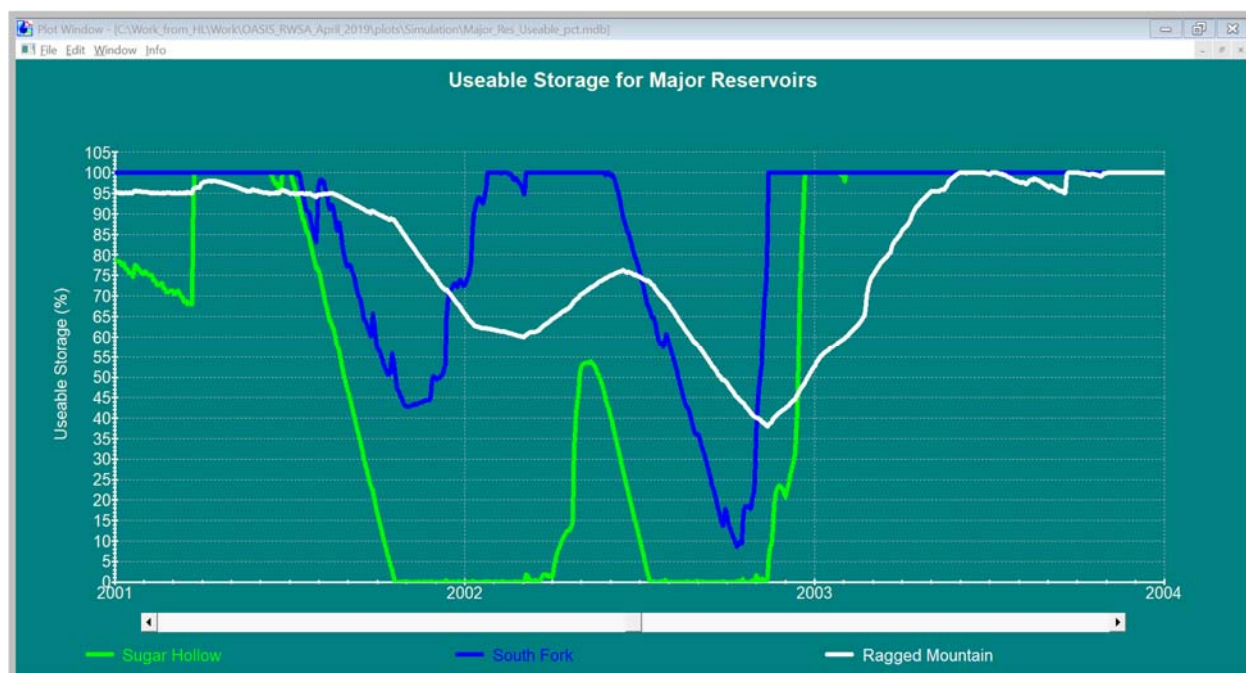
DEQ regulatory safe yield uses the same assumptions as the “operational” yield scenario except for one additional limitation: inclusion of a 60-day system storage reserve. This reserve is equivalent to 60-days of demand, and means that when calculating yield, system storage cannot be depleted below this reserve in the worst drought. With this additional limitation, the yield declines further, to 12.0 mgd based on 2020 operational and storage conditions. In the 2020 model run, the true impact of the 60-day reserve is not reflected in the incremental decrease from the operational safe yield. This is because there was 20% useable reservoir capacity remaining in the 2020 operational safe yield run that is being accounted for in the 60-day storage reserve.

For the 2023 condition, the DEQ Regulatory safe yield will be 12.9 mgd, compared to the operational safe yield of 15.1 mgd, which reflects a much higher reduction in safe yield. In the 2023 operational yield run, Ragged Mountain storage can be fully used to support a higher level of demand. In the DEQ regulatory run, it cannot be fully used or else the 60-day system storage reserve would not be met, and so the demand that Ragged Mountain can support is lower.

Figure 5-5 shows system storage not dropping below the yellow line that represents the 60-day system storage reserve. The reserve is equal to 60 days of equivalent system demand, which varies monthly since a monthly pattern is used. The only difference relative to the “operational” safe yield determination is the 60-day reserve. Significant demand reductions would again be necessary to preserve storage. Figure 5-6 shows that to maintain this reserve, not all of the storage in South Fork and Ragged Mountain can be utilized.



**Figure 5-5: DEQ Regulatory Safe Yield Determination for Drought of Record
(Using 2020 Storage Conditions)**



**Figure 5-6: Useable Storage by Reservoir from DEQ Regulatory Safe Yield Run
(Using 2020 Storage Conditions)**

Evaluation of Operational Yield Over the Planning Horizon

Following review of the matrix of yield results, RWSA focused on the operational safe yield scenarios since they were most representative of the actual physical characteristics and limitations within the water supply, conveyance, and treatment system. Use of the traditional “theoretical” safe yield implies that the water in all the reservoirs can be treated as needed at all the water treatment plants, which is not currently possible and provides unattainable results. Planning for the DEQ regulatory safe yield at this time is overly conservative as there is little guidance and no formal regulation in this matter; however, this scenario should continue to be monitored.

RWSA used this evaluation to determine the impact of structural and non-structural constraints, such as pipelines and treatment capacity, and how the Drought Response and Contingency Plan can help preserve supply during drought periods. This provided valuable information as to the timing of improvements and impacts to safe yield.

Figure 5-7 shows the result for operational yield and how the yield will change over time due to loss of useable storage in South Rivanna as a result of sedimentation. As noted, current system operational yield is 12.8 mgd. Capacity upgrades to the OWTP are planned for 2023, explaining the large increase in yield between years 2020 and 2030.

Also plotted in Figure 5-7 are the current water raw water demand projections. In 2060, the demand is projected to reach the operational yield.

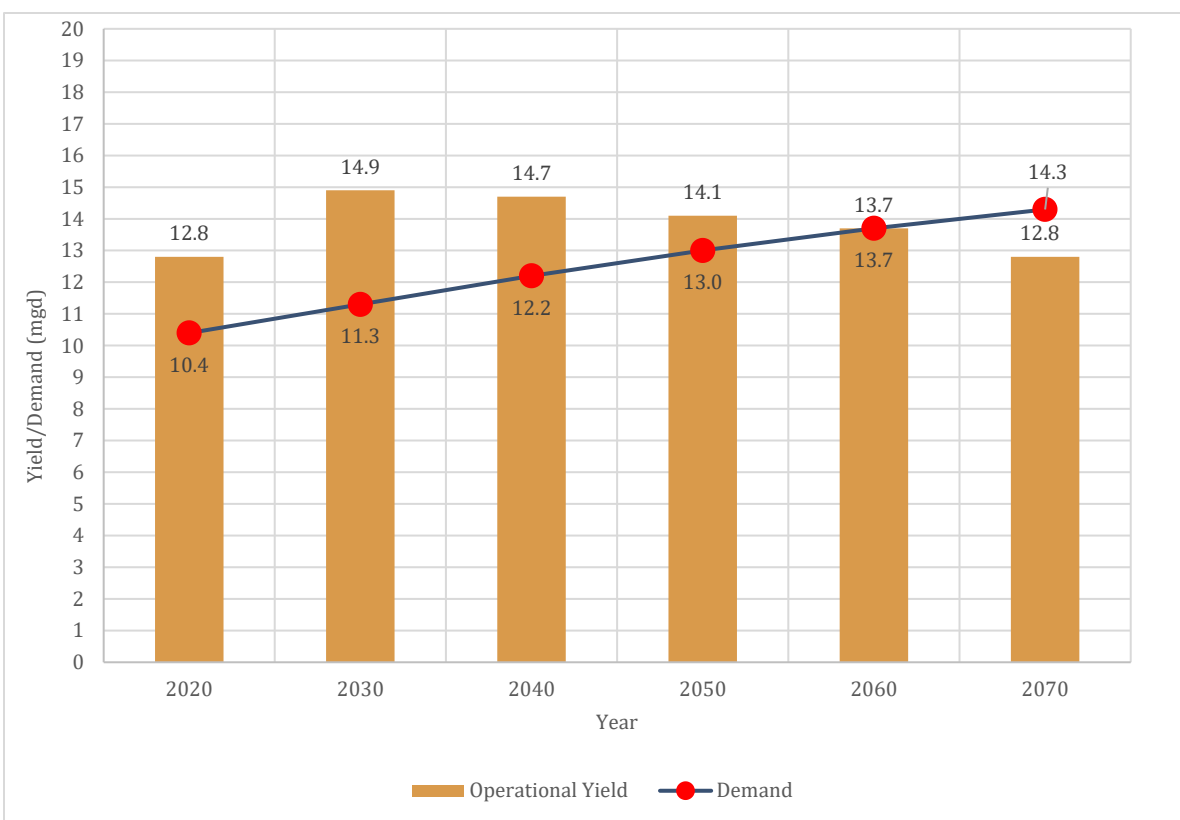


Figure 5-7: Operational Yield Over the Planning Horizon

To provide for adequate yield to meet projected demands over the planning horizon, RWSA evaluated three buildout scenarios that varied by the timing of those actions.

Buildout Scenario A

(Raise Ragged Mountain Pool and Add South Rivanna to Ragged Mountain Pipeline in 2035)

The first scenario involves two buildout actions in 2035 that would be within the term of a renewed VWP permit (2038): raising Ragged Mountain pool by an additional 12 feet and the addition of a pipeline connecting South Fork and Ragged Mountain. As noted, the system is impacted by multi-year droughts like 2001-02, so being able to accelerate Ragged Mountain refill prior to the second year of a drought with surplus South Fork inflows allows storage to be rebalanced and increases yield over the course of the drought. The Ragged Mountain refill operating rule developed in consultation with RWSA staff is 25 mgd from South Fork when South Fork is above 75% full, 10 mgd when it is above 25% full, and no transfer otherwise.

Figure 5-8 shows the water demand and operational safe yield at five-year increments and is reflective of the 2023 expansion to 10 mgd in the Observatory WTP capacity. The increase in yield in 2035 is substantial, increasing from approximately 15 mgd to 21.5 mgd. This increase is the result of extra storage in Ragged Mountain, and the ability to move water between reservoirs (and treatment plants) to take advantage of that extra storage. The reductions in yield beyond 2035 occur because of South Fork sedimentation, but are not necessarily linear, mainly because the drought plan is active in these runs. The

drought plan contains three triggers that lead to increasing levels of demand reduction. Triggers may be active more often, or for a longer duration, as system demands increase, helping to preserve storage.

If extended beyond 2070, the demand and yield would not intersect until approximately 2120, thus providing an adequate supply for well beyond the planning horizon.

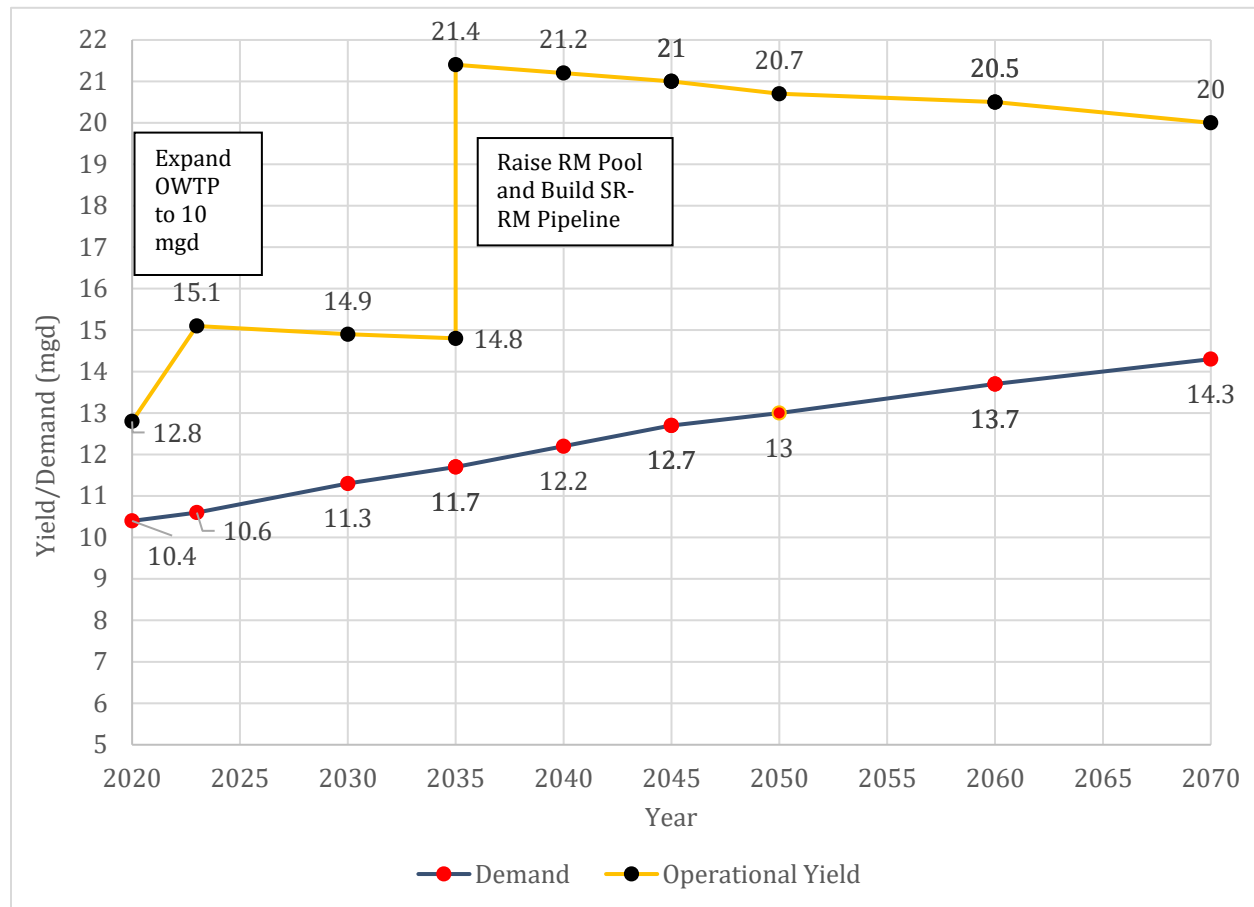


Figure 5-8: Operational Yield with Ragged Mountain Pool Raise and South Rivanna to Ragged Mountain Pipeline in 2035

Buildout Scenario B

(Add South Rivanna to Ragged Mountain Pipeline in 2045 and Raise Ragged Mountain Pool in 2060)

Figure 5-9 shows the yield results associated with buildout scenario B: building the South Rivanna to Ragged Mountain pipeline in 2045 (when water demand is 85% of yield) and raising the Ragged Mountain pool in 2060 (when water demand reaches 85% of yield again). The 85% threshold was selected based on common practice in water supply planning. The increase with the pipeline alone provides approximately 15 years until the 85% threshold is reached. The pipeline alone provides the flexibility in operation of the reservoirs and treatment plants; however, it does not provide the maximum capacity of Ragged Mountain storage. With the pipeline in place, the subsequent raise of the Ragged

Mountain pool results in a large increase in yield as the extra storage in Ragged Mountain can be fully utilized.

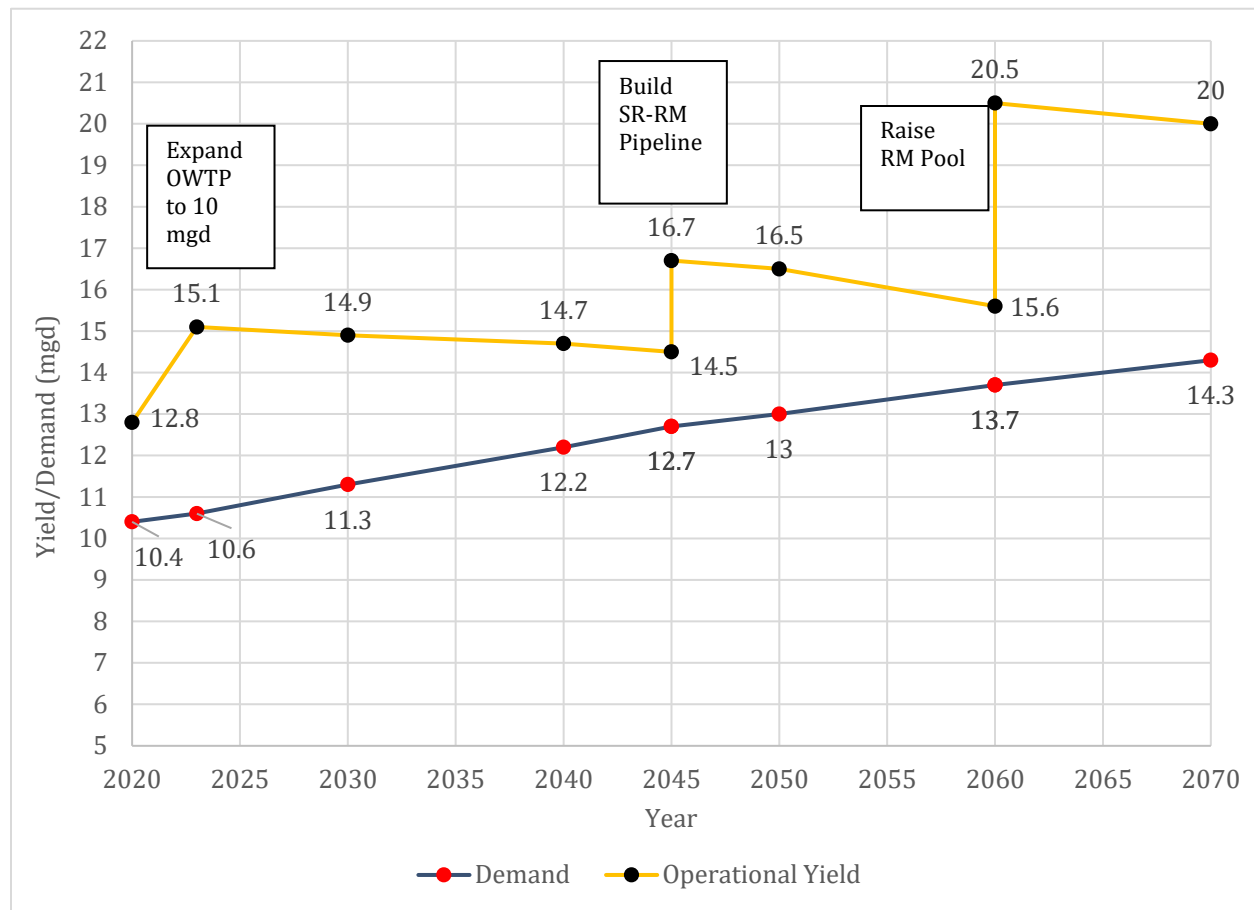


Figure 5-9: Operational Yield with South Rivanna to Ragged Mountain Pipeline in 2045 and Ragged Mountain Pool Raise in 2060

Buildout Scenario C

(Raise Ragged Mountain Pool in 2045 and Add South Rivanna to Ragged Mountain Pipeline in 2050)

The final scenario involves reversing the actions from scenario B and raising the Ragged Mountain pool first (in 2045), then building the pipeline (in 2050), both of which occur when demand reaches 85% of yield. A pool raise alone provides significant additional storage, but as shown in Figure 5-10, a relatively small increase in yield because the operational constraints with no SF-RM pipeline in place still exist which only allow the Ragged Mountain water supply to be treated at OWTP.

The yield increase associated with the pool raise alone (less than 1 mgd) is only realized for approximately 5 years when water demand reaches 85% of the yield again. The full benefit of the extra storage in Ragged Mountain is realized in 2050 when the pipeline is added, increasing yield significantly because water can be utilized flexibly at both South Rivanna and Observatory WTPs.

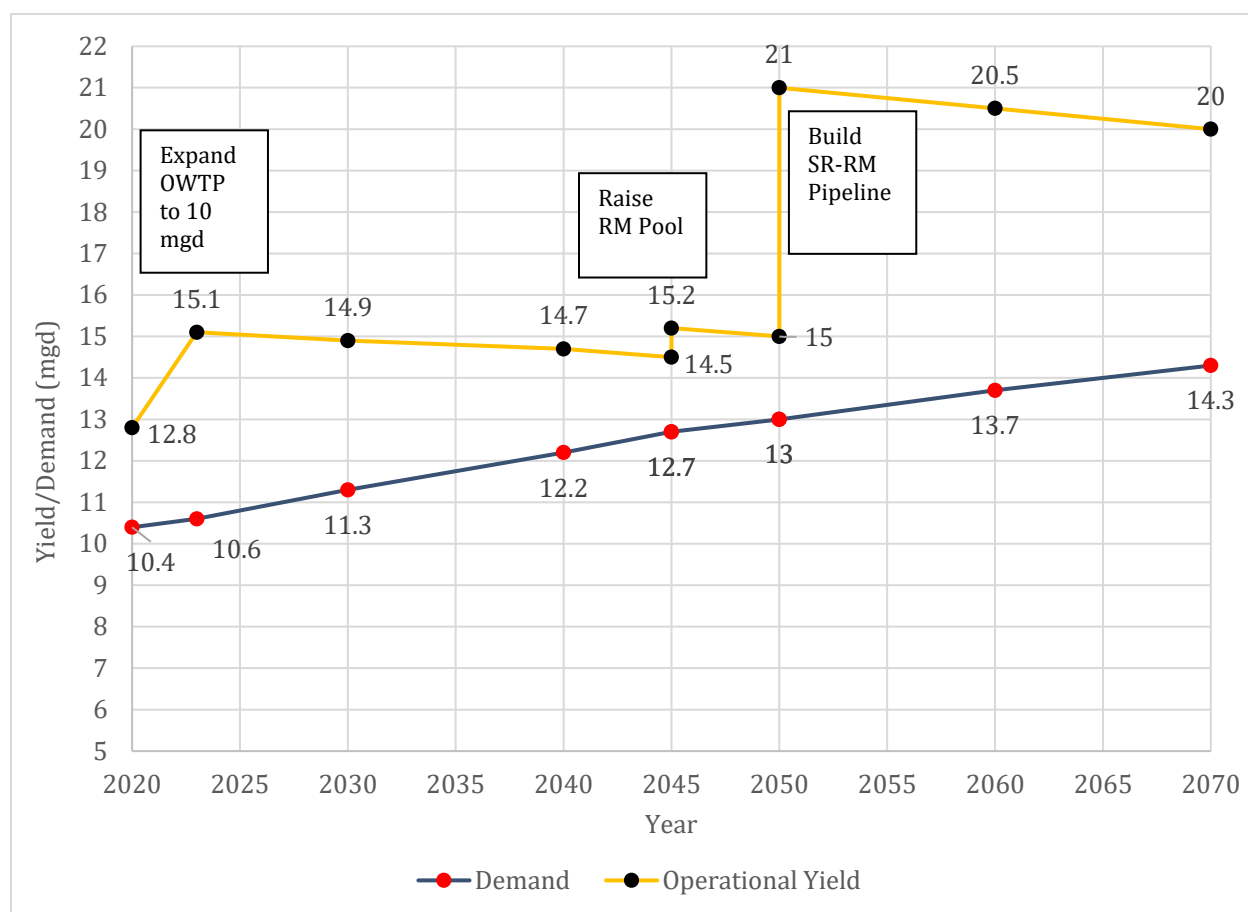


Figure 5-10: Operational Yield with Ragged Mountain Pool Raise in 2045 and South Rivanna to Ragged Mountain Pipeline in 2050

6. Conclusions

RWSA relied on the OASIS model to determine safe yield for a wide range of structural and non-structural constraints, such as pipelines and treatment capacity, and how actions like implementation of the Drought Response and Contingency Plan can help preserve supply during drought periods. This provided valuable information as to the timing of improvements and impacts to safe yield.

Safe yield has traditionally been computed without consideration of operational constraints. “Theoretical” safe yield implies that the water in all the reservoirs can be treated as needed at all the water treatment plants, which is not currently possible and provides unattainable results. RWSA considered two alternative approaches to computing safe yield, “operational” and “DEQ regulatory”, and concluded that “operational” is the most representative of the current physical characteristics and limitations within the water supply, conveyance, and treatment system.

Therefore, the safe yield analysis focused on operational yield and the timing of needed improvements to ensure an adequate water supply over the planning horizon. Three scenarios were considered, in which the improvements associated with the Ragged Mountain pool raise and South Fork to Ragged Mountain pipeline were phased in at various times over the 50-year planning horizon.

Results showed that the benefits on yield with the pool raise are only fully realized with the addition of the South Fork to Ragged Mountain pipeline. The pipeline allows flexibility in the use of the supply sources and the ability to treat that water. Therefore, to maximize supply reliability, not to mention other benefits like supply redundancy and environmental streamflow benefits, executing the improvements at the same time is warranted. RWSA identified joint improvements in the year 2035, meaning these can be completed within the term of the new VWP permits. Whether done jointly or staged, however, the results show that resulting yield will be significant enough to provide adequacy of water supply out to year 2120 based on the projected demand growth and current regulations.

Appendix A: Ragged Mountain Dam Project Agreement

Albemarle County
TMP # 07500-00-00-00100
TMP # 04500-00-00-067A0
TMP # 04500-00-00-069A0

Prepared by:
McGuireWoods LLP

**EXEMPTED FROM RECORDATION TAXES UNDER
SECTION 58.1-811.A.3 OF THE
CODE OF VIRGINIA (1950), AS AMENDED**

RAGGED MOUNTAIN DAM PROJECT AGREEMENT

This **RAGGED MOUNTAIN DAM PROJECT AGREEMENT** (this "Agreement") made for purposes of identification this 1st day of January, 2012, by and between the **CITY OF CHARLOTTESVILLE, VIRGINIA**, a municipal corporation (the "City"), Grantor for indexing purposes; the **ALBEMARLE COUNTY SERVICE AUTHORITY**, a public body politic and corporate ("ACSA"), Grantor and Grantee for indexing purposes; and the **RIVANNA WATER AND SEWER AUTHORITY**, a public body politic and corporate ("RWSA"), Grantee for indexing purposes.

WITNESSETH:

A. RWSA owns and/or operates facilities for the receipt and treatment of potable water pursuant to the terms of a Four-Party Agreement dated June 12, 1973, among the City, RWSA, ACSA and the Board of Supervisors of Albemarle County (the "Four-Party Agreement") and several supplementary agreements.

B. The facilities operated by RWSA include the Lower and Upper Ragged Mountain Reservoir Dams located on a parcel of land designated as Albemarle County Tax Map 75, Parcel 1, and the South Rivanna Reservoir Dam, located on a parcel of land designated as

Albemarle County Tax Map 45, Parcel 67A, as more particularly described in the Deed referenced in Recital E below.

C. Pursuant to Article IV of the Four-Party Agreement, the City and ACSA have agreed upon a project, not contemplated by their previous agreements, for the construction by RWSA of an earthen dam at the current site of the Ragged Mountain Reservoir to replace the existing dams at the Ragged Mountain Reservoir and increase the pool elevation of the existing Ragged Mountain Reservoir. The new earthen dam will increase the safe yield of the urban water system consisting of all water-related facilities within or serving the City of Charlottesville and the urban growth area of Albemarle County surrounding the City of Charlottesville and includes the areas served by public community water supply from the South Fork Rivanna Water Treatment Plant, the Observatory Water Treatment Plant, and the North Fork Rivanna Water Treatment Plant, as well as all reservoirs, dams, pipelines, pumping stations, storage tanks and other appurtenances connected to water plants and operated by RWSA (the “Urban Water System”).

D. ACSA and the City have reached an agreement concerning the sharing of costs for construction of the new earthen dam and related improvements and the amount of compensation for the increased area required to construct the dam and which will be inundated by the reservoir pool supported by the new dam, all as more particularly set forth in the Water Cost Allocation Agreement, dated January 1, 2012 (the “Cost Allocation Agreement”).

E. ACSA, the City and RWSA desire to set forth their understandings with respect to the construction of the dam and improvements in phases and the rights of RWSA to build the dam and related improvements upon the land where the existing Ragged Mountain Reservoir is located, which land is owned by the City subject to certain rights conveyed by the City to RWSA

pursuant to the Four-Party Agreement as set forth in the Deed and Bill of Sale dated June 13, 1983, recorded in the Clerk's Office of the City of Charlottesville in Deed Book 438 at page 854 and in the Clerk's Office of the County of Albemarle in Deed Book 768 at page 277 (the "Deed").

NOW, THEREFORE, for and in consideration of the premises, the cost allocations and other expense reimbursements set forth in the Cost Allocation Agreement, and other good and valuable consideration, the receipt of all of which is hereby acknowledged, the City, ACSA and RWSA agree as follows:

AGREEMENT

1. Specification of the Project. Pursuant to Article IV of the Four-Party Agreement, ACSA and the City agree to and direct RWSA, and RWSA agrees, to proceed to construct and perform the following (hereinafter referred to as the "Project"):

(a) New earthen dam on the site of and downstream of the existing Lower and Upper Ragged Mountain Dams sufficient to impound and raise the existing maximum normal operating reservoir pool level (641' above mean sea level) an additional forty-two feet (42') (683' above mean sea level) utilizing soil from certain borrow areas on the site to the extent feasible (the "New Ragged Mountain Dam"); provided, however, that until satisfaction of the conditions set forth in Paragraph 3 below, the normal operating reservoir pool level shall be limited to an additional thirty feet (30') (671' above mean sea level) above the existing normal operating reservoir pool level (the "Initial Pool Level"), and only upon satisfaction of such conditions shall the normal operating reservoir pool level be raised an additional twelve feet (12') above the Initial Pool Level (the "Additional Pool Level").

- (b) Separate rock-lined spillway for the New Ragged Mountain Dam.
- (c) Intake tower for the New Ragged Mountain Dam, with intake gates and a normal spillway at heights necessary to support the Initial Pool Level, constructed in such a manner as to allow the operation of an additional intake gate and spillway to support the Additional Pool Level upon satisfaction of the conditions set forth in Paragraph 3 of this Agreement.
- (d) A proposed pipeline, including tunnel, pumping facilities and related infrastructure, connecting the reservoir formed by the New Ragged Mountain Dam (such reservoir, including any expansion as provided in Paragraph 3 of this Agreement, hereinafter referred to as the “Ragged Mountain Reservoir”) to the existing South Rivanna Reservoir and connecting to an existing pipeline serving the Observatory Water Treatment Plant (such pipeline, tunnel, pumping facilities and related infrastructure hereinafter referred to as the “SRR-RMR Pipeline”).
- (e) A floating pedestrian trail bridge and spill boom across the Ragged Mountain Reservoir to be located north of Interstate 64 with truck access to construct and maintain such improvements, including periodic removal of debris from the spill boom (hereinafter referred to as the “Floating Bridge and Spill Boom”).
- (f) Removal of trees and other vegetation in the areas necessary to construct the improvements described in clauses (a) through (e) above and in the area which will be inundated by the Initial Pool Level and, upon satisfaction of the conditions set forth in Paragraph 3 of this Agreement, in the area which will be inundated by the Additional Pool Level.
- (g) Breach of the existing Lower and Upper Ragged Mountain Dams.

(h) Other construction and work necessary or desirable for the purposes set forth in this Agreement to construct and complete the improvements or to satisfy federal, state or local regulations applicable to the activities described in clauses (a) through (g) above, including all mitigation and restoration required by such permits.

The portion of the Project to be constructed on the Ragged Mountain Reservoir site shall be located substantially as shown on the "Land Use Map for the New Ragged Mountain Dam", prepared by Schnabel Engineering dated July 19, 2011, Sheets 1 – 7, a copy of which is attached hereto and recorded herewith, with the exception of the Floating Bridge and Spill Boom, which shall be constructed in coordination with the City's design and development of a trail system within the Ragged Mountain Reservoir site. RWSA shall be responsible for all aspects of the design, right-of-way and easement acquisition, and construction of the Project. RWSA shall require and verify that all individuals and entities under contract with RWSA to perform construction activities pursuant to this Agreement on any property owned by the City of Charlottesville agree to indemnify and hold harmless the City and its officers, officials and employees, and to include the City of Charlottesville as an additional insured on any applicable general liability insurance policies.

2. Confirmation and Grant of Water Rights, Leases, Easements and Rights of Access for the Project. Pursuant to Section 6.1 of the Four Party Agreement RWSA is the sole producer and seller of potable water to the City and ACSA. Further, pursuant to Section 3.2(c) of the Four-Party Agreement and Paragraph V of the Deed, the City leased to RWSA, for so long as the Four-Party Agreement remains in effect, "all water rights in and to....the two Ragged Mountain Reservoirs and the South Rivanna Reservoir, including the rights to maintain and operate all impoundment and pumping facilities, and to withdraw all water that may be available." To the

extent not already provided in the Four-Party Agreement, the City hereby leases to RWSA, for so long as the Four-Party Agreement remains in effect, but not to exceed forty (40) years from the date hereof, all water rights in and to the Ragged Mountain Reservoir, including the rights to maintain and operate all impoundment and pumping facilities, and to withdraw all water that may be available, all as provided in Article V of the Four Party Agreement. The City further grants to RWSA a temporary construction easement and right of access necessary to construct, and install the Project to inundate and support a reservoir pool to the Initial Pool Level and, subject to satisfaction of the conditions set forth in Paragraph 3 of this Agreement, to increase the normal operating reservoir pool to the Additional Pool Level and to construct that portion of the SRR-RMR Pipeline to be constructed on the Ragged Mountain Reservoir site and the South Rivanna Reservoir site.

The City further leases to RWSA, commencing upon the date RWSA begins construction of the SRR-RMR Pipeline and continuing for so long as the Four-Party Agreement remains in effect, but not to exceed a period of forty (40) years from the commencement date, the parcel of land adjacent to the South Rivanna Reservoir consisting of approximately 5.45 acres, more or less, designated in the Albemarle County land records as Tax Map 45, Parcel 69A, and more particularly described in Exhibit A attached hereto and recorded herewith to construct, install, operate, maintain, repair, replace, relocate and extend that portion of the SRR-RMR Pipeline to be located in and adjacent to the South Rivanna Reservoir.

3. Increase to Additional Pool Level. RWSA shall perform bathymetric surveys of the South Rivanna Reservoir and current water demand analyses and water demand projections in accordance with, and at intervals governed by, approved state and federal permits and the Commonwealth of Virginia's Local and Regional Water Supply Planning regulations (9VAC 25-

780), but at least every ten (10) years after the date of this Agreement, with the first such survey to be performed not later than the year 2020. RWSA shall update the analysis of safe yield of the Urban Water System following each new bathymetric survey of the South Rivanna Reservoir performed after the date of this Agreement using the latest available data on useable storage in the South Rivanna Reservoir, the Ragged Mountain Reservoir, and the Sugar Hollow Reservoir. All such bathymetric surveys, water demand projections and safe yield analyses will be performed by an outside consultant selected by RWSA. The method for determining safe yield shall be as set forth in the regulations of the Virginia Department of Health. At any such time that (i) the actual Urban Area water demand (measured as combined flow of treated water entering the Urban Water System from water treatment plants) as an average daily demand over a trailing twelve (12) consecutive month period or (ii) the average daily demand over a period of twelve (12) consecutive months projected out ten (10) years reaches eighty-five percent (85%) or more of the safe yield determined from the most recent safe yield analysis, RWSA, upon the written request of ACSA or the City and without further authorization or approval from the other party, shall modify the intake towers and remove trees and other vegetation necessary to allow the New Ragged Mountain Dam to impound and support a reservoir pool to the Additional Pool Level, and shall raise the reservoir pool to the Additional Pool Level.

4. Permits. The City, as the landowner of record of the parcels referenced in Recital B and Paragraph 2 above hereby authorize RWSA to apply for and secure all permits and approvals necessary for or mandated by the Project and the Project's expansion pursuant to Paragraph 3 of this Agreement.

5. Dredging. Pursuant to Article IV of the Four-Party Agreement, the City and ACSA agree to and direct RWSA, and RWSA agrees, to perform such dredging projects at the

South Rivanna Reservoir as may be specified jointly by the City and ACSA pursuant to the Water Cost Allocation Agreement.

6. Miscellaneous. In the event any one or more of the terms or provisions contained in this Agreement should be held invalid or unenforceable in any respect, the validity and enforceability of the remaining terms and provisions will not in any way be affected or impaired. Any invalid or unenforceable term or provision will be deemed to be void and of no force and effect only to the minimum extent necessary to cause such term or provision to become valid and enforceable, and the balance of this Agreement will be fully enforceable.

IN WITNESS WHEREOF, the duly authorized officers of the City of Charlottesville, Virginia, the Albemarle County Service Authority and the Rivanna Water and Sewer Authority have executed this Agreement as of the date first above written.

[SIGNATURES ON FOLLOWING PAGE]

CITY OF CHARLOTTESVILLE, VIRGINIA

APPROVED AS TO FORM:

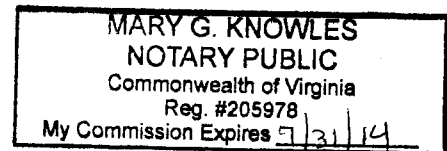
By: Maurice Jones (SEAL)
Maurice Jones, City Manager

Craig Brown
Craig Brown, City Attorney

COMMONWEALTH OF VIRGINIA
CITY OF CHARLOTTESVILLE, to wit:

The foregoing instrument was acknowledged before me this 24th day of
JANUARY, 2012, by Maurice Jones as City Manager of the City of Charlottesville,
Virginia.

Mary G. Knowles
Notary Public
Registration No.: 205978



My Commission Expires: JULY 31, 2014

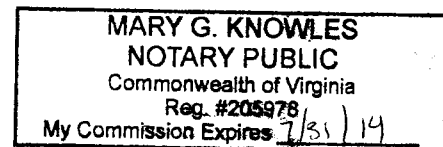
ALBEMARLE COUNTY SERVICE AUTHORITY

By: Gary B. O'Connell (SEAL)
Gary B. O'Connell, Executive Director

COMMONWEALTH OF VIRGINIA
COUNTY OF ALBEMARLE, to wit:

The foregoing instrument was acknowledged before me this 24th day of
JANUARY, 2012, by Gary B. O'Connell as Executive Director of the Albemarle
County Service Authority.

Mary G. Knowles
Notary Public
Registration No.: 205978



My Commission Expires: JULY 31, 2014

RIVANNA WATER AND SEWER AUTHORITY

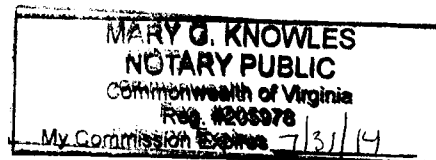
By: [Signature] (SEAL)
Thomas L. Frederick, Jr., Executive Director

COMMONWEALTH OF VIRGINIA
COUNTY OF ALBEMARLE, to wit:

The foregoing instrument was acknowledged before me this 24th day of
JANUARY, 2012, by Thomas L. Frederick, Jr. as Executive Director of the Rivanna
Water and Sewer Authority.

Mary G. Knowles
Notary Public
Registration No.: 205978

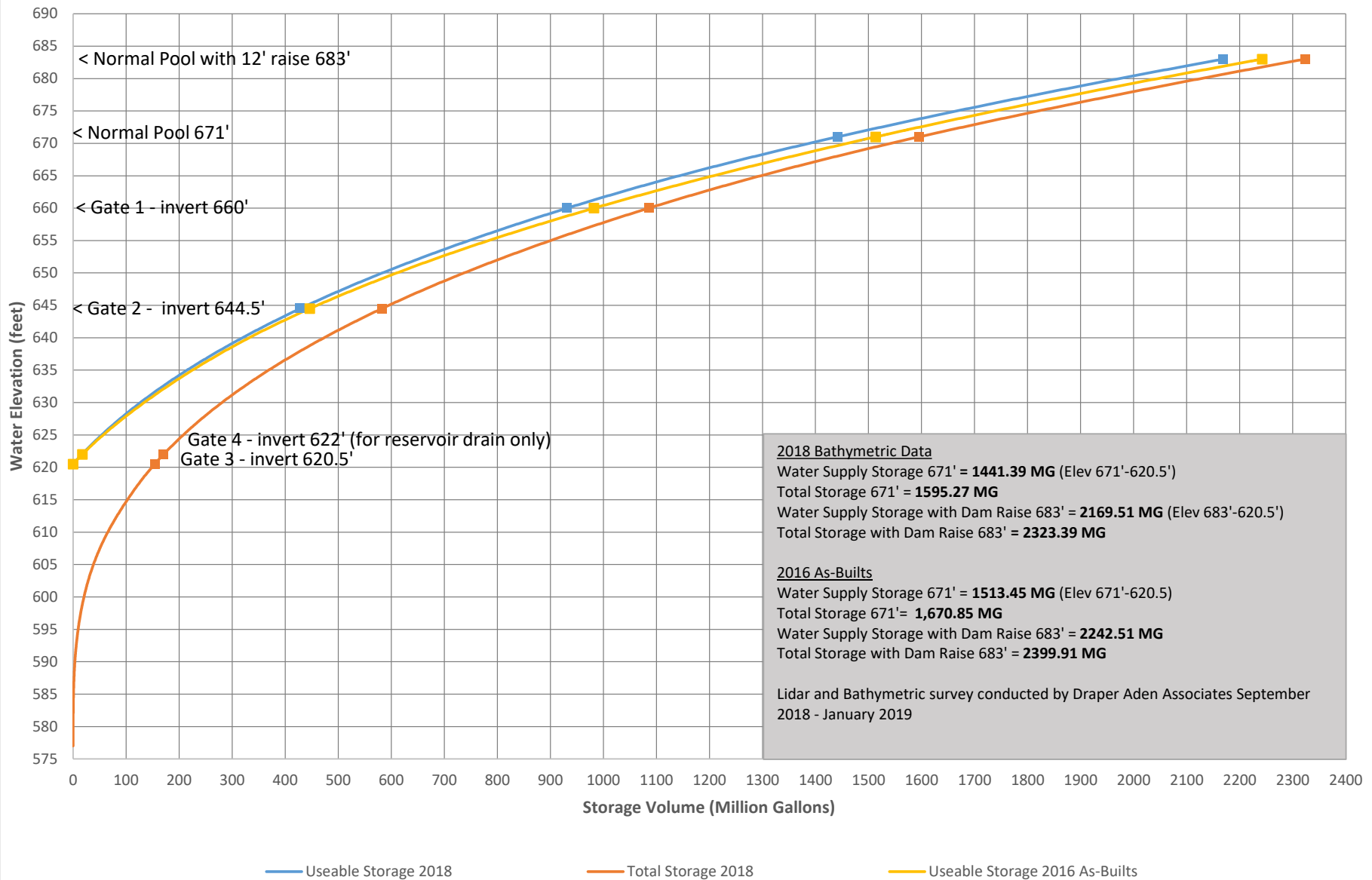
My Commission Expires: JULY 31, 2014



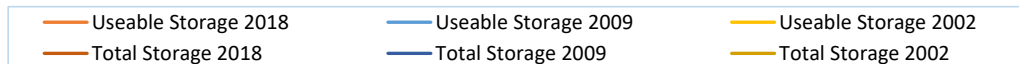
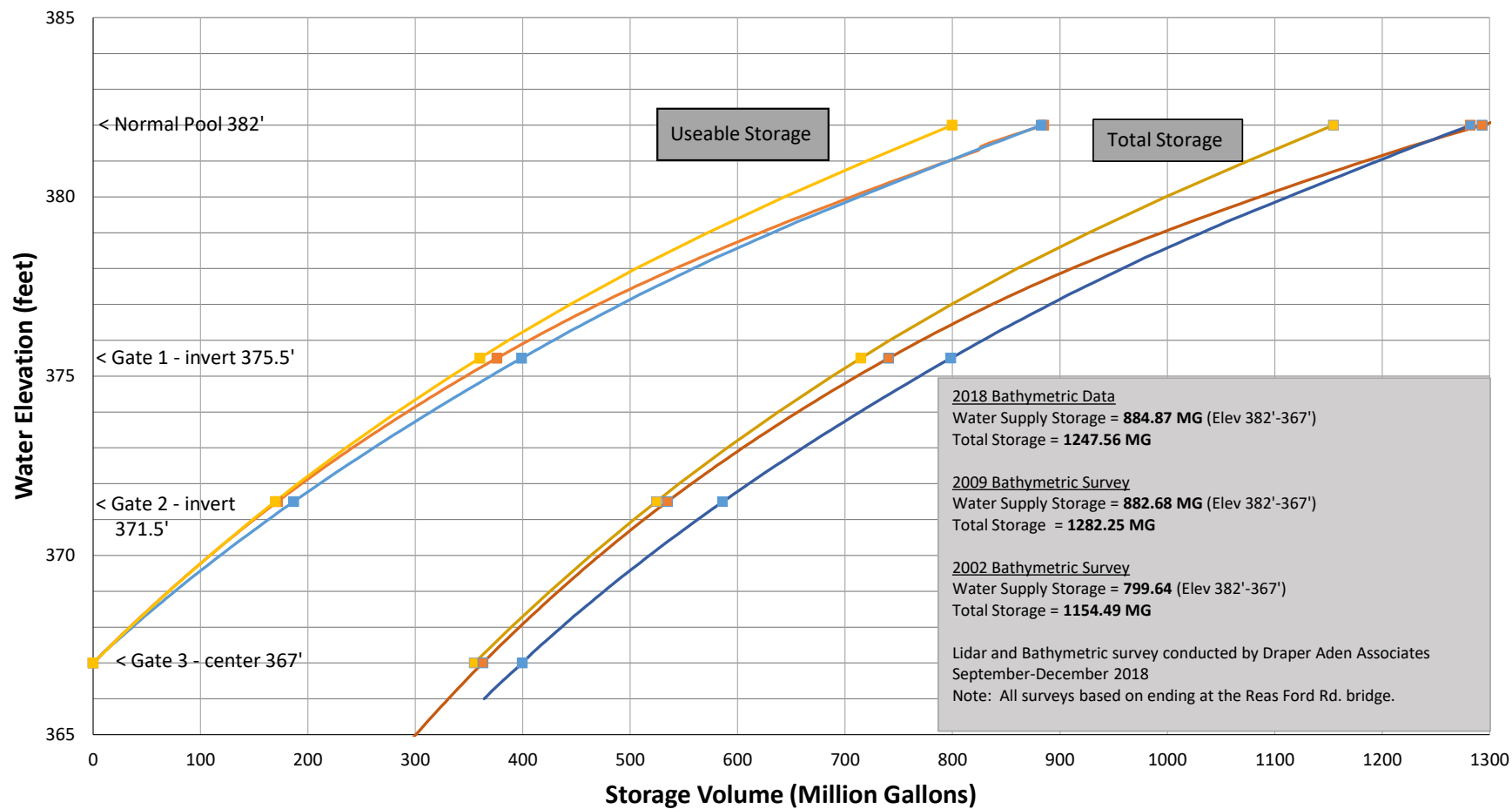
V29741428.13

Appendix B: Urban Reservoir Bathymetry

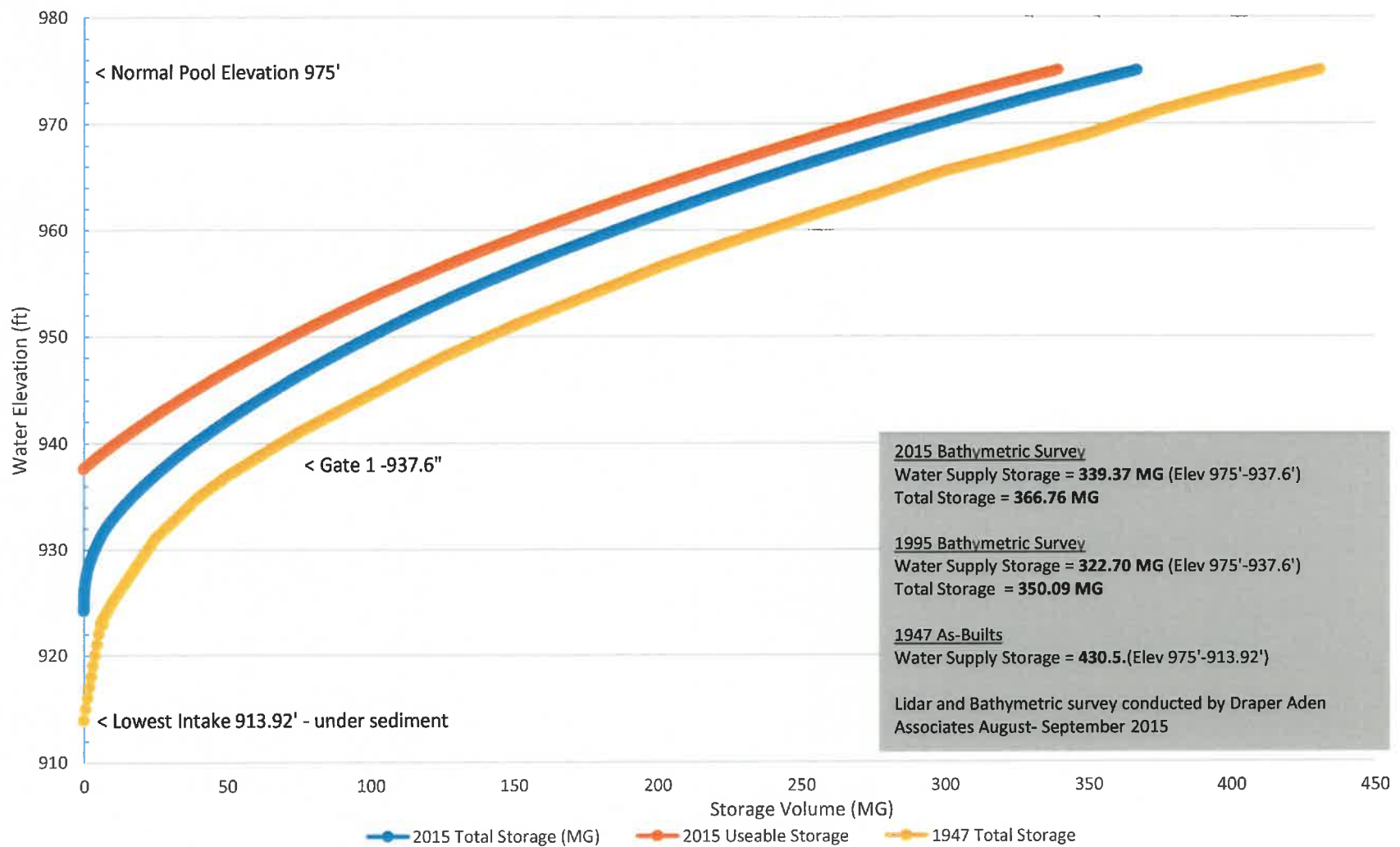
Stage Storage Curve - Ragged Mountain Reservoir 2018



Stage Storage Curve - South Fork Rivanna Reservoir 2018



Stage Storage Curve - Sugar Hollow Reservoir



Appendix C: Monthly Demand Pattern

Month	Fraction of Annual Average
January	0.86
February	0.92
March	0.92
April	0.99
May	1.00
June	1.08
July	1.15
August	1.16
September	1.17
October	1.06
November	0.96
December	0.84

- Used in calculation of operational and DEQ regulatory safe yields. In this case, using July as an example, July demand is 1.15 times the annual average demand. Theoretical safe yield assumes each month's fraction is 1.0, so monthly average demand is the same as the annual average demand.