

MEMORANDUM

**TO: RIVANNA WATER & SEWER AUTHORITY
BOARD OF DIRECTORS**

FROM: THOMAS L. FREDERICK, EXECUTIVE DIRECTOR

SUBJECT: MINIMUM IN-STREAM FLOWS

DATE: MAY 21, 2007

As the Board and public are aware, the RWSA staff has been in active discussions with The Nature Conservancy (TNC) since the summer of 2004 to develop a new program for releases of water from the Sugar Hollow and South Fork Reservoirs. During this time, based on a Board of Directors' voluntary policy adopted a few years ago, RWSA has been providing that a minimum of "8 MGD or natural inflow" flow past the South Fork Dam and a minimum of "400,000 gallons per day flow past the Sugar Hollow Dam" at times when the useable water supply storage in the Sugar Hollow Reservoir is greater than 80%.

Throughout our discussions, we have been trying to manage two separate objectives which can compete for the same limited water supply during drought periods. The first objective, clearly stated by an overwhelming majority of interested citizens and local boards, is that the Urban Water System's future water supply remains "within our own watershed area". The second objective is to provide stream flows as close to natural conditions as is possible without undue risk of interrupting the public water supply. In order to optimize both of these objectives, RWSA and TNC have traveled a long journey looking for a solution that provides a flow to the streams that mimics close to natural conditions during dry weather periods, and replenish this storage by "shaving" the peaks from the spikes in natural stream flow during wet weather events. This principle is reflected in detail in Brian Richter's book, Rivers for Life: Managing Water for People and Nature.

First, I'd like to express sincere gratitude to TNC and their organization for all of the assistance and ideas they have provided throughout this process. This process has been both educational and fun, and has resulted in a new and innovative procedure that we believe may rewrite "the book" on how releases from reservoirs throughout Virginia and the nation are regulated in the future.

In January 2007 the Virginia Department of Environmental Quality (DEQ) shared with RWSA and TNC some of their initial thoughts for stream flow requirements that could be incorporated into RWSA's permit for the expanded Ragged Mountain Reservoir, based on current DEQ policy. One condition that we have carried forward from this draft is a requirement that the flow past the new Ragged Mountain Dam into the unnamed tributary of Moores Creek never be less than 23,800 gallons per day. With respect to Sugar Hollow and South Fork, recognizing that RWSA and TNC were attempting to conclude voluntary

negotiations, DEQ suspended its development of permit conditions and asked that RWSA and TNC complete their discussions and RWSA make a proposal for DEQ review. At the time, DEQ stated they would need approximately three months to complete the issuance of a Ragged Mountain permit once they received our proposal. In an attempt to stay on a July schedule for receiving a permit, RWSA set April 1 as a target date for completing the discussions with TNC. Before the end of January, RWSA and TNC had met and agreed conceptually on how to develop a better stream flow program, but the details of the program were still dependent upon further computer modeling and technical work. This work has exceeded our target date, but was completed and a proposal was submitted to DEQ for review on May 14.

In order to work through the details, a significant amount of refinement of computer modeling has been required. In order to optimize stream flow conditions without compromising the effective safe yield for public water supply, a computer model used by Hydrologics for TNC had to be calibrated with a model used by Gannett Fleming for RWSA in the Community Water Supply Plan. Further, the nature of optimizing both stream flow and water supply conditions is necessarily an iterative process. Earlier computer runs using early stream flow proposals by TNC were shown through modeling to “bottom out” reservoirs before the end of a severe drought, forcing iterative reconsideration of the proposal. Through continuing refinement, a flow requirement procedure has now been developed for the South Fork Rivanna Reservoir that has been fully endorsed by both TNC and the RWSA staff. Under this agreed procedure, minimum flows past the South Fork Rivanna Dam would be as follows:

South Fork Rivanna Reservoir – Proposed Flow Past the Dam Requirements	
Total Useable Water Supply Storage Available, in Billion Gallons ³	Minimum Flow Past the Dam ^{1,2}
Greater Than or Equal to 2.36	70% of Natural Inflow
Greater Than or Equal to 1.36, But Less Than 2.36	50% of Natural Inflow
Less Than 1.36	30% of Natural Inflow
1At no time will flow past the dam be less than 1.3 mgd as long as useable water supply storage remains available in the South Fork Reservoir. If useable storage is depleted (severe drought condition), the minimum flow past the dam would be achieved by allowing all of the flow from the upstream river that reaches the dam to pass through.	
2When the reservoir is full and spilling, flow past the dam will almost always exceed these minimums, often approaching 100% of natural inflow. During the few periods when the reservoir is less than full, flow past the dam is not required to exceed the capacity of the outlet structures through the dam, or 20 mgd.	
3Upon completion of water supply improvements recommended in June 2006, total water supply useable storage (Sugar Hollow, Ragged Mountain, and South Fork Reservoirs combined) is expected to be 2.75 billion gallons in 2055. 2.36 billion gallons would represent 87% of this storage and 1.36 billion gallons would represent 50% of this storage.	

The conditions in the table can be complex to follow, but the benefits to the stream can be better illustrated by looking at the flow duration graph in Figure 1. In this figure, the current voluntary policy of “8 MGD or inflow” is compared to the terms in the table above for 2055 water demand conditions (18.7 MGD) applied over the historical record of stream flow. To read this graph, results are closer to natural flow when the graph is closer to the Y-axis (the left side of the graph) between 0 and 100 percent of natural inflow, as read on the vertical axis. Figure 1 shows that the proposed requirements in our recent submittal to DEQ will more closely represent natural flow, particularly in the range between 30% and 70% of natural inflow.

With respect to flows past the Sugar Hollow Dam to the Moormans River, there is complete agreement between RWSA and TNC on a procedure to be in effect after both the new Ragged Mountain Reservoir and the pipeline between the South Fork and Ragged Mountain Reservoirs are built. First, the existing Sugar Hollow to Ragged Mountain pipeline would no longer be used to transfer water. Second, the Sugar Hollow Reservoir would remain full, except during a drought requiring stored water to be transferred via the Moormans River to the South Fork Reservoir. During these rare periods of transfer, when Sugar Hollow is not full, a minimum of 90% of natural inflow would be released to the Moormans River through the conduit within the existing dam, up to the conduit's capacity of 10 mgd. Finally, if during a very rare severe drought the water supply storage were exhausted (the water level dropped to the bottom of the lowest intake structure), the intake valve would be left fully opened so that any new water passing into the reservoir to the dam would be automatically released through the conduit to the Moormans River. This procedure will extensively improve the Moormans River flow, essentially restoring natural flow variations almost all of the time. As illustrated in Figure 2, the dashed line is far to the left end of the graph in the range between 0 and 100 percent of natural inflow, which shows a very good correlation to natural flow under a full range of weather conditions.

One final hurdle remained in developing a draft downstream flow procedure to submit to DEQ for review. As RWSA staff has explored financing the improvements under the Community Water Supply Plan, it has become clear to staff that the new Ragged Mountain Dam (\$37 million) and the new South Fork pipeline (\$52 million) cannot be built simultaneously without a very large shock to the Urban Water Rate as well as significant uncertainty in how such large bonds for an organization our size might be rated by the bond market. The total cost of both of these two projects (\$89 million) represents two-thirds of the cost (\$130 million) of the entire 50-year plan, which would also be an enormous "front-ending" of costs by existing water users. Because RWSA is under a mandate from Virginia Dam Safety to correct public safety concerns with the existing 100-year old Ragged Mountain Dam, it has already been recognized that the dam must come first. Therefore, we need to plan for an interim period when there is a new dam and reservoir in-place without the new pipeline.

The hurdle entails how to significantly improve the stream flow in the Moormans River during this interim period. Through joint discussions, RWSA and TNC agreed to a concept that enhances the Moormans River by "peak shaving". Figure 4 illustrates this concept graphically. When natural inflows are below an established set point, the flow past the dam will equal natural inflow. As it rains and natural inflow rises sharply, RWSA would allow flow past the dam at the set point when the reservoir is not full, and capture the "peak" inflow above this set point until either the natural inflow drops back to the set point or the reservoir is full.

The critical decision becomes where to define that set point at a "balance" so that the stream flow deviates from natural flow as little as possible, the water supply does not go dry in a severe drought, and the reservoir recovers after a drought within a reasonable time. We initiated this decision for the Sugar Hollow Reservoir by a trial modeling 10 million gallons per day (mgd) as the first trial set point, because this was the rated capacity of the conduit through the Sugar Hollow Dam. Through modeling by both Gannett Fleming and Hydrologics, we all quickly learned our first lesson: if 10 mgd is the set point, the entire Ragged Mountain Dam (2.19 billion gallons of useable storage, 112 feet high or 45 feet raise) would need to be built in one phase to provide sufficient storage to get through a drought of record without depleting the water supply. In other words, in order to build a smaller dam "as

a first phase”, the set point would need to be significantly less than 10 mgd. On the basis of work done by the RWSA staff on developing a phasing plan (described in a separate agenda item), there are other reasons for building the dam in one phase, and the flow requirements described in the remainder of this report assume the new Ragged Mountain Dam will be built in one phase.

Two other concerns were identified in modeling the 10 mgd set point. The first concern involves the initial filling of the Ragged Mountain Dam after it is initially completed; the second involves the time required to refill the Ragged Mountain Reservoir after a severe drought. These issues will be addressed one-at-a-time.

Gannett Fleming has advised RWSA that at the time the new Ragged Mountain Dam is constructed, before it is permitted to fill with water, dam safety practice will require that the pool levels of the existing reservoir be reduced substantially in order to “breach” the old dams. The timing of this work will need to be carefully coordinated because the very limited water storage during this period will leave RWSA vulnerable if a drought began shortly after the “breach”. To properly address this issue, RWSA staff is recommending that the increased flow to the Moormans River be slowly ramped up during the initial filling of the new Ragged Mountain Dam, beginning with the existing voluntary policy (400,000 gpd), then progressively increasing so that during the final 30 percent of the filling of the reservoir, releases to the Moormans River will be natural inflow up to 10 mgd.

Regarding the refill time, computer modeling using a constant 10 mgd set point through the historical record identified two droughts where the refill would have exceeded two years in duration. Under weather conditions like an early-1930s severe drought, the new Ragged Mountain Reservoir would be continuously below full for 2.8 years before refilling. Under conditions like a mid-1960s moderate drought, the new Ragged Mountain Reservoir would not refill for 4.7 years. When modeling was modified to allow the set point to drop to 2 mgd during periods when Ragged Mountain was below 70 percent full, we learned that the refill time could be shortened to within two years (in the case of the 1960s drought, it creates two separate periods the reservoir would drop, with a period of “full” in between). Within these two drought periods, the natural inflow on the Moormans River at Sugar Hollow is below 2 mgd a significant percentage of the time.

Gannett Fleming has recommended that our proposal to DEQ for the interim period include an allowance to reduce the set point to 2 mgd when Ragged Mountain is below 70 percent full, based on some uncertainties regarding the risks of very long reservoir refill times. These uncertainties are summarized below:

- (1) Computer models cannot simulate every “real world” condition, and extremely long reservoir recovery times increase the risk that real conditions will drift from simulated conditions in a way that threatens the public water supply. As an example, computer models did not provide for leakage in the Sugar Hollow pipeline, however, in practice we would expect leakage to be occurring especially given the age of the pipe and the potential for the joint seals of this age to be less ductile.
- (2) Extremely long reservoir recovery periods of 3 to 4 years have not been widely practiced in the water utility industry, if at all, and public acceptability is uncertain. For acceptance, the public must be willing to endure long periods seeing exposed banks with limited vegetation, limited recreational opportunity, and there are uncertainties of the effects of long recovery on the aquatic life in the reservoir, including trout at Sugar Hollow.

- (3) In practice, some form of water use restrictions usually remain in place after a drought until reservoirs refill. Although continuous public education to permanently change water use habits in favor of conservation should be encouraged at all times, drought restrictions that remain in effect over extremely long recovery periods may not receive the continuously strong public support that shorter restrictive periods would obtain, thereby limiting the effectiveness of an overall drought response program.
- (4) The long recovery periods modeled by computer simulation assume that the South Fork Water Treatment Plant is maximized and the Observatory Water Plant is minimized to accelerate recovery as much as possible. During very long recovery times, it may not be possible to consistently maximize the South Fork Water Plant, especially given the age of some of the plant equipment, and periods of reservoir water quality that require South Fork filter rates to be reduced to maintain high quality drinking water.
- (5) Although DEQ wishes to reserve final judgment on the proposed program until all details have been reviewed, the DEQ staff has expressed some concern to Gannett Fleming with modeled reservoir recovery times in excess of two years, and felt that such conditions would warrant much closer scrutiny on their part.
- (6) Our quantitative understanding of droughts is limited to 80 years of historical record and the impact of climate change is uncertain, allowing for the possibility that a future drought could be more severe than those modeled.

On the basis of the above discussion, we propose that the flow past the Sugar Hollow Dam, following the successful initial filling of the new Ragged Mountain Dam, be based on the following minimum conditions until the new South Fork pipeline is completed:

Sugar Hollow Reservoir - Interim Period - Flow Past the Dam Requirements		
Ragged Mountain Reservoir Useable Water Supply Storage Available, in Billion Gallons	Minimum Flow Past the Dam	Percent of Historical Record
Greater Than or Equal to 1.53 ($\geq 70\%$ of Full Height Useable Storage)	Natural Inflow up to 10 MGD	91% or Greater
Less Than 1.53	Natural Inflow up to 2 MGD ¹	9% or Less
<small>1Although the proposal to DEQ would permit the "peak shaving" set point to be lowered to 2 MGD when Ragged Mountain useable storage is less than 70% full, RWSA staff agrees to actively manage future droughts and recovery from droughts through computerized probability forecasting in an attempt to minimize or avoid the actual use of the lower set point.</small>		

Figure 3 provides the flow duration curves for the Moormans River under the interim condition. Note how far the curve moves to the left with the new proposed requirements as compared to the existing voluntary policy. We also note that the curve labeled "1 Tier", which represents a set point of 10 mgd under all conditions, is very close to the curve labeled "2 Tiers", represented by the conditions in the table above.

During our discussions regarding the development of these interim conditions, TNC appropriately challenged us to consider ways to further reduce or even eliminate the need for the lower tier with a set point of 2 MGD. We identified from these discussions that probability forecasting, similar to what was done in the development of our Drought

Monitoring and Response Policy, could be a tool to aid in this goal. This type of forecasting would be used during a drought “in progress”, we believe it would be helpful, and we accept TNC’s challenge to continue to refine our process.

In the meantime, staff recommends we move forward to support the DEQ review process on a plan for minimum in-stream flows as outlined in this memorandum. By completing the permitting process leading to the design and construction of a new Ragged Mountain Reservoir, we take a huge step forward for both the water supply needs and improvements to stream flows, especially improvements to the Moormans River. Further, in moving forward, we should also continue to pursue refining our plan as appropriate, and we should take the positive steps that will allow us to build the South Fork pipeline as soon as it is possible to finance.

Board Action Requested:

Staff recommends the Board of Directors authorize the Executive Director to take the necessary steps to complete the agency review process for a Ragged Mountain permit, based on the stream flow proposal outlined in this memorandum.