CITY of HARRISONBURG

Raw Water Supply

Management Plan

FY2023: 10th Edition

December 31, 2015

July 31, 2023

I. INTRODUCTION

This document partially recaptures the Harrisonburg Department of Public Utilities (HPU) master plan to develop a business model to supply potable water to its customers. This document is dedicated to the business model's raw water supply development component. The elements of the Raw Water Supply Management Plan (RWSMP) recapture the strategies to the following questions:

Q1. What quantities of water should Harrisonburg pursue long-term planning?

Harrisonburg has developed a business model for 15.0 million gallons per day (MGD) potable water supply.

Q2. What water sources will be used to meet the demands identified in the business model?

- **Dry River (DRI)- an existing source water of raw water.**
- **North River (NRI)- an existing source water of raw water.**
- **South Fork Intake (SFI)- a future raw water source.**
- **Augmentation source(s): a group of potential raw water sources for drought reliability.**

Q3. What strategies are necessary to ensure that the management plan is reliable and sustainable?

- **Normal Operations strategy component.**
- **Drought Operations strategy component.**
- **Risk Management strategy component.**
- **Asset Management strategy component.**
- **Regulatory Management strategy component.**

II. WATER DEMAND FORECASTING

What quantities of water should Harrisonburg pursue for long-term planning?

The following table summarizes the work of a city inter-departmental committee that identified existing and future land occupancy and water demand relationships within the city by determining occupied and vacant land (per adopted land use guidelines) and then developing existing land category usage rates.

To integrate seasonal peak demands into determining raw water and treatment capacity planning, the average demands must be increased to 129% (12.9 average annual daily demand = 15.0 Peak design demand). The increase has been determined from historical records of Harrisonburg use patterns referencing peak weekly criteria. The Table below shows the average annual demand.

Average Daily Demand Forecast	
Existing City Sales	4.7 MGD
Existing External Sales	0.8 MGD
Rockingham County Tier 1 Contract	0.5 MGD
External Reserved Commitments	0.2 MGD
WTP Processing	0.1 MGD
Unaccounted water	1.3 MGD
Existing Total Demand	**7.6 MGD**
Future City Sales	3.2 MGD
Open Market External Sales	1.1 MGD
Rockingham County Tier 2 Contract	0.5 MGD
WTP Processing	0.1 MGD
Unaccounted water	0.4 MGD
Demand Potential	**5.3 MGD**
Total	**12.9 MGD**

- Rockingham County Tier 1 contract commitments are firm; Tier 2 refers to the contract language that identifies an additional 0.5 MGD without reason for denial.
- External Reserved Commitments are letters of commitment for easements for Daley (170,00 gallons per day (gpd) and Erwin Michael (90,000 gpd).
- WTP processing is backwash daily volume at a future output and current unit volume generation rate (2.2%).
- Unaccounted water loss is 15%.

III. OVERVIEW OF HARRISONBURG RAW WATER SYSTEM

What water sources will be used to meet the demands identified in the business model?

The following table provides an inventory of both existing and potential water sources that Harrisonburg considers viable for its RWSMP. Additional information for each source is provided in the appendices of this document.

Raw Water Sources	*Current Capacity*	*Future Capacity*	*Drought Capacity*
Dry River (DRI)	4.0 MGD	13.5 MGD	0.0 MGD
North River (NRI)	7.6 MGD	7.5 MGD	2.5 MGD
South Fork Shenandoah River (SFI)	0.0 MGD	13.2 MGD	9.1 MGD
Total	**11.6 MGD**	**34.2 MGD**	**11.6 MGD**
Potential Raw Water Sources			
SFI Groundwater Wells (SGW)			3.4 MGD
DRI NRI Groundwater Wells (WGW)			3.4 MGD
Silver Lake (SLI)			1.5 MGD
Frazier Quarry (FQI)			3.4 MGD
Dry River-Switzer Reservoir (D-SR)			3.4 MGD

DRI

Commissioned in 1898, the current capacity is 4.0 MGD; completion of the 30" pipe will expand capacity to 13.5 MGD. Dry River is not reliable during drought under status.

NRI

Commissioned in 1970 and rated at 7.6 MGD capacity by VDH.

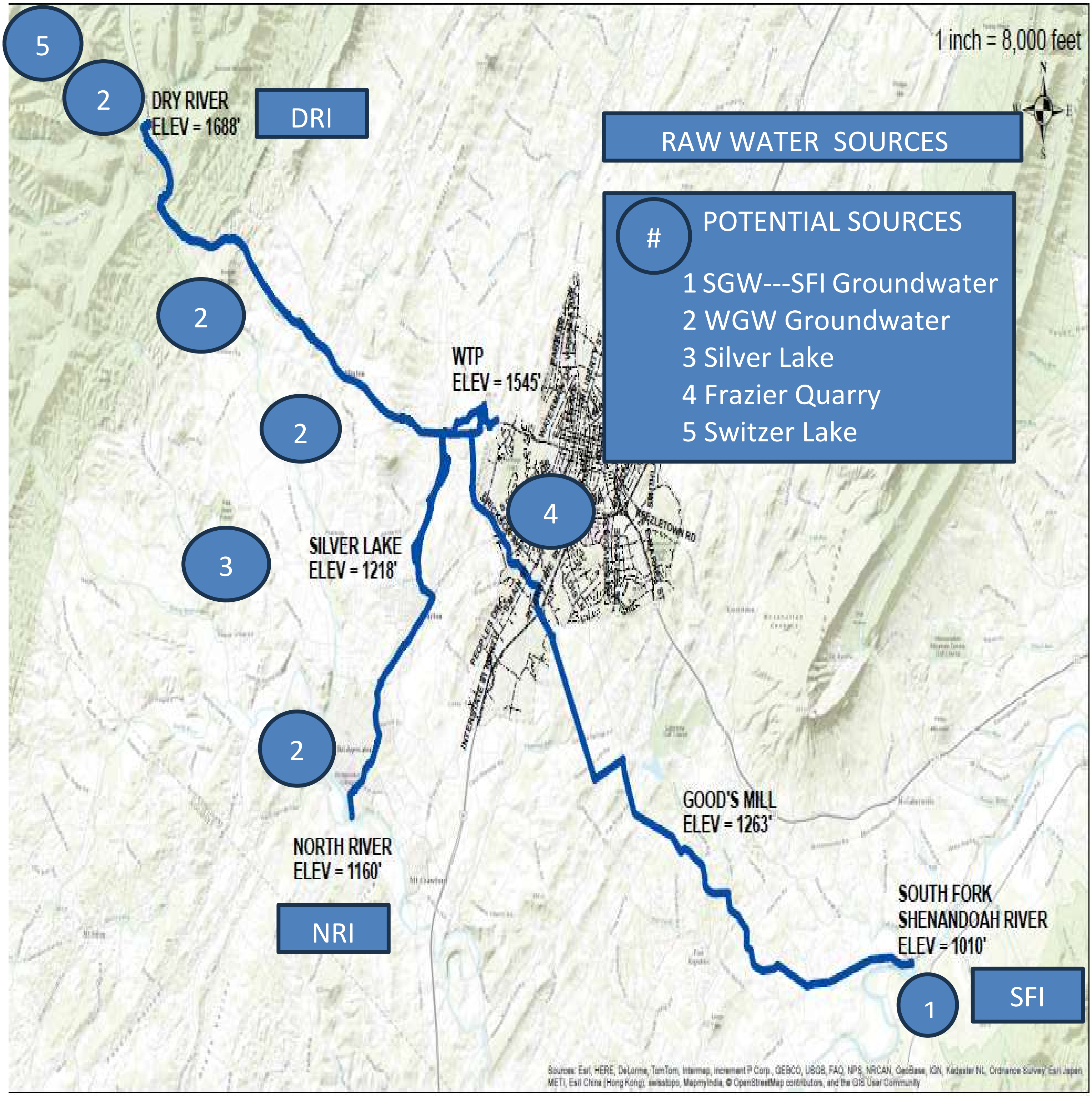
SFI

Anticipated commissioning in 2025 with a VDH rating of 13.2 MGD.

POTENTIAL SOURCES

These raw water sources are under consideration for future specific use in mitigating the loss of supply during drought conditions.

A geographical overview of the raw water sources is shown below:



IV. RAW WATER SUSTAINABILITY UNDER NORMAL OPERATIONS

What strategies are necessary to ensure that the master plan is reliable and sustainable?

The general theme for normal operations as adopted under Harrisonburg's Raw Water Supply Management Plan is generalized as follows:

- Maximize the usage of raw water from the Dry River.
- Minimize the usage of raw water from the Shenandoah River.
- Gap fill with raw water from the North River.

The table below shows the preferred sources of raw water for each decision criteria listed above. Preferred sources are listed higher in the table. Dry River is the preferred source for all three parameters. The Shenandoah River is the least preferred source concerning its higher specific energy requirements. The North River is a difficult source to qualify or quantify for water quality and treatability because its makeup varies widely with its high increase of in-stream flows and accompanying influences from agriculture.

Harrisonburg Source Water Preference Table

Social Stewardship	Financial Stewardship	Environmental Stewardship
DRI	DRI	DRI
NRI	NRI	SFI
SFI	SFI	NRI

Future WTP operating strategy shall require the selection and proportioning of differing source waters among the Dry River (DRI), North River (NRI), and the South Fork Shenandoah River (SFI). *F*orecasts to achieve the most probable use of water supply sources will require:

1) Social stewardship through water quality.
2) Financial stewardship through the efficiency of supply and treatment.
3) Environmental stewardship through electrical energy management and instream aquatic protection.

Social Stewardship: Water Quality & Treatability

- **DRI**: The Dry River is a pristine source with little concern for human waste. The most serious concern for this source is a corrosive index and an absence of alkalinity. The corrosive characteristic, if not adequately addressed at selected stages of conveyance and treatment, can be a concern as a contributing cause for leaching metal from pipes and plumbing. The absence of alkalinity must be addressed to enhance the coagulation process essential to the water treatment.
- **NRI**: The North River is a wild card for water quality and treatability. The North River is downstream of the Dry River and, therefore, has the potential to have similar favorable water characteristics; however, quick-rising tributaries and agricultural exposure can push contaminant levels to the undesired extreme for specific parameters such as Total Organic Carbon (TOC), bacteria, and nutrients.
- **SFI**: The Shenandoah River is a lower watershed source. This source is subject to more exposure to natural and human waste. Therefore, the variety of contaminants is more significant; however, the higher volume of water creates an effect by which contaminant concentrations can be diluted to generally lower levels.

Financial Stewardship: Efficiency through supply and treatment

Specific Energy (SE) is the benchmark for managing energy costs. SE is simply the kilowatt hours of electricity required to pump one million gallons of water. The lower the benchmark's value, the better the energy optimization.

Treatability is a second financial relationship between the use of chemicals and the cost of obtaining final effluent quality. Harrisonburg raw water sources are compared as follows:

Water Source	SE	Treatability
DRI	Zero	Raw waters are pristine and require minimal chemicals but to add alkalinity.
NRI	2,150	Raw waters are susceptible to wide turbidity ranges and require increasing amounts of coagulation chemicals.
SFI	3,108	Raw waters are suggested to be like NRI but with less diverse of turbidity and the associated use of coagulation chemicals.

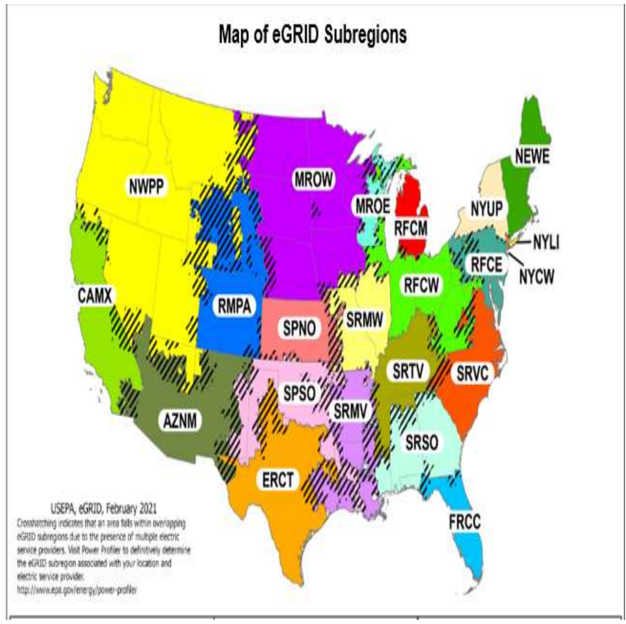
Environmental Stewardship: through electrical energy management and instream aquatic protection.

Specific Energy (SE) is also the benchmark for indirectly managing contributions to carbon emissions. The environmental carbon footprint for electrical energy consumption among HPU raw water sources is shown below with a map of the Emissions and Generation Resource Integrated Database (**eGRID**) Subregions-a primary source of data on the environmental characteristics of almost all electric power generated in the United States including different type of emission rates. The previously referenced strategy to maximize DRI, minimize SFI, and gap-fill with NRI is primarily driven by the carbon footprint.

DRI = Zero kW-hrs. / MG
Zero lbs. COe / MG

NRI = 2,150 kW-hrs. / MG
1,382 lbs. COe / MG

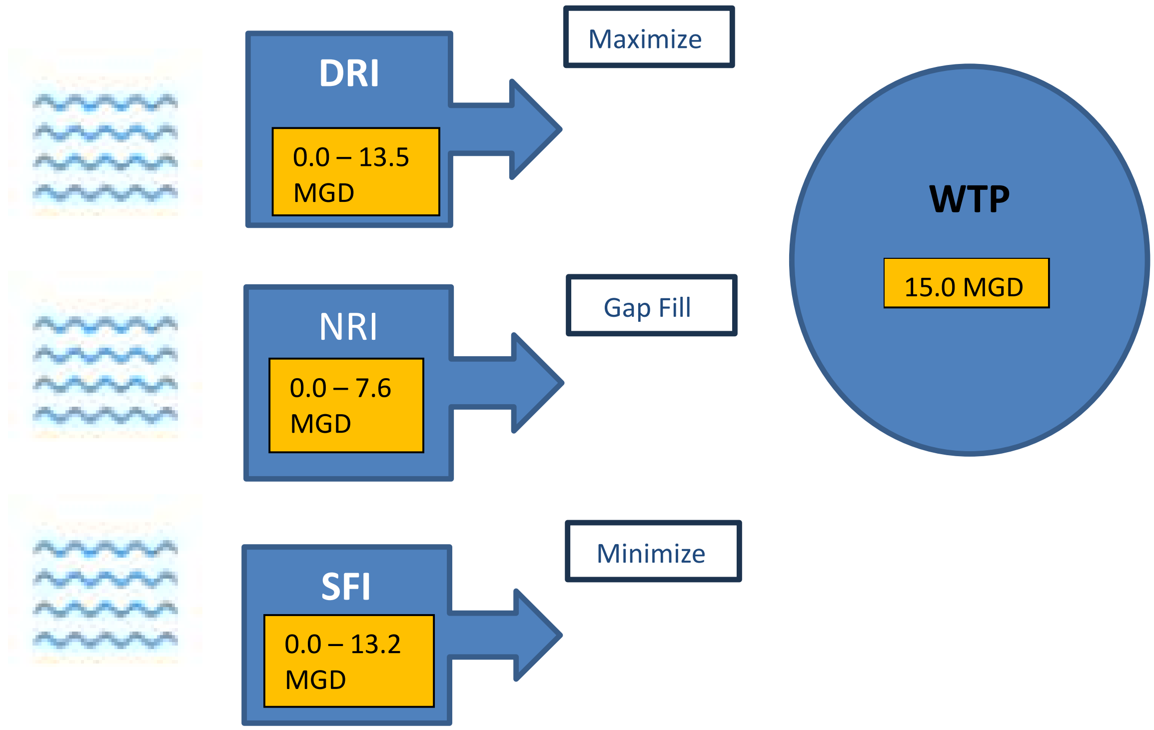
SFI = 3,108 kW-hrs. / MG
1,998 lbs. COe /MG



eGRID Subregion	CO_2	CH_4	N_2O	CO_2e	Annual NO_X	Ozone Season NO_X	SO_2
SRVC	639.7	0.052	0.007	642.9	0.3	0.3	0.2

As a second environmental measure, the water sources at DRI, NRI, and SFI are provided in-stream environmental protection as regulated under Virginia Water Withdrawal Permit #16-0730. HPU must provide 500,000 gpd flow-by at DRI, 88% in-stream flow-by at NRI, and 90% flow-by at SFI. As a third measure, each source is provided with 2 mm mesh screens to protect against entrainment and entrapment of egg larvae and juvenile aquatic fish life, respectively.

City of Harrisonburg Normal Operations RWSMP



Priority actions to establishing the "Normal Mode of Operations" are:

1) Near 2025, HPU will add a new water source by completing its Shenandoah Raw Water Project. At the same time, and as an action of environmental stewardship, Harrisonburg will incur its drought restrictions (loss of 5.4 MGD capacity) at North River.
2) From 2023 to 2035, HPU will cash fund to construct the 30" western source raw water pipe from Belleview Road to VPGA, and then around 2035, Harrisonburg will engage bond funding to construct the 30" western source raw water pipe from VPGA to Cooper's Mountain.

V. RAW WATER SUSTAINABILITY UNDER DROUGHT OPERATIONS

What strategies are necessary to ensure the master plan is reliable and sustainable?

Drought conditions dictate the critical parameters under which Harrisonburg must evaluate its water system reliability. This section of the RWSMP has been prepared for Harrisonburg to understand how, when, and why its future demands will require proactive planning and action for drought reliability. The table below is a recapture of the drought data from the table in Section III.

Raw Water Sources	***Drought Capacity***
Dry River (DRI)	0.0 MGD
North River (NRI)	2.5 MGD
South Fork Shenandoah River (SFI)	9.1 MGD
Total	**11.6 MGD**
Potential Raw Water Sources	
SFI Groundwater Wells (SGW)	3.4 MGD
DRI Groundwater Wells (WGW)	3.4 MGD
Silver Lake (SLI)	1.5 MGD
Frazier Quarry (FQI)	3.4 MGD
Dry River -Switzer Reservoir (D-SR)	3.4 MGD

Withdrawals at DRI, NRI, and SFI are dictated by VWWP #16-0730 based on the protection of instream flow rates as follows:

- **DRI**-Withdrawals shall be adjusted at the Dry River Intake to a minimum of 0.744 c.f.s. (0.5 MGD) is released to the Dry River below the low-head dam.
- **NRI**-At no time shall the withdrawals from North River exceed 12% of the stream flow as estimated at the intake. HPU recognizes that North River is a target for water protection; this effort began with the proposed Surface Water Management Area (SWMA) in the 1990s and takes even greater focus under the Local and Regional Water Supply Plan (9VAC 780) and VWWP #16-0730 that are relevant today. The

withdrawal limitation has progressively decreased from the 1Q10 criteria of 13.6 MGD prior to the 1990s to 5.5 MGD (13% MAF) with the SWMA, to 2.5 MGD (12% in-stream flow) with the VWWP.

- **SFI**-At no time shall "Net Withdrawal" exceed 10% of the stream flow at the South Fork Intake. Net withdrawal equals the total volume withdrawn from the South Fork plus 66% in recognition of the "Return Flow" at HRRSA. Under historic low flow in stream conditions, the Shenandoah Project will provide 9.1 MGD of reliable water supply.

POTENTIAL SOURCES

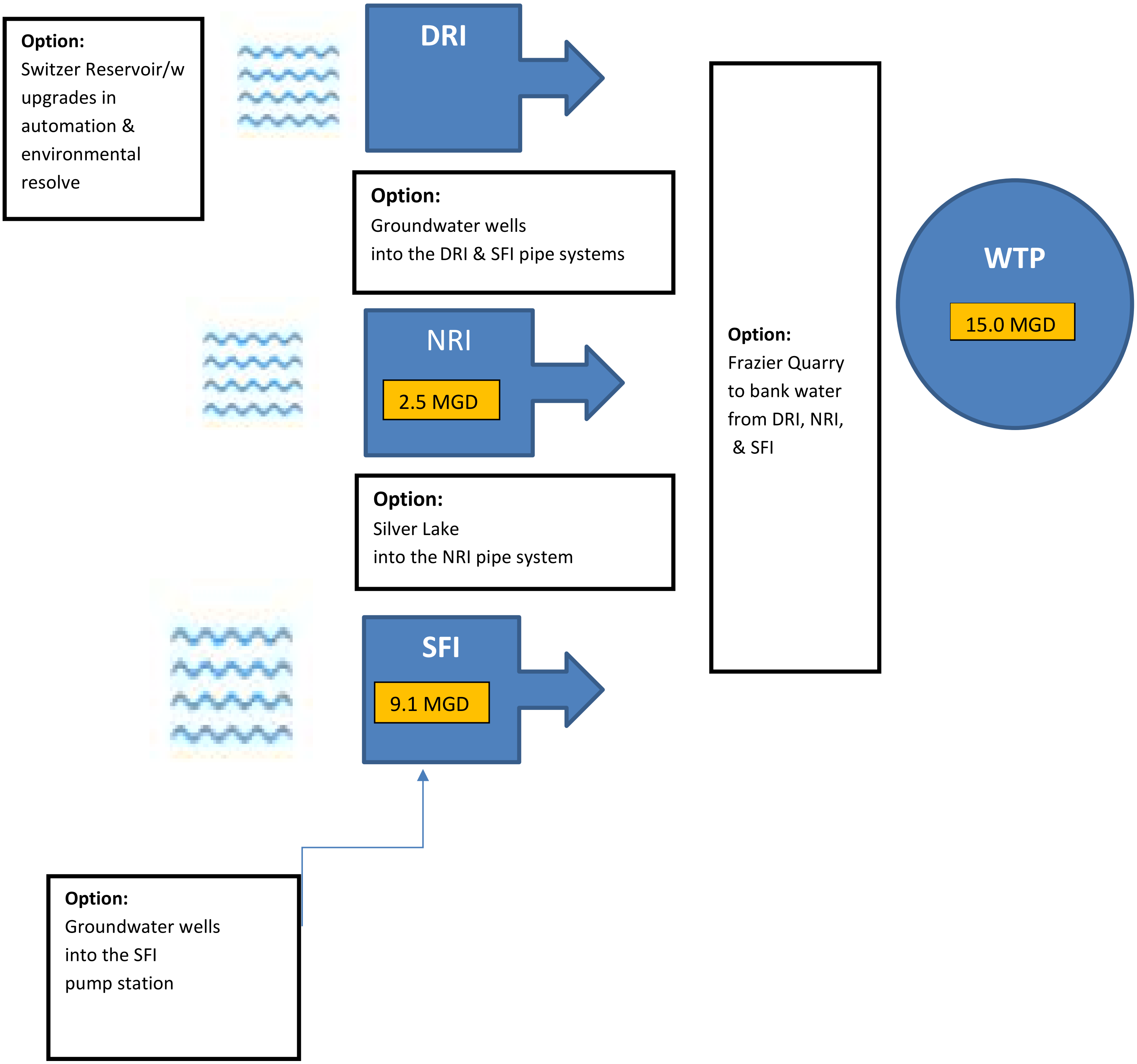
HPU currently has the potential sources under consideration as follows:

- **SGW**-The SFI pump station is under design to supply 13.2 MGD with drought limitations at 9.1 MGD. This allows the use of groundwater limitations to augment the SFI intake waters. HPU has located potential well sites near its SFI intake, but the yields have not been validated. In addition, Rockingham County has nearby wells that perhaps HPU could pursue to use cooperatively for augmentation.
- **WGW**-HPU has identified potential groundwater sites along its DRI and NRI pipelines, but yields are expected to be low. Likely high mineral content is probable at many sites.
- **SLI**-Silver Lake Is under the ownership of Harrisonburg but would require the construction of intake facilities and coordination with the Town of Dayton.
- **FQI**-Would engage a unique use of the 850 million gallons storage volume in the quarry to bank water from other raw water sources.
- Switzer Lake holds 1.5 billion gallons of water with an estimated safe yield of 8.3 MGD. Making these waters reliable during drought requires balancing automation of releases from the lake, management of losses between the lake and DRI, and Dry River in-stream aquatic protection.

HPU's timeline in pursuing the additional drought-reliable raw water sources is the year 2030-2037, as shown below:

2023-Drought Reliability (NRI = 2.5 MGD + SFI @ 9.1 MGD = 11.6 MGD)
2023-7.87 MGD Raw Water withdrawal = 10.15 MDG Capacity
2030-8.93 MGD Raw Water withdrawal = 11.60 MDG Capacity—1% growth
2037-8.93 MGD Raw Water withdrawal = 11.65 MDG Capacity---2% growth

City of Harrisonburg Drought Condition RWSMP



VI. RAW WATER RISK MANAGEMENT STRATEGY

Risk planning for the Harrisonburg Raw Water System consisted of identifying and evaluating significant risks to reliable water supply and then identifying possible measures to reduce or mitigate the effects. The following risks were identified:

a) Total Loss of Water Source

The cause would most likely be contamination, effects from floods or other natural disasters, or a catastrophic failure of system infrastructure. Occurrence of this type is generally not easily or quickly remediated, so multiple alternative sources are preferred as mitigation options.

b) Electrical Failures

The cause would be failed service delivery by the electric purveyor through some grid failure. Occurrence of this type can generally be mitigated by installing an electrical backup generator. In some cases, pumps using an alternative fuel can be used.

c) Unit Failure

The cause would be mechanical, electrical, or other physical failure of one or more units of the on-site infrastructure of the pump station, intake, or conveyance system. Occurrences of this type can generally be mitigated by the installation of duplicity for applicable components.

d) Drought

This RWSMP includes a previous section dedicated entirely to drought; this condition is a prominent area of the planning agenda.

The table as follows itemized each of the risks above. The benchmark goal for success was a total raw water supply of 15.0 MGD or greater. The evaluation included:

- Independent loss of total source, power, or single unit operations at each source.
- Simultaneous loss of power at all sources.
- Simultaneous effects of drought at all sources; DRI included analysis with and without augmentation from Switzer Lake.
- Simultaneous loss of power to all sources during the effects of drought; DRI included analysis with and without augmentation from Switzer Lake.

CITY OF HARRISONBURG RAW WATER RISK ANALYSIS

Source	SRI			NRI			DRI		Total
	Pumps	Generator	MGD	Scenario	Generator	MGD	Scenario	MGD	MGD
Total Loss of Source									
...SRI (Mitigation #1)	out of service	None	0.0	3 pumps	1 pump (demand)	7.6	max flow	4.0+	**11.6+**
...NRI (Mitigation #2))	3 pumps	1 pump (power mgmt.)	13.2	out of service	none	0.0	max flow	4.0+	17.2+
...DRI (Mitigation #2)	3 pumps	1 pump (power mgmt.)	13.2	1 pump	none	3.5	out of service	0.0	16.5
	2 pumps	None	9.1	3 pumps	1 pump power mgmt.)	7.6	out of service	0.0	16.7
Power Loss									
...SRI (Mitigation #3)	1 pump	1 pump	4.6	3 pumps	1 pump (power mgmt.)	7.6	max flow	4.0+	16.2+
	2 pumps	2 pumps	9.1	1 pump	none	3.5	max flow	4.0+	16.6+
...NRI	2 pumps	None	9.1	None	none	0.0	max flow	4.0+	13.2+
...SRI & NRI (Mitigation #5)	2 pumps	2 pumps (reliability)	9.1	1 pump	1 pump	3.5	max flow	4.0+	16.6+
Loss of a Single Unit									
...SRI or NRI	2 pumps	None	9.1	1 pump	none	3.5	max flow	4.0+	16.6+
...SRI or NRI	1 pump	None	4.6	2 pumps	none	5.7	max flow	4.0+	14.3+
...DRI	3 pumps	1 pump (power mgmt.)	13.2	1 pump	none	3.5	out of service	0.0	16.7
	2 pumps	None	9.1	3 pumps	1 pump (power mgmt..)	7.6	out of service	0.0	16.7
Drought									
...SRI & NRI &DRI (Mitigation #4 & #7)	2 pumps	1 pump (power mgmt.)	9.1	1 pump	None	2.5	w/ Switzer	4.0	15.6
...SRI & NRI &DRI (Mitigation #4 and #7)	3 pumps	1 pump (power mgmt.)	9.1	1 pump	None	2.5	wo / Switzer	0.0	**11.6**
Drought + Power Loss									
...SRI & NRI &DRI (Mitigation #6 and #7 or #8)	2 pumps	2 pumps (reliability)	9.1	1 pump	1 pump	2.5	w/ Switzer	4.0	15.6
...SRI & NRI &DRI (Mitigation #6 and #7 or #8)	2 pumps	2 pumps (reliability)	9.1	1 pump	1 pump	2.5	wo / Switzer	0.0	**11.6**

Mitigations	
DRI Upgrade	1: Total loss of the SRI source supports upgrading the DRI pipeline to 8.4 MGD minimu
SRI Generator Design	2: Total loss of NRI or DRI source supports 1 generator at SRI for power cost management. 3: Loss of power at SRI supports 1 generator at SRI. 4: Drought effects at SFI would support 1 generator for power cost management. 5: Loss of power at SRI and NRI supports 2 pump generator capacity at SRI 6: Loss of power at NRI during drought supports 2 pump generator capacity at SRI
Drought Mitigation	7: Add 3.4 MGD reliable drought sources; 8: Add 0.6 MGD and control reserves in Switzer Lake to provide up to 4.0 MGD during peak drought. Risky due to duration and counter-productive to downstream aquatic protection.

VII. ASSET MANAGEMENT STRATEGY

HPU's asset management programs include predictive maintenance, preventive maintenance, repair maintenance, and capital projects that engage project management principles to provide rehabilitation and retirement (R&R) or expansion (addition of new assets). The raw water assets are inclusive of the HPU programs.

Predictive Maintenance:

HPU uses Supervisory Control and Data Acquisition (SCADA) as the AI tool to monitor and control raw water delivery. The SCADA system provides outputs useful in predicting pump and motor functionality and performance at the pump stations.

Preventive Maintenance:

HPU performs regular preventive maintenance on pumps, motors, and instrumentation as the manufacturer recommends. Air valves and stop valves provide preventative maintenance simultaneously with potable distribution assets. HPU is considering the installation of pigging stations to allow for internal pipe cleaning.

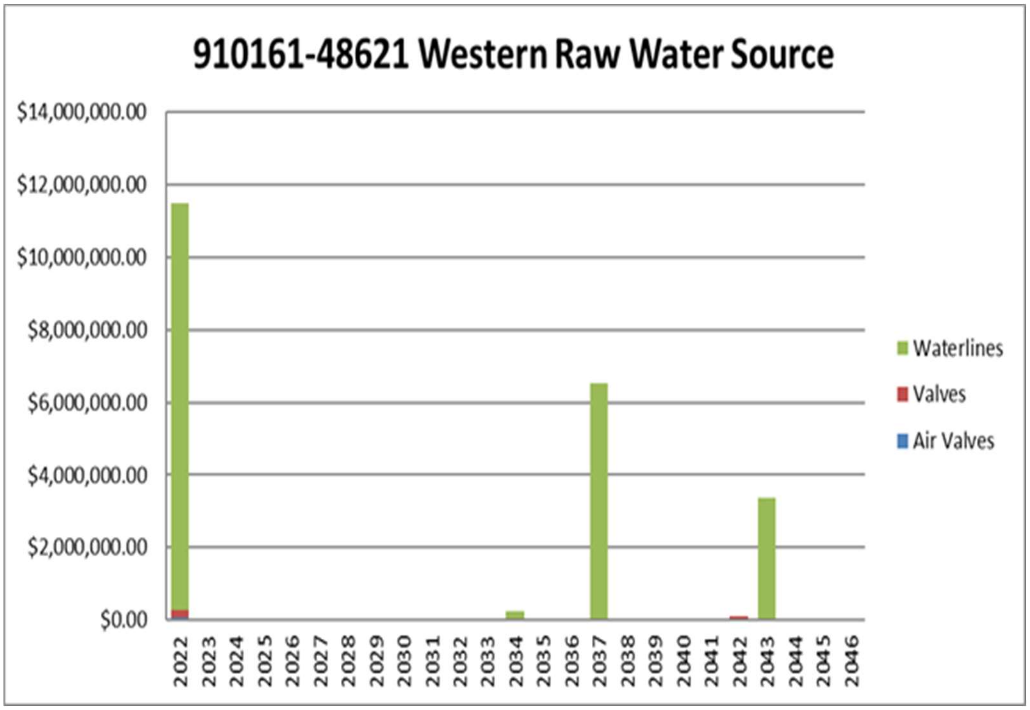
Repair Maintenance:

HPU performs repair maintenance on an as-needed basis. HPU holds staff skills that generally make repairs within 24 hours. Some repair maintenance on pumps and motors is contracted.

Capital:

A) Rehab & Retirement (R&R)

For CIP funding purposes, HPU forecasts asset retirement dates and corresponding costs using the Manufacturer's Anticipated Service Life (MASL) and typical inflation rates. Funding is pursued from the forecasted cash flow as shown below:



A unique variance to the above replacement strategy is in place for the western raw system under a chartered project entitled "Route 33 West Asset Management Plan".

- Raw water assets (12" pipe) shown to retire in FY2002 will be in-situ evaluated and temporarily used to mitigate risk in the potable system until the 16" pipe is converted to potable status. The 12" pipe will then be abandoned when the cost of continued maintenance meets threshold costs.

- Raw water assets (16" pipe) shown to retire in FY 2037 will be in-situ evaluated and rehabilitated to extend their useful life beyond 2037. This pipe will be converted to potable status.

- Raw water assets (20" pipe) shown to retire in FY 2043 will be provided corrosion protection to extend their useful life beyond 2043.

- Other pipe in the system is scheduled to retire beyond 2046 but is not shown above.

- The raw water pumping and conveyance system from the South Fork Shenandoah has not yet been commissioned, and therefore, it is not included in the planning.

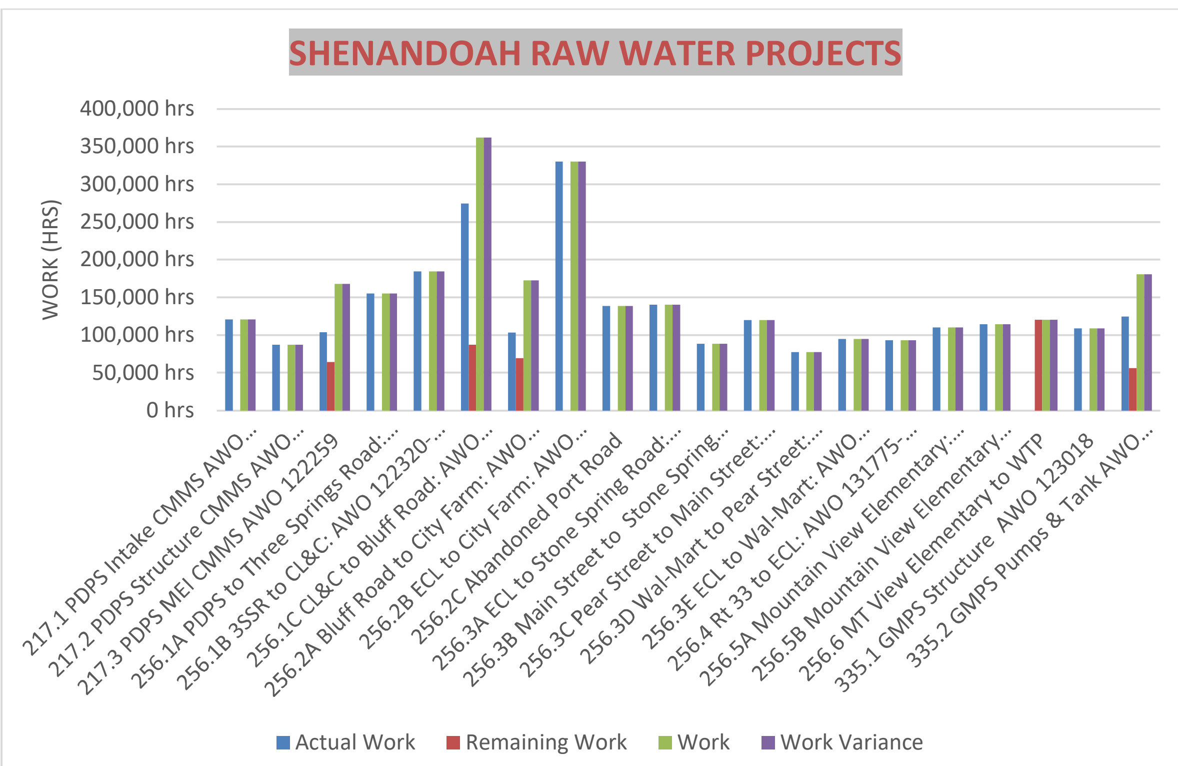
B) Expansion

Additional CIP funding is required for expansion, adding new assets to the inventory. Five projects comprise future expansion for the raw water system:

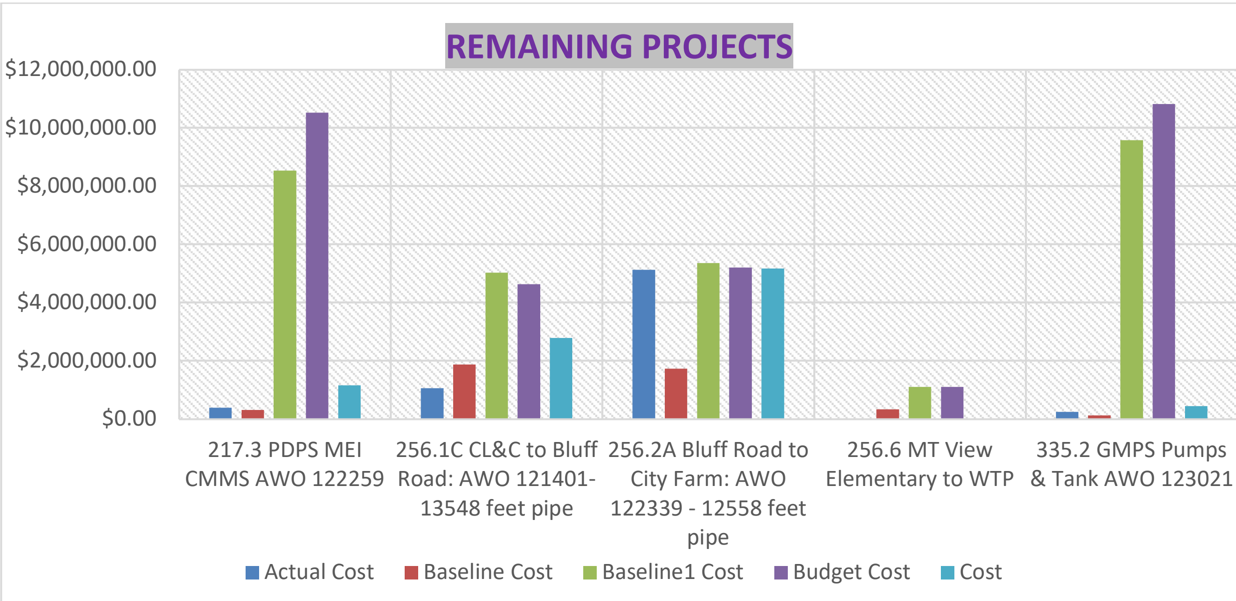
1) **Shenandoah Raw Water Project**

   The project portfolio comprises 20 projects; 15 have been completed and 5 remain in progress. In summary, 87% and 57% of the work by duration and cost has been completed, respectively. The project schedule will be completed in 2025 and deliver 13.2 MGD to the WTP. The table and chart below show a high-level project overview: scope, schedule, and cost. The project cost forecasts closure at $2,527,011 over budget.

Name	Start	Finish	% Work Complete	Budget Cost	Baseline1 Cost	Cost	% Work Complete ($)
SHENANDOAH RAW WATER PROJECT-PMO HPU	Thu 5/1/97	Wed 12/31/25	87%	$53,196,163.00	$50,669,152.00	$30,455,872.00	57%



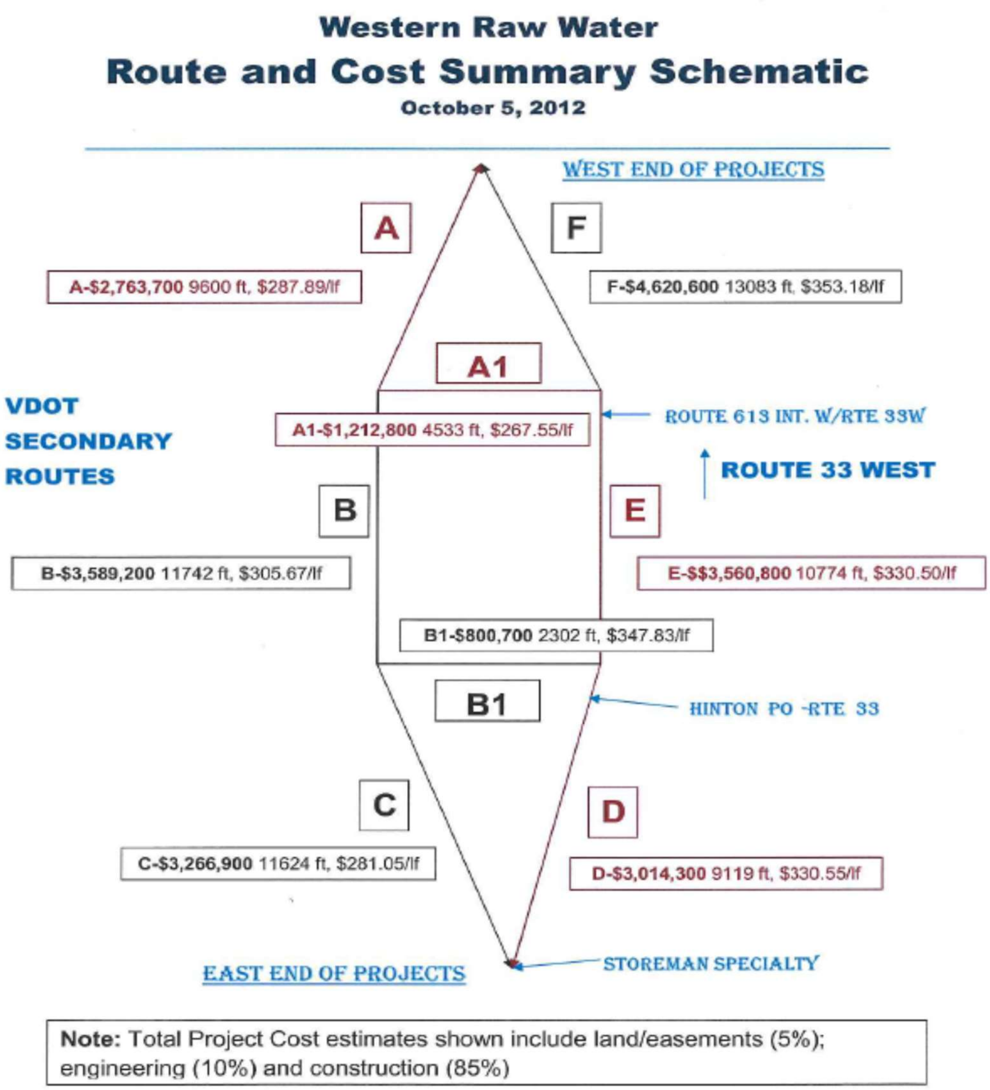
The chart and table below show the five remaining projects in detail, including the Budget Cost (CIP Budget at Completion), Cost (Current Total Project Cost), Actual Cost (what has been paid presently), and Baseline 1 Cost (2021 Bond Baseline).



Name	Budget Cost	Cost	Actual Cost	Baseline1 Cost
217.3 PDPS MEI CMMS AWO 122259	$10,521,327.00	$1,159,021.00	$389,557.80	$8,533,595.00
256.1C CL&C to Bluff Road: AWO 121401-13548 feet pipe	$4,631,995.00	$2,778,994.00	$1,056,911.30	$5,025,759.00
256.2A Bluff Road to City Farm: AWO 122339 - 12558 feet pipe	$5,195,118.00	$5,169,752.00	$5,122,511.85	$5,354,292.00
256.6 MT View Elementary to WTP	$1,095,050.00	$0.00	$0.00	$1,095,050.00
335.2 GMPS Pumps & Tank AWO 123021	$10,815,643.00	$435,642.00	$244,896.50	$9,575,931.00

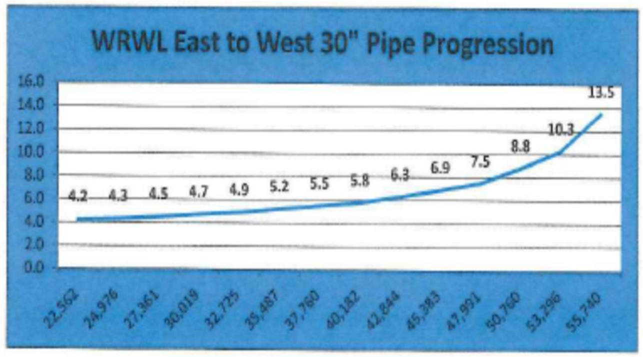
2) **Western Raw Water Project**

This project was initiated in the 1990s and targeted a new 30" waterline from DRI to the WTP. Approximately 22,562 feet of 55,000 feet of new pipe have been installed. The approximate amount of pipe will be cash-funded annually until 2035. The remaining 21,600 feet will then be funded to completion using borrowed funds. The new pipe will increase incrementally, as shown below until it conveys 13.5 MGD to the WTP. The general concept of completion is shown below.



WESTERN RAW WATERLINE DELIVERY PLANNING SCHEDULE

Updated:	April, 2015
CURRENT AMOUNT OF 30" PIPE IN GROUND	22,562
REMAINING PIPE TO INSTALL	33,178



Project Completed West to East

#256	2,418
#273	1,180
#297	3,498
#345	2,364
#388	2,135
	11,595

Incomplete Projects	CUM FT	MGD
	22,562	4.2
2,414	24,976	4.3
2,385	27,361	4.5
2,658	30,019	4.7
2,706	32,725	4.9
2,762	35,487	5.2
2,273	37,760	5.5
2,422	40,182	5.8
2,662	42,844	6.3
2,539	45,383	6.9
2,608	47,991	7.5
2,769	50,760	8.8
2,536	53,296	10.3
2,444	55,740	13.5
33,178		

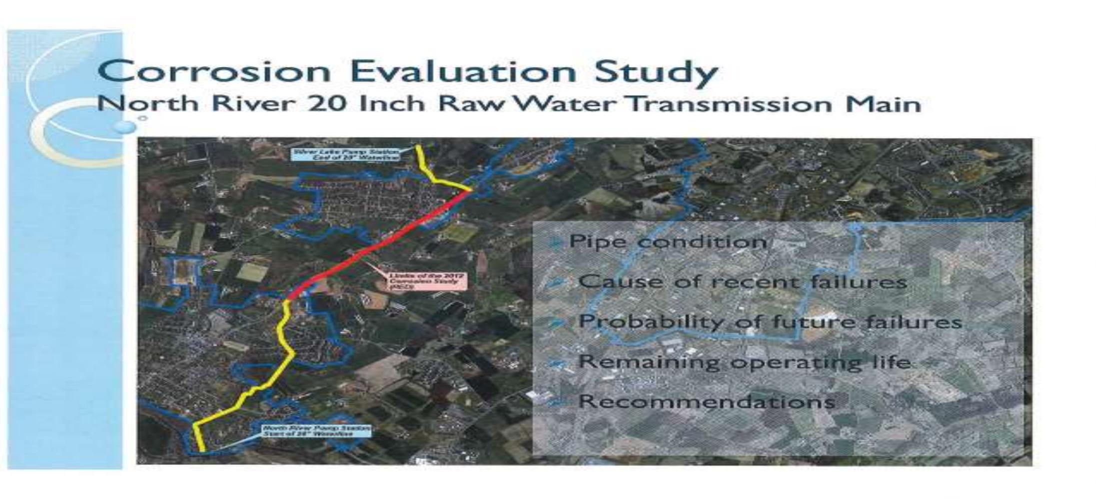
Data taken from W&W Report "Updated Flow Projections and Implementation recommendations for the Western Raw Waterlne Upgrade Project; Feb 2008.

CURRENT AMOUNT OF 30" PIPE IN GROUND	22,562	feet	
REMAINING PIPE TO INSTALL	33,178	feet	
ROUTE D 9,119 feet to Hinton (cash funded)	31,681	feet	4.8 MGD
ROUTE E 10,774 feet to RT 613 (cash funded)	42,455	feet	6.3 MGD
ROUTE A1 & A 14,133 FEET (Bond Funded)	56,588	feet	13.5 MGD

Projects Completed East to West

#199	3837
#99	2715
#136	4415
	10,967

3) **VWWP Compliance**
   HPU's water withdrawal permit requires the installation of micro screens at DRI, NRI, and SFI. HPU has programmed the completion of these projects into the CIP Program. SFI will be completed by 2025, and the DRI-NRI projects will be completed by 2030.
4) **NRI Corrosion Project**
   The 20" pipe from NRI to Dayton has been identified with severe corrosion. HPU is currently installing anodes onto the pipe annually through 2029.



5) **Drought Augmentation**
The purpose for completing the project(s), forecasted to be completed before 203 to 2037, will provide 3.4 MGD of water supply for establishing drought reliability. The appendices of this document provide insight into some of the projects.

- APPENDIX C: SWITZER DAM ON DRY RIVER SOURCE
- APPENDIX F: SILVER LAKE SOURCE
- APPENDIX G: SFI WELL SITES
- APPENDIX H: NRI & DRI GROUNDWATER ZONES
- APPENDIX I: FRAZIER QUARRY

VIII. Water Supply Management Plan Overview

The RWSMP requires HPU to coordinate and manage the following appropriately:

1) Mandates within its Virginia Waterworks Permit #016-0730.
2) Compliance with Virginia statute 9-VAC-780 for Local and Regional Water Supply Plans.
3) Performance to meet benchmarks in its preplanned maintenance agenda.
4) HPU Capital Improvement Plan for Western Raw Water System.
5) HPU Capital Improvement Plan for Eastern Raw Water System.
6) Integration of raw water asset needs into the Water Long Term Financial Model (WLTFM).

VAC Local and Regional Water Supply Plan

Plan Recommendation #1	Status - FY 2023
Maintain compliance with Virginia Administrative Code requirements for a regional and local water supply plan.	✓ 2013: Original "Plan" was adopted by resolution of City Council and approval by DEQ ✓ 2018: Updated "Plan" was reapproved • 2023: HPU is awaiting instructions from DEQ for a format update to revise the submittal of an individual plan.

VWWP #16-0730

Plan Recommendation #2	Status - FY 2023

Renew Virginia Water Withdrawal Permit #16-0730.
 	
Comply with the requirements of the re-issued permit.
	✓ 2016 permit was re-issued; expires 2031.
	• Permit requirements:
	  ✓ Conservation Ordinance adopted.
	  ▪ HPU has submitted a compliance plan for intake screens and is awaiting a response from DEQ.
	  ▪ Comply with maximum withdrawals

Dry River

Plan Recommendation #3	Status - FY 2023

• Upgrade 55,000' raw water pipe. • Transition the 1959 pipe to potable water. • Decommission 1929 pipe. • Decommission 1898 pipe.	✓ 22,000 feet complete CIP and LTFM Planning • 11,400 feet of raw water 30" pipe during 2023-2035: $6.1M Convert 16" pipe to potable status. HPU is awaiting the disbursement of funds and instructions from federal state funding sources. • 21,600 feet of raw 30" pipe 2035 CIP: $12.2M Convert 16" pipe to potable status.

North River

Plan Recommendation #4	Status - FY 2023
• Upgrade North River Pump Station ▪ Variable output; energy efficient ▪ Retire critical assets. ▪ Add power loss response. ▪ Model for PDPS & GMPS • NRPS: Add Energy AI Technology • 20" pipe rehab & retirement • 24" pipe rehab & retirement	✓ NRS Project 100% complete $1.6M ✓ Energy Optimizer installed in 2021. CIP and LTFM Planning • 20" pipe corrosion protection 2022-2029 • 24" pipe retirement-post 2050

South Fork Shenandoah River

Plan Recommendation #5	Status - FY 2023
Finalize the South Fork Shenandoah River Raw Water Project's scope, cost, schedule, and completion. 90,000 feet pipe & 2 Pump Stations $53M – 65,000 feet pipe complete 25,000 feet 2023-2024 PDPS 50% complete GMPS 25% complete	CIP and LTFM Planning • PD & GM PS……… 2023-2025 ✓ 256.1A……………… Complete PDPS + 2,200 feet pipe ✓ 256.1B……………… Complete 256.1A + 17,275feet pipe • 256.1C………………2023-2024 256.1B + 9,479feet pipe ✓ 256.2ARX………….. Complete 3 Bores-256.2A • 256.2A ……………..2022-2023 Port Republic Road Corridor 16,670 feet pipe ✓ 256.2B …………….. Complete Port Republic Road to ECL ✓ 256.3A-E ………….. Complete ECL to WCL ✓ 256.4 ………………. Complete WCL to Rt 33 ✓ 256.5 A&B ………… Complete ✓ 256.6…………………2024 Mt View School to WTP

Drought Reliable Sources

Plan Recommendation #6	Status - FY 2023
Pursue the best alternative for 3.4 MGD drought-reliable raw water.	• SFI Wells………… Located • WGW………………Located • Silver Lake………...TBD • Switzer Dam....……. TBD • Frazier Quarry……...TBD

APPENDIX A: HARRISONBURG WATER SUPPLY CHRONOLOGY

History of Harrisonburg Water Supply

- 1779 – Thomas Harrison deeds the "Big Spring" for public use.
- 1798 – Town Council commits $35.00 to wall the Big Spring (See Spring House replica at Court Square).
- 1890 – Ten miles of hand-laid 10" cast iron pipe supplies pristine waters from Dry Run, Gum Rum, and Rocky Run surface water dams.
- 1914 – Construction of a 5 million gallons reservoir at Tower Street improves service reliability to town customers.
- 1920 – Two projects significantly enhance water supply:
    1) A 12" cast iron waterline was constructed parallel to the previous 10" pipe.
    2) Construction of a 16 million gallons reservoir at Tower Street increases storage to 21 million gallons.
- 1930– The Research Service in Washington D.C. designs and oversees town forces to construct a unique below-ground collection gallery at Rawley Springs.
- 1950 – A 16" cast iron waterline is constructed parallel to the 10" and 12" pipes from Rawley Springs.
- 1960 – A pump station and pipeline for Silver Lake are implemented as the auxiliary drought supply option.

<u>Clean Water Act mandates filtration technology: City targets 5.0 MGD</u>

- 1970 – A 7.5-mile pipeline to the North River in Bridgewater and the city's first filtration plants are placed in operation. Switzer Dam is constructed as a flood control dam, but the City pays to increase the capacity for water supply purposes.
- 1980 – The City's filtration capacity is increased from 5.0 MGD to 7.7 MGD by operation management practices and without capital dollars; this is the the first plant in the state to operate at 6 GPM/sf filtration.

<u>Annexation: City targets 10.0 MGD interim to 15.0 MGD</u>

- 1989-1991: The City upgraded its 24" pipe from Silver Lake to Grandview Drive and then upgraded its North River Pump Station capacity rating to 7.6 MGD from VDH.
- 1990-1993: The city's filtration capacity is increased to 10.0 MGD without capital dollars. The plant becomes the first 8 GPM/sf filtration plant in Virginia.

<u>Annexation: City targets 10.0 MGD interim to 15.0 MGD</u>

- 1991-1993: The City considered a pipeline to Switzer Dam for long-term planning agenda; this alternative was rejected due to environmental constraints.

- 1993-1997: Bridgewater requests designation of the North River Surface Water Management Area concludes with Harrisonburg's statement to reject a supporting role. However, Harrisonburg established an agenda to pursue an alternative water source to meet future needs with no greater than 5.5 MGD withdrawals from the North River.
- 1993-1997: Harrisonburg pursues groundwater in the Dry River and North River corridors as an alternative to the Riven Rock to Switzer pipeline. This alternative was abandoned due to the tiny yields of recommended well sites.
- 1994: Dry River underground collection gallery was upgraded.
- 1995: Harrisonburg proposes to participate in Rockingham County's construction of its "Three Springs Water Treatment Plant"; joint proposal rejected by Rockingham County.
- 1996-1999: City studies and chooses the South Fork of Shenandoah River as the third source of raw water.
- 1996-2009: Completed various sections of 30" pipe between Dry River Intake and Water Treatment Plant.
- 1999: VWWP #98-1672 was issued for ten years.
- 2000: The City evaluates the optimum location for WTP for the Shenandoah water source
- 2001: Groundwater source evaluated on the South Fork of Shenandoah River as an augmentation source to the river intake to address temporary concerns for water quality and environmental stewardship.
- 2002: Harrisonburg evaluates Dry River Dam as an enhancement of the Dry River water supply; alternative abandoned due to environmental objections and cost.
- 2002: Shenandoah pipeline easement acquisition begins.
- 2004: Remnant of the old hydroelectric dam was removed on the South Fork of Shenandoah River.
- 2005: City constructed the intake on the South Fork of the Shenandoah River.
- 2005: The Shenandoah project was organized into 20 subprojects, which are in various phases of planning, design, construction, managerial, and closure.
- 2007-2011: HPU completed various phases of 30" pipe to Shenandoah River.
- 2009: VWWP #98-1672 was re-issued for five years.
- 2014: Dayton's water lease rights at Silver Lake expire; Harrisonburg gains first withdrawal right by redrafting the lease contract.
- 2015: Bridgewater Pump Station was upgraded.
- 2016: VWWP #16-0730 was re-issued to replace VWWP #98-1672 for 15 years.
- 2018-2023: PU completed various phases of 24" pipe to Shenandoah River.

APPENDIX B: DRY RIVER SOURCE

Longitude 78.971 Latitude 38.371

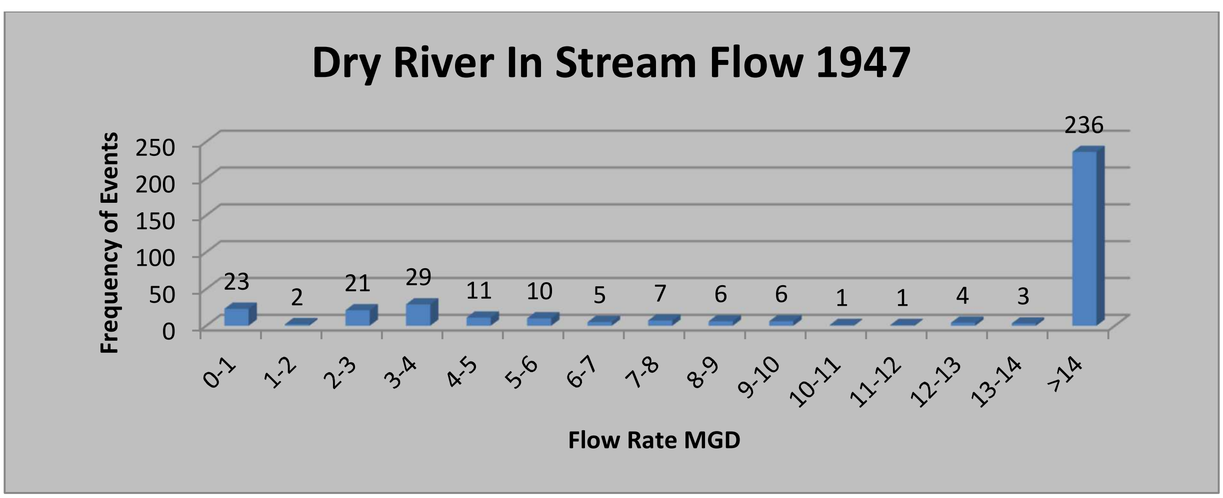
Intake Capacity 4.0 MGD

Dry River Source

The **Dry River** was Harrisonburg's original viable raw water source when commissioned in the late 1890s. Maximizing the use of the Dry River source water remains an inherent priority to the City's past, current, and future raw water management strategies. Use patterns for this source are typically constant and at 100% capacity (4.0 MGD) under all scenarios of normal operations. Harrisonburg's withdrawal is regulated under VWWP #16-0730. The City is required to bypass a minimum of 0.5 MGD around its intake to maintain an in-stream flow. The bypass originated through a handshake agreement with local Verona-based DGIF staff during the drought in the late 1990s and has been carried forth through the withdrawal permit.

DEQ has yet to rate the Dry River for a safe yield; however, records from a long-removed stream gage station and everyday observations suggested the flow approached nearly zero on many occasions. The following graph displays the frequency of stream flow quantities from 1947; this drought-type year was selected arbitrarily from the limited available data. Significant to the chart is the following frequency of low-flow events.

- 23 days throughout the year, the flow was less than 1.0 MGD.
- In 75 days, the flow was below the City's current system conveyance capacity of 4.0 MGD.
- On 129 days, the flow was below (thus, on 236 days, the flow was above), and the future expanded raw water pipe network conveyance capacity at 13.5 MGD.



Harrisonburg Assets

The city obtained access to the Dry River in the 1890s by installing 55,000 feet of 10" pipe that began at Dry River/Rocky Run/Gum Run intakes at Rawley Springs and extended to the reservoirs that were located within the city borders. Near the years of 1923 and 1947, 12" and 16" diameter pipes were respectively installed in parallel to the 10" diameter pipe. In 1934, a unique combined surface water / subsurface alluvial groundwater intake structure was installed, later to be upgraded in the early 2000s. The structure consisted of a concrete dam, a bar screen, an underground collection pipe, and a collection gallery. See the 1934 ENR Article that follows.

Until 1970, the pipe system conveyed potable water until the addition of the water treatment plant at Grand View Drive. At that time, all pipes were converted to raw water conveyance from Rawley Springs to the new water treatment plant; the exception was the 10" diameter pipe that was retained to convey potable water but in the direction from the new water treatment plant to Rawley Springs. Since the early 2000s, the city has embarked on a concept to install a new 30" diameter pipe, accompanied by conversion of the 12" and 16" pipes to potable water. This provides a progressive engagement of the life cycle management approach to retire older assets and simultaneously expand raw water conveyance capacity to 13.5 MGD when completed. The current Dry River Raw Water System includes the following assets:

- A unique underground collection gallery
- 30" pipe, 17,805 feet
- 30 pipes, 7,405 feet
- 16" pipe, 45,036 feet
- 12" pipe, 25,108 feet

Zero energy consumption is a primary advantage to maximizing the Dry River source as follows:

a) System 143 feet TDH
b) Energy 0 kW-hrs./MG by gravity delivery
c) Power 0 kW

Dry River Risk

- **Drought**-DRI Withdrawals shall be adjusted at the Dry River Intake to a minimum of 0.744 CFS. (0.5 MGD) is released to the Dry River below the low-head dam.
- **Flood**-In recent history, the hurricane events of 1985 and 1993 saw the pipe conveyance system lost for a substantial period.

- **Asset**-Mechanical, electrical, and control failures are less prominent with the gravity intake features.
- **Contamination**-No significant contamination has been incurred from the Dry River; however, five miles of the riverbed in the upstream watershed can be easily contaminated by a vehicular accident along the highly traveled Route 33 corridor in some places. The frequent small in-stream flow in the presence of a contaminant pays special attention to this concern.

As noted earlier, a unique intake gallery is part of the DRI Assets inventory. More information about this gallery was provided in the newspaper clip below, dated December 13, 1934.

ENGINEERING NEWS-RECORD DECEMBER 13, 1934 757

Groundwater Cutoff Wall Provides New Water Supply

Harrisonburg, Va., adds to its supply by building concrete wall in valley from surface to bedrock to intercept underflow

By A. B. McDaniel
Consulting Engineer, Washington, D. C.

LED BY the water shortage that developed during the great drought of 1930 to give consideration to an addition to its water-supply facilities, Harrisonburg, Va., has built an unusual groundwater-supply system, comprising essentially a concrete cutoff wall to intercept the underflow in the valley of the Dry River. Directly behind the wall there was built a collecting gallery, from which the water is conveyed by pipe line to the existing supply mains.

The city of Harrisonburg is situated in the Shenandoah Valley about 6 miles west of the southern extremity of Massanutten Mountain and about 12 miles east of the easterly slope of the North Mountain Range. The business section of the city lies at an elevation of 1,320 ft. above sea level, and the principal residential district is located on the eastern slope of a hill that rises to a height of about 100 ft. above Main Street. On this ridge above the city are the two distribution reservoirs, one having a capacity of 6,000,000 gal. and the other 15,000,000 gal.

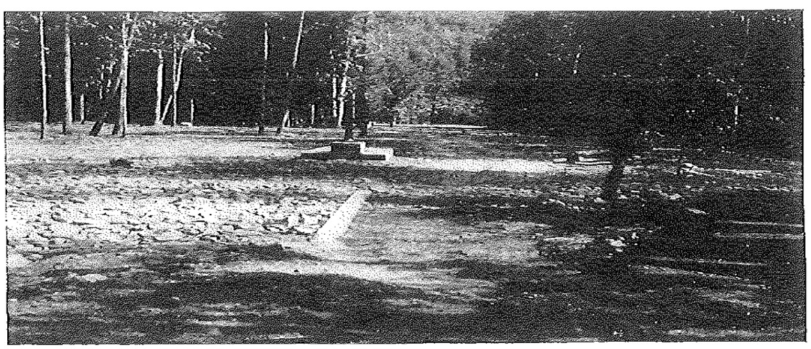


FIG. 1—TOP OF THE COLLECTING GALLERY and a portion of the top of the cutoff wall in new groundwater supply of Harrisburg, Va.

In 1921 the city constructed a concrete dam 100 ft. long and 10 ft. high in the channel of Dry River, 15 miles west of the city. About a quarter of a mile below the dam and on the west side of the valley is the intake works, the construction of which was begun in 1899. It consists of a concrete flume and a pool or collecting basin that receives the flow from a spring-fed stream along the west side of the valley. A 12-in. pipe carries the water during the low-flow period of the summer months from a small collecting basin behind the dam in the river channel to a 12-in. cast-iron main that is one of two parallel supply lines from the intake pool to the city. The other supply line is a 10-in. cast-iron main. The 10-in. main is also supplied with water from the bed of the main river channel during low-water periods by an 8-in. cast-iron pipe which runs to a sump in the bed of the river about 800 ft. below the dam. The general layout of the intake works, dam and pipe lines are shown in Fig. 2. The watershed area above the intake works is about 57 square miles.

Due to the great deficiency of flow in the Dry River Basin during the summer of 1930, the city found it necessary to secure an auxiliary supply. This supply was provided by an 8-in. cast-iron pipe line 2 miles long from Silver Lake to the 12-in. main at Dale Enterprise. The water was pumped from the lake at the rate of 600,000 gal. a day for 133 days, at an operating expense of $10,305. Early in January, 1931, the surface-water supply at Rawley Springs picked up sufficiently to do away with the auxiliary supply, which was objectionable both for domestic and industrial use on account of its high total hardness of 251.

Preliminary investigation

At the request of the city council, the author's firm began a field investigation and study for the improvement of and addition to the water supply of the city. A survey was made of all existing sources of water supply, including springs, spring-fed lakes, surface-water streams, wells and storage. It was recommended that further investigation be made of the economic practicability of building an impounding and regulatory reservoir in the Skidmore Fork Basin in the headwaters of the Dry River watershed.

A field investigation was made that included core drill holes, churn drill borings and test pits at proposed dam sites in the Skidmore Fork and Gum Run basins, and in the territory adjacent to the city's intake. These investigations showed the economic impracticability of constructing a dam at either of the two proposed locations in the Skidmore Fork and Gum Run basins and of securing water from wells near the city's intake.

Geologic studies and pumping tests in the pits across the valley from the dam in the river channel clearly indicated the presence of groundwater flow over the valley floor in many isolated streams and the practicability of intercepting this flow by an underground dam extending across the valley. Recommendation was made to the city council to construct a system of groundwater intercepting and collecting works comprising a reinforced-concrete wall or dam extending from the old dam in the river channel to the rock cliff on the west side of the valley, a distance of about 900 ft. These works would be located 1,200 ft. up the valley from the city's intake and would make possible the diversion of the underflow from a collecting gallery in a natural gorge on the west side of the valley through a supply main by gravity flow to the existing intake works. The city council approved of this project. In November 1933, authorization was given for the preparation of an application on behalf of the city for a PWA loan and grant of $50,000. This application was approved by the state PWA engineer, but was indefinitely held up in Washington on account of the overallotment of funds for the state of Virginia for PWA projects. In March, 1934, the city council authorized the construction of the proposed ground-

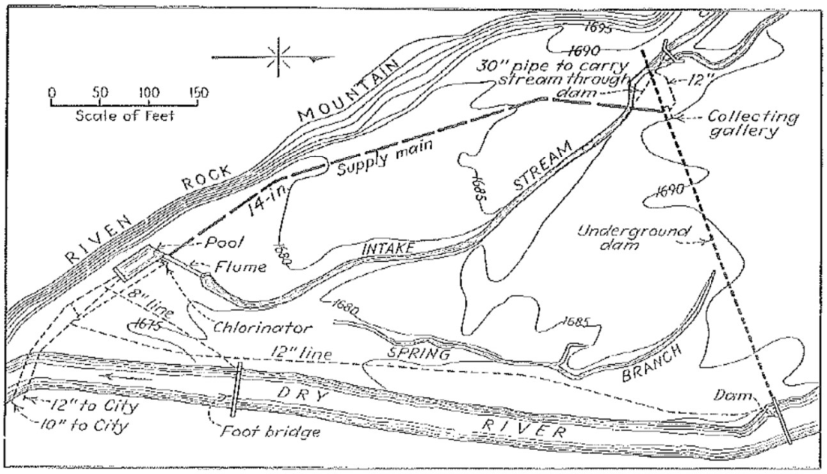


FIG. 2—UNDERFLOW down the valley of the Dry River is intercepted by the underground dam and is conveyed to the existing supply mains.

water collecting works with funds secured from local banks, the work to be done by local labor forces under the immediate supervision of the city engineer.

Construction of project

During the last week of March the city engineer initiated the construction work with the building of a small office building, tool house, blacksmith shop and cement sheds adjacent to the site of the proposed submerged dam. During the latter part of April, actual construction was begun with the excavation of the trench and the laying of 600 ft. of 14-in. cast-iron pipe at the intake end of the proposed supply line and 100 ft. of 30-in. cast-iron pipe and headwall for carrying the intake stream through the submerged dam. During the month of May the remaining 576 ft. of the 14-in. supply line were laid.

The excavation for the submerged dam was begun at the west side of the valley early in May. The first 150 ft. of this excavation was done entirely by hand labor. West of the 30-in. pipe line an excavator equipped with a 43-ft. boom and ¼-yd. clamshell bucket excavated the trench to a top width of about 20 ft. and a depth of 10 to 12 ft. The lower section of the trench was excavated by hand labor. The trench prism was so located as to provide sufficient space on the upstream side of the dam for the handling of the groundwater, which was largely confined in a channel along the upstream face of the trench. Along the west side of the valley especially there was some groundwater flow out of the downstream face of the trench, which was largely backflow from the intake stream. Every effort was made to confine this backflow to a minimum by carrying the intake stream in a wooden flume about 150 ft. below the downstream end of the 30-in. pipe.

The excavation of the footing trench

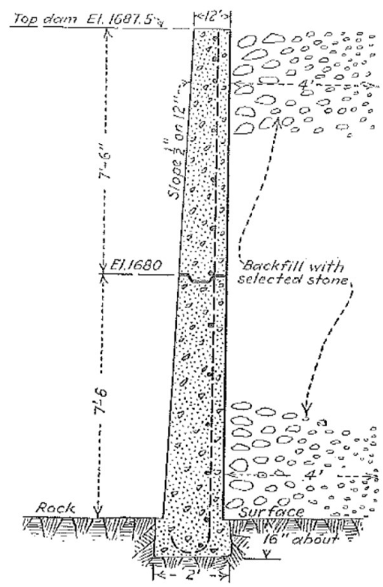


FIG. 4—THE CUTOFF WALL was built in two sections, the first extending from rock to within 7½ ft. of the top. The top is level with the spillway of the existing dam in Dry River.

in the valley floor was done largely by quarrying, using a pavement breaker operated by a portable air compressor. In one or two sections it was necessary to blast out short lengths of the rock trench. This was done with center holes and light charges of 40 per cent dynamite, so as not to open up adjacent seams or contact planes in the valley floor.

The results of the excavation of the trench across the valley fully confirmed the indications made by the test pits and the reports of the consulting geologists, Charles Butts and Irving Crosby, who cooperated in the preliminary investigation of 1931-32. The valley floor consists of a fine-grained, closely cemented, hard sandstone, the Pocono sandstone. At the west side of the valley the narrow gorge exposed a narrow stratum of a hard, dark-colored, indurated shale. The preliminary investigation and subsequent excavation showed that this shale is as tight and impervious to the flow of water as is the sandstone.

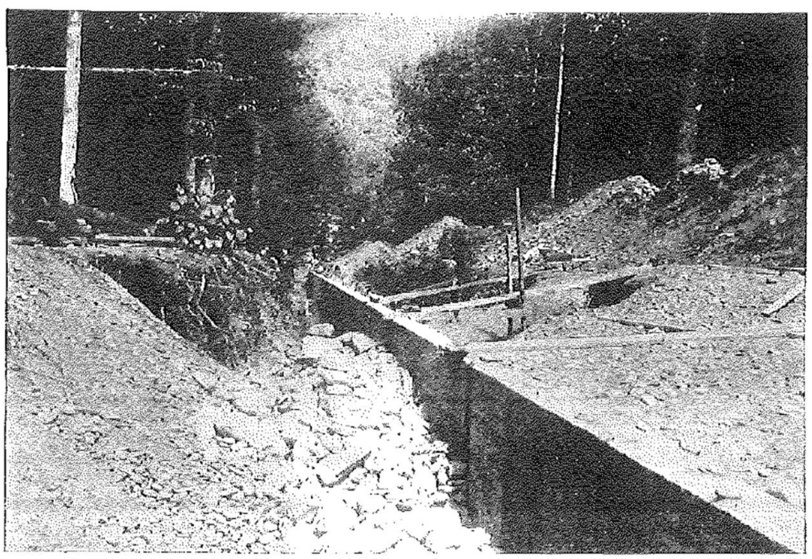


FIG. 3—SELECTED STONE from the excavated material was used as backfill on the upstream side of the wall and around the collecting gallery.

About twelve large underground streams were encountered across the valley. Between these major streams there were minor flows through the overburden or drift. The flow of these streams varied from about 150 to 300 gal. per minute, as nearly as could be estimated. The most difficult part of the construction work was the intercepting of these streams, especially during the pouring of the footing sections of the concrete wall. The pumping requirements were taken care of by one 4-in. and one 6-in. centrifugal pump, and a gasoline-engine-driven diaphragm pump. The total pumping capacity of this equipment was about 800 gal. per minute.

To secure a fairly accurate estimate of the amount of groundwater flow during the construction period, three series of measurements were made by an engineer of the state water resources and power office. These measuremnts were made on July 19, Aug. 27 and Sept. 26, 1934. The following data give the essential results:

1. Flow in intake stream at upper end of 30-in. pipe on upstream side of submerged dam:
   - 1,467 g.p.m. on July 19.
   - 1,260 g.p.m. on Aug. 27.
   - 1,395 g.p.m. on Sept. 26.
2. Flow in intake stream at concrete flume of intake works:
   - 1,350 g.p.m. on July 19.
   - 1,170 g.p.m. on Aug. 27.
   - 1,620 g.p.m. on Sept. 26.
3. Groundwater flow collected along submerged dam at exit end of pipe at intake works:
   - 594 g.p.m. on July 19.
   - 590 g.p.m. on (includes estimated amount of about 10 per cent of total) Aug. 27.
   - 1,125 g.p.m. on (about 10 per cent of which was from extraneous sources) Sept. 26.

It will be noted that the groundwater flow on July 19 and Aug. 27 was about the same—namely, about 850,000 gal. per day. The surface flow decreased during this five-week period about 300,000 gal. per day, while the groundwater flow remained nearly constant. This condition is accounted for by the normal summer drop of surface flow and the increase in groundwater flow due to the extension of the excavation for the trench and the resulting addition of several underground streams. The considerable increase in both surface and groundwater flows shown by the Sept. 26 measurements was due to the excessive rainfall during the month of September. It should be noted in this connection that the rainfall shown by the records of the Dale Enterprise Weather Bureau station, for the first six months of 1934, indicate a subnormal condition. During July and August the rainfall was about that of the 54-year average.

The groundwater collecting works comprise a reinforced-concrete dam or wall and a collecting gallery on the upstream face of the wall in the gorge near the western side of the valley. The wall has a top width of 12 in.; the upstream face is vertical, and the downstream face has a slope of ½ in. to the foot.

The wall was built in two sections, a footing section and a wall section, the former stopping at El. 1680. The wall section has a constant height of 7½ ft., and the top is level with the top of the dam in the river channel.

The collecting gallery is a rectangular chamber 25 ft. long, 5 ft. wide and 16.5 ft. high inside. At the ends of the gallery, about 2 ft. above the floor, are the intake openings, which are 3 ft. square and protected with cast-iron gratings. The water is carried from the collecting gallery in a 14-in. cast-iron outlet pipe, which is provided with a gate valve at its intake end in the chamber. The water in the intake stream flows through the 30-in. line and can be diverted to the collecting gallery through a 12-in. main. Such a diversion will be made during low water or drought periods, to avoid loss through seepage and evaporation. The intake openings are controlled by sluice gates operated by stands at the top of the collecting gallery, which extends about 3 ft. above the adjacent ground surface.

For drainage, a perforated concrete pipe line was laid along the upstream toe of the dam. Opposite each of the major underground streams, a tee was placed in the pipe line, and a line of smaller pipe extended to the outpouring of the stream at the upstream face of the trench.

On the upstream side of the dam the trench was backfilled over the drainage pipe with rock graduated from the large-sized stone on the bottom and against the wall to the smaller stone and sand at the top and along the outer face of the trench. Back of the wall the trench was backfilled with earth and small stone. About 8,300 cu.yd. of material was handled at an average unit cost of 37c. per cu.yd.

The total cost of the project was $37,567, of which $17,624 was spent for labor and $14,875 for materials. Miscellaneous expenditures included $2,025 for the rental of the excavator, $30 for office expenses, $542 for workmens' compensation insurance, and $2,470 for engineering, testing and inspection. The estimated cost of the project, based on handling the work two years ago by competitive bids and lump-sum contract, was $35,000. Assuming a 20 per cent increase in the cost of executing the work during the summer of 1934 on the competitive contract basis, it is possible that the city of Harrisonburg may have effected a saving of about $4,500 by doing the work by force account—utilizing its available resources of labor, materials, equipment and machinery as far as practicable.

The field surveys, studies and design were made largely by the writer. He also supervised the later stages of the construction. Valuable assistance in the preparation of the working drawings and early supervision of construction was rendered by Harry W. Thompson. William G. Myers, city engineer of Harrisonburg, was in direct charge of construction.

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Volume 113, No. 24

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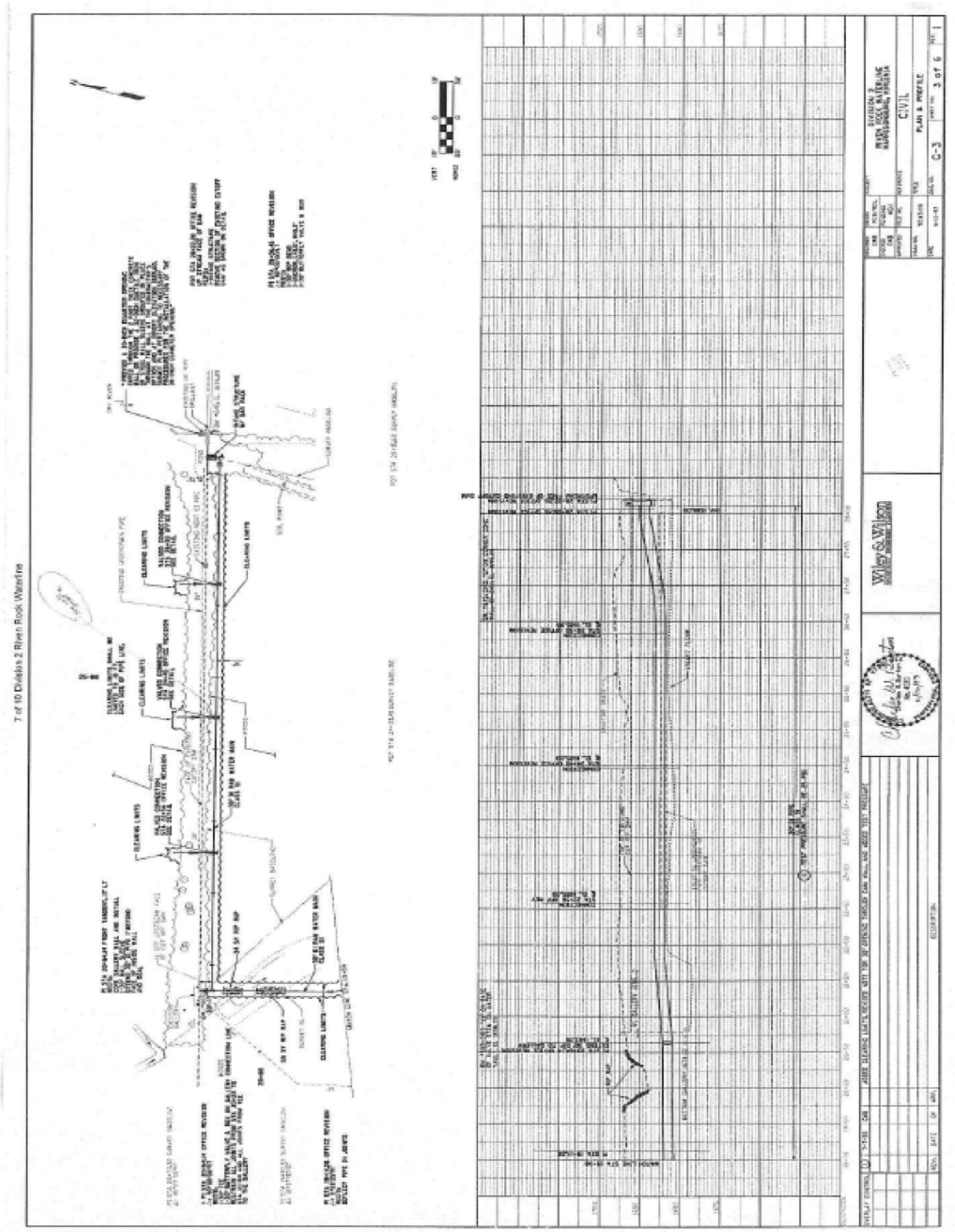
December 13, 1934

Below the Surface

GEOLOGICAL CONDITIONS in the valleys of streams frequently result in extensive subsurface flows. Understood and appreciated by geologists, this condition should not be overlooked by those communities which have developed surface supplies and subsequently find them inadequate in the normal process of expanding demand. The intercepting of the underflow of a stream from which the surface flow has been utilized may provide an economic supplemental supply, as in the case of Harrisonburg, Va., where an expenditure of $37,500 for a subsurface dam and collecting system developed 850,000 gal. per day, as described on another page in this issue. There is also the fundamental advantage that the use of underflow provides for complete development of a stream before another water supply resource must be sought. The possibilities for this type of inexpensive


7 of 10 Division 2 Riven Rock Waterline
Wiley&Wilson
CIVIL
PLAN & PROFILE
C-3
3 of 6

APPENDIX C: SWITZER DAM ON DRY RIVER SOURCE

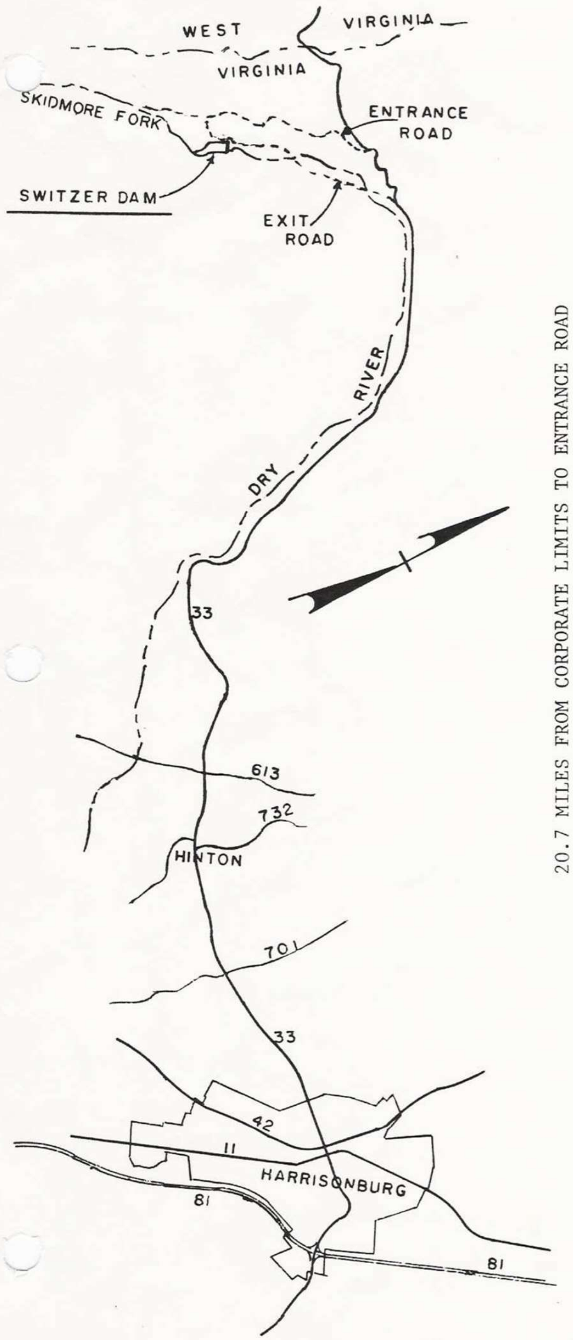
Dry River Source with Switzer Dam

Unlike conditions of 1947 in Dry River, the in-stream flow can be influenced by upstream reservoir operations. Approximately five miles upstream of the City's Dry River intake is the reservoir known as Switzer Dam. In the 1970s, the city added water supply functions to the original designed flood control dam. Switzer Dam was designed and constructed to hold 1.6 billion gallons of water; DEQ rated it to have a safe yield of 8.3 MGD. Initially, the City could not use the water supply privileges until financing bond payments had been completed, a status which has now long passed (1990). There are currently no formal restrictions to the City's use of the dam.

Through the wetter part of the annual season, the dam is at an overflow level where flow out of the dam nearly equals flow into the dam (except for precipitations and evaporation). During other times when the water is below overflowing level, actions to control releases from the dam would be through one of the five gates in the outlet tower. One gate is a drain gate, and two others are below a significant benchmark of 400,000,000-gallon reserve storage level. The remaining two gates are strategically placed above the 400,000,000 level. Controls for the gates are not readily usable; therefore, it is infeasible for the city to adjust the gate settings.

Informally, the city has engaged two environmental stewardship activities: the first to maintain a minimum of 400,000,000 gallons in reserve and the second to maintain a release of water from the reservoir. The reserve storage concept was initiated by informal discussions with DGIF staff in the 1990s to protect aquatic life in the lake. The release was in recognition of certain local groups who expect the city to maintain a minimum release from Switzer Dam to sustain fish and aquatic life in the immediate downstream reaches of Skidmore Fork, a tributary to Dry River. The city generally leaves the second-highest gate at a partially opened position. The discharge can vary from approximately 8.0 MGD when the water level is overflowing to 0.0 MGD at the open gate level. The stationary positioning of the gates, plus some escape of water from outlet structure leakage, generally provided environmental stewardship for both in-lake and downstream aquatic protection.

In the fall season of a dry 1999, the city evaluated the dam release and intake capture relationship during the peak season for evaporation/transpiration. The general conclusion was that a release of 8.3 MGD maintained a capture of 5.5 MGD at the City's intake located five miles downstream. During the study, the water reservoir above 400,000,000 gallons was exhausted in 132 days. The Switzer Dam release – City intake recapture relationship must be recognized and refined in the RWSMP.



SWITZER DAM

Joint Water Storage-Flood Control

Water Surface Area	119 acres
Drainage Area	9,414 acres
Storage to Emergency Spillway	2,255,000,000 gals.
Storage at Normal Ht.	1,600,000,000 gals.
Height of Dam	138 feet
Length of Dam Crest	1,500 feet
Thickness of Dam Base	720 feet
Width of Dam Top	40 feet
Volume of Fill	2,137,000 cu. yds.
Flood Storage Above Permanent Pool	27 feet
Concrete Riser Height	101 feet
Length of 42" Pipe Through Dam	720 feet
Sandstone Spillway-Ridge Cut	139,000 cu. yds.
Service Road Constructed	2 miles

Cost

U. S. Soil Conservation Service	$1,900,000
City of Harrisonburg	$1,600,000
Total	$3,500,000

APPENDIX D: NORTH RIVER SOURCE

Longitude 80.847 Latitude 37.662

Intake Capacity 7.6 MGD

North River Source

The **North River** source was commissioned in the early 1970s. The North River has given Harrisonburg a significant tool to adjust for daily and seasonal variations in demand. Harrisonburg's Bridgewater Pump Station (BWPS) withdraws raw water from the North River. DEQ has rated North River to have a safe yield of 13.6 MGD. The source water has been under demand from Harrisonburg, Bridgewater, and irrigation practices, so a "Surface Water Management Declaration" was considered in the 1990s. The declaration did not move forward, but Harrisonburg informally declared that its intention was not to use the North River beyond 5.7 MGD in times of drought. Under current VWWP regulations, in combination with historic low flow in-stream records, the withdrawal is regulated by VWWP #16-0730 to no more than 12% of the in-stream flow. Harrisonburg's available withdrawal may be limited to 2.5 MGD.

Harrisonburg Assets

The city obtained access to the North River in 1970. The Bridgewater Pump Station / Intake and 20" pipe to adjoin the Silver Lake System (see Appendix F) were constructed. In the early 1990s, a 24" pipe was constructed parallel to the Silver Lake to Route 33 pipe system. In the early 2000s, another 24" pipe was extended to the water treatment plant in the Route 33 corridor. These additions accommodated growth from the 1983 City annexation by increasing North River capacity to 7.6 MGD.

The current North River Raw Water System includes:

- 20" pipe, 26,312 feet
- 24" pipe, 12,591 feet
- 24" pipe, 3,969 feet
- Pump Station and Intake

A check valve in the 24" diameter pipe at the North River Valve Vault (NRVV) was installed in 2016 and provides risk reduction from Dry River hydraulic influences such as backflow and higher pressures during static conditions. As a second risk management effort, the pipe network was isolated and separated to convey only North River water until it adjoins with the Dry River network at the water treatment plant. These arrangements provided risk reduction through prevention, mitigation, and enhanced recovery toward potential pipe ruptures.

The Virginia Department of Health rates the North River Pump Station at 7.6 MGD. At the intake is an in-stream concrete structure where bar screens protect from debris entering two parallel pipes that route water to the pump station wet well. From 1970 until mid-2015, the station had three vertical turbine pumps in active service, each driven by a 350-horsepower motor. The pumps and motors were started with across-the-line configurations and then operated at full speed for all individual pumps and motors. Output performances with one, two, and three pumps in parallel operations provided the city wastewater treatment plant with 3.7 MGD, 5.7 MGD, and 7.6 MGD, respectively. With the North River Pump Station upgrade using 400 motors and variable speed drives, the output flows range from 2.5 MGD to 7.6 MGD. Operators frequently select the best SE point for operations.

a) System: 3,950 GPM @ 514 feet TDH @ 79% PE & 90% ME
b) Energy: 2,150 kW-hrs./MG
c) Power: 530 kW plus house load

Electrical power and energy usage are constraints to using this source. The Bridgewater Pump The station at the North River is the single most significant demand for electricity for HPU. As shown in the summary below for 2018-2023, energy use required an average annual energy usage of 2, 818,000 KW-hrs. At approximately $221,000.

	Pump Hours (SCADA)	Volume (SCADA)	Electric $ (BILL)	KW-HRS (BILL)	Carbon	KWH/MG
North River Water Subtotal	71,516	6,299,891,560	$ 1,104,952	14,090,967	4,763	2,236.70

North River Risk

Harrisonburg's North River source is most susceptible to several potential risk causes.

- Drought: At no time shall the withdrawals from North River exceed 12% of the stream flow as estimated at the intake. HPU recognizes that North River is a target for water protection; this effort began with the proposed Surface Water Management Area (SWMA) in the 1990s and takes even greater focus under the Local and Regional Water Supply Plan (9VAC 780) and VWWP #16-0730 that are relevant today. The withdrawal limitation has progressively decreased from the 1Q10 criteria of 13.6 MGD before the 1990s to 5.5 MGD (13% MAF) with the SWMA to 2.5 MGD (12% in-stream flow) with the VWWP. The flow characteristics of the North River are shown below.

- Flood: Hurricane Event 1985 inundated the pump station with severe impacts on electrical equipment.
- Contamination: Recent alerts have been issued due to contamination from agricultural activities, which are intense along the banks of the North River and upstream tributaries of Dry River and Mossy Creek. Like Dry River, the frequent small in-stream flow in the presence of a contaminant poses special attention to the concern.
- Assets: The Bridgewater Pump Station has the potential for mechanical, electrical, and instrumentation failure. Generally, the city has in place some abilities to operate one pump under most causes of mechanical, electrical, and instrumentation duress.

POTOMAC RIVER BASIN

01622000 NORTH RIVER NEAR BURKETOWN

LOCATION: LATITUDE 382025 LONGITUDE 0785450 HYDROLOGIC UNIT: 02070005 COUNTY: ROCKINGHAM

PERIOD OF RECORD: OCT 1925 TO SEP 1972; MAY 1975 TO SEP 1986 DRAINAGE AREA: 379 MI^2. AVERAGE DISCHARGE: 372 CFS

REMARKS: THE HIGH FLOW MONTHS ARE NOT CONTIGUOUS. THE HIGH FLOW 7 DAY 10 YEAR FLOW CANNOT BE CALCULATED.

JANUARY - MAY

CORRECT

********** FLOW STATISTICS (CFS) **********

7 DAY 10 YR FLOW:	40
HIGH FLOW 7 DAY 10 YR FLOW:	NONE 65

1 DAY 30 YR FLOW:	27
HARMONIC MEAN:	142

********** MONTHLY FLOW (CFS) **********

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
MINIMUM	87	107	140	174	213	263	251	182	128	93	85	79
MEAN	253	289	327	392	524	693	605	476	325	199	237	185
MAXIMUM	1486	1478	1388	1384	1786	2567	1981	1860	1623	685	1129	847

********** DAILY FLOW DURATION (CFS) **********

PERCENT OF TIME FLOW EXCEEDS INDICATED VALUE									
5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
1251	809	604	40	406	348	300	265	231	200
174	150	130	113	98	84	73	63	52	---
55%	60%	65%	70%	75%	80%	85%	90%	95%	---

486

74 CFS = 20%

********** LOW FLOW FREQUENCY (CFS) **********

		DURATION IN DAYS								
		1	3	7	14	30	60	90	183	365
RECURRENCE IN YRS	100	23	26	29	31	32	35	36	38	111
	50	25	29	32	33	35	38	39	44	133
	40	26	30	33	34	36	39	40	47	141
	25	28	32	35	36	38	41	42	53	161
	20	29	33	36	37	39	42	44	56	172
	10	33	37	40	41	44	47	49	70	211
	5	39	43	45	47	50	54	58	91	263
	2	54	58	60	63	67	75	86	152	373

EXPLANATION

- Recent daily or average flow values
- 95th percentile to maximum daily flow
- 90th percentile to 95th percentile
- 75th percentile to 90th percentile
- 25th percentile to 75th percentile
- 10th percentile to 25th percentile
- 5th percentile to 10th percentile
- Minimum daily flow to 5th percentile
- Median flow
- Instantaneous minimum flow

Streamflow Statistics based on average flows

Daily | 7-Day | 14-Day | 28-Day

Duration-plot description

Percentile Definition

Duration Table of Daily Streamflow

Flow values in cubic feet per second

01622000 NORTH RIVER NEAR BURKETOWN, VA

	Minimum daily flow	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile	Maximum daily flow		Years of record
January	28.0	58.0	71.2	147	271	479	888	1,370	13,700		85
February	35.0	78.0	108	194	326	588	1,020	1,530	6,230		85
March	52.0	142	187	293	477	820	1,400	2,090	13,600		85
April	80.0	154	188	258	396	703	1,250	1,780	10,000		85
May	84.0	118	144	210	328	572	1,010	1,460	14,500		85
June	49.0	83.0	96.0	130	182	308	627	1,030	29,900		87
July	30.0	55.0	66.8	90.0	123	190	340	566	6,300		87
August	32.0	44.0	52.0	71.0	105	196	413	772	12,700		87
September	22.0	46.0	53.0	66.0	95.0	171	379	687	32,000		87
October	25.0	48.0	54.0	66.0	99.0	190	430	747	20,100		86
November	24.0	48.0	57.0	76.0	128	297	631	965	30,000		85
December	25.0	52.0	60.0	106	225	403	772	1,150	14,800		85

Instantaneous minimum flow for period of record = 16.0 cubic feet per second.

The current daily value for 12/06/2015 is 730 cubic feet per second.

---- Provisional Data Subject to Revision ----

APPENDIX E: SOUTH FORK SHENANDOAH RIVER SOURCE

Longitude 78 43.8'   Latitude 38 20.2'
Intake Capacity 13.2 MGD

South Fork of the Shenandoah River Source

Harrisonburg's Power Dam Road Pump Station will withdraw raw water from the South Fork of the Shenandoah River; the withdrawal is permitted under Virginia Water Withdrawal Permit #16-0730. The lower reaches of the watershed lend to a lesser quality of raw water than other available sources. A submerged structure is located in the stream where bar screens protect from debris entering two parallel pipes that route water to the pump station wet well. DEQ has rated the in-stream safe yield at 78.0 MGD at the exact location.

Harrisonburg Assets

The intake structure and pump wet well are a unique collaboration between the City, DEQ, and various agencies responding under the input format of the Virginia Marine Resources Commission. The City pump station is located in an abandoned hydroelectric canal at the site of the original turbines; the initial intake design proposed to resurrect somewhat the hydroelectric concept that used a flow-through side stream to bring source water to the turbines (pumps). The idea was also planned to facilitate boat access through the canal to overcome the hindrances to float travel caused by the in-stream dam remnants.

Through the collaboration previously mentioned, an alternative concept was chosen. The concept avoided the placement of difficult-to-maintain small screens in the mainstream river. The in-stream hydroelectric dam remnants were removed, an intake with debris screen was installed at an alternative in-stream location, and a flow-through pump station wet well was installed at the site of the original turbines. The latter was a unique installation that allowed water to flow continuously from the in-stream structure to the pump wet well and then back into the original canal as it returned to the river's mainstream. This unique design retained provisions to avoid the intake and impingements of aquatic organisms by pumps and upon smaller screens, respectively, while allowing the City to have its 2-millimeter micro-screens located for easy access and repair. VWWP #16-0730 requires the city to re-evaluate using 1-millimeter screens.

The pump station housing structure has been constructed on the old turbine support structures. The pumps to this facility are expected to be three units with 600 horsepower motors. The operation and control configuration will be much like the North River Pump Station, as the latter's 2015 upgrade will serve as a model for the final design at the Power Dam Road Pump Station. The Power Dam and Goods Mill Pump Stations have not yet been commissioned but have the following characteristics:

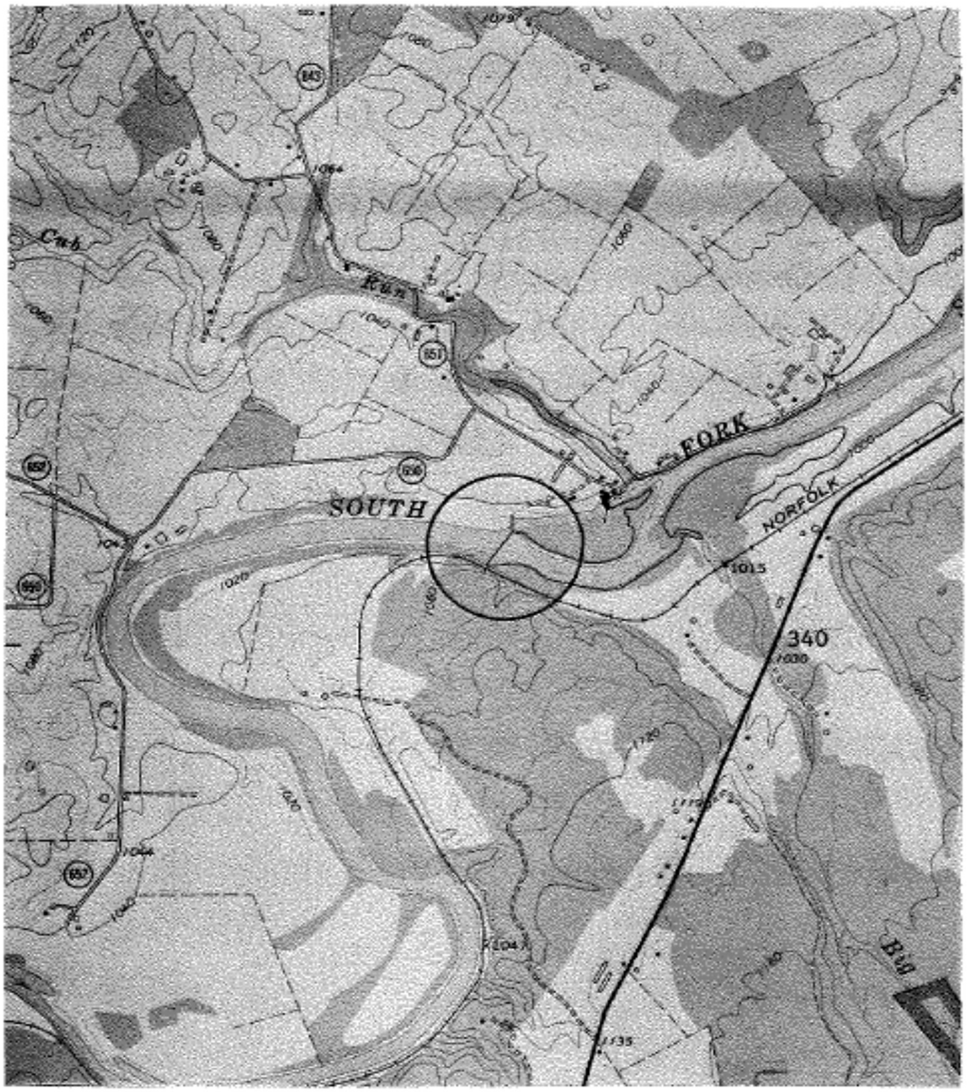
a) System 2,778 GPM @ 651 feet TDH @ 72% PE & 90% ME
b) Energy 3,108 kW-hrs./MG
c) Power 705 kW

Shenandoah River Source Risks:

- **Drought**-At no time shall "Net Withdrawal" exceed 10% of the stream flow at the South Fork Intake. Net withdrawal equals the total volume withdrawn from the South Fork plus 66% in recognition of the "Return Flow" at HRRSA. Under historic low flow in stream conditions, the Shenandoah Project will provide 9.1 MGD of reliable water supply. In-stream flow rates and probabilities of occurrence are shown below.
- **Flood**-The South Fork is subject to significant flood levels, but all assets are designed above the 100-year flood level. n-stream flow rates and probabilities of occurrence are shown below.
- **Contaminations**-contrast to the Dry River and North River, the Shenandoah River has a much higher in-stream flow pattern with characteristics typical of its location in the lower drainage basin. Changes in flow rate and water quality generally occur over longer durations. More pollution and dilution are prevalent; the latter has a significant mitigation influence.
- **Assets**-The future Power Dam Road Pump Station will have the potential for mechanical, electrical, and instrumentation failure. Future design will attempt to mitigate these risks.

DAM LOCATION MAP

McGAHEYSVILLE DAM



McGAHEYSVILLE QUADRANGLE

7.5 MINUTE SERIES (TOPOGRAPHIC)

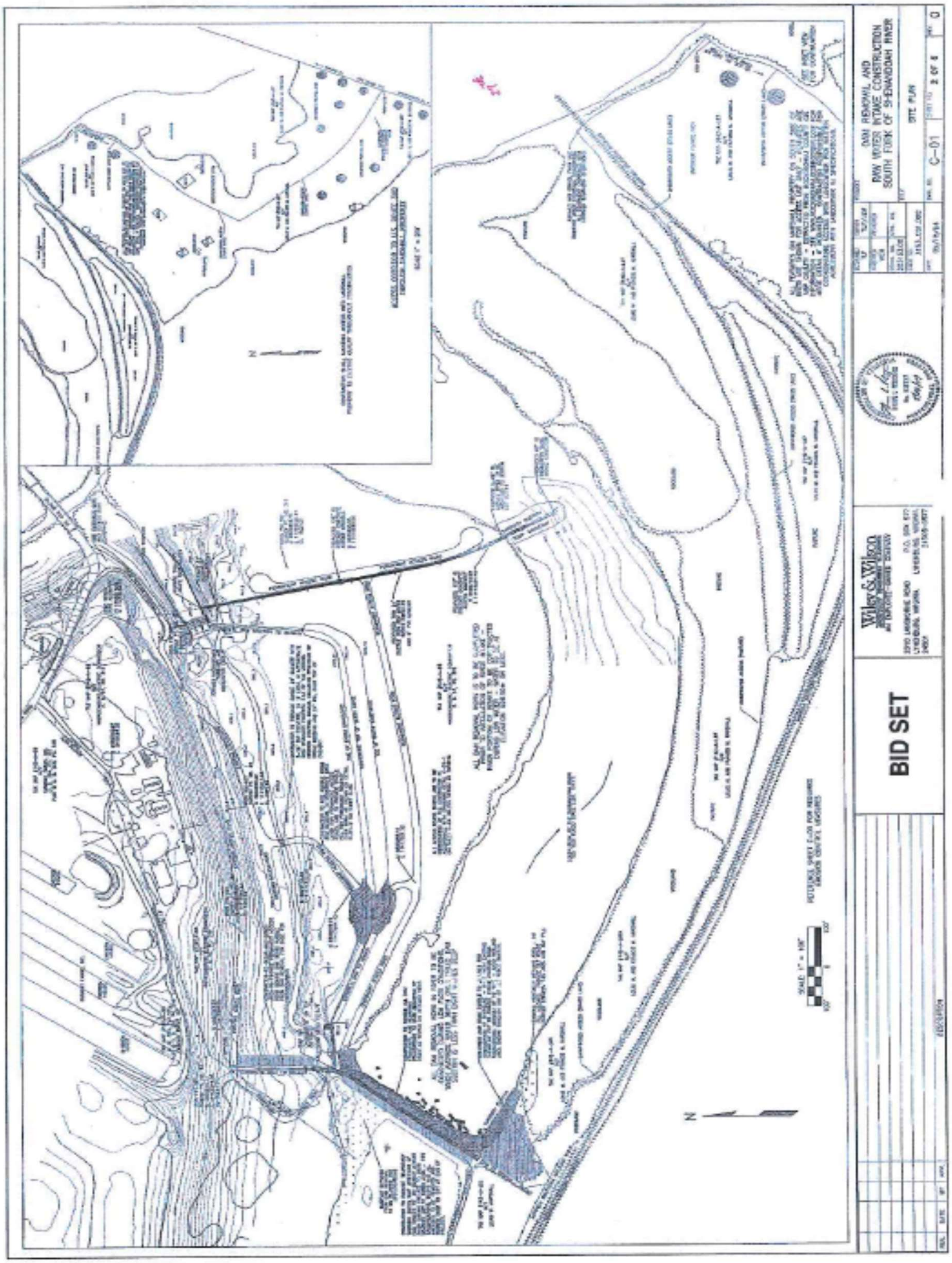
QUADRANGLE LOCATION

SCALE 1:24 000

1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 KILOMETER


BID SET
Wiley & Wilson
DAM REMOVAL AND
RAW WATER INTAKE CONSTRUCTION
SOUTH FORK OF SHENANDOAH RIVER
SITE PLAN
C-01

STREAM FLOW DATA

South Fork Shenandoah River near Lynnwood
Gaging Station 1-6285

Location: 1.2 miles northeast of Lynnwood, Rockingham County and 3.3 miles downstream from confluence of North and South rivers.

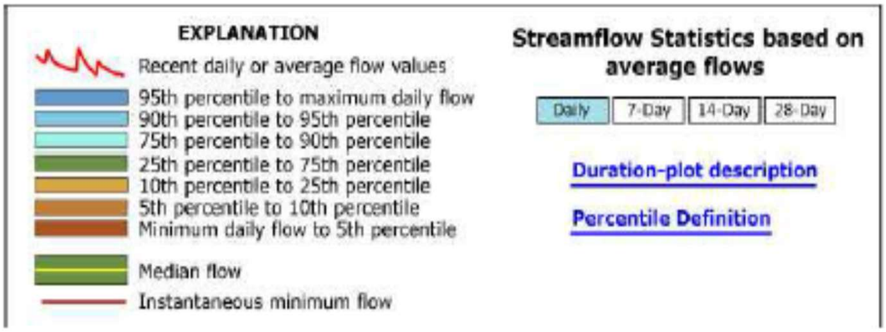
Drainage Area: 1,084 square miles

Average Discharge: 977 cfs

Length of Record: 46 years

Flow Duration Data

Percent Exceedance	Flow in C.F.S.
99.8	120
97.7	170
94.0	200
87.5	240
81.1	280
73.5	340
66.8	400
58.4	480
50.8	570
43.2	680
35.7	810
28.9	960
24.0	1100
17.1	1400
14.0	1600
10.5	1900
7.5	2300
4.1	3200
2.0	4600



Duration Table of Daily Streamflow

Flow values in cubic feet per second

01628500 SOUTH FORK SHENANDOAH RIVER NEAR LYNNWOOD, VA

	Minimum daily flow	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile	Maximum daily flow		Years of record
January	130	218	267	462	798	1,370	2,460	3,430	39,300		84
February	133	270	390	600	952	1,600	2,690	3,940	21,100		84
March	148	449	532	817	1,250	2,080	3,570	5,220	52,400		84
April	292	452	550	726	1,040	1,760	3,060	4,250	30,800		84
May	250	388	451	593	880	1,350	2,270	3,170	22,400		84
June	134	267	310	411	560	840	1,440	2,360	41,500		84
July	84.0	206	240	310	407	562	886	1,310	7,720		84
August	84.0	174	204	259	348	533	973	1,600	32,600		84
September	95.0	175	192	235	315	499	994	1,800	63,500		84
October	100	178	190	237	318	539	1,210	2,090	42,700		84
November	114	185	220	268	405	792	1,630	2,540	60,000		84
December	129	193	225	332	650	1,100	2,040	3,040	31,200		84

Instantaneous minimum flow for period of record = 32.0 cubic feet per second.

The current daily value for 12/06/2015 is 1750 cubic feet per second.

---- Provisional Data Subject to Revision ----

APPENDIX F: SILVER LAKE SOURCE

Longitude 79.057 Latitude 38.521

Intake Capacity 0.0 MGD

Silver Lake Source

Harrisonburg owns **Silver Lake**. Formal privileges and restrictions upon the City's withdrawals are relevant to a contractual relationship with the Town of Dayton. The city purchased the Silver Lake source in 1947 as a drought supplement to the Dry River source. The purchase, however, came with significant restrictions in the format of first rights of withdrawal to the Town of Dayton. The Town held a ninety-nine-year lease of first rights to water withdrawal under a contract that preceded the city's 1947 purchase. The lease ran from 1915 to 2014. With the redraft of the lease, the city now holds the first right of withdrawal for the initial 1.5 MGD.

DEQ has rated Silver Lake to have a safe yield of 1.5 MGD. The City's withdrawal is a grandfathered activity compared to a Virginia Water Withdrawal permit. The feed location to Silver Lake is an underground spring opening from which the groundwater enters Silver Lake. The Town of Dayton has installed horizontal well screens into the spring by which raw water is routed through a manifold and suction pipe to the Town's pump station. In contrast, the City's abandoned intake pipe laid supported on wooden cross ties from the pump station structure to a location just outside the spring/lake interface. The City's intake location was not ideal from the water quality perspective due to high algae contents, which significantly deleterious effects on water treatment filter operations.

Harrisonburg Assets

Upon purchase, the City immediately constructed a pump station plus 10,854 feet of 16" pipe from Silver Lake to adjoin the Dry River pipe system at Route 33. Silver Lake Pump Station is inactive but has the following characteristics:

a) System 929 GPM @ 378 feet TDH @72% PE & 90% ME
b) Energy 1,805 kW-hrs./MG
c) Power 137 kW

As the need for water grew, the city operated the pump station as a significant water supply component, but not without careful respect to the Town of Dayton. Beginning with mild drought conditions, the City's raw water supply from the Silver Lake source would come into an unreliable status that depended upon the relationship between the available water and the unrestricted withdrawals made by the Town of Dayton. This constraint was significant in the City's water management operations until the North River source became available in 1970.

From 1970 until 1990, the city used Silver Lake under limited application except for the catastrophic effects of the hurricane of 1985, which turned off both the Dry River and North River sources for a short period. As the 1990s approached, the pump station needed consideration for an upgrade as it had reached the end of its useful life and became non-functional. Given the City's longer-term raw water supply needs, the smaller safe yield of Silver Lake, the water quality and quantity issues, and contractual obligations / future considerations to the Town of Dayton, the City opted not to invest at Silver Lake but to undertake efforts to the South Fork of the Shenandoah River. In conclusion, the decision to upgrade the Silver Lake Pump Station was delayed until the City could consider its first rights to the water and with perspective on the progress made towards the Shenandoah project.

Silver Lake Risks

The Silver Lake source is fed from groundwater under surface water's influence. Although the surface water influence is a concern for contamination, its risk for exposure is far less than any other Harrisonburg raw water source. The Silver Lake Pump Station is currently out of operation and is considered to be in non-salvageable status.

Obligations and Considerations

The Town of Dayton's lease agreement for Silver Lake expired in 2014. On July 29, 2014, the City of Harrisonburg and the Town of Dayton entered into an extension of the Silver Lake Lease Agreement, permitting the Town of Dayton to continue withdrawing raw water from Silver Lake. However, the terms now give Harrisonburg the first right of withdrawal for the first 1.5 MGD.

It should be noted and addressed that the city cannot effectively capture raw water from Silver Lake unless it gains access to the spring. Two options can achieve this goal: Harrisonburg can either share the current infrastructure owned by the Town of Dayton, or the City can obtain sole ownership by purchase or new installation. Condition No. 4 in the referenced lease extension provides Harrisonburg with the former option. The lease follows on the following pages.

SILVER LAKE AGREEMENT

This Silver Lake Agreement ("Agreement") is made and entered into this 29th day of July, 2014, by and between the CITY OF HARRISONBURG, VIRGINIA, a Virginia municipal corporation (the "City"), and the TOWN OF DAYTON, VIRGINIA, a Virginia municipal corporation (the "Town").

RECITALS:

A. The City owns Silver Lake in Rockingham County, Virginia.

B. The Town has drawn water from Silver Lake to provide water to the residents and businesses located within the Town since 1915.

C. The Town previously entered into a 99 year lease with the Silver Lake Improvement Company, Inc., the predecessor in interest to the City in order to withdraw water from Silver Lake. This lease term commenced on August 2, 1915 for a term of 99 years, which term shall shortly expire.

D. The Town desires to continue to draw water from Silver Lake to provide water to the residences and businesses located within the Town.

NOW, THEREFORE, for and in consideration of the promises and mutual benefits and covenants contained herein, the City and Town agree as follows:

1. Subject to paragraph two, the Town shall be allowed to withdraw water as needed from Silver Lake.

2. The first 1.5 million gallons per day of water from Silver Lake will always be available to the City upon notice to the Town of Dayton. This would be in effect if the City needs the water for any reason, including drought conditions or if any other City water source is unavailable for any reason.

3. The Town shall pay to the City $1,100 per month in consideration for taking water from Silver Lake.

4. The Town has installed a well screen at the 5 foot by 2 foot cave that leads to the Town's pump. This limits access by the City to the clear water that the City wants. The Town shall cooperate in providing access to the Spring by allowing the City to join in to the Town's pumping infrastructure or otherwise providing access that is acceptable to the City.

5. This Agreement shall be for a term of six months, and thereafter shall be on a month to month basis until terminated by either party upon 30 days written notice.

6. This Agreement embodies the entire contract and agreement between the parties and there are no other agreements or understandings, oral or written, between the City and Town except as recited herein. No amendment of this Agreement shall be valid unless in writing and signed by the parties thereto.

IN WITNESS WHEREOF, each of the undersigned has caused this Silver Lake Agreement to be signed on their behalf by their duly authorized representative.

CITY OF HARRISONBURG, VIRGINIA

By: ______________________
Kurt D. Hodgen

Its: City Manager

Approval as to form:

By: ______________________
Chris Brown

Its: City Attorney

TOWN OF DAYTON, VIRGINIA

By: ______________________
John D. Crim

Its: Town Superintendent

Approval as to form:

By: ______________________
Jason J. Ham

Its: Town Attorney

- 3 -

APPENDIX G: SFI Well Sites

Results of Hydrological Study on South Fork Property by Emery & Garret Groundwater Inc. February 19, 1999

III. DISCUSSION/RECOMMENDATIONS

Based upon the hydrogeologic data collected to date, EGGI recommends that this groundwater exploration program proceed to Phase III (test well drilling). The hydrogeologic conditions elucidated during this study suggest that the potential exists for developing *moderate to very substantial* volumes (i.e., thousands of gallons per minute) of groundwater resources at this study site from the bedrock and/or the alluvial deposits of South Fork.

Analysis of the geophysical data generated during this investigation, combined with information from Phase I efforts, resulted in the identification of 19 potential test well sites; 3 bedrock aquifer test wells and 16 sand and gravel test wells (Plate 1 and Figure 1). Note that one of the proposed sites will be investigated for bedrock and sand and gravel aquifers.

The proposed well sites have been separated into three sequences of numbers as a guide for the order in which each group should be drilled. The sequences start with HSF-B, HSF-S, and HSF-G (Figure 1, Plate 1). The HSF-B wells are the bedrock well locations whereas the other two sequences are sand and gravel well sites. The sand and gravel well sites have been separated into two groups to reflect the possible location of two separate water collection systems. The wells within each sequence should be drilled starting with the number one well and progressing sequentially to higher numbers[2]; i.e. HSF-S1 should be drilled first followed by HSF-S2, etc.

The bedrock wells will have to be staked by an EGGI geologist and inspected by personnel from the County and State Health Departments. The sand and gravel wells will be resources, will be most cost effective. Since the permitting of water withdrawal from the South Fork will be an important issue in the development of water resources at this site, the next work phases will also investigate the source(s) of recharge for each aquifer(s).

drilled as monitoring wells and therefore, will not require permitting. The County and State Health Department will likely need to be contacted for permitting the water collection system as part of the system design process.

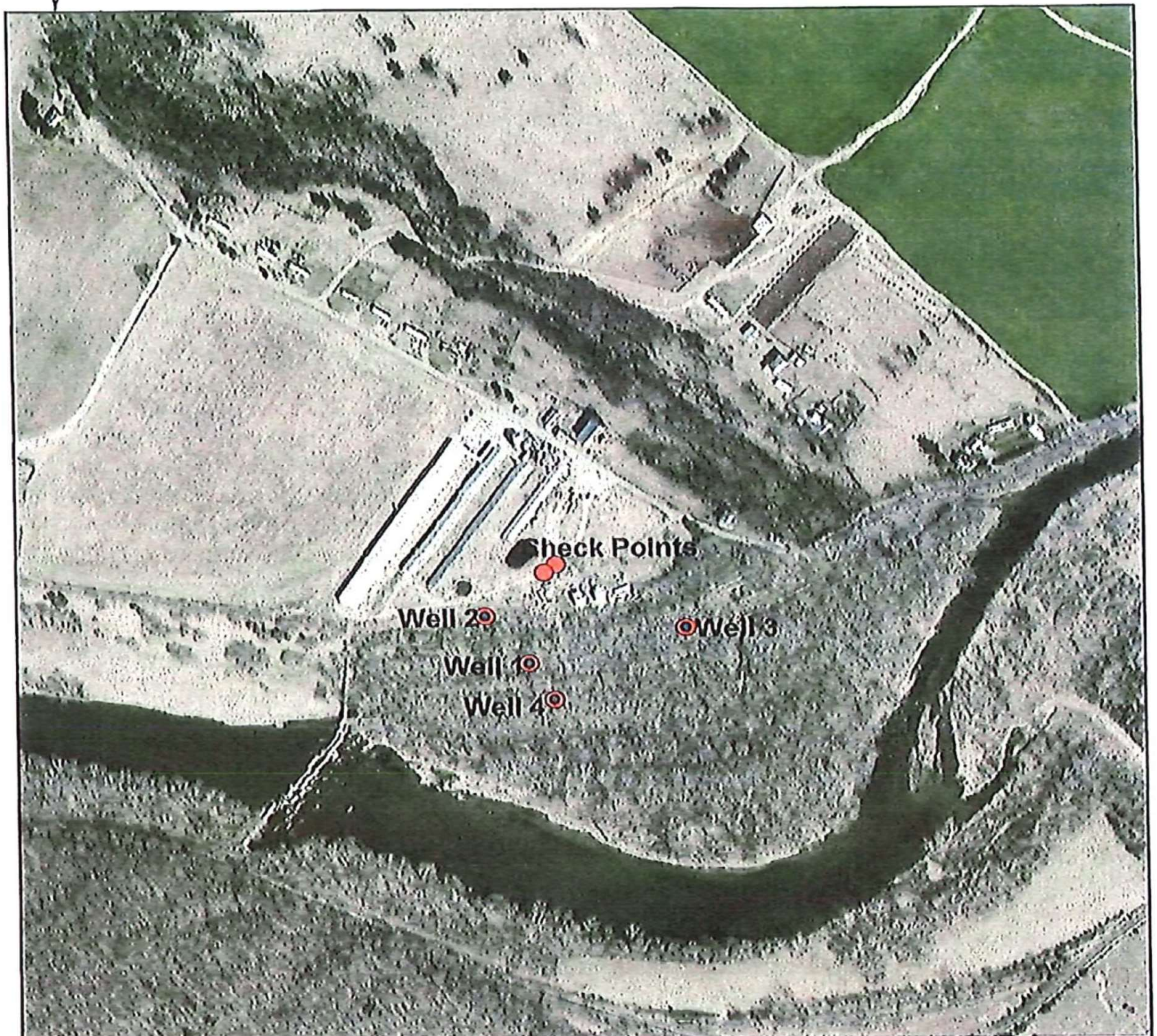
Predicting the ultimate yields of wells targeted for drilling is difficult prior to a subsurface investigation (i.e., drilling and pumping test phases). An initial estimate of aquifer productivity will be made during the drilling program by measuring the air-lift yield of bedrock wells with the drill rig[3] or by conducting short pumping tests in the sand and gravel wells using a centrifugal pump. Bedrock test wells yielding the greatest quantities of water with the highest quality will be converted to larger-diameter production wells. Yield data collected from the sand and gravel exploration wells will be incorporated into the design of gravel pack well field(s) or water collection system(s)[4]. In both types of aquifers, the *actual* sustainable yield of any well, well field, or water collection system will be determined with the aid of properly conducted long-term pumping tests.

Drilling of the proposed bedrock and sand and gravel wells will require different types of equipment and varying amounts of access preparation. The sand and gravel wells will be installed first with the use of auger drilling equipment. This equipment allows the installation of test wells (typically constructed of two- or four-inch diameter PVC) and sampling of the sediments and water quality. A track mounted auger rig is recommended to reach the sites located on the island. This would minimize, if not eliminate, the need for road fill and grading in order to reach the proposed test well sites. A moderate to minor amount of tree and shrub clearing will be required to reach some of the proposed sand and gravel test well sites. In addition, a temporary bridge will likely be required to cross the power plant water channel.

The bedrock wells will be drilled using air-rotary, mud-rotary, or reverse-rotary equipment[5]. Drilling of the sand and gravel wells first will provide an insight into which of these methods is most appropriate. The sites selected for bedrock drilling are located near the houses on the property or near the power plant road. Therefore, access to the sites will require relatively little preparation; i.e. minor clearing, grading, and gravel fill.

As noted above, the bedrock and/or sand and gravel groundwater resources developed at the South Fork site will serve to replace or supplement surface water obtained from South Fork. It is likely that any water source developed at this study area will be considered "under the influence" of surface water and therefore will require full treatment. The results of the drilling and pumping test phases of EGGI's water development program will provide the background information needed to make decisions about which of these resources, or combination of

Shenandoah River Well Sites



Coordinates

Well 1:	11417882.803820	6806238.758169
Well 2:	11417726.917706	6806406.635523
Well 3:	11418314.488443	6806358.670565
Well 4:	11417942.760018	6806118.845774

APPENDIX H: NRI & DRI GROUNDWATER ZONES
Results of North River Hydrological Study by Emery & Garret Groundwater Inc. February 19, 1999

III. RECOMMENDATIONS

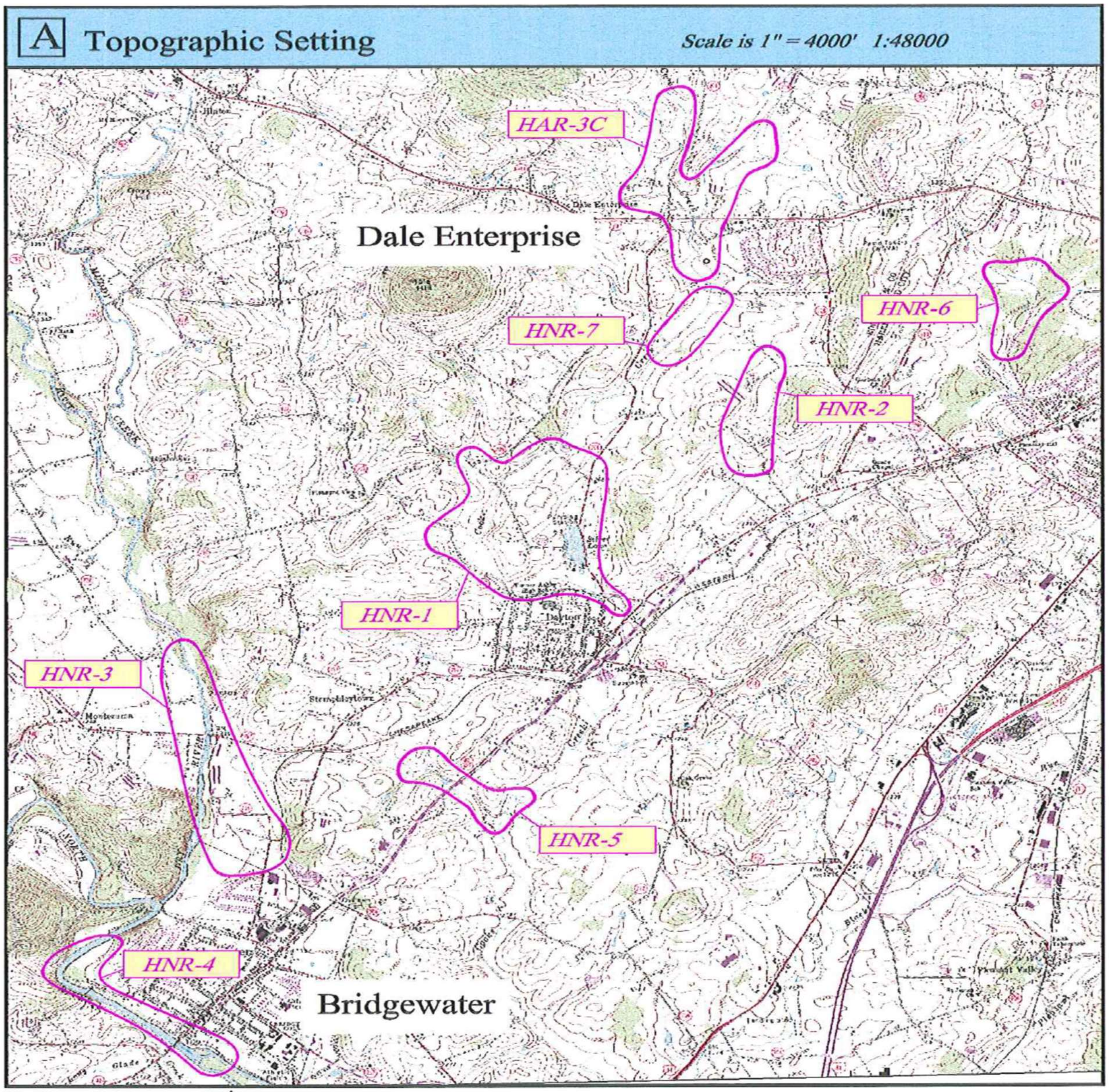
This Phase II geophysical investigation led to the selection of twenty proposed test well targets within the five groundwater development zones studied (Table II and Figures 2 through 6). These test well targets were selected to investigate a range of hydrogeologic and geophysical conditions that are considered to offer the potential for development of significant groundwater resources. For example, the selection of test well HNR-1W1 is based on the presence of the following characteristics: a valley topographic setting, recharge potential created by the presence of alluvial materials, intersecting lineaments, and a cavern-like feature observed in one of the resistivity cross-sections (Figure 8). By contrast, the HNR-7W1 test well site is located near significant isolated magnetic and VLF anomalies.

TABLE III
List of Proposed Exploration Test Wells

Test Well #	Tax Map-Lot #	Test Well #	Tax Lot #
HNR-1W1	107-149	HNR-3CW3	107-(A) 172 (or 92-180)
HNR-1W1alt	107-150 (or 157)	HNR-3CW4	92-(A) 83A
HNR-1W2	107-149 (or (A) 104)	HNR-3CW5	107-(A) 172
HNR-1W3	107-112	HNR-3CW6	107-169
HNR-1W4	107-131	HNR-5W1	123((1)) 2A (or 2C)
HNR-1W5	107-143	HNR-5W2	107-((2)) 1
HNR-2W1	107-203	**HNR-7W1**	107-160 (or 166)
HNR-2W2	107-201	HNR-7W2	107-160
HNR-3CW1	107-(A) 172	HNR-7W3	107-157
HNR-3CW2	107-(A) 55	HNR-7W4	107-167B (or 167)

***Well targets in bold type reflect the initial priority of wells for drilling.**

FIGURE 1 - Groundwater Development Zones for the Harrisonburg North Corridor Hydrogeologic Study



Contour Interval = 20'

Polyconic Projection. 1927 North American Datum.
Base map information from USGS topographic quadrangle map of Bridgewater, Virginia

Emery & Garrett Groundwater, Inc. *56 Main Street, Meredith, NH 03253* *FIGURE 1*

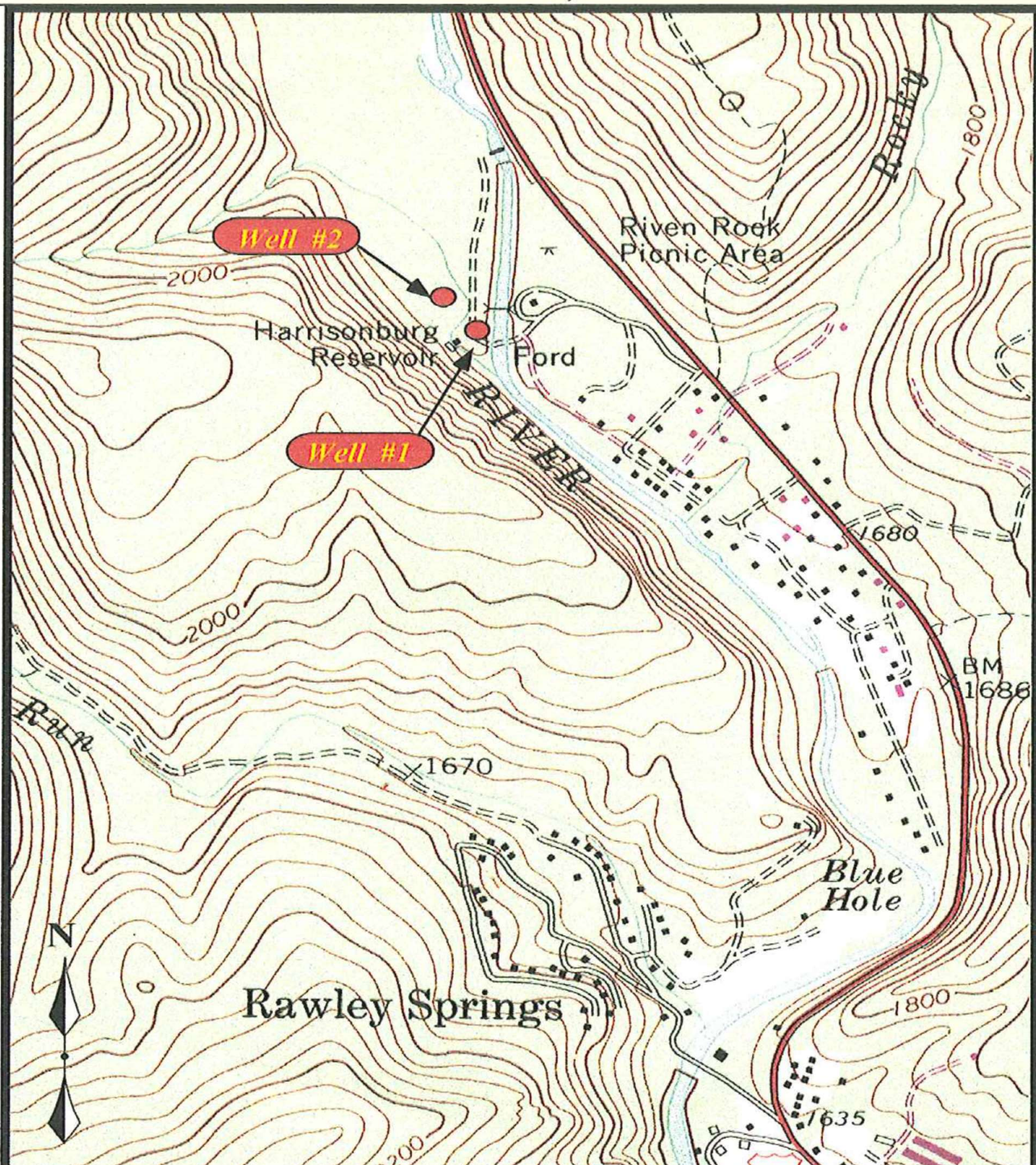
Results of Pumping Test Conducted at DRI by Emery & Garret Groundwater Inc. February 19, 1099

VIII. CONCLUSIONS AND RECOMMENDATIONS

Based on the hydrogeologic testing performed on Riven Rock Wells #1 and #2, the following conclusions can be drawn:

- Wells #1 and #2 can sustain simultaneous, short-term pumping (i.e., 24 hours) at rates of 180 gpm and 225 gpm, respectively. This could produce a combined yield of 405 gpm or **583,000 gpd**.
- Pumping of either well will cause minor hydraulic interference with the other well.
- Iron (1.6 ppm), manganese (0.14 ppm), and turbidity (8 ntu) levels measured in Well #1 exceed the MCLs for these constituents. Treatment of this water or dilution of the supply with other water sources would be necessary to utilize this well as a public water supply.
- ***Water produced from Well #2 is of excellent quality.*** Iron (.05 ppm), manganese (<.01 ppm), and turbidity (0.3 ntu) levels in Well #2 are below MCLs. This well would *not* require treatment for these parameters to be used as a public water source.
- The 1997 pumping tests produced no evidence that water from these wells will carry high loads of suspended sediments that might cause difficulties at the treatment plant.
- The data collected from video logs of each well indicate that the wells are not constructed in accordance with Virginia Water Works Regulations. Water is derived through a slotted portion of the steel casing (20-40 feet below ground surface). The fact that iron and manganese concentrations decreased during the 24-hour pumping period suggests that the water pumped from these wells is likely being influenced by surface water. It is EGGI's professional opinion that water used from these wells will need to be pumped to the City's treatment plant.

FIGURE 1 - LOCATION MAP FOR RIVEN ROCK WELLS #1 AND #2 RAWLEY SPRINGS, VIRGINIA



Base map information from 7.5' Rawley Springs, VA, USGS quadrangle.

0 500 1000 1500 2000 FEET

Scale is 1:12,000 1"=1000'

FIGURE 1

APPENDIX I: FRAZIER QUARRY

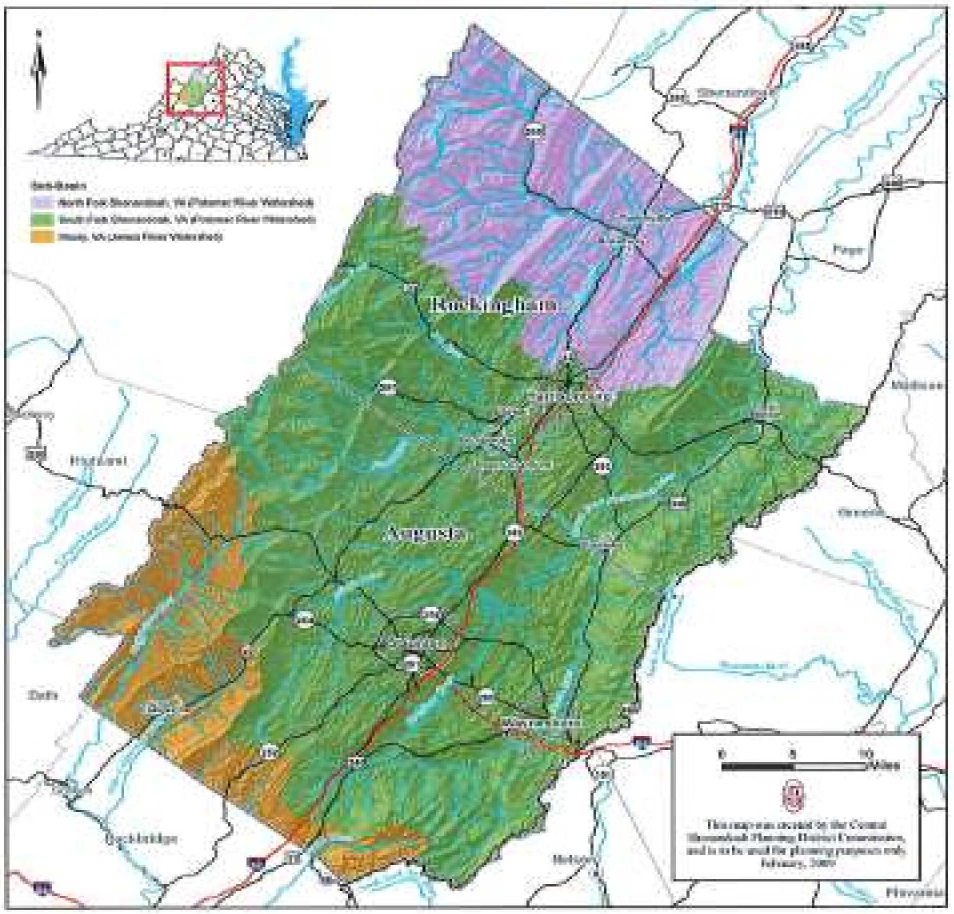
TO BE ADDED

APPENDIX J: VAC LOCAL AND REGIONAL WATER SUPPLY PLAN

The Commonwealth of Virginia is comparatively water-rich; however, following the drought of 1999-2002, the state engaged a statute (9VAC25-780) calling for Local and Regional Water Supply Planning. Under this statute, each locality was required to submit a plan that identified their water needs throughout 2040. The city was one of 48 plans submitted by the 2011 deadline. The city opted to submit the plan using a regional approach culminating in Harrisonburg City Council's action to adopt the "Upper Shenandoah River Basin Water Supply Plan."

The information from 48 plans has been reviewed by the Department of Environmental Quality (DEQ) to develop a State Water Resources Plan (SWRP). The objective is to make recommendations to protect all beneficial uses. DEQ has analyzed the data and has forecasted that the daily statewide water usage will increase by 32% to 450 MGD by 2040. In a proactive approach, DEQ has published a list of 12 recommendations that reflect how they plan to meet the statute's intent based on the SWRP data. DEQ's intentions toward Harrisonburg are displayed in the re-issuance of VWWP #16-0730.

Upper Shenandoah River Basin Water Supply Plan



CSPDC

Prepared and Submitted By:

Central Shenandoah Planning District Commission

November 2011

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