VWP CIA Summary - [INSERT PROJECT NAME HERE]

03/18/2022

# VAHydro Model:

## VAHydro

The comprehensive VAHydro hydrologic model is used by the DEQ Office of Water Supply to evaluate instream and off-stream beneficial uses for non-tidal surface water withdrawals throughout Virginia. This model also simulates streamflow with inputs such as precipitation, climate, land use, and topography, as well as local data collected through DEQ water supply planning and reporting programs, which includes all known withdrawals and discharges, as well as operational rules of Virginia Water Protection (VWP) permits and major hydrologic features such as reservoirs.

The VAHydro model is built on the rainfall-evaporation-runoff (RER) time-series from the Chesapeake Bay Model Phase 6[[1]](#footnote-20). The VAHydro model simulates conditions from 1984-2014 in the Chesapeake Bay watershed drainage, and 1984-2005 in the rivers flowing outside of the Chesapeake Bay watershed. The VAHydro model features high-resolution hydrologic subsections called “river segments” (over 600 river segments in total), roughly the size of HUC 10 hydrologic units, with additional high-resolution segments added for VWP modeling projects as needed.

## Cumulative Impact Analysis (CIA)

DEQ assesses water supply sustainability through Cumulative Impact Analysis (CIA). CIA is a modeling and analysis approach that takes into account the varied hydrologic processes occurring throughout a river network (including meteorological and human water use). By simulating a daily water balance for every individual river segment within a watershed, DEQ is able to evaluate the potential “cumulative impact” of all streamflow changes occurring upstream and downstream of any location within the river system, as well as the downstream impact of a specific proposed or permitted surface water withdrawal.

The goal of the following analysis is to estimate the potential impacts of the proposed water withdrawal upon existing beneficial uses, including both in-stream and off-stream uses. In addition, cumulative impacts from all existing withdrawals are included in the evaluation.

# Project Introduction

This project consists of an existing water intake constructed in the 1960’s with an upgrade in the early 1980’s. The Town owns and operates the Big Cherry Dam located approximately 3 miles upstream from the intake structure. The Town’s water treatment plant operators control the amount of water discharging the dam into the Powell River and all of the stream by-pass flow to meet the previous permit requirements of 4.0 MOD of maximum withdrawal and 0.50 MGD of by-pass flow. This is always true unless the dam is overflowing exceeding the amount of water required from various rainfall events. Therefore, the existing/proposed maximum withdrawal amounts will not have an impact on the stream in terms of rates, volumes, frequency, etc. This is a daily activity as it serves the existing water treatment plant.

Permit: Big Cherry Dam, 01-0688  
Permit Dates: 2003-08-23 to 2018-08-22

* **Annual Withdrawal Limit** = 1168 MG/yr (3.2 MGD)
  + (historically they withdraw ~2 MGD on average)
* **Daily Withdrawal Limit** = 4 MGD
* **Flow-by** = 0.5 MGD

## Location Map

*No location map available for this facility model*

# Model Overview and Scenario Descriptions

**River Model Description** This segment of the James River model stretches from just downstream of Cartersville to the Huguenot Bridge. It has a total drainage area of approximately 6,769 square miles.

**Facility & Intake Model Description** The James River Correctional Center intake from the James River is located near the confluence with Beaverdam Creek. The facility returns process water flows to Beaverdam creek, and transfers water to Goochland County.

The following model scenarios were simulated in order to determine the most effective means of meeting the project need and all other in-stream beneficial uses:

* **Current permit, 2.0 mgd and 90% Flow-By** (Current Permit) - The current permit scenario uses a maximum annual demand of 730.0 million gallons, and a maximum withdrawal rate of 2.0 MGD. Allowable withdrawal at this intake is based on a 90% flowby, as calculated from the previous days flow at the James River Cartersville gage, USGS 02035000. Although the maximum daily withdrawal in this scenario is equal to 2.0 mgd, the daily withdrawal rate is modeled as a function of historical monthly use patterns, and winter withdrawals range from 1.8-1.9 mgd. Therefore, the average rate of withdrawal simulated is approximately 1.95 MGD.
* **Descriptive name for titles, ex: Proposed permit conditions with 90% flowby** (3.0 MGD, 90% Flow-by) - The proposed permit scenario evaluated the cumulative impacts of a maximum annual demand of 1,08.0 million gallons, and a maximum withdrawal rate of 3.0 MGD. Allowable withdrawal at this intake is based on a 90% flowby, as calculated from the previous days flow at the James River Cartersville gage, USGS 02035000. Although the maximum daily withdrawal in this scenario is equal to 3.0 mgd, the daily withdrawal rate is modeled as a function of historical monthly use patterns, and winter withdrawals range from 2.7 to 2.8 mgd. Therefore, the average rate of withdrawal simulated is approximately 2.9 MGD.

**Historical Intake Flows and Drought Flow Indicators**

The VAHydro model is used to estimate flows at the project intake, including the impact of all cumulative withdrawals, discharges and management rules upstream of the withdrawal location. The models estimates of currently available flows are presented in Table 1. The Virginia Drought Assessment and Response Plan[[2]](#footnote-27) employs non-exceedance flow percentiles as indicators of drought conditions at particular stream-gaging stations used to monitor drought conditions. Representative daily streamflows above the 25th percentile for return flow frequency represent normal conditions with respect to drought. Representative daily streamflows between the 10th and 25th percentiles represent drought watch conditions. Representative daily streamflows between the 5th and 10th percentiles represent drought warning conditions. Representative daily streamflows below the 5th percentile indicate drought emergency conditions.

**Table 1:** Modeled monthly current flow statistics for James River intake in cubic feet per second (cfs). Columns show the minimum (Min) and average (Mean) modeled flow, and a range of non-exceedance flow percentiles, that is, the column header indicates the percent of flows that do *not* exceed the given value. For example, the “10%” states that only 10% of flows in the given month are expected to be less than the indicated value, and therefore, 90% of the flows in that month are expected to be greater than the given value. For example, in the table below the 10% column states that 10% of flows within the month of January would be less than 3076 cfs.

| **Month** | **Min** | **5%** | **10%** | **25%** | **30%** | **50%** | **Mean** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Jan | 1,749 | 2,595 | 3,076 | 4,781 | 5,520 | 7,524 | 9,810 |
| Feb | 1,755 | 3,319 | 4,080 | 5,555 | 5,990 | 7,877 | 10,173 |
| Mar | 1,641 | 3,717 | 4,353 | 6,460 | 7,217 | 9,663 | 12,246 |
| Apr | 2,396 | 3,306 | 3,693 | 5,390 | 5,816 | 7,952 | 11,167 |
| May | 1,930 | 2,835 | 3,242 | 4,399 | 4,922 | 6,663 | 8,436 |
| Jun | 1,249 | 1,728 | 2,205 | 2,974 | 3,257 | 4,283 | 6,118 |
| Jul | 1,022 | 1,245 | 1,489 | 1,880 | 1,995 | 2,585 | 4,063 |
| Aug | 736 | 959 | 1,170 | 1,515 | 1,620 | 2,282 | 2,993 |
| Sep | 656 | 989 | 1,136 | 1,406 | 1,529 | 2,136 | 4,904 |
| Oct | 567 | 901 | 1,096 | 1,631 | 1,875 | 2,678 | 5,185 |
| Nov | 514 | 820 | 1,141 | 1,993 | 2,212 | 3,828 | 6,595 |
| Dec | 570 | 1,048 | 1,861 | 4,013 | 4,594 | 6,706 | 8,636 |

# Results

## Summary

Four scenarios are presented below to examine the alternatives for this permit re-issuance. A summary of how permit rules affect available water for this permit, and how this operation may impact instream beneficial uses, and other downstream water withdrawals is presented.

* **Current permit, 2.0 mgd and 90% Flow-By** - Due to the size of the demand in the existing permit relative to flows in the James River, the full demand of 2.0 mgd can be met at all times in the simulated period.
* **Descriptive name for titles, ex: Proposed permit conditions with 90% flowby** - The model analysis from of flow conditions from 1984-2014 show that the full proposed withdrawal can be met during all simulated conditions. The net consumptive loss is estimated to be approximately 0.3 MGD after considering wastewater treatment return flows, and so individually this project has a very low impact on the flow in the James River. Taken collectively with all other permits in the watershed run at their permitted maximum, the cumulative flow changes in the James River are estimated to be less than -2% in average daily flow. However, during low flows, consumptive losses in this stream can be significant, amounting to approximately 7% during drought watch (10% non-exceedance flow), and 8% during drought emergencies (when flow is less than 5% non-exceedence flow). This part of the James River has a previously completed IFIM habitat study, which shows that the majority of species/life-stages considered maintain habitat losses below 10%, although adult redhorse and BJA do see losses over 10% for 1-3 months of drought warning conditions.

## Conclusion

* **Descriptive name for titles, ex: Proposed permit conditions with 90% flowby** -

## Detailed Cumulative Impact Analysis

The following “Summary of Results” table summarizes the cumulative impacts to flows, aquatic life, and off-stream demand for the project. The section entitled “River Segment Model Statistics” contains mean flows (Flow Out), and drought flows (30 and 90 Day Low Flow), as well as an estimated Consumptive Use Fraction (See description below) as a result of all withdrawals (Cumulative Withdrawal) and discharges (Cumulative Point Source) in the watershed. Minimum Days of Storage Remaining describes the number of days of remaining storage available during the driest period of the model simulation (applicable to impoundment models only). Total Number of Days with Storage < 50% describes the number of days in the simulation in which reservoir levels fall below 50% of full storage. The section entitled “Facility Model Statistics” shows the withdrawals, return flows (Point Source), and the model estimate for potential unmet demand due to demands exceeding the allowable withdrawal at the intake based on the cumulative conditions in the watershed and the flow-by rules in effect. There will be one or more columns in this table representing each scenario considered for this analysis.

### Glossary of Cumulative Impact Modeling Terms

* Consumptive Use Fraction (CU): This is calculated as a fraction of modeled Flow, so it is CU = 1.0 - (Flow / Flow\_Baseline), where Flow\_Baseline = (Flow + WD - PS), and WD and PS are the total cumulative withdrawals and point source discharges above the point in the stream. In other words, for calculating baseline flow, we take modeled outflow from the river, add the withdrawals back in, and subtract the point source in order to estimate a baseline flow balance. This almost always ends up being a higher number than the modeled Flow out, so it tells us the fraction of baseline flow that is consumed. Occasionally there are water transfers and point sources from groundwater, or point sources that cross watershed boundaries that can make the CU fraction in some watersheds negative, i.e. Flow > Flow\_Baseline.
* 30 Day Low Flow: \*DESCRIPTION NEEDED
* 90 Day Low Flow: \*DESCRIPTION NEEDED
* \*Additional DESCRIPTIONS NEEDED for other table metrics that aren’t clearly understood

### Summary of Results:

| **Description** | **400** | **600** |
| --- | --- | --- |
| River Segment Model Statistics: | James River @ Huguenot Bridge | James River @ Huguenot Bridge |
| Flow Out (cfs) - (i.e mean flow) | 7,403.15 | 2,494.26 |
| Minimum Days of Storage Remaining | NA | NA |
| 30 Day Low Flow (cfs) (i.e drought flow) | 595.87 | 239.95 |
| 90 Day Low Flow (cfs) (i.e drought flow) | 1,018.61 | 440.63 |
| Consumptive Use Fraction | 0.02 | 0.05 |
| Cumulative Withdrawal (MGD) | 248.4 | 193.13 |
| Cumulative Point Source (MGD) | 168.34 | 113.17 |
| Withdrawal (MGD) | 48.85 | 49.8 |
| Point Source (MGD) | 0 | 0 |
| Facility Model Statistics: | JAMES RIVER CORR. CNTR WTP:James River | JAMES RIVER CORR. CNTR WTP:James River |
| Base Demand (MGY) | 709.96 | 1,057.29 |
| Withdrawal (MGY) | 709.96 | 1,057.29 |
| Unmet Demand (MGY) | 0 | 0 |
| Requested Demand (MGD) | 1.95 | 2.9 |
| Withdrawal Met (MGD) | 1.95 | 2.9 |
| Point Source (MGD) | 1.75 | 2.61 |
| Groundwater Demand (MGD) | 0 | 0 |
| Maximum 30 day potential unmet demand (MGD) | 0 | 0 |

### Analysis of Reservoir Storage:

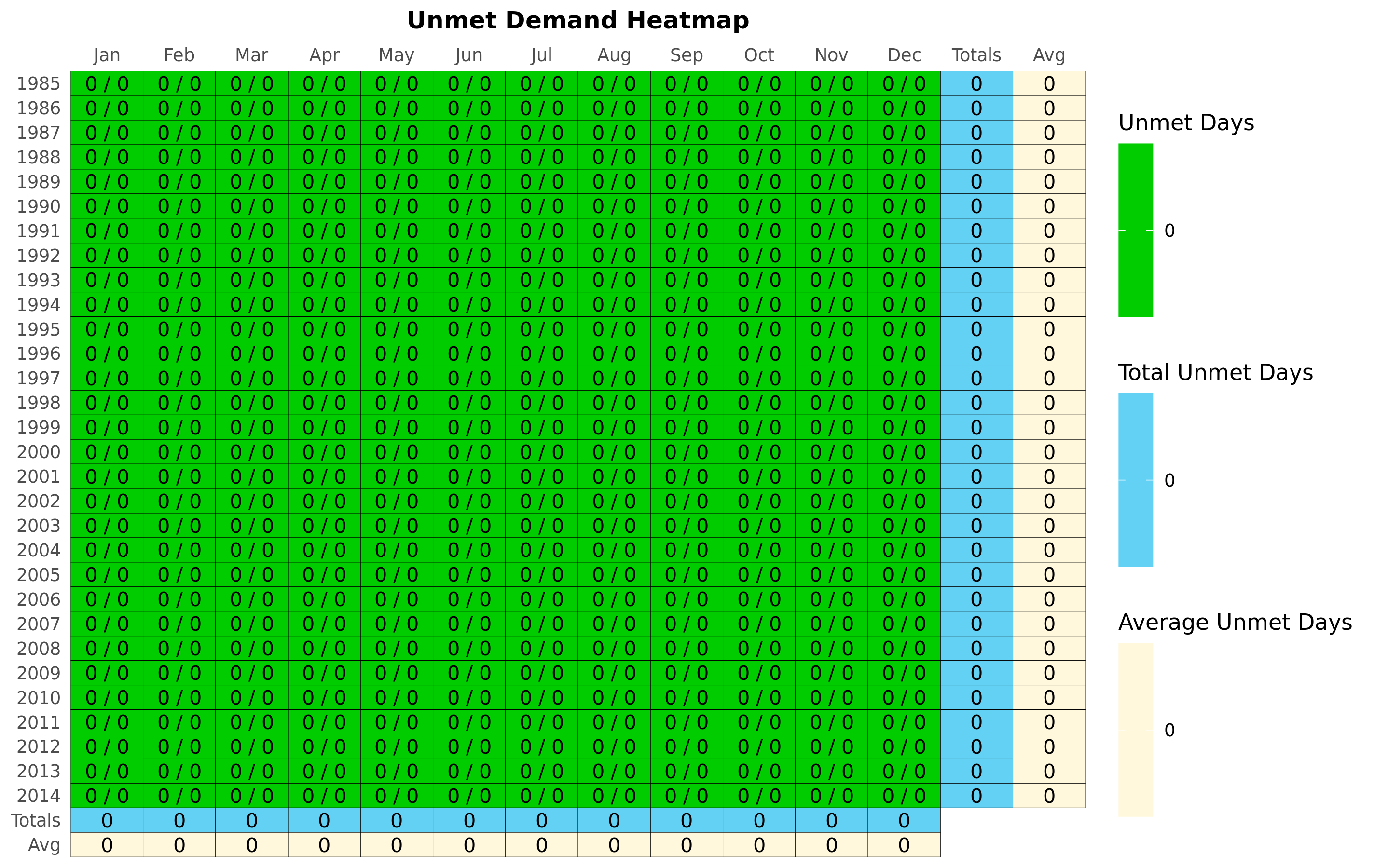
The following reservoir storage plots depict changes in reservoir storage under each scenario (indicated in black), as well as simulated inflow to the reservoir (blue), simulated outflow from the reservoir (green), and system demand for the given scenario (red). For water supply reservoirs, a minimum of 60 days of remaining storage over the course of the simulation is recommended. System demand varies seasonally.

[1] “No active impoundment found for run id runid\_400” [1] “No active impoundment found for run id runid\_600”

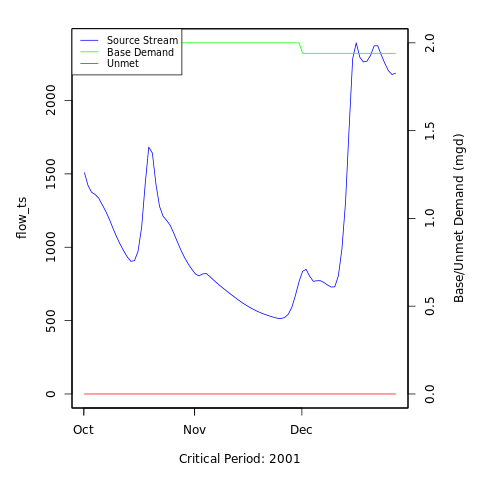
### Analysis of Potential Unmet Demand at the River Intake:

Heatmaps are data plotting tools that help visualize data as magnitudes of color intensity. The following heatmaps depict the number of days with unmet demands for each month of the simulation (due to demands exceeding allowable withdrawal at the intake based on the cumulative conditions in the watershed and the flow-by rules in effect). The heatmap cells show the amount of unmet demand for each month [Number of Unmet Days & Amount (MGD)]. Hydrographs are shown for the period of the simulation with greatest unmet demand.

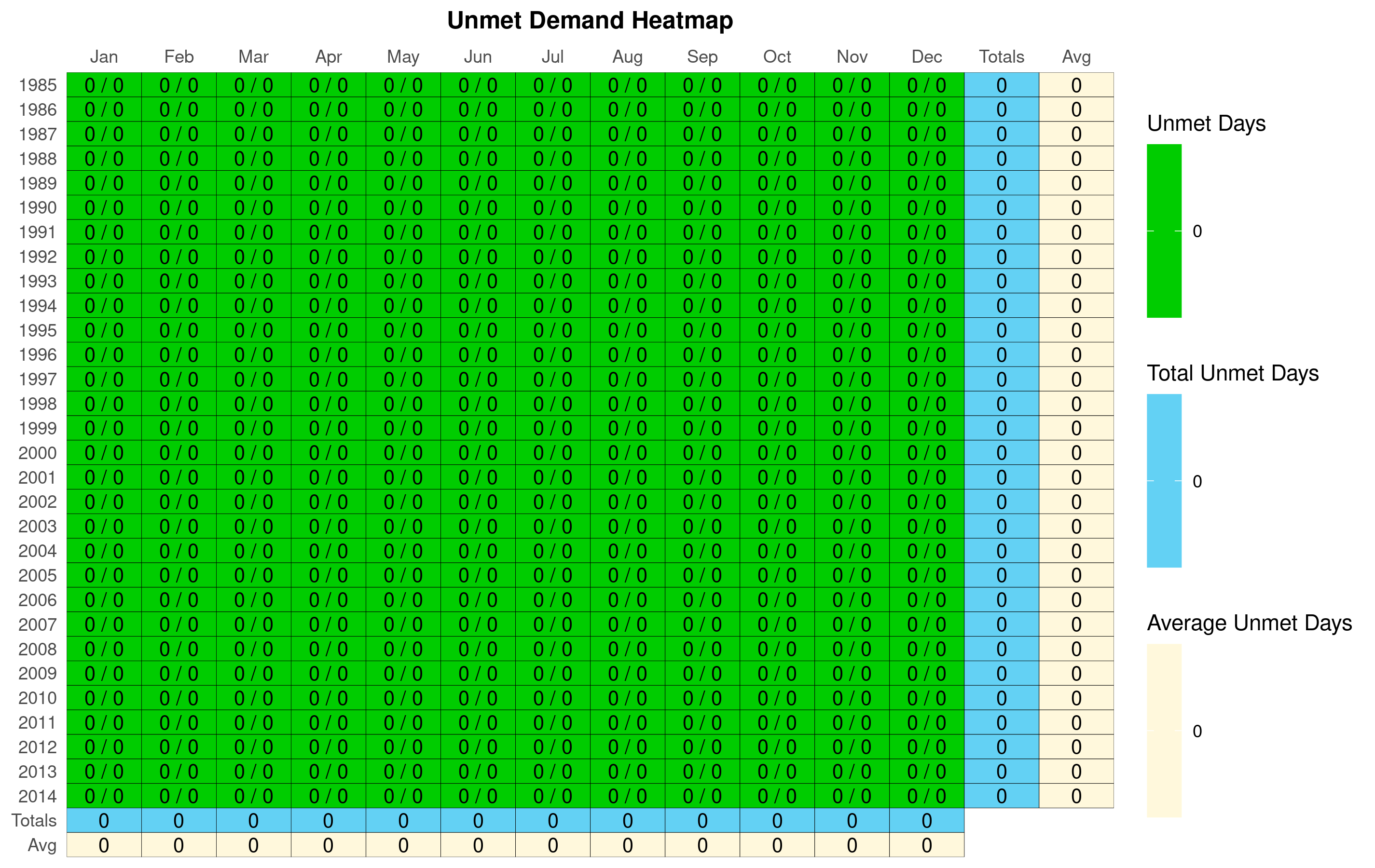
#### Heatmap: Current Permit



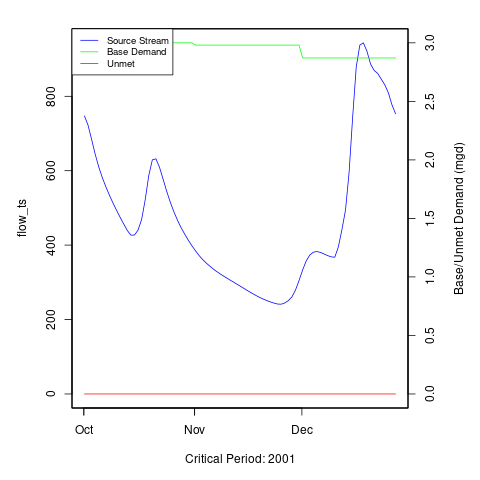
#### Hydrograph: Current Permit

 [1] “No local facility impoundment for Current Permit”

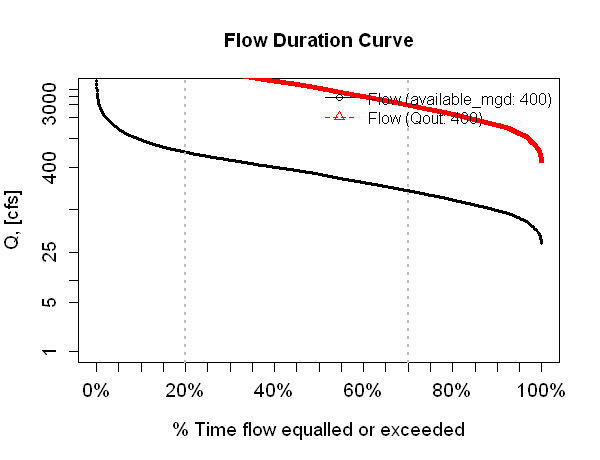
#### Heatmap: 3.0 MGD, 90% Flow-by

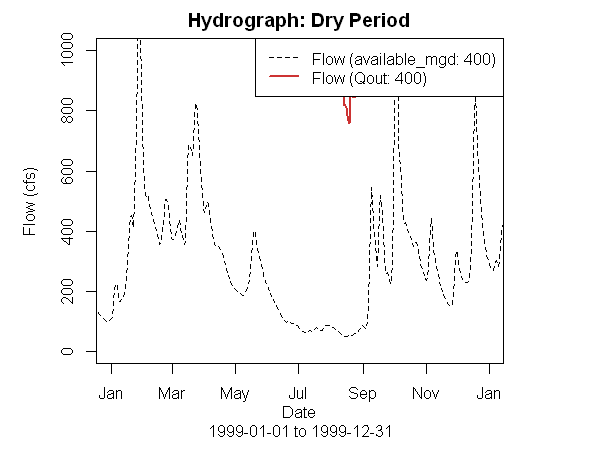


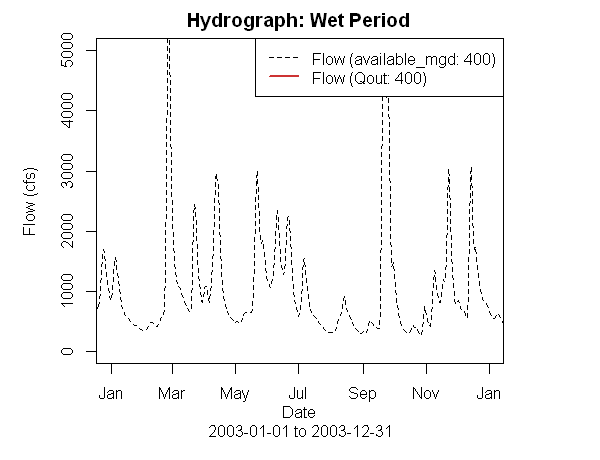
#### Hydrograph: 3.0 MGD, 90% Flow-by

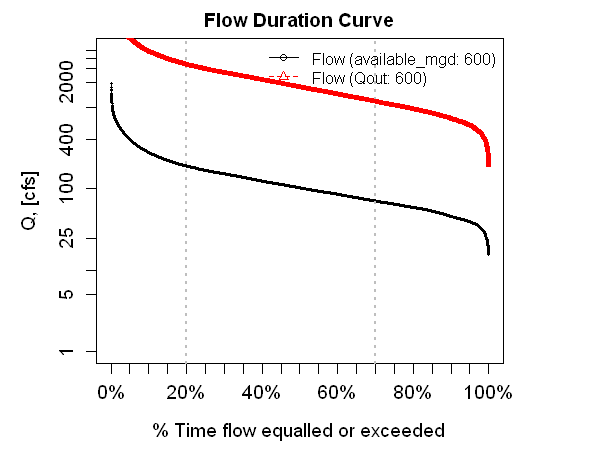
 [1] “No local facility impoundment for 3.0 MGD, 90% Flow-by”

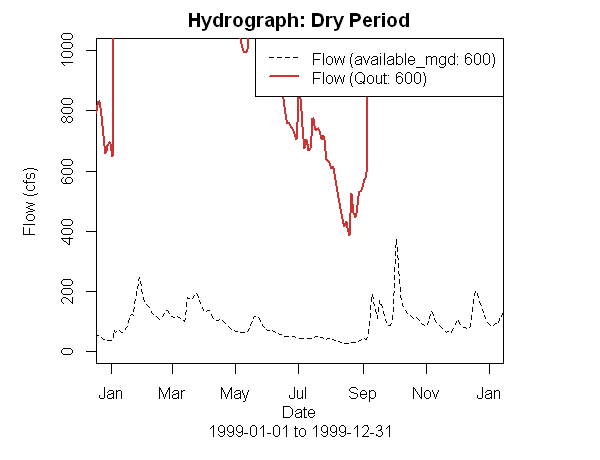
### Additional Model Flow Plots:

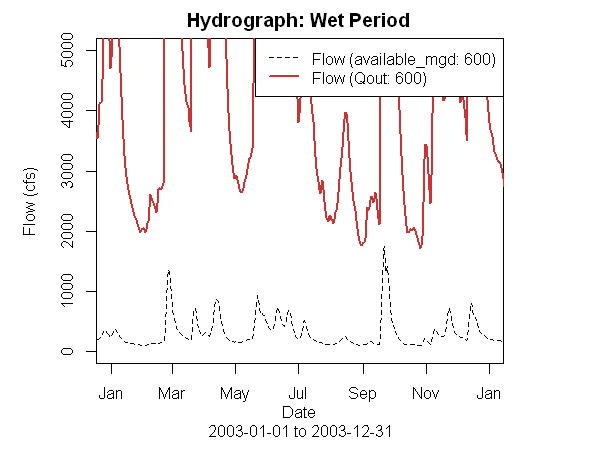










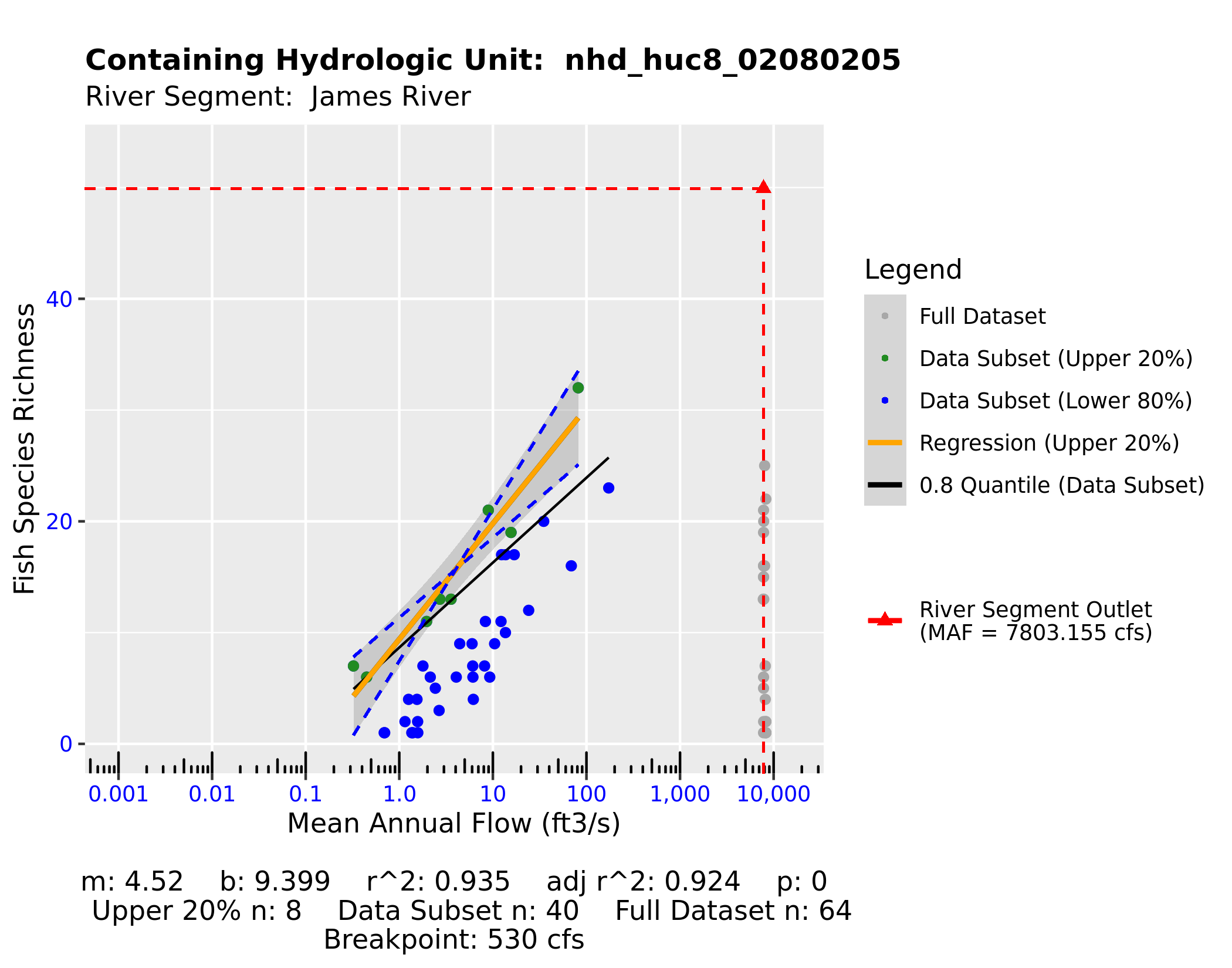


# Appendix A - Ecological Impacts Assessment:

## Elfgen:

In response to a need for better environmental flow metrics, DEQ has developed a new framework for characterizing relations between streamflow and aquatic organism species richness. Part of an evolving approach to managing environmental flows for maintaining aquatic life; this methodology builds on existing minimum instream ow approaches, allowable withdrawals as a percentage of flow, and extensive flow-habitat studies. For the first time this new framework may allow quantification of potential species loss resulting from flow change, and may offer an improved understanding of aquatic life risk variability due to geographic location, stream size and local scale.

This new flow-ecology framework referred to as “elfgen” (*pronounced elf-jen*) derives its name from Ecological Limit Function (ELF) generation (*ELF-gen*). In order to calculate river segment-level richness change, elfgen is first used to produce ELFs, or relations between stream flow and species richness at the HUC 8 scale (See plot below). This is achieved using long term datasets for both ecological and hydrologic data. Ecological data (Fish species richness) is sourced from the VAHydro-EDAS dataset. Hydrologic data (Average Annual Flow) is sourced from the National Hydrography Dataset Plus. The Richness Change values presented in the table below are derived from this flow-ecology relation.



## Richness Change Metric Table:

Estimates for richness change are presented both as an absolute number of species (Richness Change (abs)) and as a percentage of the total number of species present (Richness Change (%)). Richness change calculations are derived from the estimated percent total consumptive use[[3]](#footnote-49). Note: elfgen methodology only applicable for watersheds < 800 cfs mean annual flow.

| **Description** | **400** | **600** |
| --- | --- | --- |
| Consumptive Use Fraction | 0.02 | 0.05 |
| Cumulative Withdrawal (MGD) | 248.4 | 193.13 |
| Richness Change (abs) | -0.07 | -0.22 |
| Richness Change (%) | -0.15 | -0.44 |

## Habitat (If Applicable):

# Appendix B - Nearby Users Table:

|  | **Sub-Watershed** | **MP Type** | **MP Status** | **MP Name** | **MP 5-yr Avg Use (MGY)** | **Facility Name** | **Facility 5-yr Avg Use (MGY)** | **Facility 2040 Use (MGY)** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | James River | intake | active | JAMES RIVER | 8,979.00 | HENRICO COUNTY WTP & Service Area | 8,979.00 | 17,374.74 |
| 2 | James River | intake | active | PIT SUMP | 278.76 | ROYAL STONE PLANT | 363.32 | 478.15 |
| 3 | James River | intake | active | JAMES RIVER | 214.13 | JAMES RIVER CORR. CNTR WTP | 214.13 | 273.00 |
| 4 | James River | intake | active | QUARRY | 107.40 | ANDERSON CREEK QUARRY | 107.40 | 47.45 |
| 5 | James River | intake | active | LITTLE TUCKAHOE CREEK TRIB | 84.56 | ROYAL STONE PLANT | 363.32 | 478.15 |
| 6 | James River | intake | active | POND | 54.48 | Independence Golf Club | 100.98 | 89.65 |
| 7 | James River | well | active | Chesterfield Well | 39.25 | Independence Golf Club | 100.98 | 89.65 |
| 8 | James River | intake | active | BROAD BRANCH PONDS #1, #2 | 35.48 | HERMITAGE GOLF COURSE | 38.13 | 66.71 |
| 9 | James River | intake | active | Kinloch Pond | 31.02 | Kinloch Golf Course | 31.02 | 75.00 |
| 10 | James River | intake | active | Irrigation Lake | 18.73 | FOUNDRY GOLF CLUB | 18.73 | 10.00 |
| 11 | James River | intake | active | Irrigation Pond | 11.93 | RICHMOND COUNTRY CLUB, INC | 11.93 | 36.50 |
| 12 | James River | well | active | Powhatan Well | 6.90 | Independence Golf Club | 100.98 | 89.65 |
| 13 | James River | intake | active | James River | 4.71 | Mary Mother of the Church Abbey/Benedictine College Preparatory | 4.71 | 0.00 |
| 14 | James River | intake | active | FARM POND | 4.50 | KELONA FARMS INC | 4.50 | 2.10 |
| 15 | James River | well | active | Well #1 | 4.45 | Envoy at the Meadows | 0.00 | 0.00 |
| 16 | James River | intake | active | Kanawha Pond | 4.16 | Kanawha Club | 4.16 | 3.65 |
| 17 | James River | well | active | TILMANS FARM WELL#1 | 3.85 | SYDNOR - small well systems | 42.35 | 3.02 |
| 18 | James River | well | active | TILMANS FARM WELL#3 | 2.65 | SYDNOR - small well systems | 42.35 | 3.02 |
| 19 | James River | well | active | WELL - SYDNOR MAINTAINED | 2.65 | HERMITAGE GOLF COURSE | 38.13 | 66.71 |
| 20 | James River | intake | active | Holding Pond | 2.35 | WINDY HILL SPORTS COMPLEX | 2.35 | 0.00 |
| 21 | James River | well | active | WELL #6 | 1.85 | MANAKIN FARMS SERVICE AREA | 21.82 | 74.19 |
| 22 | James River | well | active | WELL #2A | 1.76 | JAMES RIVER EST SERVICE AREA | 3.35 | 0.00 |
| 23 | James River | well | active | WELL #7 | 1.76 | MANAKIN FARMS SERVICE AREA | 21.82 | 74.19 |
| 24 | James River | well | active | WELL #6 | 1.60 | LAKE SHAWNEE SERVICE AREA | 5.95 | 13.73 |
| 25 | James River | well | active | WELL #2 | 1.51 | JAMES RIVER EST SERVICE AREA | 3.35 | 0.00 |
| 26 | James River | well | active | EAST BOUND WELL | 1.31 | I-64 GOOCHLAND REST AREA | 2.26 | 0.00 |
| 27 | James River | well | active | WELL #5 | 1.23 | LAKE SHAWNEE SERVICE AREA | 5.95 | 13.73 |
| 28 | James River | well | active | Well | 1.17 | Strange's Garden Center W. Broad St. | 1.17 | 0.00 |
| 29 | James River | well | active | CROZIER WELL #1A | 0.97 | Crozier | 0.00 | 0.00 |
| 30 | James River | well | active | WEST BOUND WELL | 0.95 | I-64 GOOCHLAND REST AREA | 2.26 | 0.00 |
| 31 | James River | well | active | SABOT HILL FARM | 0.78 | SYDNOR - small well systems | 42.35 | 3.02 |
| 32 | James River | well | active | WELL #3A | 0.24 | POWHATAN Courthouse SERVICE AREA | 24.64 | 312.32 |
| 33 | James River | well | active | OILVILLE Pit Stop | 0.21 | SYDNOR - small well systems | 42.35 | 3.02 |
| 34 | James River | well | active | WELL #3 | 0.19 | POWHATAN Courthouse SERVICE AREA | 24.64 | 312.32 |
| 35 | James River | well | inactive | WELL #1 | 0.08 | JAMES RIVER EST SERVICE AREA | 3.35 | 0.00 |
| 36 | James River | well | active | TCC RESTROOM #6 | 0.03 | The Country Club of Virginia-James River | 46.30 | 47.29 |
| 37 | James River | well | active | JRC RESTROOM 14TH GREEN | 0.01 | The Country Club of Virginia-James River | 46.30 | 47.29 |
| 38 | James River | well | active | TCC FARMHOUSE WELL | 0.01 | The Country Club of Virginia-James River | 46.30 | 47.29 |
| 39 | James River | well | inactive | WELL #1A | 0.00 | JAMES RIVER EST SERVICE AREA | 3.35 | 0.00 |
| 40 | James River | well | active | WELL #1 | 0.00 | ROYAL STONE PLANT | 363.32 | 478.15 |
| 41 | James River | intake | inactive | BEAVERDAM CREEK | 0.00 | JAMES RIVER CORR. CNTR WTP | 214.13 | 273.00 |
| 42 | James River | intake | inactive | JAMES RIVER | 0.00 | The Country Club of Virginia-James River | 46.30 | 47.29 |
| 43 | James River | intake | inactive | TUCKAHOE CREEK | 0.00 | The Country Club of Virginia-James River | 46.30 | 47.29 |
| 44 | James River | intake | active | TCC KANAWHA CANAL | 0.00 | The Country Club of Virginia-James River | 46.30 | 47.29 |
| 45 | James River | intake | active | JRC KANAWHA CANAL | 0.00 | The Country Club of Virginia-James River | 46.30 | 47.29 |
| 46 | James River | well | active | WELL #4 | 0.00 | MANAKIN FARMS SERVICE AREA | 21.82 | 74.19 |
| 47 | James River | well | active | WELL #1 | 0.00 | LAKE SHAWNEE SERVICE AREA | 5.95 | 13.73 |
| 48 | James River | well | active | WELL #2 | 0.00 | LAKE SHAWNEE SERVICE AREA | 5.95 | 13.73 |
| 49 | James River | well | active | WELL #2A | 0.00 | LAKE SHAWNEE SERVICE AREA | 5.95 | 13.73 |
| 50 | James River | well | active | SALEM BAPTIST CH | 0.00 | Previously SYDNOR - small well systems | 0.20 | 0.00 |
| 51 | James River | intake | active | JAMES RIVER | 0.00 | BROOKVIEW FARM | 0.00 | 0.00 |
| 52 | James River | well | inactive | RICHMOND COUNTRY CLUB | 0.00 | Previously SYDNOR - small well systems | 0.20 | 0.00 |

1. [Chesapeake Bay Program Phase 6 Model](https://www.chesapeakebay.net/documents/Phase_6_Modeling_Tools_1-page_factsheet_12-18-17.pdf). [↑](#footnote-ref-20)
2. [Virginia Drought Assessment and Response Plan](https://www.deq.virginia.gov/home/showpublisheddocument/5115/637490843054630000), developed by the Drought Response Technical Advisory Committee in response to Executive Order #39, March 28, 2003. [↑](#footnote-ref-27)
3. Kleiner et al: <https://onlinelibrary.wiley.com/doi/full/10.1111/1752-1688.12876> & Rapp et al: <https://onlinelibrary.wiley.com/doi/full/10.1111/1752-1688.12877> [↑](#footnote-ref-49)