Barren River and Nolin River Reservoirs

Engineering Report

for

Winter Pool Raise

May 2016

Louisville District, USACE

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Appendices

1. Introduction

During the Louisville District's (LRL) Screening Portfolio Risk Assessment (SPRA) for Barren and Nolin River Reservoirs, the operation of higher winter conservation pools than those documented in the Projects authorized Water Control Plans (WCPs) was questioned. Nolin River Reservoir was targeting a winter pool elevation two feet higher than shown in the WCP (492 instead of 490) with little documentation indicating how this change was made or receipt of official approval to do so. Conversations with the former (now retired) Water Management (WM) Team Lead revealed that the request to target a winter pool elevation of 492 was made by Operations Division, in order to facilitate removal of vegetative debris which had accumulated under Wax Marina. Similarly, Barren River Reservoir has been targeting a winter pool elevation three feet higher than shown in the WCP (528 instead of 525) when the State Park Marina requested the higher winter pool due to sedimentation issues adversely impacting their facility. Further exacerbating the sedimentation issue at both projects is the fact that the Commonwealth of Kentucky experienced periods of drought (December 1999 – March 2000 and December 2002 – March 2003) when the Great Lakes and Ohio River Division approved even higher temporary winter pool elevations at Nolin (498) and Barren (532).

In 2013, LRL sent a memorandum to LRD requesting a permanent change to the Authorized Winter Pool for Nolin River Lake. On 12 September 2013, LRD denied LRL's request for a permanent change to the Authorized Winter Pool for Nolin River Lake. In addition to this decision, the Memorandum outlined the process to be followed in order for LRL to proceed.

On 10 October 2013, a vertical team conference call was held to discuss and clarify the necessary actions for revising the authorized winter pool at Nolin and included discussion for the same process to be utilized at Barren. A memorandum of the minutes from this meeting was prepared on 11 October. Section 3 of this memorandum outlined the agreed upon course of action which consisted of three items. The third action item was the compilation of this Engineering Report.

A single Project Management Plan (PMP) was developed for both Barren River Lake and Nolin River Lake (Project No. 128606 / 128623). The PMP's Scope of Work documented the need for an Engineering Analysis, whose main aspect was a pool elevation frequency analysis and subsequent comparison between the "Authorized" Winter Pool elevations and the higher "Current" Winter Pool elevations currently utilized for project operation. If the pool elevation frequency analysis indicates negligible impact to pool elevations and ancillary authorized project purposes, the guide curves will be revised and incorporated into the Water Control Manuals for each project to bring the operation at the Current (higher) Winter Pool elevations into compliance. If a significant impact to pool elevations and/or ancillary authorized purposes is identified, the operation of the project(s) will be returned to the Authorized Winter Pool elevation currently specified in the water control plan and guide curve.

Included in the PMP was the Agency Technical Review (ATR) of the Engineering Analysis detailed in Chapter 2 of this report. ATR was provided by Mr. Kevin Grode, P.E., Northwestern Division, MRBWM Reservoir Regulation Team Lead.

2. Engineering Analysis Summary

2.1 RES-Sim Modeling Results

In order to determine the effect on the peak pool frequency relationships resulting from a change in winter target pool elevation, i.e. guide curve, for the Barren and Nolin River Reservoir projects, a series of reservoir routing simulations were performed for both basins. This modeling effort was performed with HEC Res-Sim using a pre-existing HEC-CWMS model of the Green River Basin.

Each basin’s modeling information was taken out of the larger Green River Basin’s CWMS model including all reservoir logic rules, storage elevation curves, downstream control points, etc. This allowed for rapid model creation with a focus on each individual reservoir system while preserving the basin integrity of the overall Green River Basin model. Minor changes were made to the modeling parameters mostly in the form of datum conversion, all elevations in the current study are in NGVD 29 to maintain consistency between data sources and modeling results.

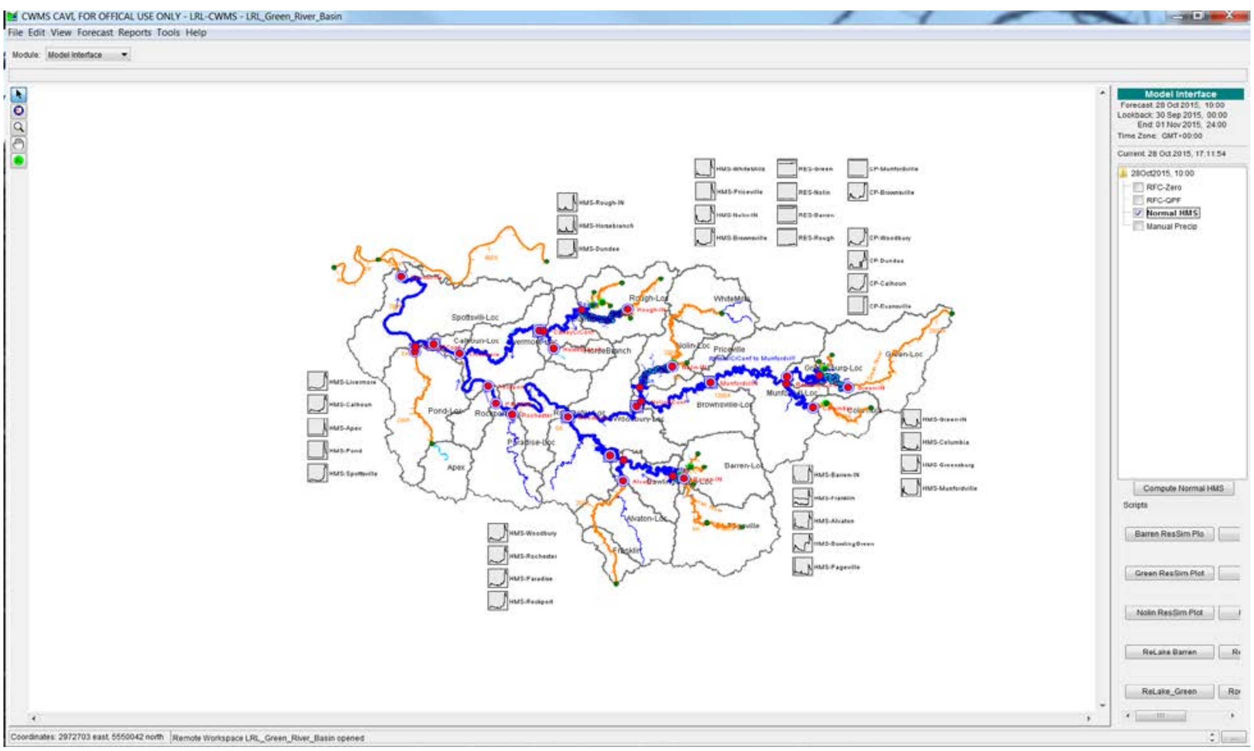

Figure 2.1: Basic Layout for Green River CWMS Model

Data was compiled for both projects from their respective start of impoundment through 2014. Data sources included the USGS, the National Weather Service, and internal USACE records. In all cases records from the USGS were used when available. However, several data sets were incomplete or had inconsistencies which were then augmented with internal USACE records. In several locations data sets were merged to simplify the modeling process especially for local sub-basin flows and tributary inflows (e.g. Drakes Creek in the Barren model).

Due to the length of time simulated (1963 to 2014) data were limited. As many older records only exist as daily average values it was decided to perform model simulations using a daily time step.

Flow Data Sources:

Barren:

> Alvaton, developed from observed USGS flow and stage readings.
> Barren-IN, OBS (Barren Inflow, calculated from Δ Storage relationship).
> Barren-OUT, OBS, Barren Outflow or model results.
> Bowling Green, combined flows from Alvaton and Barren outflows

Nolin:

> Munfordville, OBS USGS
> Brownsville, routed (Muskingum) Nolin outflows combined with routed (Puls) flows from Nolin.
> Woodberry, routed (Muskingum) flows from Brownsville.
> Nolin-IN, OBS (Barren Inflow, calculated from Δ Storage relationship).
> Nolin-OUT, OBS, Barren Outflow or model results.

Methodology:

From the Green River CWMS model two separate HEC Res-Sim models were created, one for each reservoir; Nolin and Barren. The modeling process was consistent between the two watershed models. Simulations were performed to examine the effects of different winter pool target reservoir elevations (guide curve) on peak pool elevations.

For both the Barren and Nolin reservoir models, every effort was made to maintain consistency with the authorized Water Control Manuals. Reservoir release rules were based on the actual schedules of releases with all constraints such as downstream control points, minimum or maximum releases, etc. being accounted for.

Barren Reservoir:

The Barren Reservoir Res-Sim model contrasted the difference in pool elevations resulting in raising the winter guide curve from an elevation of 525 ("Authorized") to 528 ("Current") feet NGVD 29 from the date of impoundment, January 1965, through 2014. All other modeling parameters and inputs were kept consistent; outflow guidelines (reservoir regulation rules), inflows, tributary flows from Drakes Creek, etc.

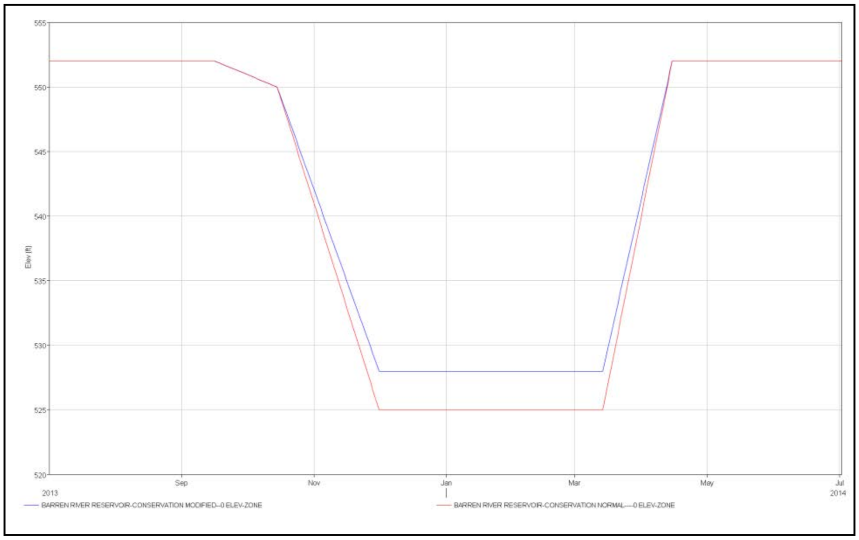

Figure 2.2: Barren Reservoir Guide Curves as modeled

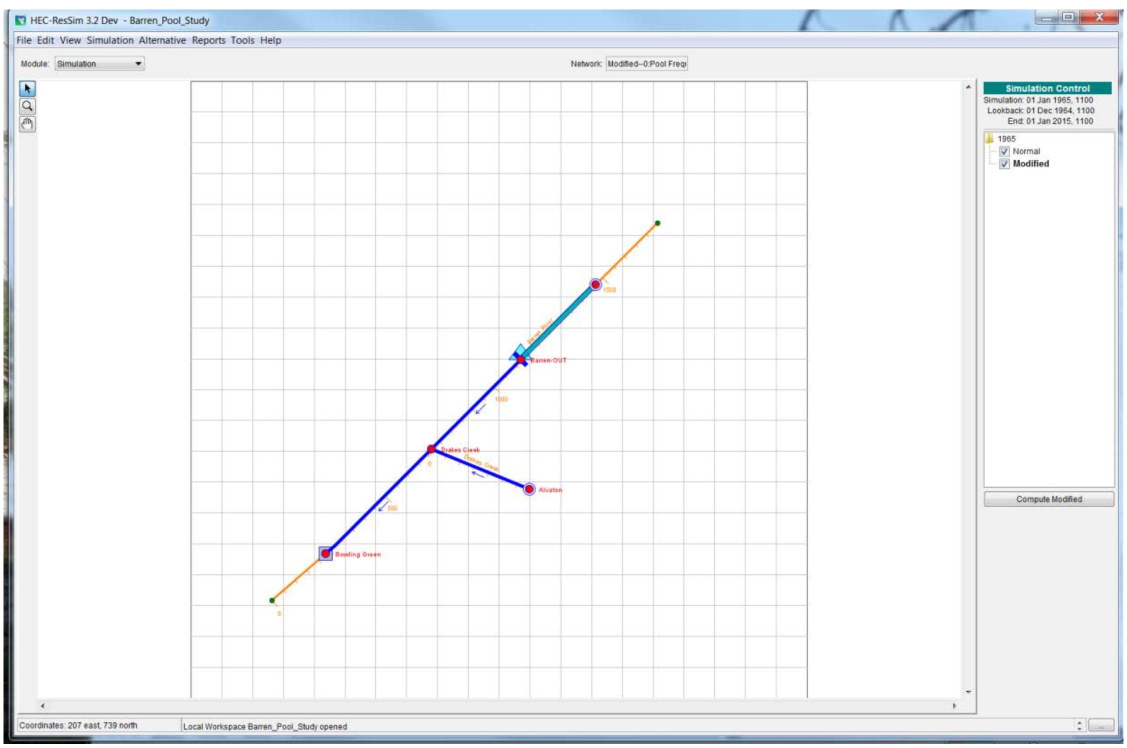

Figure 2.3: Layout for Barren Res-Sim Model

Nolin Reservoir:

The Nolin Reservoir Res-Sim model contrasted the difference in pool elevations resulting in raising the winter guide curve from an elevation of 490 ("Authorized") to 492 ("Current") feet NGVD 29 from the date of impoundment, July 1963, through 2014. All other modeling parameters and inputs were kept consistent; outflow guidelines (reservoir regulation rules), inflows, tributary flows from the Green River, etc.

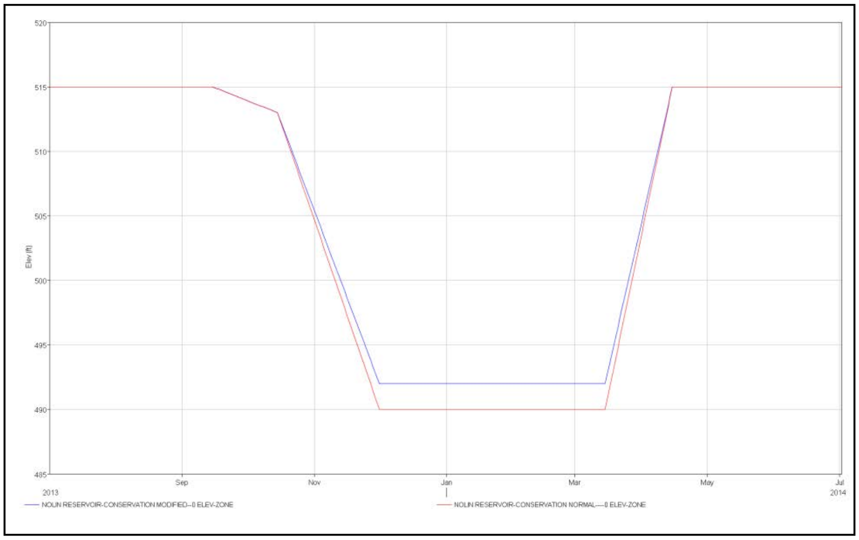

Figure 2.4: Nolin Reservoir Guide Curves as modeled

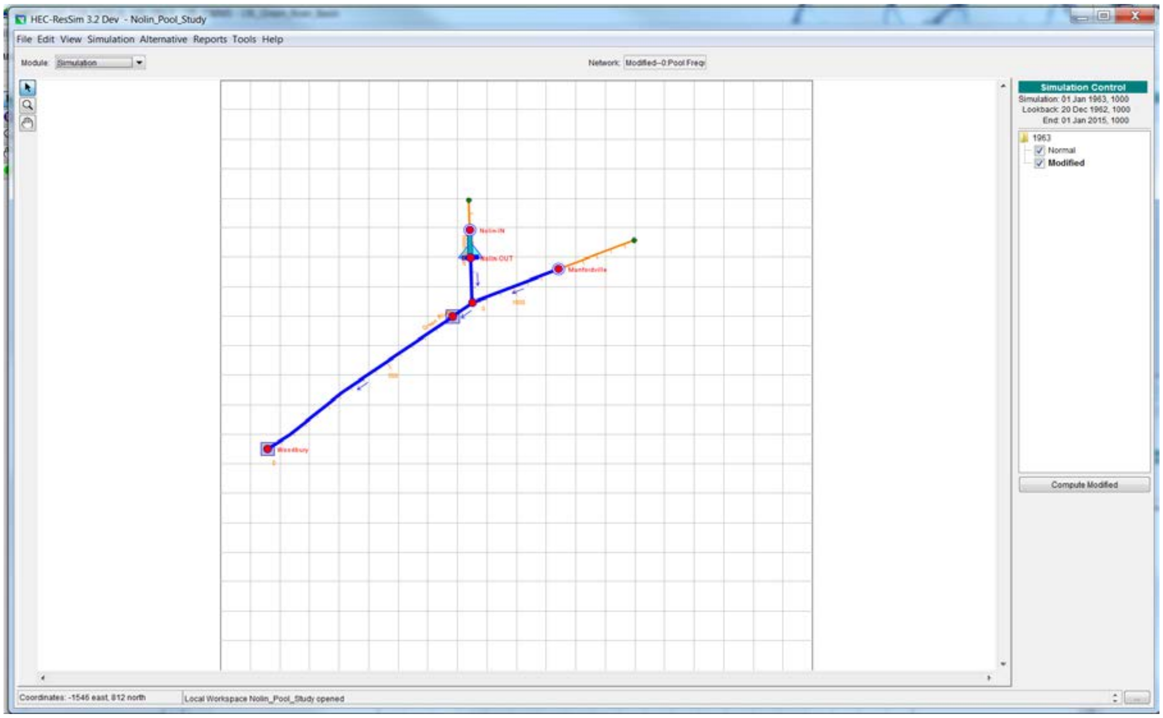

Figure 2.5: Layout for Nolin Res-Sim Model

Calibration:

Both the Barren and Nolin Res-Sim models were derived from the calibrated Green River CWMS model. An independent in-house calibration effort was undertaken for this study. Modeled pool elevation results for the "Authorized" simulations were compared to observed pool elevations and these results underwent two internal reviews by three other members of the LRL water management team. In both reservoir models all major differences in modeled vs. observed pool elevations were attributable to operational deviations. Examination of local USACE records show that the reasons for the discrepancies in all cases were the result of changes to normal operations due to maintenance, drought contingencies, flood operations, ecological considerations, and actual operational changes (adoption of or removal of operational rules).

Both modeling simulations for Barren and Nolin guide curves (Authorized and Current) were performed from the date of impoundment through 2014, and the peak pool elevations were then used to develop a peak pool frequency relationship.

2.2 Pool Frequency Analysis and Storage Utilization Comparison

In order to evaluate the impact to storage utilization between the Authorized and Current winter pool levels, pool frequency curves were developed using the Authorized and Current Res-Sim analysis results. A graphical frequency analysis was performed by assigning Weibull plotting positions to annual peak pool elevations (on a water-year basis) and median plotting positions to partial-duration peak pool elevations as recommended in EM 1110-2-1415. Partial-duration peaks were identified using engineering judgment to account for years that experienced multiple flood events. The annual and partial peak pool elevations were plotted on a probability scale at their computed plotting position. Best estimate curves were fitted to both the Authorized and Current data to compare storage utilization at each frequency. Figures 2.5 and 2.6 show the graphical pool frequency curves developed for Barren and Nolin, respectively. Tables 2.1and 2.2 show the increase in storage utilization comparing the Authorized and Current graphical pool frequency analysis.

Review of both sets of Figures and Tables indicate that there is a very small increase in the peak pool elevations for both Barren and Nolin resulting from the Current winter pools when compared to the Authorized winter pools. The maximum percent increase to flood control storage utilized was noted as 2.3% for Barren and 2.7% for Nolin.

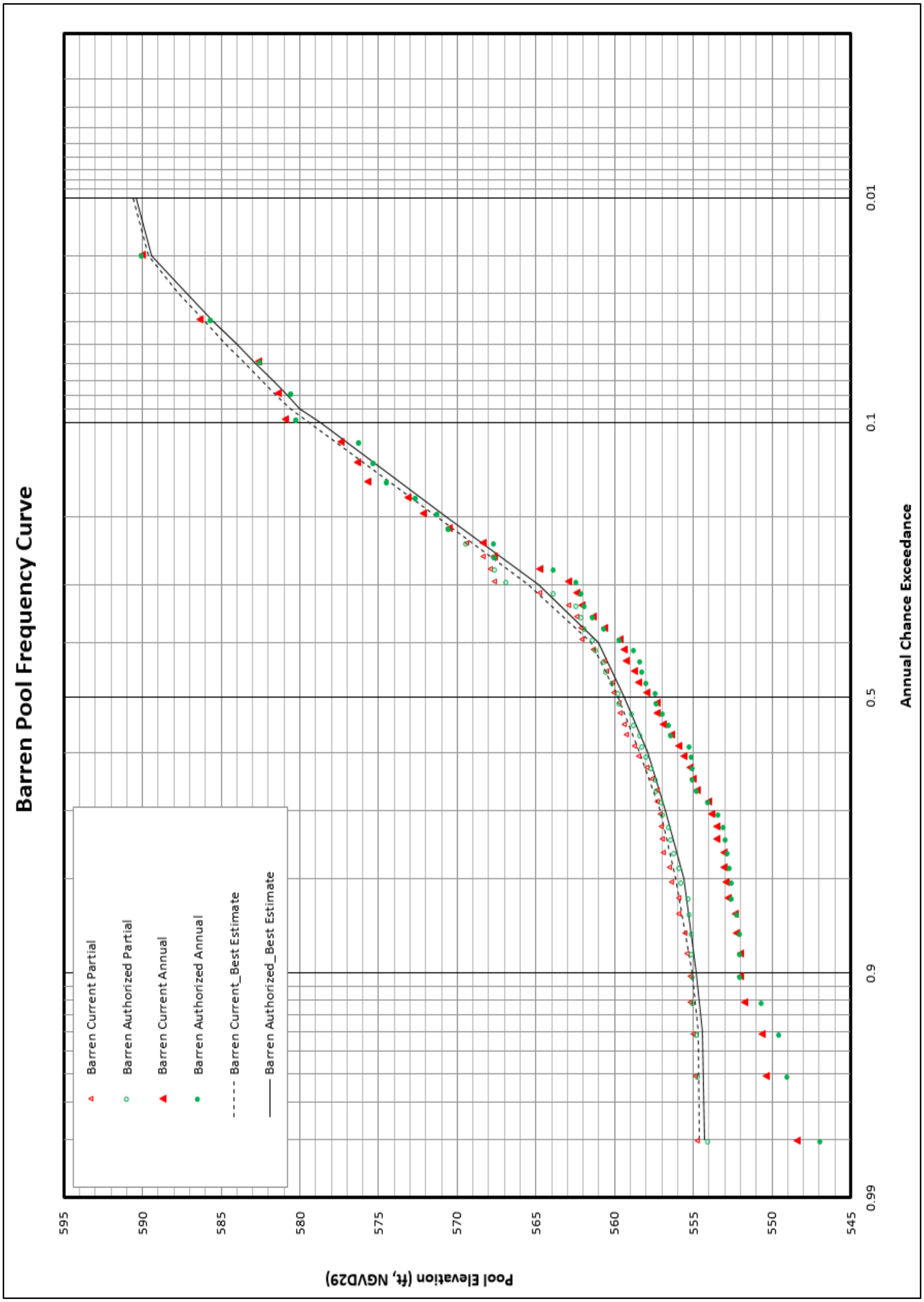

Figure 2.5: Barren River Authorized and Current Pool Frequency Curves

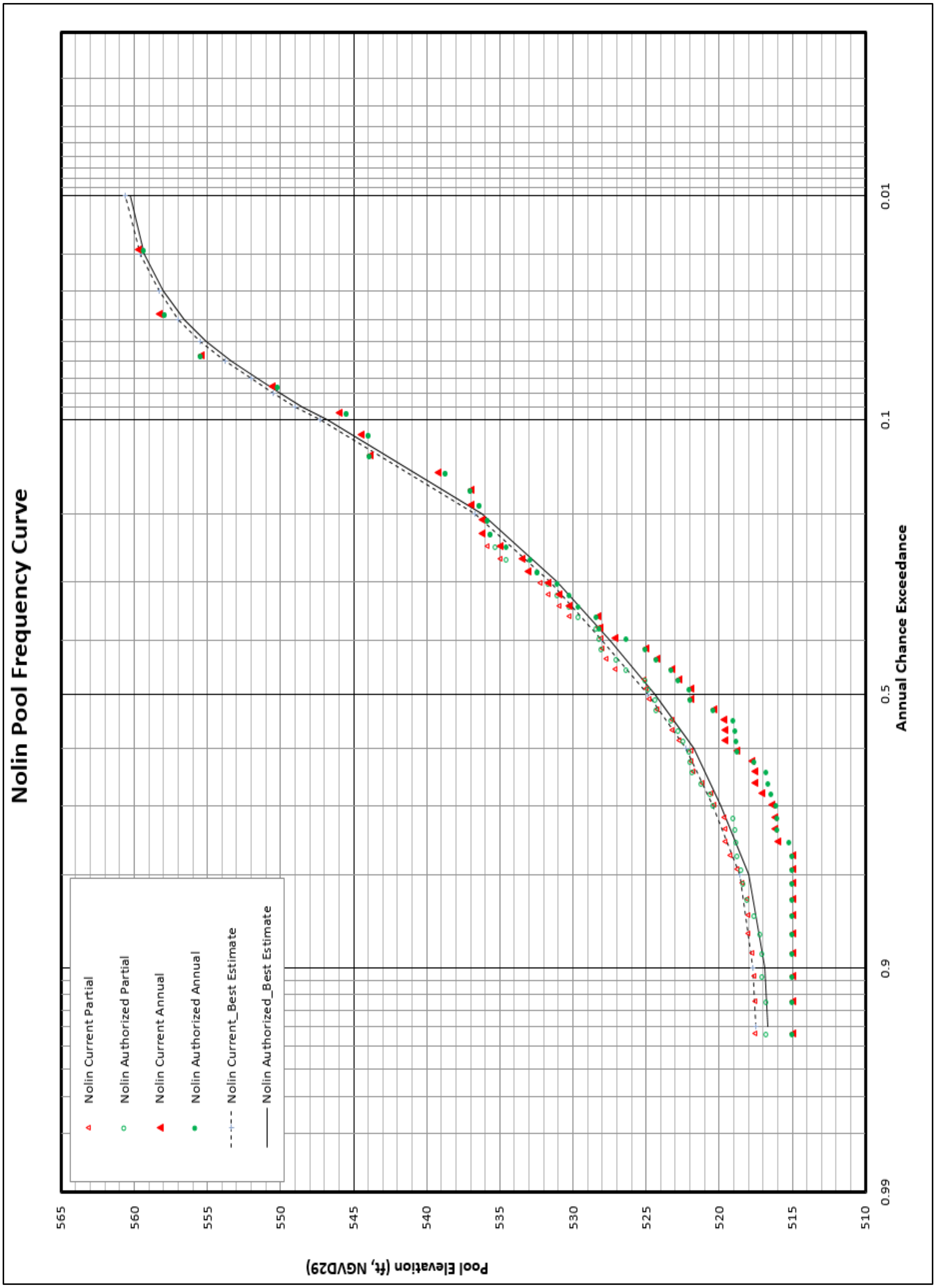

Figure 2.6: Nolin River Authorized and Current Pool Frequency Curves

Table 2.1: Barren River Reservoir Storage Utilization Comparison

Frequency (ACE)	Barren Authorized (525)	Barren Current (528)	Difference (Current minus Authorized)	% increase in storage
98%	554.6	554.3	0.30	1.1%
94%	554.7	554.4	0.30	1.1%
90%	555.1	554.8	0.30	1.1%
80%	556.1	555.6	0.50	1.8%
70%	557.1	556.8	0.30	1.1%
60%	558.4	557.9	0.50	1.8%
50%	559.8	559.4	0.40	1.4%
40%	561.5	561	0.50	1.7%
30%	565.5	564.8	0.70	2.3%
20%	571.3	570.7	0.60	1.8%
10%	579.4	578.7	0.70	1.9%
9%	580.6	580	0.60	1.6%
8%	581.5	580.8	0.70	1.9%
7%	582.4	581.7	0.70	1.9%
6%	583.5	582.8	0.70	1.8%
5%	584.7	584	0.70	1.8%
4%	586	585.5	0.50	1.3%
3%	587.7	587.2	0.50	1.3%
2%	589.6	589.4	0.20	0.5%
1%	590.6	590.4	0.20	0.5%

Table 2.2: Nolin River Reservoir Storage Utilization Comparison

Frequency (ACE)	Nolin Current (492)	Nolin Authorized (490)	Difference (Current minus Authorized)	% increase in storage
94%	517.5	516.7	0.80	2.7%
90%	517.7	516.9	0.80	2.7%
80%	518.6	518.0	0.60	2.0%
70%	520.4	519.9	0.50	1.7%
60%	522.3	521.7	0.60	1.9%
50%	524.9	524.4	0.50	1.6%
40%	528.0	527.5	0.50	1.5%
30%	531.6	531.1	0.50	1.5%
20%	536.7	536.2	0.50	1.4%
10%	547.3	546.8	0.50	1.3%
9%	549.0	548.5	0.50	1.3%
8%	550.5	550.0	0.50	1.3%
7%	552.0	551.6	0.40	1.0%
6%	553.8	553.4	0.40	1.1%
5%	555.5	555.1	0.40	0.9%
4%	557.0	556.6	0.40	1.0%
3%	558.3	558.0	0.30	0.7%
2%	559.6	559.3	0.30	0.7%
1%	560.6	560.3	0.30	0.7%

3. Impacts to Authorized Project Purposes

The following table for Barren River Reservoir lists positive and negative impacts for the Authorized and Current winter pool elevations, and reflects a compilation of correspondence with the Kentucky Department of Fish and Wildlife Resources (Fisheries Division), Barren River Lake State Park, local water treatment facilities, and project personnel. Several of the comments were brought to light during 2013 discussions concerning the possible negative impacts to the State Park Marina caused by the return to the Authorized winter pool of elevation 525.

Table 3.1: Positive (+) and Negative (-) Impacts of Authorized and Current Winter Pool Elevations at Barren River Reservoir

Barren River Reservoir	Return to Authorized Winter Pool of 525		Adopt Current Winter Pool of 528	
Flood Mitigation Storage	Total Storage Available = 749,030 ac-ft	+	Total Storage Available = 735,290 ac-ft (reduction of 1.8%)	-
Recreation	Damage to State Park facilities Loss of State Park Revenue & Visitation Boat Ramps less accessible & reduction of revenue	- -	No damage to State Park facilities State Park Revenue & visitation remains at current levels Boat Ramps and revenue remain at current levels	+ + +
Water Supply	Negative impacts to Water Quality, intakes and increased treatment cost	-	Positive impacts to Water Quality, intakes and decreased treatment cost	+
Fish & Wildlife Enhancement			Larger water surface area for Sandhill Cranes	+

The following table for Nolin River Reservoir lists positive and negative impacts for the Authorized and Current winter pool elevations, and reflects a compilation of correspondence with the Kentucky Department of Fish and Wildlife Resources (Fisheries Division), Nolin River Lake State Park, local water treatment facilities, and Nolin project personnel.

Table 3.2: Positive (+) and Negative (-) Impacts of Authorized and Current Winter Pool Elevations at Nolin River Reservoir

Nolin Lake	Return to Authorized Winter Pool of 490		Adopt Current Winter Pool of 492	
Flood Mitigation Storage	Total Storage Available = 545,590 ac-ft	+	Total Storage Available = 539,620 ac-ft (reduction of 1.1%)	-
Recreation	Increased damage to the Wax Marina Reduction in the number of vessels which can be moored at Wax Marina Inability of vessels to travel upstream of Wax Boat Ramp due to blocking of the channel by the marina (December – March) Probable loss of the use and visitation to Wax Boat Ramp due to silt; impacts recreation, USACE access, Marina repair work, and repair work to the Edmonson County Water District's intake. Increased maintenance to all Public Boat Ramps due to siltation issues. Decrease visitation and revenue at the Nolin Lake Lodge (Concessionaire operation with restaurant at Wax Recreation Area).	- - - - -	Decreased damage to Wax Marina. No reduction in Marina utilization Boat Ramp visitation will remain unchanged. Wax Ramp will remain usable for recreation and maintenance access. Navigation upstream of Wax Marina will be possible. No loss of visitation at Wax Boat Ramp	+ + + + + +
Water Supply	Edmonson County Water Intake is adversely impacted by sedimentation and would need to be reconfigured. Increased maintenance cost due to silt.	- -	Water intake can operate as currently configured. Silt related maintenance costs remain at present levels	+ +
Fish & Wildlife Enhancement	Inability to access upper portion of the lake during key study and sampling seasons for Crappie, Walleye, and White Bass. Possible impacts to cool water habitat in the summer months, would adversely impact the very successful Walleye fishery.	- -	Fewer sport fish lost through the outlet works. Ultimately results in improved cool water habitat during the summer months – benefits walleye population. Increased winter habitat/decreased angler pressure	+ + +

The above tables were developed independently of each other yet present very similar results. Return to the Authorized Winter Pool elevations will provide a small increase to the total volume of flood mitigation storage at both projects. The impact to other authorized project purposes favor adoption of the Current Winter Pool elevations.

4. Impacts Downstream of the Projects due to Higher Releases.

The modeled outflows resulting from operations based upon both Authorized and Current Winter Pool guide curves were reviewed and compared for both projects. For both projects, prior to a runoff event, target pools were maintained by releasing inflow. When a runoff event occurred within the respective basin and control points exceeded their respective thresholds, outflows were set to their respective flood settings and remained there until the downstream control points receded and allowed for the safe evacuation of excess storage. The volume of storage captured during an event was identical, regardless of target winter pool, and was released in accordance to the conditions of the respective WCPs until the target pool was achieved. Minor differences in outflow were noted during the fill and depletion portion of the Authorized verses Current guide curves resulting from the different slopes of these filling and depletion curves.

Nolin River Reservoir:

There were instances when the outflow resulting from the Current Winter Pool guide curve exceeded the outflow when compared to the Authorized Winter Pool guide curve. This occurred when the downstream conditions allowed for a greater release rate and the pool elevation was not yet at its target level. One such instance is illustrated in the table below for Nolin Lake for 23-27 April 2008. (Note: the target pool for Nolin from 15 April thru 15 September is elevation 515.0)

Table 4.1: Comparison of outflow for Authorized and Current Winter Pools at Nolin River Reservoir

Date	Pool Elevation Current (WP elev 492)	Outflow Current (WP elev 492)	Pool Elevation Authorized (WP elev 490)	Outflow Authorized (WP elev 490)
23April2008	521.2	7,250 cfs	520.3	7,320 cfs
24April2008	518.9	8,370 cfs	517.8	8,850 cfs
25April2008	515.9	10,000 cfs	515.0	9,090 cfs
26April2008	515.0	3,330 cfs	515.0	720 cfs
27April2008	515.0	675 cfs	515.0	675 cfs

All outflows in this table are at or below the maximum authorized release of 10,000 cfs therefore there are no adverse downstream impacts due to releases associated with holding a winter pool of 492. No spillway flow occurred during the simulation period, therefore releases from the project greater than the maximum authorized did not occur.

Barren River Reservoir:

During mid-April of 1979, the modeled pool elevation for both the Authorized and Current guide curves exceeded the uncontrolled spillway crest elevation. The Authorized guide curve resulted in one day of spillway flow with a peak daily outflow of 7,770 cfs on 15 April. The Current guide curve resulted in two days of spillway flow with a peak daily average outflow of 10,000 cfs on 14 April and an average daily outflow of 8,150 cfs on 15 April.

Most of the impacts immediately below Barren River Lake are agricultural, until the river reaches the city of Bowling Green, Kentucky. Bowling Green is the third largest city within the Commonwealth of Kentucky. The peak flow at Bowling Green resulting from this event occurred on 13 April, prior to the spillway flow, while the project was releasing at its flood setting (300 cfs) for both modeled scenarios, as per the Water Control Plan. The modeled peak for this event was 18,680 cfs, approximately two feet below the NWS action stage and four feet below the National Weather Service's Minor Flood Stage of 28 feet at Bowling Green and was a result of the local inflow below Barren River Lake. The project's spillway flow resulting from both the Authorized and Current simulations backfilled the natural recession with no adverse impact to the actual crest at Bowling Green. See table below for a comparison of the modeled flows at Bowling Green and Barren's outflow for both the Authorized Guide curve and the Current guide curve.

Table 4.1: Comparison of outflow for Authorized and Current Winter Pools at Barren River Reservoir

Date	Flow @ Bowling Green Authorized (WP elev 525)	Barren Outflow Authorized (WP elev 525)	Flow @ Bowling Green Current (WP elev 528)	Barren Outflow Current (WP elev 528)
12 April1979	11,000 cfs	300 cfs	11,000 cfs	300 cfs
13 April1979	18,680 cfs	300 cfs	18,680 cfs	300 cfs
14 April1979	8,160 cfs	300 cfs	17,800 cfs	10,000 cfs
15 April1979	11,660 cfs	7,770 cfs	12,000 cfs	8,150 cfs
16 April1979	7,250 cfs	3,980 cfs	7,250 cfs	3,980 cfs
17 April1979	5,880 cfs	3,170 cfs	5,880 cfs	3,170 cfs

Barren River Reservoir only controls approximately 50% of the drainage area at Bowling Green. While reviewing these results it was noted that on 3 April 1979, a previous event resulted in a daily average flow of 23,500 cfs at Bowling Green due to uncontrolled runoff while Barren River Reservoir (both scenarios) was releasing at its flood setting of 300 cfs. Although the outflow from Barren River Dam was higher under the Current modeled scenario, there were no adverse impacts because flow at Bowling Green corresponding to this release was still well below Action Stage.

5. Environmental Impacts

Environmental Assessments (EAs) were compiled in May of 2014 for both Barren River and Nolin Lakes. Both assessments evaluated the impacts of raising the authorized winter pools to their current operational levels. In both instances, the impacts to the environment were found to be cumulatively insignificant.

In accordance with the provisions of the National Environmental Policy Act (NEPA) and the Corps of Engineers Regulation ER 200-2-2 for implementing NEPA, a 30-day period for the public, agency, and governmental officials to offer comments to the Louisville District regarding the EAs was held in May thru June, 2014. All comments received were considered in the decision to sign a Finding of No Significant Impacts.

6. Impacts from Climate Change

Green River Basin

USACE projects, programs, missions, and operations have generally proven to be robust enough to accommodate the range of natural climate variability over their operating life spans. However, recent scientific evidence shows that in some places and for some impacts relevant to USACE operations, climate change is shifting the climatological baseline about which that natural climate variability occurs, and may be changing the range of that variability as well. This is relevant to USACE because the assumptions of stationary climatic baselines and a fixed range of natural variability as captured in the historic hydrologic record may no longer be appropriate for long-term projections of the climatologic parameters, which are important in hydrologic assessments for inland watersheds, such as the Green River Basin.

Literature Review:

A January 2015 report[1] conducted by the USACE Institute for Water Resources summarizes the available literature for the Ohio Region, which includes the Green River Basin. The report focuses on both observed climatic trends, as well as projected future findings. While the observed trends may prove to be of some importance, it is the projected findings which are of the most significance.

The report finds a strong consensus supporting trends of increasing air temperatures. Average minimum temperatures are expected to experience a small increase, while temperature maximums are predicted to undergo a large increase. Projected increases of mean annual air

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[1] USACE Institute for Water Resources. (2015). *Recent US Climate Change and Hydrology Literature Applicable to the US Army Corps of Engineers Missions - Ohio Region.*

temperature range from 0 to 8º C by the latter half of the 21st century. Projections regarding precipitation and hydrologic streamflow trends are less certain, with some studies calling for increases whereas others call for decreases.

Nonstationarity Detection Tool:

Other tools also exist for analyzing climatic trends and projections in the Green River Basin; one such tool is the Nonstationarity Detection Tool[2]. This tool analyses whether the assumption of stationarity, which is the assumption that statistical characteristics of time-series data are constant over the period of record, is valid for a given hydrologic time-series data set.

This tool was utilized using data collected from Lock 2 at Calhoun on the Green River, which was chosen as it is a control point for Nolin River Lake as well as other USACE operated reservoirs. The tool identified multiple nonstationarities in the data collected during water years 1963 – 1965. However, nonstationarities are to be expected in this time range, as the impoundment of Rough, Nolin, and Barren River Lakes took place in 1959, 1963, and 1964, respectively. In addition to these three reservoirs, Green River Lake was impounded in 1969, however no nonstationarities were detected during this time frame. Other than those created by the reservoirs' construction, no other nonstationarities were detected at the Calhoun Gage on the Green River. Figure 1, Appendix A, displays the Nonstationarity Detection Tool's output.

Observed Trends:

In addition to the existing literature and nonstationarity tool summarized above, a qualitative analysis[3] was conducted using data from gages located within the Green River Basin. 2 qualitative methods were utilized and accessed daily discharge data from Lock 2 at Calhoun on the Green River. The period of record was limited to 1970 – 2014 in an effort to avoid the statistical changes imposed on the stream by the construction of the four dams mentioned in the previous section. The first qualitative method involves performing a linear regression of the annual maximum daily discharge and is shown as Figure 2. The second method is similar to the first, however it uses the largest 3-day annual maximum discharge and is shown as Figure 3, Appendix B. Note that in both Figures 2 and 3, p is equal to 0.979 and 0.975, respectively. In both cases, p is greater than 0.05 and therefore the data does not exhibit a statistically significant slope and no trends are apparent.

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[2] Friedman, D., J. Schechter, B. Baker, C. Mueller, G. Villarini, and K. D. White. (2016), US Army Corps of Engineers Nonstationarity Detection. US Army Corps of Engineers: Washington, DC.

[3] United States Corps of Engineers. (2014). *Engineering and Construction Bulletin: Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects.*

Projected Future:

Figure 4, Appendix B, displays the range of the forecast annual maximum monthly flows computed by 93 different hydrologic climate models for a period of 2000 – 2099. These forecast flows display trends consistent with that of observed data as well as available literature. No substantial trend is visible within the projected flows.

Conclusions:

Overall, no strong signal exists within the data to indicate what definitive impacts climate change will hold. While the literature indicates a slight increase in observed precipitation, there seems to be no substantial increase in observed streamflow. The literature is also conflicted as to projected streamflow, indicating flow magnitude and occurrence do not exhibit any apparent trends. The strongest consensus amongst the literature supports the trend of increasing temperatures.

Based on this assessment, which shows no significant signals, the recommendation is to treat the potential effects of climate change as occurring within the uncertainty range calculated for the current hydrologic analysis.

7. Public Involvement Process

If LRD concurs with the recommendation below; to permanently raise the winter pool at one or both of the projects, public involvement will be coordinated with the respective project(s). This involvement will consist of providing information to the public conveying the adoption of the Current Winter Pool as the new "Authorized" Winter Pool. LRL Public Affairs Office will notify the appropriate local media outlets and announce the purpose, time and location of an "Open House". This information will be provided 30 days prior to the Open House, to be held at the affected reservoir project office where questions will be answered by project staff and a member of the LRL Water Management Team.

8. Recommendation

This report illustrates that adoption of the "Current" higher Winter Pools at both projects results in negligible adverse impact to the projects' flood mitigation mission and many positive impacts on the projects' ancillary purposes. The Louisville District recommends that the Barren River Reservoir's authorized winter pool of 525.0 be raised to 528.0. The District also recommends that Nolin Reservoir's authorized winter pool be raised from elevation 490.0 to 492.0.

Appendix A

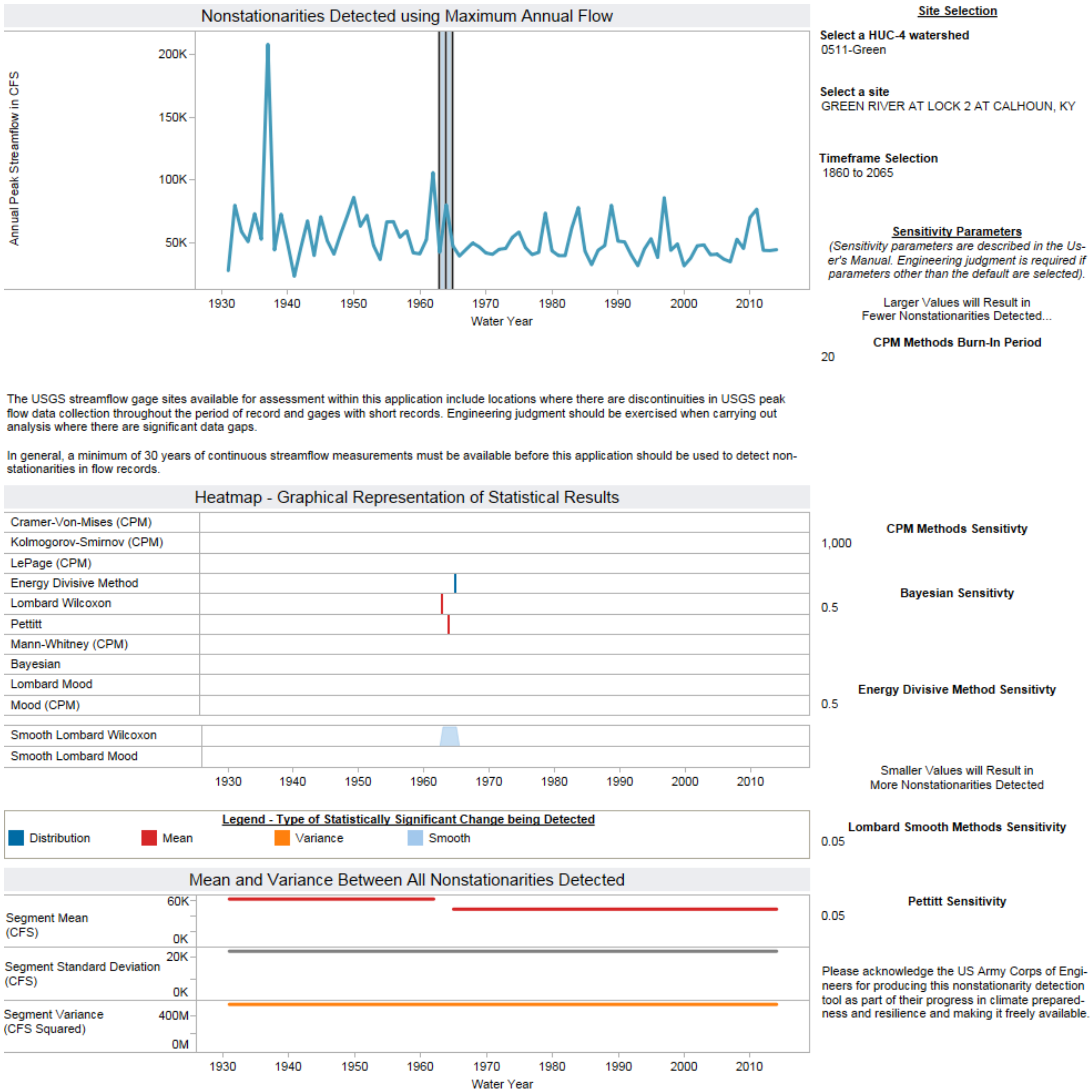

Figure 1

Appendix B

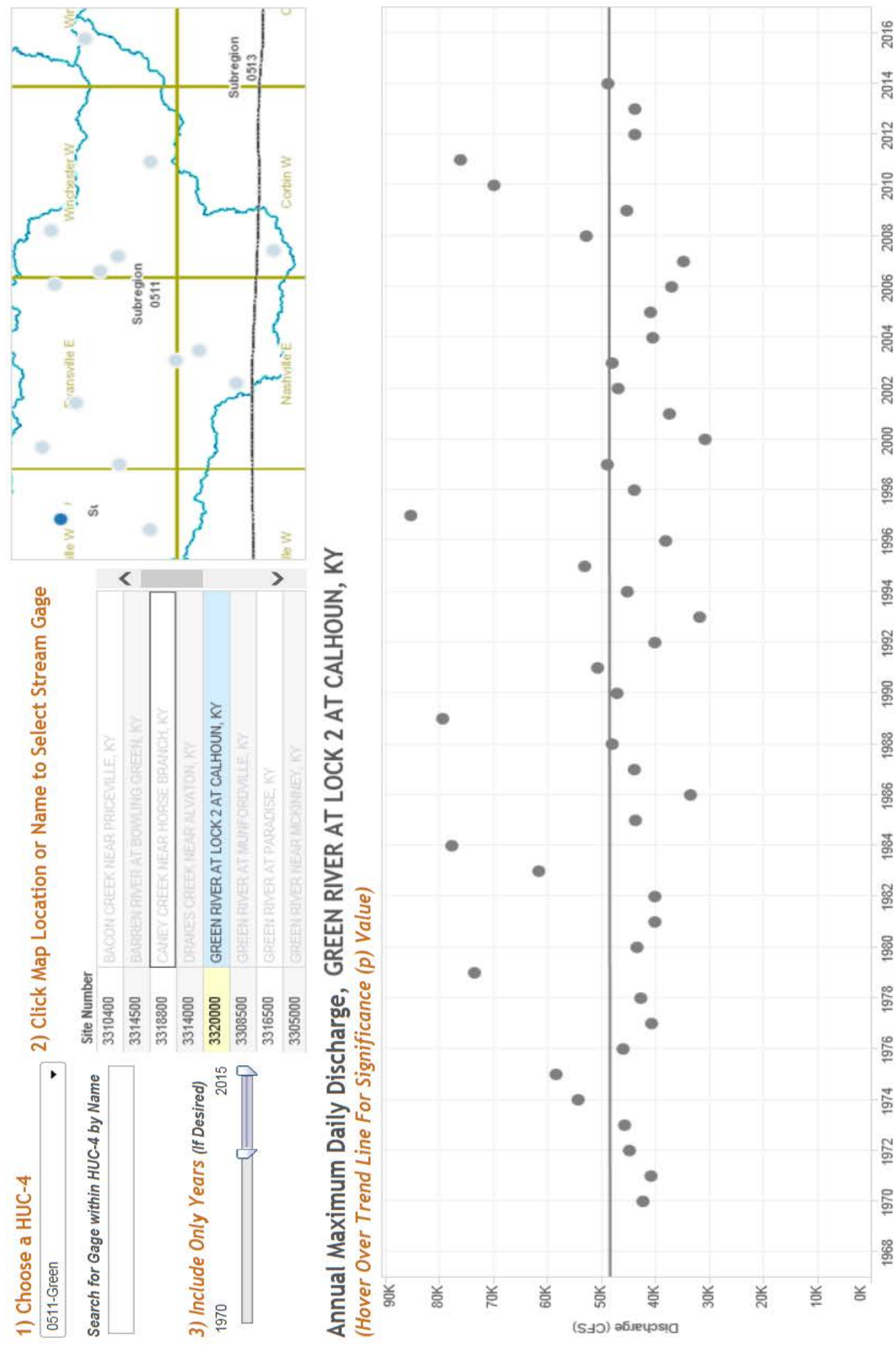

Figure 2
Trendline Equation: Q = 3.96574 * (Water Year) + 40480.2
p = 0.979

Appendix C

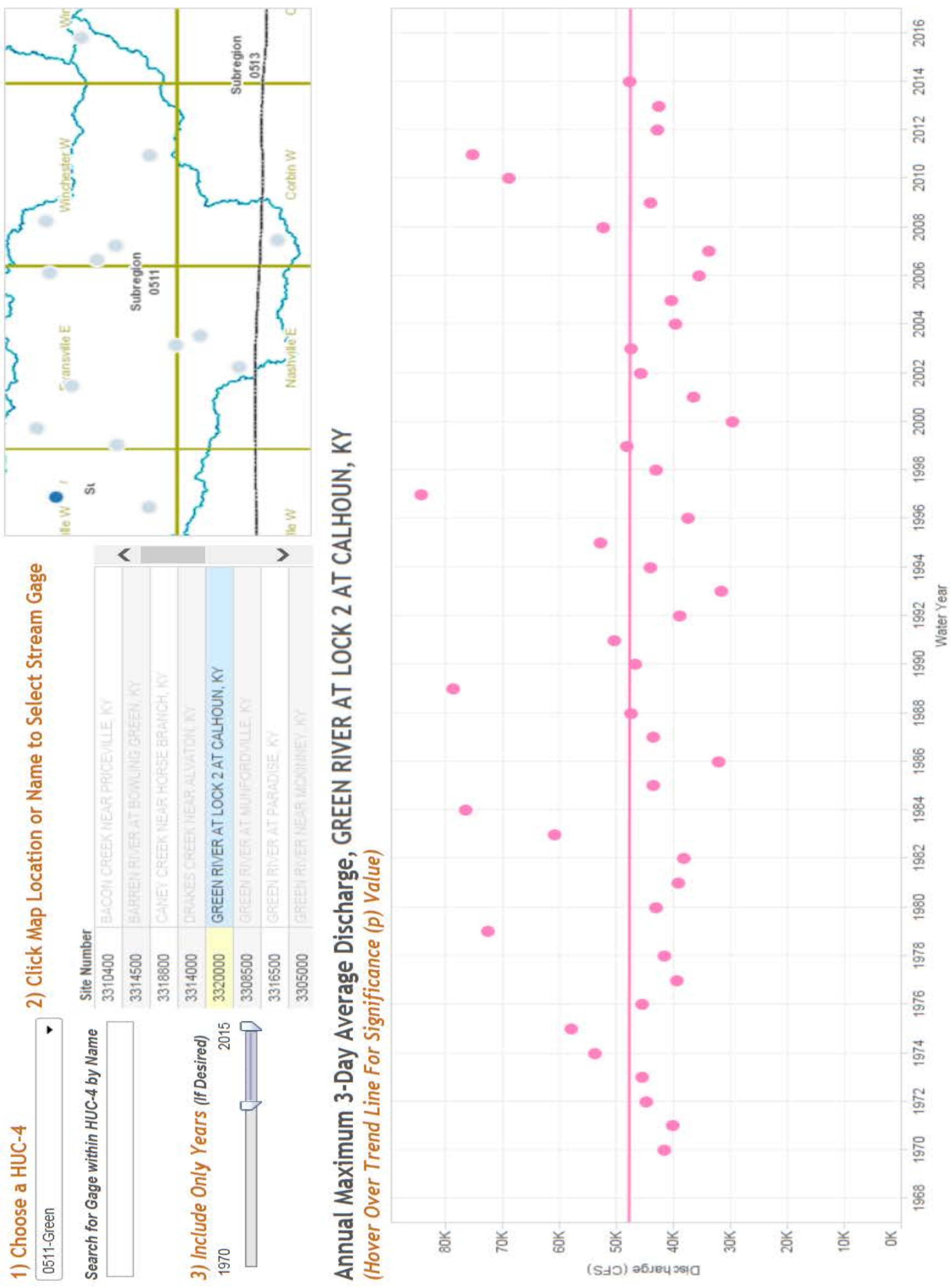

Figure 3
*Trendline Equation: Q = -4.80896 * (Water Year) + 57175.7*
p = 0.975

Appendix D

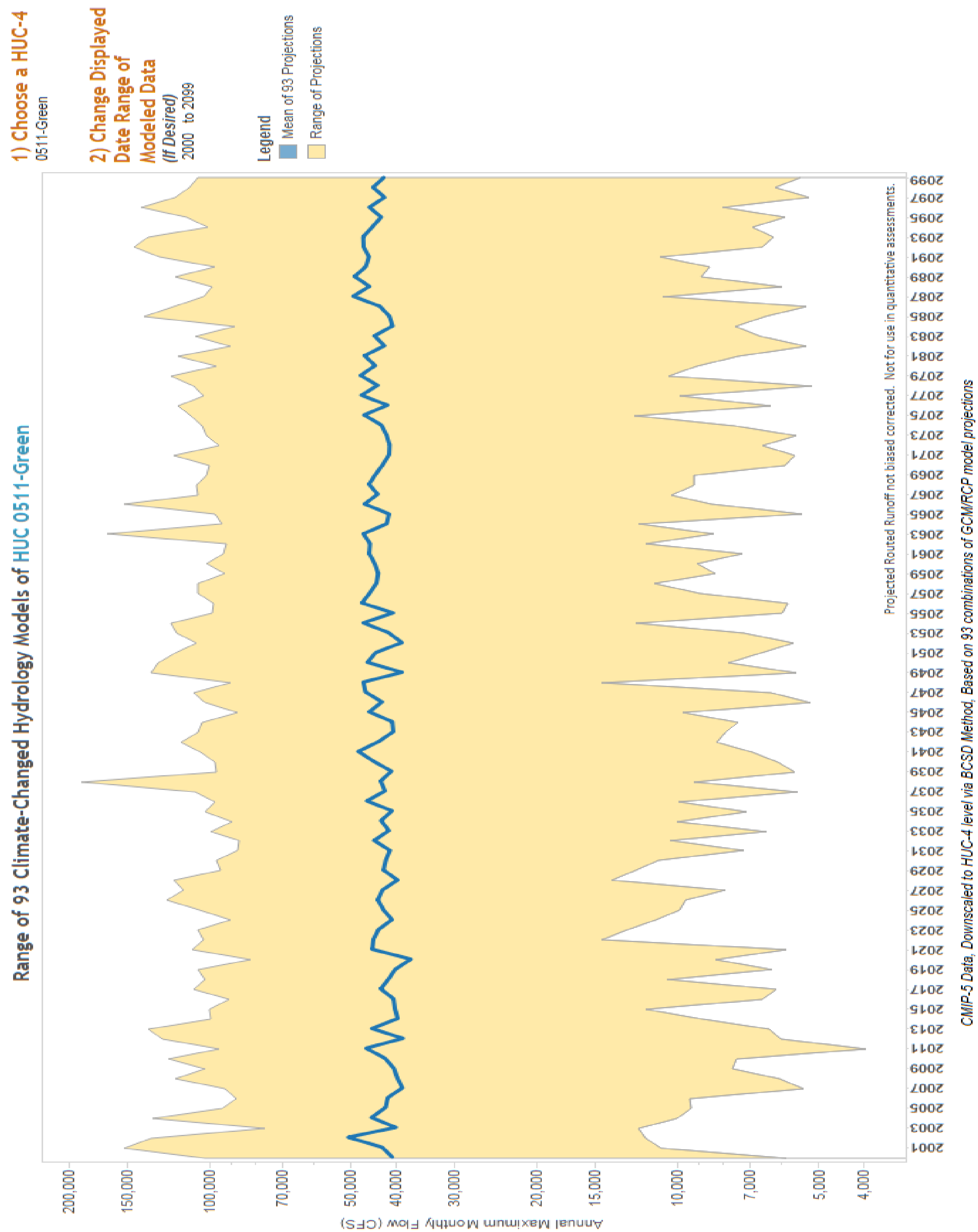

Figure 4