November 2020

Allatoona Lake Water Supply Storage Reallocation Study and Updates to Weiss and Logan Martin Reservoirs Project Water Control Manuals

Final Feasibility Report and Integrated Supplemental Environmental Impact Statement

Appendix C. Modeling and Engineering (Attachments 9–11)

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Attachment 9. Stage and Flow Hydrographs

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APPENDIX C. ATTACHMENT 9: STAGE AND FLOW HYDROGRAPHS

C.1 Description and Use

The purpose of this attachment is to provide stage and flow hydrographs for selected locations along the Etowah, Oostanaula, and Coosa River. For every location a graph is presented for each of the modeled storms. Each graph shows the base as well as the proposed hydrograph. Each river mile reflects a specific HEC-RAS cross section. Maps are provided along with descriptions to better understand the physical location that each graph represents.

C.2 Location Descriptions

Table 1 below describes the locations of the sites chosen to display output data below Allatoona Dam, while Figure 1 gives a visual location of the sites (the "Map Location" field of the table should be used to match the location to the river mile).

Table 1: Description of model output locations below Allatoona Dam

Map Location	River Mile*	Location Description
Etowah River		
A	48.2	Just Downstream of Allatoona Dam
B	39.21	Near Cartersville
C	20.62	Near Kingston
D	1.7675	Upstream of Turner McCall Blvd.
E	0.325	Upstream of South Broad Street
Oostanaula River		
F	2.3384	Upstream of Veteran's Memorial Pkwy
G	0.89	Adjacent to the Upstream end of the Rome Levee
H	0.37	Downstream of 5th Ave
Coosa River		
I	271.16	Adjacent to the gated road closure in the Rome Levee
* River mile values reflect specific HEC-RAS Cross Sections		

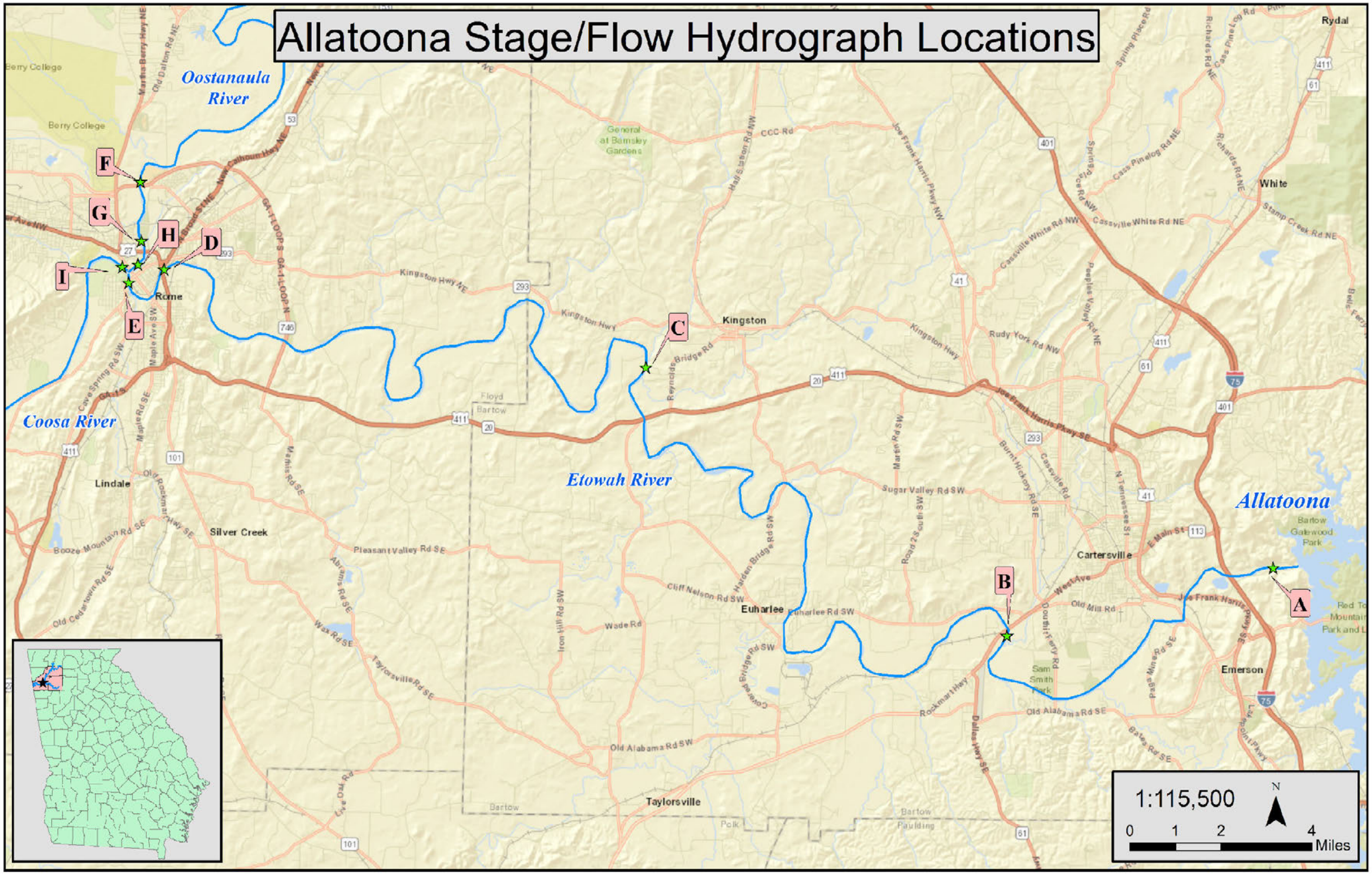


Figure 1: Allatoona Stage/Flow Hydrograph Location

Table 2 describes the locations of the sites chosen to display output data below Wiess and Logan Martin Dams, while Figure 2 and Figure 3 give a visual location of the sites (the "Map Location" field of the table should be used to match the location to the river mile).

Table 2: Description of model output locations below Weiss and Logan Martin Dams

Map Location	River Mile*	Location Description
Weiss		
A	213.98	Downstream of Weiss Spillway
B	195.22	Downstream of Weiss Powerhouse
C	192.04	River Adjacent to Coosa Drive
D	187.35	River Adjacent to Longview Drive
E	166.33	River Adjacent to power plant and Goodyear
F	163.39	River Upstream of the 759 Bridge
G	138.66	Downstream of Neely Henry Dam
H	113.63	River Upstream of the I-20 Bridge
Logan Martin		
I	90.65	Downstream of Logan Martin Dam
J	84.45	Adjacent to the Childersburg Industrial Complex
K	81.51	Adjacent to the Paper Mill
L	78.8	River Upstream of the 38 Bridge in Childersburg
M	69.33	Adjacent to the Power Plant
N	44.43	Downstream of Lay Dam
* River mile values reflect specific HEC-RAS Cross Sections		

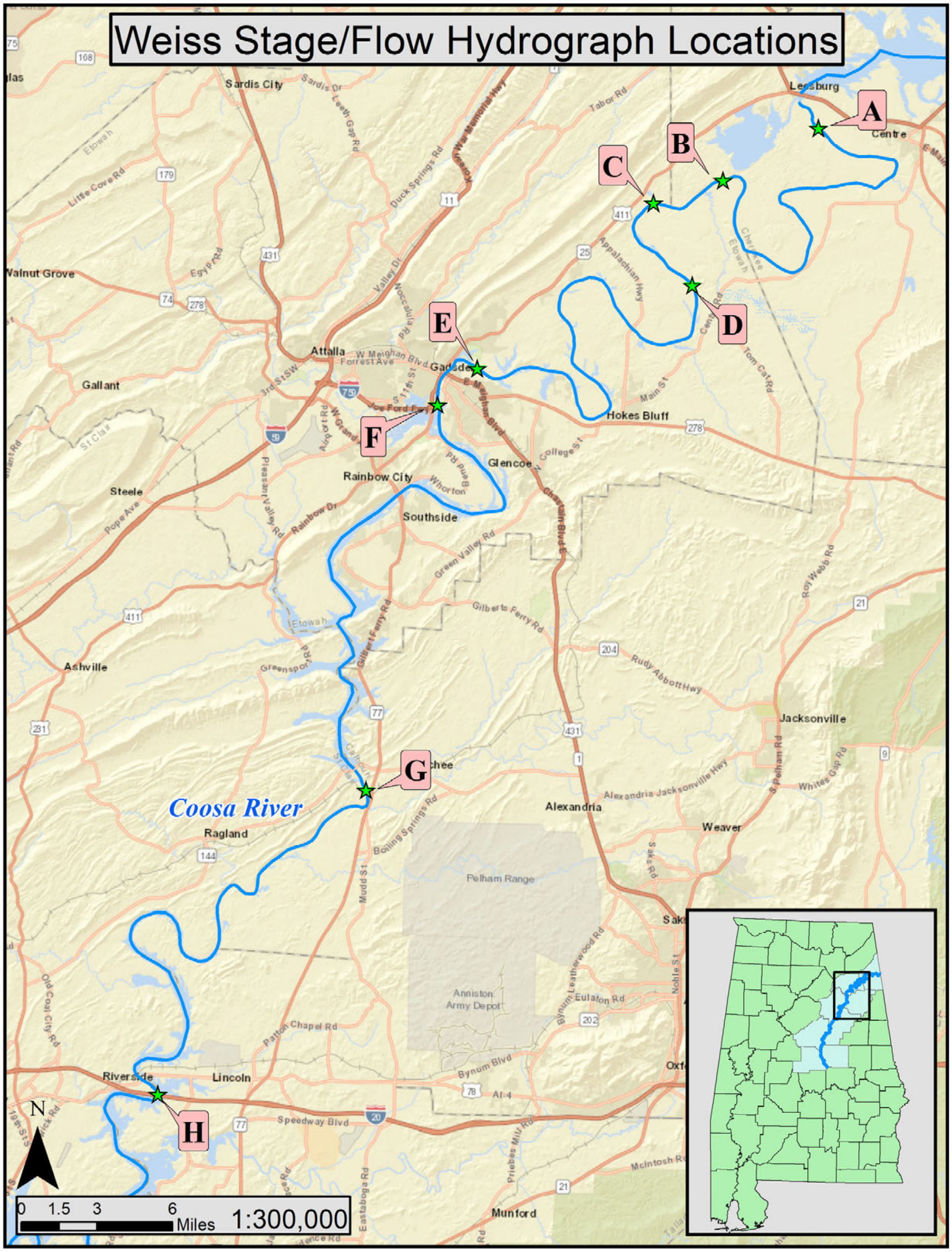


Figure 2: Weiss Stage/Flow Hydrograph Locations

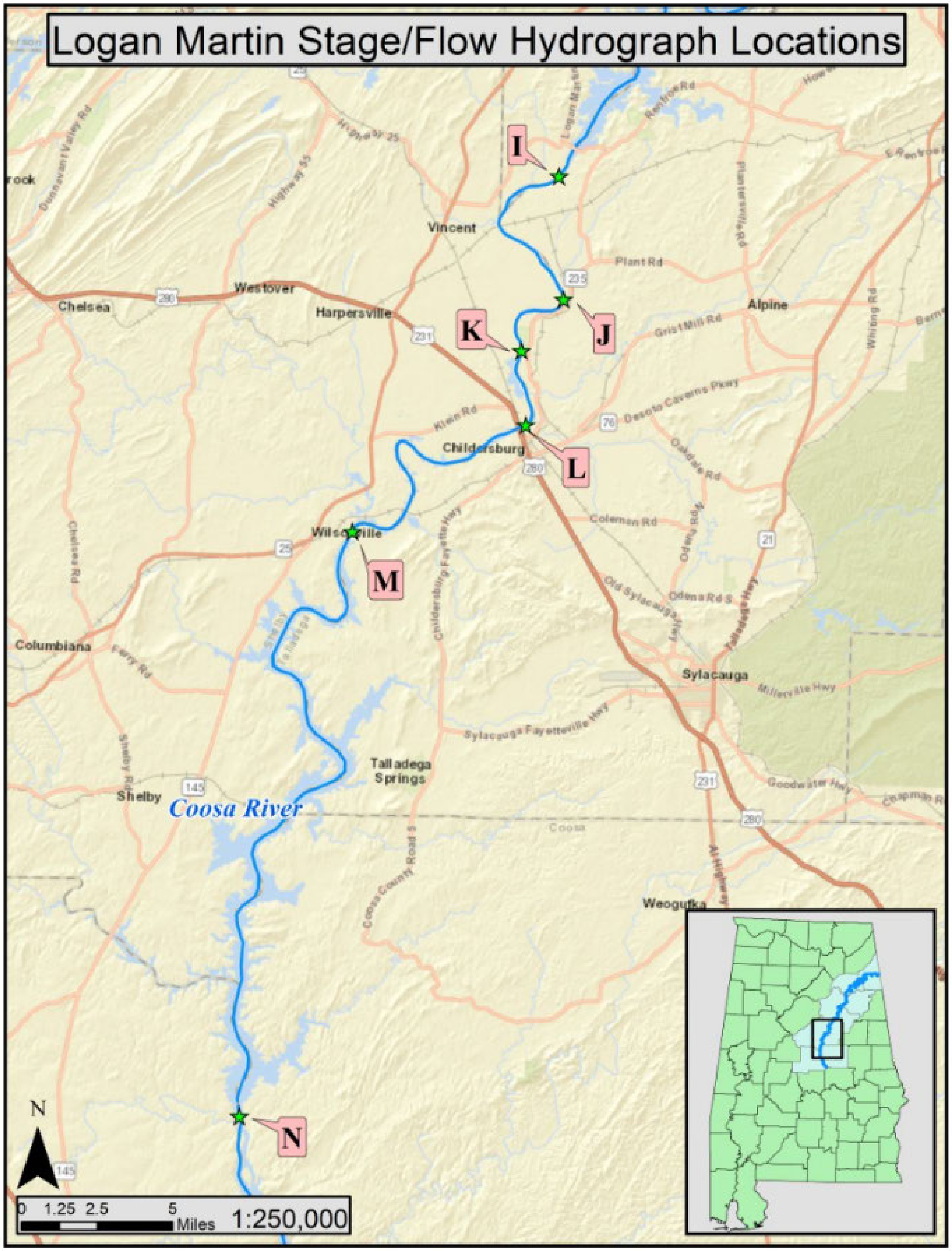
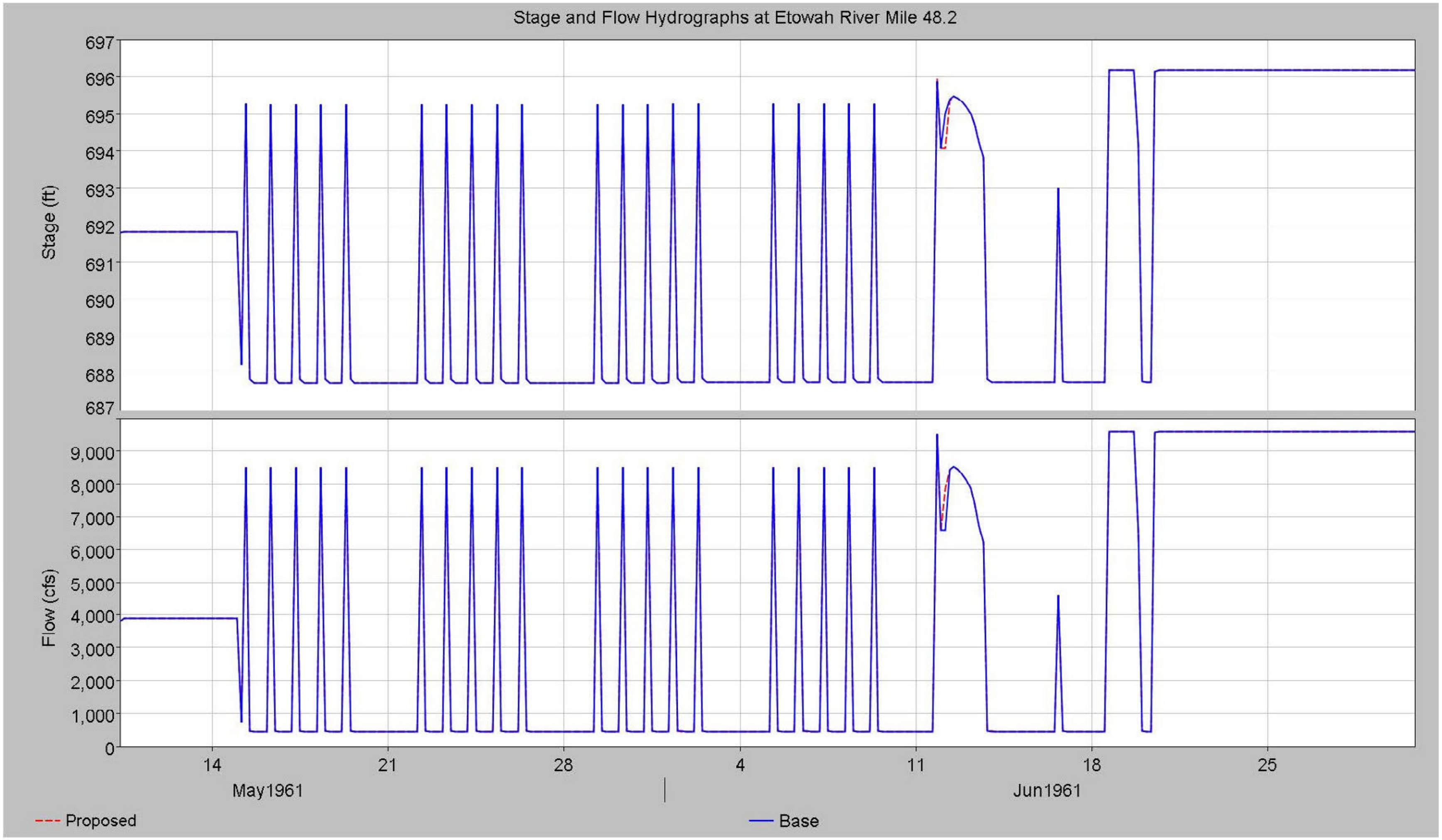
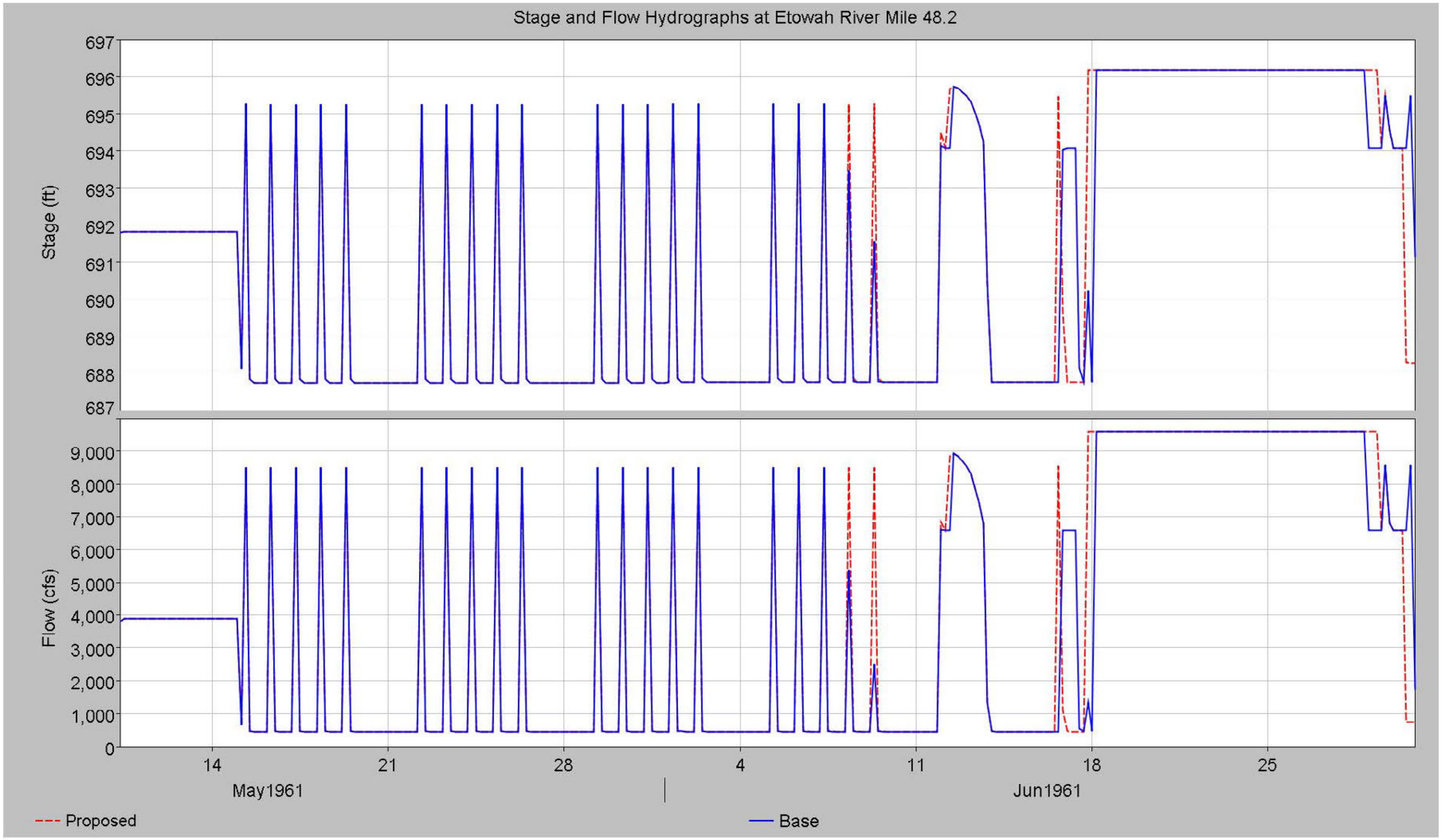


Figure 3: Logan Martin Stage/Flow Hydrograph Locations

C.3 Stage Flow Hydrographs



Stage/Flow at Etowah River Mile 48.2 Dowstream of Allatoona Dam for the 1961 Storm Scaled to a 0.2% ACE



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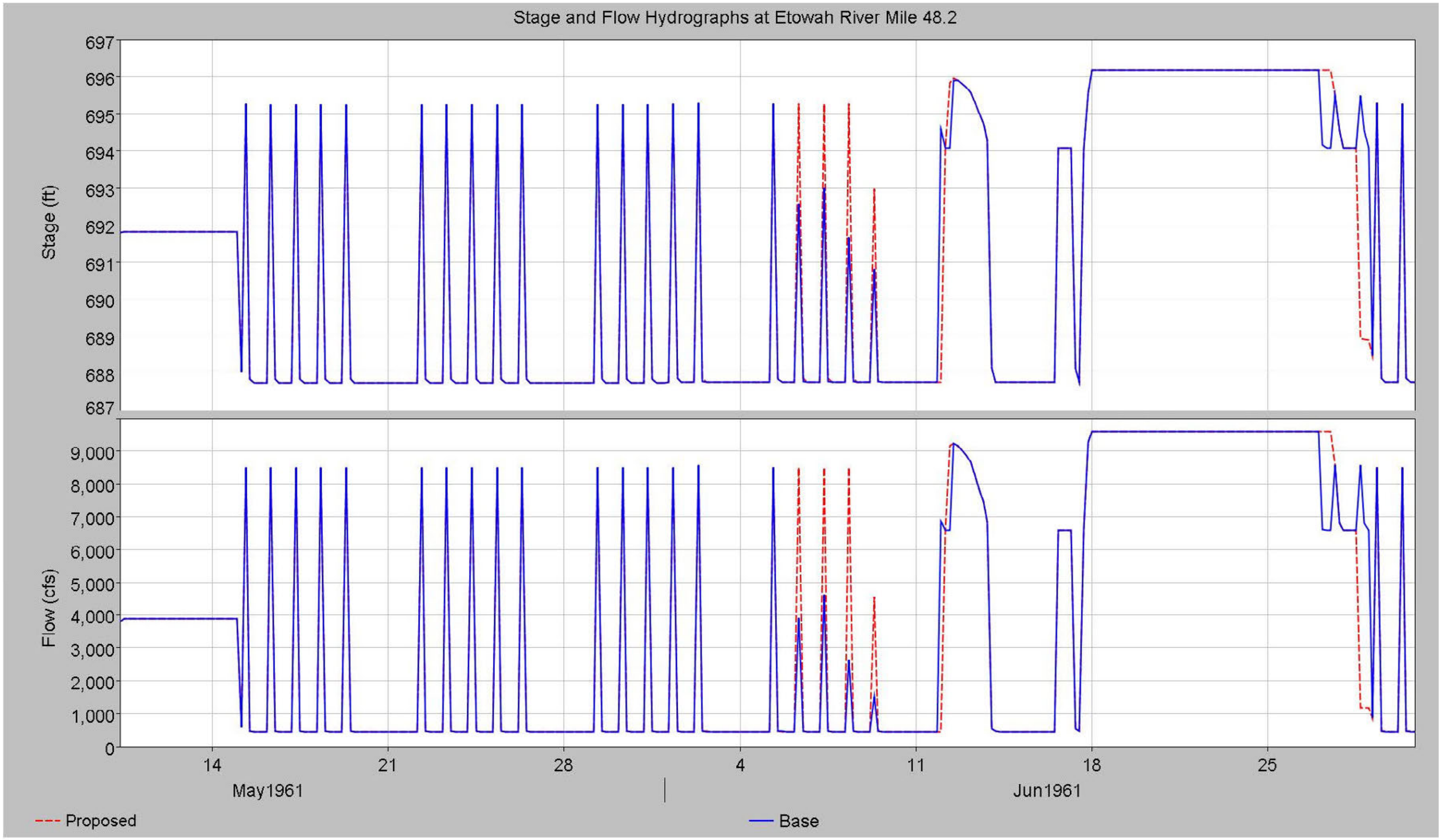

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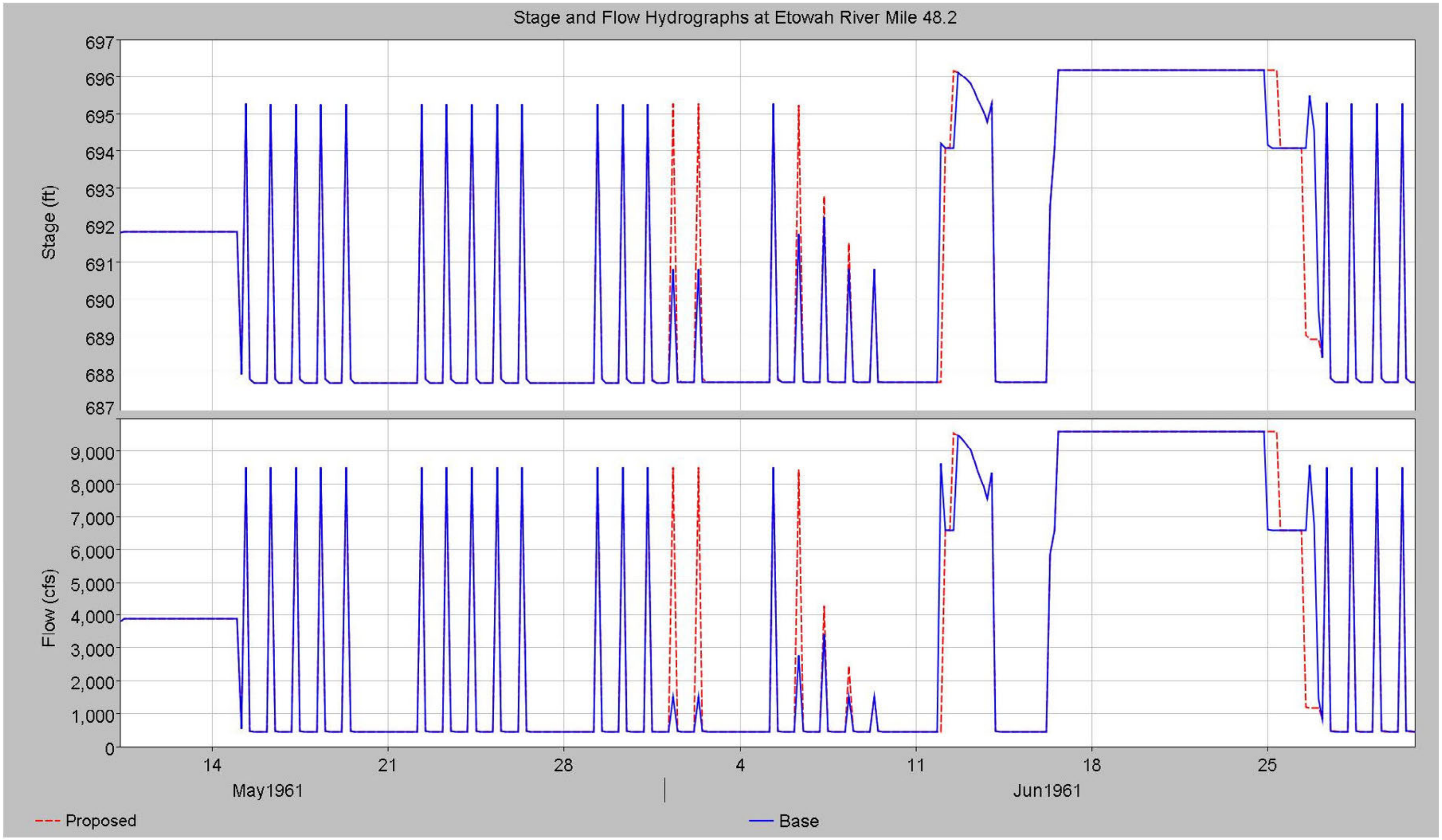

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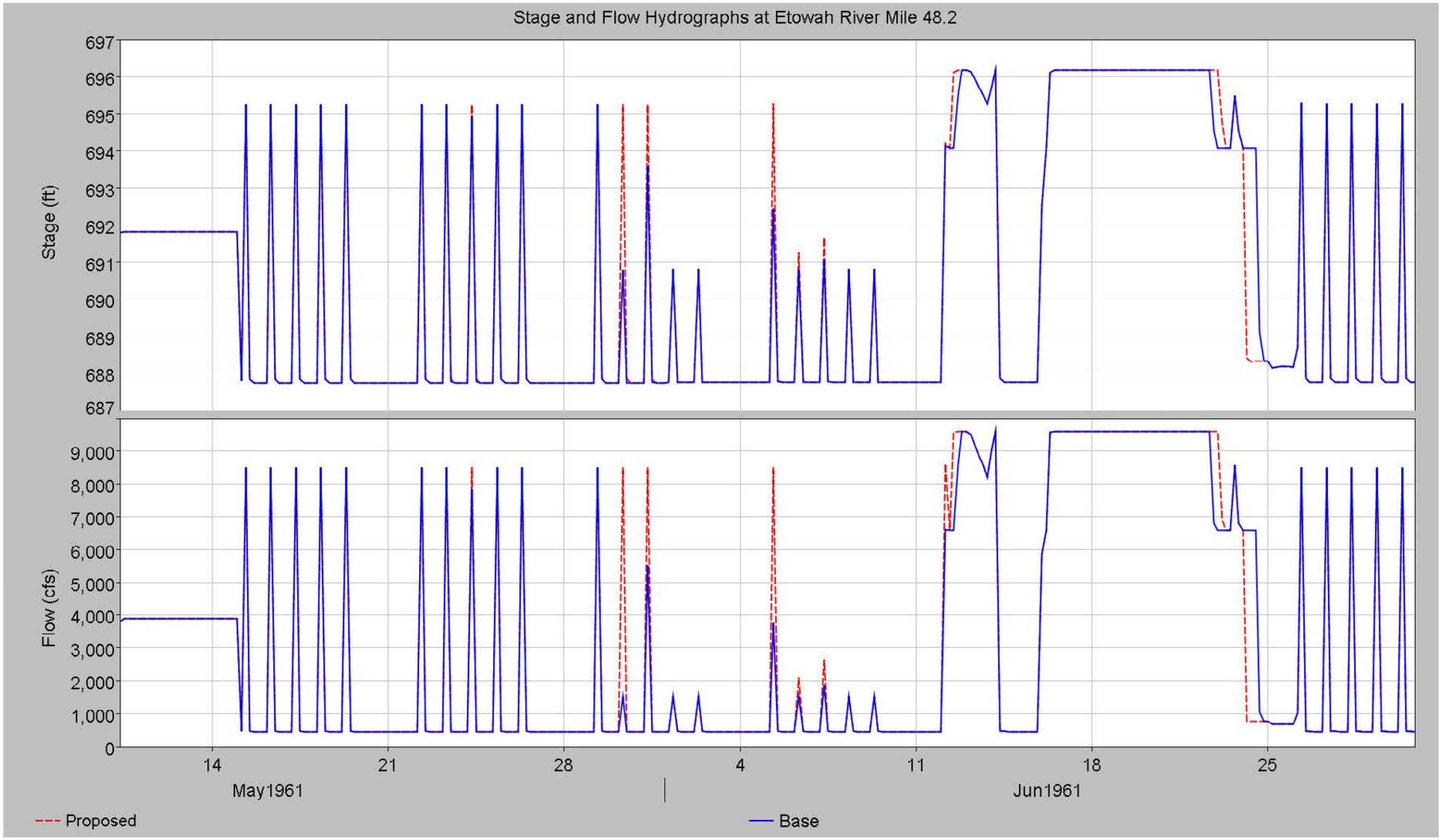

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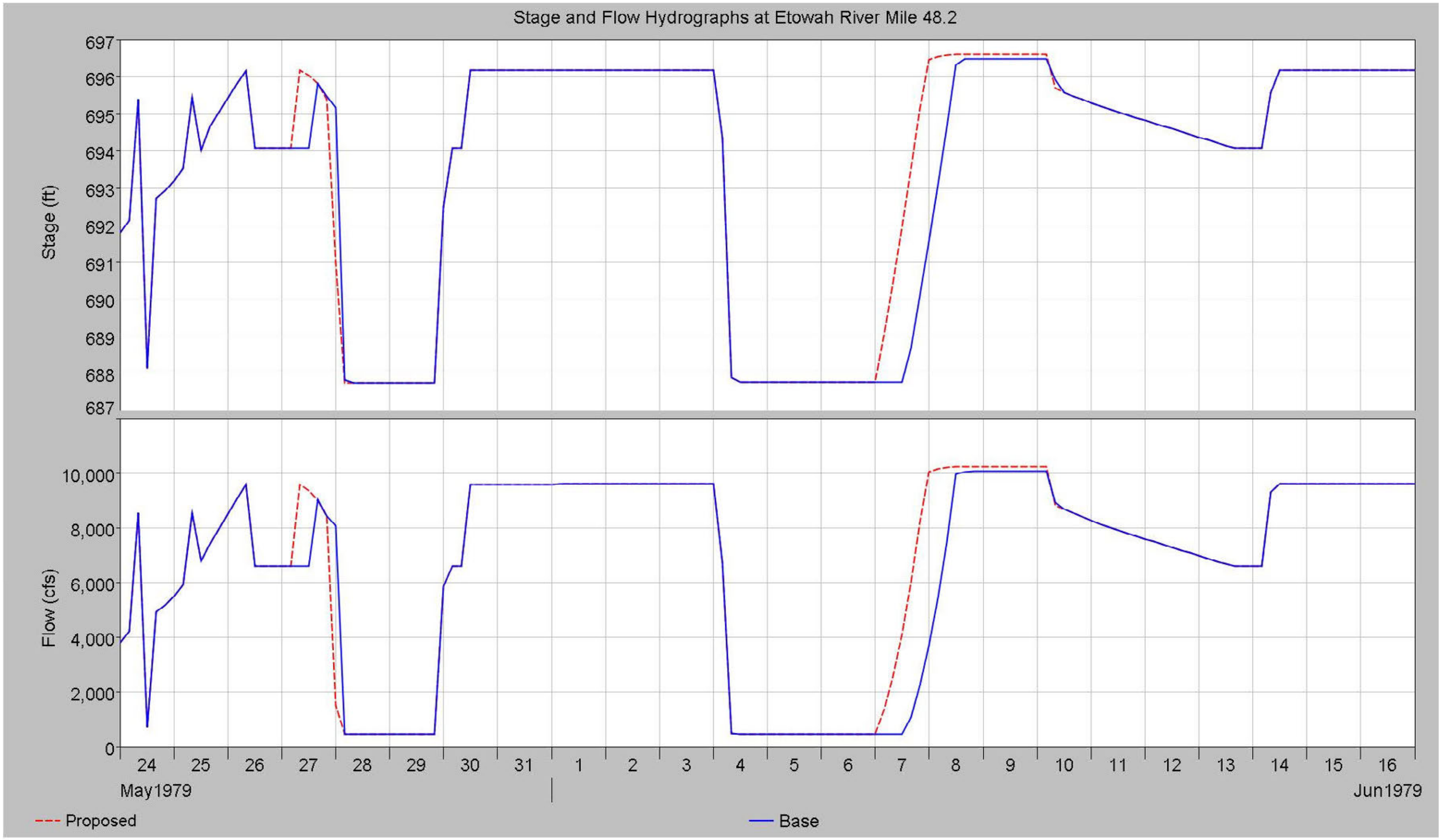

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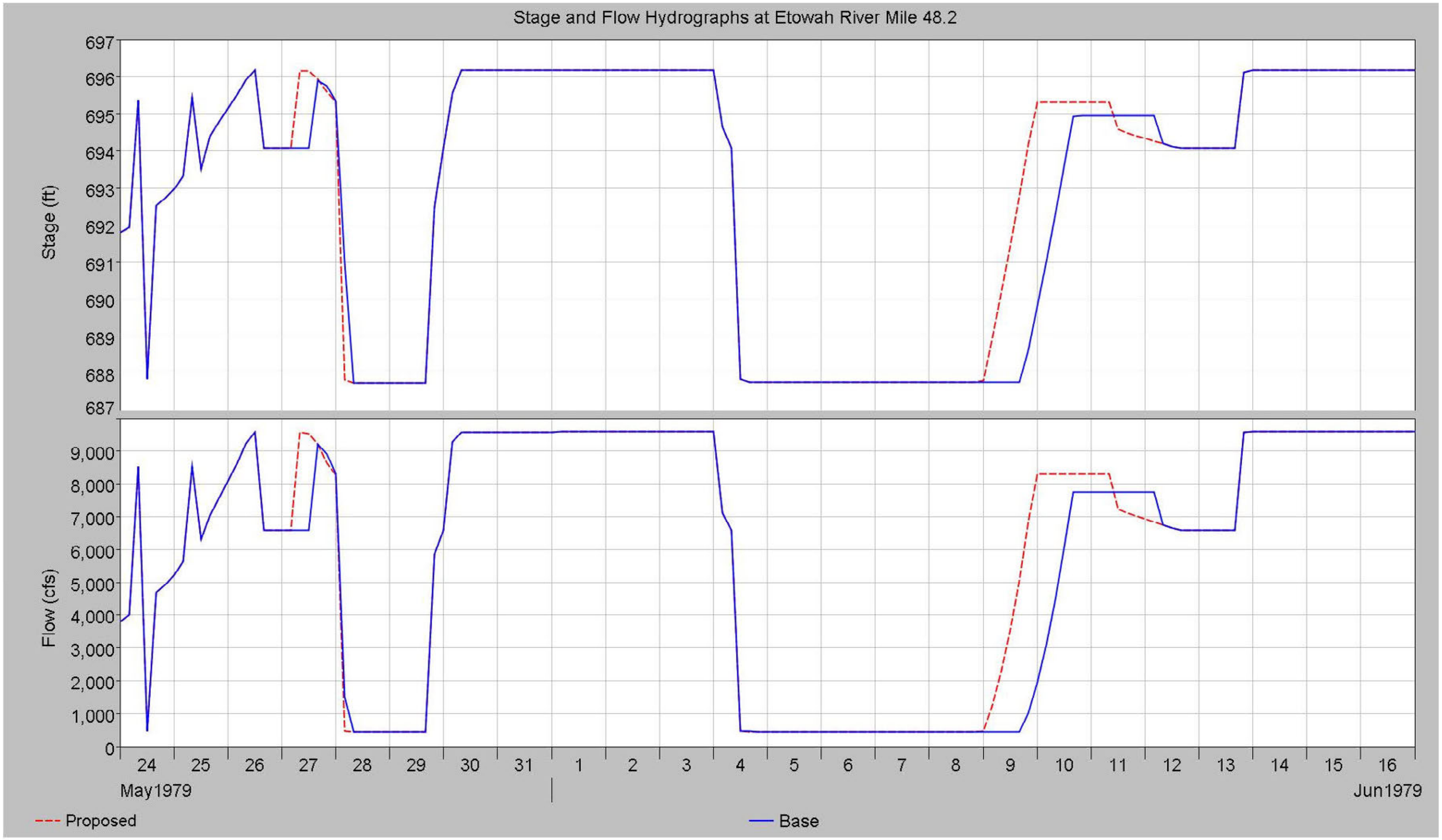

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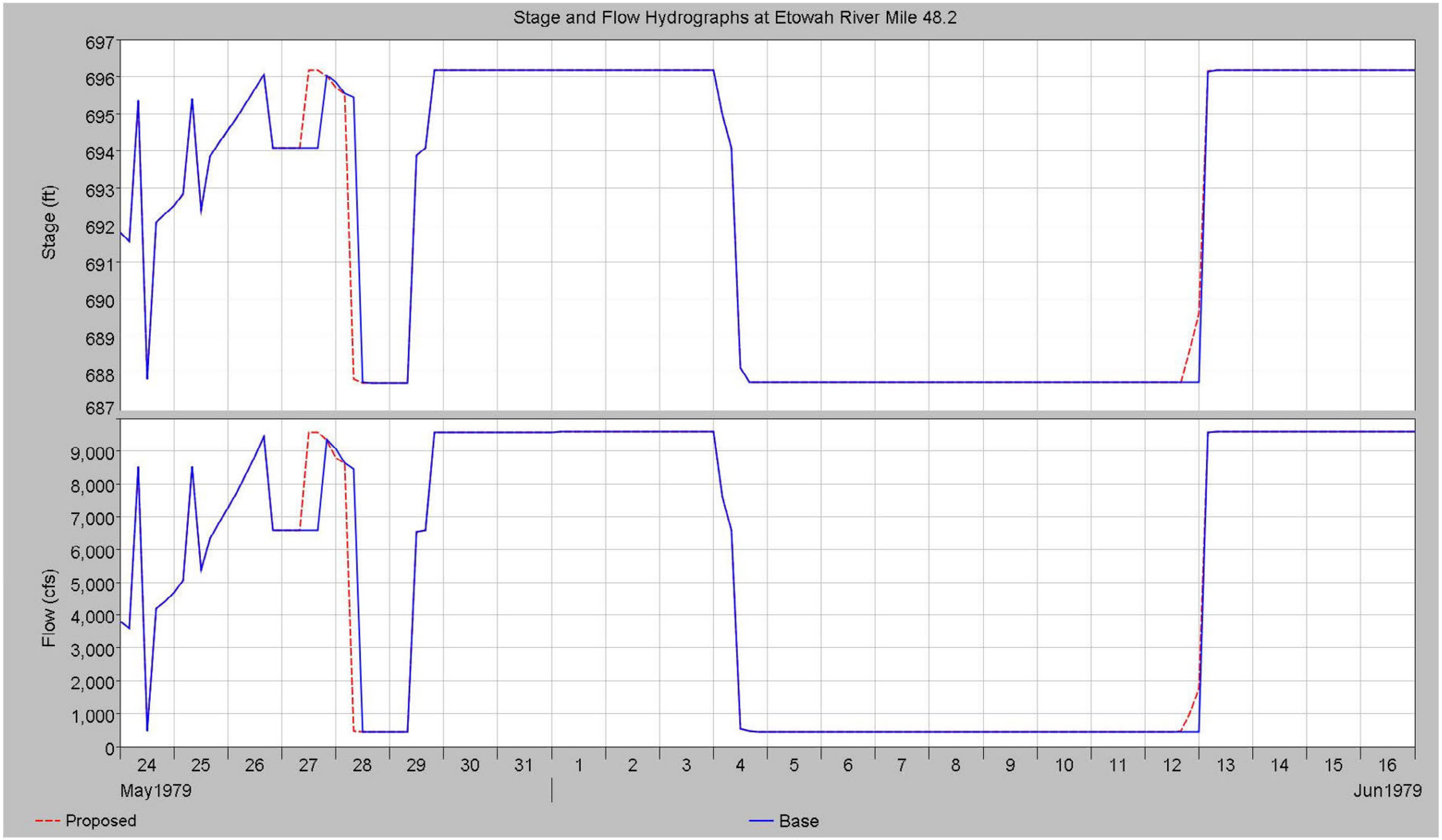

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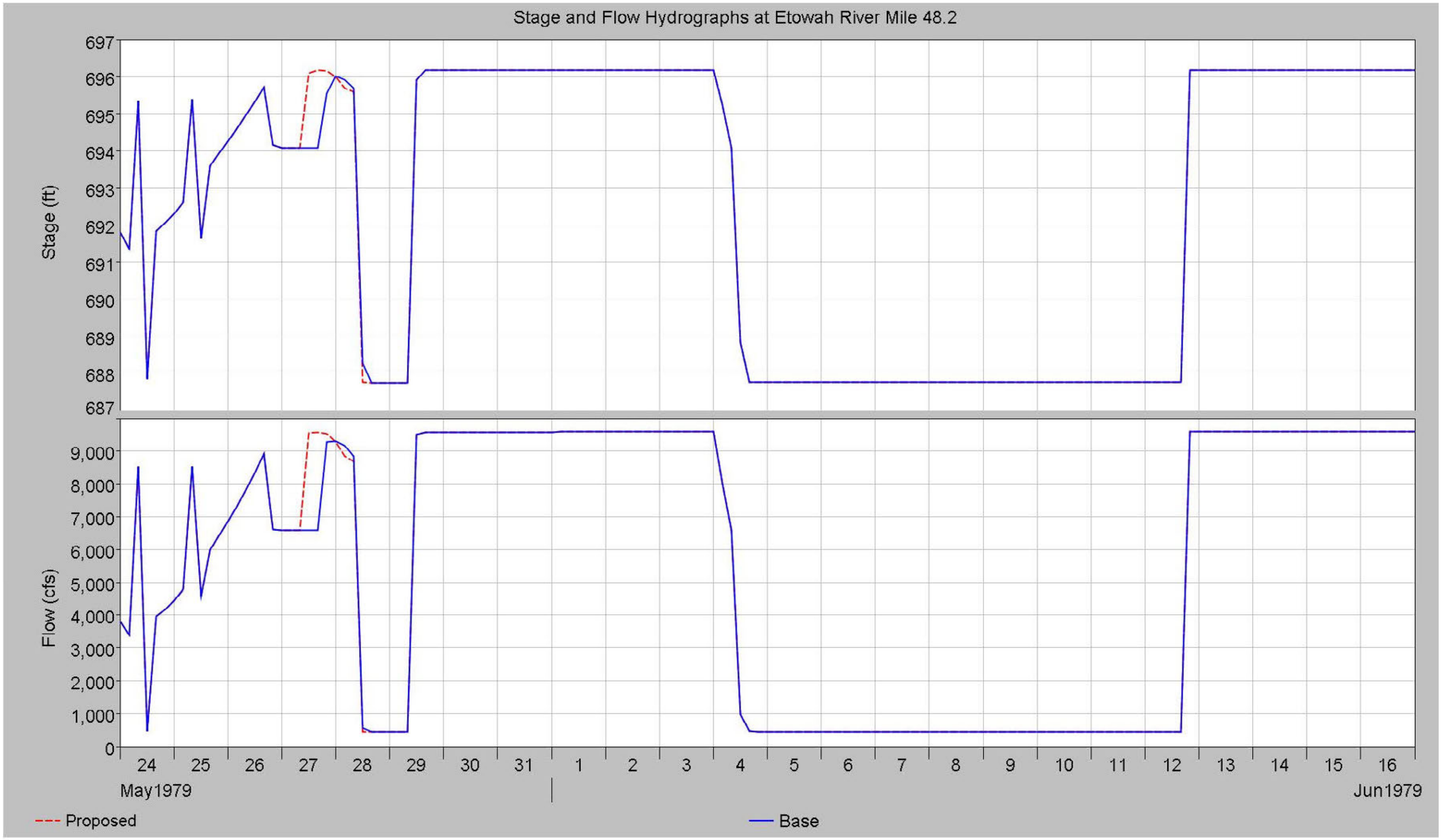

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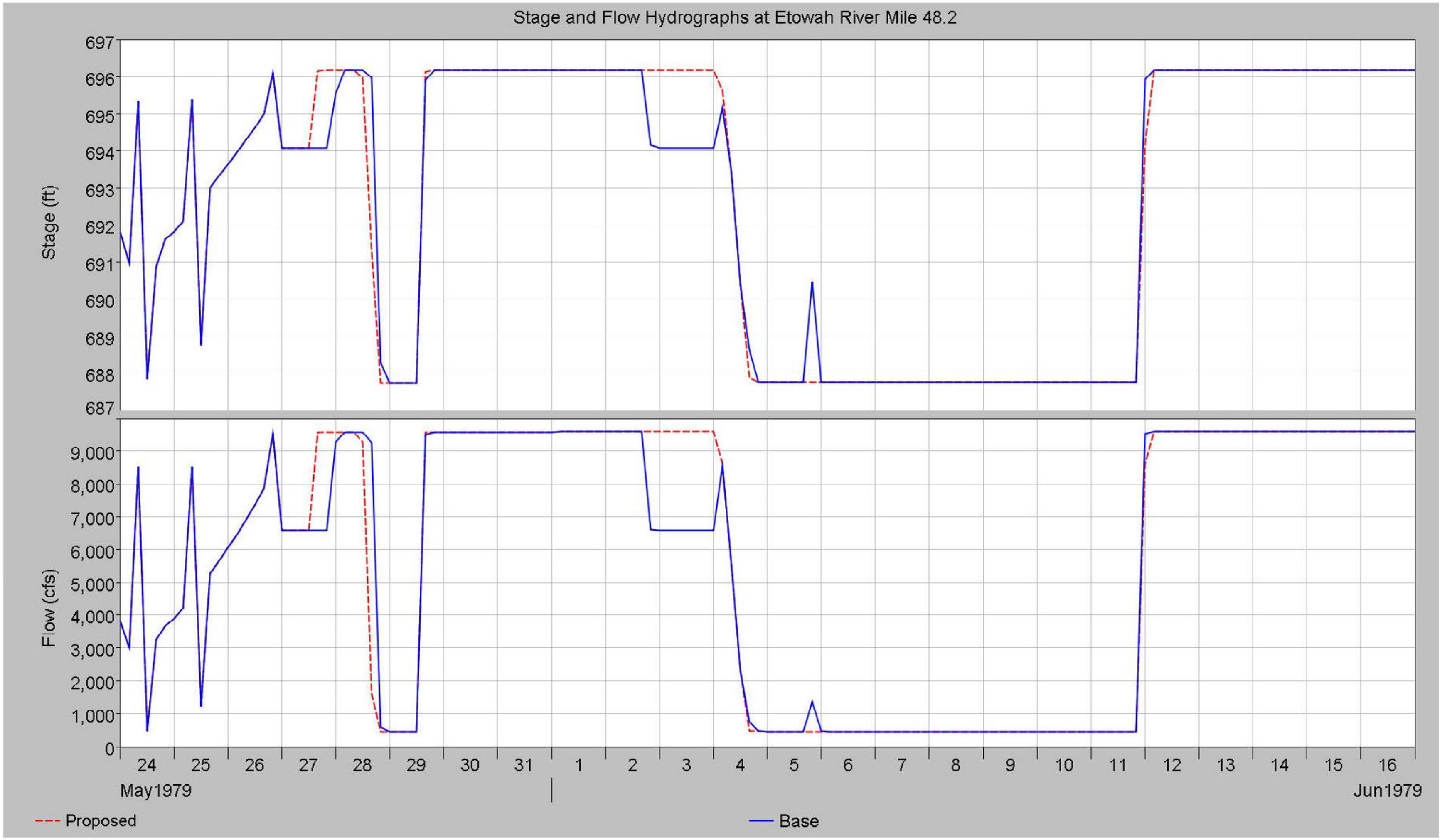

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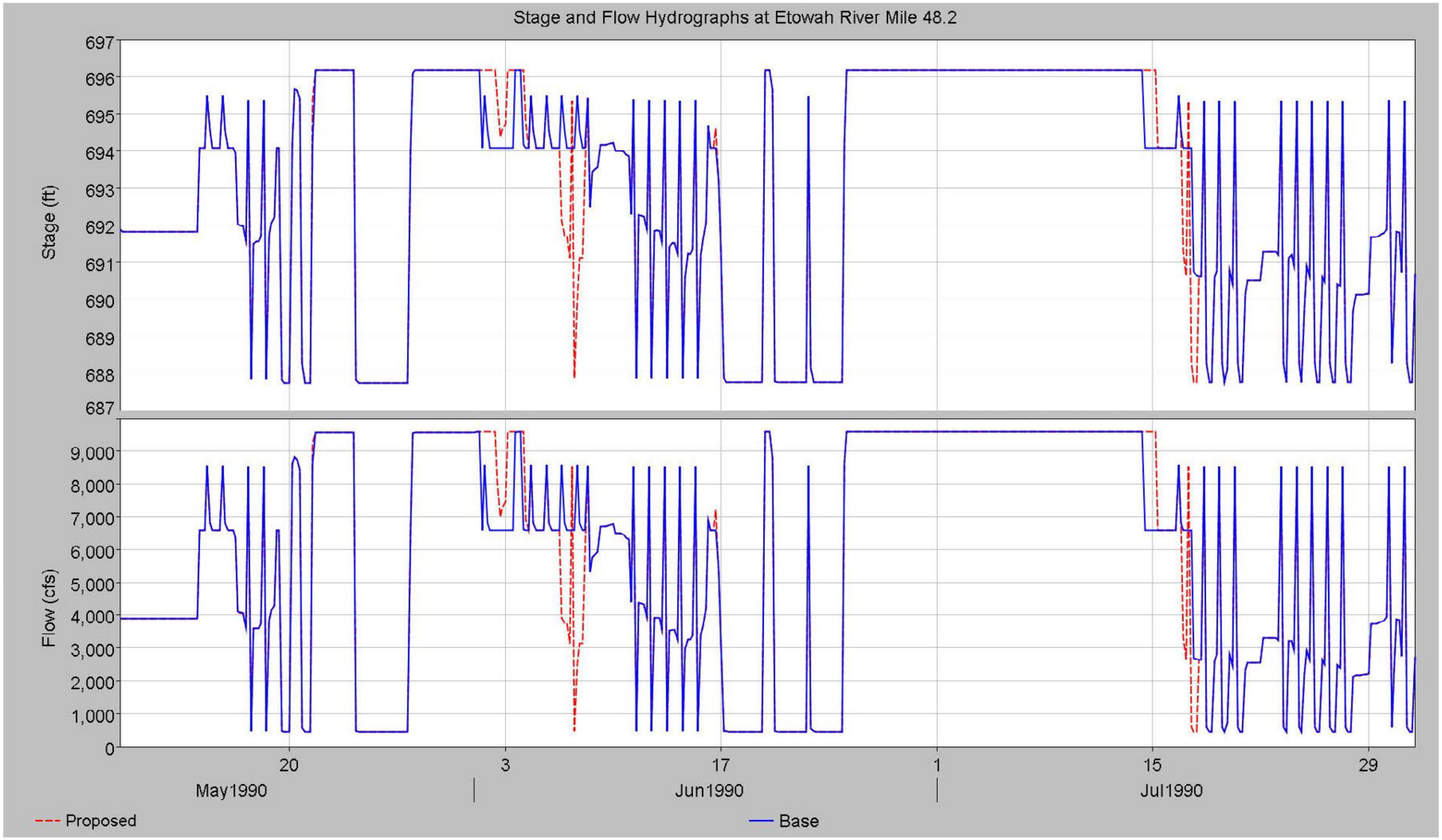

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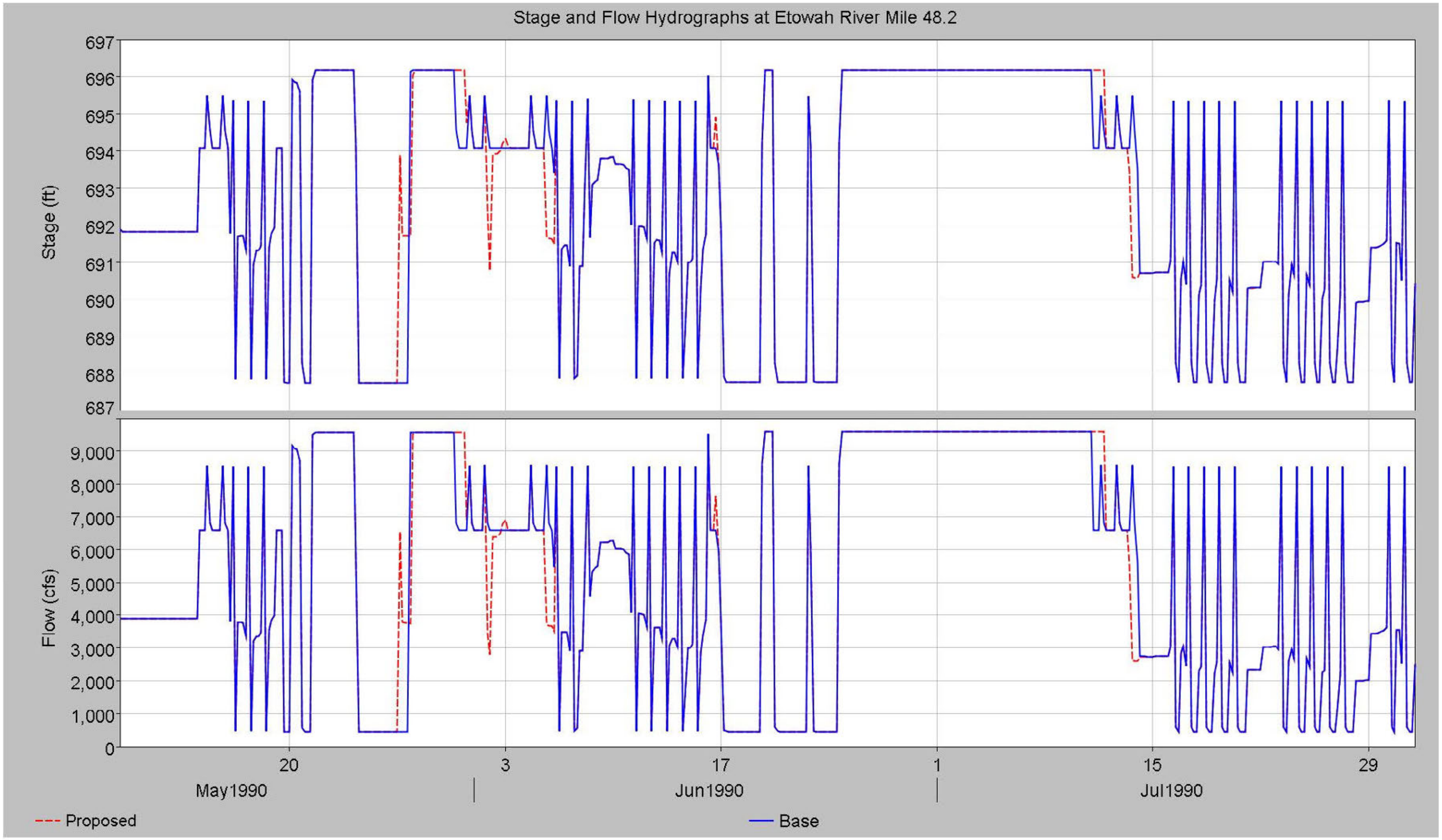

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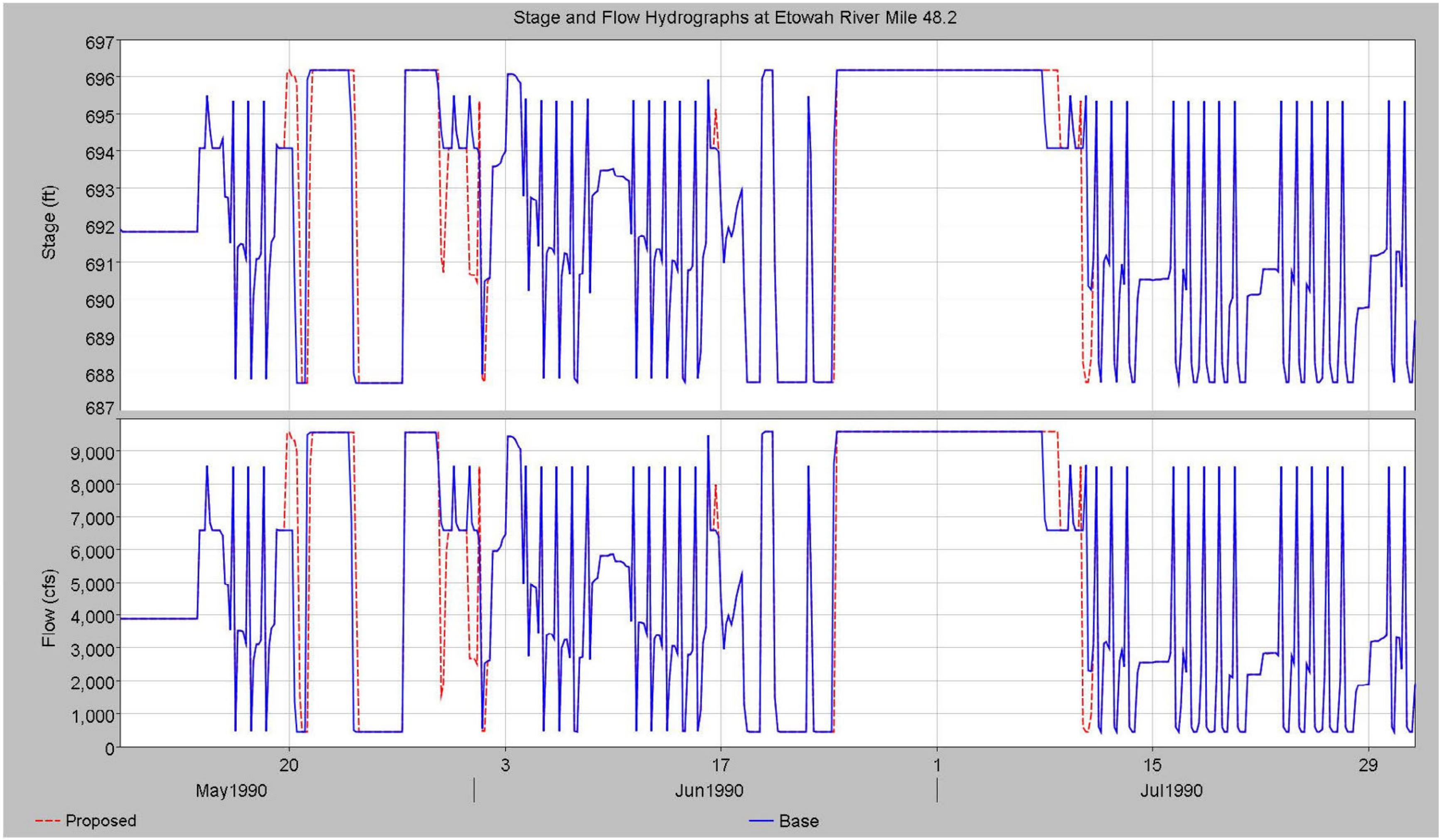

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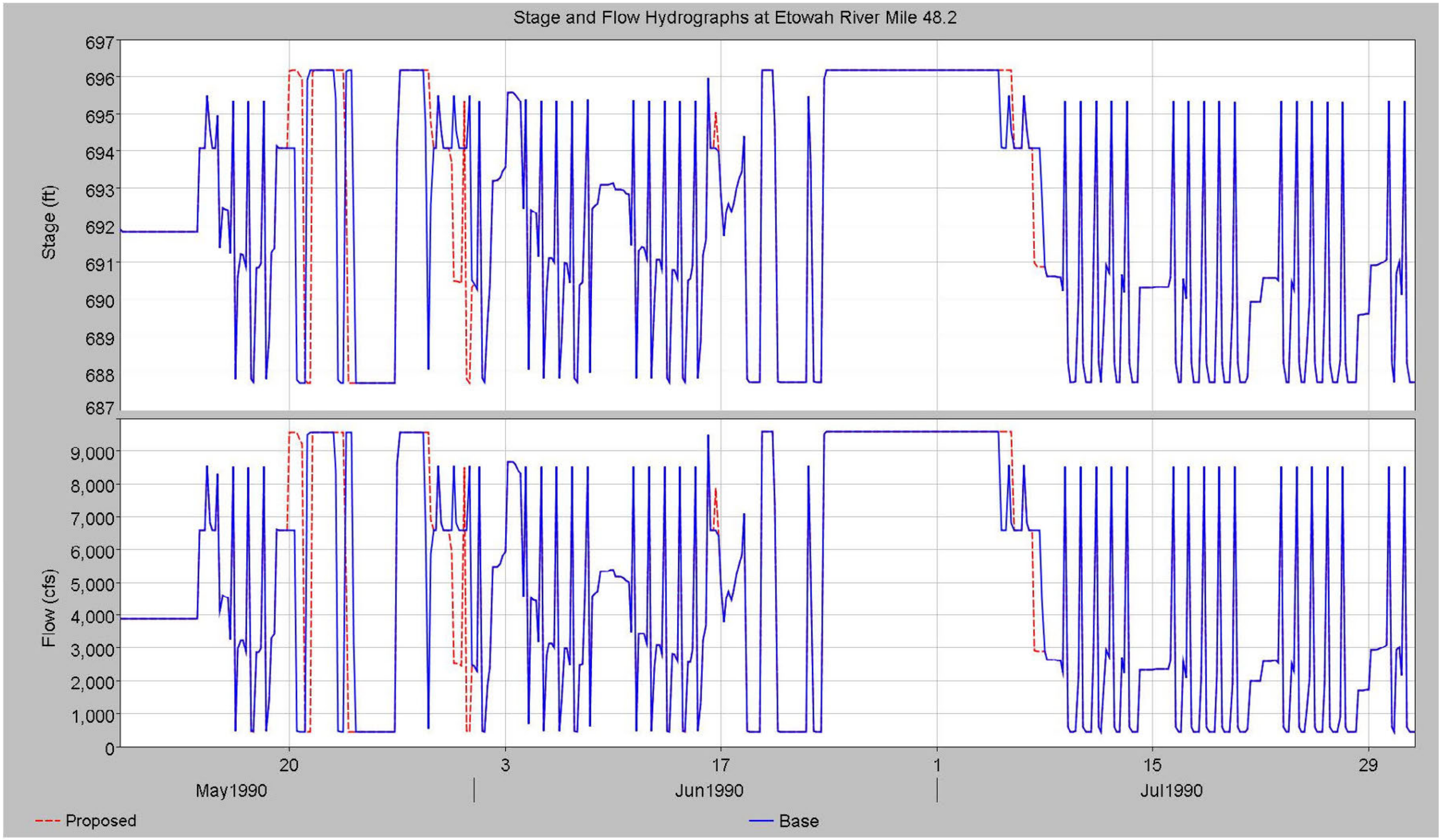

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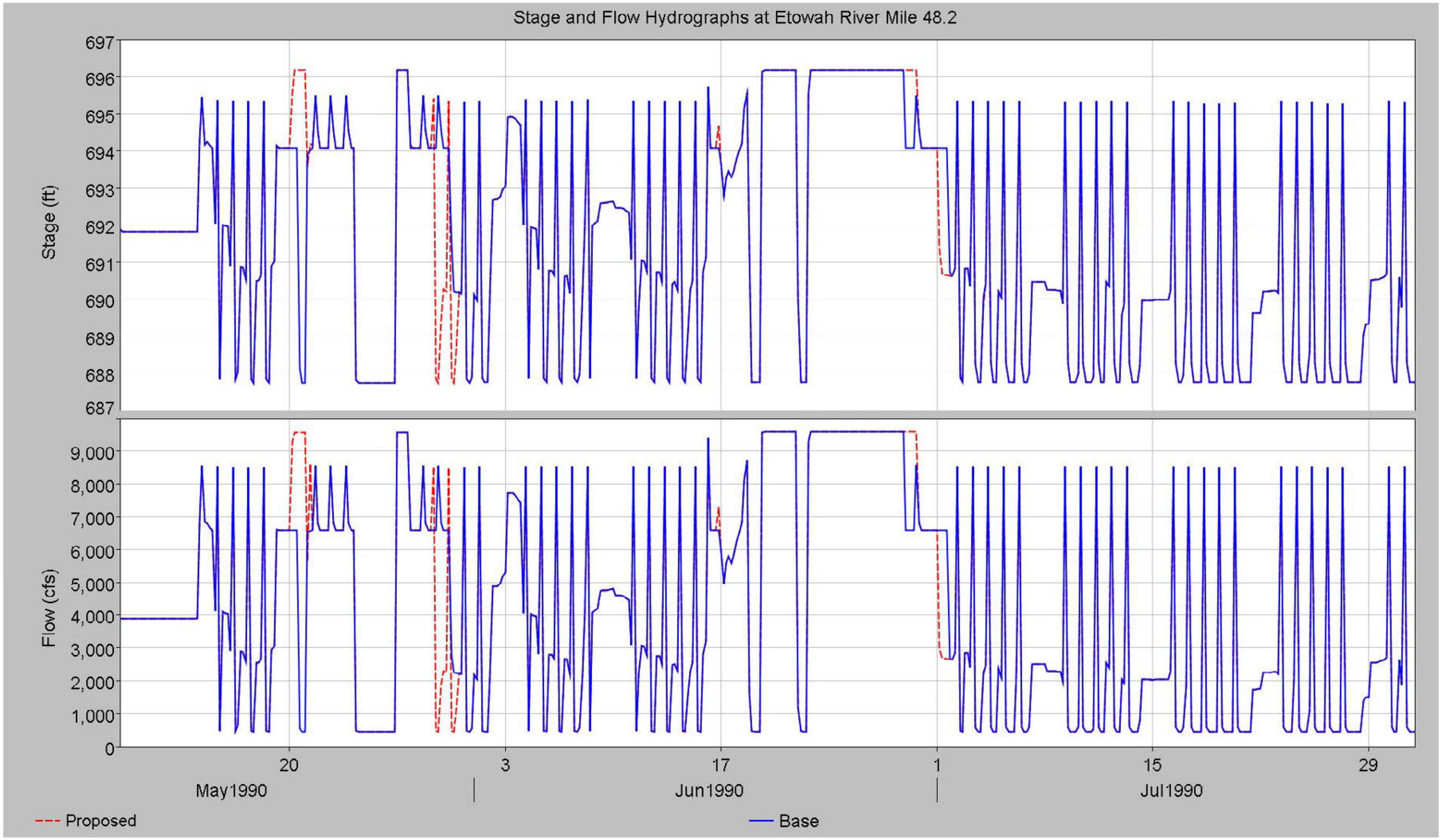

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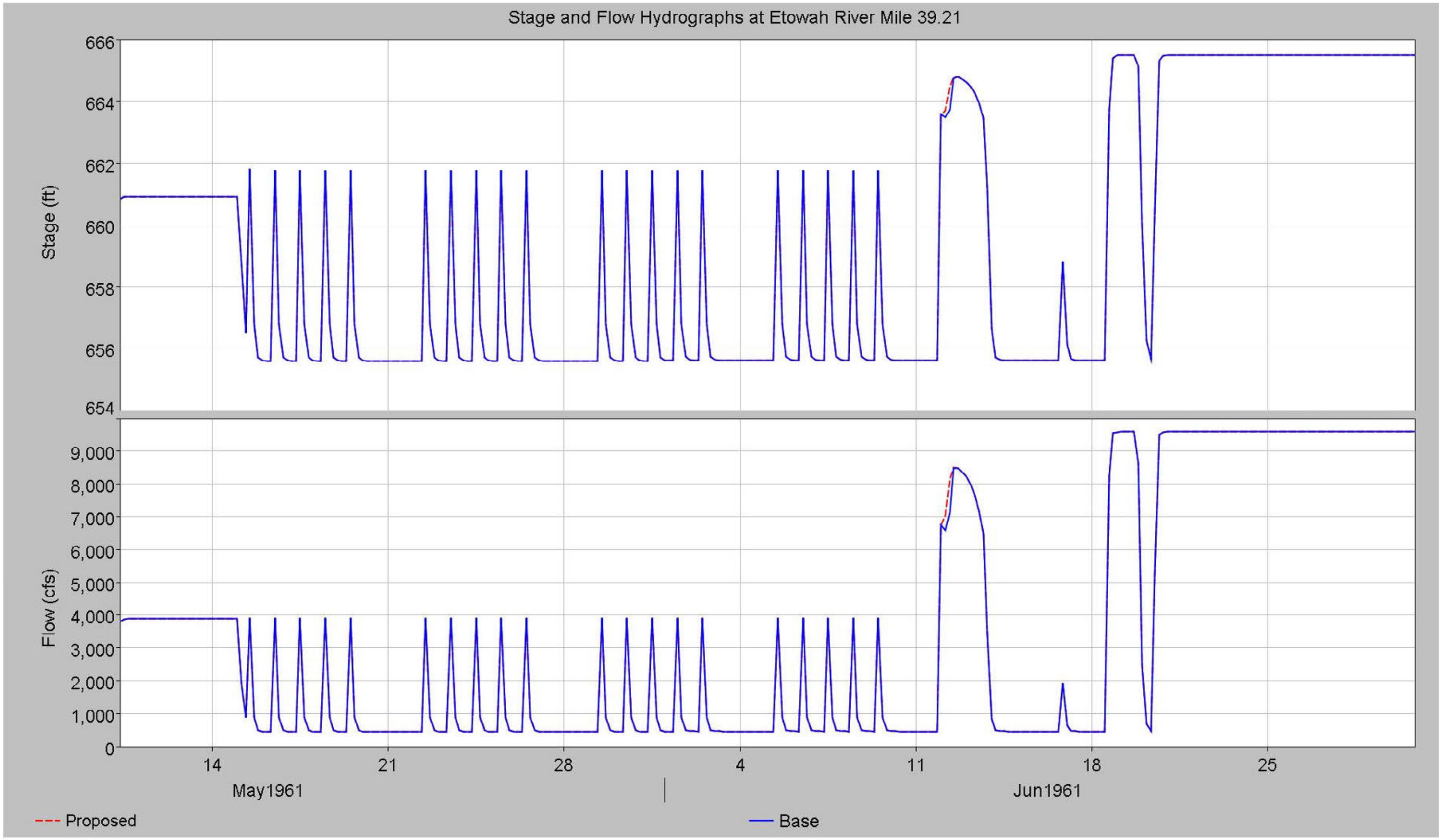

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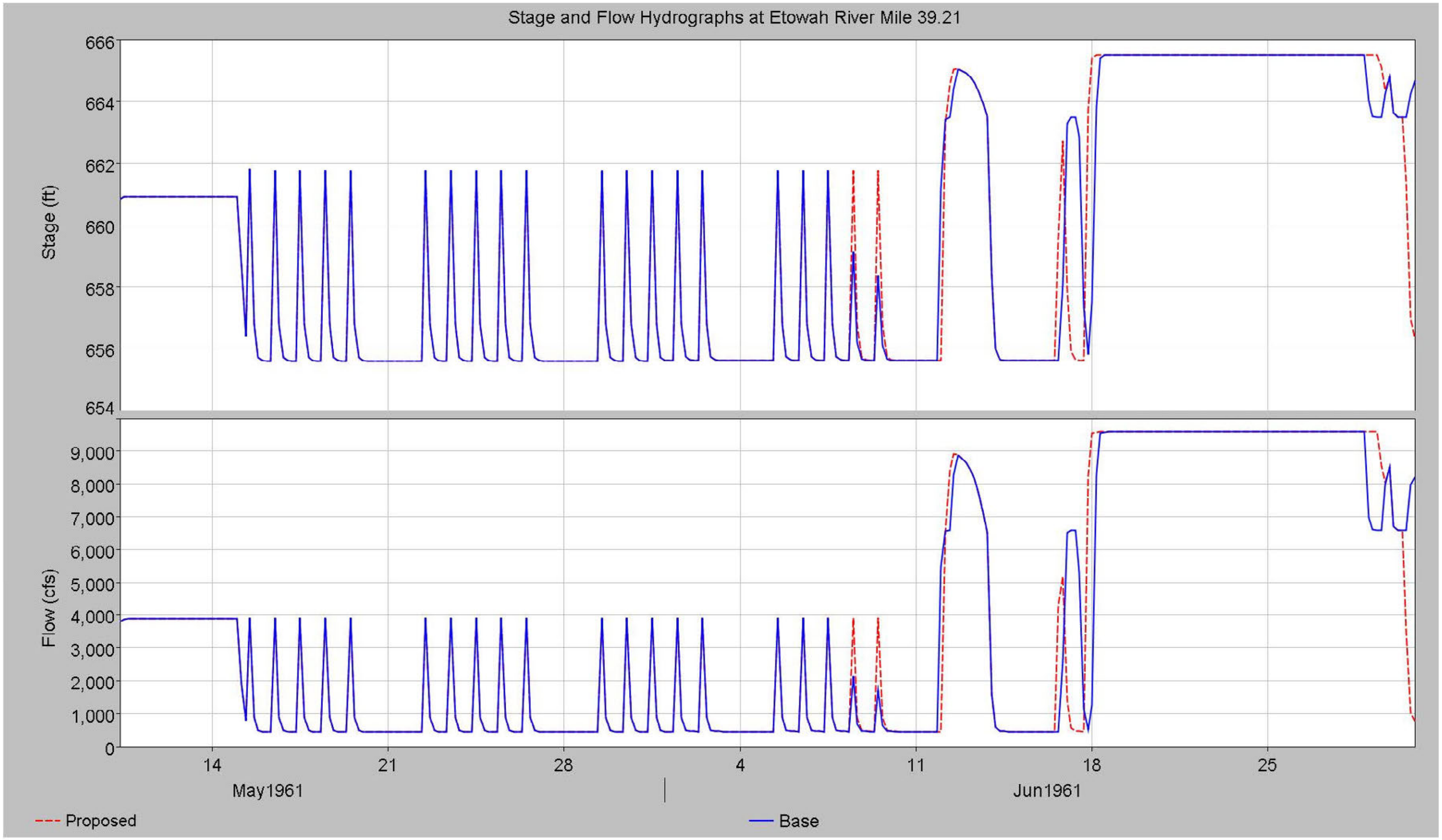

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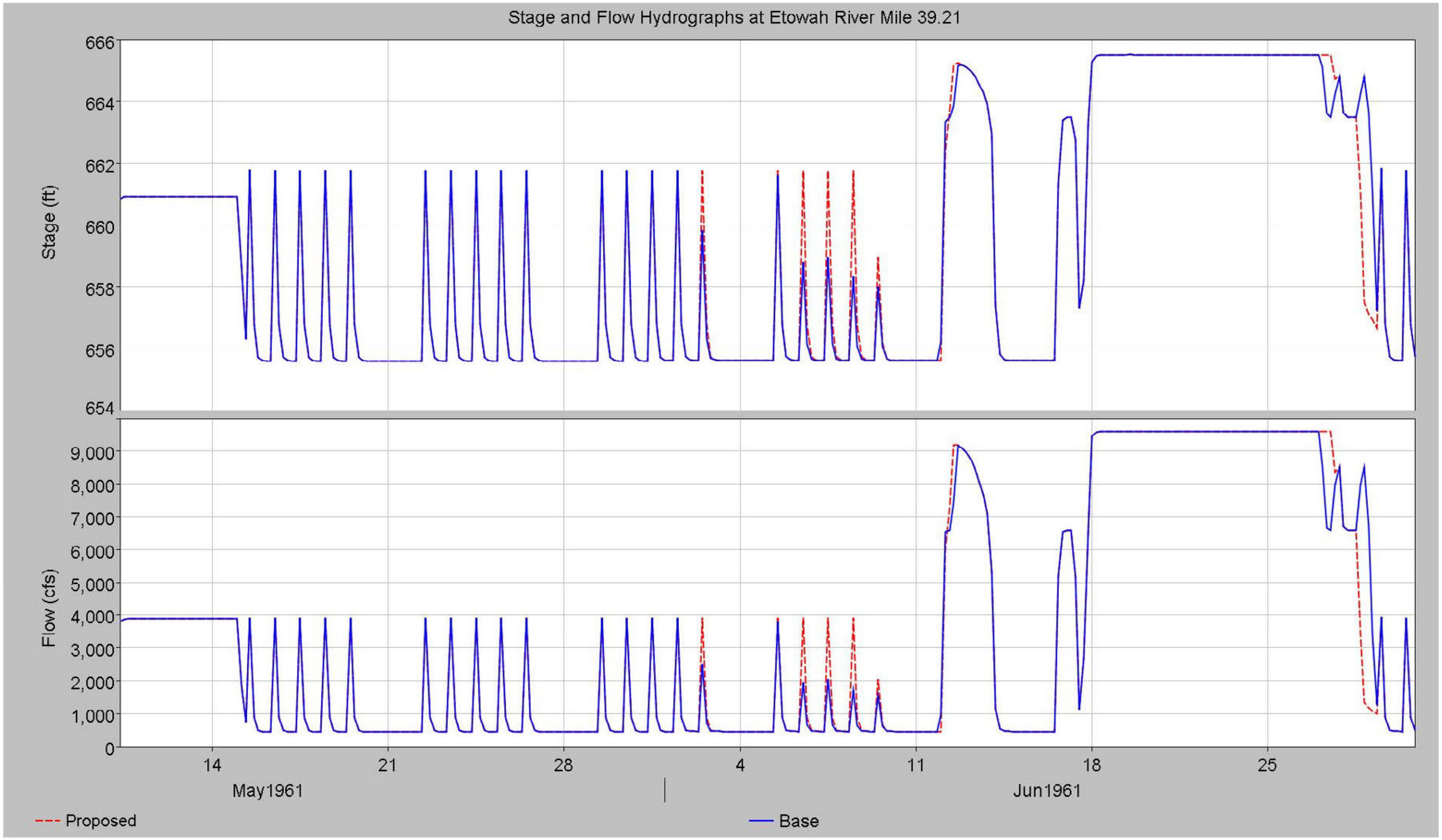

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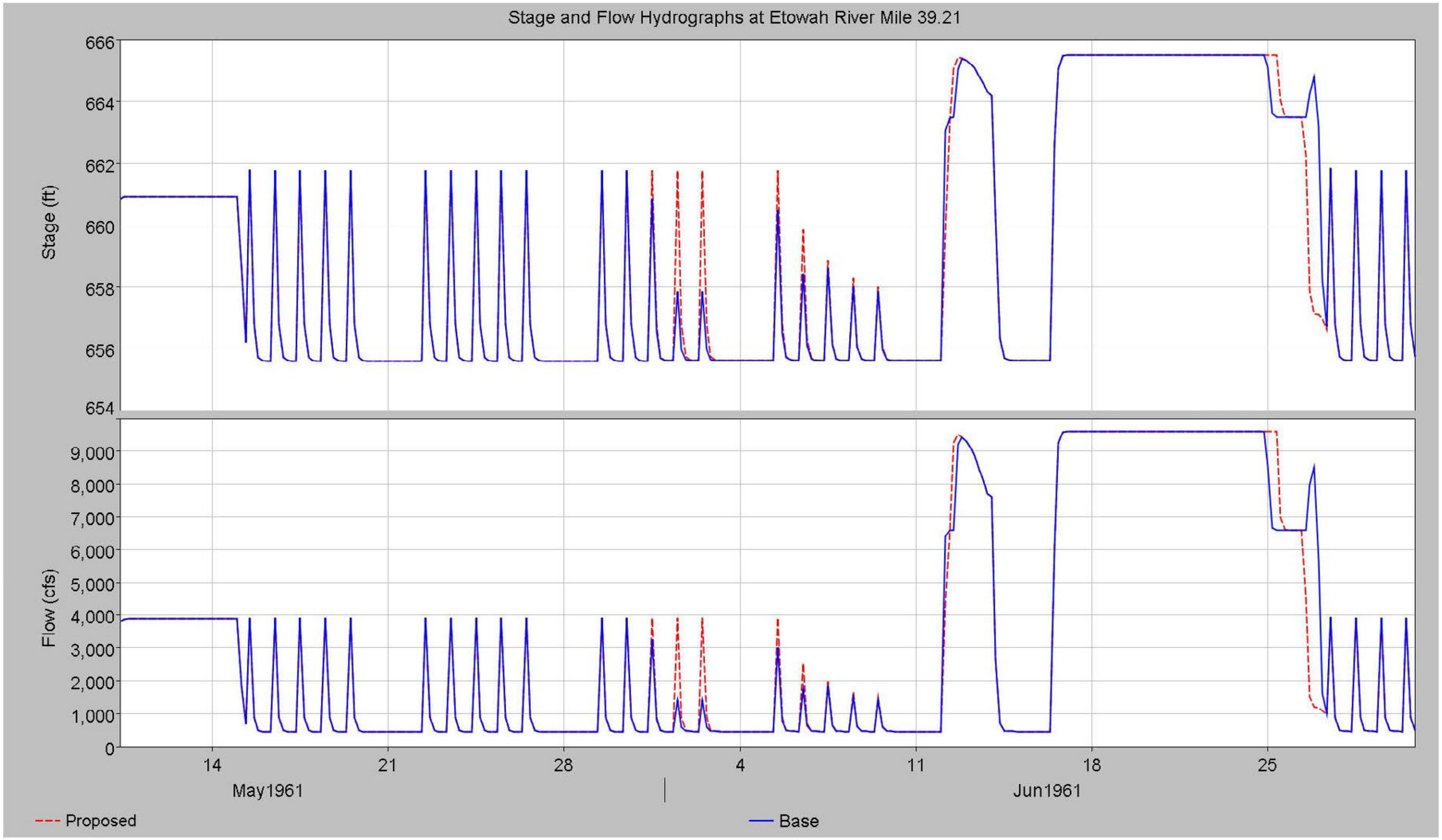

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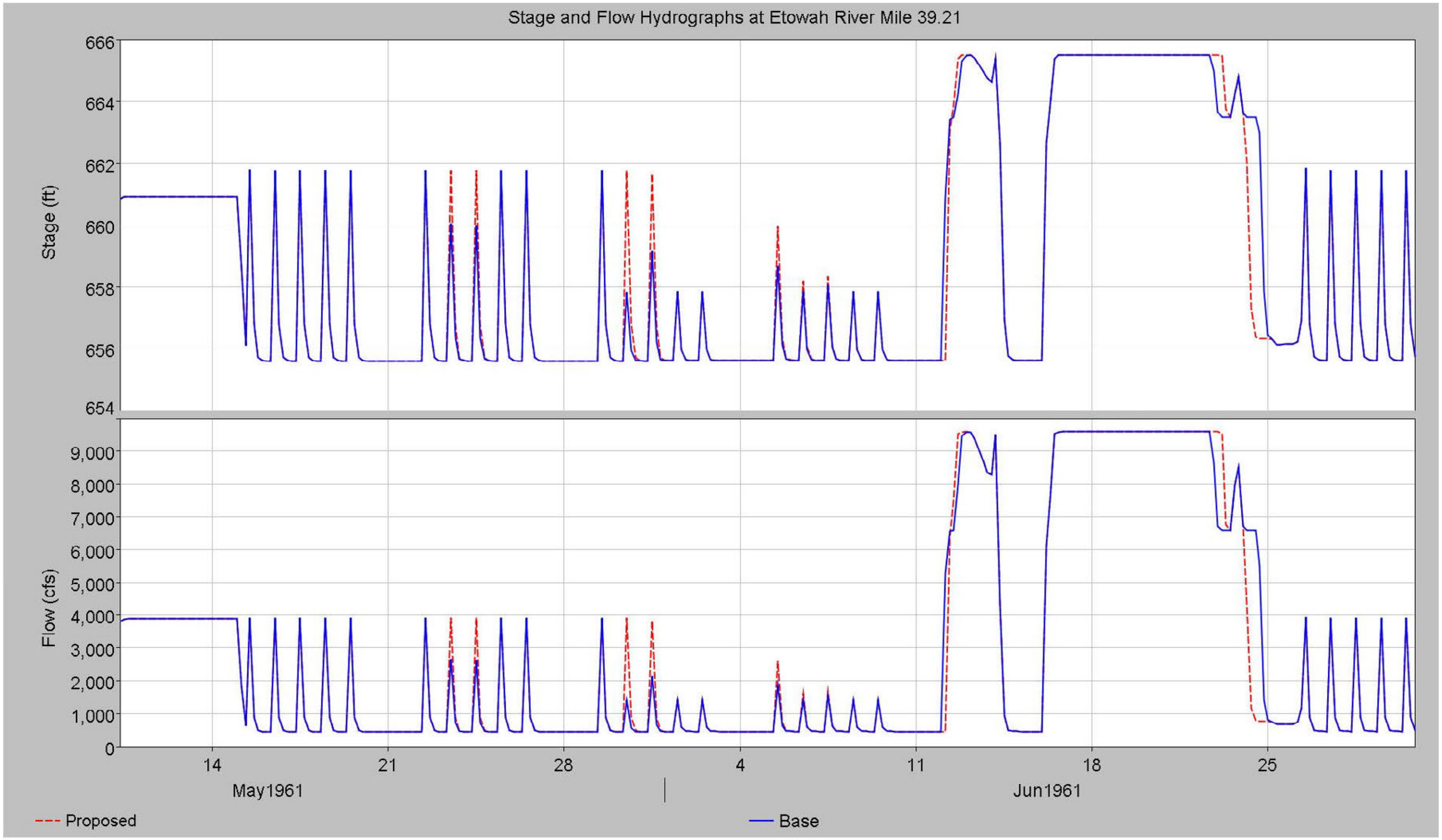

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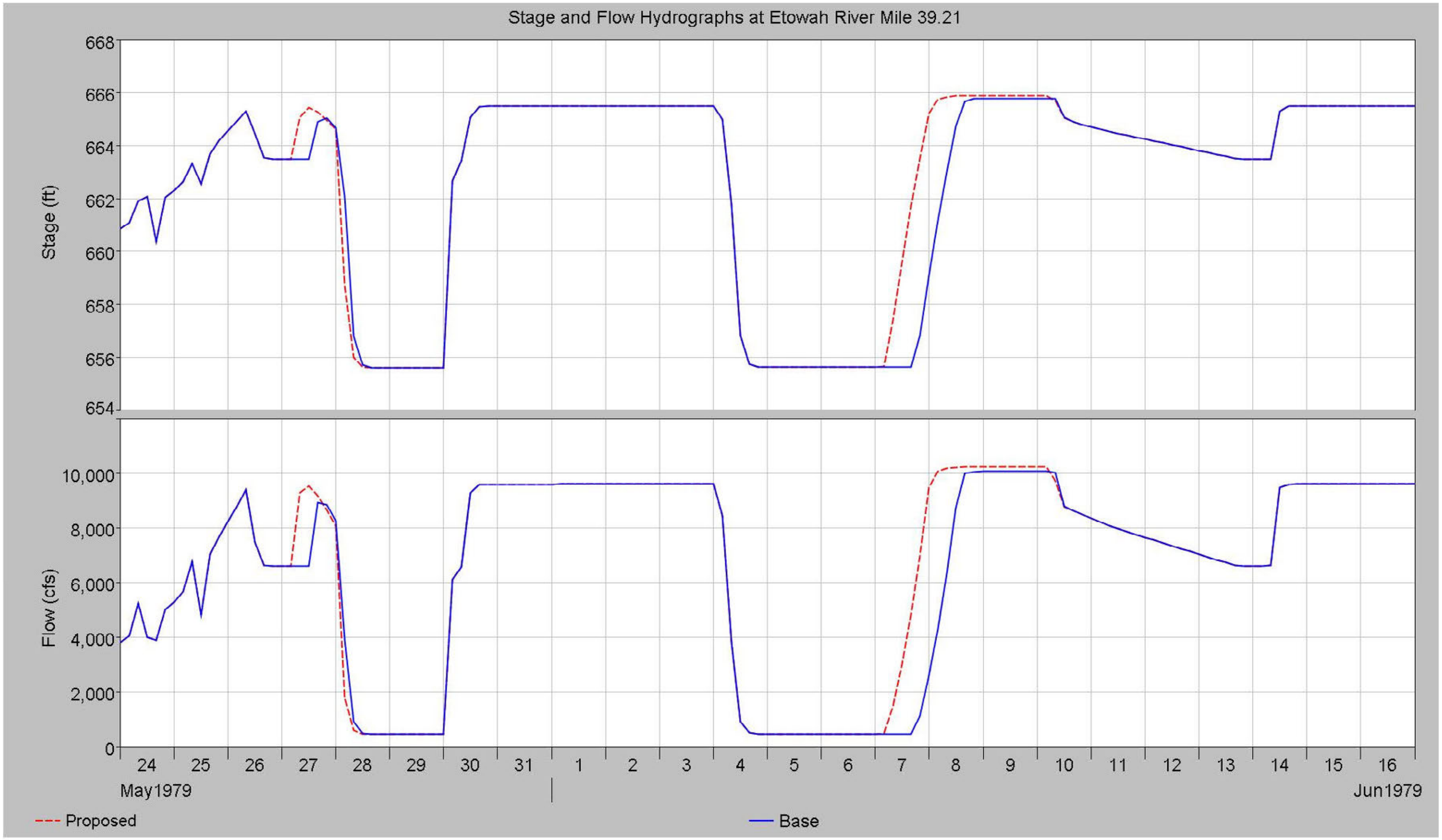

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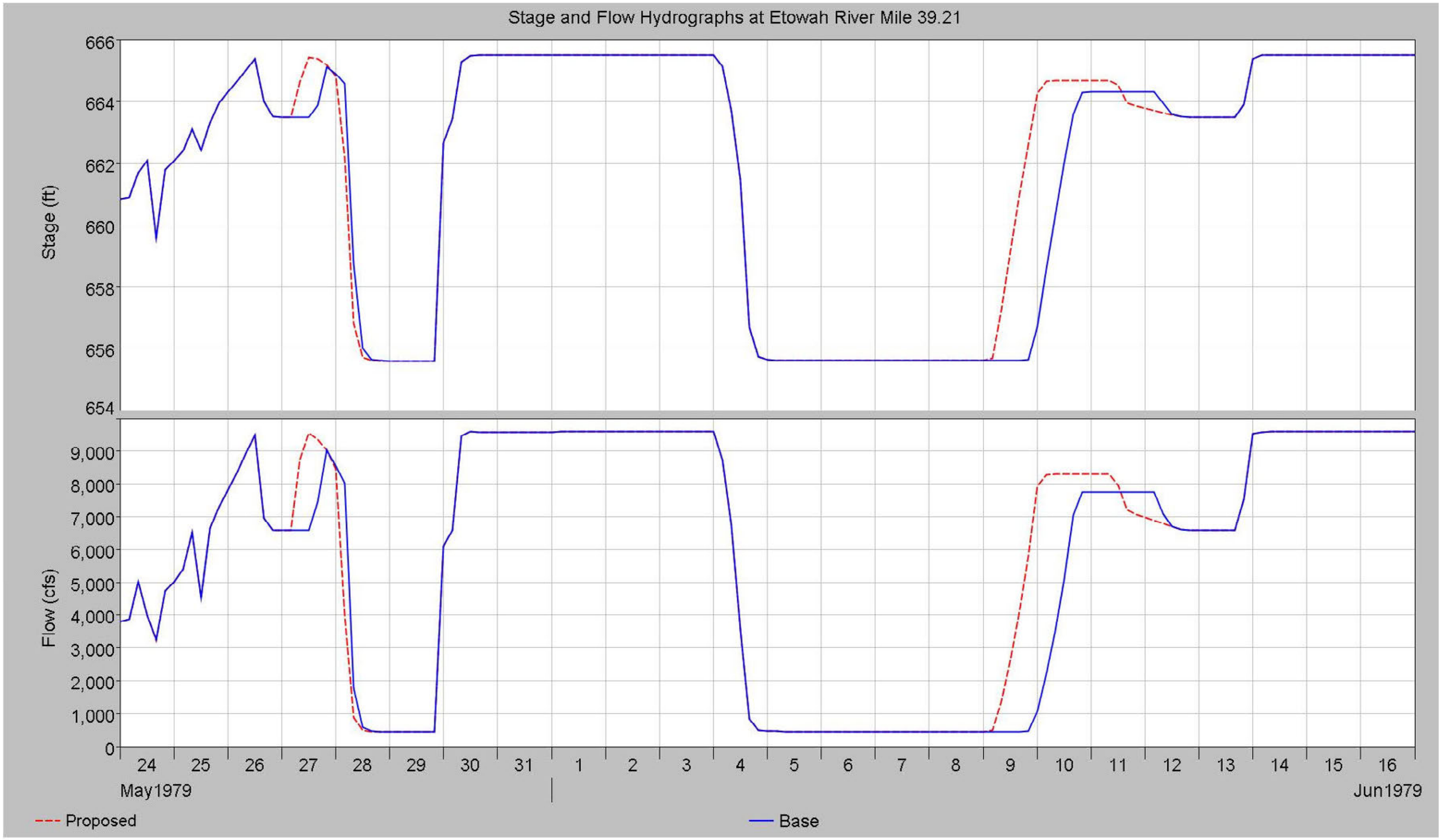

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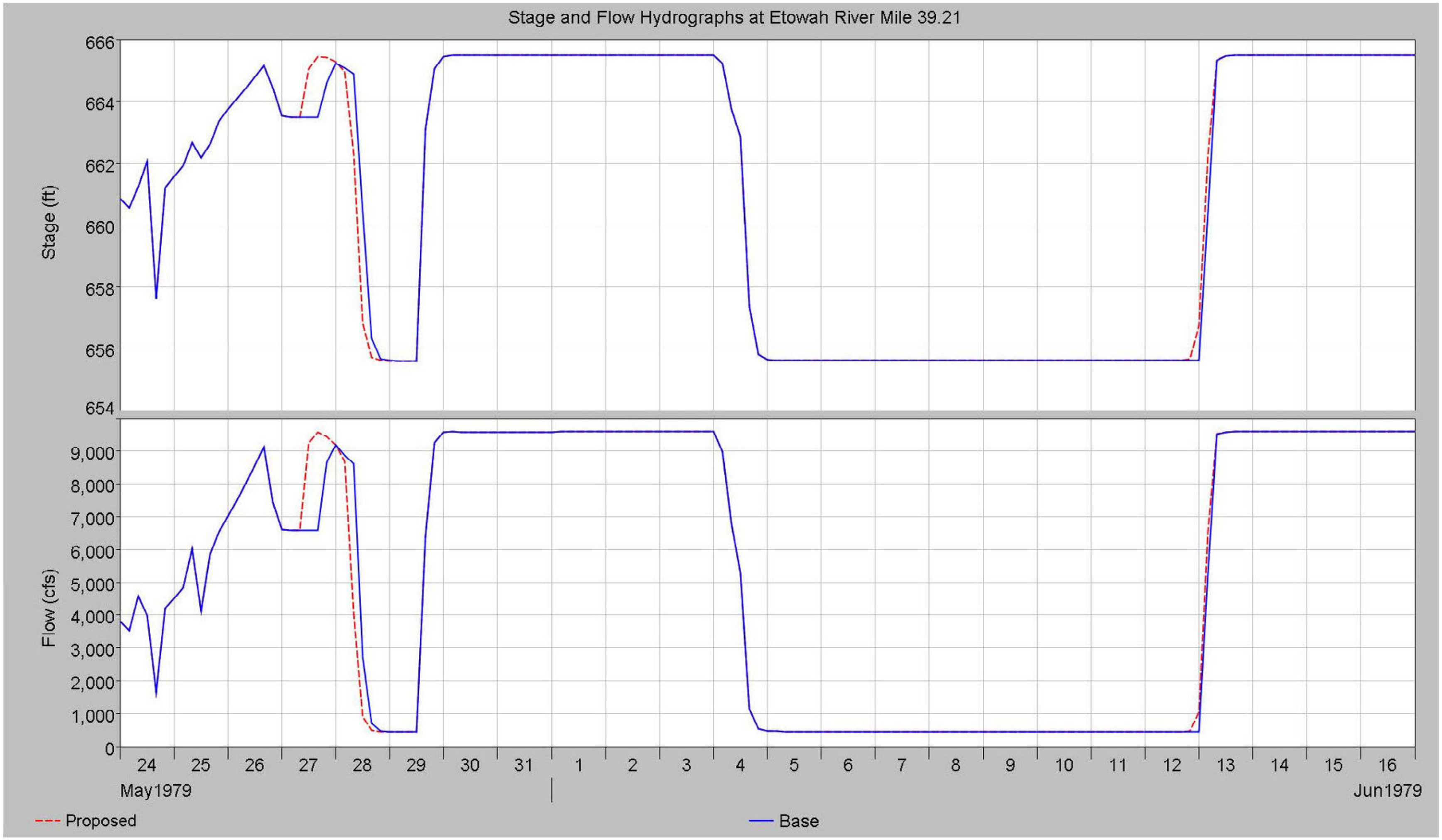

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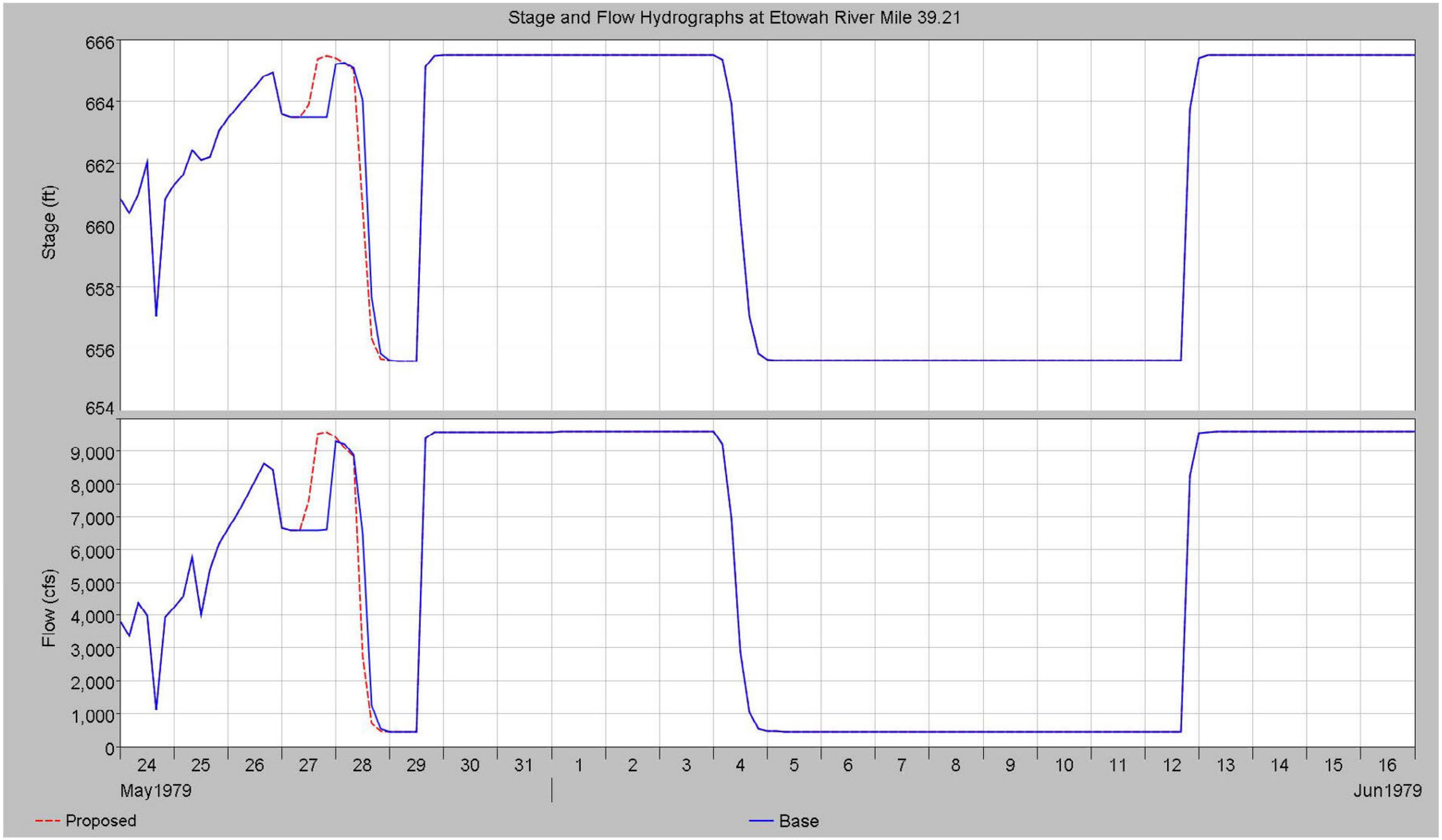

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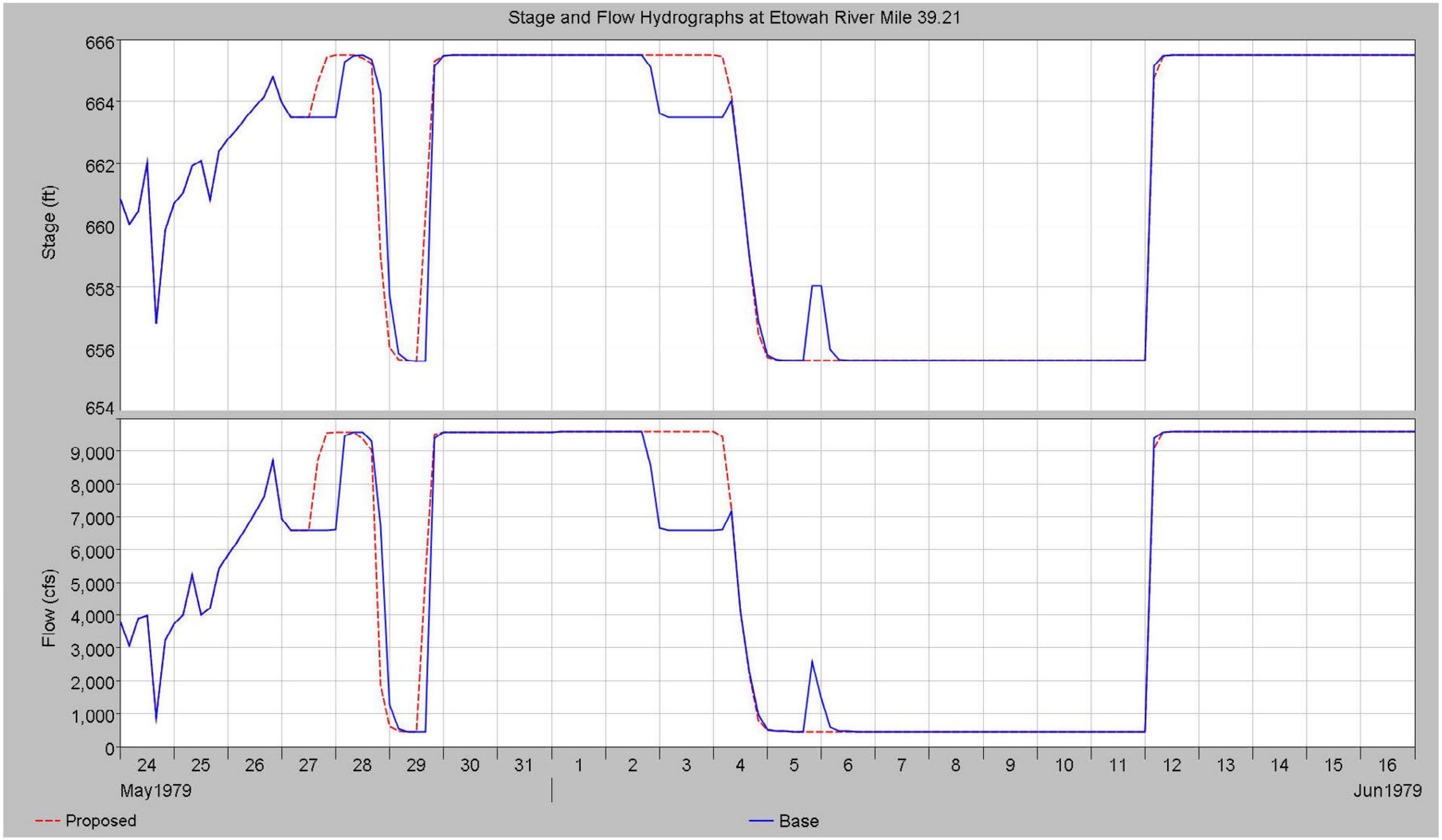

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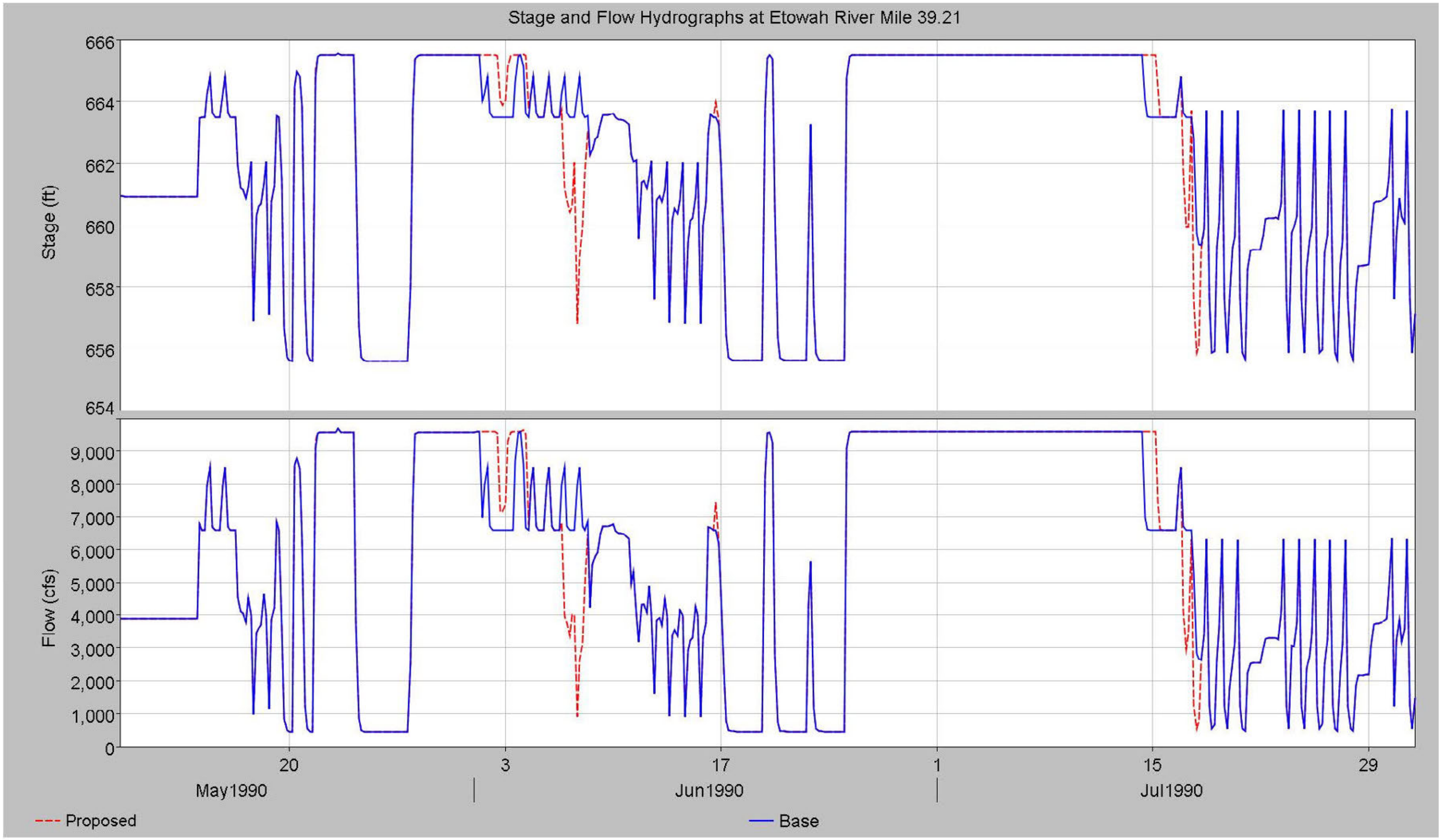

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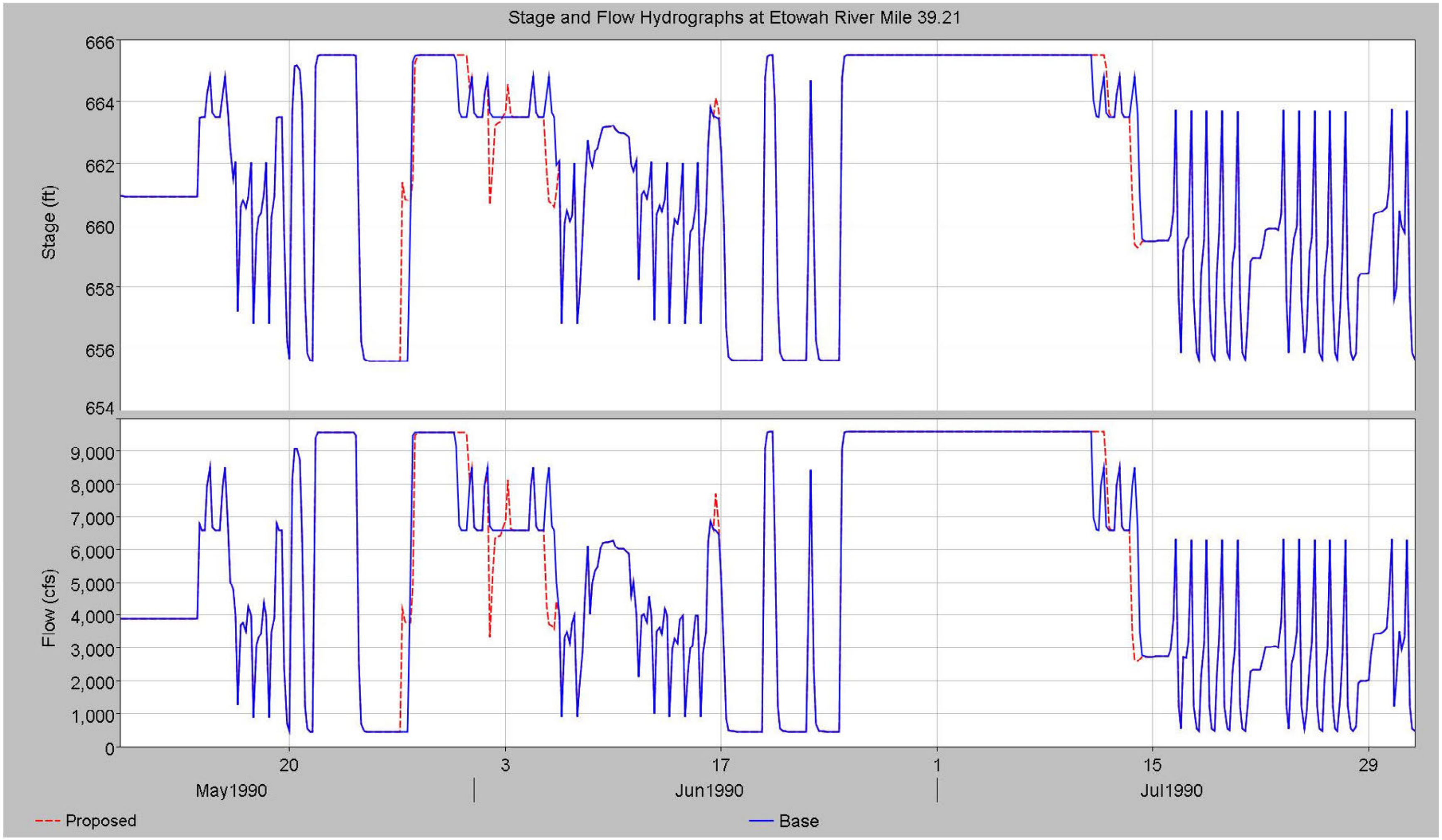

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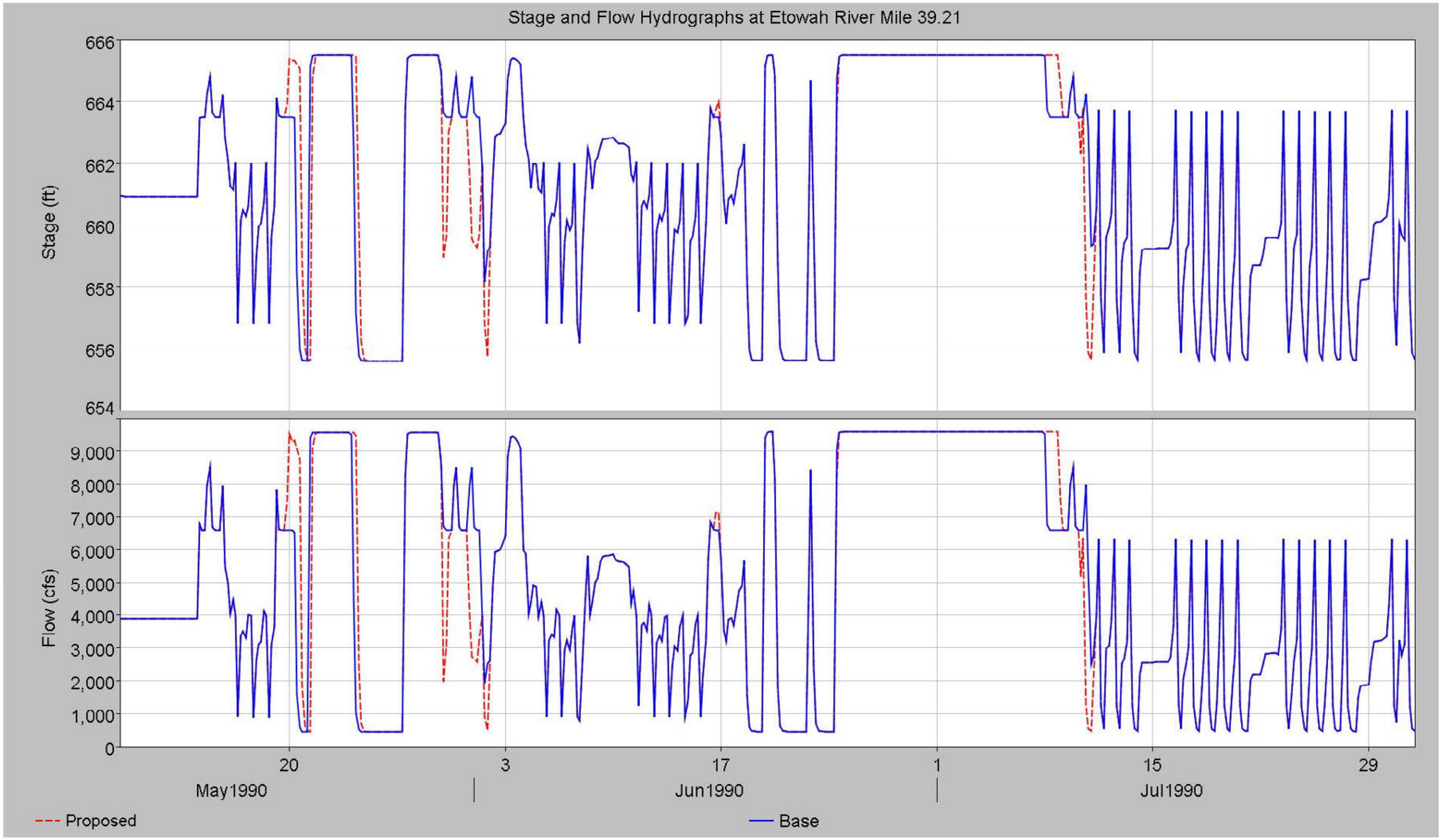

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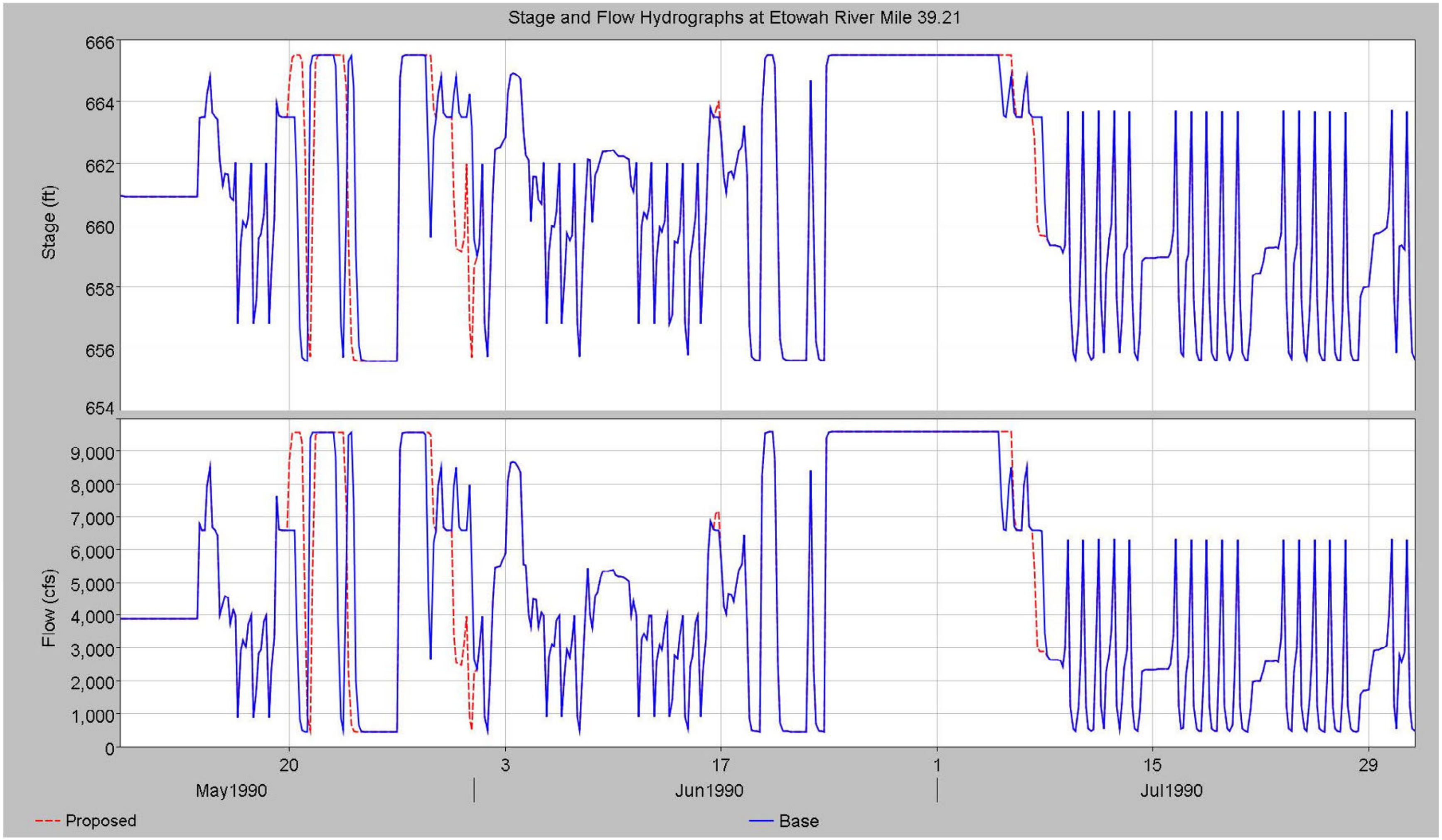

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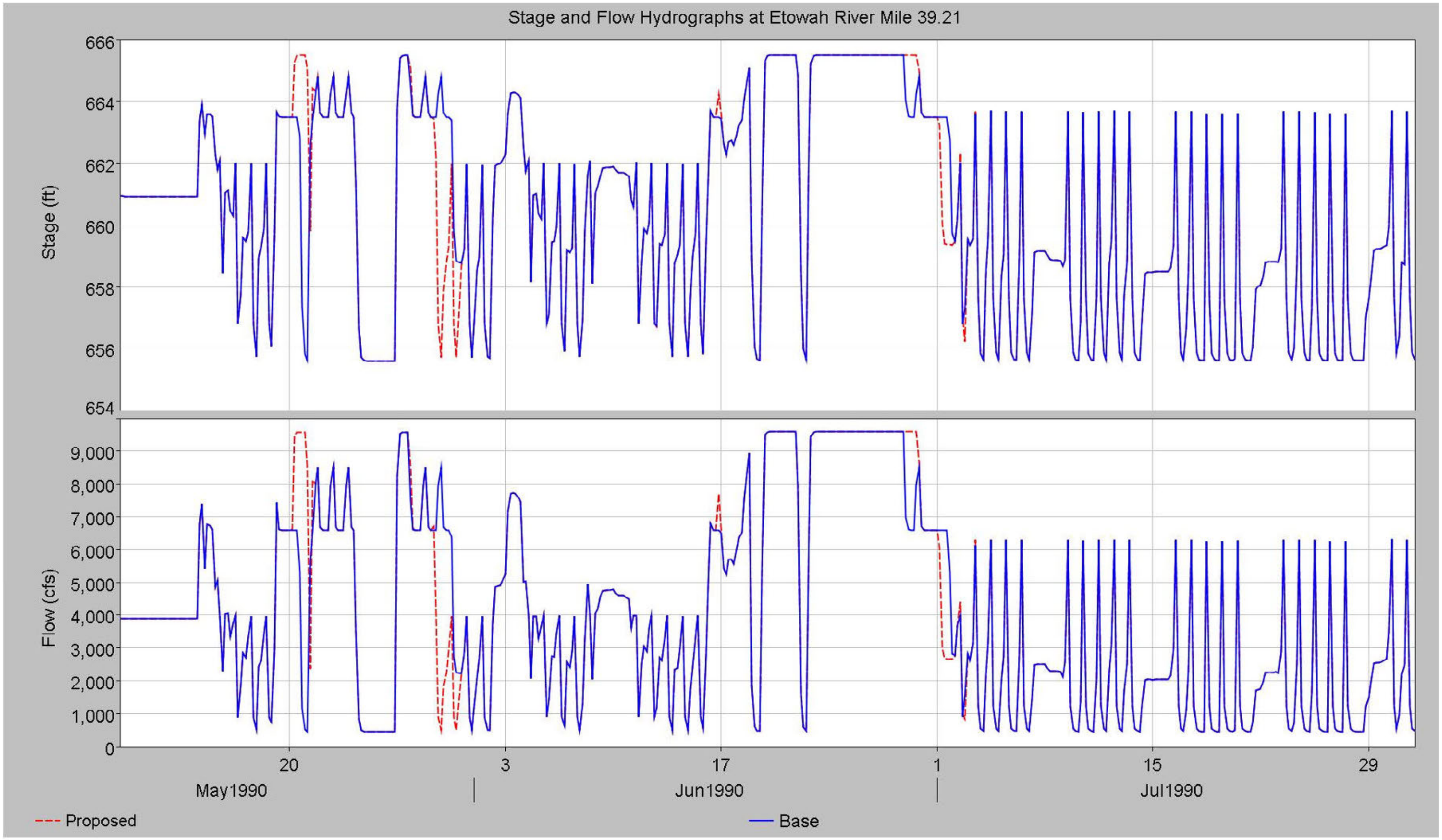

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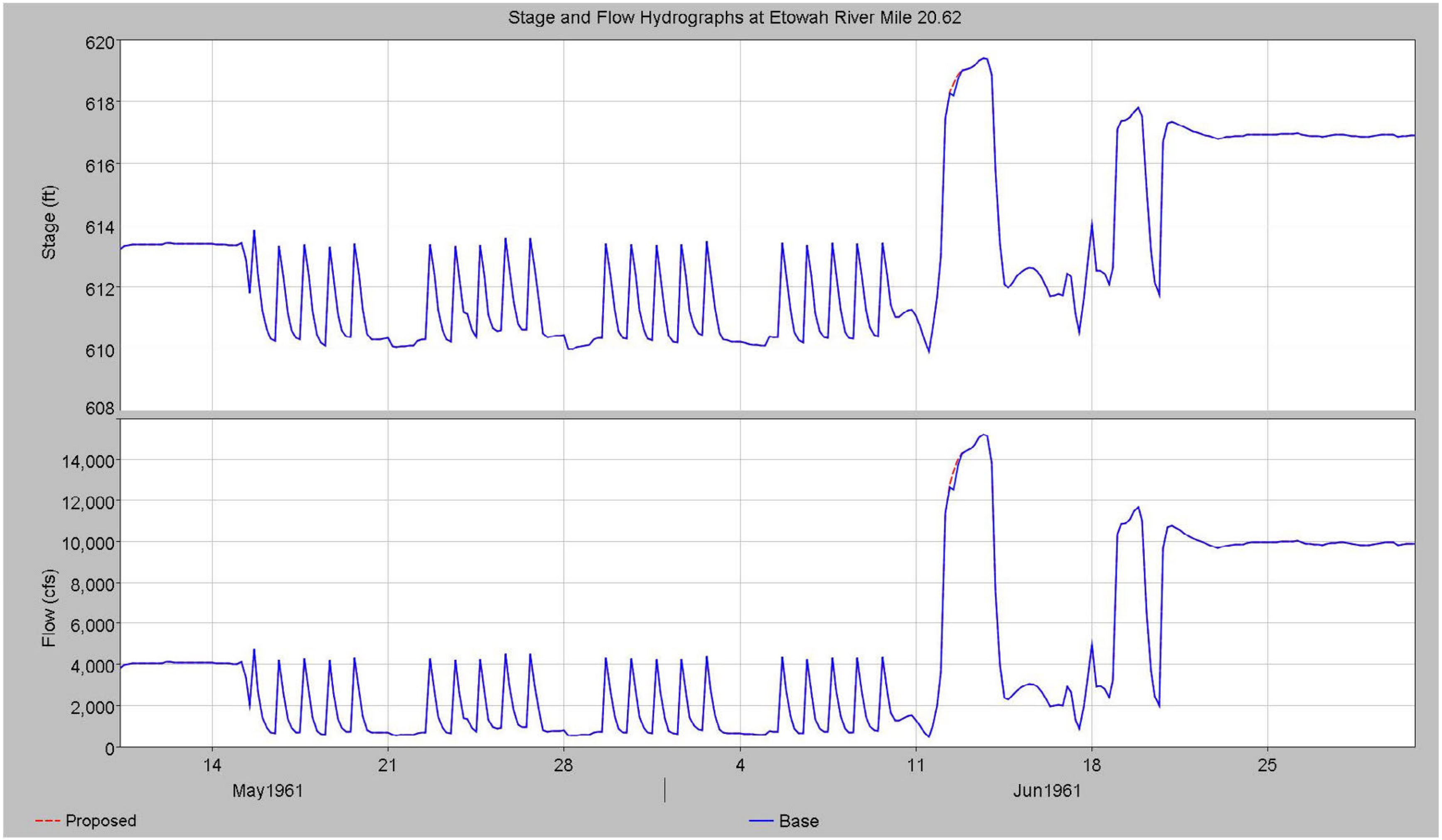

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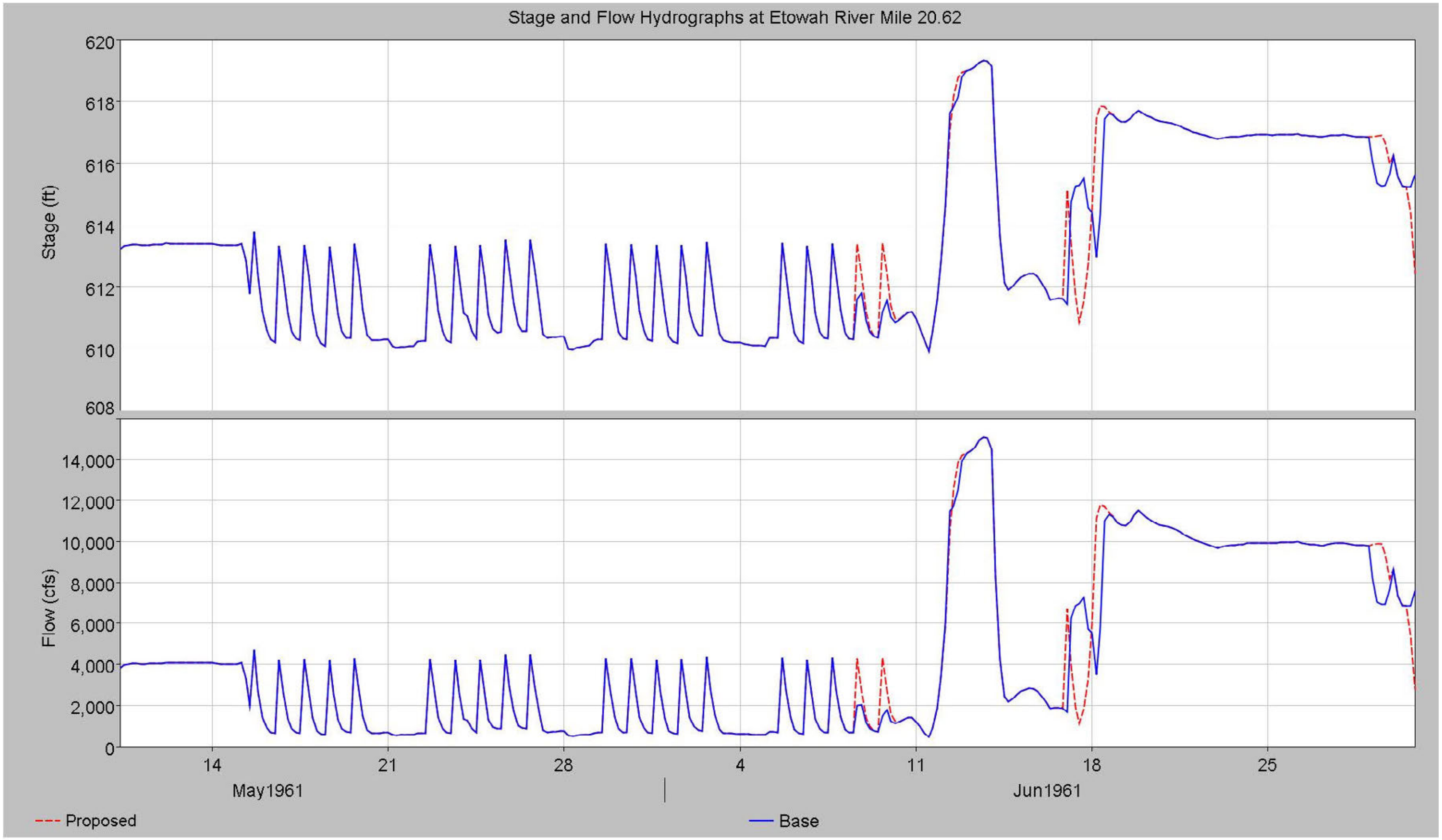

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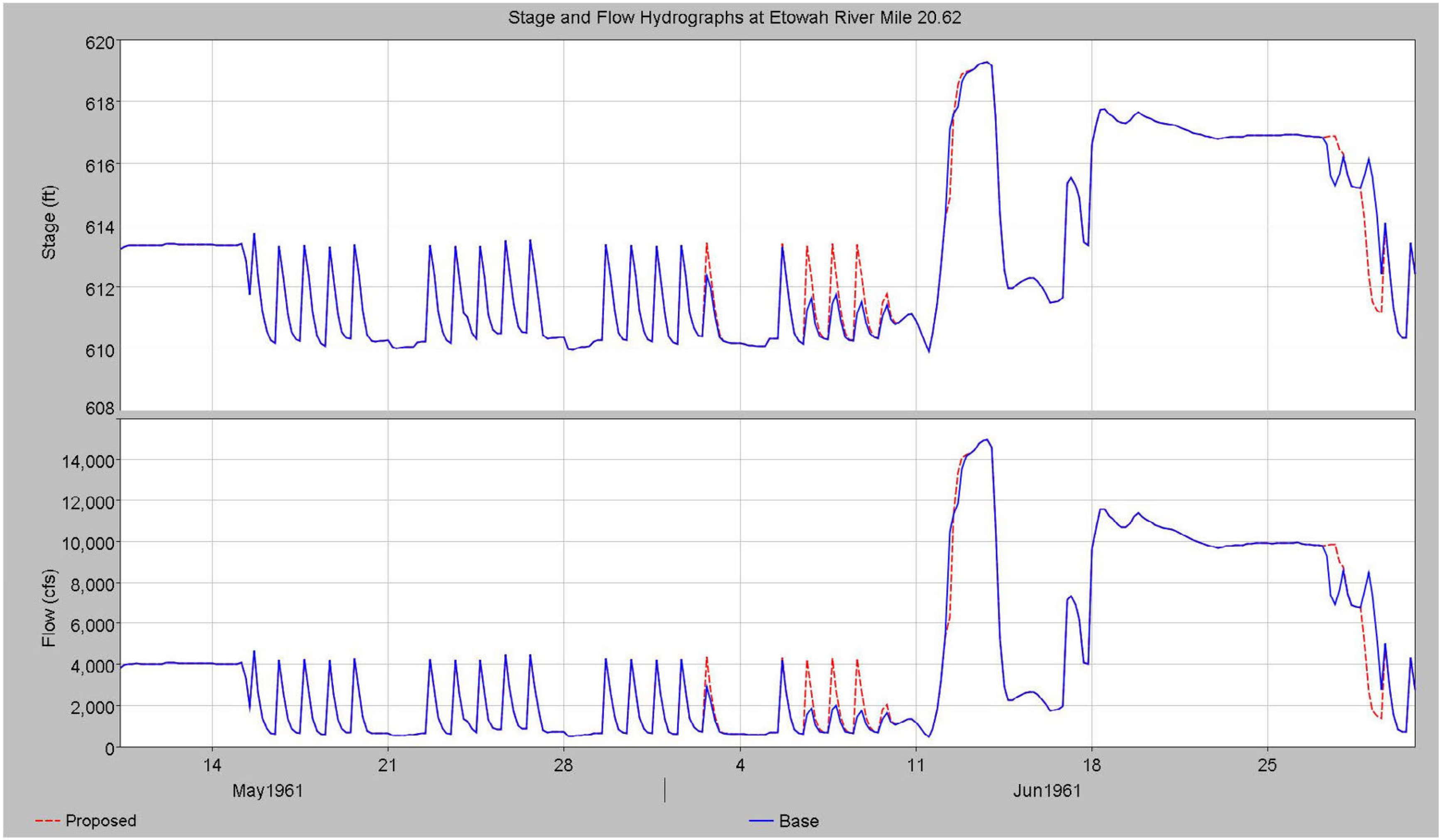

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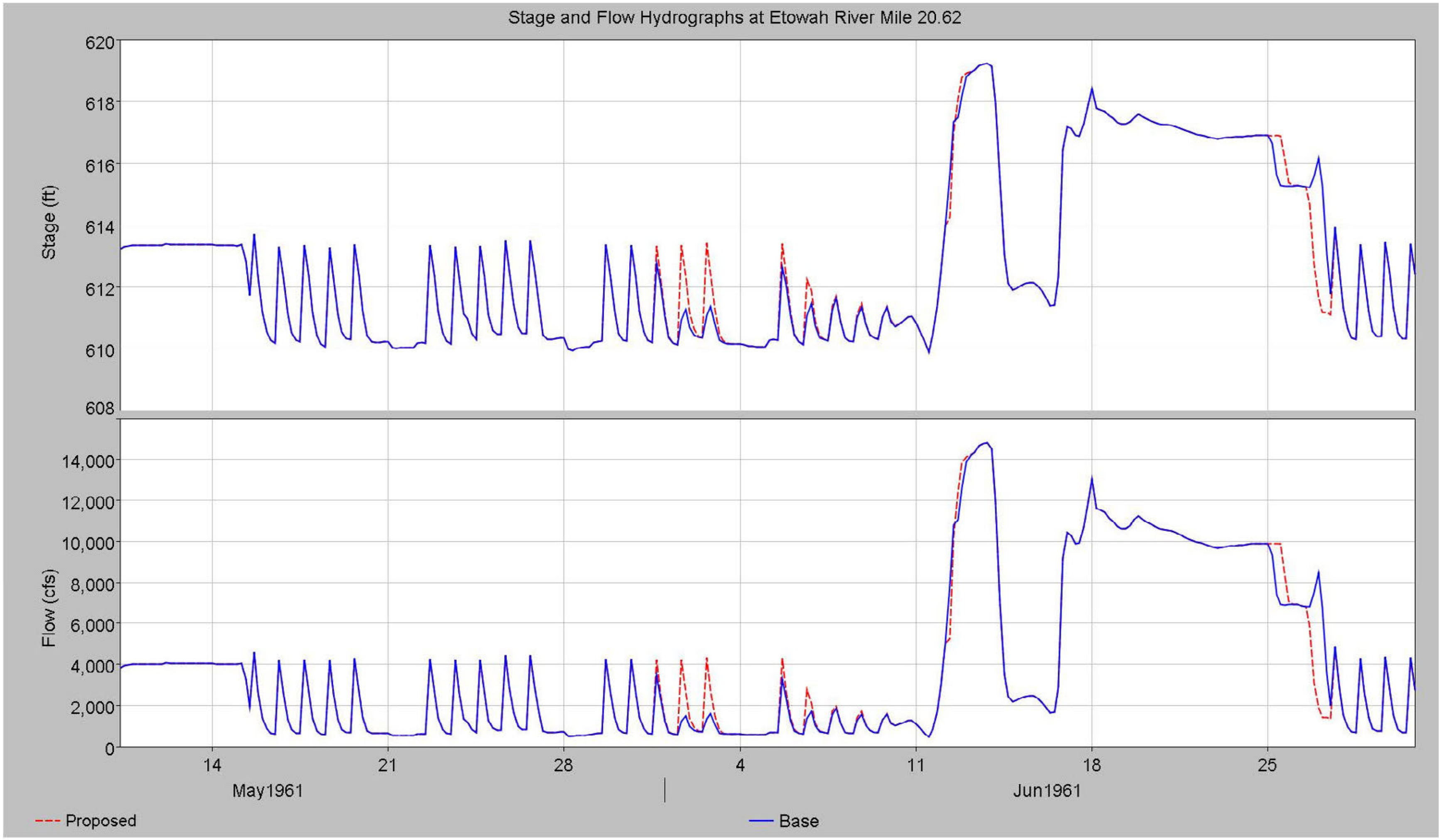

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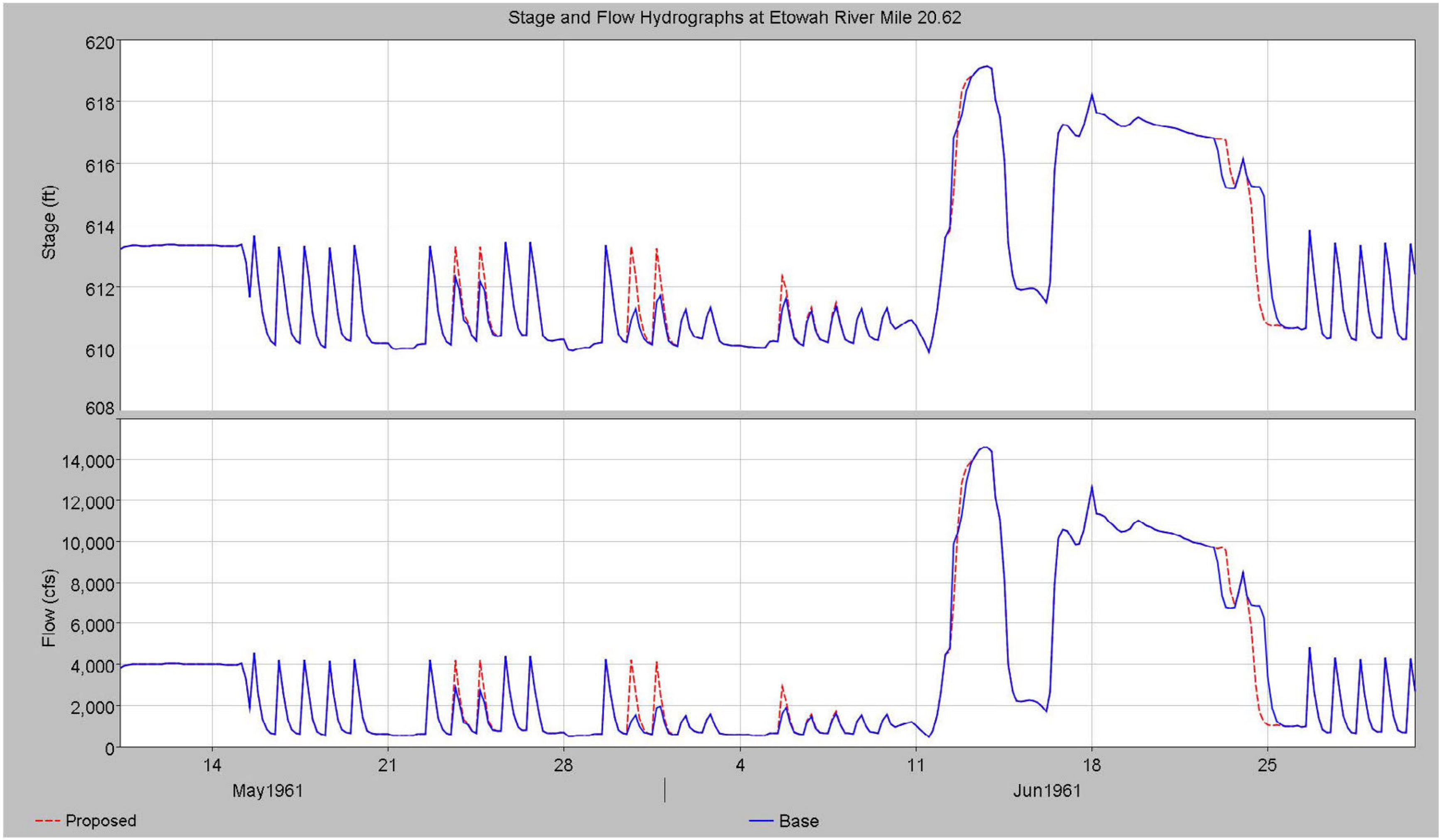

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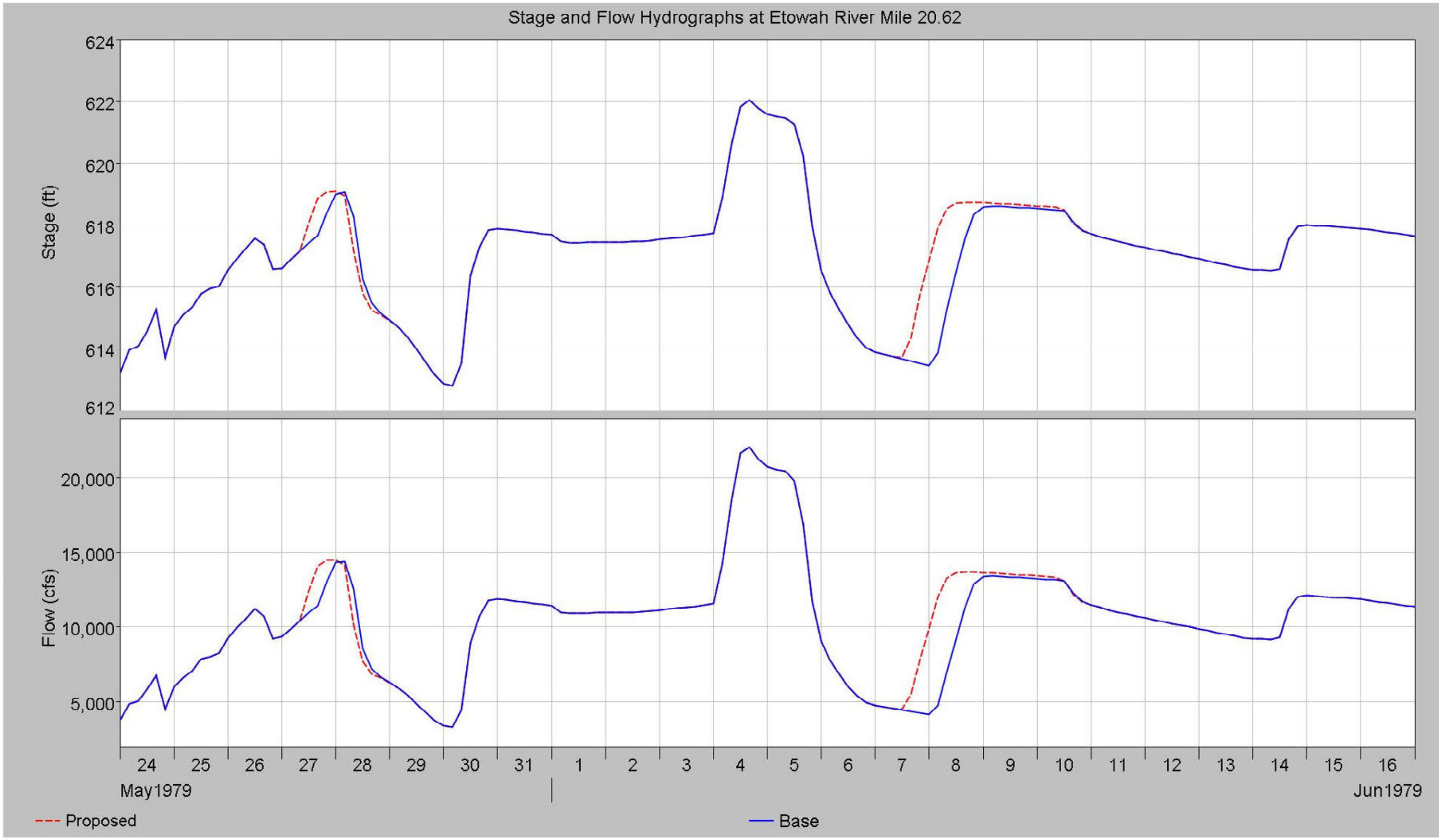

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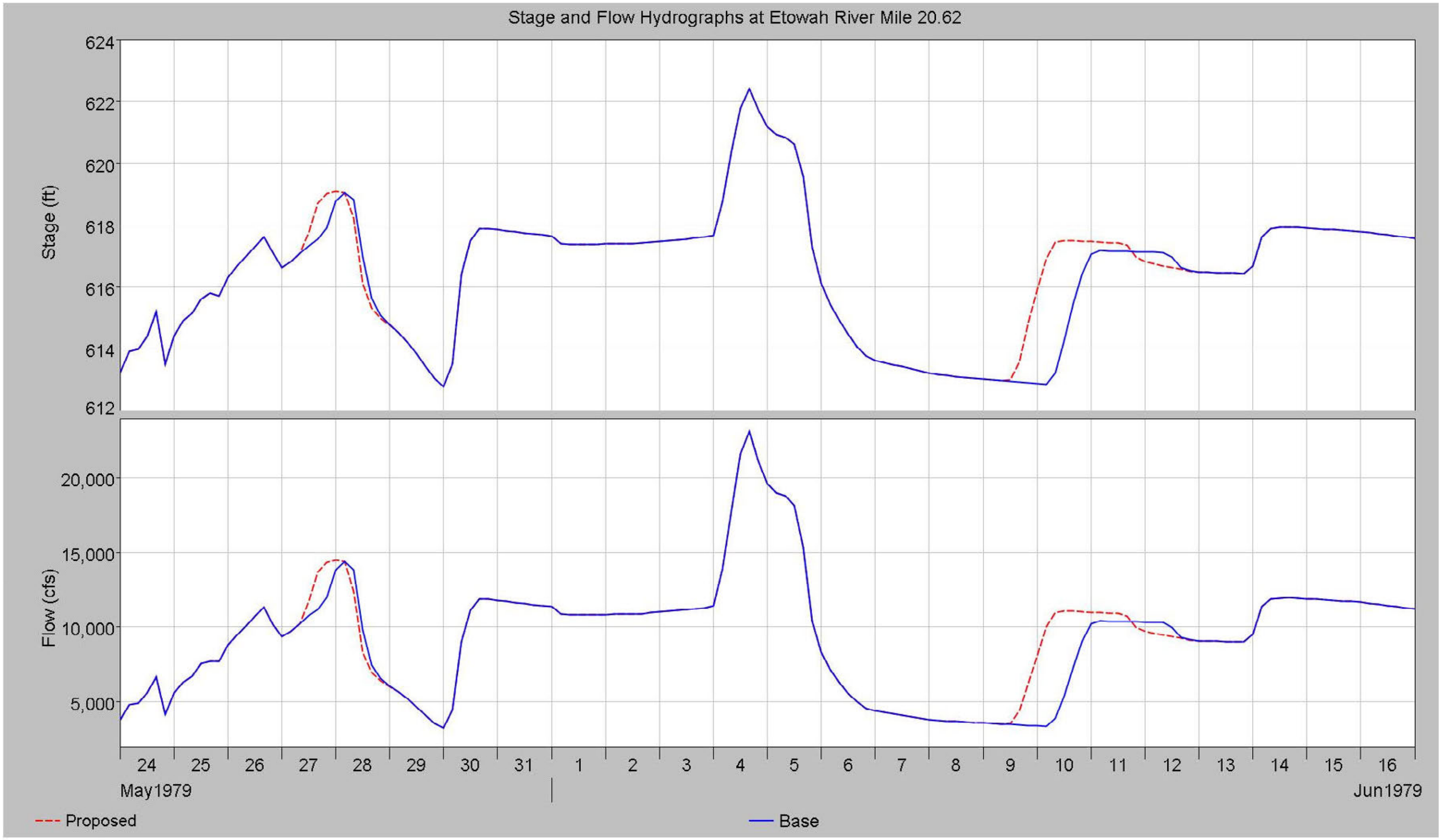

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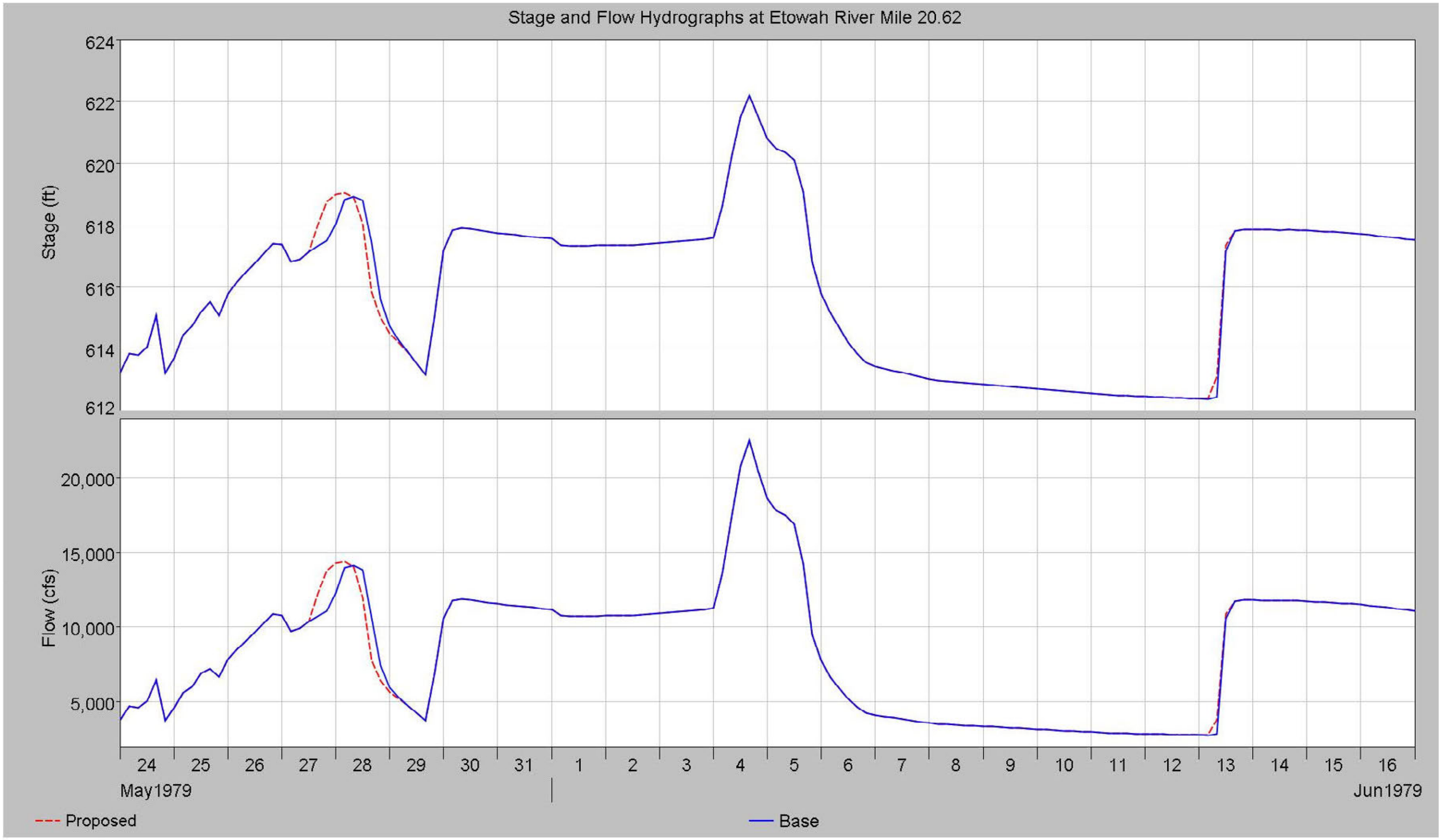

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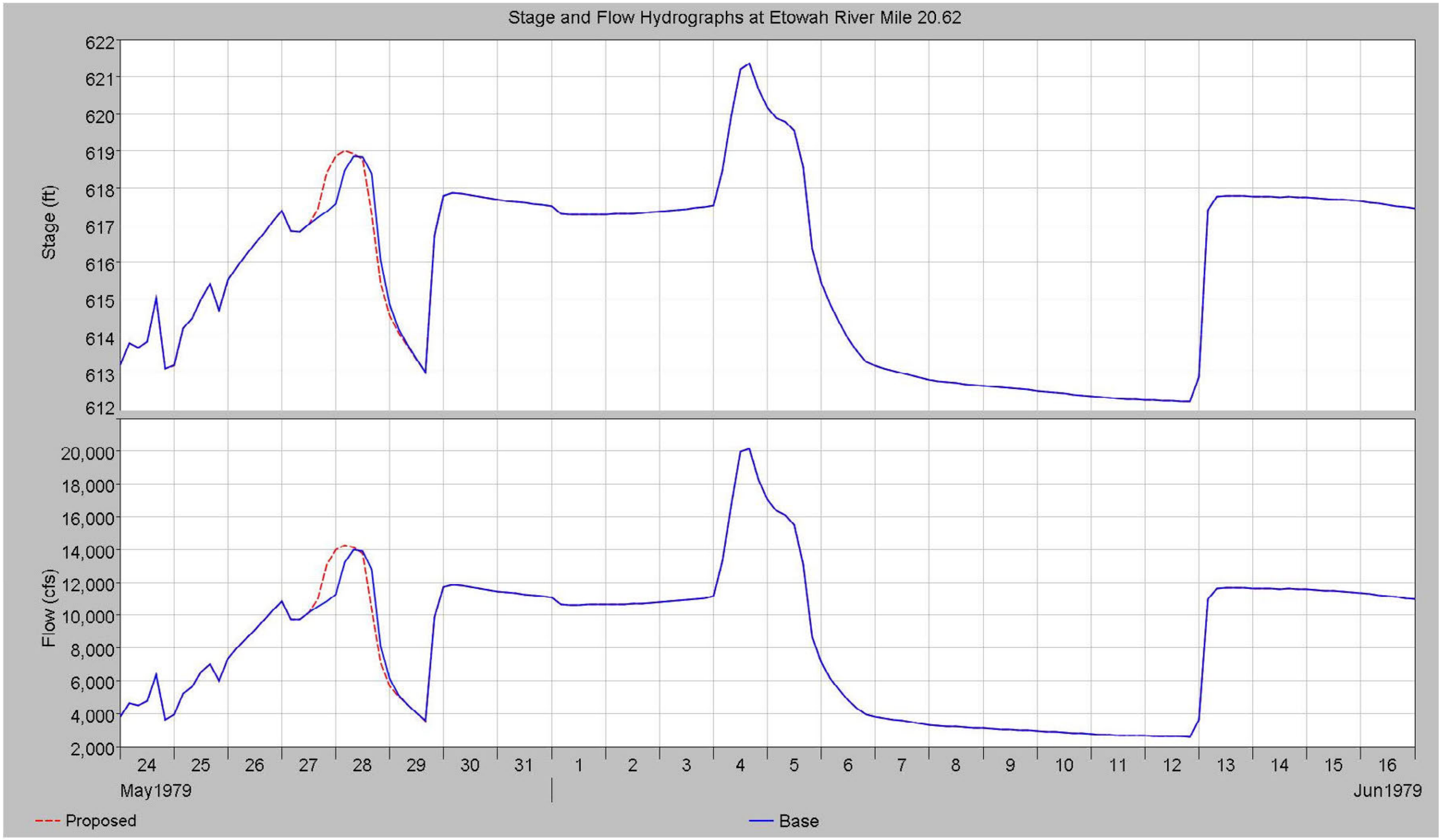

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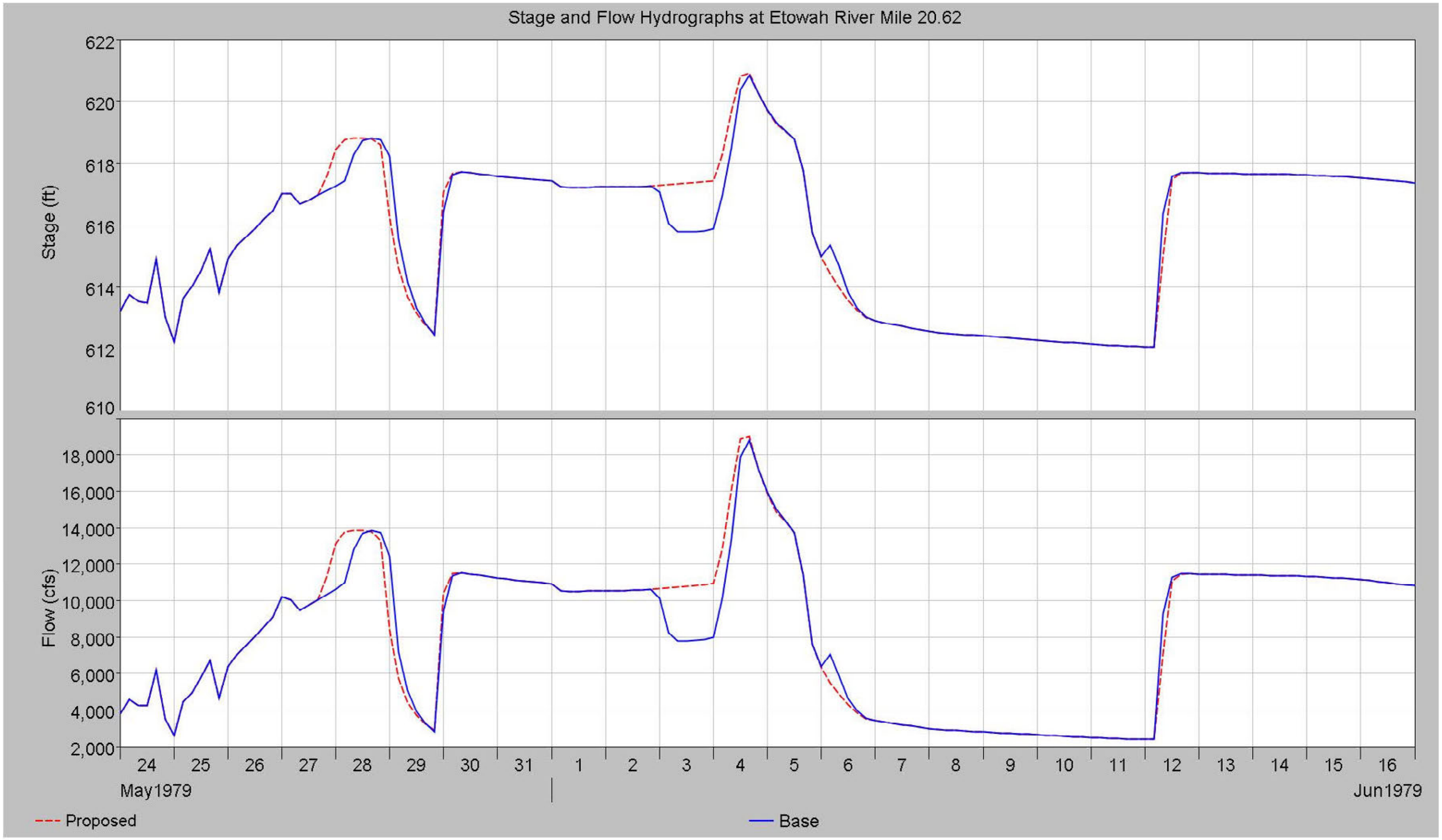

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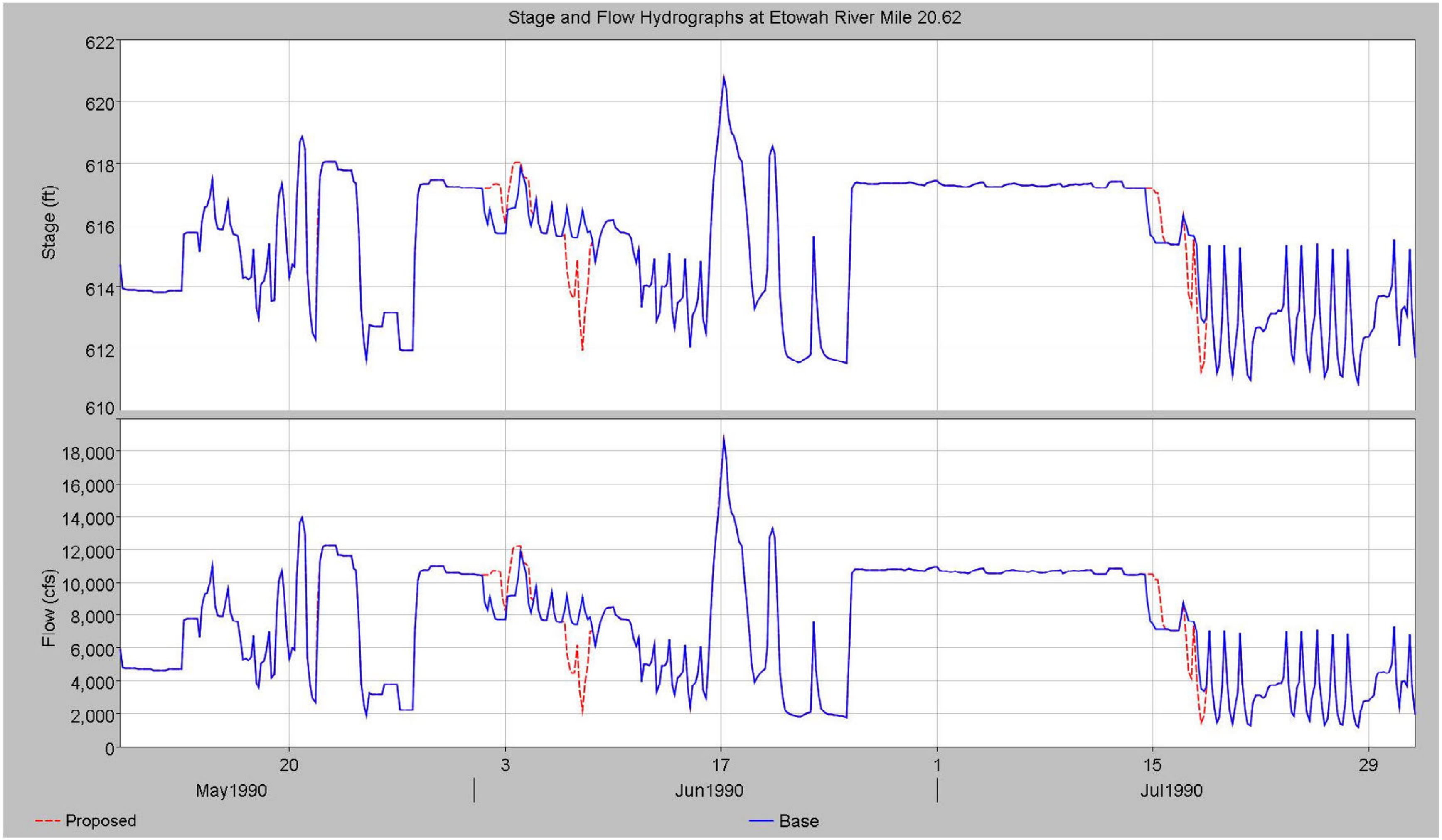

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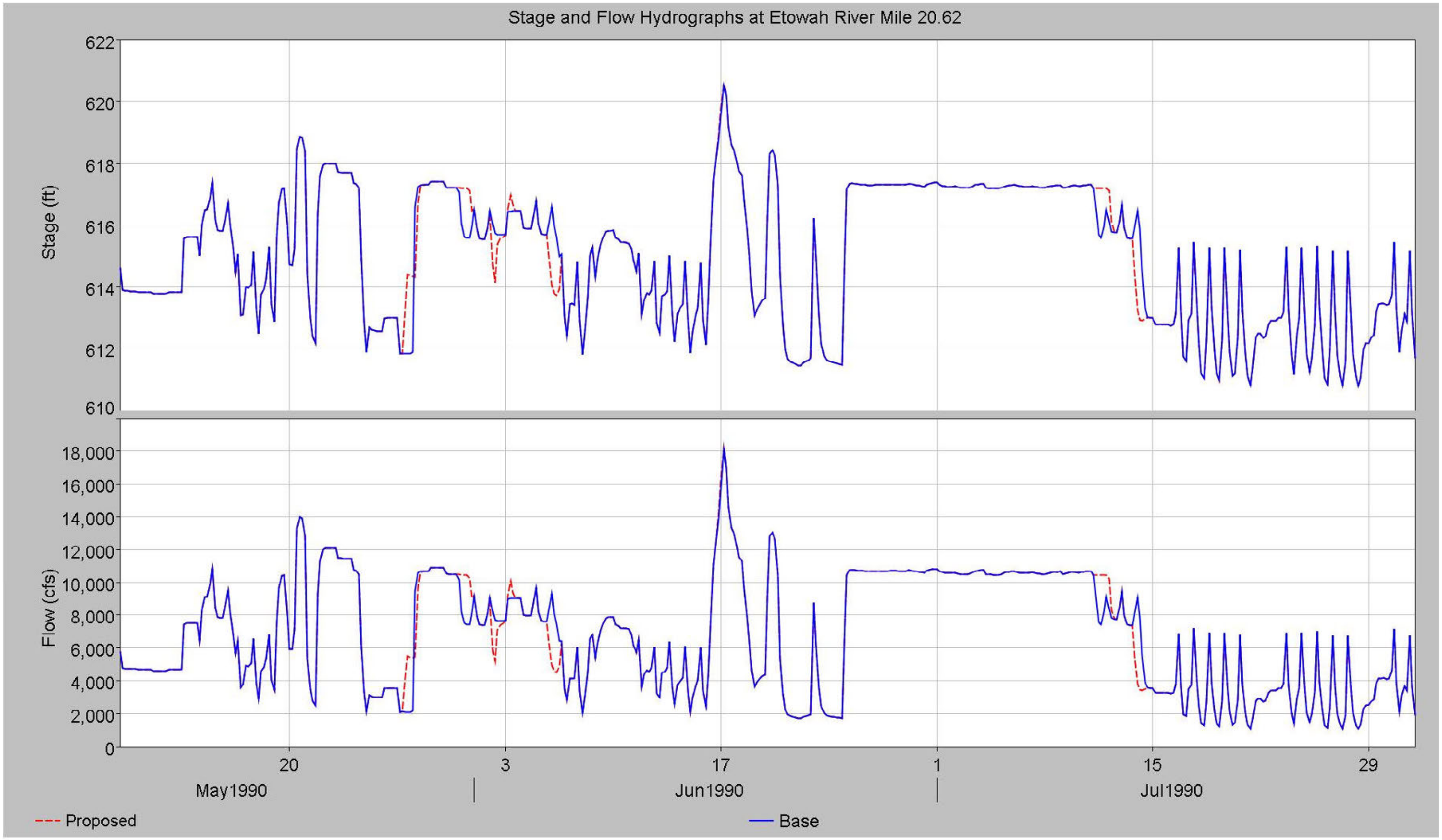

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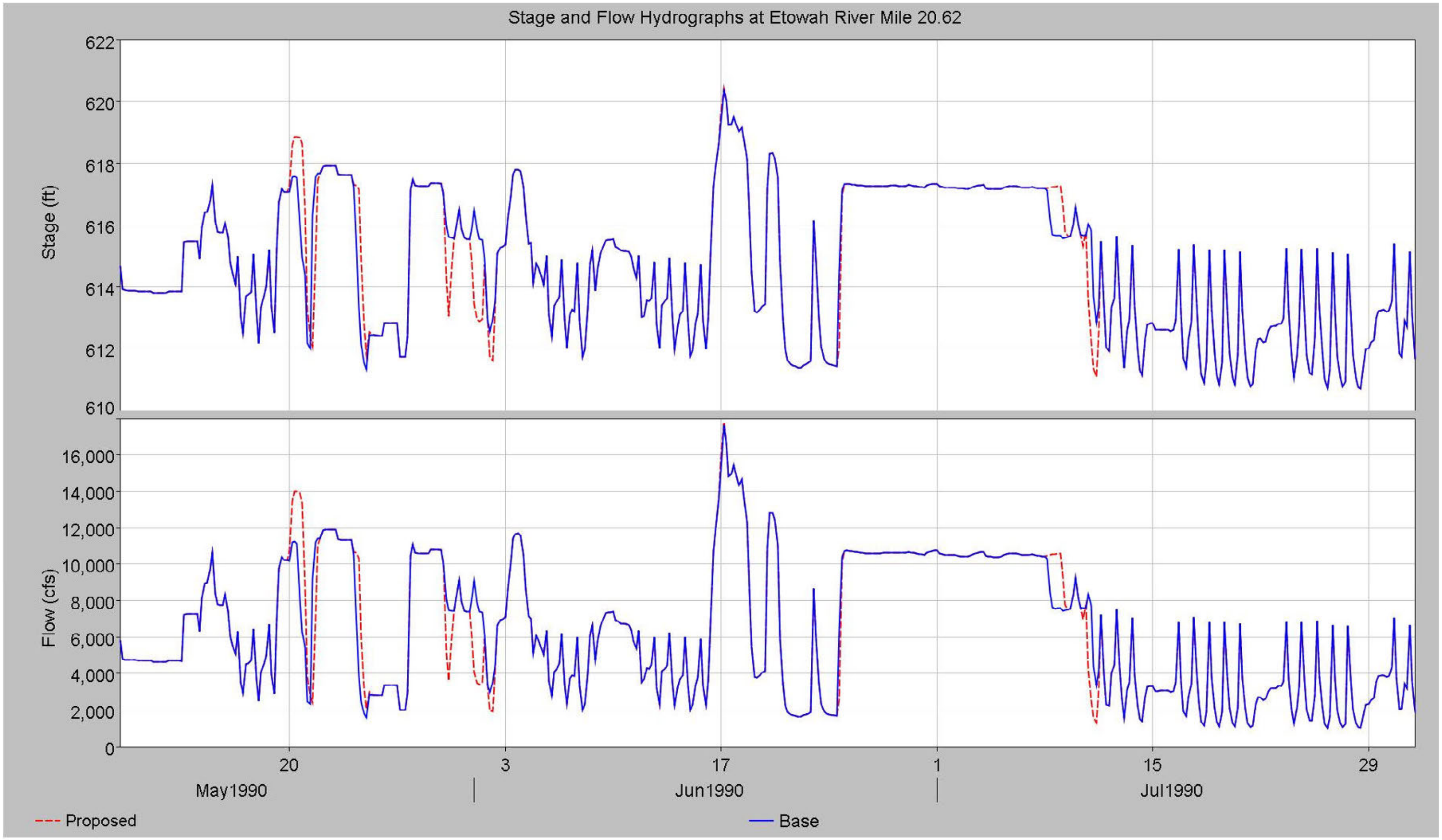

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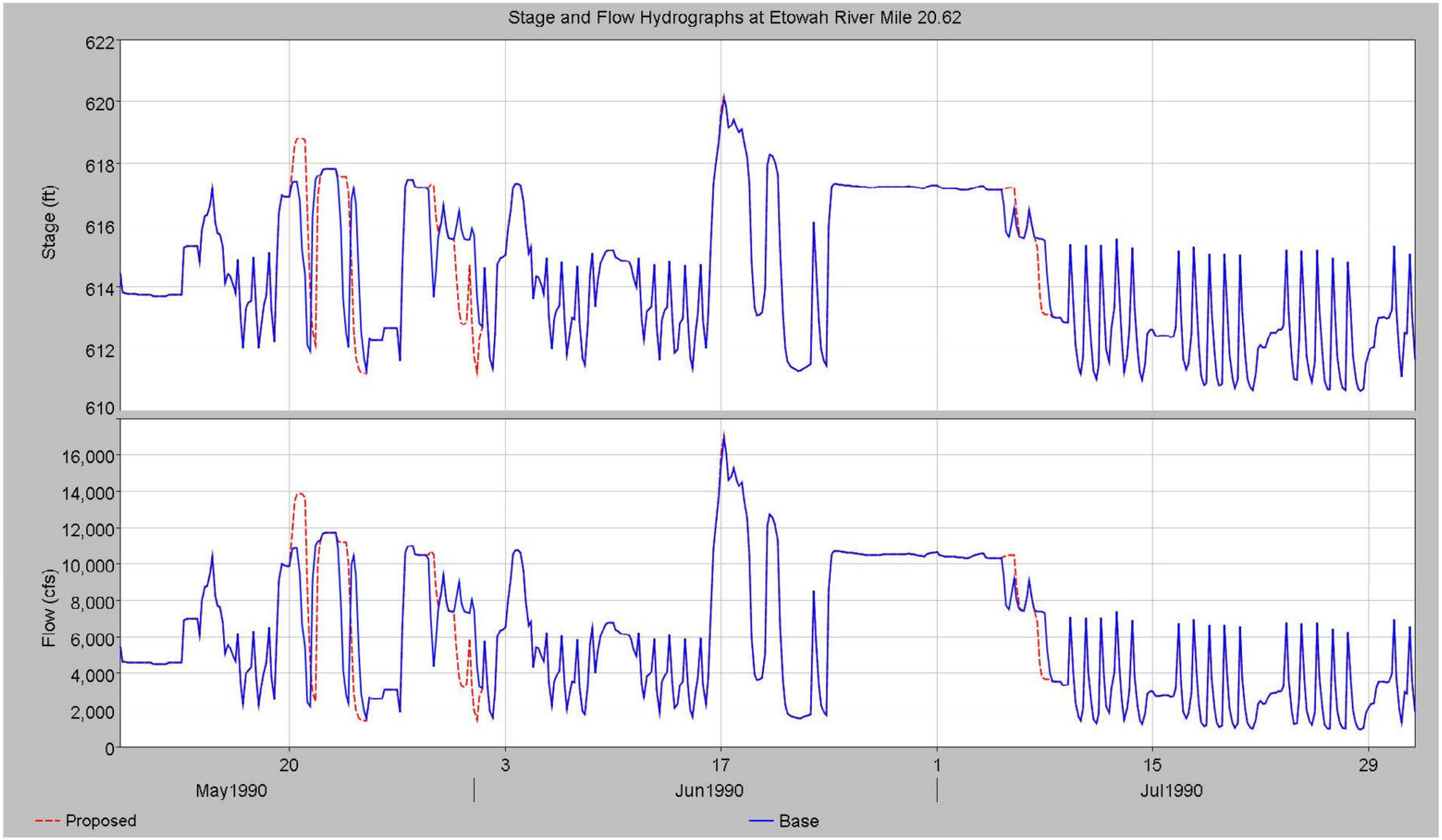

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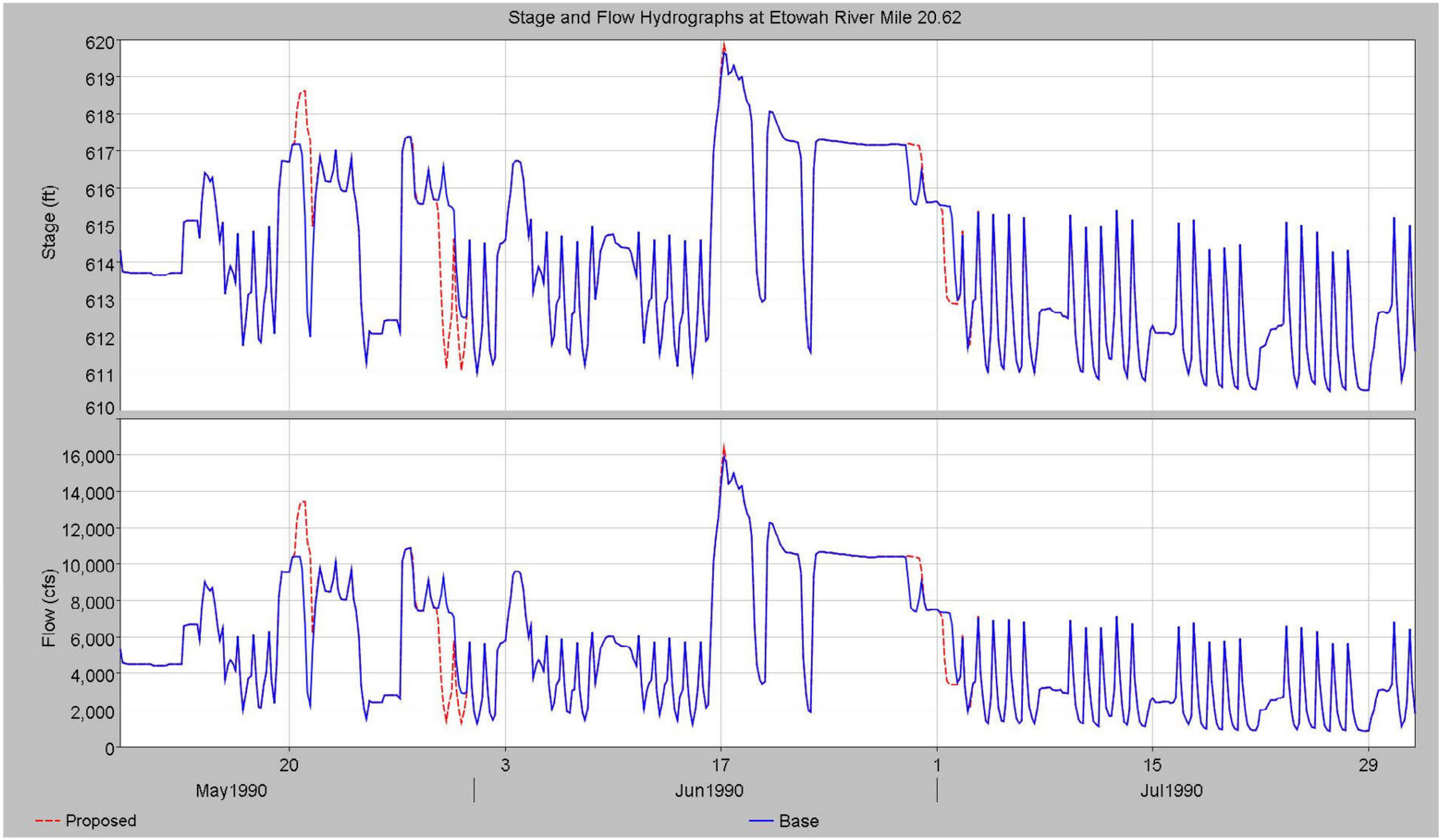

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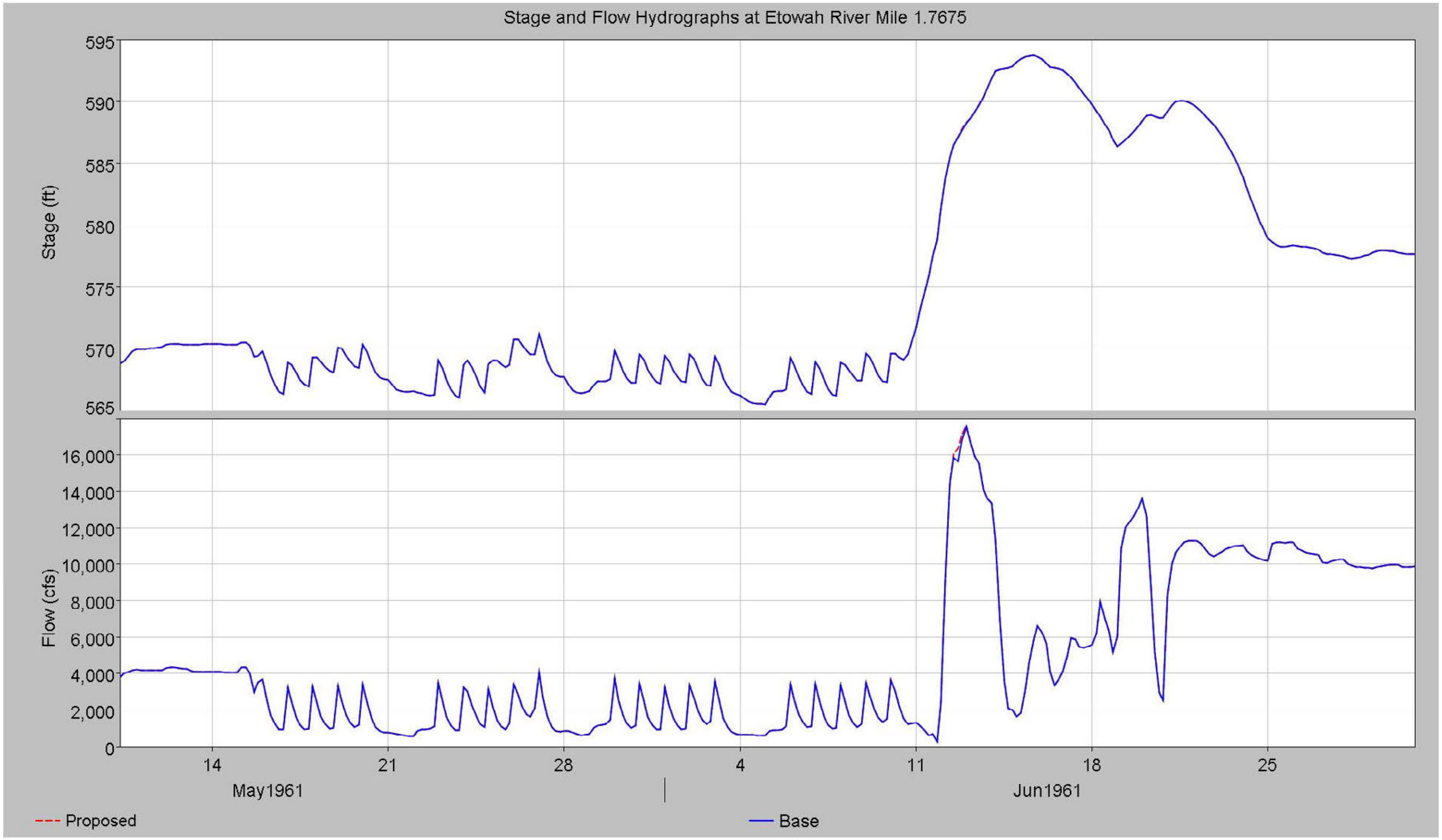

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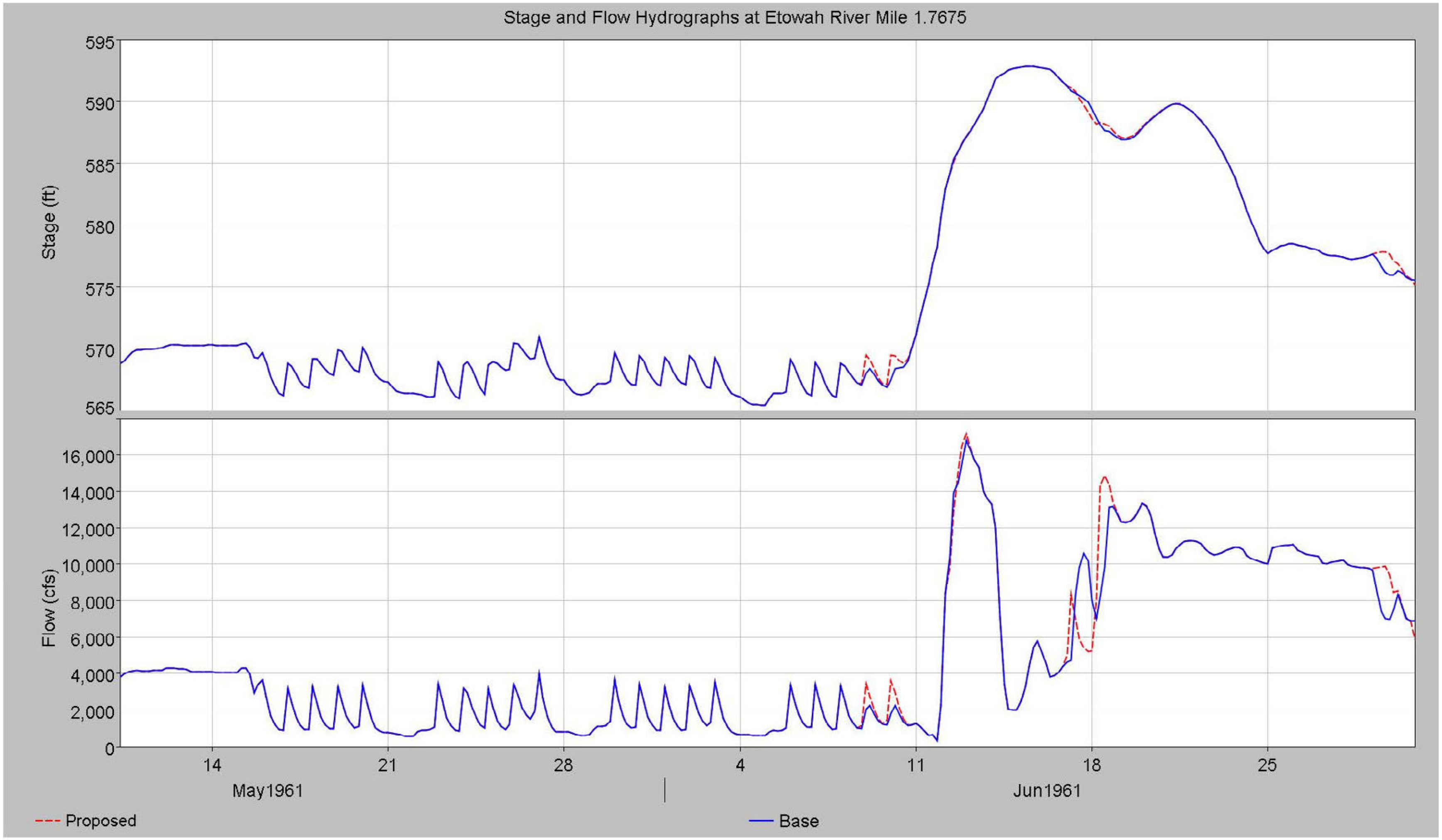

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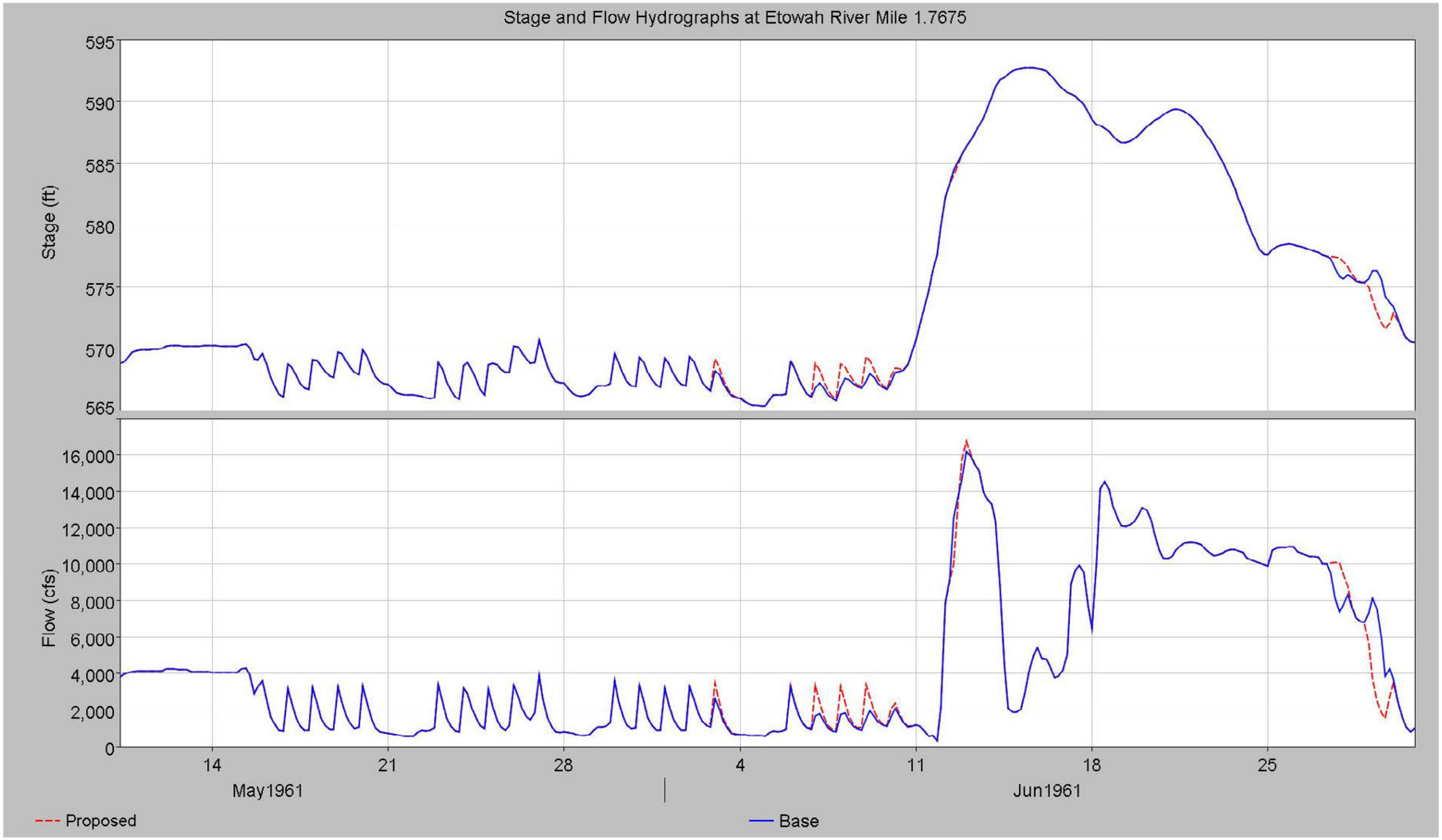

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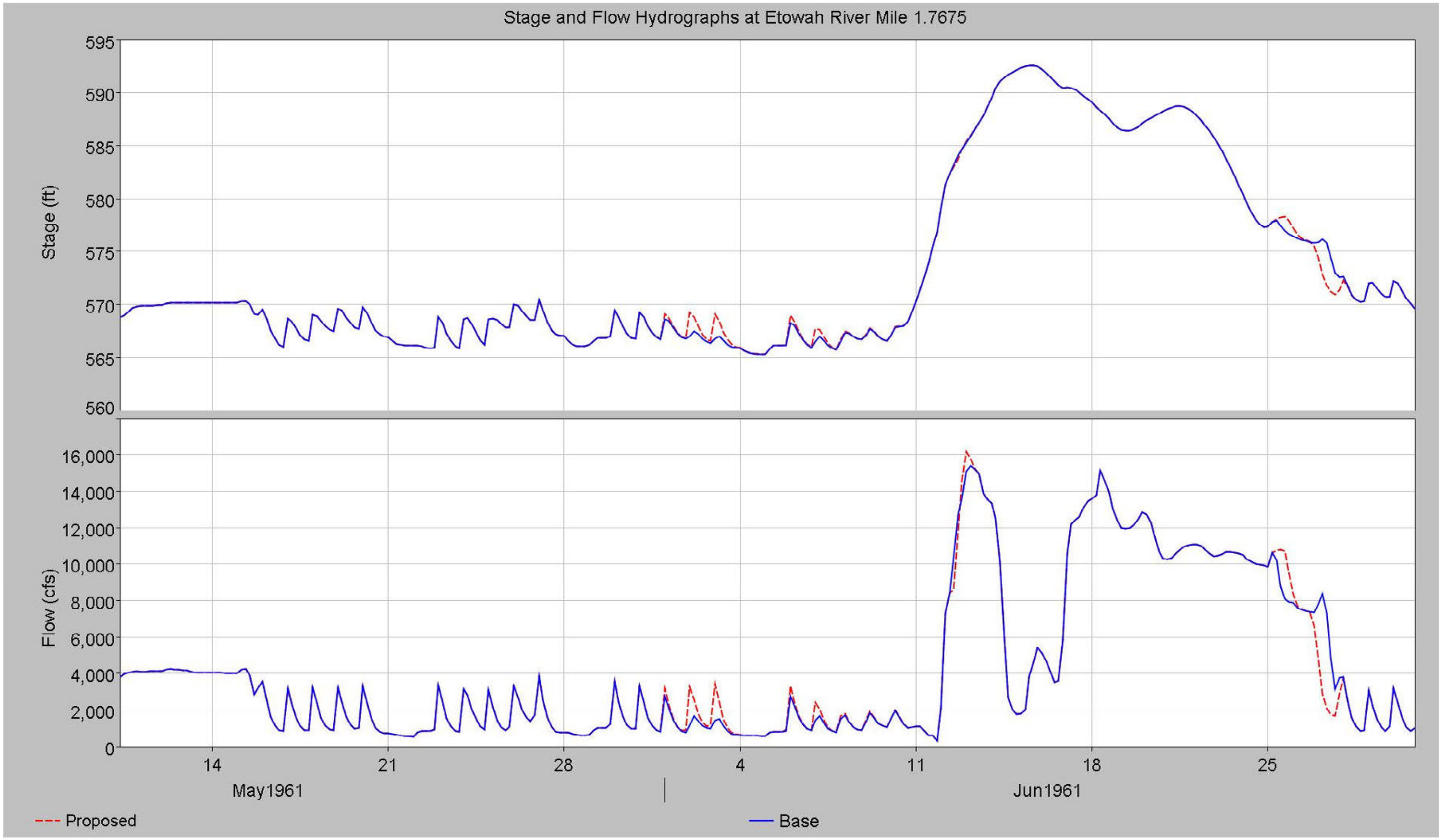

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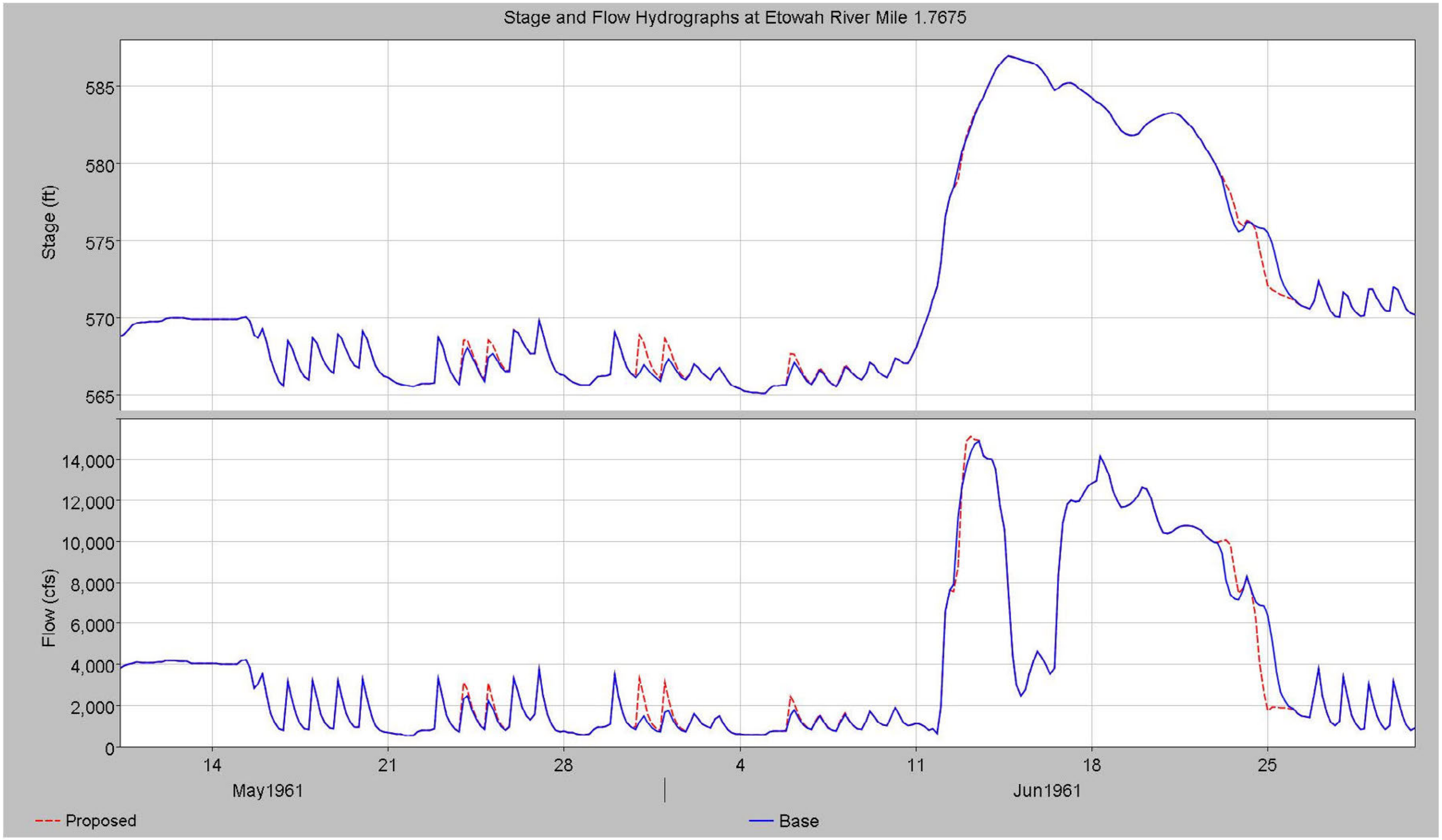
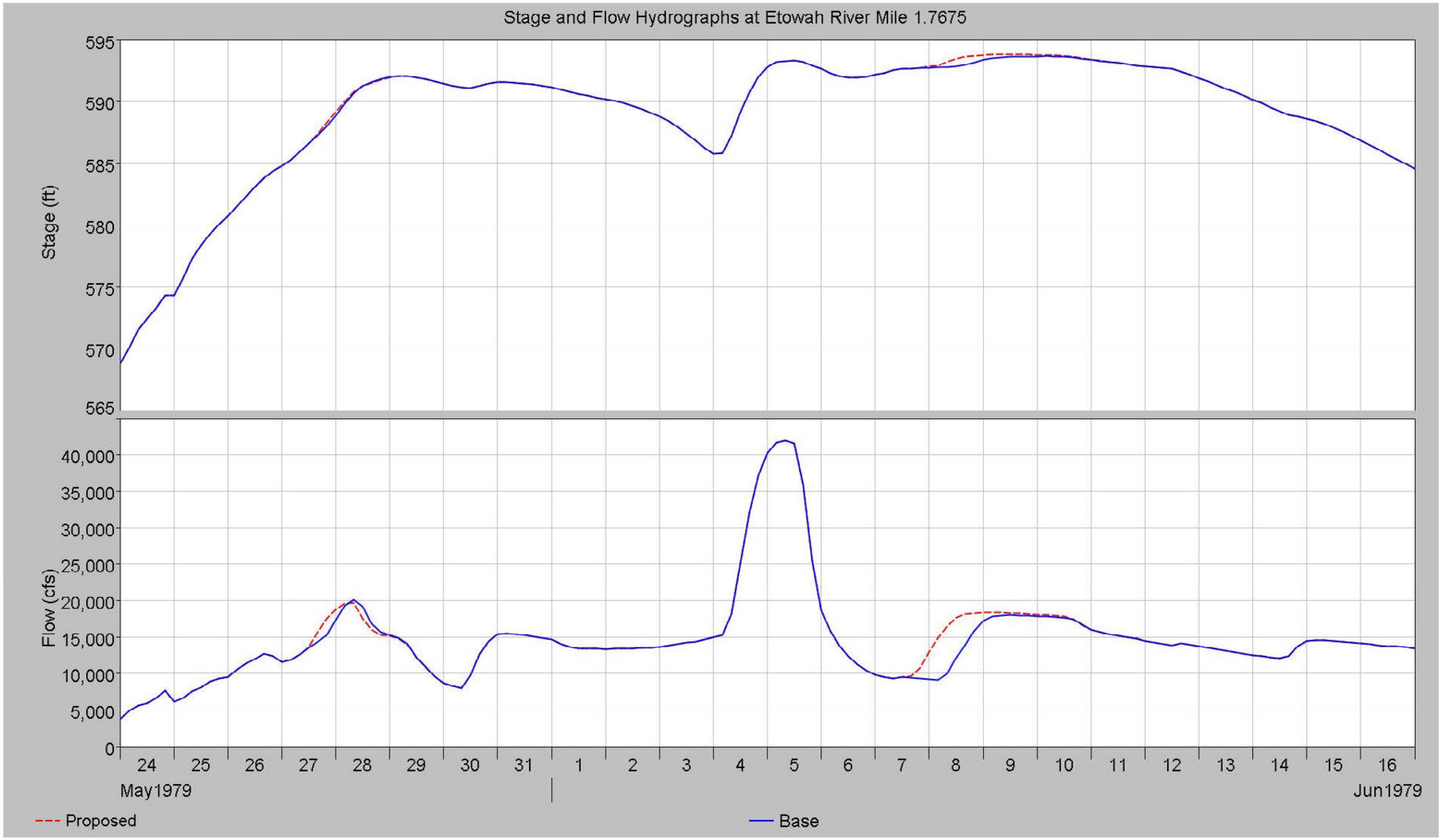
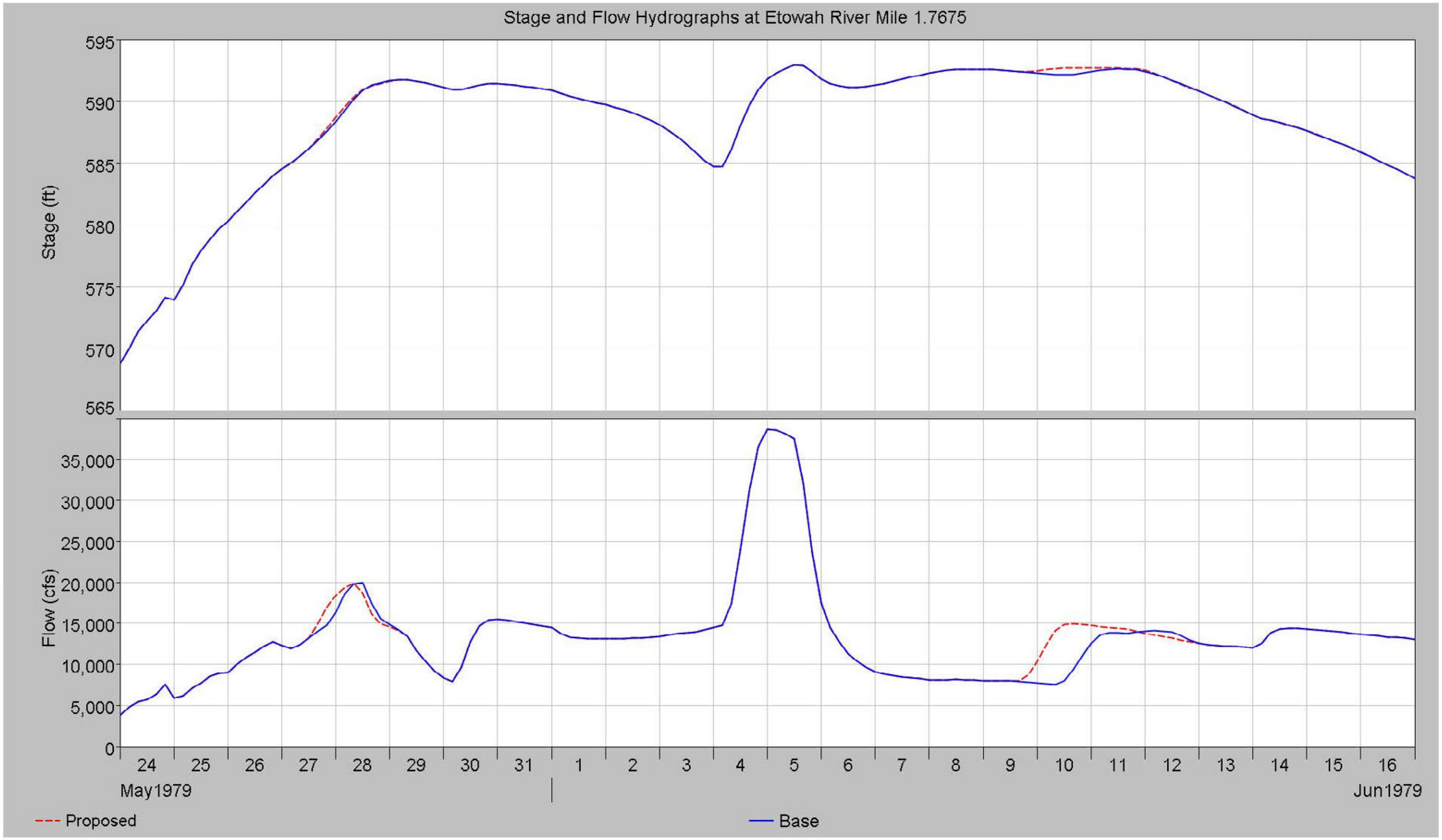


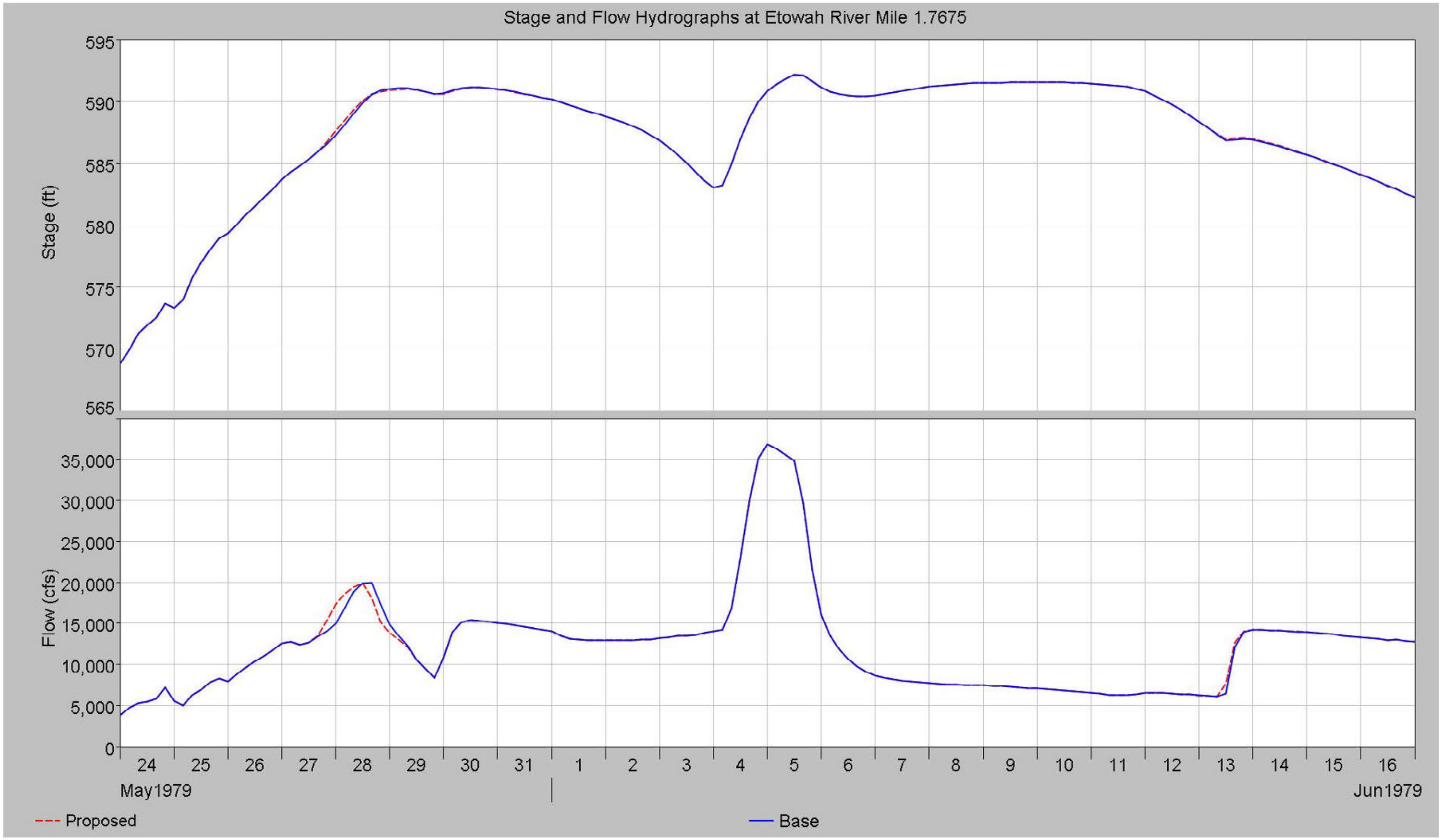
Stage/Flow at Etowah River Mile 1.7675 U/S of Turner McCall Blvd for the 1961 Storm Scaled to a 5.0% ACE



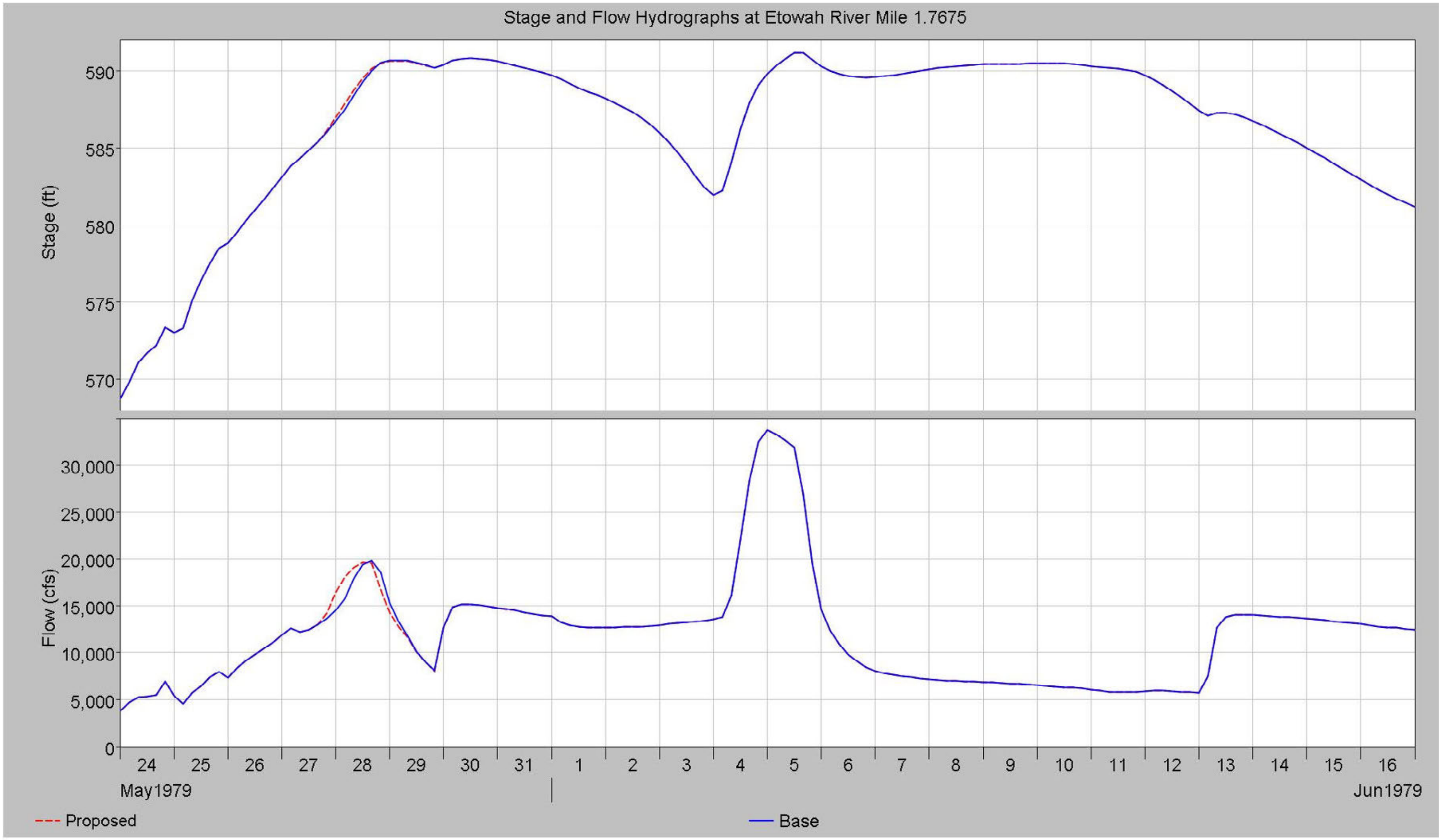
Stage/Flow at Etowah River Mile 1.7675 U/S of Turner McCall Blvd for the 1979 Storm Scaled to a 0.2% ACE



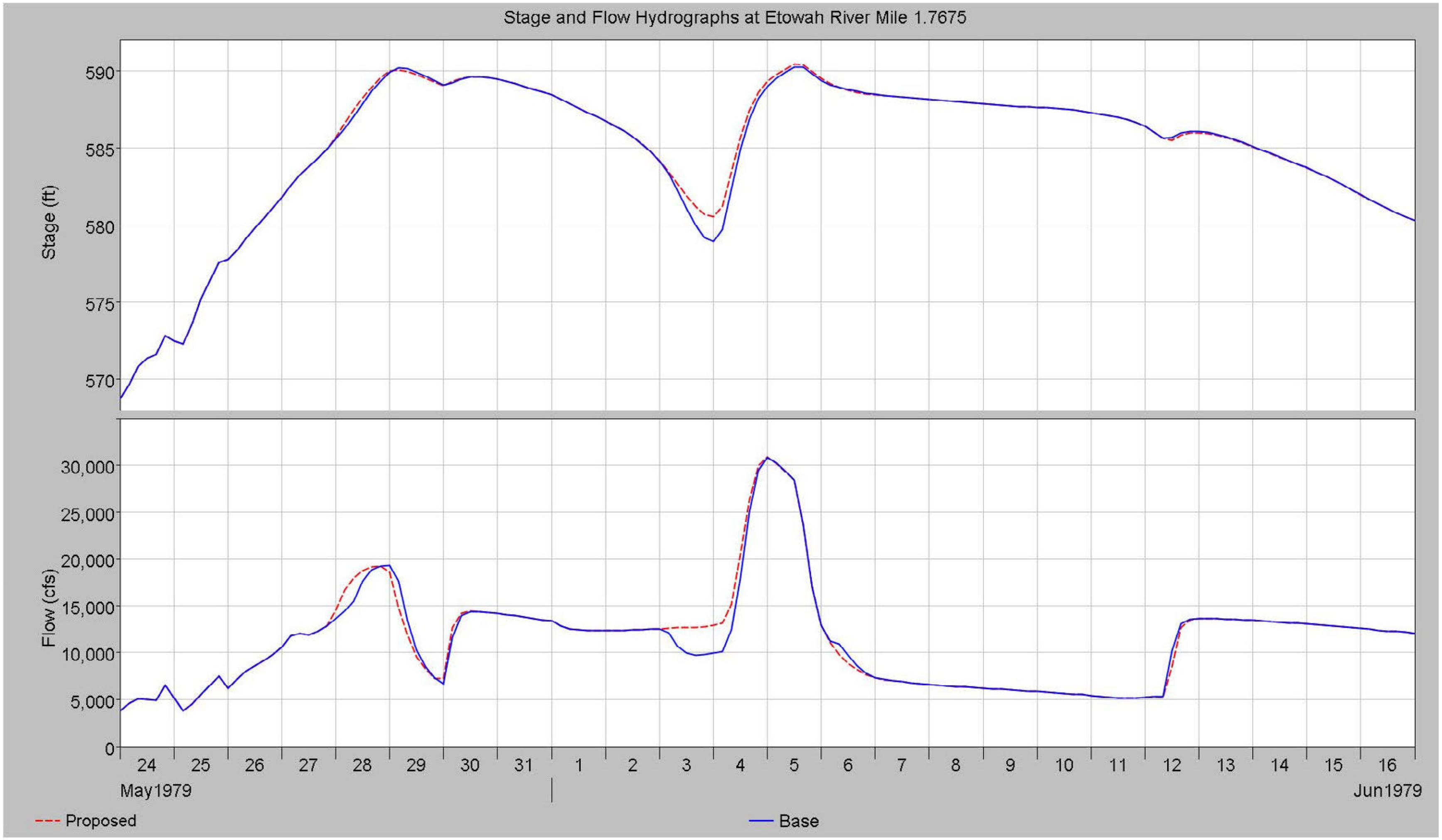
Stage/Flow at Etowah River Mile 1.7675 U/S of Turner McCall Blvd for the 1979 Storm Scaled to a 0.5% ACE



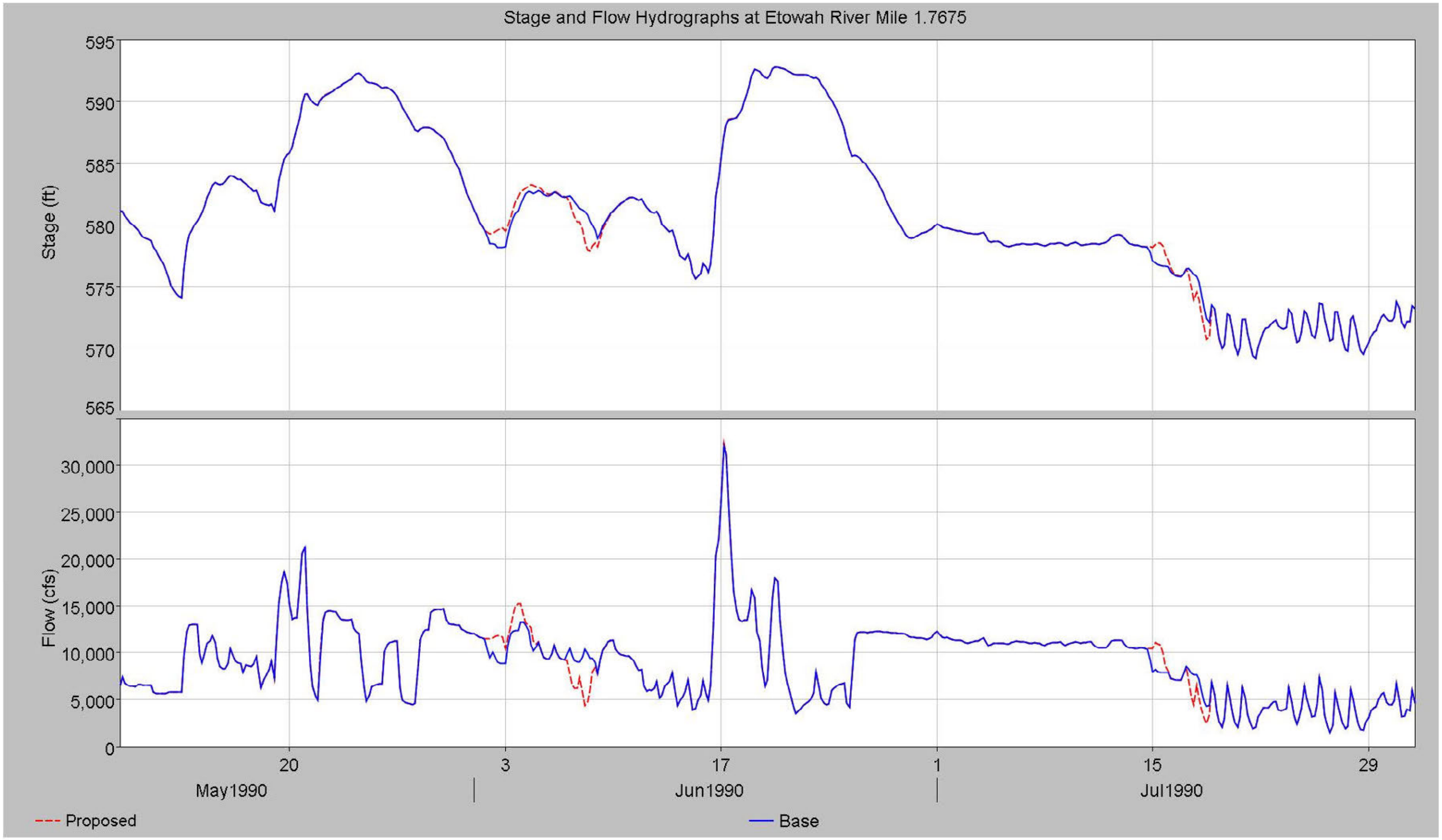
Stage/Flow at Etowah River Mile 1.7675 U/S of Turner McCall Blvd for the 1979 Storm Scaled to a 1.0% ACE



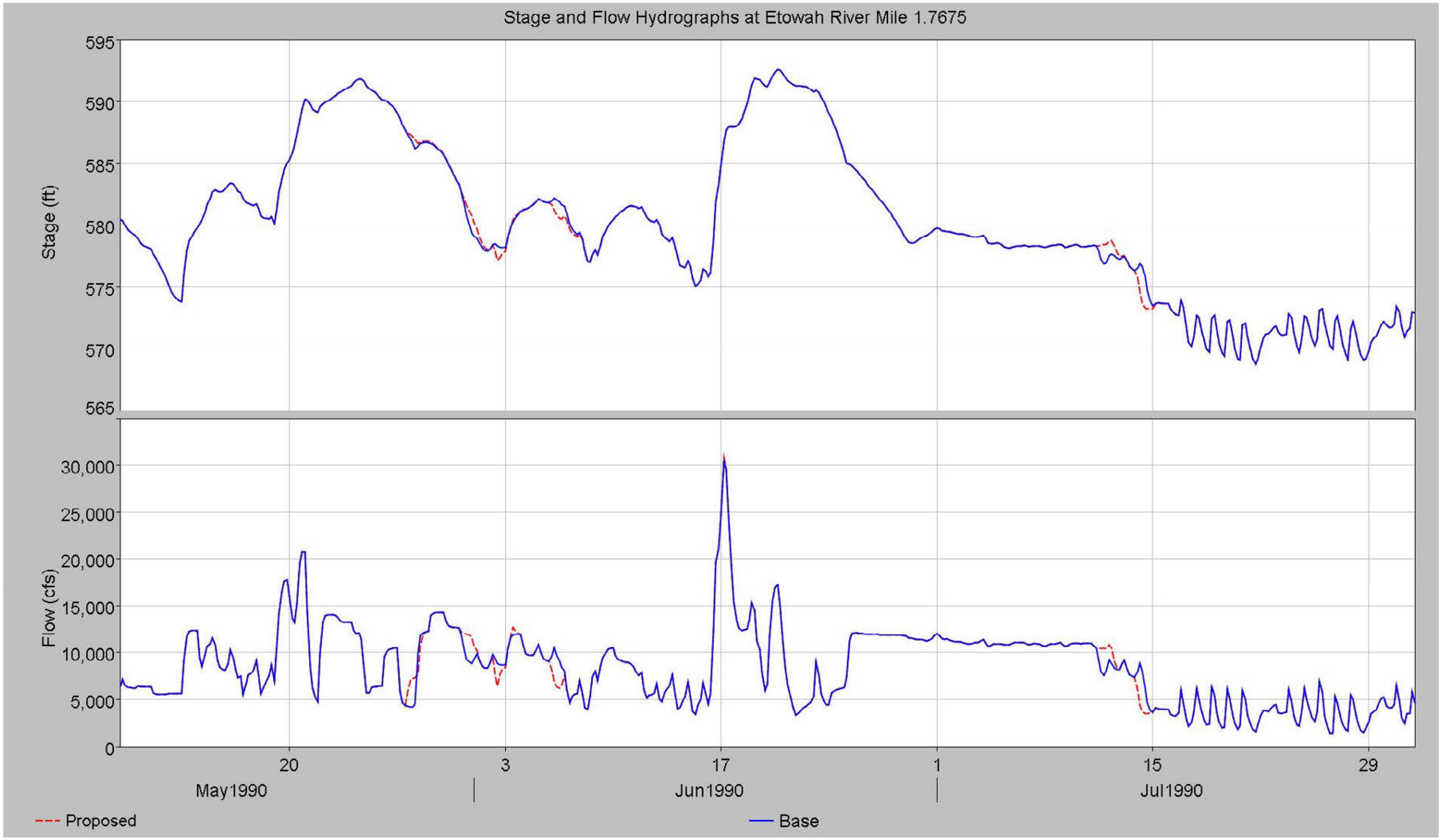
Stage/Flow at Etowah River Mile 1.7675 U/S of Turner McCall Blvd for the 1979 Storm Scaled to a 2.0% ACE



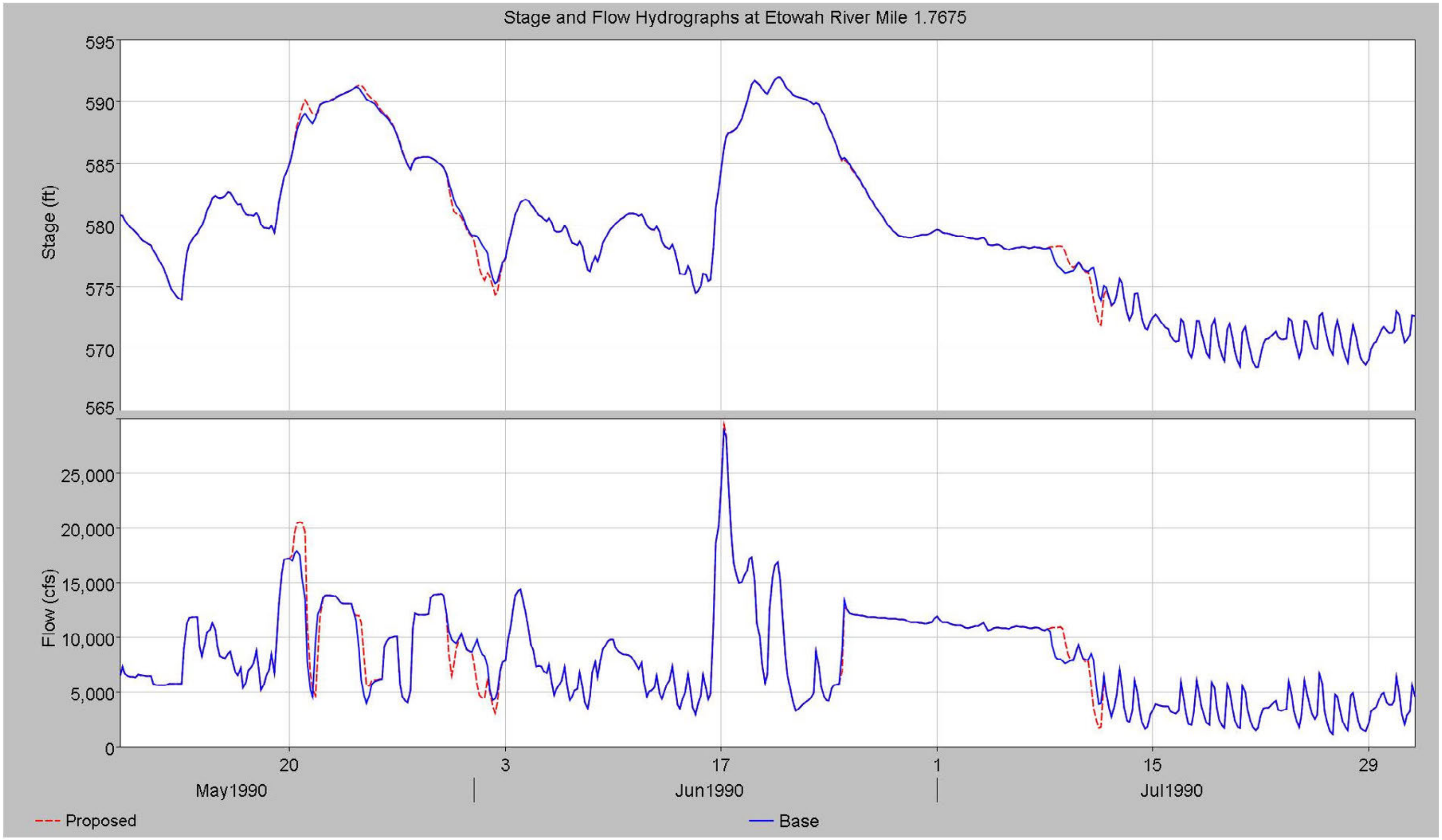
Stage/Flow at Etowah River Mile 1.7675 U/S of Turner McCall Blvd for the 1979 Storm Scaled to a 5.0% ACE



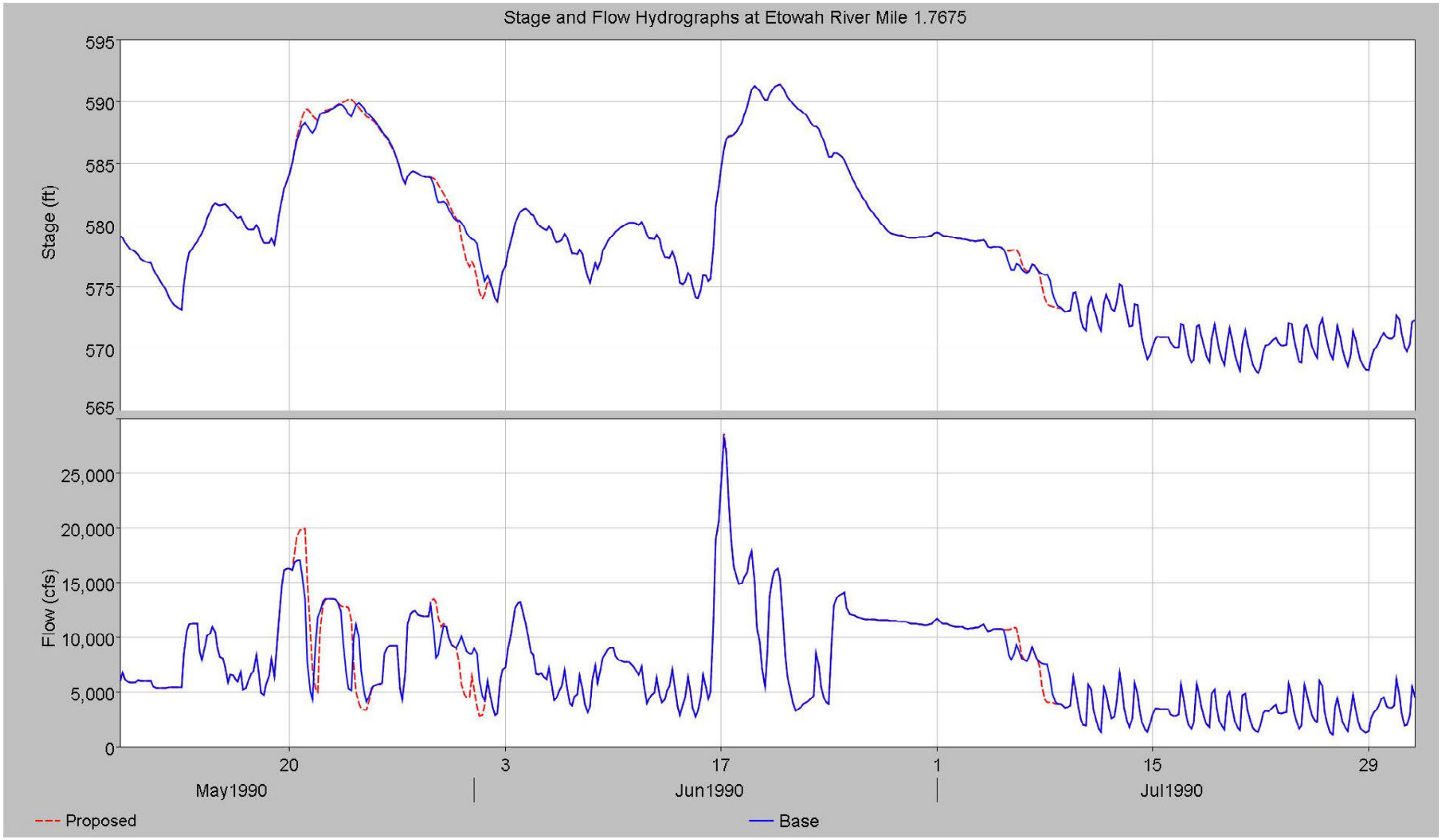
Stage/Flow at Etowah River Mile 1.7675 U/S of Turner McCall Blvd for the 1990 Storm Scaled to a 0.2% ACE



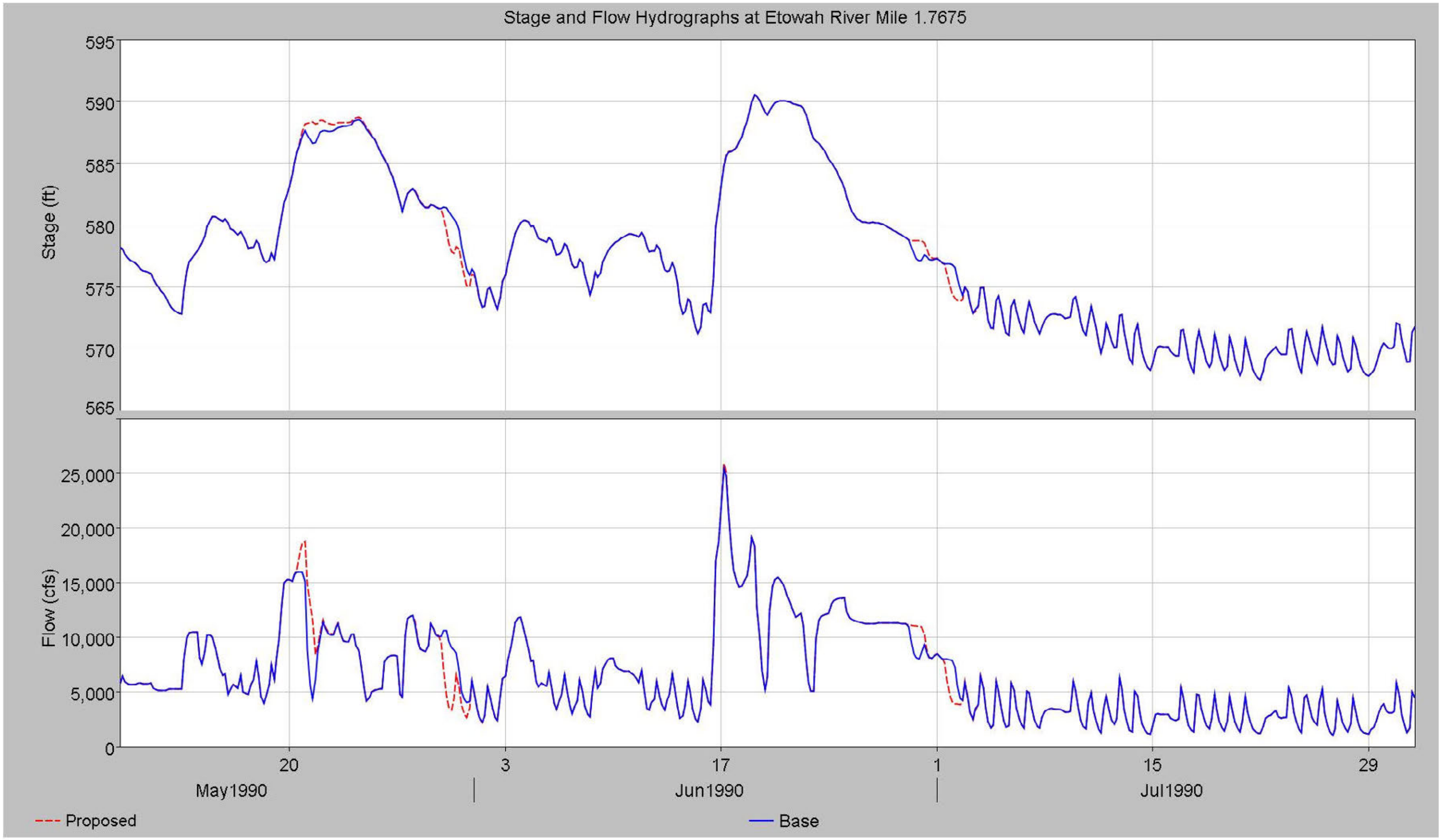
Stage/Flow at Etowah River Mile 1.7675 U/S of Turner McCall Blvd for the 1990 Storm Scaled to a 0.5% ACE



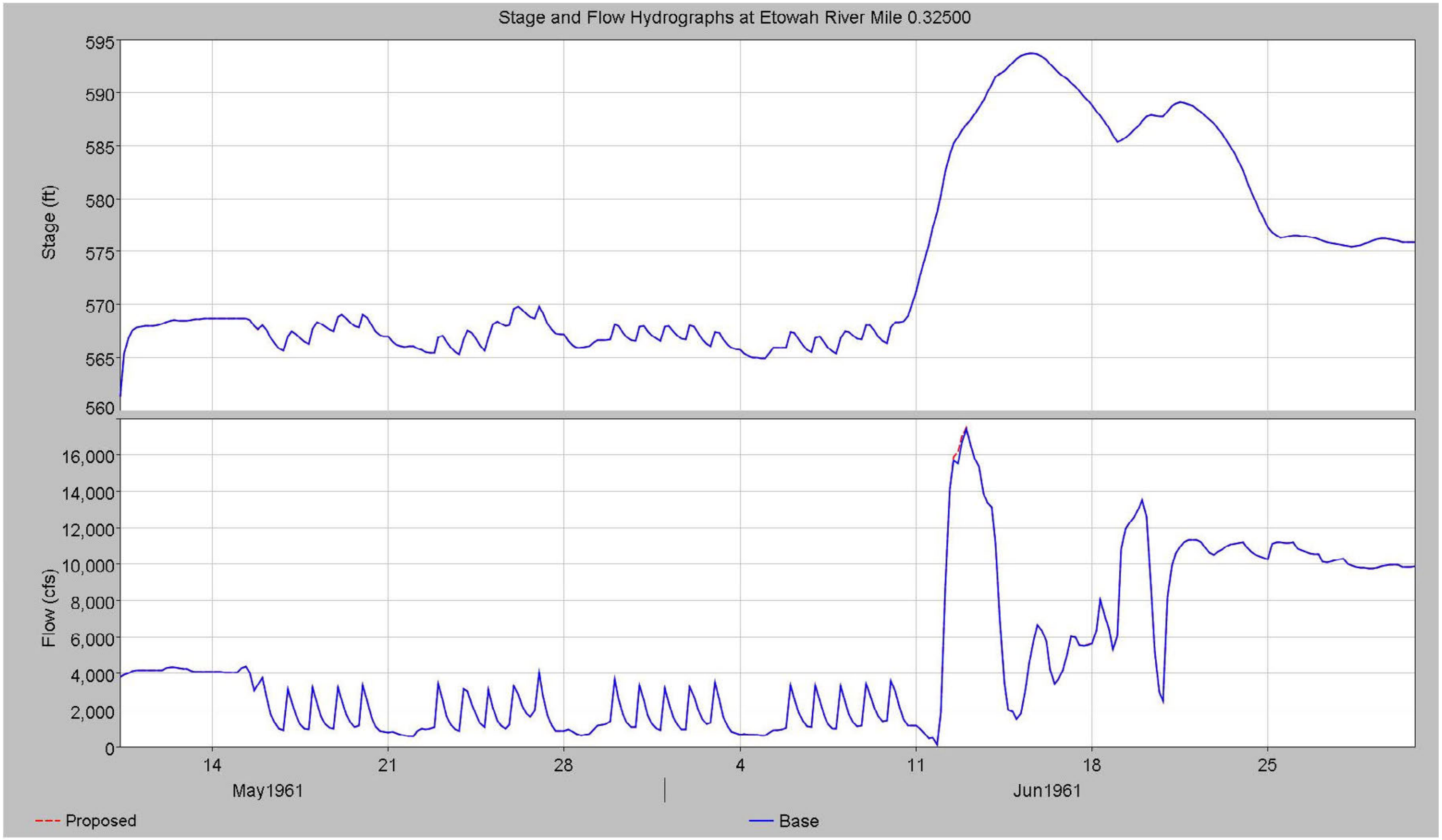
Stage/Flow at Etowah River Mile 1.7675 U/S of Turner McCall Blvd for the 1990 Storm Scaled to a 1.0% ACE



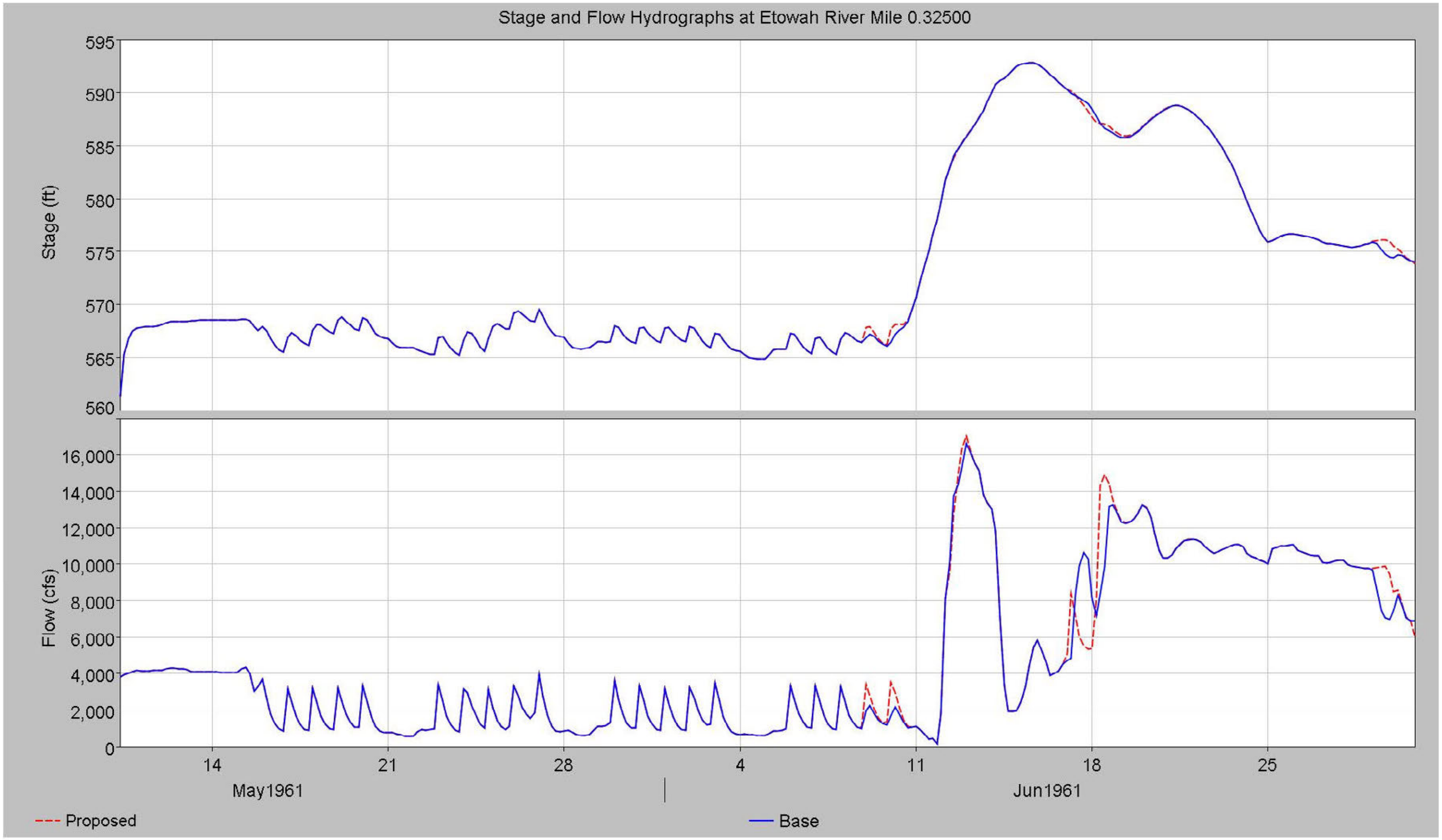
Stage/Flow at Etowah River Mile 1.7675 U/S of Turner McCall Blvd for the 1990 Storm Scaled to a 2.0% ACE



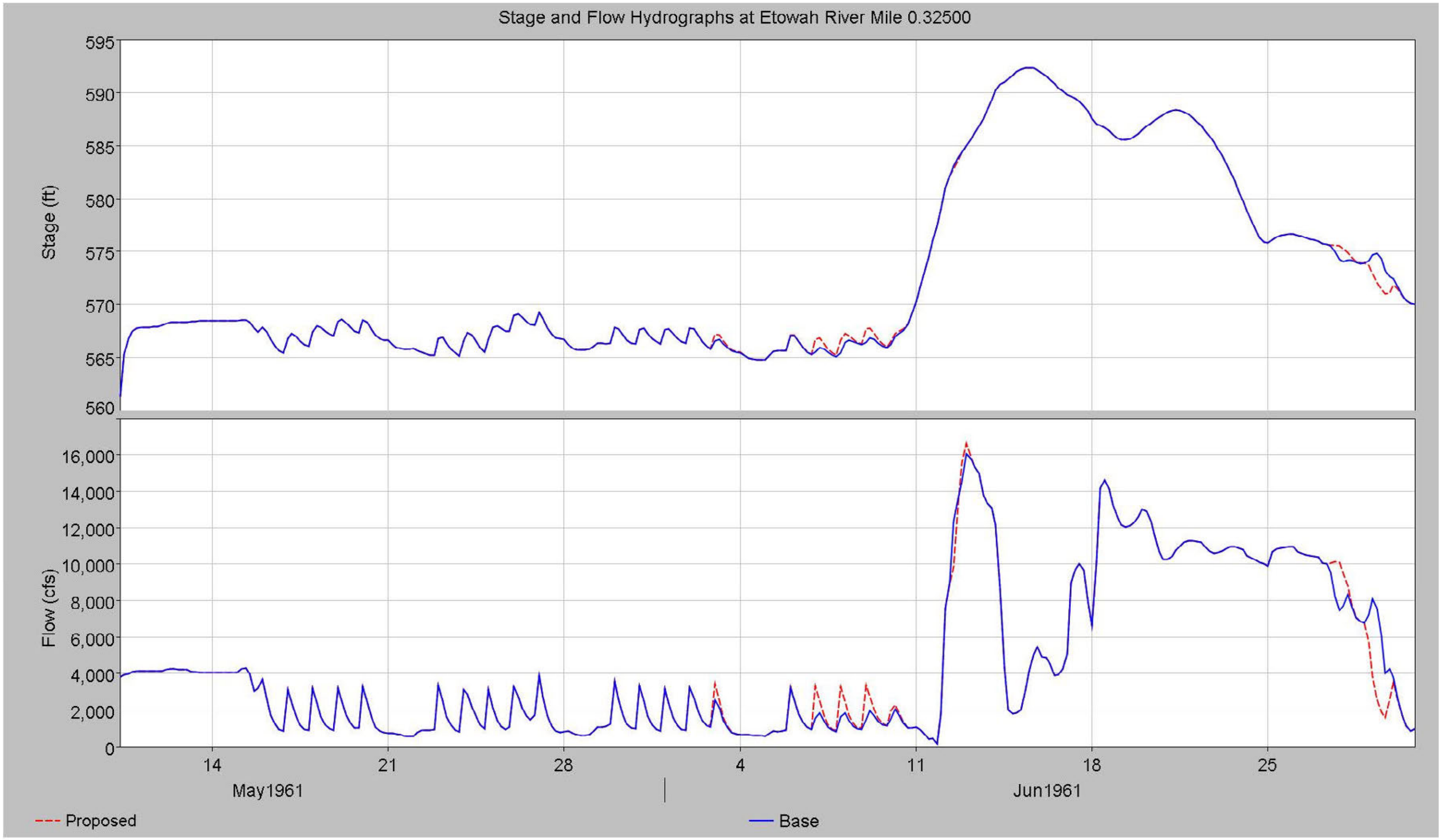
Stage/Flow at Etowah River Mile 1.7675 U/S of Turner McCall Blvd for the 1990 Storm Scaled to a 5.0% ACE



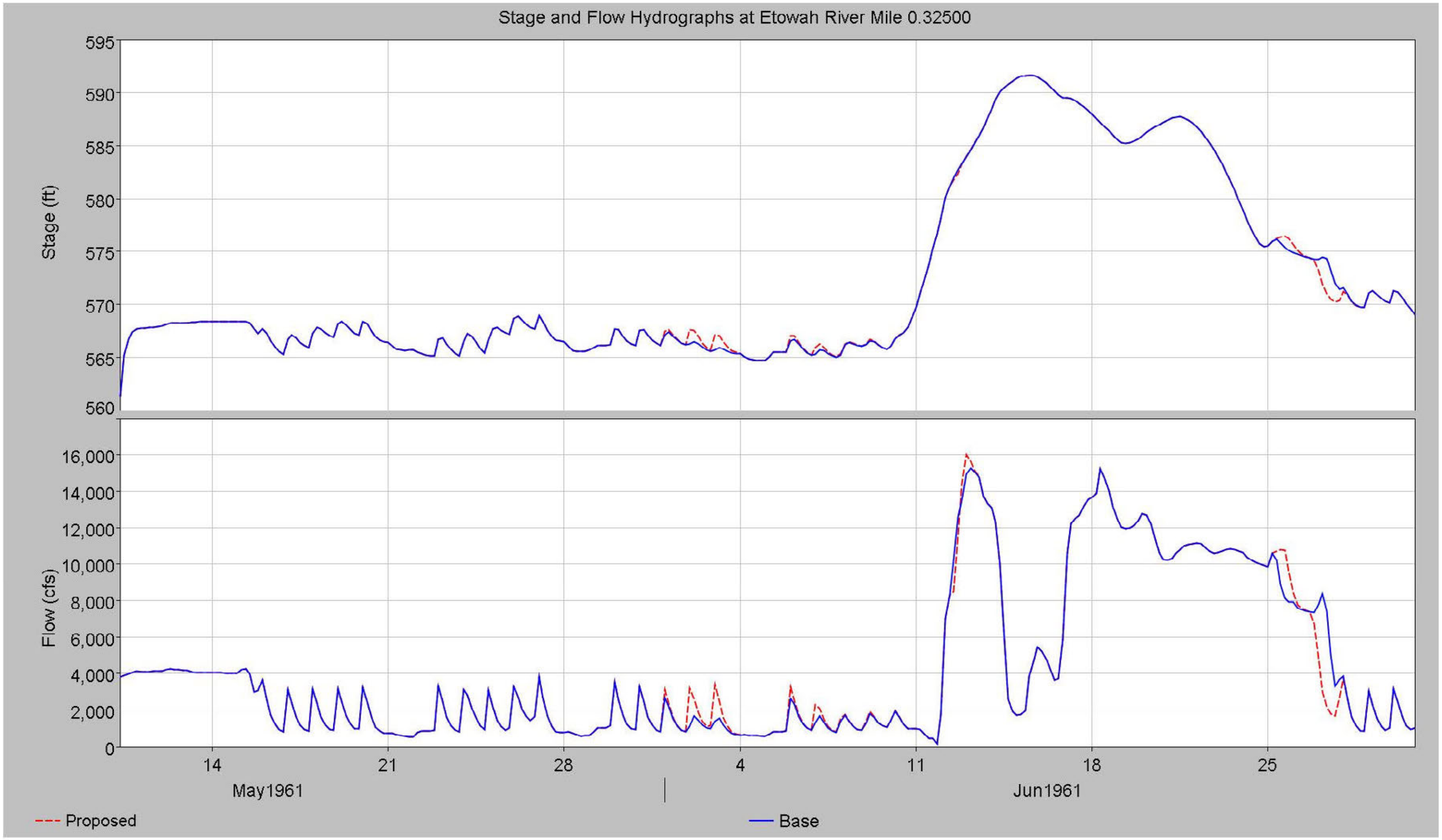
Stage/Flow at Etowah River Mile 0.32500 U/S of South Broad Street for the 1961 Storm Scaled to a 0.2% ACE



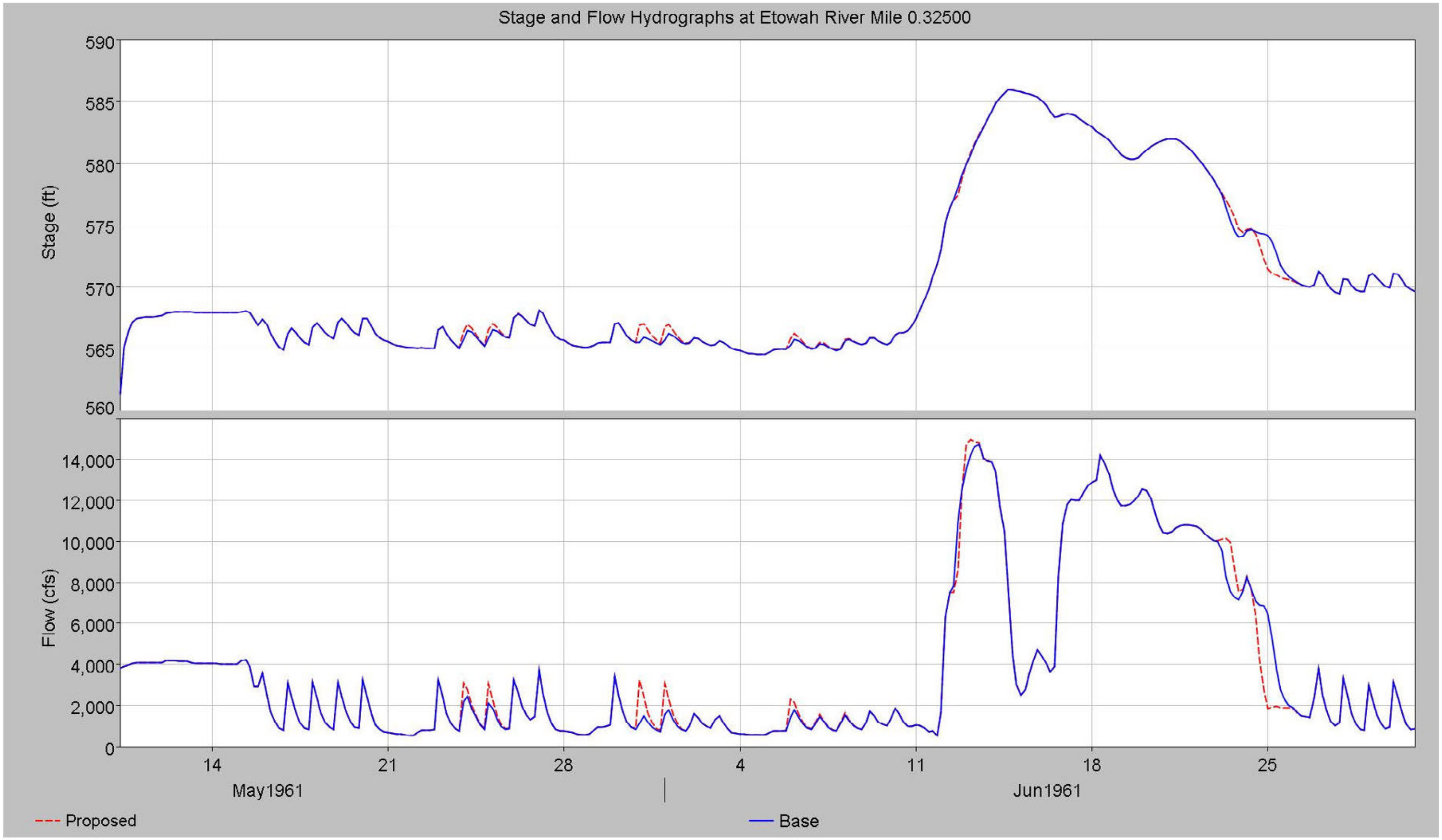
Stage/Flow at Etowah River Mile 0.32500 U/S of South Broad Street for the 1961 Storm Scaled to a 0.5% ACE



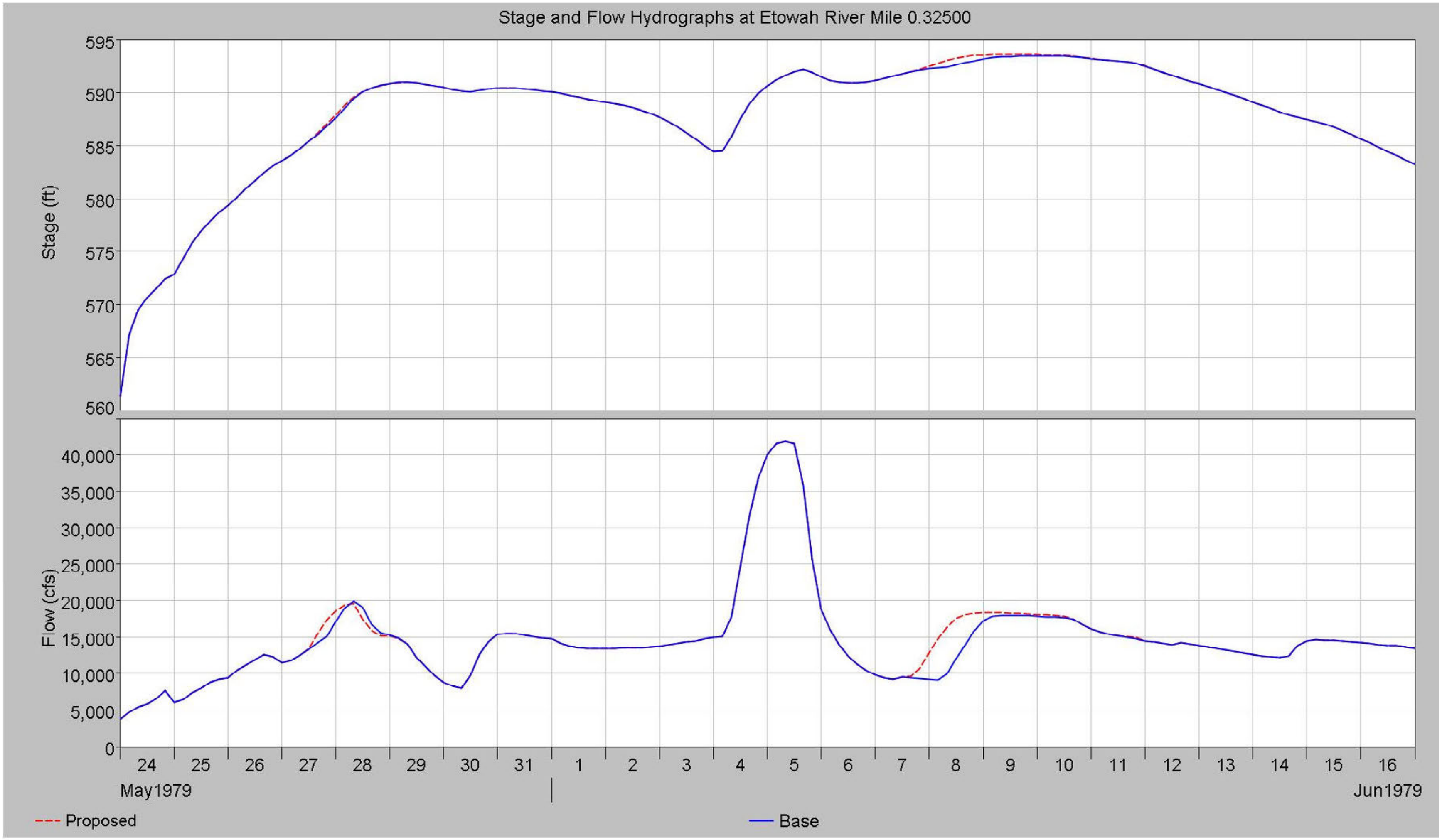
Stage/Flow at Etowah River Mile 0.32500 U/S of South Broad Street for the 1961 Storm Scaled to a 1.0% ACE



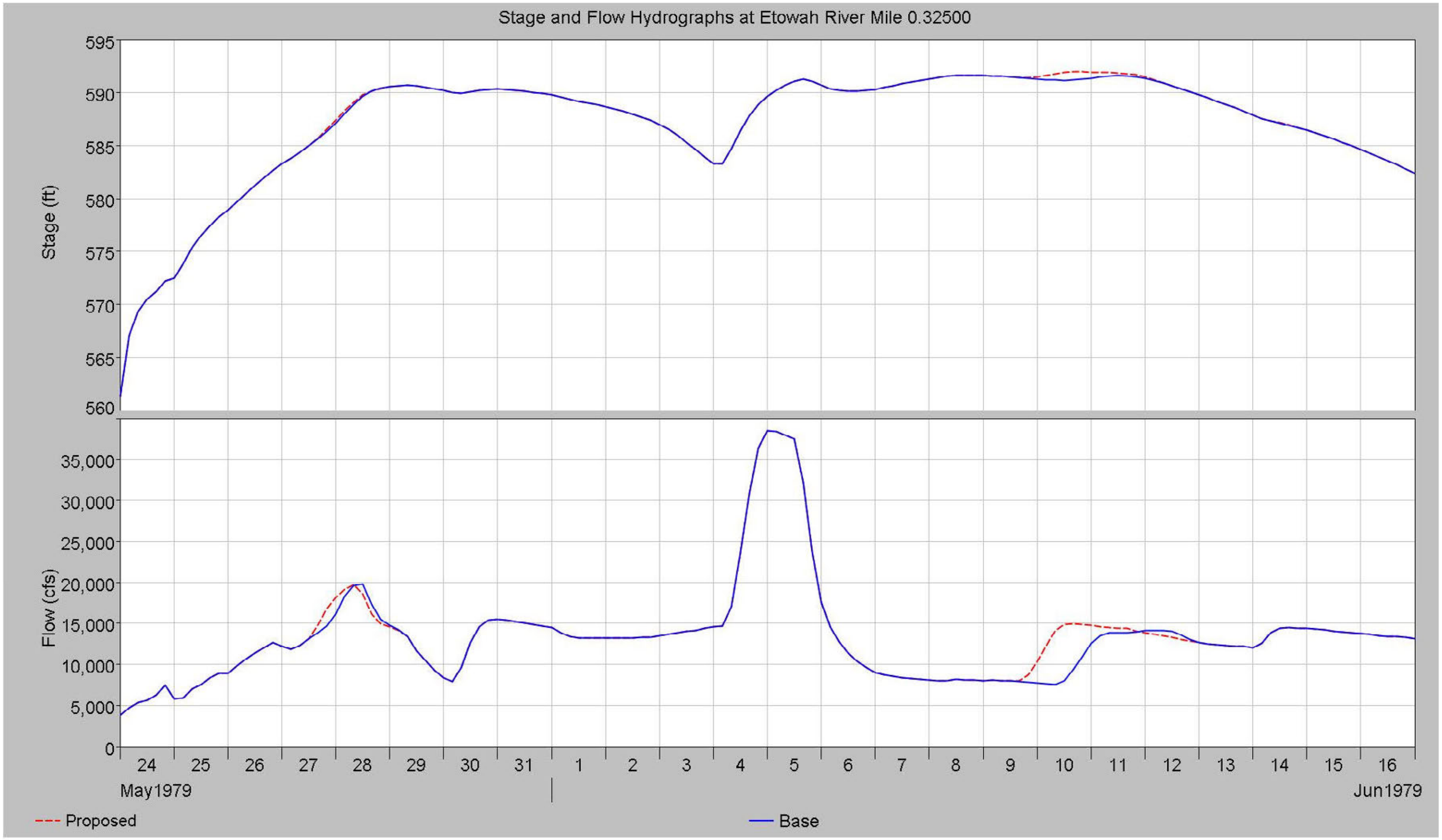
Stage/Flow at Etowah River Mile 0.32500 U/S of South Broad Street for the 1961 Storm Scaled to a 2.0% ACE



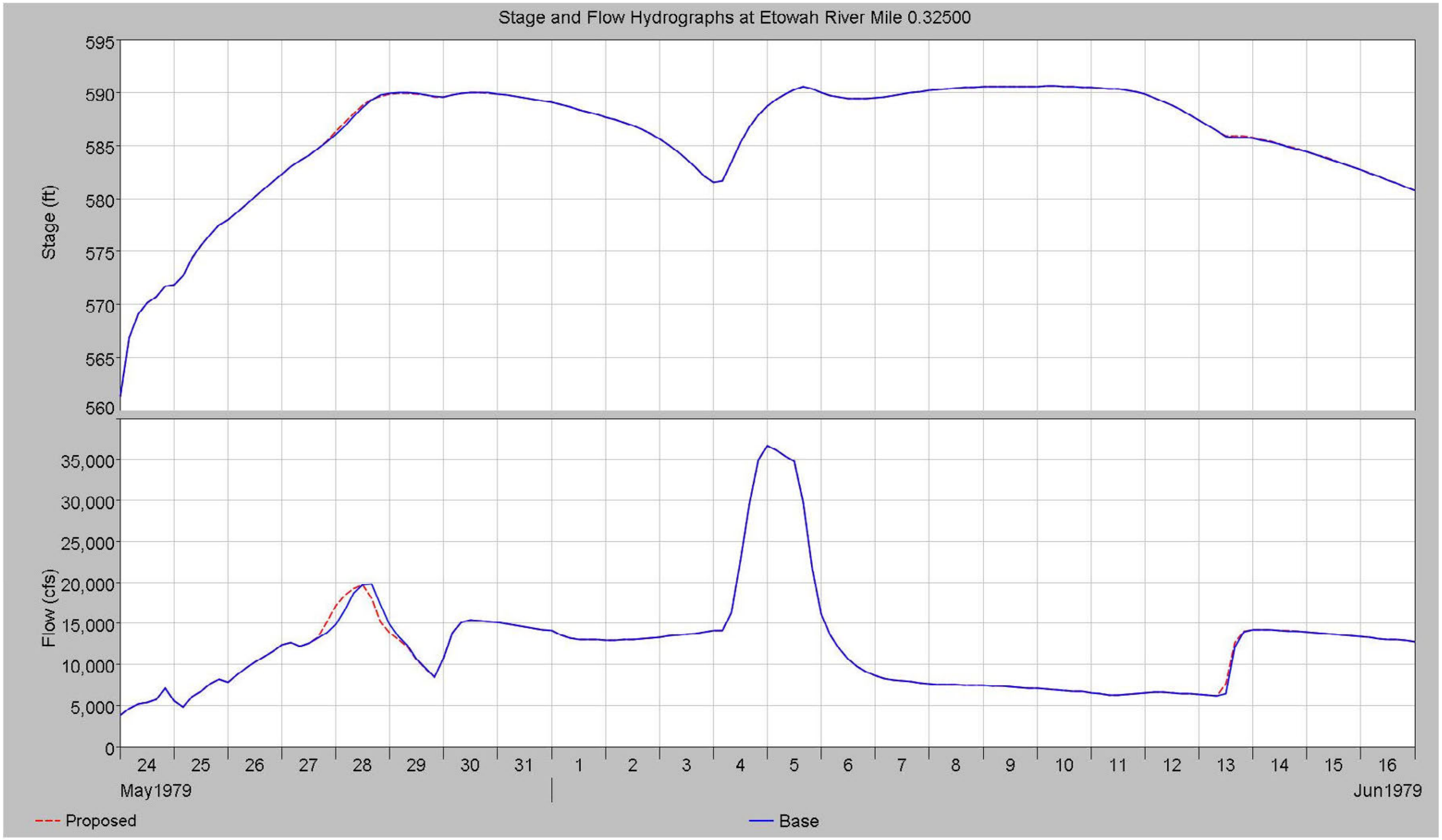
Stage/Flow at Etowah River Mile 0.32500 U/S of South Broad Street for the 1961 Storm Scaled to a 5.0% ACE



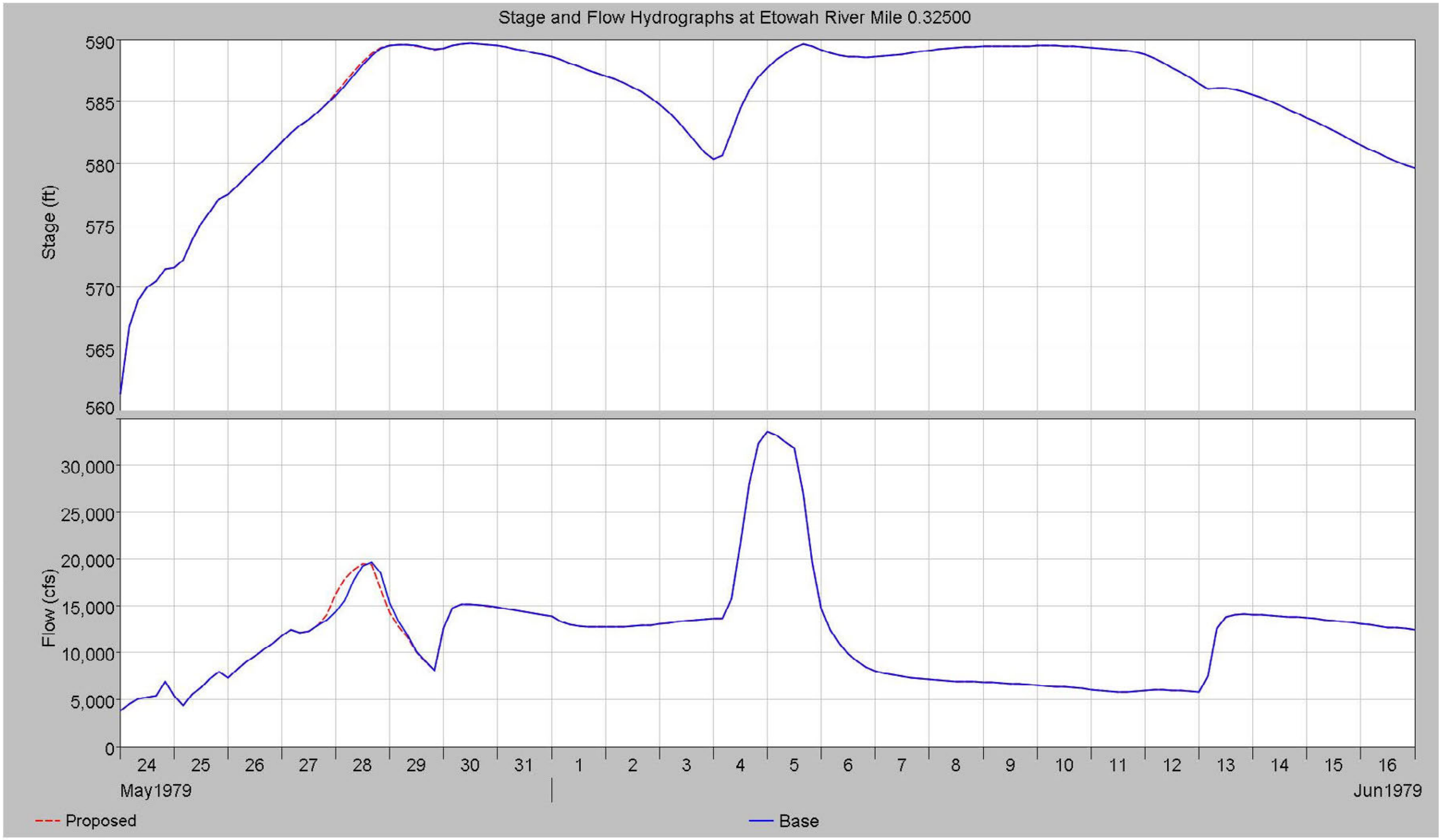
Stage/Flow at Etowah River Mile 0.32500 U/S of South Broad Street for the 1979 Storm Scaled to a 0.2% ACE



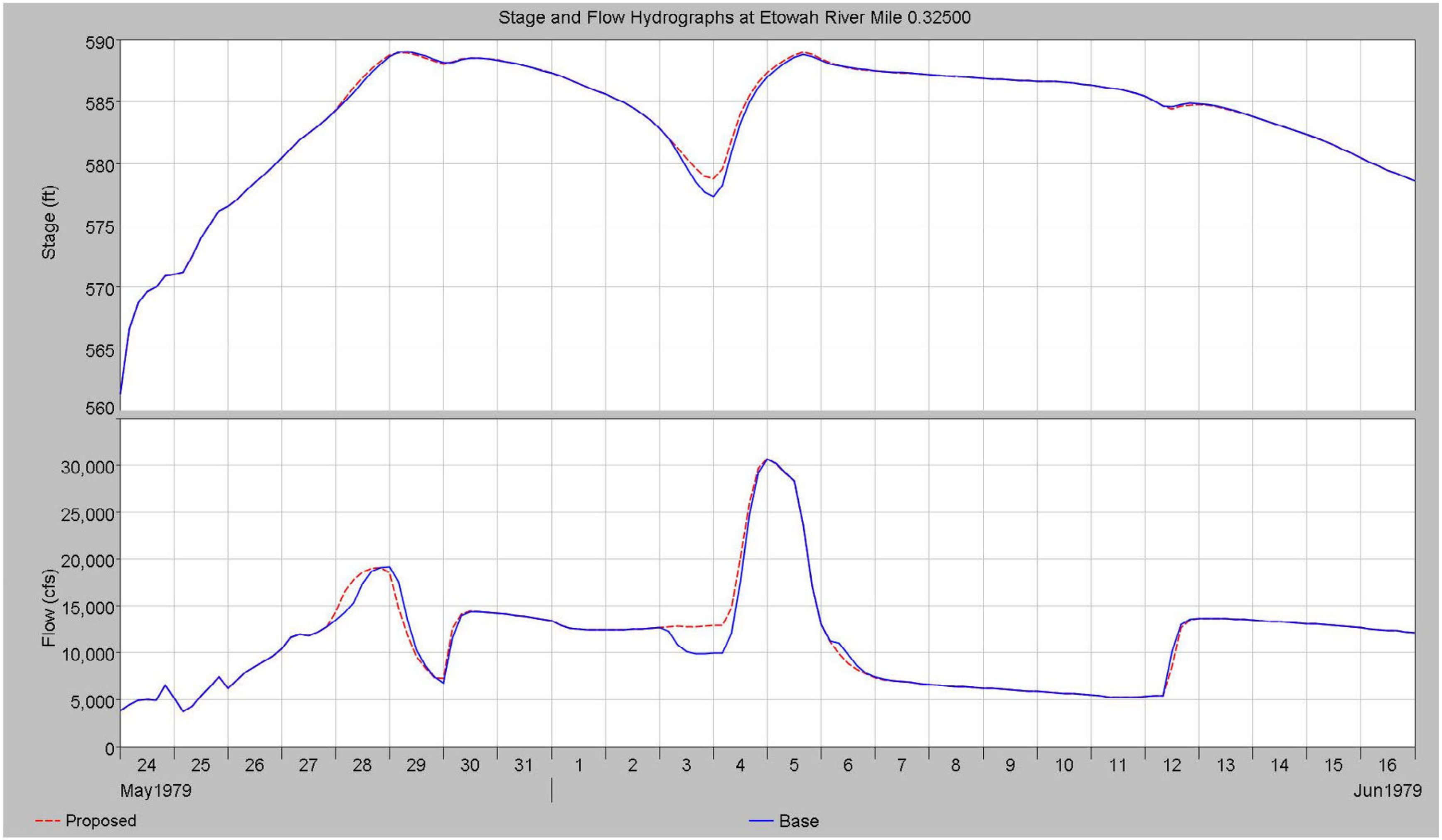
Stage/Flow at Etowah River Mile 0.32500 U/S of South Broad Street for the 1979 Storm Scaled to a 0.5% ACE



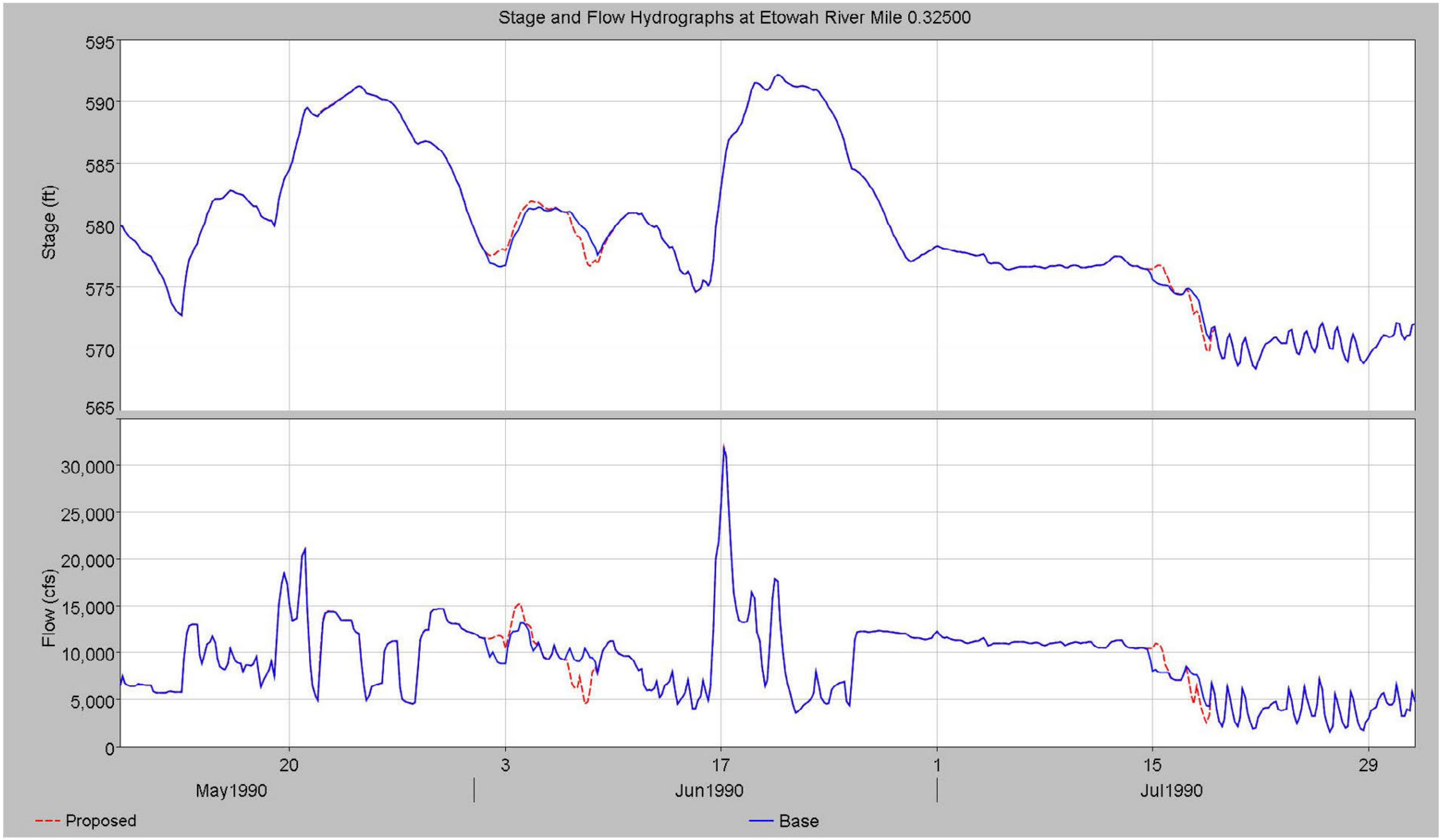
Stage/Flow at Etowah River Mile 0.32500 U/S of South Broad Street for the 1979 Storm Scaled to a 1.0% ACE



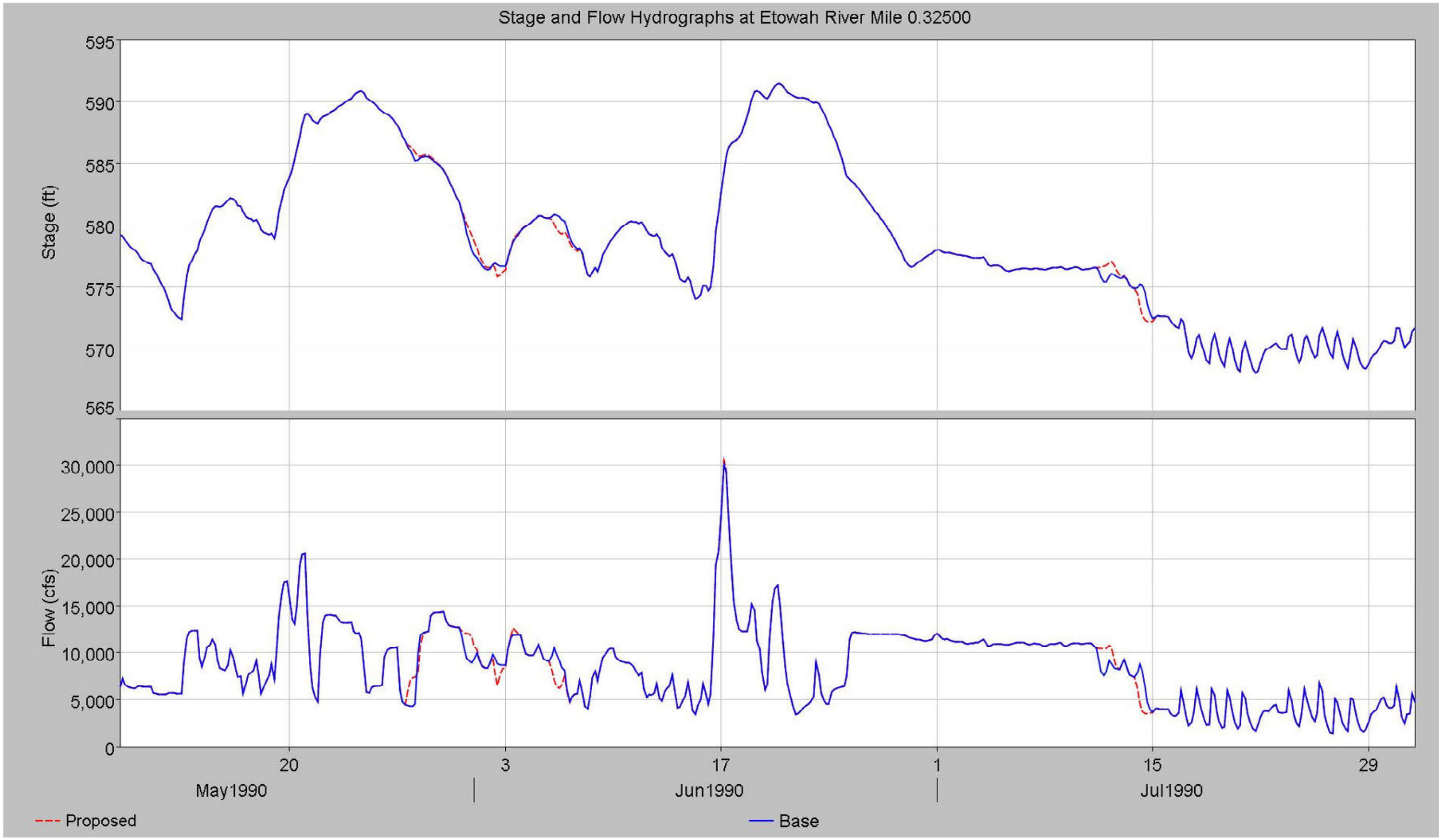
Stage/Flow at Etowah River Mile 0.32500 U/S of South Broad Street for the 1979 Storm Scaled to a 2.0% ACE



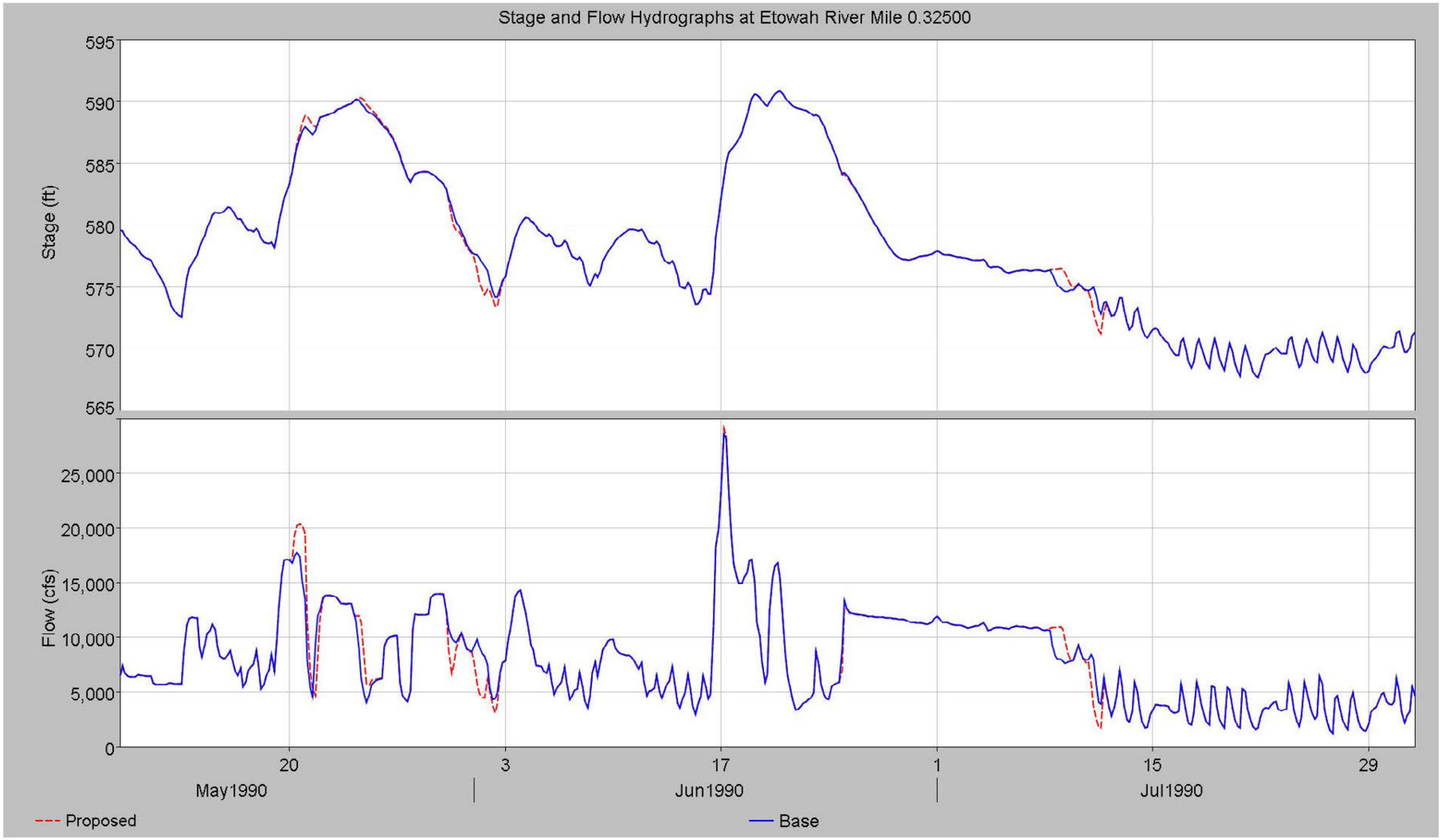
Stage/Flow at Etowah River Mile 0.32500 U/S of South Broad Street for the 1979 Storm Scaled to a 5.0% ACE



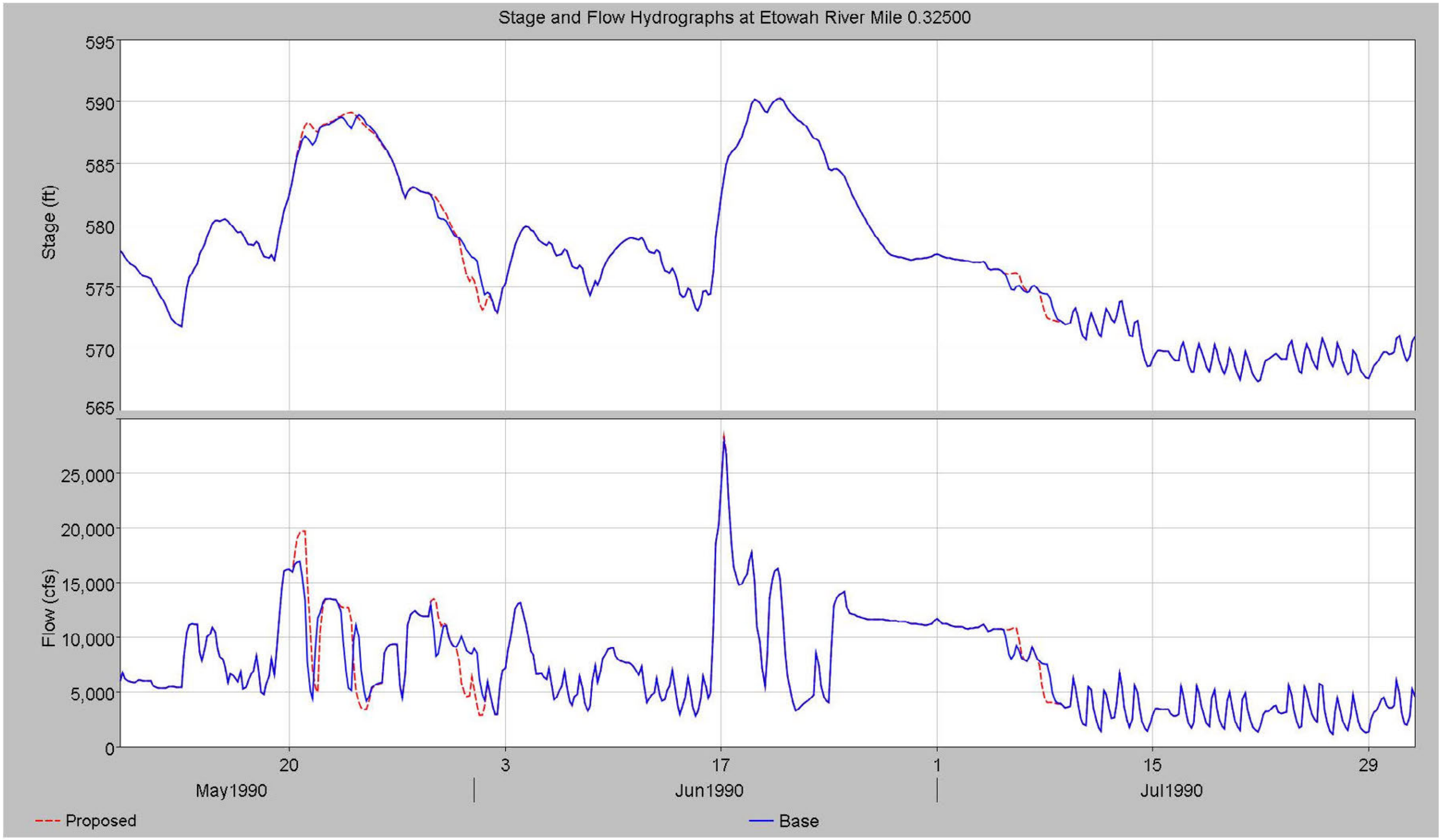
Stage/Flow at Etowah River Mile 0.32500 U/S of South Broad Street for the 1990 Storm Scaled to a 0.2% ACE



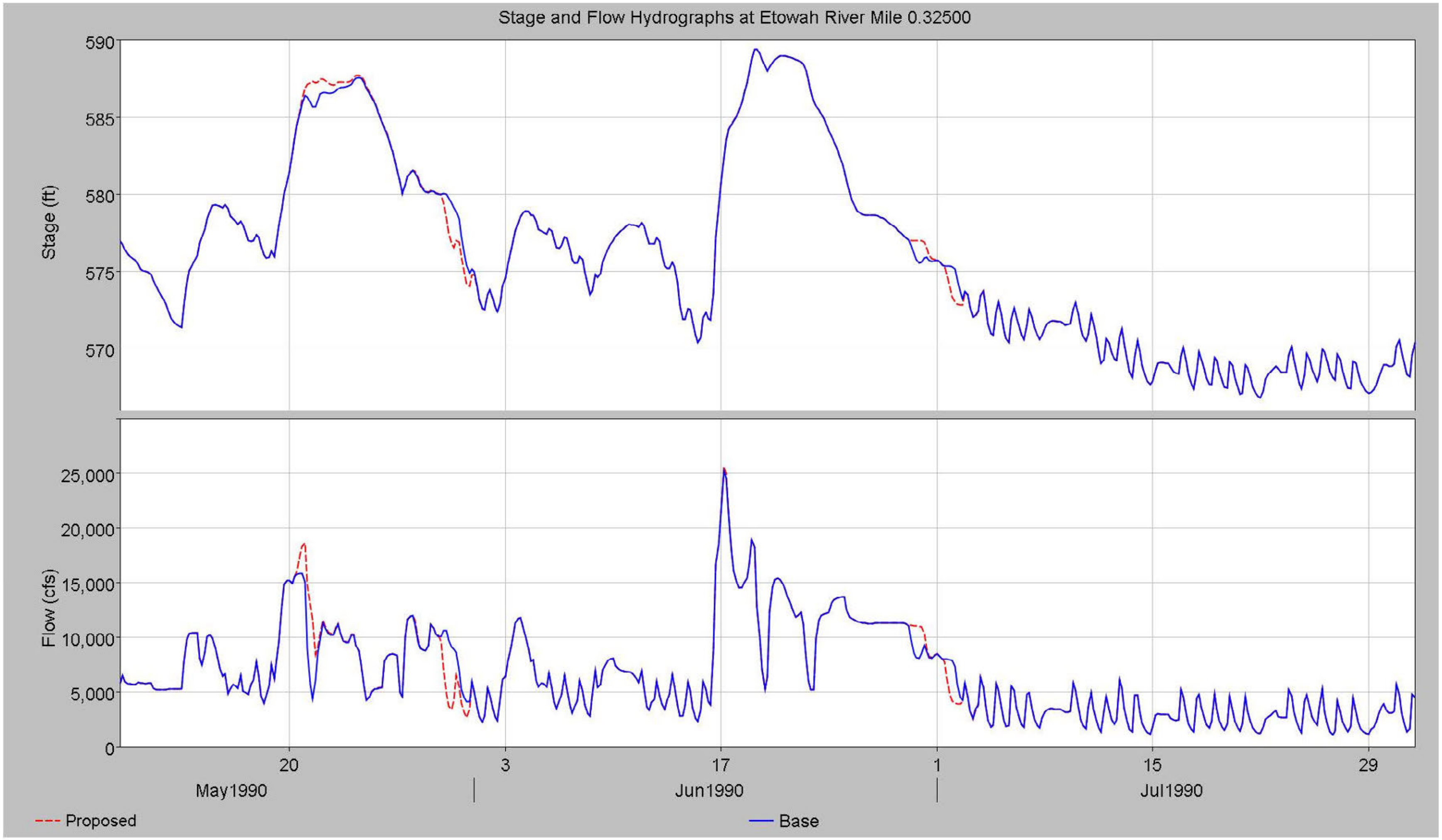
Stage/Flow at Etowah River Mile 0.32500 U/S of South Broad Street for the 1990 Storm Scaled to a 0.5% ACE



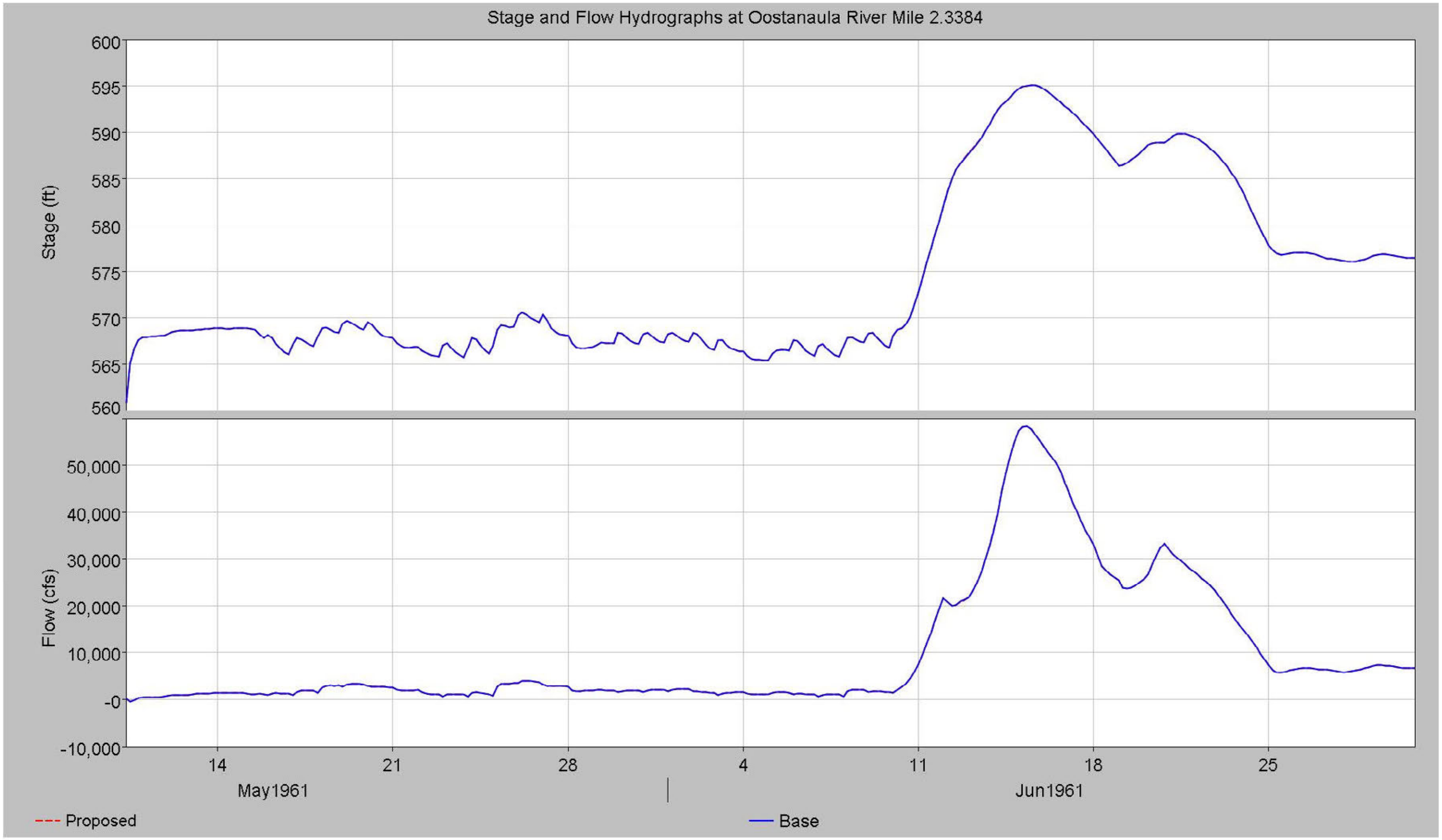
Stage/Flow at Etowah River Mile 0.32500 U/S of South Broad Street for the 1990 Storm Scaled to a 1.0% ACE



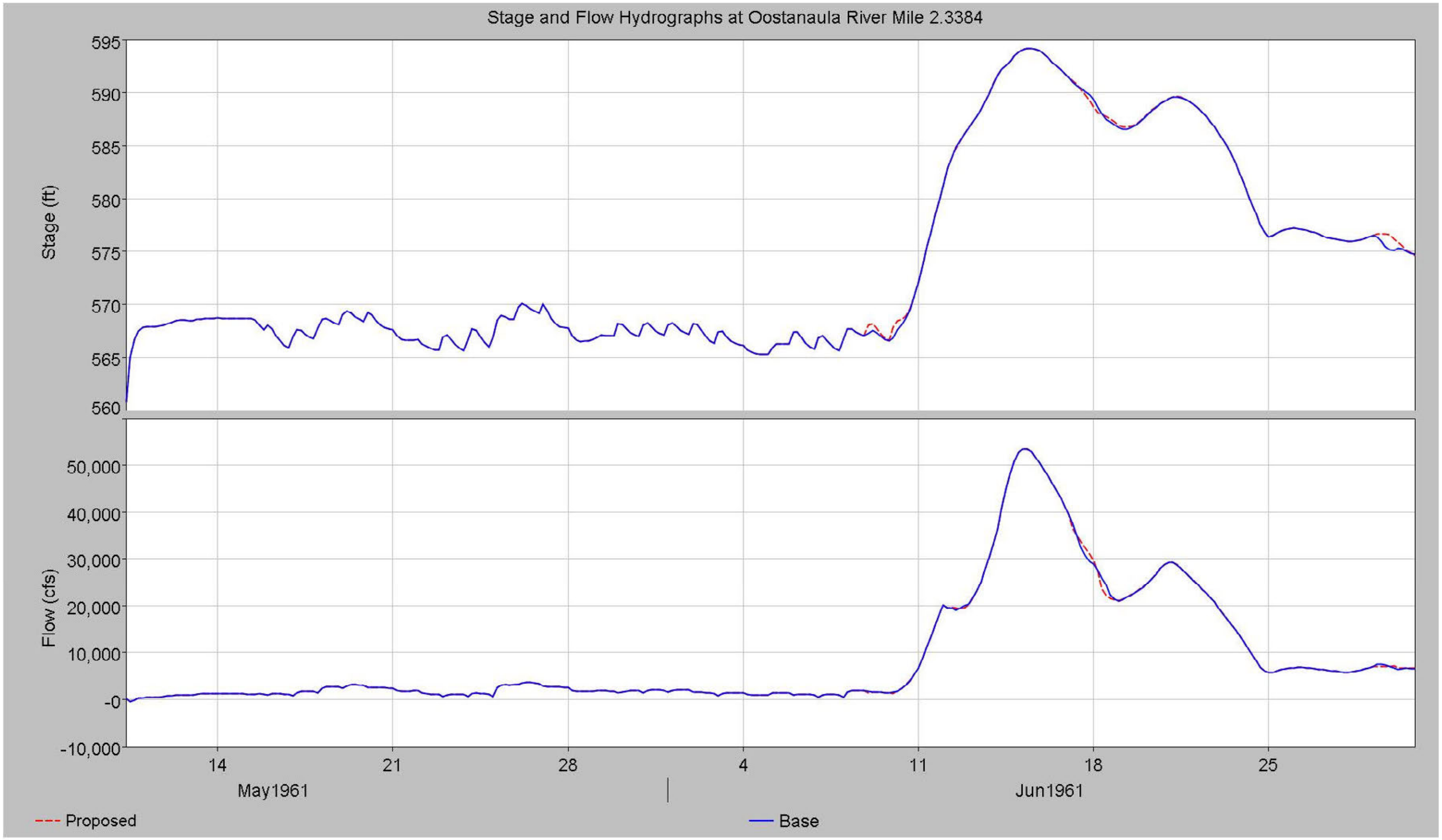
Stage/Flow at Etowah River Mile 0.32500 U/S of South Broad Street for the 1990 Storm Scaled to a 2.0% ACE



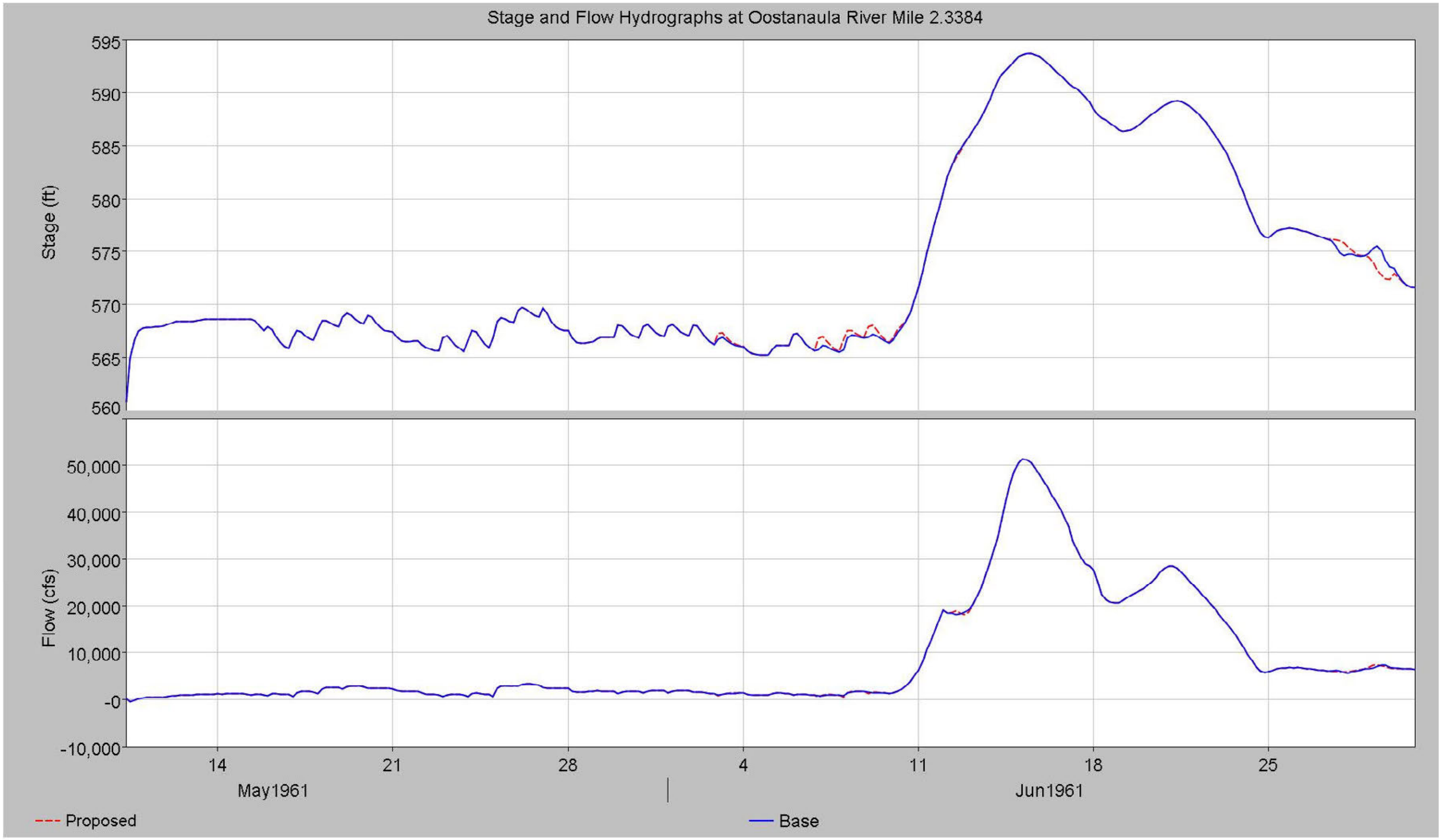
Stage/Flow at Etowah River Mile 0.32500 U/S of South Broad Street for the 1990 Storm Scaled to a 5.0% ACE



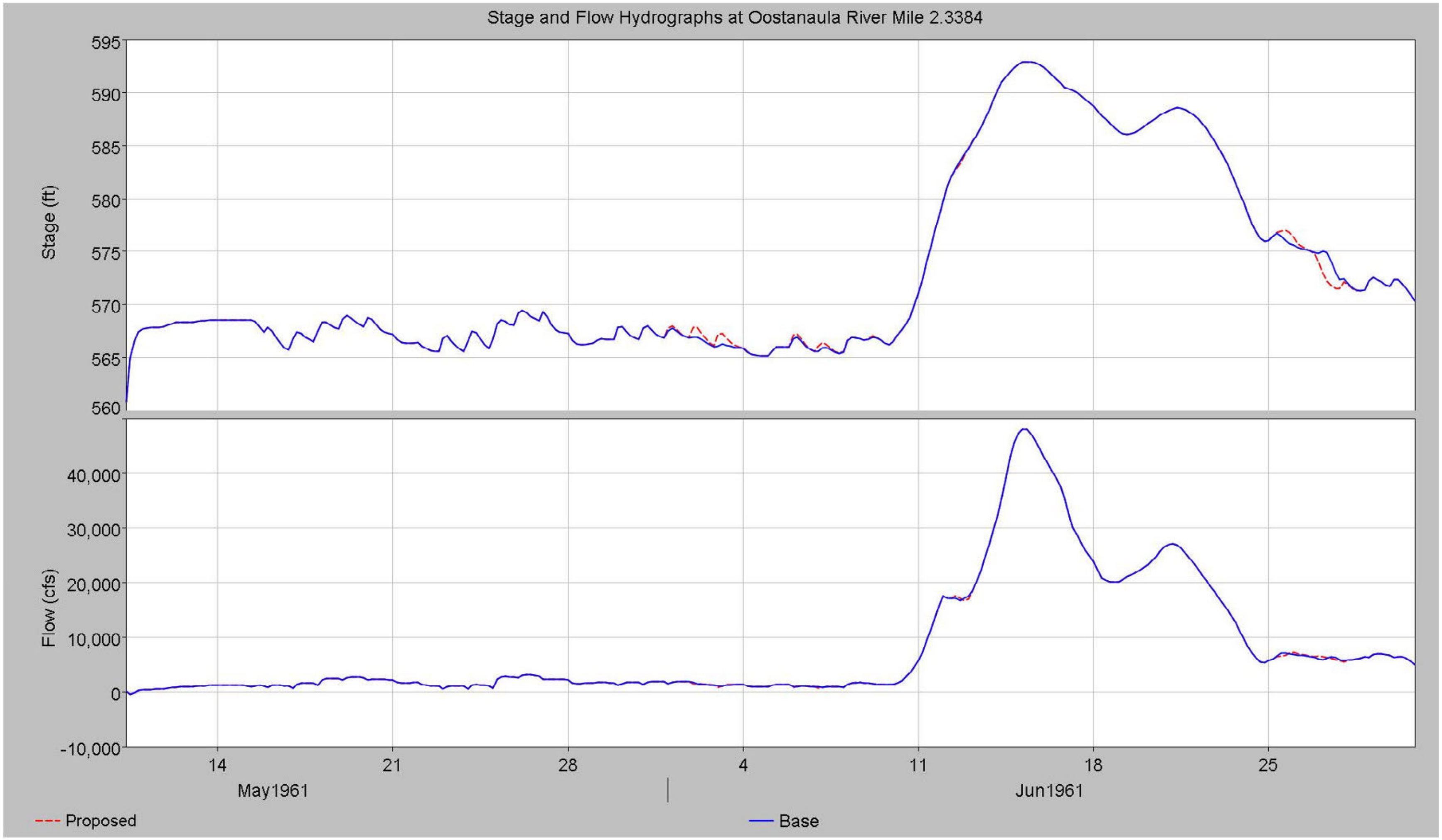
Stage/Flow at Oostanaula River Mile 2.3384 U/S of Veteran's Memorial Pkwy for the 1961 Storm Scaled to a 0.2% ACE



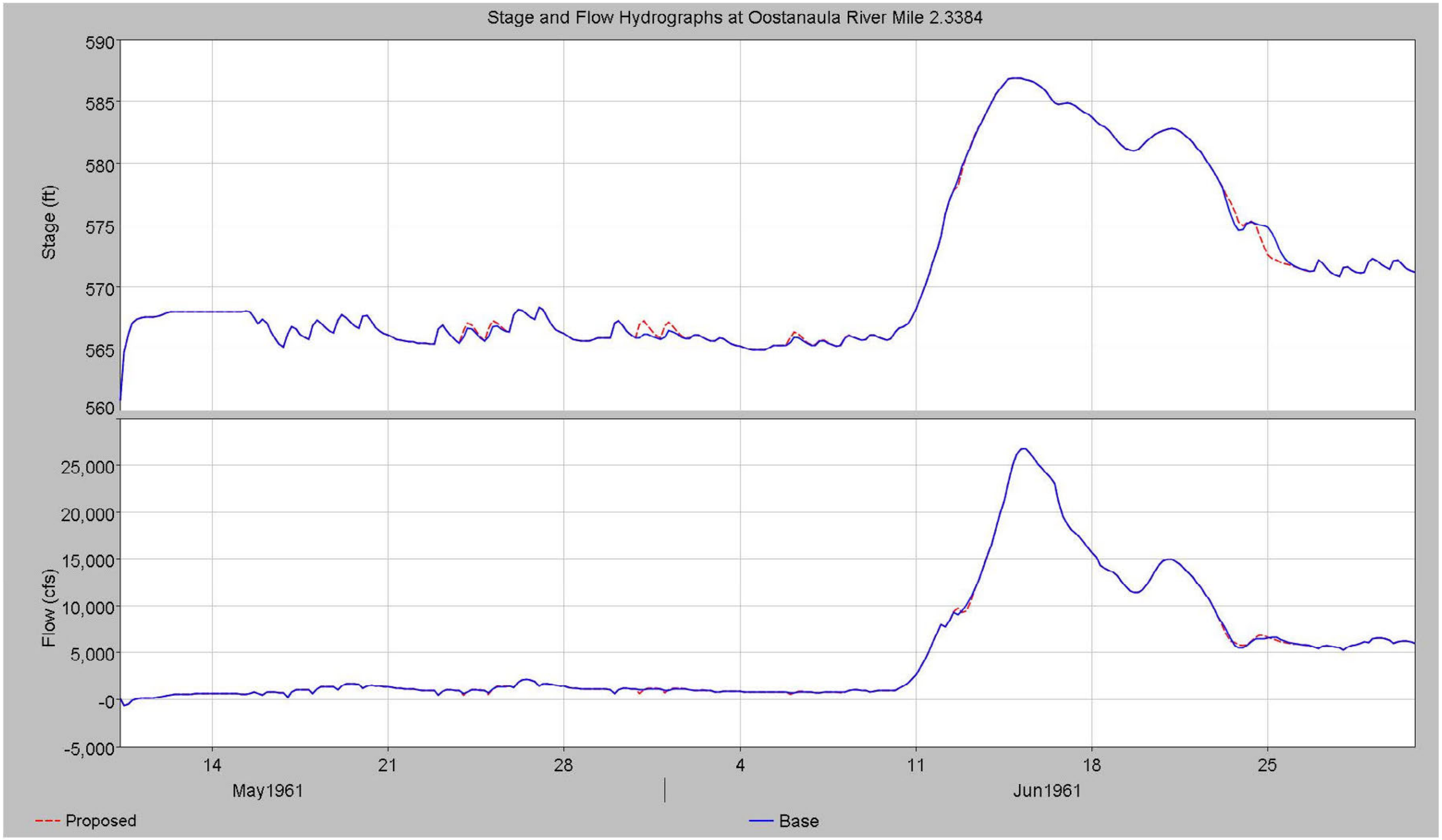
Stage/Flow at Oostanaula River Mile 2.3384 U/S of Veteran's Memorial Pkwy for the 1961 Storm Scaled to a 0.5% ACE



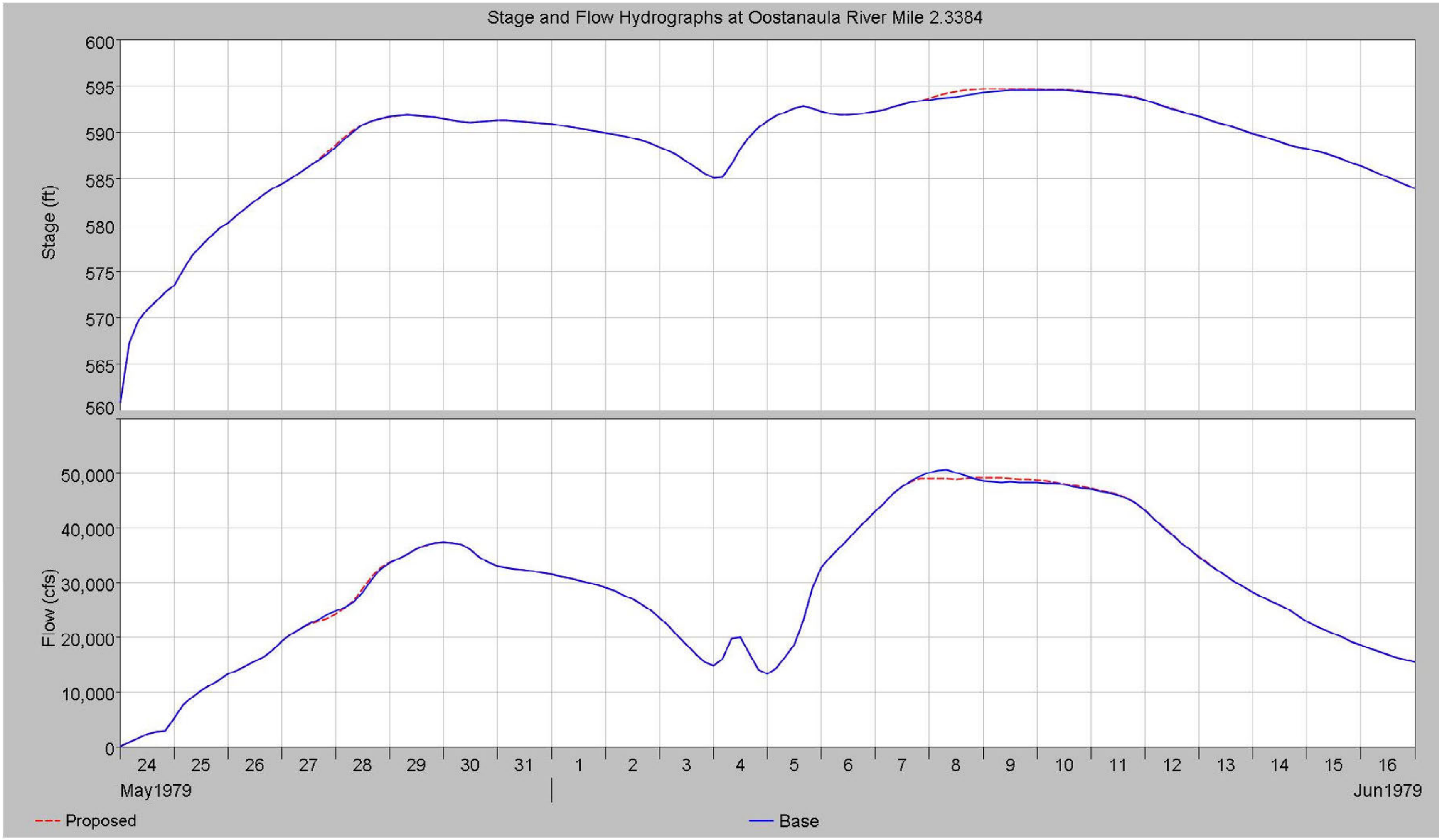
Stage/Flow at Oostanaula River Mile 2.3384 U/S of Veteran's Memorial Pkwy for the 1961 Storm Scaled to a 1.0% ACE



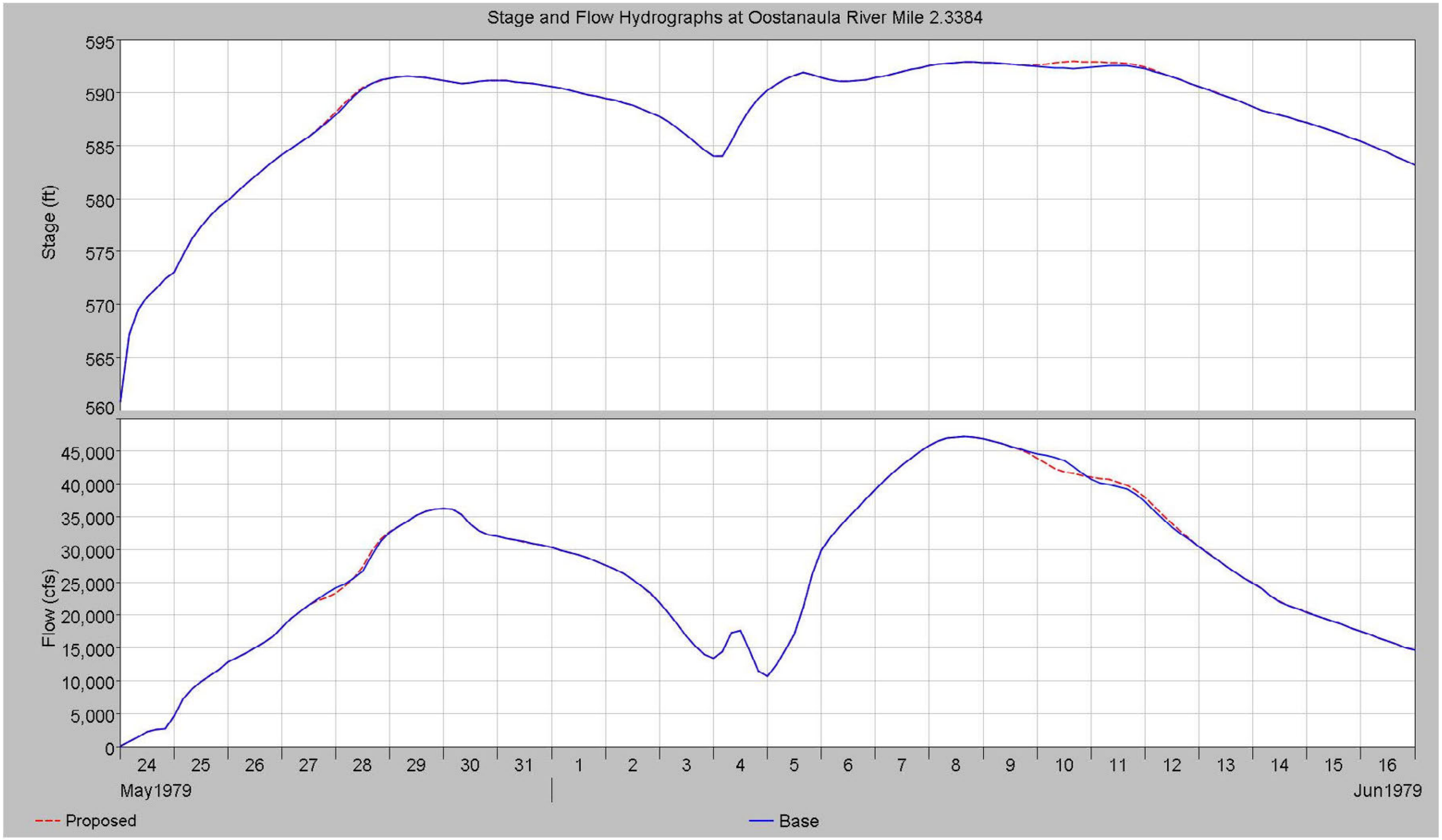
Stage/Flow at Oostanaula River Mile 2.3384 U/S of Veteran's Memorial Pkwy for the 1961 Storm Scaled to a 2.0% ACE



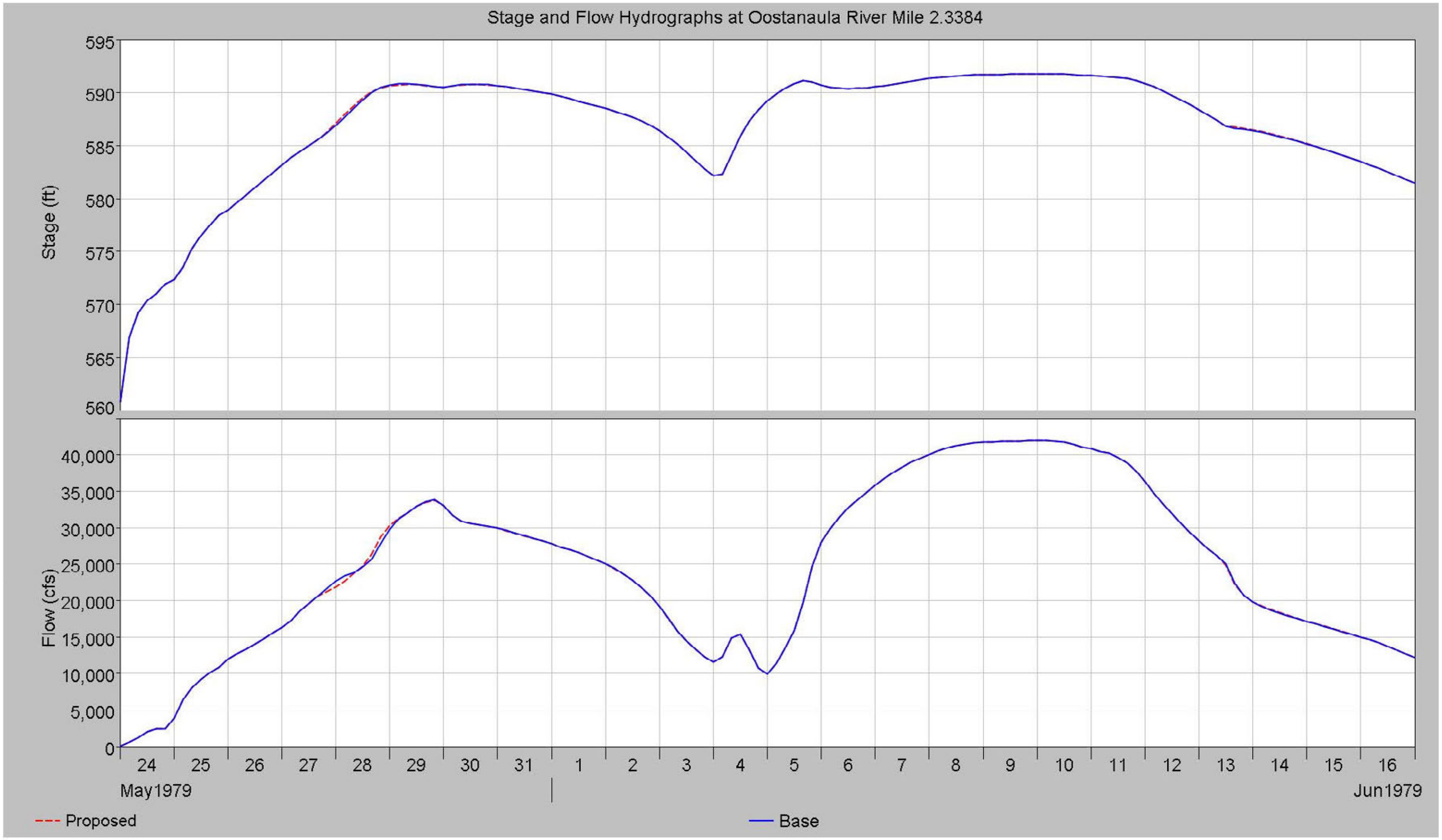
Stage/Flow at Oostanaula River Mile 2.3384 U/S of Veteran's Memorial Pkwy for the 1961 Storm Scaled to a 5.0% ACE



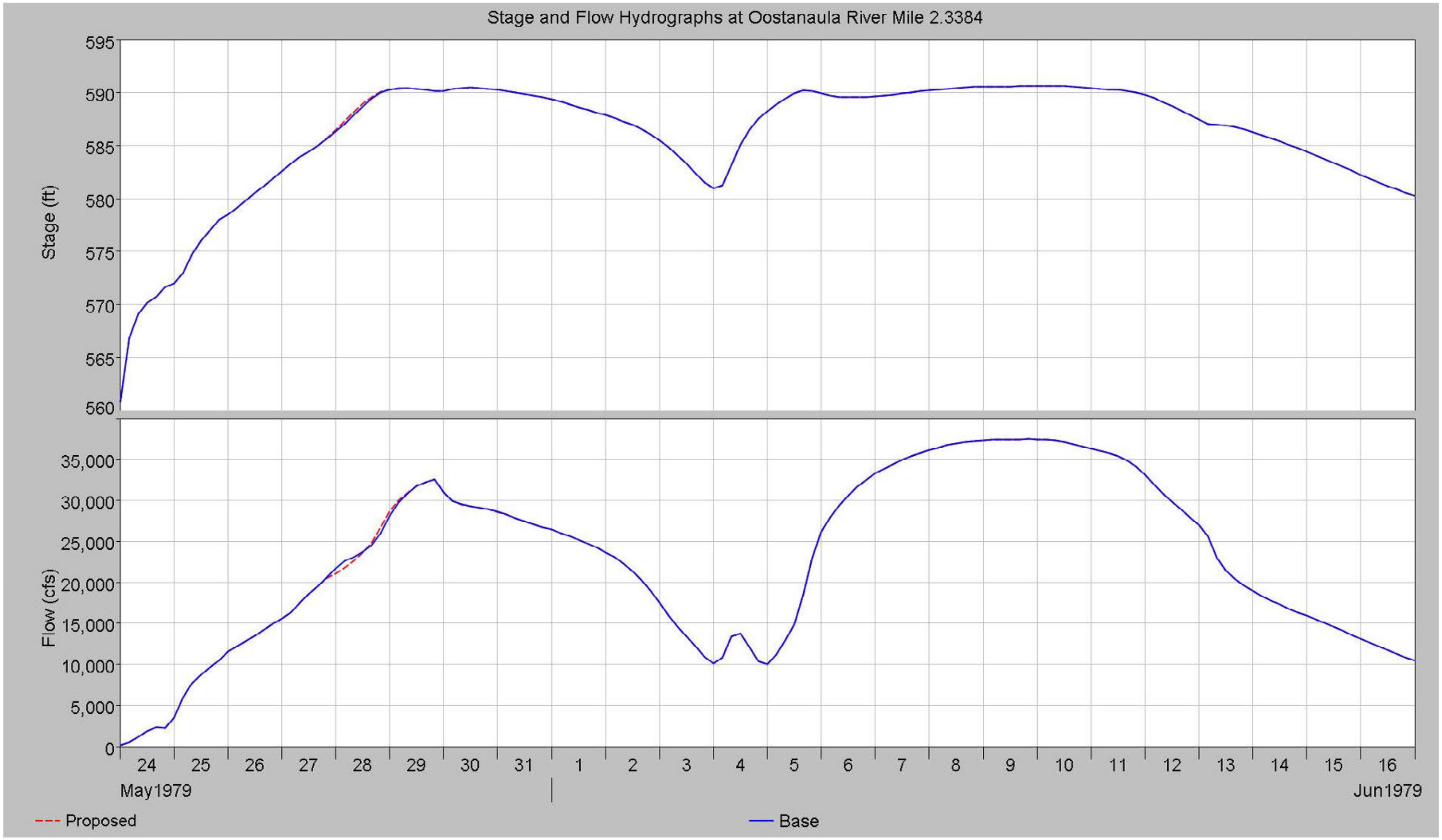
Stage/Flow at Oostanaula River Mile 2.3384 U/S of Veteran's Memorial Pkwy for the 1979 Storm Scaled to a 0.2% ACE



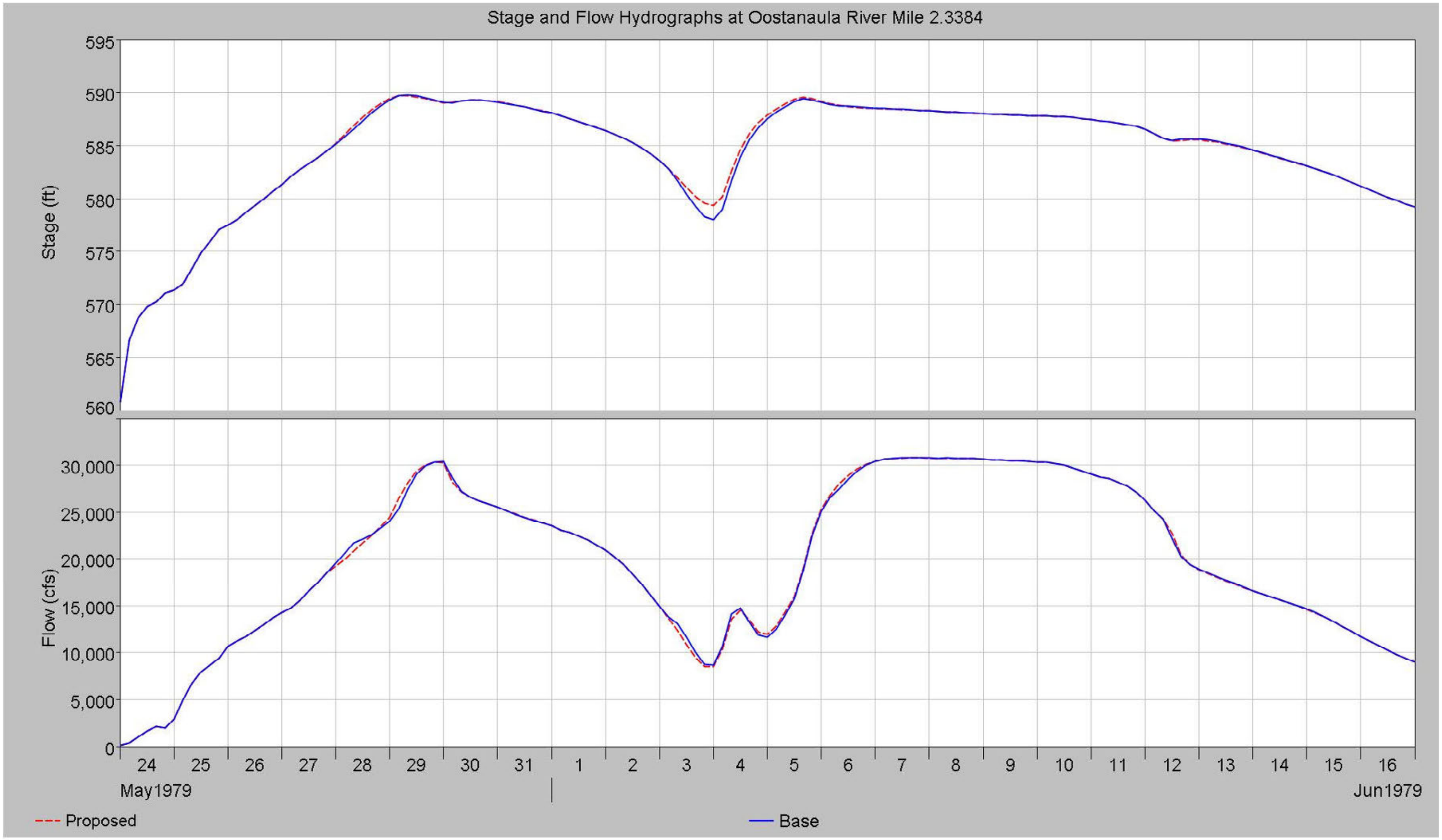
Stage/Flow at Oostanaula River Mile 2.3384 U/S of Veteran's Memorial Pkwy for the 1979 Storm Scaled to a 0.5% ACE



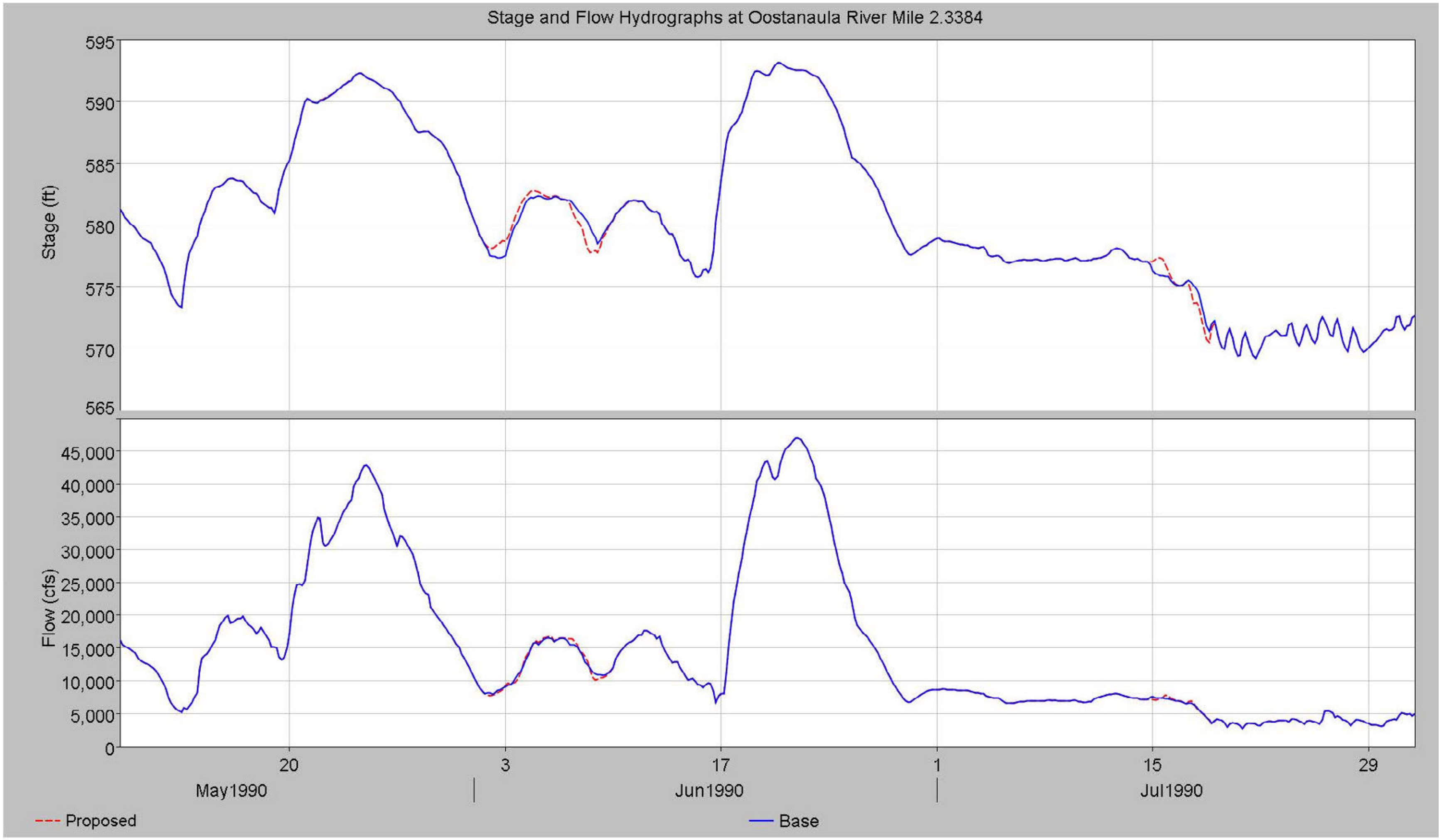
Stage/Flow at Oostanaula River Mile 2.3384 U/S of Veteran's Memorial Pkwy for the 1979 Storm Scaled to a 1.0% ACE



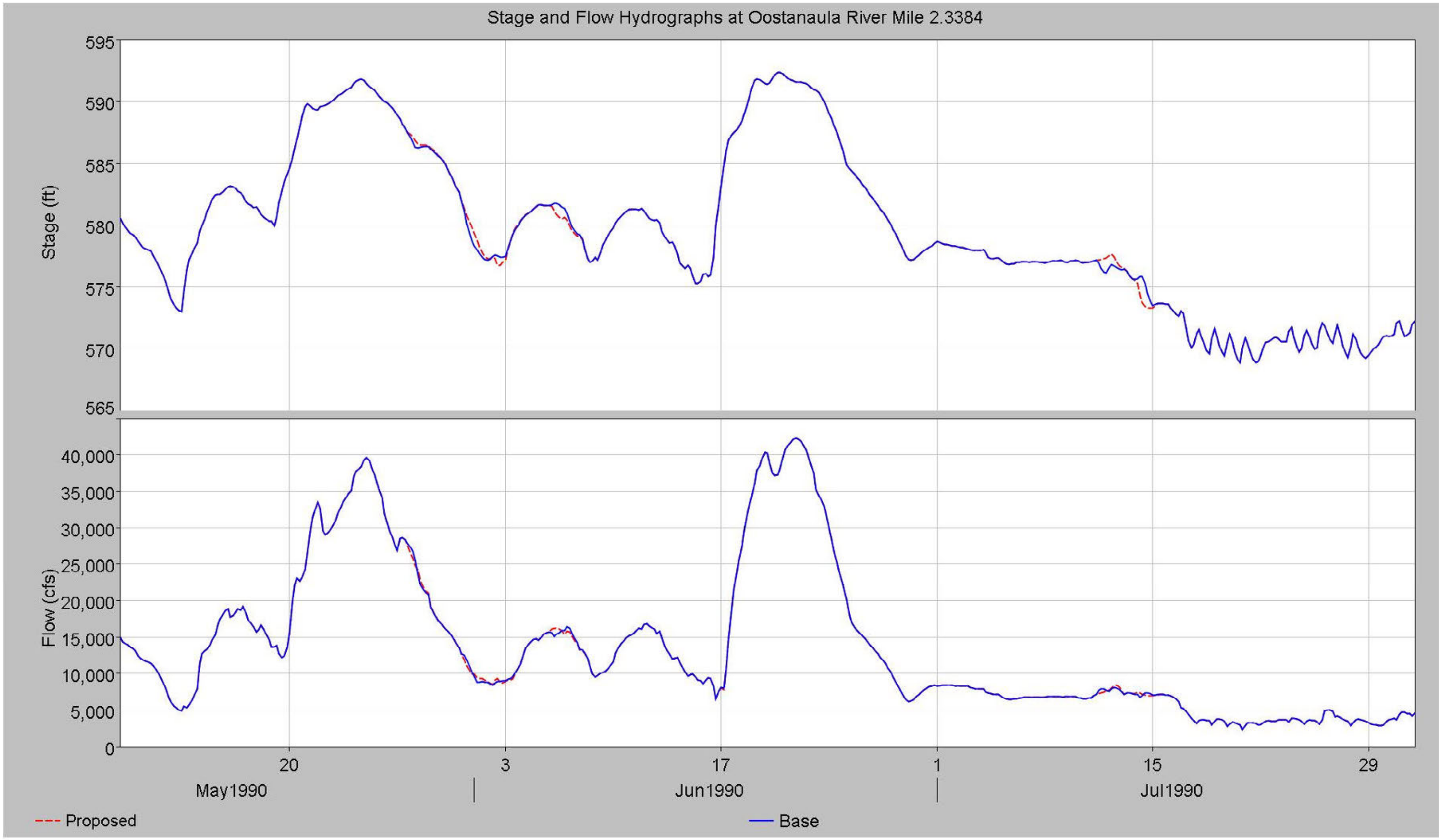
Stage/Flow at Oostanaula River Mile 2.3384 U/S of Veteran's Memorial Pkwy for the 1979 Storm Scaled to a 2.0% ACE



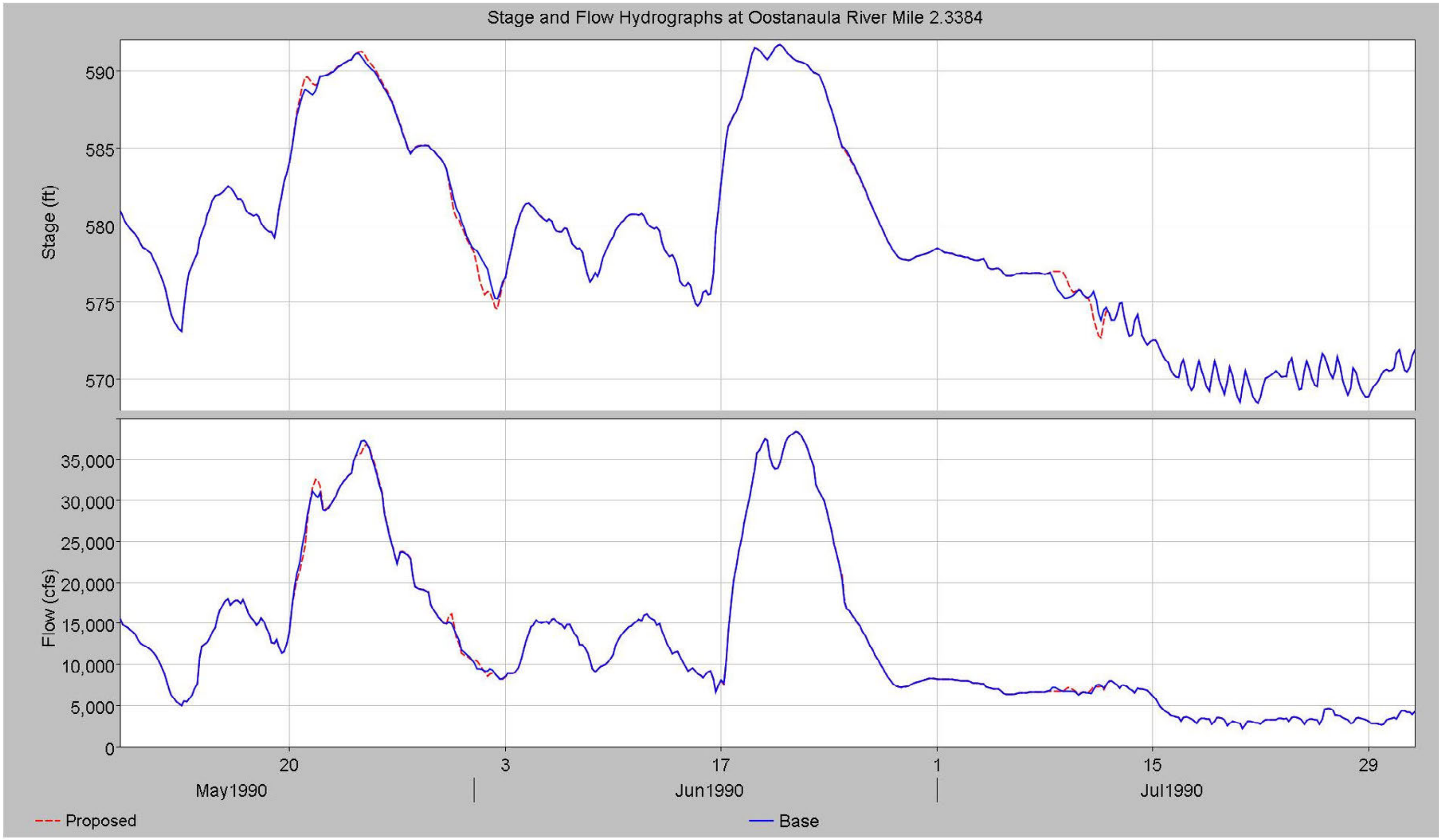
Stage/Flow at Oostanaula River Mile 2.3384 U/S of Veteran's Memorial Pkwy for the 1979 Storm Scaled to a 5.0% ACE



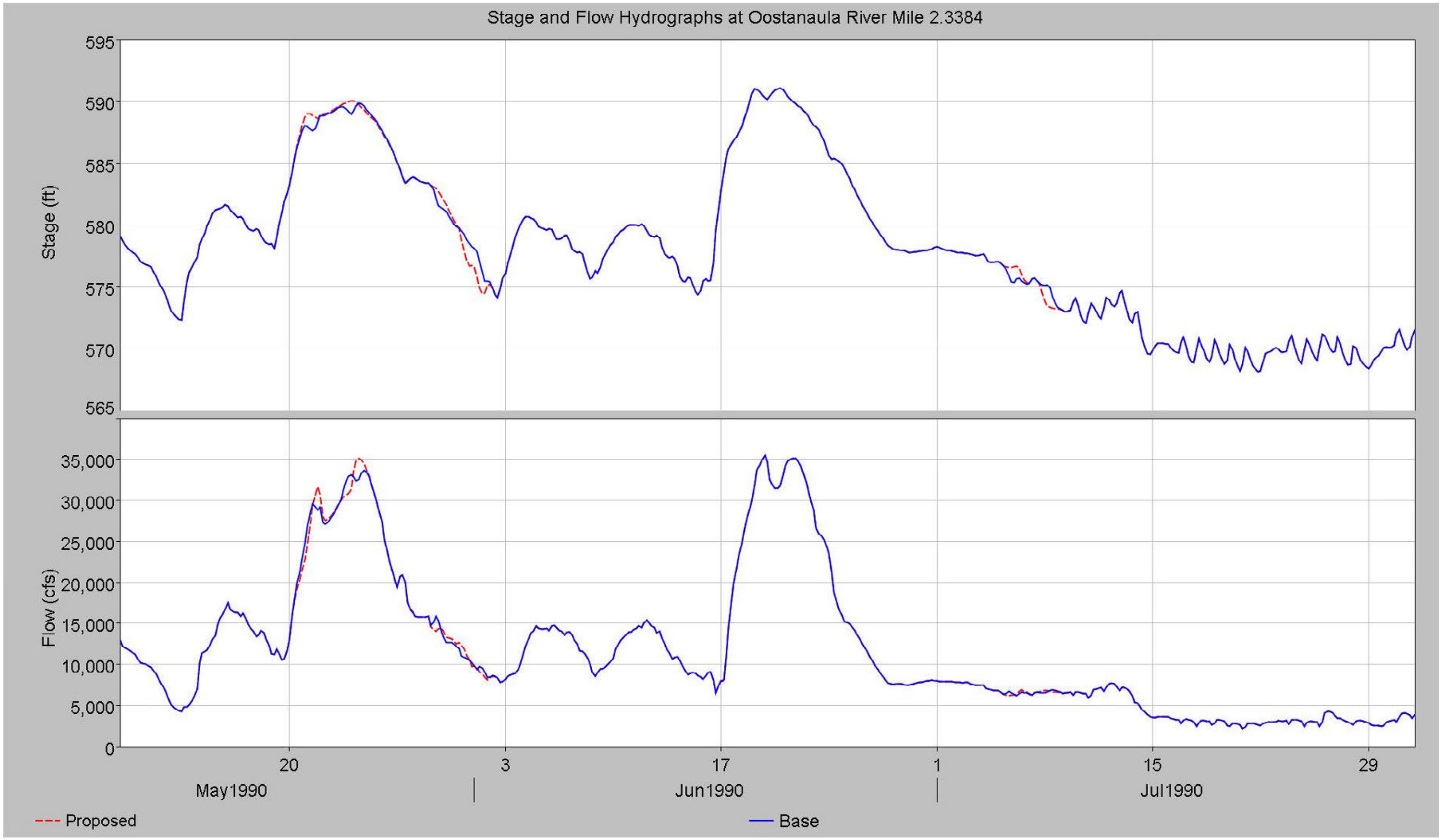
Stage/Flow at Oostanaula River Mile 2.3384 U/S of Veteran's Memorial Pkwy for the 1990 Storm Scaled to a 0.2% ACE



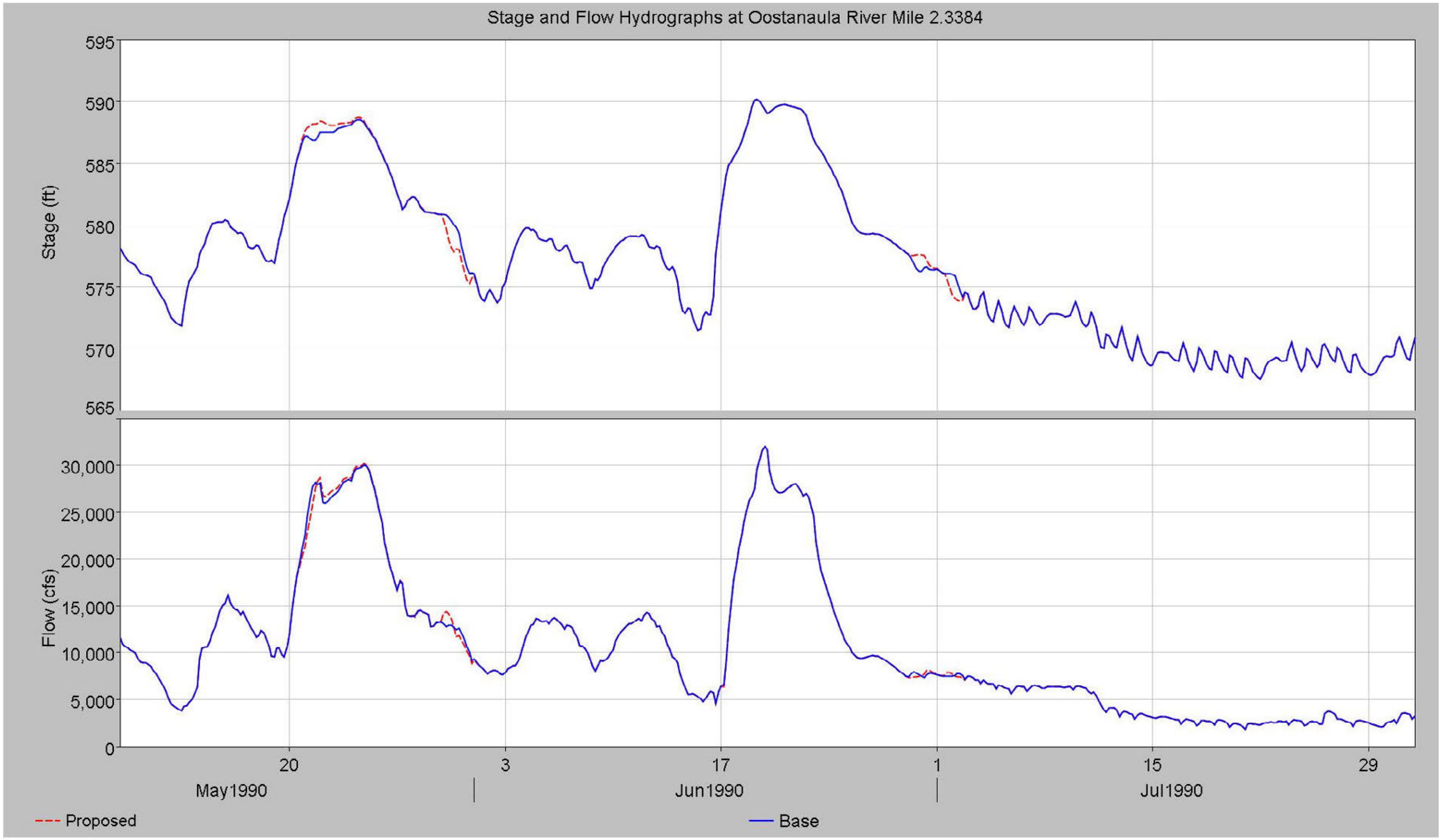
Stage/Flow at Oostanaula River Mile 2.3384 U/S of Veteran's Memorial Pkwy for the 1990 Storm Scaled to a 0.5% ACE



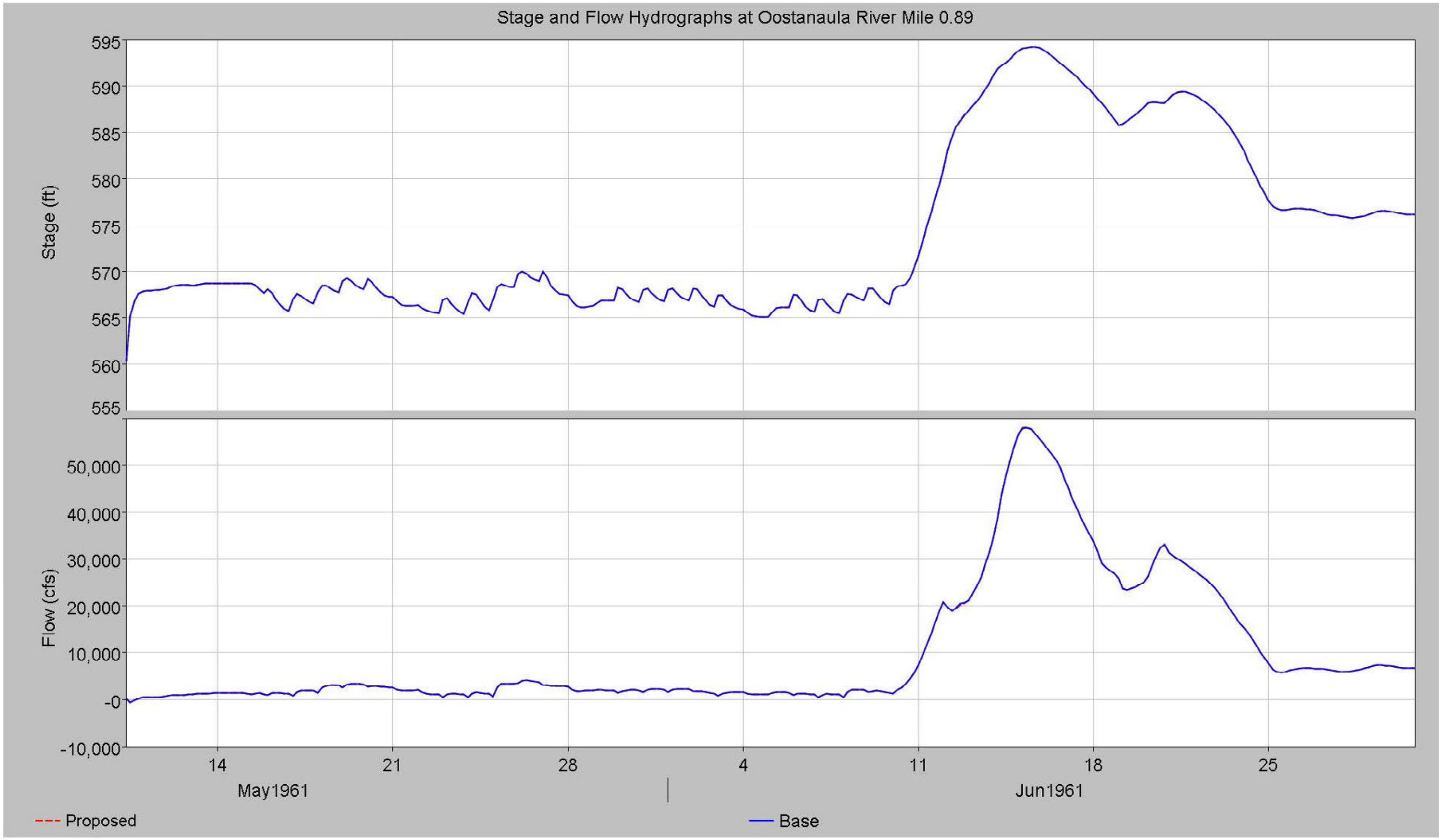
Stage/Flow at Oostanaula River Mile 2.3384 U/S of Veteran's Memorial Pkwy for the 1990 Storm Scaled to a 1.0% ACE



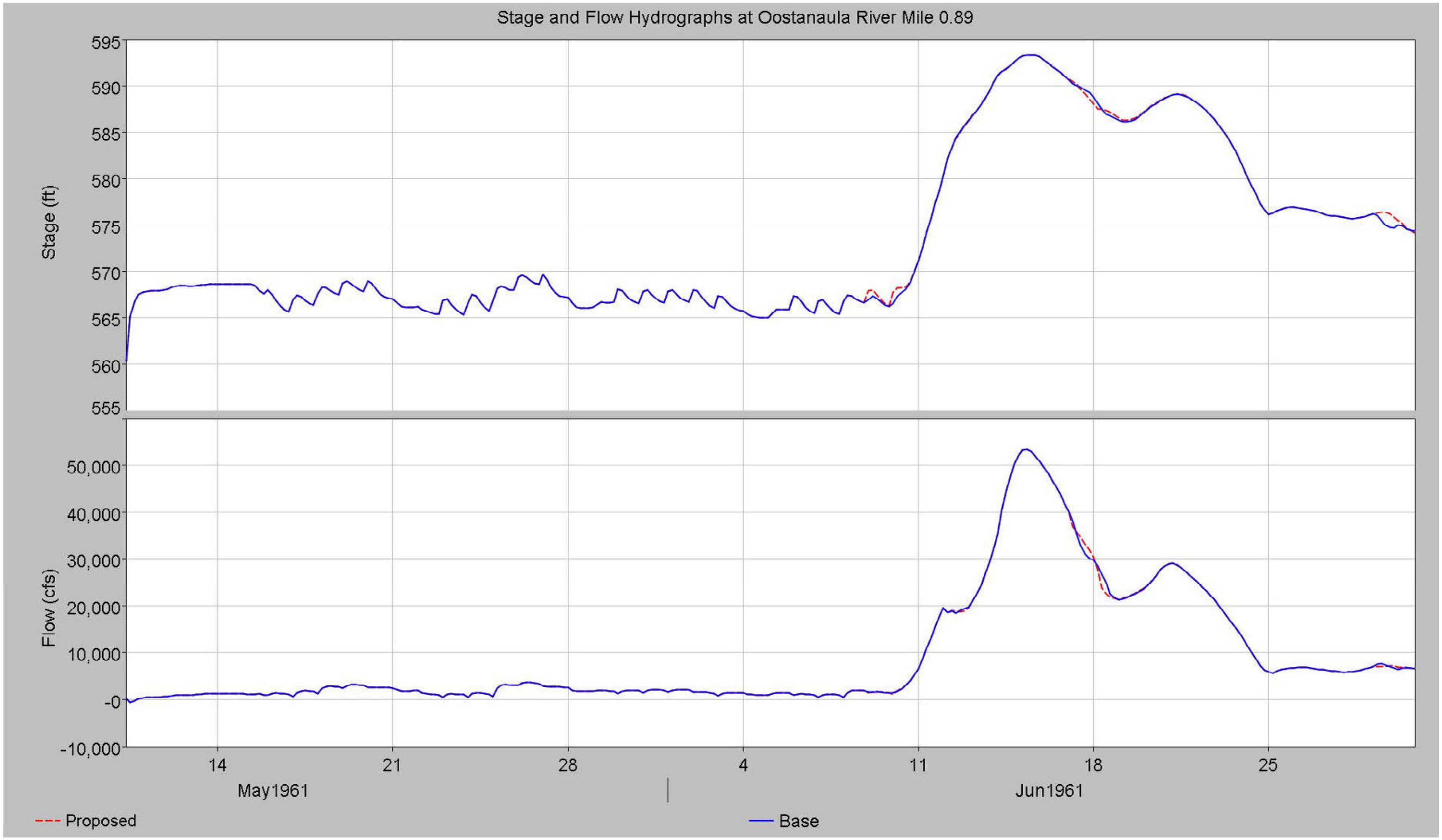
Stage/Flow at Oostanaula River Mile 2.3384 U/S of Veteran's Memorial Pkwy for the 1990 Storm Scaled to a 2.0% ACE



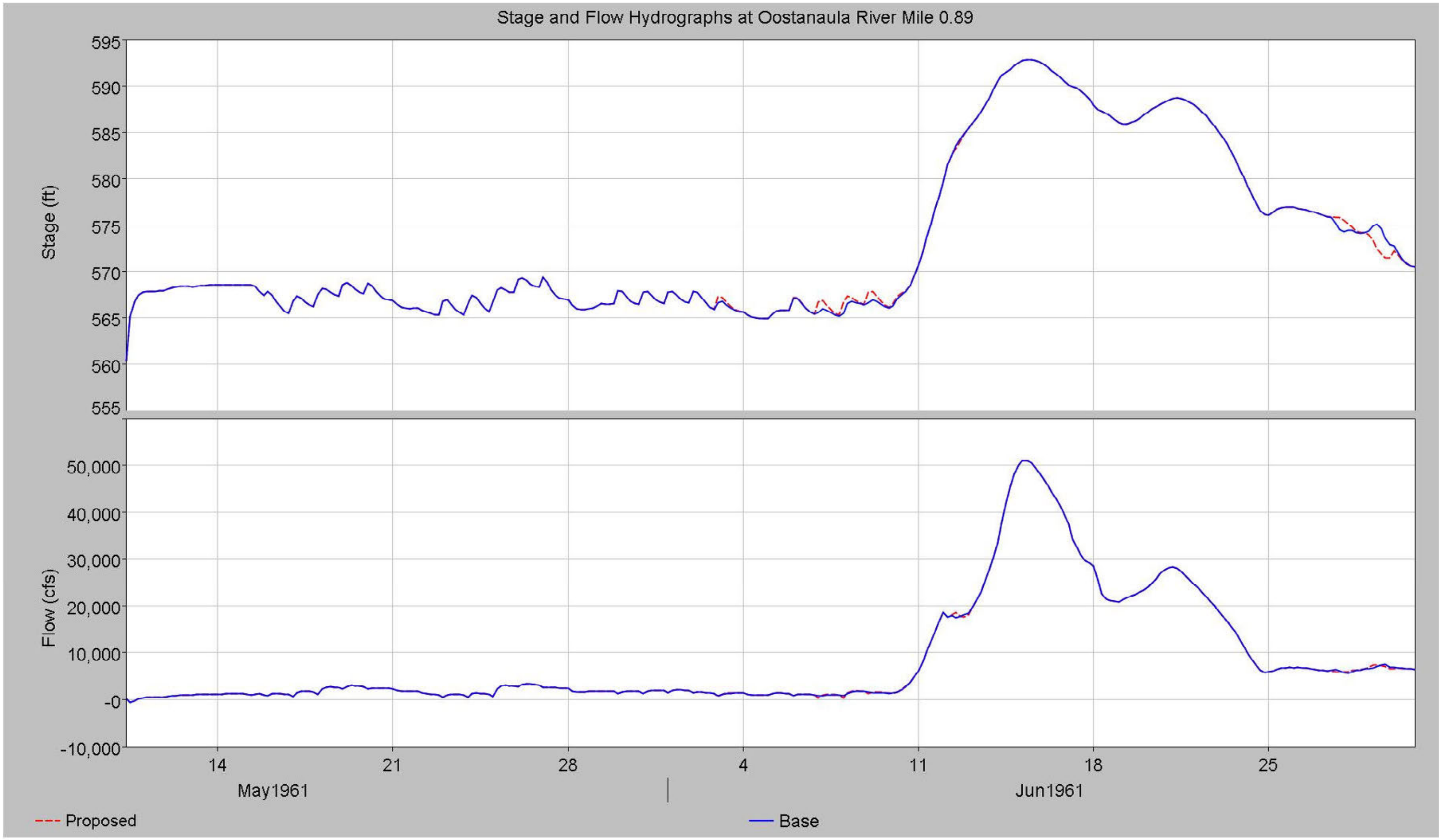
Stage/Flow at Oostanaula River Mile 2.3384 U/S of Veteran's Memorial Pkwy for the 1990 Storm Scaled to a 5.0% ACE



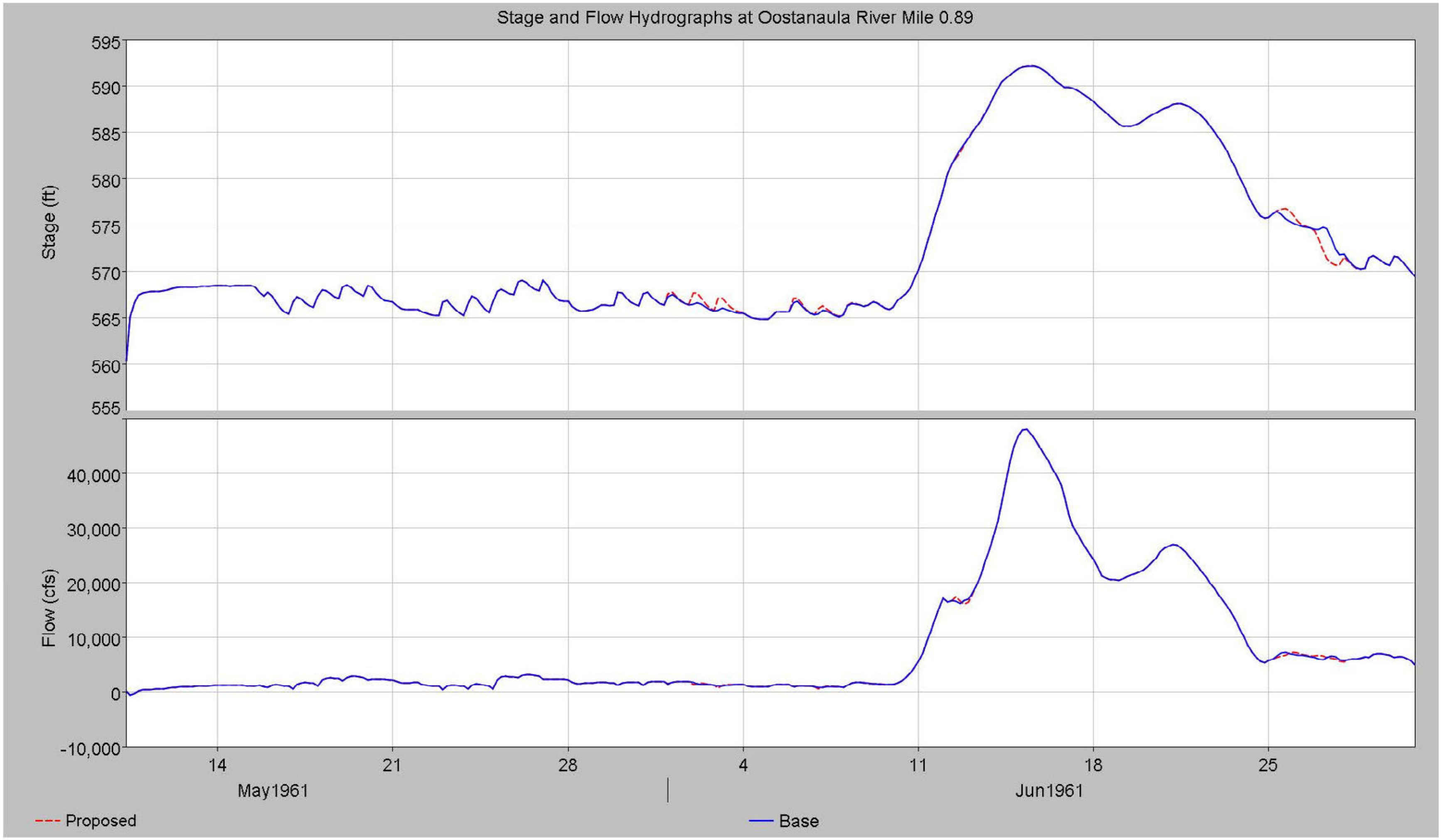
Stage/Flow at Oostanaula River Mile 0.89 Adjacent to Sewer Lift Station on Levee for the 1961 Storm Scaled to a 0.2% ACE



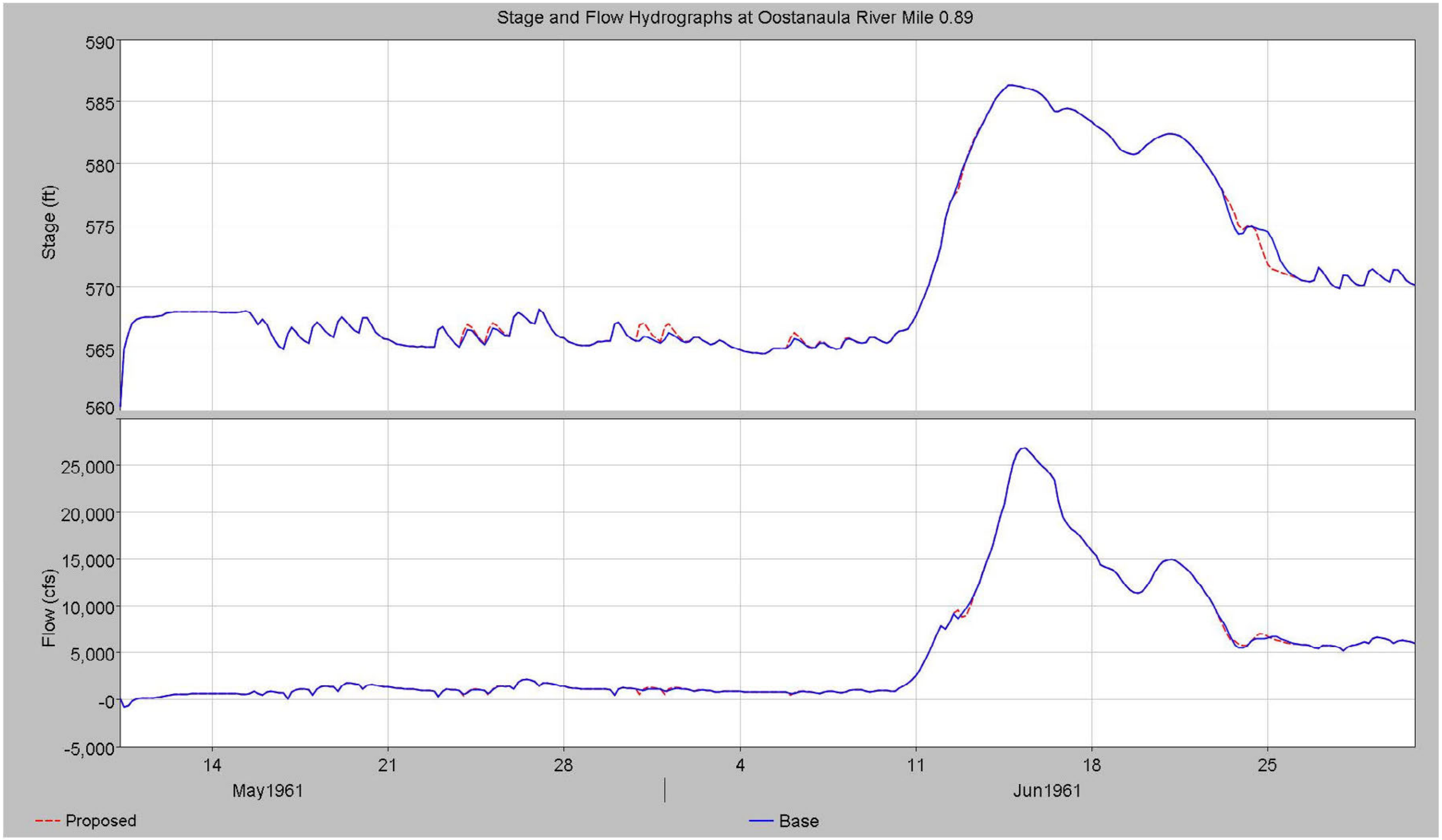
Stage/Flow at Oostanaula River Mile 0.89 Adjacent to Sewer Lift Station on Levee for the 1961 Storm Scaled to a 0.5% ACE



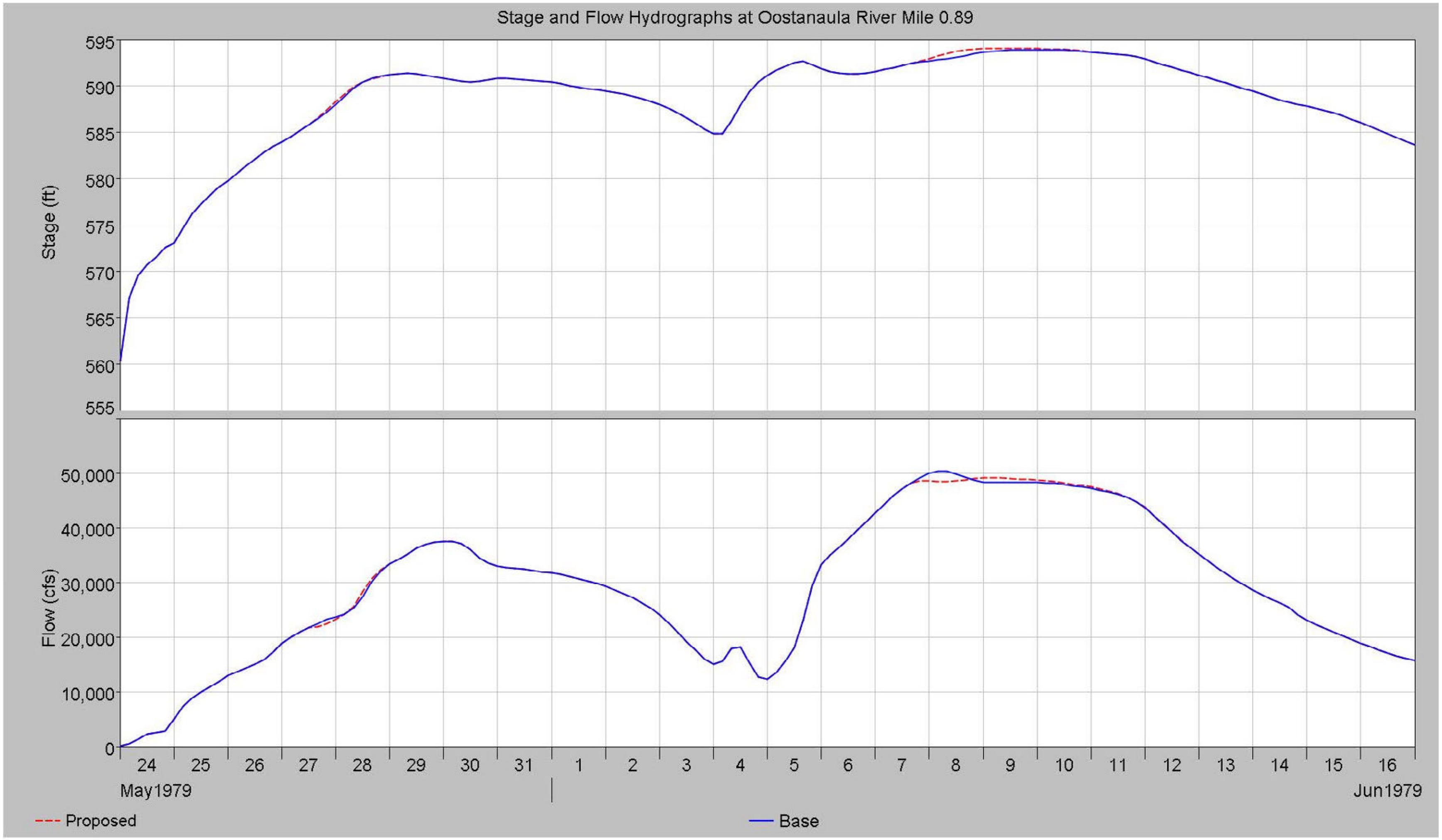
Stage/Flow at Oostanaula River Mile 0.89 Adjacent to Sewer Lift Station on Levee for the 1961 Storm Scaled to a 1.0% ACE



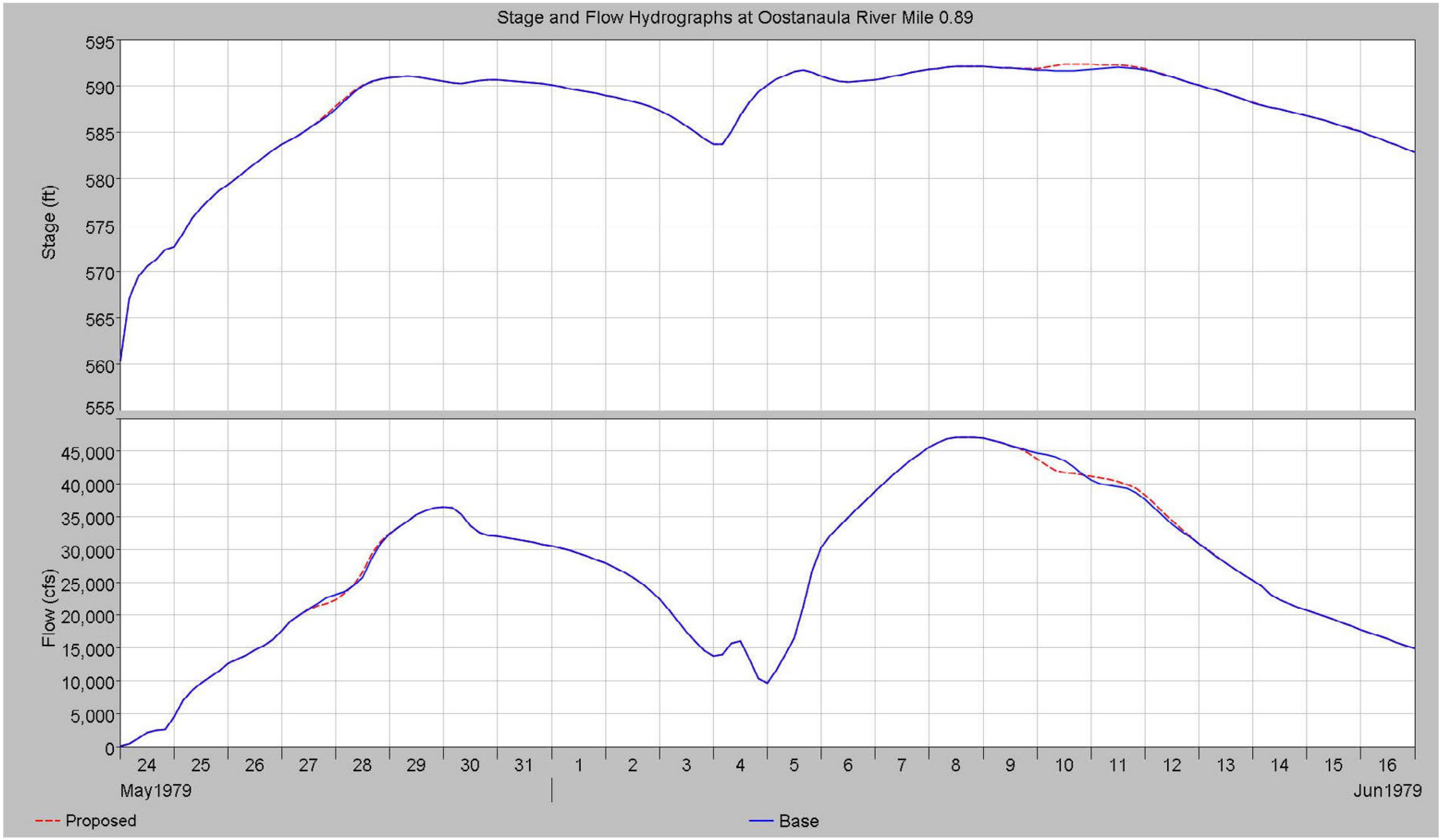
Stage/Flow at Oostanaula River Mile 0.89 Adjacent to Sewer Lift Station on Levee for the 1961 Storm Scaled to a 2.0% ACE



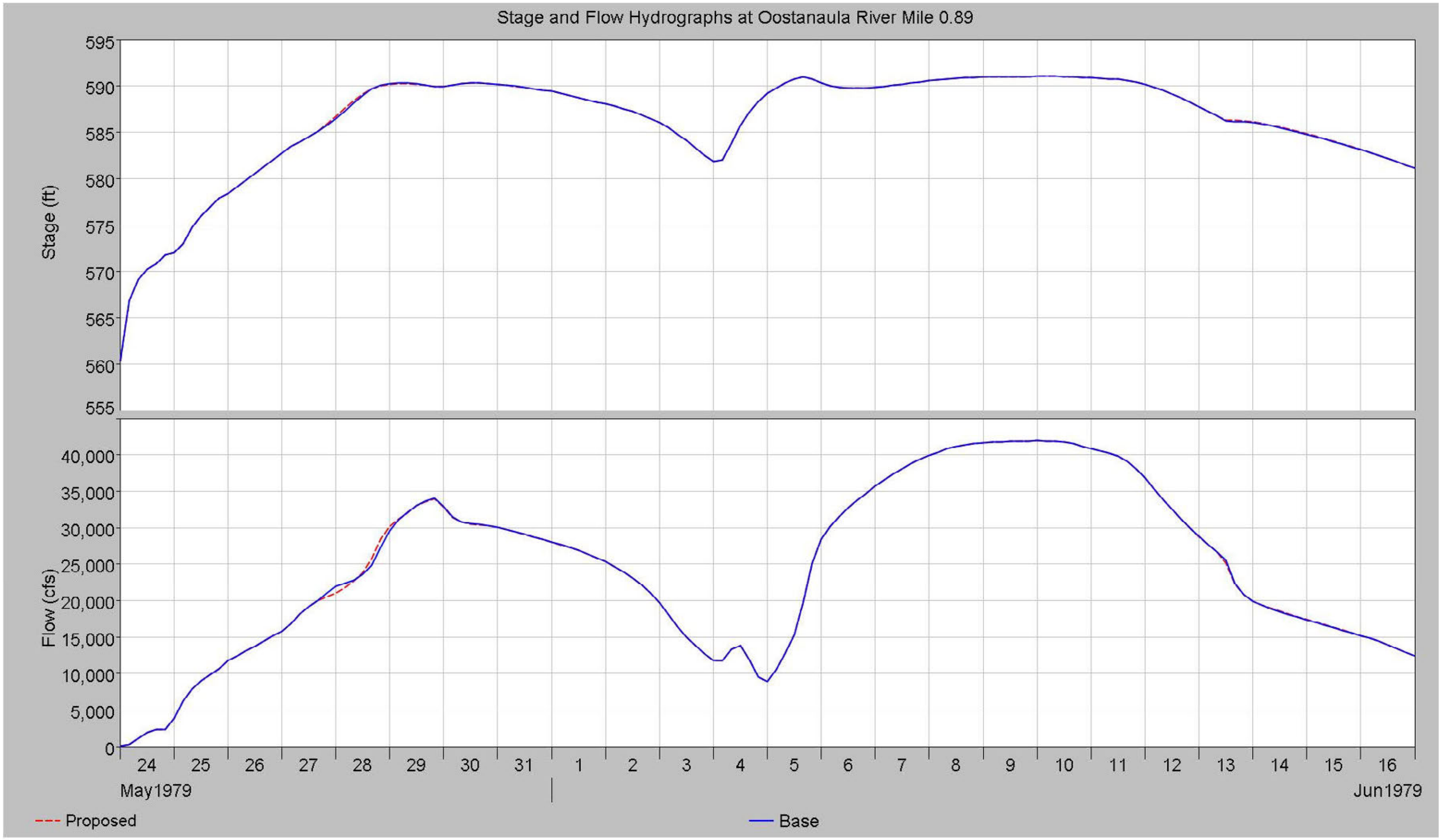
Stage/Flow at Oostanaula River Mile 0.89 Adjacent to Sewer Lift Station on Levee for the 1961 Storm Scaled to a 5.0% ACE



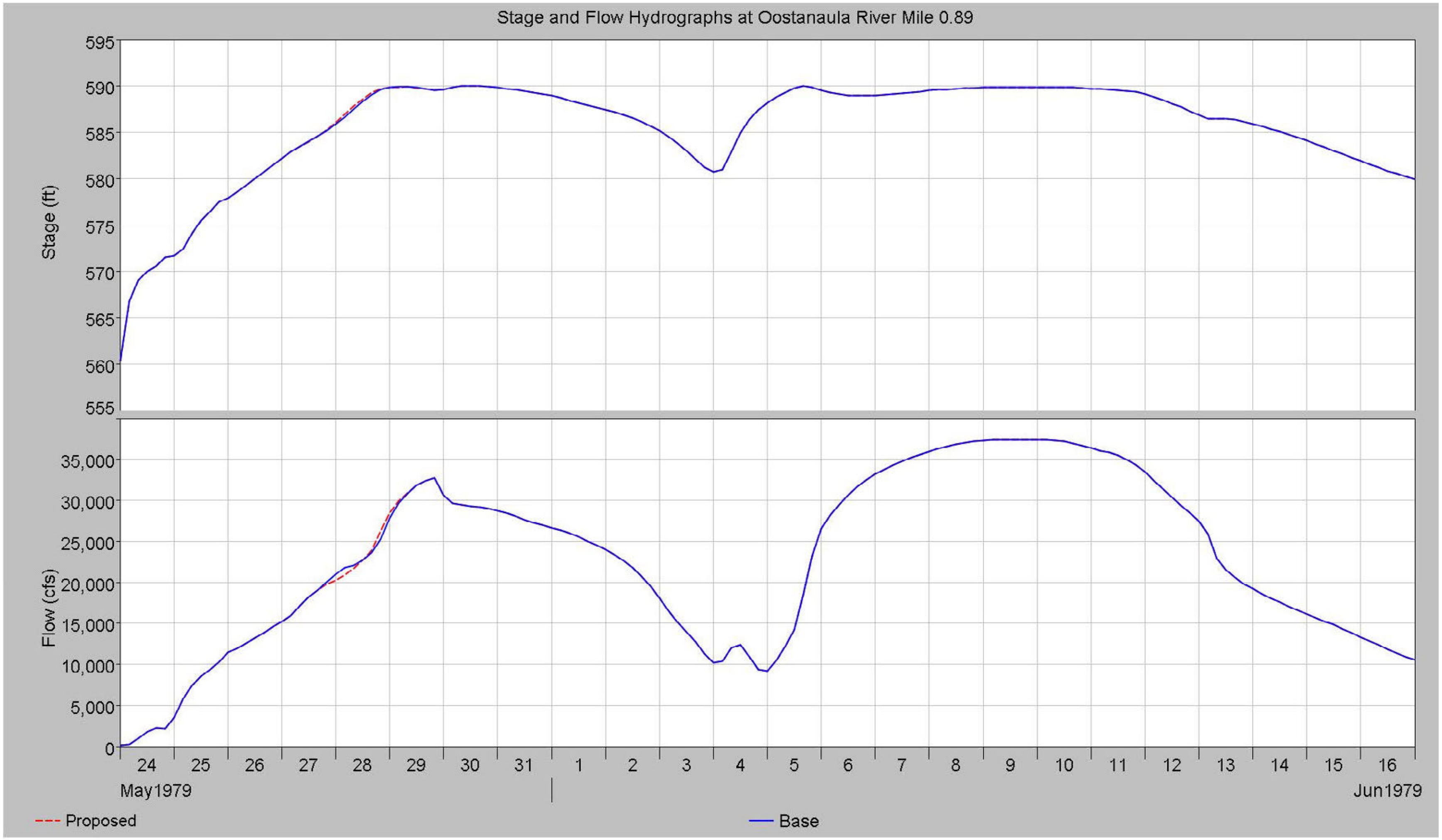
Stage/Flow at Oostanaula River Mile 0.89 Adjacent to Sewer Lift Station on Levee for the 1979 Storm Scaled to a 0.2% ACE



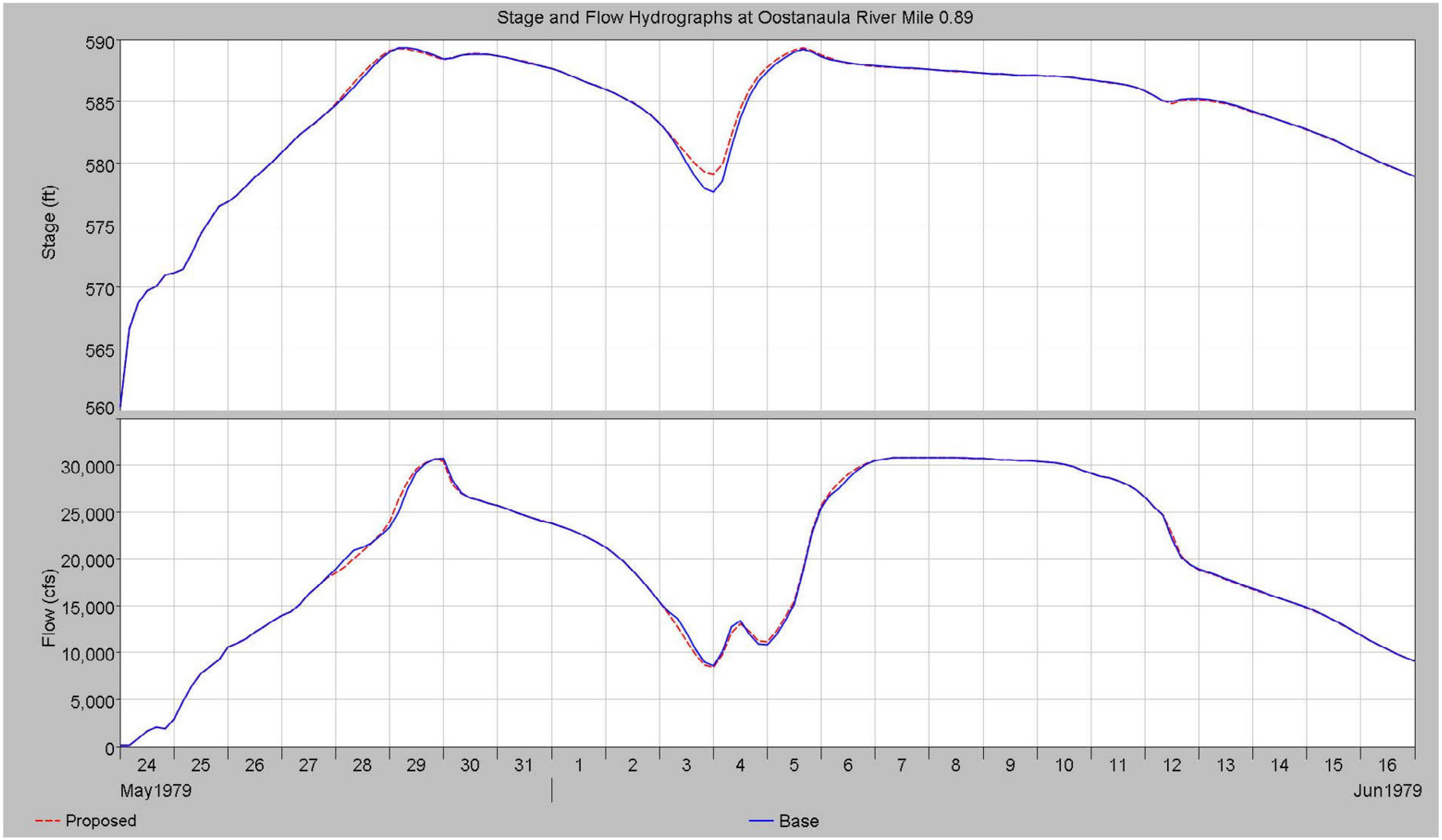
Stage/Flow at Oostanaula River Mile 0.89 Adjacent to Sewer Lift Station on Levee for the 1979 Storm Scaled to a 0.5% ACE



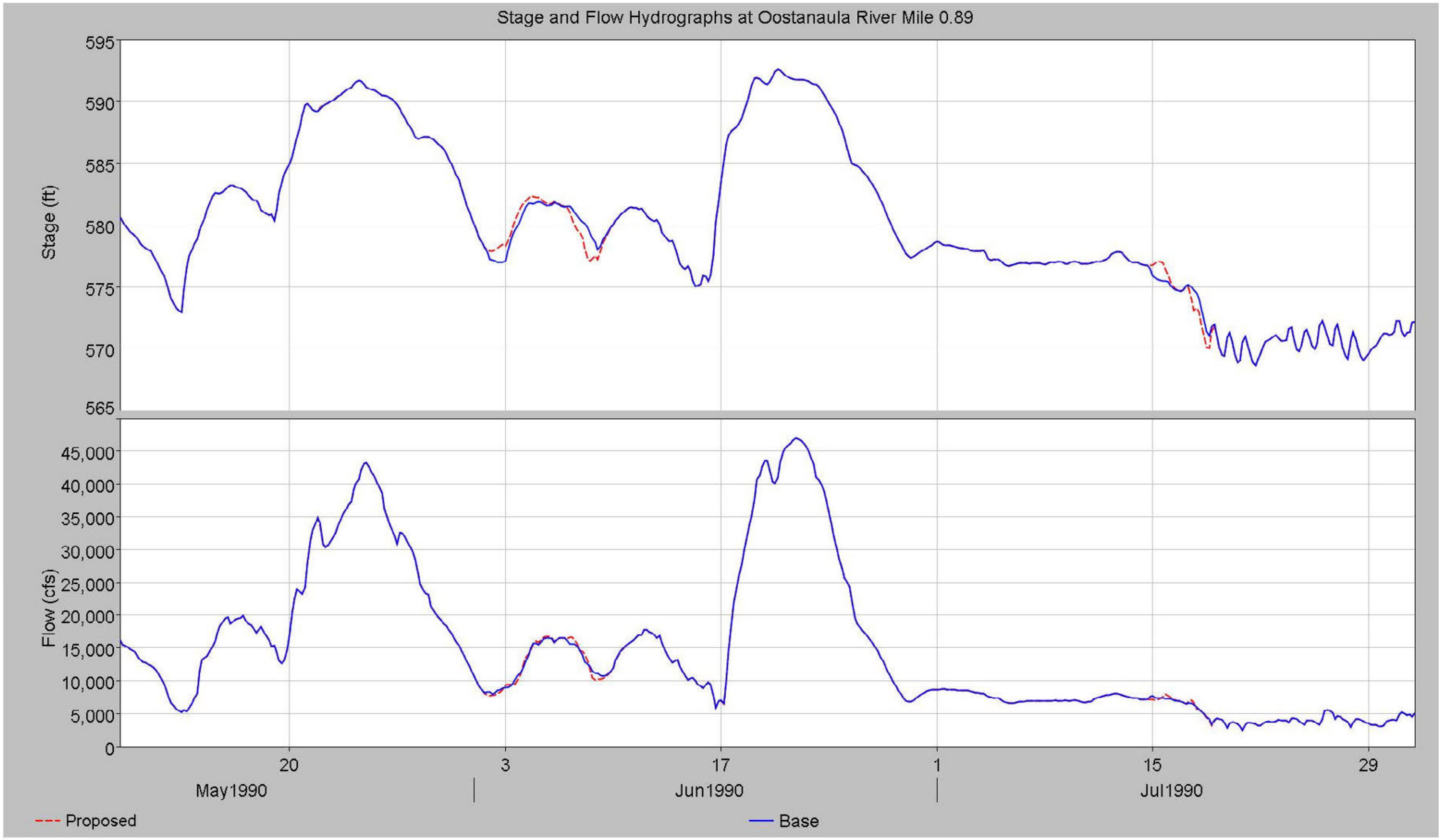
Stage/Flow at Oostanaula River Mile 0.89 Adjacent to Sewer Lift Station on Levee for the 1979 Storm Scaled to a 1.0% ACE



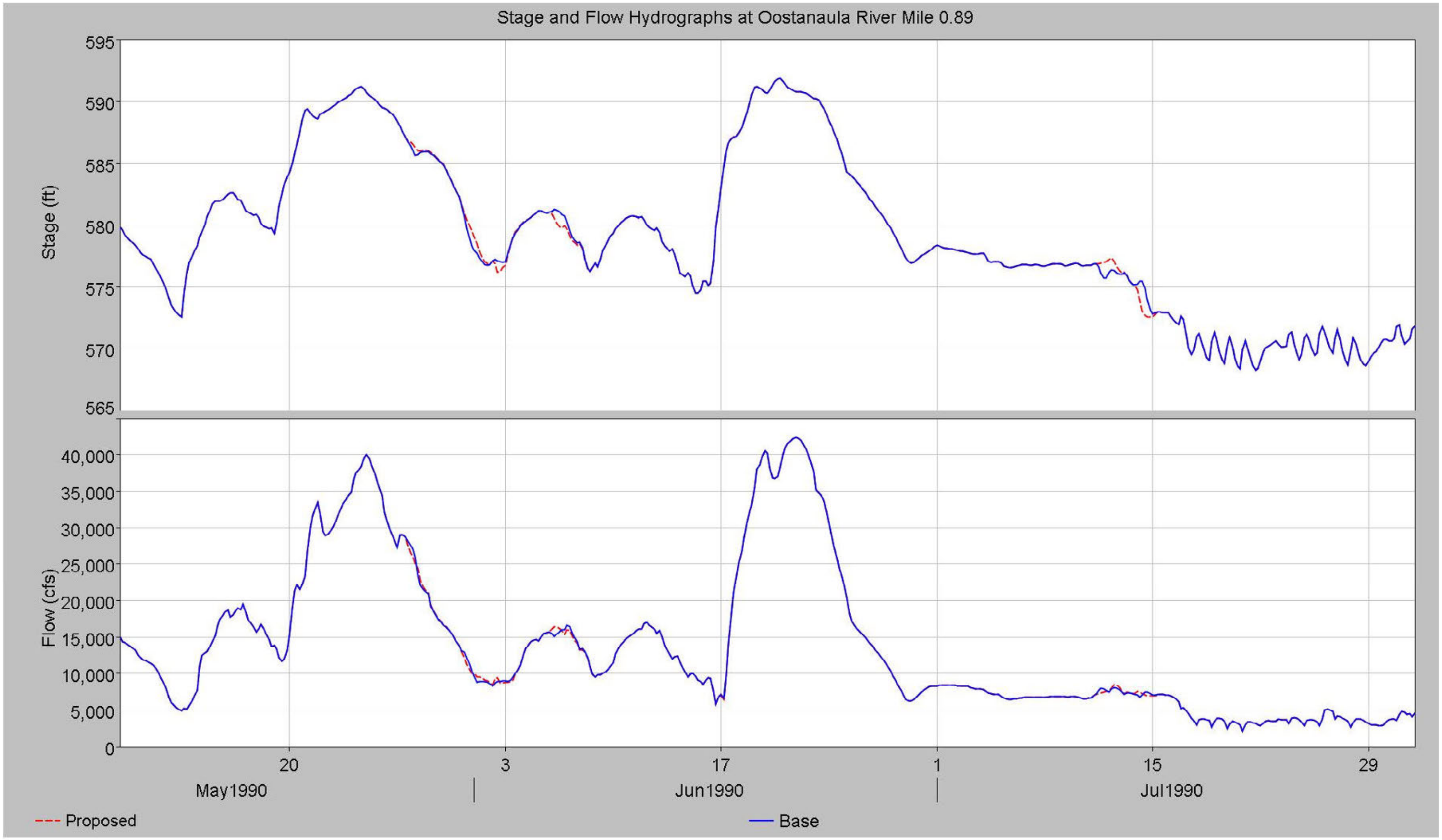
Stage/Flow at Oostanaula River Mile 0.89 Adjacent to Sewer Lift Station on Levee for the 1979 Storm Scaled to a 2.0% ACE



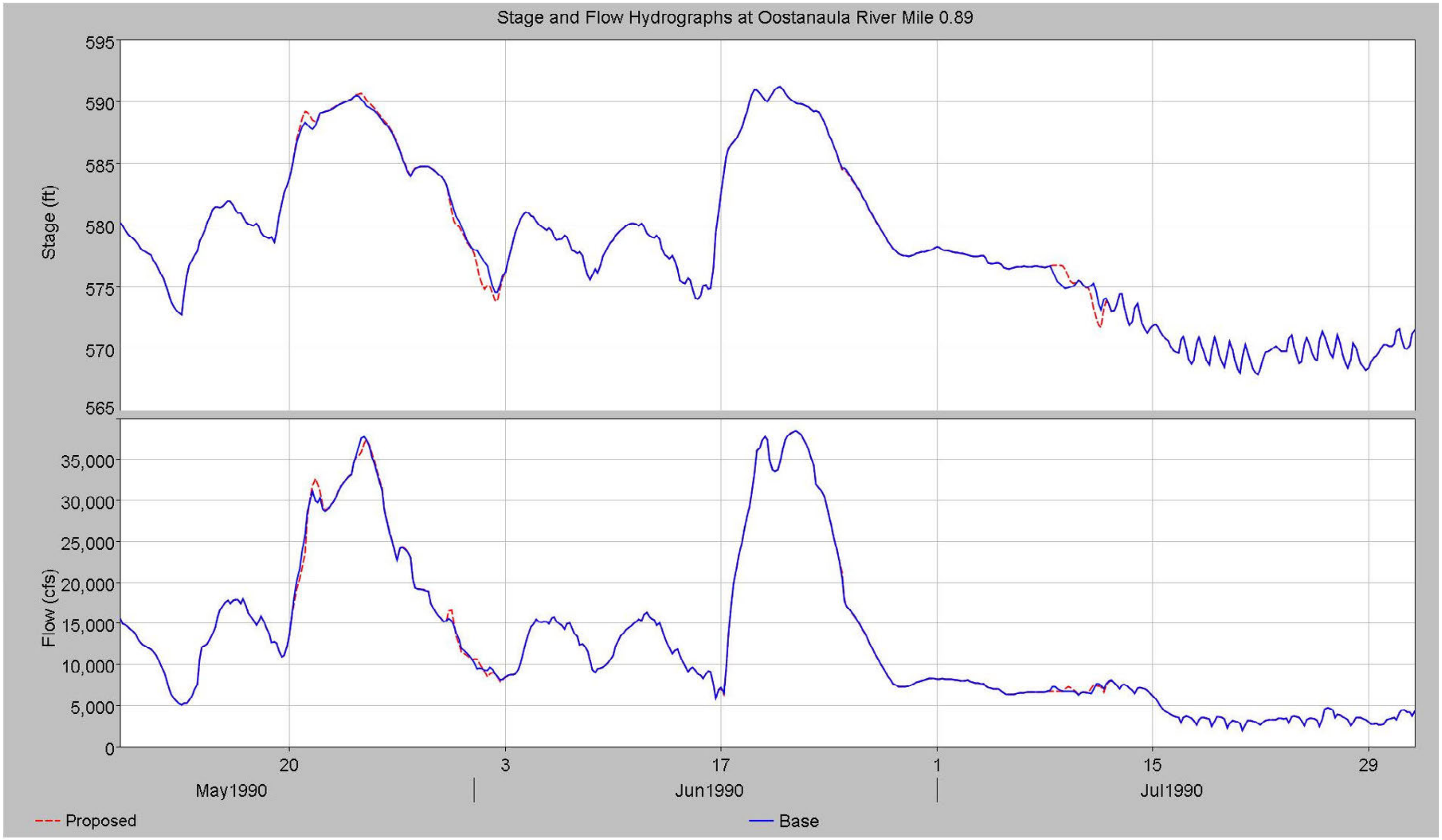
Stage/Flow at Oostanaula River Mile 0.89 Adjacent to Sewer Lift Station on Levee for the 1979 Storm Scaled to a 5.0% ACE



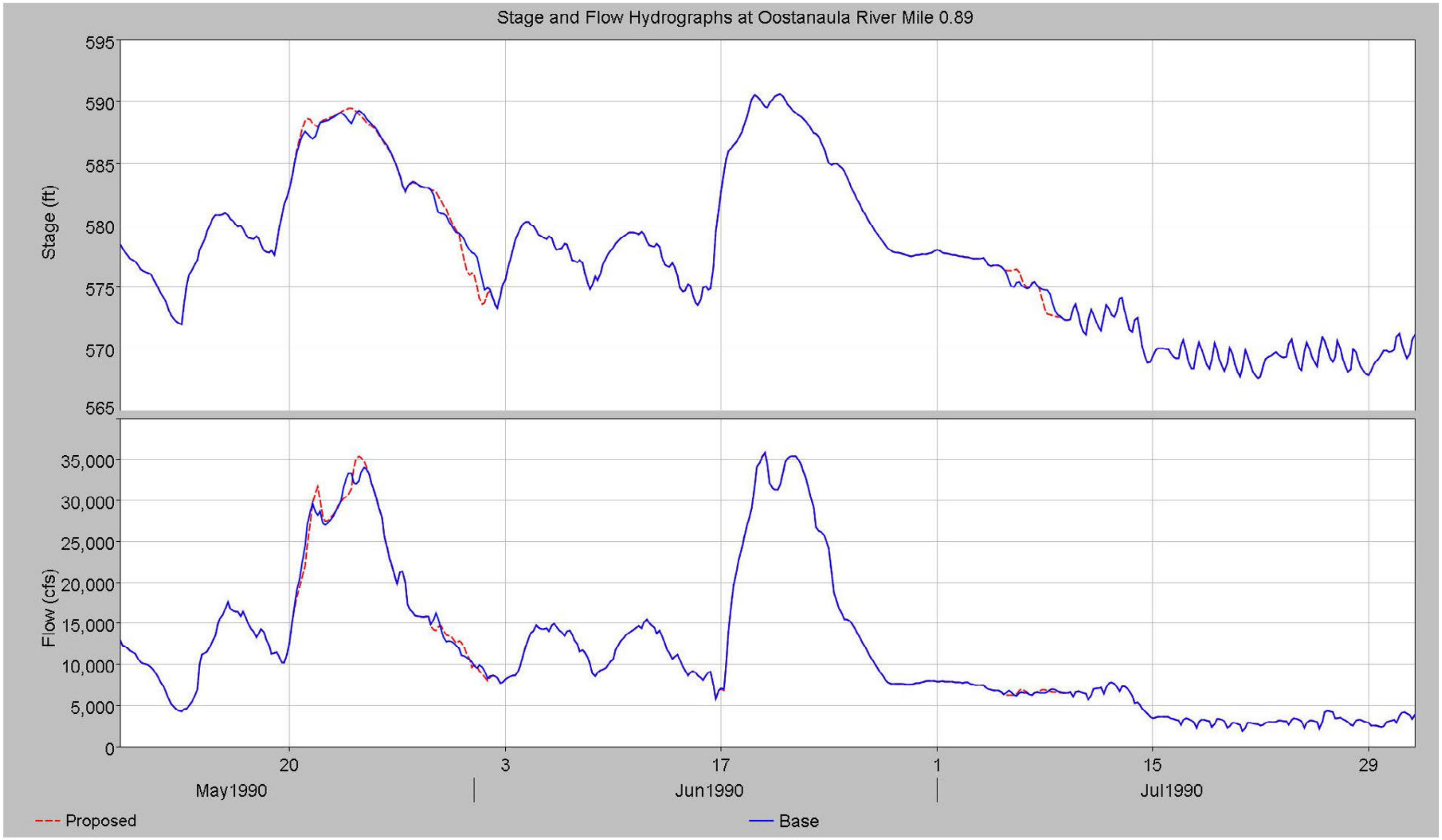
Stage/Flow at Oostanaula River Mile 0.89 Adjacent to Sewer Lift Station on Levee for the 1990 Storm Scaled to a 0.2% ACE



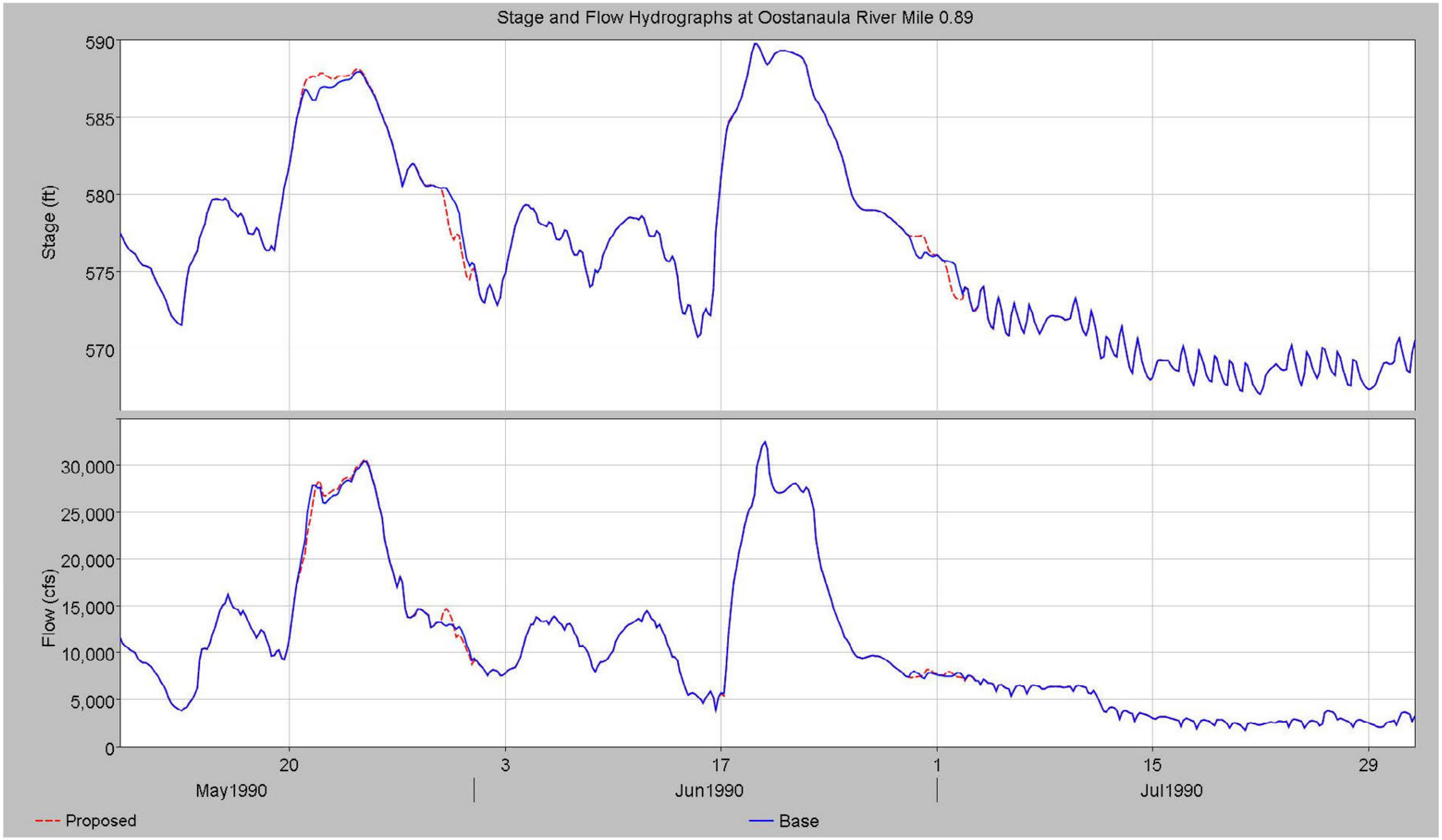
Stage/Flow at Oostanaula River Mile 0.89 Adjacent to Sewer Lift Station on Levee for the 1990 Storm Scaled to a 0.5% ACE



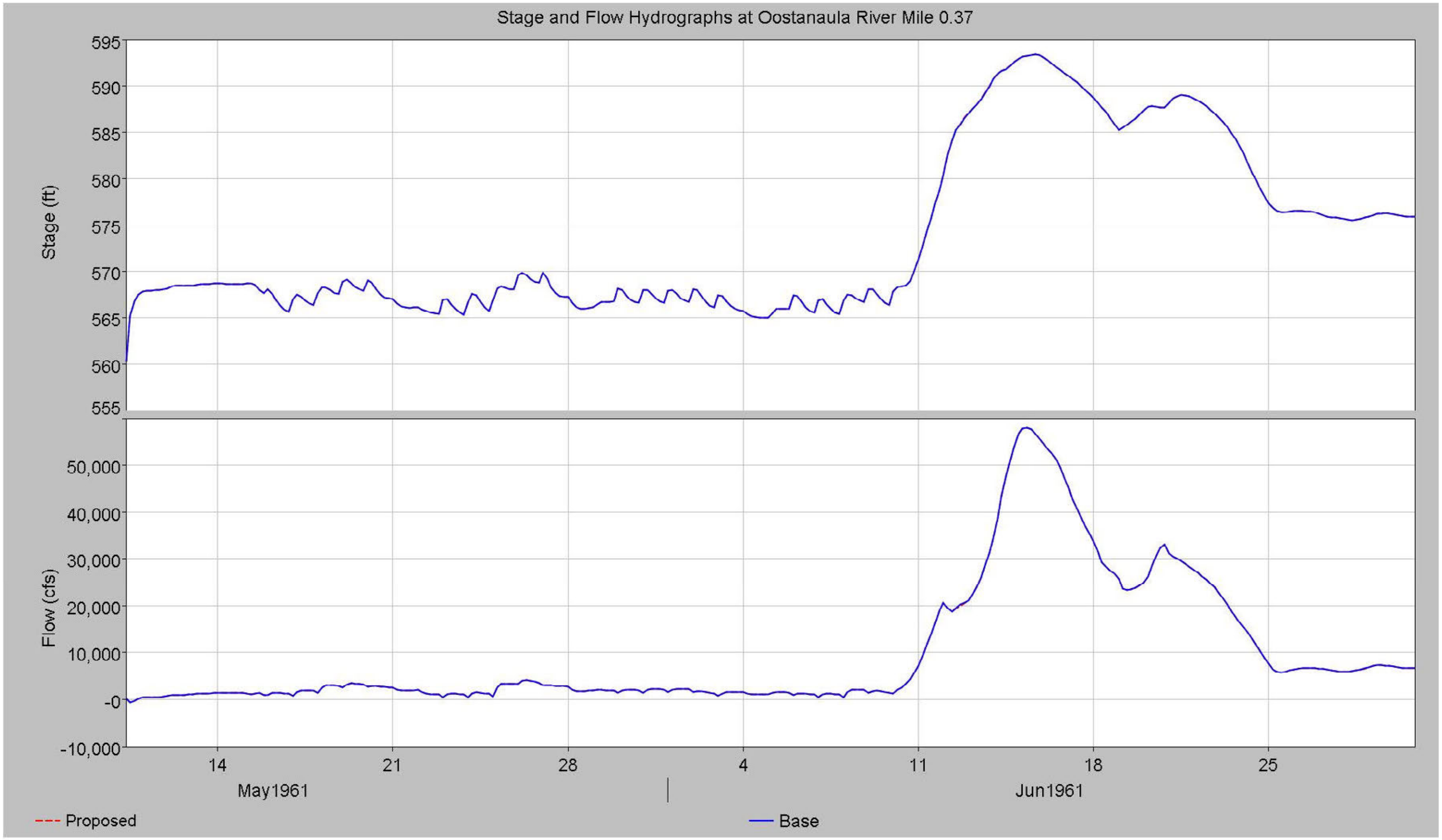
Stage/Flow at Oostanaula River Mile 0.89 Adjacent to Sewer Lift Station on Levee for the 1990 Storm Scaled to a 1.0% ACE



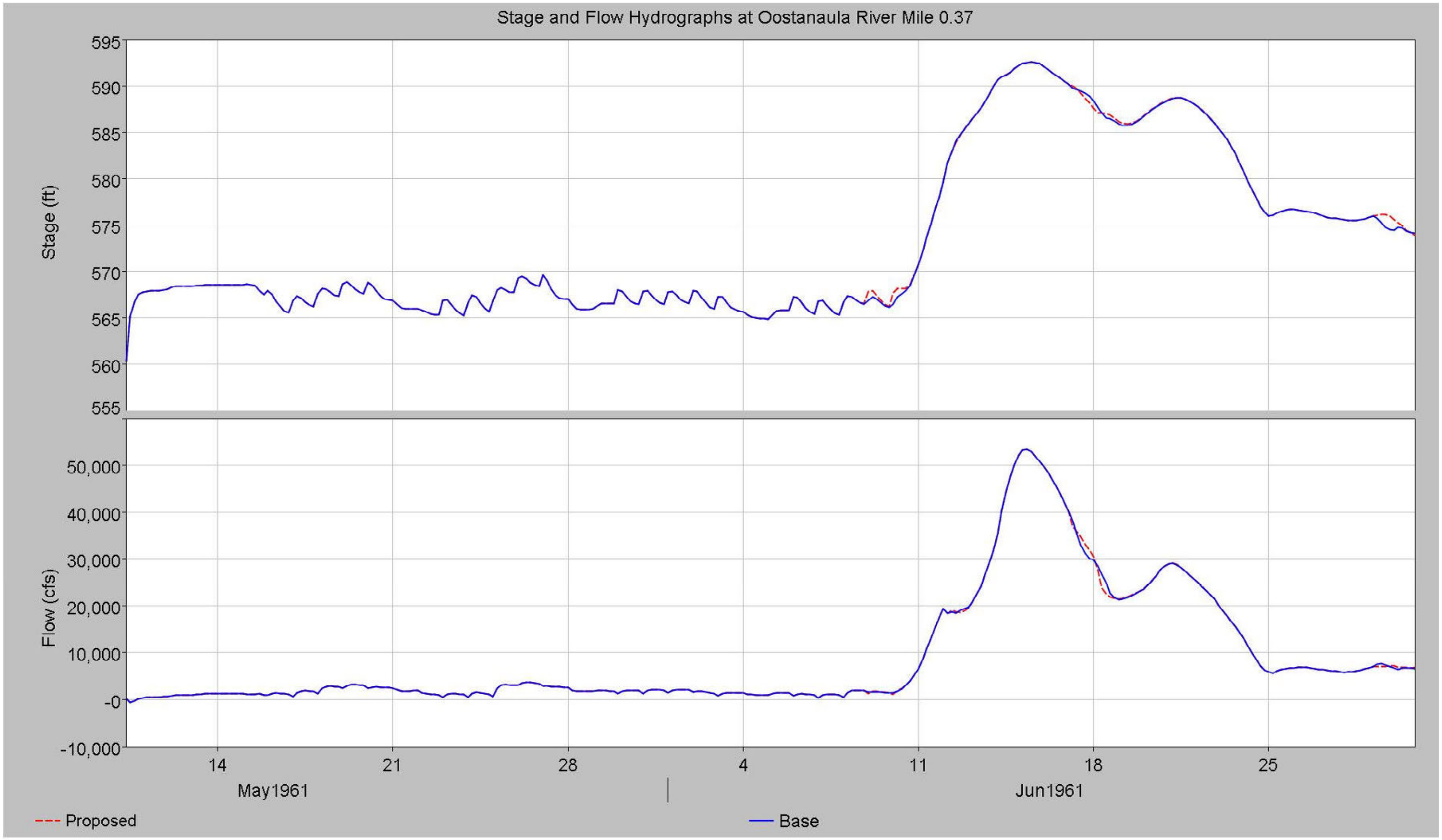
Stage/Flow at Oostanaula River Mile 0.89 Adjacent to Sewer Lift Station on Levee for the 1990 Storm Scaled to a 2.0% ACE



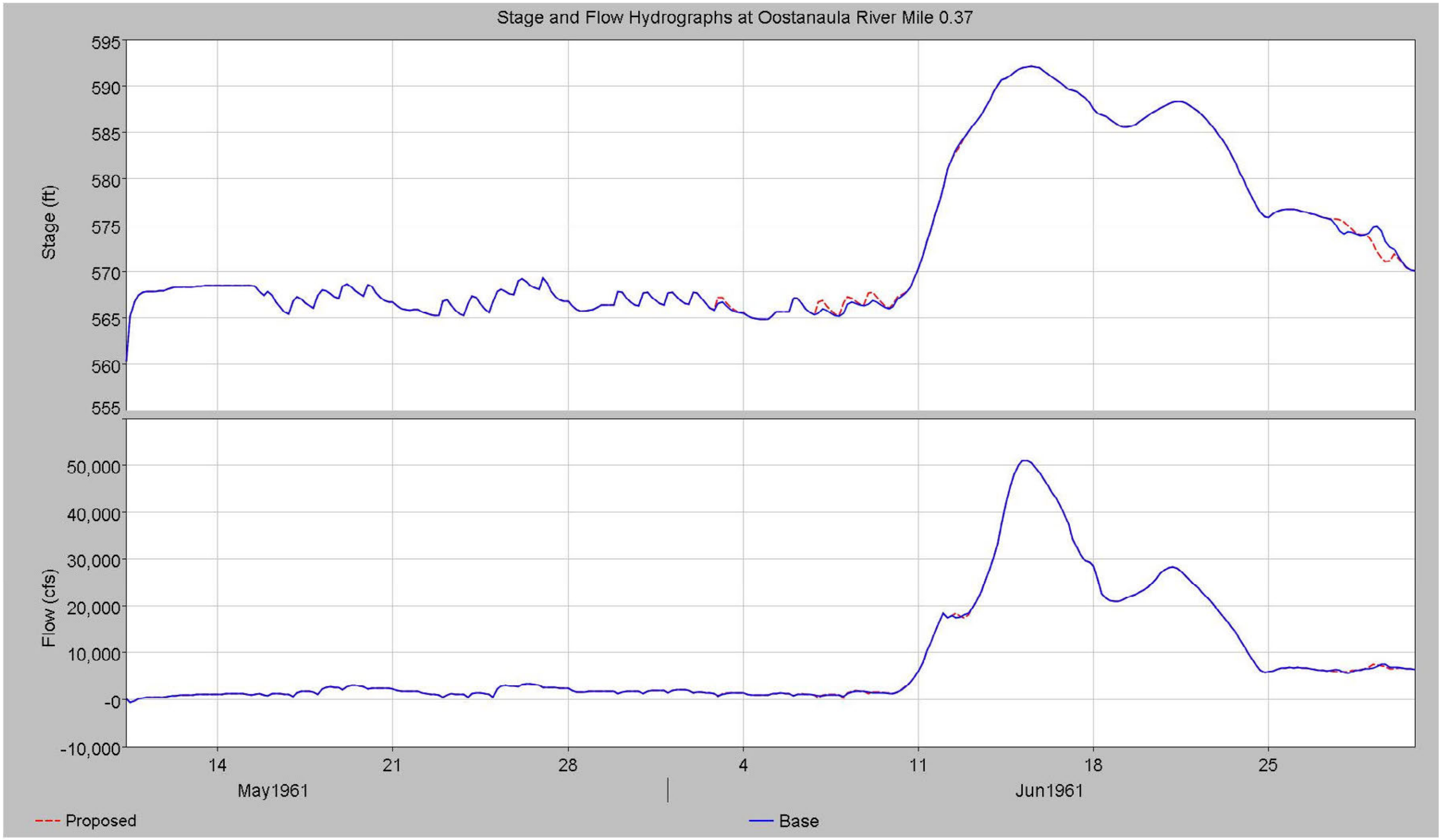
Stage/Flow at Oostanaula River Mile 0.89 Adjacent to Sewer Lift Station on Levee for the 1990 Storm Scaled to a 5.0% ACE



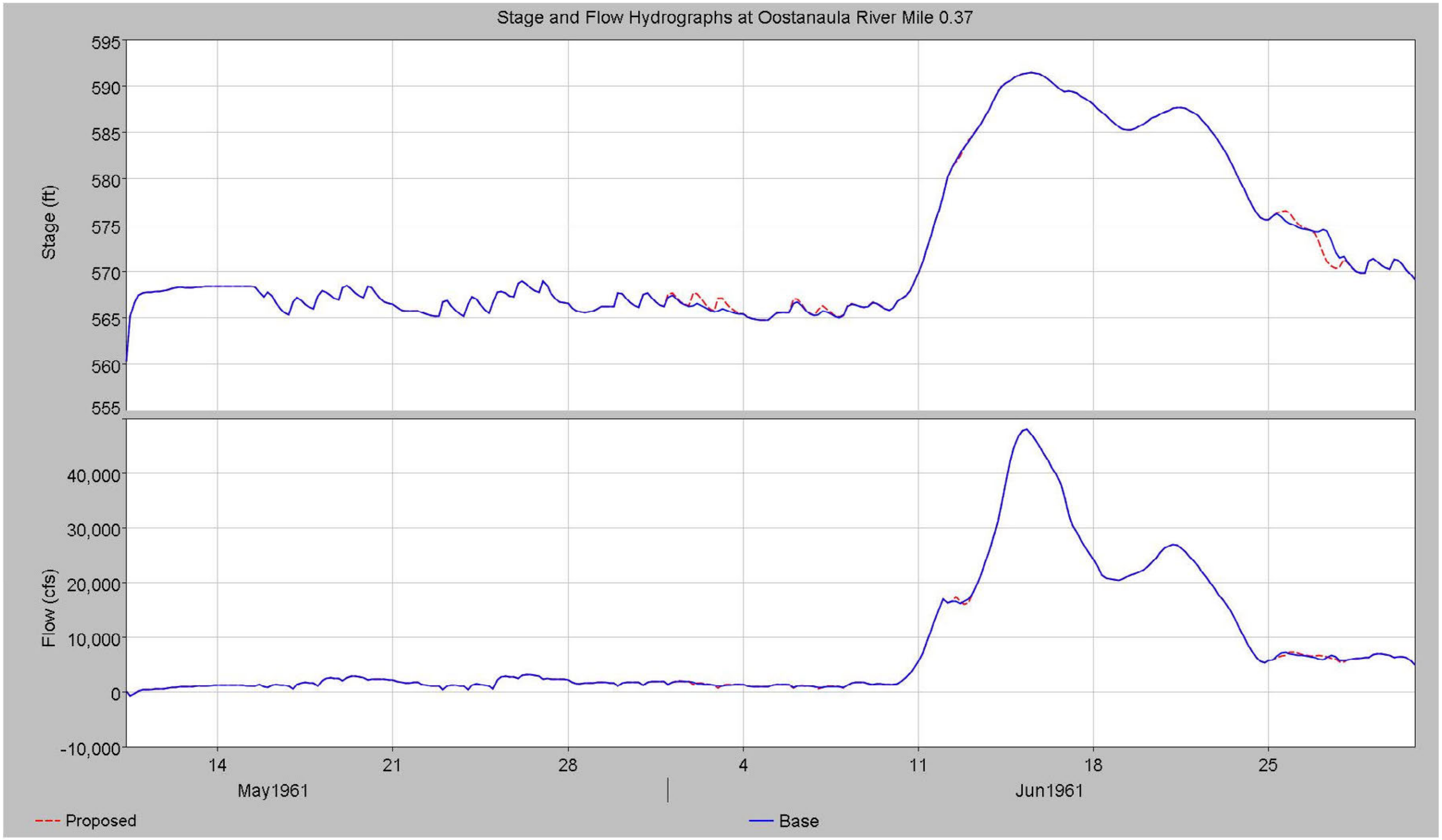
Stage/Flow at Oostanaula River Mile 0.37 D/S of West 5th Avenue for the 1961 Storm Scaled to a 0.2% ACE



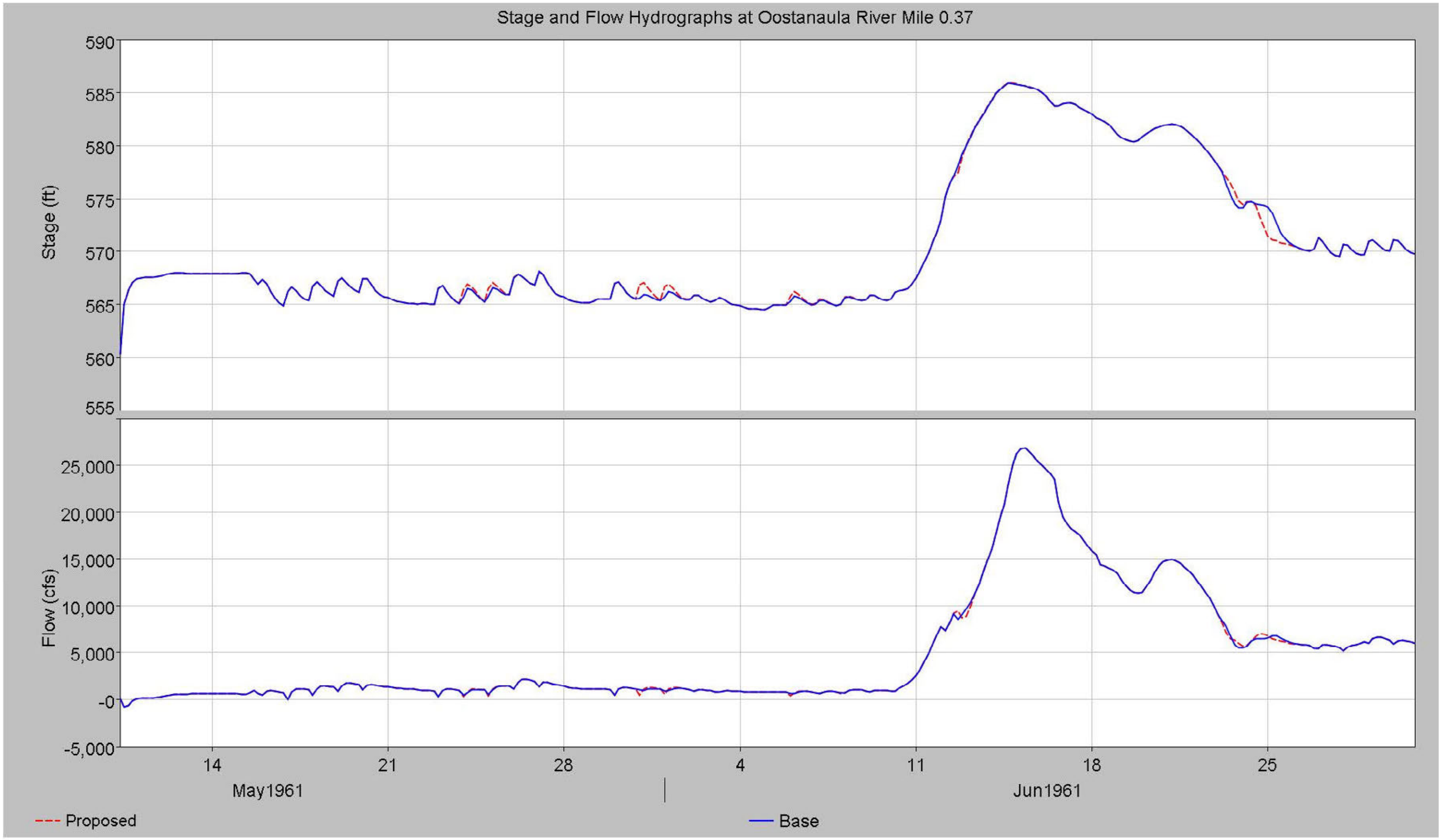
Stage/Flow at Oostanaula River Mile 0.37 D/S of West 5th Avenue for the 1961 Storm Scaled to a 0.5% ACE



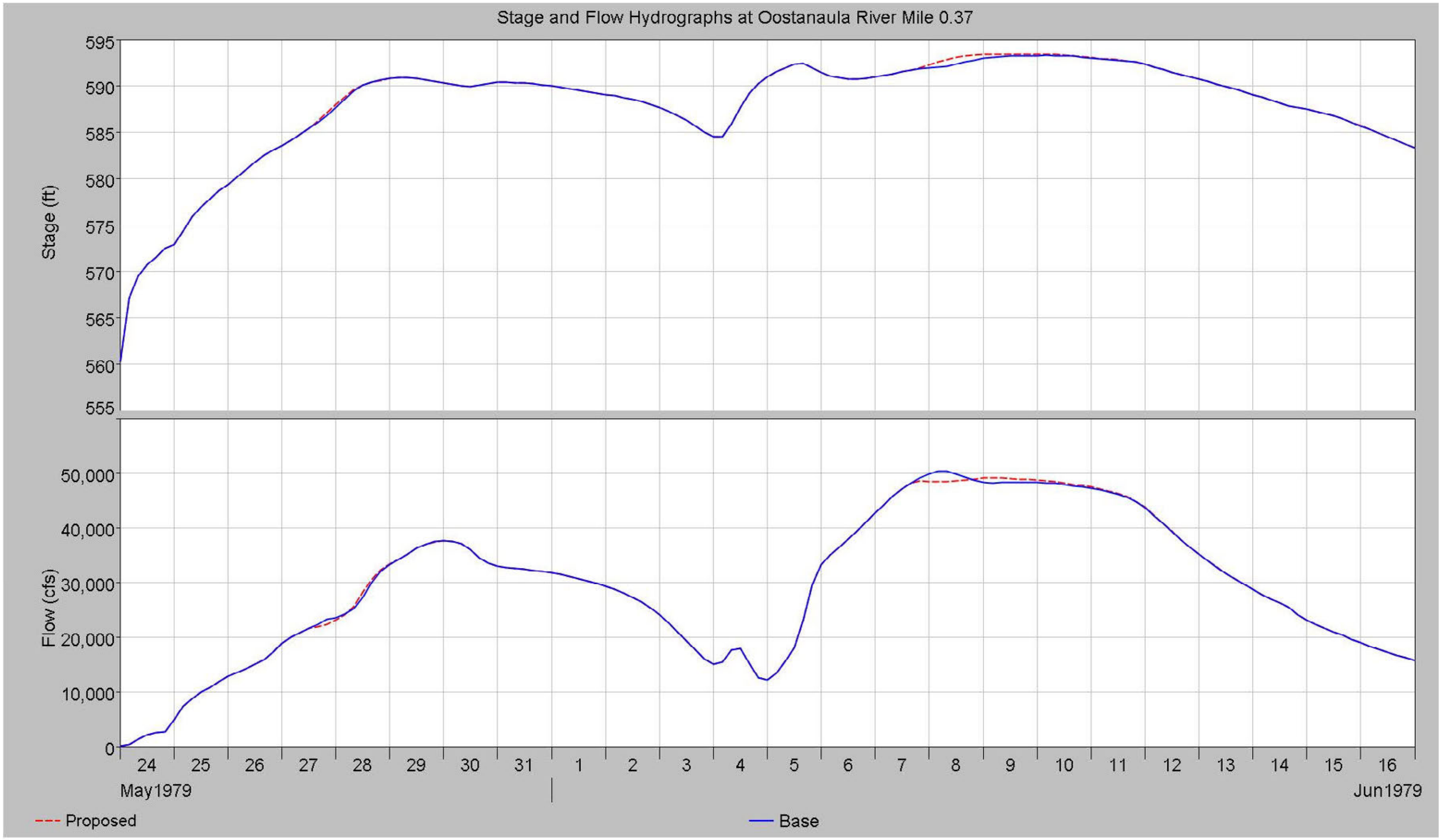
Stage/Flow at Oostanaula River Mile 0.37 D/S of West 5th Avenue for the 1961 Storm Scaled to a 1.0% ACE



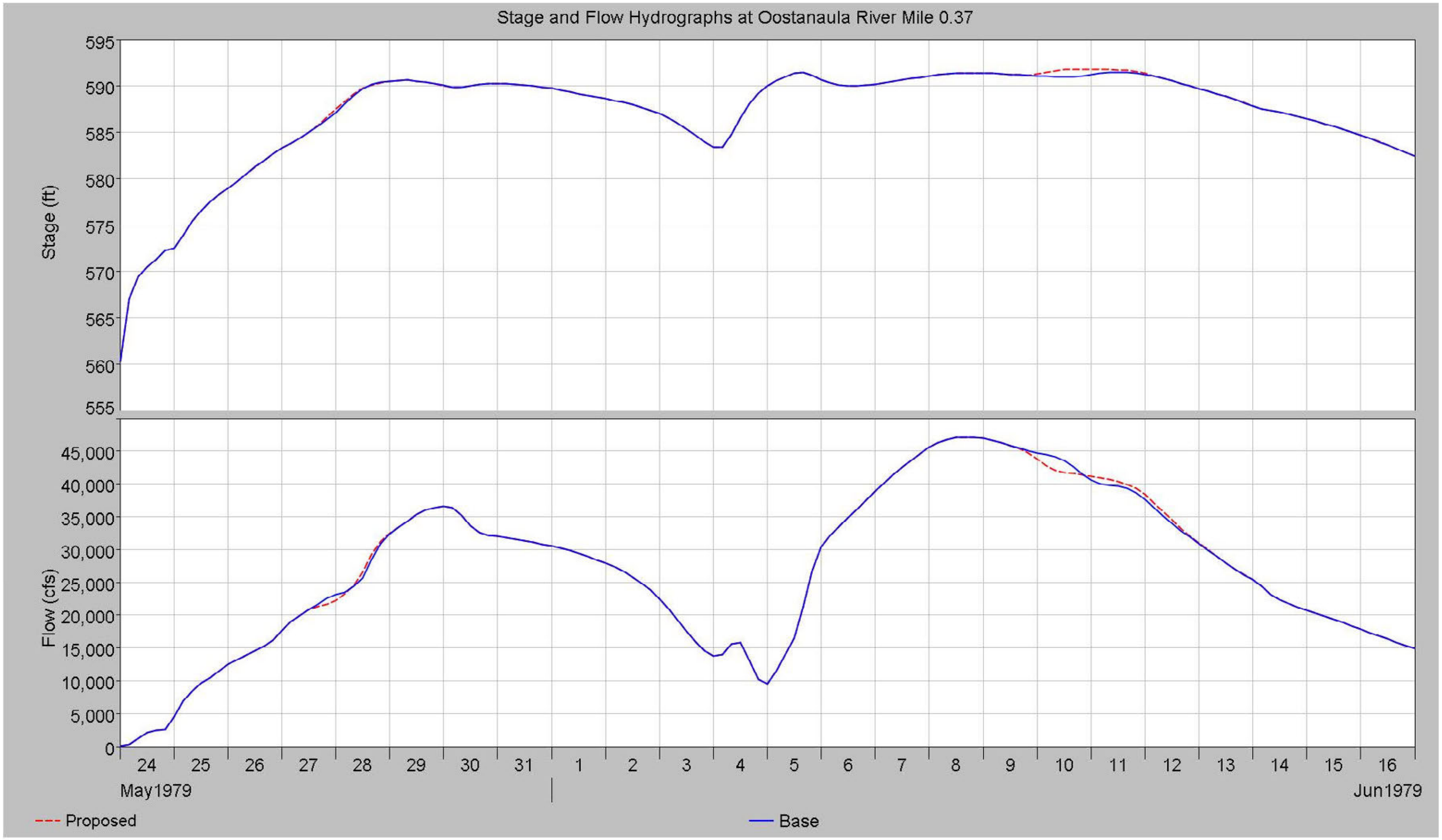
Stage/Flow at Oostanaula River Mile 0.37 D/S of West 5th Avenue for the 1961 Storm Scaled to a 2.0% ACE



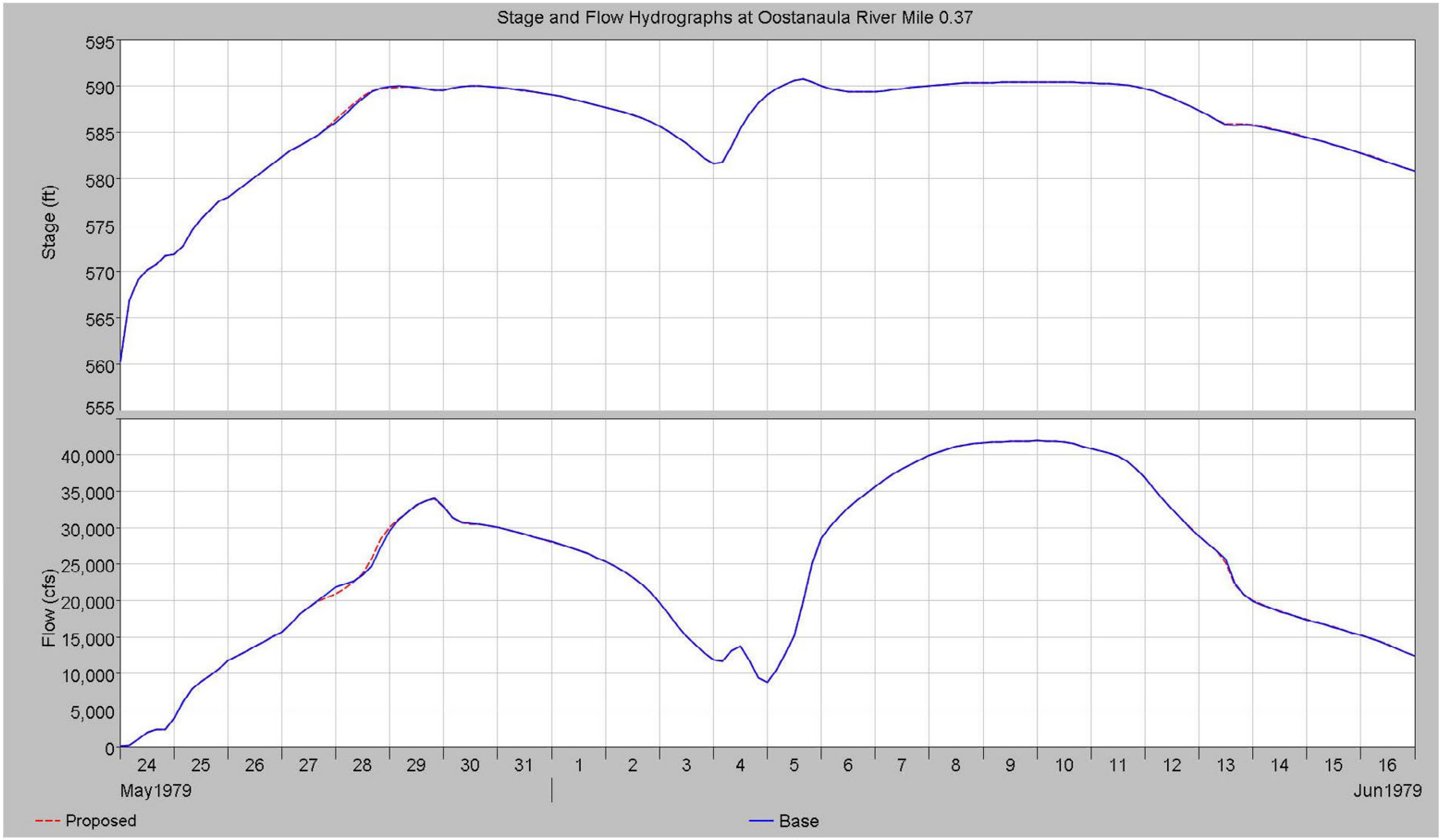
Stage/Flow at Oostanaula River Mile 0.37 D/S of West 5th Avenue for the 1961 Storm Scaled to a 5.0% ACE



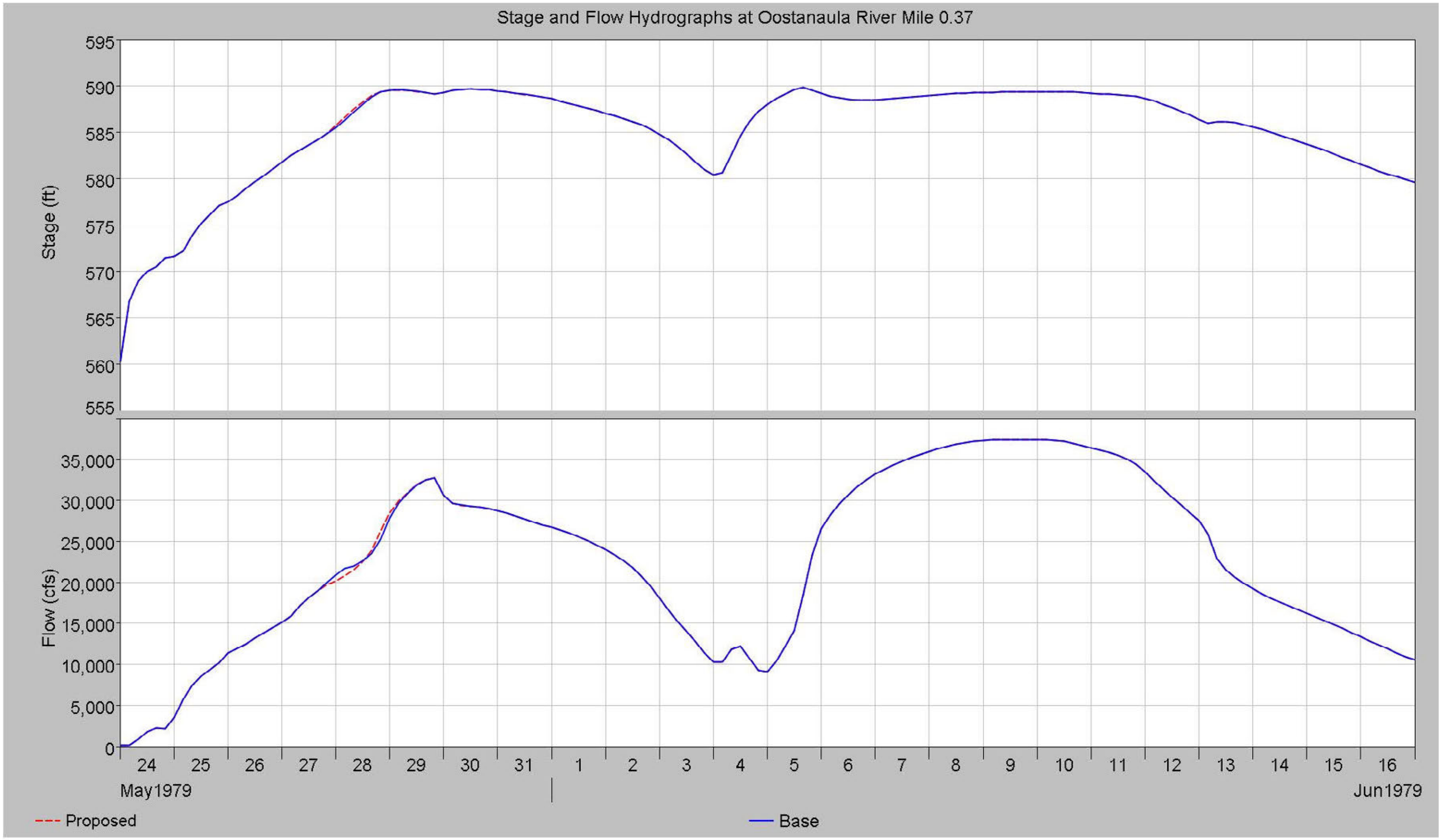
Stage/Flow at Oostanaula River Mile 0.37 D/S of West 5th Avenue for the 1979 Storm Scaled to a 0.2% ACE



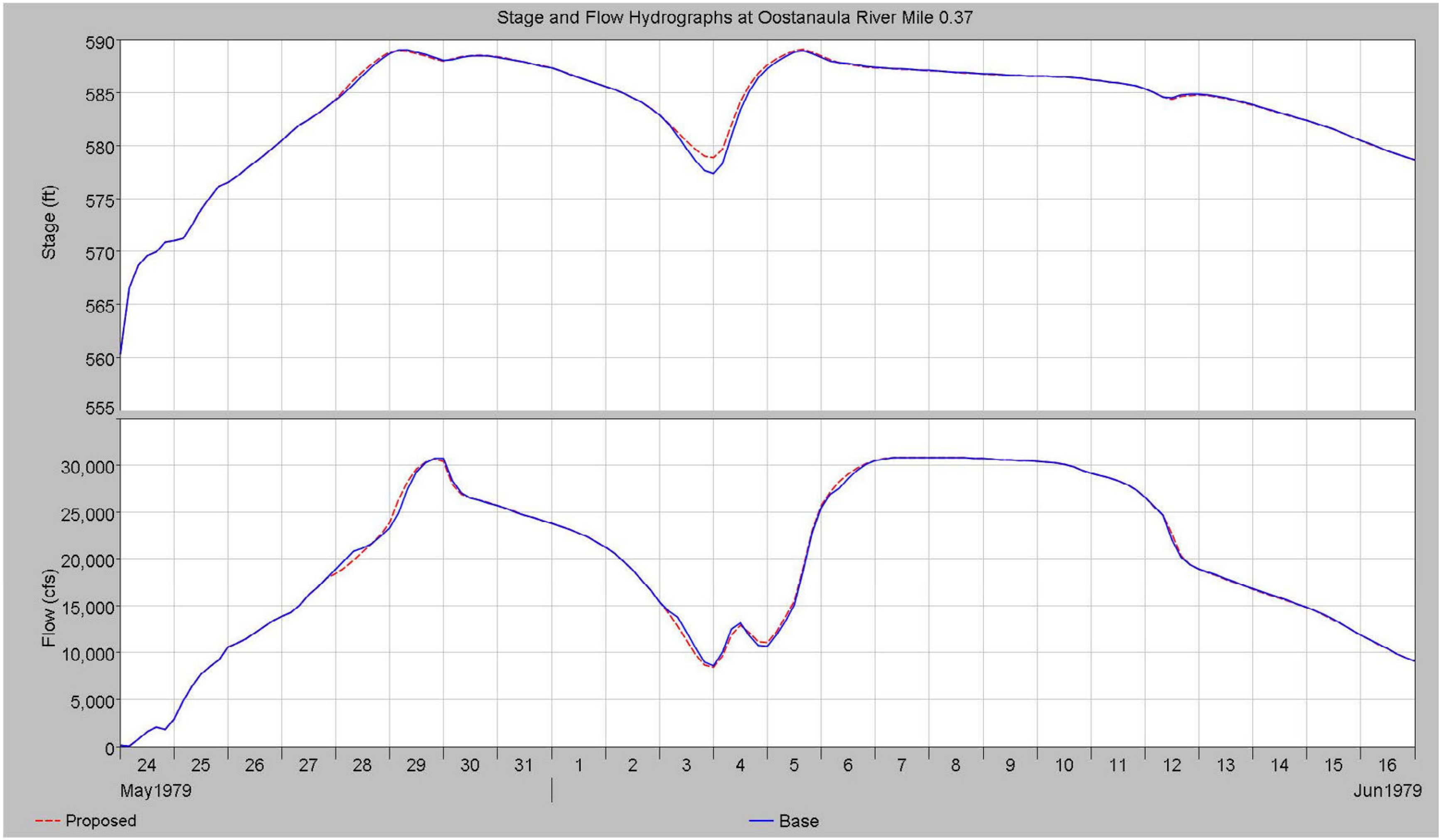
Stage/Flow at Oostanaula River Mile 0.37 D/S of West 5th Avenue for the 1979 Storm Scaled to a 0.5% ACE



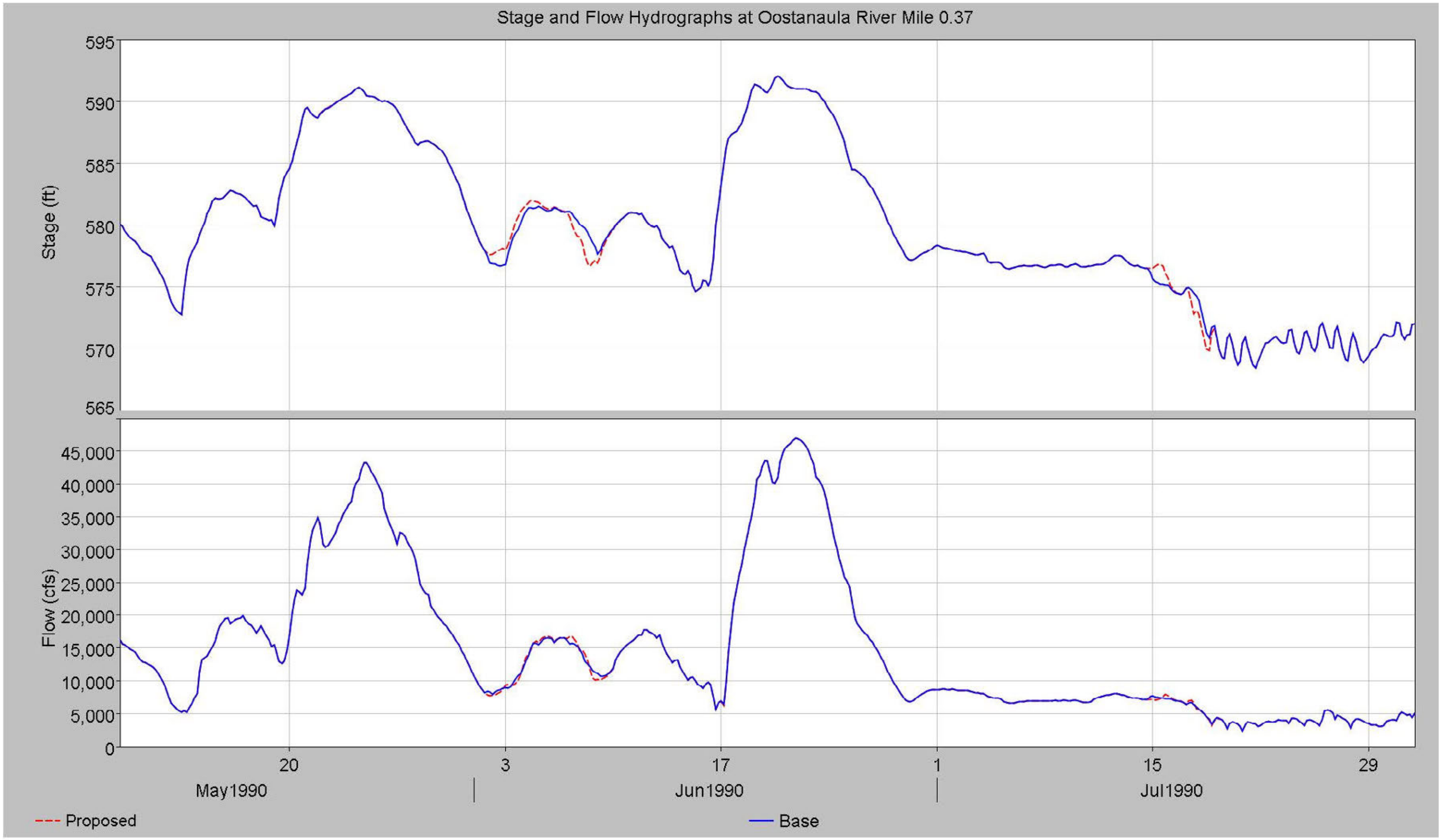
Stage/Flow at Oostanaula River Mile 0.37 D/S of West 5th Avenue for the 1979 Storm Scaled to a 1.0% ACE



Stage/Flow at Oostanaula River Mile 0.37 D/S of West 5th Avenue for the 1979 Storm Scaled to a 2.0% ACE



Stage/Flow at Oostanaula River Mile 0.37 D/S of West 5th Avenue for the 1979 Storm Scaled to a 5.0% ACE



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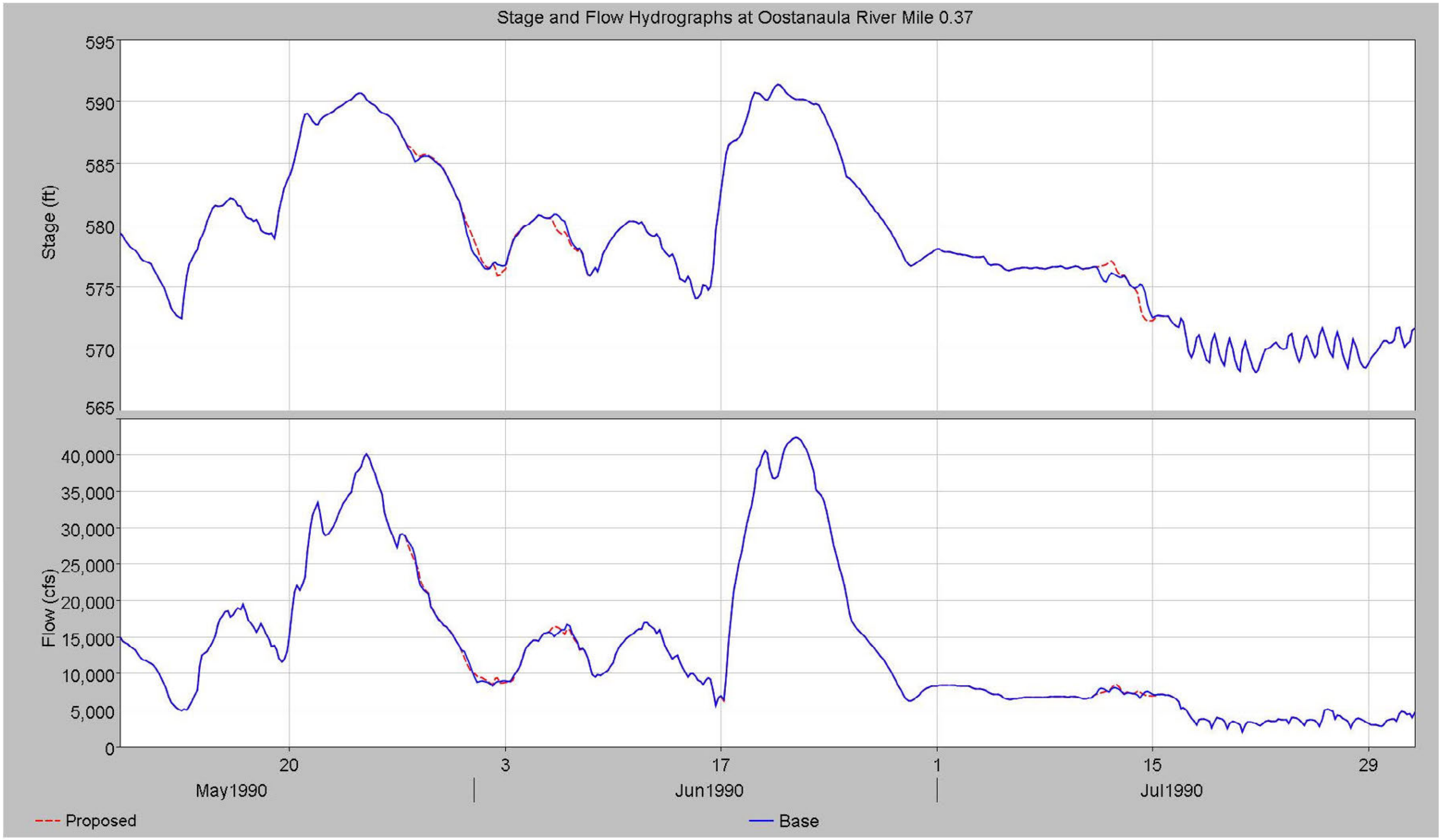
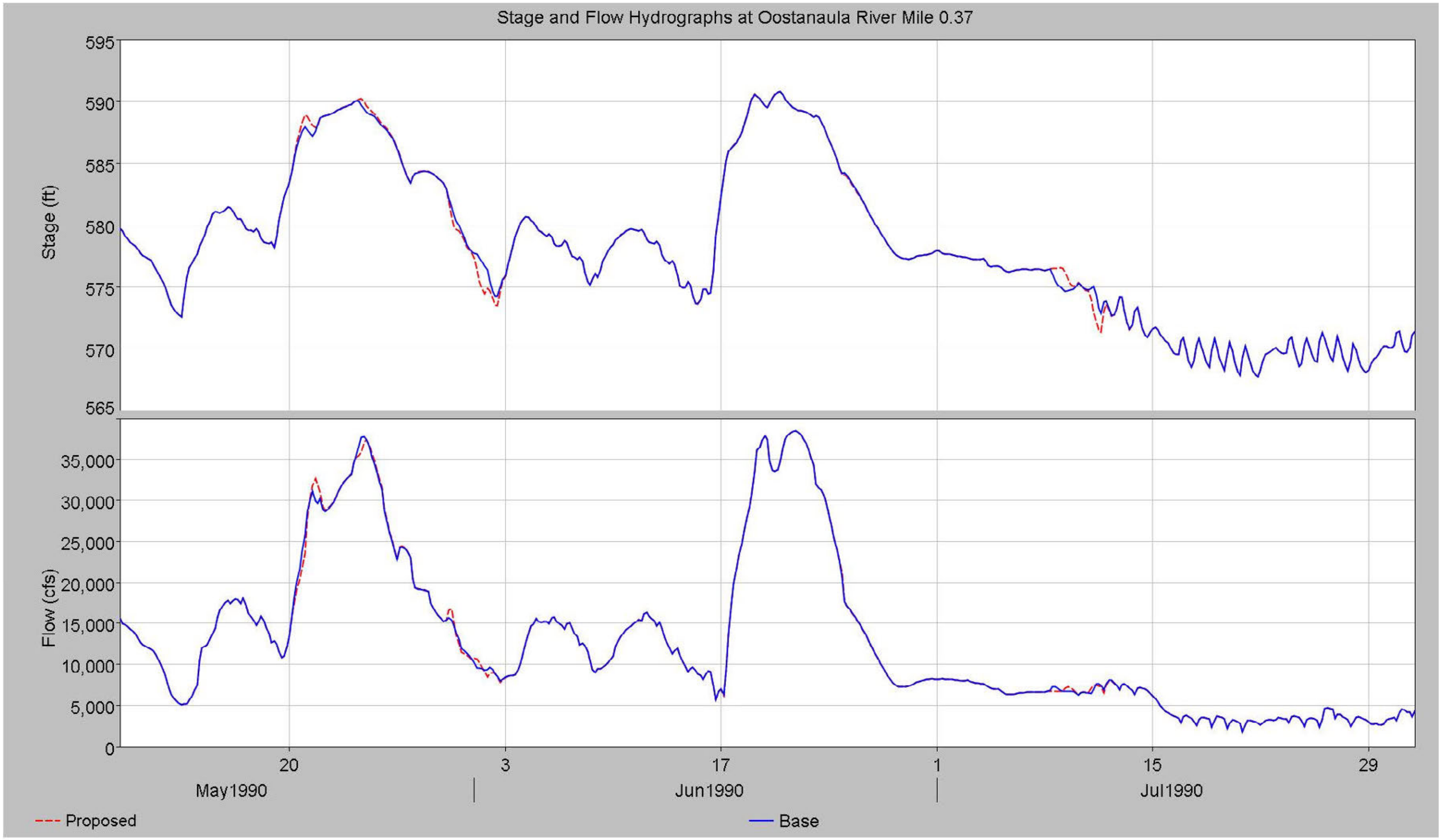
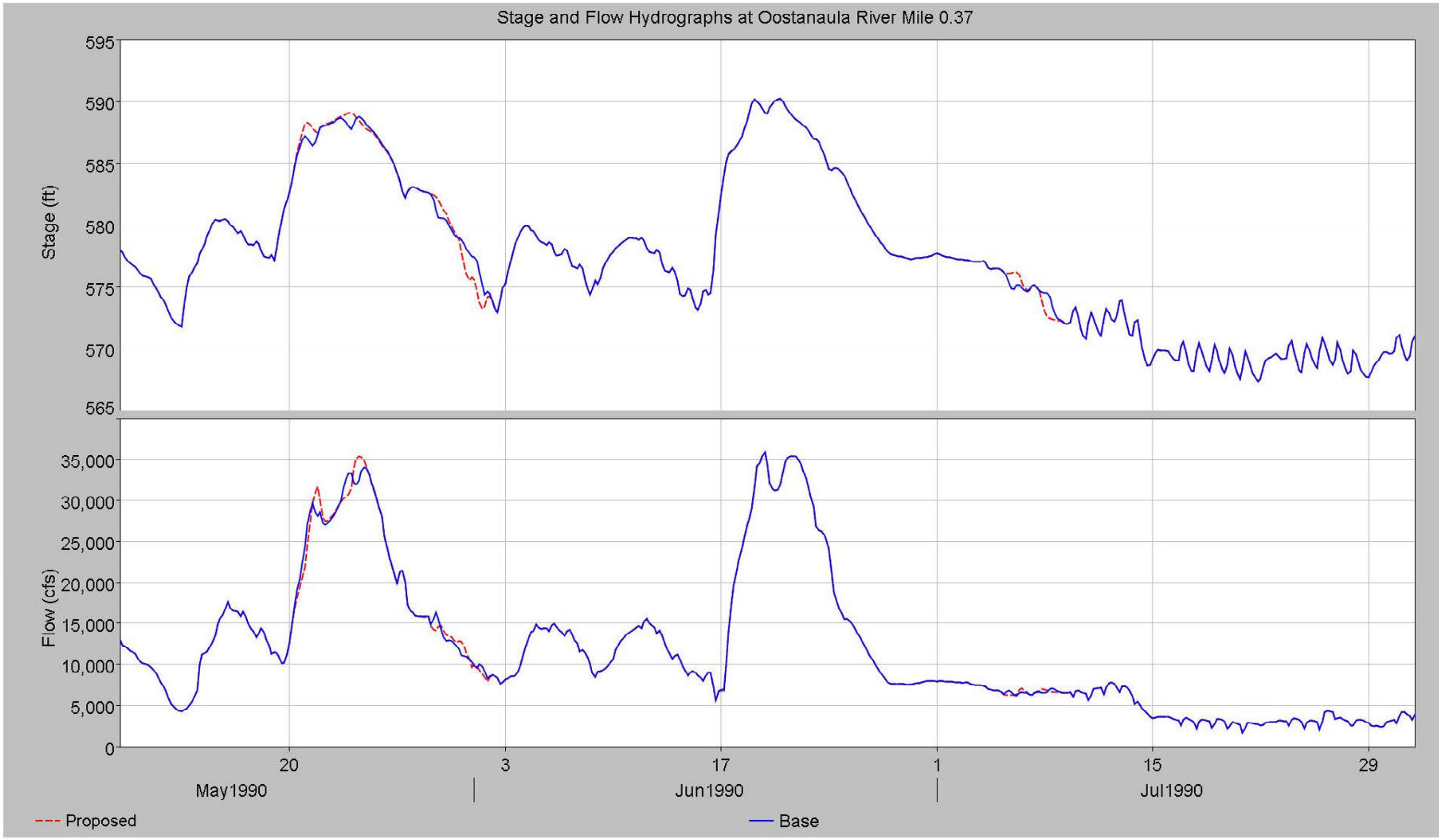


Stage/Flow at Oostanaula River Mile 0.37 D/S of West 5th Avenue for the 1990 Storm Scaled to a 0.5% ACE



Stage/Flow at Oostanaula River Mile 0.37 D/S of West 5th Avenue for the 1990 Storm Scaled to a 1.0% ACE



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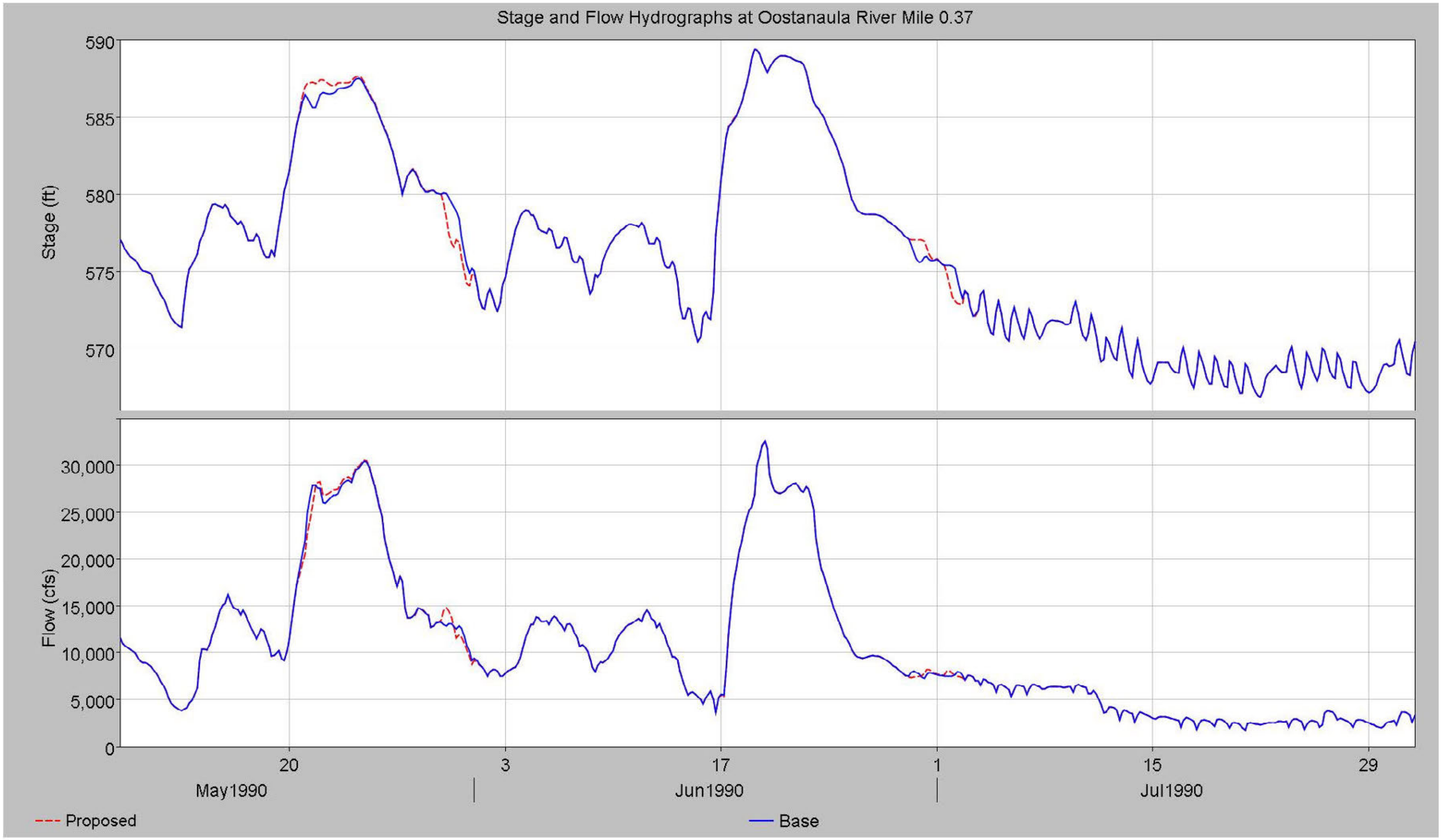

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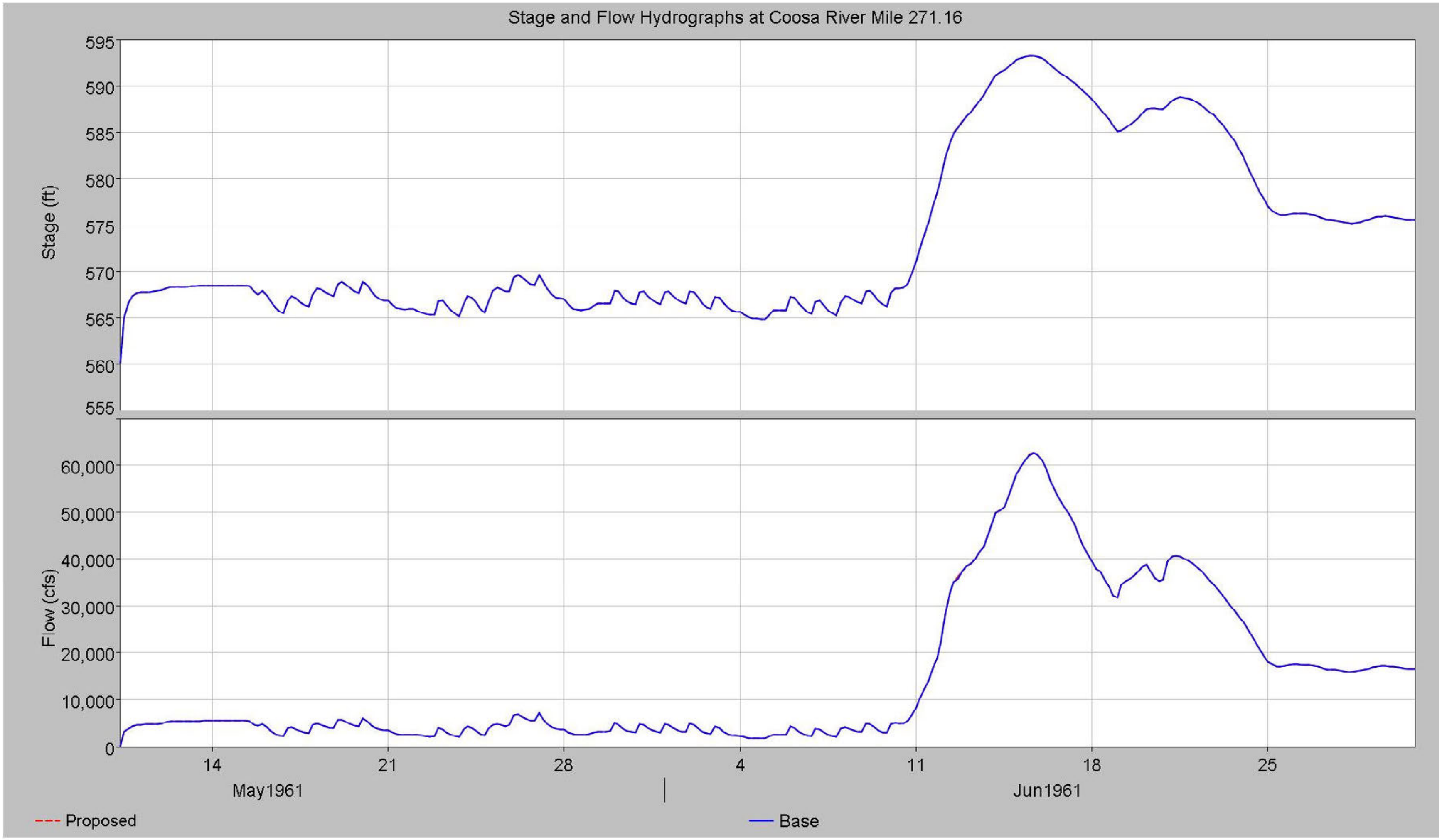
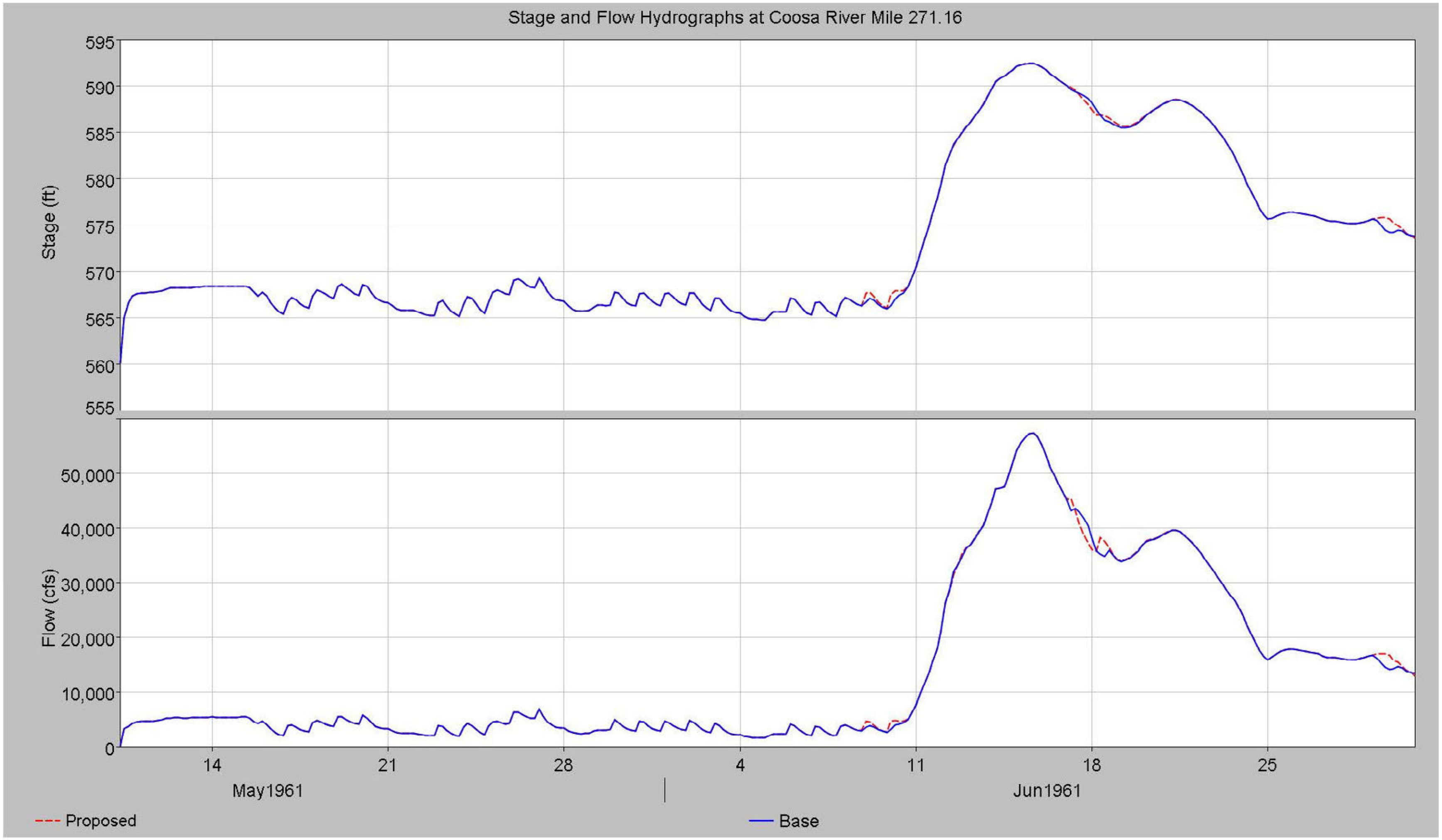
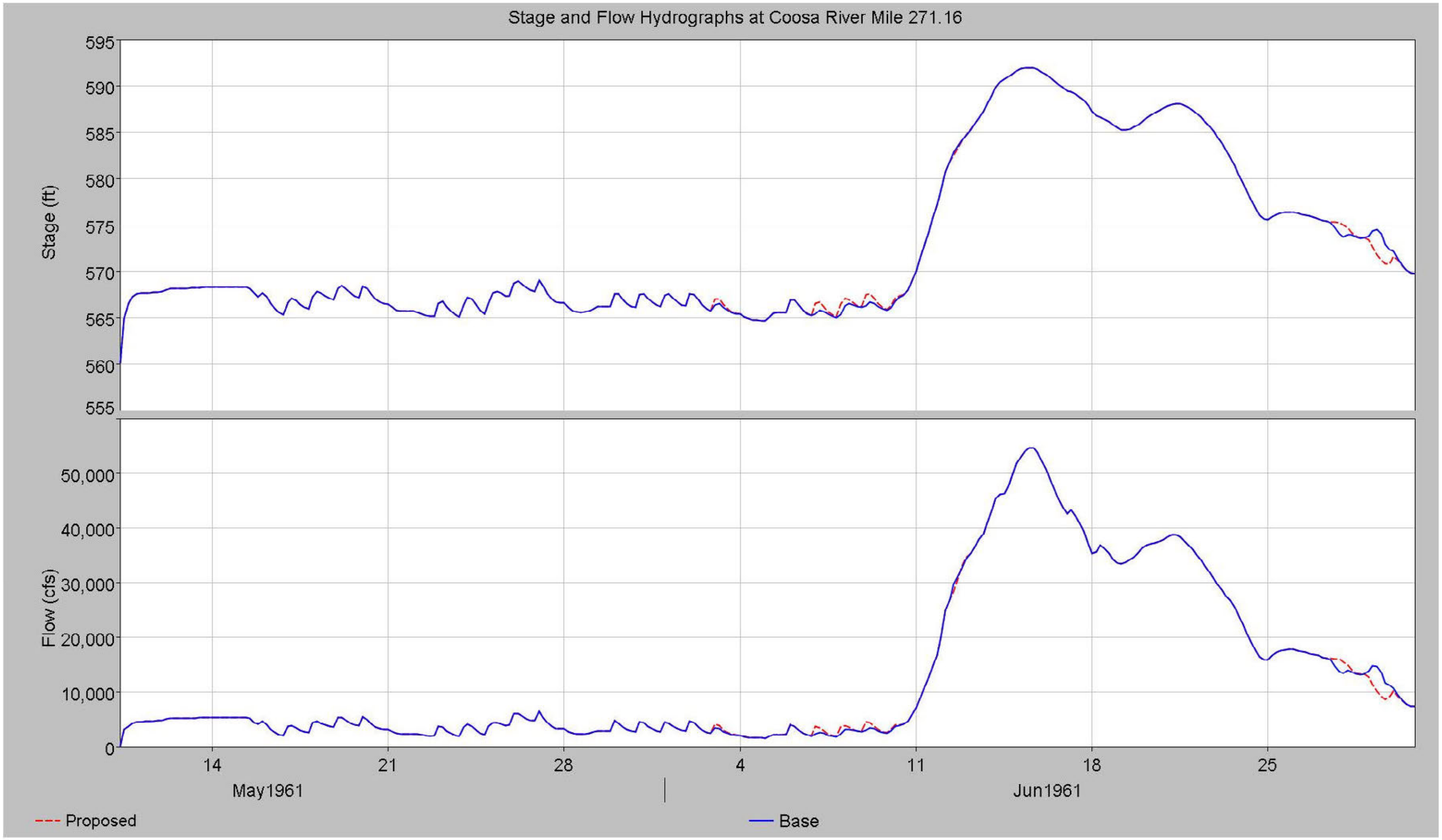


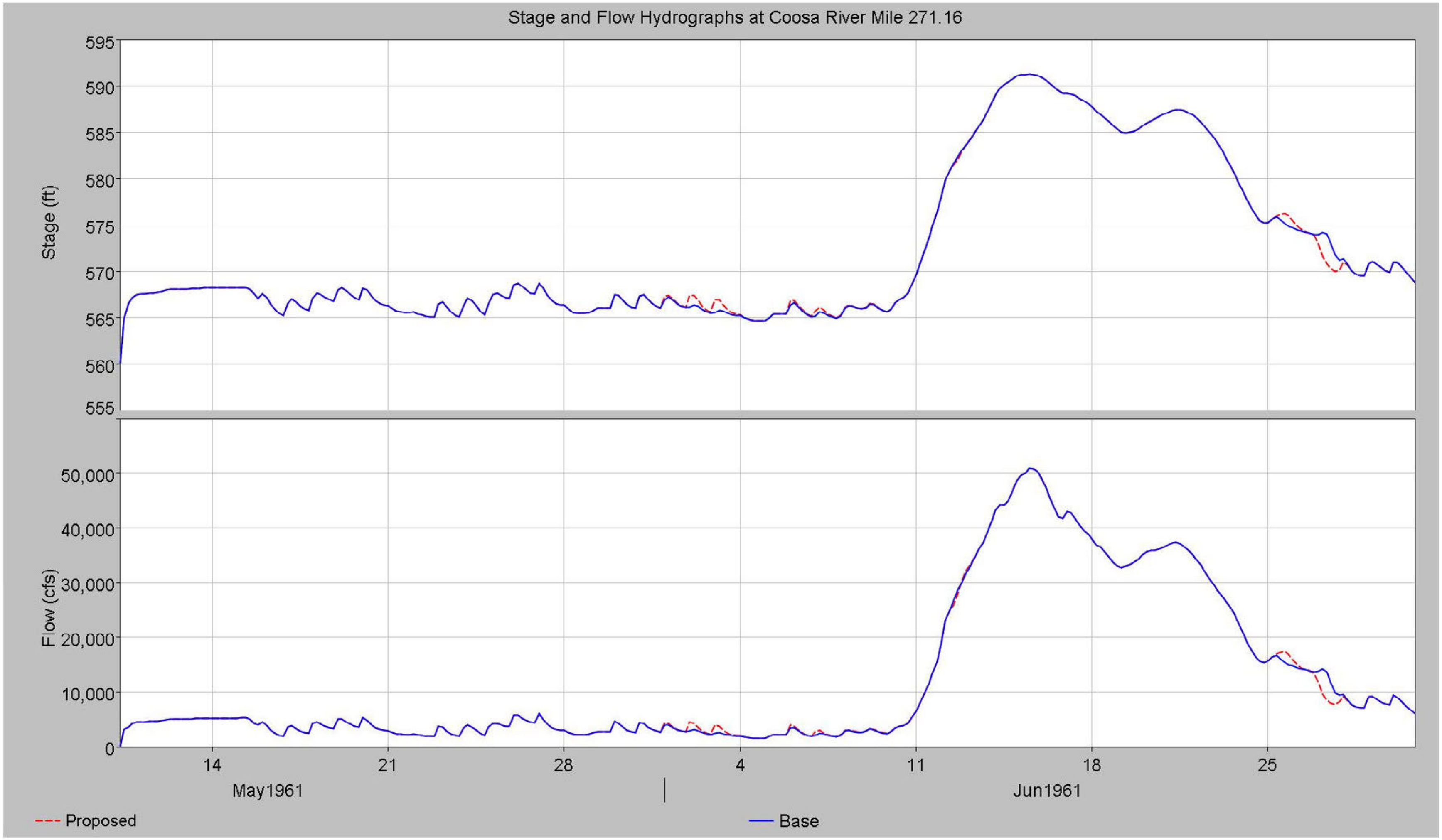
Stage/Flow at Coosa River Mile 271.16 D/S of Confluence for the 1961 Storm Scaled to a 0.2% ACE



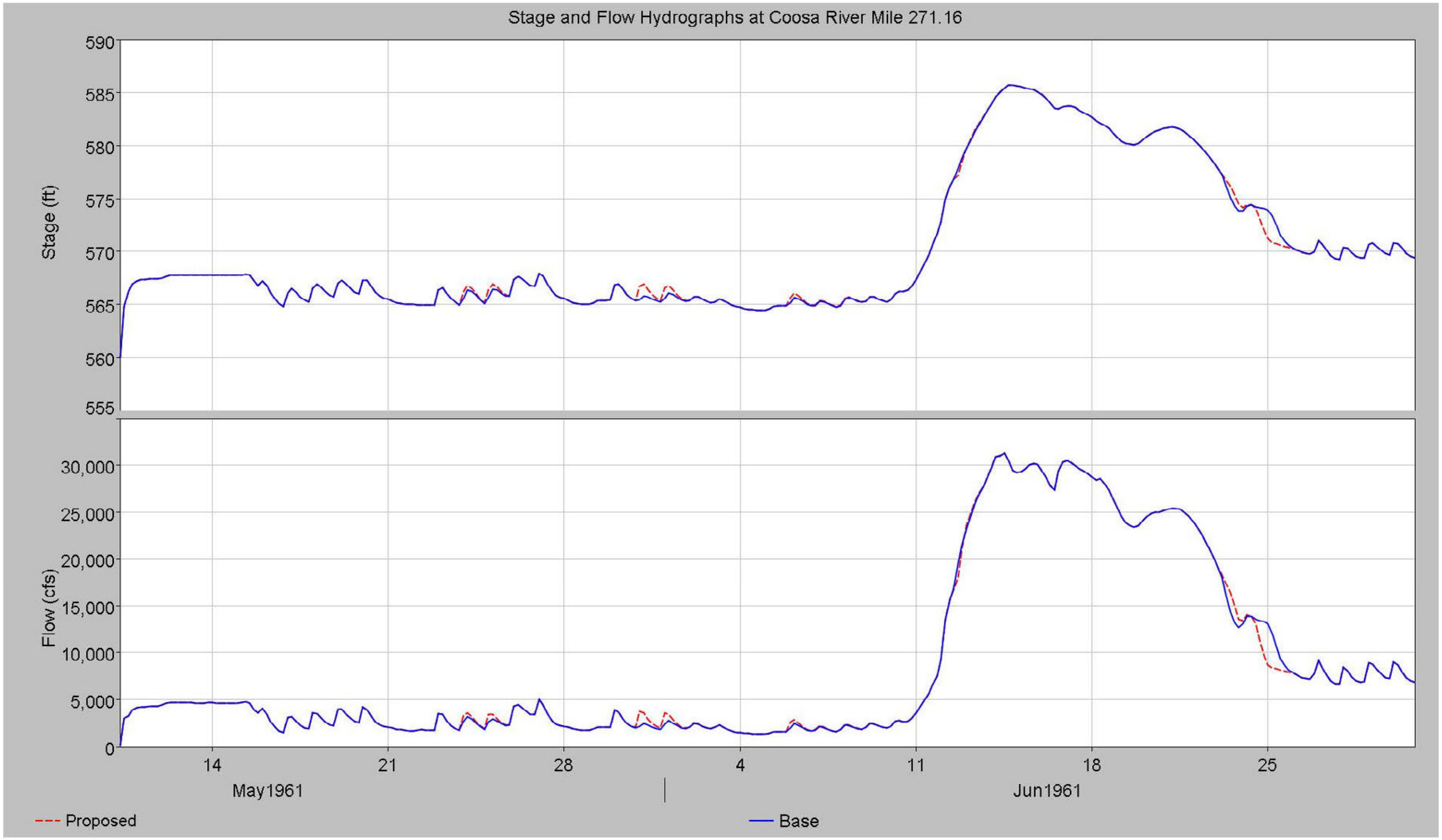
Stage/Flow at Coosa River Mile 271.16 D/S of Confluence for the 1961 Storm Scaled to a 0.5% ACE



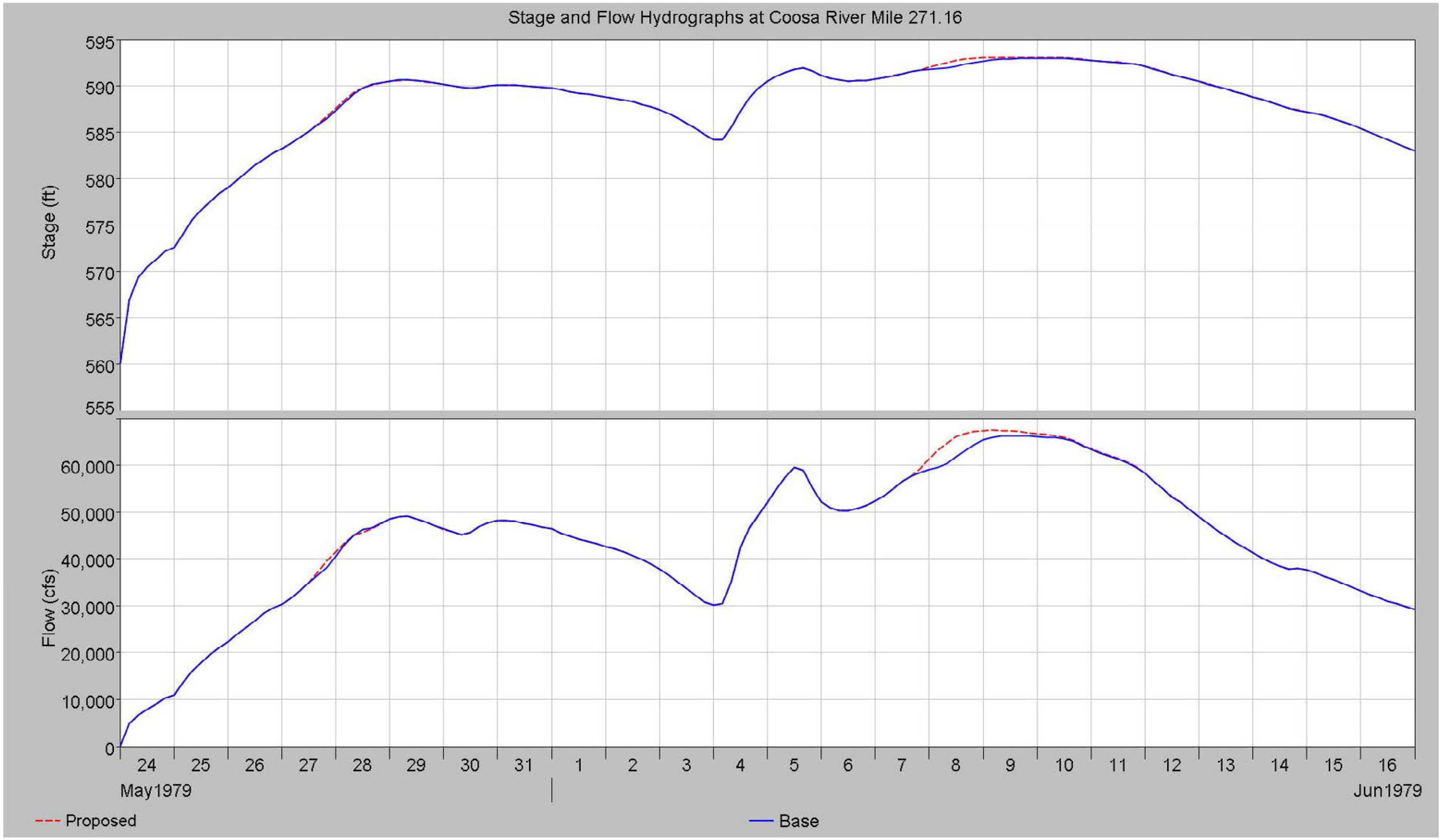
Stage/Flow at Coosa River Mile 271.16 D/S of Confluence for the 1961 Storm Scaled to a 1.0% ACE



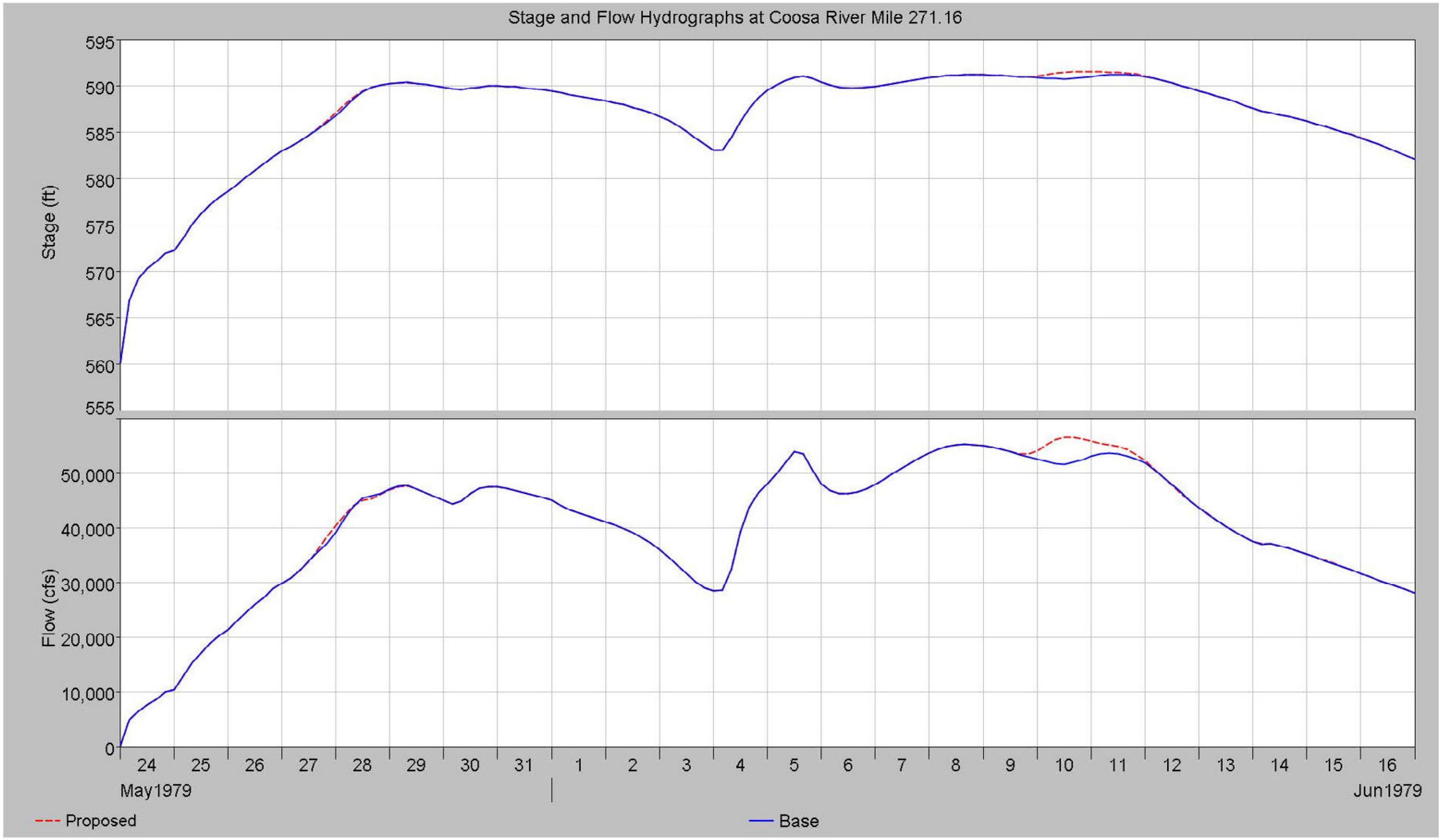
Stage/Flow at Coosa River Mile 271.16 D/S of Confluence for the 1961 Storm Scaled to a 2.0% ACE



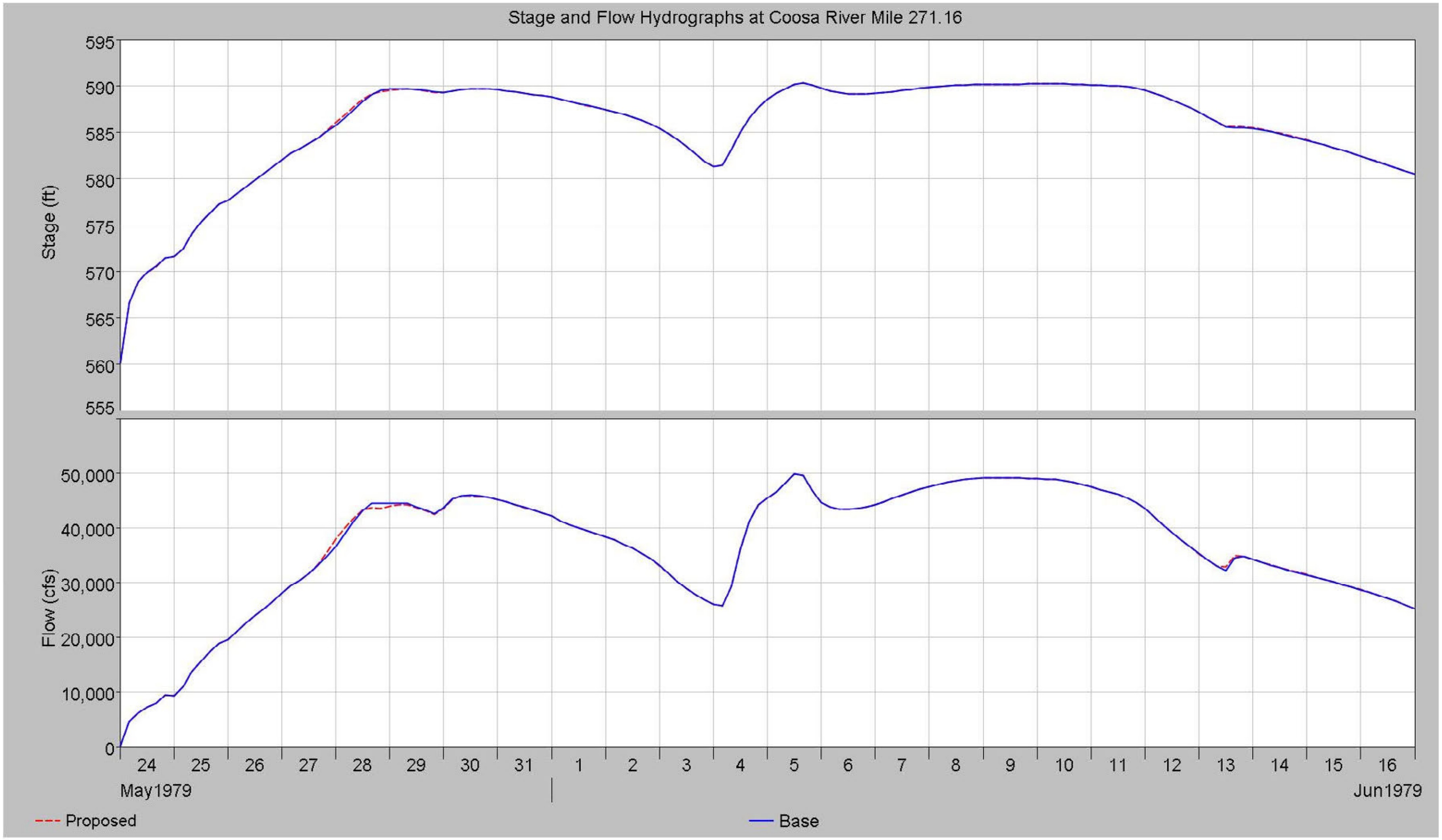
Stage/Flow at Coosa River Mile 271.16 D/S of Confluence for the 1961 Storm Scaled to a 5.0% ACE



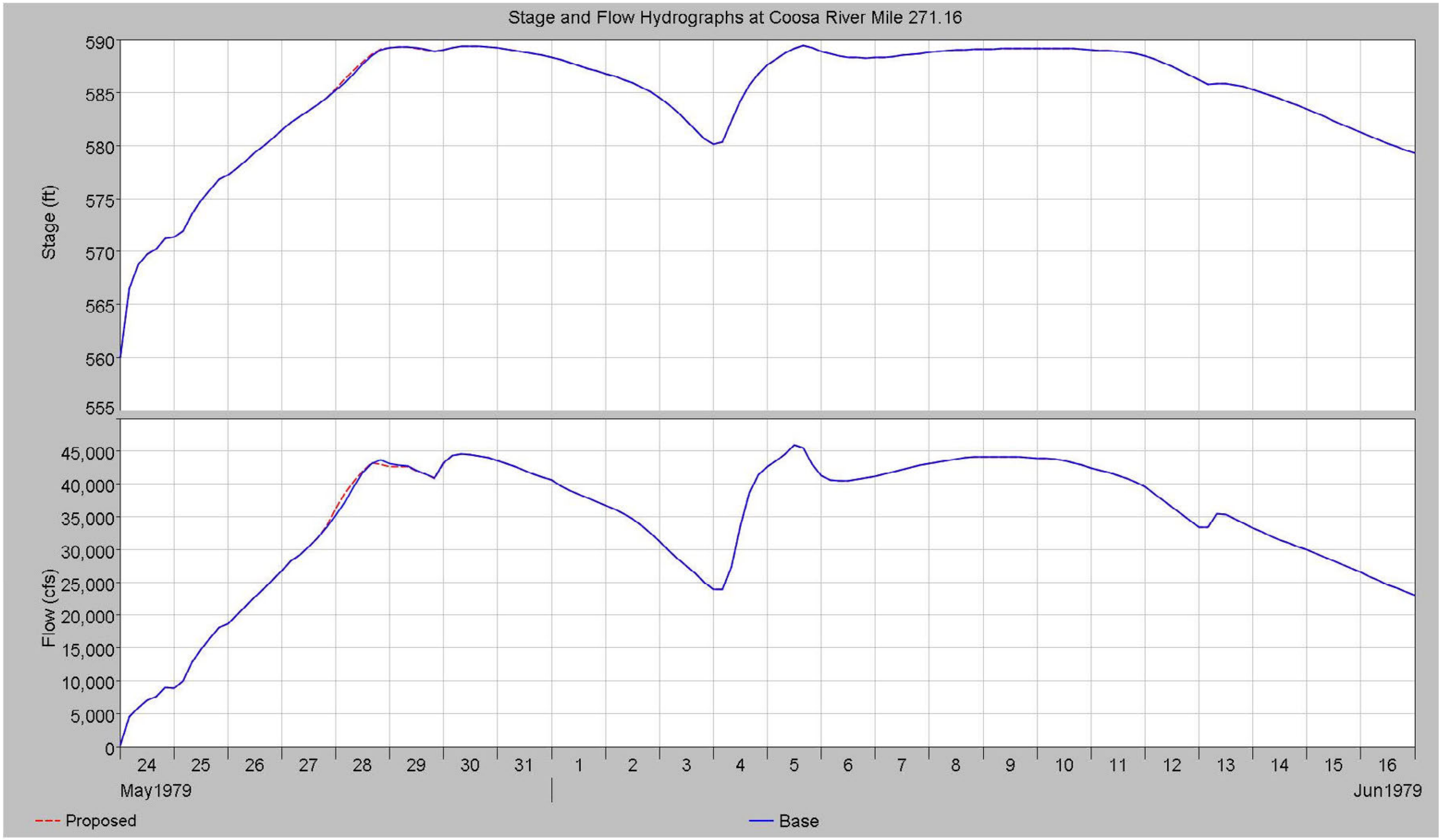
Stage/Flow at Coosa River Mile 271.16 D/S of Confluence for the 1979 Storm Scaled to a 0.2% ACE



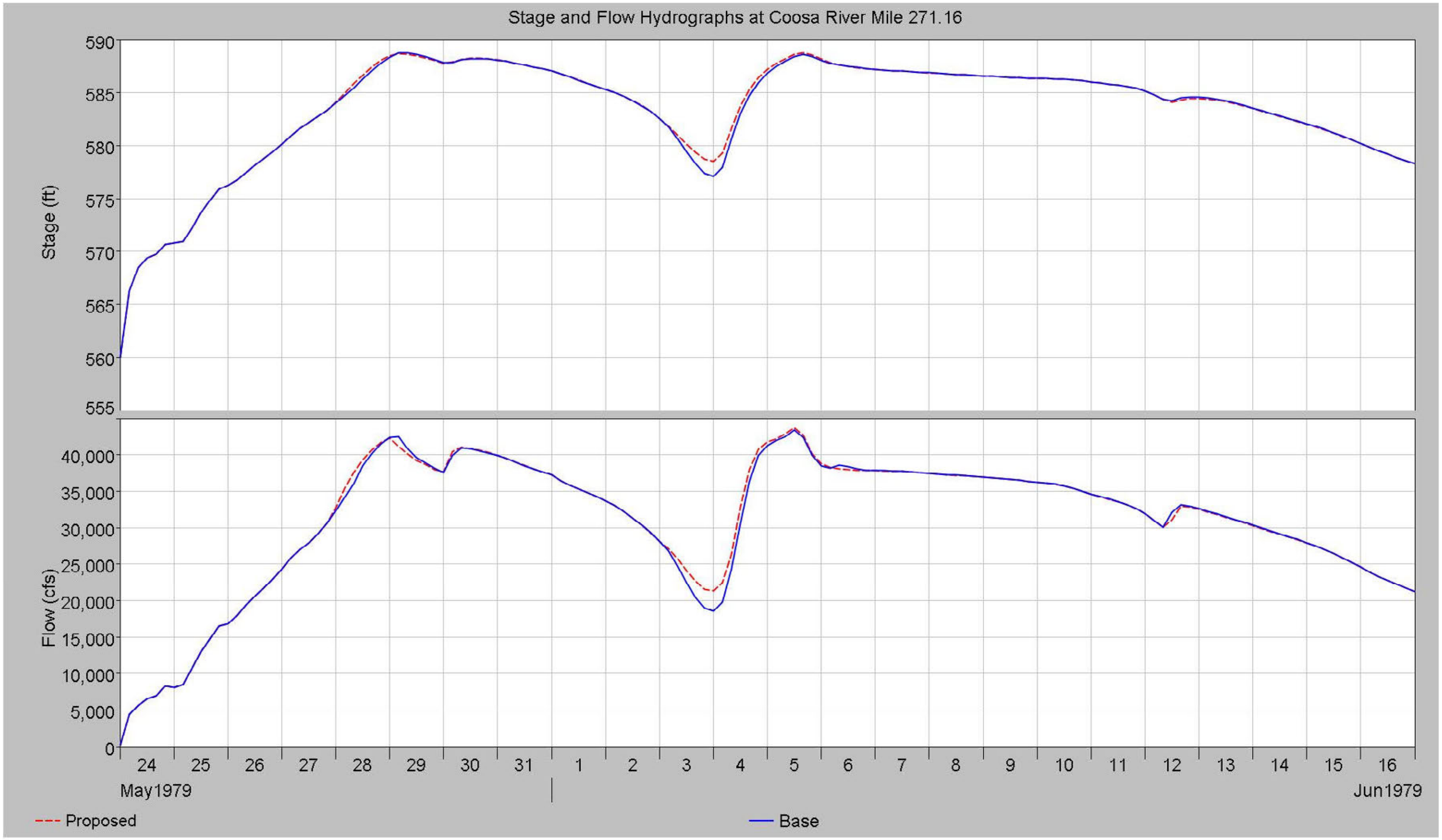
Stage/Flow at Coosa River Mile 271.16 D/S of Confluence for the 1979 Storm Scaled to a 0.5% ACE



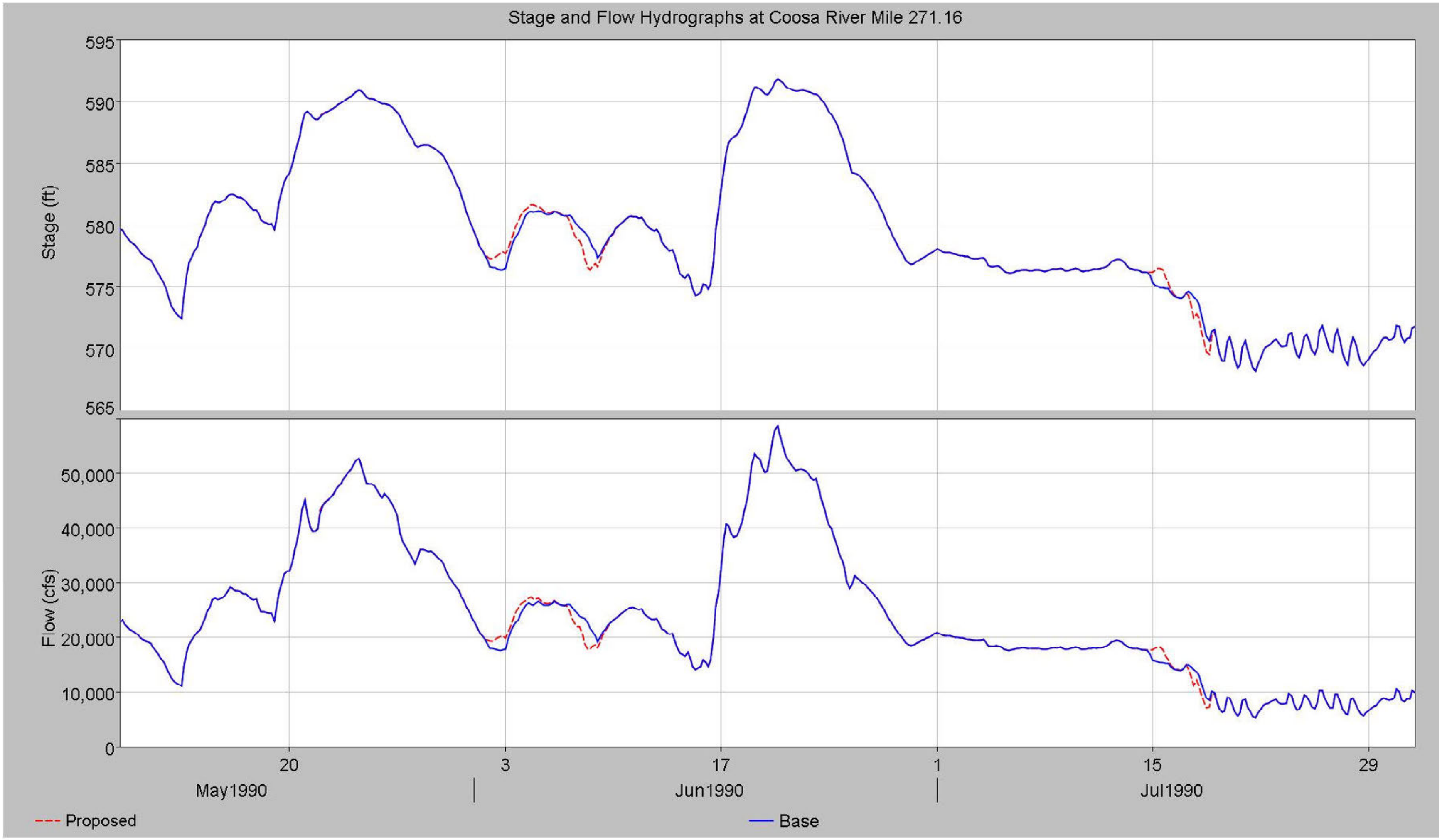
Stage/Flow at Coosa River Mile 271.16 D/S of Confluence for the 1979 Storm Scaled to a 1.0% ACE



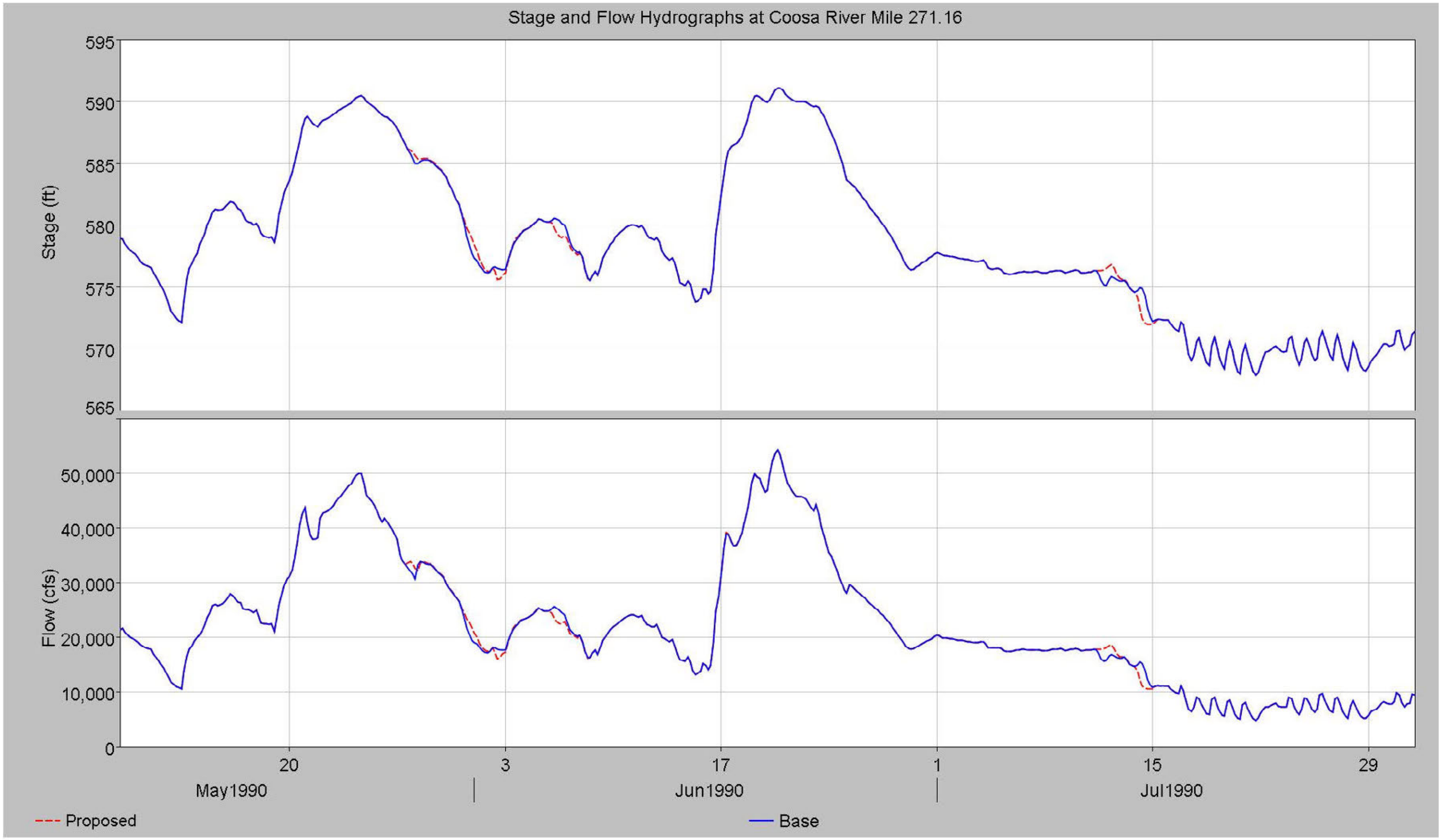
Stage/Flow at Coosa River Mile 271.16 D/S of Confluence for the 1979 Storm Scaled to a 2.0% ACE



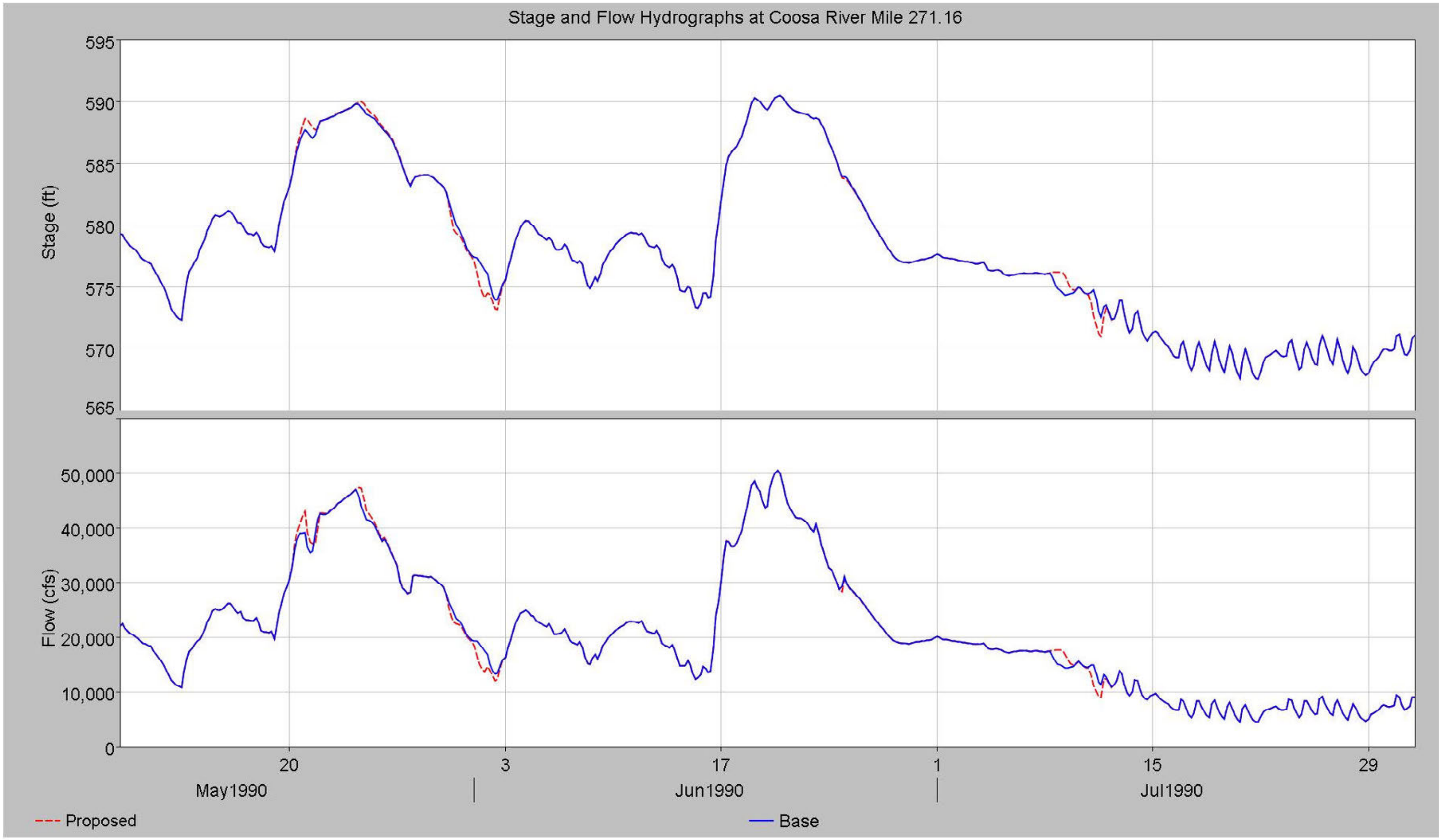
Stage/Flow at Coosa River Mile 271.16 D/S of Confluence for the 1979 Storm Scaled to a 5.0% ACE



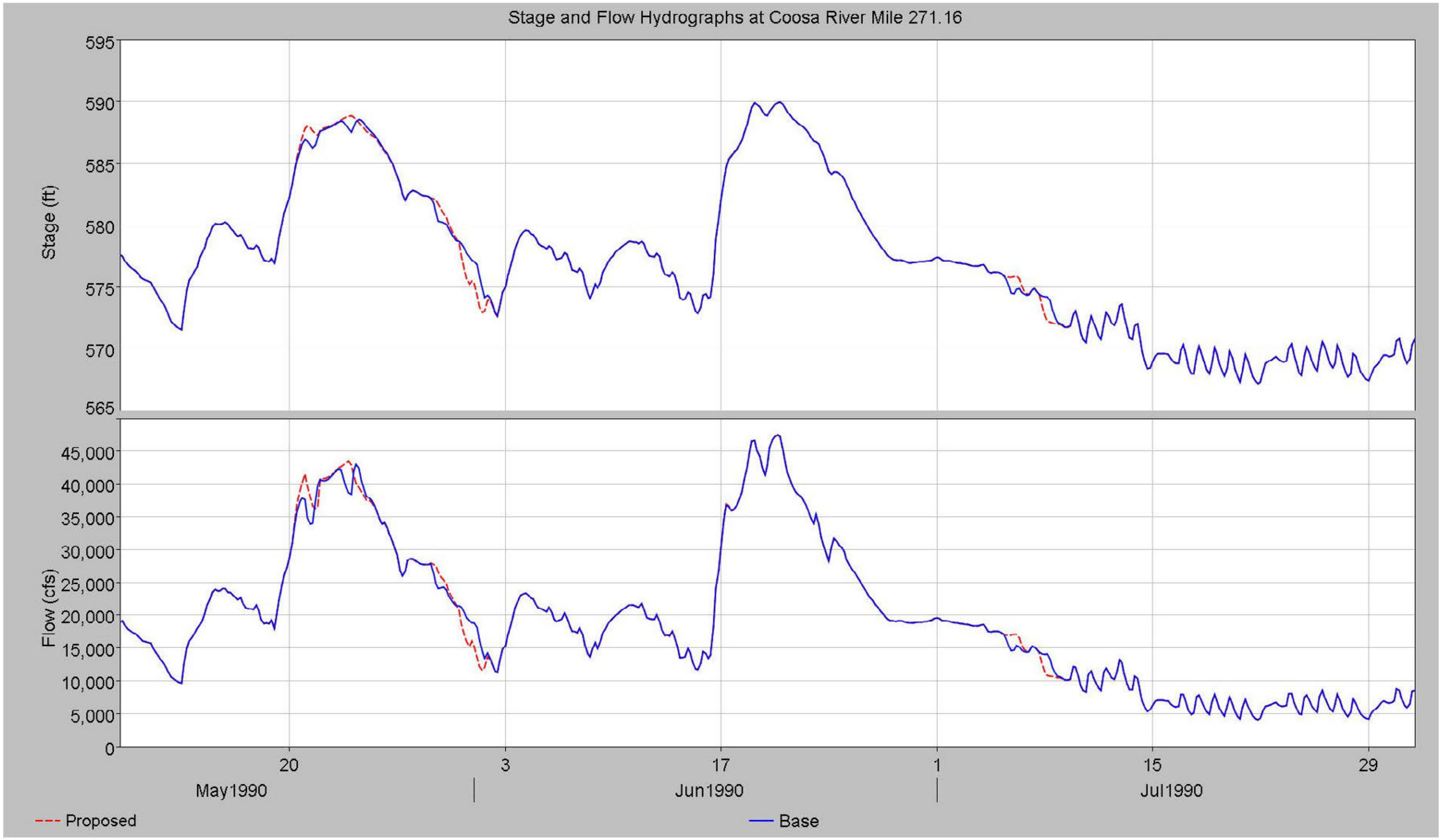
Stage/Flow at Coosa River Mile 271.16 D/S of Confluence for the 1990 Storm Scaled to a 0.2% ACE



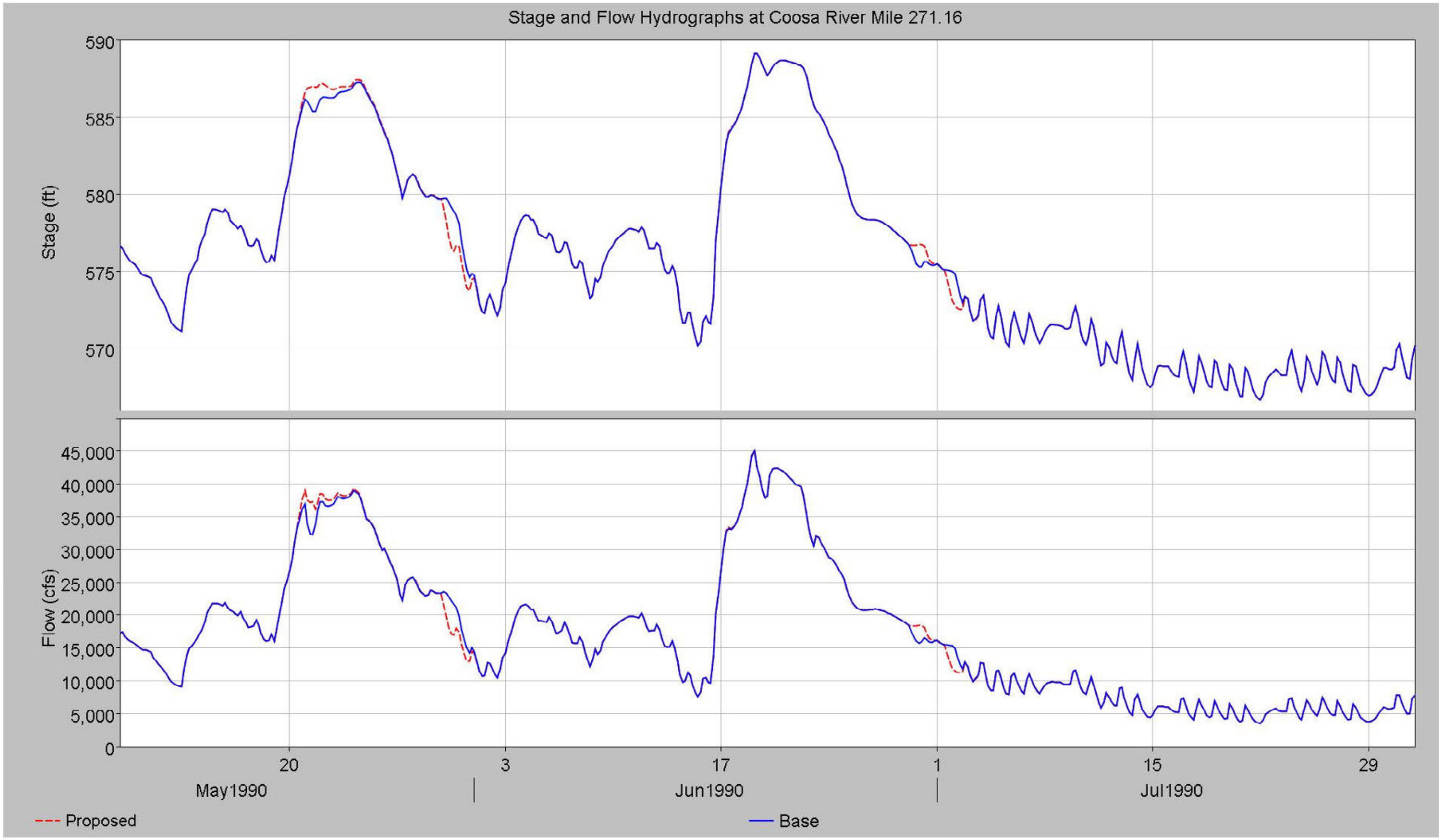
Stage/Flow at Coosa River Mile 271.16 D/S of Confluence for the 1990 Storm Scaled to a 0.5% ACE



Stage/Flow at Coosa River Mile 271.16 D/S of Confluence for the 1990 Storm Scaled to a 1.0% ACE

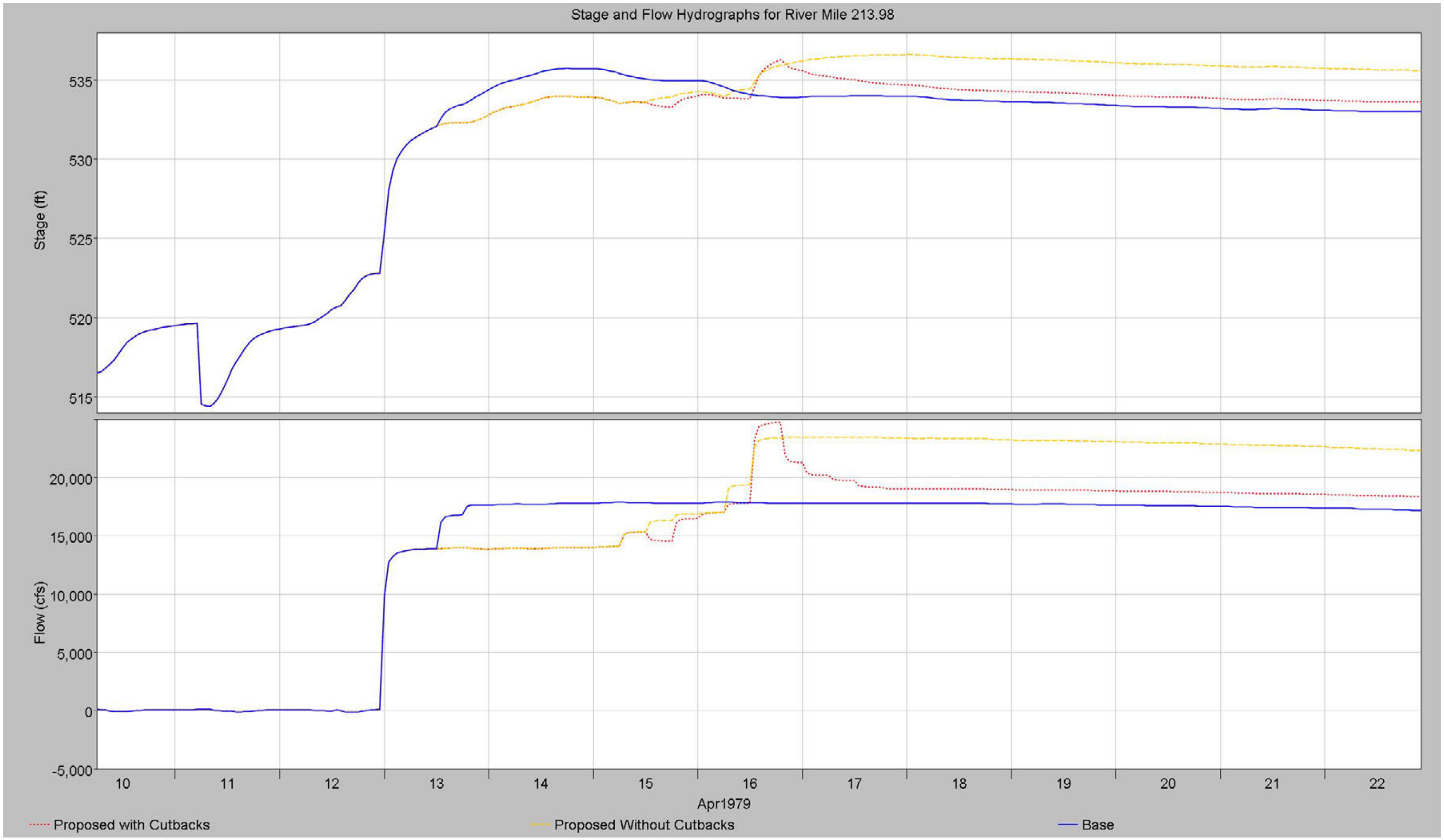


Stage/Flow at Coosa River Mile 271.16 D/S of Confluence for the 1990 Storm Scaled to a 2.0% ACE

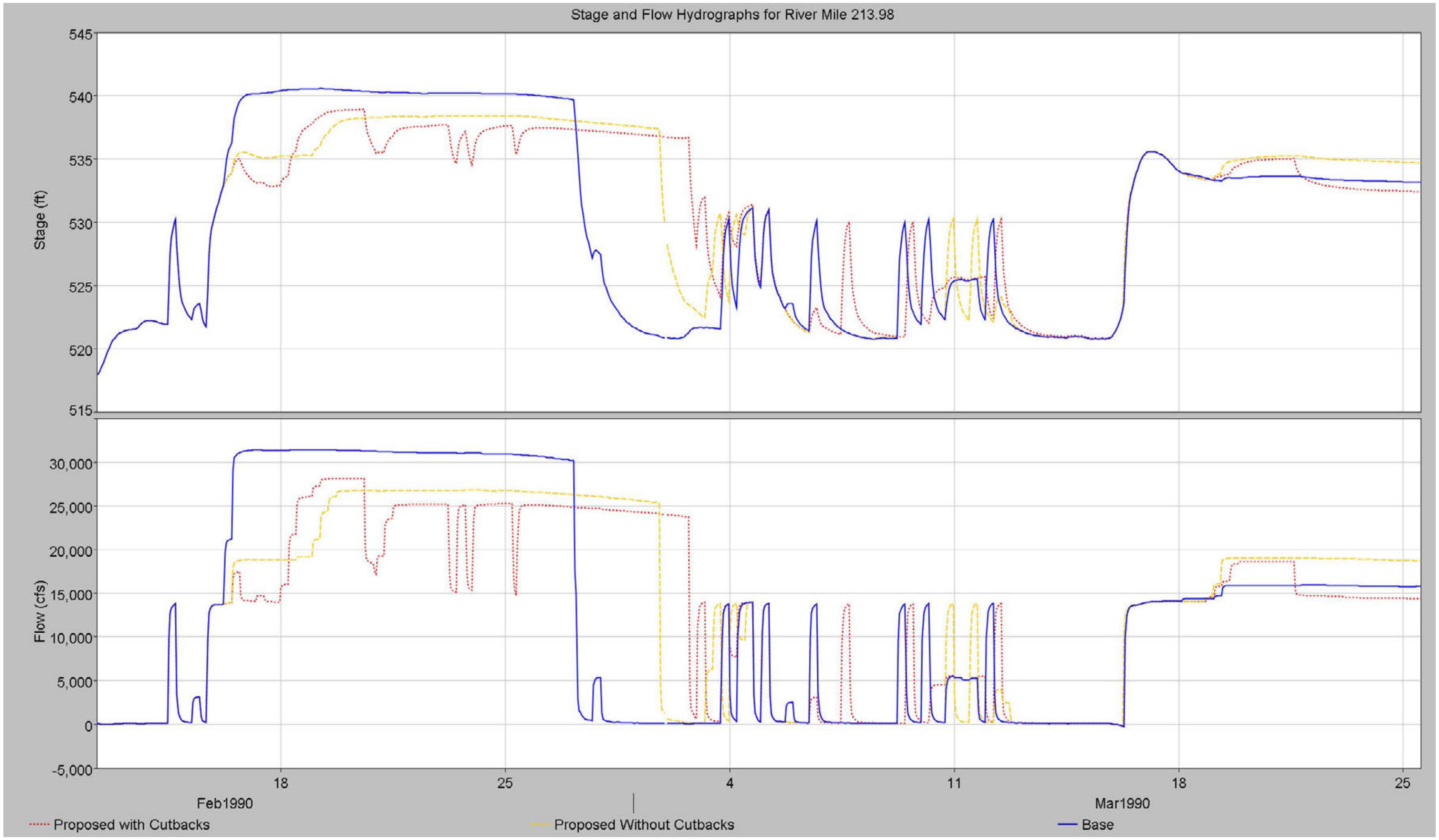


Stage/Flow at Coosa River Mile 271.16 D/S of Confluence for the 1990 Storm Scaled to a 5.0% ACE

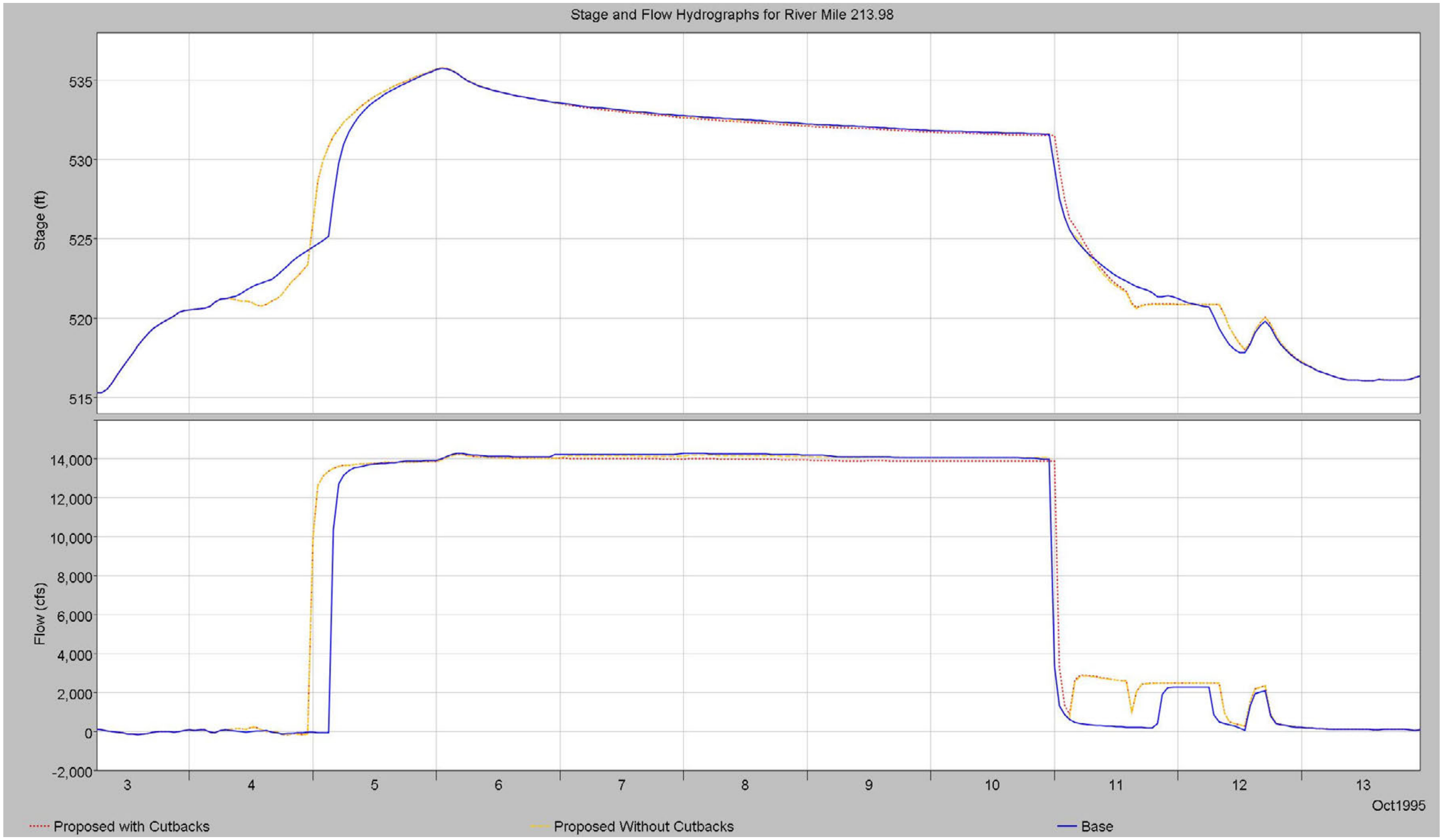
APC Analysis Results



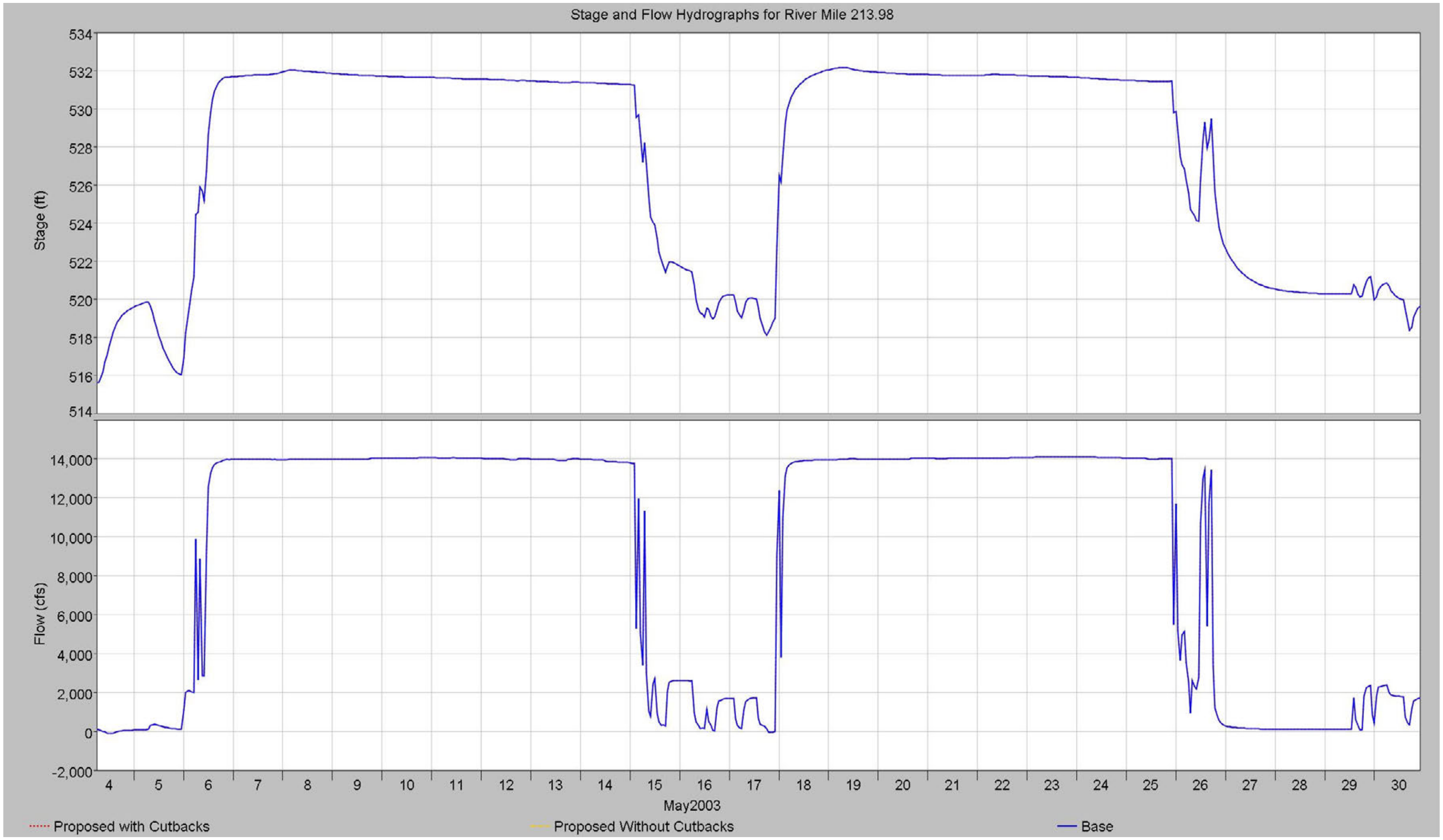
Stage/Flow at Coosa River Mile 213.98 Downstream of the Weiss Spillway for the April 1979 Storm



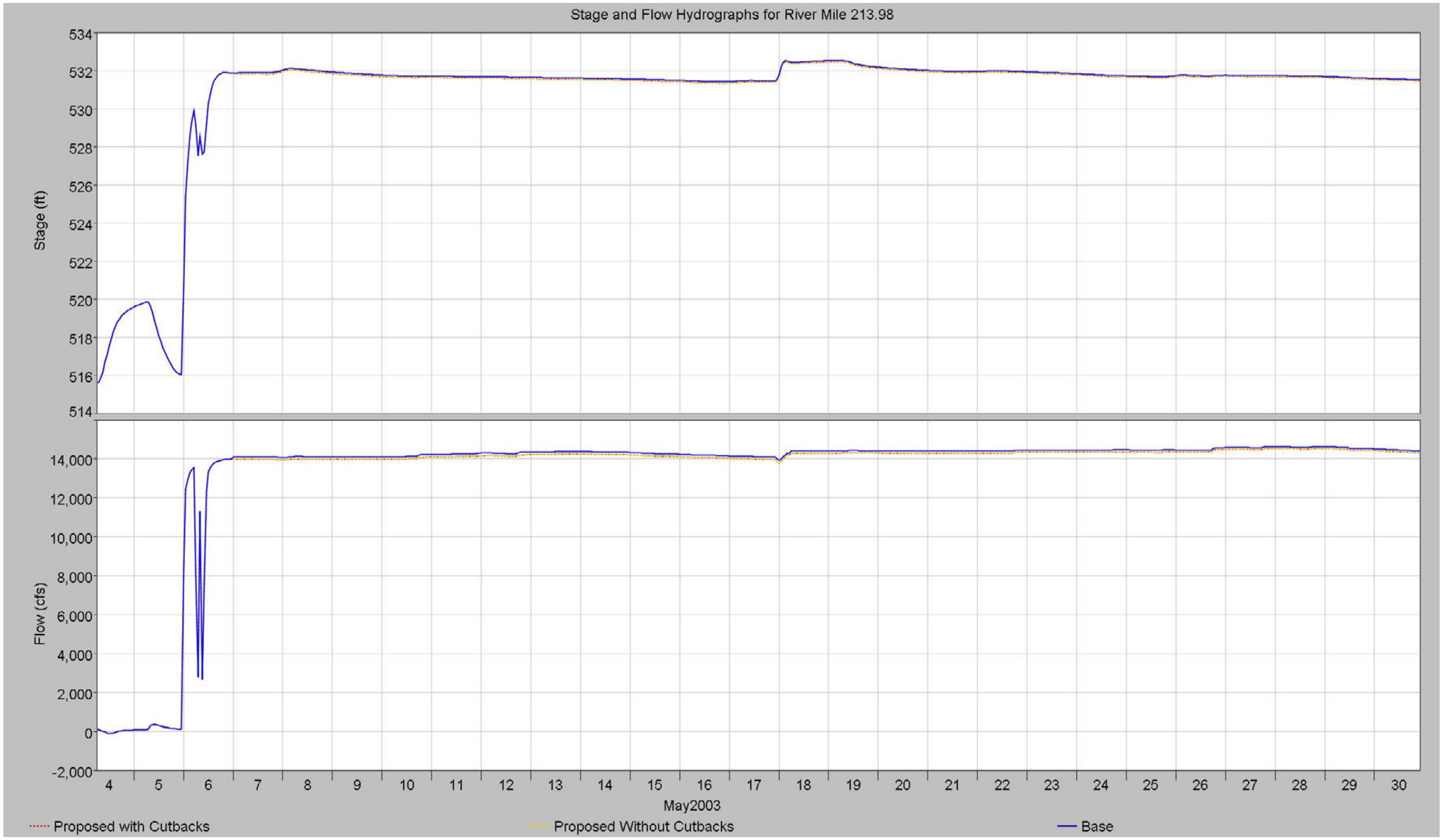
Stage/Flow at Coosa River Mile 213.98 Downstream of the Weiss Spillway for the February 1990 Storm.



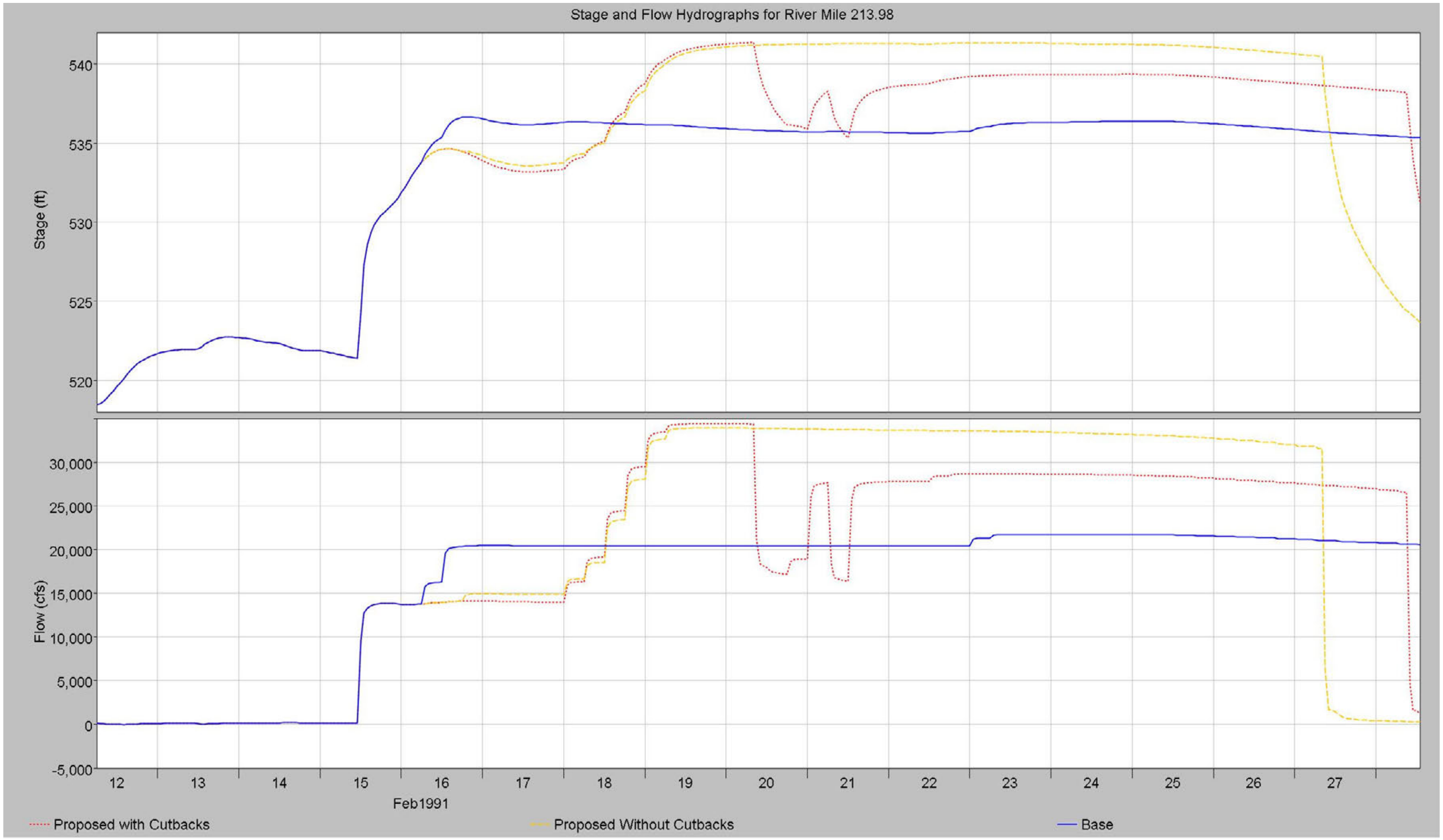
Stage/Flow at Coosa River Mile 213.98 Downstream of the Weiss Spillway for the October 1995 Storm.



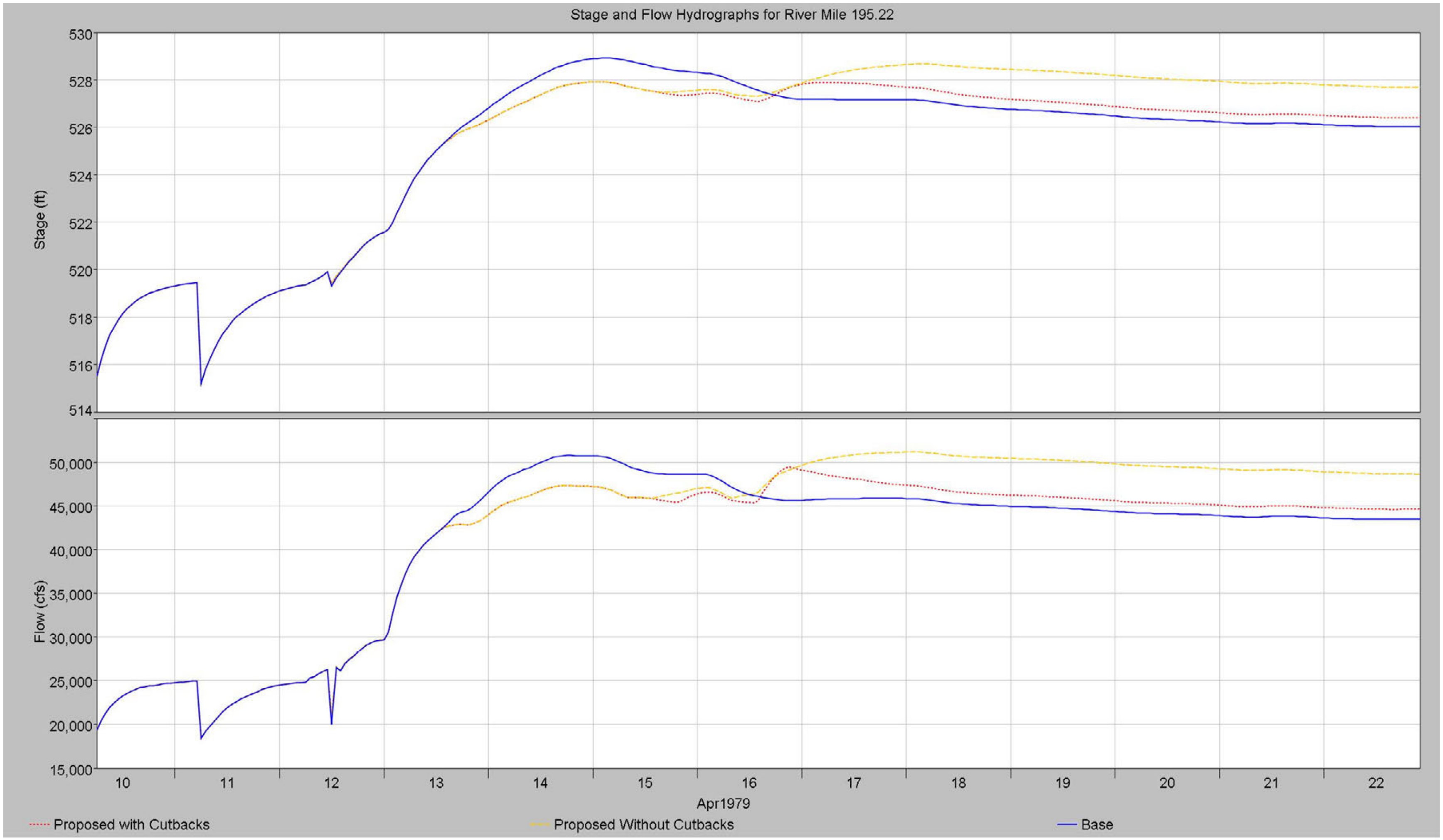
Stage/Flow at Coosa River Mile 213.98 Downstream of the Weiss Spillway for the May 2003 Storm.



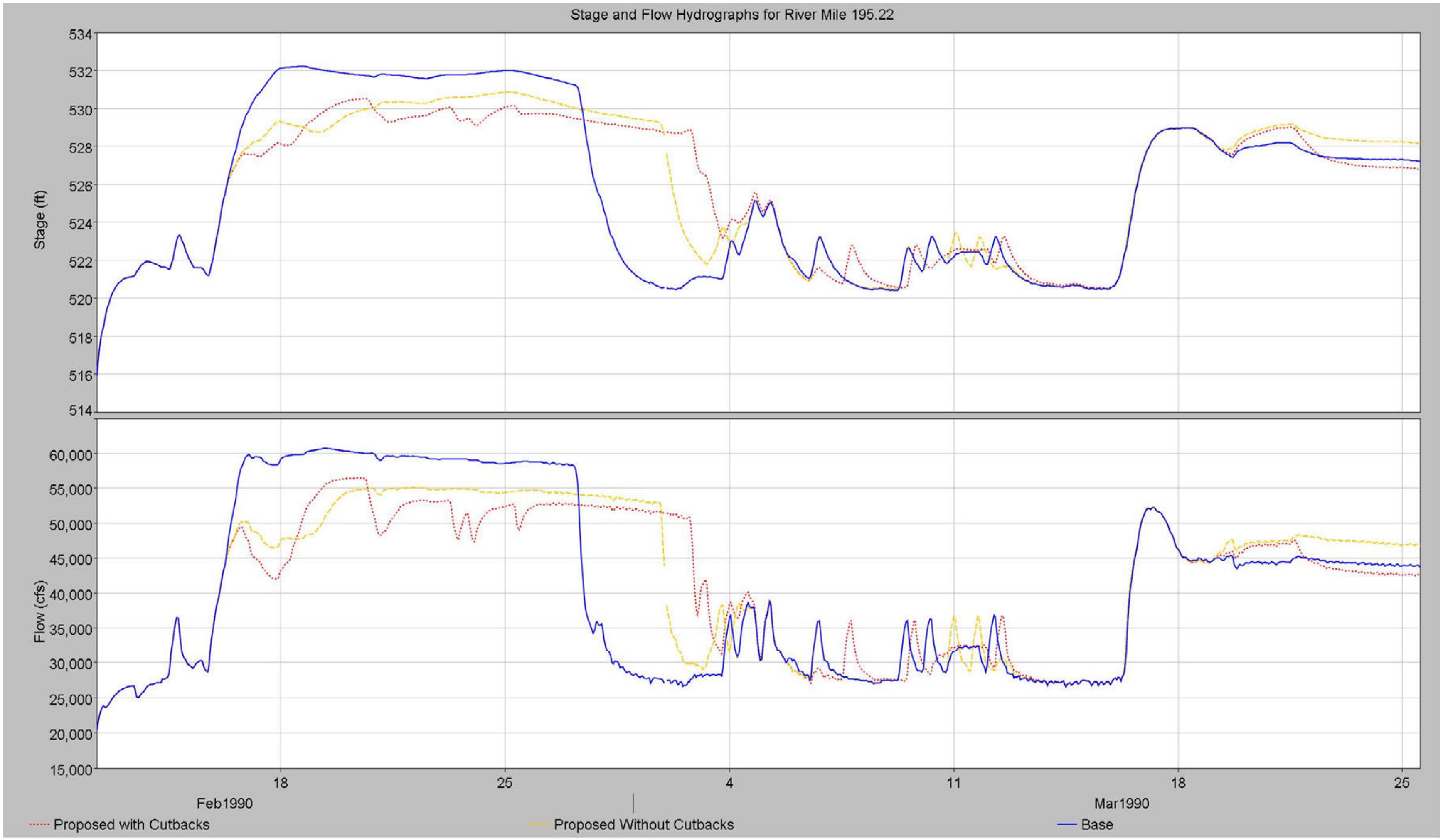
Stage/Flow at Coosa River Mile 213.98 Downstream of the Weiss Spillway for the Back to Back Storm.



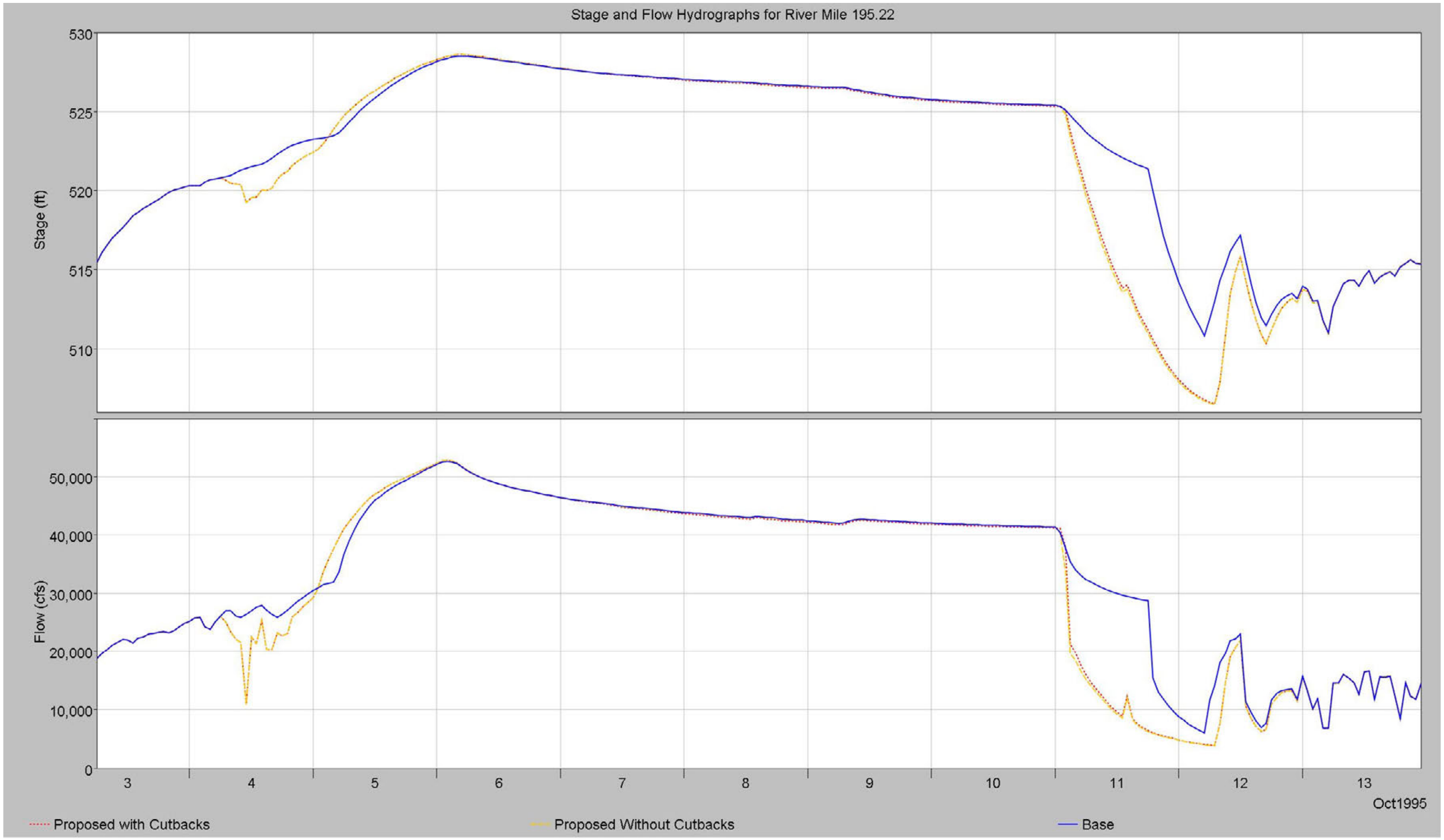
Stage/Flow at Coosa River Mile 213.98 Downstream of the Weiss Spillway for the Unregulated 0.01 ACE Storm.



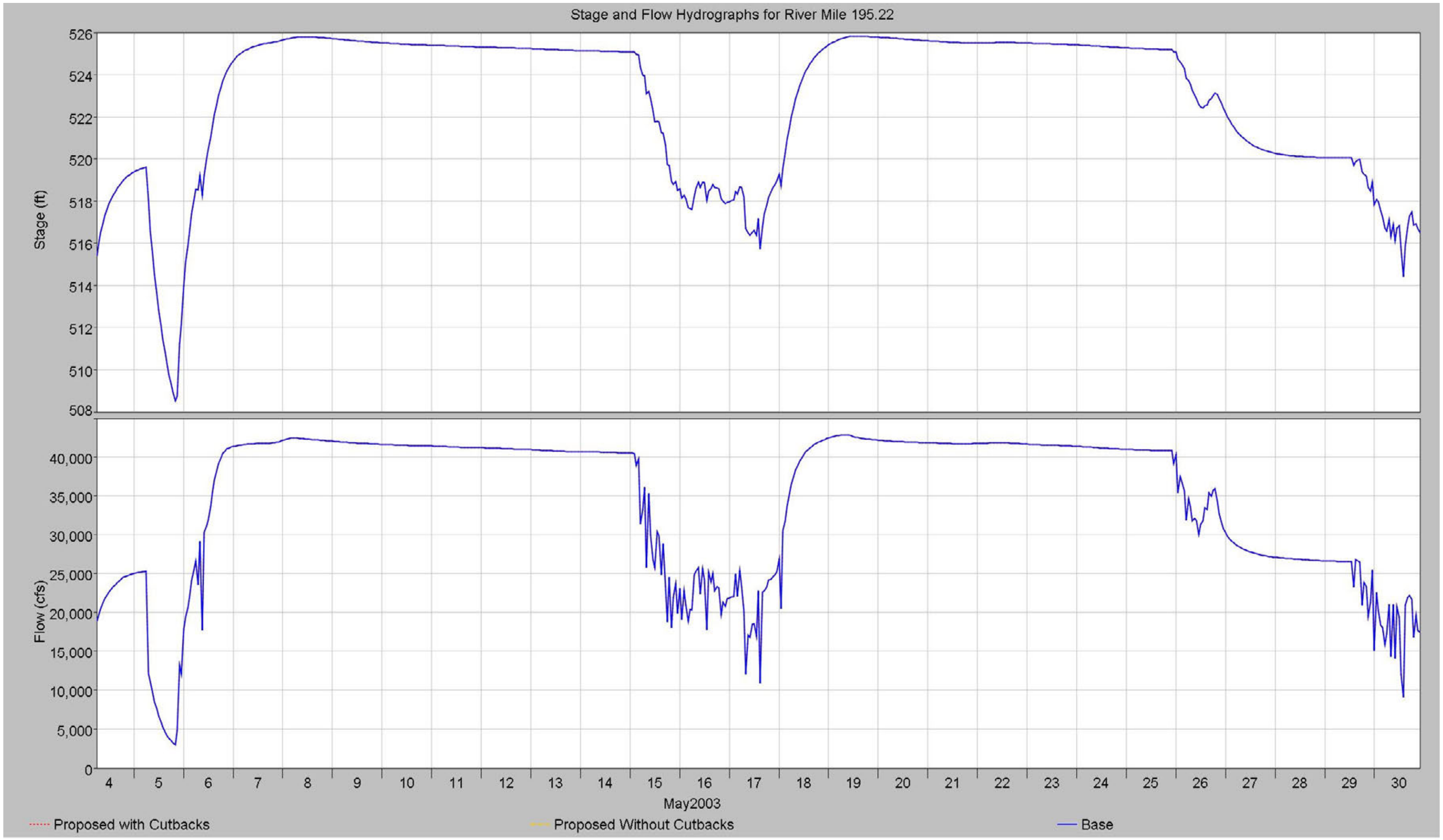
Stage/Flow at Coosa River Mile 195.22 Downstream of the Weiss Powerhouse for the April 1979 Storm



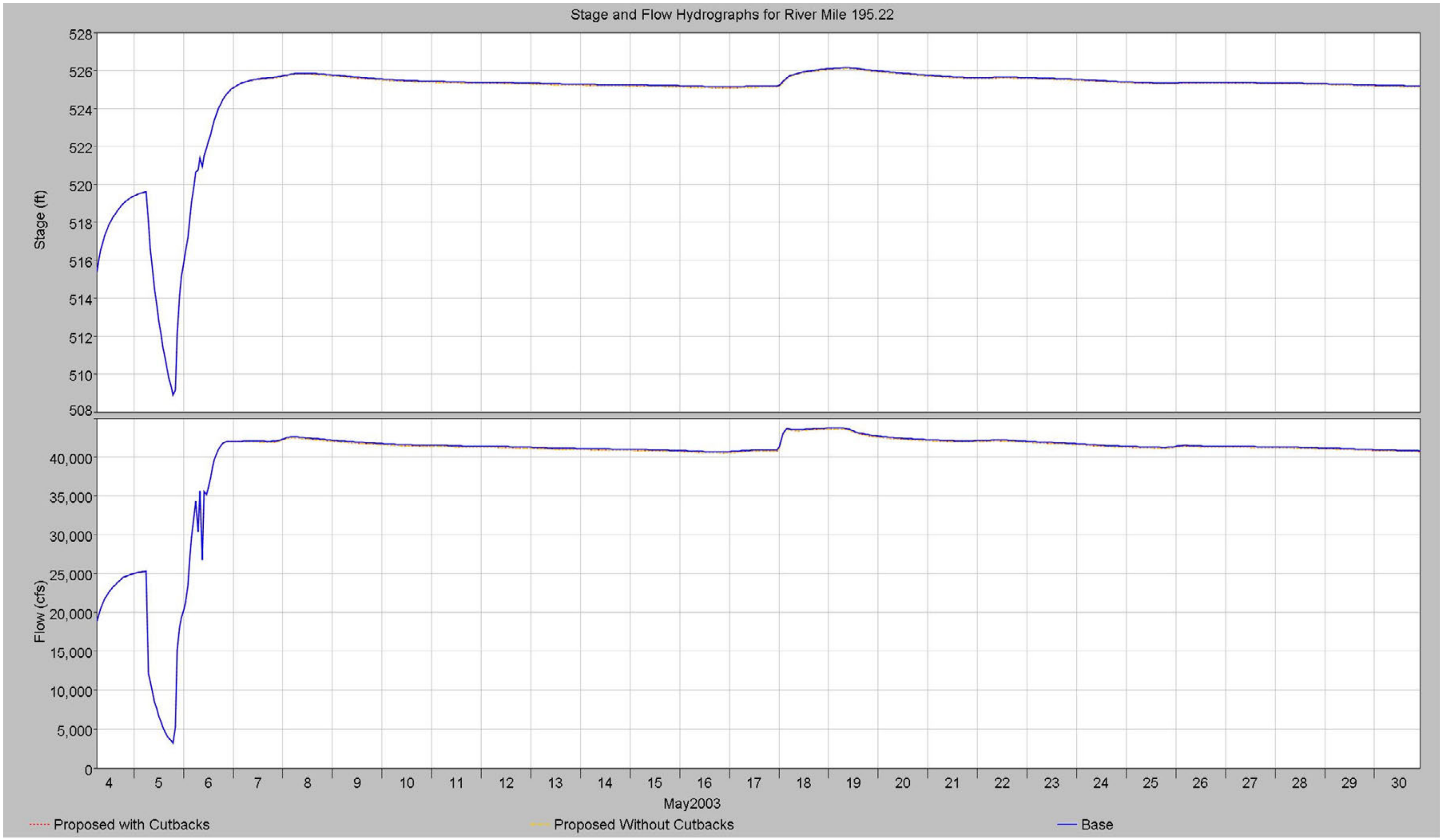
Stage/Flow at Coosa River Mile 195.22 Downstream of the Weiss Powerhouse for the February 1990 Storm.



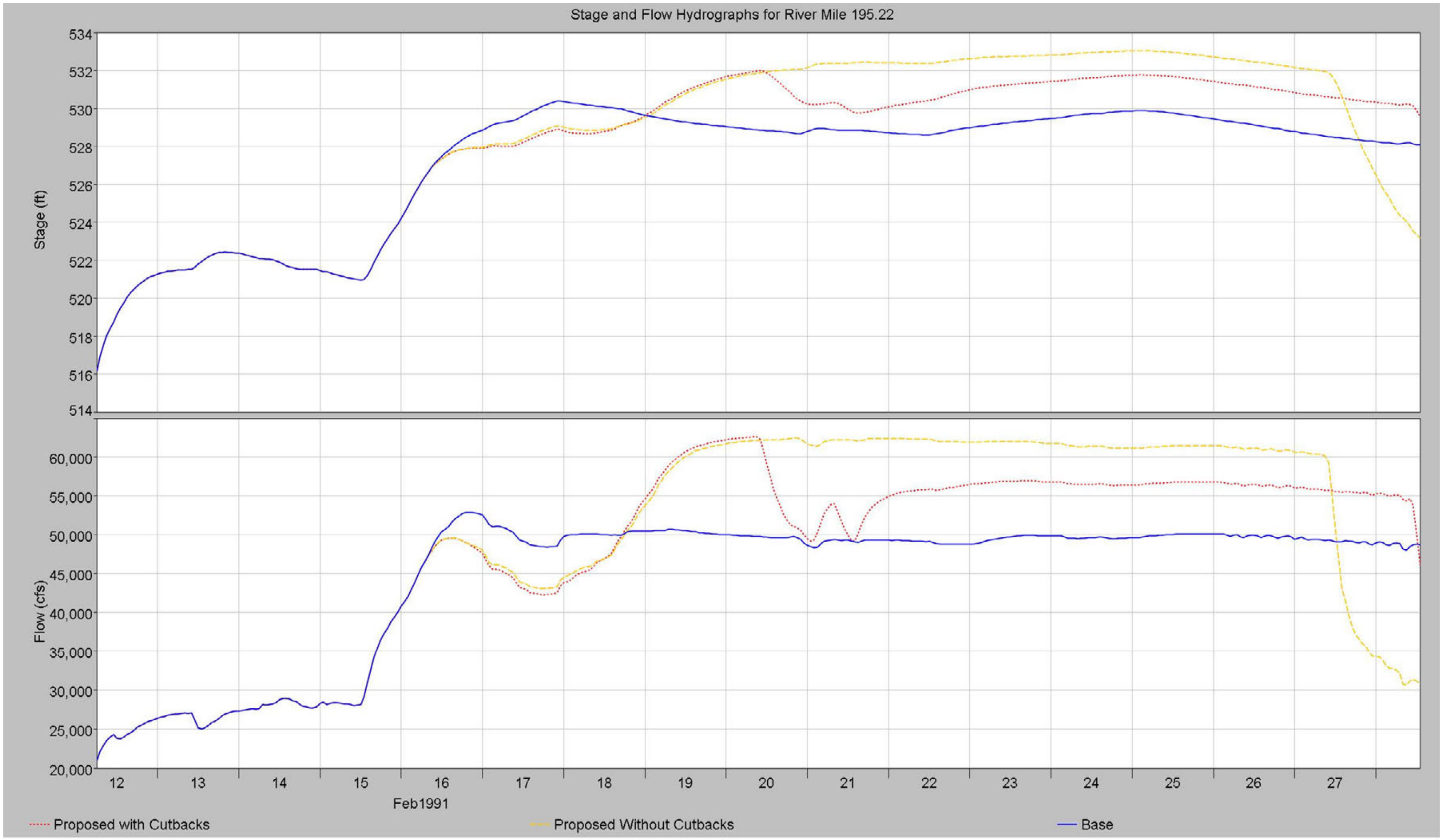
Stage/Flow at Coosa River Mile 195.22 Downstream of the Weiss Powerhouse for the October 1995 Storm.



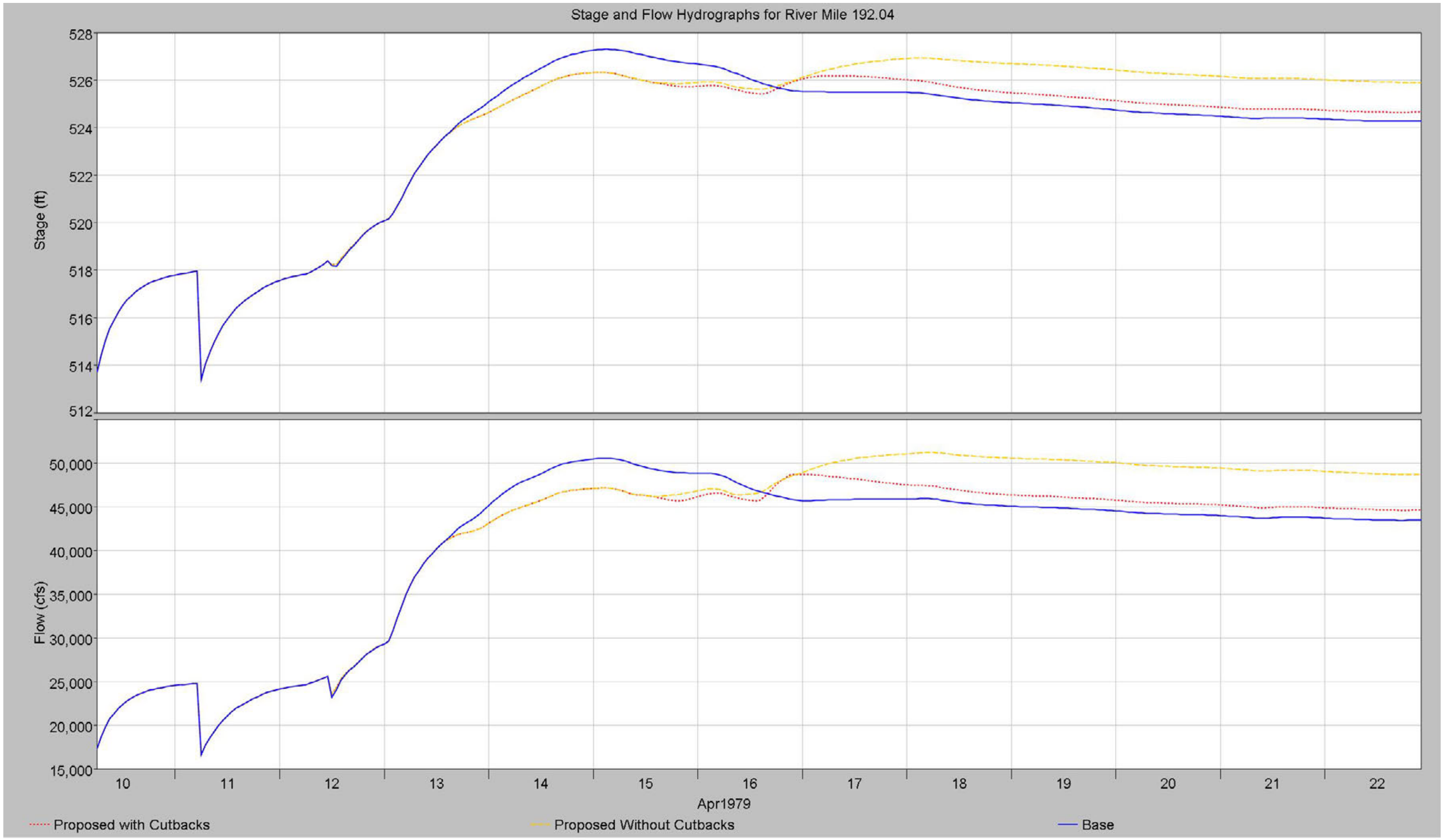
Stage/Flow at Coosa River Mile 195.22 Downstream of the Weiss Powerhouse for the May 2003 Storm.



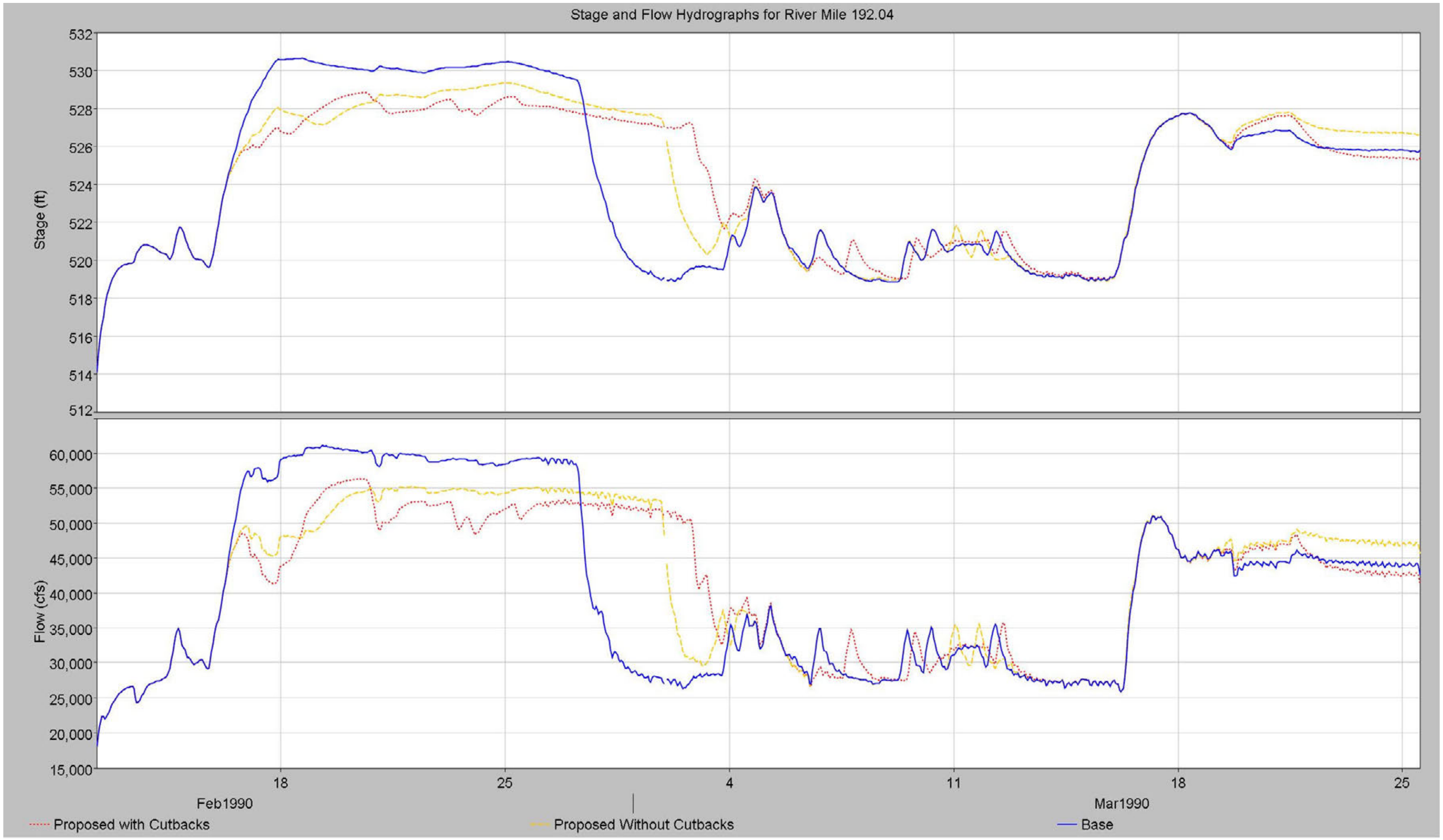
Stage/Flow at Coosa River Mile 195.22 Downstream of the Weiss Powerhouse for the Back to Back Storm.



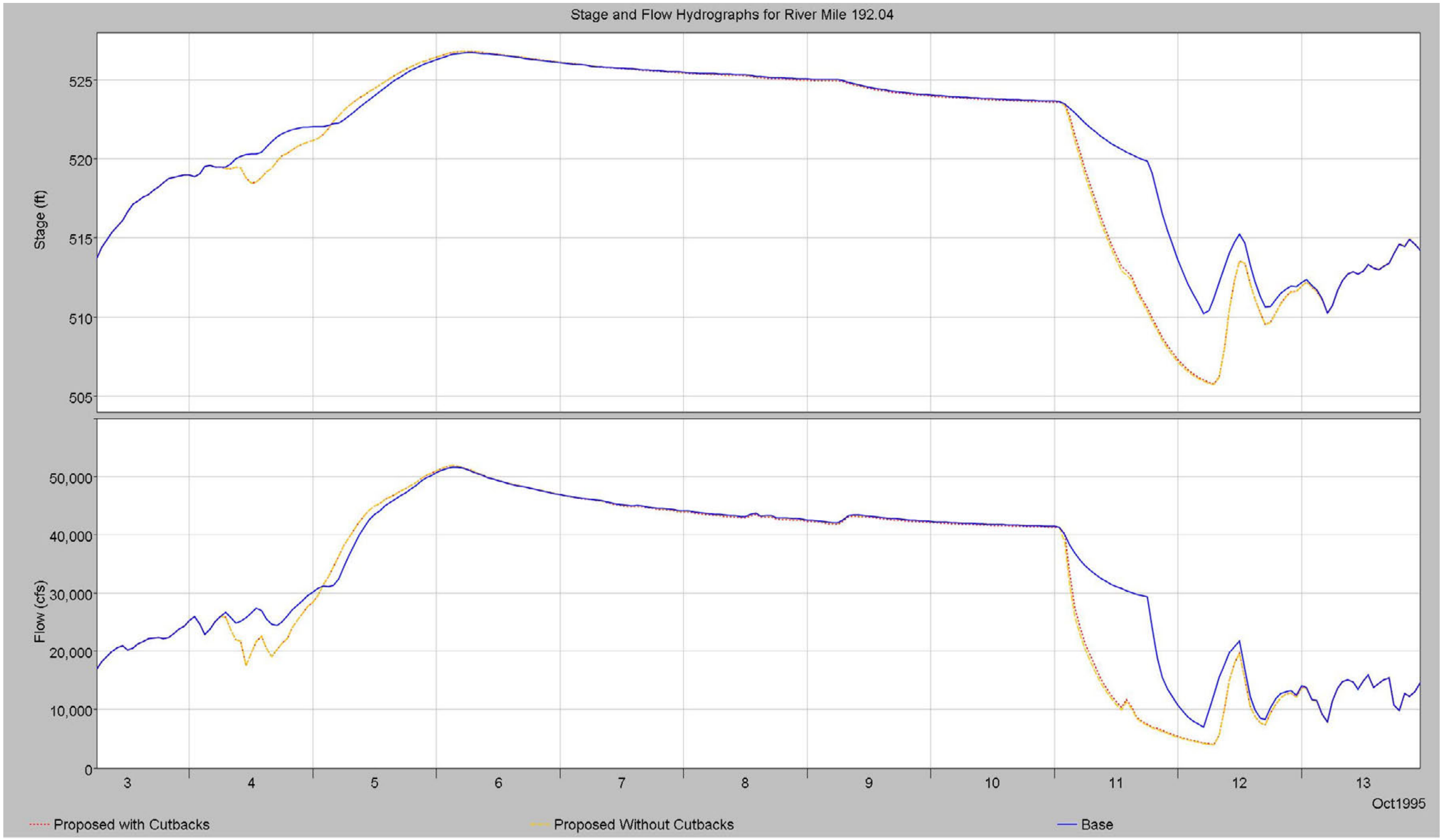
Stage/Flow at Coosa River Mile 195.22 Downstream of the Weiss Powerhouse for the Unregulated 0.01 ACE Storm.



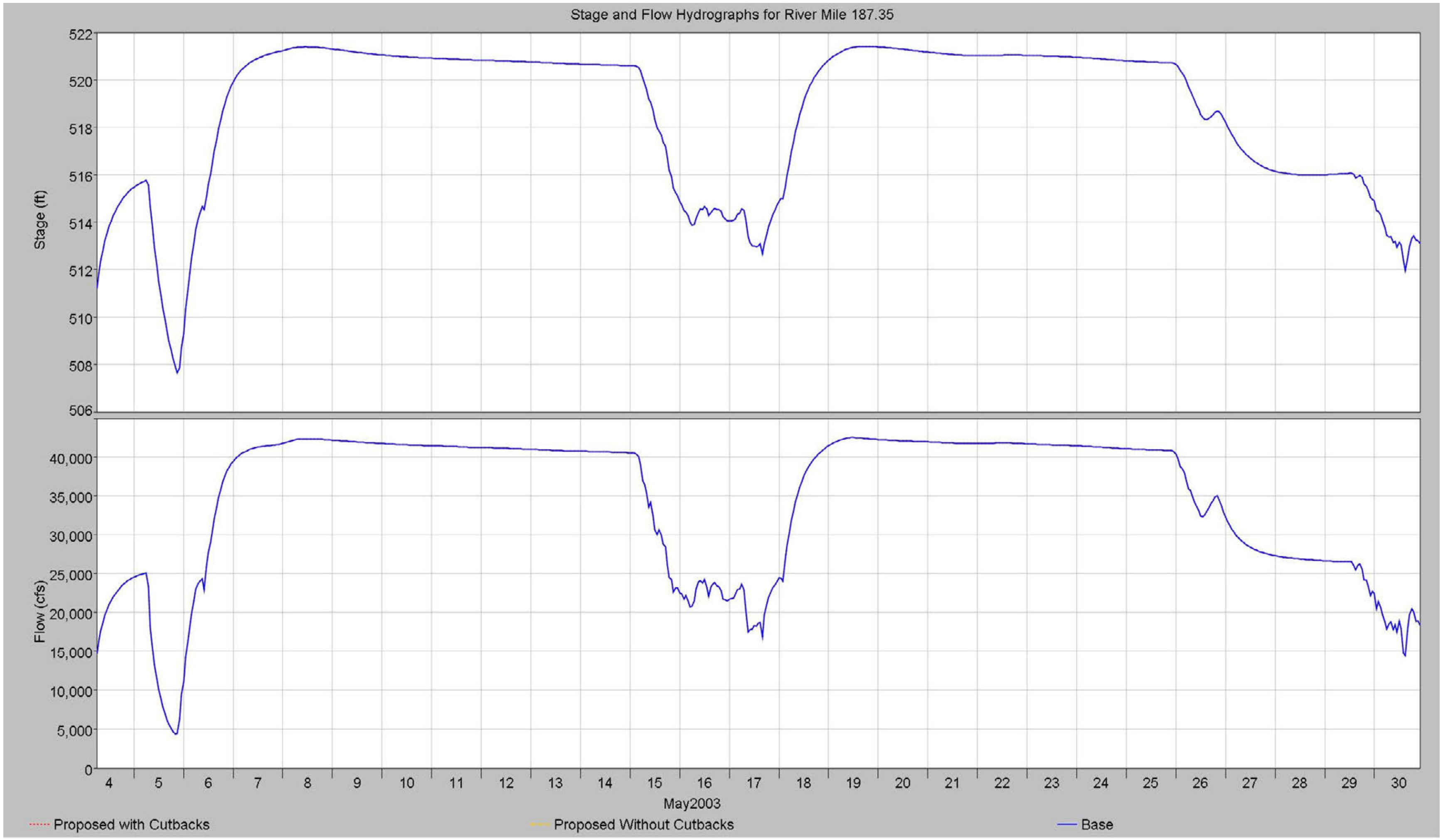
Stage/Flow at Coosa River Mile 192.04 Adjacent to Coosa Drive for the April 1979 Storm.



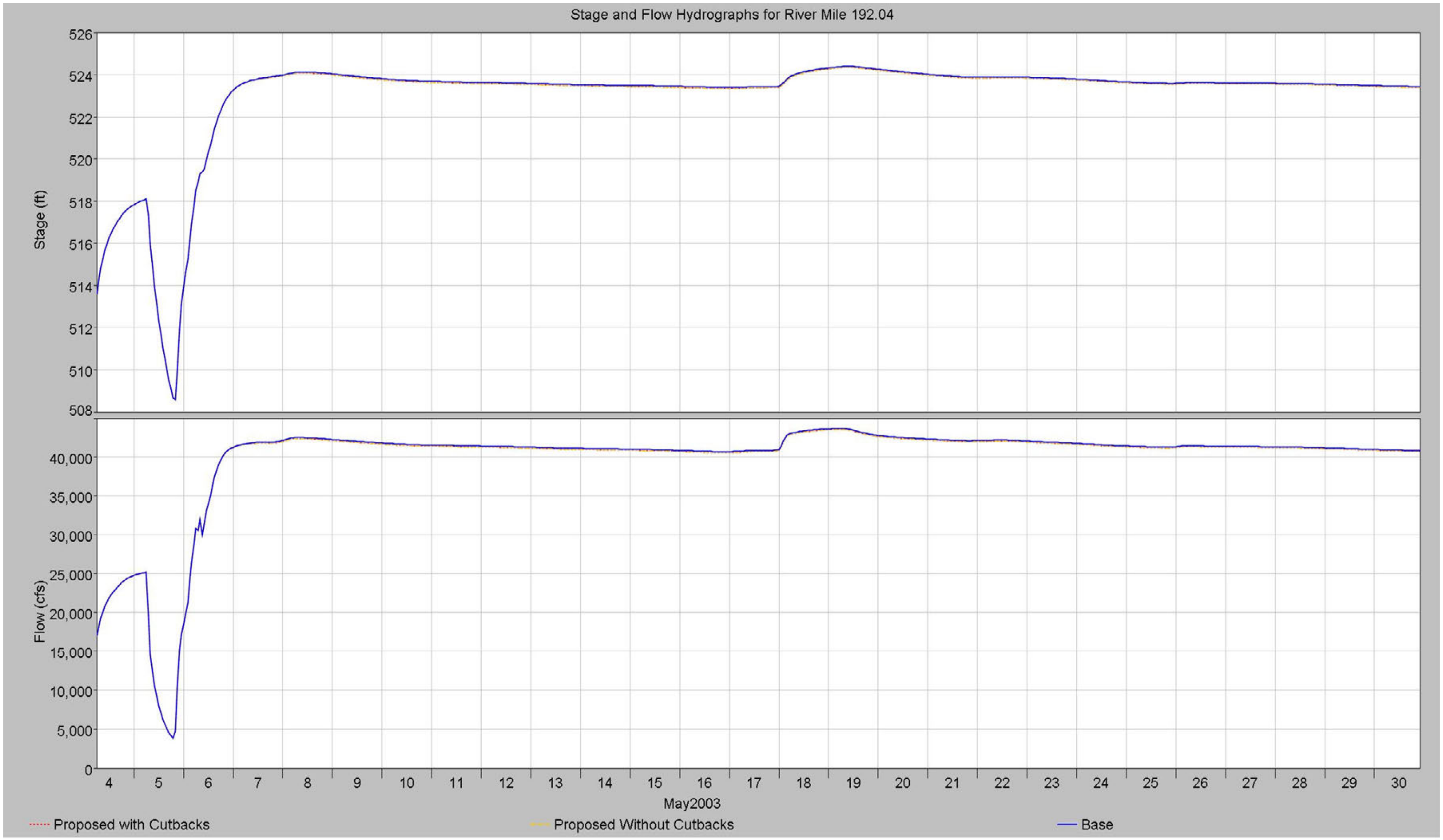
Stage/Flow at Coosa River Mile 192.04 Adjacent to Coosa Drive for the February 1990 Storm.



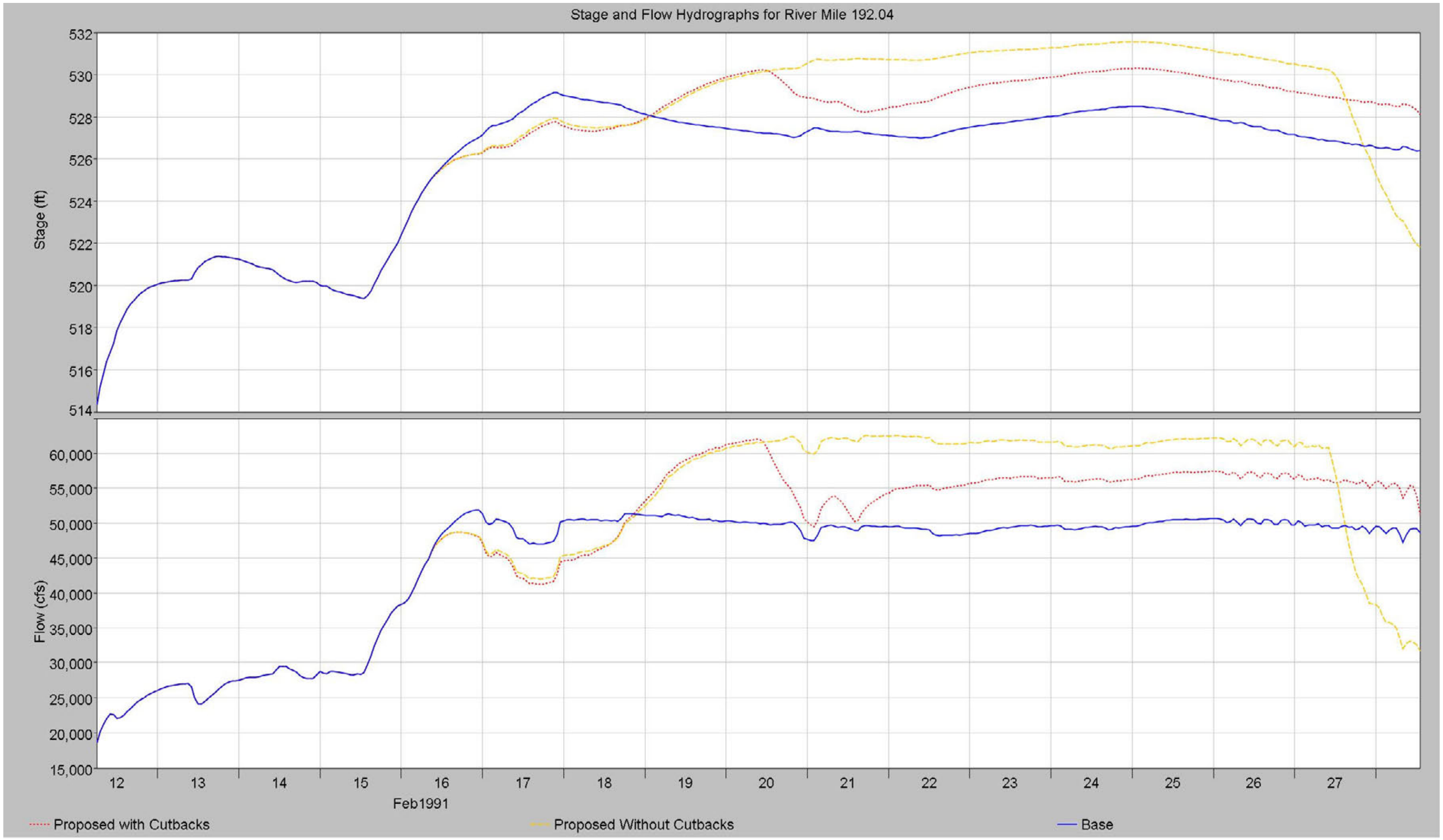
Stage/Flow at Coosa River Mile 192.04 Adjacent to Coosa Drive for the October 1995 Storm.



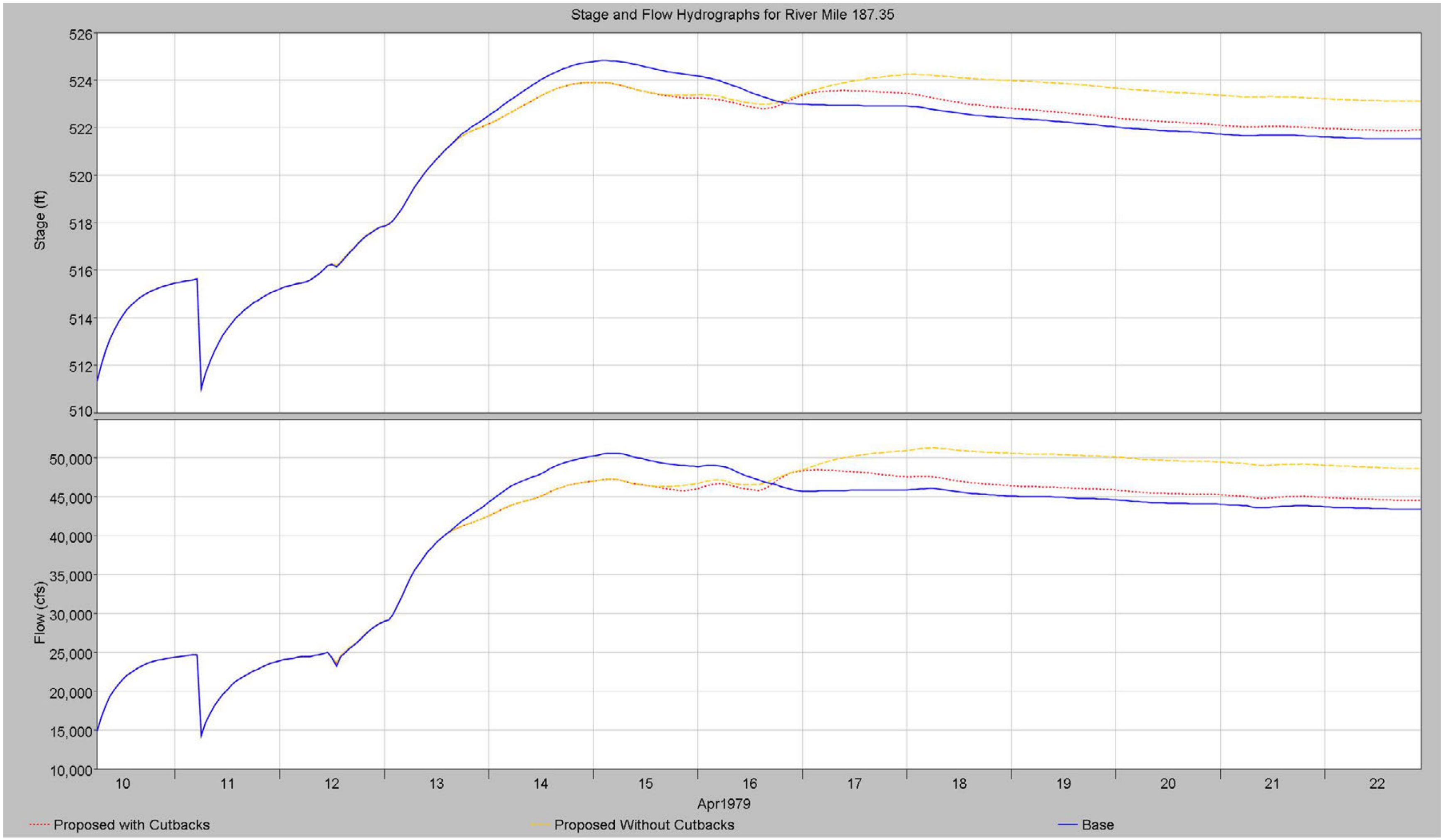
Stage/Flow at Coosa River Mile 192.04 Adjacent to Coosa Drive for the May 2003 Storm.



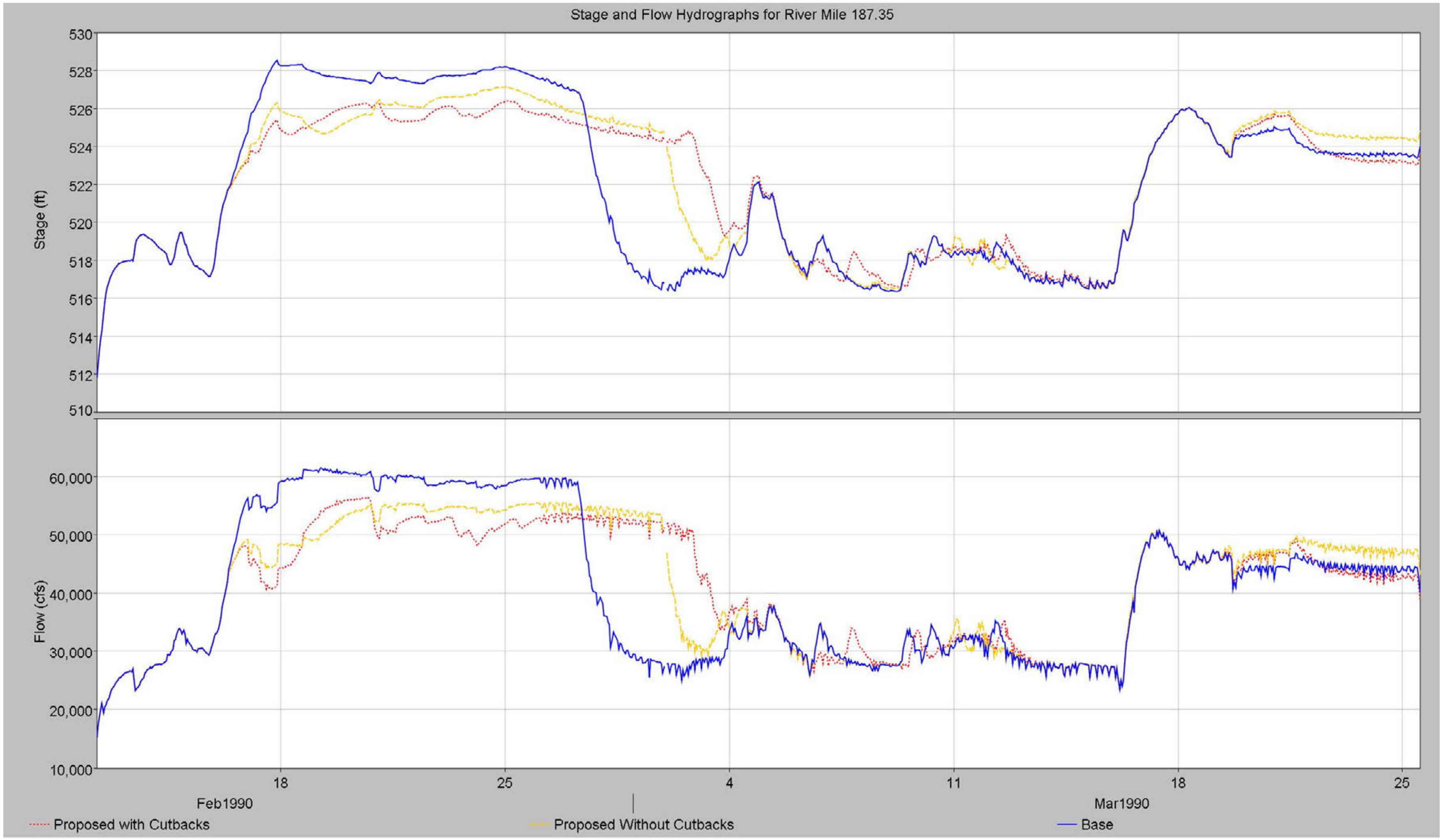
Stage/Flow at Coosa River Mile 192.04 Adjacent to Coosa Drive for the Back to Back Storm.



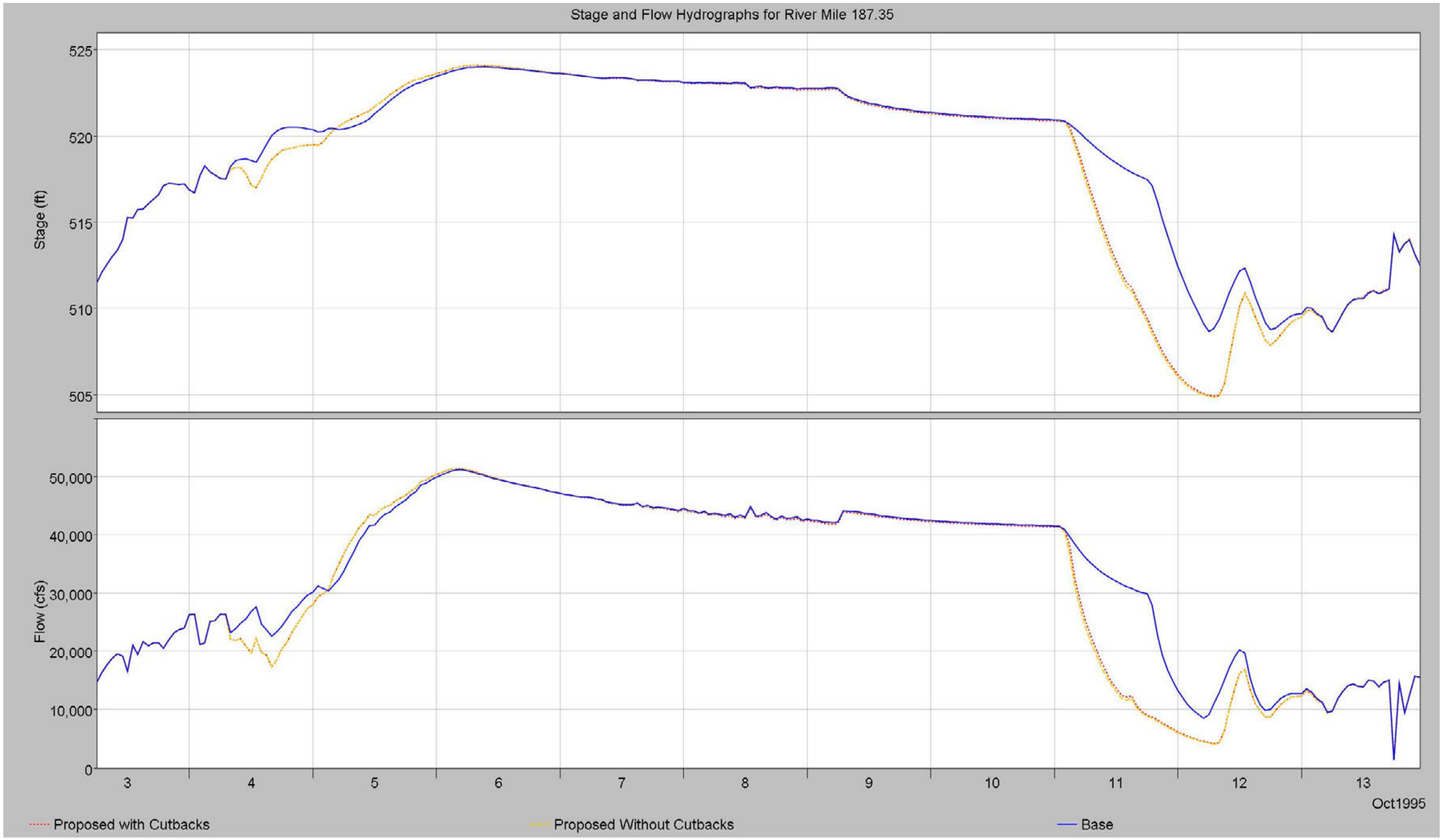
Stage/Flow at Coosa River Mile 192.04 Adjacent to Coosa Drive for the Unregulated 0.01 ACE Storm.



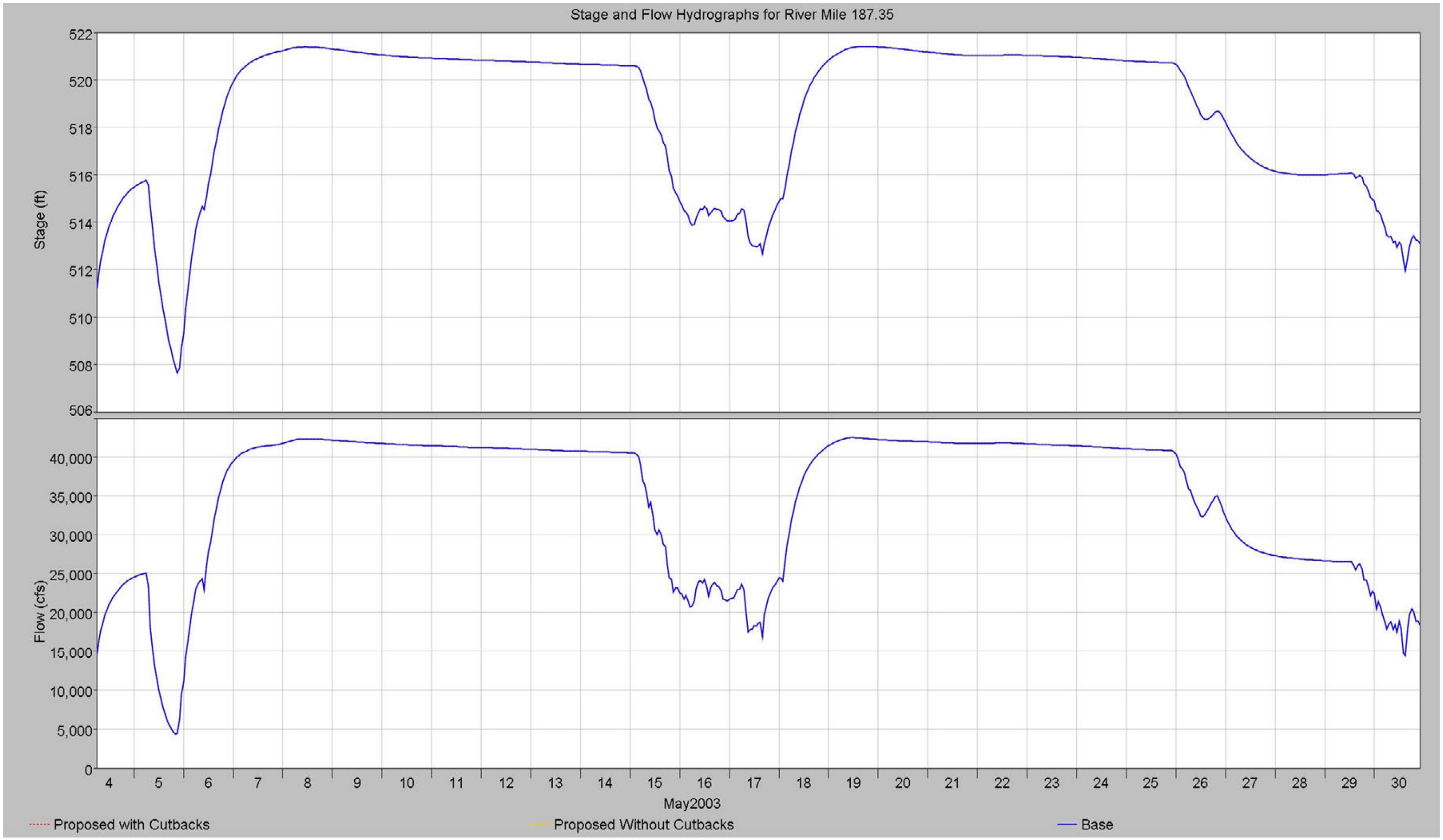
Stage/Flow at Coosa River Mile 187.35 Adjacent to Longview Drive for the April 1979 Storm.



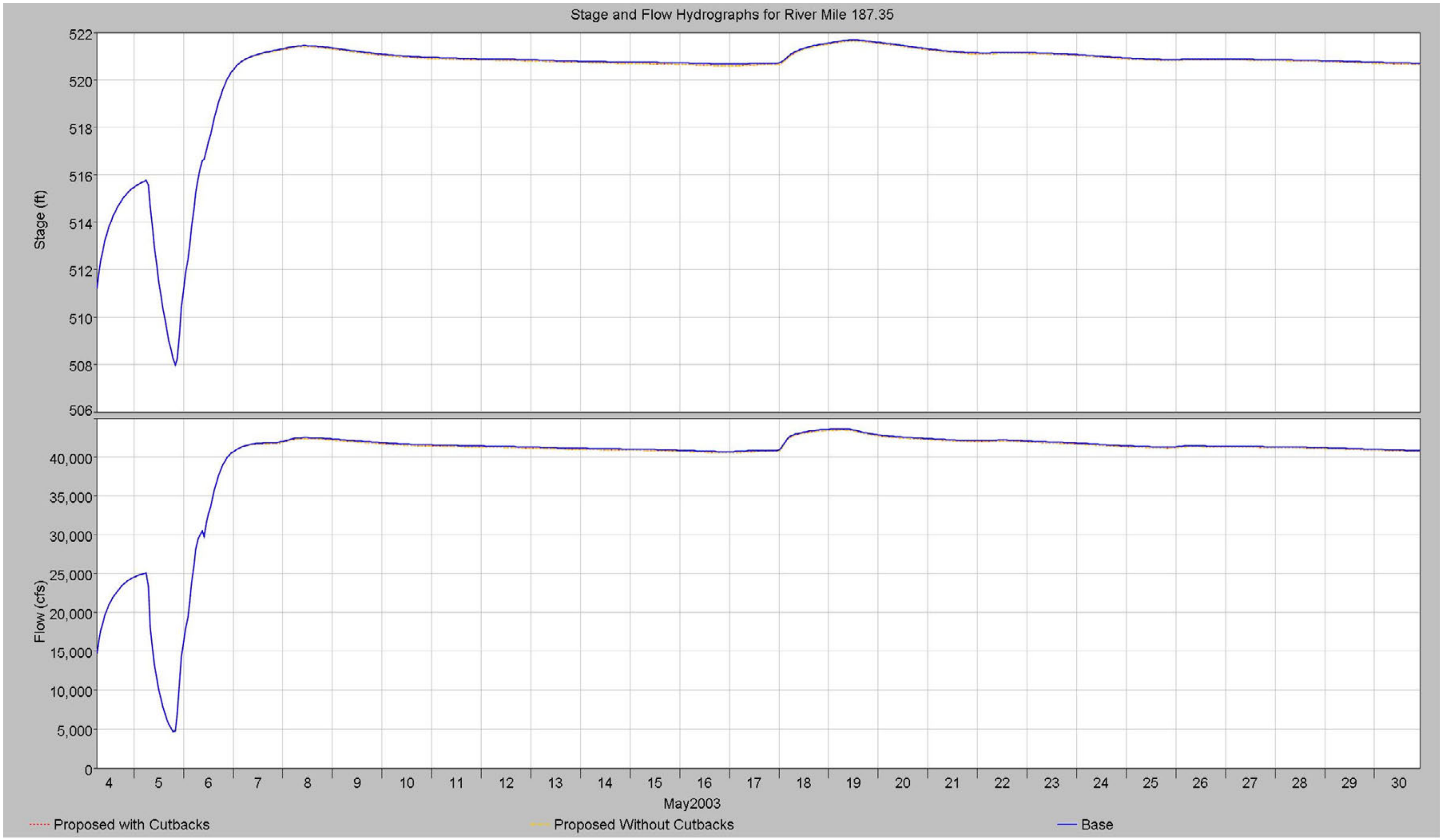
Stage/Flow at Coosa River Mile 187.35 Adjacent to Longview Drive for the February 1990 Storm.



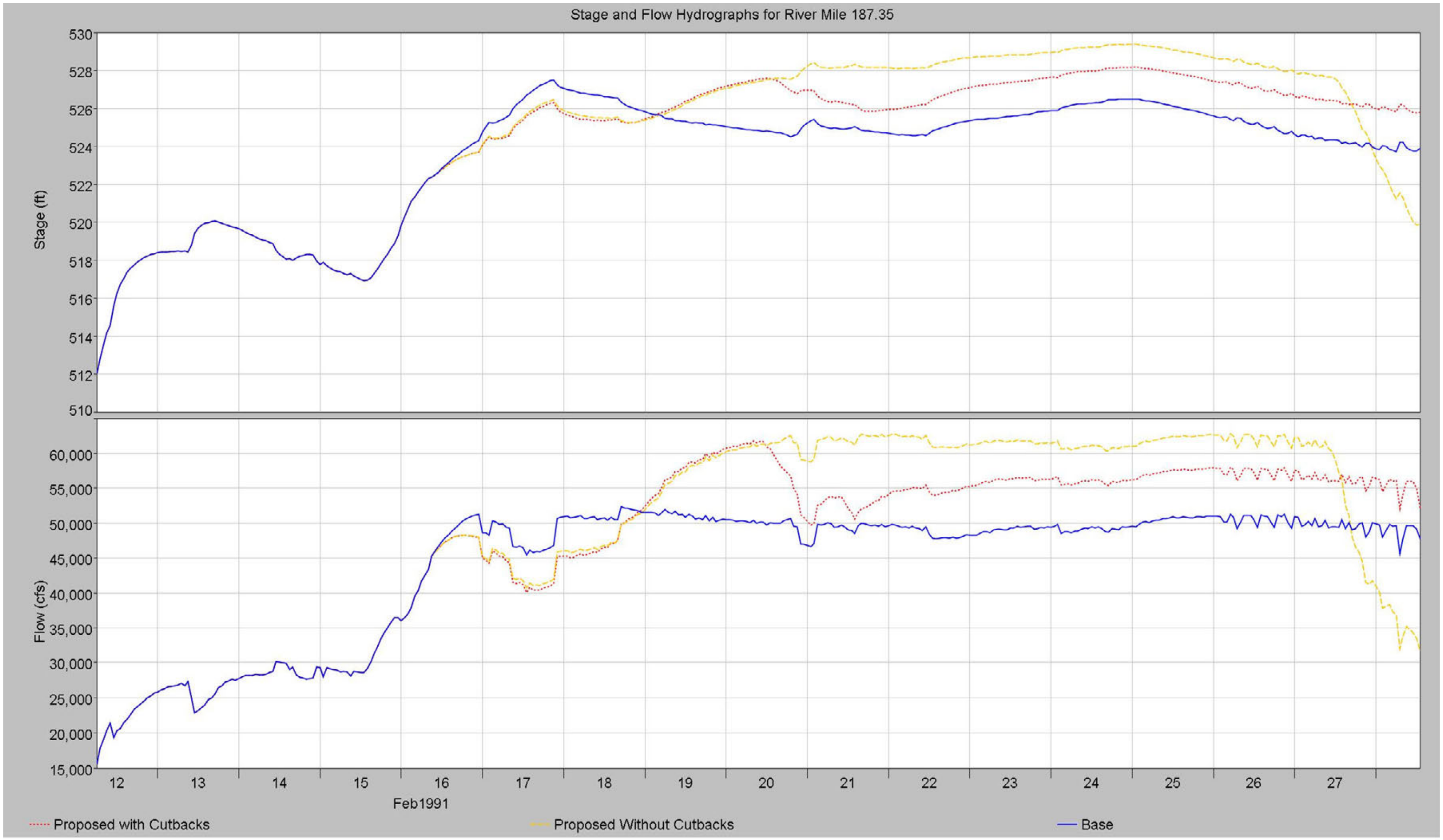
Stage/Flow at Coosa River Mile 187.35 Adjacent to Longview Drive for the October 1995 Storm.



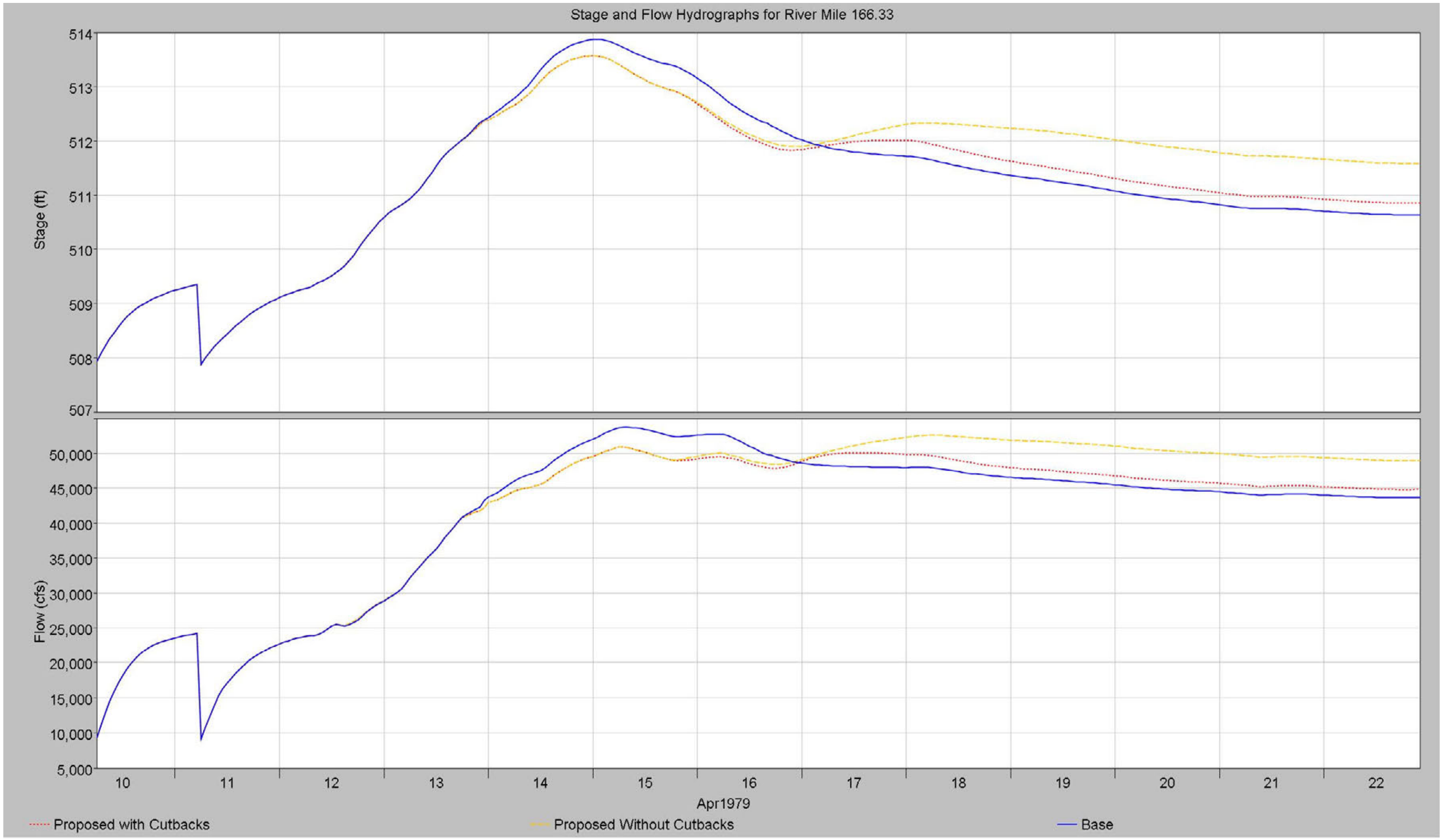
Stage/Flow at Coosa River Mile 187.35 Adjacent to Longview Drive for the May 2003 Storm.



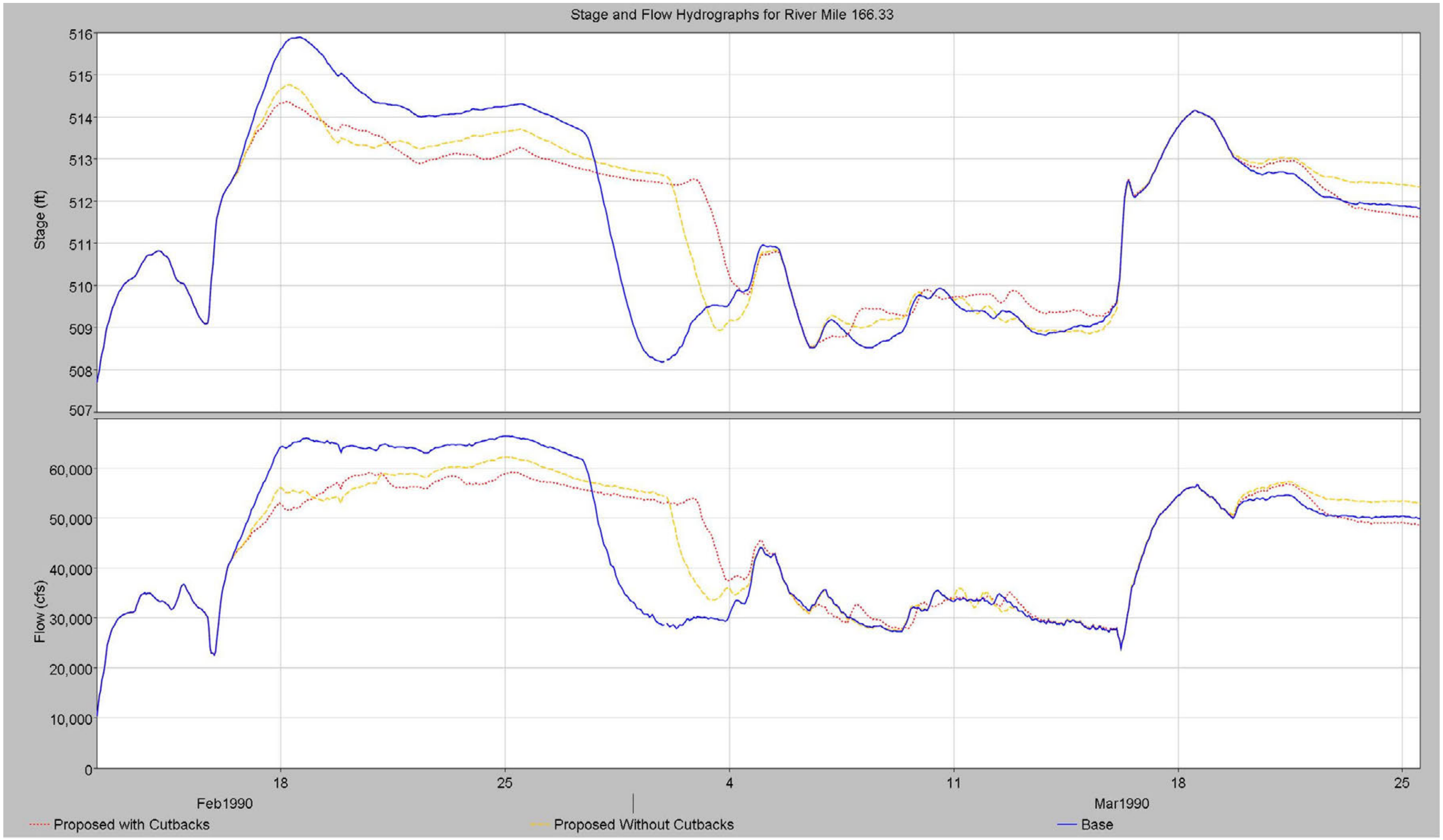
Stage/Flow at Coosa River Mile 187.35 Adjacent to Longview Drive for the Back to Back Storm.



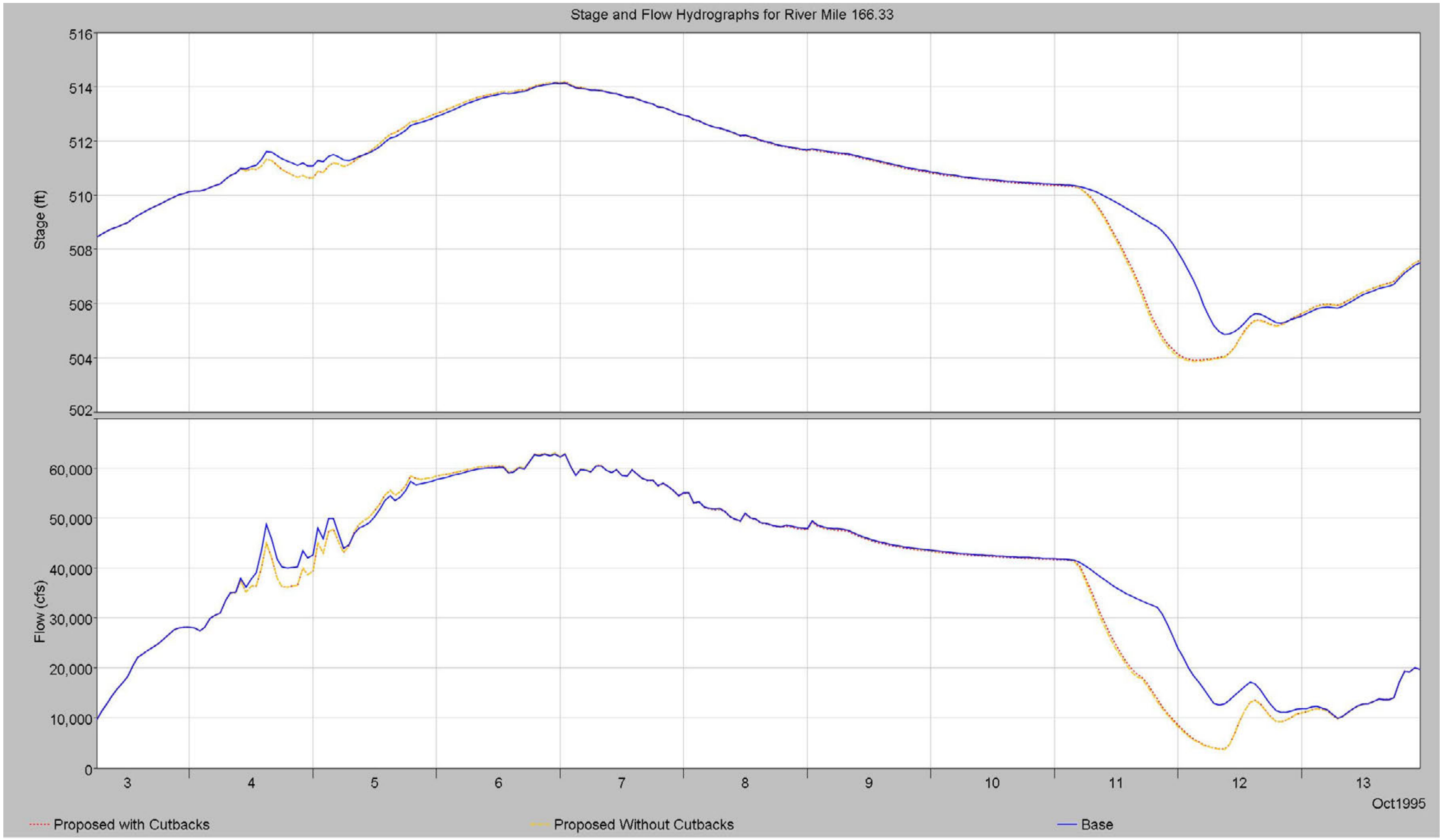
Stage/Flow at Coosa River Mile 187.35 Adjacent to Longview Drive for the Unregulated 0.01 ACE Storm.



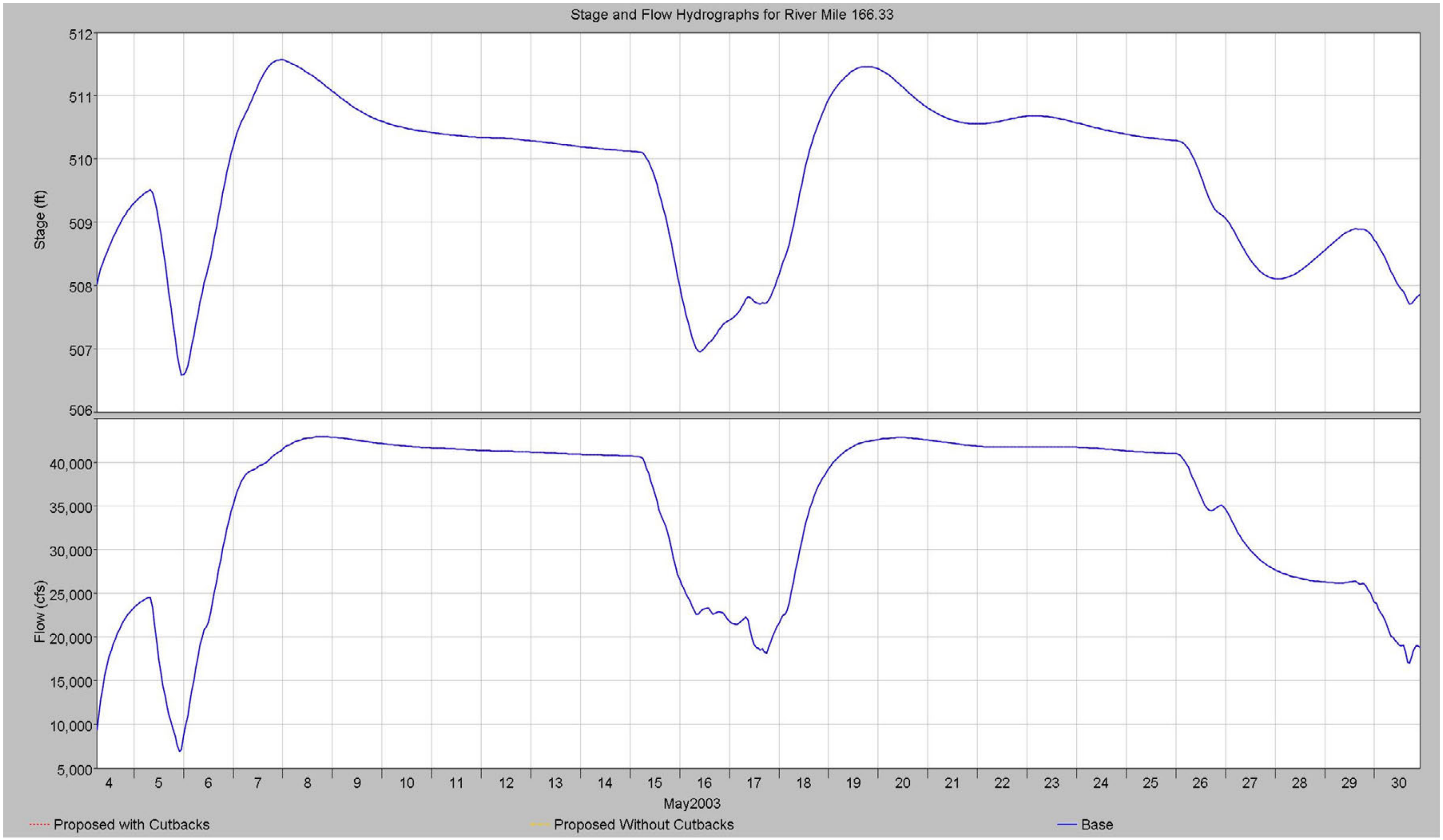
Stage/Flow at Coosa River Mile 166.33 Adjacent to the Gadsden Power Plant and the Goodyear Tire Plant for the April 1979 Storm.



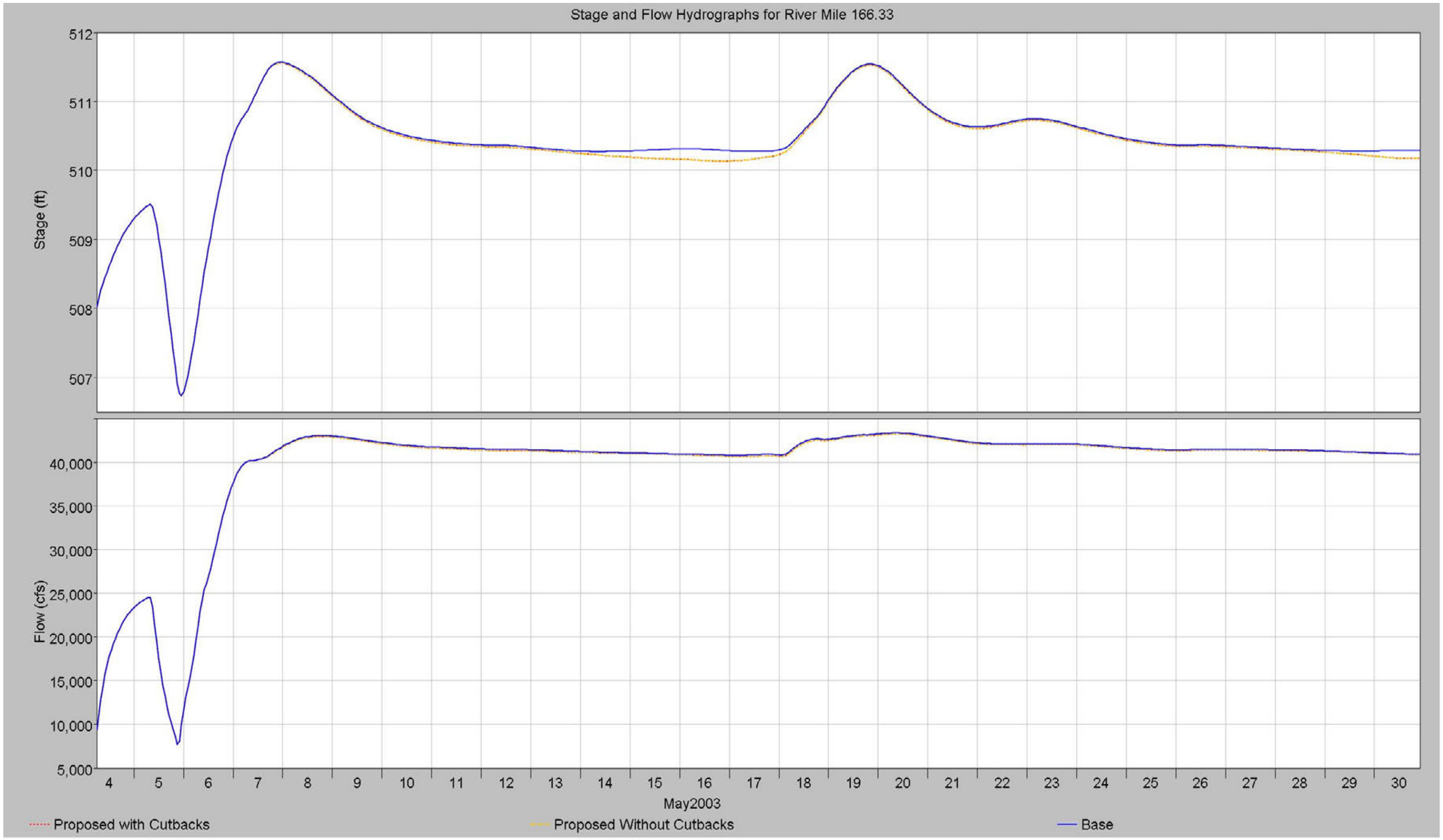
Stage/Flow at Coosa River Mile 166.33 Adjacent to the Gadsden Power Plant and the Goodyear Tire Plant for the February 1990 Storm.



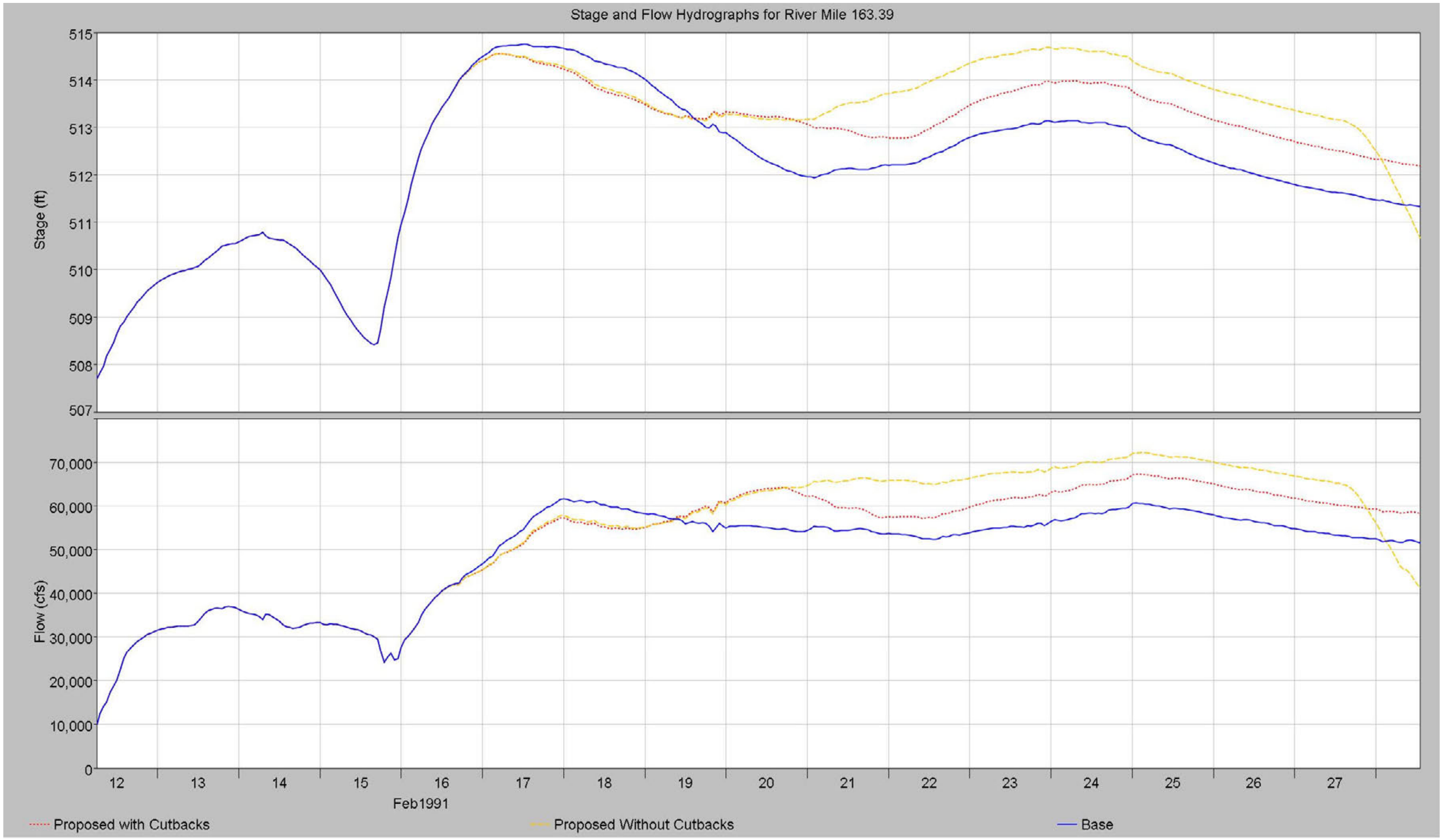
Stage/Flow at Coosa River Mile 166.33 Adjacent to the Gadsden Power Plant and the Goodyear Tire Plant for the October 1995 Storm.



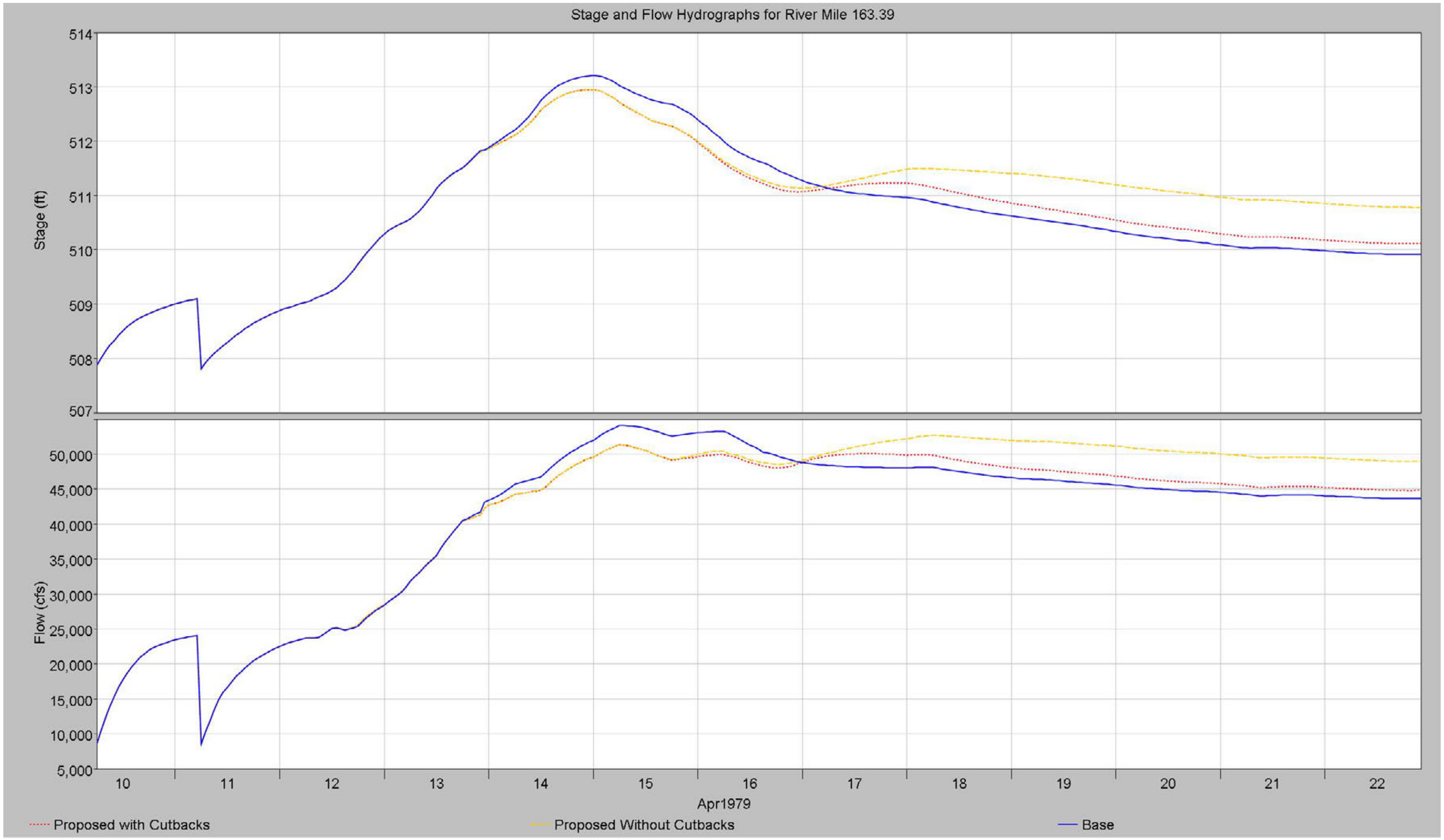
Stage/Flow at Coosa River Mile 166.33 Adjacent to the Gadsden Power Plant and the Goodyear Tire Plant for the May 2003 Storm.



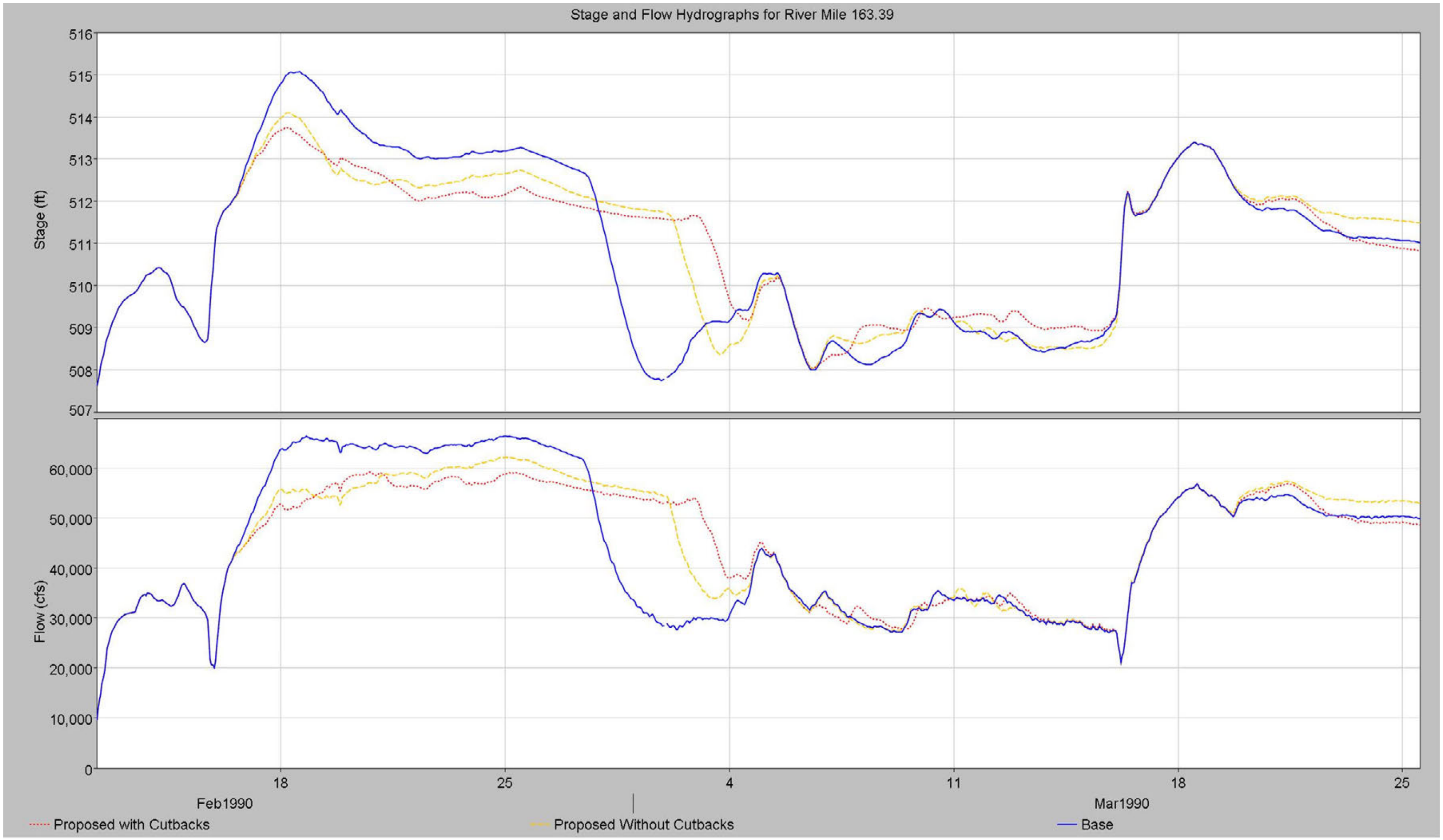
Stage/Flow at Coosa River Mile 166.33 Adjacent to the Gadsden Power Plant and the Goodyear Tire Plant for the Back to Back Storm.



Stage/Flow at Coosa River Mile 166.33 Adjacent to the Gadsden Power Plant and the Goodyear Tire Plant for the Unregulated 0.01 ACE Storm.



Stage/Flow at Coosa River Mile 163.39 Upstream of I-759 for the April 1979 Storm.



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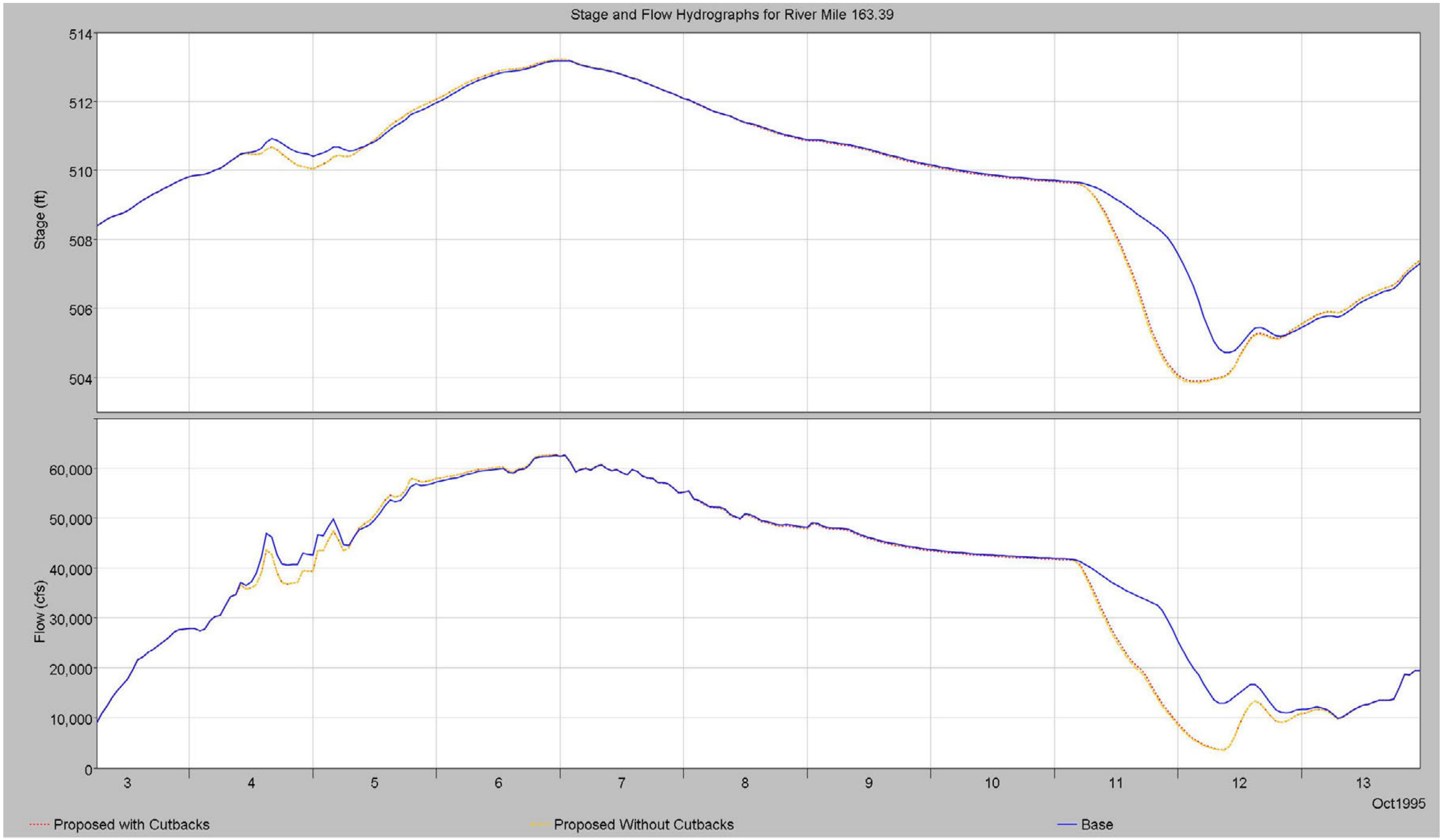

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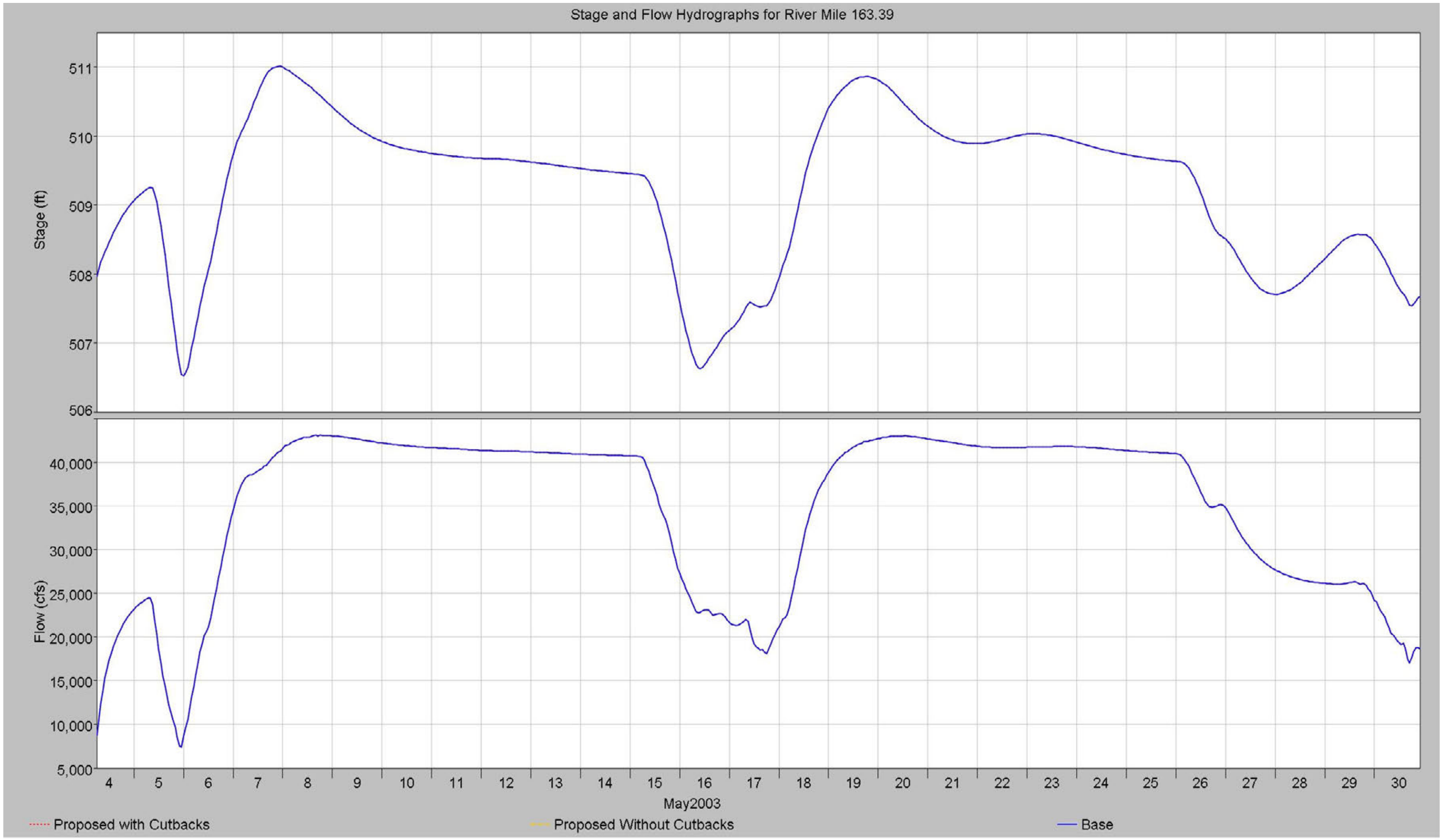

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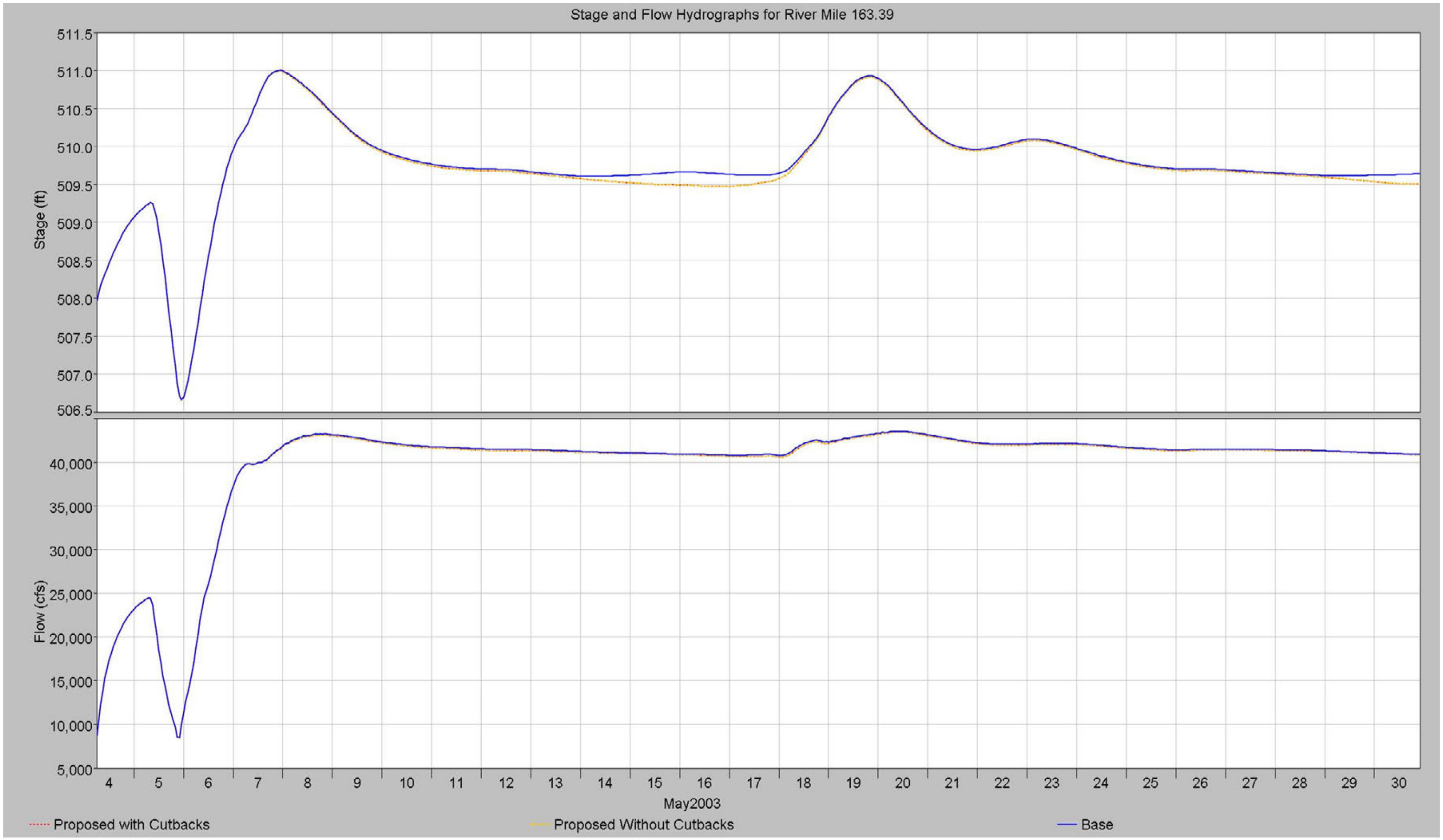

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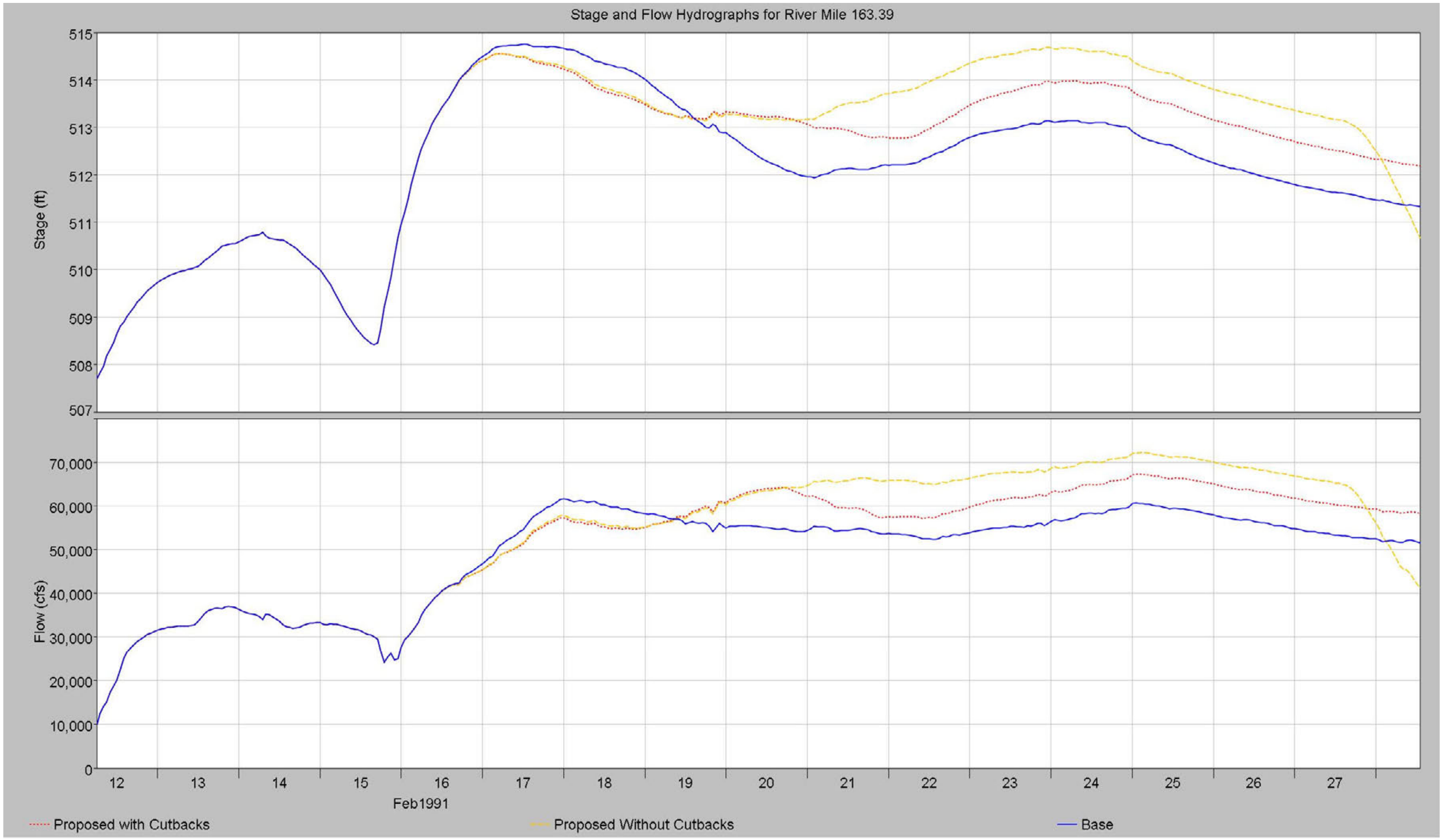

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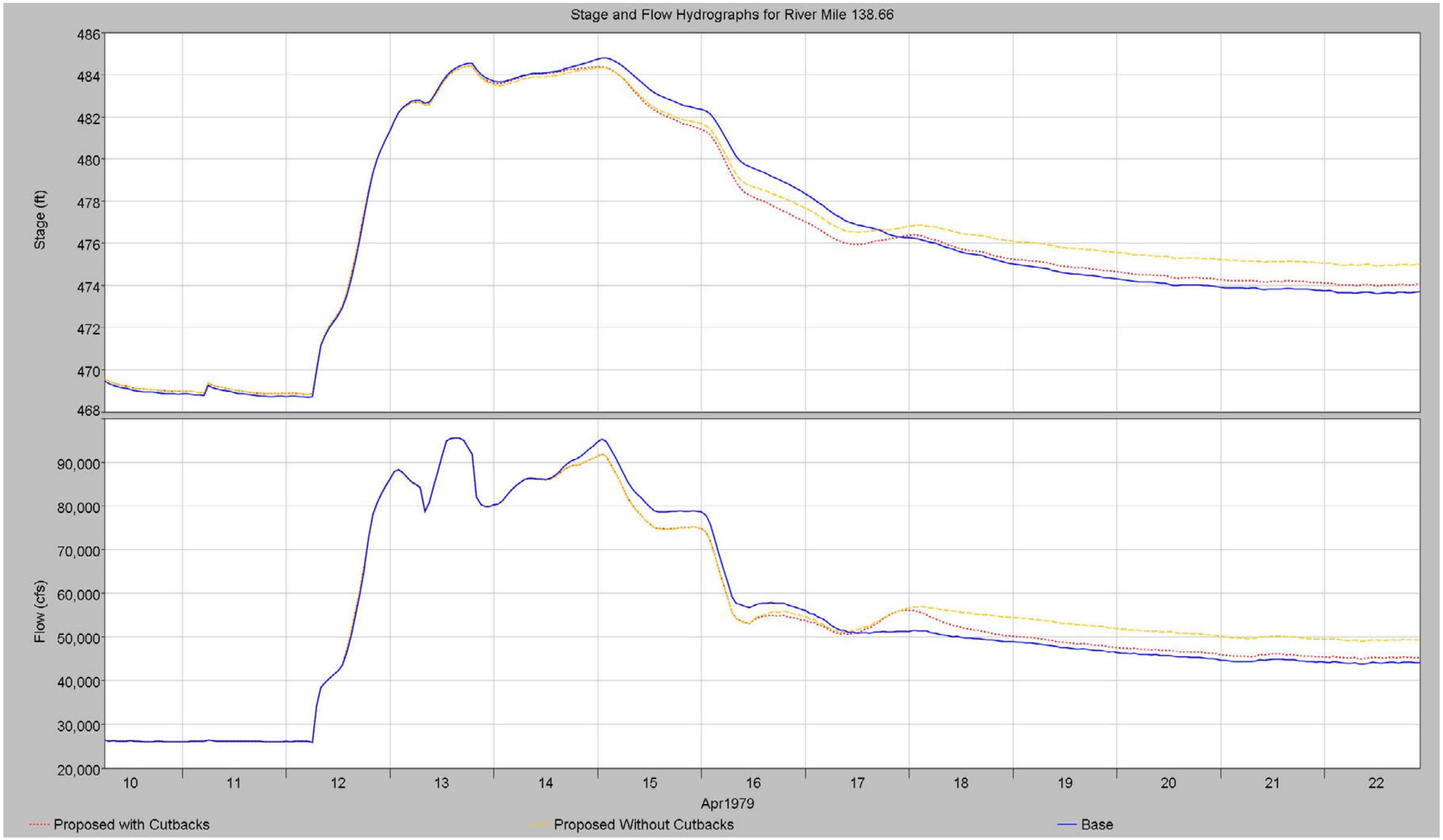

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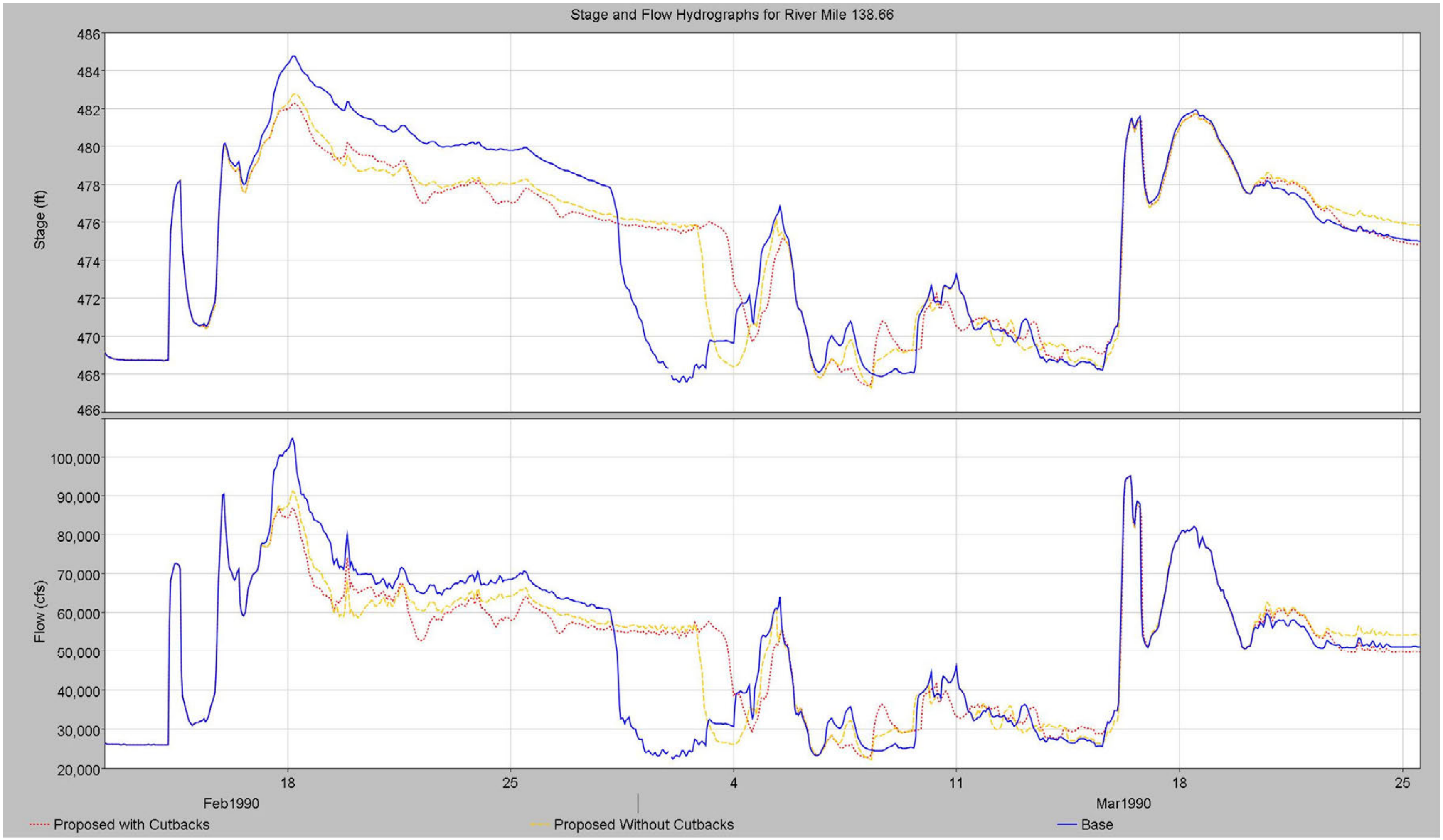

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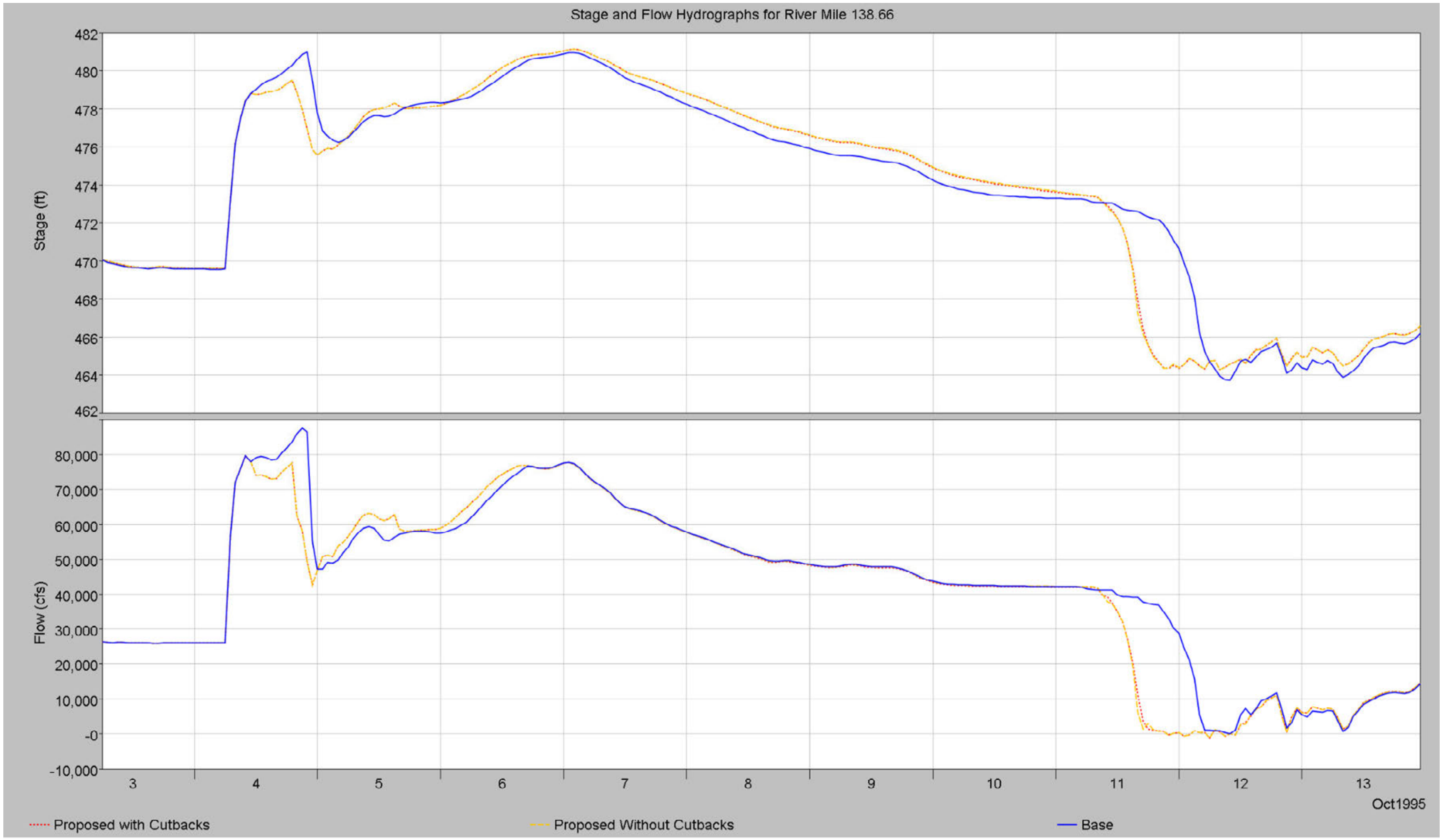

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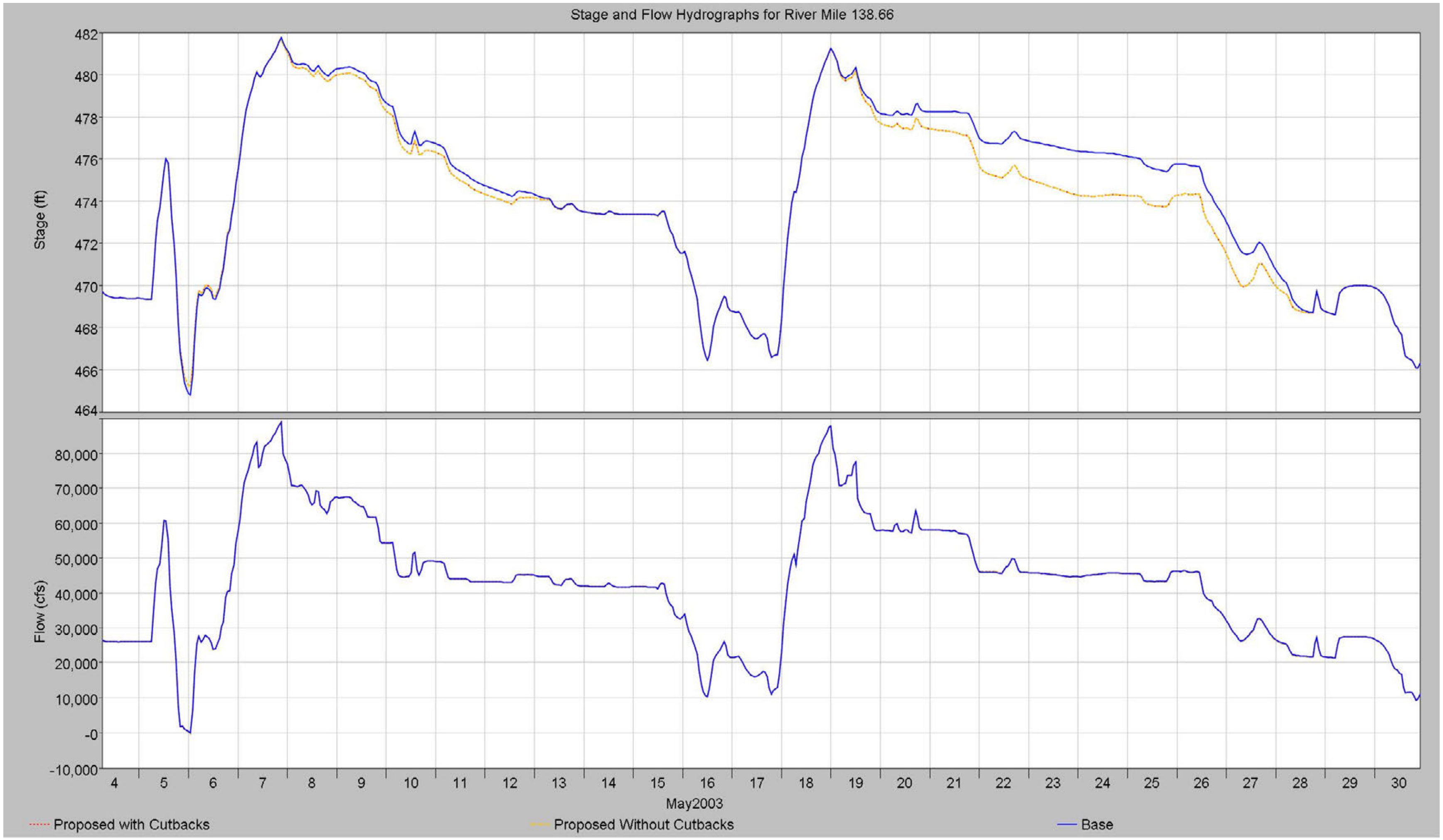

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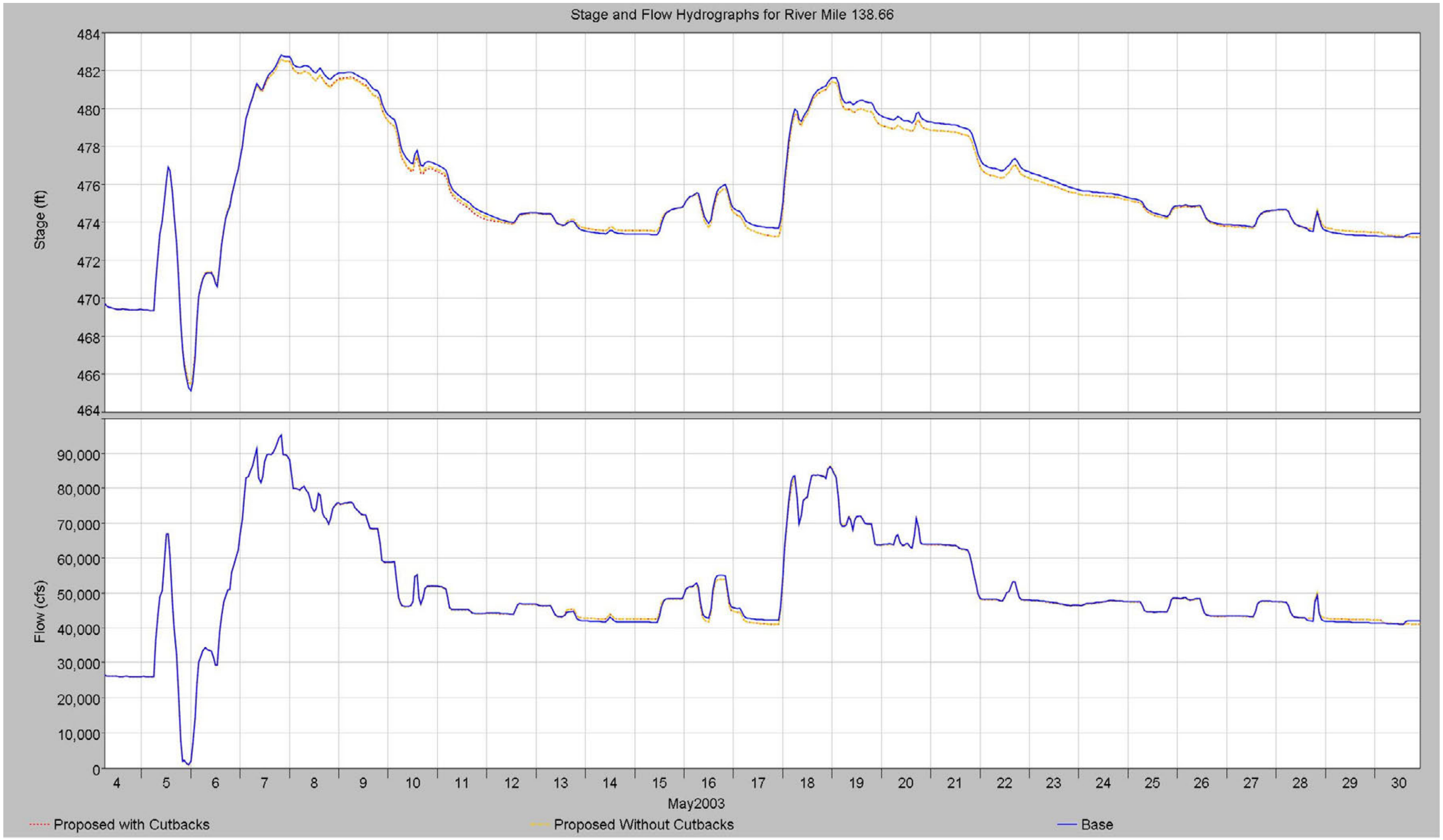

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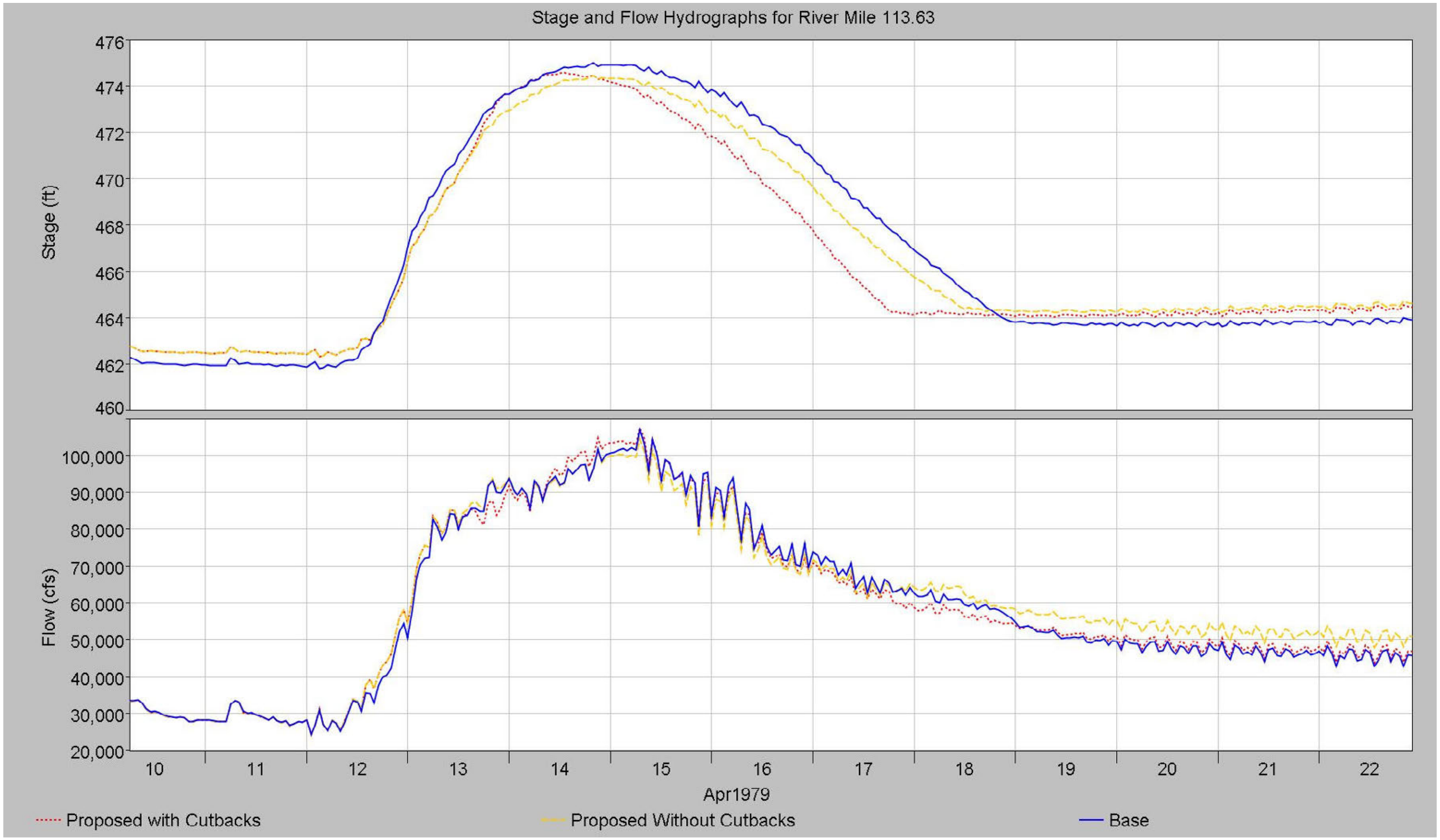

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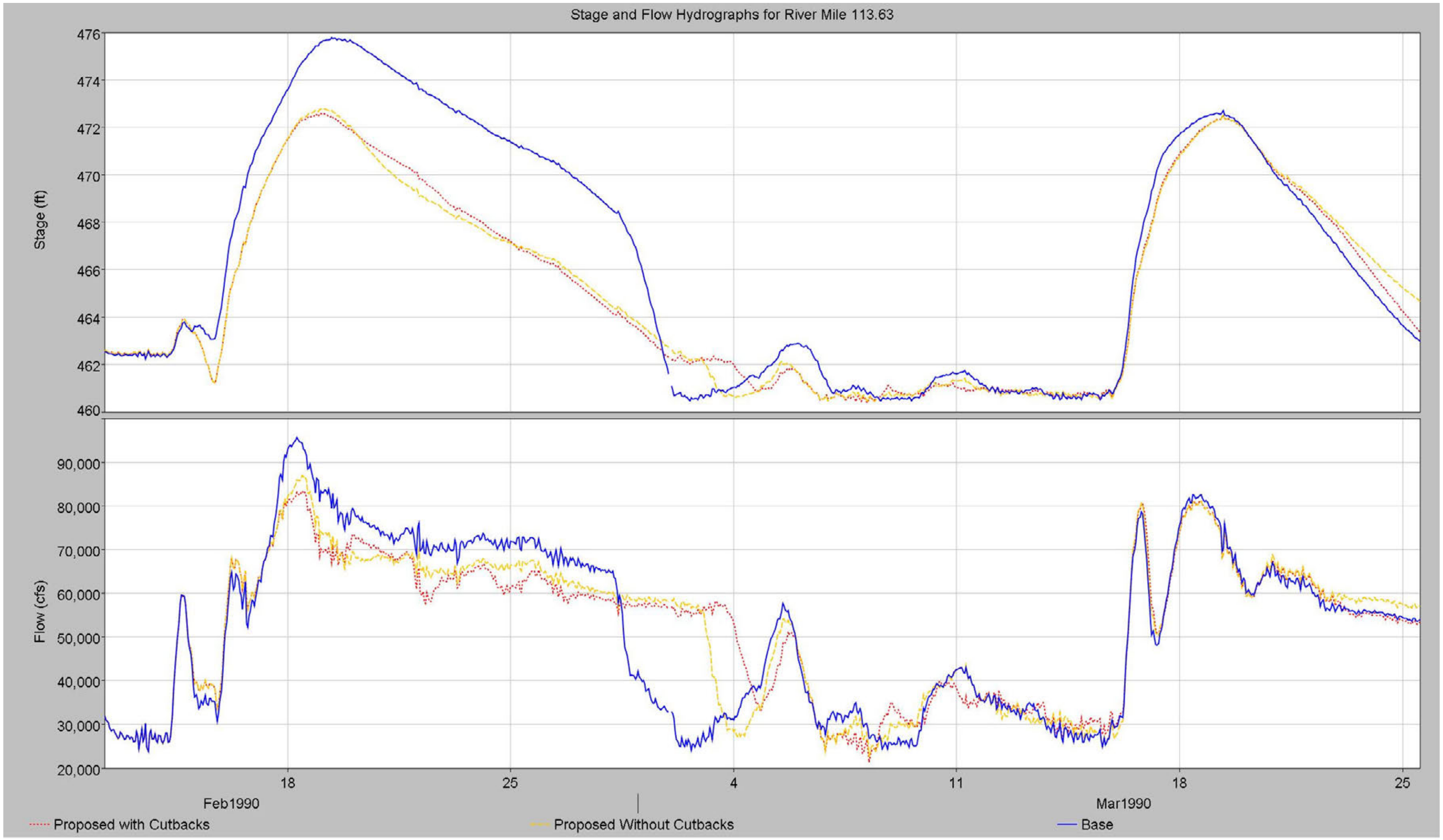

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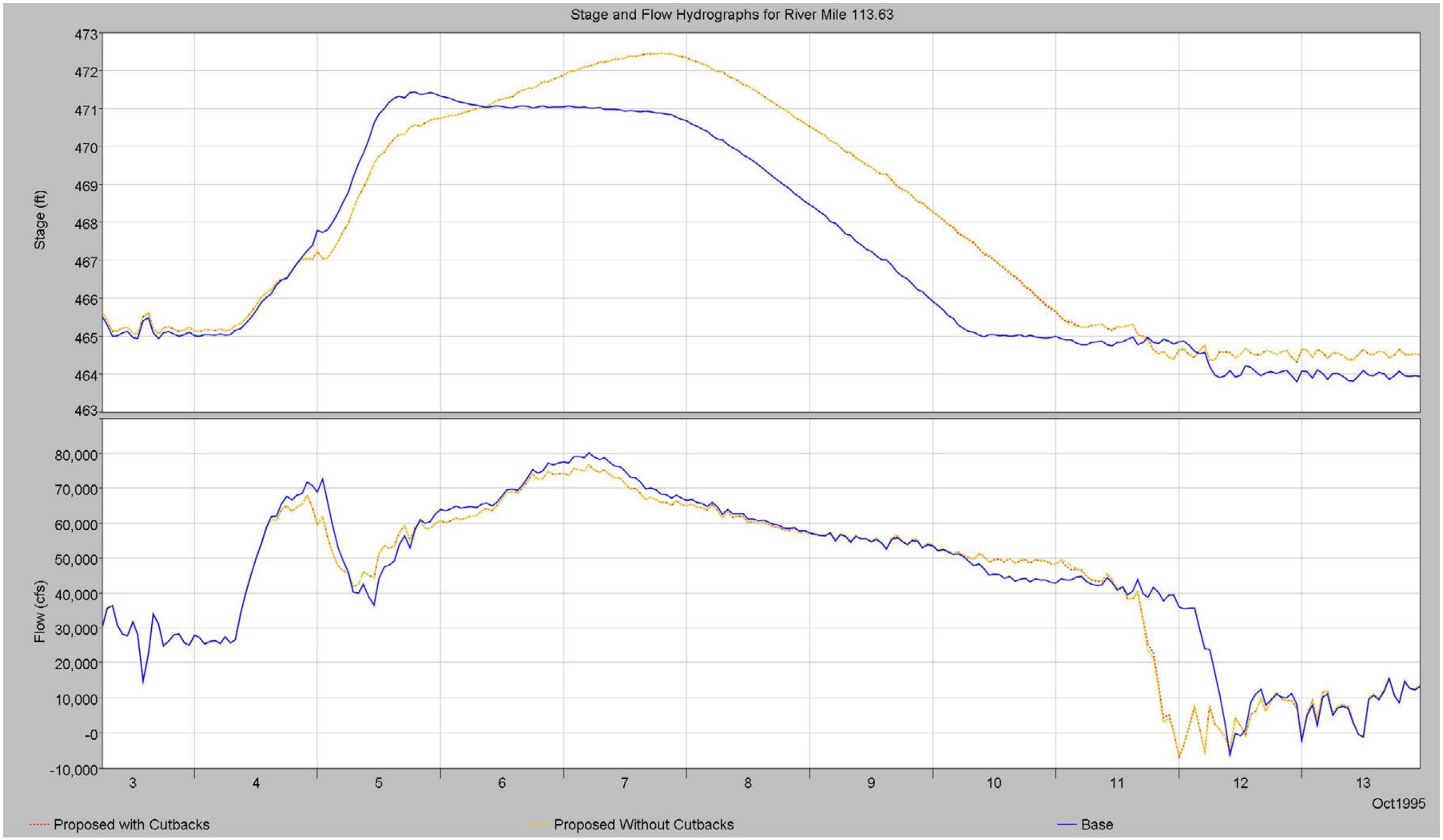

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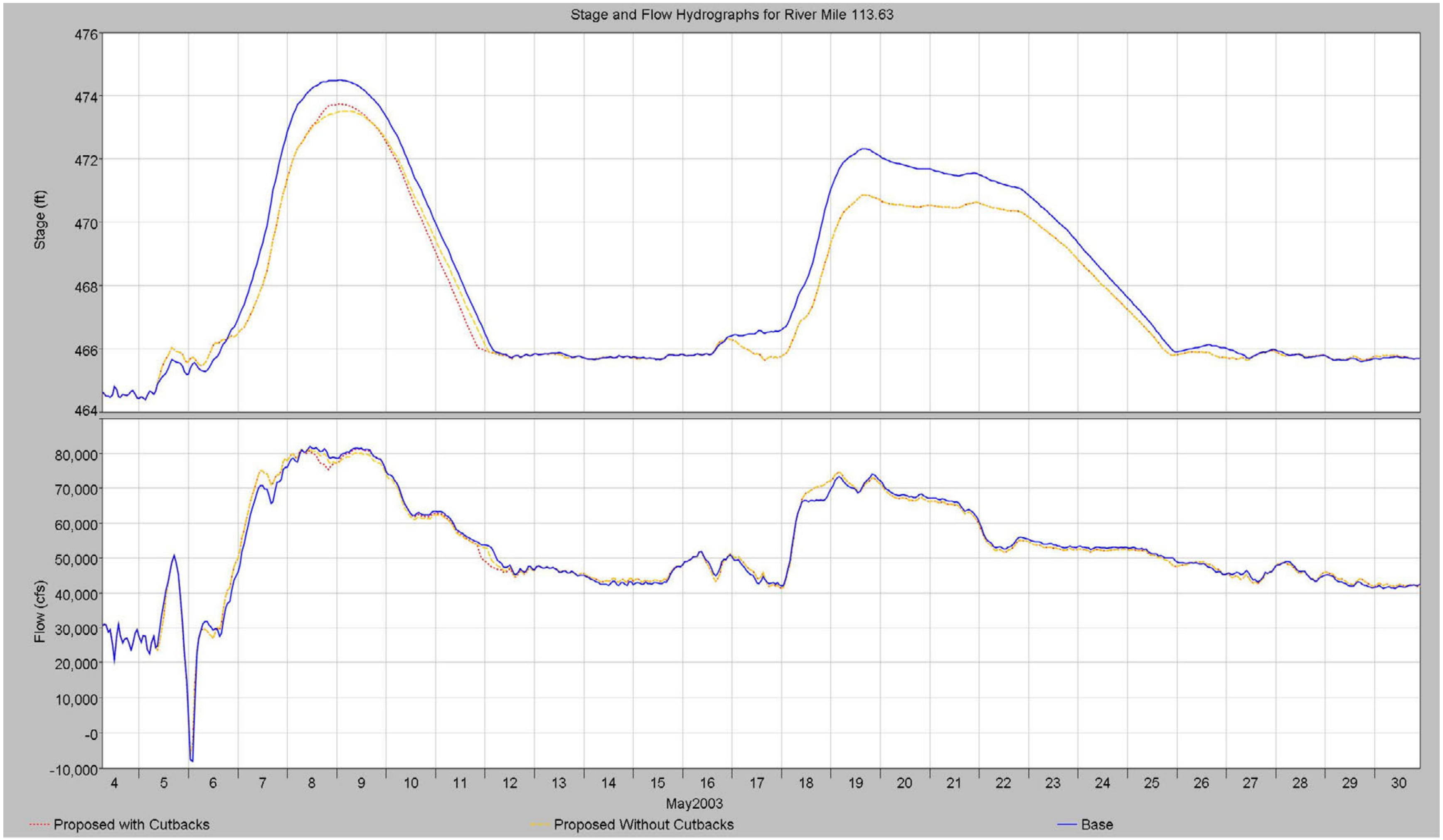
Stage/Flow at Coosa River Mile 113.63 Upstream of I-20 for the May 2003 Storm.



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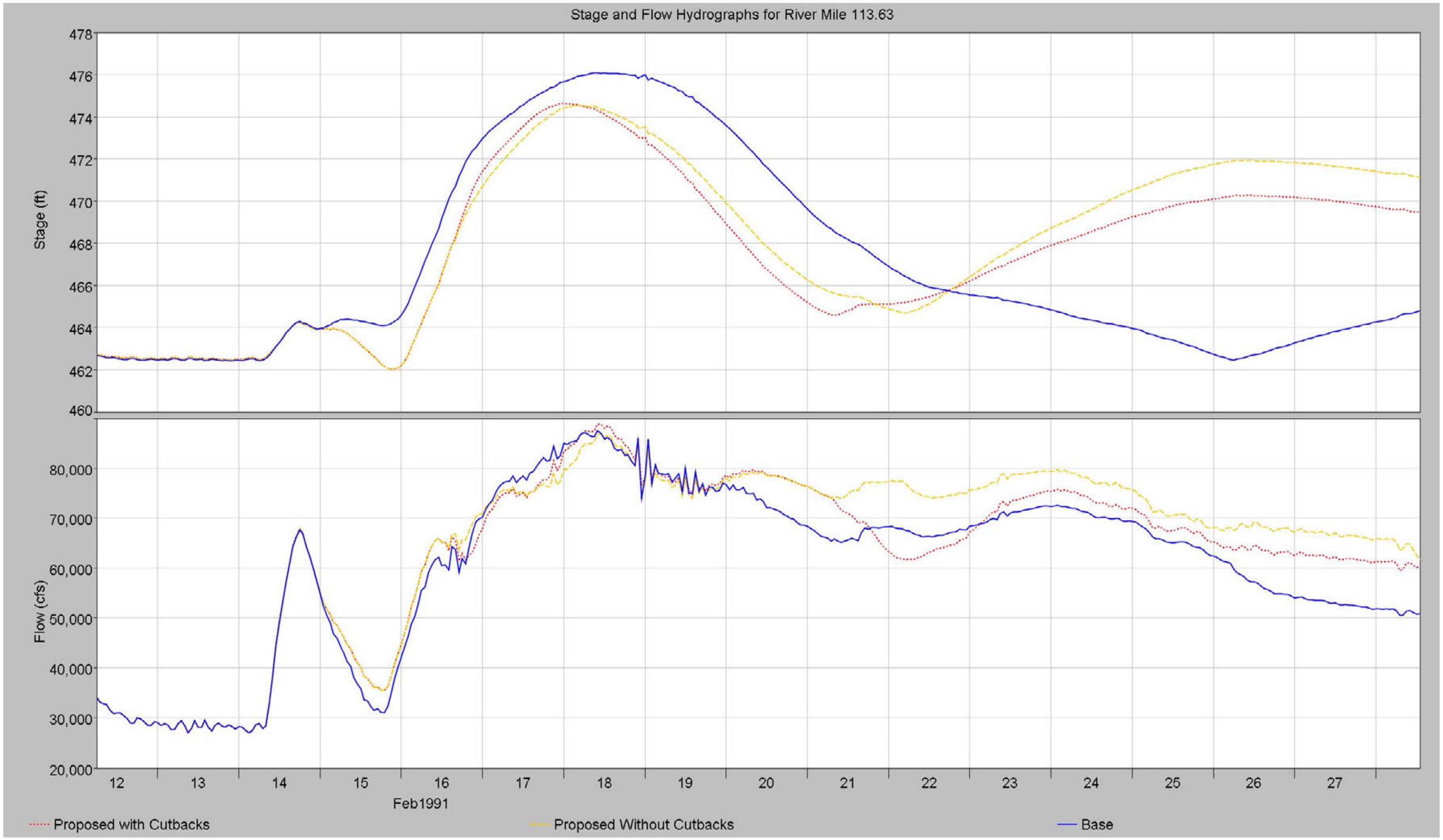

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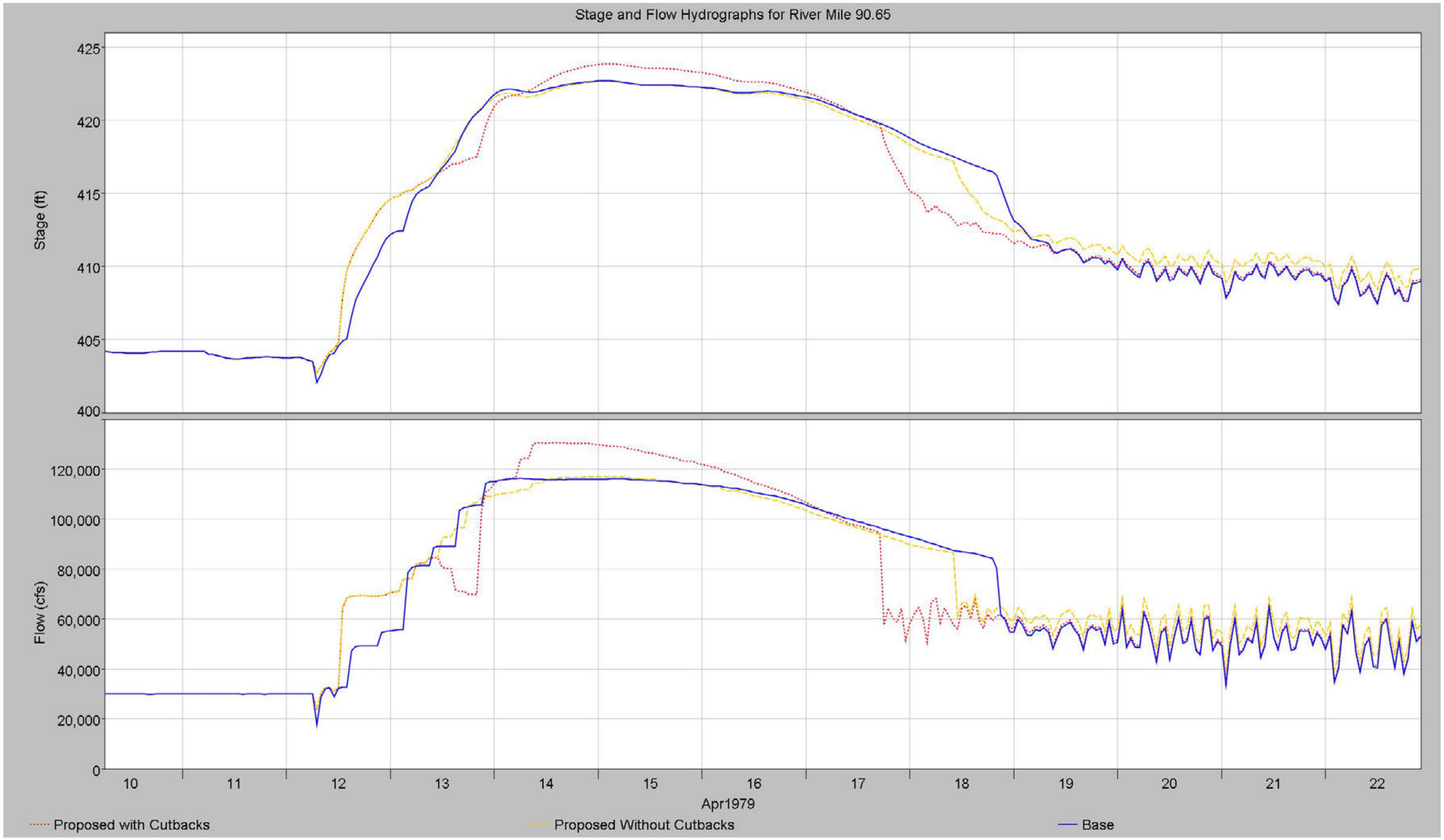
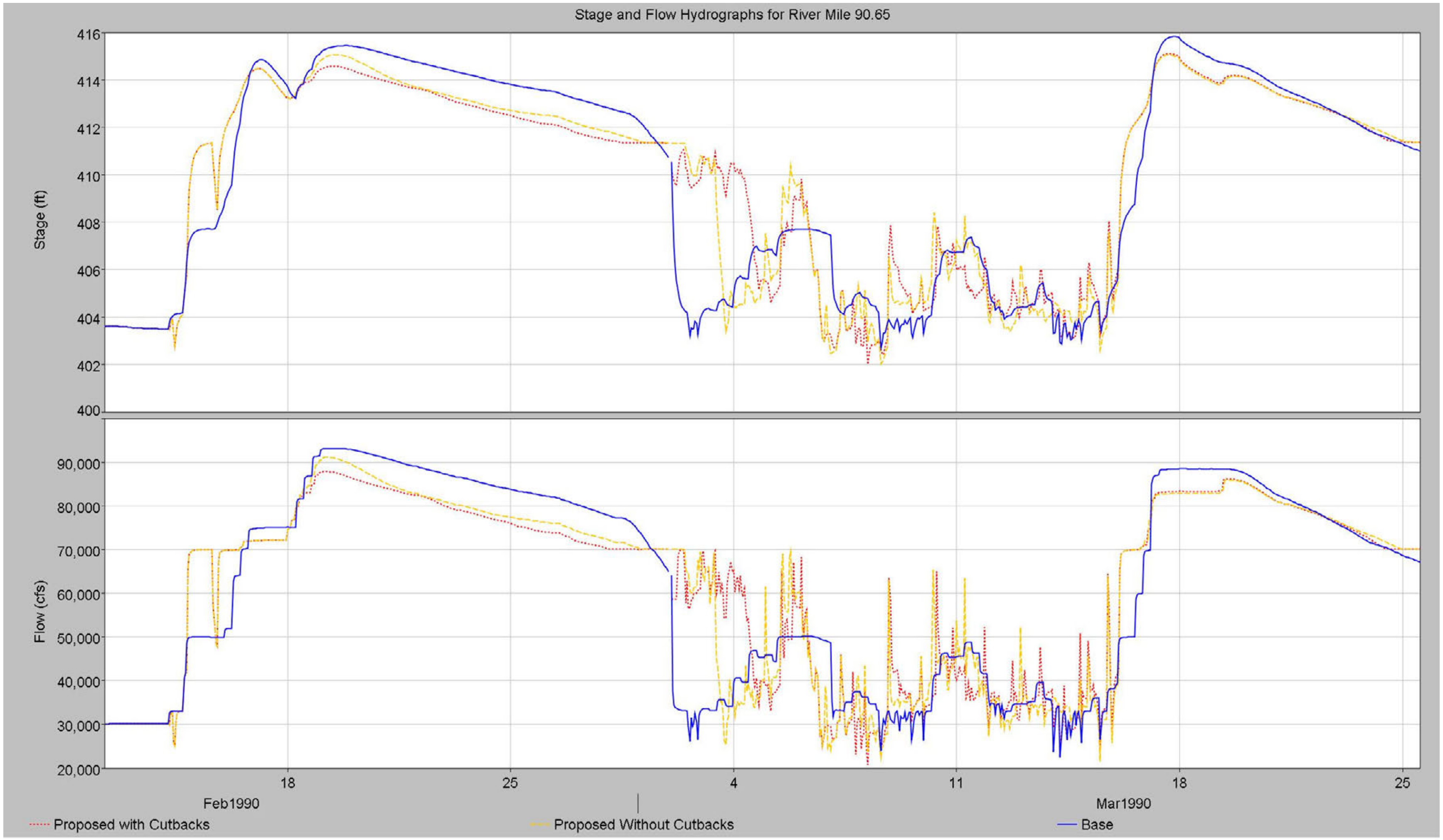


Stage/Flow at Coosa River Mile 90.65 Downstream of Logan Martin Dam for the April 1979 Storm.



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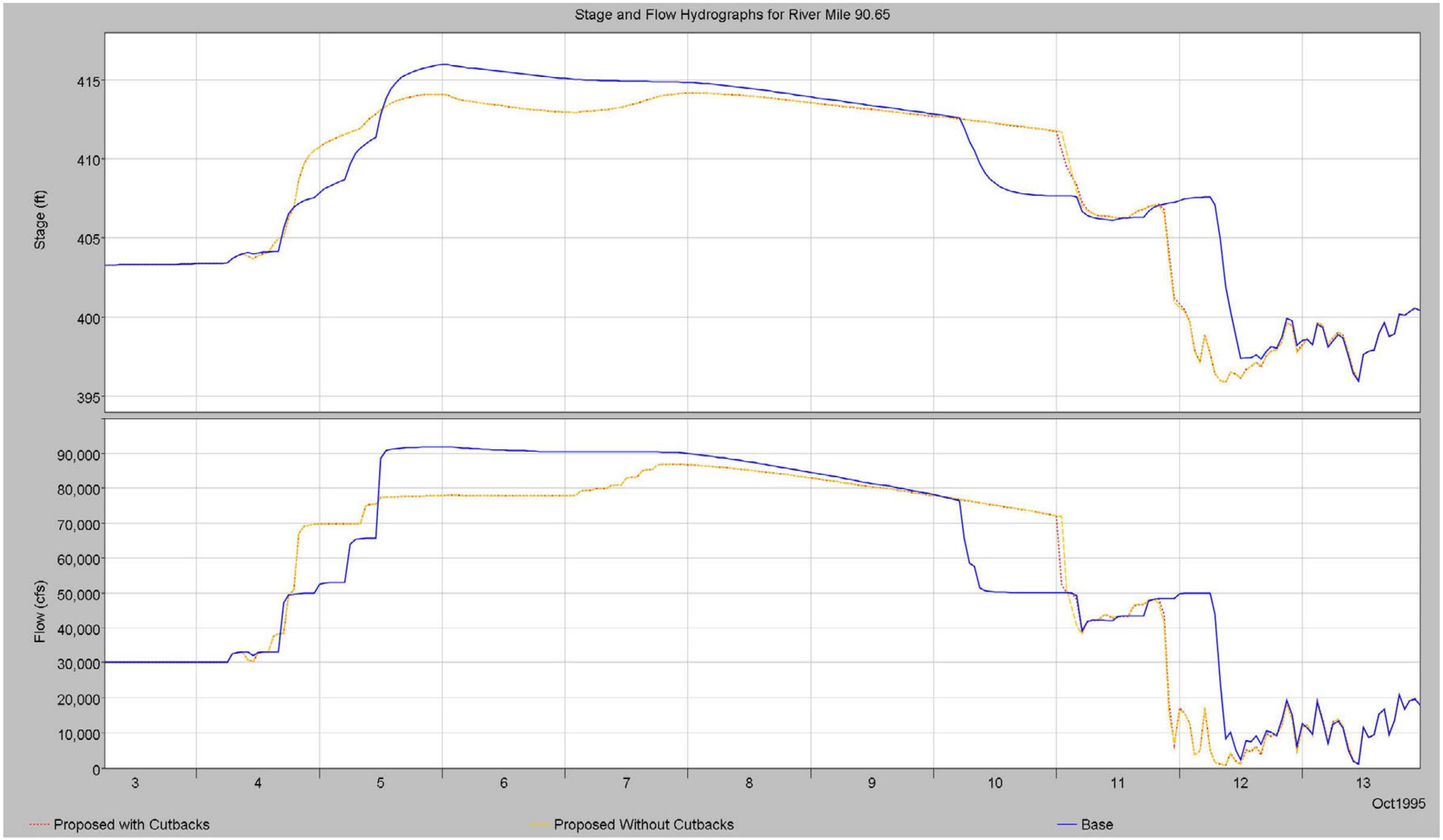

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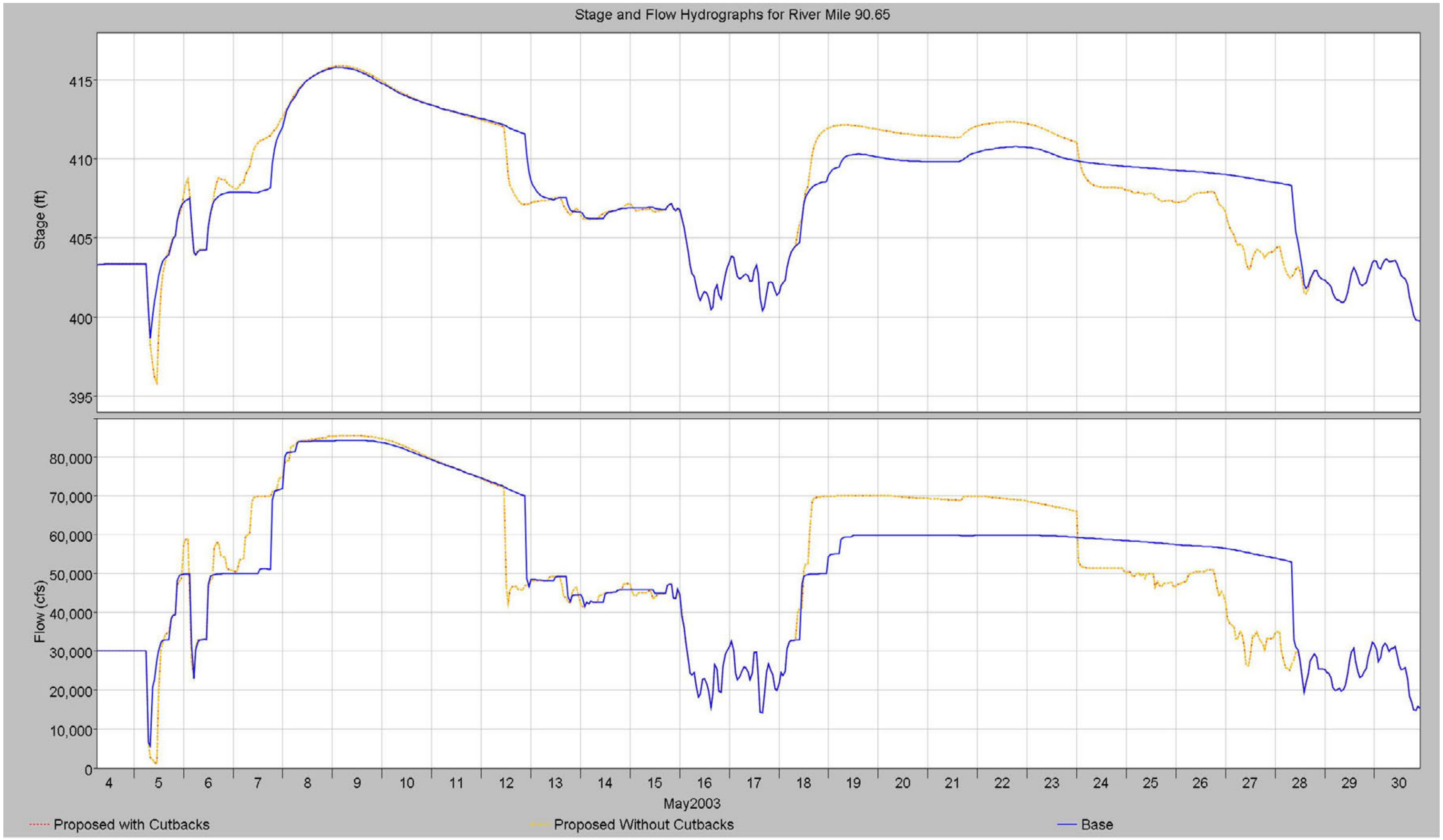

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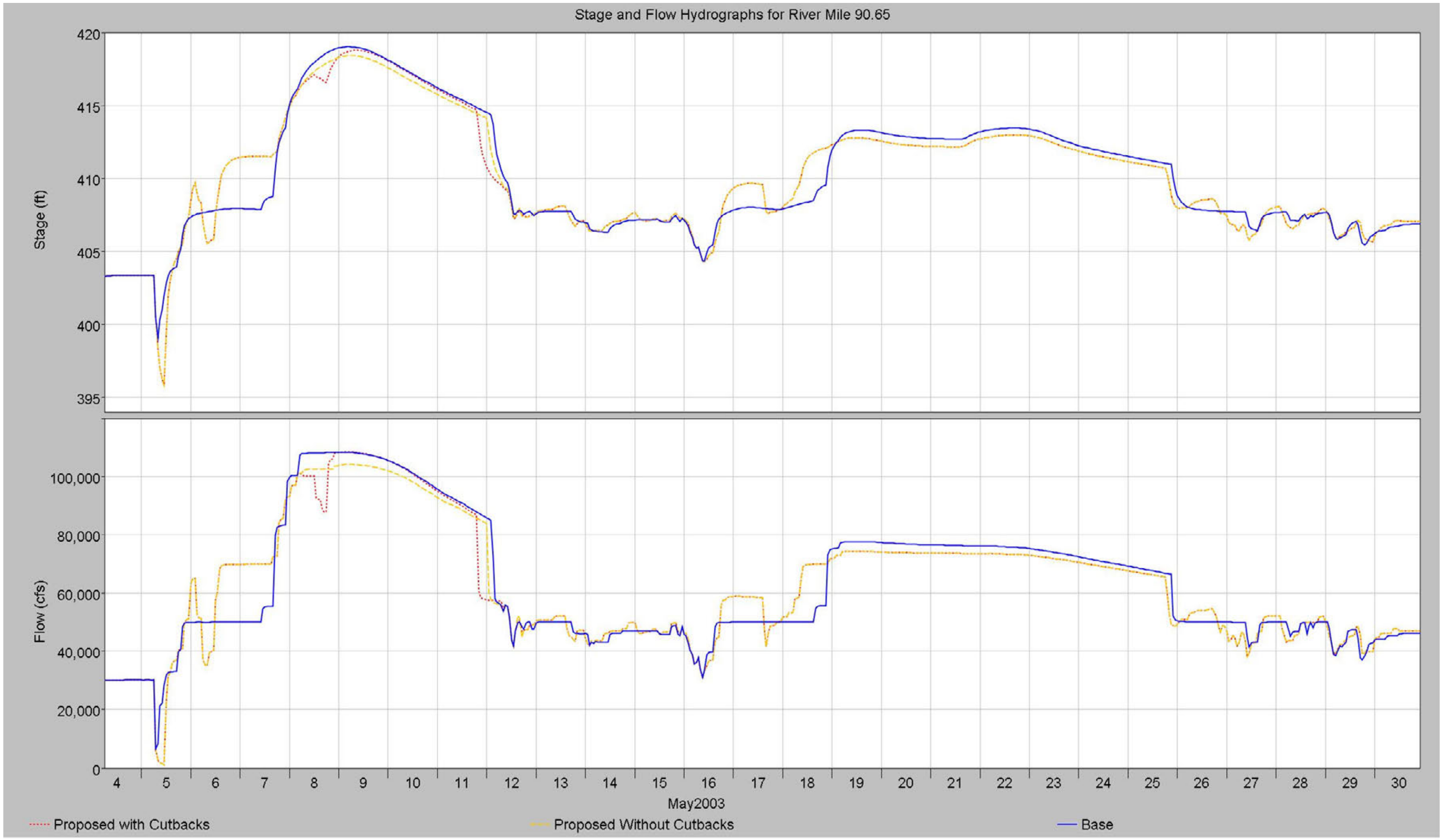

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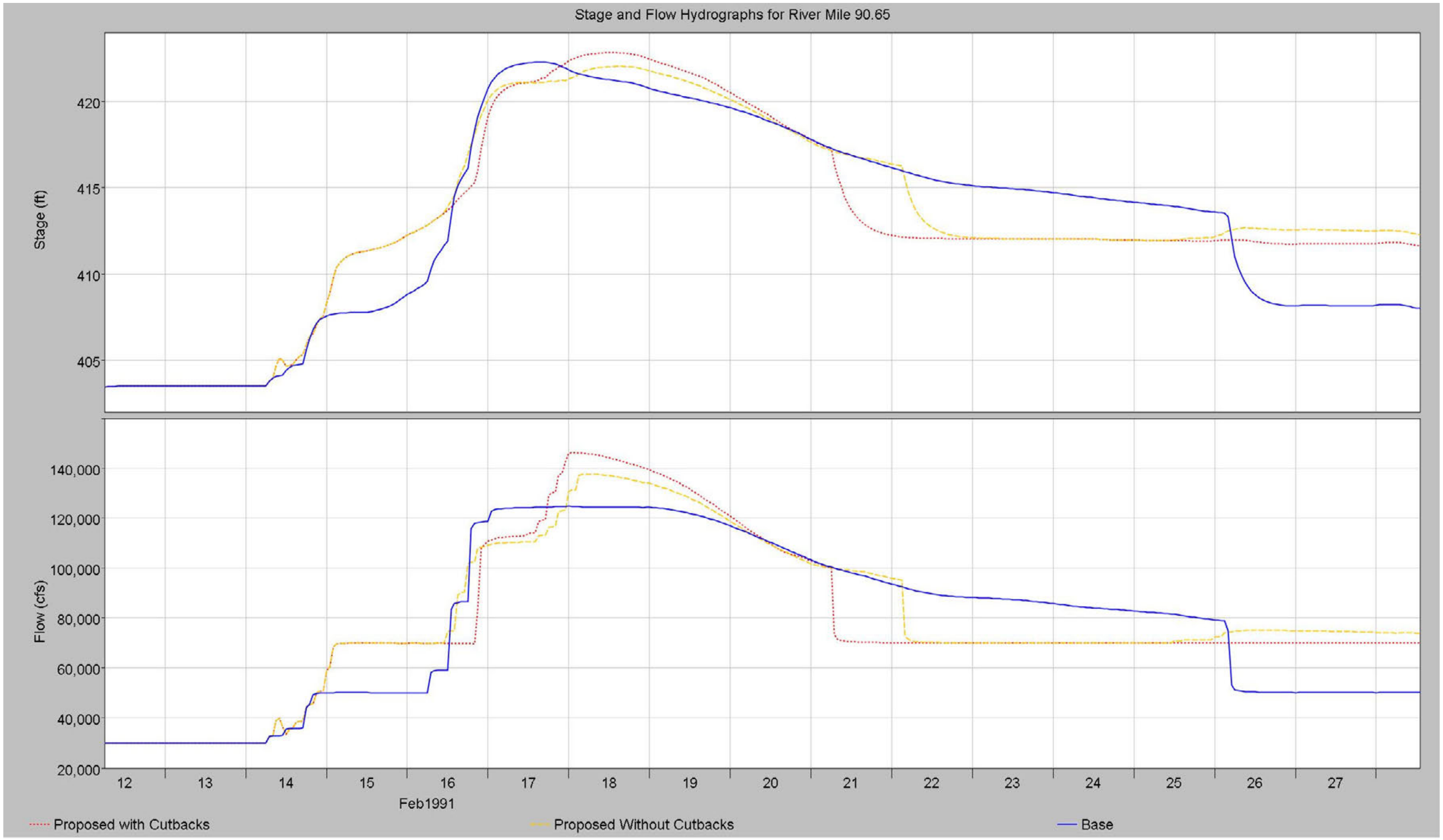

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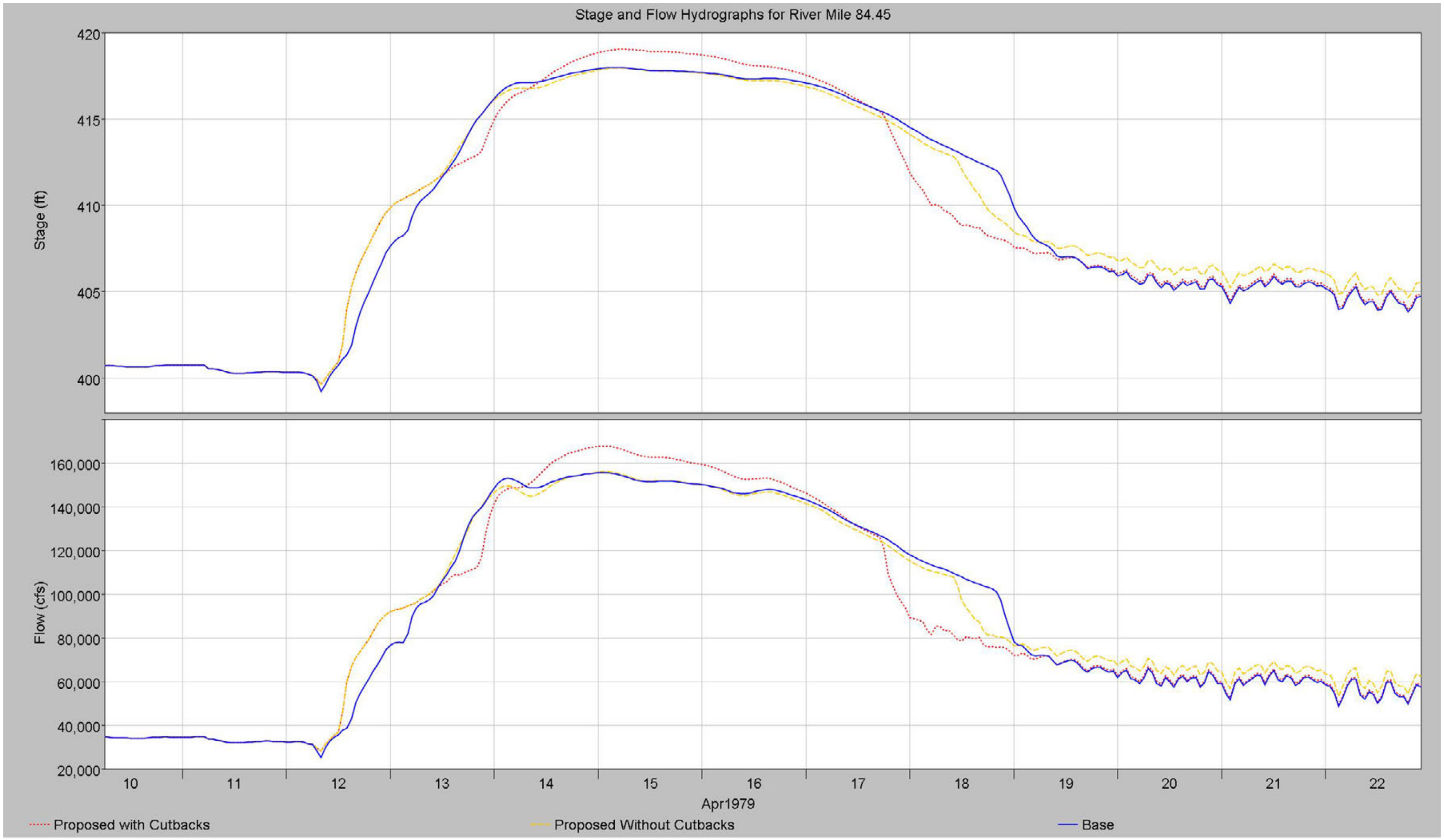
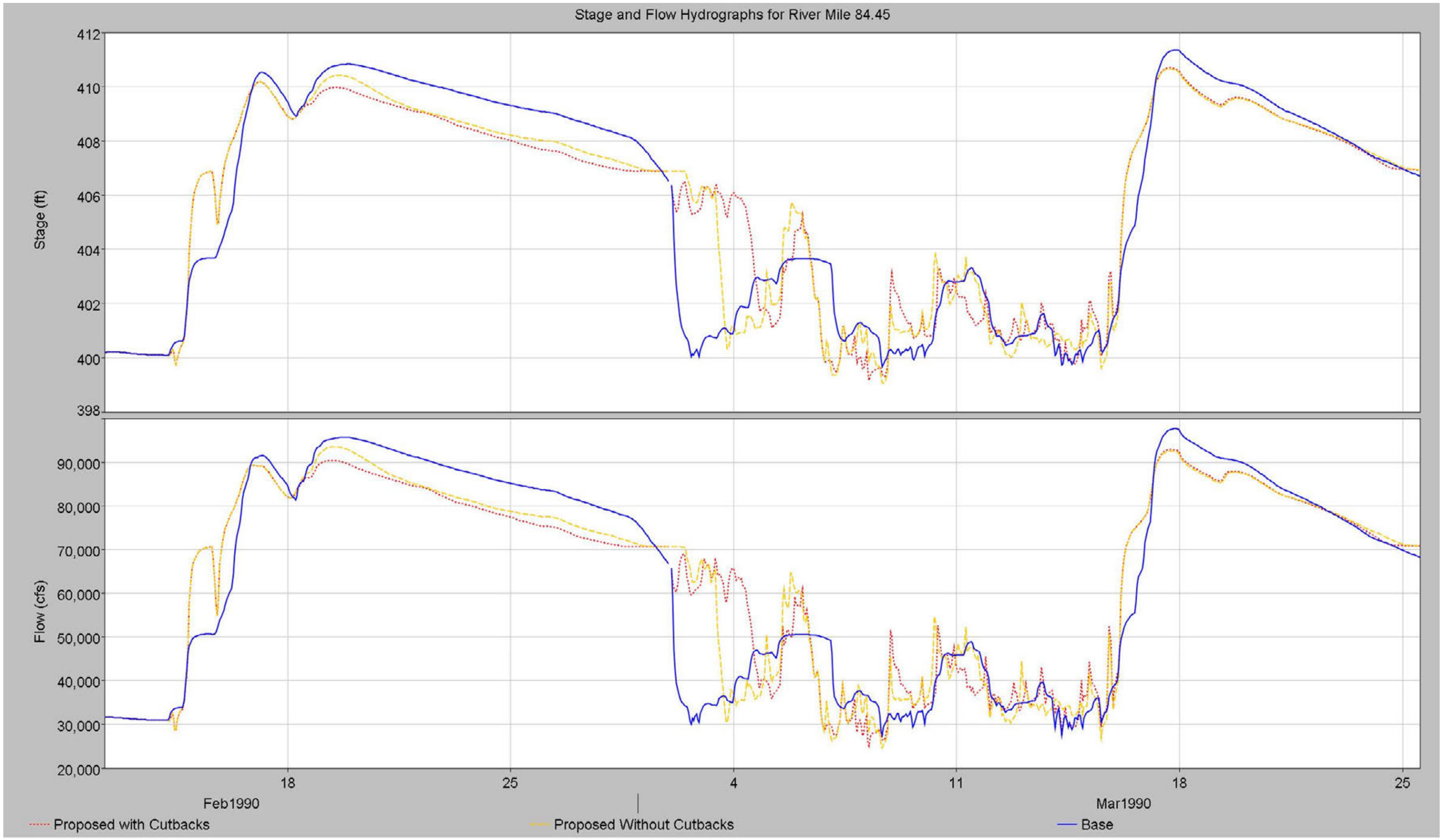


Stage/Flow at Coosa River Mile 84.45 Adjacent to the Coosa Industrial Complex for the April 1979 Storm.



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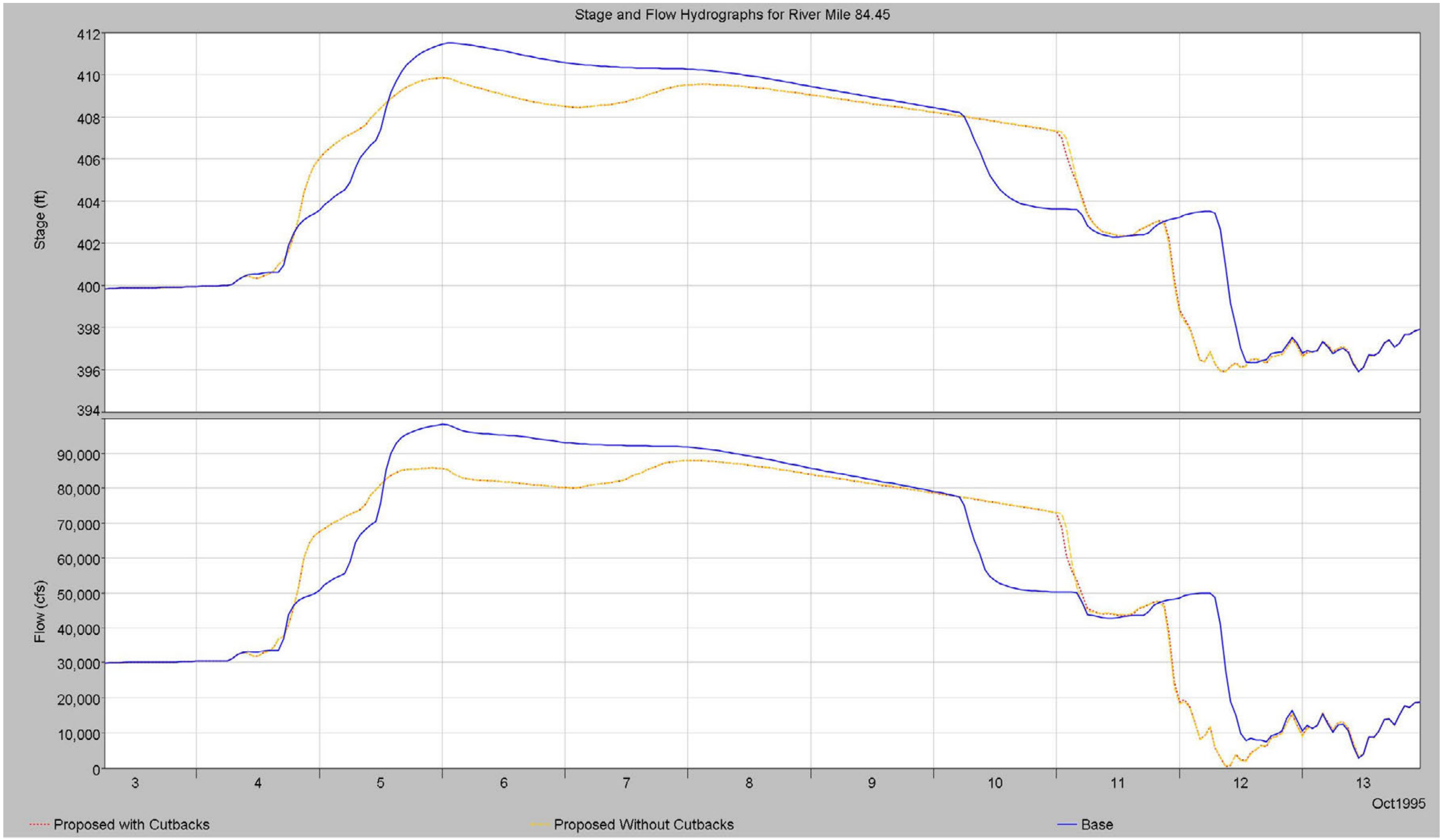

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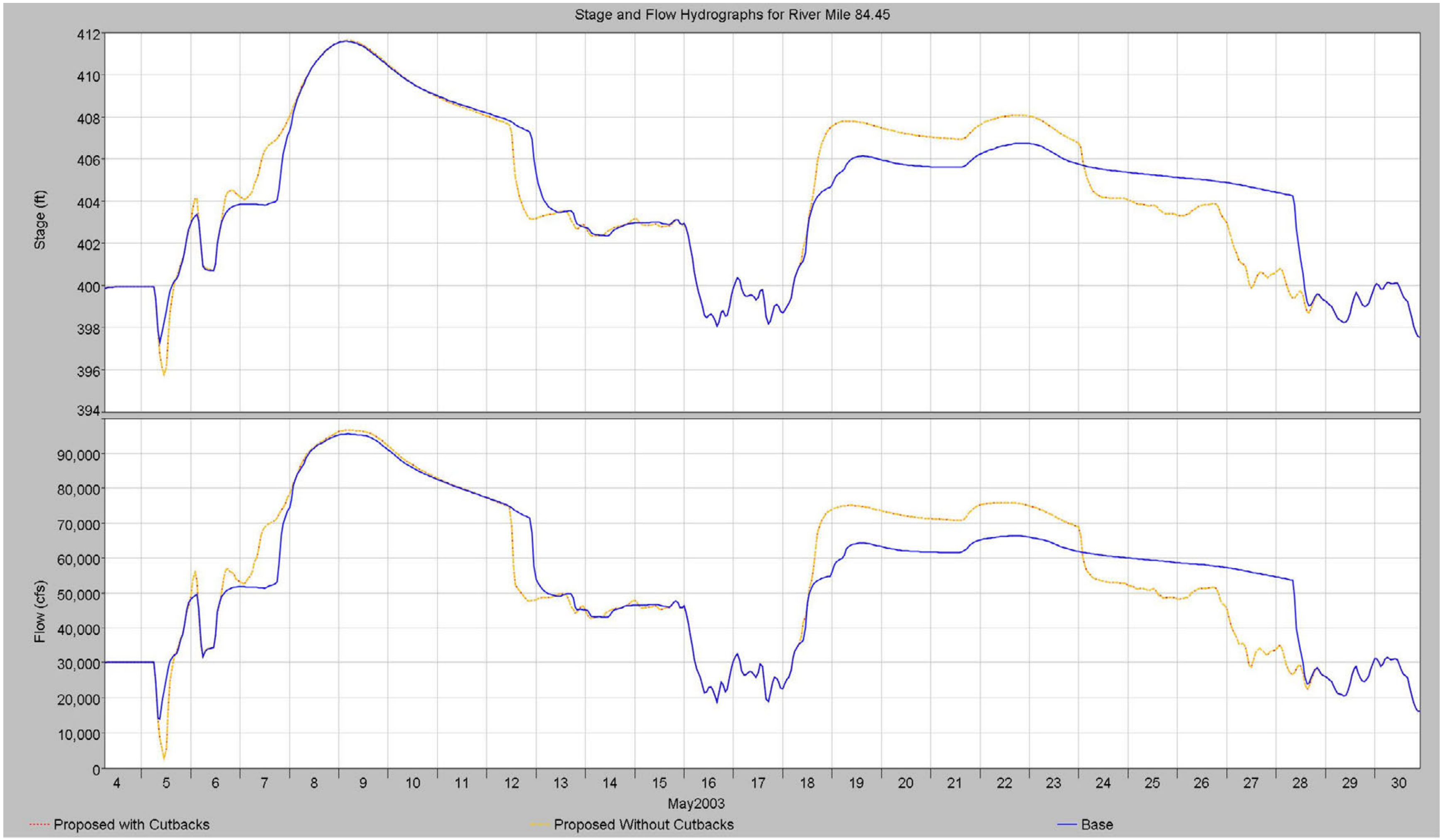

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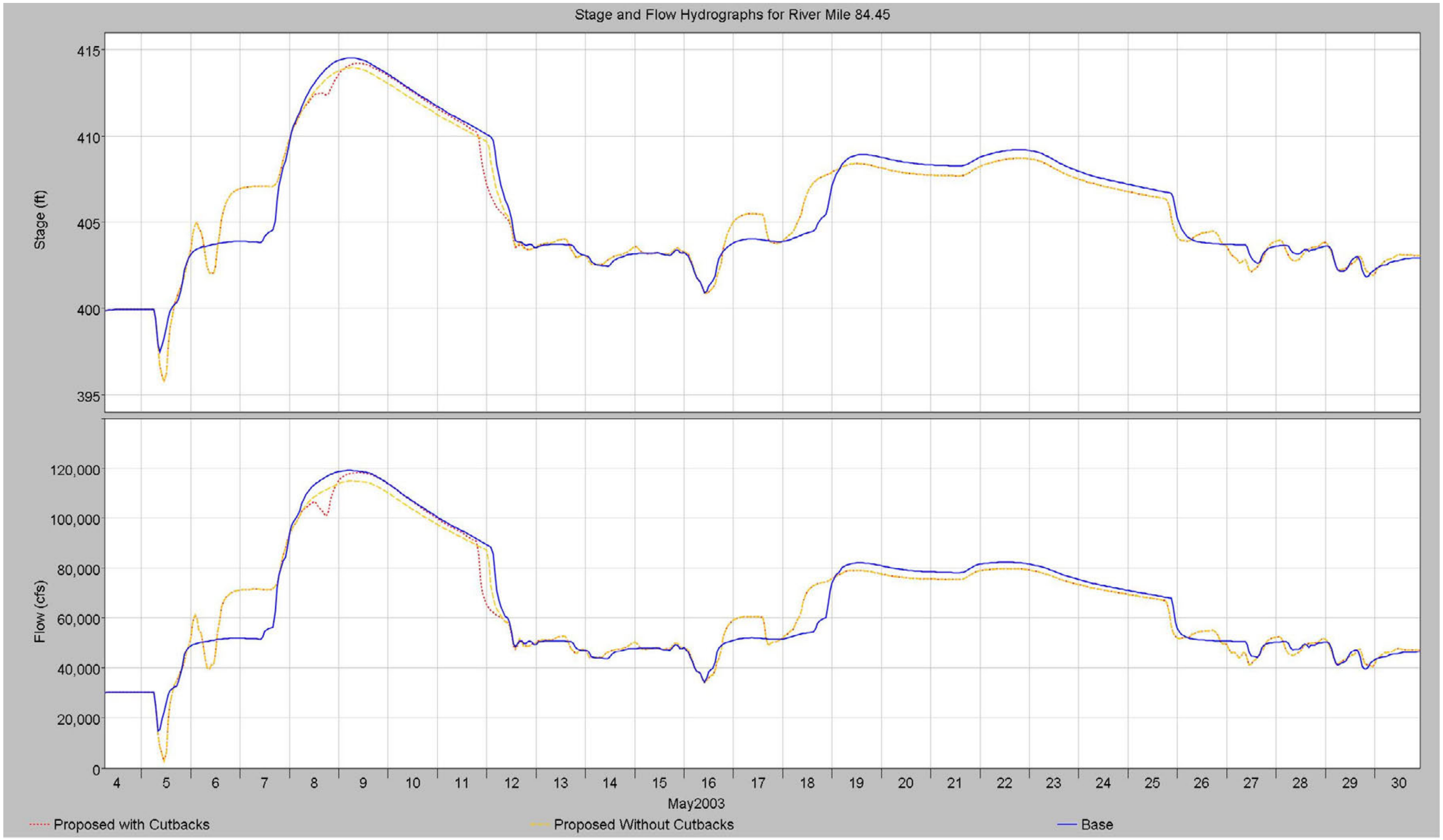

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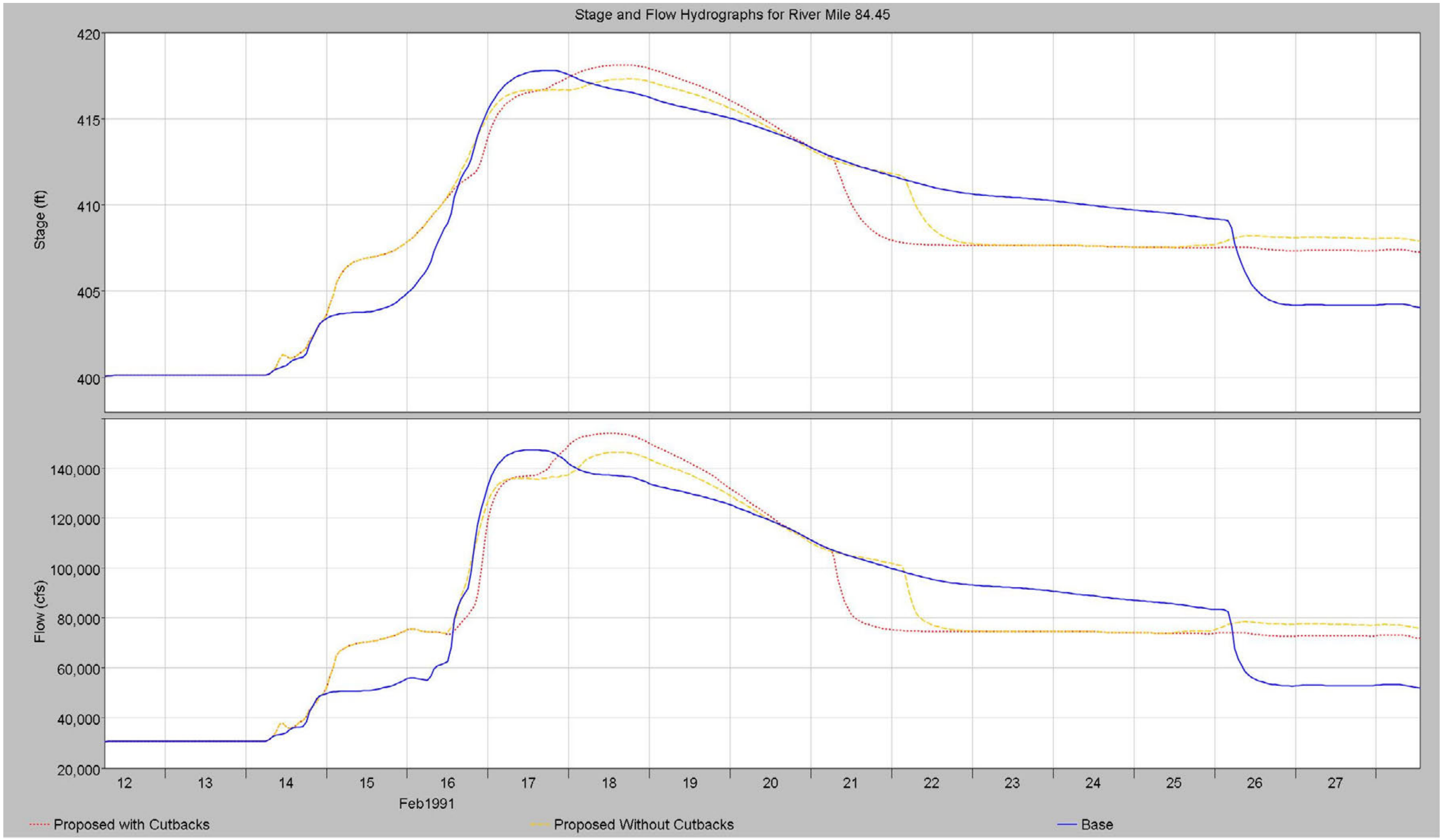

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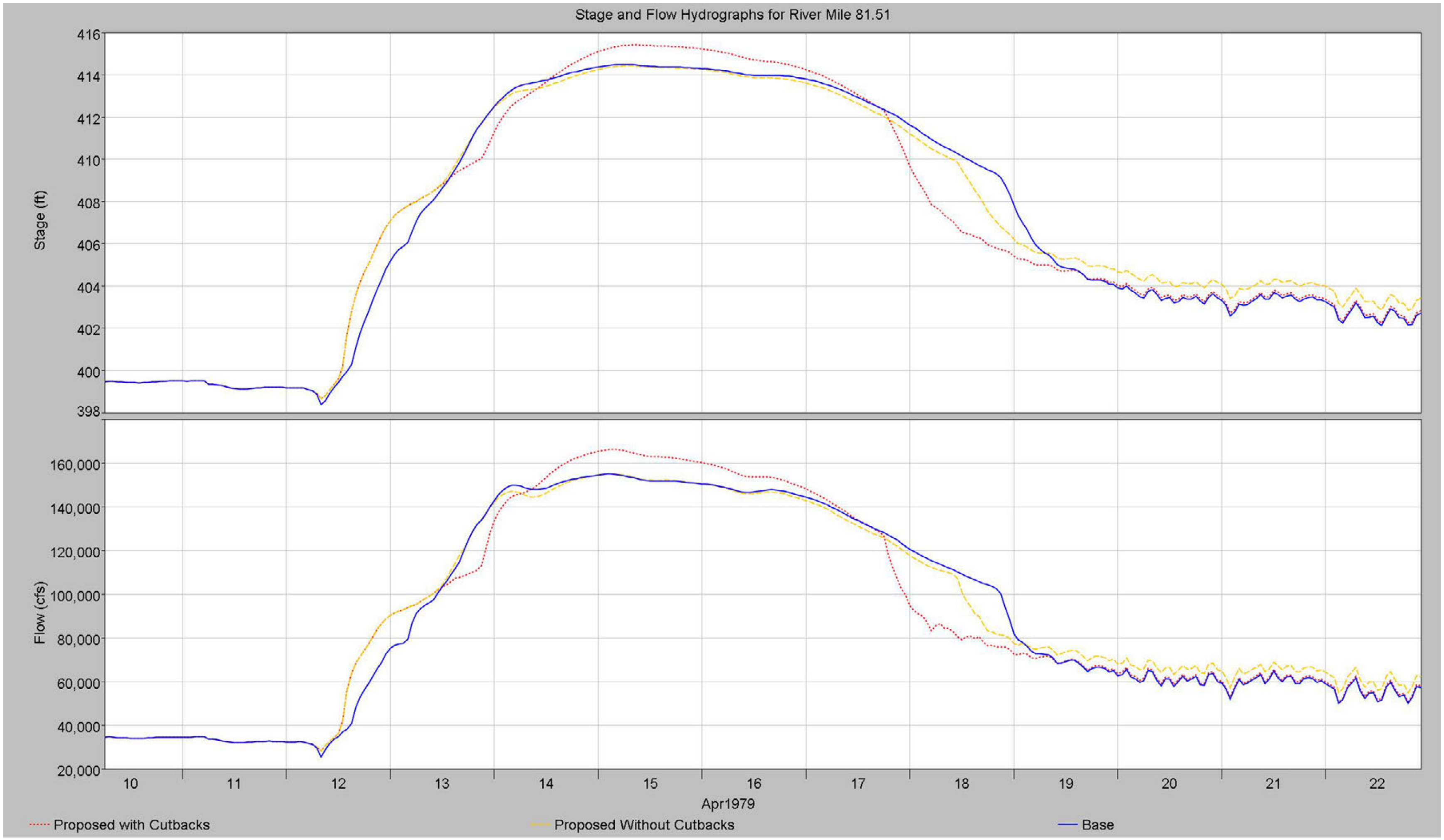
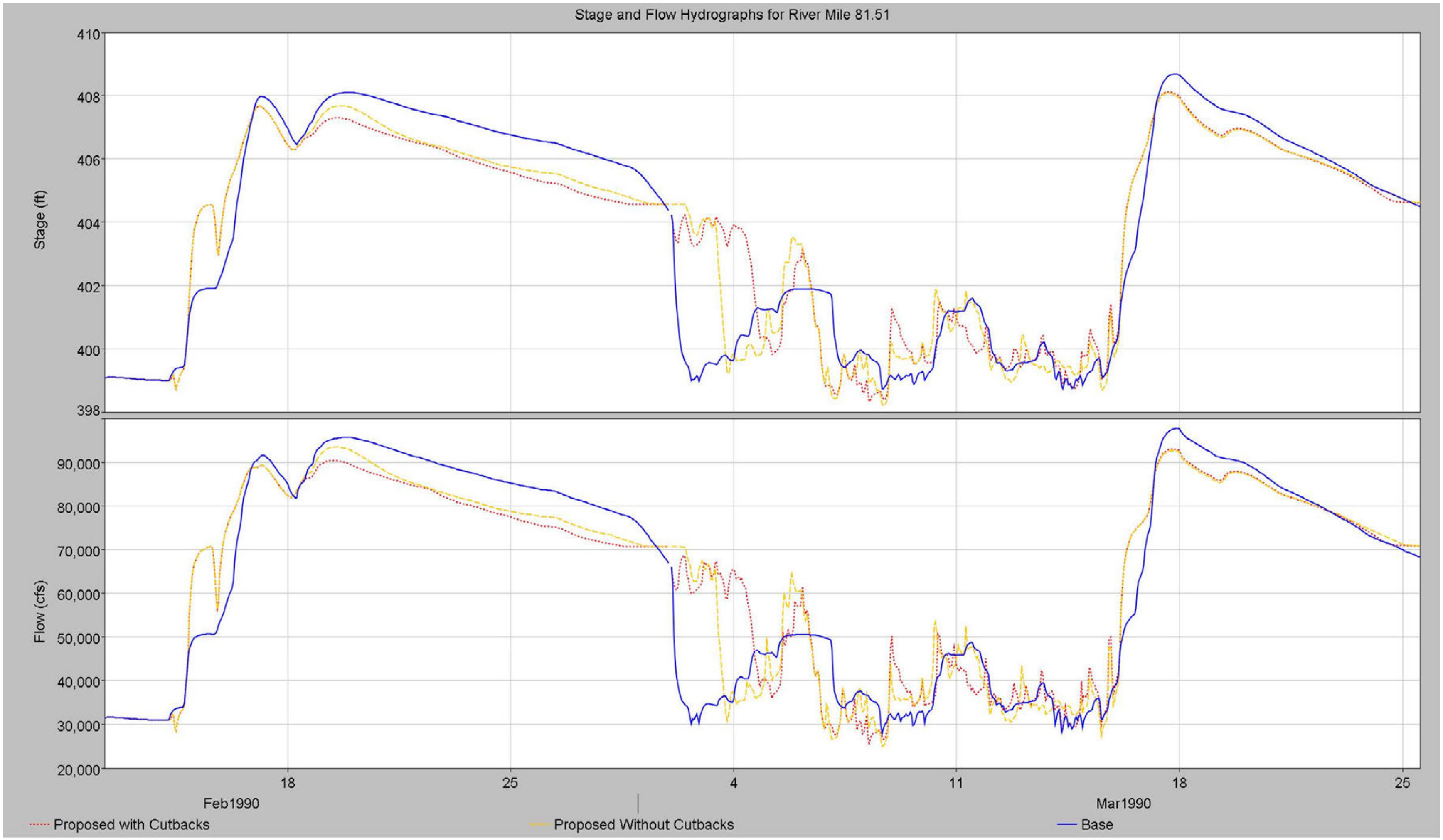


Stage/Flow at Coosa River Mile 81.51 Adjacent to the Coosa Pines Paper Mill for the April 1979 Storm.



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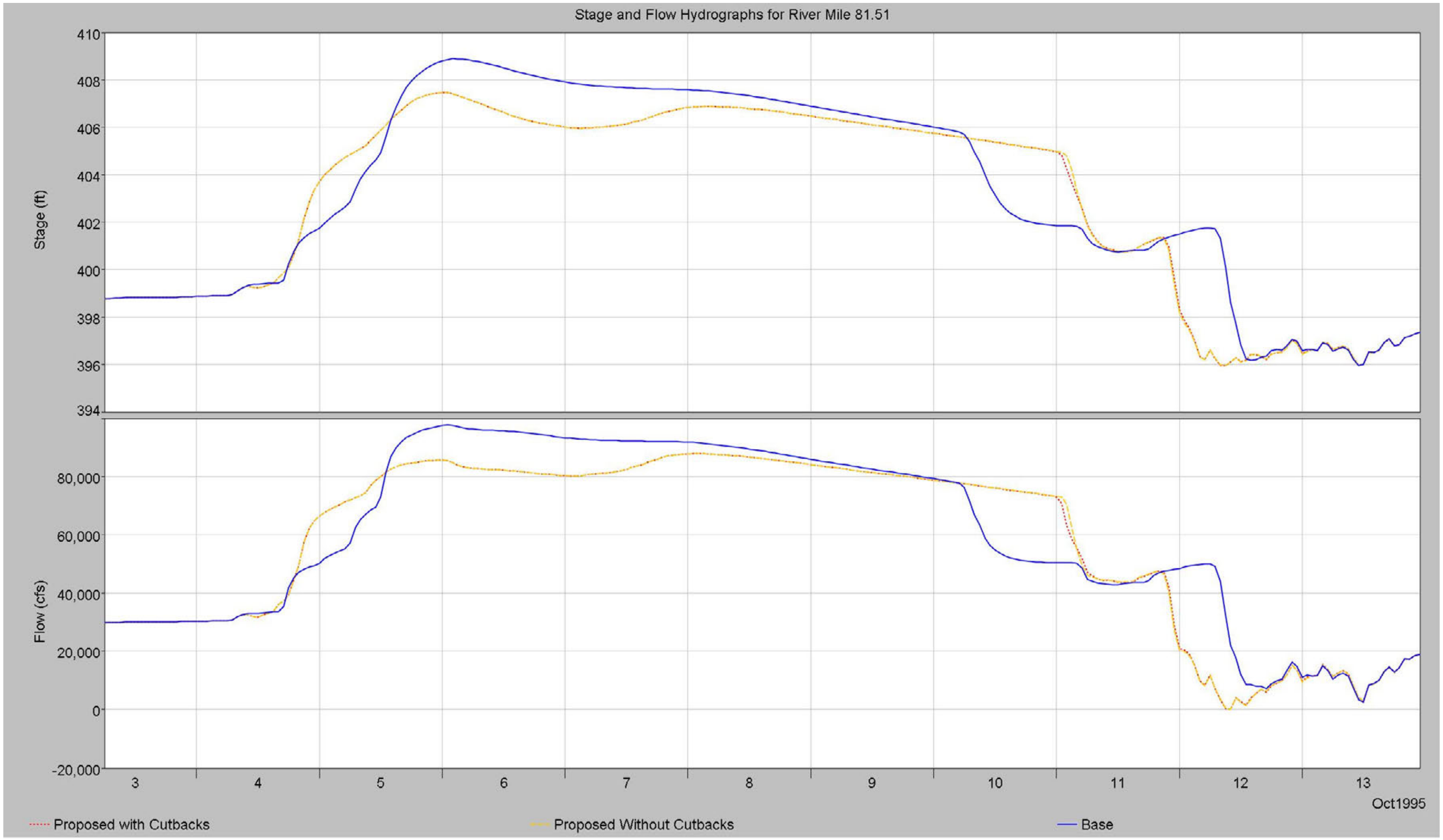

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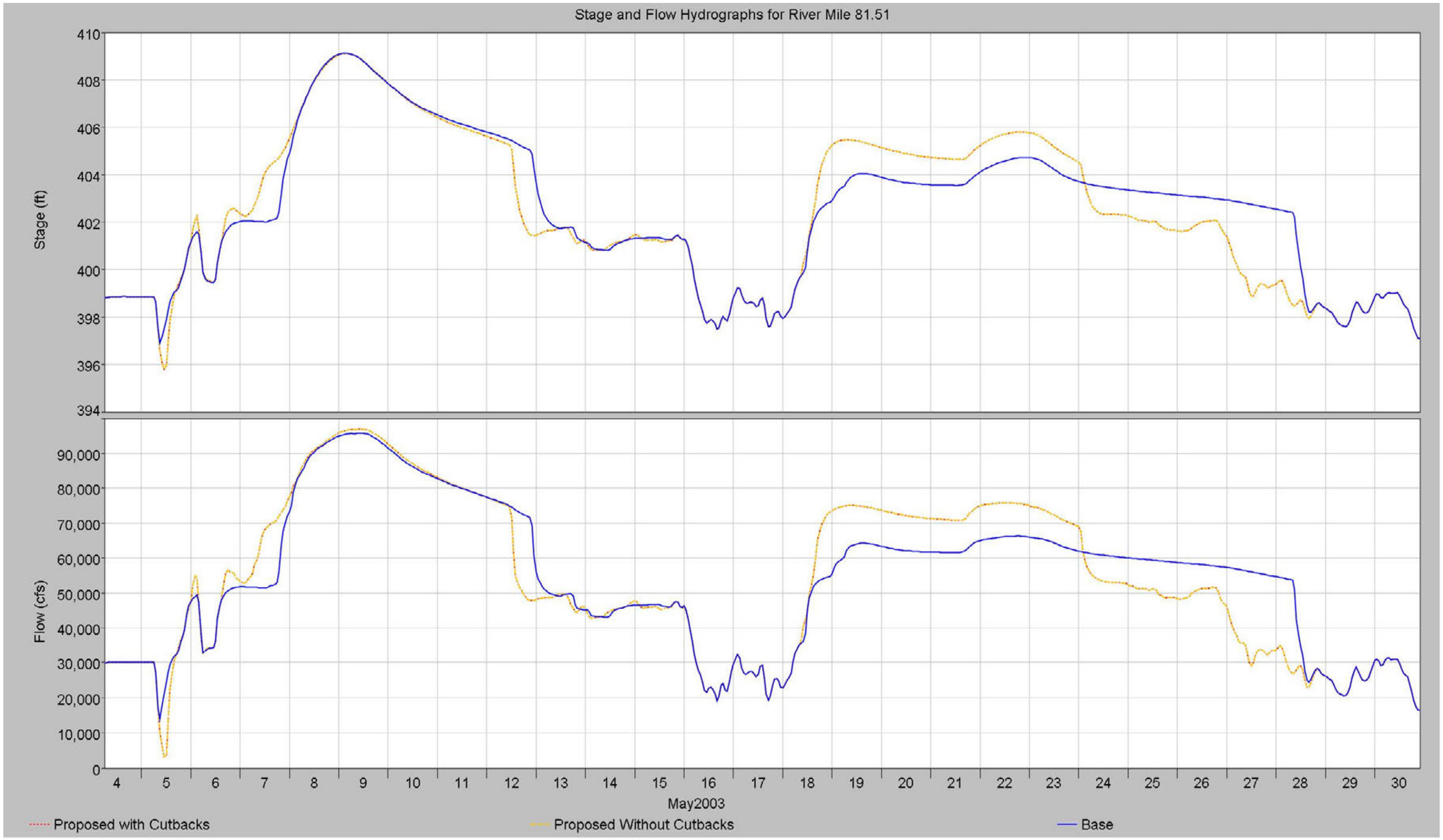

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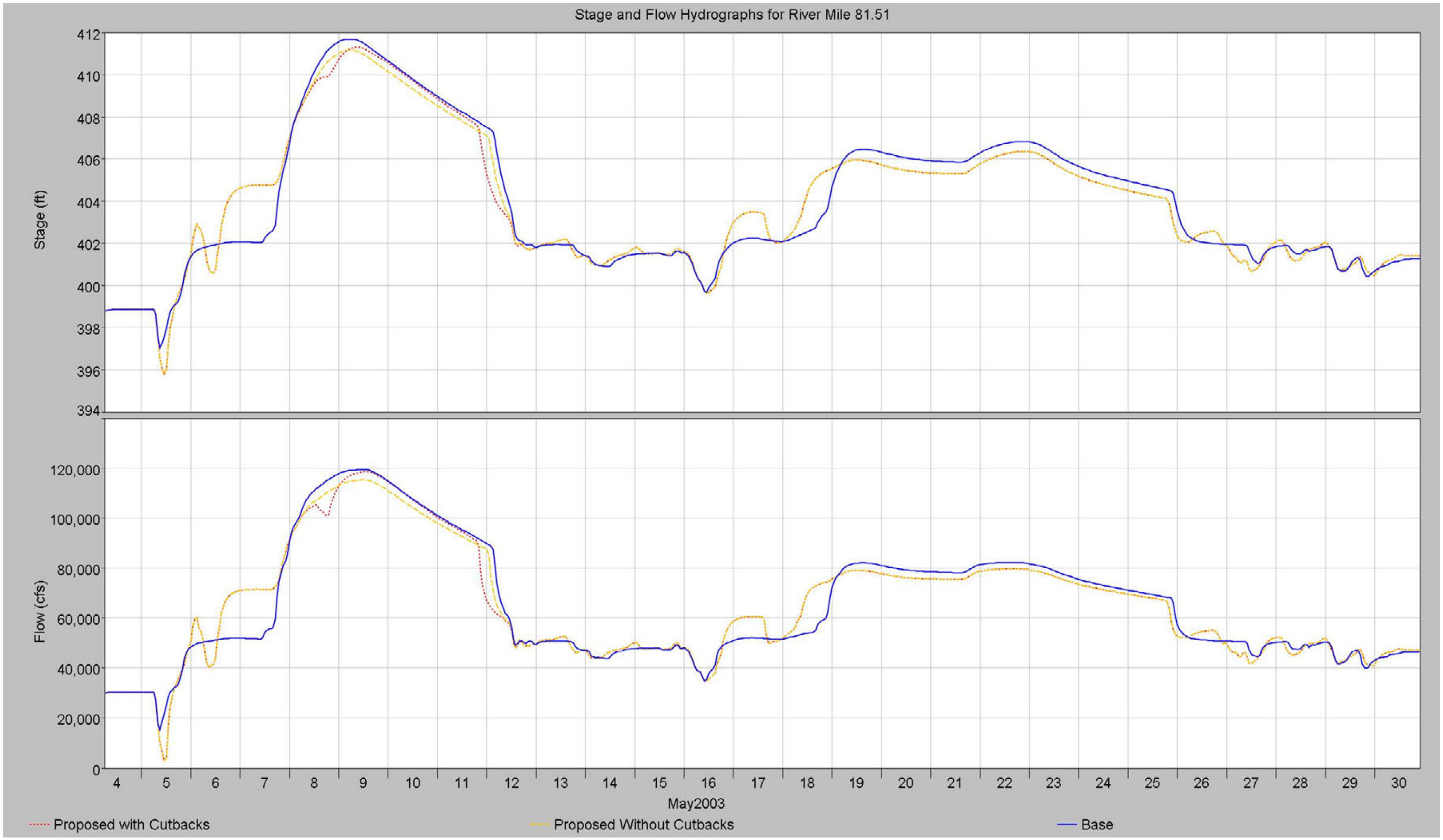

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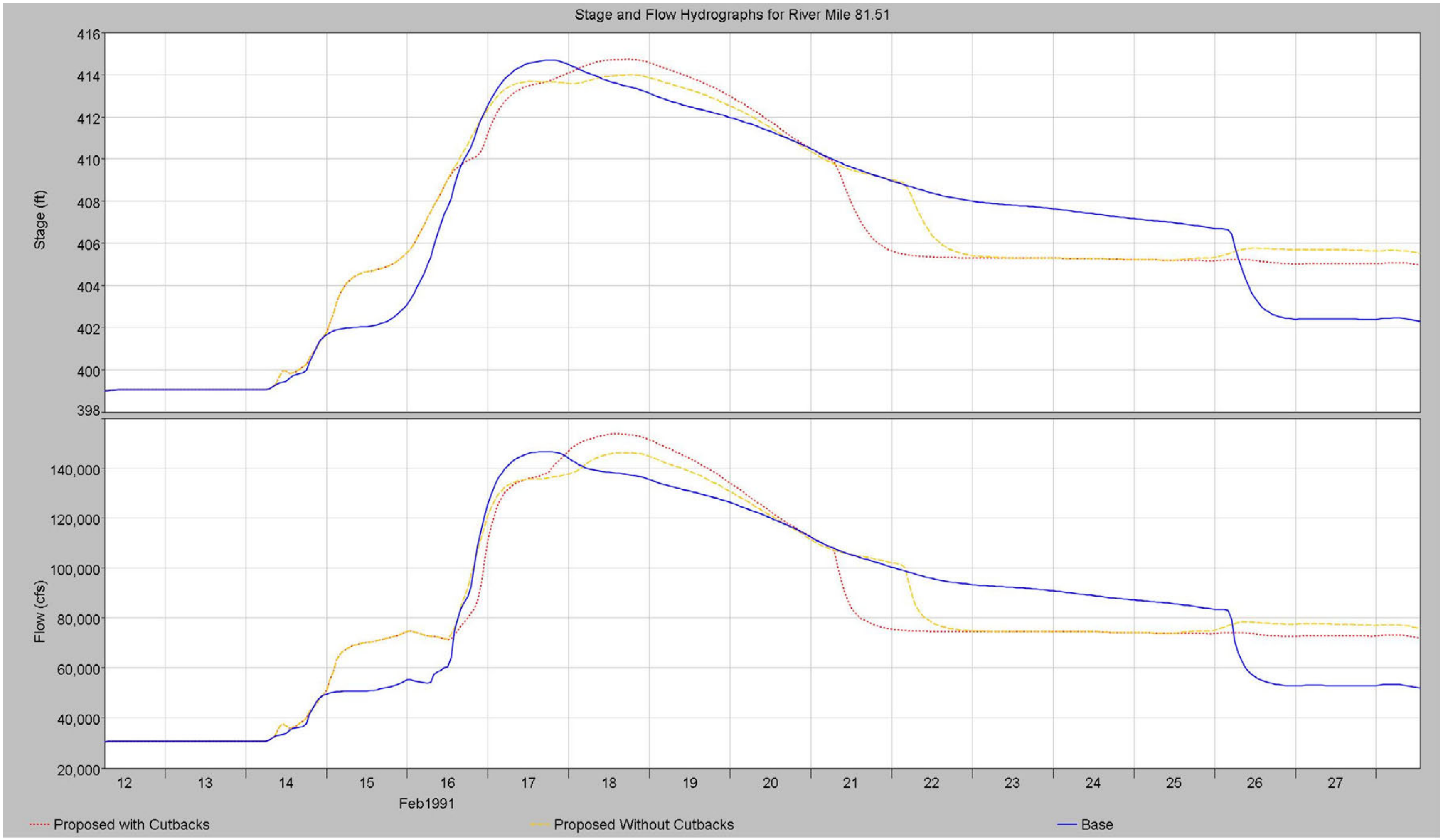

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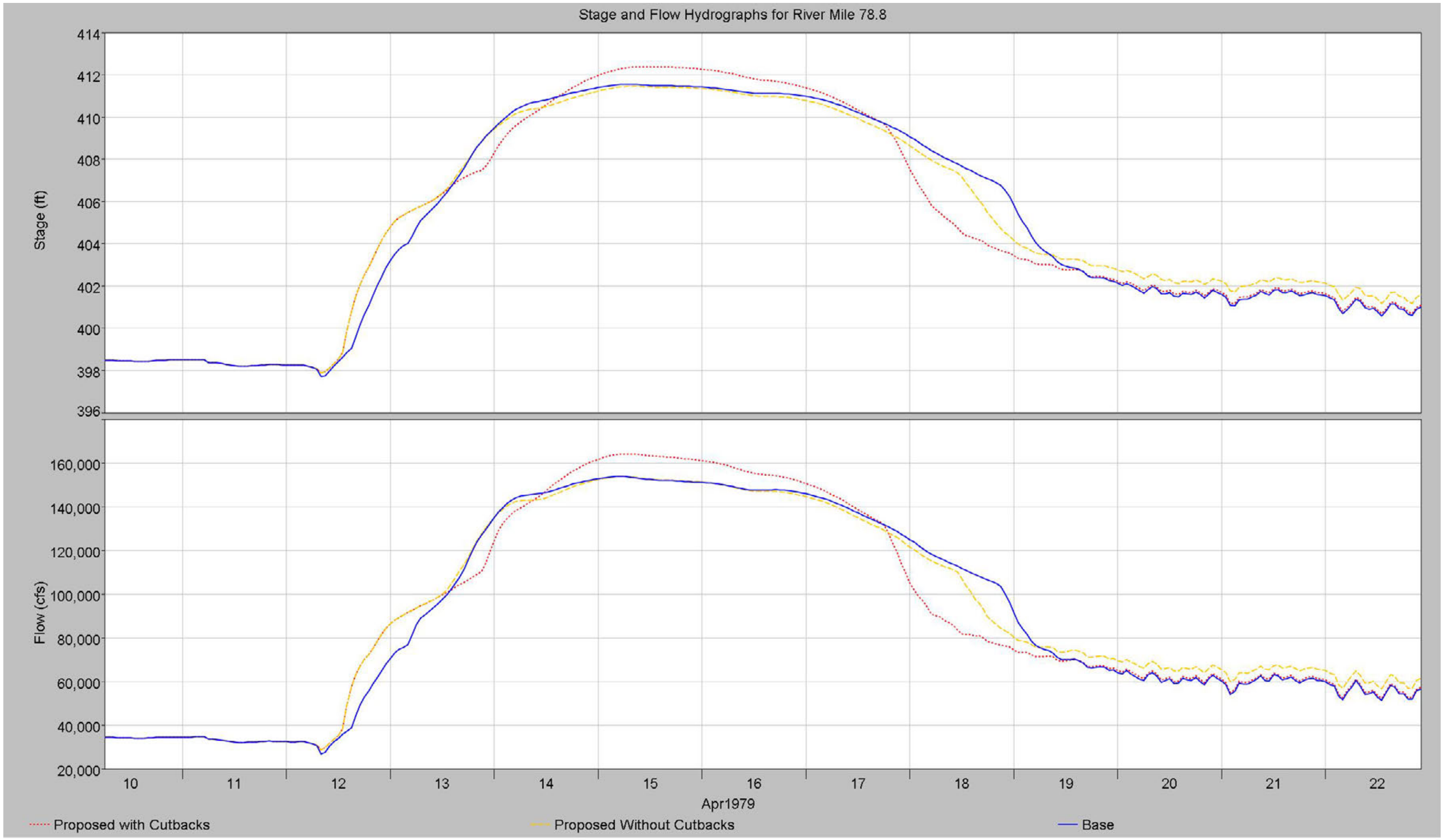
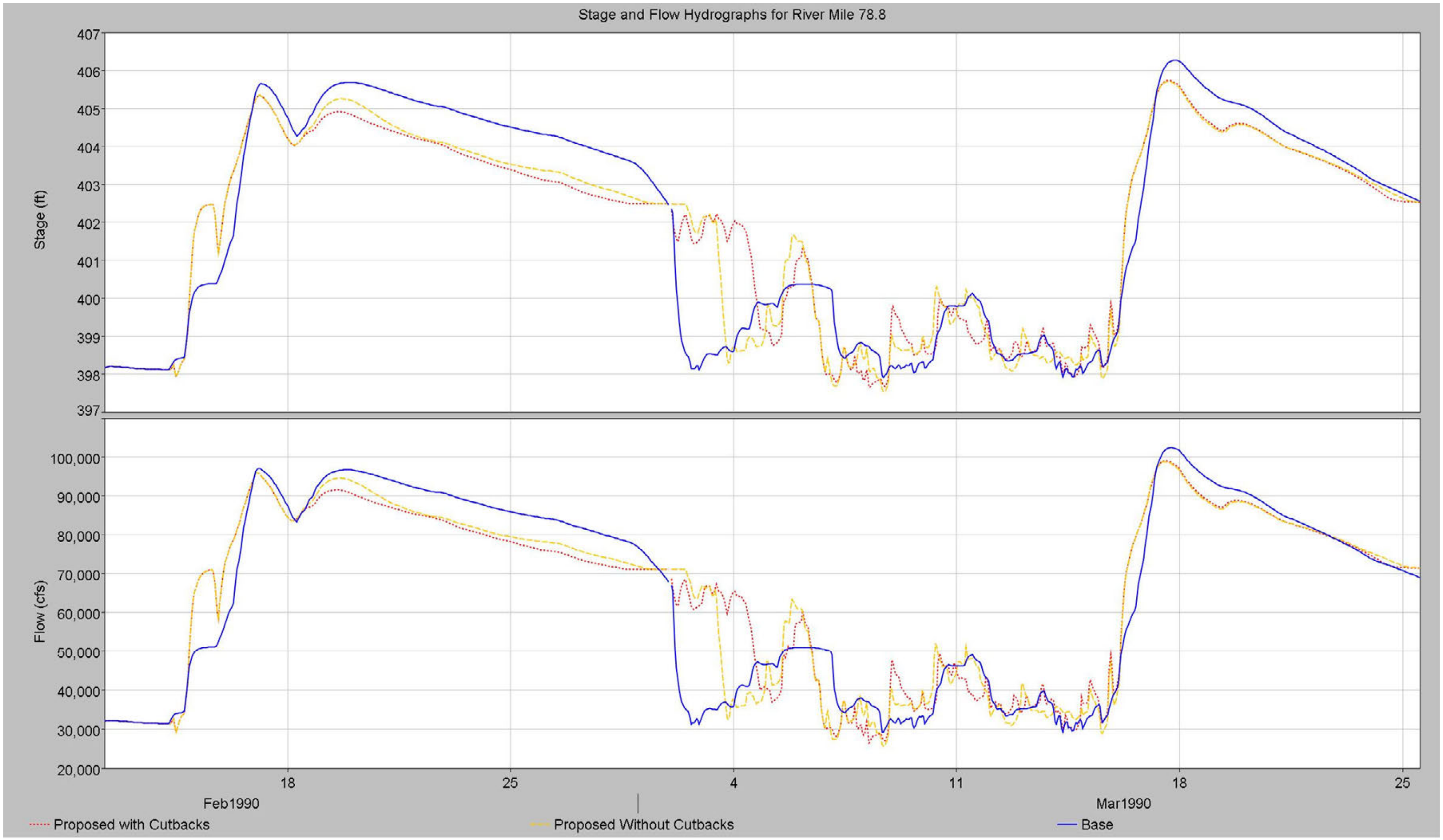


Stage/Flow at Coosa River Mile 78.8 Upstream of Highway 38 for the April 1979 Storm.



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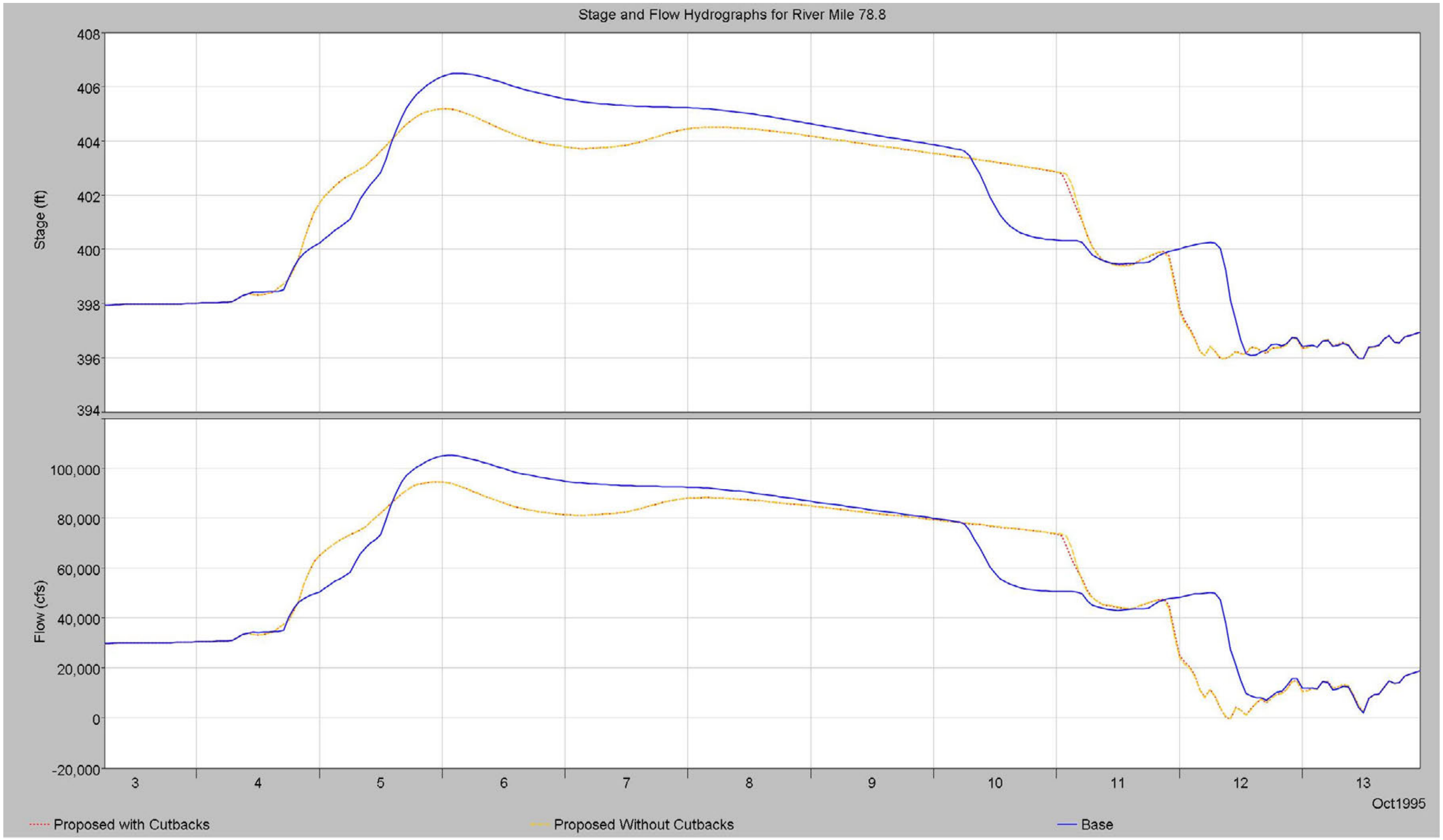

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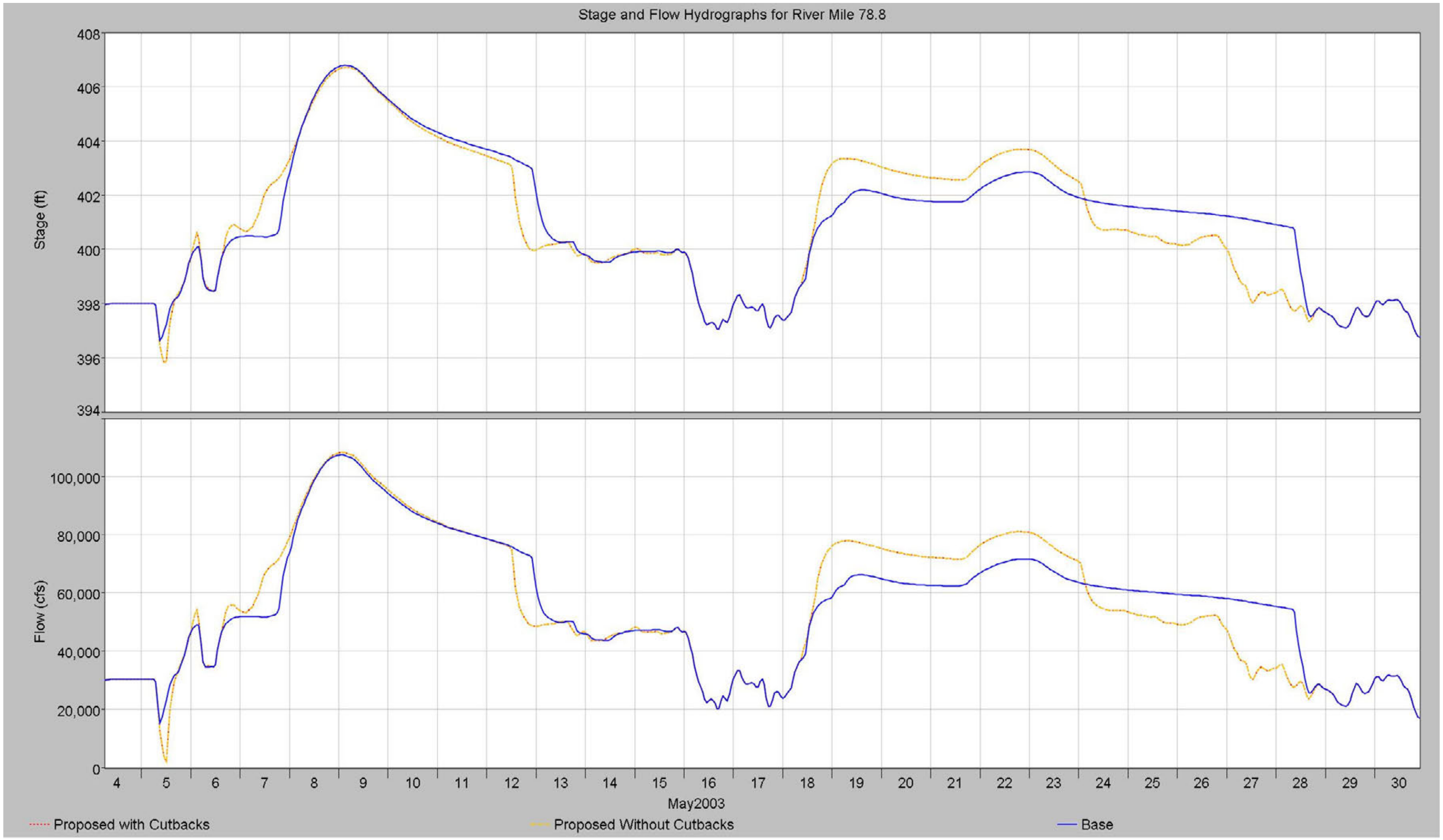

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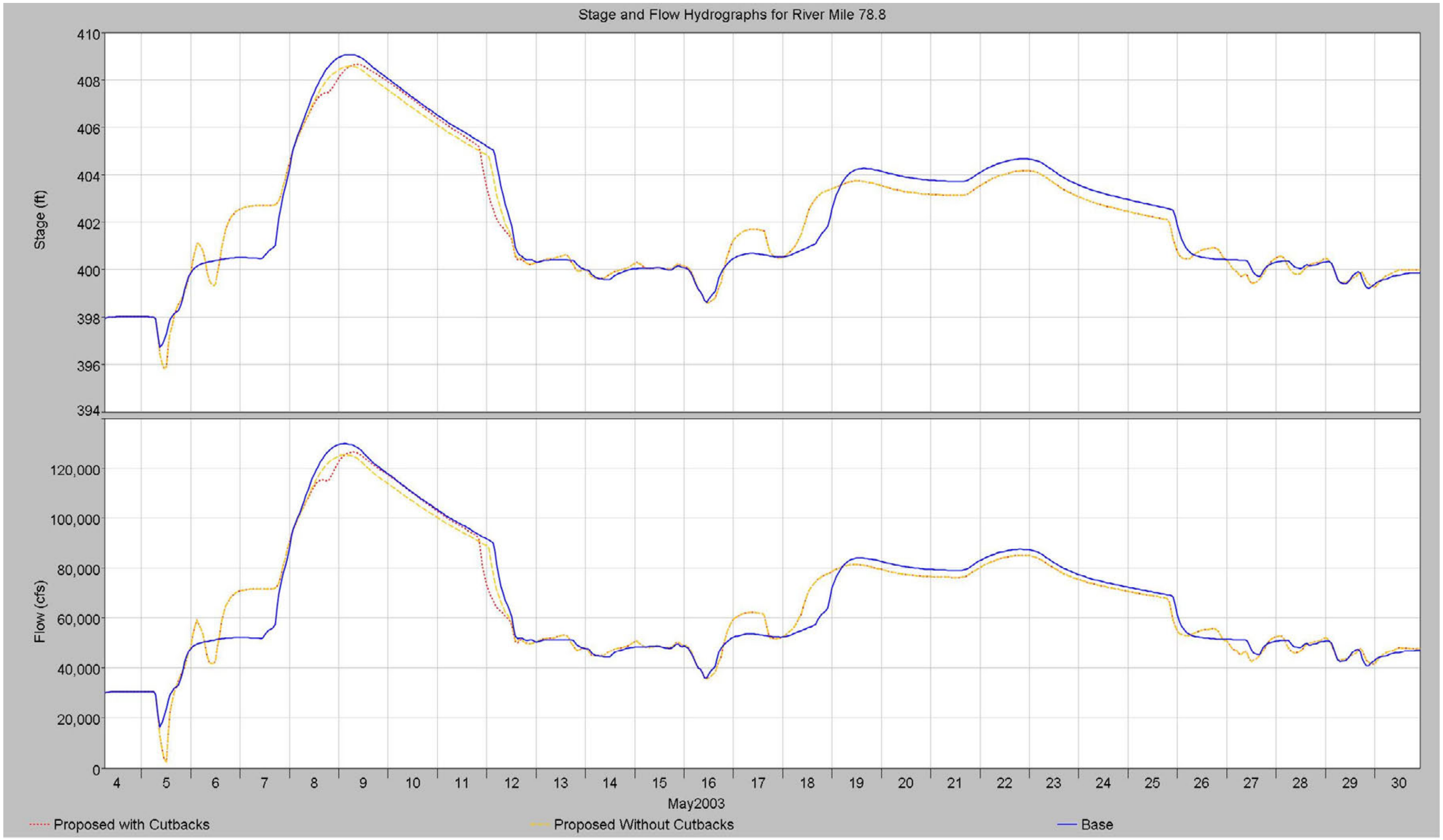

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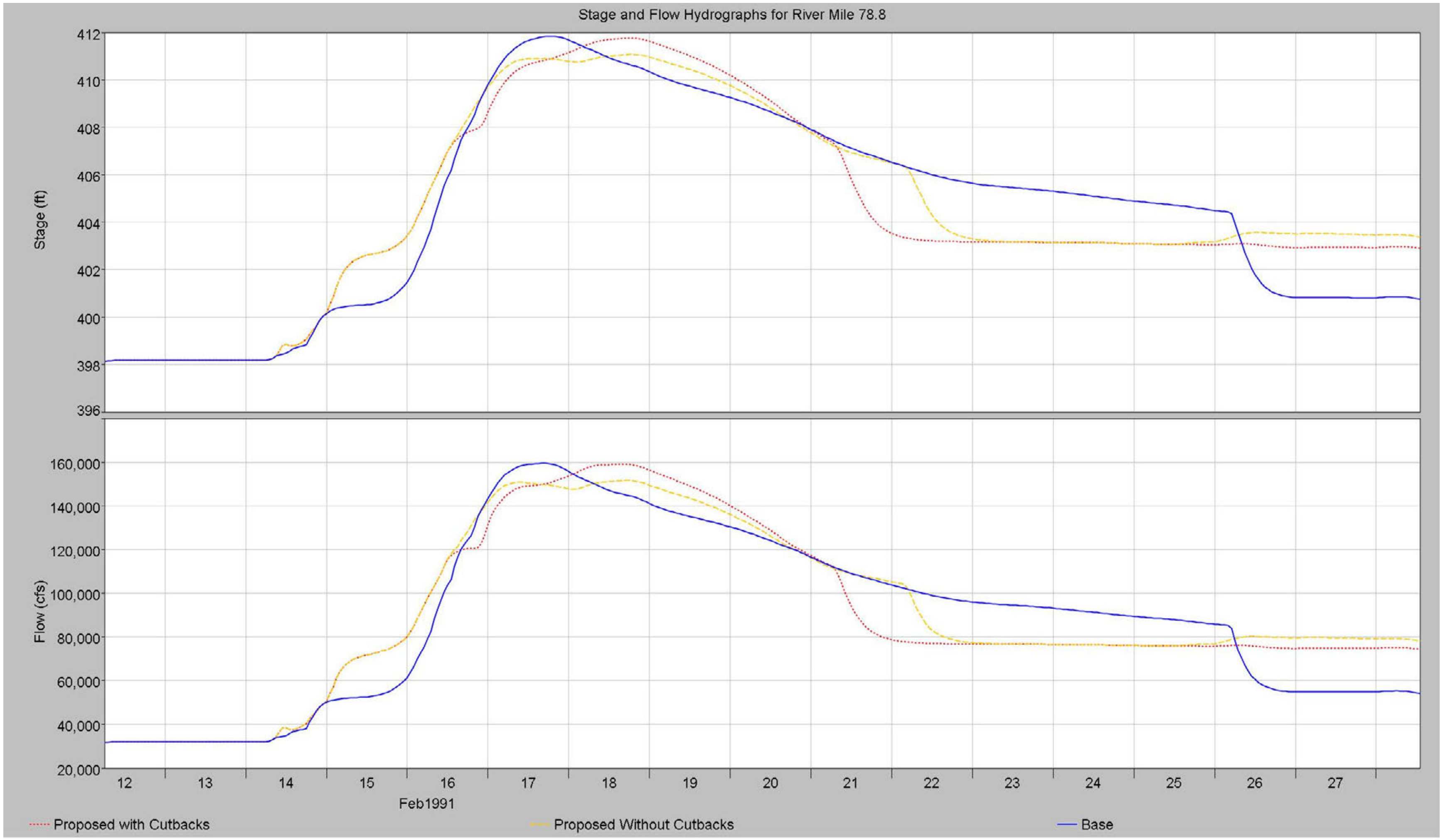

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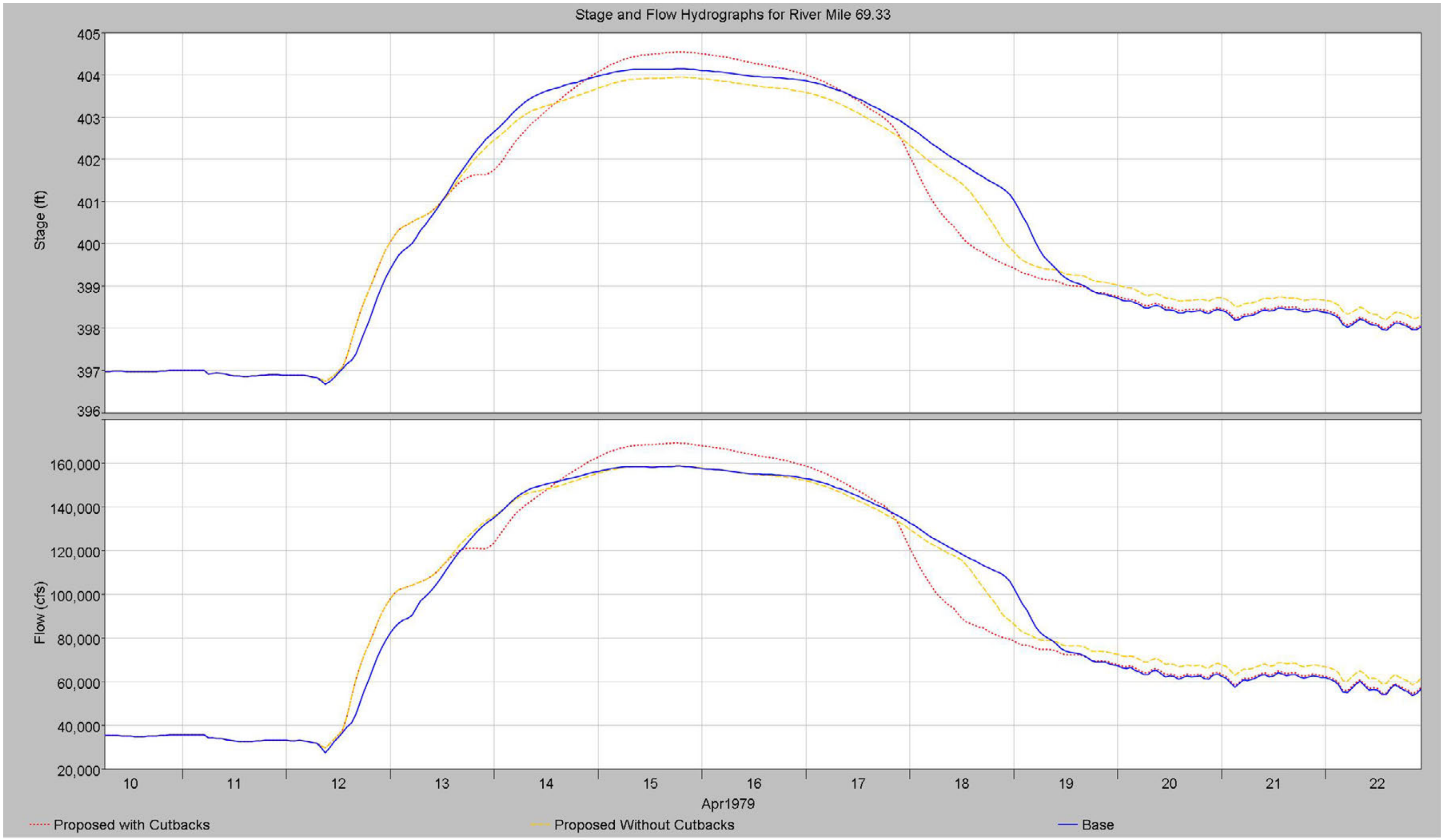
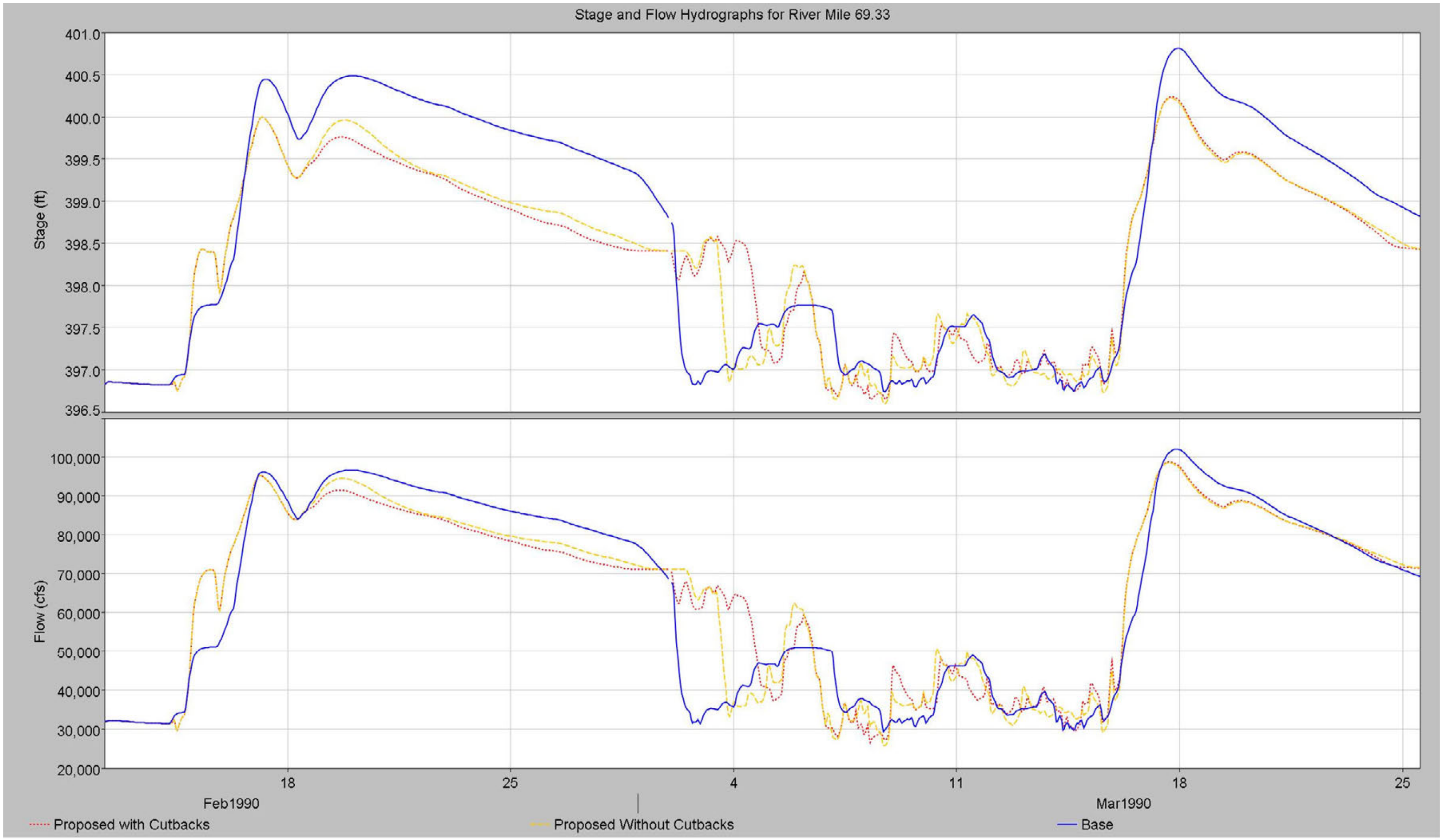


Stage/Flow at Coosa River Mile 69.33 Adjacent to the Gaston Power Plant for the April 1979 Storm.



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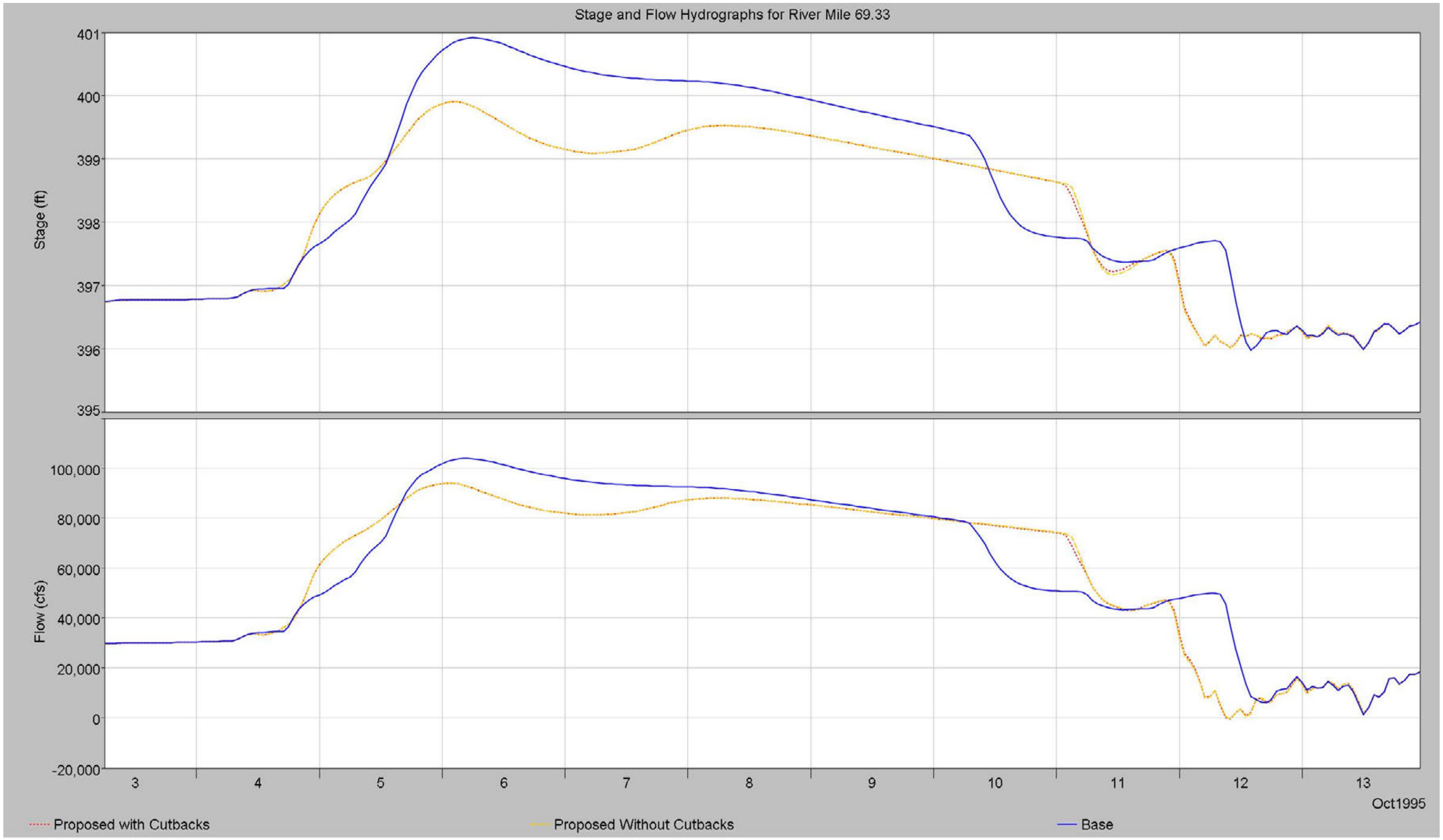

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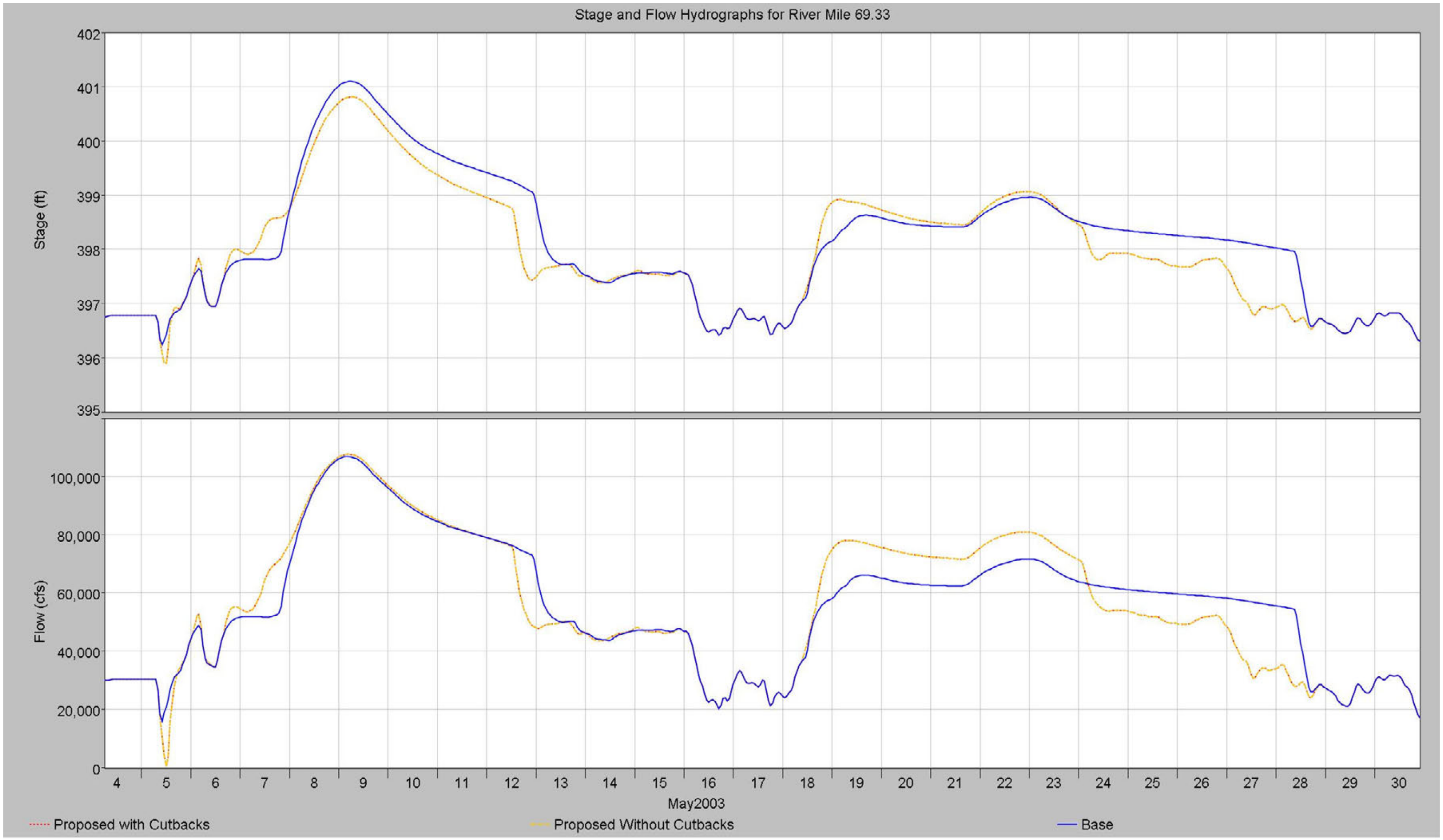

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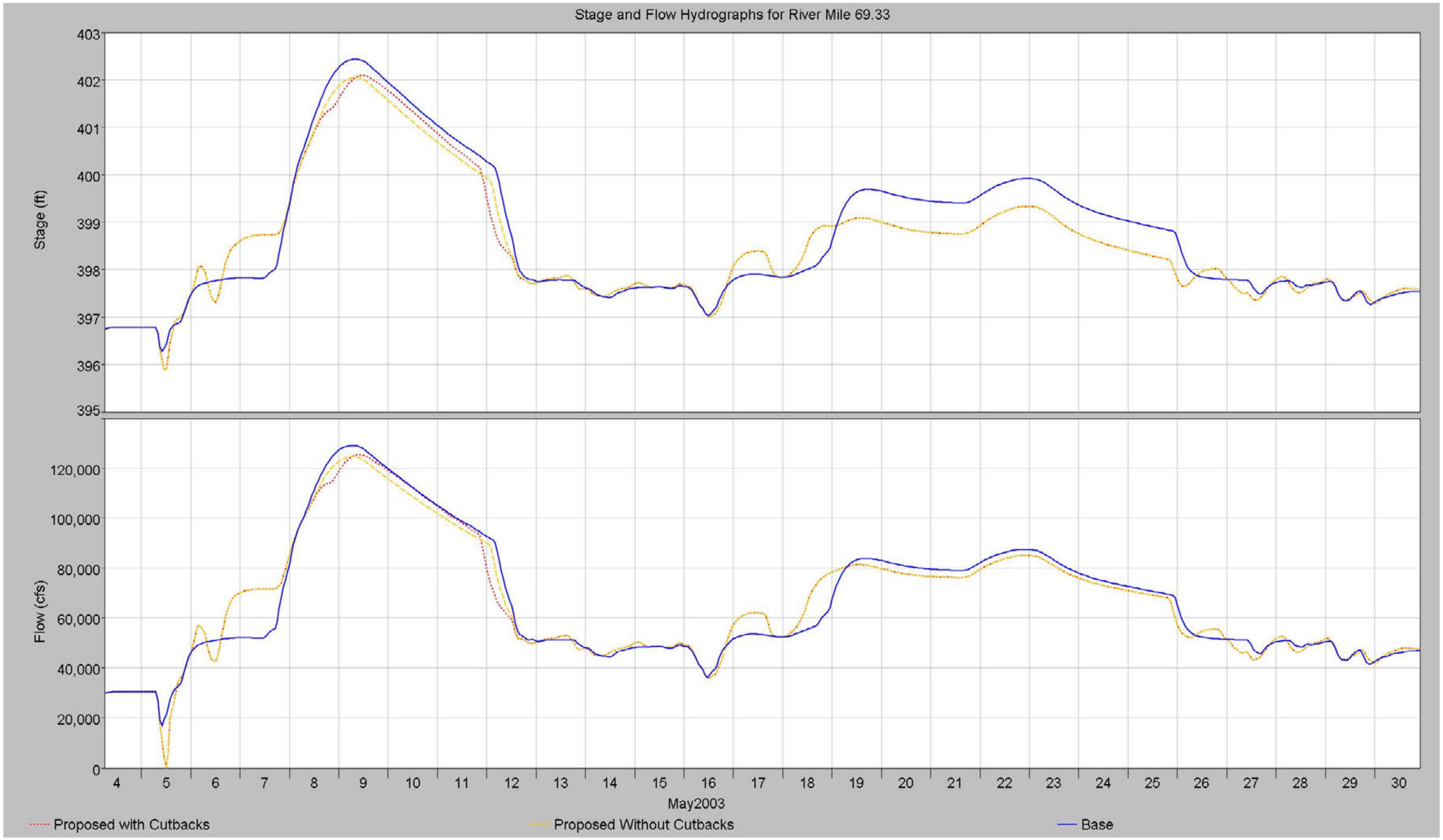

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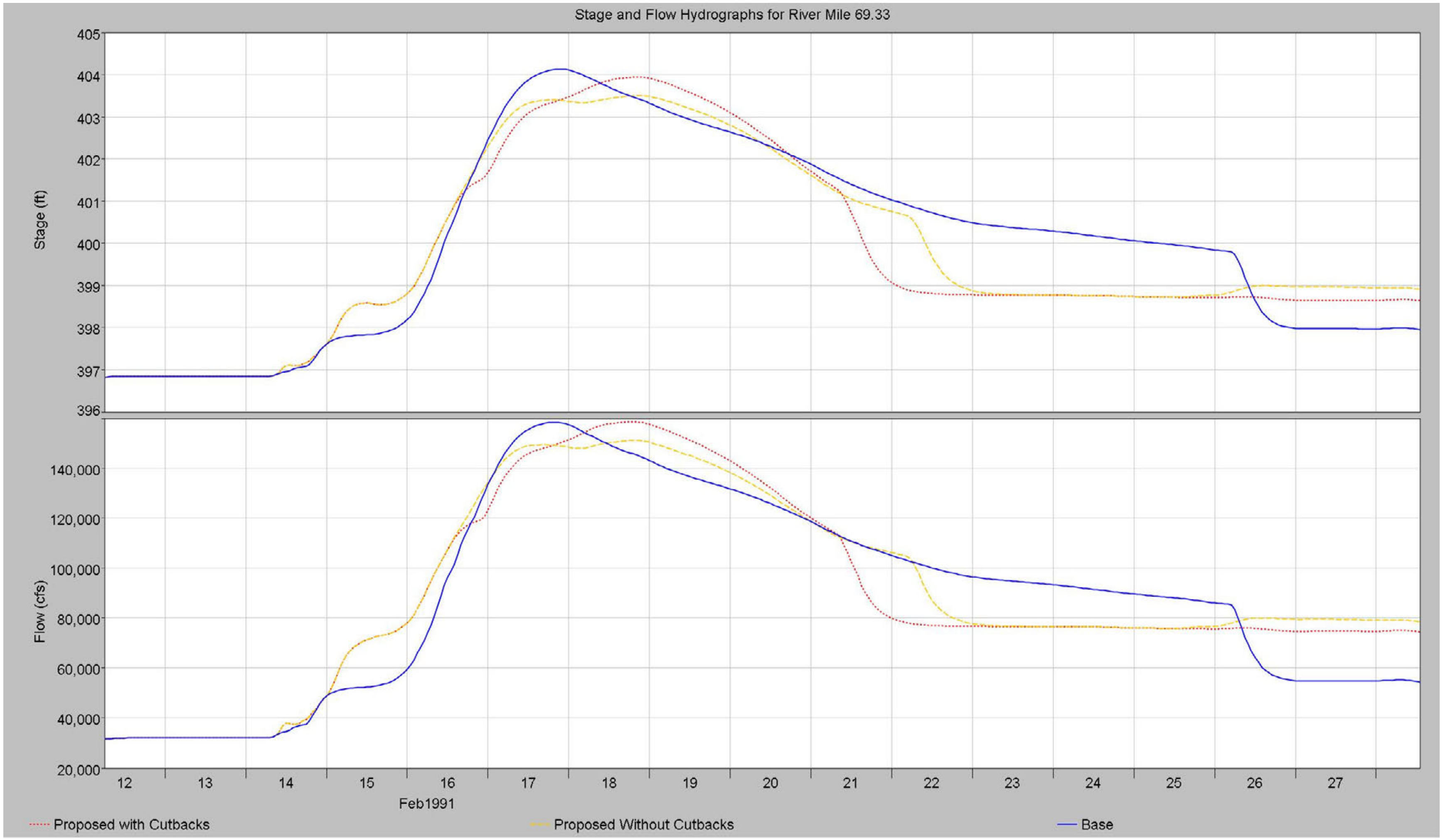

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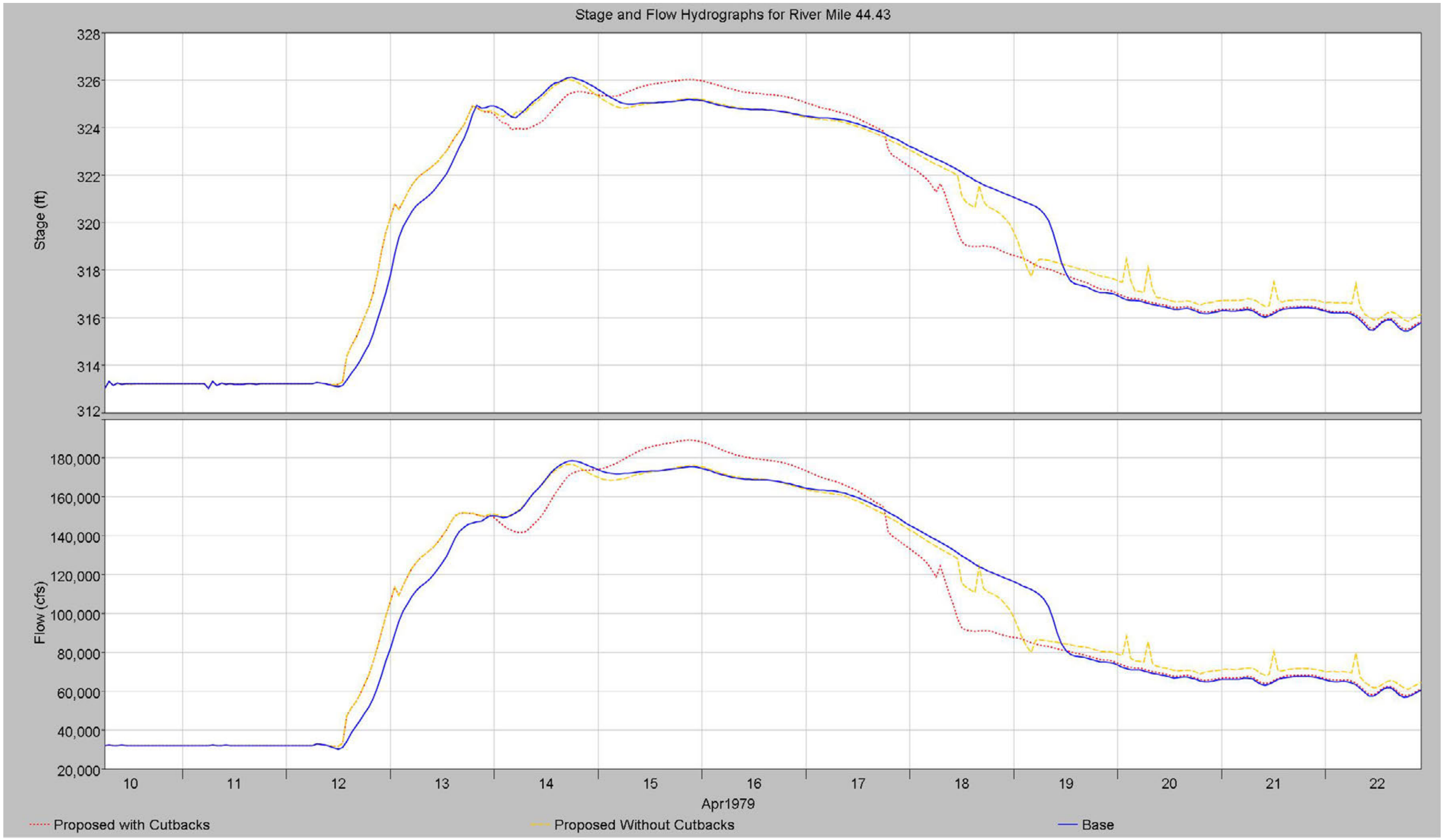
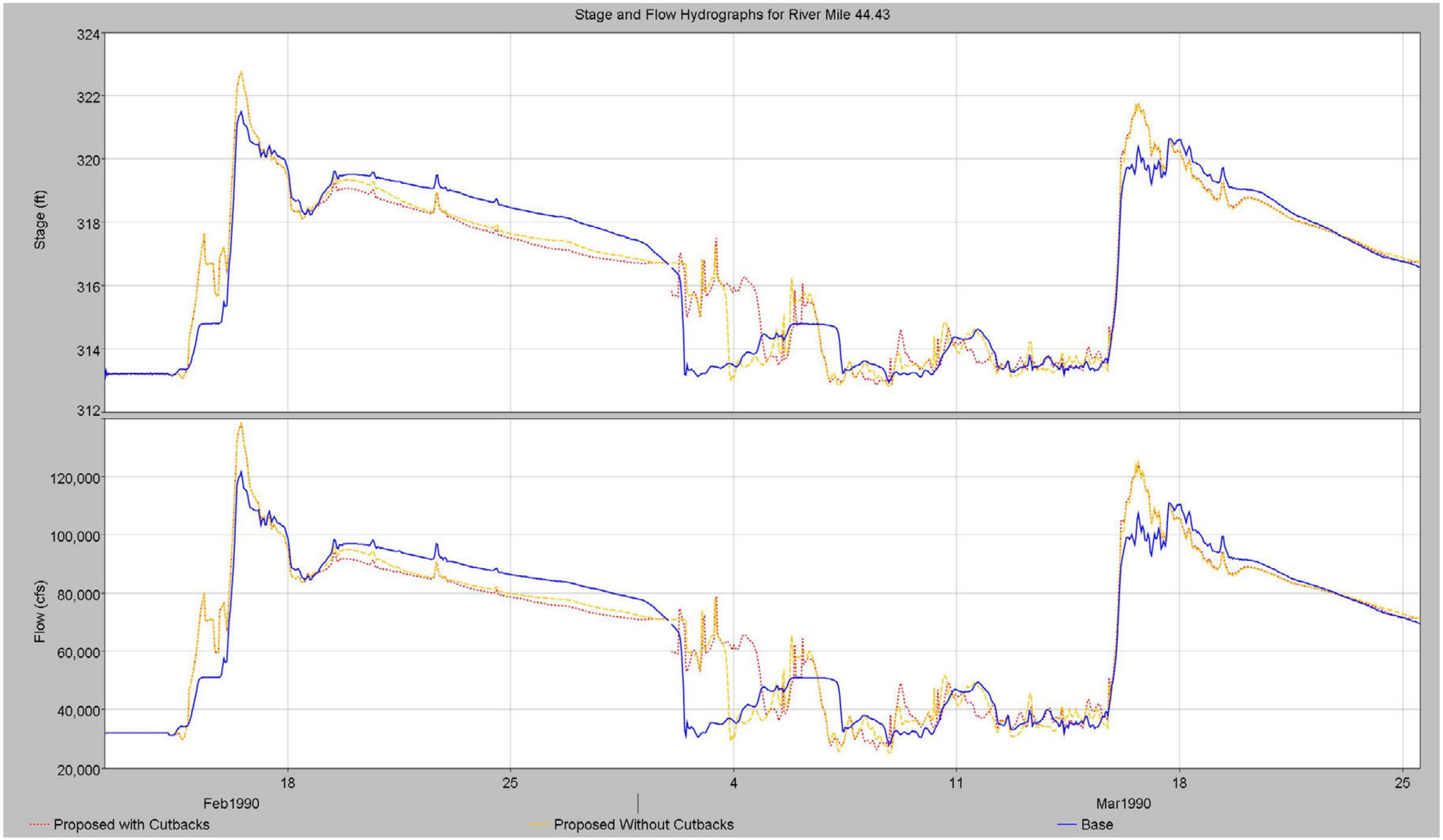


Stage/Flow at Coosa River Mile 44.43 Downstream of Lay Dam for the April 1979 Storm.



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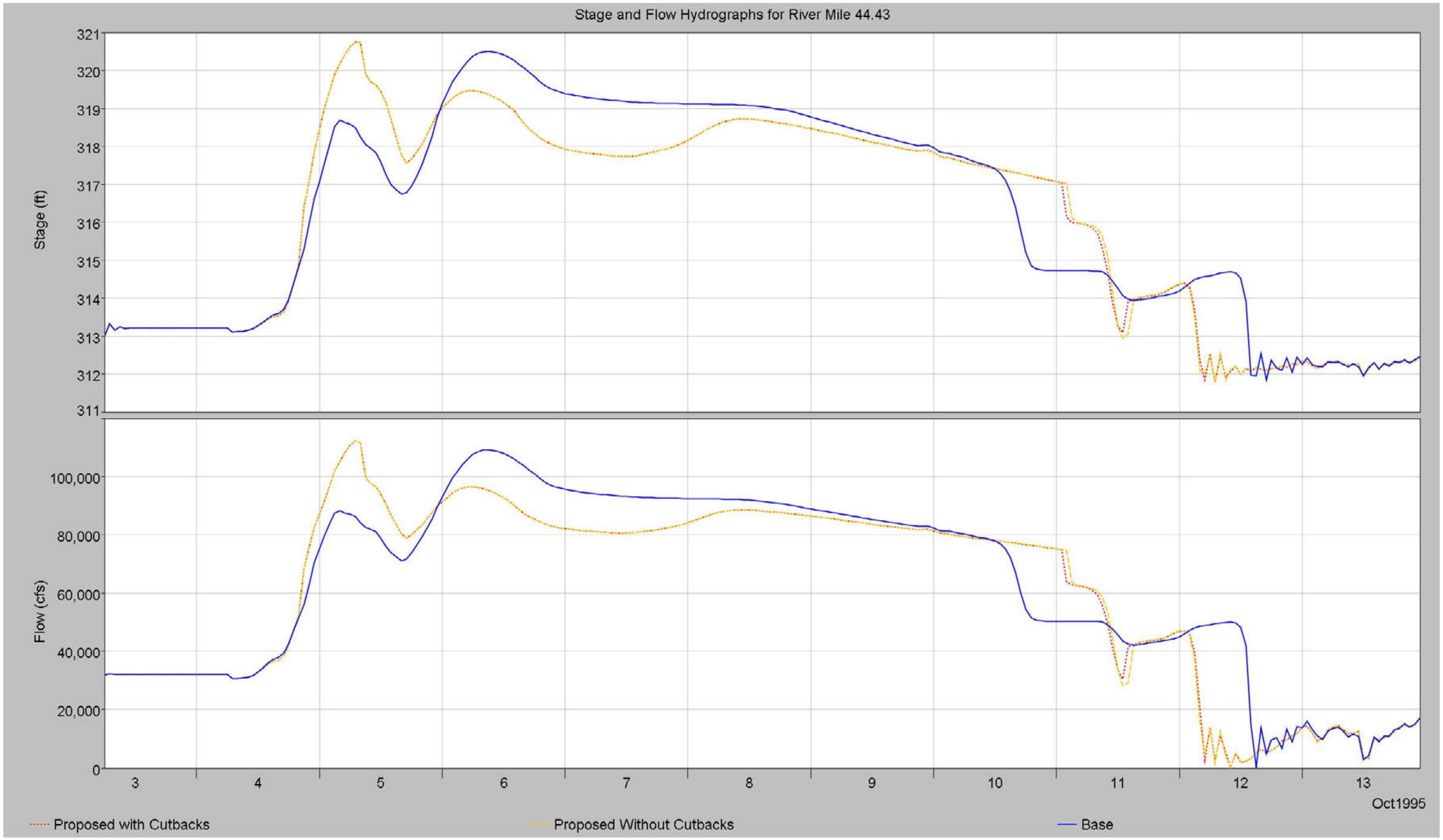

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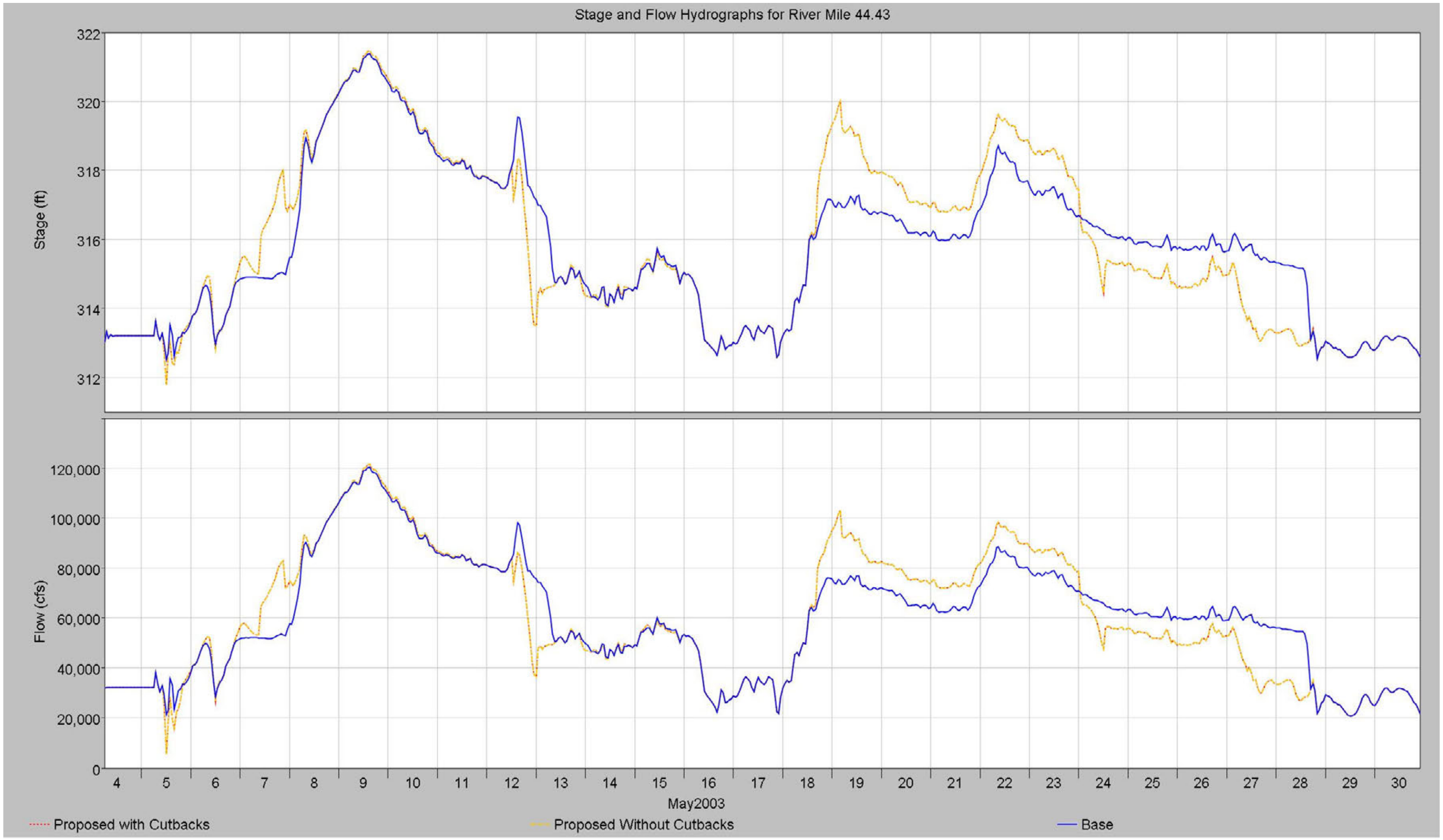

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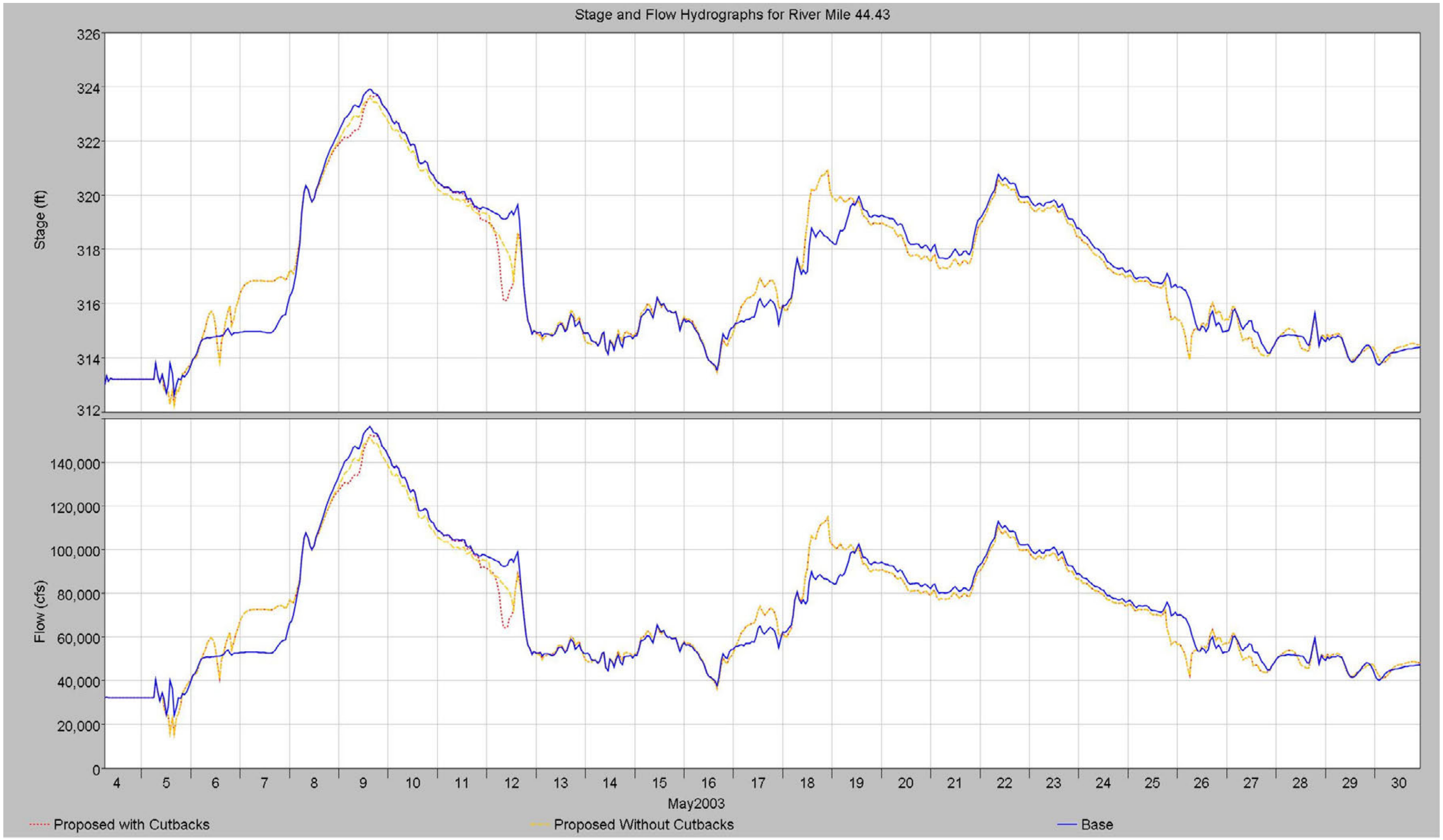

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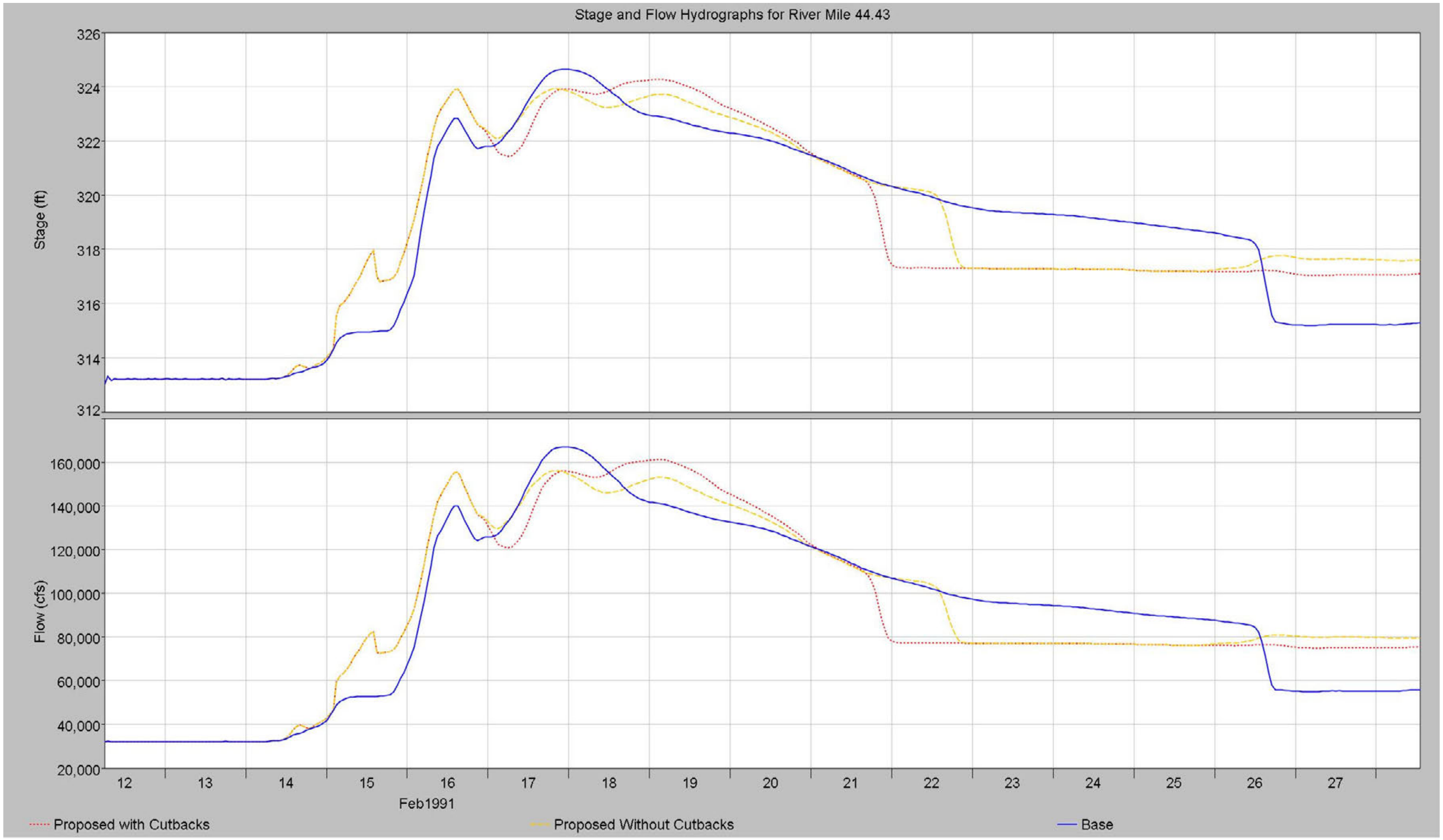

Stage/Flow at Coosa River Mile 44.43 Downstream of Lay Dam for the Unregulated 0.01 ACE Storm.

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Attachment 10. ACT River Basin Critical Yield Analysis Report

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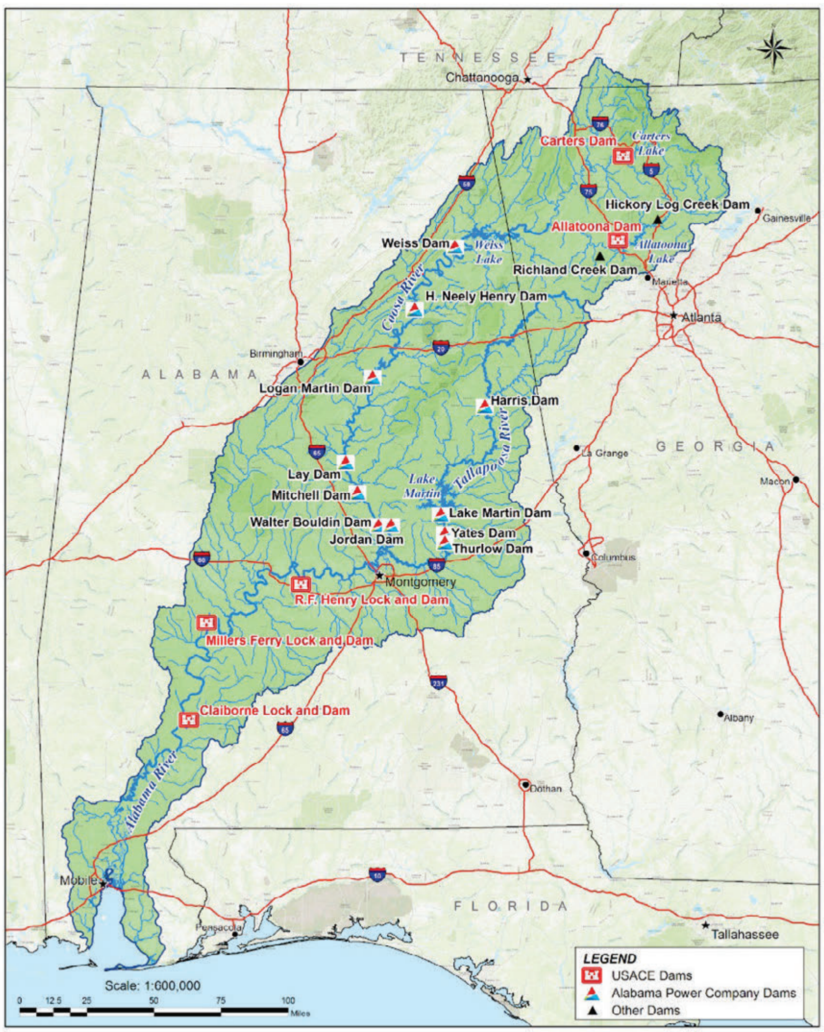
US Army Corps
of Engineers®
Mobile District

FEDERAL STORAGE RESERVOIR CRITICAL YIELD ANALYSES

ALABAMA-COOSA-TALLAPOOSA (ACT) RIVER BASIN



June 2020

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TABLE **DESCRIPTION**

Appendix E – Allatoona Dam Area Capacity Comparison

FIGURE **DESCRIPTION**

FEDERAL STORAGE RESERVOIR
CRITICAL YIELD ANALYSES

EXECUTIVE SUMMARY

Alabama-Coosa-Tallapoosa and
Apalachicola-Chattahoochee-Flint River Basins

1 SCOPE AND PURPOSE

The Federal Storage Reservoir Critical Yield Analyses, Alabama-Coosa-Tallapoosa (ACT) Basin (Critical Yield Report) provides information and technical analysis in response to Congressional direction in reports accompanying the Energy and Water Development and Related Agencies Appropriations Act, 2010 (H.R. 3183; Public Law 111-85) which includes the following language:

"*Alabama-Coosa-Tallapoosa [ACT], Apalachicola-Chattahoochee- Flint [ACF] Rivers, Alabama, Florida, and Georgia.—The Secretary of the Army, acting through the Chief of Engineers, is directed to provide an updated calculation of the critical yield of all Federal projects in the ACF River Basin and an updated calculation of the critical yield of all Federal projects in the ACT River Basin within 120 days of enactment of this Act*."

Pursuant to this language, the U.S. Army Corps of Engineers (Corps), Mobile District and Hydrologic Engineering Center (HEC), developed updated critical yields for the Federal projects in the ACT Basin in July 2019. This analysis is an update, to the February 2010 critical yield analysis.

Federal reservoirs in the ACT River Basin that are included in these analyses are Carters Dam and Allatoona Dam (reference Figure 1), because they hold the majority of water storage in the Federal projects on the ACT System. The Carters Dam System consists of two dams: the main dam and a small, downstream dam impounding discharges from the main dam for pump back purposes. Only the main dam is included in the critical yield evaluations. R.F. Henry Lock and Dam, Millers Ferry Lock and Dam and Claiborne Lock and Dam are Federal reservoirs on the ACT System that are excluded from the critical yield analyses. These reservoirs are excluded from the analyses because they are 'run of river' impoundments with little or no usable water storage and cannot significantly contribute to critical yield.
In addition, two reservoirs, Richland Creek and Hickory Log Creek, exists in the model with no impact on the yield results at Carters Dam and Allatoona Dam.
Proposed changes to the Hickory Log Creek operation in support of water supply withdrawal from Allatoona Reservoir could impact yield results from Allatoona Dam. However, those proposed changes are subject of the USACE proposed water supply rulemaking. Once water supply rulemaking finalized, the yield analysis will be updated if necessary.

Detailed critical yield analyses for the ACT Basin is presented in the appendices.

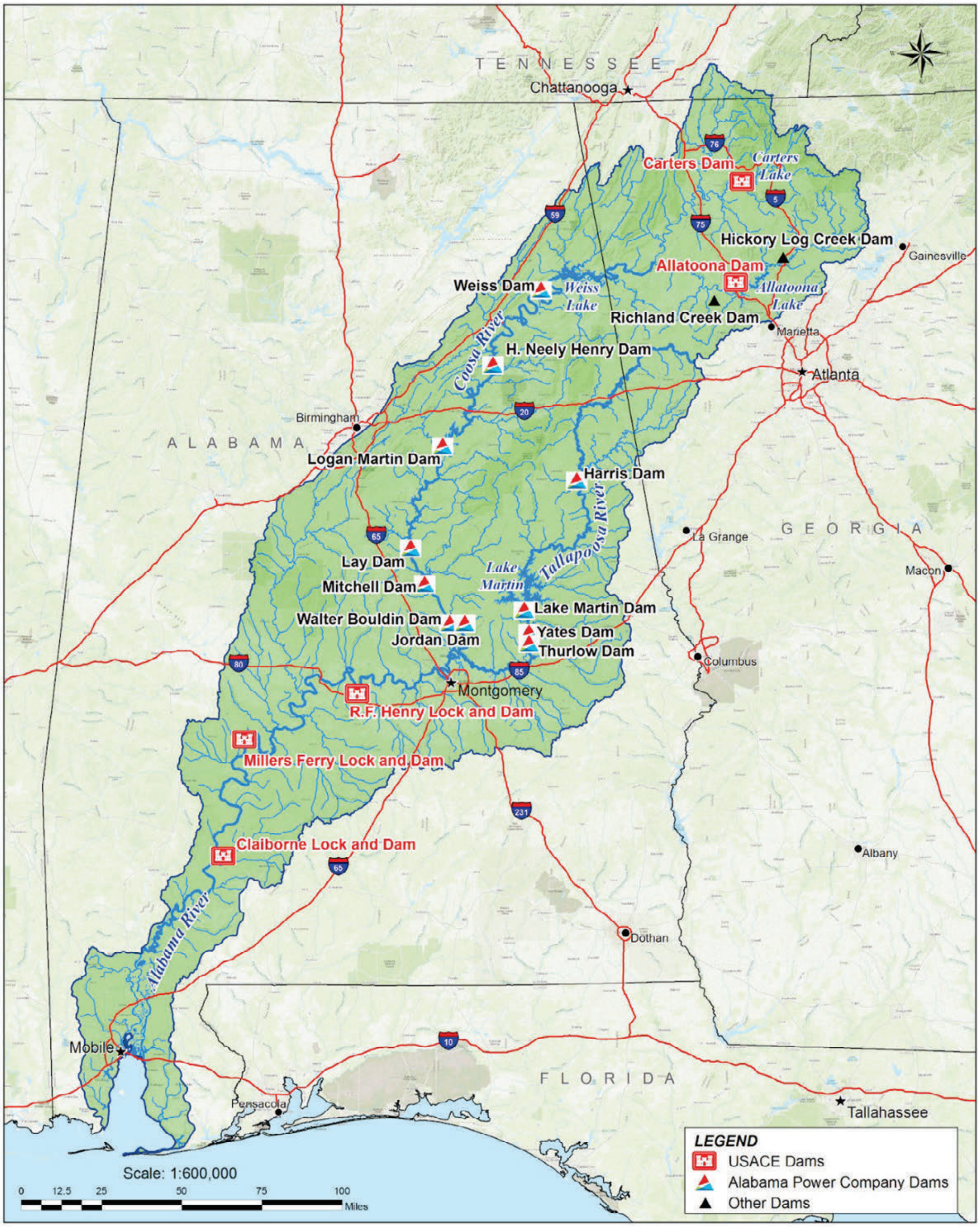


Figure 1. Federal Reservoir Projects in the ACT Basin

2 CRITICAL YIELD

Critical yield is the maximum flowrate that can be continuously removed from a reservoir through releases from the dam and/or withdrawals from the reservoir, even during the most severe drought in the period of record (1939-2012), while completely (and exactly) depleting the reservoir conservation storage. Conservation storage is the amount of water available in a reservoir to meet project purposes other than flood control. . The Corps cannot guarantee critical yield will always be available because future droughts may be worse than droughts of the period of record, requiring more conservative regulation of reservoirs. Critical yield has been previously referred to as prime flow.

Critical yield is important because it is the basis from which water stored in a reservoir is allocated to various project purposes. The amount or volume of water stored in a reservoir can be allocated to a specific project purpose, such as hydropower or water supply, based on a percent of critical yield. A change in critical yield could result in modifications of the allocations for a project purpose.

Critical yield can be expressed in cubic feet of water per second (cfs), but can be expressed in any other reasonable flow rate units representing the rate at which water can be removed. Critical yield can also be expressed in millions of gallons per day (mgd) or acre-feet per year (ac-ft/yr), representing the volume of water that can be removed from a reservoir. The conversions between rate and volume are:

$$1 \text{ cfs} = 0.6464 \text{ mgd} = 722.7 \text{ ac-ft/yr}$$

The analysis in this critical yield report expresses critical yield in cfs.

3 METHODOLOGY

This section briefly describes how the Corps determined critical yield and crucial datasets that significantly affect analyses results. A more detailed description of this process is provided in Appendix A - Critical Yield Methodology.

3.1 Unimpaired Flow Data Set

The unimpaired flow data set is historically average daily observed flows, adjusted for some of the human influence within the ACT river basin. Man-made changes in the river basin influence water flow characteristics and are reflected in measured flow records. Determining critical yield requires removing identifiable and quantifiable man-made changes such as municipal and industrial water withdrawals and returns, agricultural water use, and increased evaporation and runoff due to the construction of Federal surface water reservoirs, from the observed flow measurements.

These quantities are used to extrapolate diversions. The difference between water withdrawn and water returned is defined as a diversion. Diversions are a net volume or quantity assumed to be permanently lost from the water system.

The unimpaired flow dataset is not a perfectly replicated flow dataset representing conditions that would exist without the influence of human activities or a precise measure of natural flow conditions. This is because all human influences, such as land use changes, cannot be accounted for, and many flow set adjustments are estimates based upon assumptions, not direct measurements of the human influences.

The original unimpaired flow data set developed as part of the Alabama-Coosa-Tallapoosa and Apalachicola Chattahoochee Flint (ACT/ACF) River Basins Comprehensive Water Resources Study, ACT/ACF Comprehensive Water Resources Study, Surface Water Availability Volume I: Unimpaired Flow, July 8, 1997 included data at over 50 locations for the 1939 to 1993 period of record. This data set had previously been extended through 2008 then recently through 2011 and is available from the Corps. Because of the occurrence of negative flows in the daily values, the data has been smoothed using 3-, 5-, or 7-day averaging. This preserves the volume of the flow and eliminates most of the small negative flows in some of the daily flow data. The primary reason for the negative local unimpaired flows is related to estimating actual routing of flows. Routing travel times are limited to 24 hours in the daily ResSim model. Actual travel time may not coincide with the 24-hour increment through the entire flow range.

3.2 Droughts

Several drought periods have been identified from the historic record and from previous yield analyses (reference Appendix D – Prior Reports and References). Drought periods were identified in 1939-43; 1954-58; 1984-89; 1998-2003, and 2006-2008. These are shown below in Table 1. Each period is referenced in accordance to the decade or most severe year of occurrence. Critical yield was computed for each of the drought periods and the lowest value selected as the critical yield value for this report.

Table 1. Drought Periods

Drought Periods	Label
1939-1943	1940
1954-1958	1950
1984-1989	1980
1998-2003	2000
2006-2008	2007

3.3 Models

A computer simulation model is a computer program that replicates a real world system. The U.S. Army Corps of Engineers' Hydrologic Engineering Center's (HEC) Reservoir System Simulation (HEC-ResSim) is a computer program comprised of a graphical user interface (GUI) and a computational engine to simulate reservoir operations. HEC-ResSim was developed to aid engineers and planners performing water resources studies by representing the behavior of reservoirs and to help reservoir operators plan releases in real-time during day-to-day and emergency operations.

The updated HEC-ResSim model used in this study has a Yield Analysis subroutine which calculates the largest, continuous release that can be reliably supplied during the flow record. The subroutine works by adjusting an operation rule, which represents a reservoir management action. The subroutine performs a model simulation run through the period of record with a suggested release toward yield, then recomputes the release, and iterates the computed release until the largest release that can always be successfully made is found. This largest release if found when exactly 100% of available storage is utilized and nothing more.

The ResSim ACT yield model includes a net precipitation-evaporation rate for each reservoir that utilizes evaporation values developed for National Oceanic and Atmospheric Administration (NOAA) Technical Reports, monthly pan evaporation rates and National Weather Service (NWS) reports of rainfall and flow rates. The net evaporation losses, evaporation minus precipitation, were computed in inches at the projects. The NOAA report was used because historic monthly evaporation data is not available at the projects. Historic monthly precipitation data was obtained from the NWS.

It is important to be aware that the most severe drought event at one reservoir may not be the most severe drought event at another reservoir in the same river system.

Critical yield at each reservoir is calculated for two conditions: without river and lake diversions and with river and lake diversions. Generally, the largest possible yield results from the no diversions condition (Method A) whereas the with diversions condition (Method B) results in the most critical, or lowest, yield. Method B also studies the effect of downstream controls on yield.

The local unimpaired flow is used as the input time series for the reservoir model. The reservoir simulation model for this yield analysis uses a daily-time step for all computations. Model runs (simulations) are performed for each identified drought periods and capture the drawdown and refill of reservoir during the drought period.

3.4 Method A (Without Diversions)

Method A assumes that there are no withdrawals from or returns to the lake and there are no withdrawals from or returns to the river as it flows between projects. This condition results in the maximum yield possible from the Federal projects. Critical yield from an upstream reservoir is assumed to be permanently removed from the system and does not contribute to the inflow at downstream reservoirs.

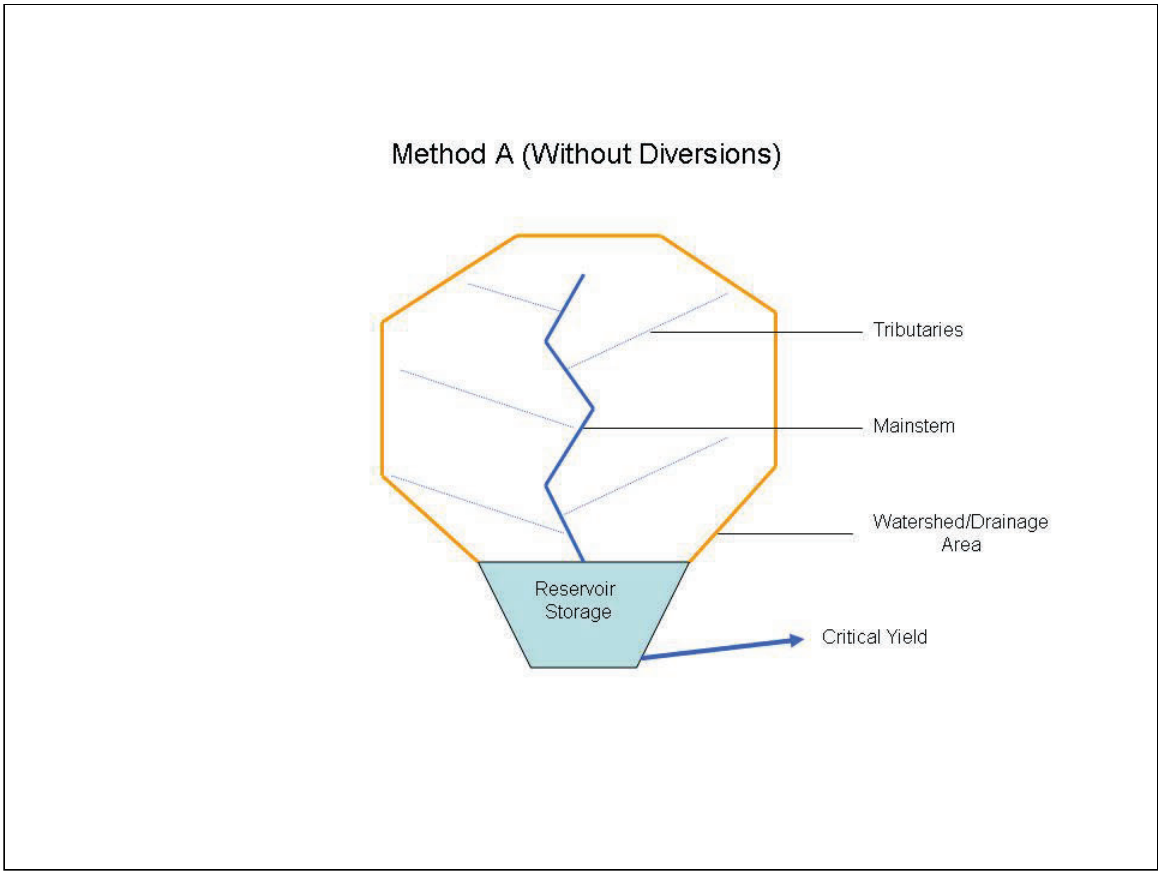


Figure 2. Critical Yield Method A (Without Diversions)

3.5 Method B (With Diversions)

Method B assumes net river withdrawals and returns are occurring; this method does not include withdrawals from the Corps reservoirs. Critical yield from an upstream reservoir is assumed to be permanently diverted from the system and does not contribute to the inflow at downstream reservoirs. This condition results in the most severe downstream impact. The results of Method B represent a conservative assessment of the critical yield available from Federal projects controlled by the Corps of Engineers. Method B used the most severe drought events documented during the hydrologic period of record and the year of maximum river withdrawals (2006 for the ACT) to make the calculations.

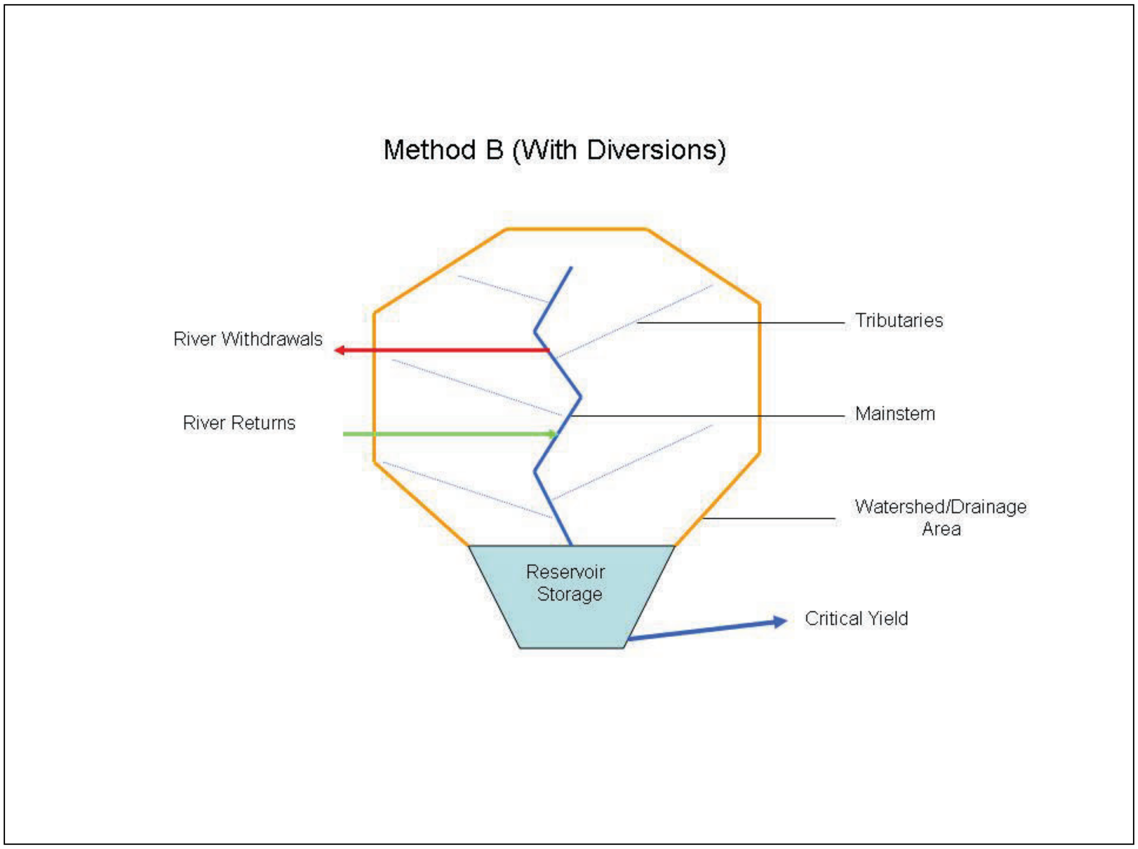


Figure 3. Critical Yield Method B (With Diversions)

3.6 Method C (River System Yield)

Method C computes a system yield for diversion from the most downstream storage reservoir. It assumes upstream reservoirs operate in tandem to maximize the critical yield at the most downstream reservoir.

ACT critical yields are computed using only Methods A and B. This is because both Carters Dam and Allatoona Dam operate independently and do not influence water availability at the other reservoir.

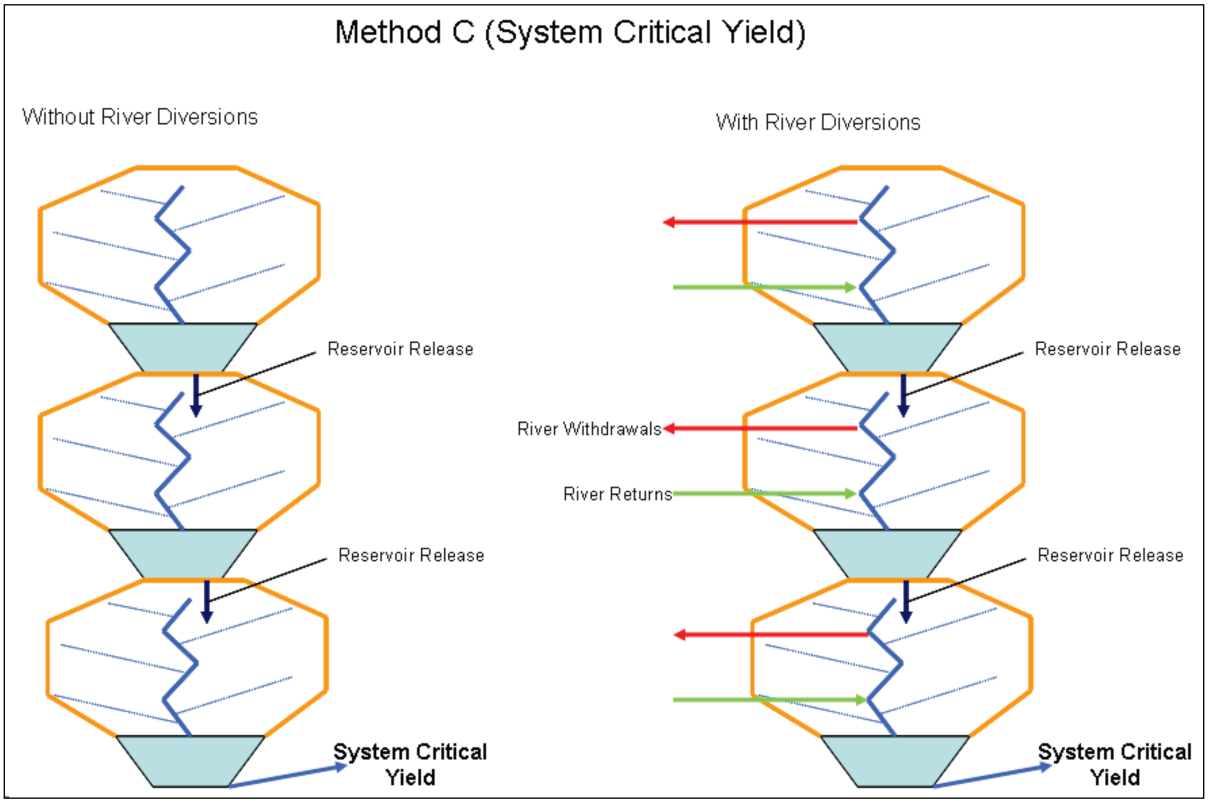


Figure 4. Critical Yield Method C (River System Yield)

3.7 Assumptions

Assumptions made for the critical yield analysis are listed below.

1. There is no attempt to address the probability that droughts more severe than those in the period of record may or may not occur.

2. The simulation model was operated primarily for critical yield. The only other operating purpose included was flood risk reduction. The critical yield represents the maximum flow that could be continuously provided to meet any, or all, demands (e.g., project purposes).

3. Yield analysis is based on currently authorized conservation storage elevations.

4. Projects are full at the beginning of the drought period simulation. The pool level at the beginning of a drought simulation is important because it is a variable that directly affects the quantity or volume of water available as critical yield.

5. None of the critical yield from the existing reservoirs is returned to the system. Critical yield is permanently diverted from the system and assumed to be consumptively used. This methodology determines the conservative individual project yield. The assumption is applicable to Methods A and B.

6. Existing area capacity curves as shown in the latest water control manuals were used.

4 CRITICAL YIELD ANALYSES RESULTS

A summary of model results is presented below. A more detailed description of basin-specific methods, modeling and results is presented in the Appendix B.

Tables 2 and 3 list the critical yield of each existing federal reservoir on the ACT System and the critical drought period used in the calculations. In both tables, the Richland Creek and Hickory Log Creek reservoirs act with no yield diverted out.

Table 2. Method A, ACT Project Critical Yield (Without Diversions)

Project	Critical Yield (cfs)	Critical Drought
Allatoona Dam	784.38	2007
Carters Dam	386.72	2007

The ACT River System diversions are municipal, industrial and agricultural withdrawals and returns from the Coosawattee River and its tributaries upstream of Carters Lake and from the Etowah River and its tributaries upstream of Allatoona Lake. Maximum diversions occurred in 2006 and are reflected in the critical yield calculation for each drought period.

Table 3. Method B, ACT Project Critical Yield (With Diversions)

Project	Critical Yield (cfs)	Critical Drought	Critical Yield Reduction Attributable To Diversions
Allatoona Dam	765.34	2007	2.43%
Carters Dam	382.81	2007	1.01%

Comparing the yield results from the Method A (Without Diversions) and Method B (With Diversions) allows us to quantify the impacts of the river withdrawals. The 2006 river diversions have a measurable impact on the critical yield, as much as 2.43 percent at Allatoona Lake (reference Table 3).

For the Allatoona Coosa Reallocation Study, the critical yield was computed for several different Allatoona conservation pool sizes which included variations of the guide curve. This analysis was performed to support the consideration of water supply reallocation from flood storage. ResSim model alternatives were created to represent the various Allatoona guide curve scenarios. For those scenarios with a seasonal guide curve, the timing of the transitioning from winter to summer and summer to winter remain unchanged from current. Yield modeling was performed for each guide curve scenario to determine Allatoona's firm yield, given the different conservation pool definitions using the 2007 critical drought. A description of the different

Allatoona conservation pool scenarios and critical yield modeling results (Method B) are listed in Table.

Table 4 Method B, Yield for different Allatoona Guide Curve Scenarios

Allatoona Guide Curve Scenario	Guide Curve Summer / Winter (ft)	Summer Conservation Storage (ac-ft)	Yield (cfs)	Yield (mgd)
Current	840 / 823	270,247	765.3	494.7
Constant Elevation at 840 ft	840 / 840	270,247	823.6	532.4
Raise Winter and Summer Elevation 1	*841 / 824.5	281,917	782.2	505.6
Constant Elevation at 842 ft	842 / 842	293,586	842.7	544.7
Constant Elevation at 844 ft	844 / 844	316,924	861.2	556.7
Constant Elevation at 844.5 ft	844.5 / 844.5	323,022	865.8	559.7
Raise Winter and Summer Elevation 2	844.5 / 842.0	323,022	862.0	557.2
Raise Winter and Summer Elevation 3	844.5 / 830	323,022	816.7	527.9
Raise Winter and Summer Elevation 4	844.5 / 837	323,022	846.4	547.1
Raise Winter and Summer Elevation 5	**844.5 / 841.5	323,022	861.2	556.7

* Selected as the revise Allatoona guide curve for combined reallocation from conservation and flood storage, Allatoona Coosa Reallocation Study
** Selected as the revised Allatoona guide curve for full reallocation from flood storage to yield an additional 60 mgd, Allatoona Coosa Reallocation Study

5 SUMMARY

The results of Method B (With Diversions) (reference Table 3) represents a realistic assessment of the critical yield from Federal projects controlled by the Corps.

Historical critical yield determinations are referenced in Appendix C - Prior Reports and References. The reader should be cautioned that there is not a direct correlation between the finding of historical critical yields and the findings of this Critical Yield Report. This is due to differences in the drought periods used in each set of analyses and methods employed to calculate the critical yield.

6 REFERENCES

USACE, July 8, 1997, “ACT/ACF Comprehensive Water Resources Study”

USACE, Mar 2010, “Federal Storage Reservoir Critical Yield Analysis ACT ACF”

USACE-HEC, Jan 2014, “Methods for Storage/Yield Analysis”

National Weather Service, June 1982, "Evaporation Atlas for the contiguous 48 United States", NOAA Technical Report NWS 33.

National Weather Service, December 1982, "Mean Monthly, Seasonal, and Annual Pan Evaporation for the United States", NOAA Technical Report NWS 34.

ACRONYMS

Acres	ac
acre-feet	ac-ft
acre-feet per year	ac-ft/yr
Alabama-Coosa-Tallapoosa	ACT
Apalachicola-Chattahoochee-Flint	ACF
cubic feet per second	cfs
elevation	Elev
Federal Energy Regulatory Commission	FERC
graphical user interface	GUI
Hydrologic Engineer Center	HEC
Hydrologic Engineering Center's, Reservoir Simulation Model	HEC-ResSim
Kilowatt	kW
Million gallons per day	mgd
Mean Sea Level	msl
Megawatt	MW
National Geodetic Vertical Datum of 1929	NGVD 29
National Oceanic and Atmospheric Administration	NOAA
National Weather Service	NWS
Revised Interim Operating Plan	RIOP
U.S. Army Corps of Engineers	Corps
United States Geological Survey	USGS

Appendix A

Critical Yield Methodology

Appendix A - Critical Yield Methodology

1 INTRODUCTION

The methodology describing how the Corps determined critical yield and crucial datasets that significantly affect analyses results is detailed below.

1.1 RIVER DIVERSIONS

The difference between water withdrawn from a river and water returned to the river is defined as a diversion. Diversions are a net volume or quantity assumed to be permanently lost from the river.

1.1.1 Unimpaired Flow Data Set

The unimpaired flow data set is average daily historically observed flows, adjusted for some of the human influence within the river basins. Man-made changes in the river basins influence water flow characteristics and are reflected in measured flow records. Determining critical yield requires removing identifiable and quantifiable man-made changes such as municipal and industrial water withdrawals and returns, agricultural water use, and increased evaporation and runoff due to the presence of surface water reservoirs, from the observed flow measurements.

The daily unimpaired flow data set is used as the input flow series for all yield model simulations and represents the Corps' best estimate of a pre-development flow series. By making these flow adjustments for man-made activities, any combination of water demands input to the ResSim model and modeled over the entire flow record (1939 – 2011), produces a consistent basis for comparing yield results. Yield simulations are computed for with no water diversion and with current water diversion scenarios using current river diversions to compute yield accounts for existing conditions.

The unimpaired flow dataset is not an exact replication of a flow dataset representing conditions that would exist without the influence of human activities or a precise measure of natural flow conditions. This is because all human influences, such as land use changes, cannot be accounted for, and many flow set adjustments are estimates based upon assumptions, not direct measurements of the human influences.

The original unimpaired flow data set developed as part of the Alabama-Coosa-Tallapoosa and Apalachicola Chattahoochee Flint (ACT/ACF) River Basins Comprehensive Water Resources Study, <u>ACT/ACF Comprehensive Water Resources Study, Surface Water Availability Volume I: Unimpaired Flow, July 8, 1997</u> . The Comprehensive Study was conducted by the States of Alabama, Florida and Georgia and the Corps pursuant to a Memorandum of Understanding. One purpose of the study was to identify available water resources and water demands in the ACT and ACF Basins, and recommend a coordination mechanism for the equitable allocation of water resources between the States. Several technical modeling and assessment tools were developed to support this process, including the unimpaired flow dataset and the HEC-5 hydrological model.

The process accumulated data at over 50 locations for the 1939 to 1993 period of record. Because of the occurrence of negative flows in the daily values, the data has been smoothed using 3-, 5-, or 7-day averaging. This preserves the volume of the flow and eliminates most of the small negative flows in some of the daily flow data. The primary reason for the negative local unimpaired flows is related to estimating actual routing of flows. Routing travel times are limited to 24 hours in the daily ResSim model. Actual travel time may not coincide with the 24-hour increment through the entire flow range.

The Mobile District modeling team develops the unimpaired flow data sets every 1 - 3 years employing water use data provided by the States of Alabama, Florida and Georgia. The unimpaired flow datasets are reviewed by the states before finalizing. All supporting data and the final results of the analyses are provided to the states. This data set has recently been extended through 2011 and is available from the Corps of Engineers.

1.2 DROUGHT PERIOD UTILIZED IN CRITICAL YIELD

Several drought periods have been identified from the historic record and from previous yield analyses (reference Appendix D - References and Prior Reports). Drought periods were identified in 1939-43; 1954-58; 1984-89; 1998-2003, and 2006-2008. These are shown below in Table A-1 and described in more detail at Appendix D - Drought Descriptions.

Each period is referenced in accordance to the decade or most severe year of occurrence. Critical yield was computed for each of the drought periods and the lowest value selected as the critical yield value for this report.

Table A- 1. Drought Periods

Drought Periods	Label
1939-1943	1940
1954-1958	1950
1984-1989	1980
1998-2003	2000
2006-2008	2007

1.3 MODELS

A computer simulation model is a computer program that simulates a simplified model of a system. The U.S. Army Corps of Engineers' Hydrologic Engineering Center's (HEC) Reservoir System Simulation (HEC-ResSim) is a computer program comprised of a graphical user interface (GUI) and a computational engine to simulate reservoir operations. HEC-ResSim was developed to aid engineers and planners performing water resources studies by representing the behavior of reservoirs and to help reservoir operators plan releases in real-time during day-to-day and emergency operations.

The HEC-ResSim Yield Analysis calculates the release for a single minimum release operation rule that drains the reservoir's pool to empty once in the period of record. This figure can also be described as the largest release that can be supplied reliably throughout the record. This "reliable release" is also known as the critical yield and in previous documents has been referred as to prime flow. The process involves computing a simulation run with an estimate of the largest release, and re-computing iteratively with successive estimates until the correct release is found

The user enters the maximum number of iterations that will be run and two tolerance values. The Storage Test Tolerance value shares the same units as the reservoir storage and is the value the reservoir must decrease in order to be considered empty. It is used as the tolerance for all the zone storage values listed in the reservoir table. The Rule Test Tolerance value shares the same units as the minimum release rule and is used in the calculations as a test for violations of the minimum release rule.

The ResSim ACT yield models include a net precipitation-evaporation rate for each reservoir that utilizes evaporation values developed for National Oceanic and Atmospheric Administration (NOAA) Technical Reports, monthly pan evaporation rates and National Weather Service (NWS) reports of rainfall and flow rates. The net evaporation losses, evaporation minus precipitation, were computed in inches at the projects. The NOAA report was used because historic monthly evaporation data is not available at the projects. Historic monthly precipitation data was obtained from the NWS.

The local unimpaired flow is used as the input time series for the reservoir model. The reservoir simulation model for this yield analysis uses a daily-time step for all computations. Model runs (simulations) are performed for each identified drought periods and capture the drawdown and refill of reservoir during the drought period.

1.4 METHODS EMPLOYED IN CRITICAL YIELD ANALYSIS

There are several ways of computing critical yield. Sequential analysis is currently the most accepted method. This method uses the conservation of mass principles to account for the water in the reservoir inflows and releases. The fundamental equation is:

$$\boldsymbol{I} - \boldsymbol{O} = \Delta \boldsymbol{S}$$

Where:

$\boldsymbol{I}$ = Total inflow during the time period, in volume units

$\boldsymbol{O}$ = Total outflow during the time period, in volume units

$\Delta \boldsymbol{S}$ = Change in storage during the time period, in volume units

Sequential routing uses an iterative form of the above equation:

$$S_t = S_{t-1} + I_t - O_t$$

Where:

S_t = Storage at the end of time t, volume units

S_{t-1} = Storage at the end of time t-1, volume units

I_t = Average inflow during time step Δ, in volume units

O_t = Average outflow during time step Δ, in volume units

The HEC-ResSim computer application uses sequential analysis and the sequential routing method with the application's Yield Analysis routine to maximize yield from a specified amount of storage.

It is important to be aware that the most severe drought event at one reservoir may not be the most severe drought event at another reservoir in the same river system. .

1.1.2 Method A (Without Diversions)

Method A assumes that there are no withdrawals from or returns to the lake or the river as it flows between projects. This condition results in the maximum yield possible from the Federal projects. Critical yield from an upstream reservoir is assumed to be permanently removed from the system and does not contribute to the inflow at downstream reservoirs.

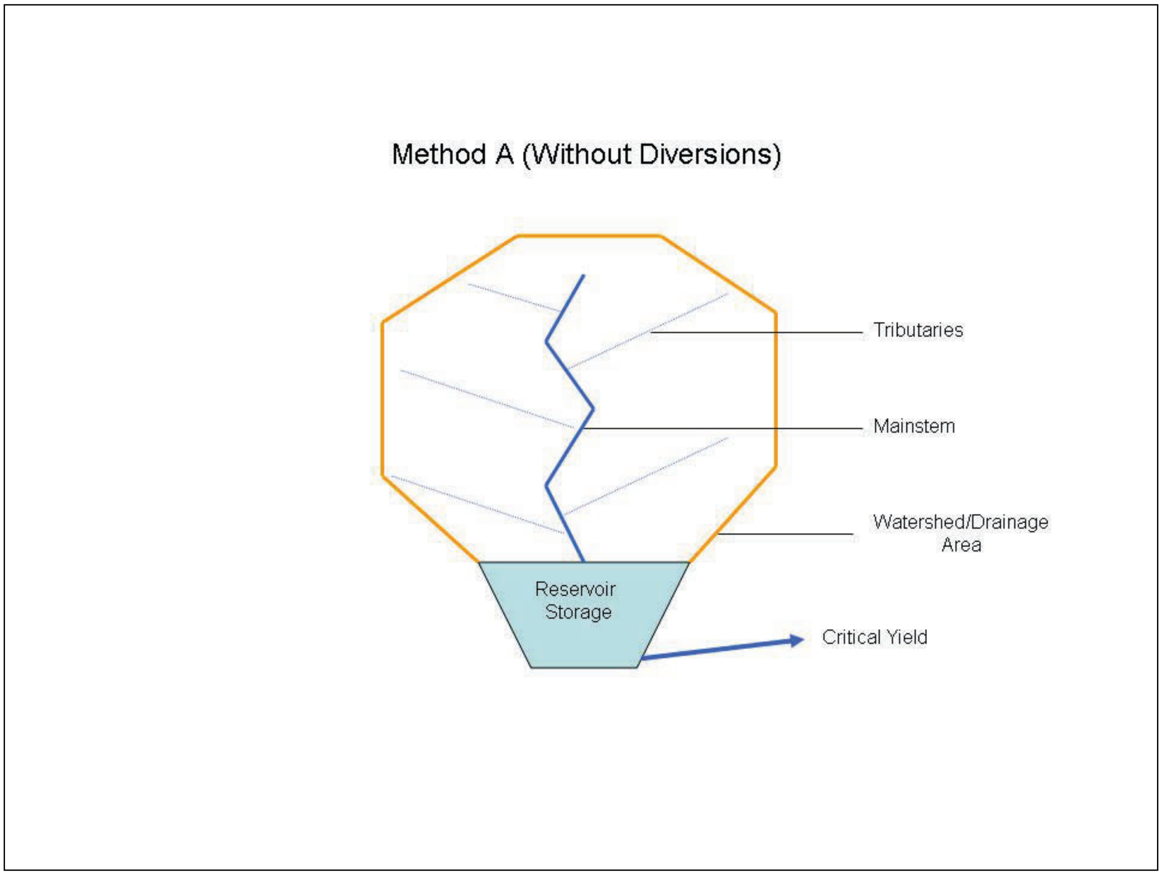


Figure A- 1. Critical Yield Method A (Without Diversions)

1.1.3 Method B (With Diversions)

Method B assumes net river withdrawals and returns are occurring; this method does not include withdrawals from the Corps reservoirs. Critical yield from an upstream reservoir is assumed to be permanently diverted from the system and does not contribute to the inflow at downstream reservoirs. This condition results in the most severe downstream impact. The results of Method B represent a realistic assessment of the critical yield available from Federal projects controlled by the Corps. Method B used the most severe drought events documented during the hydrologic period of record and the year of maximum river withdrawals (2006 for the ACT) to make the calculations.

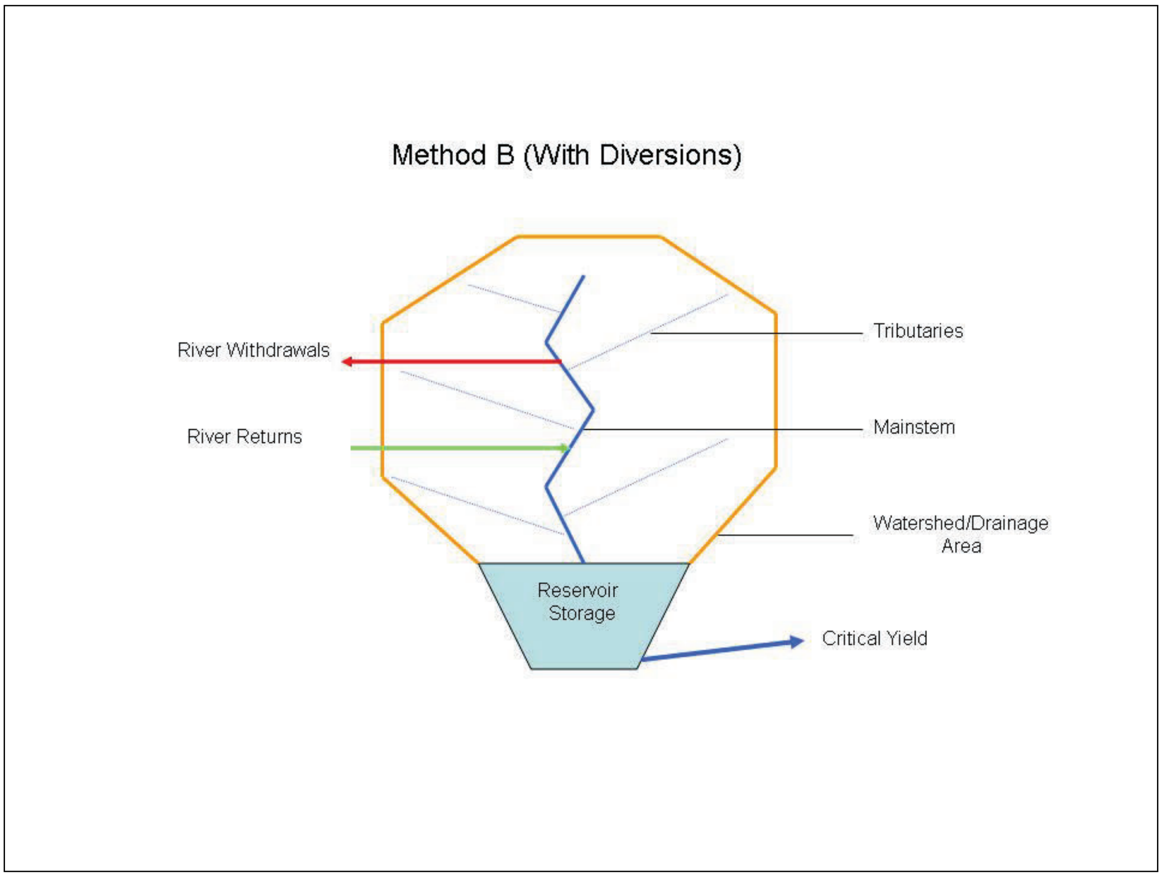


Figure A- 2. Critical Yield Method B (With Diversions)

1.1.4 Method C (River System Yield)

Method C computes a system yield for diversion from the most downstream storage reservoir. It assumes upstream reservoirs operate in tandem to maximize the critical yield at the most downstream reservoir. Method C computes critical yield for the ACF River System with and without net river withdrawals. The with net river withdrawals condition results represent the Corps' yield. The without net river withdrawals condition results represent the system theoretical maximum yield.

ACT critical yields are computed using only Methods A and B. This is because both Carters Dam and Allatoona Dam operate independently and do not influence water availability at the other reservoir.

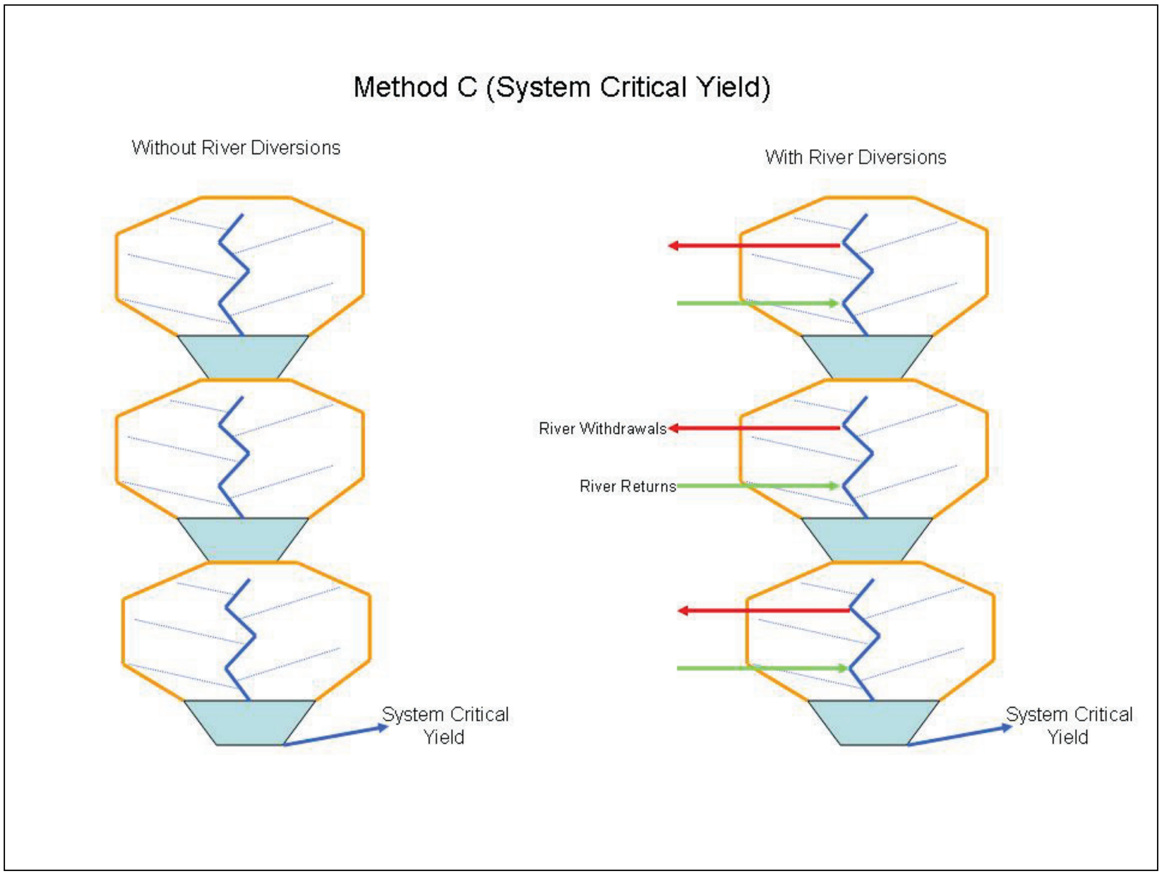


Figure A- 3. Critical Yield Method C (System Critical Yield)

1.5 SEASONAL STORAGE

The amount of conservation storage (storage resulting from operating at the conservation pool) is seasonal at federal projects because of the seasonal drawdown to support flood reduction operations. Table A-2 lists the elevation difference in the guide curve and reduction in conservation storage for the federal projects.

Table A- 2. Seasonal Conservation Storage Reduction

Project	Elevation Difference (feet)	Storage Difference (ac-ft)	Percent Reduction In Conservation Storage
Allatoona	17 = 840-823	156,609	54%
Carters	2 = 1074-1072	6,491	5%

For Allatoona, the yield of these projects is highly dependent on the beginning of the critical dry period. In other words, it matters whether the critical period begins during the winter, summer, or transition level of the guide curve. Although the project has a high probability of refill to summer pool from a low winter level, extreme rare events will prevent the project from refilling. Consequently, if the critical period begins before the reservoir reaches full summer level the critical yield will be lower than when compared to starting at full summer level. For the determination of critical yields, the yield simulation begins approximately one year before the drought period begins. The analyses assume about one year of normal flows prior to the beginning of the drought period. Drawdown could start whenever flows were low enough for the lake to fall below a target level, be it winter, summer or transition. For the efficiency of computations, separate drought periods were run, always considering the prior year average flows and assuming the highest possible elevation on the guide curve as the target level.

Appendix B

Alabama-Coosa-Tallapoosa (ACT) Basin

Appendix B - Alabama-Coosa-Tallapoosa (ACT) Basin

1 ACT BASIN

1.1 DESCRIPTION OF BASIN

The headwater streams of the Alabama-Coosa-Tallapoosa (ACT) System rise in the Blue Ridge Mountains of Georgia and Tennessee and flow southwest, combining at Rome, Georgia, to form the Coosa River. The confluence of the Coosa and Tallapoosa Rivers in central Alabama forms the Alabama River, which flows through Montgomery and Selma and joins with the Tombigbee River at the bottom of the ACT Basin about 45 miles above Mobile to form the Mobile River. The Mobile River flows into Mobile Bay at an estuary of the Gulf of Mexico. The total drainage area of the ACT Basin is approximately 22,800 square miles.

Progressing downstream from the headwater are the Cities of Rome, Georgia, Gadsden, and Montgomery, Alabama in the central portion of Alabama. The largest metropolitan area in the basin is Montgomery, Alabama.

Figure B- 1. ACT Basin

1.1.1 Physical Description

Beginning in the headwaters of northeast Georgia with spring fed mountain streams the slope is steep, with rapid runoff during rainstorms. Some of the most upstream tributaries are the Oostanaula River, the Conasauga River, Ellijay River, the Cartecay River and Etowah River.

The Etowah River, which joins the Oostanaula River at Rome, Georgia, to form the Coosa River, lies entirely within Georgia. It is formed by several small mountain creeks which rise on the southern slopes of the Blue Ridge Mountains at an elevation of about 3,250 feet. The river flows southerly, southwesterly, and then northwesterly for 150 miles to Rome, Georgia. The drainage basin of 1,860 square miles has a maximum width of about 40 miles and a length of about 70 miles. Allatoona Dam is located on the Etowah River near Cartersville, Georgia. It is a multiple-purpose Corps project placed in operation early in 1950 and provides storage for power and flood control. Principal tributaries of the Etowah River are Amicalola, Settingdown, Shoal, Allatoona, Pumpkinvine and Euharlee Creeks and Little River. Three of these, Allatoona and Shoal Creeks, and Little River drain into Lake Allatoona.

The Coosawattee River is 45 miles long; and has a fall of 650 feet, an average of 14.4 feet per mile. The Carters Project is located on the Coosawattee River at river mile 26.8. This federal project consists of an earth-fill dam, and a downstream re-regulation reservoir that accommodates pump-back operations.

The Conasauga River, with its tributary Jacks River, rises on the northern slopes of the Cohutta Mountains in Fanning County, Georgia, at an elevation of about 3,150 feet. Its drainage basin, 727 square miles, has a maximum width of 25 miles and a length of 40 miles. The eastern and northern portions of the basin are rugged and mountainous, containing peaks over 4,000 feet in elevation. The river flows 90 miles from the headwater to join the Coosawattee River to form the Oostanaula River.

From its source at the confluence of the Coosawattee and Conasauga Rivers at Newtown Ferry, Georgia., the Oostanaula River meanders southwesterly through a broad plateau for 47 miles to its mouth at Rome, Georgia. Its total drainage area is 2,160 square miles.

The Coosa River, which is formed by the Etowah and Oostanaula Rivers at Rome, Georgia, flows first westerly, then southwesterly and finally southerly a total distance of 286 miles to its mouth, 11 miles below Wetumpka, Alabama, where it joins the Tallapoosa to form the Alabama River. The drainage area of the Coosa River is approximately 10,200 square miles. Alabama Power Company operates eleven dams with seven on the Coosa River. These are Weiss Dam, H. Neely Henry Dam, Logan Martin Dam, Lay Dam, Mitchell Dam, and Jordan-Bouldin Dams.

The Tallapoosa River, with a drainage area of 4,680 square miles, rises in northwestern Georgia at an elevation of about 1,250 feet, and flows westerly and southerly for 268 miles, joining the Coosa River south of Wetumpka, Alabama to form the Alabama River. There are four large power dams owned by the Alabama Power Company on the Tallapoosa River. These are Harris Dam, Martin Dam, Yates Dam, and Thurlow Dam.

The Alabama River meanders from the head near Wetumpka through the Coastal Plain westerly for about 100 miles to Selma, Alabama. From there it flows southwesterly 214 miles to its mouth near Calvert, Alabama. There are three Corps projects on the Alabama River. Robert F. Henry Lock and Dam and Millers Ferry Lock and Dam provide for hydropower and navigation. Claiborne Lock and Dam provides for navigation only.

1.1.2 Climate

The chief factors that control the climate of the Alabama-Coosa-Tallapoosa Basin are its geographical position in the southern end of the Temperate Zone, its proximity to the Gulf of Mexico and South Atlantic Ocean, and its range in altitude from almost sea level at the southern end to over 4,000 feet in the Blue Ridge Mountains to the north. The proximity of the warm South Atlantic and the semitropical Gulf of Mexico insures a warm, moist climate. Extreme temperatures range from near 110 degrees in the summer to values below zero in the winter. Severe cold weather rarely lasts longer than a few days. The summers, while warm, are usually not oppressive. In the southern end of the basin the average maximum January temperature is 60 degrees and the average minimum January temperature is 37 degrees.

The Maximum average July temperature is 91 degrees; in the southern end of the basin the corresponding minimum value is 69 degrees. The frost-free season varies in length from about 200 days in the northern valleys to about 250 days in the southern part of the basin. Precipitation is mostly in the form of rain, but some snow falls in the mountainous northern region on an average of twice a year.

1.1.3 Precipitation

The entire ACT Watershed lies in a region which ordinarily receives an abundance of precipitation. The watershed receives a large amount of rain and it is well distributed throughout the year. Winter and spring are the wettest periods and early fall the driest. Light snow is not unusual in the northern part of the watershed, but constitutes only a very small fraction of the annual precipitation and has little effect on runoff. Intense flood producing storms occur mostly in the winter and spring. They are usually of the frontal-type, formed by the meeting of warm moist air masses from the Gulf of Mexico with the cold, drier masses from the northern regions, and may cause heavy precipitation over large areas. The storms that occur in summer or early fall are usually of the thunderstorm type with high intensities over smaller areas. Tropical disturbances and hurricanes can occur producing high intensities of rainfall over large areas.

1.1.4 Storms and Floods

Major flood-producing storms over the ACT Watershed are usually of the frontal type, occurring in the winter and spring and lasting from 2 to 4 days, with their effect on the basin depending on their magnitude and orientation. The axes of the frontal-type storms generally cut across the long, narrow basin. Frequently a flood in the lower reaches is not accompanied by a flood in the upper reaches and vice versa. Occasionally, a summer storm of the hurricane type, such as the storms of July 1916 and July 1994, will cause major floods over practically the entire basin. However, summer storms are usually of the thunderstorm type with high intensities over small areas producing serious local floods. With normal runoff conditions, from 5 to 6 inches of intense and general rainfall are required to produce wide spread flooding, but on many of the minor tributaries 3 to 4 inches are sufficient to produce local floods.

Historically, minor or major floods within the ACT Basin occur about two times per year. The storms which occurred in July 1916, December 1919, March 1929, February 1961, and July 1994 are of special interest because of the intensities of precipitation over large areas. It should be noted that they represent both the hurricane and frontal types which produce the great floods in this area.

1.1.5 Runoff Characteristics

Within the ACT Basin rainfall occurs throughout the year but is less abundant during the August through November time frame. The amount of this rainfall that actually contributes to streamflow varies much more than the rainfall. Several factors such as plant growth and the seasonal rainfall patterns contribute to the volume of runoff.

Table B-1 and Table B-2 present the average monthly runoff for the basin. These tables divide the basin at Rome Georgia to show the different percentages of runoff verses rainfall for the northern and southern sections. The mountainous areas exhibit flashier runoff characteristics and somewhat higher percentages of runoff.

Figure B-2 and Figure B-3 present the same information in graphical form.

Table B- 1. Average Monthly Runoff at Rome, Georgia

AVERAGE MONTHLY RUNOFF IN ACT BASIN MEASURED AT ROME GEORGIA												
MONTH	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
AVG MONTHLY FLOW (CFS) AT ROME	6,525	9,602	11,652	12,828	10,565	7,038	4,636	4,234	3,188	2,778	2,867	4,162
AVG RUNOFF IN INCHES AT ROME	1.86	2.47	3.33	3.54	3.01	1.94	1.32	1.21	0.88	0.79	0.79	1.19
AVG RAINFALL IN INCHES	5.15	4.97	5.96	4.79	4.22	3.92	4.89	3.77	3.82	3.05	3.90	4.87
PERCENT OF RAINFALL AS RUNOFF	36%	50%	56%	74%	71%	50%	27%	32%	23%	26%	20%	24%

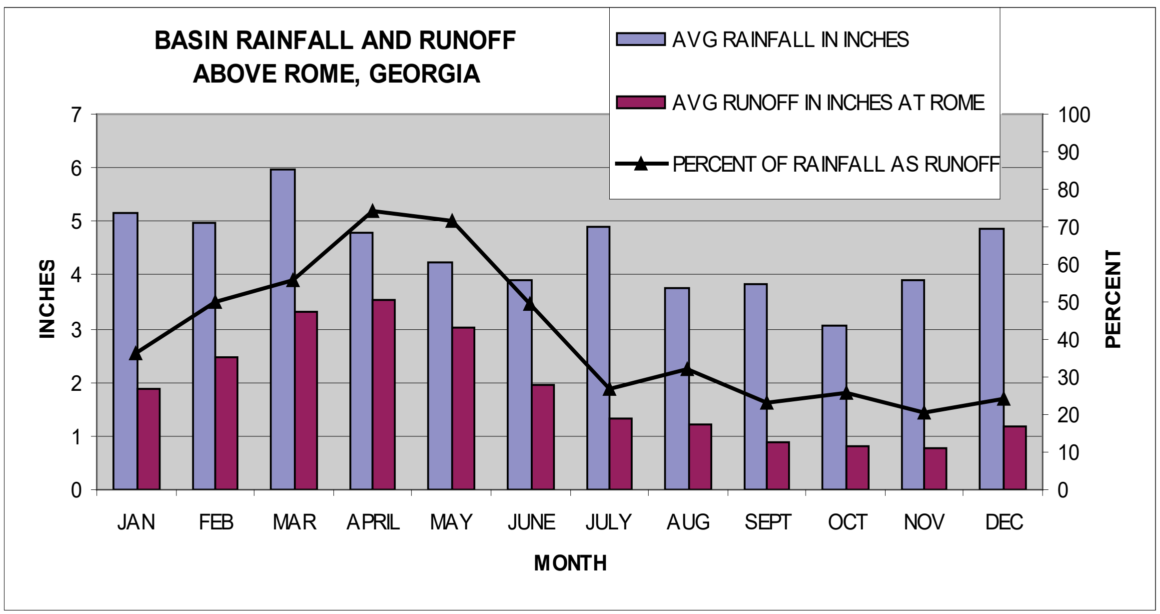


Figure B- 2. Basin Rainfall and Runoff above Rome, Georgia

Table B- 2. Average Monthly Runoff at Claiborne, Alabama

AVERAGE MONTHLY RUNOFF IN ACT BASIN MEASURED AT CLAIBORNE ALABAMA												
MONTH	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
AVG MONTHLY FLOW (CFS) AT CLAIBORNE	31,529	47,762	58,487	69,862	57,732	32,294	19,981	18,553	14,386	11,346	11,279	16,606
INCREMENTAL FLOW BETWEEN CLAIBORNE AND ROME	25,004	38,160	46,835	57,034	47,167	25,256	15,345	14,319	11,198	8,568	8,412	12,444
AVG RUNOFF IN INCHES BETWEEN CLAIBORNE AND ROME	1.65	2.52	3.10	3.77	3.12	1.67	1.01	0.95	0.74	0.57	0.56	0.82
AVG RAINFALL IN INCHES	5.19	5.15	6.10	4.90	4.18	4.16	5.28	3.95	3.63	2.84	4.07	4.93
PERCENT OF RAINFALL AS RUNOFF	32%	49%	51%	77%	75%	40%	19%	24%	20%	20%	14%	17%

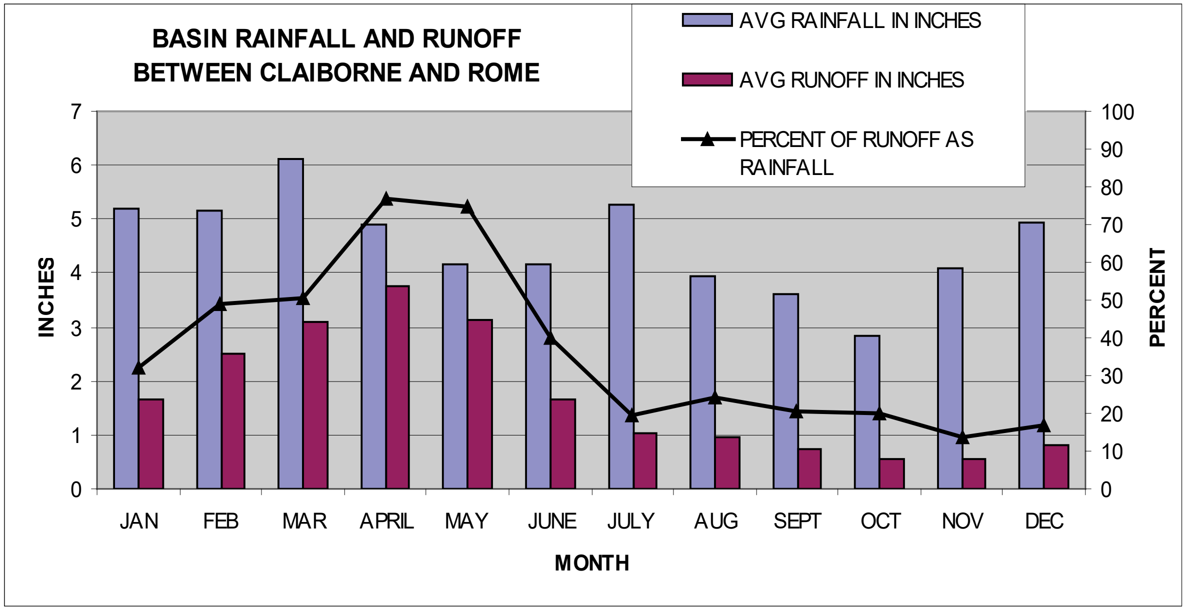


Figure B- 3. Basin Rainfall and Runoff between Claiborne, Alabama and Rome, Georgia

1.2 RESERVOIRS

1.2.1 Reservoir Storage

Within the Alabama-Coosa-Tallapoosa River Basin there are five (5) federally owned reservoir projects; Carters Dam (Carters Lake), Allatoona Dam (Allatoona Lake), R.F. Henry Lock and Dam (Jones Bluff Powerhouse and Woodruff Reservoir), Millers Ferry Lock and Dam (William Danelly Lake), and Claiborne Lock and Dam (Claiborne Lake). These projects were built and are operated by the Corps, Mobile District Office. The Alabama Power Company owns and operates seven dams on the Coosa River and four on the Tallapoosa River.

The reservoir storage in the basin controlled by each of the reservoirs is listed in Table B-3 and shown graphically in Figure B-4. Claiborne Lock and Dam is not shown because the storage is insignificant.

Table B- 3. ACT Basin Conservation Storage Percent by Acre-Feet

Project	Conservation Storage (ac-ft)	Percentage
*Allatoona	270,247	10%
*Carters	141,402	5%
Weiss	263,417	10%
Neely Henry	118,210	5%
L Martin	144,383	6%
Lay	92,352	4%
Mitchell	51,577	2%
Jordan/Bouldin	19,057	1%
Harris	207,317	8%
Martin	1,202,340	46%
Yates	6,928	0.3%
*RF Henry (Jones Buff)	36,450	1%
*Millers Ferry	46,704	2%
Total	**2,600,384**	

* Federal project

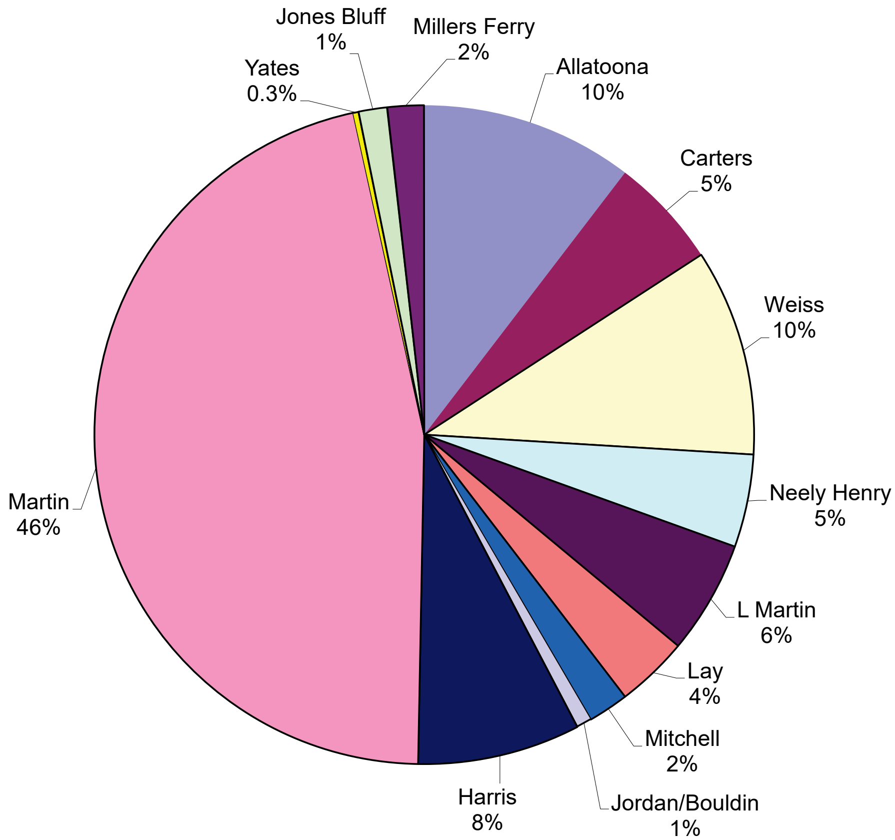


Figure B- 4. ACT Basin Reservoir Conservation Storage Percent by Acre-Feet

The figure shows the greatest conservation storage (46%) in the basin is from the Alabama Power Company Lake Martin project on the Tallapoosa River. In addition, the Alabama Power Company controls 81% of the basin storage; federal projects (RF Henry, Millers Ferry, Allatoona, and Carters) control only 19%.

1.2.2 Reservoirs Selected for Yield

As shown above the only federal projects with significant storage are Allatoona and Carters. These two projects in the upper basin account for 15% of the total basin conservation storage. Therefore, yield analyses was performed on these two projects. These analyses are presented separately.

1.3 ALLATOONA DAM (ALLATOONA LAKE)

Allatoona Dam is located on the Etowah River in Bartow County, Georgia, about 32 miles northwest of Atlanta and 26 miles northeast of Rome, Georgia. The reservoir lies within Bartow, Cobb, and Cherokee Counties. The 1,110 square miles drainage area lies on the southern slopes of the Blue Ridge Mountains and consist of steep sloping mountain terrain.

Allatoona Dam is a multiple purpose project with principal purposes of flood control, hydropower, navigation, water quality, water supply, fish and wildlife enhancement and recreation. Its major flood protection area is Rome, Georgia, about 48 river miles downstream. Allatoona Dam operations, along with those of Carters Dam on the Coosawattee River which also contributes to flow at Rome, Georgia provide flood stage reductions at Rome. The project was completed in December 1949. An aerial photo of the dam is shown in Figure B-5.

Figure B- 5. Allatoona Dam

1.3.1 Drainage Area

The Etowah River and its upstream tributaries originate in the Blue Ridge Mountains of northern Georgia, near the western tip of South Carolina. The northern boundary of the Allatoona drainage area is shared with the Carters Dam drainage area along a high ridge varying from elevation 1300 to 3800 feet NGVD and with the Tennessee and Chattahoochee Rivers along the eastern and southern boundaries along a lower ridge varying from elevation 1200 to 1900 feet NGVD. The creeks along the upper Etowah River have steep mountainous slopes which produce rapid runoff. However, the main stem above the reservoir is more than 70 miles long which produces large flood inflows that often persist for several days. The drainage area above the Allatoona Dam is 1,122 square miles.

The basin drainage area is shown on the following Figure B-6.

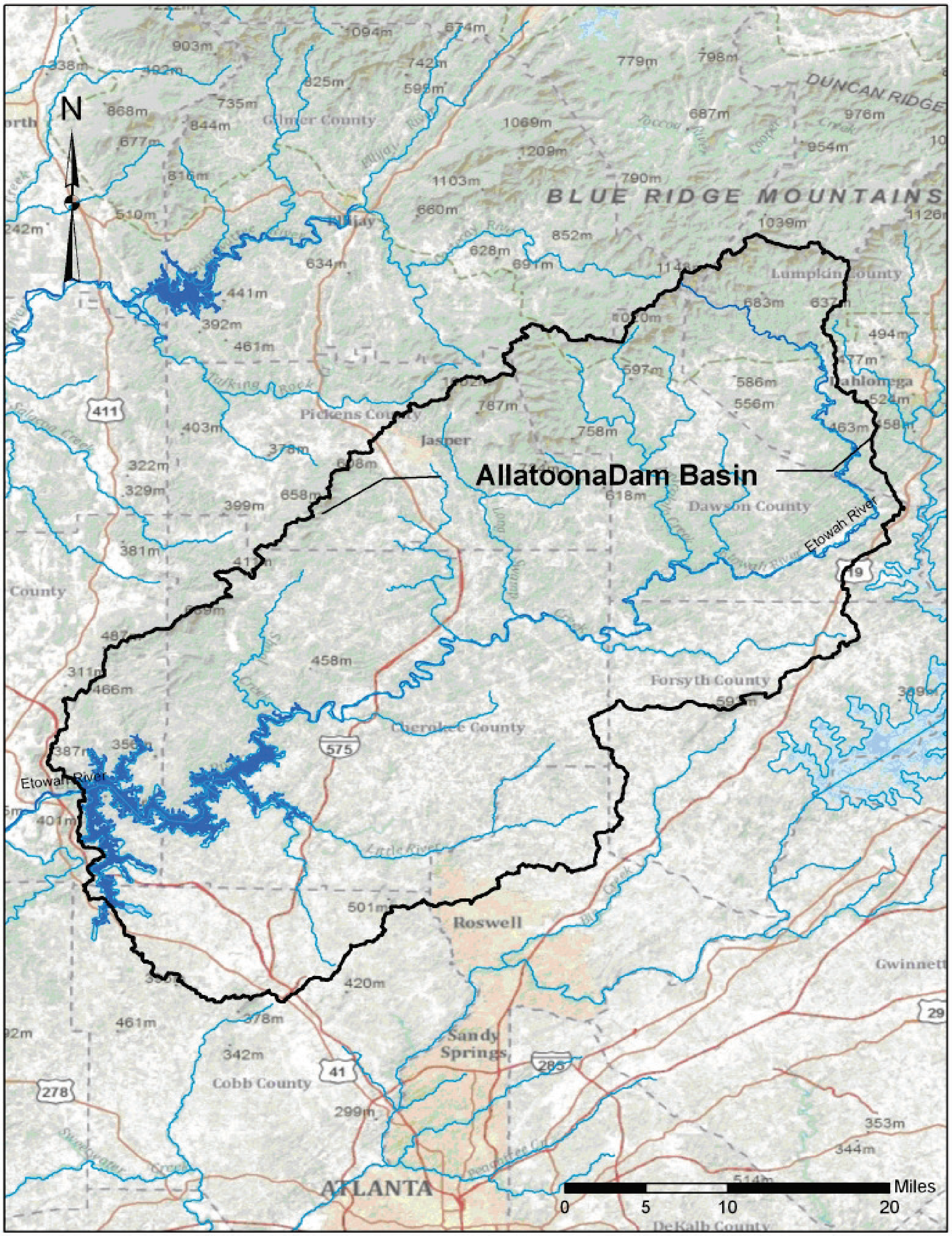


Figure B- 6. Allatoona Basin Map

The Allatoona Dam basin controls five percent of the total ACT Basin area. The relation of the Allatoona drainage basin to the ACT Basin is shown in the following Figure B-7. The figure also shows where ACT flow may be influenced by the operation or presence of federal or

Alabama Power Company dams. The basin drainage areas above the federal dams and the Alabama Power Company dams are designated in different colors. The lower federal reservoirs are essentially run-of-the-river projects with limited storage.

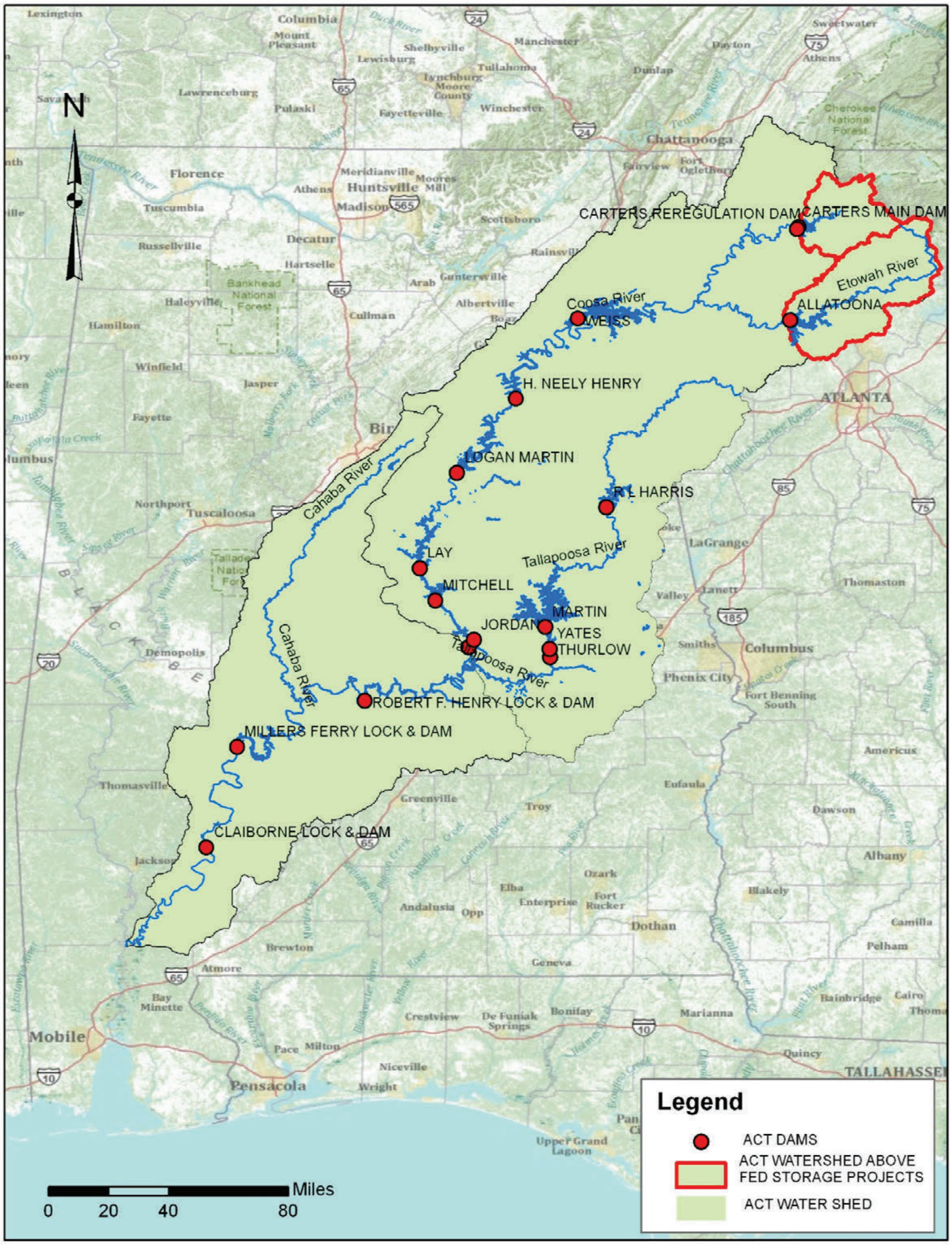


Figure B- 7. Drainage Areas for Projects on the ACT

1.3.2 General Features

The project consists of Allatoona Lake extending 28 miles up the Etowah River at full summer conservation pool of 840 feet, a concrete gravity-type dam with gated spillway, earthen dikes, a 74,400 kilowatt (kW) power plant and appurtenances. The spillway section of the dam, with a crest at elevation 835 feet NGVD, has a total flow length of 500 feet, a net length of 400 feet, and a discharge capacity of 184,000 cfs at elevation 860 feet, full flood-control pool. It is equipped with 11 tainter gates. The powerhouse has two 36,000 kW main units and one 2,400 kW service unit, making a total power installation of 74,400 kW.

1.3.2.1 Dam

The dam is a concrete gravity-type structure with curved axis convex upstream, having a top elevation of 880 feet NGVD and an overall length of approximately 1,250 feet. The maximum height above the existing river bed is 190 feet. An 18-foot wide roadway is provided across the entire length of the dam.

1.3.2.2 Reservoir

The reservoir has a total storage capacity of 626,859 acre-feet at full flood-control pool, elevation 860 feet NGVD. At this elevation the reservoir covers a surface area of 18,737 acres (29.3 square miles) or 2.6 percent of the dam site drainage area. At full summer-level conservation pool, elevation 840 feet NGVD, the reservoir covers 11,164 acres and has a total storage capacity of 338,253 acre-feet; at full winter pool of elevation 823, the reservoir covers 6,962 acres and has a capacity of 181,644 acre-feet, at minimum conservation pool, elevation 800 feet, the area covered is 3,109 acres and the capacity is 68,006 acre-feet. Area and capacity curves are shown on Figure B-8 and in Table B-4.

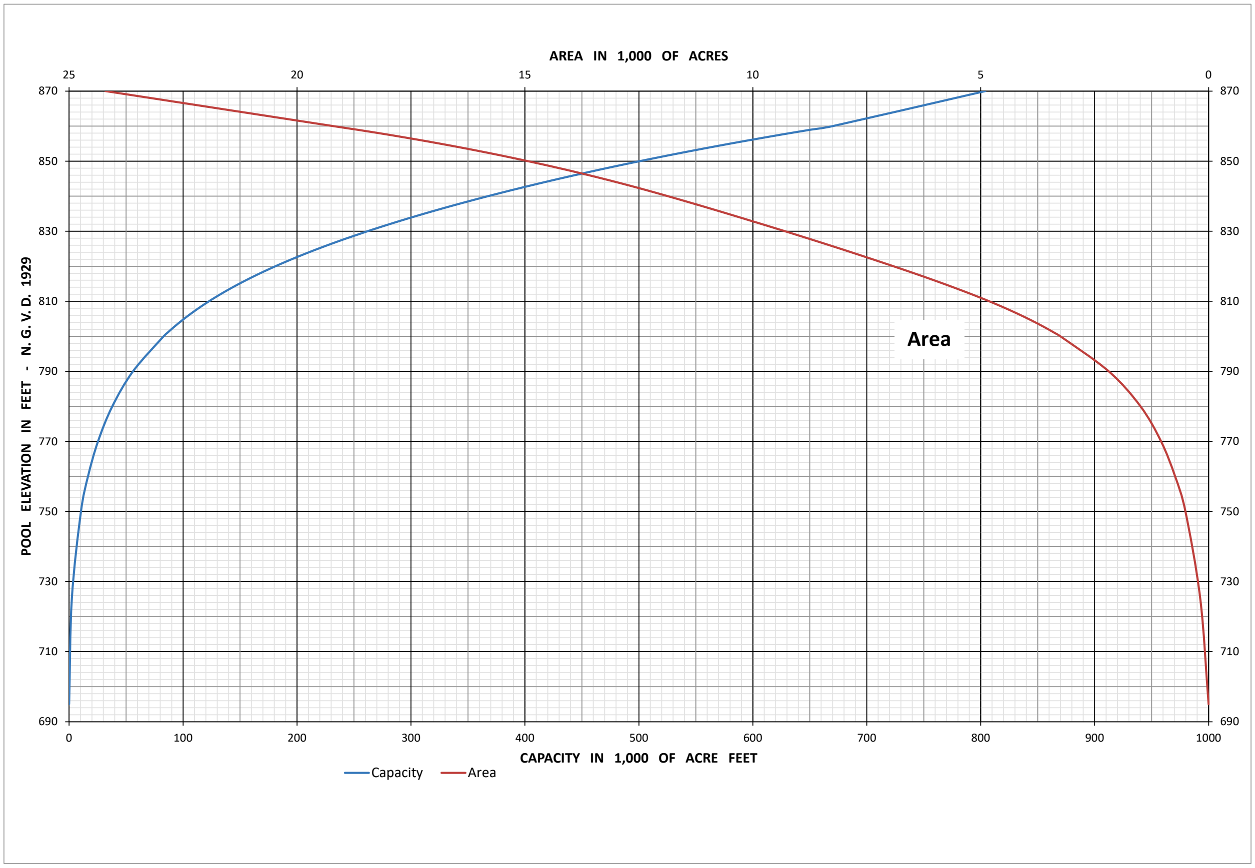


Figure B- 8. Allatoona Area – Capacity Curves (circa 2011)

Table B- 4. Lake Allatoona Area and Capacity (circa 2011)

Pool Elev	Total Area	Total Storage	Pool Elev	Total Area	Total Storage
(NGVD 29)	(ac)	(ac-ft)	(NGVD 29)	(ac)	(ac-ft)
695	0	0	828	8343	219756
710.5	17	62	829	8637	228248
720	75	524	830	8914	237023
730	142	1599	831	9181	246070
740	234	3457	832	9444	255380
750	342	6276	833	9703	264953
760	512	10494	834	9948	274778
770	801	16984	**835	10184	284843
780	1265	27217	836	10397	295135
790	1938	43045	837	10592	305628
800	3109	68006	838	10782	316314
810	4608	106228	839	10971	327189
815	5567	131724	***840	11164	338253
816	5737	137376	845	12453	396600
817	5916	143202	855	15838	534474
818	6078	149202	****860	17530.5	603411
819	6232	155356	*****865	21637	719245
820	6388	161666	870	24536.5	811630.5
820.5	6472	164881	875	27436	904016
821	6555	168137	880	30335.5	996401.5
821.5	6649	171438			
822	6751	174788			
822.5	6855	178189			
*823	6962	181644			
823.5	7071	185152			
824	7192	188717			
825	7470	196044			
826	7760	203659			
827	8048	211562			

* Bottom of conservation pool
** Top of winter conservation pool
*** Top of summer conservation pool
**** Top of Flood pool
***** Top of Surcharge pool

1.3.3 Top of Conservation Pool

The Allatoona Lake top of conservation pool is elevation 840 feet NGVD29 during the late spring and summer months (May through August); transitions to elevation 835 feet NGVD29 in the fall (October through mid-November); transitions to a winter drawdown to elevation 823 feet NGVD29 (1-15 January); and refills back to elevation 840 feet NGVD29 during the winter and spring wet season as shown in the water control plan guide curve, as shown in Figure B-9.

1.3.4 Regulation Plan

The Allatoona pool is generally regulated between winter pool elevation 823 and summer pool elevation 840. The pool may rise above elevation 840 for short periods of time during high flow periods. The top of the flood control pool is elevation 860. At this elevation, the area of the pool is 18,737 acres and the storage is 626,859 acre-feet.

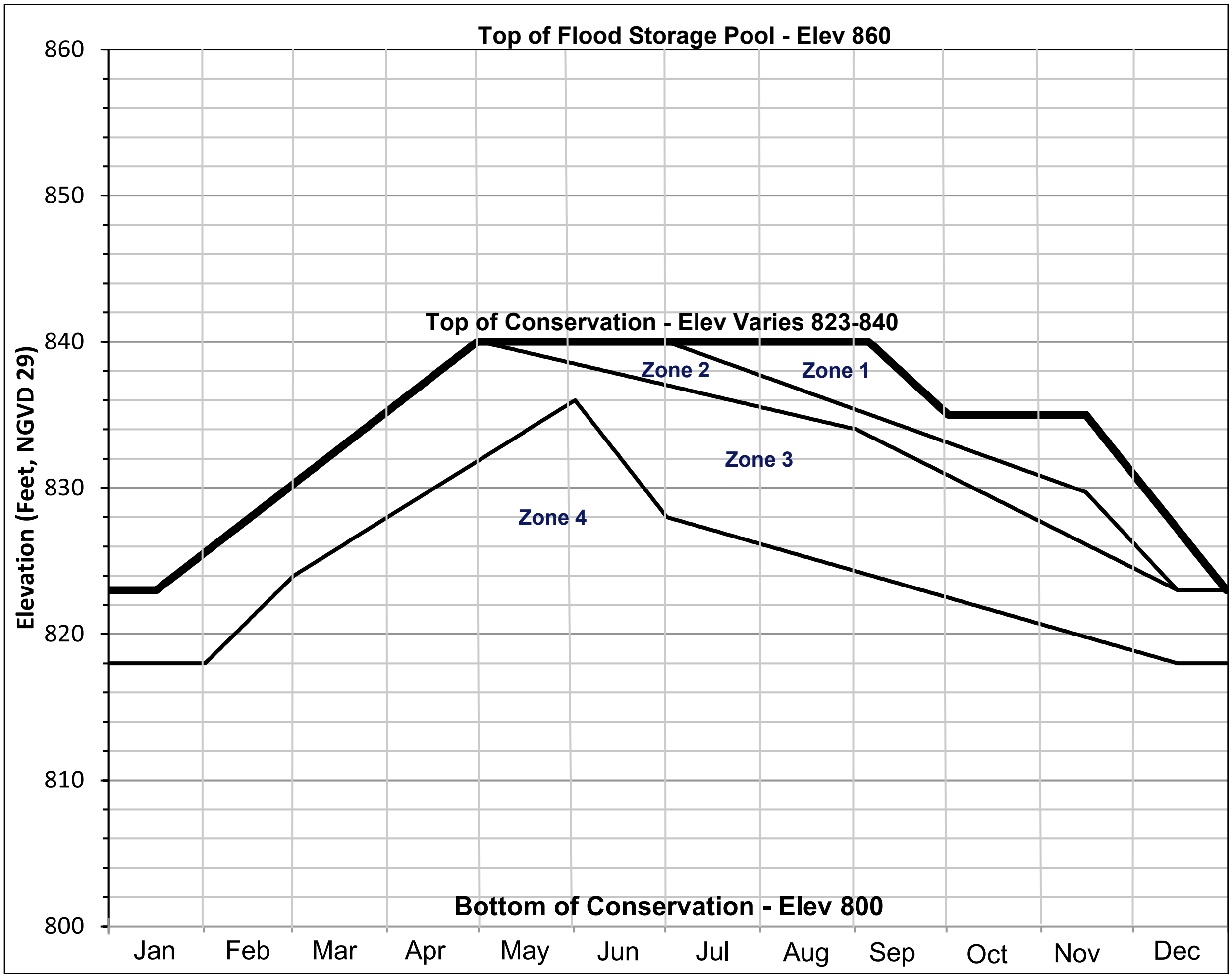


Figure B- 9. Top and Bottom of Allatoona Conservation Pool

The storage for the yield analysis will be based on the storage in the conservation pool from elevation 800 to 823-840 (depending on the time of year).

1.3.5 Surface Water Inflows

Observed daily inflow, outflow (discharge), and pool elevation data for the period of record starting in March 1950, just after the pool filled, through the present (Oct 2009) are available. The data are presented in the following Figure B-10.

1.3.6 Unimpaired Flow

The existing unimpaired flow data set was updated through 2011 for use in the yield analysis. The daily data was smoothed using 3-, 5-, or 7-day averaging to eliminate small negative values. Although this averaging affects the peak values, the volume is the same and the yield computations were done on the smoothed data. A plot of this smoothed unimpaired daily flow averaged over each year for the period of record 1939 - 2011 is shown in Figure B-11. Daily flows for critical drought periods are plotted in more detail in Figures B-12 - B-16.

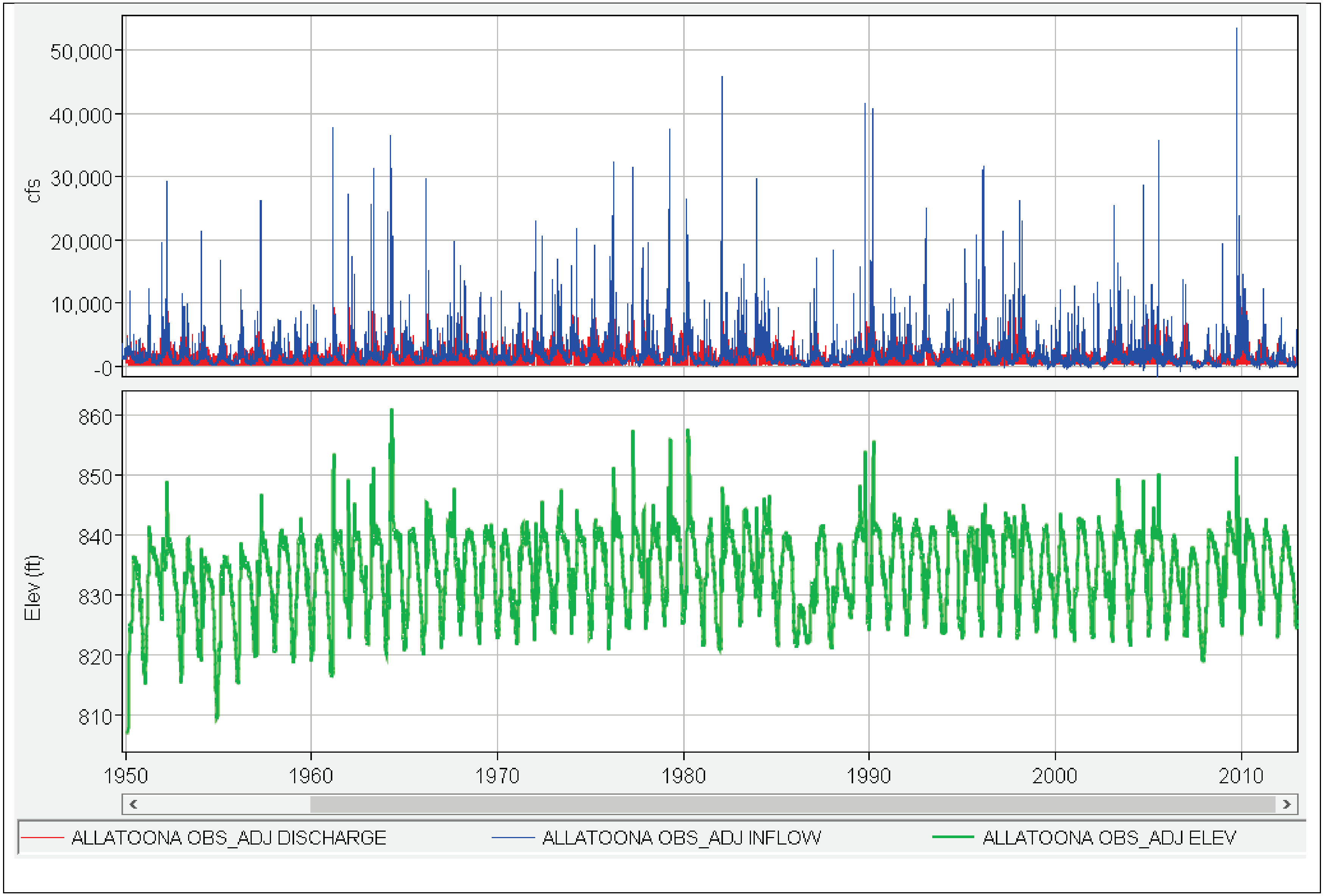


Figure B- 10. Allatoona Inflow-Outflow-Pool Elevation (Jan 50 – Dec 2012)

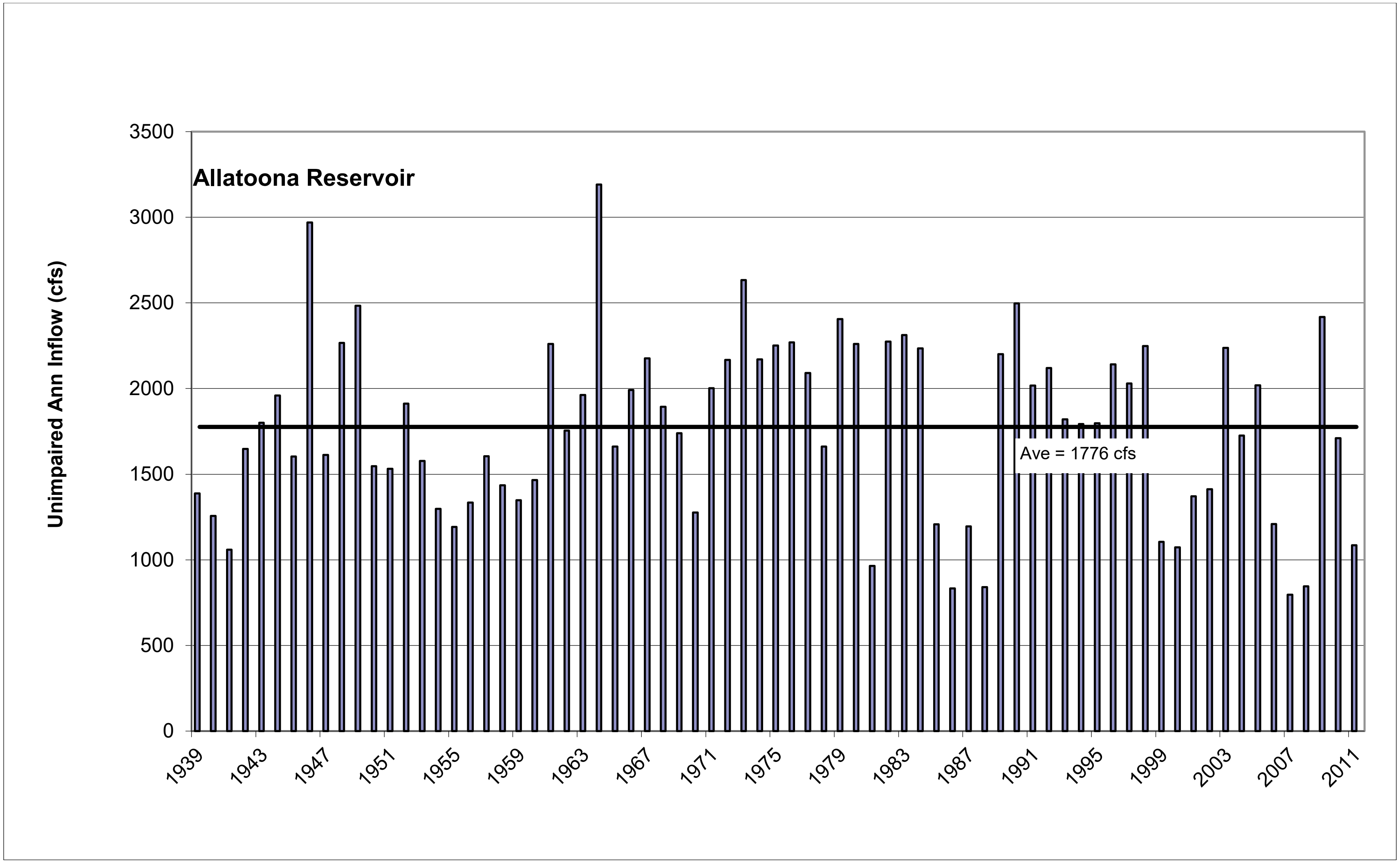


Figure B- 11. Allatoona Unimpaired Annual Inflow Jan 1939 to Dec 2011

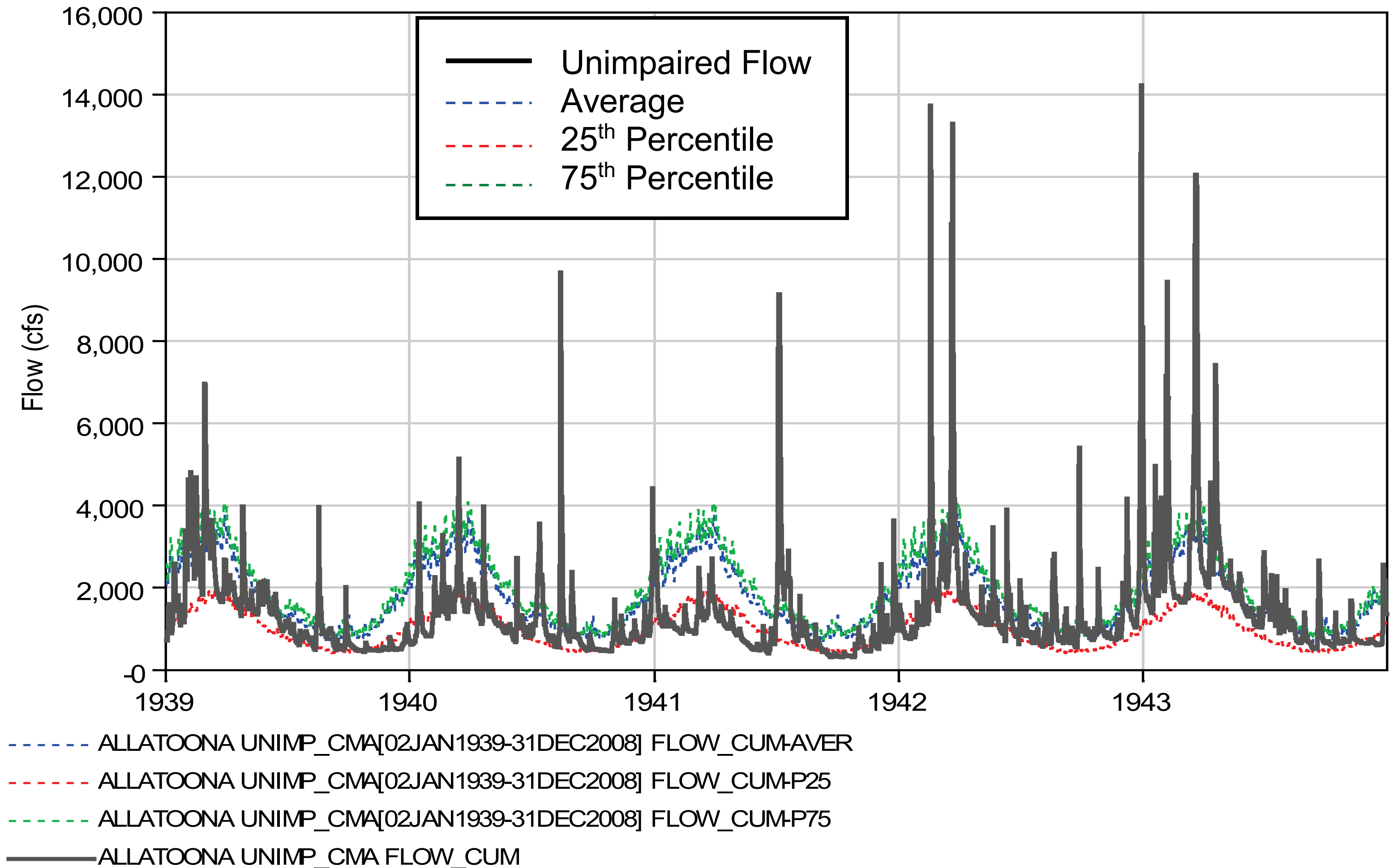


Figure B- 12. Allatoona Unimpaired Inflow – 1939 - 1943 Drought; 75th Percentile, Average and 25th Percentile Flow

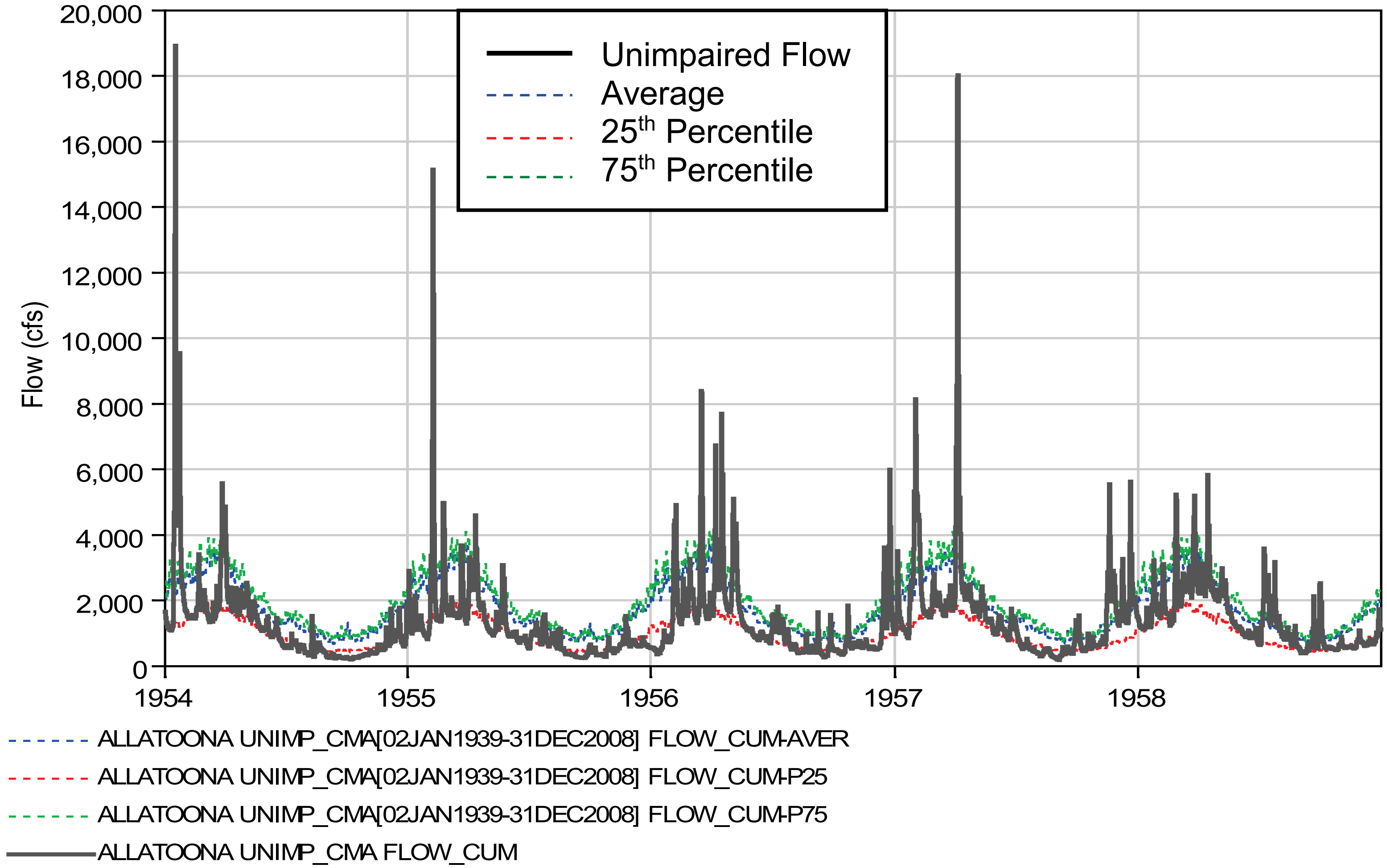


Figure B- 13. Allatoona Unimpaired Inflow – 1954 - 1958 Drought; 75th Percentile, Average and 25th Percentile Flow

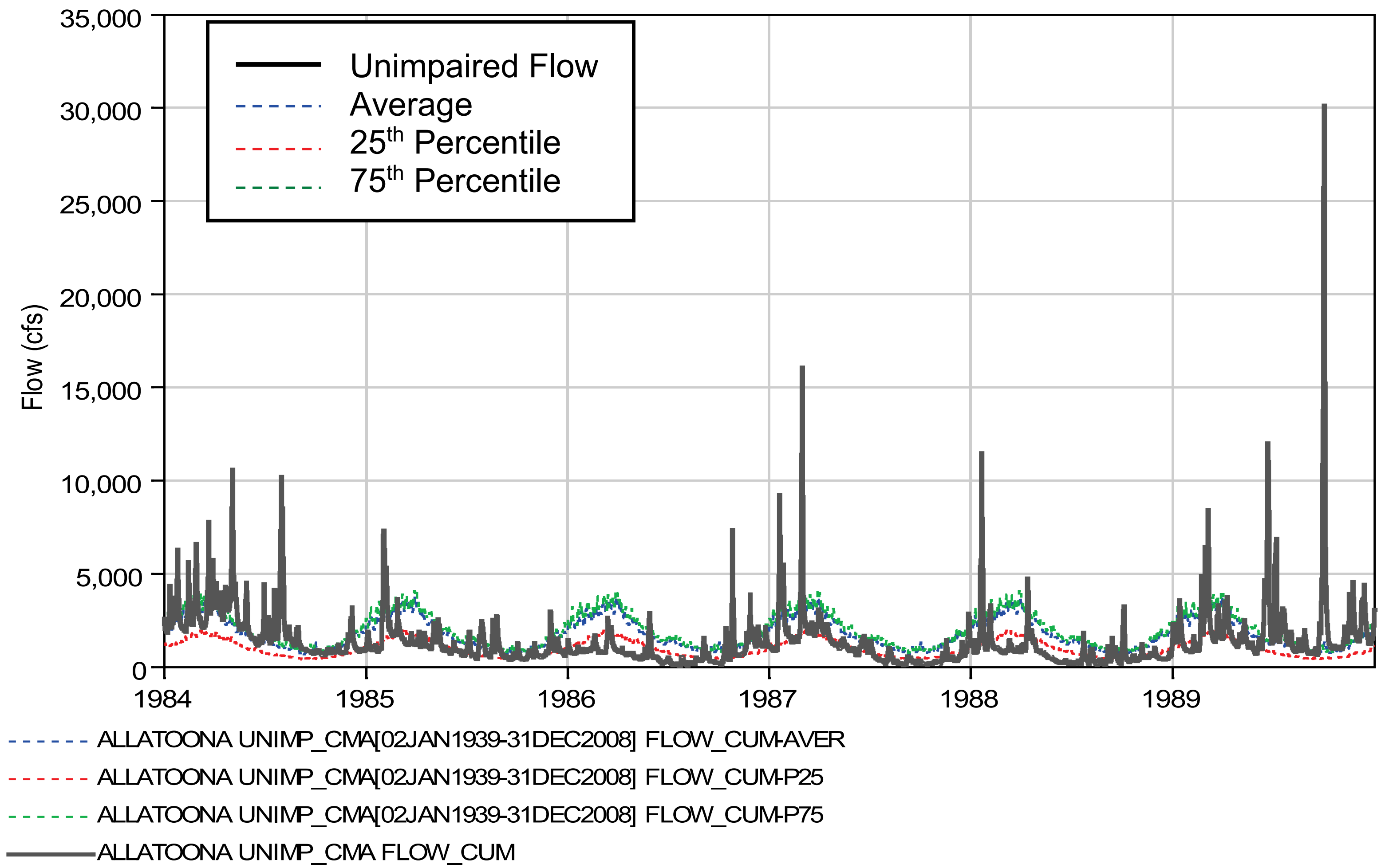


Figure B- 14. Allatoona Unimpaired Inflow – 1984 - 1989 Drought; 75th Percentile, Average and 25th Percentile Flow

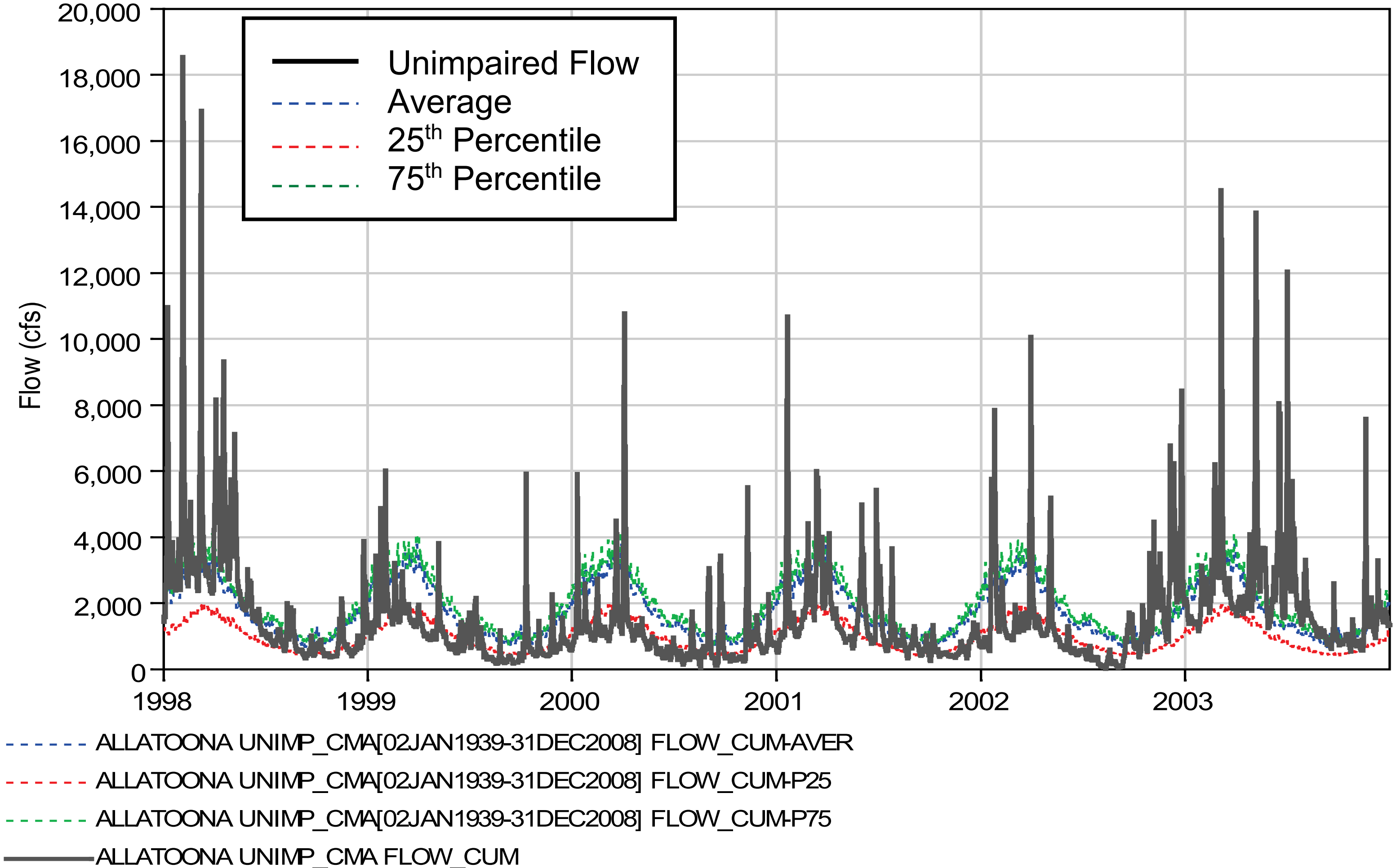


Figure B- 15. Allatoona Unimpaired Inflow – 1998 - 2003 Drought; 75th Percentile, Average and 25th Percentile Flow

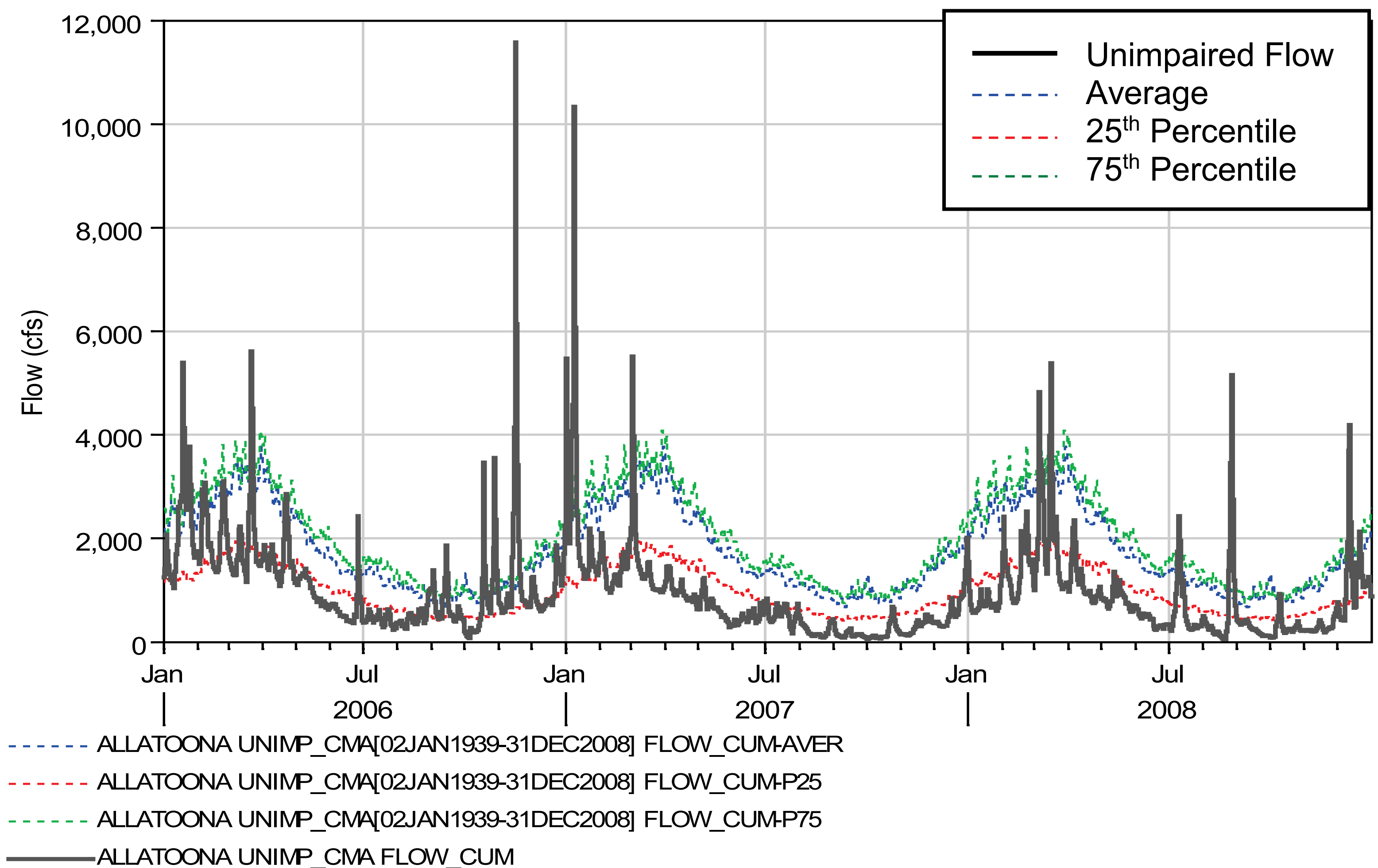


Figure B- 16. Allatoona Unimpaired Inflow – 2006-2008 Drought; 75th Percentile, Average and 25th Percentile flow

1.4 CARTERS DAM (CARTERS LAKE)

The Carters project consists of the Carters Main Dam and the Reregulation Dam. The project is located on the Coosawattee River approximately 1.5 miles upstream of Carters, Georgia in northwest part of the state. It is about 60 miles north of Atlanta, Georgia, and approximately 50 miles southeast of Chattanooga, Tennessee. The reregulation dam was constructed approximately 1.8 miles downstream from the main dam. Both dams are located in Murray County with a large portion of the main reservoir extending into Gilmer County. The upper reaches of the reregulation pool extends into both Gordon and Gilmer Counties. The project was completed in 1975.

Carters project is designed primarily for flood control and hydroelectric power. Recreation, fish and wildlife conservation, and, water quality control are additional benefits of the project. An aerial photo of the dam is shown in Figure B-17.

Figure B- 17. Carters Dam and Reregulation Dam

1.4.1 Drainage Area

The drainage area above Carters project is 373 square miles. The project is located at the northern end of the ACT River Basin. It is roughly square in shape with a maximum length and width of the basin is approximately 25 and 25 miles respectively. The Coosawattee River is formed by the juncture of the Ellijay and Cartecay Rivers at Ellijay, Georgia, about 21 miles upstream from the Carters project. These tributary streams rise in the Blue Ridge Mountains which have peaks up to 4000 feet NGVD. The southern boundary of the basin is shared with the northern boundary of the Allatoona Dam basin, which drains into the Etowah River. The Carters project basin is predominantly undeveloped. The basin drainage area is shown on the following Figure B-18.

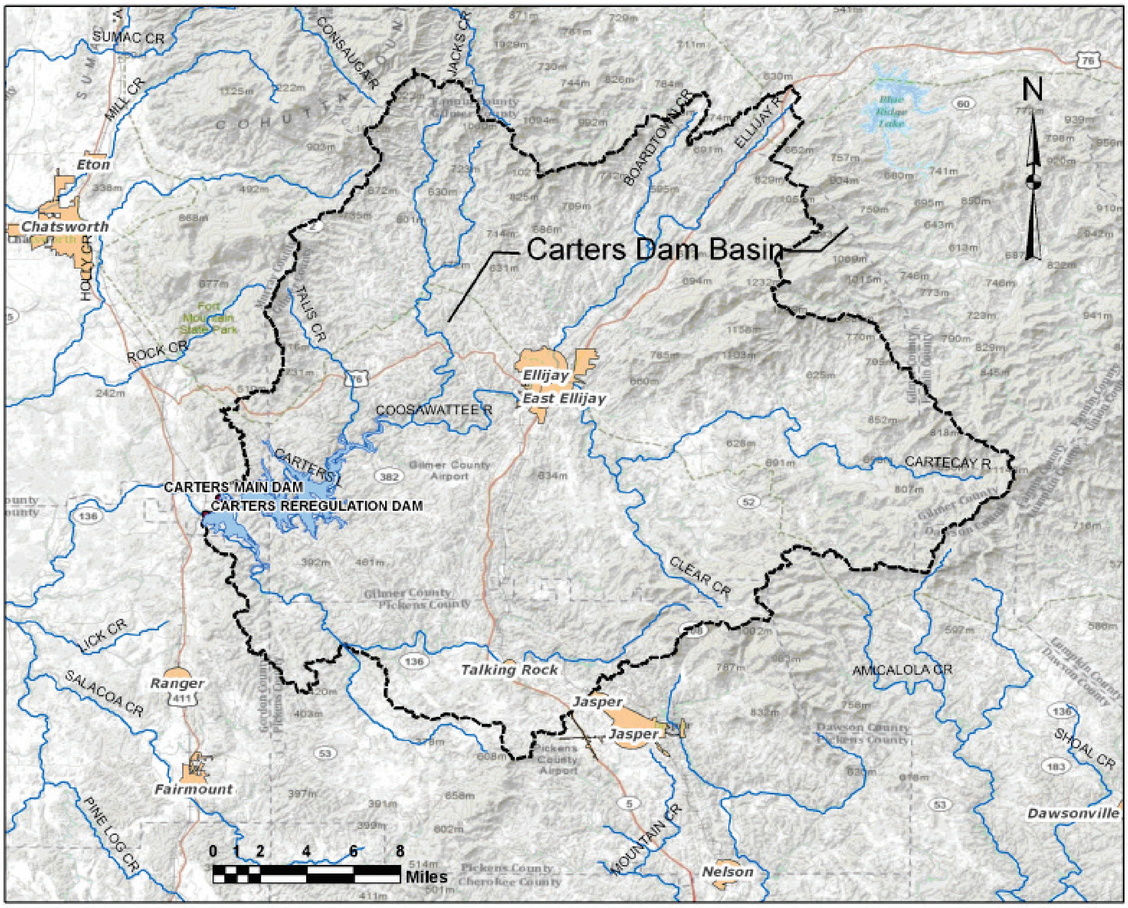


Figure B- 18. Carters Basin Map

The Carters Dam basin controls two percent of the total basin area. The relation of the Carters drainage basin to the ACT Basin is shown in the following Figure B-19.

1.4.2 General Features

1.4.2.1 Main Dam

For the purposes of the yield analysis, only the influence of main dam will be analyzed since the reregulation dam has very little storage. The main dam consists of a 445-foot high rolled rock structure with an impervious earth core, powerhouse, an emergency gated spillway, saddle dikes, and low level sluice. The power house has two conventional 125,000 kW hydrogenerator turbine units (1 & 2) and two reversible 125,000 kW pump-turbine units (units 3 & 4), an erection bay, unloading bay and an entrance wing. The pump-back units are used along with the Carters Reregulation Dam, located 1.8 miles downstream of the main dam, to pump back water to the main reservoir during times of low power use. The reregulation dam consists of a gated spillway with earth and rock-fill dikes extending on either side to higher ground. The storage of the reregulation reservoir is not significant for yield computations. The overall length of the main dam is 2,053 feet.

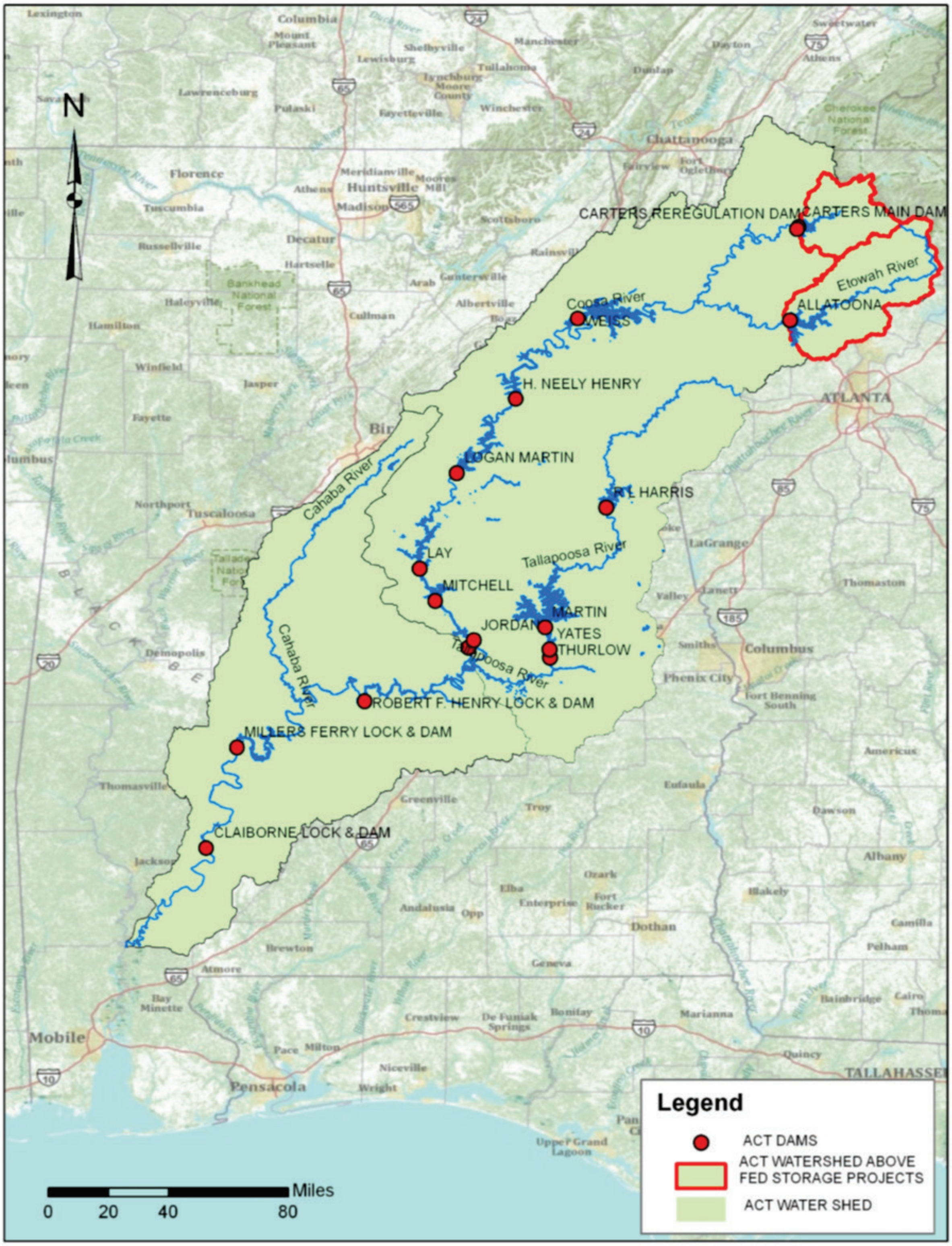


Figure B- 19– Drainage Areas For Projects on the ACT

1.4.2.2 Reservoir

The reservoir at maximum summer operating level (conservation pool) of elevation 1074, covers an area of 3,275 acres and has a total storage of 383,564 acre-feet. At the minimum operating level (conservation pool), elevation 1022, the reservoir covers an area of 2,196 acres and has a total storage of 242,164 acre-feet. Area and capacity curves are shown on Figure B-20 and in Table B-5.

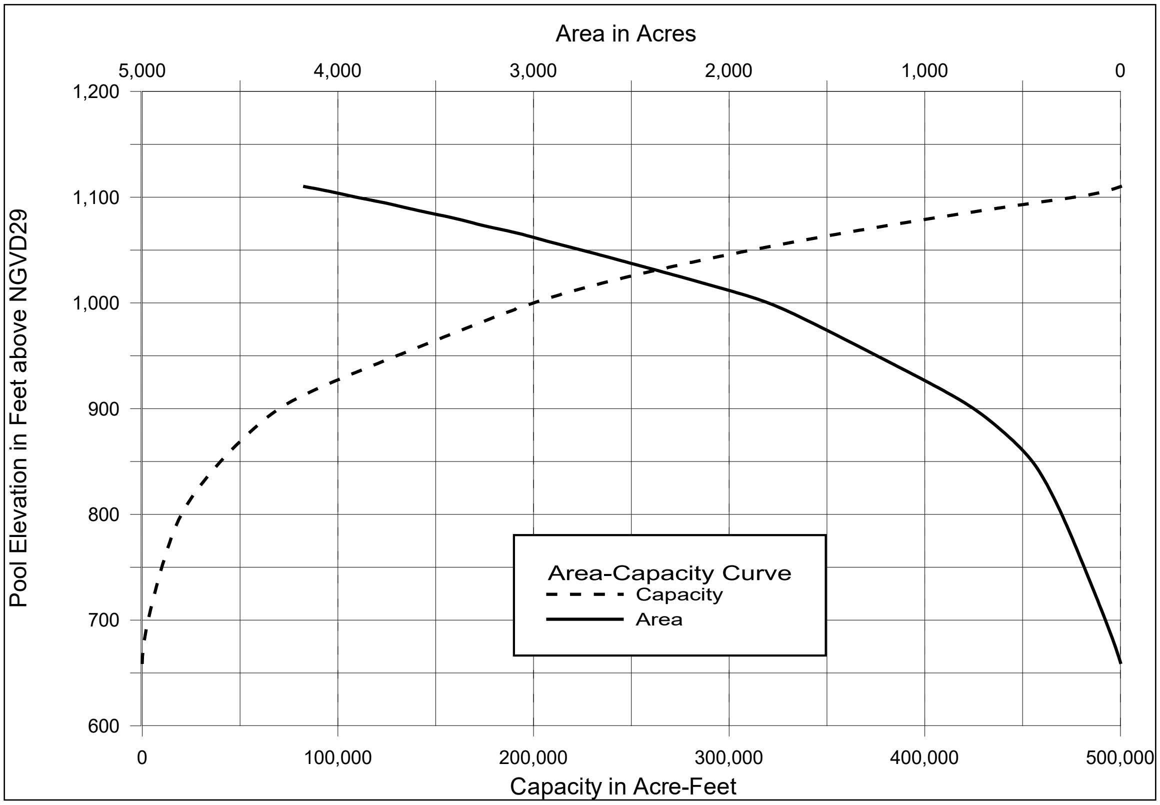


Figure B- 20. Carters Area – Capacity Curves (circa 1979)

Table B- 5. Carters Reservoir Area and Capacity (circa 1979)

Pool Elev	Total Area	Total Storage
(NGVD 29)	(ac)	(ac-ft)
660	0	0
800	300	20000
850	450	40000
900	750	70000
1000	1800	200000
1020	2158	237810
*1022	2196	242164
1030	2353	260355
1040	2552	284879
1050	2754	311402
1060	2962	339972
1065	3060	355050
1070	3179	370670
**1072	3230	377073
***1074	3275	383564
1080	3402	403588
1085	3530	420922
1090	3651	438869
1095	3770	457441
****1099	3880	472757
1105	4030	491029
1115	4170	521482

* Bottom of conservation pool
** Top of winter conservation pool
*** Top of summer conservation pool
**** Top of Flood pool

1.4.3 Top of Conservation Pool

The top of conservation pool varies during the year from elevation 1072 to 1074 feet. Whenever surplus water is available the criteria is to hold the pool at elevation 1074 from 1 May to 1 November, then decrease to 1072 feet by 1 December, then hold 1072 feet unti1 1 January, and then increase to 1074 feet by 1 May, as shown in Figure B-21.

1.4.4 Regulation Plan

The Carters pool is generally operated between the winter pool elevation 1072 and summer pool elevation of 1074. The pool may rise above elevation 1074 for short periods of time during high flow periods. The top of the flood control pool is elevation 1099. At this elevation, the area of the pool is 3,880 acres and the storage is 472,757 acre-feet.

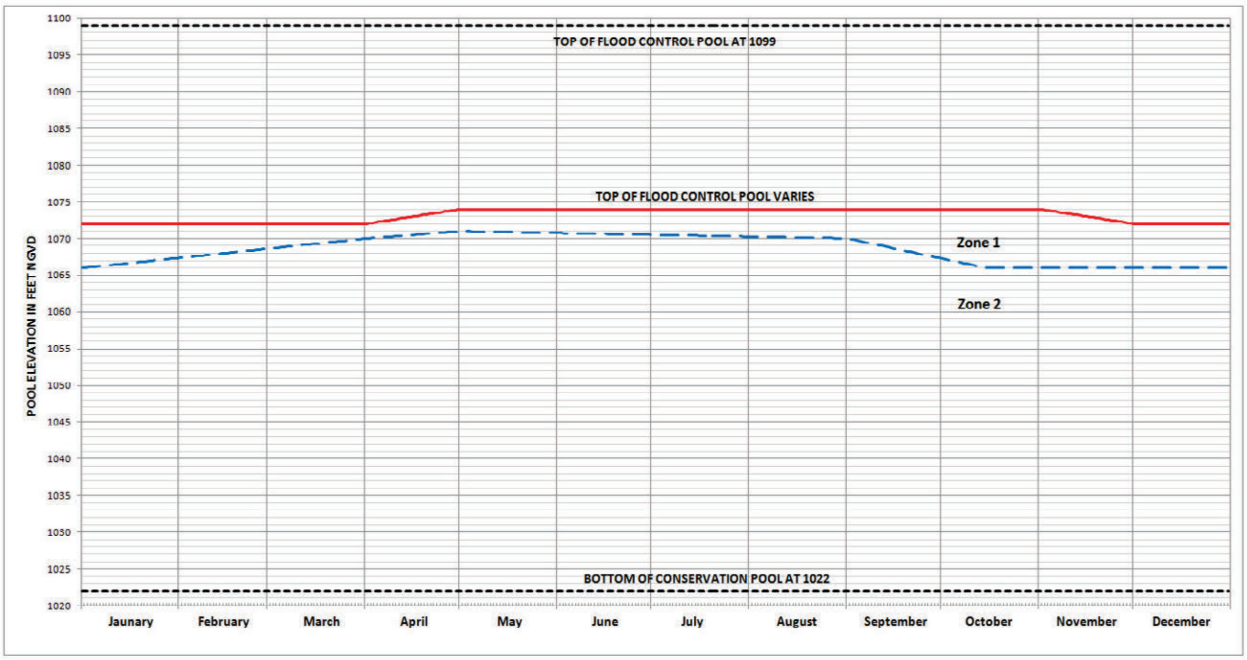


Figure B- 21. Top and Bottom of Carters Conservation Pool

The storage for the yield analysis will be based on the storage in the conservation pool from 1022 to 1072-1074 (depending on the time of year).

1.4.5 Surface Water Inflows

Observed daily inflow, outflow (discharge), and pool elevation data for the period of record starting in July 1975, just after the pool filled, through the present (Oct 2009) are available. The data are presented in Figure B-22.

1.4.6 Unimpaired Flow

The existing unimpaired flow data set was updated through 2011 for use in the yield analysis. The daily data was not smoothed because no negative flows were present in the unimpaired flow. A plot of this unimpaired daily flow averaged over each year for the period of record 1939 – 2011 is shown in Figure B-23. Daily flows for critical drought periods are plotted in more detail in Figures B-24 – B-28.

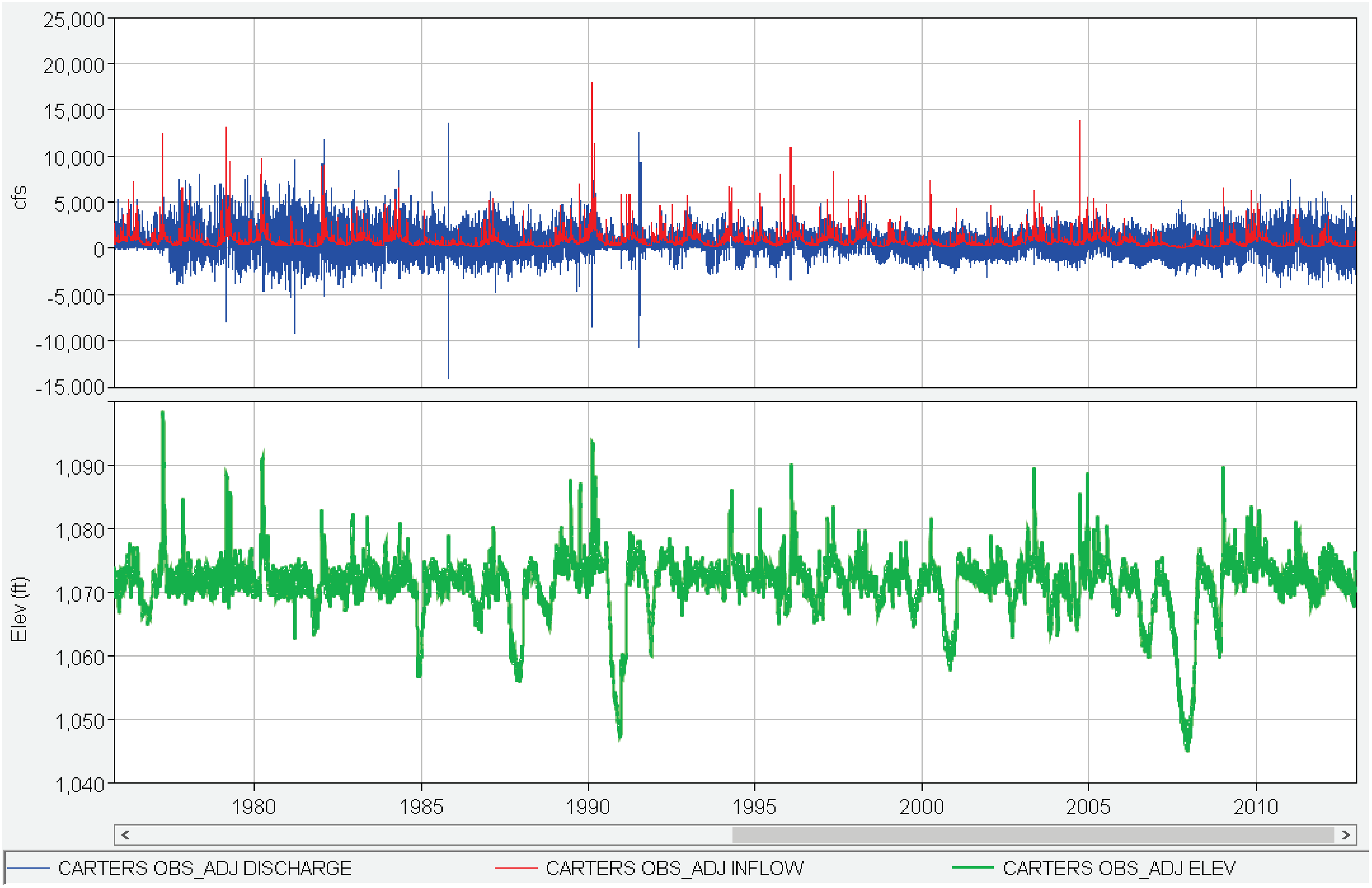


Figure B- 22. Carters Inflow-Outflow-Pool Elevation (Jul 1975 – Dec 2012)
Note discharge values are negative because water is pumped back to the main reservoir.

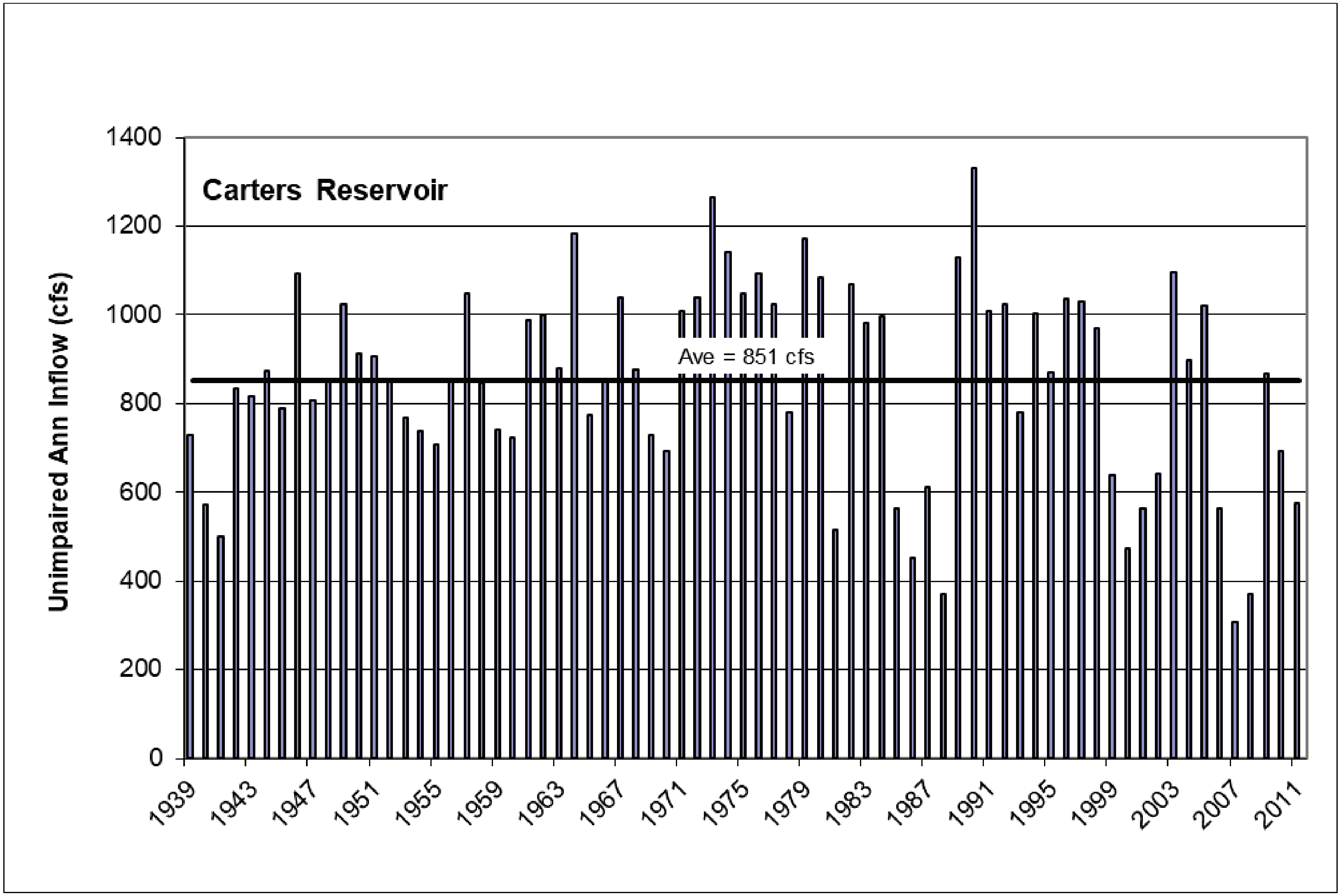


Figure B- 23. Carters Unimpaired Annual Inflow Jan 1939 to Dec 2011

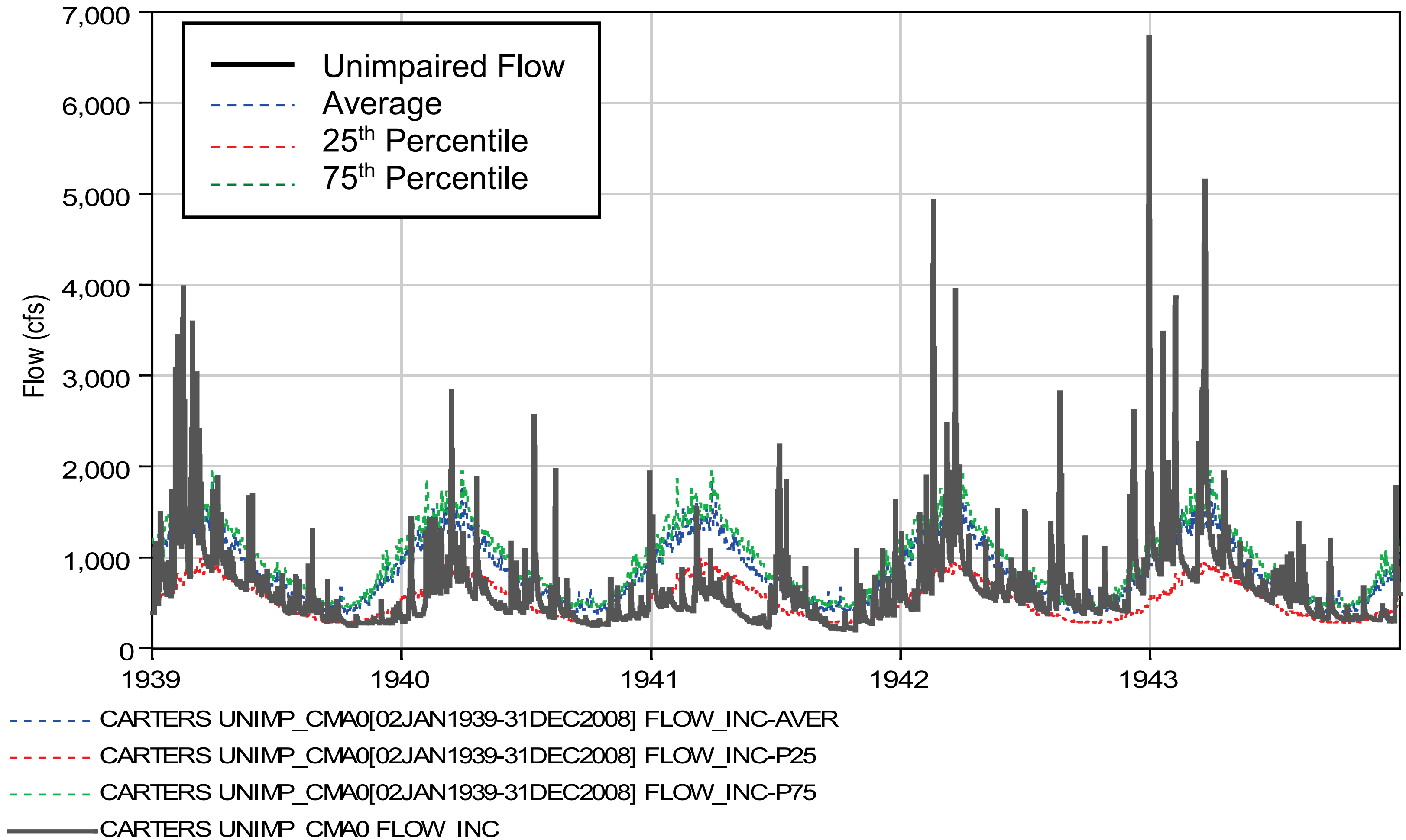


Figure B- 24. Carters Unimpaired Inflow – 1940's Drought; 75th Percentile, Average and 25th Percentile Flow

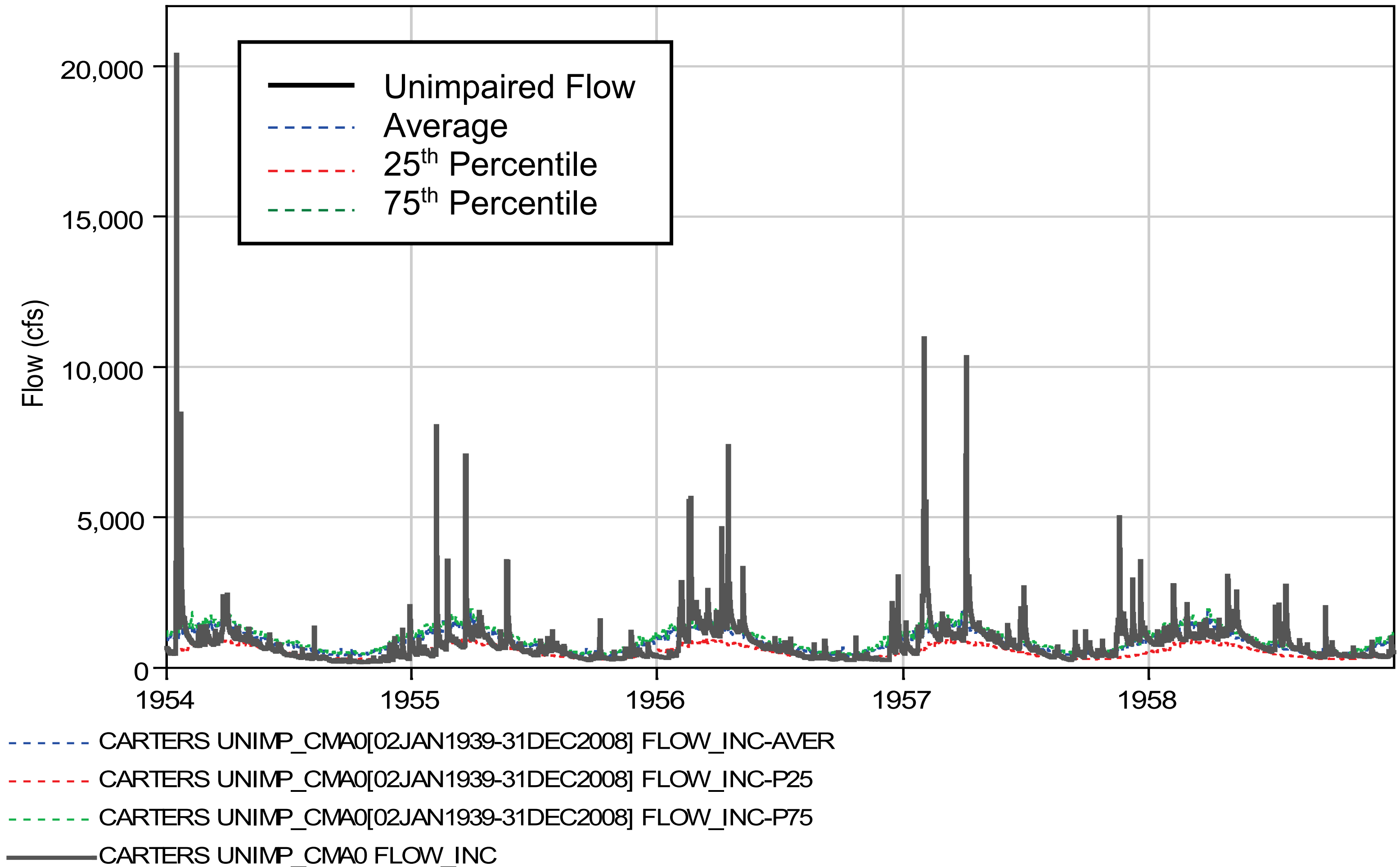


Figure B- 25. Carters Unimpaired Inflow – 1950's Drought; 75th Percentile, Average and 25th Percentile Flow

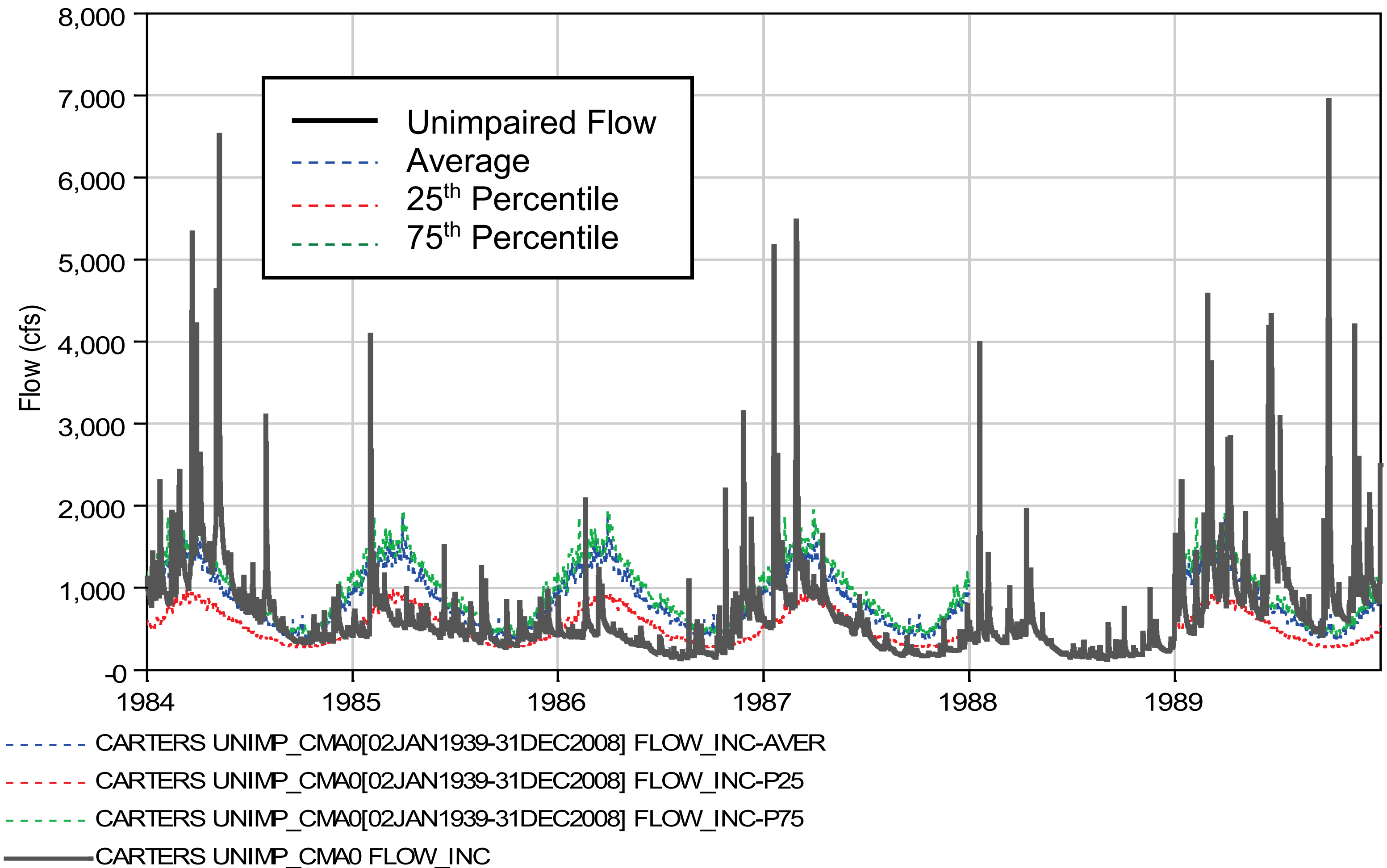


Figure B- 26. Carters Unimpaired Inflow – 1980's Drought; 75th Percentile, Average and 25th Percentile Flow

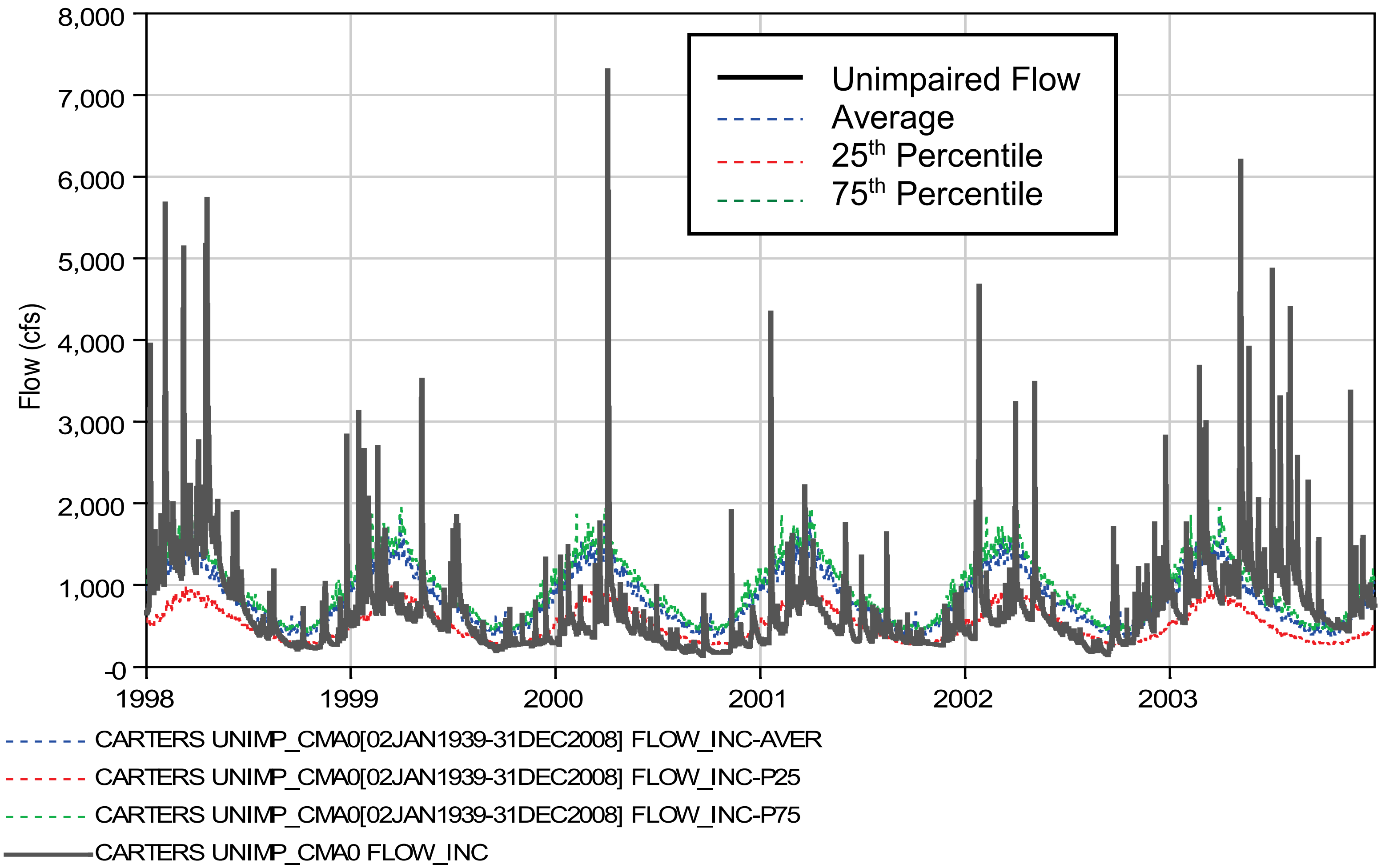


Figure B- 27. Carters Unimpaired Inflow – 2000 Drought; 75th Percentile, Average and 25th Percentile Flow

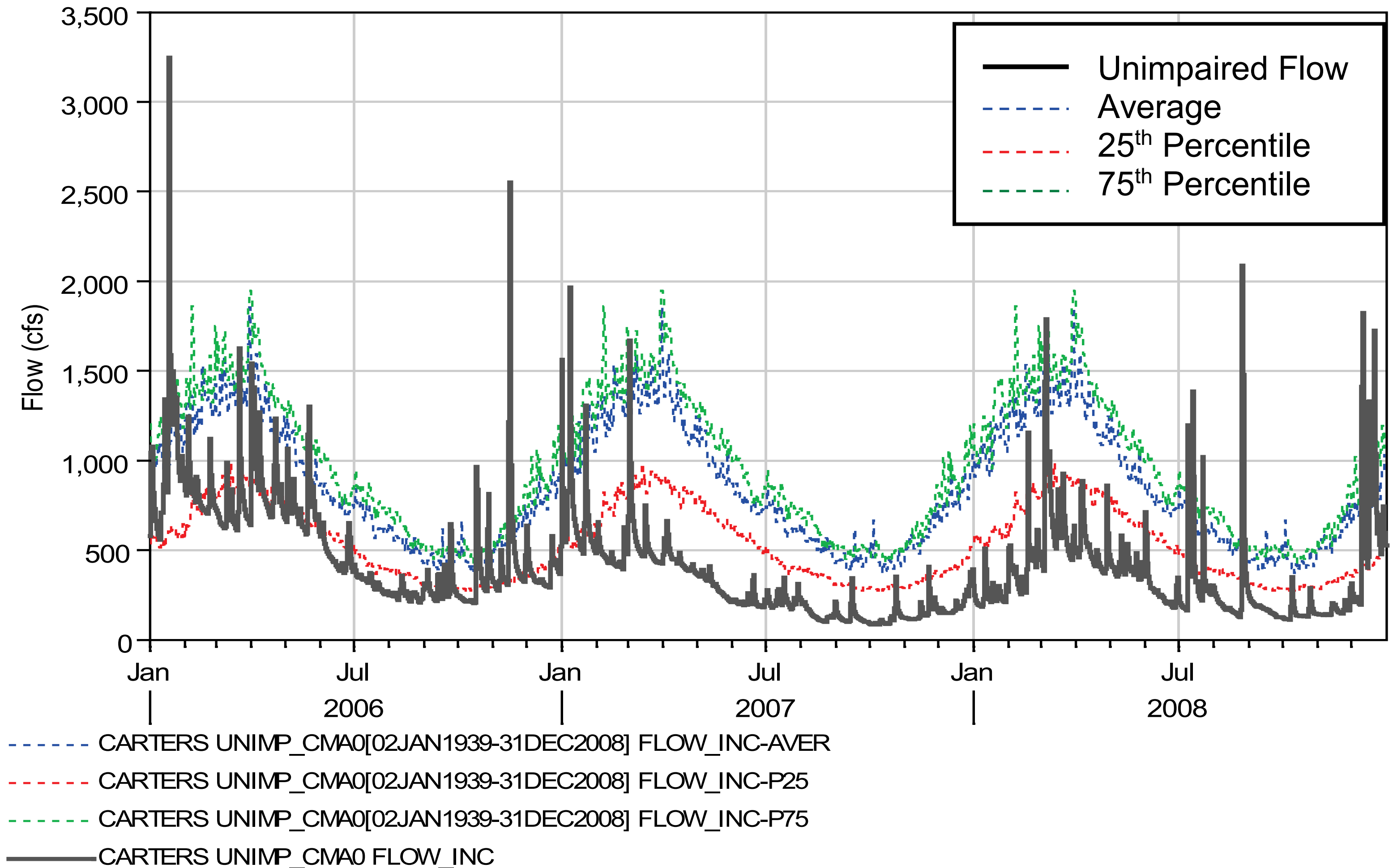


Figure B- 28. Carters Unimpaired Inflow – 2007 Drought; 75th Percentile, Average and 25th Percentile Flow

1.5 ResSim MODELING

The ResSim model for the ACT Basin is shown below in Figure B-29.

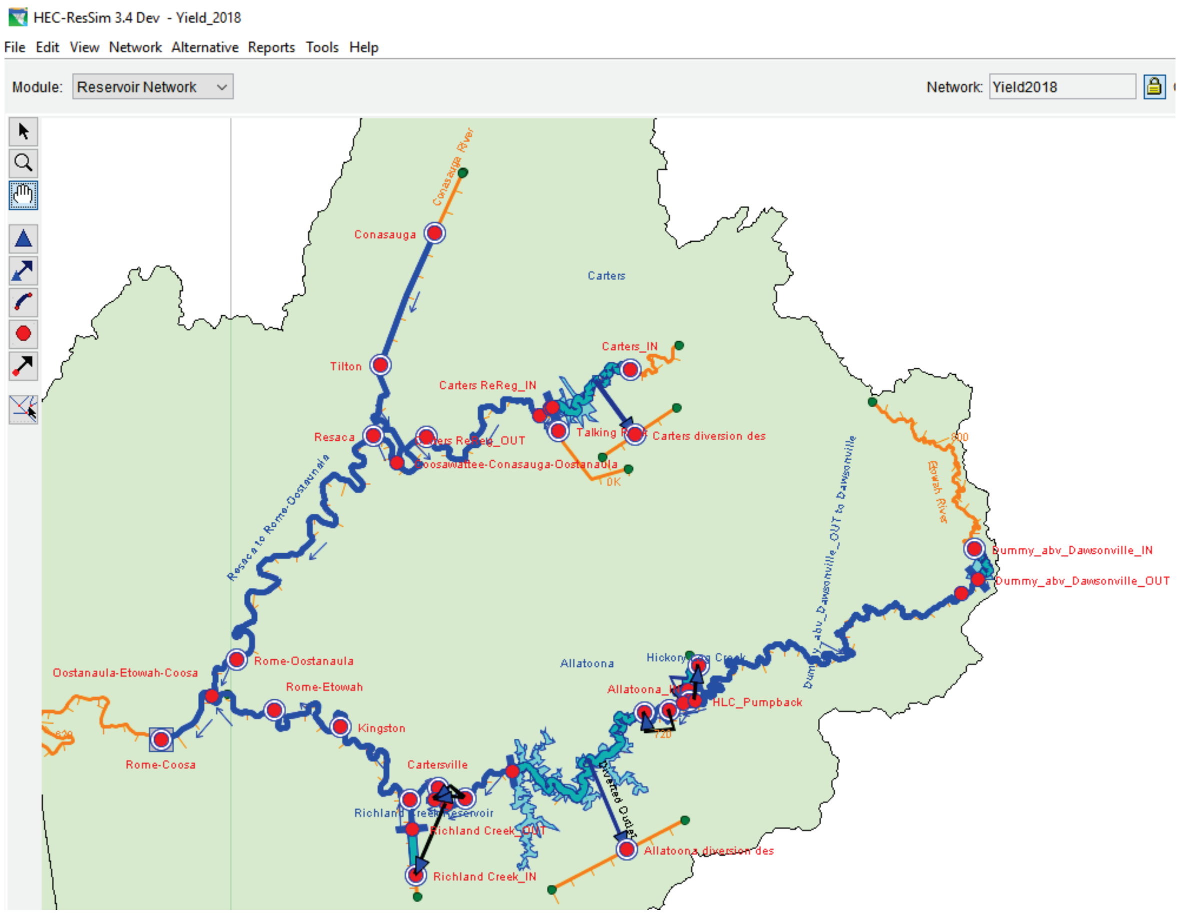


Figure B- 29. ACT ResSim Model Schematic

ResSim version 3.4 Dev, May 2018 was utilized using the ResSim Watershed "Yield_2018_09102018.7z" and the network "Yield_2018" The ACT ResSim model includes two reservoirs, 12 non-reservoir locations and two diversion destinations. Since the ACT yield analysis is limited to the two headwater projects (Carters and Allatoona), only the upper portion, Etowah and Coosawattee Basins were included in the ACT model for yield. This includes the confluence of the Etowah and Coosawattee Rivers to the headwaters of Carters and Allatoona. Physical characteristics of each reservoir were incorporated into the model using the latest published reservoir operation manual. Yield computations are dependent on the conservation storage and hydrology. The regulation plan section for each reservoir above describes the conservation storage. The ResSim operation set only includes the diversion yield rules and the downstream flood control rules. Reservoir guidelines for determining releases are defined using the operation set.

Simulations were created for each of the five indentified drought periods and the entire period of record. The length of the period was selected to capture the drawdown and refill of all projects. Since Allatoona has the greatest amount of storage, it determined the duration of the simulation period. Each yield method (A and B) includes five simulations for a total of 10 simulations. Each simulation determined the yield for a particular reservoir and drought period. Simulation naming, Method A - Year n Div, Method B - Year w Div.

Method A does not include the net river withdrawals and Method B does include the net river withdrawals in the yield determination. Each storage reservoir has a different operating set for the Method A and B alternatives, YieldNoDiv and YieldWDiv respectively.

For Methods A and B the upstream reservoir is the primary reservoir and the yield is met first before proceeding downstream. None of the yield is returned to the system. This assumes that the yield is diverted from the system and is consumptively used. For instance, on the ACT, this means that the critical yield computed at Carters was not counted as flow to meet a downstream flow target. This methodology determines the conservative individual project yield.

A diversion outlet is added to the each of the two reservoirs, Allatoona and Carters. Water from the reservoir is diverted through the outlet to a dummy location not connected to the system. None of the diverted water is returned to the system. The yield represents the maximum continuous flow of water through this outlet during one of the five drought periods, using all available conservation storage.

The Allatoona reservoir was modified by removing leakage from the dam. In the ACT yield analysis the reservoir is not operating. The task requires computing the maximum continuous release through the project and this would include any leakage through the powerhouse. So for our purpose all flows contributing to the existing leakage should be assigned to the diverted outlet. In the prior yield model (ACT 2010) 75 cfs was considered as the leakage from the dam and consequently reduced the project yield modeling results. Updated model does not include a leak amount.

A resurvey of the Allatoona sedimentation ranges was performed in 2010. Area-capacity curves were updated as a result of changes in sedimentation in the reservoir. The effects of sedimentation resulted in capacity changes to the top of conservation in summer from 379,469 acre-feet to 349,922 acre-feet, in winter from 214,473 acre-feet to 192,381 acre-feet, the bottom of conservation from 82,891 acre-feet to 68,006 acre-feet and the top of flood storage from 670,047 acre-feet to 626,860 acre-feet. The ResSim model was updated to reflect the changes to the reservoir. Table B-4 Lake Allatoona Area and Capacity list the updated elevation, area and capacity (storage) values and Figure E-1 compares the historic and current area-storage.

1.6 RESULTS

Table B-6 presents the results from each of the simulations for Method A. The pool elevations and yield flow values are presented graphically in Figures B-30 – B-31. The flow represents the total release from the reservoir. When the flow hydrograph rises above the constant yield value, flows are released through the reservoir.

Table B- 6. ACT Project Yield Analysis without River Diversions, Method A

	Drought Period					
Project	**1940**	**1950**	**1980**	**2000**	**2007**	**Critical Yield (cfs)**
Allatoona	1165.2	1157.38	847.05	1105.52	784.38	784.38
Carters	577.64	672.54	458.01	554.01	386.72	386.72

Method A critical yield for Allatoona is 784.38 cfs and the critical period is the 2007 drought period.
Method A critical yield for Carters is 386.72 cfs and the critical period is the 2007 drought period.

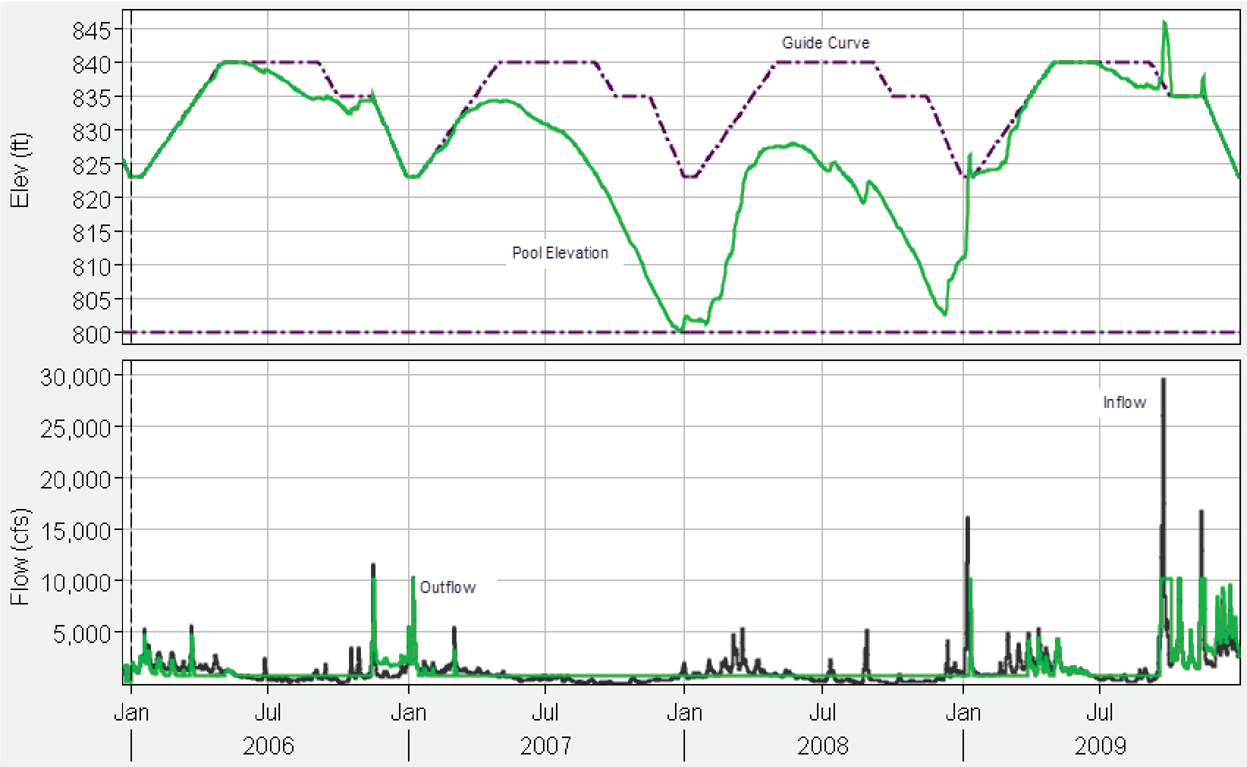


Figure B- 30. Allatoona Critical Yield Result, Method A (No Diversions)

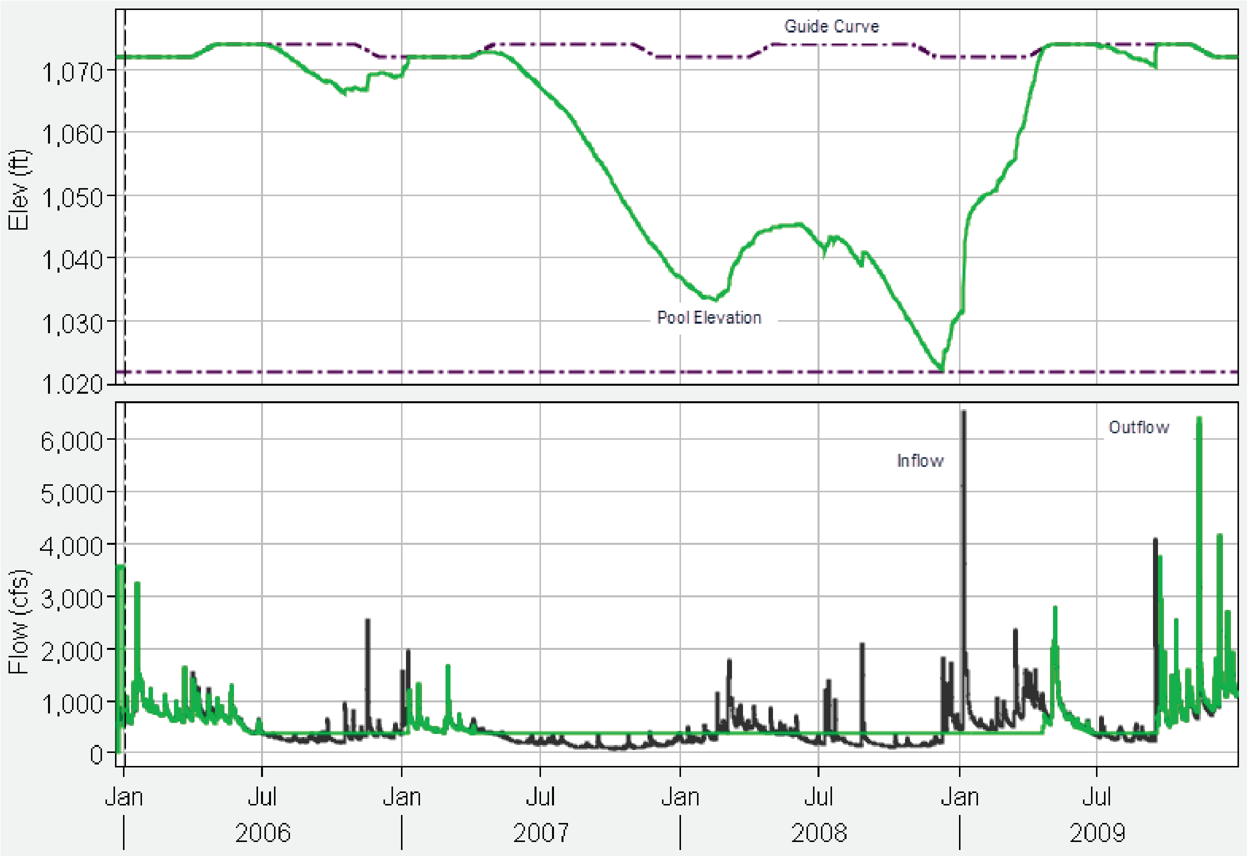


Figure B- 31. Carters Critical Yield Result, Method A (No Diversions)

The drawdown period for each drought period is listed in Table B-7.

Table B- 7. ACT Yield Drawdown Period

Drought Label	Allatoona	Carters
1940's	Jan 1941 - Mar 1942	Jul 1939 - Aug 1942
1950's	May 1954 - May 1956	Jun 1954 - Mar 1956
1980's	Jan 1986 - Jan 1987	Apr 1986 - Apr 1989
2000	Mar 1999 - May 2001	Aug 1999 - Feb 2003
2007	Mar 2007 – Jan 2009	Apr 2007 – Apr 2009

Method B (With Diversions) simulation results are presented below in Table B-8. The yield values listed capture the impact of net year 2006 river withdrawals above the Carters lakes from the Coosawattee River and tributaries, and above the Allatoona lakes from the Etowah River and tributaries. Graphical results of the pool elevation and yield flow values are presented in Figure B-32 and Figure B-33. As expected the yield values are reduced because the inflow into the reservoirs is reduced by the river withdrawal amounts. The critical yield reduction from Method A (784.38 cfs) to Method B (765.34 cfs) for Allatoona is 2.43% and for Carters the reduction from 386.72 cfs to 382.81 cfs is 1.01%.

Table B- 8. ACT Projects Yield Analysis with River Diversions, Method B

	Drought Period					
Project	**1940**	**1950**	**1980**	**2000**	**2007**	**Critical Yield**
Allatoona	1147.47	1139.45	827.42	1087.53	765.34	765.34
Carters	574.22	669.92	454.1	550.78	382.81	382.81

Method B critical yield for Allatoona is 765.34 cfs and the critical period is the 2007 drought period.
Method B critical yield for Carters is 382.81 cfs and the critical period is the 2007 drought period.

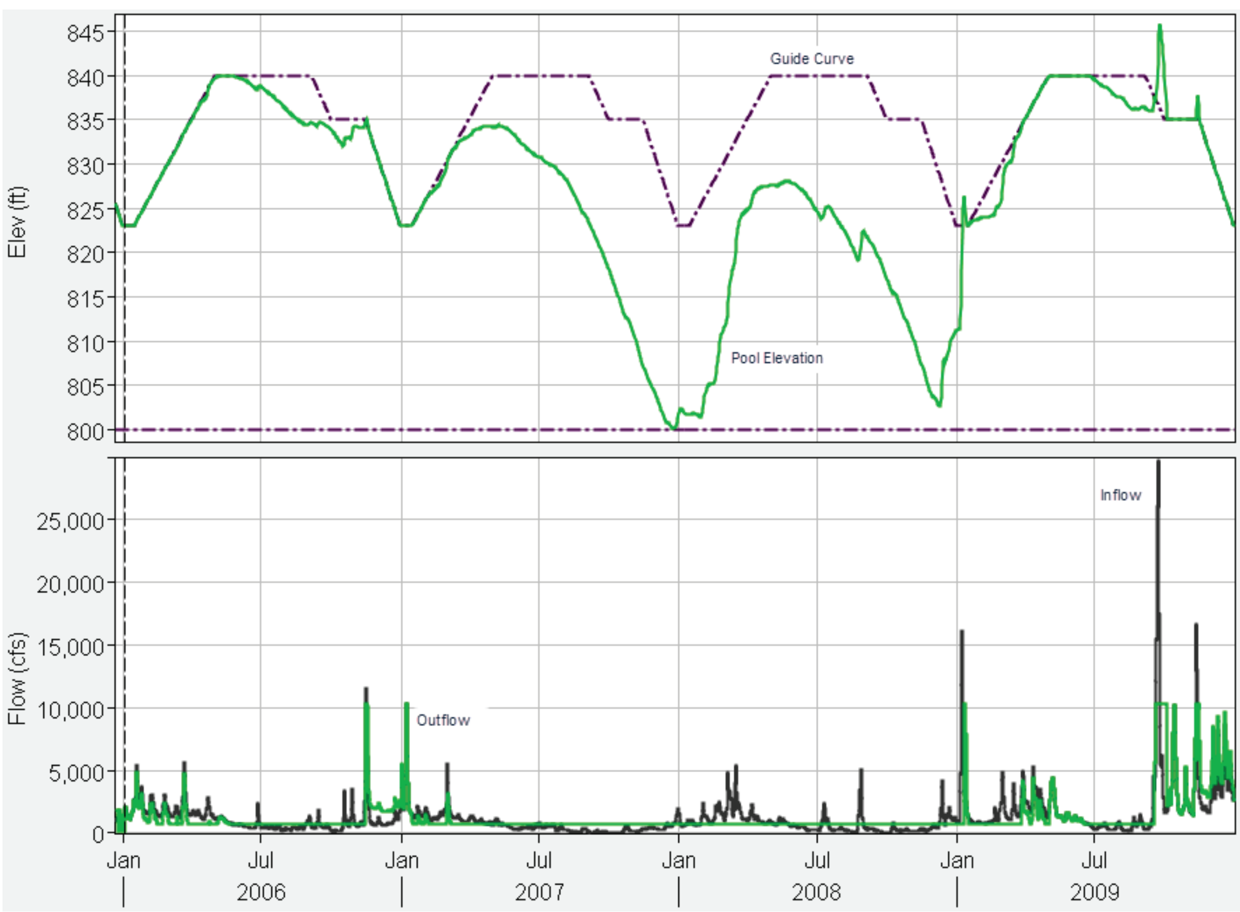


Figure B- 32. Allatoona Critical Yield Result Method B (With Diversions)

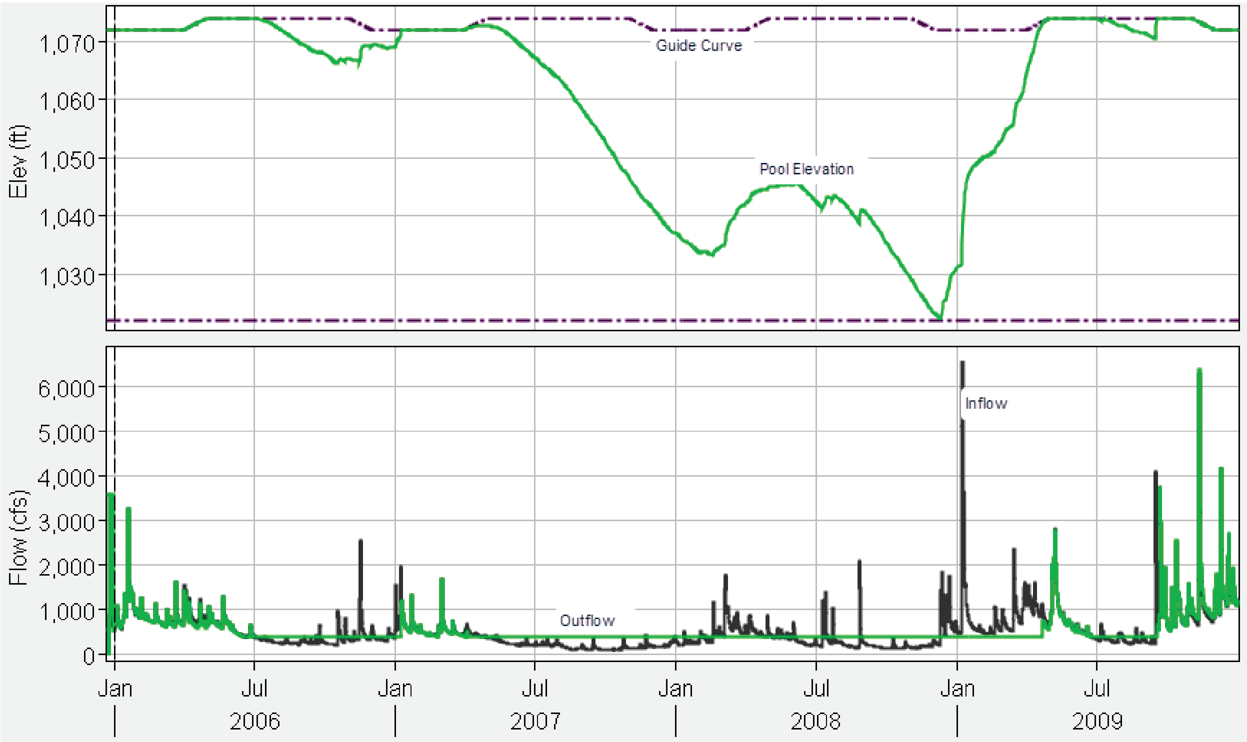


Figure B- 33. Carters Critical Yield Result Method B (With Diversions)

To av

Appendix C

Prior Reports and References

1. PRIOR REPORTS AND REFERENCES

The Corps has calculated and published critical yield for the ACT federal projects many times throughout project lifespans. Yield values have been updated as more observed hydrologic data has become available. This information can be used to determine the severity of droughts throughout the period of record.

Reports printed prior to 1980 may employ the term prime flow. Prime flow, when used in these reports, is synonymous with critical yield or firm yield.

Table C- 1. Prior Reports

Project	Critical Yield (cfs)	Critical Period	Source	Conservation Storage Pool (Elevation-Feet)	Conservation Storage (ac-ft)	Winter/ Summer Pool
Allatoona	1,220	1930-31	Definite Project Report for Allatoona Dam and Reservoir, 1941	848 - 788	456,000	Unavailable
Allatoona	1,160	1939-1942	1966, Cartersville, GA and 1963, Cobb County Marietta Storage Contracts	823-800 (Winter) 840-800 (Summer)	284,580 (Winter) 119,878 (Summer)	840/823
Allatoona	1,186 1,156 1,103 748	1942 1956 1981 1986	1999, Water Supply Reallocation Report	823-800 (Winter) 840-800 (Summer)	119,878 (Winter) 284,580 (Summer)	840/823
Allatoona	1159	Unavailable	Storage Contract	Unavailable	Unavailable	Unavailable
Allatoona*	1064 1057 746 999 693	1942 1956 1981 1986 2007	February 2010, Federal Storage Reservoir Critical Yield Analyses, Alabama-Coosa-Tallapoosa (ACT) and Apalachicola-Chattahoochee-Flint (ACF)	823-800 (Winter) 840-800 (Summer)	119,878 (Winter) 284,580 (Summer)	840/823
Carters	424	Unavailable	Carters Lake Water Supply Reallocation Report, June 1989	1074 - 1022	Unavailable	1072/1074

Project	Critical Yield (cfs)	Critical Period	Source	Conservation Storage Pool (Elevation-Feet)	Conservation Storage (ac-ft)	Winter/ Summer Pool
Carters	550	1939-1942	Carters Dam Design Memorandum No. 4, Hydroelectric Power Capacity, 25 April 1962	1072 - 998	Unavailable	1070/1072
Carters	510	Unavailable	1991, City of Chatsworth, Georgia Storage Contract	1072 - 1022	134,900	Unavailable
Carters*	575 671 455 555 387	1942 1956 1981 1986 2007	February 2010, Federal Storage Reservoir Critical Yield Analyses, Alabama-Coosa-Tallapoosa (ACT) and Apalachicola-Chattahoochee-Flint (ACF)	1074 - 1022	134,909 (Winter) 141,400 (Summer)	1072/1074

*Yield based on Method B as described in the report.

Appendix D

Drought Description

1 DROUGHT DESCRIPTIONS

Five major, long-term (3 or more years) drought episodes have been identified during the period of record for the ACF and ACT River Basins in Alabama and Georgia. Each of these drought episodes displays differing spatial and temporal characteristics.

1.1 2006-2008

The 2006-08 drought was by far the most devastating drought recorded in Alabama and western Georgia. Precipitation declines began in December, 2005. These shortfalls continued through Winter 2006-07 and Spring 2007, exhibiting the driest winter and spring in the period of record. The drought reached peak intensity in 2007, resulting in a D-4 Exceptional Drought Intensity (the worst measured) throughout the Summer, 2007. Lakes and reservoirs dropped to the lowest levels ever recorded. Rainfall at Gainesville, Georgia (Lake Lanier) was only 20 inches for the entire year.

1.2 1998-2003

This period initiated the most recent multi-year drought "cycle". The drought reached peak severity in Summer, 2000, accompanied by all-time record high temperatures in many areas.

1.3 1984-1989

In the extreme northern portions of the ACF and ACT Basins, the 1984-89 drought was the worst drought known until that time. Precipitation from December 1985 through July 1986 was less than 40 percent of normal. Birmingham, Alabama and Chattanooga, Tennessee received only 17 inches of precipitation. The drought climaxed in July 1986, exacerbated by extremely high temperatures.

1.4 1954-1958

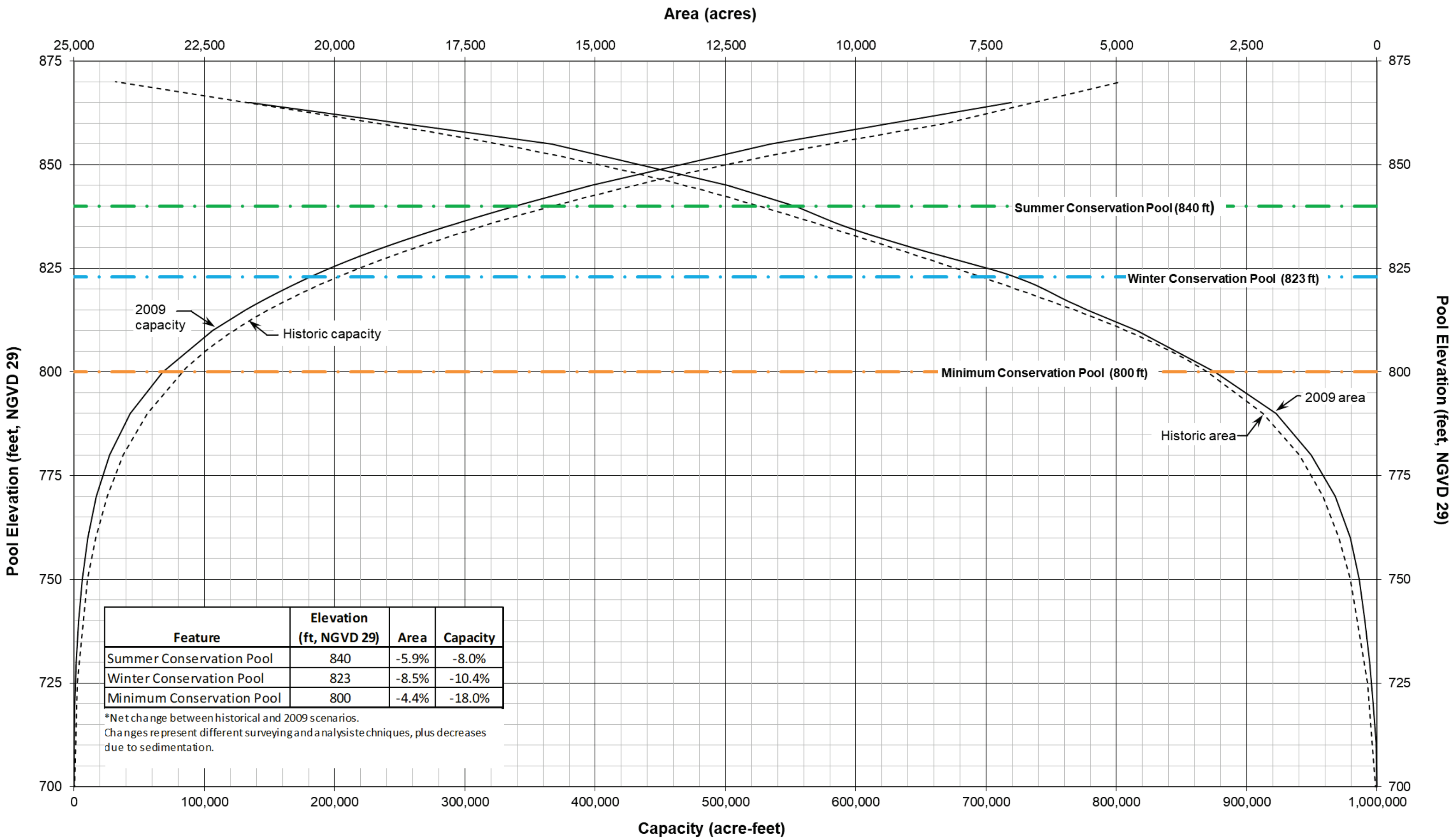
1954-58 was the most widespread, extreme and prolonged drought across the southern United States since the Dust Bowl of the 1930`s. The drought peaked in calendar year 1954; it was the driest of record statewide for Alabama since records began in 1895. Rainfall for 1954 was only 40 percent of normal across southeast Alabama.

1.5 1939-1943

Northwest Georgia experienced one of the driest springs of record in 1941. It was followed by drier than normal conditions across north Alabama during 1942-43.

Appendix E

Allatoona Area Capacity Comparison



Feature	Elevation (ft, NGVD 29)	Area	Capacity
Summer Conservation Pool	840	-5.9%	-8.0%
Winter Conservation Pool	823	-8.5%	-10.4%
Minimum Conservation Pool	800	-4.4%	-18.0%

*Net change between historical and 2009 scenarios.
Changes represent different surveying and analysis techniques, plus decreases due to sedimentation.

Figure E-1 Allatoona Dam Storage-Area Comparison, Historic vs 2009

Attachment 11. Climate Change Effects of the ACR Recommended Plan – Qualitative Assessment

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Attachment 11: Climate Change Assessment for the Allatoona Coosa Reallocation Study

1.1 Introduction

In 2016, USACE issued Engineering and Construction Bulletin No. 2016-25 (hereafter, ECB 2016-25) which mandated climate change be considered for all federally funded projects in planning stages(USACE, 2016). This guidance was updated with ECB 2018-14 (USACE, 2018), which mandates a qualitative analysis of historical climate trends and assessment of future projects. Even if climate change does not appear to be an impact for a particular region of interest, the formal analyses outlined in the guidance, result in better-informed planning and engineering decisions.

This study assesses the allocation of additional water from Lake Allatoona as well as a reduction in conservation and flood storage from Weiss Lake and Logan Martin Lake. Seasonal precipitation in the winter and spring months are the primary driver refilling Lake Allatoona as the flood season ends. As seasonal rains are the primary source of water supply in the southeast, climatological changes in intensity and frequency of storms or an increase in the intensity and frequency of droughts can have a substantial impact to the ability to meet water supply requirements from the lake. Furthermore, a shift in the seasonality of high flows can affect the ability of the lake to refill to full summer pool. An understanding of the historic and forecasted hydrologic conditions with respect to changes in climate is important to have confidence that the selected plan can address the water supply need. At Weiss and Logan Martin, the frequency and intensity of flood events is the primary driver for use of the flood pool. Therefore, an understanding of historic and forecasted changes in high flow events is paramount in assessing the risk associated with the selected plan.

This assessment addresses changes in climatological conditions with respect to water supply and flood risk management. Therefore temperature, precipitation and hydrologic response will be the primary focus of the assessment as these are the primary hydrologic drivers in the southeast.

1.2 Literature Review

A literature review was performed to summarize climate change literature and highlight both observed and projected assessments of climate change variables relevant to the study area. Since this study deals with flood risk management and water supply, the primary variable that is relevant is streamflow. This variable is primarily affected by precipitation and air temperature. Therefore, this review of relevant climate literature focuses on observed and projected changes in precipitation, air temperature, and hydrology.

1.2.1 Temperature.

Observed Temperature

The Fourth National Climate Assessment (USGCRP, 2017) states that observed temperatures in the United States have increased up to 1.9 degrees Fahrenheit since 1895, with an acceleration in increasing temperatures since the 1970s. Warming is projected for all parts of the United States (USGCRP, 2017).

The USACE Institute for Water Resources (IWR) conducted a review in 2015 which summarized the available literature on climate change for the South Atlantic-Gulf Region, including the study area (USACE, 2015). In general, studies have shown that over the last century, a period of warming in the region has been observed since a transition point in the 1970s. This transition period was precluded by an observed cooling period (see Patterson et al., 2012; Laseter et al., 2012; and Dai et al., 2011). The overall warming trend is fairly inconsistent for the region over the last century. The IWR report indicates only mild increases in annual temperature for the region with significant variability. However, there is a clear consensus in general warming since the early 1970s (USACE, 2015).

The project area for this study consists of the entire ACT basin and covers several regions in the southeast stretching from the Gulf of Mexico to northern Georgia. Therefore, it was important to consider climate data from multiple areas throughout the basin. Climate data from a NOAA gage located in Selma, AL (beginning in 1895) was going to be analyzed, however, the dataset has large gaps for the more recent years. The trend from this data shows a decreasing trend, which is inconsistent with the national and regional reports. Therefore, the NOAA gage located in Marion Junction, AL with a record from 1951 - 2017 (continuous record 1955 – 2017) was used to analyze temperature trends in the southern part of the basin.

A statistical analysis was performed on the entire period of record from Marion Junction, AL seen in Figure 1-1 with the associated p-value. The alternative hypothesis of an apparent trend is accepted to be true at the 0.05 significance level, meaning that p-values less than 0.05 are indicative of statistical significance. This is a threshold commonly adopted within statistical references, but consideration should also be given to trends whose p-values are close to this reference threshold. In this case, the period of record data produces a high p-value of 0.444272; therefore it is not considered to have a significant increasing or decreasing trend. However, performing the same test of average annual temperatures from 1970 - 2017, seen in Figure 1-2, produces a p-value of 0.0000216. This would be considered very indicative of a statistically significant upward trend in temperatures.

The temperature gage located in Rome, GA was used for the middle to northern portion of the basin, shown in Figure 1-3. The p-value for the entire period of record is 0.000482, which indicates the downward trend is statistically significant. However, there is a cooling period that occurred in the 1970s that may be skewing the data. Figure 1-4 shows the Rome, GA gage temperature data from 1970 -2018.

Both gages have a statistically significant upward trend 1970 – 2018. Visually, there appears to be an oscillating pattern with the annual average temperature. The temperatures prior to the cooling period (1970s) look similar to temperatures in the early and mid-1900s. Without longer periods of record to compare with, it is difficult to come up with a conclusion. The Canton, Georgia gage, located above Allatoona Dam and shown in Figure 1-5, also shows a rise in temperature since the 1970s, but this is not considered statistically significant.

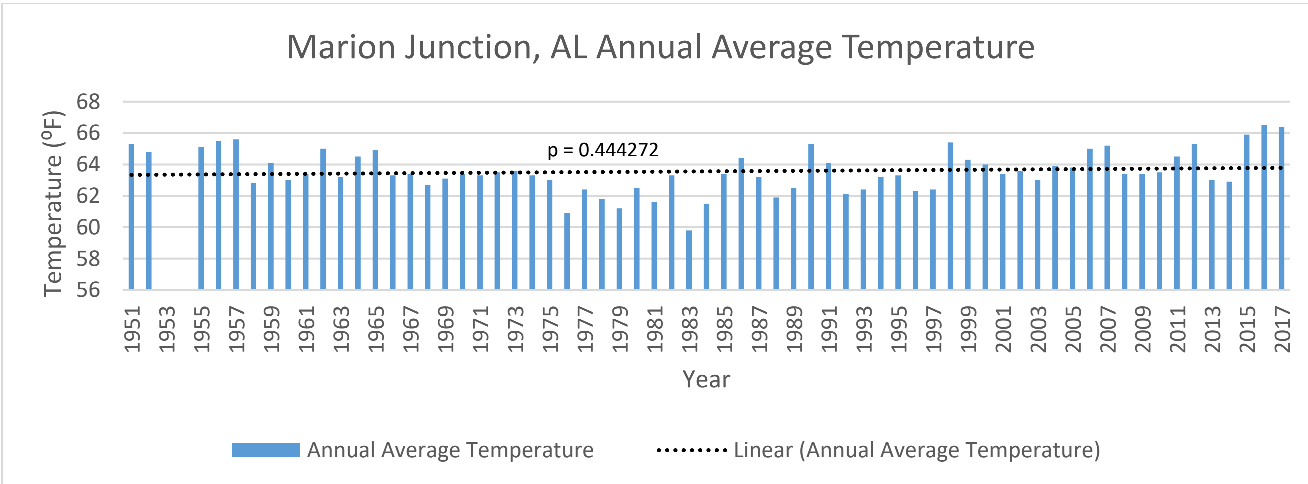


Figure 1-1: Annual average temperature and p-value from 1951 - 2017 for Marion Junction, AL gage.

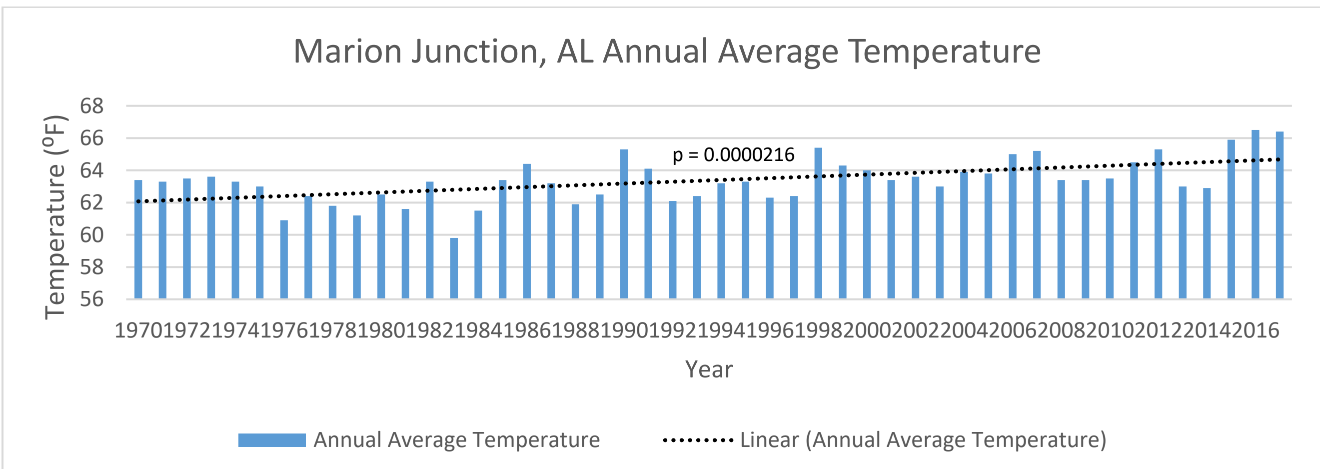


Figure 1-2: Annual average temperature and p-value from 1970 - 2017 for Marion Junction, AL gage.

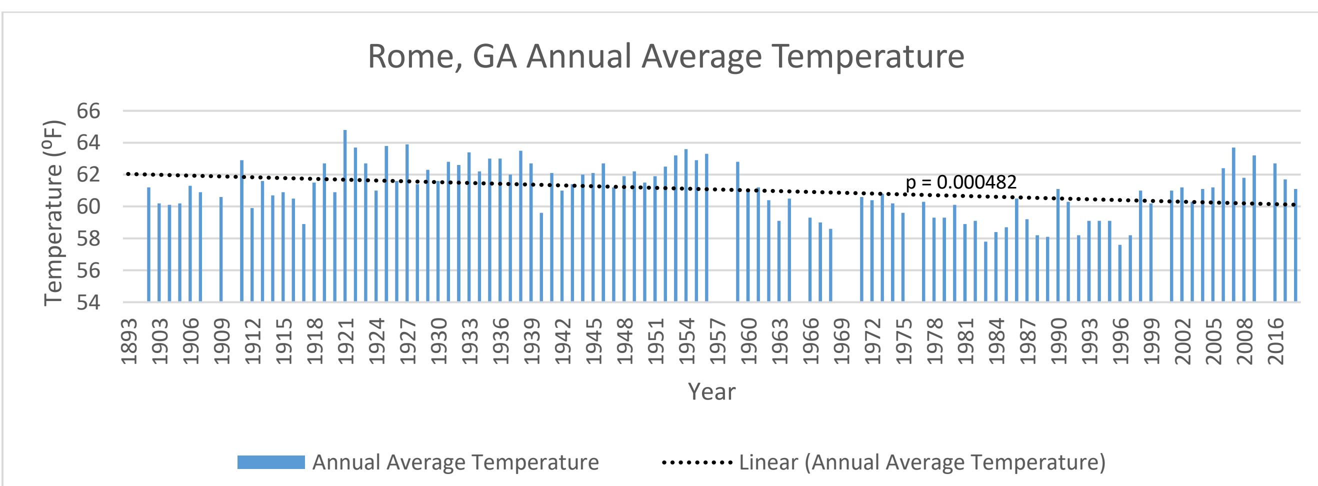


Figure 1-3: Annual average temperature and p-value from 1902 - 2018 for Rome, GA gage.

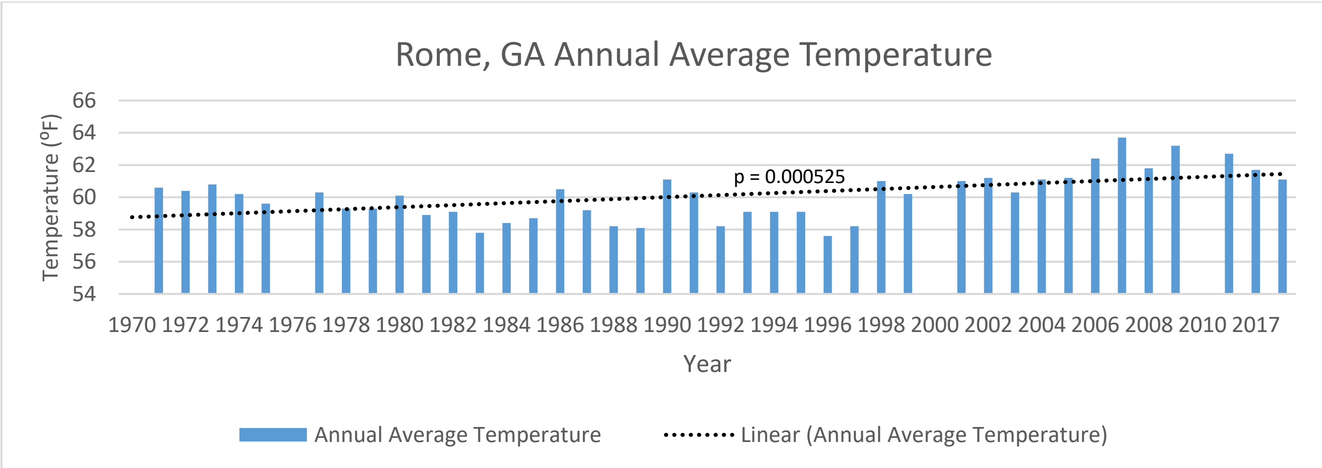


Figure 1-4: Annual average temperature and p-value from 1970 - 2018 for Rome, GA gage.
Projected Temperature

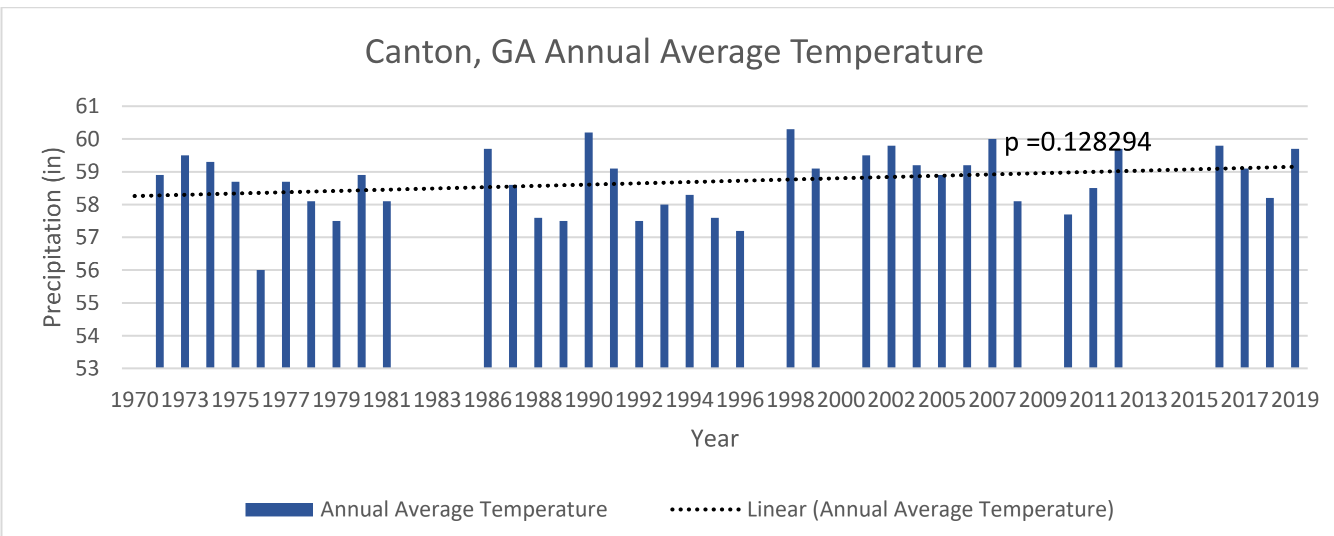


Figure 1-5: Annual average temperature and p-value from 1970 - 2018 for Rome, GA gage.

Projected Temperature

Global Circulation/Climate Models (GCMs) have been used to project future climate conditions in the U.S. including the southeast regions. Results show a significant warming trend at a national and regional scale. Figure 1-r shows the projected changes in seasonal maximum air temperatures based a report by Liu et al. (2013) assuming a “worst case” greenhouse gas emissions scenario. This shows that overall, there is a projected warming trend of 2 to almost 4 degrees by 2070.

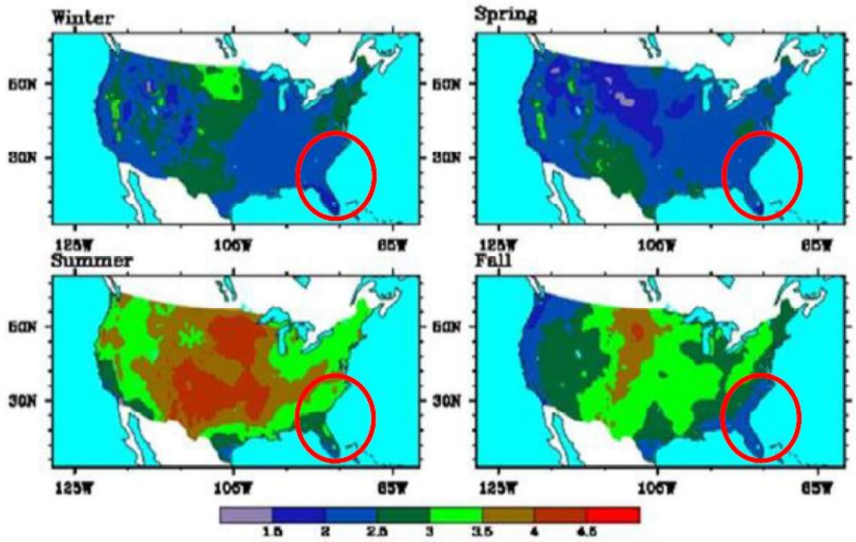


Figure 1-6: Projected changes in seasonal maximum air temperature, ^{o}C, 2041 – 2070 vs. 1971 – 2000. The South Atlantic-Gulf Region is within the red oval (Liu et al., 2013; reprinted from USACE, 2015).

1.2.2 Precipitation

Observed Precipitation

The Fourth National Climate Assessment (USGCRP, 2017) states that there is over a 15% increase in annual precipitation in the southeast regions of the United States from 1901 – 2015. There has been a 27% increase for the heaviest precipitation days as well as a 50% increase in the number of 5 year, 2 day events in the southeast U.S.

The IWR report (USACE, 2015) shows there is a general increase in precipitation for the southeast region; however, it is highly variable for the region. Analysis of gridded data including years 1950 -2000 showed that winter precipitation has consistently increased over the last century (Wang et al., 2009) Other seasons have shown high variability including increases, decreases, and little change in precipitation across the region.

A study by Patterson et al. (2012) did not identify any patterns of precipitation change using monthly and annual trend analysis for a number of climate and streamflow stations within the South Atlantic-Gulf Region (data included 1934 - 2005). However, the study found that more sites exhibited mild increases in precipitation than those that exhibited decreases.

Similar results were seen at the NOAA gage in Selma, AL of an increasing trend. The gage has a large record for precipitation spanning from 1895 – 2018, however, the p-value is 0.1547541 which means there is no statistical significance (see Figure 1-7). The gage located near Canton, GA has a record from 1892 – 2011 and shows little to no trend with a p-value of 0.226714 (Figure 1-8). Visually, both datasets seems to be consistent with high and low values being similar throughout the entire record. However, it appears that there are more low values for precipitation in the last 30 years, even though the trend appears to remain constant or increase overall.

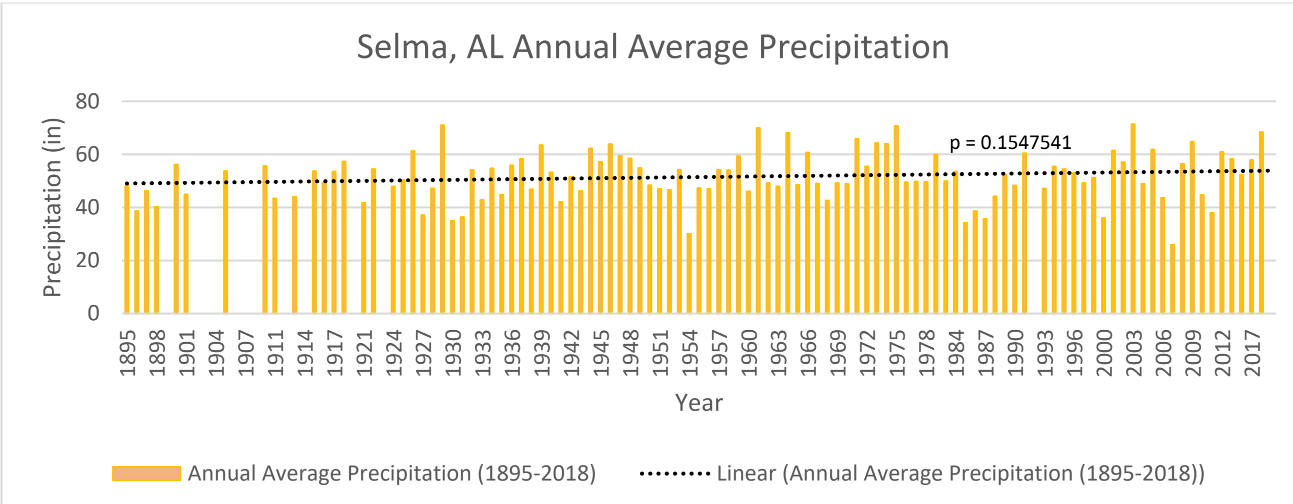


Figure 1-7: Annual total precipitation and p-value from 1895 - 2018 for Selma, AL gage.

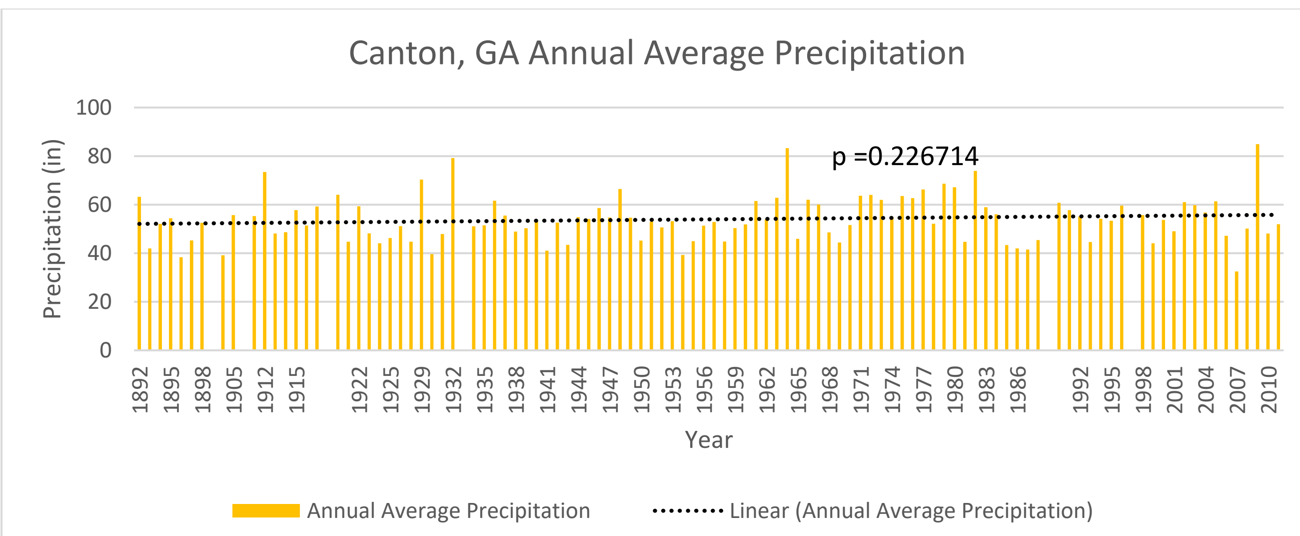


Figure 1-8: Annual total precipitation and p-value from 1892 - 2011 for Canton, GA gage

Most studies analyzed by the IWR (USACE, 2015) suggests significant increasing precipitation severity and frequency trends in observed storms are not definitive. Some of the analyzed literature shows mild increasing trends in these parameters. For instance, Li et al. (2011) investigated anomalous precipitation (based on deviation from the mean) in summer months in the southeastern U.S. and found a greater number of climate stations within the region did not exhibit increasing trends in the frequency of occurrence of heavy rainfall. Increases were also shown by Wang and Killick (2013), who found that 20% sites analyzed, within 56 southeastern watersheds, exhibited increasing trends for the 90th quantile precipitation months. Though there is not a strong consensus regarding trends in extreme precipitation events, it is important to remain mindful of the identified increasing trends in intensity and frequency of rainfall within the region.

Projected Precipitation

Projected of future changes in precipitation for the southeast region are variable and lack consensus. The Liu et al. study (2013) quantified significant increases in winter and spring precipitation associated with a 2055 future condition for the South Atlantic Region. However, other seasons showed almost no increase or a slight decrease in precipitation. Figure 1-p illustrates the projected change in seasonal precipitation. The authors also project increases in the severity of future droughts for the region, leading to projected temperature and ET impacts that outweigh the increases in precipitation.

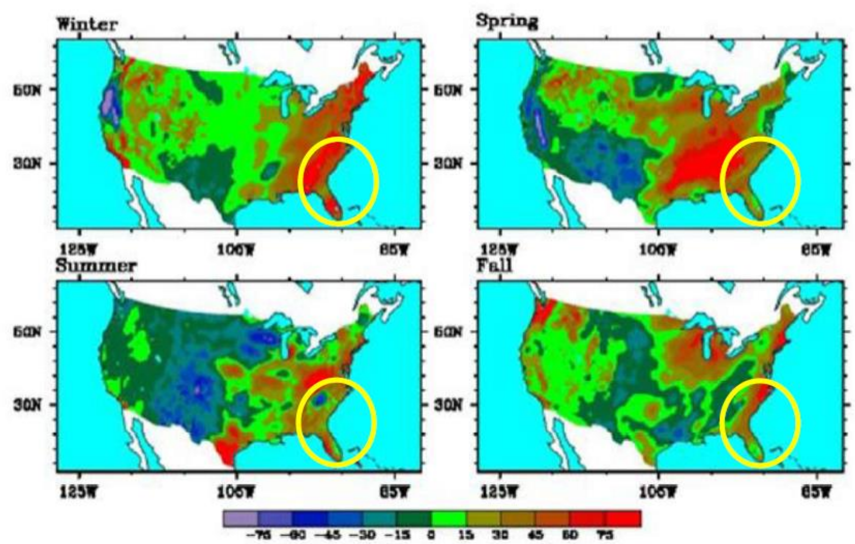


Figure 1-9: Projected changes in seasonal precipitation, 2055 vs. 1985, mm. The South Atlantic-Gulf Region is within the yellow oval (Liu et al., 2013; reprinted from USACE, 2015).

1.2.3. Hydrology

Observed Streamflow

Generalized observations of streamflow trends in the southeast lack a clear consensus, with some models showing positive trends in some areas and others showing negative. Generally, most studies in the southeast showed no trend in streamflow or a negative trend. Most notably, studies have shown that the negative trend in streamflow being more consistent for the region since the 1970s (Kalra et al., 2008; and Patterson et al., 2012).

For the study area, three streamgages with long flow records were analyzed to determine if there are any significant trends in observed streamflow. There is a noticeable decreasing trend in peak annual streamflow in the Alabama River. At the gage USGS 02420000 near Montgomery, AL, the p-value is 0.004737 which indicates the trend is statistically significant (Figure 1-10). Similarly, at the gage located on the Etowah River near Canton, GA, (Figure 1-11) there is a decreasing trend in peak annual streamflow but it is not considered statistically significant. At the gage USGS 02428400 Alabama River at Claiborne L&D near Monroeville, there is a decreasing trend. However, it is not considered statistically significant since the p-value is 0.236750 (Figure 1-11). The trendline of the gage data indicate visually that there is some decreasing trends in peak annual stream flow for the Alabama Basin based on the observed data. This could be the result from flood control projects in the upper portions of the basin above Claiborne and Montgomery. Some of the larger projects were built prior to 1976, therefore the notably decreasing trend in peak annual streamflow may not be as apparent compared to the Montgomery, AL stream gage.

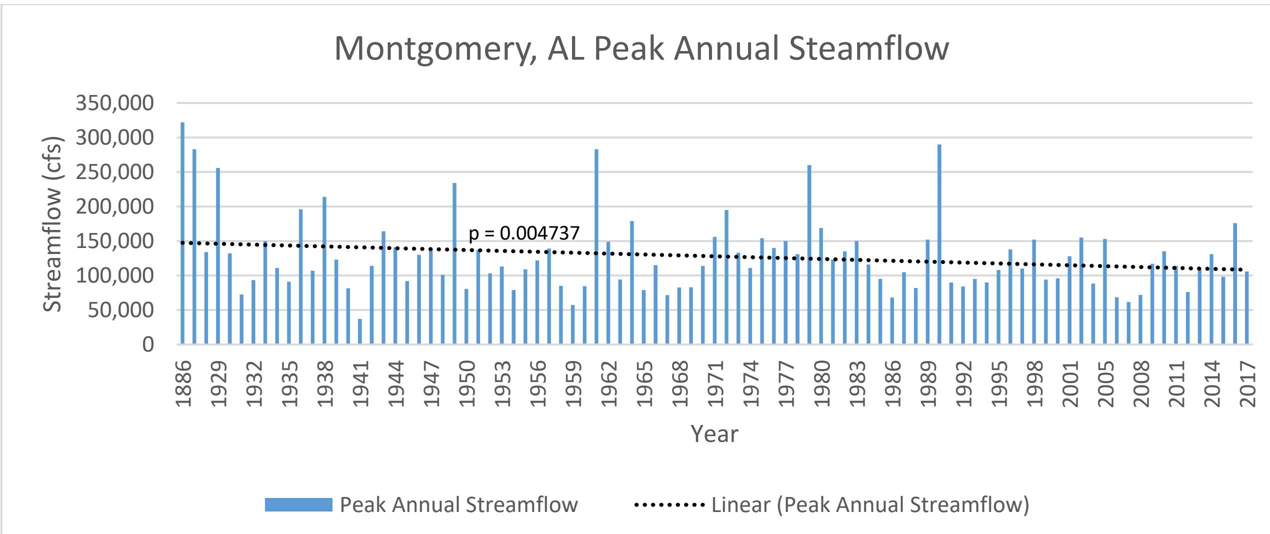


Figure 1-10: Annual Peak Streamflow USGS 02420000 Alabama River near Montgomery, AL.

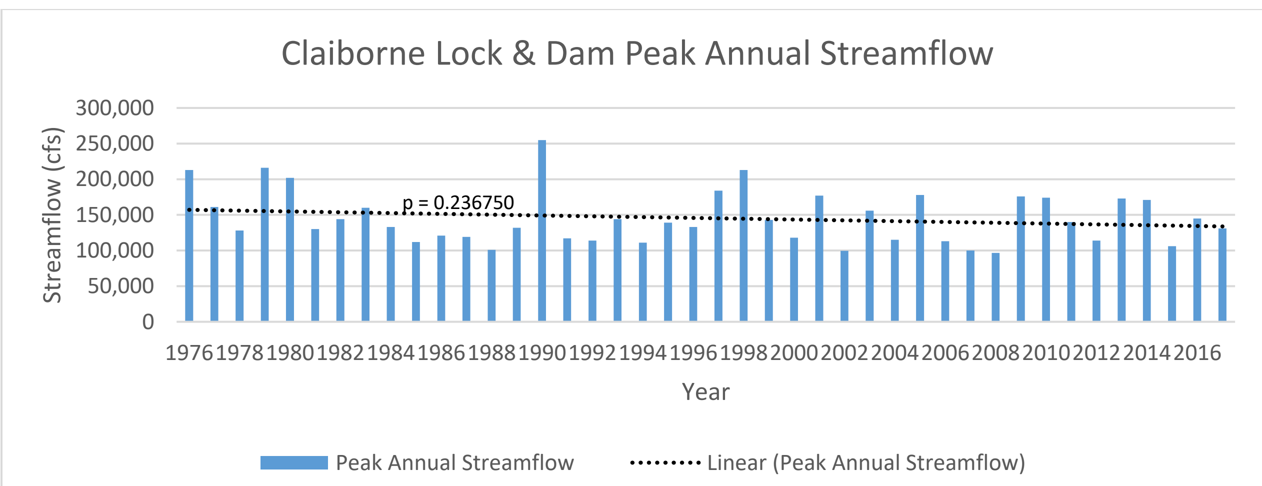


Figure 1-11: Annual Peak Streamflow at USGS 02428400 Alabama River at Claiborne L&D near Monroeville.

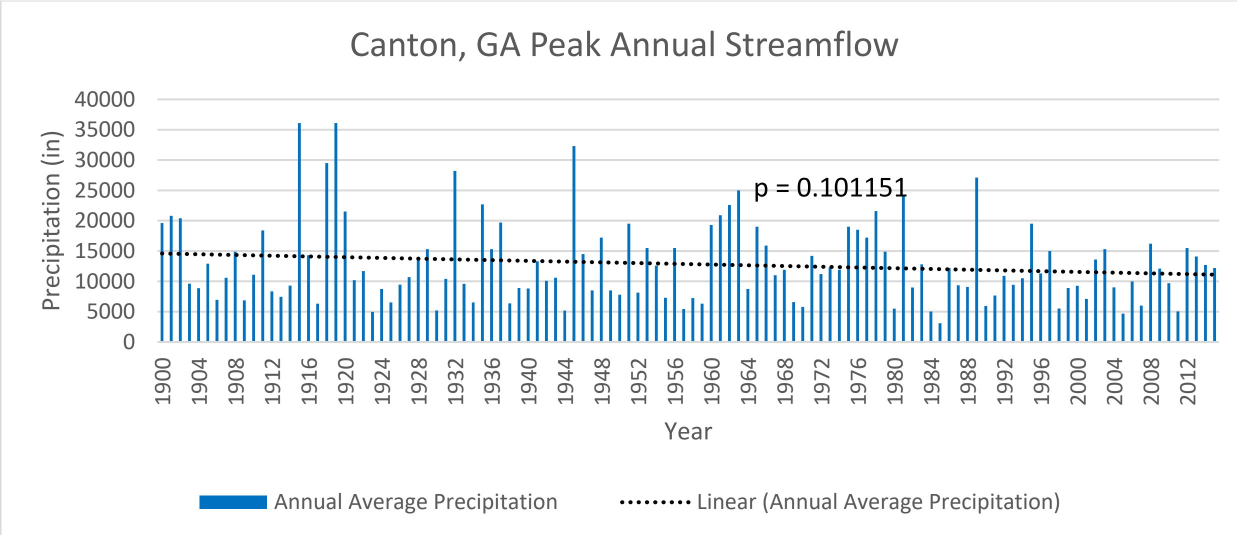


Figure 1-12: Annual Peak Streamflow at USGS 02392000 Etowah River near Canton, GA.

Projected Streamflow

The literature review of projected hydrology for the southeast region show that there is very low consensus in projected changes. This is due to the additional uncertainties that are added when coupling climate models to hydrologic models, both of which carry their own uncertainties. Overall, there are little indications of an increasing or decreasing trend in hydrology based on the reviewed literature presented in IWR report (USACE, 2015).

1.2.4. Summary

Figure 1-13 shows the discussed variables and their overall consensus in trends for both observed and projected scenarios based on the findings of the Fourth National Climate Change Assessment and the 2015 USACE IWR literature synthesis. There is evidence that supports an increasing temperature trend from the observed data and less supporting evidence for trends in precipitation or streamflow for a majority of the region. However, there is some evidence that precipitation is increasing, while streamflow appears to be decreasing in some areas within the region.

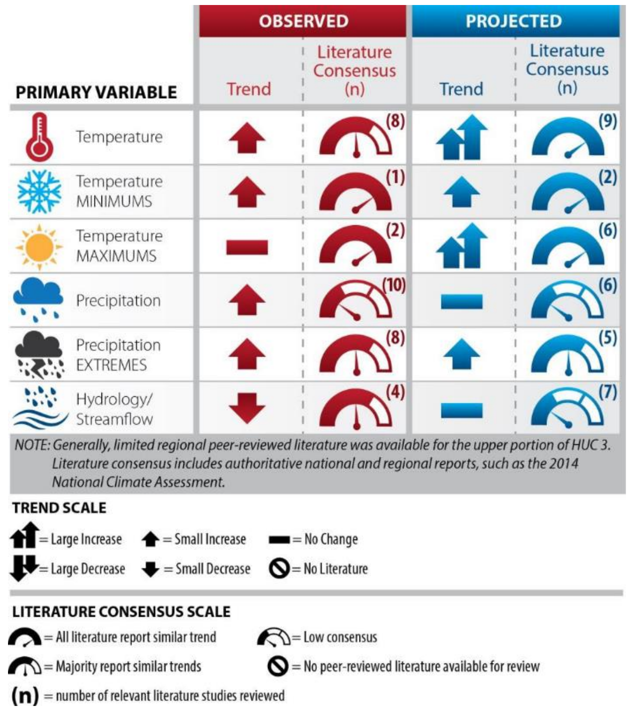


Figure 1-13: *Summary matrix of observed and projected climate trends and literary consensus (reprinted from USACE, 2015).*

Projections indicate a strong consensus of an increase in projected temperature of approximately 2 to 4 degrees Celsius by the late 21st century. There is some consensus that precipitation extremes may increase in future both in terms of intensity and frequency. However, in general, projections of precipitation have been shown to be highly variable across the region. An analysis of streamgages within the basin show streamflow slightly decreasing through the period of record of each gage. But overall, in the southeast, there is not a consensus regarding the directionality of trends in observed streamflow. Very few conclusions can be drawn regarding future hydrology in the region largely due to the substantial amount of uncertainly in these projections when coupling climate models with hydrology models.

1.3 Non-Stationarity Assessment

In accordance with ECB 2018-14, a stationarity analysis was performed to determine if there are long-term changes in peak streamflow statistics within the study area and its vicinity. Assessing trends in peak streamflow is considered appropriate as one of the primary purposes of this feasibility study is to assess operational changes to flood risk management structures.

The USACE Non-Stationarity Tool was used to assess possible trends and change points in peak streamflow in the region. USGS 02420000, USGS 0228400, and USGS 02397000 was used for this analysis. In Figure 1-13, the green area encompasses the entire drainage area delineated from Claiborne Lock and Dam and shows the location of the three gages used for this analysis.

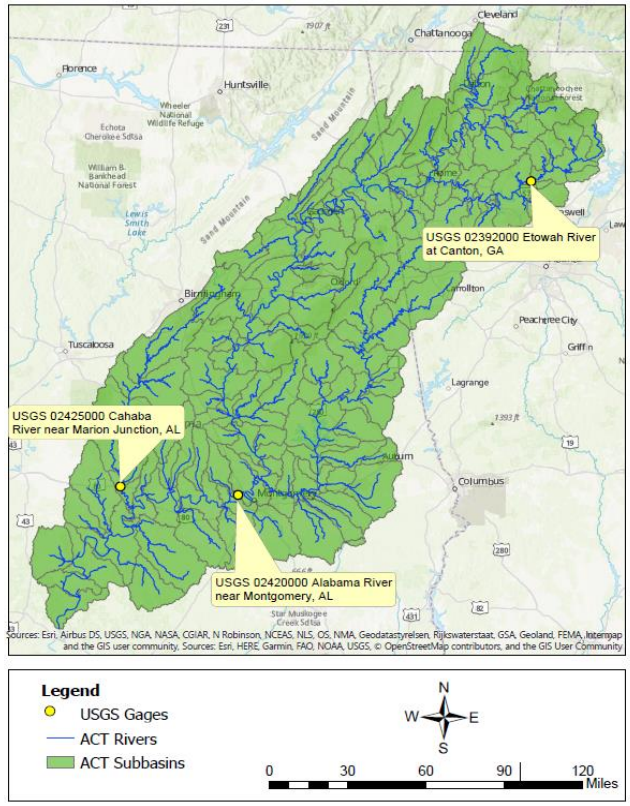


Figure 1-14: Study area and locations of the Montgomery, AL gage, Claiborne Lock and Dam gage, Selma, AL gage, and Rome, GA gage used in this analysis.

The first gage used in this analysis is located 83 miles upstream of Selma on the Alabama River near Montgomery, AL. The gage has a long and nearly continuous record starting in 1928, includes two historical events, and is only missing one year (2003). Figure 1-15 shows the time series of Annual Peak Streamflow (APF) for the gage located near Montgomery, AL.

The second gage used in this analysis is located at Claiborne Lock and Dam on the Alabama River, which is located approximately 79 miles downstream from Selma, AL. This gage has a continuous record from 1976 to present. Figure 1-16 shows the time series of Annual Peak Streamflow (APF) for the gage located at Claiborne Lock and Dam.

The third gage used in this analysis is located near Canton, GA on the Etowah River. The drainage area for this gage is approximately 613 square miles. Figure 1-17 shows the time series of Annual Peak Streamflow (APF) for the gage located at Canton, GA. There is a noticeable decrease in the streamflow at this gage after the early 1990s.

In order to run the non-stationarity tool, it is recommended to have at least 30 continuous years of record. All four of these gages meet that requirement.

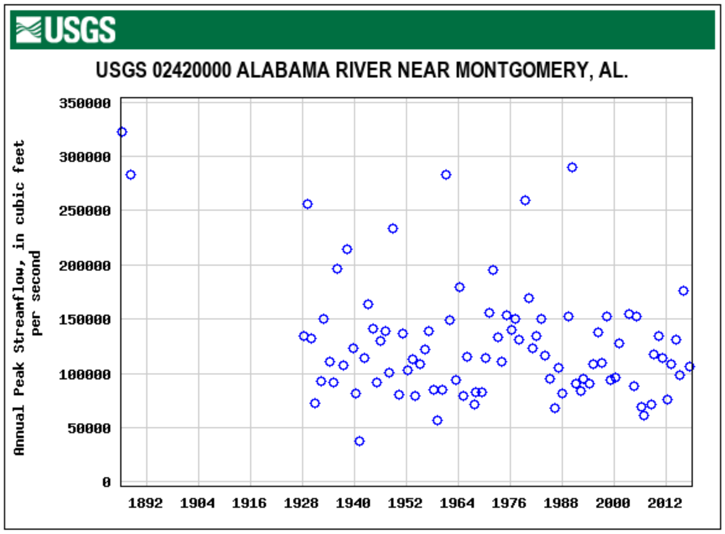


Figure 1-15: *APF at USGS 02420000 Alabama River near Montgomery, AL.*

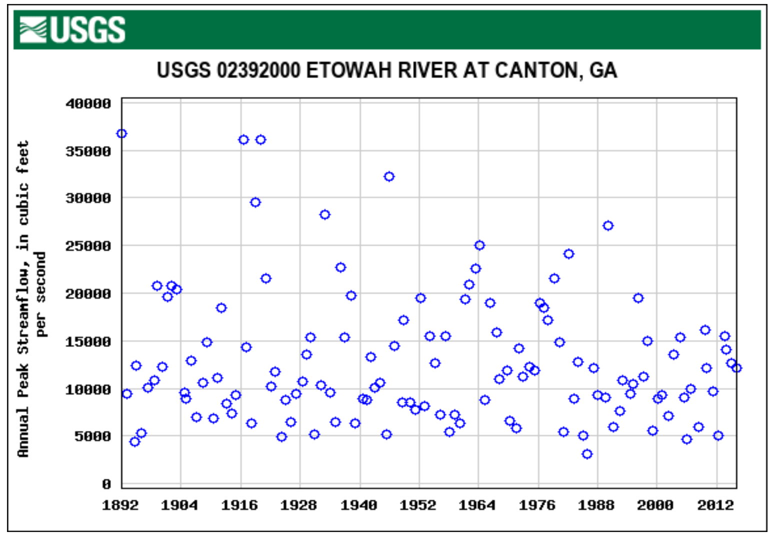


Figure 1-16: *APF at USGS 02392000 Etowah River at Canton, GA*

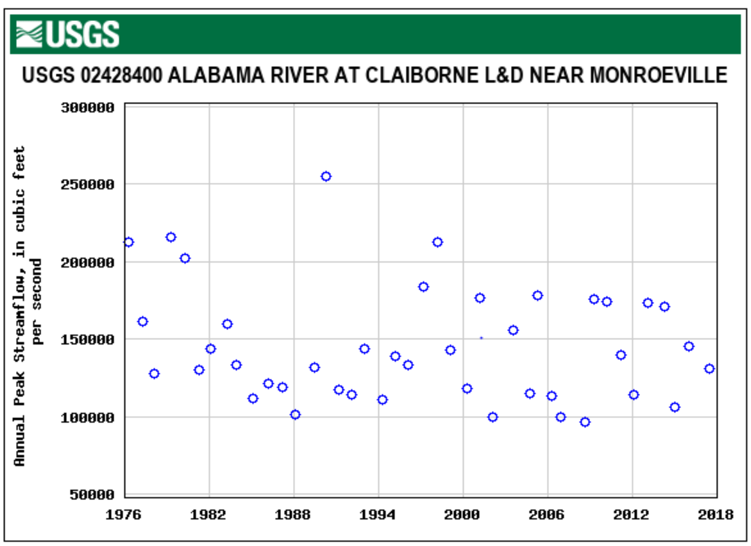


Figure 1-17: *APF at USGS 02428400 Alabama River at Claiborne L&D near Monroeville.*

The following 16 statistical tests were conducted on the APF time series shown in Figure 1-2 using the Non-Stationarity Tool:

1. Cramer-von-Mises distribution
2. Kolmogorov-Smirnov distribution
3. LePage distribution
4. Energy Divisive distribution
5. Lombard (Wilcoxon) abrupt mean
6. Pettitt mean
9. Lombard (Mood) abrupt variance
10. Mood variance
11. Lombard (Wilcoxon) smooth mean
12. Lombard (Mood) smooth variance
13. Mann-Kendall trend
14. Spearman rank trend

7. Mann-Whitney mean
8. Bayesian mean
15. Parametric trend
16. Sen's slope trend

Tests 1-12 are used to detect change points in the distribution, mean, and/or variance of the time series. These non-stationarity tests can be useful in detecting changes in annual instantaneous streamflow peaks driven by natural and human driven changes in the climate, addition/removal of water control structures, changes in land cover, and any other drivers of non-stationarity. Meanwhile, tests 13-16 are used to analyze monotonic trends. The variety of tests is essential for increasing confidence in the overall stationarity analysis. Significant findings in one or two tests are generally not enough to declare non-stationarity.

For this analysis, three USGS gages were used including Canton, GA, Montgomery, AL, and Claiborne Lock and Dam. The continuous period of water years 1976-2014 for the gage located at Claiborne Lock and Dam, water years 1928-2002 for the gage located near Montgomery, AL were used. All sensitivity parameters were left in their default positions. The ACT basin is a heavily regulated system with 5 flood risk management dams. These dams have been placed in operation at different times through the period of record above the Claiborne and Montgomery gages starting in 1950 and ending in 1976. The addition of these projects in the basin could cause a non-stationarity to be identified by the tool as peak flows would now be reregulated during high flow events. However, for the Claiborne and Montgomery gages, there were no non-stationarities detected, as seen in Figures 1-18 and 1-19. The monotonic trend test indicates that there are no trends for the entire record (not including historical peaks) for both gages, Figures 1-20 and 1-21.

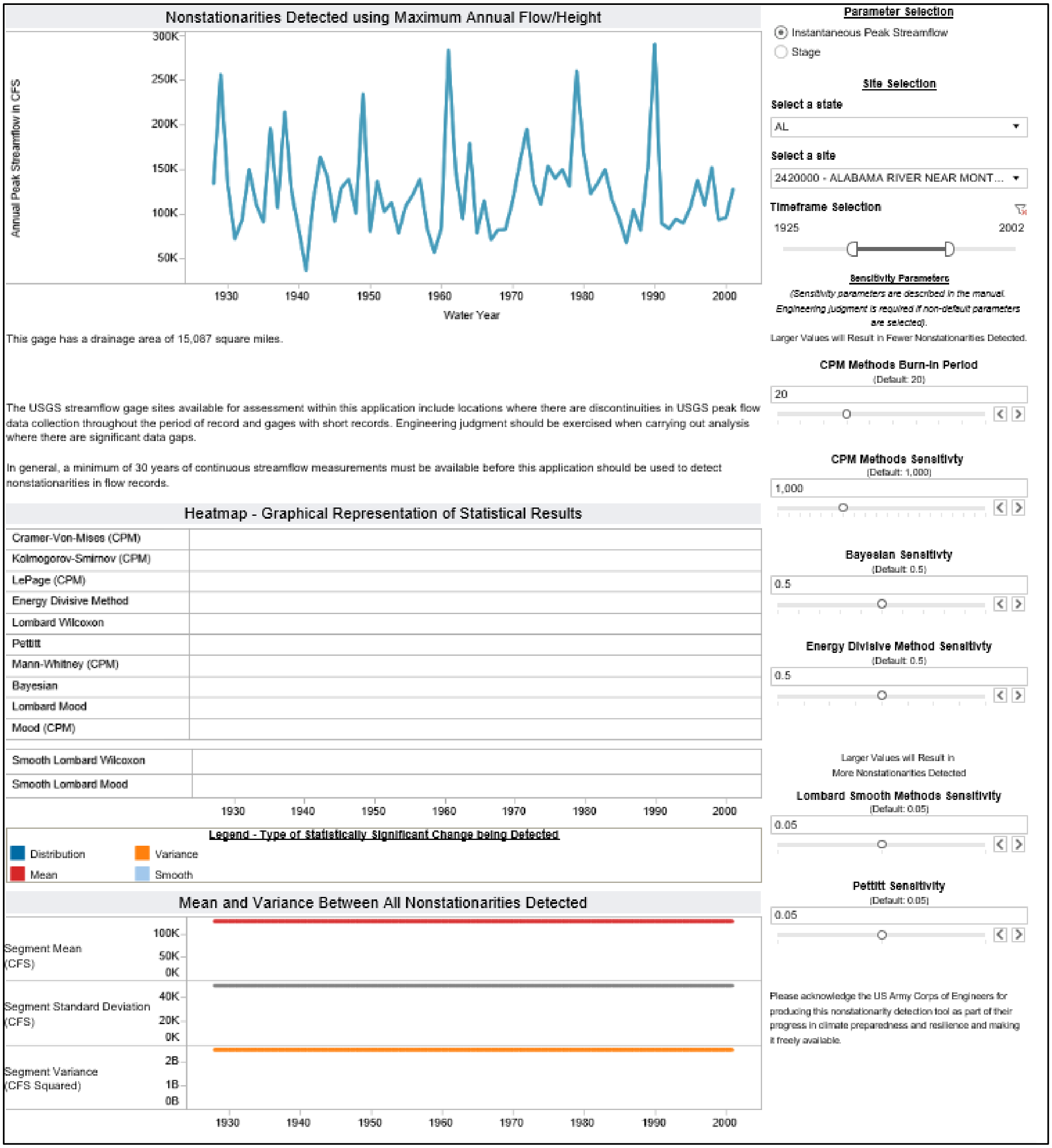


Figure 1-18: Non-Stationarity Tool result for USGS 2420000 located near Montgomery, AL.

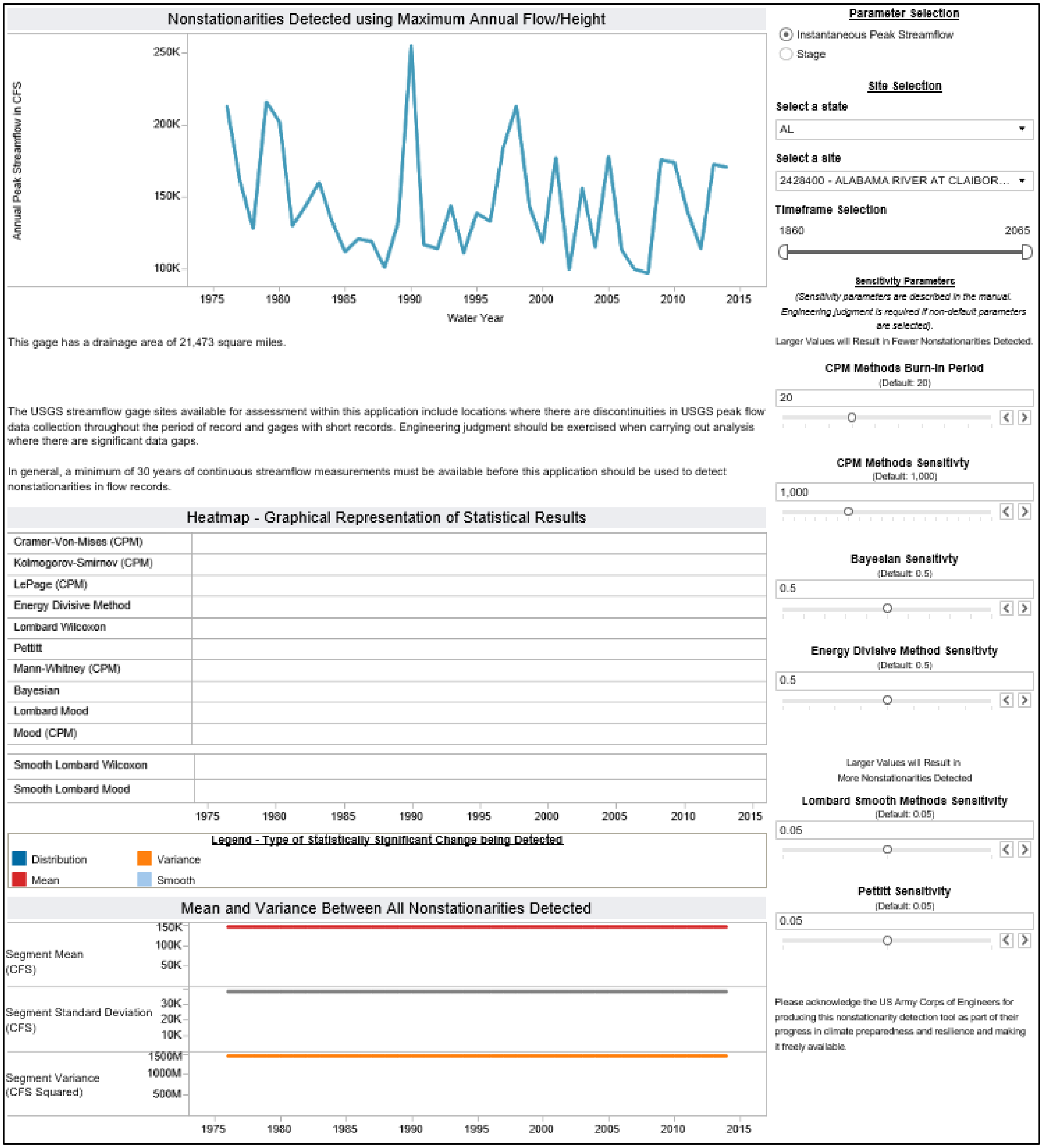
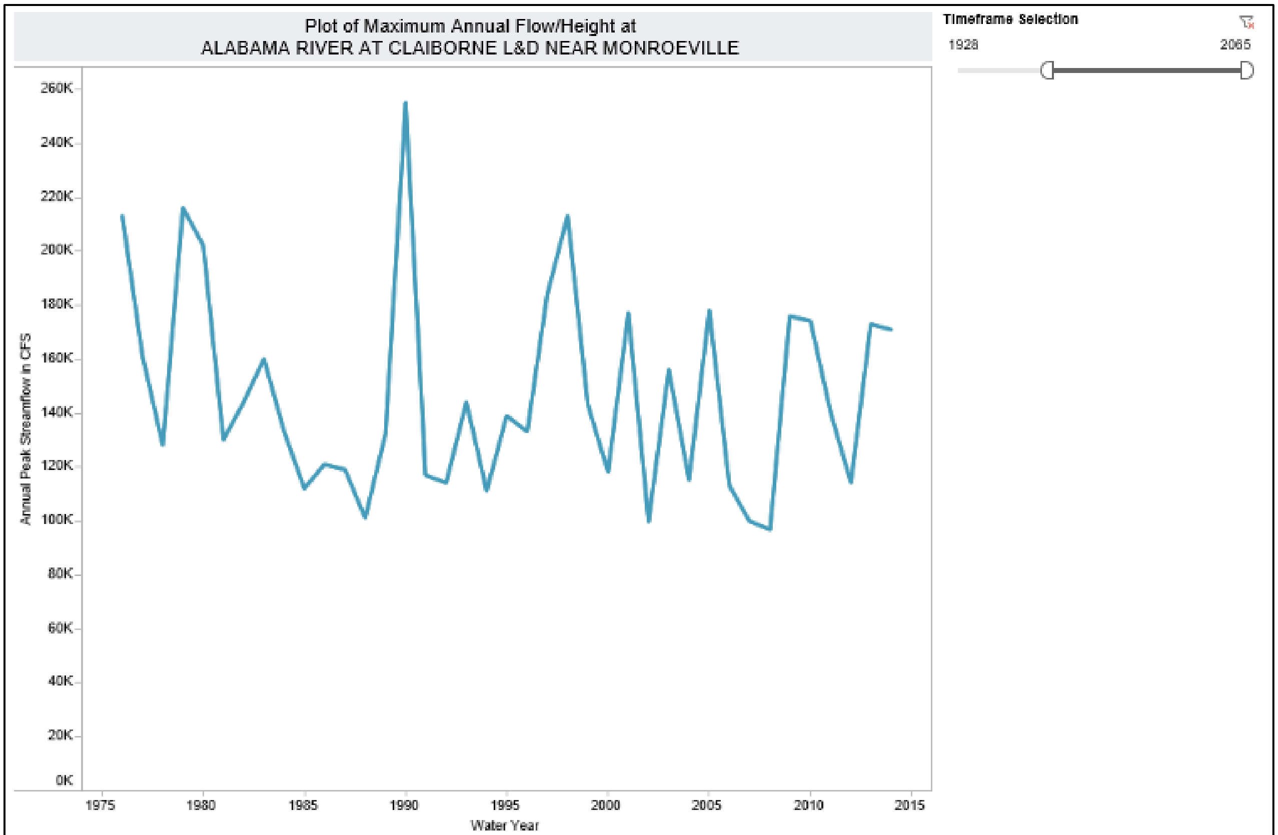


Figure 1-19: Non-Stationarity Tool result for USGS 2428400 located at Claiborne Lock and Dam.



Monotonic Trend Analysis

Is there a statistically significant trend?
No, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.298.
No, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was Null.

What type of trend was detected?
Using parametric statistical methods, **no trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Figure 1-20: Monotonic trend analysis for USGS 2420000 located near Montgomery, AL.

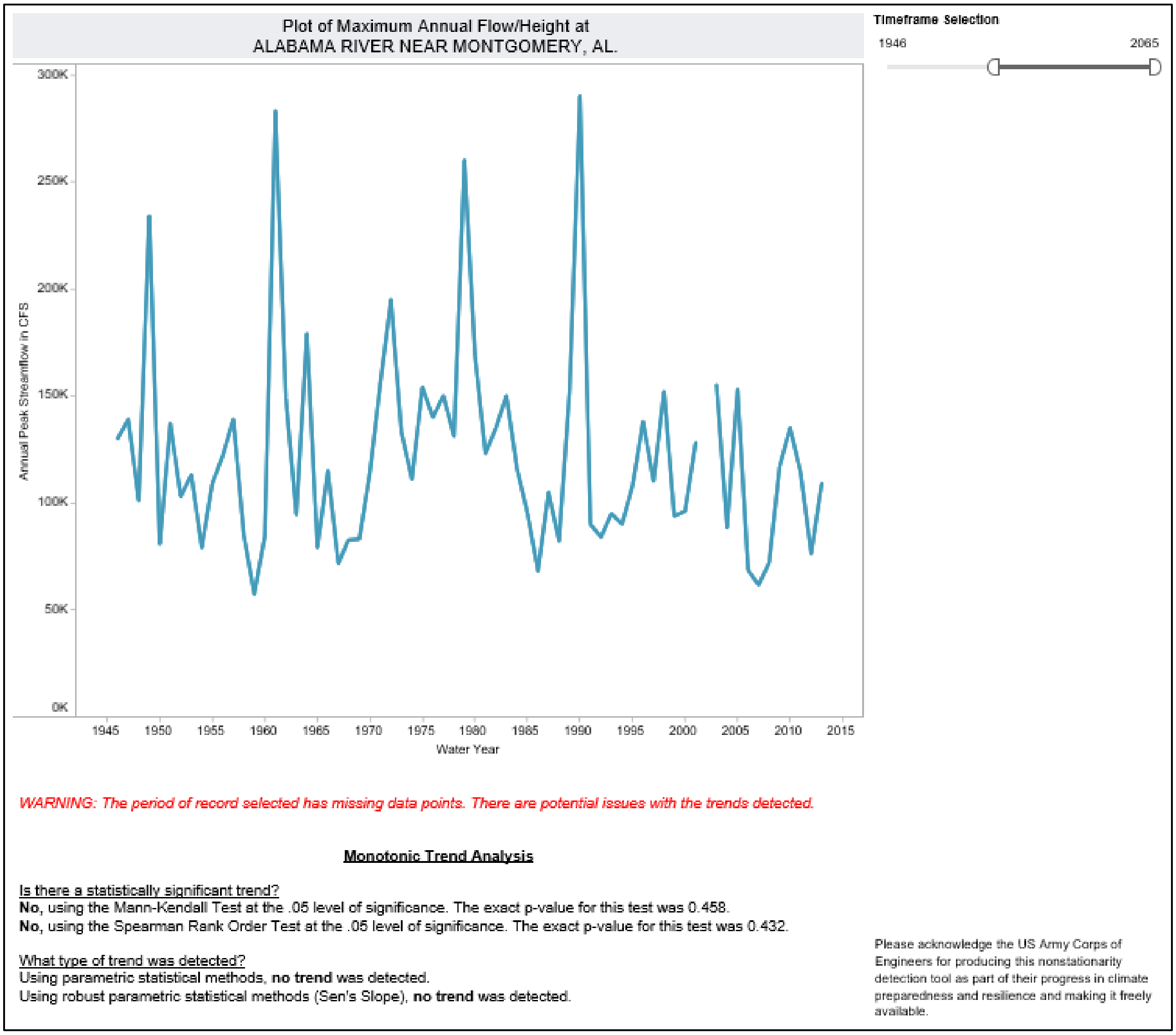


Figure 1-21: Monotonic trend analysis for USGS 2428400 located at Claiborne Lock and Dam.

The Canton, GA (Figure 1-22) is located above Allatoona and above any significant regulation throughout the period of record of the gage. There are two non-stationarities identified at this location. One in 1981 and one in 1982. As these occur within a short period of time (less than 5 years) they should be considered one non stationarity. Both these tests identify a change in the mean of the annual peak streamflow.

There is a consensus on the presence of a non-stationarity if two or more of the tests targeting either changes in the mean, distributional characteristics or variance are detecting a change point. This would be considered robust if tests targeting changes in two or more different statistical properties (mean, variance and/or overall distribution) of the dataset are indicating a statistically significant change point. Based on the two tests, there is a consensus that there is a change point in the mean of the annual peak streamflow around 1981. However, this would not be considered robust as both tests are segmented mean test. Magnitude of the change is also important to consider. The change in mean annal peak streamflow is significant, especially with respect to water supply and flood risk management. The segmented mean drops almost 20%. This would have a positive impact on flood risk management int that this would directly translate into less flood storage being used. This could potentially have a positive or negative effect water supply. Less water obviously could translate into less water supply however, a reduction in the magnitude of extreme flows also translates to a reduction in sedimentation into the reservoir.

One contributor to this non-stationarity is the several high flow events occurring in the late 1970s followed by an extreme drought beginning in the early 1980s. Also, as has been noted several times in this assessment, annual peak streamflow has been consistently lower in recent years, specifically starting in the early 1980s with the exception of a very large event in 1990. As there is a statically significant and abrupt change in this dataset, it should not be considered homogenous and should not be lumped together for many types of analysis.

The monotonic trend test performed show that in the datasets before and after the change points, there is no significant trend in the datasets. This means that the statistical properties within the dataset are relatively constant. In other words, no statistically significant conclusion can be drawn with these subsets of data with respect to an increasing or decreasing trend. What appears clear is that there has been a shift in annual peak streamflow in the last three decades. Peak annual streamflow from the early 1900s through the early 1980s is consistently higher than peak annual streamflow from the early 1980s through present day.

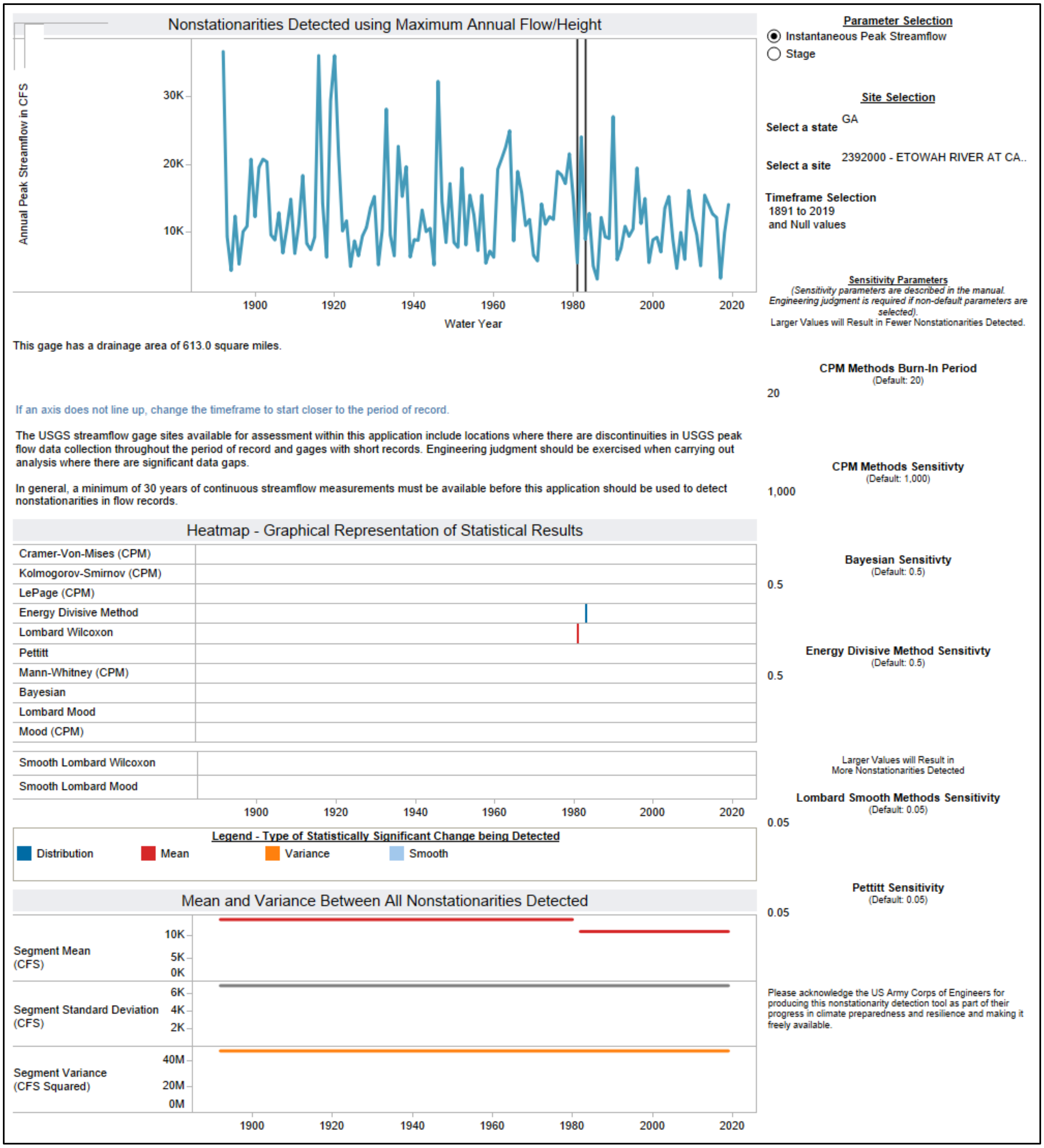


Figure 1-22: Non-Stationarity Tool result for USGS 02392000 located on the Etowah River at Caton, GA

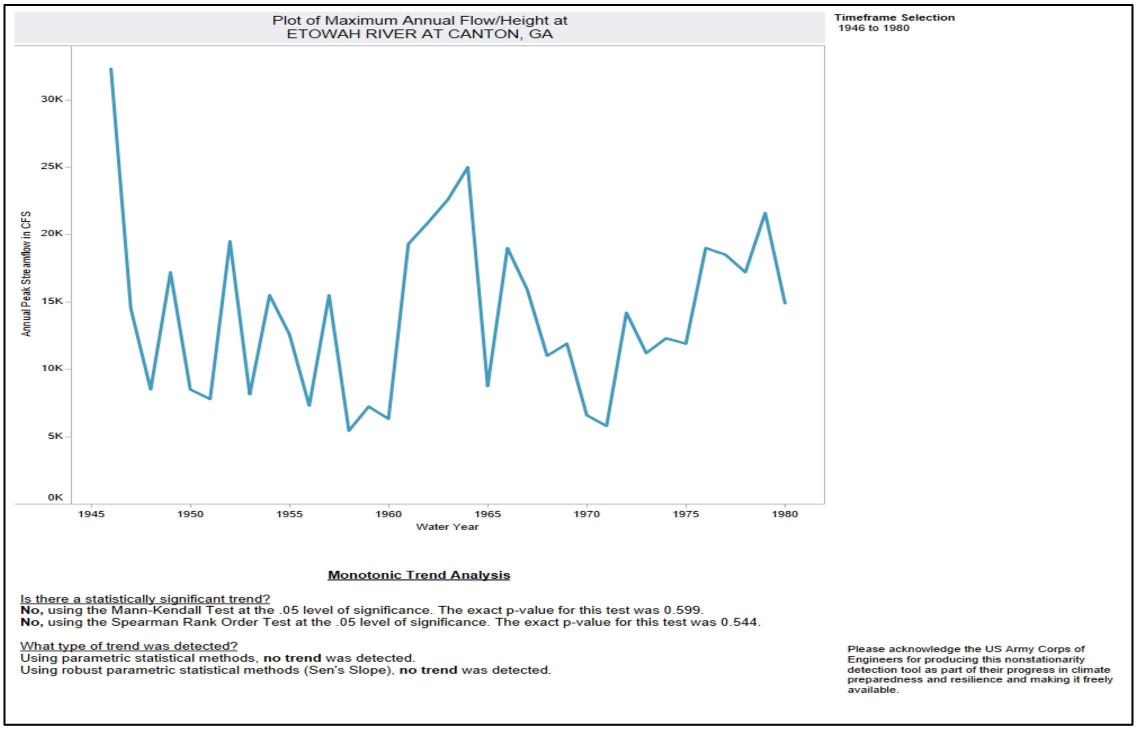


Figure 1-23: Monotonic trend analysis for USGS 02392000 located on the Etowah River at Caton, GA.

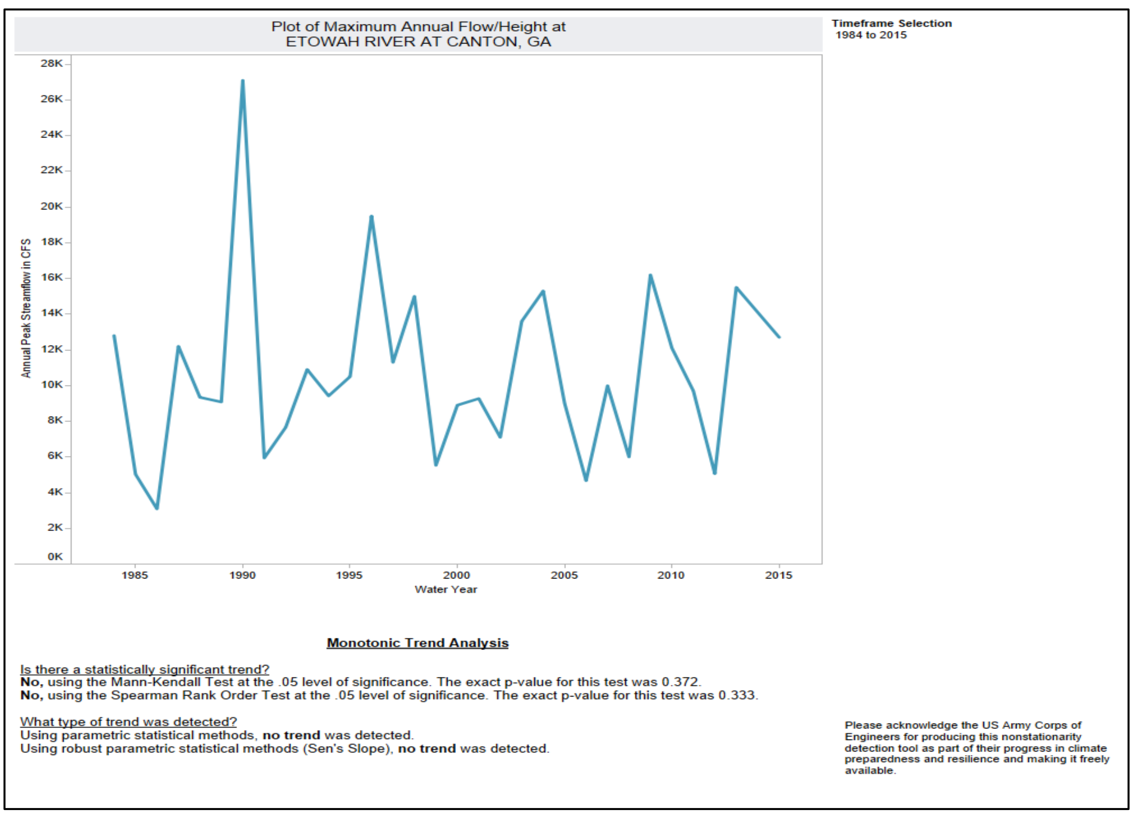


Figure 1-24: Monotonic trend analysis for USGS 02392000 located on the Etowah River at Caton, GA.

USGS water year summaries where checked for all the gages and do not reveal any information that would indicate gage errors or issue with flow recording for the three gages. For the gage located near Montgomery, AL, the two extremes recorded prior to the period of record were estimated based off flood marks and an extended rating curve. The two extremes were excluded from the non-stationarity analysis. The gage located on the Etowah River near Canton, GA has had no changes above the gage that would cause a shift in peak annual streamflow. The water summary does not provide further information that would help identify the cause of the change point.

In addition to the stationarity assessment, the USACE Climate Hydrology Assessment Tool (CHAT) was used to assist in the determination of future streamflow conditions. The CHAT tool is used to assess and observed and future streamflow trends at a USGS gage. A trend is considered significant if the p-value is less than 0.05 however, consideration should be given to any values falling just above 0.05 as this value is somewhat arbitrary and only associated with a 5% risk of a type 1 error. The ACT basin in this tool is referred to by its USGS HUC-4 name. In this case, that is the Alabama Basin. For this assessment, three gages were considered within the Alabama Basin. Each represents a different area within the over 17,000 square mile ACT Basin. Figure 1-25 shows the CHAT output for USGS 02428400 located at Claiborne Lock and Dam for the period of record. Figure 1-26 shows the same gage but only for the period after upstream regulation changes stopped. It is useful to look at trends in the entire period of record however, it is extremely important to look for trends after the influence of changes in upstream regulation have ceased. Therefore, for each of these gages, the entire period of record as well as the period after regulation changes had ceased, has been run for each gage. There were no changes in regulation above Claiborne Lock and Dam after 1984. The pre and post regulation P-values for Claiborne are 0.380259 and 0.503474 respectively. Both fall well outside of a value that would be considered statistically significant.

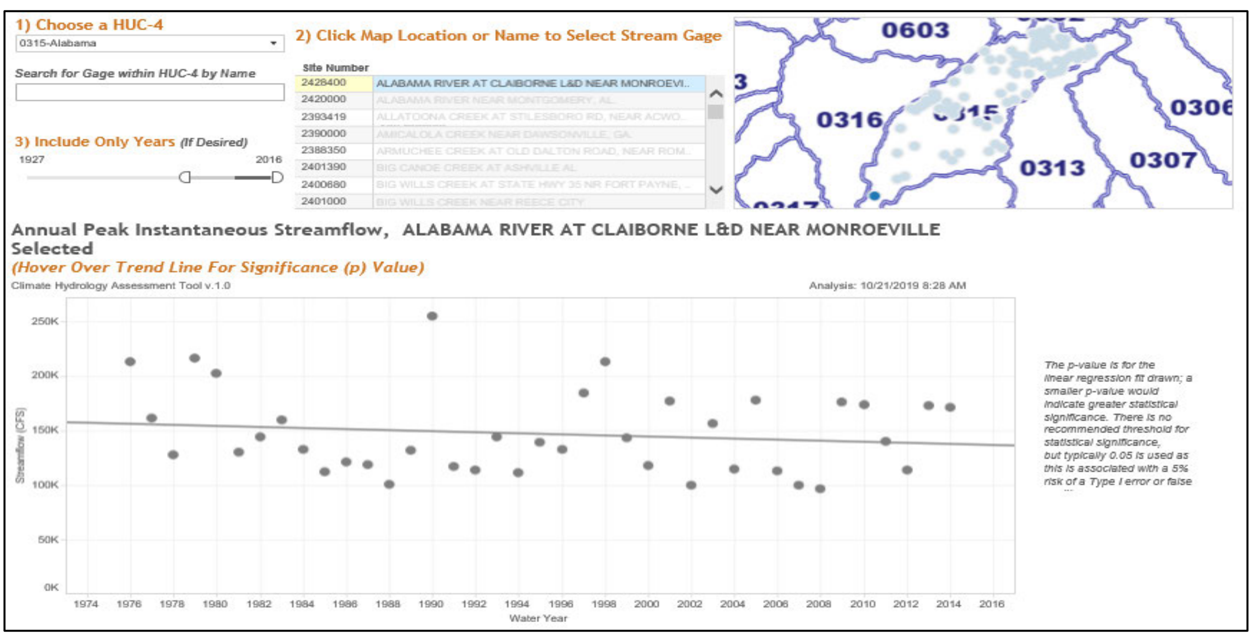


Figure 1-25: CHAT output for USGS 02428400 Alabama River at Claiborne Lock and Dam 1974-2015. (P-value: 0.380259 R-Squared: 0.0208689 Eq: -483.138*WY+1.11069e+06).

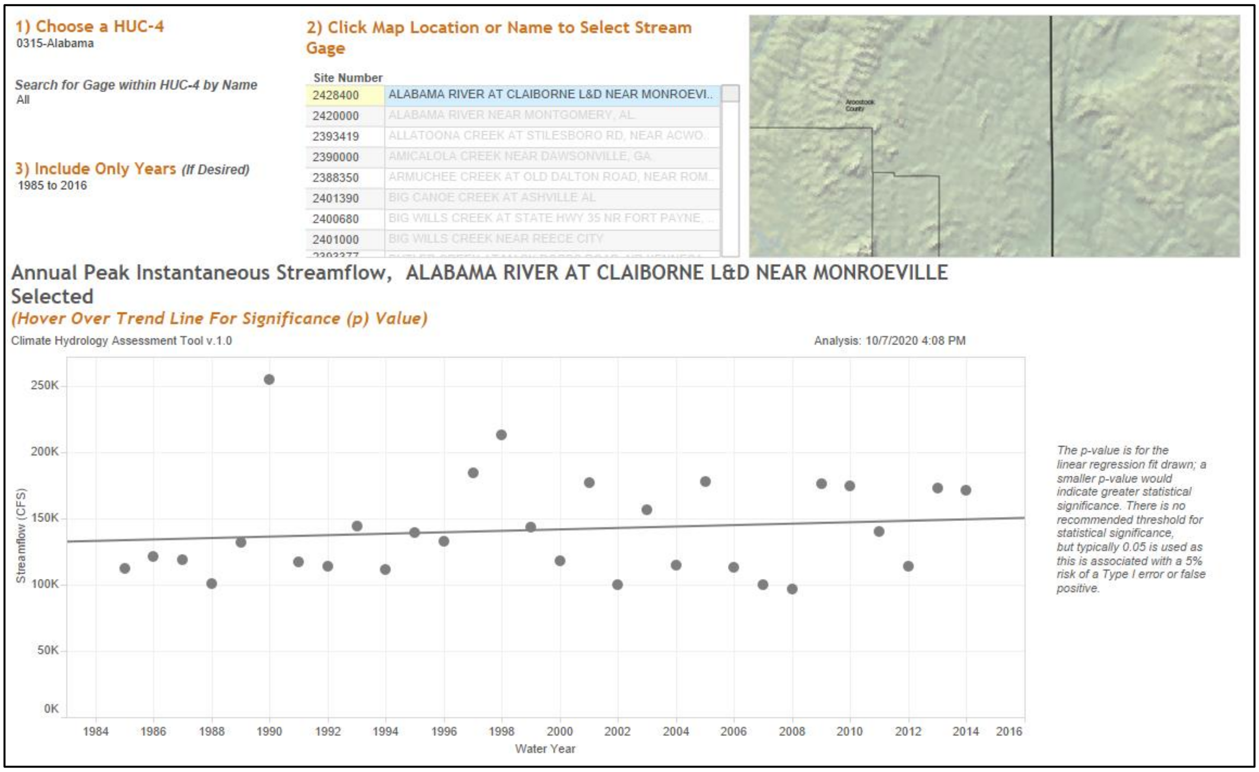


Figure 1-26: CHAT output for USGS 02428400 Alabama River at Claiborne Lock and Dam 1984-2015. (P-value: 0.503474 R-Squared: 0.0161418 Eq: 542136*WY-942690

Figures 1-27 and 1-28 show the CHAT output for USGS 02420000 located near Montgomery, AL. The p-values for this gage is 0.275589 and 0.550152. While there does appear to be a downward sloping trend in the streamflow trend lines, neither are close to being considered a statistically significant trend. It is worth noting that even after regulation changes ceased, there could be a very slight decrease in peak annual streamflow at this gage.

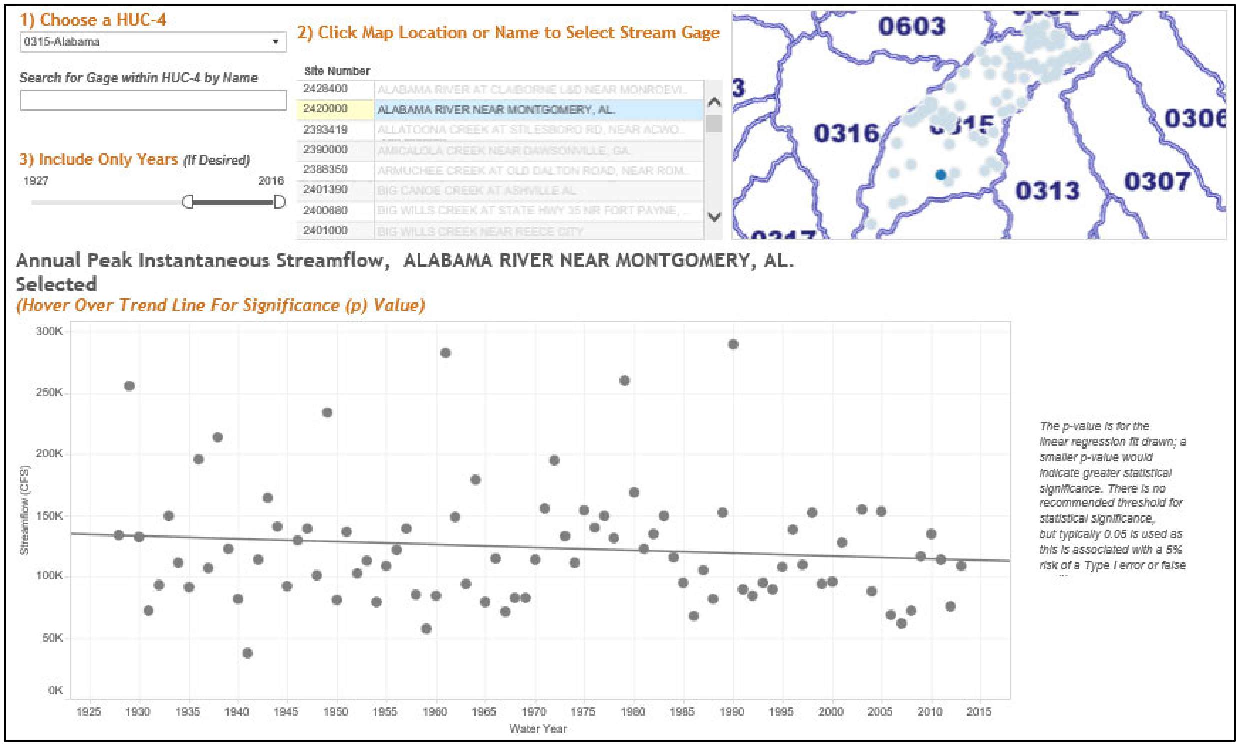


Figure 1-27: CHAT output for USGS 02420000 Alabama River near Montgomery, AL 1927-2015. (P-value: 0.275589 R-Squared: 0.014305 Eq: -234.672*WY+586134).

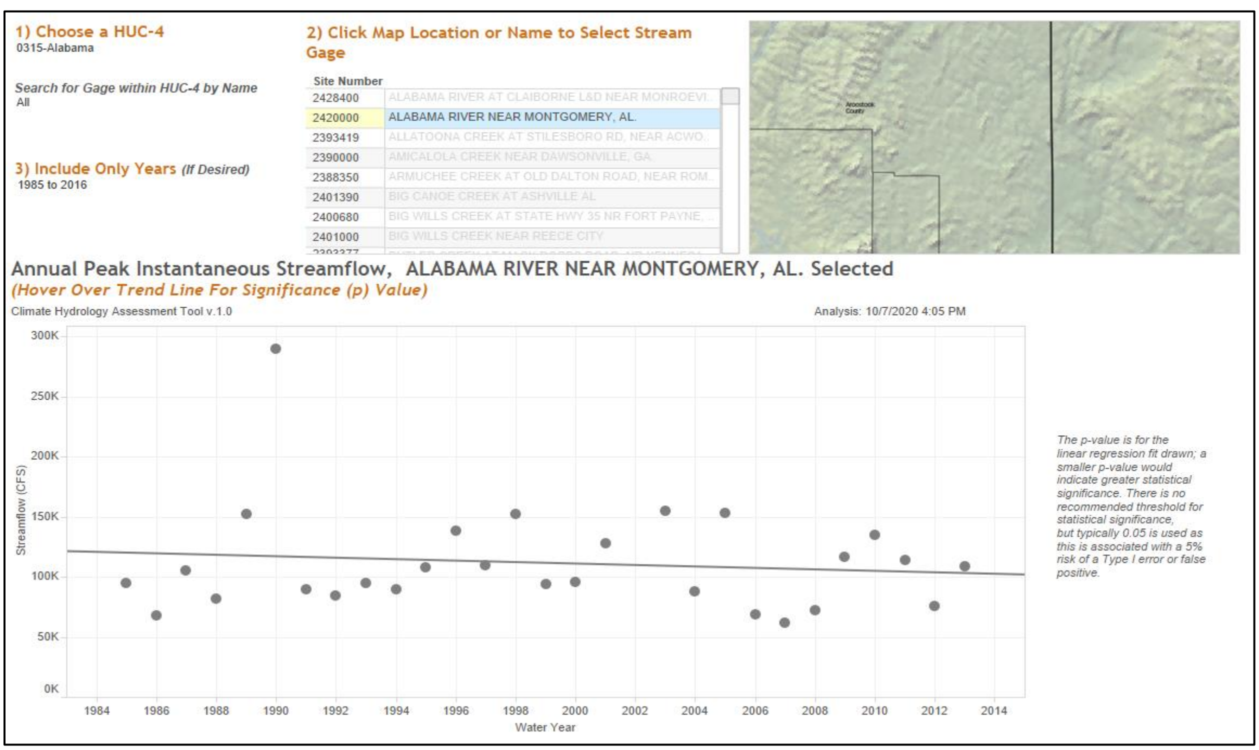


Figure 1-28: CHAT output for USGS 02420000 Alabama River near Montgomery, AL 1984-2015. (P-value: 0.550152 R-Squared: 0.0139012 Eq: -607.28*WY+1.32555e+06).

Figure 1-29 shows the CHAT tool output for the USGS gage 02392000 at Canton, GA. This gage is located upstream of Allatoona dam and has seen no regulation changes over the period of record of the gage. The P-value for the trendline for this gage is 0.0204529. This means there had been a statistically significant trend in the streamflow above the damsite in the Allatoona basin. The trendline itself shows a near 30% drop in annual maximum streamflow through the period of record. While there is an anticipated increase in extreme precipitation events, this may largely be offset by increasing temperatures and longer droughts. As we see in the review of observed precipitation and temperatures in the sections above, we have seen little change in precipitation in the region, however temperatures have increased and peak annual flows have decreased in many areas.

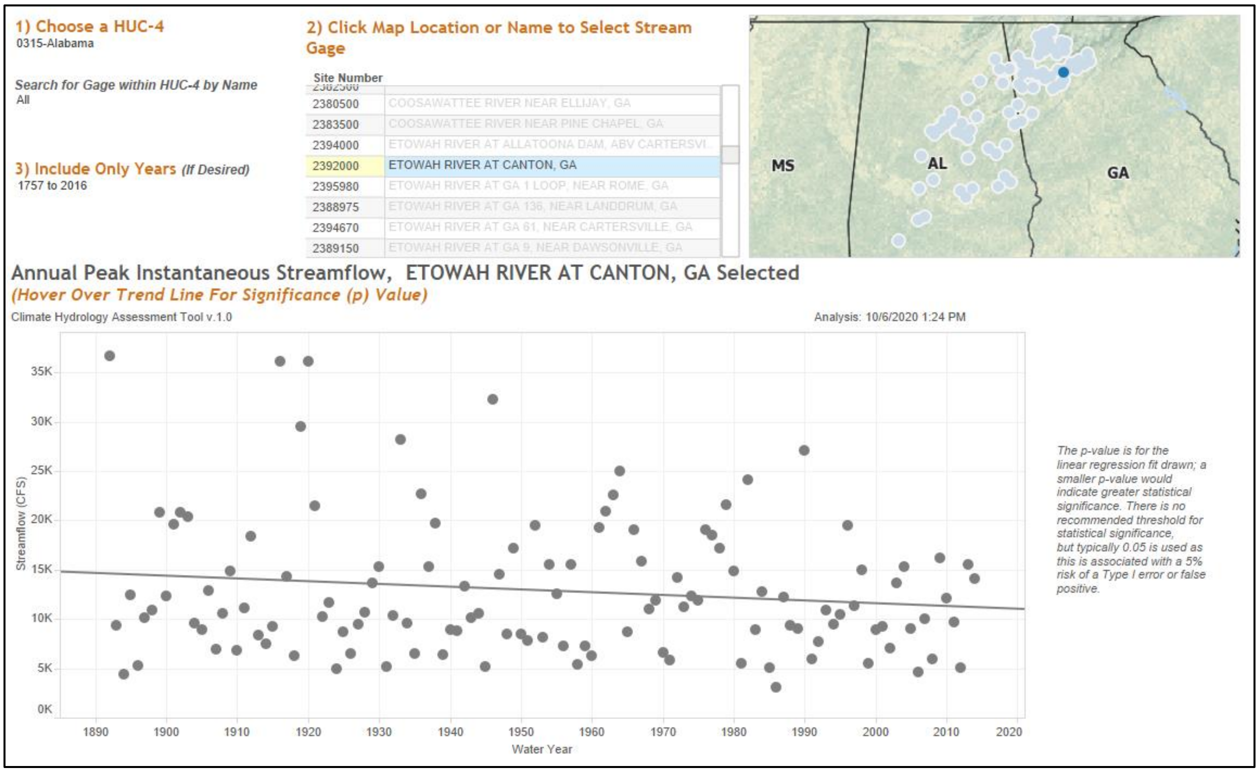


Figure 1-29: CHAT output for USGS 02392000 Etowah River near Canton, GA 1890-2015. (P-value: 0.11456 R-Squared: 0.0204529 Eq: -27.8744*WY+6.7345.5).

A Hydrologic Unit Code 4 (HUC-4) level analysis of mean projected annual maximum monthly streamflow was also performed using the CHAT tool. The trends in mean projected annual maximum monthly streamflow presented in this analysis represent outputs from the Global Climate Models (GCMs) using different representative concentration pathways (RCPs) of greenhouse gasses that are then translated into a hydrologic response using the United States Bureau of Reclamation (USBR) Variable Infiltration Capacity (VIC) model. The VIC model, forced with GCM meteorological outputs is used to produce a streamflow response for both the hindcast period (1950-1999) and the future period (2000-2099). The streamflow values in this tool are representative of flows at the outlet of the entire Alabama River HUC-4 Basin. This dataset is unregulated and does not account for the many flood control structures located on the mainstem rivers within this HUC-4 basin and therefore is a good indicator of climate effects in the absence of regulation.

The analysis indicates an upward trend in mean projected annual maximum monthly streamflow for the Alabama Basin, as shown in Figure 1-30. The forecast visually indicates an upward trend in projected streamflow from years 2000 to 2099 within the basin and is considered statistically significant with a p-value of 0.01442. The hindcast data shows no statistically significant trend from 1950 to 1999 (p-value: 0.795219) and visually, appears to decrease slightly.

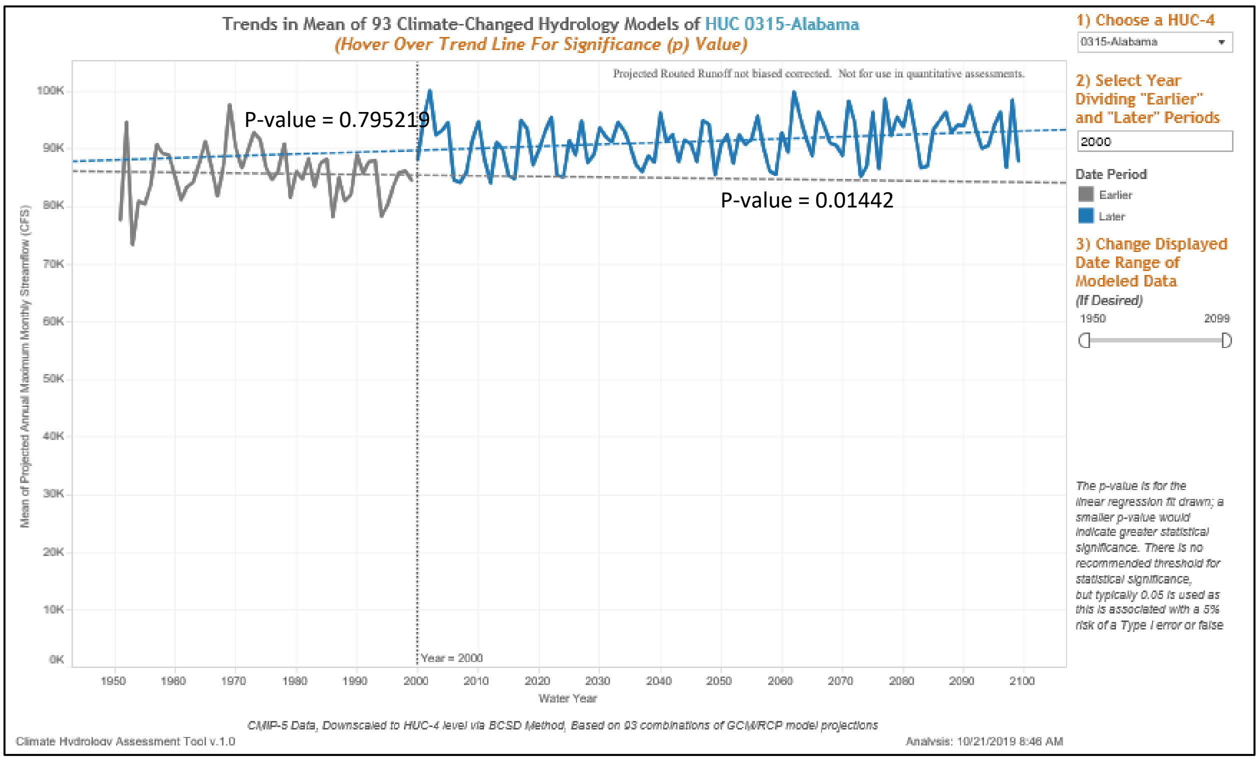


Figure 1-30: Mean projected annual maximum monthly streamflow for the Alabama HUC-4.

Figure 1-31 provides the mean value of the 93 projections of future, streamflow projections considered through water year 2099, as well as the range of projected streamflow values produced for the watershed at its outlet. The variability of the spread is fairly consistent for the projected portion of the record: 2000 to 2099.

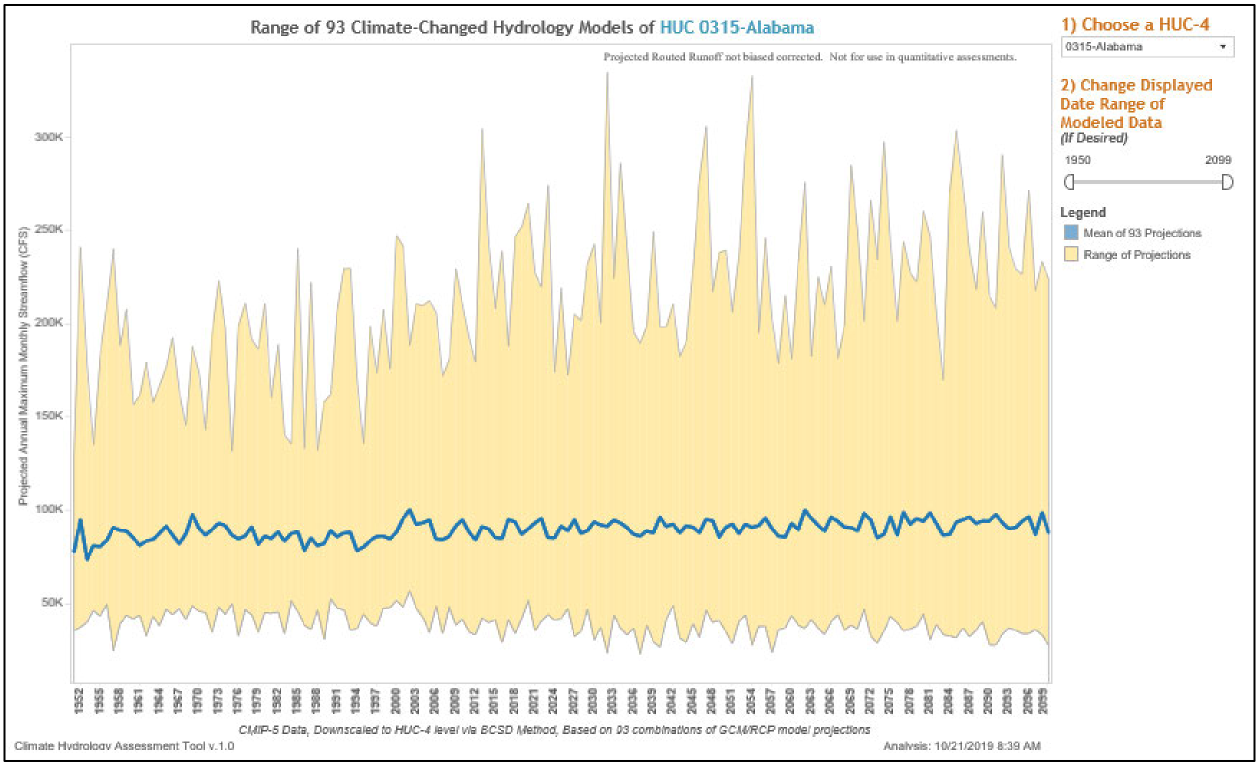


Figure 1-31: Projected hydrology for the Alabama HUC-4 base on the output from 93 projections of climate changed hydrology.

It can be seen in Figure 1-31 above that there is significant uncertainty in projections of future streamflow. The yellow shaded area is indicative of the spread in the data produced. It is important to understand that this uncertainty comes from each of the model sources that are used to develop the projected streamflow datasets. GCMs have uncertainty in the bounds of their atmospheric input such as the RCPs. Downscaling the output of these models to a smaller region may not account for some regional effects.

Changes in future conditions that drive the hydrologic model are also a major uncertainty. An example of this is land use changes, such as increased impervious areas can have a major effect on peak streamflow. There are many different land use projections for this region from many sources. Areas around Rome, Georgia and Montgomery, Alabama will continue to see increased urbanization and therefore increase impervious area, increasing runoff. Other more rural areas may continue to develop as well. Areas outside of population centers are either heavily forested or in some cases well maintained farmland. Other uncertainties such as changes in temperature extremes and the seasonality of the extreme precipitation could also have a significant effect on the rainfall/runoff transformation. For these reasons, this quantitative analysis should be used with caution, with an understanding that this data should only be considered within the large uncertainly bounds of the analysis.

1.4 Vulnerability Assessment

To understand potential climate change effects and to increase resilience/decrease vulnerability of both water supply and flood risk management alternatives to climate change, the relative vulnerability of the basin to such factors was analyzed. In accordance with ECB 2018-14, the USACE Watershed Climate Vulnerability Assessment tool was used to identify vulnerabilities to climate change on a HUC-4 watershed scale relative to other HUC-4 basins across the nation. As this study is an assessment of water supply and flood risk management alternatives, vulnerability with respect to these two business lines are presented in this analysis.

To address vulnerabilities due to climate change, the Vulnerability Assessment tool utilizes two 30-year epochs centered on 2050 (2035-2064) and 2085 (2070-2099) as well as a base epoch. These epochs, while fairly arbitrary, line up well with other national climate change assessments. For each epoch, the tool utilizes the results of 100 combinations of Global Circulation/Climate Models (GCM) run using different Representative Concentration Pathways of greenhouse gas emission to produce 100 traces per epoch for a given watershed. The results of the GCMs are translated into flow and are then sorted by cumulative runoff projections. Traces of the highest 50% of cumulative runoff are categorized as wet and traces with the lowest 50% of cumulative runoff are categorized as dry. This provides two scenarios (wet and dry) for each of the two epochs, excluding the base epoch. Consideration of both wet and dry scenarios reveals some of the uncertainties associated with the results produced using the climate changed hydrology and meteorology used as inputs to the vulnerability tool.

The tool uses specific indicators of vulnerability relative to the business line being considered. There are a total of 27 indicators in the tool, 5 of which are used to derive the vulnerability score in the Alabama HUC 4 with respect to the Flood Damage Reduction business line and 5 used with respect to water supply. Tables 1-1 and 1-2 list the indicators and their descriptions.

Table 1-1: Indicator Variables used to derive the flood risk management vulnerability score for the Alabama Basin as determined by the Vulnerability Assessment tool.

Indicator Short Name	Indicator Full Name	Description
175C_ANNUAL_COV	Annual CV of unregulated runoff (cumulative)	Long-term variability in hydrology: ratio of the standard deviation of annual runoff to the annual runoff mean. Includes upstream freshwater inputs (cumulative).
277_RUNOFF_PRECIP	% change in runoff divided by % change in precipitation	Median of: deviation of runoff from monthly mean times average monthly runoff divided by deviation of precipitation from monthly mean times average monthly precipitation.
568L_FLOOD_MAGNIFICATION	Flood magnification factor (local)	Change in flood runoff: Ratio of indicator 571L (monthly runoff exceeded 10% of the time, excluding upstream freshwater inputs) to 571L in base period.
568C_FLOOD_MAGNIFICATION	Flood magnification factor (cumulative)	Change in flood runoff: ratio of indicator 571C (monthly runoff exceeded 10% of the time, including upstream freshwater inputs) to 571C in base period.
590_URBAN_500YRFLOODPLAIN_	Acres of urban area within 500-year floodplain	Acres of urban area within the 500-year floodplain.

Table 1-2: Indicator Variables used to derive the water supply vulnerability score for the Alabama Basin as determined by the Vulnerability Assessment tool.

Indicator Short Name	Indicator Full Name	Description
95_DROUGHT_SEVERITY	Drought Severity Index	Greatest precipitation deficit: The most negative value calculated by subtracting potential evapotranspiration from precipitation over any 1-, 3-, 6-, or 12-month period.
156_SEDIMENT	Change in sediment load due to change in future precipitation	The ratio of the change in the sediment load in the future to the present load.
175C_ANNUAL_COV	Annual CV of unregulated runoff (cumulative)	Long-term variability in hydrology: ratio of the standard deviation of annual runoff to the annual runoff mean. Includes upstream freshwater inputs (cumulative).
221C_MONTHLY_COV	Monthly CV of runoff (cumulative)	Measure of short-term variability in the region's hydrology: 75th percentile of annual ratios of the standard deviation of monthly runoff to the mean of monthly runoff. Includes upstream freshwater inputs (cumulative).
277_RUNOFF_PRECIP	% change in runoff divided by % change in precipitation	Median of: deviation of runoff from monthly mean times average monthly runoff divided by deviation of precipitation from monthly mean times average monthly precipitation.

Figure 1-32 and 1-33 shows a comparison of WOWA scores for the flood risk reduction business line for HUC-4 watersheds nationally, and for the South Atlantic Division only, for the wet and dry scenarios as well as the 2050 and 2085 epochs. This shows that the WOWA score for the Alabama HUC-4 Basin (highlighted in yellow) is not relatively vulnerable to climate change impacts for the flood risk management business line. In Figure 1-32 the HUC-4 watersheds with the lowest vulnerability scores (less vulnerable) are highlighted in yellow, while more vulnerable watersheds are highlighted in fuchsia. Out of the 202 HUC-4 watersheds in the continental United States 41 of them are identified as being vulnerable to climate change impacts for flood risk management. The other 161 watersheds, including the Alabama basin are considered less vulnerable to climate change impacts. Within the South Atlantic Division, for both epochs for the wet subset of traces there are only two HUC-4 watersheds, and for the dry subset of traces there are only three HUC-4 watersheds that are considered relatively vulnerable to climate change for the flood risk management business line. All three watersheds in question are in Florida. This further reinforces that the Alabama basin is does not have significant vulnerabilities to the Flood Risk Reduction business line with respect to other watersheds in the United States or the region. Figure 1-34 shows the dominate indicators for basins with respect to the flood risk management business line.

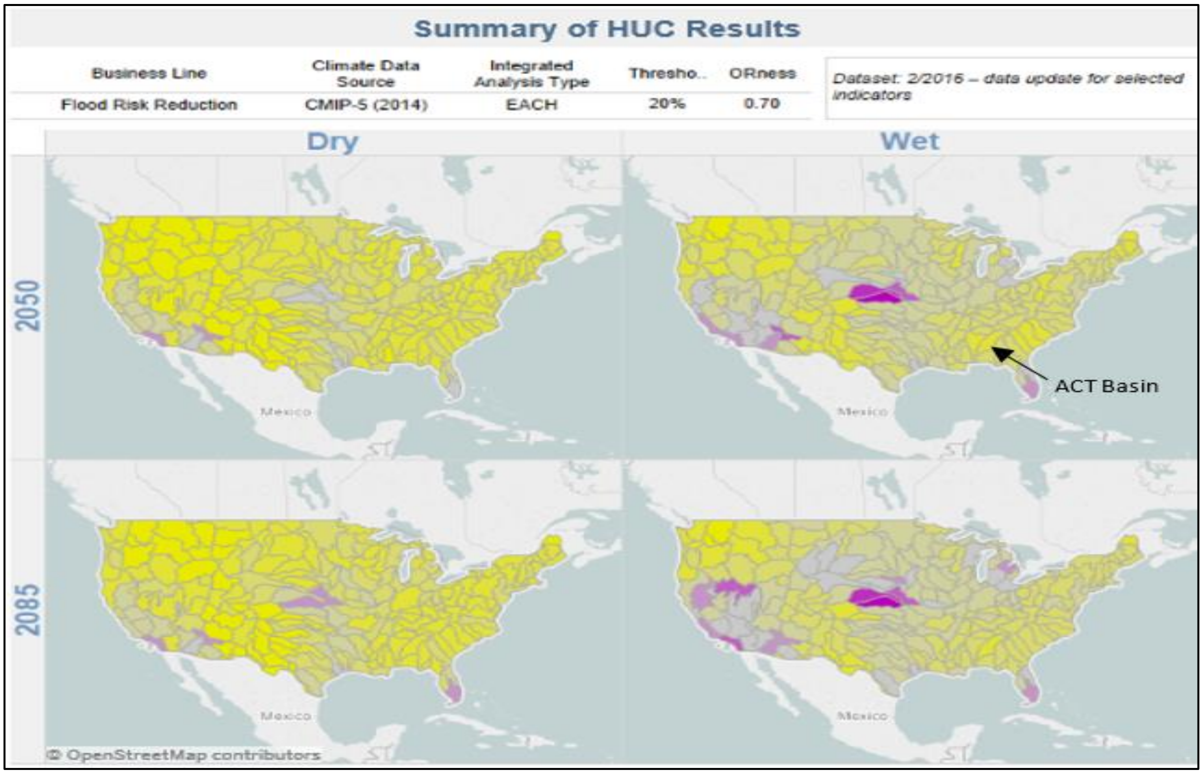


Figure 1-32: Comparison of national vulnerability scores for CONUS HUC-4s.

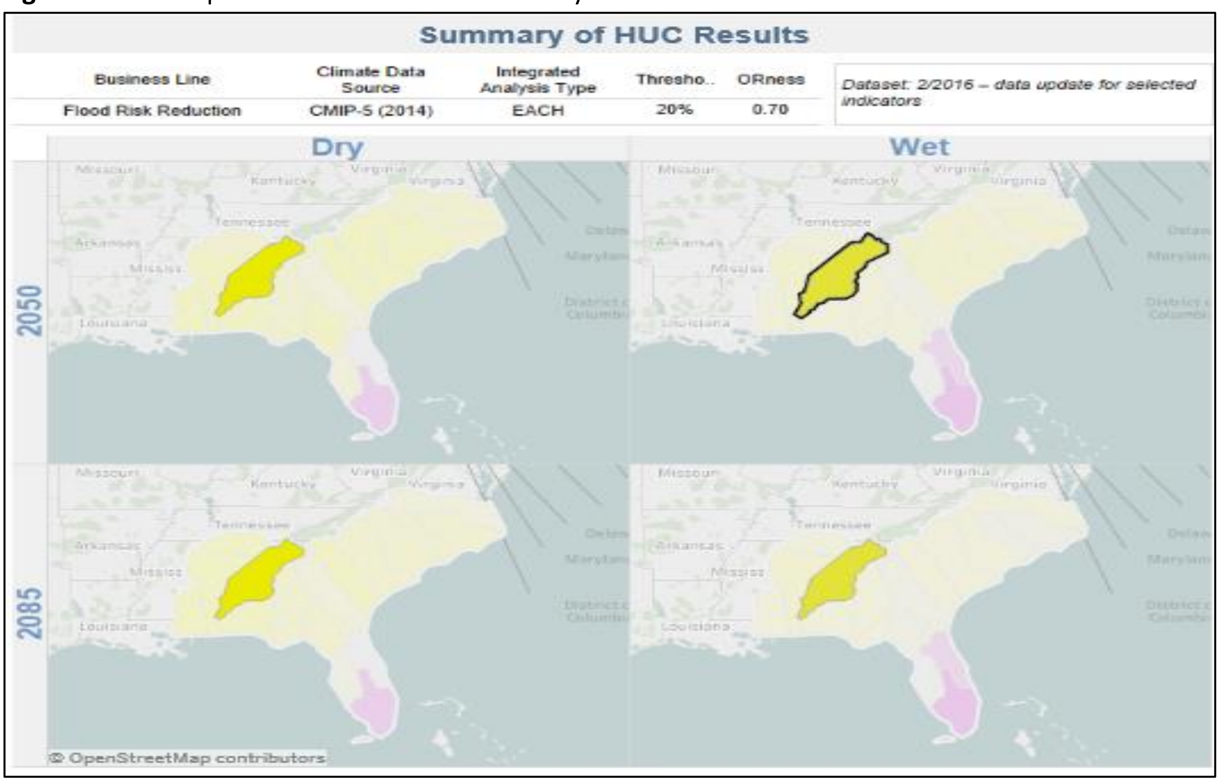


Figure 1-33: Comparison of national vulnerability scores for South Atlantic Division HUC-4 with respect to flood risk management.

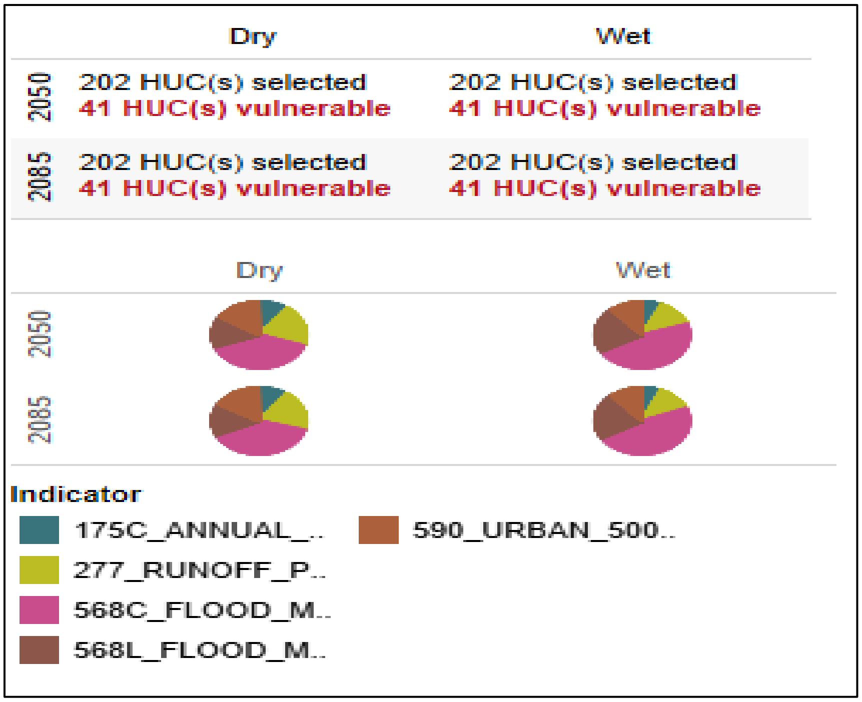


Figure 1-34: Dominate indicators with respect to flood risk management

Figures 1-35 and 1-36 shows a comparison of WOWA scores for the water supply for HUC-4 watersheds nationally, and for the South Atlantic Division only, for the wet and dry scenarios as well as the 2050 and 2085 epochs. This shows that the WOWA score for the Alabama HUC-4 Basin (highlighted in yellow) is not relatively vulnerable to climate change impacts for the water supply business line but somewhat more vulnerable than other basins in the South Atlantic Division. In Figure 1-35 the HUC-4 watersheds with the lowest vulnerability scores (less vulnerable) are highlighted in yellow, while more vulnerable watersheds are highlighted in fuchsia. Out of the 202 HUC-4 watersheds in the continental United States on 72 have WOWA scores relative to water supply. Of those 72 watersheds, 15 of them are identified as being vulnerable to climate change impacts for water supply. The other 57 watersheds, including the Alabama basin are considered less vulnerable to climate change impacts. Within the South Atlantic Division, for both epochs for the wet subset of traces there are no HUC-4 watersheds, and for the dry subset of traces there are no HUC-4 watersheds that are considered relatively vulnerable to climate change for the flood risk management business line. This demonstrates that the Alabama basin is does not have significant vulnerabilities to the water supply business line with respect to other watersheds in the United States. Figure 1-37 shows the dominate indicators for basins with respect to the water supply business line.

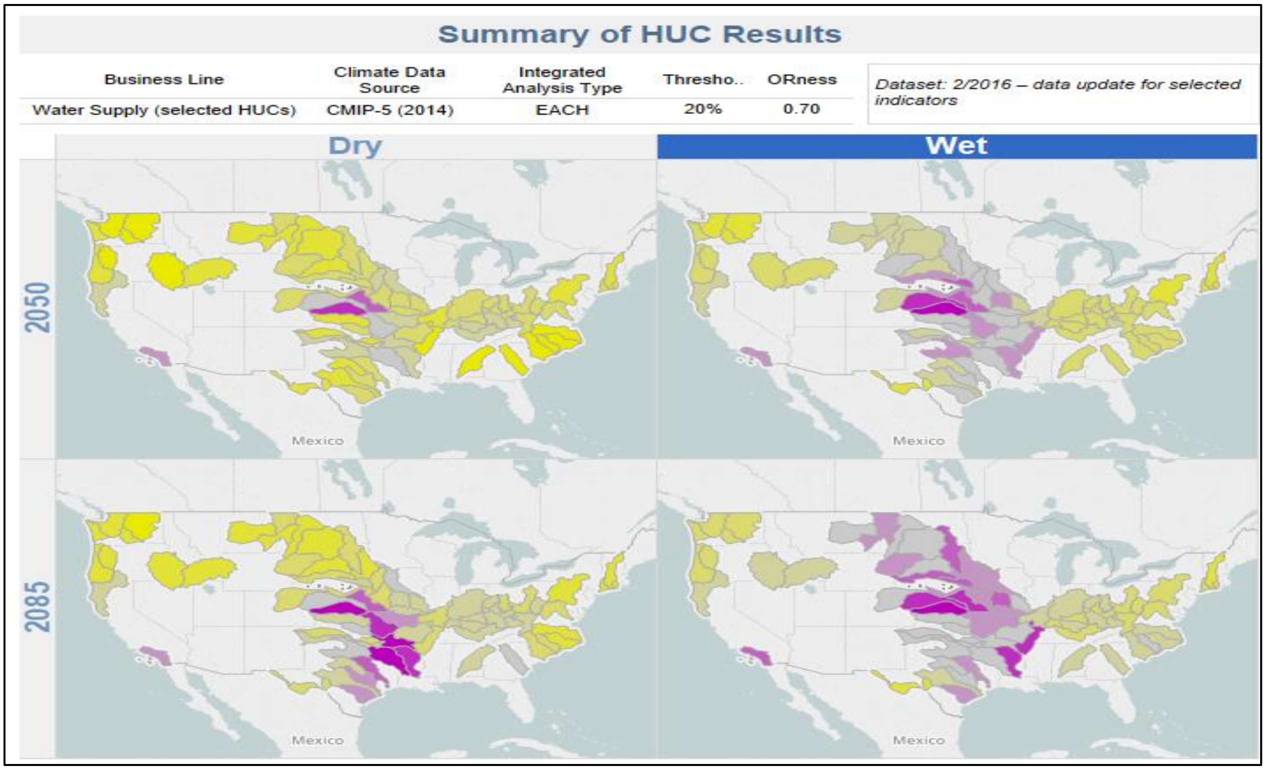


Figure 1-35: Comparison of national vulnerability scores for CONUS HUC-4s with respect to water supply.

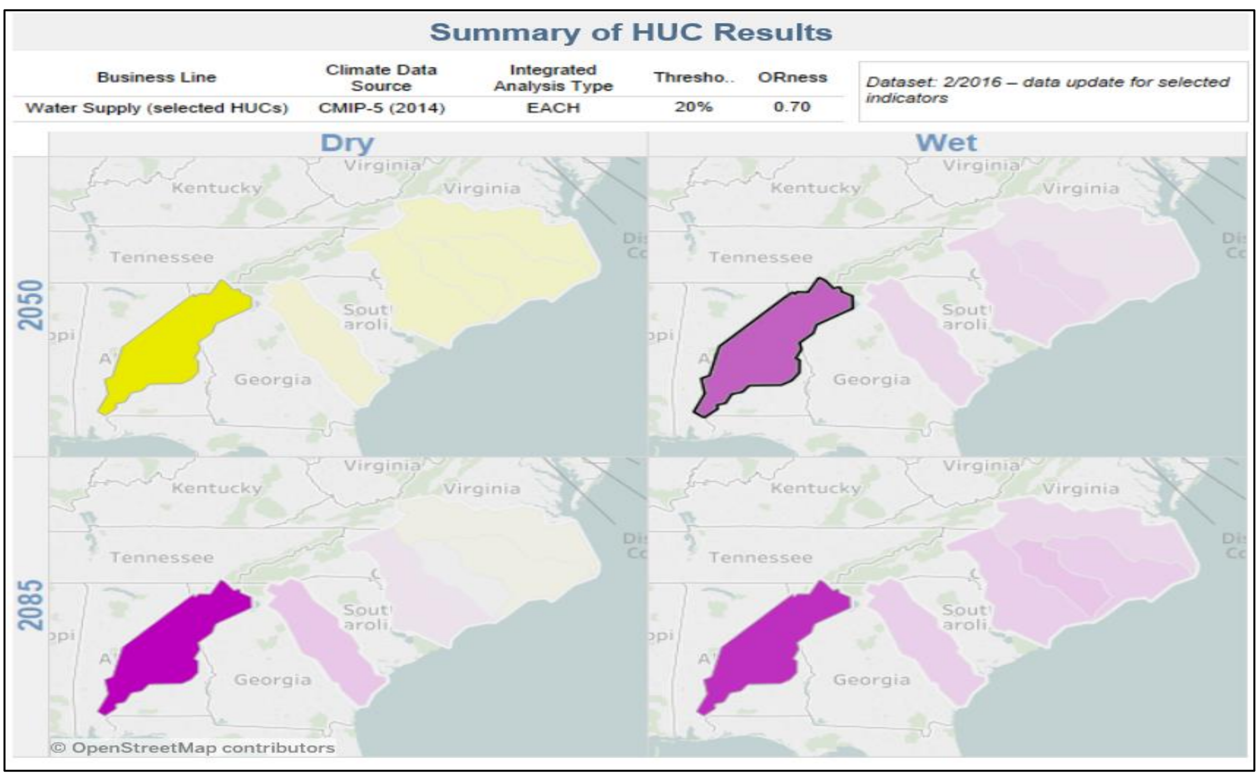


Figure 1-36: Comparison of national vulnerability scores for CONUS HUC-4s with respect to water supply

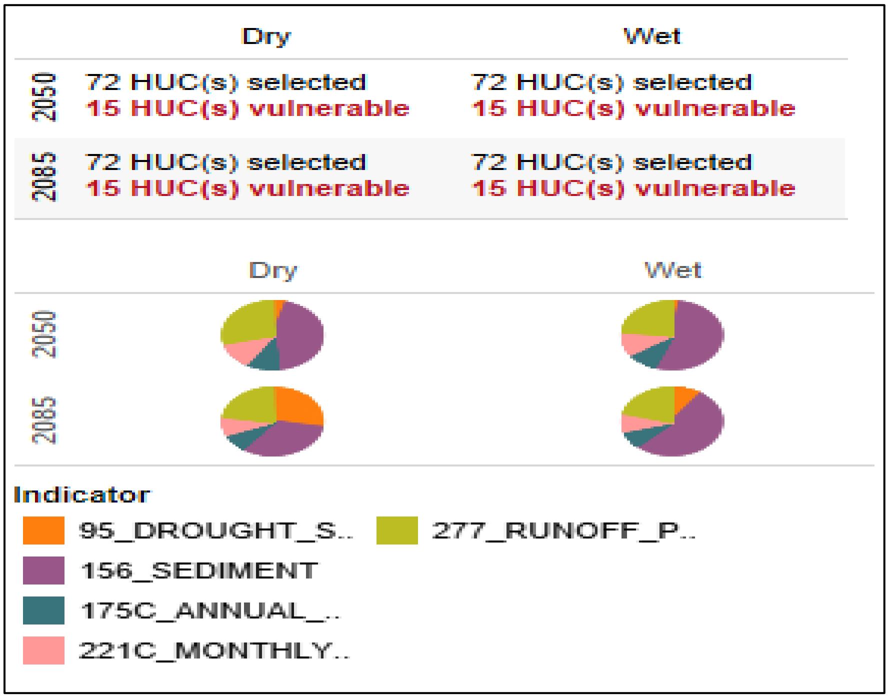


Figure 1-37: Dominate indicators with respect to water supply.

It is important to note that the vulnerability assessment only indicates vulnerability relative to the rest of the nation. It does not state that the basin itself is invulnerable to impacts of climate change on the Flood Risk Reduction and Water Supply business lines. Therefore, it is beneficial to understand the composition of the relevant HUC 04's (Alabama Basin) vulnerability score, in terms of how much each flood risk reduction indicator variable contributes to the vulnerability score for each subset of traces and for both epochs of time. Figures 1-34 and 1-37 show the dominant indicators relative to Flood Risk Reduction Water Supply respectively. Flood Magnification is the prevailing indicator variable driving the Flood Damage Reduction vulnerability score, followed by the Urban 500 Year Floodplain for both the dry and wet scenarios. This aligns with the literature review that indicates the potential for more frequent and more severe storms in the southeast. For water supply, changes in sedimentation due to changes in precipitation is the primary driver.

1.5 Risk Assessment

The TSP for this study includes 4 measures. They are a reallocation of storage from the Flood Risk Management pool at Allatoona Dam, Weiss Dam and Logan Martin dam and, a reallocation from conservation storage at Allatoona Dam. Table 1-3 provides a summary of the qualitative risk assessment done regarding each of these measures.

Table 1-3: Risk assessment results of each measure in the Tentatively Selected Plan.

Feature or Measure	**Trigger**	**Hazard**	**Harm**	**Qualitative Likelihood**
Allatoona Reallocation from FRM Pool	Increase in frequency and magnitude of extreme storms	Reduced flood storage capacity and increase in downstream flooding	Increase in damage to homes and agriculture.	Unlikely
Allatoona Reallocation from Conservation	Increase in frequency and magnitude of droughts	Reduced storage capacity	Project purposes including water supply cannot me met.	Unlikely
Weiss Reallocation from FRM Pool	Increase in frequency and magnitude of extreme storms	Reduced flood storage capacity and increase in downstream flooding	Increase in damage to homes and agriculture.	Unlikely
Logan Martin Reallocation from FRM Pool	Increase in frequency and magnitude of extreme storms	Reduced storage capacity and increase in downstream flooding	Increase in damage to homes and agriculture.	Unlikely

Reallocation from the conservation pool at Lake Allatoona would result in decreased storage capacity in the conservation pool. The harm this could cause would be a loss of storage for project purposes including water supply. This study addresses these concerns in depth. The conservation pool has never been exhausted. It possible however, in the face of increasing water supply and an increase in the severity of droughts that in the future this could happen. The harm in this case would result in a lack of water for water supply and the inability to meet other project purposes. This is considered unlikely in the foreseeable future, but certainly possible. There are several mitigating factors that would be considered if it became clear the conservation storage would be exhausted including use of additional "inactive" storage to meet project demands including water supply.

With consideration for floods and a reallocation from the dedicated conservation pool at Allatoona, changes in precipitation such as an increase in frequency and magnitude of storms would be unlikely to trigger a more harmful flood event or effect the ability of the project to store floodwater. Over the last 30 years we have seen a decrease in peak annual streamflow. Furthermore, conservation storage is not considered for use for flood risk reduction.

Reallocation from the Allatoona flood pool could result in higher flows downstream of the project during certain events. Since the impoundment of the lake in 1950, the flood pool at Allatoona has never been exhausted. Despite increases in precipitation in the region, the most extreme events at Allatoona occurred in the 1960s. The dam performed well in those events and continues to perform well in recent high flow events. The flood pool is designed to completely hold the current 100 year or 0.01 AEP flood event. While this could be exacerbated in the future by the potential for the increased frequency and magnitude of extreme storms, removal of 2.4% would only have a small effect when the flood storage was close to being exhausted. The realization of the harm of increased damages downstream would still be considered unlikely to occur. There is no increase in risk with respect to dam safety associated with this plan as the dam can still pass the probable maximum flood which considers an antecedent pool condition well above the reallocated storage.

Reallocation from any one of the other two flood risk management pools at Weiss and Logan Martin would reduce the storage capacity used to reduce flooding downstream. This would also be exacerbated in the future by the potential for the increased frequency and magnitude of extreme storms. A magnitude storm that would completely exhaust the flood pool at any of these projects, leading to increased damages downstream would still be considered unlikely but possible. An assessment of the downstream flooding risk at these projects for the existing conditions has been performed as part of this study based on quantitative increases in future hydrology. There is no increase in risk with respect to dam safety associated with this plan as the dam can still pass the probable maximum flood which considers an antecedent pool condition well above the reallocated storage.

1.6 Conclusions

Based on the literature review of relevant climate data, there is some consensus that there will be mild increases in the severity and frequency of storms in the region. However, there is no consensus on future changes in hydrology. Observed data from near the study area shows temperatures have been gradually rising since the 1970s, after a cooling period in the middle part of the century. Looking several of the gages in the watershed, it is difficult to come to a conclusion on whether temperature is increasing or if this is a reoccurring pattern. Annual precipitation seems to be variable for the region. It appears there may be more extremes occurring in recent years, such as extreme low annual precipitation values. However, the overall trends appear to be constant or increasing slightly. There is some consensus on peak streamflow for the region decreasing since the middle of the century, however, the literature lacks a clear consensus. For the Alabama Basin, this decreasing streamflow could be related to the increase in flood control projects within the region since the late 1940s.

The non-stationarity assessment on the Alabama River Basin was performed using two gages. The gages are USGS 02420000 Alabama River near Montgomery, AL and USGS 02428400 Alabama River at Claiborne Lock and Dam. Both gages did not have any non-stationarities and monotonic trends detected. However, for the USGS gage located near Canton, GA on the Etowah River had a non-stationarity, which occurred in the years 1981 and 1983. There is no explanation for these changes outside of changes in climate.

The USACE CHAT tool indicates that there is no statistically significant trend in the two streamflow datasets for USGS 02420000 Alabama River near Montgomery, AL and USGS 02428400 Alabama River at Claiborne Lock and Dam. However, the CHAT tool was used to detect any changes in streamflow further upstream in the Alabama Basin at USGS 02392000 Etowah River at Canton, GA. The tool indicates that a drop in streamflow but not a statistically significant one. Despite the high p-value of 0.11, it should be noted it is clear annual peak streamflow at the gage has decreased.

Furthermore, the HUC-4 analysis on streamflow on the Alabama basin only shows an increasing trend in projected streamflow based on GCM model output translated into a hydrologic response. These analyses provide some indication that there will be increases in mean monthly streamflow in the future as a result of climate change but do not speak to the frequency of extreme events. These projections seem to be opposite of the trend in observed flow and caution should be used in making any definitive statements on potential future hydrology as there is substantial uncertainty in both the climate and hydrologic models that drive these analyses. The vulnerability assessment helps to further reinforce a lack of evidence in increasing flood risk or risk to water supply. Findings of the vulnerability assessment show that the Alabama HUC-4 basin is not considered vulnerable to increased flood risk or water supply as a result of climate change, with respect to other HUC-4s in the nation.

Based on the results of this assessment, including considerations of observed precipitation, temperature, and streamflow in the basin, there is not strong evidence suggesting increasing peak annual streamflow will occur in for the future within the region. Furthermore, there is only some consensus the region might see a mild increase in the frequency and severity of precipitation events. This evidence, by itself does not indicate high confidence in an increase in peak flows in the Alabama basin. Based on the lack of clear evidence showing an increase in streamflow, the effects of climate change can be considered within the standard uncertainty bounds associated with the hydrologic/hydraulic analysis being conducted as part of this study.

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